بسم الله الرحمن الرحيم

NLAP-WEDC Final Report (2012 - 2020)

Waste Incineration Electrical Power Plant Technology

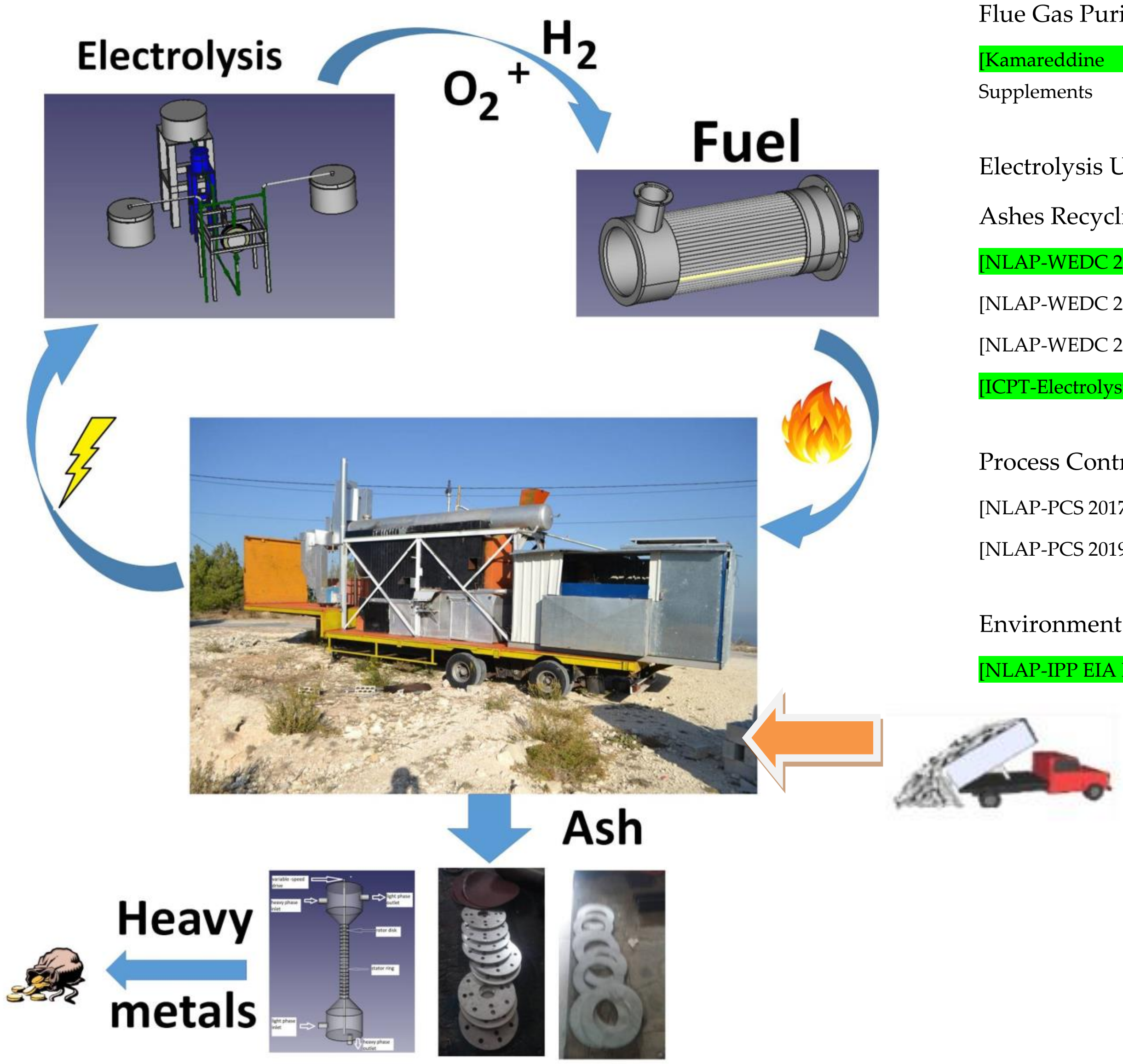
- Part 1 -

AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region

طاقة الشمال
North Lebanon Alternative Power

NLAP-WEDC Waste to Electricity

Demonstration cycle



Based on the following research reports:

Demonstration Incineration Power Plant NLAP-IPP

[TEMO-STPP/IPP 2012]

[TEMO-IPP 2013]

[TEMO-IPP 2014]

[Kamareddine 2016]

Flue Gas Purification

[Kamareddine 2016] and Supplements

Electrolysis Unit,

Ashes Recycling Unit

[NLAP-WEDC 2017]

[NLAP-WEDC 2018]

[NLAP-WEDC 2019]

[ICPT-ElectrolysisFuelBurner 2020]

Process Control System

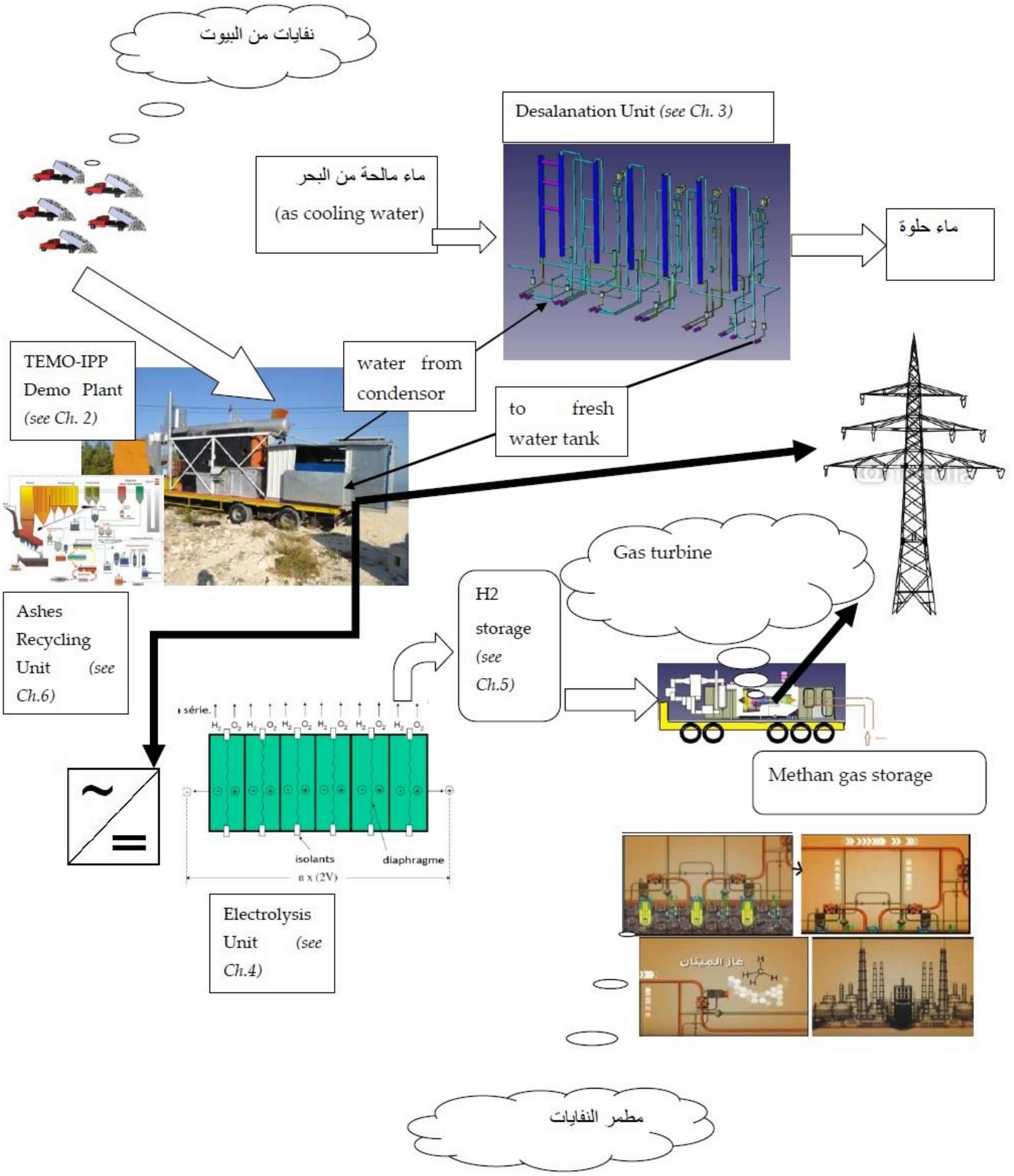
[NLAP-PCS 2017]

[NLAP-PCS 2019]

Environment Impact Assessment

[NLAP-IPP EIA Rayhaniyye 2018]

Last Update: 28.09.2020 12:53



نفايات من البيوت

Desalanation Unit *(see Ch. 3)*

ماء مالحة من البحر

(as cooling water)

ماء حلوة

TEMO-IPP Demo Plant *(see Ch. 2)*

water from condensor

to fresh water tank

Gas turbine

H2 storage *(see Ch.5)*

Ashes Recycling Unit *(see Ch.6)*

Methan gas storage

Electrolysis Unit *(see Ch.4)*

مطمر النفايات

Content in short

Content

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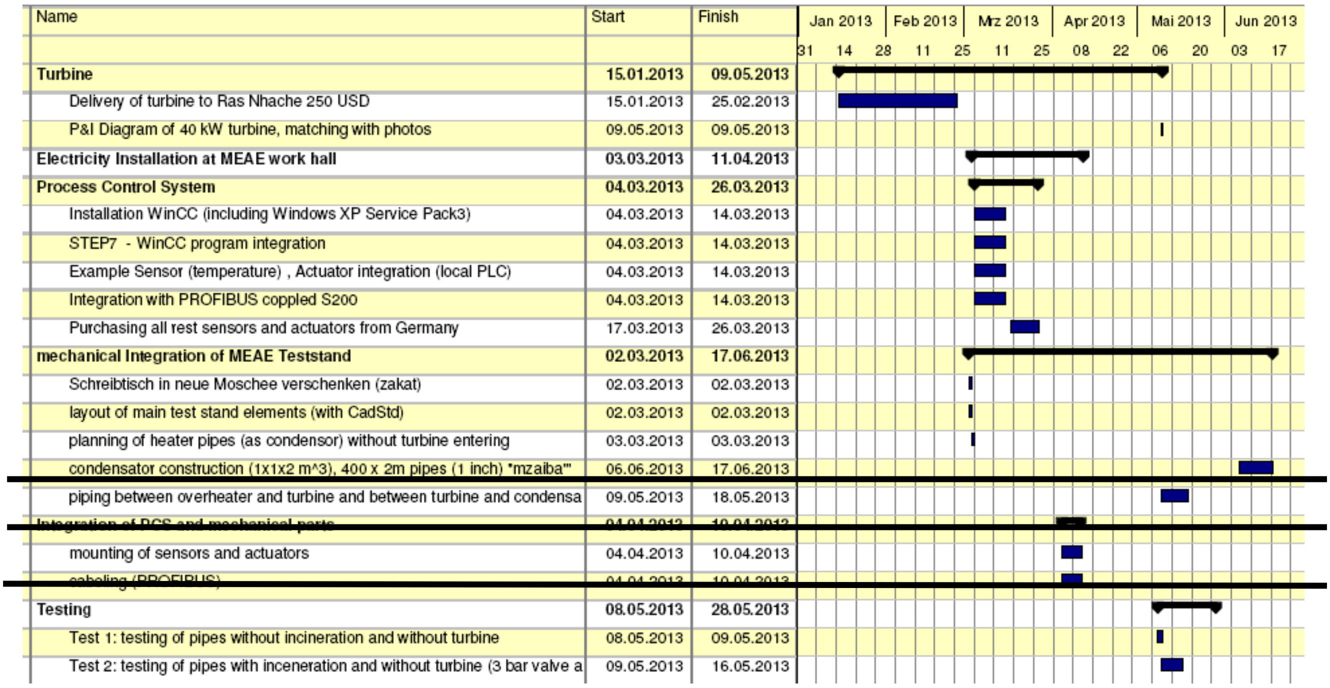
1 Project Management 2013 / إدارة المشروع

1.1 Time Schedule / الجدول الزمني

1.1.1 Jan-Jun 13



Name	Start	Finish
Turbine	**15.01.2013**	**09.05.2013**
Delivery of turbine to Ras Nhache 250 USD	15.01.2013	25.02.2013
P&I Diagram of 40 kW turbine, matching with photos	09.05.2013	09.05.2013
Electricity Installation at MEAE work hall	**03.03.2013**	**11.04.2013**
Process Control System	**04.03.2013**	**26.03.2013**
Installation WinCC (including Windows XP Service Pack3)	04.03.2013	14.03.2013
STEP7 - WinCC program integration	04.03.2013	14.03.2013
Example Sensor (temperature) , Actuator integration (local PLC)	04.03.2013	14.03.2013
Integration with PROFIBUS coppled S200	04.03.2013	14.03.2013
Purchasing all rest sensors and actuators from Germany	17.03.2013	26.03.2013
mechanical Integration of MEAE Teststand	**02.03.2013**	**17.06.2013**
Schreibtisch in neue Moschee verschenken (zakat)	02.03.2013	02.03.2013
layout of main test stand elements (with CadStd)	02.03.2013	02.03.2013
planning of heater pipes (as condensor) without turbine entering	03.03.2013	03.03.2013
condensator construction (1x1x2 m^3), 400 x 2m pipes (1 inch) "mzaiba"	06.06.2013	17.06.2013
piping between overheater and turbine and between turbine and condensa	09.05.2013	18.05.2013
~~**Integration of PCS and mechanical parts**~~	~~**04.04.2013**~~	~~**10.04.2013**~~
mounting of sensors and actuators	04.04.2013	10.04.2013
~~cabeling (PROFIBUS)~~	~~04.04.2013~~	~~10.04.2013~~
Testing	**08.05.2013**	**28.05.2013**
Test 1: testing of pipes without incineration and without turbine	08.05.2013	09.05.2013
Test 2: testing of pipes with inceneration and without turbine (3 bar valve a	09.05.2013	16.05.2013

Working package	Description	Planned period	In deed worked period with situation	Man power
Process Control system:	**Monitoring and controlling software**	**1 month**	**5 week (1 week delay)**	**700$**
WinCC work	1st monitoring choise	2 week	2 week (**Stopped** doesn't done because of license end)	
SIMATIC manager work	For controlling	1 week	2 week (**Done** without Profibus)	
Python software	2nd monitoring choise	1 week	1 week (**Done**)	
Integration of mechanical parts:				
Test 1	Only water	1 day	1 day (failed) caused 3 days delay	100$
Test 2	Testing of	1 day	2 week (failed) caused I month delay	500$

At the left side of the time schedule the material costs + foreign personal costs appear.

في الجانب الأيسر من الجدول الزمني تظهر تكاليف المواد + تكاليف عمّال من خارج مؤسسة AECENAR.

1.1.2 Planned Scedules for the PCS work:

- **Driver built:**

ربط و تهيئة جهاز ال PLC S7-300 بالإضافة إلى ال Profibus

- **Analog reading with temp. calculation**

كتابة برنامج ال LAD على ال SIMATIC manager ليقوم بإستقبال بيانات Analog من ال Termocouples

sensor و معالجتها و حساب الحرارة الفعلية منها

- **Valve and pumpe control circuit:**

بناء دارة تحكم تقوم بالتحكم بالمضخاة والصمامات في محطة الطاقة من خلال ال PLC او ال Velleman board

- **User interface software (GUI)**

كتابة برنامج تفاعلي لمراقبة و التحكم بمحطة الطاقة من جهاز الكمبيوتر. الطريق الأولى WinCC, الطريقة الثانية

Python program

1.1.3 Mounting overheater with turbine (Sep 13)

Practicant work, Material costs: 100 EUR

1.1.4 Mounting cooling for condenser (same time using it as building heating at Qubaisi center) (Oct-Dec 13)

Costs: ca. 1.600 EUR

1.2 موجز للتكاليف/ Costs Jan-Dec 13

تجهيز المكان لتجيع المحطة الطاقة التجاربية في قاعة 100 متر مربع	Rent for hall (100 qm hall) for 2013	2.500 €	
أنابيب للكوندينسور	Condenser pipes in working hall	560 €	
	Burning chamber	400 €	
	Personal Costs TEMO-STPP 4-8/13	1.300 €	
	Cooling for Condensor in Qubaisi Center	1.600 €	
	Total:	**6.360 €**	

1.3 Offer to LASER (Lebanese Association for Scientific Research) in Dec 2014

AECENAR
Association for Economical and Technological Cooperation
in the Euro-Asian and North-African Region
www.aecenar.com

Bismillah

To

LASER Tripoli

President Prof. Mustapha Jazzar

Investment Offer

Dear sirs and madams,

AECENAR offers LASER the following:

LASER becomes investment partner in the AECENAR power plant project TEMO-STPP demonstration plant. TEMO-STPP demonstration plant is a small scale power plant project, which is planned to use mainly incineration to produce electrical power of 40 kW.

The total investment sum of TEMO-STPP demonstration plant is $ 75.380 (please refer to the attached calculation).

According to this sum an investment partnership could be established. E.g. if LASER pays 50% of the total investment sum, the LASER will get 50% of the win, when the plant is selled or the electricity of it. In case of selling only the electricity (and not the plant), the win percentage will be for a period of 20 years.

AECENAR offers LASER to invest an amount between 35.000 $ and 50.000 $. This amount is excluding VAT.

The actual not finished plant is installed at Qubaisi Center in Ras Nhache/Batroun. According to the calculation there is still missing $33.580 to finish the plant.

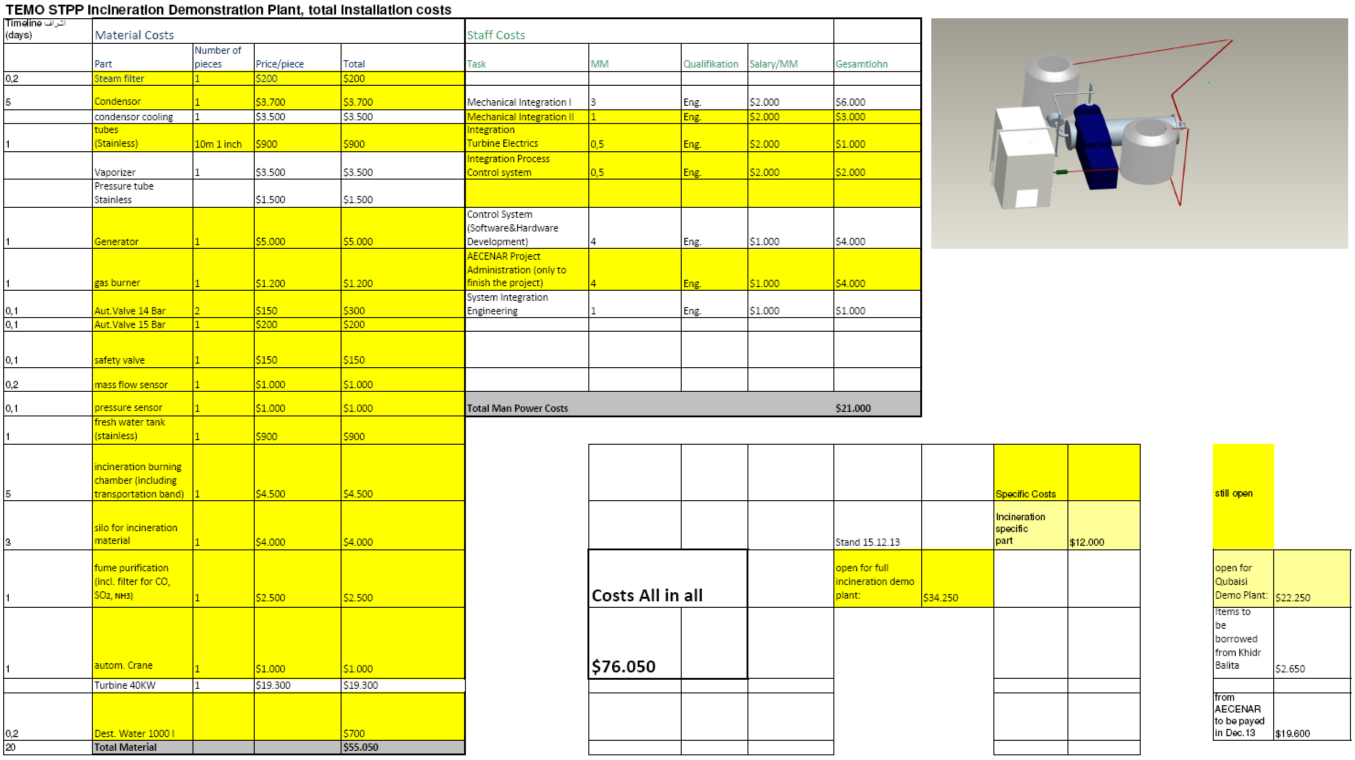
Please note that there are two potential clients interested in buying the plant (respectively the electricity) and further plants from us. One of them is Bader Hassun (Khan as-Sabun). The other is Khidr Balita, an owner of an international operating company. Khidr Balita will provide also insha Allah some parts for the plant, which are still missing.

Ras Nhache/Batroun, 15.12. 2013

Samir Mourad (President AECENAR)

Attachments:

Calculation (updated after offer)



TEMO STPP Incineration Demonstration Plant, total installation costs

Timeline اشراف (days)	Material Costs			
	Part	Number of pieces	Price/piece	Total
0,2	Steam filter	1	$200	$200
5	Condensor	1	$3.700	$3.700
	condensor cooling	1	$3.500	$3.500
1	tubes (Stainless)	10m 1 inch	$900	$900
	Vaporizer	1	$3.500	$3.500
	Pressure tube Stainless		$1.500	$1.500
1	Generator	1	$5.000	$5.000
1	gas burner	1	$1.200	$1.200
0,1	Aut.Valve 14 Bar	2	$150	$300
0,1	Aut.Valve 15 Bar	1	$200	$200
0,1	safety valve	1	$150	$150
0,2	mass flow sensor	1	$1.000	$1.000
0,1	pressure sensor	1	$1.000	$1.000
1	fresh water tank (stainless)	1	$900	$900
5	incineration burning chamber (including transportation band)	1	$4.500	$4.500
3	silo for incineration material	1	$4.000	$4.000
1	fume purification (incl. filter for CO, SO_2, NH_3)	1	$2.500	$2.500
1	autom. Crane	1	$1.000	$1.000
	Turbine 40KW	1	$19.300	$19.300
0,2	Dest. Water 1000 l			$700
20	Total Material			$55.050

Staff Costs				
Task	MM	Qualifikation	Salary/MM	Gesamtlohn
Mechanical Integration I	3	Eng.	$2.000	$6.000
Mechanical Integration II	1	Eng.	$2.000	$3.000
Integration Turbine Electrics	0,5	Eng.	$2.000	$1.000
Integration Process Control system	0,5	Eng.	$2.000	$2.000
Control System (Software&Hardware Development)	4	Eng.	$1.000	$4.000
AECENAR Project Administration (only to finish the project)	4	Eng.	$1.000	$4.000
System Integration Engineering	1	Eng.	$1.000	$1.000
Total Man Power Costs				$21.000

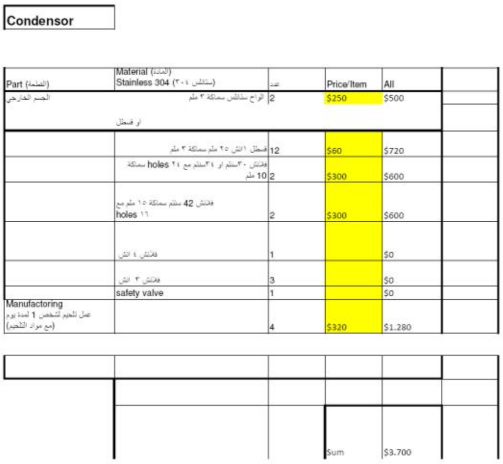
		Specific Costs	
	Stand 15.12.13	Incineration specific part	$12.000
Costs All in all	open for full incineration demo plant:	$34.250	
$76.050			

still open	
open for Qubaisi Demo Plant:	$22.250
Items to be borrowed from Khidr Balita	$2.650
from AECENAR to be payed in Dec.13	$19.600

Response of LASER

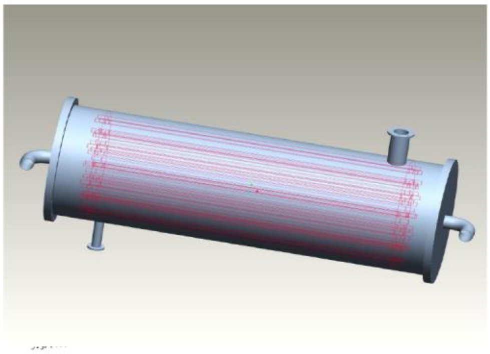
The response was positive, the next meeting between AECENAR and LASER is planned on 9.1.14

1.4 Condensor Construction Dec 2013



Condensor

Part (القطعة)	Material (المادة) Stainless 304 (ستانلس ٣٠٤)	عدد	Price/Item	All
الجسم الخارجي	ألواح ستانلس سماكة ٣ ملم او قسطل	2	$250	$500
	قسطل ١ انش ٢٥ ملم سماكة ٣ ملم	12	$60	$720
	فلانش ٣٠سنتم او ٣١سنتم مع ٢١ holes سماكة 10 ملم	2	$300	$600
	فلانش 42 سنتم سماكة ١٥ ملم مع ١٦ holes	2	$300	$600
	فلانش ٤ انش	1		$0
	فلانش ٣ انش	3		$0
	safety valve	1		$0
Manufactoring عمل تلحيم لشخص 1 لمدة يوم (مع مواد التلحيم)		4	$320	$1.280
			Sum	$3.700



1.4.1 Offer from Naouchi

Materials price

December 22, 2013 at 8:22:35 pm

وبركاته _ ورحمة عليكم السلام

Naouchi stainless steel

Material price:

1- Rolled Pipe: 32 cm x 250 cm x 3 mm + 2 cap = 400$

2- Seamless (dt. Nahtlos) Pipe: 1'' x 6 m x 3 mm , 6 pcs = 500$

3- Seamless Pipe: 4'' x 1 m x 3mm = 64$

4- Seamless pipe: 3'' x 1 m x 3mm = 48$

5- Socket weld Flange : 15mm Thickness, 4 pcs = 900$

6- Socket weld Flange : 4'' - 2 pcs = 320$

7- Socket Weld Flange : 3'' - 2 pcs = 280$

8- Bolts/Nuts & Gaskets = 60$

9- Argon Gas + welding rods = 200$

10- Helpers = 150$

11- Material Transport = 200$

Total price = 3122$

Best Regards

Hilal Naouchi

Trading & Contracting.

Lebanon- Tripoli - El-mina - Bawabeh Street

hilalnaouchi@hotmail.com

Phone: +961 6 218060

Fax : +961 6 218060

Cell: +961 3 503431 / +961 3 446027

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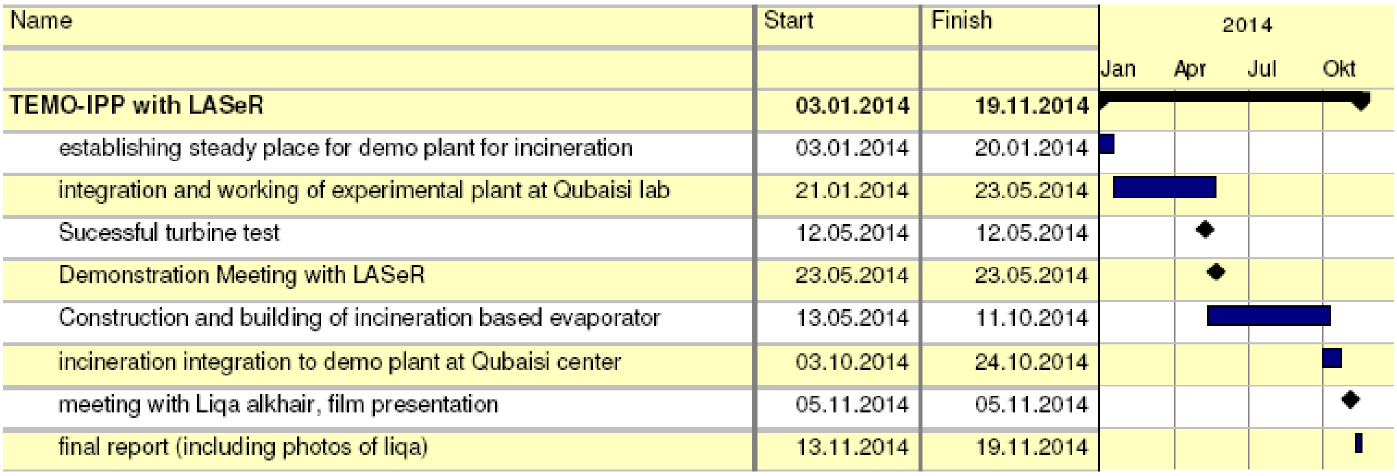
2 إدارة المشروع / Project Management 2014

2.1 مقدمة والهدف من هذا العمل / goal of this work

The goal of this project phase (Jan – Nov 2014) was to finish the demonstration power plant such that it can be commercialized

الهدف هو اكمال مشروع المحطة الطاقة التجاربية حتى يكون المشروع جاهز ان يصبح مشروع استثمارى

2.2 الجدول الزمني / Time Schedule



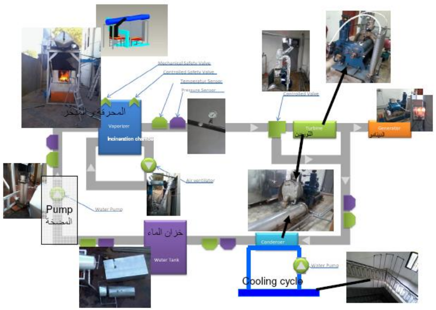
Name	Start	Finish
TEMO-IPP with LASeR	**03.01.2014**	**19.11.2014**
establishing steady place for demo plant for incineration	03.01.2014	20.01.2014
integration and working of experimental plant at Qubaisi lab	21.01.2014	23.05.2014
Sucessful turbine test	12.05.2014	12.05.2014
Demonstration Meeting with LASeR	23.05.2014	23.05.2014
Construction and building of incineration based evaporator	13.05.2014	11.10.2014
incineration integration to demo plant at Qubaisi center	03.10.2014	24.10.2014
meeting with Liqa alkhair, film presentation	05.11.2014	05.11.2014
final report (including photos of liqa)	13.11.2014	19.11.2014

Costs /موجز للتكاليف 2.3

Total Costs 2.3.1

File path and name: D:\AECENAR\Administration\Planning\2014\111114AECENAR_Businessplan_Budget2014.xls
last update: 11.11.2014

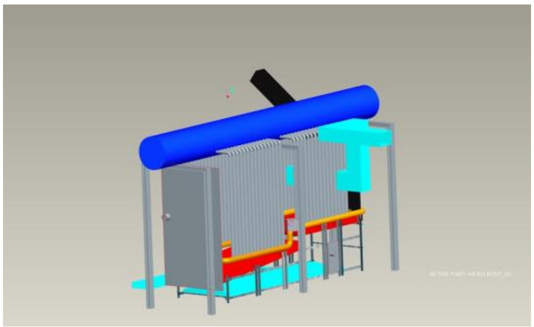
TEMO STPP Incineration Demonstration Plant, total installation costs

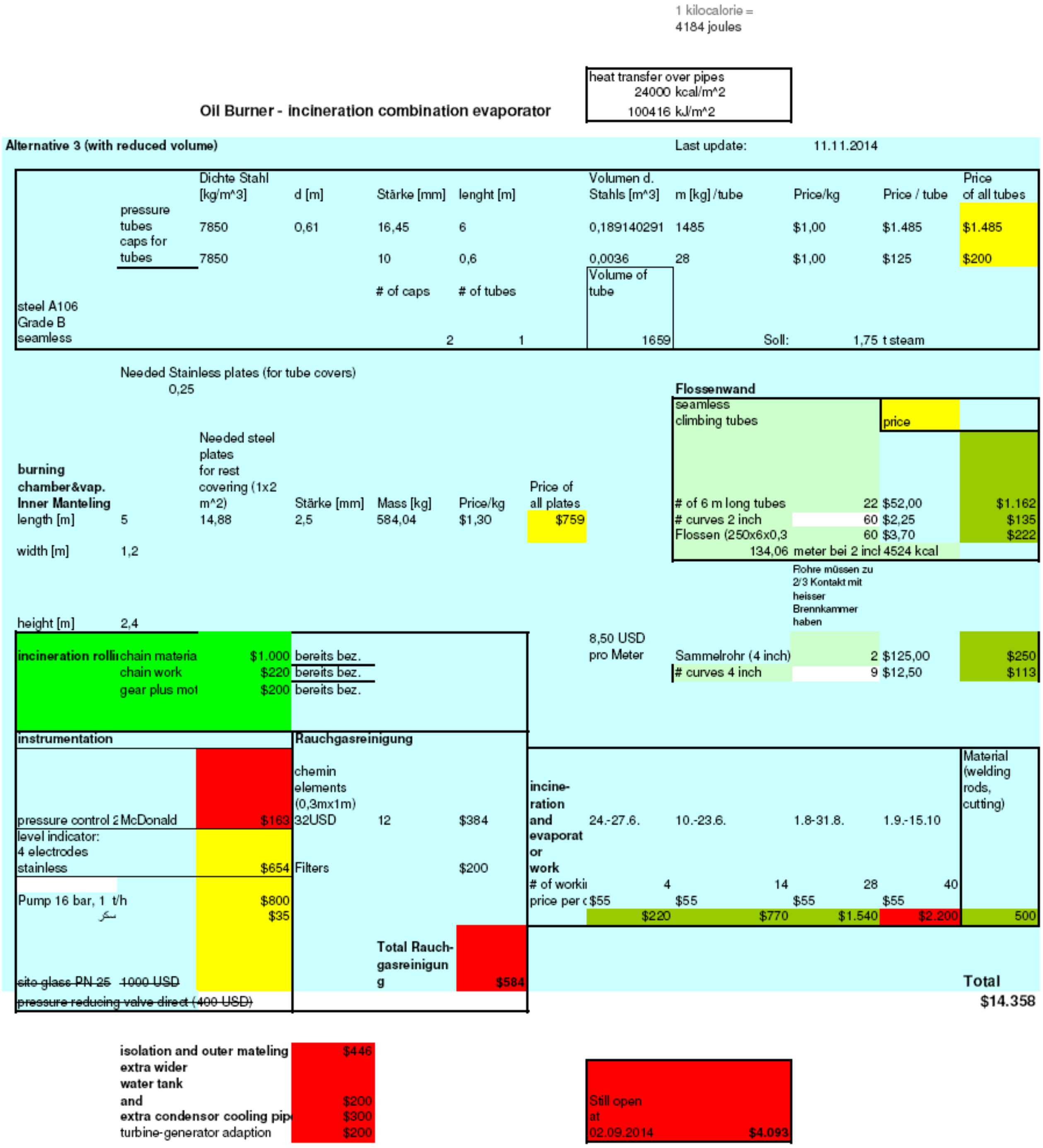


Material Costs (including workers for manufatoring)				
Part	Number of pieces	Price/piece	Total	
Steam filter	1	$200	$200	
Condensor	1	$3.000	$3.000	
condensor cooling	1	$3.500	$3.500	
tubes (Stainless)	10m 1 inch	$900	$900	
Test Vaporizer	1	$3.500	$3.500	
Test Vap. Pressure tube Stainless		$1.500	$1.500	
Generator	1	$650	$650	
diesel burner including fuel feed	1	$750	$750	
safety valve 15 bar	1	$500	$500	
	0	$1.000	$0	
pressure sensors	5	$60	$300	**Originally Estimated Costs from Originally Contract with LASER**
fresh water tank (stainless)	1	$900	$900	**$75.380**
incineration burning chamber (including transportation band)&vaporizer (climbing tubes...)	1	$14.358	$14.358	**Extra Budget** **$29.978**
fume purification (incl. filter for CO, SO_2, NH_3)	1	$2.500	$2.500	**Costs All in all**
				$105.358
Turbine 40KW	1	$19.300	$19.300	LASeR payed 50% of costs
Total Material			**$51.858**	

Engineering Staff Costs				
Task	MM	Qualifikation	Salary/MM	Total Salary
Integration with Test Vaporizer	4	Eng.	$2.000	$8.000
Integration with Incineration Vap.	2	Eng.	$2.000	$4.000
Integration Turbine Electrics	0,5	Eng.	$2.000	$1.000
Integration Process Control system	0,5	Eng.	$2.000	$1.000
Control System (Software&Hardware Development)	4	Eng.	$2.000	$8.000
AECENAR Project Management	9	Eng.	$3.500	$31.500
Total Man Power Costs				**$53.500**

2.3.2 المحرقة و المبخر





1 kilocalorie =
4184 joules

heat transfer over pipes	
24000	kcal/m^2
100416	kJ/m^2

Oil Burner - incineration combination evaporator

Alternative 3 (with reduced volume) Last update: 11.11.2014

		Dichte Stahl [kg/m^3]	d [m]	Stärke [mm]	lenght [m]	Volumen d. Stahls [m^3]	m [kg] /tube	Price/kg	Price / tube	Price of all tubes
	pressure tubes	7850	0,61	16,45	6	0,189140291	1485	$1,00	$1.485	$1.485
	caps for tubes	7850		10	0,6	0,0036	28	$1,00	$125	$200
				# of caps	# of tubes	Volume of tube				
steel A106 Grade B seamless				2	1	1659		Soll:	1,75 t steam	

Needed Stainless plates (for tube covers)
0,25

burning chamber&vap. Inner Manteling		Needed steel plates for rest covering (1x2 m^2)	Stärke [mm]	Mass [kg]	Price/kg	Price of all plates
length [m]	5	14,88	2,5	584,04	$1,30	$759
width [m]	1,2					
height [m]	2,4					

Flossenwand

seamless climbing tubes		price	
# of 6 m long tubes	22	$52,00	$1.162
# curves 2 inch	60	$2,25	$135
Flossen (250x6x0,3	60	$3,70	$222
134,06	meter bei 2 incl	4524 kcal	

Rohre müssen zu 2/3 Kontakt mit heisser Brennkammer haben

8,50 USD pro Meter

Sammelrohr (4 inch)	2	$125,00	$250
# curves 4 inch	9	$12,50	$113

incineration rolli	chain materia	$1.000	bereits bez.
	chain work	$220	bereits bez.
	gear plus mot	$200	bereits bez.

instrumentation		
pressure control 2	McDonald	$163
level indicator: 4 electrodes stainless		$654
Pump 16 bar, 1 t/h		$800
	سكر	$35
~~site glass PN 25~~	~~1000 USD~~	
~~pressure reducing valve direct (400 USD)~~		

Rauchgasreinigung		
chemin elements (0,3mx1m) 32USD	12	$384
Filters		$200
Total Rauchgasreinigung		$584

incineration and evaporator work	24.-27.6.	10.-23.6.	1.8-31.8.	1.9.-15.10	Material (welding rods, cutting)
# of workii	4	14	28	40	
price per c	$55	$55	$55	$55	
	$220	$770	$1.540	$2.200	500

Total
$14.358

isolation and outer mateling	$446
extra wider water tank and	$200
extra condensor cooling pip	$300
turbine-generator adaption	$200

Still open at 02.09.2014 $4.093

2.3.3 Budget Feb 2014: 5000 USD

Date	Part/Eng.	Place of integration	Amount	
15.02.2014	Condenser	Ras Nhache, later Anfe	$2.700	partly paid
	Integration cooling		$200	already paid
	purified water		$200	
	cooling valves (2 3-path electronic valves, max. 150°C)		$316	already paid
	vaporizer safety valve			
	pump	Ras Nhache, later Anfe	$1.000	
	fresh water tank	Ras Nhache, later Anfe	$500	
		Total	$4.916	

2.3.4 Budget March-Apr 2014: 25000 USD

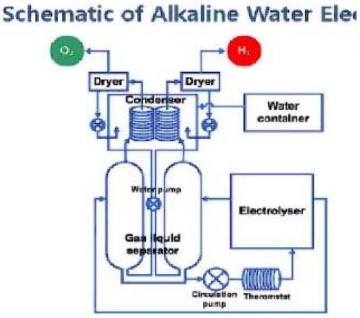
Date	Part/Eng.	Place of integration	Amount	
	Incineration&Vaporizer	Anfe	$8.000	
	Container 20 feet		$2.300	
	Engineering Omar		$1.500	
	Valves&Instrumentation	Ras Nhache	$2.000	
	Piping			
	Measurement Instrument	Ras Nhache	$1.500	
		Total	$15.300	

2.3.5 Budget May-Nov 2014: 16000 USD

Was not enough. An amount of about 5000 USD had to be paid extra from Samir Mourad.

3 Project Management 2018

080318Tasks_NLAP-WEDC_ElectrolysisUnit_IncludingH2O2Storage.xlsx - 08.03.2018



Schematic of Alkaline Water Ele

Module of 2.5kW Electrolyser

Specification

Size:
52cm X 30cm X 50cm
Power Consumption:
<2.5kW
Gas production per hour:
hydrogen gas 500liter;
oxygen gas 250liter, separately
Pressure:
5 bar
Temperature:
50~80℃
Purity of gas:
hydrogen gas 99.9%,
oxygen gas 98%

NLAP-WEDC Electrolysis Unit /
Hydrogen and Oxigen Storage

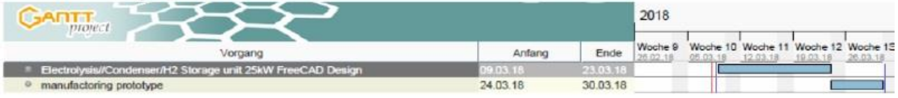
08.03.2018
http://

Project managers:	Samir
Dates:	09.03.2018 - 31.03.2018
Complete:	0%
Tasks:	2
People:	2

Tasks

Vorgang	Anfang	Ende
Electrolysis//Condenser/H2 Storage unit 25kW FreeCAD Design System FreeCAD Design - 25 kW Electrolysis Unit - Condensor (H2/O2 purification unit) - H2 Storage - O2 Storage (Each device in 1 file, the whole system in 1 file) Documentation: Piece List with prices	09.03.18	23.03.18
manufactoring prototype	24.03.18	30.03.18

Gantt-Diagramm



Vorgang	Anfang	Ende
Electrolysis//Condenser/H2 Storage unit 25kW FreeCAD Design	09.03.18	23.03.18
manufactoring prototype	24.03.18	30.03.18

4 NLAP-WEDC Demonstration Cycle Facility

4.1 أوراق حمالة محطة حرق النفايات

رسم: ١٠٠٠٠٠
عدل: ٣٠٠٠
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تحرير: [illegible]
طباعة: [illegible]
نقابة محامين: [illegible]
طابع مالي: ٥٠٠٠
إيصال: ١٥٠
إنتقال: ٠
المجموع: [illegible] ل.ل.

الجمهوريـــة اللبنانيـــة
وزارة العدل
الكاتب العدل في جبيل
فيرا داود
مكتب: ٠٩/٩٤٥٤٧١ – ٠٣/٦١١٩٧٤
عـــــدد: ٥٥٠٩٨ / ٢٠١٧

وكالة بيع سيارة/ مقطورة

في يوم الثلاثاء الواقع في الثالث من شهر تشرين الاول عام الفين وسبعة عشر

حضر أمامي انا فيرا داود الكاتب العدل في جبيل، السيد **ربيع وهيب طنـــوس**، من الجنسية اللبنانية، المولود في البتـــرون ١٩٨٠، سجل ١٩/دريا –البترون، والدته ماري دوميط حامل بطاقة هوية عليها رسمه الشمســـي رقـــم: ٠٠٠٠٤١٤٥٤٦٩٥ صـــادرة بتاريخ ٢٠٠٦/٤/١٢ ، الحائز على الأهلية القانونية، **بوكالته عن نبيل وهيب طنوس بموجب وكالة مسجلة لدى الكاتب العدل في البترون الاستاذة مايا تونيا الفخري برقم ٢٠١٥/٤١٠١ تاريخ ٢٠١٥/٦/٩**

وبحضوري وحضوره صرح الحاضر المذكور طائعا مختارا وهو بأكمل الأوصاف المعتبرة قانونا بما يلي: اني وكلت وفوضت السيد خالد وليد مراد اللبناني سجل ٩/ راسنحاش - البترون المقيم في: راسنحاش - البترون حي الحمرا - الطابق الارضي - هاتف ٩٨٥١٠٩ /٧١

ببيع وفراغ وتسجيل كامل السيارة ماركة FRUEHAUFF C307 mod 1975 لون اصفر

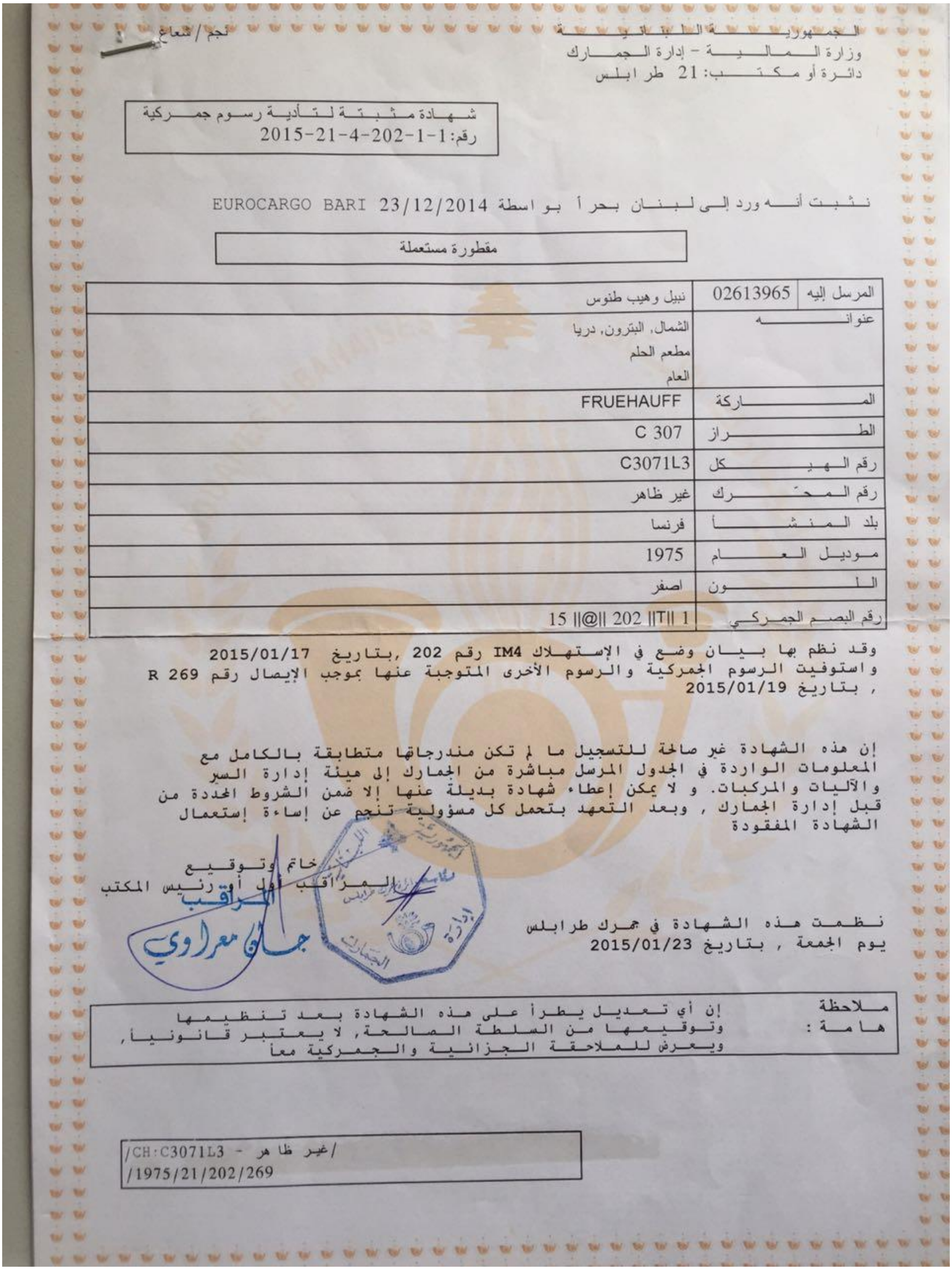
مجمركة بموجب شهادة جمركية رقم 2015-21-1-202.1.1 صادرة بتاريخ 23-01-2015

رقم المحرك غير ظاهر رقم الشاسي C30713

بيعا باتا أو بالتقسيط مع حق التحويل والتجيير وممن يشاء بالثمن الذي يراه مناسبا وقبض الثمن وفك الرهن وقبض قيمته والاقرار والابراء وتوقيع جميع العقود والأوراق والمعاملات اللازمة، مع حق بيع كل من الأنقاض واللوحات على حدة أو مجتمعين والإستحصال على رخصة سير بدل عن ضائع ورفع الحجز وتمثيلي بأية قضية تتعلق بالسيارة المذكورة والصلح والاسقاط والإقرار والإبراء والتنازل، وتخليصها من الجمرك وتوقيفها عن السير والمرافعة والمدافعة بكل دعوى لها أم عليها أمام جميع المحاكم والمراجع، وللوكيل حق التجول في هذه السيارة في كافة البلاد العربية والأوروبية وقطع دفاتر المرور، مع حق التسجيل لأقرب الأشخاص إليه ، وكالة **غير قابلة العزل** لتعلق حق الغير بها سندا للمادتين ٨١٠ و ٨١٨ من قانون الموجبات والعقود اللبناني ، **على أن يتحمل الوكيل كامل المسؤوليات الناتجة عن هذه السيارة تجاهه وتجاه الغير من تاريخه وصاعدا** . علـــما انّ هذه الوكالة تخضع لغرامة تأخير قدرها /١٠٠,٠٠٠ ل.ل. **مئة الف ليرة لبنانية** / عن كلّ أسبوع تأخير في التسجيل بعد مرور شهرين من تاريخه عملاً بقانون السير رقم ٢٤٣ تاريخ ٢٢/ ٢٠١٢/١٠ وطلب الي انا الكاتب العدل، تنظيم هذا السند المتضمن جميع ما ذكر أعلاه، فعليه صار تنظيم هذا السند باليوم والتاريخ المذكورين بالدائرة المذكورة وبعد تلاوتها جهرا وعلنا وتفهيم المقررة المذكورة مندرجاته واعترفت بمضمونه وإذ جاء قرارها مطابقا للطلب وقع مني ومنها وسجل.

الموكـــــــل
بالوكالة
ربيع وهيب طنوس

الكاتب العدل في جبيل
فيرا جرجي داود
٣ - تشرين ١ ٢٠١٧



نجم / شعاع

الجمهورية اللبنانية
وزارة المالية - إدارة الجمارك
دائرة أو مكتب: 21 طرابلس

شهادة مثبتة لتأدية رسوم جمركية
رقم: 1-1-202-4-21-2015

نثبت أنه ورد إلى لبنان بحراً بواسطة 23/12/2014 EUROCARGO BARI

مقطورة مستعملة

المرسل إليه	02613965	نبيل وهيب طنوس
عنوانه		الشمال، البترون، دريا مطعم الحلم العام
الماركة		FRUEHAUFF
الطراز		C 307
رقم الهيكل		C3071L3
رقم المحرك		غير ظاهر
بلد المنشأ		فرنسا
موديل العام		1975
اللون		اصفر
رقم البصم الجمركي		1 ||T|| 202 ||@|| 15

وقد نظم بها بيان وضع في الإستهلاك IM4 رقم 202 ,بتاريخ 2015/01/17
واستوفيت الرسوم الجمركية والرسوم الأخرى المتوجبة عنها بموجب الإيصال رقم R 269
بتاريخ 2015/01/19 ,

إن هذه الشهادة غير صالحة للتسجيل ما لم تكن مندرجاتها متطابقة بالكامل مع المعلومات الواردة في الجدول المرسل مباشرة من الجمارك إلى هيئة إدارة السير والآليات والمركبات. و لا يمكن إعطاء شهادة بديلة عنها إلا ضمن الشروط المحددة من قبل إدارة الجمارك , وبعد التعهد بتحمل كل مسؤولية تنجم عن إساءة إستعمال الشهادة المفقودة

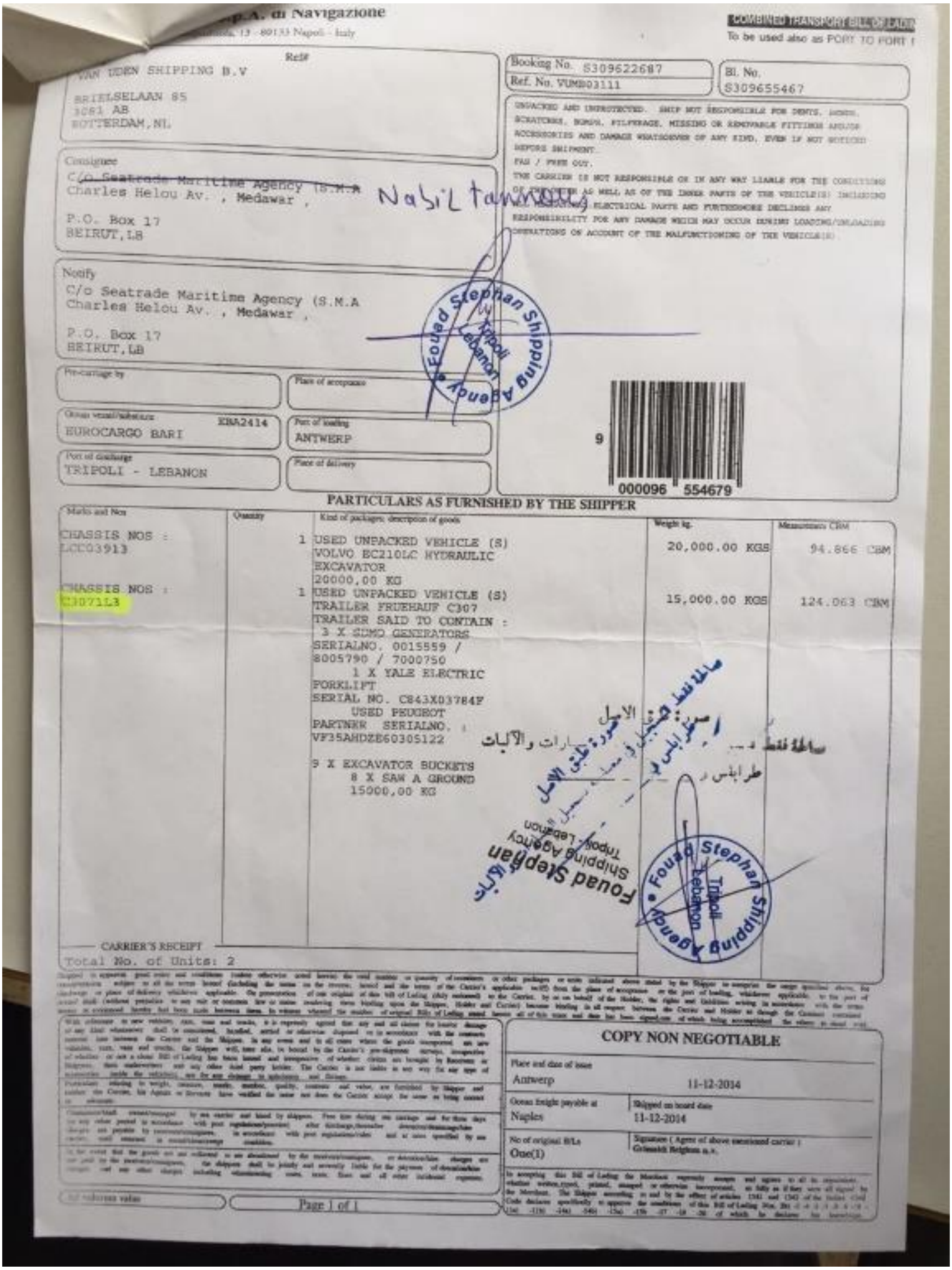
خاتم وتوقيع
المراقب أول أو رئيس المكتب

المراقب
جان معراوي

نظمت هذه الشهادة في جمرك طرابلس
يوم الجمعة , بتاريخ 2015/01/23

ملاحظة هامة :	إن أي تعديل يطرأ على هذه الشهادة بعد تنظيمها وتوقيعها من السلطة الصالحة, لا يعتبر قانونياً, ويعرض للملاحقة الجزائية والجمركية معاً

/CH:C3071L3 - غير ظاهر/
/1975/21/202/269



p.A. di Navigazione
13 - 80133 Napoli - Italy

COMBINED TRANSPORT BILL OF LADIN
To be used also as PORT TO PORT

Ref#
VAN UDEN SHIPPING B.V
BRIELSELAAN 85
3081 AB
ROTTERDAM,NL

Booking No. S309622687
Ref. No. VUMB03111

Bl. No.
S309655467

UNPACKED AND UNPROTECTED. SHIP NOT RESPONSIBLE FOR DENTS, BENDS, SCRATCHES, BURNS, PILFERAGE, MISSING OR REMOVABLE FITTINGS AND/OR ACCESSORIES AND DAMAGE WHATSOEVER OF ANY KIND, EVEN IF NOT NOTICED BEFORE SHIPMENT.
FAS / FREE OUT.
THE CARRIER IS NOT RESPONSIBLE OR IN ANY WAY LIABLE FOR THE CONDITIONS OF THE AS WELL AS OF THE INNER PARTS OF THE VEHICLE(S) INCLUDING ELECTRICAL PARTS AND FURTHERMORE DECLINES ANY RESPONSIBILITY FOR ANY DAMAGE WHICH MAY OCCUR DURING LOADING/UNLOADING OPERATIONS ON ACCOUNT OF THE MALFUNCTIONING OF THE VEHICLE(S).

Consignee
~~C/O Seatrade Maritime Agency (S.M.A~~ Nabil tannous
Charles Helou Av. , Medawar ,
P.O. Box 17
BEIRUT,LB

Notify
C/o Seatrade Maritime Agency (S.M.A
Charles Helou Av. , Medawar ,
P.O. Box 17
BEIRUT,LB

Fouad Stephan Shipping Agency
Tripoli Lebanon

Pre-carriage by	Place of acceptance
Ocean vessel/substitute EBA2414 EUROCARGO BARI	Port of loading ANTWERP
Port of discharge TRIPOLI - LEBANON	Place of delivery

PARTICULARS AS FURNISHED BY THE SHIPPER

Marks and Nos	Quantity	Kind of packages; description of goods	Weight kg.	Measurements CBM
CHASSIS NOS : LCC03913	1	USED UNPACKED VEHICLE (S) VOLVO EC210LC HYDRAULIC EXCAVATOR 20000,00 KG	20,000.00 KGS	94.866 CBM
CHASSIS NOS : C307113	1	USED UNPACKED VEHICLE (S) TRAILER FRUEHAUF C307 TRAILER SAID TO CONTAIN : 3 X SDMO GENERATORS SERIALNO. 0015559 / 8005790 / 7000750 1 X YALE ELECTRIC FORKLIFT SERIAL NO. C843X03784F USED PEUGEOT PARTNER SERIALNO. VF35AHDZE60305122 9 X EXCAVATOR BUCKETS 8 X SAW A GROUND 15000,00 KG	15,000.00 KGS	124.063 CBM

صورة طبق الأصل

Fouad Stephan Shipping Agency
Tripoli - Lebanon

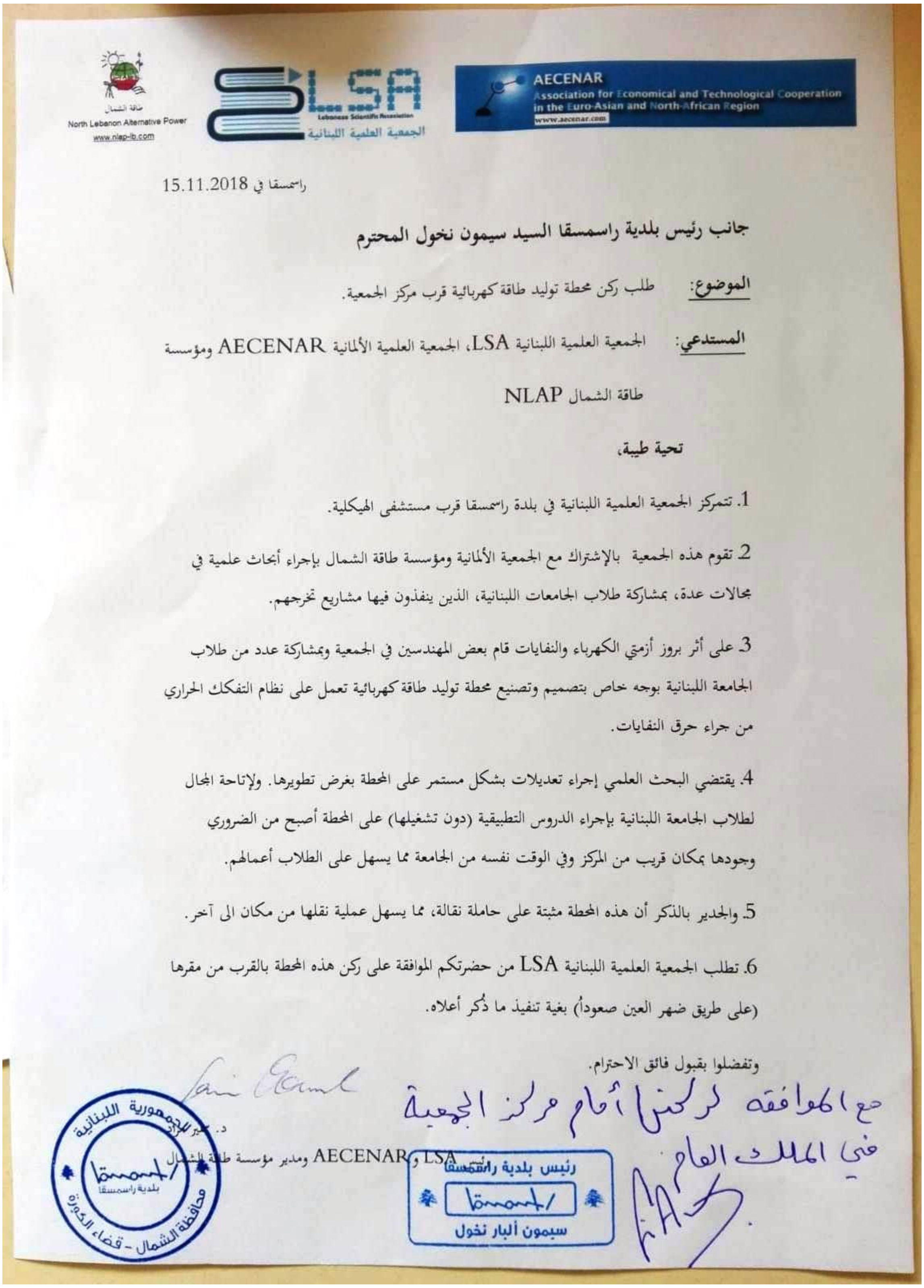
CARRIER'S RECEIPT
Total No. of Units: 2

COPY NON NEGOTIABLE

Place and date of issue Antwerp 11-12-2014	
Ocean freight payable at Naples	Shipped on board date 11-12-2014
No of original B/Ls One(1)	Signature (Agent of above mentioned carrier) Grimaldi Belgium n.v.

Page 1 of 1

4.2 أوراق ادارية بخصوص الموقع في راسمقا



طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.com

LSA
Lebanese Scientific Association
الجمعية العلمية اللبنانية

AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region
www.aecenar.com

راسمسقا في 15.11.2018

جانب رئيس بلدية راسمسقا السيد سيمون نخول المحترم

الموضوع: طلب ركن محطة توليد طاقة كهربائية قرب مركز الجمعية.

المستدعي: الجمعية العلمية اللبنانية LSA، الجمعية العلمية الألمانية AECENAR ومؤسسة طاقة الشمال NLAP

تحية طيبة،

1. تتمركز الجمعية العلمية اللبنانية في بلدة راسمسقا قرب مستشفى الهيكلية.

2. تقوم هذه الجمعية بالإشتراك مع الجمعية الألمانية ومؤسسة طاقة الشمال بإجراء أبحاث علمية في مجالات عدة، بمشاركة طلاب الجامعات اللبنانية، الذين ينفذون فيها مشاريع تخرجهم.

3. على أثر بروز أزمتي الكهرباء والنفايات قام بعض المهندسين في الجمعية وبمشاركة عدد من طلاب الجامعة اللبنانية بوجه خاص بتصميم وتصنيع محطة توليد طاقة كهربائية تعمل على نظام التفكك الحراري من جراء حرق النفايات.

4. يقتضي البحث العلمي إجراء تعديلات بشكل مستمر على المحطة بغرض تطويرها. ولإتاحة المجال لطلاب الجامعة اللبنانية بإجراء الدروس التطبيقية (دون تشغيلها) على المحطة أصبح من الضروري وجودها بمكان قريب من المركز وفي الوقت نفسه من الجامعة مما يسهل على الطلاب أعمالهم.

5. والجدير بالذكر أن هذه المحطة مثبتة على حاملة نقالة، مما يسهل عملية نقلها من مكان الى آخر.

6. تطلب الجمعية العلمية اللبنانية LSA من حضرتكم الموافقة على ركن هذه المحطة بالقرب من مقرها (على طريق ضهر العين صعوداً) بغية تنفيذ ما ذُكر أعلاه.

وتفضلوا بقبول فائق الاحترام.

Sami Kamel

د. سمير مراد
رئيس LSA, AECENAR ومدير مؤسسة طاقة الشمال

مع الموافقة لركنها أمام مركز الجمعية
في الملك العام

رئيس بلدية راسمسقا
سيمون ألبار نخول

بلدية راسمسقا

طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.com

LSA
Lebanese Scientific Association
الجمعية العلمية اللبنانية

AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region
www.aecenar.com

راسمسقا في 27.08.2019

جانب رئيس بلدية راسمسقا السيد سيمون نخول المحترم

الموضوع: طلب تشغيل ماكينة التفكك الحراري على سبيل التجربة.

المستدعي: الجمعية العلمية اللبنانية LSA، الجمعية العلمية الألمانية AECENAR ومؤسسة طاقة الشمال NLAP

تحية طيبة، وبعد

1. إلحاقاً بالطلب المقدم سابقاً من قبل الجهات المذكورة أعلاه

2. وإستناداً إلى التجارب الناجحة المنجزة في بلدة راسنحاش قضاء البترون، التي أثبتت أن مستوى الإنبعاثات الضارة الناجمة عن عملية الحرق ما تزال تحت المستوى المشار إليه من قبل وزارة البيئة اللبنانية.

3. وبعد مناقشة ملف هذه الماكينة فيما يتعلق بالتقنية المعتمدة في الفلاتر المستخدمة فيها، وذلك في وزارة البيئة مع المستشار البيئي السيد المهندس شاكر نون بحضور الأستاذ غسان براس في تاريخ 21 .05 .2019

4. ونظراً لما يتطلبه البحث العلمي من إعادة متكررة للتجارب العلمية، نتقدم من حضرتكم بالسماح بتشغيل الماكينة لمدة تتراوح من 3 إلى 7 أيام، بغرض إثبات فعالية الماكينة أمام المعنيين بهذا الشأن

5. تتعهد الشركة المشغلة للماكينة بعدم صدور أي إزعاج أو إضرار بالسكان المقيمين في نطاق الماكينة.

بلدية راسمسقا
تاريخ الورود ٢٠١٩/٨/٢٧
رقم ٦٩٤

وتفضلوا بقبول فائق الاحترام.

د. سمير مراد
LSA و AECENAR ومدير مؤسسة طاقة الشمال

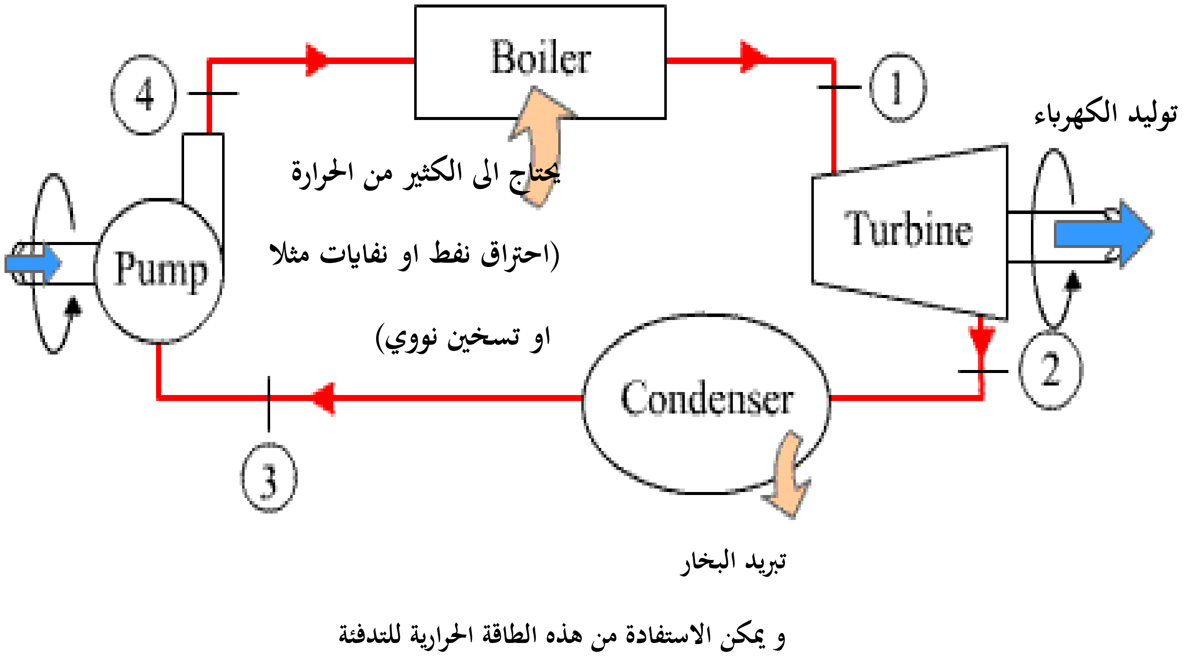
مع الموافقة دون أي مسؤولية مترتبة على البلدية

رئيس بلدية راسمسقا
سيمون [illegible] نخول

Basics

5 محطة طاقة مع توربين تعمل على البخار بشكل عام (Steam power plant)

- دورة الماء مُغلقة و تتغير حالة الماء ما بين سائل و بخار.
- وظيفة المحطة هي نقل الطاقة الحرارية الى طاقة كهربائية.



The theoretical basic is the Claude-Rankine-Cycle. For thermodynamical basics and elements of a power plant please refer to “TEMO-STPP Project Report 1 (2006-2008)” and “TEMO-STPP Project Report 2 (2009-2010)”.

6 General Information on Incineration Power Plants[1]

INCINERATION is a waste treatment technology that involves burning commercial, residential and hazardous waste. Incineration converts discarded materials, including paper, plastics, metals and food scraps into bottom ash, fly ash, combustion gases, air pollutants, wastewater, wastewater treatment sludge and heat.

It follows several steps illustrated in figure 1-1.

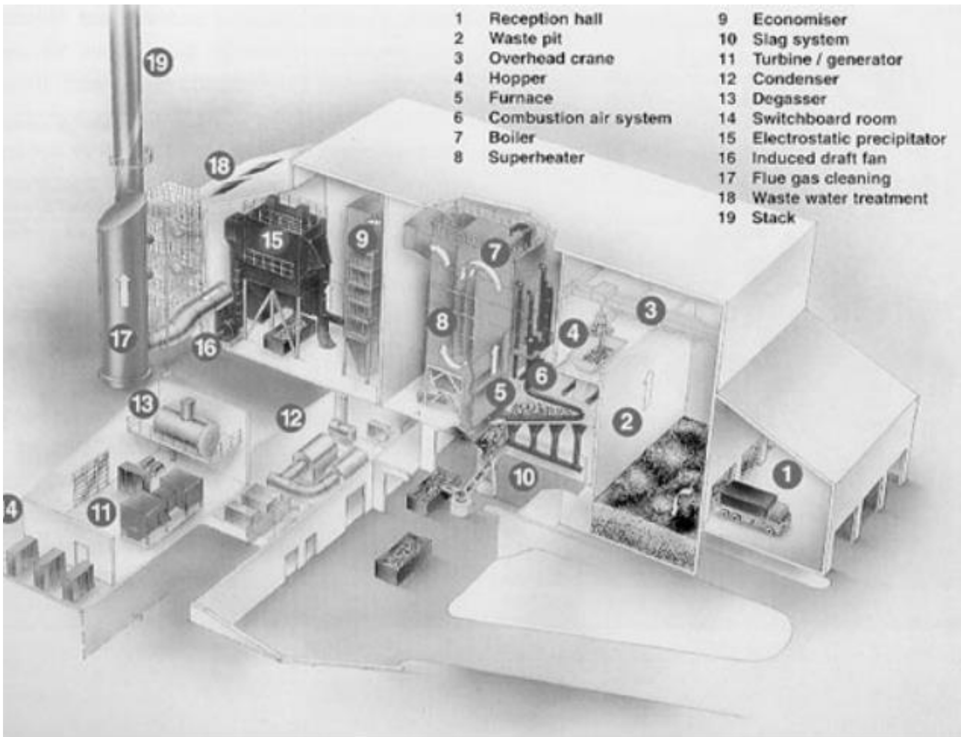


Figure 6-1: steps in a incineration an power plant

The ENERGIZE multistage grate is the core and the bottom surface of the furnace. It carries and transports the burning solid matter from the feeding section to the ash extractor.

The grate consists of identical elements grouped in 3 zones:

Drying zone, combustion zone, burnout zone.

1. In the drying zone, moisture in the waste is evaporated by the heat in the furnace and the radiation from the first empty pass which is positioned just above this zone.

2. In the combustion zone, the actual combustion takes place.

3. The burnout zone is a buffer to guarantee the burnout quality and to cool the ashes.

A step between each zone causes the waste to drop from one zone to the next, creating the necessary mixing of the burning matter[1].

The 3 zones illustrate in the figure 1-2.

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[1] from [FatimaHamed 2015]

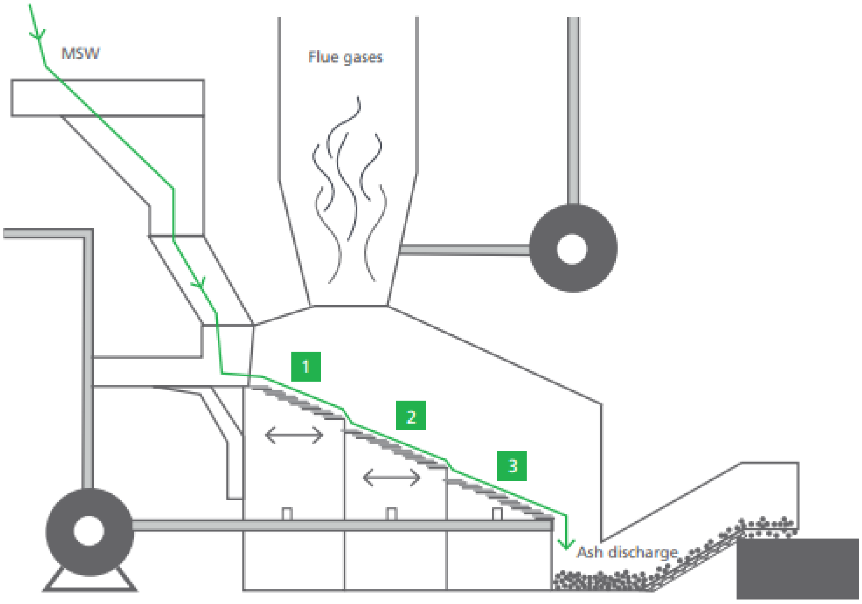

Figure 6-2: illustrating of the incineration power plant zone

There are many applications of waste incineration power plants, especially in Europe, see Figure 1-3, and it is necessary to study them. But it is impossible to view published studies in internet; we can only see the incineration power plant's design with global studies.

Figure 6-3: Distribution of incineration power plant in Europe

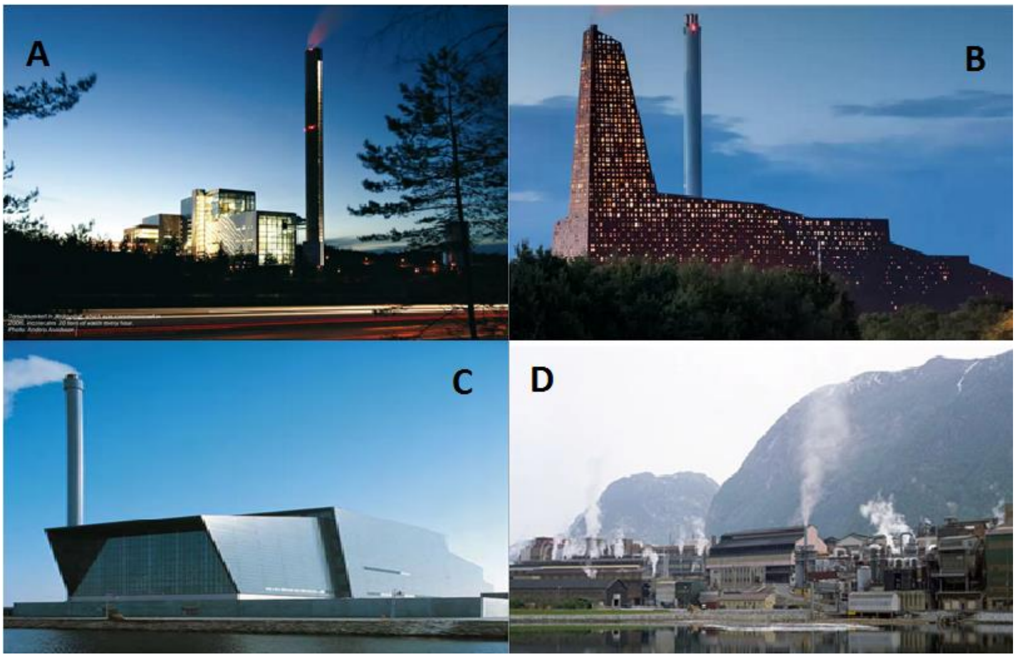

Figure 6-4: An incineration power plant in (A) Torsviksverket in Jönköping (B) Roskilde, Denmark (C) Esbjerg Denmark (D) near Bergen (Oslo).

An incineration plant in Sweden Figure 2-2 (A) represents a similar amount of waste in the industry as well. Waste incineration provides heat corresponding to the needs of 810,000 homes, around 20 per cent of all the district-heating produced. It also provides electricity corresponding to the needs of almost 250,000 homes. International comparisons show that Sweden is the global leader in recovering the energy in waste[2].

In Roskilde, Denmark figure 2-2 (B) when waste from nine surrounding municipalities and from places abroad will be incinerated at the Roskilde plant. According to its developer KARA/NOVEREN, this will be enough to produce electricity for around 65,000 homes and heat for around 40,000 homes[3].

We can say that the incineration power plant of in Esbjerg, Denmark figure 2-2 (C), attached with some historic study concerning development of the incineration power plant design and CFD information[4] in figure 2-3:

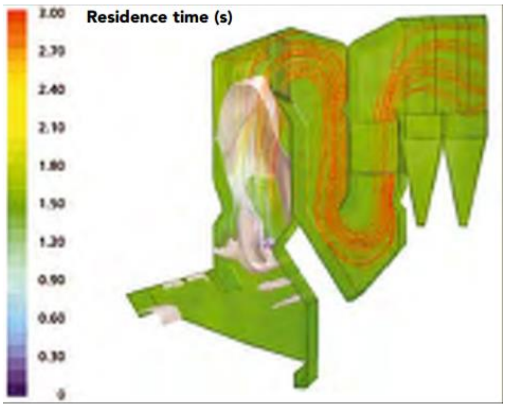

Figure 6-5: CFD plot for assessment of residence time in an afterburning chamber in Esberg, Denmark incineration power plant.

Christoffer Back Vestli says, communications adviser for the Oslo in Bergen figure 2-2 (D): municipality. "At the moment, the city of Oslo can take 410,000 tonnes of waste a year and we import 45,000 tonnes from the UK. Europe as a whole currently dumps 150m tonnes of waste in landfills every year, so there is clearly great potential in using waste for energy."[5]

6.1 Arguments supporting and against incinerations

Usage of incineration for waste management is divisive. The debate for incinerators generally involves business interests, regulations of government, activists of environment and citizens.

6.1.1 Arguments supporting incinerations

The first concern for incineration stands against its injurious effects over health due to production of furans and dioxin emission. However, the emission is controlled to greater extent by developing of modern plants and governmental regulations.

Incineration plants are capable for producing energy and can substitute power generation plants of other sort.

The bottom ash after the process is completed is considered non-injurious that still is capable for being land filled and recycled.

Fine particles are removable by processing through filters and scrubbers.

Treating and processing medical and sewage waste produces non-injurious ash as product.

6.1.2 Arguments against incinerations

Extremely injurious matter needs adequate disposing off. This requires additional miles and need special locations for land filling this material.

Although after a lot of regulations and restrictions and developments concerns are still alive about emission of furans and dioxins.

Incinerating plants are producers of heavy metals, which are injurious even in minor amounts.

IBA (**Incinerator Bottom Ash**) is consistent over a considerably high level of heavy metals and can prove fatal if they are not disposed off or reused properly.

Initial investment costs are only recovered through long periods of contract for incinerating plants.

Local communities always have opposed the presence of incinerating plant in the locality.

The upheld view is to recycle, reuse and waste reduction instead of incineration[6].

6.2 History

In the past, incineration was conducted without separating materials thus causing harm to environment. This unseparated waste was not free from bulky and recyclable materials, even. This resulted in risk for plant workers health and environment. Most of such plants and incinerations never generated electricity.

Incineration reduces the mass of the waste from 70 to 80 percent. This reduction depends upon the recovery degree and composition of materials. This means that incineration however, does not replace the need for landfilling but it reduced the amount to be thrown in it.

Incineration comes with a number of benefits in specific areas like medical wastes and other life risking waste. In this process, toxins are destroyed when waste is treated with high temperature.

Incineration or thermal treatment of waste is much popular in countries like Japan where there is scarcity of land. The energy generated by incineration is highly demanded in countries like Denmark and Sweden. In the year 2005 it was estimated that 4.8 percent of the electricity consumed by Danish nation was produced by incineration and the amount of heat was some 13.7 percent out of total. Other than Denmark and Sweden many European countries are recovering heat and electricity from waste[6].

During the last three or four decades, computer simulations of physical processes have been used in scientific research and in the analysis and design of engineered systems. The systems of interest have been existing or proposed systems that operate at design conditions, off-design conditions, failure-mode conditions, or accident scenarios. The systems of interest have also been natural systems. For example, computer simulations are used for environmental predictions, as in the analysis of surface-water quality and the risk assessment of underground nuclear-waste repositories. These kinds of predictions are beneficial in the development of public policy, in the preparation of safety procedures, and in the determination of legal liability. Thus, because of the impact that modeling and simulation predictions can have, the credibility of the computational results is of great concern to engineering designers and managers, public officials, and those who are affected by the decisions that are based on these predictions[7].

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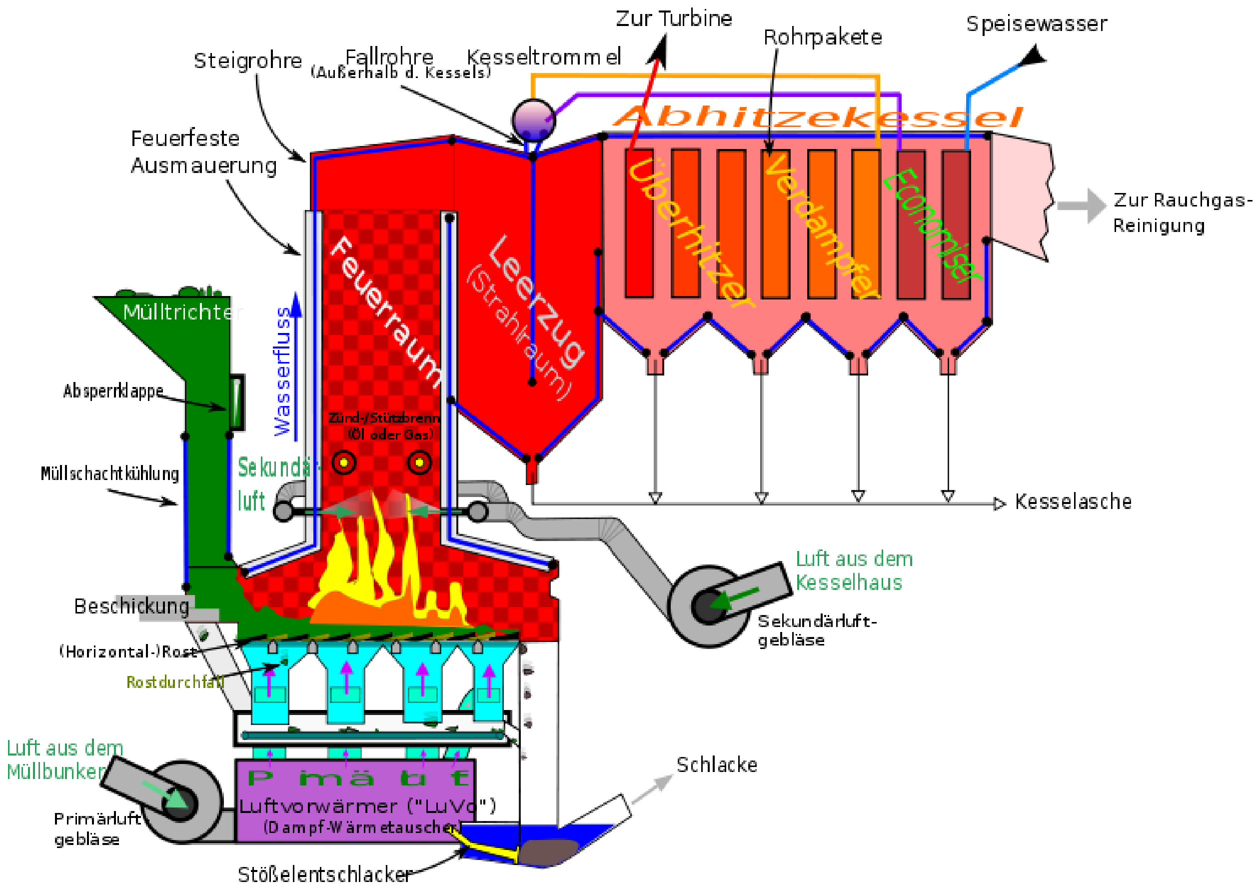
7 Waste Incineration chamber technology[2]

7.1 Incineration (dt. Müllverbrennungsanlage) - Overview / ترميد النفايات - نظرة عامة



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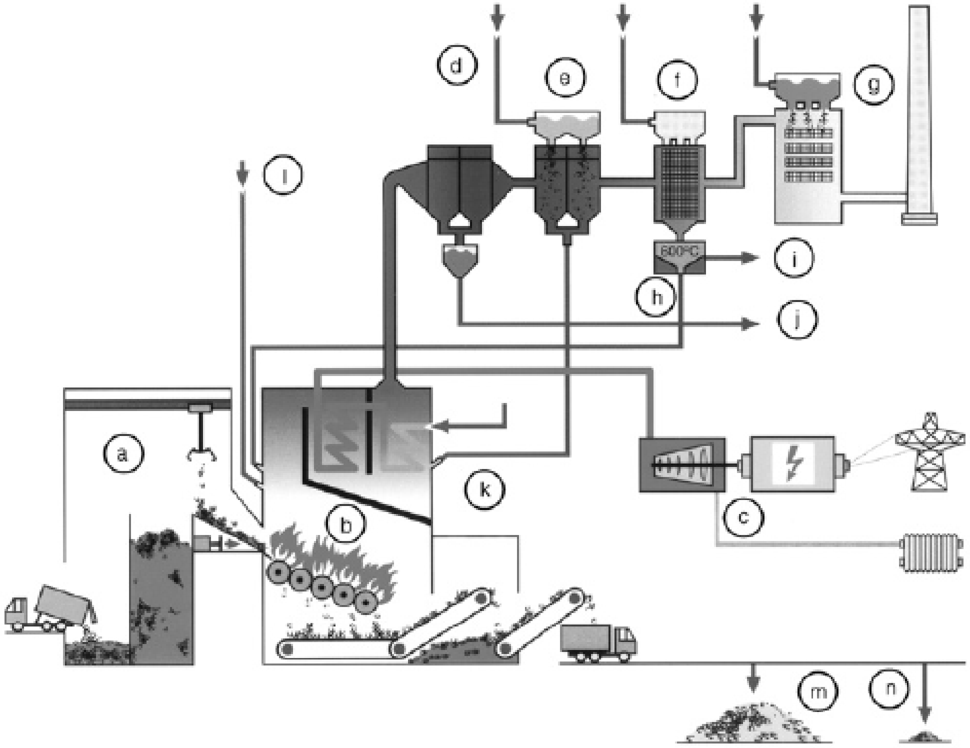
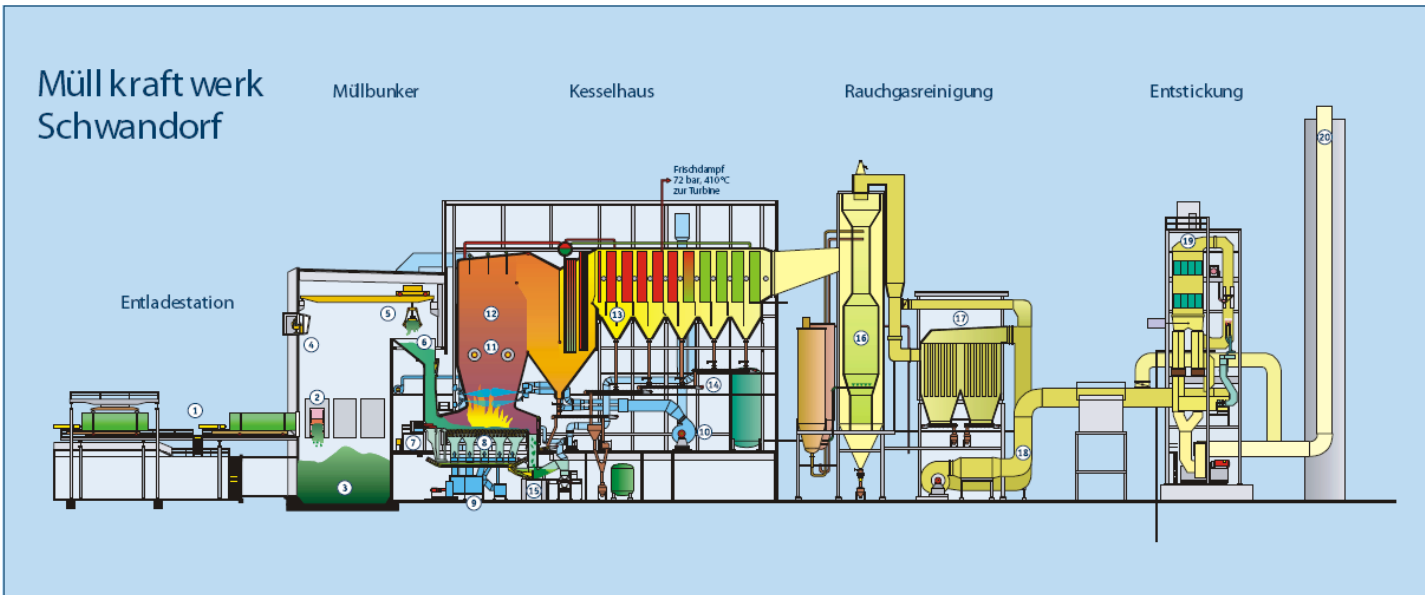
[2] [TEMO-STPP/IPP 2011-2013]



a: Müllbunker, b: Rostfeuerung und Dampferzeugung, c: Turbosatz mit Wärmeauskopplung, d: Elektrofilter, e: Kalkreaktor (Säureabscheidung), f: Aktivkohlefilter (Dioxin/Furan und Schwermetall-Abscheidung), g: SCR Anlage (Entstickung), h: Desorption Aktivkoks, i: Schwermetallausschleusung, j: Rauchgasreinigungs-Reststoffe, k: Reaktionsprodukte aus Kalkreaktor, l: Ammoniakwasser (zur Entstickung), m: Schlacke, n: Schrott

Bild 16.2: Schematischer Schnitt durch ein Müllkraftwerk mit Rostfeuerung [16.5]

(Bild aus Zahornsky, “Energietechnik”)

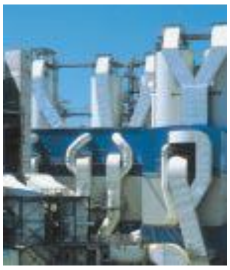


Erläuterung

1. Die Anlieferung von ca. 80 Prozent des Mülls erfolgt über das Ferntransportsystem. An der Müllentladestation wird dieser auf den neun Müllumladestationen von der Straße auf die Schiene umgeschlagene Abfall in den Müllbunker entleert.
2. Ca. 20 Prozent des Abfalls werden mit Müllfahrzeugen direkt auf der Straße angeliefert.
3. Der Müllbunker dient zur Zwischenlagerung des Mülls bis zur Verbrennung. Sein Stapelvolumen von ca. 16.000 m³ reicht beim Betrieb von vier Ofenlinien je nach Fahrweise ca. vier bis sechs Tage.
4. Die Bedienung der Müllkräne erfolgt von der Kranführerkabine aus, die rund um die Uhr besetzt ist. Der Kranführer hat die Aufgabe, die Anlieferung und den Müllbunker zu überwachen, den Müll umzustapeln, zu mischen und die Öfen zu beschicken.
5. Das Fassungsvolumen des Greifers beläuft sich auf 5 m³ bzw 2,5 bis 3 Tonnen.
6. Durch den gefüllten Müllschacht mit Aufgabetrichter wird der Feuerraum gegenüber dem Müllbunker abgeschlossen.
7. Der hydraulische Zuteiler sorgt für eine gleichmäßig dosierte Aufgabe des Mülls auf den Verbrennungsrost.
8. Der Rost wälzt den Müll durch den Feuerraum und gewährleistet eine gute Vermischung mit Verbrennungsluft. Er besteht aus zwei Rostbahnen (links und rechts) sowie vier bzw fünf Verbrennungszonen, die zum Teil wassergekühlt sind.
9. Mit dem Primärluftgebläse wird die notwendige, auf ca. 120 - 160°C vorgewärmte Verbrennungsluft dem Müllbett zugeführt. Die Primärluft wird aus dem Müllbunker abgesaugt, um dort einen leichten Unterdruck zu erzeugen, der den Austritt von Gerüchen und Staub verhindert. Der Luftbedarf je Ofenlinie beträgt je nach Fahrweise zwischen 40.000 und 85.000 m³/h.
10. Durch die Eindüsung von Sekundärluft erfolgt eine Nachverbrennung der entstehenden Gase und eine Verwirbelung. Der Bedarf pro Ofenlinie beträgt je nach Fahrweise zwischen 15.000 und 40.000 m³/h.
11. Die Zünd- und Stützbrenner für leichtes Heizöl werden benötigt, um den Kessel nach Abstellungen wieder aufzuheizen und gegebenenfalls die gesetzlich vorgeschriebene Mindesttemperatur von 850°C bei allen Betriebszuständen zu gewährleisten.
12. Im Feuerraum findet über einen Zeitraum von 1,5 bis 2 Stunden die eigentliche Verbrennung bei Temperaturen bis zu 1.000°C statt.
13. Im anschließenden Kesselteil wird die Temperatur des Rauchgases über eingebaute Wärmetauscher (Überhitzer, Verdampfer und Economiser) bis auf 220°C abgekühlt. Das in den Rohren umfließende Wasser wird dabei verdampft.
14. Der im Rauchgas enthaltene Feststoffanteil, die sog. „Kesselasche", wird an den Heizflächen teilweise abgeschieden und abtransportiert.
15. Die bei der Verbrennung entstandene Schlacke fällt in den Stößelentschlacker, ein mit Wasser gefülltes Becken. Darin wird die glühende Schlacke abgelöscht und der Feuerraum abgedichtet
16. Die erste Stufe der Rauchgasreinigung findet im sog. „Reaktor" statt. Darin wird das 220°C heiße Rauchgas durch Eindüsen von Wasser auf ca. 140°C abgekühlt. Anschließend wird aus den Silos Kalk in den Reaktor eingedüst, der die sauren Bestandteile des Rauchgases, wie z. B. HCl und SO_2 an sich bindet.
17. Im Gewebefilter werden die staubförmigen Bestandteile des Rauchgases ausgefiltert und über entsprechende Fördereinrichtungen in die Reststoffsilos transportiert.
18. Das sog. „Saugzuggebläse" fördert das entstaubte Rauchgas zur nächsten Rauchgasreinigungsstufe.
19. In der Entstickungsanlage werden Stickoxide und Dioxine zerstört.
20. Über den 80 Meter hohen Kamin werden die gereinigten Rauchgase abgeleitet.

Technische Daten

Kapazität:	450.000 t/a
- Kessel 1-3:	je 13,5 t/h
- Kessel 4:	je 23,5 t/h
Dampfmenge:	
- Kessel 1-3:	je 42 t/h
- Kessel 4:	72 t/h
- Hilfskessel	30 t/h
Dampfparameter:	
- Kessel1-4:	72 bar/410°C
- Hilfskessel:	6 bar/158°C
Turbinen:	
- Entnahme-Kondensation:	
- Inst. Leistung:	2 x 11 MW 1 x 32 MW
Rauchgasreinigung:	
- CDAS-Reaktoren:	5
- Gewebefilter:	4
- DeNOx-Linien:	3
- Katalysatorvol.:	3 x 43 m³



Das Werk - Der Weg durchs Feuer

Der über die Schiene antransportierte Müll wird an der Entladestation in den Müllbunker gekippt. Mit großen Greifern wird er in die Aufgabetrichter gefüllt. Von dort aus kommt der Müll in eine der vier Ofenlinien.

Bei Temperaturen zwischen 850° und 1000°C wird der Müll über ein Gegenlauf-Überschubrost-System in knapp zwei Stunden durch den Feuerraum gewälzt und verbrennt dabei. Der Heizwert des Mülls ist dabei so hoch, dass der Brennvorgang ohne Zusatzbrennstoffe auskommt. Lediglich zum Aufheizen des Ofens ist leichtes Heizöl erforderlich. In der Ofenlinie 4 beispielsweise werden 23 Tonnen Müll pro Stunde verbrannt.

Die anfallende Schlacke wird über einen Nassentschlacker abgekühlt. Durch ein Förderband wird sie zum Schlackebunker abtransportiert. Mit einer Magnettrommel werden die Eisenteile aus der Schlacke abgetrennt.

Der Eisenschrott wird in der Stahlindustrie wiederverwertet. Die verbleibende Schlacke wird nach der Aufbereitung in der Deponie Mathiasgrube abgelagert. Sickerwasser wird dort in einer modernen Sickerwasserbehandlungsanlage gereinigt. Die Restschlacke entspricht etwa einem Zehntel des ursprünglichen Müllvolumens.
Mit der bei der Verbrennung gewonnenen**Wärmeenergie** wird im Kessel Dampf erzeugt. Ein Teil wird als Prozessdampf an benachbarte Industriebetriebe abgegeben. Über drei Turbinen wird elektrische Energie gewonnen und ins öffentliche Netz eingespeist.

Seit 1996 versorgt das Müllkraftwerk auch das Fernwärmenetz der Städtischen Wasser- und Fernwärmeversorgung Schwandorf mit **Fernwärme**. Deren Nutzung spart Primärenergie ein, vermindert Emissionen und leistet einen Beitrag zum Klimaschutz.

Die **Rauchgasreinigungsanlage** nach modernsten Gesichtspunkten, die den strengen gesetzlichen Vorgaben zur Luftreinhaltung entspricht, ist zweistufig aufgebaut.

Im ersten Teil, der sog. „CDAS-Anlage"
(= Conditioned Dry Absorption System) wird in einem Reaktor eine Grobstaubabscheidung durchgeführt und werden Schadstoffe gebunden. Diese werden auf dem anschließenden Gewebefilter abgeschieden.

Im zweiten Teil, der „DeNOx-Anlage", erfolgt eine katalytische Zerstörung von Stickoxiden und organischen Schadstoffen (Dioxine, Furane). Die sichere Einhaltung der vorgegebenen Grenzwerte wird durch eine Vielzahl kontinuierlicher Messungen nachgewiesen.

TECHNISCHE DATEN

Kapazität:	**450.000 t/a**

Kessel 1-3:	je 13,5 t/h
Kessel 4:	23,5 t/h
Dampfmenge:	
Kessel 1-3:	je 42 t/h
Kessel 4:	72 t/h
Hilfskessel:	30 t/h
Dampfparameter:	
Kessel1-4:	72 bar / 410°C
Hilfskessel:	6 bar / 158°C
Turbinen:	
Entnahme-Kondensation:	
Inst. Leistung:	2 x 11 MW, 1 x 32 MW
Rauchgasreinigung:	
CDAS-Reaktoren:	5
Gewebefilter:	4
DeNOx-Linien:	3
Katalysatorvol.:	3 x 43 m

7.2 Combustion chamber / غرفة الاحتراق

7.2.1.1 Brennkammer bei Rostfeuerung

Aus Strauss, “Kraftwerkstechnik”:

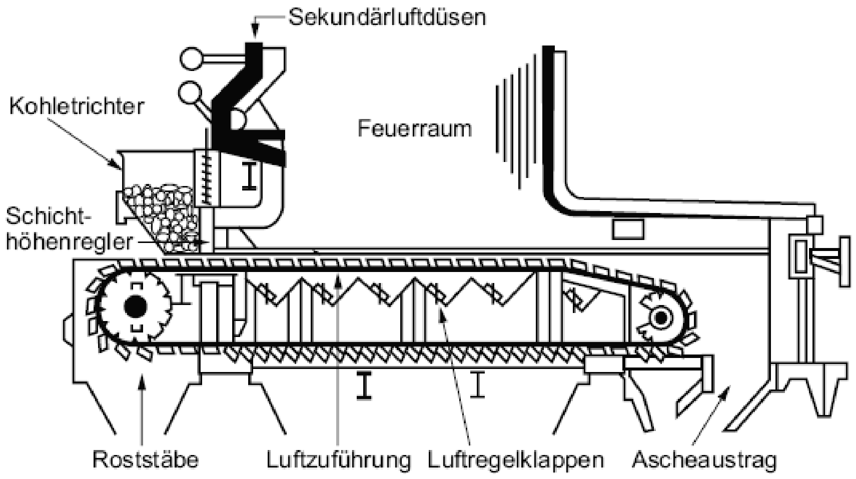
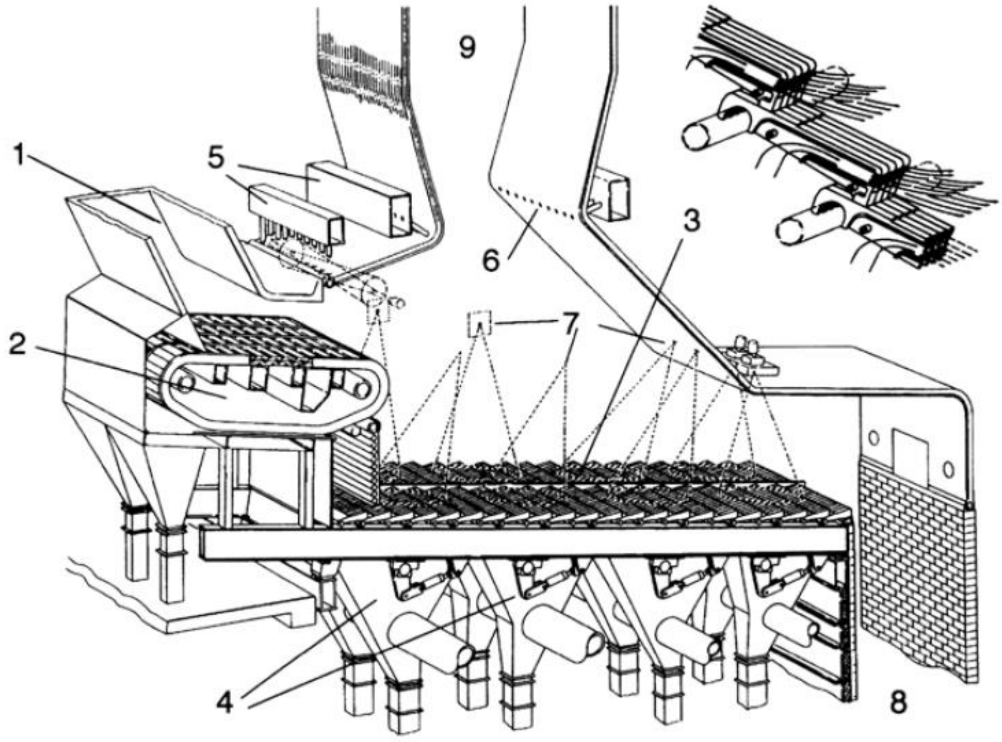


Abbildung 6.3. Schuppen-Wanderrost, Bauart EVT [5]

- Brennstoff- und Luftstellglieder: Zuteiler, Frischlüfter etc.,
- Verbrennungseinrichtung,
- Feuerraum,
- Einrichtungen zum Austrag der Verbrennungsrückstände.

Aus Strauss, “Kraftwerkstechnik”



1 Fülltrichter
2 Beschickungsrost
3 Vorschubrost
4 Primärluftzufuhr
5 Luftkanäle
6 Sekundärluftdüsen
7 Temperaturwächter
8 Aschetrichter
9 Rauchgaskanal

Abbildung 6.6. Vorschubrost zur Müllverbrennung mit mechanischem Antrieb der Roststäbe der Firma EVT [5]

Aus Strauss, "Kraftwerkstechnik"

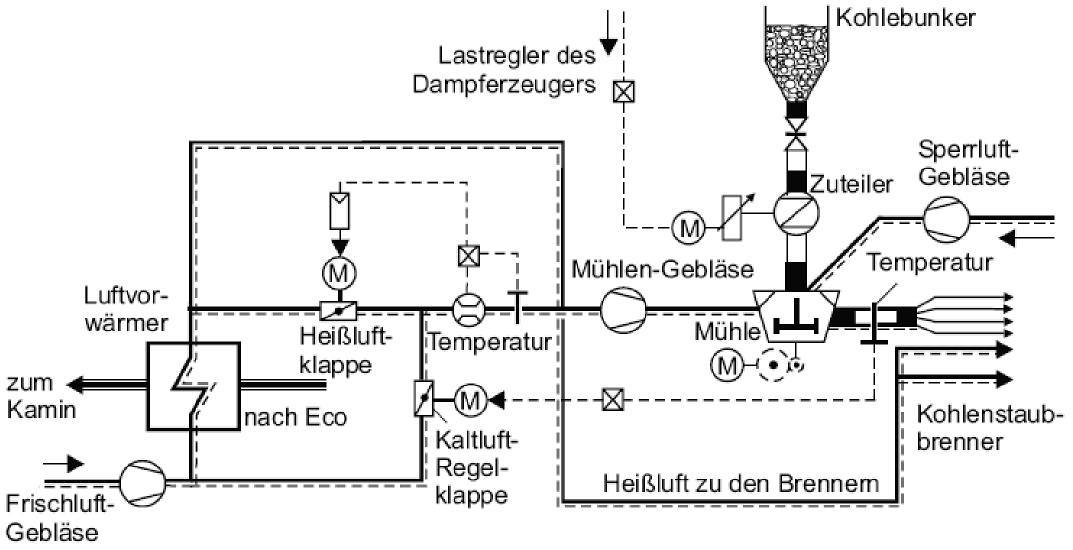
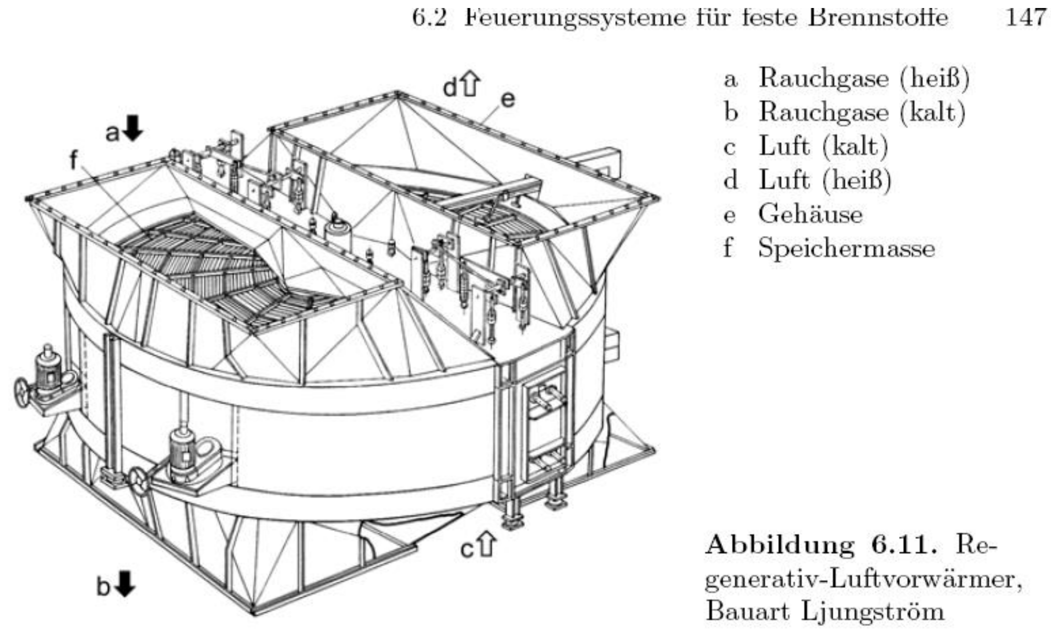


Abbildung 6.7. Schema einer Mahl- und Feuerungsanlage mit Mühlenluftvorwärmer für Steinkohlen

Aus Strauss, "Kraftwerkstechnik"

7.2.2 Air preheater

7.2.2.1 Luftvorwärmer



6.2 Feuerungssysteme für feste Brennstoffe 147

a Rauchgase (heiß)
b Rauchgase (kalt)
c Luft (kalt)
d Luft (heiß)
e Gehäuse
f Speichermasse

Abbildung 6.11. Regenerativ-Luftvorwärmer, Bauart Ljungström

Aus Strauss, “Kraftwerkstechnik”

Steam Generation / توليد البخار 7.3

7.3.1 Border of the combustion chamber

7.3.1.1 Umrandung der Brennraums (des Feuerraums)[3]

Die Dampferzeuger der 1950er-Jahre bestanden fast vollständig aus Mauerwerk, das mit Rohren ausgekleidet war. Die thermischen Belastung, denen die Mauern ausgesetzt waren, führten immer wieder zu Undichtigkeiten und Rauchgasaustritten. Entsprechend oft musste das Mauerwerk repariert werden. Ausserdem entzogen die Mauersteine dem System relativ viel Wärme. Das Mauerwerk limitierte auch die Grösse des Dampferzeugers, denn tragfähige und reparable Kesselhäuser konnten nicht beliebig in die Höhe wachsen.

Erst mit der Entwicklung der Flossenwand, die auch als Membranwand bezeichnet wird, konnte auf das anfällige Mauerwerk verzichtet werden. Eine Flossenwand ist aus senkrecht stehenden, parallelen Rohrsträngen (Steigrohre) aufgebaut, in denen das Wasser siedet (siehe Abbildung 7). Grundlage für die Entwicklung der Flossenwand war die Rohr-Steg-Konstruktion, in der senkrecht stehende Kesselrohre miteinander über Stege gasdicht verschweisst werden. In den 1960er-Jahren vollzog der Kraftwerksbau schliesslich den Übergang von den gemauerten Umfassungswänden zu den vollverschweissten Rohrwänden. Seither werden bei einem Wasserrohrkessel der gesamte Feuerraum und die Strahlungszüge durch Flossenwände ausgebildet, die druckdicht miteinander verschweisst werden, und die von einer thermischen Isolierung aus Mineralwolle umhüllt werden.

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[3] Aus Dr.-Ing. M. Franz, “Dampferzeuger”,www.axpo-holz.ch/Dampferzeuger.pdf

Abbildung 7 Membranwand eines Wasserrohrkessels

Abbildung 8, Erster Kesselzug eines Wasserrohrkessels für 44 t/h Dampferzeugung, aus Franz, „Dampferzeuger“

Austausch der schrägen Hinterwand 1-Zug K 13 (Januar 2010)

7.3.1.2 Strahlungsraum und Konvektionsraum

Das Rohrsystem des Wasserrohrkessel bietet eine bei Beachtung gewisser Randbedingungen ansonsten freizügige konstruktive Gestaltung, wodurch es möglich ist, den Kessel bezüglich Grösse und Form den Feuerräumen und den rauchgasführenden Zügen anzupassen. Im Hochtemperaturbereich des Kessels werden die Rauchgase mit Temperaturen von mehr als 1000°C an Flossenwänden entlang geführt, an die sie ihre Wärmeenergie abstrahlen. Die Intensität der Gasstrahlung hängt neben der Temperatur auch von der Anzahl der im Strahlengang befindlichen Moleküle ab. Die Rauchgase werden daher im Strahlungsteil des Kessels in leeren Kanälen mit grossen Querschnitten (Kesselzügen) geführt, um die für eine Intensivierung der Abstrahlung erforderlichen dicken Gasschichten zu schaffen. In Temperaturzonen mit weniger als 1000°C wird der Wärmeübergang vorwiegend durch Konvektion bewirkt. Im Konvektionsteil des Kessels sind die Rohre daher in enge Pakete gebündelt, die allseitig von den heissen Rauchgasen umströmt werden. Die Kessel werden so ausgelegt, dass ein Grossteil der Wärme als Strahlungswärme übertragen wird.

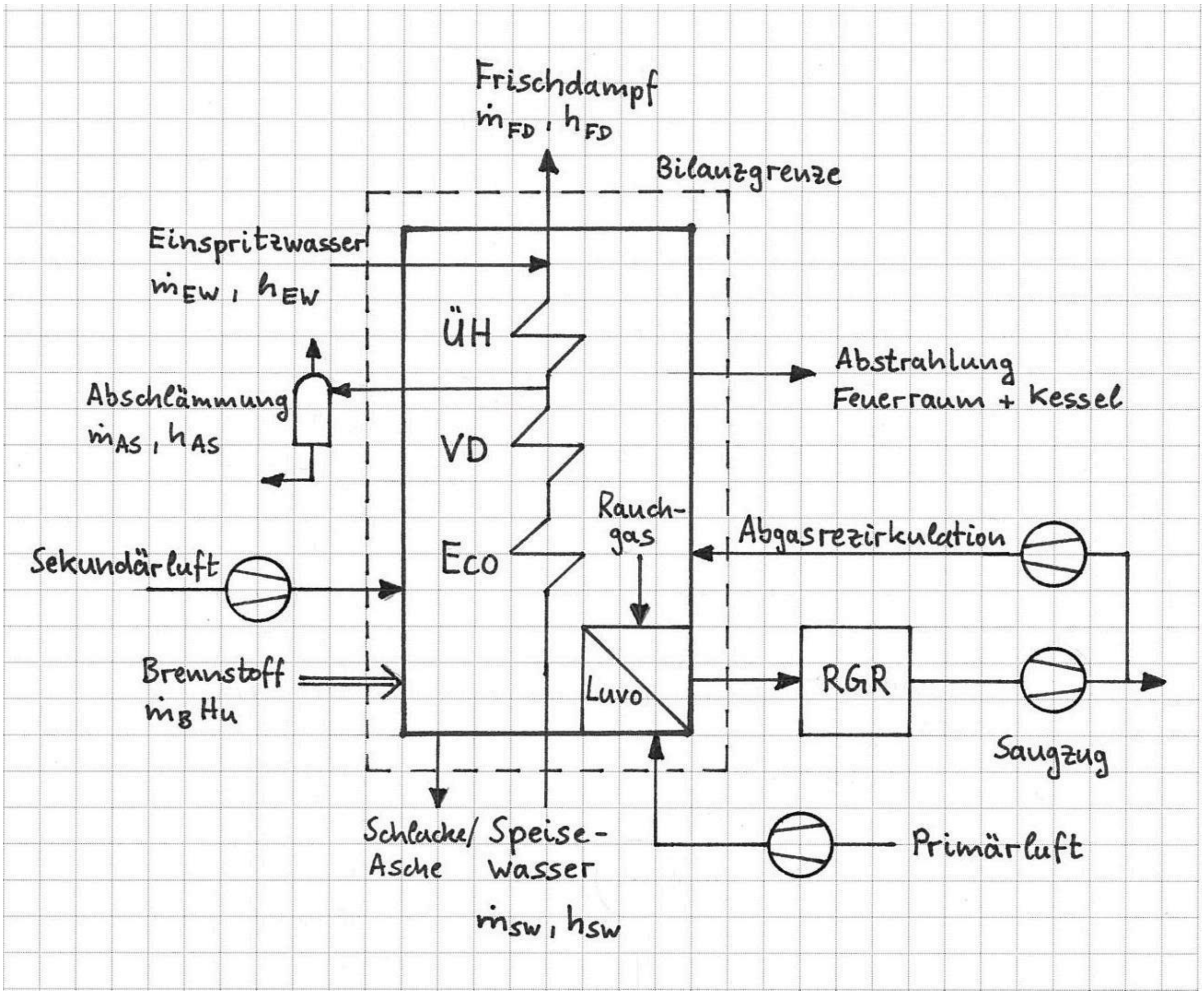


Abbildung 9, Systemgrenzen des Dampferzeugers mit den zu- und abgeführten Wärme- und Masseströmen (Normalsystem) für Abnahmeversuch. Aus Franz, „Dampferzeuger".

Die wichtigste Voraussetzung für die Berechnung des Wirkungsgrades ist die Festlegung der Systemgrenze, über die sich die Energiebilanz des Dampferzeugers erstreckt. Die Systemgrenze muss sich zum einen mit der Liefergrenze des Dampferzeugers decken, zum anderen müssen an den Schnittstellen die Energieströme eindeutig messbar sein. In Abbildung 9 ist die Systemgrenze mit allen zu- und abgeführten Massen- und Wärmeströmen skizziert, die im Normalfall einem Abnahmeversuch zugrunde gelegt wird. Dieses Normal-System umfasst das gesamte Wasser-Dampf-System des Kessels mit Economiser, Verdampfer-Umlaufsystem und Überhitzer, die Feuerung und den Luftvorwärmer. In diesem System sind nicht enthalten die Ventilatoren des Primärluft-, Sekundärluft- und Rauchgasrezirkulationssystems sowie die Rauchgasreinigung mit dem Saugzugventilator.

Die Wärmeverluste des Dampferzeugers setzen sich zusammen aus:

- Rauchgasabwärme nach Luvo
- Verlust durch unverbranntes CO im Rauchgas
- Verluste durch die Enthalpie und das Unverbrannte in der Schlacke und im Flugstaub
- Abstrahlungsverluste von Feuerraum und Kessel

Für die Berechnung des Wirkungsgrades nach der indirekten Methode sind insofern folgende Messgrössen zu ermitteln:

- Rauchgasmassenstrom
- Rauchgastemperatur
- CO-Gehalt des Rauchgases
- Schlackenmassenstrom
- Schlackentemperatur
- Flugstaubmassenstrom
- Anteil an Unverbranntem in der Schlacke
- Anteil an Unverbranntem im Flugstaub

Da die Wärmeverluste durch Strahlung und Leitung $\dot{Q}_{SL}$ im Allgemeinen nicht gemessen werden können, werden hierfür Erfahrungswerte eingesetzt, die in der Gleichung

$$\dot{Q}_{SL} = C\,\dot{Q}_N^{0.7}$$

zusammengefasst wurden, wobei im Falle von Biomassekesseln für die Konstante C der Wert 0.0315 verwendet wird.

7.3.1.3 Siedekrise 1.Art (Rohrplatzgefahr!) und 2.Art

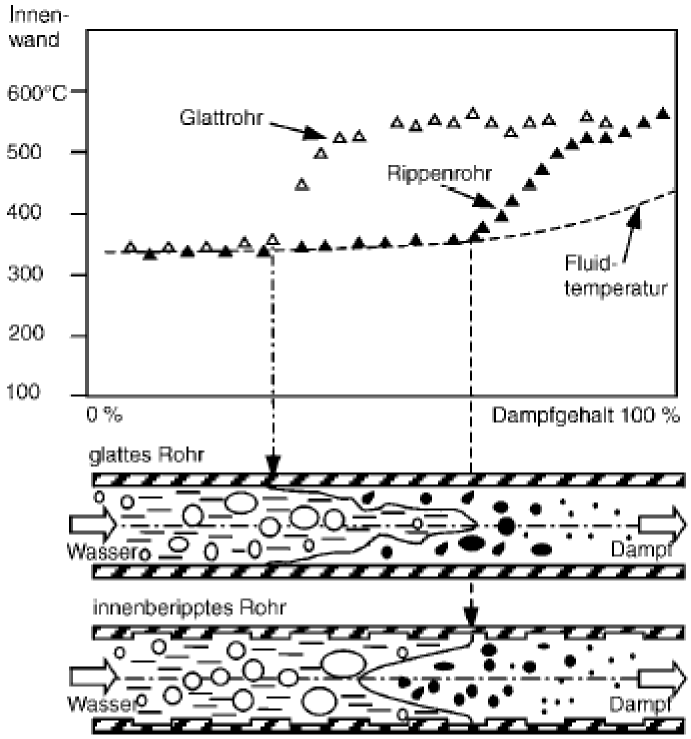


Bild 4.22:
Temperaturerhöhung der Rohrwandung durch die Siedekrise 1. Art (DNB)

In **Bild 4.22** ist die Temperaturerhöhung der Rohrwandung durch DNB aufgezeichnet [4.13]. Die Temperaturerhöhung beträgt in diesem Fall beim glatten Rohr bei einem Dampfgehalt von ca. 55 % über 150 °C. Demgegenüber zeigt das innenberippte Rohr, das in Bild 4.22 dem Glattrohr gegenübergestellt ist, keine Siedekrise 1. Art. Erst im Austrocknungspunkt (Siedekrise 2. Art) bei einem Dampfgehalt von über 90 % steigt die Temperatur des innenberippten Rohres an.

7.3.2 Natural circulation is the choice for biomass power plants

7.3.2.1 Naturumlauf ist die Wahl für Biomassekraftwerke

Die verbreiteteste Kesselbauart in Biomassekraftwerken sind Naturumlauf-Dampferzeuger, die im Vergleich zu den Zwangsdurchlaufkesseln der grossen Kohlekraftwerke mit einem geringeren technischen Aufwand gebaut werden können und einfacher betrieblich zu handhaben sind. Da der Wasserumlauf im Rohrsystem des Naturumlauf-Verdampfers nicht mit Pumpen sondern allein durch Dichteunterschiede angetrieben wird, kann auf eine Umlaufpumpe im Verdampfersystem sowie auf zugehörige Armaturen und Regelsysteme verzichtet werden.
Der Vorteil der Naturumlaufkessel liegt weiter in der einfachen Regelung. Einerseits reguliert sich der Wasserumlauf im Kessel in Abhängigkeit der Beheizung von selbst, andererseits beeinflussen sich die üblichen drei Regelkreise Überhitzertemperatur-Einspritzwasserstrom, Trommelwasserstand-Speisewasserstrom und Dampfleistung-Feuerungsleistung gegenseitig nicht oder nur so, dass sich keine besonderen regelungstechnischen Schwierigkeiten ergeben. Im Ganzen resultiert eine einfachere und fehlertolerante Betriebsweise eines Naturumlaufkessels.

$$\Delta p_H = g\ H\ (\rho' - \rho_m)$$

In Abhängigkeit der Beheizung stellt sich diejenige Umlaufgeschwindigkeit ein, bei der der Druckverlust des Rohrsystems gleich dem treibenden Umtriebsdruck Δp_H ist.

Damit ein stabiler Naturumlauf möglich ist, muss in der Kesseltrommel die Trennung von Wasser und Dampf gut funktionieren. Insbesondere muss durch konstruktive Massnahmen verhindert werden, dass Dampfblasen in die Fallrohre mitgerissen werden. Denn dadurch würde sich der Dichteunterschied zwischen Fall- und Steigrohren verringern. Die Trommel wird daher mit Dampfseparatoren ausgestattet, mit denen sichergestellt werden kann, dass in der Trommel absolut dampffreies Wasser verbleibt. Darüber hinaus werden am Einlauf in die Fallrohre Strudelbrecher angebracht, und die Fallrohre werden mit grossen Durchmessern ausgeführt, um geringe Strömungsgeschwindigkeiten zu erhalten.

Das Naturumlaufprinzip ist ein selbstregulierendes System. Die Kühlung der Verdampferrohre erfolgt durch die umlaufenden Wassermengen, die sich in Abhängigkeit von der Beheizung selbständig einstellen. Eine stärkere Beheizung der Verdampferrohre führt zwangsläufig zu einem höheren Umtriebsdruck und somit zu grösseren Umlaufgeschwindigkeiten. Aufgrund der höheren Strömungsgeschwindigkeiten werden die Verdampferrohre besser gekühlt, so dass keine Gefahr der Überhitzung der Verdampferrohre besteht, was ein grosser Vorteil des Naturumlaufs ist. Da die Dampfabfuhr bereits bei ganz geringen Leistungen erfolgt, ist das Anfahren eines Naturumlaufkessels problemlos. Das Verdampfersystem kann fast bis zur Teillast Null betrieben werden.

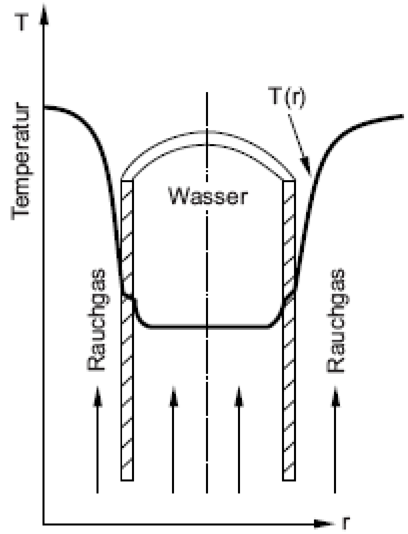


Bild 4.16:
Radialer Temperaturverlauf in und um Verdampferrohr

Bild 4.17 veranschaulicht die Anordnung der einzelnen Wärmeübertragungsstrecken im Dampferzeuger und **Bild 4.18** den Temperaturverlauf mit den Wärmestromdichten. Die Anordnung der Überhitzerstrecken und des Economizers kann vom Schema des Bildes 4.17 abweichen. Anstatt oberhalb des Brennraumes können die Überhitzerstrecken und der Eco auch auf gleicher Ebene daneben gebaut werden, wobei das Rauchgas nach unten geführt wird. Es ergibt sich dann ein niedriger Dampferzeuger, allerdings mit größerem Flächenbedarf. Die Brennkammerwandung ist bei allen Wasserrohrkesseln ähnlich gebaut. Die Rohre sind gasdicht zusammengeschweißt, um einen möglichst großen Wärmestrom zu gewährleisten. Hierzu können die Rohre direkt oder über Zwischenstege (Flossen) zusammengeschweißt sein.

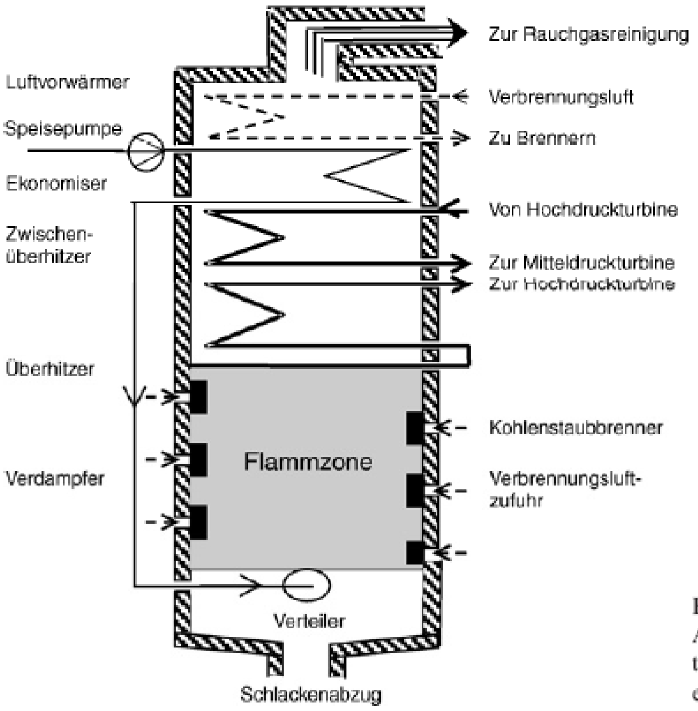
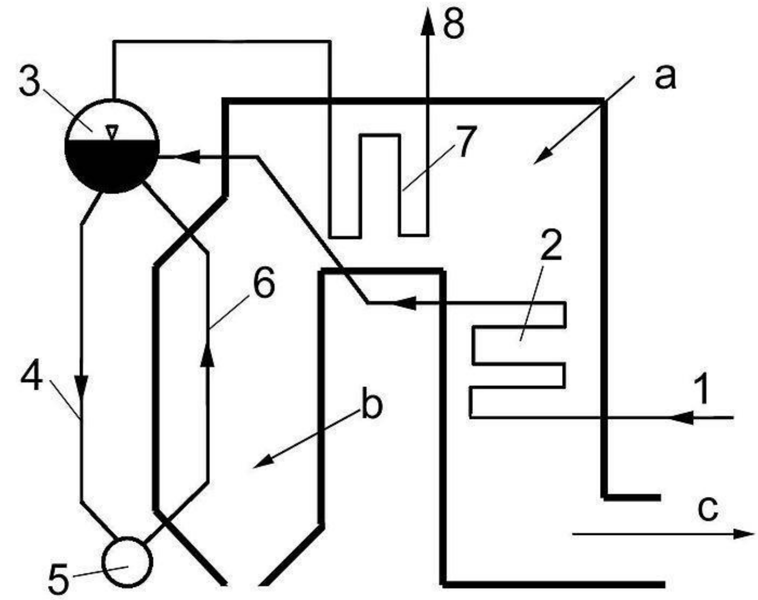


Bild 4.17:
Anordnung der Wärmeübertragerstrecken in einem Dampferzeuger



Naturumlauf-Dampferzeuger: a: Rauchgaskanal, b: Brennraum, c: zur Rauchgasreinigung, 1: von Speisewasserbehälter, 2: Speisewasservorwärmung (ECO), 3: Trommel, 4: Fallrohre, 5: Verteilersammler, 6: Steigrohre, 7: Überhitzer, 8: zur Turbine

7.3.3 Calculation of rise and fall pipes

7.3.3.1 Umlaufberechnung von Steig- und Fallrohren[4]

In Abhängigkeit der Wärmestromdichte in der Brennkammer und des Systemdrucks muss der Naturumlauf zu ausreichend hohen Massenstromdichten in den Verdampferrohren führen, damit deren sichere Kühlung gewährleistet werden kann. Das Umlaufsystem muss daher so ausgelegt werden, dass eine ausreichende und stabile Zirkulation bei allen Lastfällen aufrechterhalten werden kann. Im Rahmen der konstruktiven Ausführung der Fall- und Steigrohre eines Umlaufsystems sollte daher stets eine genaue Umlaufberechnung durchgeführt werden, um zu überprüfen, ob mit den gewählten Rohrquerschnitten und Rohrführungen insbesondere auch bei Teillastbetrieb, d.h. bei geringen Wärmestromdichten, die Umtriebskräfte genügen, um einen ausreichenden Umlauf zu bewerkstelligen.

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[4] Gemäß Franz, „Dampferzeuger“ angewendet auf TEMO-STPP

7.3.3.2 Kräftegleichgewicht am Fallrohr

Zur Umlaufberechnung werden im ersten Schritt die Kräftebilanzen am Fall- und Steigrohr aufgestellt. Das Kräftegleichgewicht am Fallrohr ist in Abbildung 11 skizziert. Die Strömung im Fallrohr soll ausgebildet sein, d.h. das Strömungsprofil ändert sich nicht und die Strömungsgeschwindigkeit am Rohreintritt ist gleich der Austrittsgeschwindigkeit. Es gibt somit keine Impulsänderungen, und es treten daher auch keine resultierenden Impulskräfte auf.

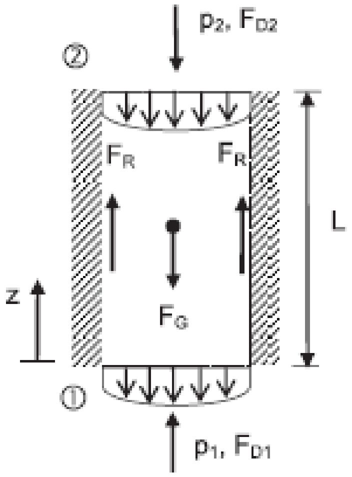


Abbildung 11 Kräftegleichgewicht am Fallrohr

Im **Fallrohr** wirken die folgenden Kräfte:

Druckkraft: $F_D = p\,A_F$

Schwerkraft: $F_G = m\,g = A_F\,H\,\rho\,g$

Reibungskraft: $F_R = \tau\,U_F\,L$

A_F ist die Rohrquerschnittsfläche, U_F ist der Rohrumfang und τ ist die Wandschubspannung, für die der folgende Dimensionsansatz mit dem Reibungsbeiwert λ gemacht wird:

$$\tau = \frac{1}{2}\,\rho\,\bar{u}^2\,\frac{\lambda}{4}$$

Am Fallrohr herrscht ein Kräftegleichgewicht zwischen Druckkräften, Schwerkraft und Reibungskräften. Das Kräftegleichgewicht führt zur Gleichung (1):

$$F_{D1} - F_{D2} + F_R - F_G = 0$$

$$p_1\, A_F - p_2\, A_F + \frac{1}{2}\,\rho\,\overline{u}^2\,\frac{\lambda}{4}\,U_F\,L - A_F\,H\,\rho\,g = 0 \tag{1}$$

Die Dichte im unbeheizten Fallrohr ist konstant und kann mit der Dichte des siedenden Wassers ρ' gleichgesetzt werden. Für das Verhältnis zwischen Rohrumfang und Rohrquerschnittsfläche gibt es einen einfachen Zusammenhang:

$$\frac{U}{A} = \frac{\pi\, D\, 4}{\pi\, D^2} = \frac{4}{D}$$

Damit wird aus Gleichung (1):

$$p_1 - p_2 + \frac{1}{2}\,\rho'\,\overline{u}^2\,\lambda\,\frac{L}{D_F} - \rho'\,g\,H = 0 \tag{2}$$

Mit Einführung der Massenstromdichte $\Phi = \rho\,\overline{u}$ schreibt sich Gleichung (2) in folgender Form:

$$p_2 - p_1 = \frac{L}{2\,D_F}\,\Phi^2\,\lambda\,\frac{1}{\rho'} - \rho'\,g\,H \tag{3}$$

Infolge der Reibungskräfte tritt im Fallrohr ein Druckverlust $\Delta p_R = p_2 - p_1$ auf, der bei einem konstanten Reibungsbeiwert λ quadratisch mit der Massenstromdichte Φ ansteigt, und der um das Gewicht der Flüssigkeitssäule im Rohr vermindert ist.

7.3.3.3 Impulsbilanz am Steigrohr

Die strömungsmechanische Situation am Steigrohr ist deutlich verschieden von der am Fallrohr. Da am Steigrohr Wärme zugeführt wird, siedet das Wasser und es bilden sich Dampfblasen. Das Wasser-Dampfgemisch steigt nach oben. Der Dampfgehalt im Steigrohr nimmt mit zunehmender Höhe zu, entsprechend nimmt die Dichte des Gemisches ab, d.h. es ist $\rho_1 > \rho_2$. Aus der Kontinuitätsgleichung folgt, dass dann die Strömungsgeschwindigkeit $\overline{u}_2$ im Steigrohraustritt grösser als die Strömungsgeschwindigkeit im Rohreintritt sein muss:

$$A_S\,\rho_1\,\overline{u}_1 = A_S\,\rho_2\,\overline{u}_2$$

$$\overline{u}_2 = \frac{\rho_1}{\rho_2}\,\overline{u}_1 > \overline{u}_1$$

Diese Strömungsbeschleunigung hat eine Änderung des Impulsstroms zur Folge. Der Impuls, der pro Zeiteinheit in das Steigrohr eingetragen wird, ist kleiner als der aus dem Steigrohr austretende

Impuls. Am Steigrohr wirken also Impulskräfte F_j, für die folgender Ansatz gemacht werden kann:

$$F_J = \rho\, \bar{u}^2\, A$$

Am Steigrohr treten die folgenden Kraftwirkungen auf:

Druckkraft: $F_D = p\, A$
Schwerkraft: $F_G = m\, g = \rho\, A\, H\, g$
Reibungskraft: $F_R = \frac{1}{2}\, \rho\, \bar{u}^2\, \frac{\lambda}{4}\, U_S\, L_S$
Impulskraft: $F_J = \rho\, \bar{u}^2\, A$

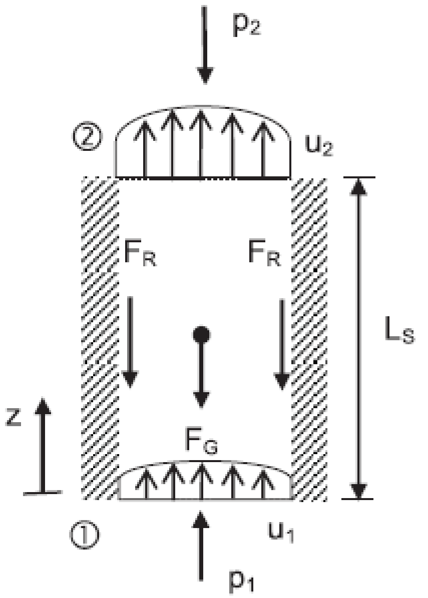
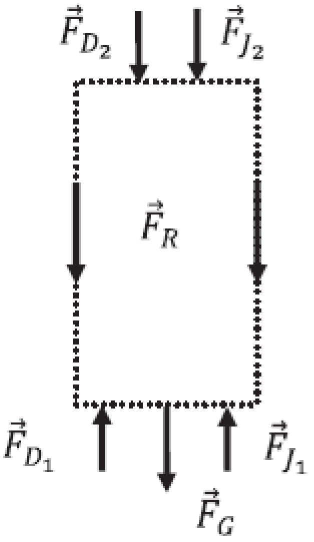


Abbildung 12 Strömung im Steigrohr



Kräfte am Kontrollraum

Abbildung 12 zeigt die Strömung in einem Steigrohr. Der Kontrollraum, der daneben dargestellt ist, und um den die Kräftebilanz aufgestellt wird, umfasst das im Steigrohr befindliche Wasser-Dampfgemisch. Für die am Kontrollraum angreifenden Impulskräfte gilt, dass sie lokal parallel zum Geschwindigkeitsvektor $\vec{u}$ liegen, und stets ins Innere des Kontrollbereichs gerichtet sind.

Der Druckabfall am Steigrohr ergibt sich aus der Impulsbilanz. Der Impulssatz für stationäre Strömungen lautet:

$$\vec{F}_J + \sum \vec{F}_a = 0$$

$$\rho_1\, \bar{u}_1^2\, A + p_1\, A - \rho_2\, \bar{u}_2^2\, A - p_2\, A - \rho_m\, A\, H\, g - \frac{1}{2}\, \rho_m\, \bar{u}_m^2\, \frac{\lambda}{4}\, U_S\, L_S = 0$$

Für ein Rohr ist $\frac{U}{A} = \frac{4}{D}$, damit folgt:

$$\rho_1 \, \overline{u}_1^2 + p_1 - \rho_2 \, \overline{u}_2^2 - p_2 - \rho_m \, H \, g - \frac{1}{2} \, \rho_m \, \overline{u}_m^2 \, \frac{\lambda}{D_S} \, L = 0$$

Mit Hilfe der Kontinuitätsgleichung $\rho_1 \overline{u}_1 = \rho_2 \, \overline{u}_2 = \Phi_S$ kann die folgende Beziehung abgeleitet werden

$$\rho_2 \, \overline{u}_2^2 - \rho_1 \, \overline{u}_1^2 = \Phi_S^2 \left(\frac{1}{\rho_2} - \frac{1}{\rho_1} \right)$$

Mit der die Gleichung weiter vereinfacht werden kann. Setzt man die Dichte ρ_1 am Eintritt in das Steigrohr gleich der Dichte des siedenden Wasser ρ′ dann folgt für den Druckverlust des Steigrohres:

$$p_1 - p_2 = \Delta p_S = \frac{L}{2 \, D_S} \, \Phi_S^2 \, \lambda \, \frac{1}{\rho_m} + \rho_m \, H \, g + \Phi_S^2 \left(\frac{1}{\rho_2} - \frac{1}{\rho'} \right) \tag{6}$$

Anhand von Gleichung (6) wird deutlich, dass sich der Druckverlust des Steigrohres aus drei Beiträgen zusammensetzt. Die beiden ersten Terme (Reibungsanteil und statischer Anteil) sind analog zum Fallrohr, wobei diesmal der hydrostatische Anteil in gleicher Richtung wie die Reibungskraft wirkt. Jedoch kommt infolge der Phasenwechselvorgänge ein dritter Term, ein Beschleunigungsanteil hinzu. Durch die Wärmezufuhr wird ein Teil des Massenstroms verdampft. Dadurch vergrössert sich das spezifische Volumen entlang des Strömungsweges, und die Strömung wird von der langsamen Geschwindigkeit der flüssigen Phase auf die der schnelleren gasförmigen Phase beschleunigt. Die Strömungsbeschleunigung führt zu einer gegen die Strömungsrichtungsrichtung, also in Richtung der Reibungskraft wirkenden Impulskraft. Der Druckverlust im Steigrohr ist demnach auch vom spezifischen Volumen im Steigrohr abhängig und kann bei grossen spezifischen Volumina, d.h. bei hohen Dampfgehalten, stark ansteigen.

7.3.3.4 Eintrittsverluste

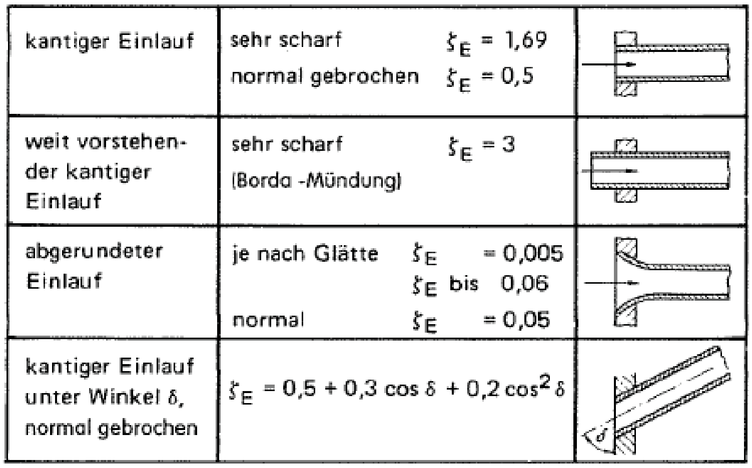
Beim Eintritt des Siedewassers aus den Sammlern in die Verdampferrohre bzw. aus der Kesseltrommel in die Fallrohre kommt es im verengten Rohreinlauf zu einer Kontraktion der Strömung. Infolge der dabei auftretenden Strömungsablösung mit Verwirbelung entstehen an den Rohreintritten immer Strömungsverluste. Zu den Druckverlusten der geraden Fall- und Steigrohrenleitungen Δp_{Rohr} sind daher jeweils noch jeweils noch die Rohreintrittsverluste Δp_E zu addieren.

$$\Delta p_{gesamt} = \Delta p_{Rohr} + \Delta p_E$$

Zur Berechnung der Rohreintrittsverluste Δp_E kann folgender Ansatz gemacht werden:

$$\Delta p_E = \zeta_E \, \frac{1}{2} \, \Phi^2 \, \upsilon' \tag{7}$$

Darin ist ζ_E der Widerstandbeiwert des Rohreintrittverlustes, der in starkem Masse von der Gestaltung der Eintrittsöffnung abhängig ist. In Abbildung 13 sind Widerstandsbeiwerte für unterschiedliche Ausbildungen des Rohreinlaufs angegeben. In den Sammlern und in der Kesseltrommel sind die Rohrmündungen normalerweise so ausgebildet, dass für den Widerstandsbeiwert ein Wert von $\zeta_E = 0.5 - 1.7$ angesetzt werden kann.



kantiger Einlauf	sehr scharf $\zeta_E = 1{,}69$ normal gebrochen $\zeta_E = 0{,}5$
weit vorstehender kantiger Einlauf	sehr scharf $\zeta_E = 3$ (Borda -Mündung)
abgerundeter Einlauf	je nach Glätte $\zeta_E = 0{,}005$ ζ_E bis $0{,}06$ normal $\zeta_E = 0{,}05$
kantiger Einlauf unter Winkel δ, normal gebrochen	$\zeta_E = 0{,}5 + 0{,}3 \cos\delta + 0{,}2 \cos^2\delta$

Abbildung 13 Widerstandsbeiwerte ζ_E für den Auslauf aus Gefässen mit ruhender Flüssigkeit. (Quelle VDI-Wärmeatlas, 10. Auflage)

7.3.3.5 Wasserumlaufberechnung

Ein stark vereinfachtes Umlaufsystem mit einem Fallrohr und einer Flossenwand bestehend aus vier Steigrohren zeigt Abbildung 14. Der gesamte Druckverlust des Druckverlust des Umlaufsystems setzt sich additiv aus dem Beiträgen der hintereinander geschalteten Glieder zusammen, und ergibt sich somit als Summe des Druckverlustes der Flossenwnad und des Fallrohres.

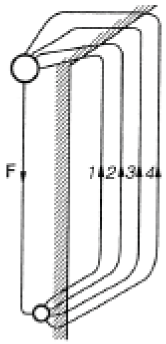


Abbildung 14 Umlaufsystem mit gemeinsamem Fallrohr und parallelen Steigrohren.

In der Flossenwand sind die Steigrohre parallel angeordnet. Für alle Steigrohre ist der Druckverlust zwischen dem unteren Sammler und der Trommel gleich. Daraus folgt, dass der Druckverlust eines beliebigen Steigrohrs gleich dem Druckverlust der Flossenwand ist. Im Umlaufsystem stellt sich der jenige Massenstrom ein, bei dem der Druckverlust in der Flossenwand gleich dem Druckverlust im Fallrohr ist. Die Summe der Druckdifferenzen von Fallrohr und Steigrohr muss Null sein.

$$\Delta p_F + \Delta p_{EF} + \Delta p_S + \Delta p_{ES} = 0$$

Für Δp_F wird Gleichung (3) eingesetzt, und für Δp_S wurde Gleichung (6) hergeleitet. Für die Eintrittsverluste Δp_{EF} bzw. Δp_{ES} wird der Ansatz nach Gleichung (7) verwendet. Dann erhält man:

$$\frac{L_F}{2\,D_F}\Phi_F^2\,\lambda_F\,\frac{1}{\rho'} - \rho' g H + \zeta_{EF}\,\frac{1}{2}\Phi_F^2\,\upsilon' + \frac{L_S}{2\,D_S}\Phi_S^2\,\lambda_S\,\frac{1}{\rho_m} + \rho_m\,Hg + \Phi_S^2\left(\frac{1}{\rho_2} - \frac{1}{\rho'}\right) + \zeta_{ES}\,\frac{1}{2}\Phi_S^2\,\upsilon' = 0$$

In dieser Gleichung ist Φ_F die Massenstromdichte im Fallrohr und Φ_S die Massenstromdichte in einem einzelnen Steigrohr, die aber in jedem der parallel geschalteten Steigrohre gleich gross ist. Wenn A_S der Rohrquerschnitt aller Steigrohre und A_F der Rohrquerschnitt des Fallrohrs ist, kann unter Berücksichtigung der Kontinuitätsgleichung, nach der die Summe der Massenströme durch die Steigrohre gleich dem Massenstrom durch das Fallrohr sein muss, die Massenstromdichte im Fallrohr als Funktion der Massenstromdichte im Steigrohr angegeben werden:

$$\Phi_S\,A_S = \Phi_F\,A_F \;\Rightarrow\; \Phi_F = \Phi_S\,\frac{A_S}{A_F}$$

Mit Hilfe dieser Beziehung wird die Massenstromdichte im Fallrohr Φ_F mit der Massenstromdichte im Steigrohr Φ_S ersetzt. Des Weiteren wird die Gleichung so umsortiert, dass die Summe der Druckverluste auf der rechten Seite und der Umtriebsdruck auf der linken Seite zu stehen kommen.

$$g\,H\,(\rho' - \rho_m) = \frac{L_F}{2\,D_F}\Phi_S^2\left(\frac{A_S}{A_F}\right)^2\lambda_F\,\frac{1}{\rho'} + \zeta_{EF}\,\frac{1}{2}\,\Phi_S^2\left(\frac{A_S}{A_F}\right)^2\upsilon' + \frac{L_S}{2\,D_S}\Phi_S^2\,\lambda_S\,\frac{1}{\rho_m} + \Phi_S^2\left(\frac{1}{\rho_2} - \frac{1}{\rho'}\right) + \zeta_{ES}\,\frac{1}{2}\Phi_S^2\,\upsilon'$$

$$g\,H\,(\rho' - \rho_m) = \frac{1}{2}\,\Phi_S^2\,\upsilon'\left[\left(\frac{A_S}{A_F}\right)^2\left\{\frac{L_F}{D_F}\lambda_F + \zeta_{EF}\right\} + \frac{L_S}{D_S}\lambda_S\frac{\upsilon_m}{\upsilon'} + 2\left(\frac{\upsilon_2}{\upsilon'} - 1\right) + \zeta_{ES}\right] \tag{8}$$

Gleichung (8) ist die Berechnungsgleichung für die Massenstromdichte Φ_S im Steigrohr. Aus Φ_S ergibt sich die Wasserumlaufgeschwindigkeit u_o die als Eintrittsgeschwindigkeit in die Steigrohre definiert ist.

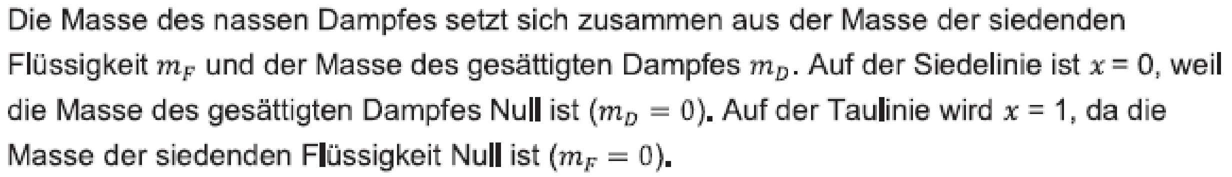
$$u_o = \Phi_S\,\upsilon' \tag{9}$$

Die Wasserumlaufgeschwindigkeit stellt sich so ein, dass die Summe der Druckverluste gleich dem Umtriebsdruck ist. Gleichung (8) lässt sich jedoch direkt nach Φ_S auflösen, da das mittlere spezifische Volumen im Steigrohr υ_m ebenfalls eine Funktion der Massenstromdichte ist.

Dampfgehalt am Ende des Steigrohrs

Zur Berechnung des mittleren spezifischen Volumens und der mittleren Dichte im Steigrohr muss der Dampfgehalt im Steigrohr bekannt sein. Der Dampfgehalt x ist definiert durch:

$$x = \frac{\text{Masse des gesättigten Dampfes}}{\text{Gesamtmasse}} = \frac{m_D}{m_F + m_D}$$



Die Masse des nassen Dampfes setzt sich zusammen aus der Masse der siedenden Flüssigkeit m_F und der Masse des gesättigten Dampfes m_D. Auf der Siedelinie ist $x = 0$, weil die Masse des gesättigten Dampfes Null ist ($m_D = 0$). Auf der Taulinie wird $x = 1$, da die Masse der siedenden Flüssigkeit Null ist ($m_F = 0$).

Die extensiven Zustandsgrößen des nassen Dampfes wie sein Volumen und seine Enthalpie setzen sich additiv aus den Anteilen der beiden Phasen zusammen. Hierzu müssen die Werte des spezifischen Volumens bzw. der speziefischen Enthalpie auf den Grenzkurven (Siedelinie bzw. Taulinie) bekannt sein. Die spezifischen Größen werden für die siedende Flüssigkeit mit einem Strich, für den gesättigten Dampf gleicher Temperatur und gleichen Drucks mit zwei Strichen gekennzeichnet. Dann gilt für das spezifische Volumen und die spezifische Enthalpie im Nassdampfgebiet:

$$v = (1 - x)\, v' + x\, v'' = v' + x(v'' - v')$$

$$h = (1 - x)\, h' + x\, h'' = h' + x\,(h'' - h')$$

Der Dampfgehalt lässt sich nun durch die spezifische Enthalpie ausdrücken. Die Differenz der Enthalpien von gesättigtem Dampf und siedender Flüssigkeit bei gleichem Druck und gleicher Temperatur nennt man die Verdampfungsenthalpie r.

$$x = \frac{h - h'}{h'' - h'} = \frac{h - h'}{r} \tag{10}$$

Am Austritt des Steigrohrs hat die spezifische Enthalpie den Wert h2. Die Enthalpiedifferenz zwischen Steigrohraustritt und Steigrohreintritt $h_2 - h'$ ergibt sich aus einer Energiebilanz um das gesamte Steigrohr.

$$\dot{m}\, h_2 = \dot{m}\, h' + \dot{q}\, L$$

$$h_2 - h' = \frac{\dot{q}\, L}{\dot{m}} \tag{11}$$

$\dot{q}$ ist eine konstante Wärmebelastung pro Längeneinheit (kW/m), mit der das Steigrohr auf der gesamten Länge L beheizt wird. Das Produkt aus beiden Grössen ergibt die gesamte auf ein einzelnes Steigrohr übertragene Wärmeleistung $\dot{Q}$.

$$h_2 - h' = \frac{\dot{Q}}{\Phi_S\, A_S} \tag{12}$$

A_s ist der Rohrquerschnitt eines einzelnen Steigrohres. Mit Gleichung (10) und (12) folgt dann für den Dampfgehalt x_2 am Steigrohraustritt:

$$x_2 = \frac{h_2 - h'}{r} = \frac{\dot{Q}}{\Phi_S\, A_S\, r} \tag{13}$$

7.3.3.6 Berechnung des mittleren spezifischen Volumens im Steigrohr

Im Steigrohr ist das spezifische Volumen im Unterschied zum Fallrohr nicht länger konstant. Am Eintritt in das Steigrohr befindet sich das Wasser im Siedezustand und hat das spezifische Volumen υ'. Infolge der Beheizung des Steigrohrs bilden sich Dampfblasen und das spezifische Volumen des nassen Dampfes vergrössert sich mit zunehmender Steigrohrhöhe. Das spezifische Volumen ist folglich in Strömungsrichtung z veränderlich, während man die Annahme treffen kann, dass im Strömungsquerschnitt das spezifische Volumen annähernd konstant ist. Um das für die praktische Anwendung benötigte mittlere spezifische Volumen υ_m im Steigrohr zu erhalten, werden die lokalen spezifischen Volumina über alle Rohrquerschnitte integriert. Dies führt zum integralen Mittelwert:

$$\upsilon_m = \frac{1}{L}\int_0^L \upsilon(z)\, dz$$

Das spezifische Volumen $\upsilon(z)$, wobei z die Koordinate in Strömungsrichtung darstellt, ist zunächst unbekannt. Jedoch kann mit Hilfe einer differentiellen Energiebilanz die Enthalpieänderung dh als Funktion der Variablen z angeben werden, so dass letztlich mittels einer Variablentransformation, in der die Variable dz durch die Variable dh ersetzt wird, das Integral gelöst werden kann.

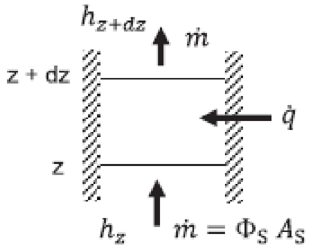


Abbildung 15 Energiebilanz an einem differentiellen Steigrohrelement

Die Enthalpieänderung des Wasser-Dampfgemisches über ein differentielles Steigrohrelement dz ergibt sich aus der in Abbildung 15 skizzierten Energiebilanz.

$$\dot{m}\, dh = \dot{q}\, dz$$

Unter Berücksichtigung von Gleichung (11), die aus einer Energiebilanz um das gesamt Steigrohr hergeleitet wurde, kann nun die Variable dz als Funktion der Enthalpieänderung dh angegeben werden.

$$dz = \frac{\dot{m}}{\dot{q}}\, dh = \frac{L}{h_2 - h_1}\, dh$$

Mittels dieser Variablentransformation ist es möglich, eine geschlossene Lösung für das Integral zu erhalten.

$$v_m = \frac{1}{h_2 - h_1} \int_{h_1}^{h_2} v(h)\, dh$$

$$\begin{aligned}
\int_{h_1}^{h_2} v\, dh &= \int_{h_1}^{h_2} v' + (h - h')\,(v'' - v')\,\frac{1}{r}\, dh \\
&= \left[v'\, h + \left(\frac{1}{2}\, h^2 - h'h\right)\,(v'' - v')\,\frac{1}{r}\right]_{h_1}^{h_2} \\
&= v'\,(h_2 - h_1) + \left[\frac{1}{2}(h_2^2 - h_1^2) - h'(h_2 - h_1)\right](v'' - v')\frac{1}{r}
\end{aligned}$$

Unter Berücksichtigung der binomischen Formel $h_2^2 - h_1^2 = (h_2 + h_1)(h_2 - h_1)$ kann die Gleichung weiter vereinfacht werden.

$$= (h_2 - h_1)\,\left[v' + \left(\frac{1}{2}\,(h_2 + h_1) - h'\right)(v'' - v')\frac{1}{r}\right]$$

Die spezifische Enthalpie im Steigrohreintritt kann mit der Enthalpie des siedenden Wassers gleichgesetzt ($h_1 = h'$). Damit ergibt sich für den Ausdruck v_m/v':

$$\frac{v_m}{v'} = 1 + \left(\frac{1}{2}\, h_2 + \frac{1}{2}\, h' - h'\right)\left(\frac{v''}{v'} - 1\right)\frac{1}{r} = 1 + \frac{h_2 - h'}{2\, r}\left(\frac{v''}{v'} - 1\right)$$

Unter Benutzung von Gleichung (13) $\frac{h_2 - h'}{r} = x_2$ folgt schliesslich:

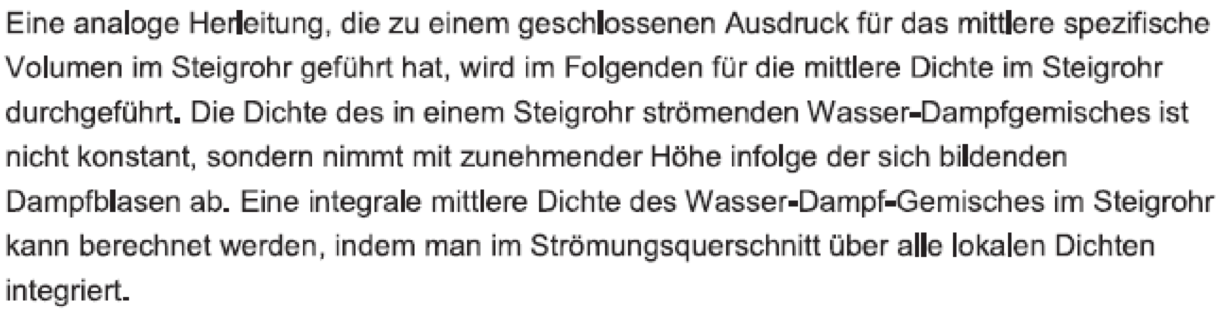
$$\frac{v_m}{v'} = 1 + \frac{x_2}{2}\,\left(\frac{v''}{v'} - 1\right)$$

Im Folgenden wird die Abkürzung m eingeführt, mit der sich in den weiteren Herleitungen die arithmetischen Ausdrücke vereinfachen lassen.

$$m = 1 + x_2\,\left(\frac{v''}{v'} - 1\right) \tag{14}$$

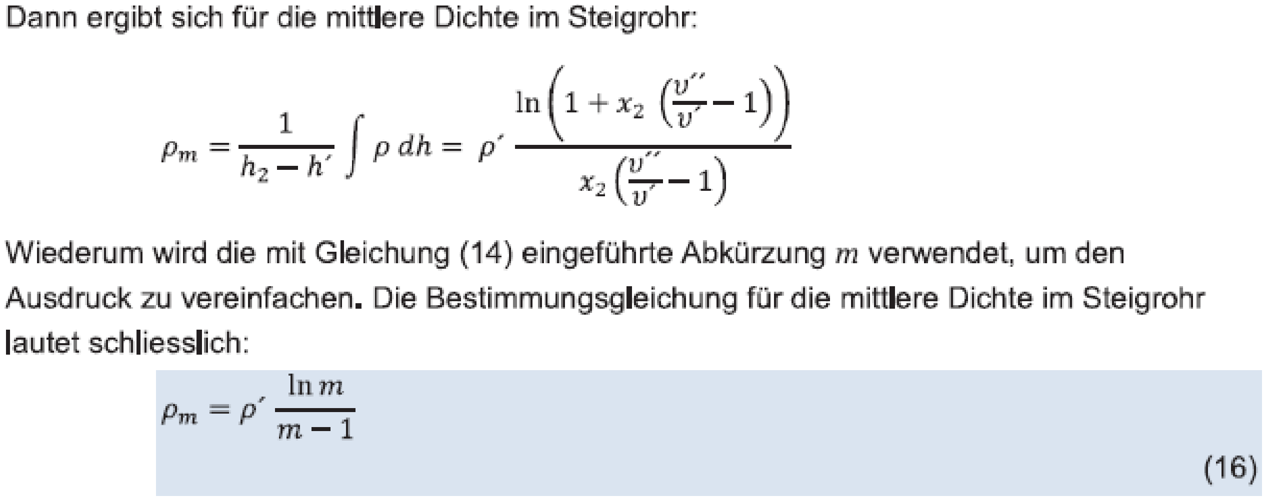
Man erhält dann die Gleichung (15), mit der das mittlere spezifische Volumen im Steigrohr bei bekanntem Dampfgehalt am Steigrohrende berechnet werden kann.

$$\frac{v_m}{v'} = \frac{1}{2}\,(1 + m) \tag{15}$$



Eine analoge Herleitung, die zu einem geschlossenen Ausdruck für das mittlere spezifische Volumen im Steigrohr geführt hat, wird im Folgenden für die mittlere Dichte im Steigrohr durchgeführt. Die Dichte des in einem Steigrohr strömenden Wasser-Dampfgemisches ist nicht konstant, sondern nimmt mit zunehmender Höhe infolge der sich bildenden Dampfblasen ab. Eine integrale mittlere Dichte des Wasser-Dampf-Gemisches im Steigrohr kann berechnet werden, indem man im Strömungsquerschnitt über alle lokalen Dichten integriert.

[…]



Dann ergibt sich für die mittlere Dichte im Steigrohr:

$$\rho_m = \frac{1}{h_2 - h'} \int \rho \, dh = \rho' \frac{\ln\left(1 + x_2 \left(\frac{\upsilon''}{\upsilon'} - 1\right)\right)}{x_2 \left(\frac{\upsilon''}{\upsilon'} - 1\right)}$$

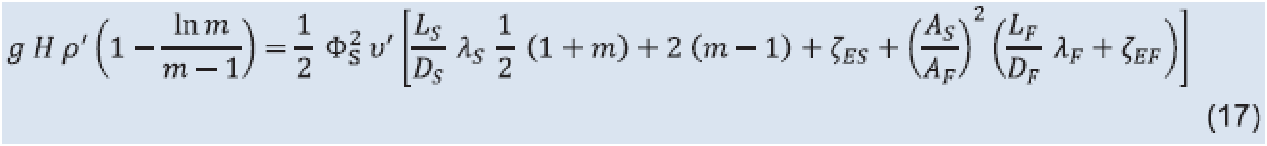
Wiederum wird die mit Gleichung (14) eingeführte Abkürzung m verwendet, um den Ausdruck zu vereinfachen. Die Bestimmungsgleichung für die mittlere Dichte im Steigrohr lautet schliesslich:

$$\rho_m = \rho' \frac{\ln m}{m - 1} \tag{16}$$

7.3.3.7 Solution of water circulation equation

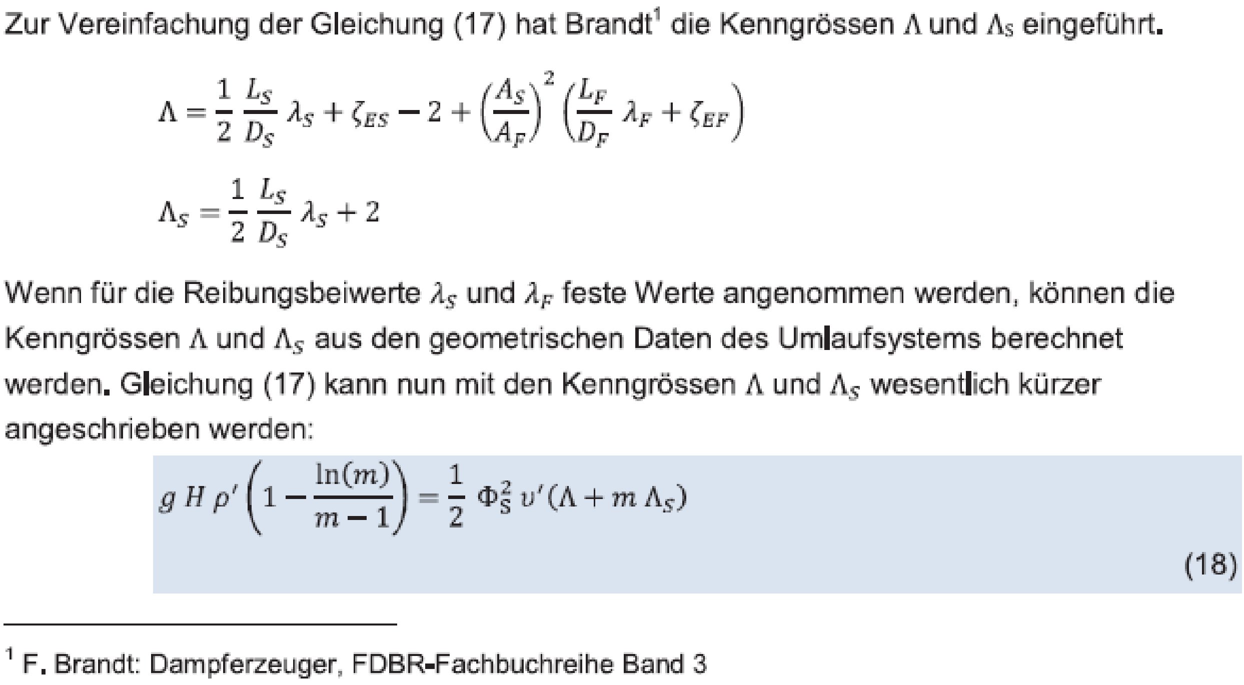
Lösung der Wasserumlaufgleichung

Das mittlere spezifische Volumen und die mittlere Dichte im Steigrohr lassen sich also mit den soeben hergeleiteten Gleichungen als Funktion des Dampfgehaltes im Steigrohraustritt berechnen. Die Parameter sind Druck und Temperatur. Die Gleichungen (15) und (16) werden nun in die Berechnungsgleichung (8) für die Massenstromdichte im Steigrohr eingesetzt, und es ergibt sich:



$$g \, H \, \rho' \left(1 - \frac{\ln m}{m - 1}\right) = \frac{1}{2} \, \Phi_S^2 \, \upsilon' \left[\frac{L_S}{D_S} \, \lambda_S \, \frac{1}{2} \, (1 + m) + 2 \, (m - 1) + \zeta_{ES} + \left(\frac{A_S}{A_F}\right)^2 \left(\frac{L_F}{D_F} \, \lambda_F + \zeta_{EF}\right)\right] \tag{17}$$

[…]



Zur Vereinfachung der Gleichung (17) hat Brandt[1] die Kenngrössen Λ und Λ_S eingeführt.

$$\Lambda = \frac{1}{2}\,\frac{L_S}{D_S}\,\lambda_S + \zeta_{ES} - 2 + \left(\frac{A_S}{A_F}\right)^2 \left(\frac{L_F}{D_F}\,\lambda_F + \zeta_{EF}\right)$$

$$\Lambda_S = \frac{1}{2}\,\frac{L_S}{D_S}\,\lambda_S + 2$$

Wenn für die Reibungsbeiwerte λ_S und λ_F feste Werte angenommen werden, können die Kenngrössen Λ und Λ_S aus den geometrischen Daten des Umlaufsystems berechnet werden. Gleichung (17) kann nun mit den Kenngrössen Λ und Λ_S wesentlich kürzer angeschrieben werden:

$$g\,H\,\rho'\left(1 - \frac{\ln(m)}{m-1}\right) = \frac{1}{2}\,\Phi_S^2\,\upsilon'(\Lambda + m\,\Lambda_S) \tag{18}$$

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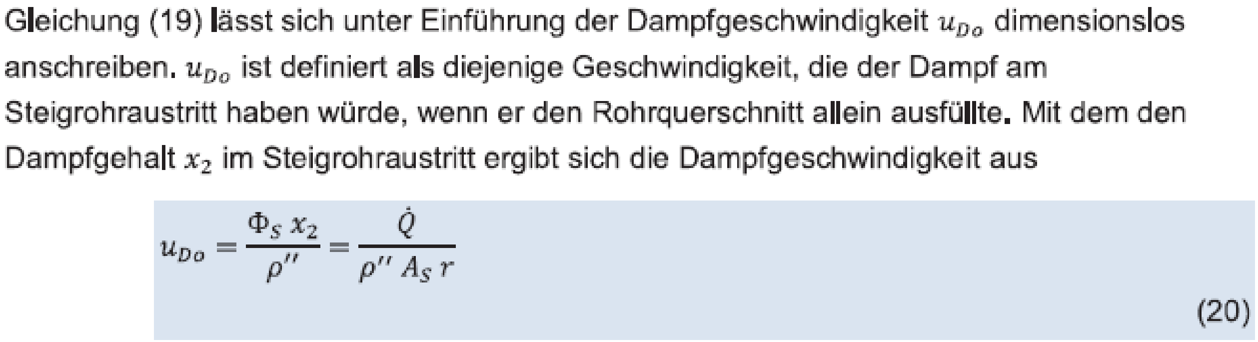
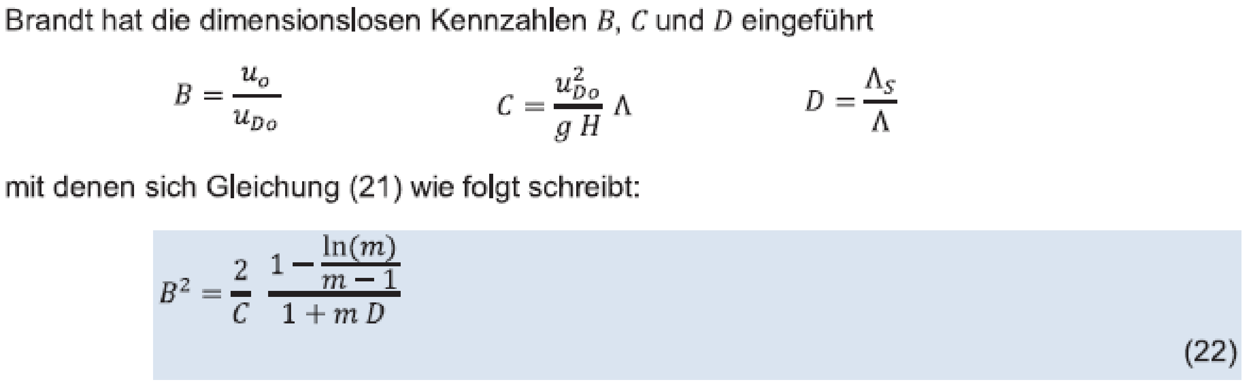
[1] F. Brandt: Dampferzeuger, FDBR-Fachbuchreihe Band 3



Gleichung (19) lässt sich unter Einführung der Dampfgeschwindigkeit u_{Do} dimensionslos anschreiben. u_{Do} ist definiert als diejenige Geschwindigkeit, die der Dampf am Steigrohraustritt haben würde, wenn er den Rohrquerschnitt allein ausfüllte. Mit dem den Dampfgehalt x_2 im Steigrohraustritt ergibt sich die Dampfgeschwindigkeit aus

$$u_{Do} = \frac{\Phi_S\,x_2}{\rho''} = \frac{\dot{Q}}{\rho''\,A_S\,r} \tag{20}$$

[…]



Brandt hat die dimensionslosen Kennzahlen B, C und D eingeführt

$$B = \frac{u_o}{u_{Do}} \qquad C = \frac{u_{Do}^2}{g\,H}\,\Lambda \qquad D = \frac{\Lambda_S}{\Lambda}$$

mit denen sich Gleichung (21) wie folgt schreibt:

$$B^2 = \frac{2}{C}\,\frac{1 - \dfrac{\ln(m)}{m-1}}{1 + m\,D} \tag{22}$$

[…]

Zur Bestimmung der Kennzahl B, aus der dann die Wasserumlaufgeschwindigkeit berechnet werden kann, muss Gleichung (22) numerisch gelöst werden. Zuvor wird mit dem bekannten

Wärmestrom $\dot{Q}$ mittels Gleichung (20) die Dampfgeschwindigkeit u_{Do} am Steigrohraustritt berechnet. Damit erhält man die Kennzahl C. Die Berechnung der Kennzahl D aus den bekannten geometrischen Grössen ist ebenfalls möglich. Dann kann Gleichung (22) numerisch gelöst werden, und aus B folgt die Wasserumlaufgeschwindigkeit.

Die im Verdampfer umlaufende Wassermenge ist eine wichtige Grösse im Kesselbetrieb. In der Praxis wird aber anstelle der Wasserumlaufgeschwindigkeit die Wasserumlaufzahl U verwendet, die definiert ist als das Verhältnis des gesamten Massenstromes in den Steigrohren zum Dampfmassenstrom am Ende der Steigrohre:

$$U = \frac{\dot{m}}{\dot{m}_D} = \frac{u_o\, \rho'\, A_S}{u_{Do}\, \rho''\, A_S} = B\, \frac{\rho'}{\rho''}$$

Der Kehrwert der Wasserumlaufzahl ist der Dampfgehalt x_2 am Ende des Steigrohres.

$$x_2 = \dot{m}_D / \dot{m} = 1/U$$

Die Wasserumlaufzahl ist stark vom Druck abhängig. Zur Sicherstellung einer ausreichenden Kühlung im Rohrsystem zwischen einem 5 bis 12-fachen Umlauf liegen. Dies entspricht einem Dampfgehalt von 20% bis 8,5% im Steigrohraustritt.

Bei kleinen Umlaufzahlen kann unter Umständen am Rohraustritt bereits überhitzter Dampf vorhanden sein, wodurch gegebenenfalls die Rohrwandtemperatur so hoch wird, dass der zulässige Festigkeitswert überschritten wird, und das Rohr reist.

7.3.3.8 Specification of Block III of wood power plant Domat / Ems from [Franz, „Dampferzeuger“]

Technische Daten des Dampferzeugers	
Frischdampfleistung	42 t/h
Frischdampfparameter	480°C, 64 bar (u)
Kesselfüllung	40 m^3
Höhe zwischen unterem Sammler und Mitte Kesseltrommel	20.25 Meter
Steigrohre	
Anzahl	350
Aussendurchmesser	44.5 mm
Innendurchmesser	35.5 mm
Wandstärke	4.5 mm
Reibungsbeiwert	0.019
Querschnittsfläche aller Steigrohre	0.346 m^2
Fallrohre	
Anzahl	2
Aussendurchmesser	329.9 mm
Innendurchmesser	285.5 mm
Wandstärke	22.2 mm
Reibungsbeiwert	0.011
Querschnittsfläche aller Fallrohre	0.128 m^2

Montage. Bei einer Feuerungswärmeleistung von 38 MW werden im Kessel 42 t/h Frischdampf mit 65 bar(a) und 480°C erzeugt. Die wirksame Höhe des Naturumlaufsystems, d.h. der Abstand zwischen den unteren Sammlern und der Kesseltrommel beträgt 20.25 m.

Der Wasserrohrkessel ist in 4-Zug-Vertikalbauweise ausgeführt. Die Wände des ersten und zweiten Rauchgaszuges bestehen aus vollverschweissten, gasdichten Flossenrohrwänden, wobei der erste Zug als reiner Strahlungsteil mit einer Schottenheizfläche ausgeführt ist. Im zweiten Zug befinden sich zwei Verdampferbündel und drei Überhitzerbündel. Der dritte und vierte Rauchgaszug sind reine Konvektionszüge ohne Flossenrohrwände, in die Economiser-Heizflächenbündel und Röhrenluftvorwärmer eingehängt sind.

Vaporizer

Der Verdampfer besteht aus vollverschweissten Flossenwänden, in denen etwa 360 Siederohre parallel geführt werden. Die Steigrohre haben Aussendurchmesser von 44.5 mm und eine Wanddicke von 4.5 mm. Die Stegbreite liegt zwischen 33 und 60.5 mm. Das Fallrohrsystem besteht aus zwei Rohren mit einem Aussendurchmesser von 330 mm, die ausserhalb der Dampferzeugerverkleidung verlegt sind. Das Flächenverhältnis der Strömungsquerschnitt von Steig- zu Fallrohren ist 2.7. Generell sollte ein Naturumlaufkessels so konstruiert werden, dass der Gesamtquerschnitt der Fallrohre 25-50% des Querschnitts aller Steigrohre beträgt. Ein grösserer Fallrohrdurchmesser erhöht die Zuverlässigkeit des Umlaufsystems, da sich die umlaufenden Massenströme vergrössern.

Zur sicheren Kühlung der Siederohre muss eine Massenstromdichte von mindest. 600 kg/(m^2 s) .

7.3.4 boiler drum - water / steam separation

Kesselrommel - Wasser/Dampftrennung

Eine Wasser/Dampftrennung wird bei Systemen mit festgehaltenem Verdampfungsendpunkt

in allen Lastbereichen durchgeführt, bei Zwangdurchlauf mit Schwachlastumwälzung dagegen nur im Schwachlastbereich. Die Wasser/Dampftrennung wird bei Naturumlauf- und Zwangumlaufsystemen in

Trommeln und bei Zwangdurchlaufsystemen in Abscheidern vorgenommen. Die Abscheider haben gegenüber den Trommeln den Vorteil, daß sie wesentlich geringere Wanddicken aufweisen und damit größere Temperaturtransienten zulässig sind, vgl. Abb. 7.4.

[…]

In den Trommeln erfolgt die Wasser/Dampftrennung bei Anlagen mit einer Dampfleistung unter ca. 250 t/h und Drücken unter ca. 140 bar im einfachsten Falle durch die Schwerkraft oder mit Hilfe von einfachen Einbauten, vgl. Abb. 7.21.

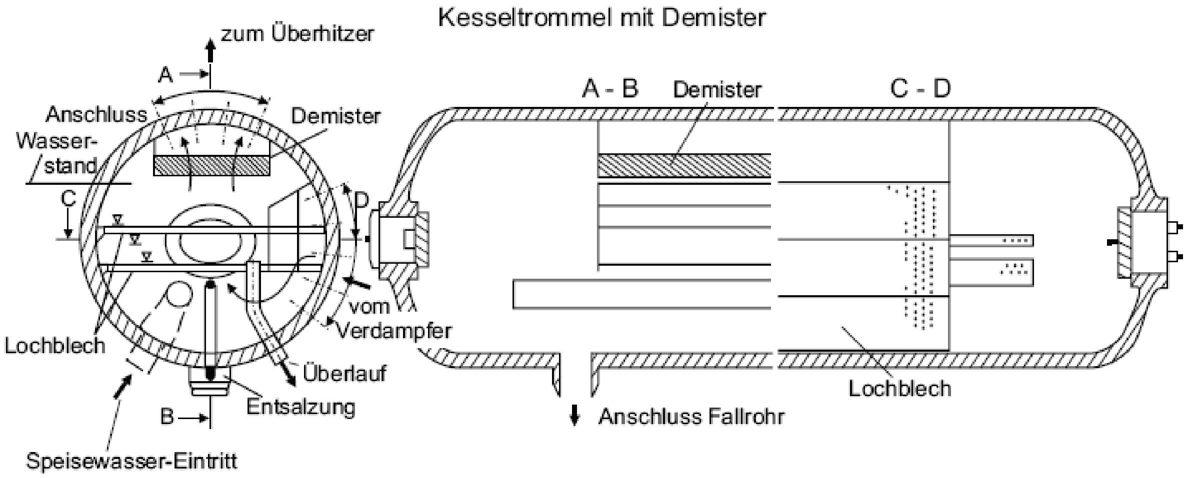


Abbildung 7.21. oben (aus Strauss, „Kraftwerkstechnik“) Trommelbauarten. Oben ist eine Trommel fuer Anlagen mit Drücken bis ca. 150 bar dargestellt, die zur Unterstützung der Dampfabscheidung

Lochbleche zur Vermeidung einer Wellenbildung und Tropfenfänger (Demister) besitzt.

Die Einbauten müssen so ausgeführt sein, dass das abgeschiedene Wasser frei in den Wasserraum ablaufen kann und nicht von anderen Dampfstrahlen wieder aufgewirbelt wird. Für eine gute Abscheidung muss eine ausreichend grosse Trennfläche zwischen der Wasser- und Dampfphase zur Verfügung stehen.

Die Geschwindigkeit des aufsteigenden Dampfes muss so gering sein, dass keine Wassertropfen mitgerissen werden. Diese Bedingung verlangt eine Mindestgrösse für den Dampfraum einer Trommel:

$$V_{\mathrm{D}} = \frac{\dot{m}_{\mathrm{D}}}{\rho_{\mathrm{D}}\,\Delta} \tag{7.17}$$

mit

V_{D} Größe des Dampfraumes in m^3,
ρ_{D} Dichte des Sattdampfes in $\mathrm{kg/m}^3$,
$\dot{m}_{\mathrm{D}}$ Dampfmassenstrom in kg/s und

Δ Dampfraumbelastung $(\dot{V}_{\mathrm{D}}/V)$ in s^{-1}.

Für die Dampfraumbelastung liegen Erfahrungswerte vor. Sie hängt wesentlich vom Dampfdruck und von der Speisewasserqualit¨at ab; f¨ur die maximal zulässige Dampfraumbelastung gilt die empirische Beziehung

$$\Delta_{\mathrm{max}} = 0{,}264 \cdot 10^3\, p^{-0{,}7}\, \lambda^{-0{,}61}\ [\mathrm{s}^{-1}]\,. \tag{7.18}$$

Hier ist p der Trommeldruck in bar und λ die elektrische Leitf¨ahigkeit des Kesselspeisewassers in Mikrosiemens pro cm (µS/cm). Zwischen der Leitf¨ahigkeit und dem Salzgehalt besteht ein direkter Zusammenhang; durchschnittlich entspricht einem Salzgehalt von 1 mg/l ein Leitf¨ahigkeitswert von 2 µS/cm. Grunds¨atzlich nimmt die Abscheidewirkung der Trommel mit zunehmender Dampfraumbelastung ab. Die zul¨assige Dampfraumbelastung h¨angt nat¨urlich auch von der Einf¨uhrung der Steigrohre in die Trommel und den Einbauten ab. Bei Dampferzeugern f¨ur Kraftwerke werden in die Trommel meist kleine Zyklone eingebaut, die die Wasser/Dampftrennung zus¨atzlich unterst¨utzen. Mit solchen Einbauten werden Abscheidegrade von > 98% erreicht, vgl. Abb. 7.21.
Die zul ¨ assige Dampfraumbelastung verliert bei dieser Konstruktion ihre Bedeutung.
Der Trommeldurchmesser wird vielmehr durch den Platzbedarf der

Zyklone bestimmt. Bei Kraftwerksdampferzeugern werden bei Trommeldurchmessern von ca. 2 m Leistungen von 50 t/h je Meter Trommell ¨ ange erreicht.
Die Zuf ¨ uhrung des Speisewassers soll gleichm ¨ aßig ¨ uber die L ¨ ange der Trommel erfolgen und darf weiter den Abscheidevorgang in der Trommel nicht st ¨ oren. ¨ Ublicherweise ist die Trommel etwa zur H ¨ alfte mit Wasser gef ¨ ullt, wo7.3

Der Verdampfungsprozeß 211
bei im Betrieb ein Mindestwasserstand nicht unterschritten und ein Höchstwasserstand
nicht überschritten werden darf. Bei zu geringem Wasserstand
besteht die Gefahr, daß die Verdampferrohre nicht ausreichend mit Wasser
versorgt und damit örtlich überhitzt werden. Bei zu hohem Wasserstand und
auch bei starken Wasserstandschwankungen sowie großen Dampfentnahmen
kann Wasser aus der Trommel in die Überhitzer mitgerissen werden. Das Mitreißen
von Wasser ist deshalb gefährlich, weil im Trommelwasser Salze gelöst
sein können. Diese lagern sich beim Verdampfen in den Überhitzerrohren ab;
durch die Isolierwirkung der Ablagerungen wird das Rohrmaterial an diesen
Stellen langsam überhitzt und kann schließlich reißen.
Bei der Konzeption derWasserstandsregelung ist zu beachten, daß es durch
die erhöhte Einspeisung von unterkühltem Speisewasser in die Trommel zu einer
Kondensation von im Trommelwasser vorhandenen Dampfblasen kommt.
Dadurch kann es unter gewissen Randbedingungen zu einer Umkehr der Niveaubewegung
kommen: Bei einer Erhöhung des Speisewasserstromes sinkt
der Wasserspiegel zunächst und beginnt erst nach einer gewissen Zeit anzusteigen.

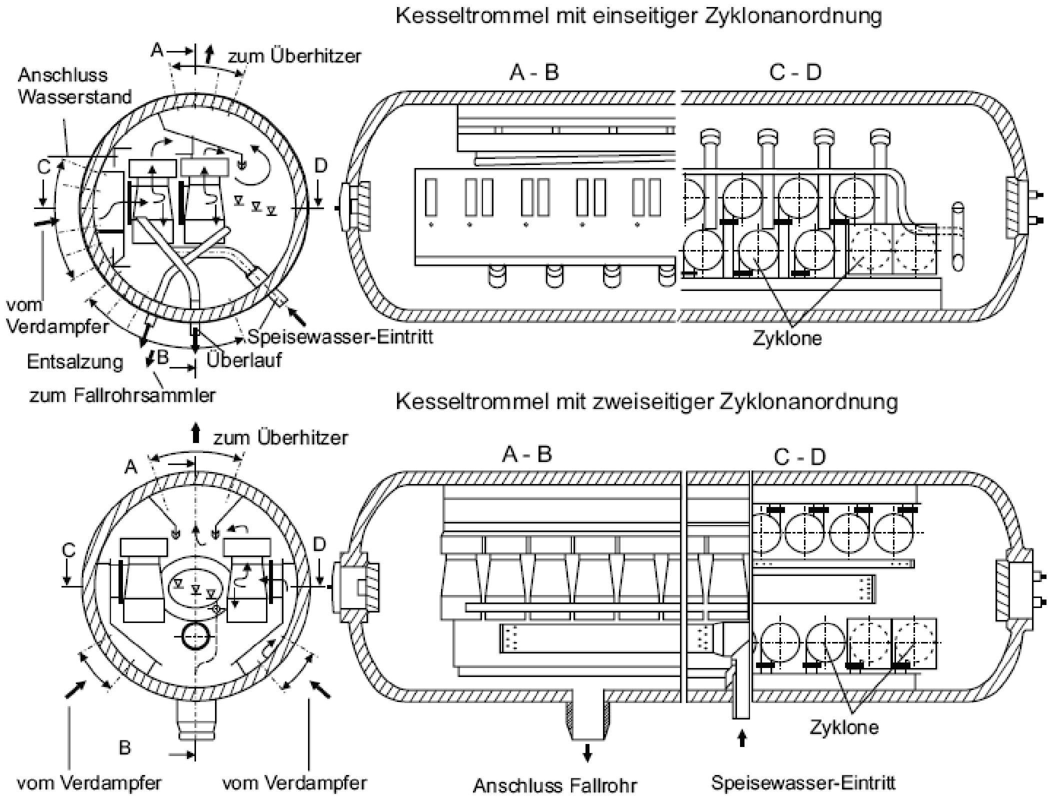
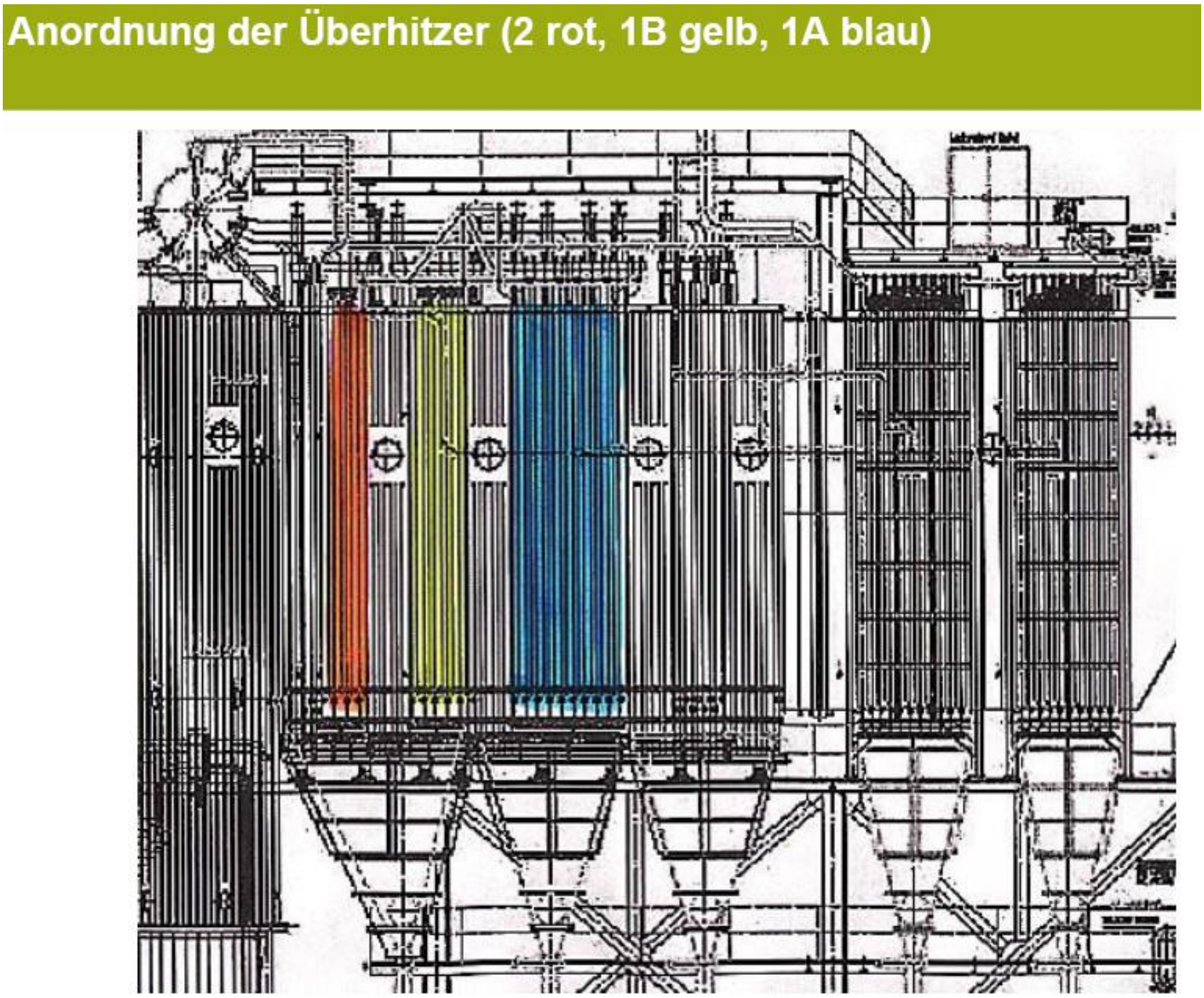


Abbildung 7.21. unten (aus Strauss, „Kraftwerkstechnik“)

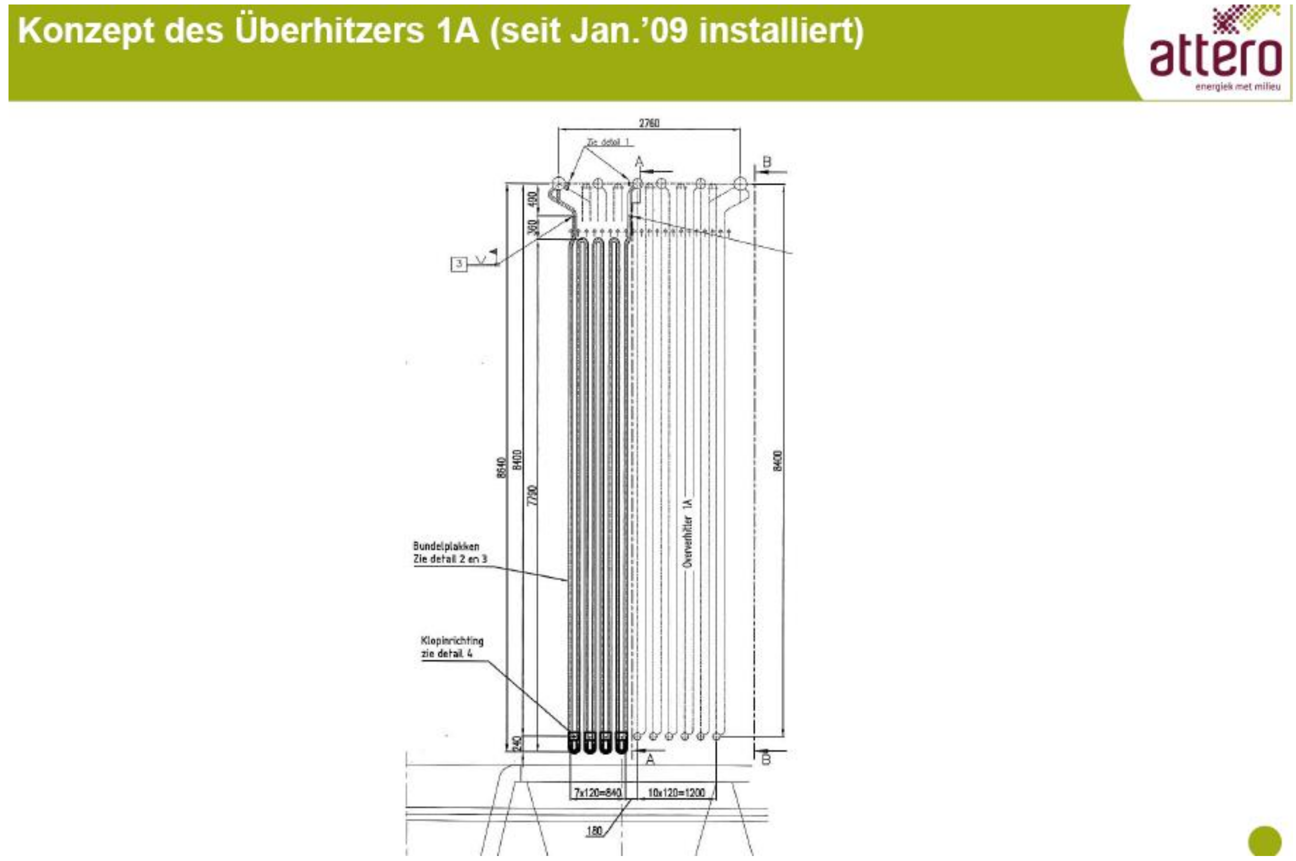
…Die beiden anderen Ausführungen werden für Drücke größer ca. 150 bar verwendet, wobei zur Unterstützung der Wasserabscheidung Zyklone und Leitbleche eingebaut sind

7.4 مسخن البخار / Overheater

7.4.1 Überhitzer



Anordnung der Überhitzer (2 rot, 1B gelb, 1A blau)



Konzept des Überhitzers 1A (seit Jan.'09 installiert)

7.5 المحاكاة CFD: توزيع درجة الحرارة في محرقة / CFD (Computational Fluid Dynamics) simulations: temperature distribution in an incinerator

CFD (Computational Fluid Dynamics) - Simulationen: Temperaturverteilung in einer Müllverbrennungsanlage

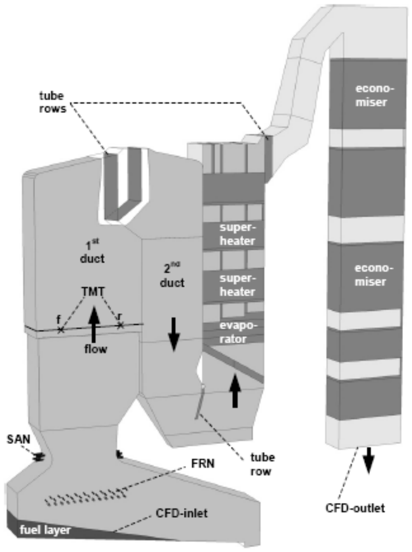
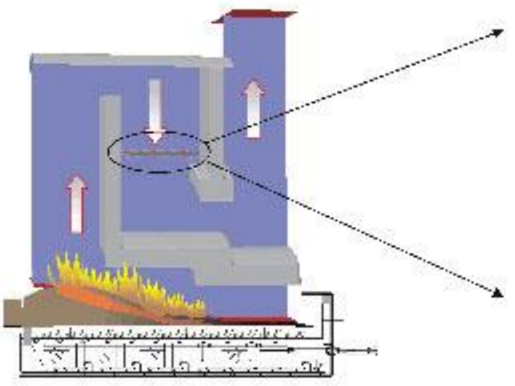
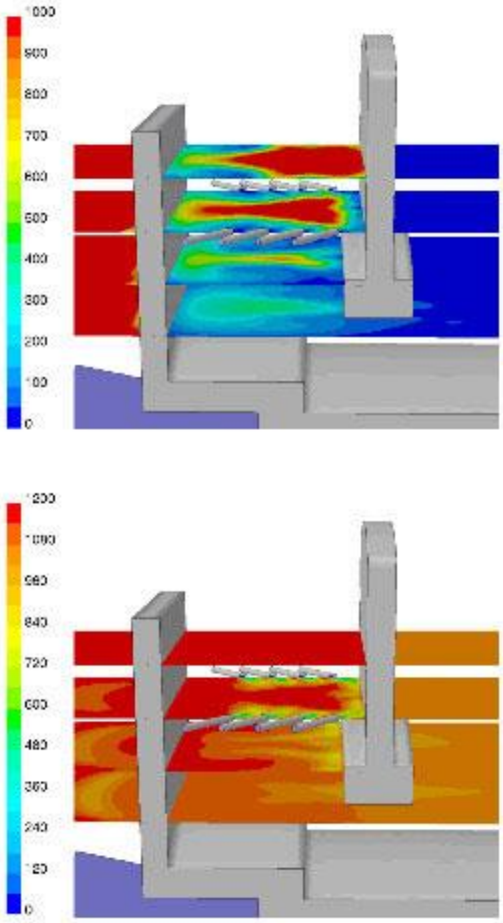


Figure 1: CFD model of the biomass furnace and boiler
Explanations: modeled tube bundles and rows are pictured dark gray; SAN…secondary air nozzles, FRN…flue gas recirculation nozzles, TMT… suction pyrometer temperature measurement traverses

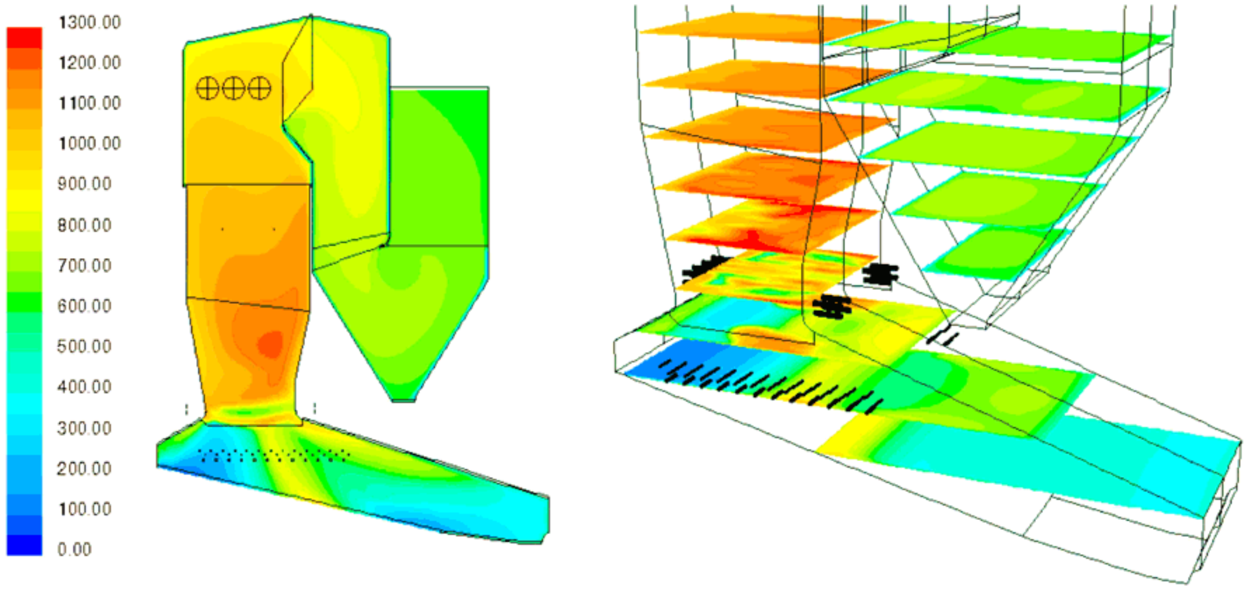
Aus: Scharler et. al. 2004, Advanced CFD analysis of large fixed bed biomass boilers …, 2nd World Conf…., Rome, 2004



Biomasse-Rostfeuerung ausgerüstet mit einem Flachschubrost



CO-Konzentrationen [v-ppm] (oben) und Temperaturverteilung [°C] (unten) in verschiedenen Querschnitten um die Sekundärluftdüsen



Isoflächen der Rauchgastemperatur [°C] in der Symmetrieebene der Feuerung (links) und in horizontalen Schnittebenen (rechts). Aus: http://www.bios-bioenergy.at/de/cfd-simulationen.html

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8 Pressure tubes

8.1 Barlow's formula[5]

Barlow's formula relates the internal pressure that a pipe[1] can withstand to its dimensions and the strength of its material.

$$P = \frac{2St}{D}$$

P = (2*S*t) / D

where

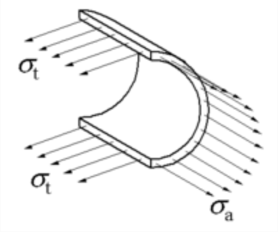
P = pressure, S = allowable stress, t = wall thickness, D = outside diameter

This formula figures prominently in the design of autoclaves and other pressure vessels.

Barlow's formula calculator[6]

8.2 Kesselformel

Die **Kesselformel** (DIN 2413) ist eine Berechnungsformel aus der Technischen Mechanik. Sie hat eine elementare Bedeutung bei der Berechnung und Auslegung von Dampfkesseln, Druckbehältern und Rohrleitungen.



Spannungen am dünnwandigen Zylinder

8.2.1 Anwendung

Die Kesselformel gibt die mechanischen Spannungen in durch Innendruck belasteten rotationssymmetrischen Körpern an, wie sie beispielsweise in Rohren oder Druckbehältern anzutreffen sind. Sie beruht als Membranspannung auf einem Kräftegleichgewicht, daher sind zur Berechnung der Spannungen weder Verformungsannahmen noch Elastizitätsgrößen notwendig.

Die Kesselformel gilt nur für dünnwandige und gekrümmte Druckbehälter. Für Kessel, die aus ebenen Blechen hergestellt sind, sowie für dickwandige Behälter, gilt die Kesselformel nicht.

Ein Druckbehälter kann als dünnwandig betrachtet werden, wenn seine Abmessungen (Durchmesser) sehr viel größer als seine Wanddicke sind (d.h. Außendurchmesser / Innendurchmesser = D/d < 1.2). Die größte Spannung ist bei zylindrischen Körpern die

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[5] From Wikipedia, the free encyclopedia

[6] http://www.aerocomfittings.com/barlows.html

Tangentialspannung σ_t, weshalb Rohre und ähnlich geformte Behälter immer in Längsrichtung platzen. Für auf Druck belastete ebene Platten ist die Kesselformel dagegen **nicht** anwendbar.

8.2.2 Berechnung

Die Tangentialspannung und Axialspannungen in einem durch Innendruck belasteten Zylinder, der an den Enden abgeschlossen ist:

$$\sigma_\mathrm{t} = \frac{p \cdot d}{2 \cdot s}$$

$$\sigma_\mathrm{a} = \frac{p \cdot d}{4 \cdot s}$$

- p = Innendruck
- d = Innendurchmesser – Außendurchmesser D – Mittel-Durchmesser $d_m = (D + d)/2$
- s = Wanddicke

- σ_t = Tangential-Spannung in der Wand
- σ_a = axiale Spannung (Längsrichtung) in der Wand

In dieser Form ist die Kesselformel auch als *Bockwurst-Formel* bekannt. Die Bezeichnung dient als Eselsbrücke, um sich zu merken, welche der beiden Spannungen die größere ist. Die Umfangsspannung ist doppelt so groß wie die Spannung in Längsrichtung, daher platzen Würste bei unsachgemäßer Erwärmung stets in Längsrichtung.

Aus der Schubspannungshypothese folgt die letzten Endes als „Kesselformel“ bezeichnete Vergleichsspannung σ_v mit

$$\sigma_\mathrm{v} = \sigma_\mathrm{max} - \sigma_\mathrm{min} = \sigma_\mathrm{t} - \sigma_\mathrm{r} = \frac{p \cdot d}{2 \cdot s} + \frac{p}{2}$$

- σ_r = Radialspannung; an der Behälterinnenseite ist $\sigma_\mathrm{r} = -p$, an der Außenseite (unbelastete Oberfläche) ist $\sigma_\mathrm{r} = 0$, in der Wandmitte wird der arithmetische Mittelwert verwendet $(\sigma_\mathrm{r} = -p/2)$

bzw.

$$\sigma_\mathrm{v} = \frac{p \cdot (d + s)}{2 \cdot s} = \frac{p \cdot d_\mathrm{m}}{2 \cdot s}$$

Inklusive Wanddickenzuschlägen errechnet sich die Mindestwanddicke mit folgender Formel:

$$s_\mathrm{min} = \frac{p \cdot d_\mathrm{m}}{2 \cdot \sigma_\mathrm{zul}} + s_1 + s_2$$

- s_1 Zuschlag für Korrosion
- s_2 Zuschlag für Toleranzfehler

Bei kugeligen Behältern gibt es keine tangentialen Spannungen; die axialen Spannungen entsprechen denen des Zylinders. Deshalb halbiert sich die minimale Wanddicke:

$$s_{\mathrm{min}} = \frac{p \cdot d_{\mathrm{m}}}{4 \cdot \sigma_{\mathrm{zul}}} + s_1 + s_2$$

8.3 Example

Die erforderliche Wanddicke des Behältermantels soll rechnerisch ermittelt werden. Für den Geschweißten zylindrischen Behältermantel wird die erforderliche Wanddicke mit der dafür vorgesehen Gleichung aus der RM Kapitel 6 Gl. (6.30a) ermittelt.

$$\boxed{t = \frac{D_a * p_e}{2\,\frac{K}{S}v + p_e} + c_1 + c_2}$$

t = Bauteildicke in mm,

D$_a$ = äußerer Manteldurchmesser in mm

p$_e$ = höchstzulässiger Betriebsdruck in N/mm$_2$

K = Festigkeitskennwert der Behälterwerkstoffe in N/mm$_2$

S = Sicherheitsbeiwert für Druckbehälter (ohne Einheit)

v = Faktor zur Berücksichtigung der Ausnutzung der zulässigen Berechnungsspannung der Schweißnaht (Druckbehälter)

C$_1$ = Zuschlag zur Berücksichtigung von Wanddickenunterschreitungen bei Druckbehältern in mm

C$_2$ = Abnutzungszuschlag zur Wanddicke bei Druckbehältern in mm ***(hierzu bitte dringend in der Formelsammlung auf Seite 52 nachschauen. Erforderlich ob die Zuschläge nötig sind oder nicht)***

Außendurchmesser gehen wir von 1150mm aus und Betriebsdruck wurde mit **12 bar=1,2N/mm^2** angegeben.

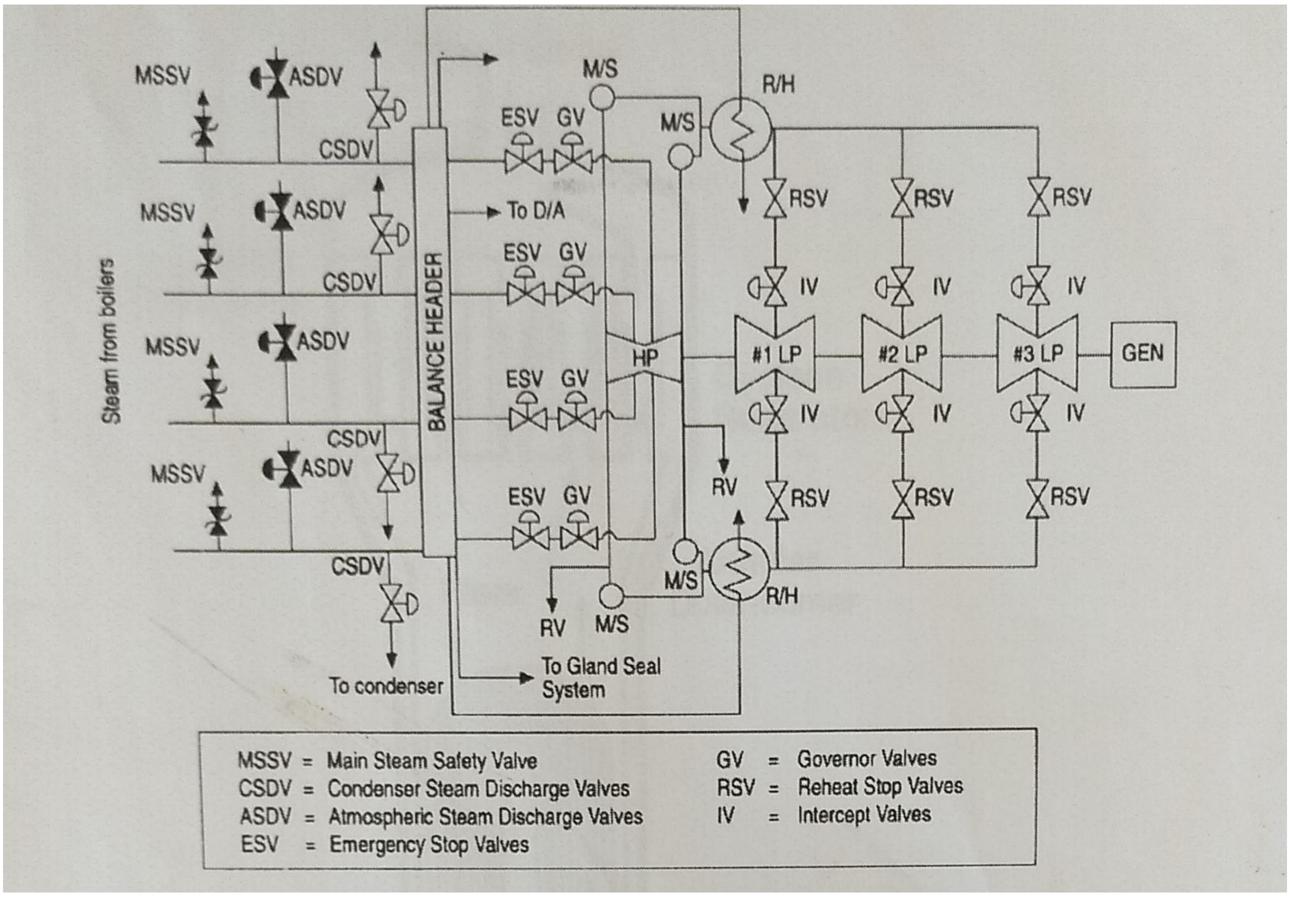
Kommen wir nun zu den Festigkeitskennwert K , diesen ermitteln wir aus der **TB 6 - 15** RM Tabellenbuch. Hier wird **235 N/mm$_2$** bis einer Behältertemperatur von **50°C** vorgeschlagen. Als Beispiel: zwischen 51°C und 120°C würde dieser Wert auf 187 N/mm$_2$ sinken. Den Sicherheitsbeiwert **S** entnehmen wir **TB 6 - 17** auf Seite 85 für Walz- und Schmiedestähle wird dieser hier mit **1,5** angegeben. Ausnutzungsfaktor **v** wird üblicherweise mit **"1"** angegeben, bei verringerten Prüfaufwand mit **0,85**, bei nahtlosen Bauteilen auch mit **1.** Zuschlag zur Berücksichtigung der zulässigen Wanddickenunterschreitung **c$_1$** bei ferritischen Stählen nach der Maßnorm, siehe **TB1 - 7 RM Tabellen**.

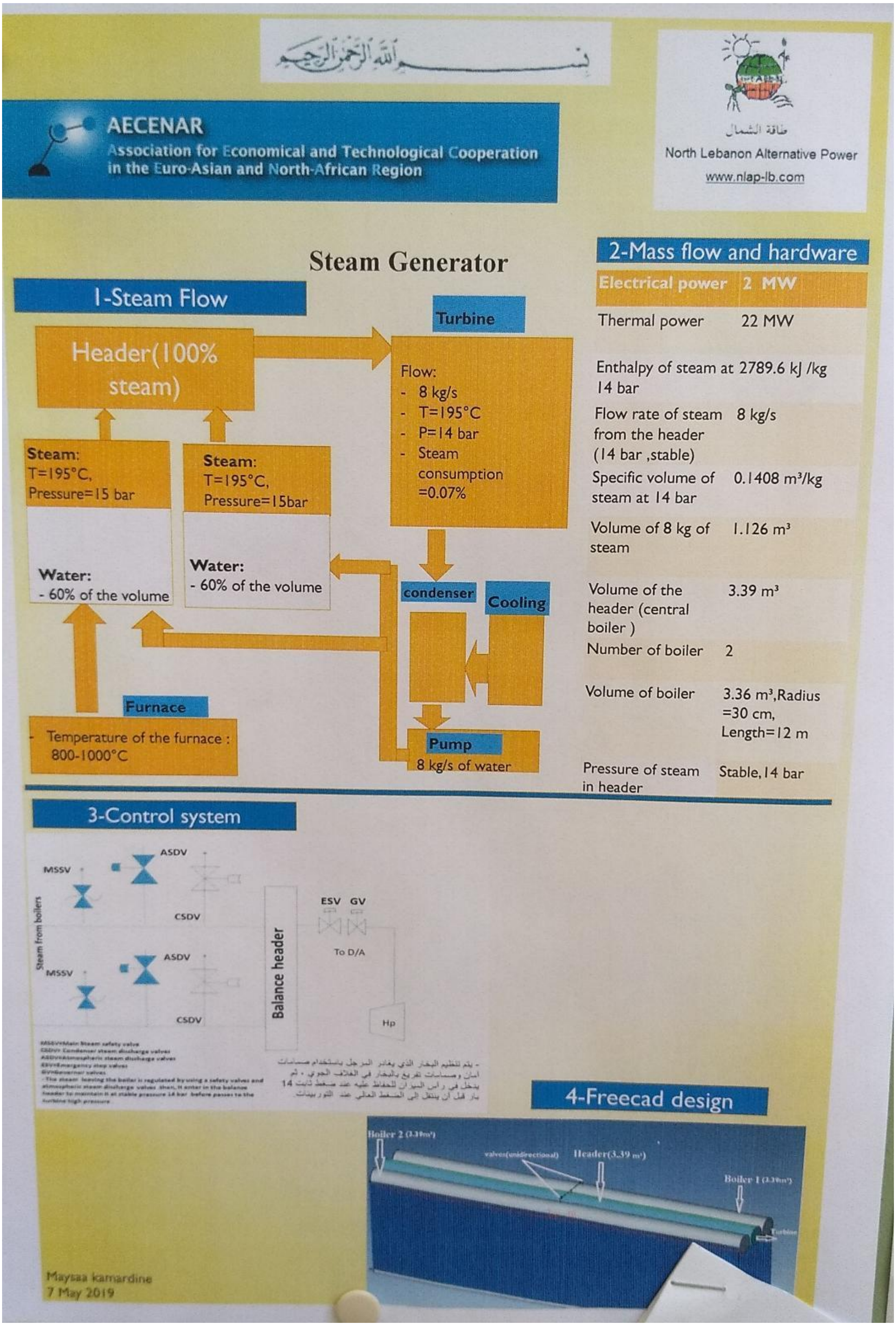
Abnutzungszuschlag der Wanddicke **c$_2$** wird bei ferritischen Stählen oder mit starker Korrosionsgefährdung mit **1** angegeben. Bei nichtrostenden Stählen, NE-Metallen geschützten Stählen wie z.B. durch Gummierung oder anderweitige Beschichtung oder Wandstärken über 30mm wird dieser Wert mit **0** angegeben.

$$t = \frac{\mathbf{1150}\boldsymbol{mm} * \mathbf{1,2}\boldsymbol{N/mm^2}}{2 * \frac{\mathbf{235}\boldsymbol{N/mm^2}}{\mathbf{1,5}} * \mathbf{0,85} + \mathbf{1,2}\boldsymbol{N/mm^2}} + \mathbf{0,4}\boldsymbol{mm} + \mathbf{1,0}\boldsymbol{mm} = \mathbf{5,2}\boldsymbol{mm} + \mathbf{1,4}\boldsymbol{mm} = \mathbf{6,6}\boldsymbol{mm}$$

Daraus ergibt sich eine benötigte Wanddicke von 6,6mm entsprechend 7mm.

9 Steam Header Control


Steam from boilers
MSSV
ASDV
CSDV
BALANCE HEADER
To D/A
ESV
GV
M/S
R/H
RSV
IV
HP
#1 LP
#2 LP
#3 LP
GEN
RV
To condenser
To Gland Seal System
MSSV = Main Steam Safety Valve
CSDV = Condenser Steam Discharge Valves
ASDV = Atmospheric Steam Discharge Valves
ESV = Emergency Stop Valves
GV = Governor Valves
RSV = Reheat Stop Valves
IV = Intercept Valves



بســـــــم الله الرحمن الرحيم

AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region

طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.com

Steam Generator

1-Steam Flow

Steam:
T=195°C,
Pressure=15 bar

Water:
- 60% of the volume

Steam:
T=195°C,
Pressure=15bar

Water:
- 60% of the volume

Flow:
- 8 kg/s
- T=195°C
- P=14 bar
- Steam consumption =0.07%

- Temperature of the furnace : 800-1000°C

Pump
8 kg/s of water

2-Mass flow and hardware

Electrical power	2 MW
Thermal power	22 MW
Enthalpy of steam at 14 bar	2789.6 kJ /kg
Flow rate of steam from the header (14 bar ,stable)	8 kg/s
Specific volume of steam at 14 bar	0.1408 m³/kg
Volume of 8 kg of steam	1.126 m³
Volume of the header (central boiler)	3.39 m³
Number of boiler	2
Volume of boiler	3.36 m³,Radius =30 cm, Length=12 m
Pressure of steam in header	Stable, 14 bar

3-Control system

MSSV=Main Steam safety valve
CSDV= Condenser steam discharge valves
ASDV=Atmospheric steam discharge valves
ESV=Emergency stop valves
GV=Governor valves
-The steam leaving the boiler is regulated by using a safety valves and atmospheric steam discharge valves then, it enter in the balance header to maintain it at stable pressure 14 bar before passes to the turbine high pressure

- يتم تنظيم البخار الذي يغادر المرجل باستخدام صمامات امان وصمامات تفريغ بالبخار في الغلاف الجوي ، ثم يدخل في راس الميزان للحفاظ عليه عند ضغط ثابت 14 بار قبل ان ينتقل الى الضغط العالي عند التوربينات

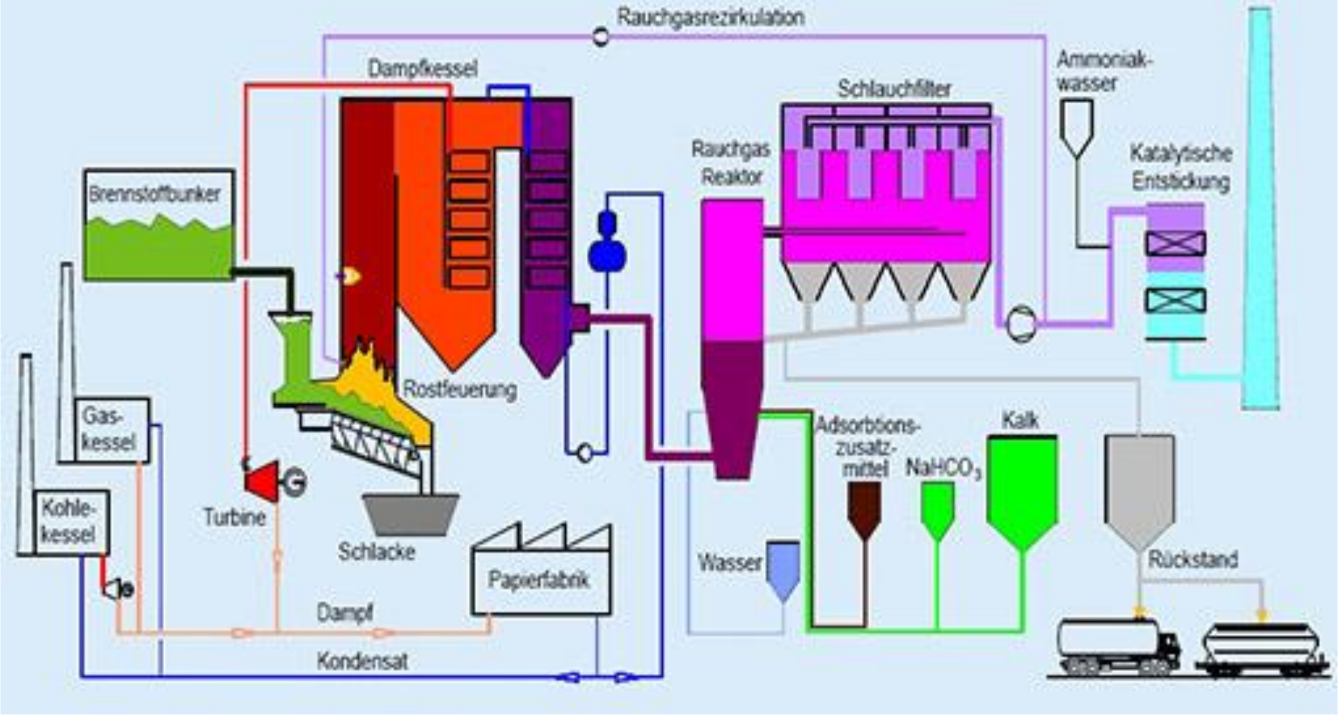
4-Freecad design

Maysaa kamardine
7 May 2019

10 Emmisions & Flue Gas Purification Basics[7]

10.1 تنقية الدخان / Flue gas cleaning

10.1.1 Rauchgasreinigung



Das Folgende ist [Seier 1999], einer Studie des Forschungszentrums Karlsruhe (FZK) zu Kleinmüllverbrennungsanlagen, entnommen.

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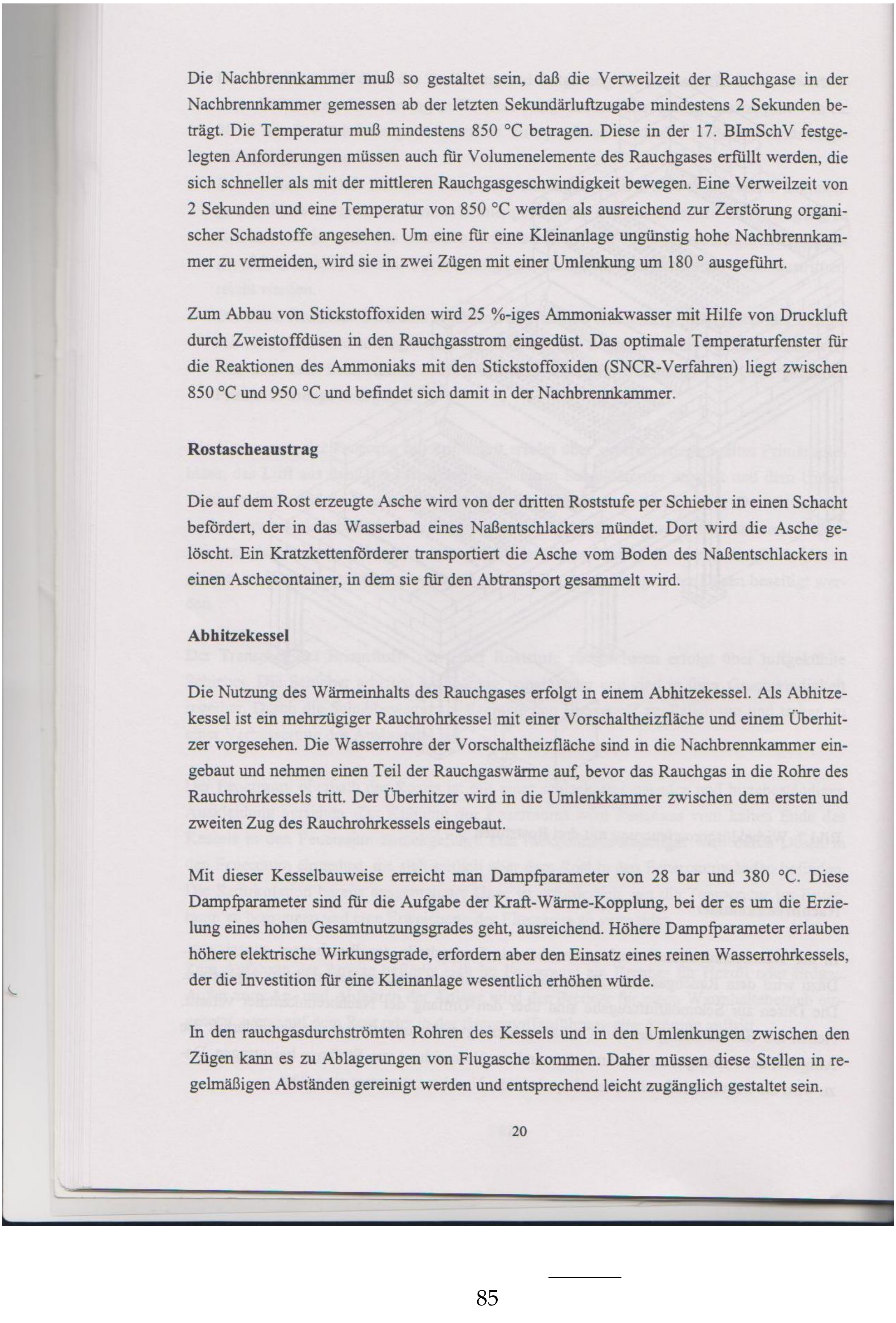
[7] from [Kamareddine 2016], Ch. Basics and [TEMO-IPP 2012]

10.1.2 Destruction of organic pollutants by afterburning in two moves (because of 2 seconds residence time of the flue gas) + addition of 25% ammonia for destruction of NOx (at 850-950 ° C) in the combustion chamber

10.1.2.1 Zerstörung organischer Schadstoffe durch Nachbrennkammer in zwei Zügen (wegen 2s Verweilzeit des Rauchgases) + Zugabe von 25%iges Ammoniak zur Zerstörung von NOx (bei 850-950°C) in der Nachbrennkammer



Die Nachbrennkammer muß so gestaltet sein, daß die Verweilzeit der Rauchgase in der Nachbrennkammer gemessen ab der letzten Sekundärluftzugabe mindestens 2 Sekunden beträgt. Die Temperatur muß mindestens 850 °C betragen. Diese in der 17. BImSchV festgelegten Anforderungen müssen auch für Volumenelemente des Rauchgases erfüllt werden, die sich schneller als mit der mittleren Rauchgasgeschwindigkeit bewegen. Eine Verweilzeit von 2 Sekunden und eine Temperatur von 850 °C werden als ausreichend zur Zerstörung organischer Schadstoffe angesehen. Um eine für eine Kleinanlage ungünstig hohe Nachbrennkammer zu vermeiden, wird sie in zwei Zügen mit einer Umlenkung um 180 ° ausgeführt.

Zum Abbau von Stickstoffoxiden wird 25 %-iges Ammoniakwasser mit Hilfe von Druckluft durch Zweistoffdüsen in den Rauchgasstrom eingedüst. Das optimale Temperaturfenster für die Reaktionen des Ammoniaks mit den Stickstoffoxiden (SNCR-Verfahren) liegt zwischen 850 °C und 950 °C und befindet sich damit in der Nachbrennkammer.

Rostascheaustrag

Die auf dem Rost erzeugte Asche wird von der dritten Roststufe per Schieber in einen Schacht befördert, der in das Wasserbad eines Naßentschlackers mündet. Dort wird die Asche gelöscht. Ein Kratzkettenförderer transportiert die Asche vom Boden des Naßentschlackers in einen Aschecontainer, in dem sie für den Abtransport gesammelt wird.

Abhitzekessel

Die Nutzung des Wärmeinhalts des Rauchgases erfolgt in einem Abhitzekessel. Als Abhitzekessel ist ein mehrzügiger Rauchrohrkessel mit einer Vorschaltheizfläche und einem Überhitzer vorgesehen. Die Wasserrohre der Vorschaltheizfläche sind in die Nachbrennkammer eingebaut und nehmen einen Teil der Rauchgaswärme auf, bevor das Rauchgas in die Rohre des Rauchrohrkessels tritt. Der Überhitzer wird in die Umlenkkammer zwischen dem ersten und zweiten Zug des Rauchrohrkessels eingebaut.

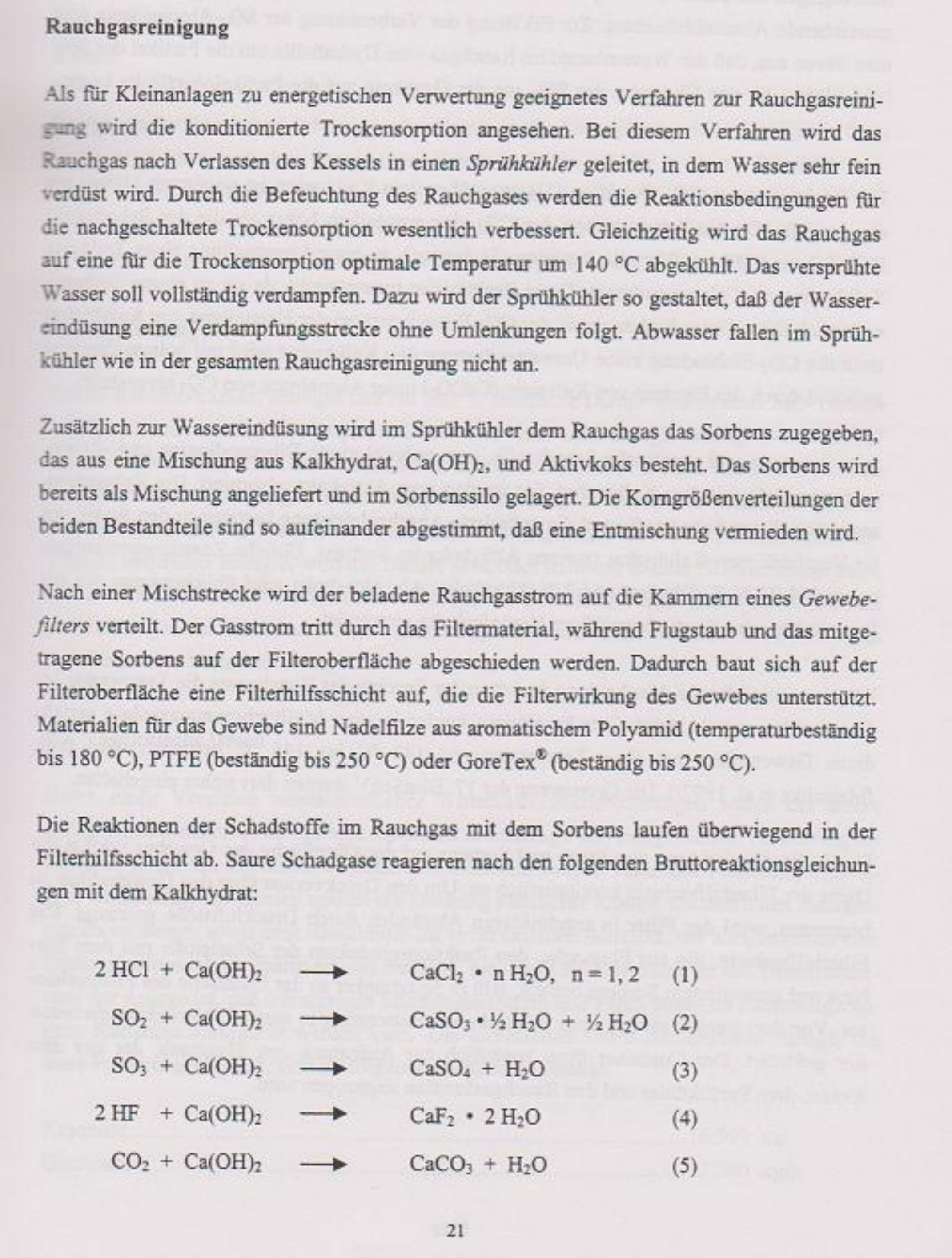
Mit dieser Kesselbauweise erreicht man Dampfparameter von 28 bar und 380 °C. Diese Dampfparameter sind für die Aufgabe der Kraft-Wärme-Kopplung, bei der es um die Erzielung eines hohen Gesamtnutzungsgrades geht, ausreichend. Höhere Dampfparameter erlauben höhere elektrische Wirkungsgrade, erfordern aber den Einsatz eines reinen Wasserrohrkessels, der die Investition für eine Kleinanlage wesentlich erhöhen würde.

In den rauchgasdurchströmten Rohren des Kessels und in den Umlenkungen zwischen den Zügen kann es zu Ablagerungen von Flugasche kommen. Daher müssen diese Stellen in regelmäßigen Abständen gereinigt werden und entsprechend leicht zugänglich gestaltet sein.

20

10.1.3 Actual flue gas cleaning

10.1.3.1 Eigentliche Rauchgasreinigung



Rauchgasreinigung

Als für Kleinanlagen zu energetischen Verwertung geeignetes Verfahren zur Rauchgasreinigung wird die konditionierte Trockensorption angesehen. Bei diesem Verfahren wird das Rauchgas nach Verlassen des Kessels in einen *Sprühkühler* geleitet, in dem Wasser sehr fein verdüst wird. Durch die Befeuchtung des Rauchgases werden die Reaktionsbedingungen für die nachgeschaltete Trockensorption wesentlich verbessert. Gleichzeitig wird das Rauchgas auf eine für die Trockensorption optimale Temperatur um 140 °C abgekühlt. Das versprühte Wasser soll vollständig verdampfen. Dazu wird der Sprühkühler so gestaltet, daß der Wassereindüsung eine Verdampfungsstrecke ohne Umlenkungen folgt. Abwasser fallen im Sprühkühler wie in der gesamten Rauchgasreinigung nicht an.

Zusätzlich zur Wassereindüsung wird im Sprühkühler dem Rauchgas das Sorbens zugegeben, das aus eine Mischung aus Kalkhydrat, $Ca(OH)_2$, und Aktivkoks besteht. Das Sorbens wird bereits als Mischung angeliefert und im Sorbenssilo gelagert. Die Korngrößenverteilungen der beiden Bestandteile sind so aufeinander abgestimmt, daß eine Entmischung vermieden wird.

Nach einer Mischstrecke wird der beladene Rauchgasstrom auf die Kammern eines *Gewebefilters* verteilt. Der Gasstrom tritt durch das Filtermaterial, während Flugstaub und das mitgetragene Sorbens auf der Filteroberfläche abgeschieden werden. Dadurch baut sich auf der Filteroberfläche eine Filterhilfsschicht auf, die die Filterwirkung des Gewebes unterstützt. Materialien für das Gewebe sind Nadelfilze aus aromatischem Polyamid (temperaturbeständig bis 180 °C), PTFE (beständig bis 250 °C) oder GoreTex® (beständig bis 250 °C).

Die Reaktionen der Schadstoffe im Rauchgas mit dem Sorbens laufen überwiegend in der Filterhilfsschicht ab. Saure Schadgase reagieren nach den folgenden Bruttoreaktionsgleichungen mit dem Kalkhydrat:

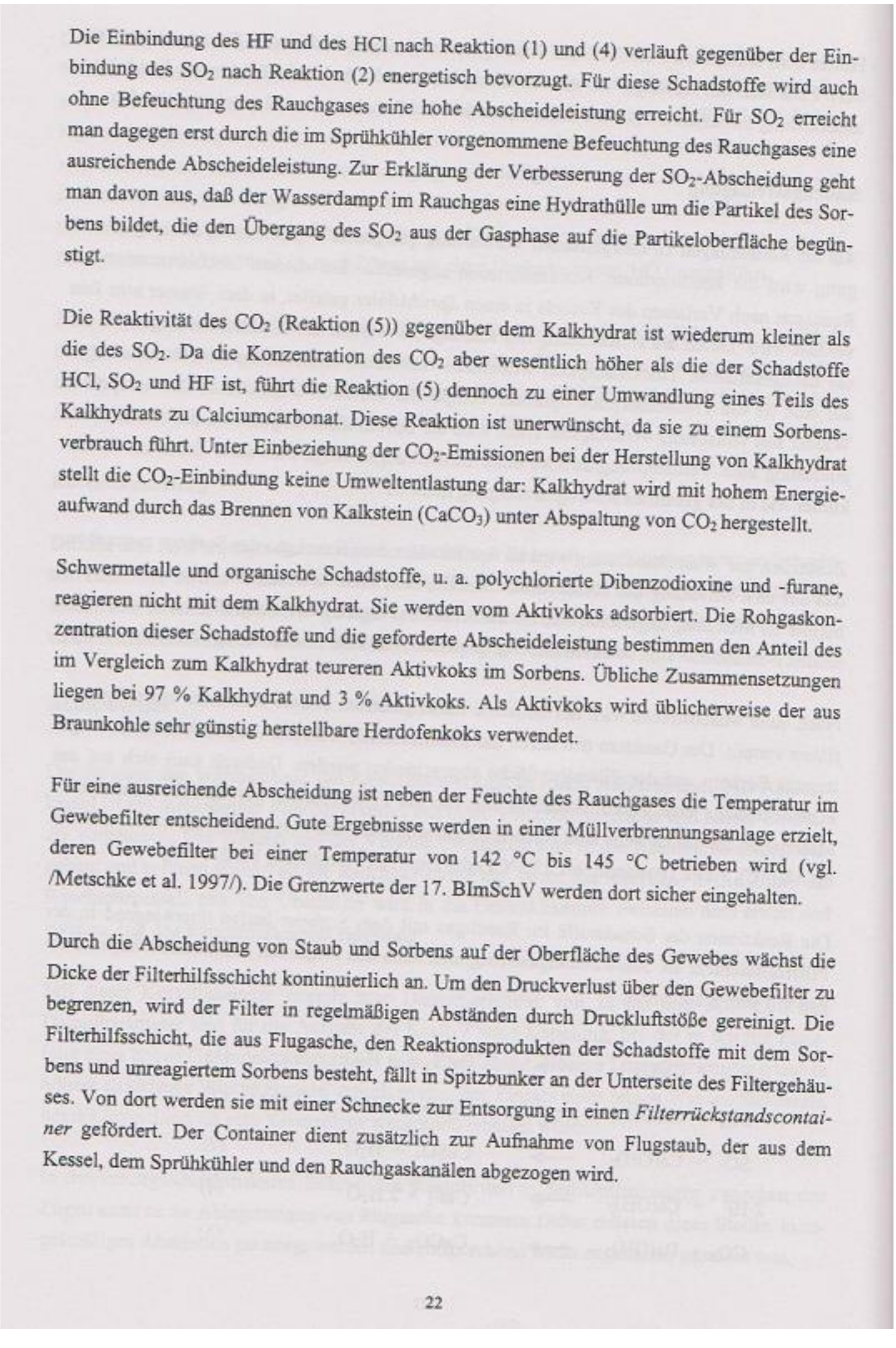
$$2\,HCl + Ca(OH)_2 \longrightarrow CaCl_2 \cdot n\,H_2O, \quad n = 1, 2 \tag{1}$$

$$SO_2 + Ca(OH)_2 \longrightarrow CaSO_3 \cdot \tfrac{1}{2}\,H_2O + \tfrac{1}{2}\,H_2O \tag{2}$$

$$SO_3 + Ca(OH)_2 \longrightarrow CaSO_4 + H_2O \tag{3}$$

$$2\,HF + Ca(OH)_2 \longrightarrow CaF_2 \cdot 2\,H_2O \tag{4}$$

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O \tag{5}$$



Die Einbindung des HF und des HCl nach Reaktion (1) und (4) verläuft gegenüber der Einbindung des SO_2 nach Reaktion (2) energetisch bevorzugt. Für diese Schadstoffe wird auch ohne Befeuchtung des Rauchgases eine hohe Abscheideleistung erreicht. Für SO_2 erreicht man dagegen erst durch die im Sprühkühler vorgenommene Befeuchtung des Rauchgases eine ausreichende Abscheideleistung. Zur Erklärung der Verbesserung der SO_2-Abscheidung geht man davon aus, daß der Wasserdampf im Rauchgas eine Hydrathülle um die Partikel des Sorbens bildet, die den Übergang des SO_2 aus der Gasphase auf die Partikeloberfläche begünstigt.

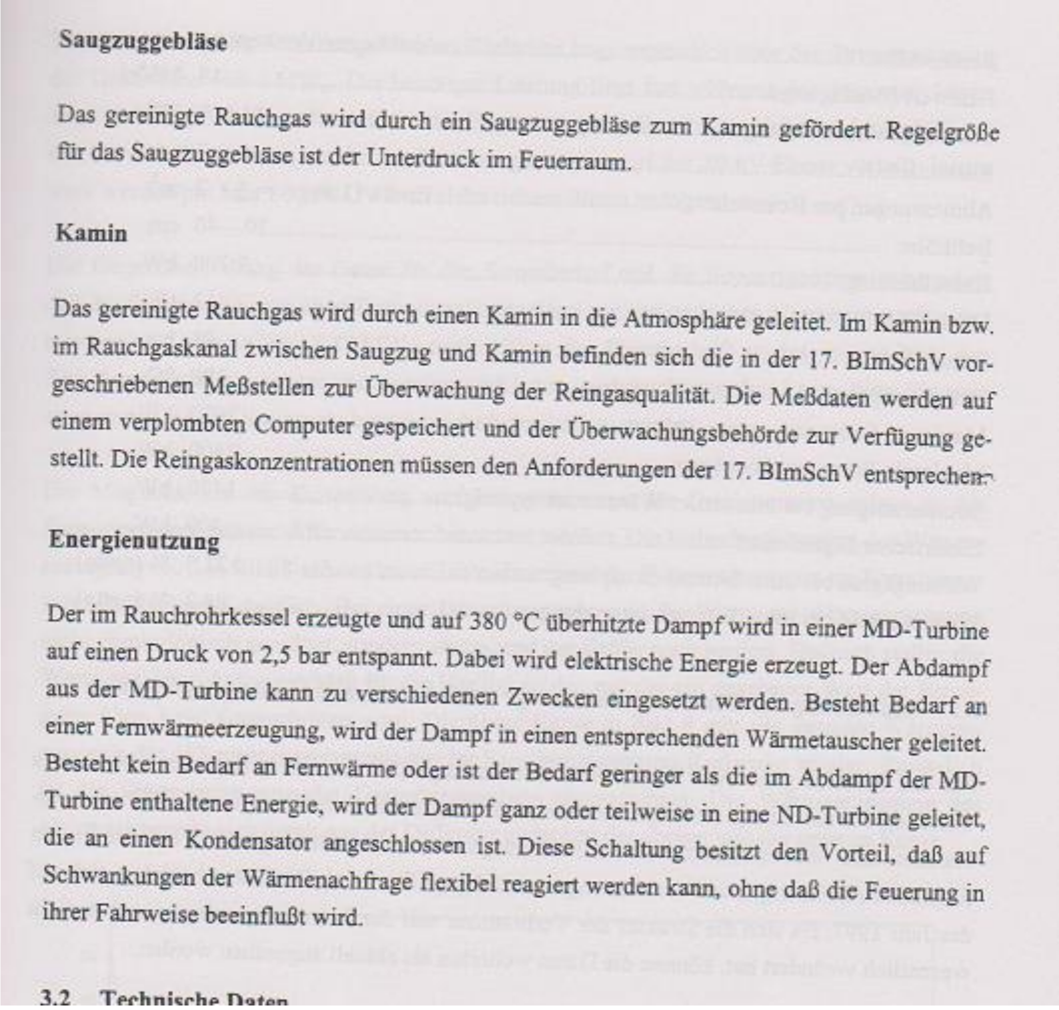
Die Reaktivität des CO_2 (Reaktion (5)) gegenüber dem Kalkhydrat ist wiederum kleiner als die des SO_2. Da die Konzentration des CO_2 aber wesentlich höher als die der Schadstoffe HCl, SO_2 und HF ist, führt die Reaktion (5) dennoch zu einer Umwandlung eines Teils des Kalkhydrats zu Calciumcarbonat. Diese Reaktion ist unerwünscht, da sie zu einem Sorbensverbrauch führt. Unter Einbeziehung der CO_2-Emissionen bei der Herstellung von Kalkhydrat stellt die CO_2-Einbindung keine Umweltentlastung dar: Kalkhydrat wird mit hohem Energieaufwand durch das Brennen von Kalkstein ($CaCO_3$) unter Abspaltung von CO_2 hergestellt.

Schwermetalle und organische Schadstoffe, u. a. polychlorierte Dibenzodioxine und -furane, reagieren nicht mit dem Kalkhydrat. Sie werden vom Aktivkoks adsorbiert. Die Rohgaskonzentration dieser Schadstoffe und die geforderte Abscheideleistung bestimmen den Anteil des im Vergleich zum Kalkhydrat teureren Aktivkoks im Sorbens. Übliche Zusammensetzungen liegen bei 97 % Kalkhydrat und 3 % Aktivkoks. Als Aktivkoks wird üblicherweise der aus Braunkohle sehr günstig herstellbare Herdofenkoks verwendet.

Für eine ausreichende Abscheidung ist neben der Feuchte des Rauchgases die Temperatur im Gewebefilter entscheidend. Gute Ergebnisse werden in einer Müllverbrennungsanlage erzielt, deren Gewebefilter bei einer Temperatur von 142 °C bis 145 °C betrieben wird (vgl. /Metschke et al. 1997/). Die Grenzwerte der 17. BImSchV werden dort sicher eingehalten.

Durch die Abscheidung von Staub und Sorbens auf der Oberfläche des Gewebes wächst die Dicke der Filterhilfsschicht kontinuierlich an. Um den Druckverlust über den Gewebefilter zu begrenzen, wird der Filter in regelmäßigen Abständen durch Druckluftstöße gereinigt. Die Filterhilfsschicht, die aus Flugasche, den Reaktionsprodukten der Schadstoffe mit dem Sorbens und unreagiertem Sorbens besteht, fällt in Spitzbunker an der Unterseite des Filtergehäuses. Von dort werden sie mit einer Schnecke zur Entsorgung in einen *Filterrückstandscontainer* gefördert. Der Container dient zusätzlich zur Aufnahme von Flugstaub, der aus dem Kessel, dem Sprühkühler und den Rauchgaskanälen abgezogen wird.

22



Saugzuggebläse

Das gereinigte Rauchgas wird durch ein Saugzuggebläse zum Kamin gefördert. Regelgröße für das Saugzuggebläse ist der Unterdruck im Feuerraum.

Kamin

Das gereinigte Rauchgas wird durch einen Kamin in die Atmosphäre geleitet. Im Kamin bzw. im Rauchgaskanal zwischen Saugzug und Kamin befinden sich die in der 17. BImSchV vorgeschriebenen Meßstellen zur Überwachung der Reingasqualität. Die Meßdaten werden auf einem verplombten Computer gespeichert und der Überwachungsbehörde zur Verfügung gestellt. Die Reingaskonzentrationen müssen den Anforderungen der 17. BImSchV entsprechen.

Energienutzung

Der im Rauchrohrkessel erzeugte und auf 380 °C überhitzte Dampf wird in einer MD-Turbine auf einen Druck von 2,5 bar entspannt. Dabei wird elektrische Energie erzeugt. Der Abdampf aus der MD-Turbine kann zu verschiedenen Zwecken eingesetzt werden. Besteht Bedarf an einer Fernwärmeerzeugung, wird der Dampf in einen entsprechenden Wärmetauscher geleitet. Besteht kein Bedarf an Fernwärme oder ist der Bedarf geringer als die im Abdampf der MD-Turbine enthaltene Energie, wird der Dampf ganz oder teilweise in eine ND-Turbine geleitet, die an einen Kondensator angeschlossen ist. Diese Schaltung besitzt den Vorteil, daß auf Schwankungen der Wärmenachfrage flexibel reagiert werden kann, ohne daß die Feuerung in ihrer Fahrweise beeinflußt wird.

3.2 Technische Daten

10.2 دراسة عن المحارق الصغيرة: أصغر نظام الاقتصادي حوالي 5 ملايين يورو، 2 ميجاوات الطاقة الكهربائية / FZK study on small incinerators: smallest economic system approximately EUR 5 million, 2 megawatts electrical power

FZK-Studie zu Kleinmüllverbrennungsanlagen: kleinste wirtschaftliche Anlage ca. 5 Mio. EUR, 2 MWel. Aus [Seier 1999]:

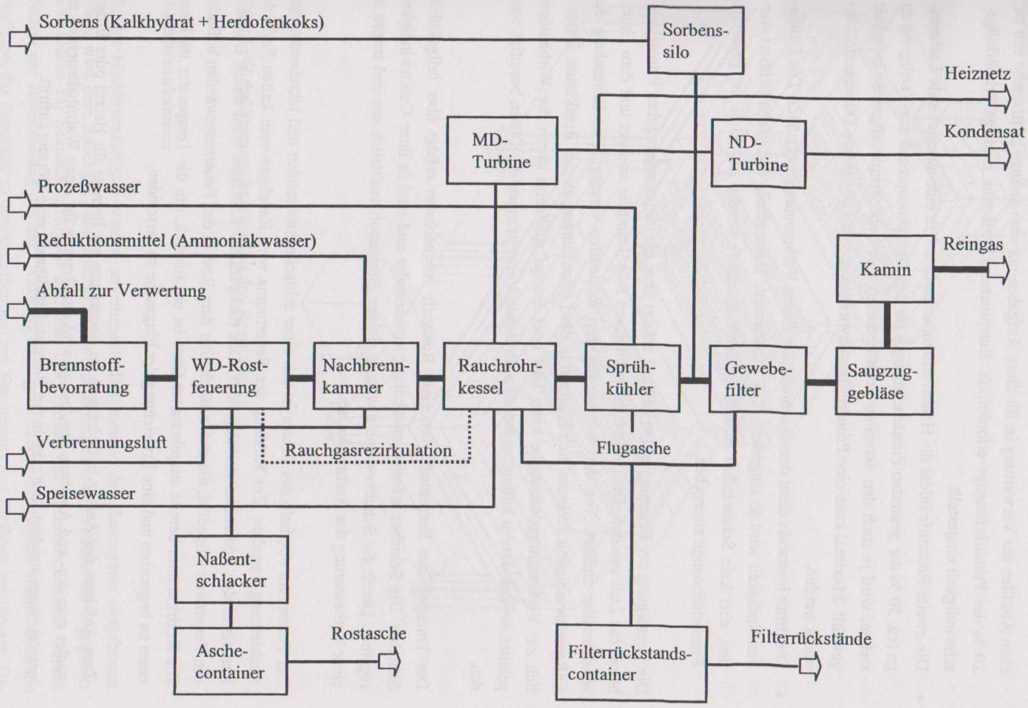
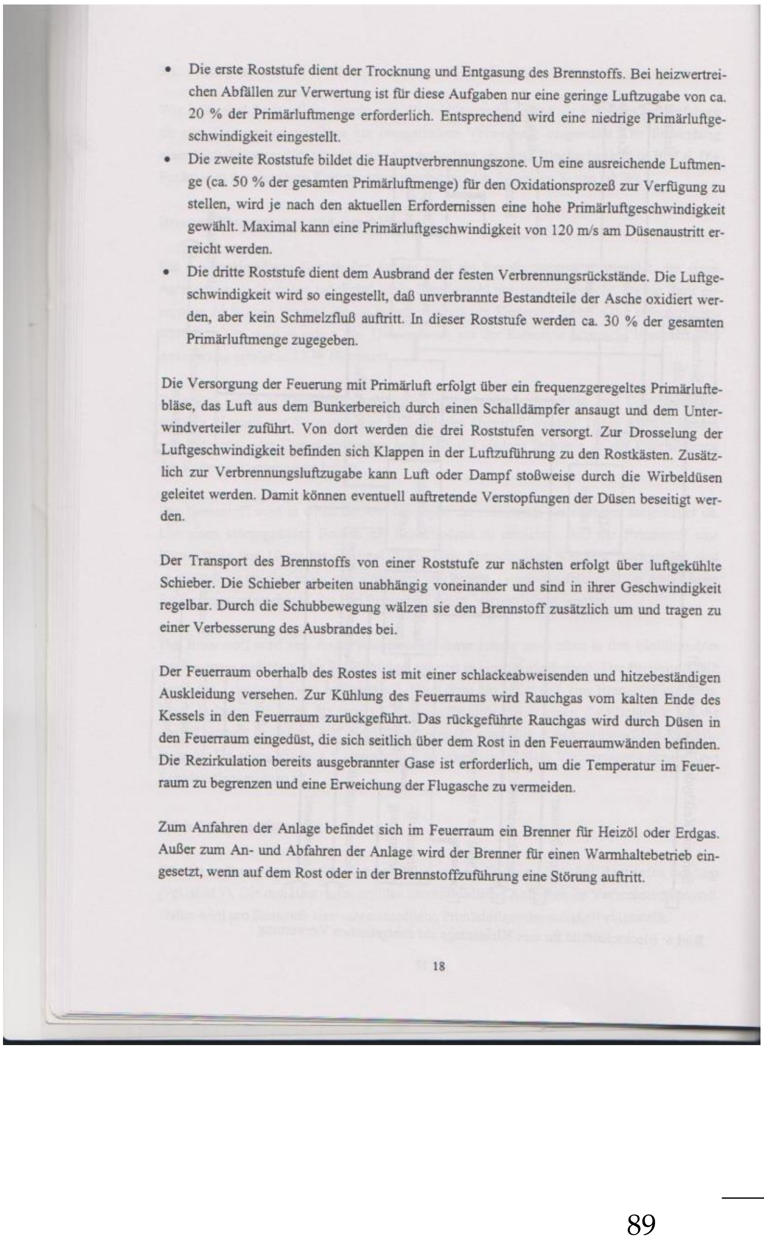


Bild 6: Blockschaltbild für eine Kleinanlage zur energetischen Verwertung

17



- Die erste Roststufe dient der Trocknung und Entgasung des Brennstoffs. Bei heizwertreichen Abfällen zur Verwertung ist für diese Aufgaben nur eine geringe Luftzugabe von ca. 20 % der Primärluftmenge erforderlich. Entsprechend wird eine niedrige Primärluftgeschwindigkeit eingestellt.
- Die zweite Roststufe bildet die Hauptverbrennungszone. Um eine ausreichende Luftmenge (ca. 50 % der gesamten Primärluftmenge) für den Oxidationsprozeß zur Verfügung zu stellen, wird je nach den aktuellen Erfordernissen eine hohe Primärluftgeschwindigkeit gewählt. Maximal kann eine Primärluftgeschwindigkeit von 120 m/s am Düsenaustritt erreicht werden.
- Die dritte Roststufe dient dem Ausbrand der festen Verbrennungsrückstände. Die Luftgeschwindigkeit wird so eingestellt, daß unverbrannte Bestandteile der Asche oxidiert werden, aber kein Schmelzfluß auftritt. In dieser Roststufe werden ca. 30 % der gesamten Primärluftmenge zugegeben.

Die Versorgung der Feuerung mit Primärluft erfolgt über ein frequenzgeregeltes Primärluftebläse, das Luft aus dem Bunkerbereich durch einen Schalldämpfer ansaugt und dem Unterwindverteiler zuführt. Von dort werden die drei Roststufen versorgt. Zur Drosselung der Luftgeschwindigkeit befinden sich Klappen in der Luftzuführung zu den Rostkästen. Zusätzlich zur Verbrennungsluftzugabe kann Luft oder Dampf stoßweise durch die Wirbeldüsen geleitet werden. Damit können eventuell auftretende Verstopfungen der Düsen beseitigt werden.

Der Transport des Brennstoffs von einer Roststufe zur nächsten erfolgt über luftgekühlte Schieber. Die Schieber arbeiten unabhängig voneinander und sind in ihrer Geschwindigkeit regelbar. Durch die Schubbewegung wälzen sie den Brennstoff zusätzlich um und tragen zu einer Verbesserung des Ausbrandes bei.

Der Feuerraum oberhalb des Rostes ist mit einer schlackeabweisenden und hitzebeständigen Auskleidung versehen. Zur Kühlung des Feuerraums wird Rauchgas vom kalten Ende des Kessels in den Feuerraum zurückgeführt. Das rückgeführte Rauchgas wird durch Düsen in den Feuerraum eingedüst, die sich seitlich über dem Rost in den Feuerraumwänden befinden. Die Rezirkulation bereits ausgebrannter Gase ist erforderlich, um die Temperatur im Feuerraum zu begrenzen und eine Erweichung der Flugasche zu vermeiden.

Zum Anfahren der Anlage befindet sich im Feuerraum ein Brenner für Heizöl oder Erdgas. Außer zum An- und Abfahren der Anlage wird der Brenner für einen Warmhaltebetrieb eingesetzt, wenn auf dem Rost oder in der Brennstoffzuführung eine Störung auftritt.

18

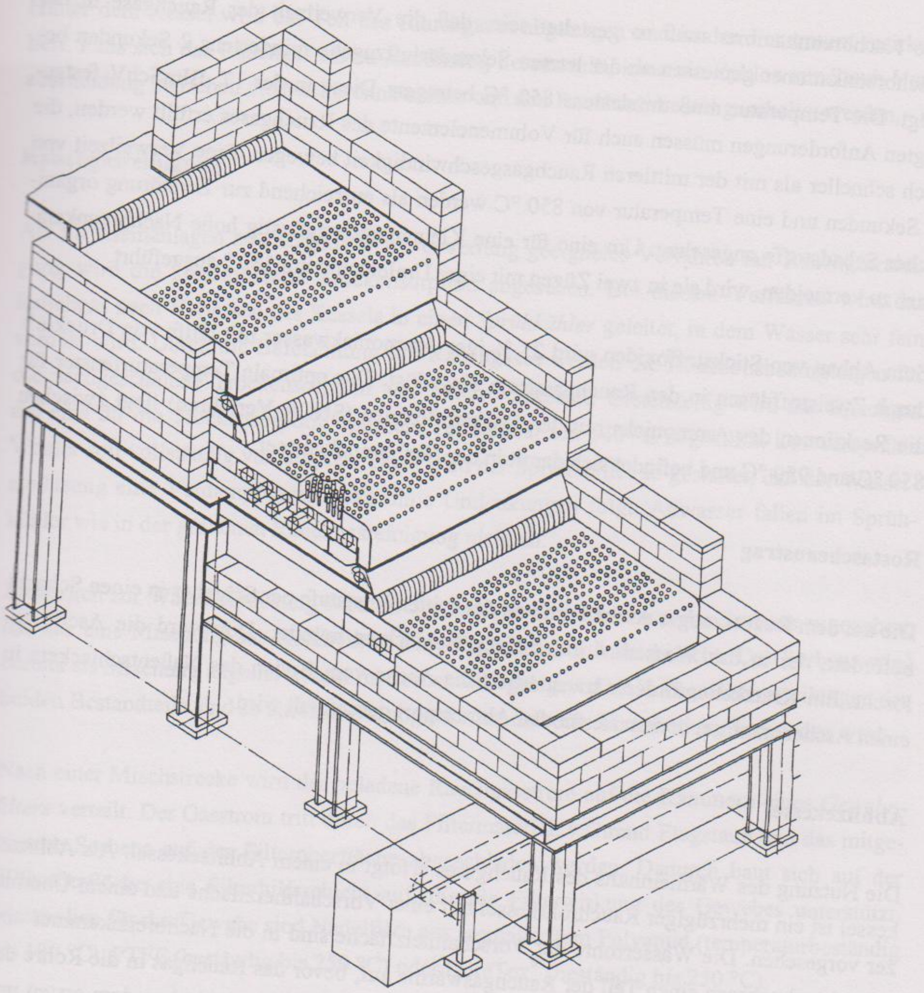


Bild 7: Wirbeldüsenrostfeuerung mit drei Roststufen

Nachbrennkammer

In der Nachbrennkammer werden unverbrannte Bestandteile des Rauchgases ausgebrannt. Dazu wird dem Rauchgas beim Eintritt in die Nachbrennkammer Sekundärluft zugegeben. Die Düsen zur Sekundärluftzugabe sind über den Umfang der Nachbrennkammer verteilt. Neben der Bereitstellung des zur Oxidation benötigten Sauerstoffs hat die Sekundärluft die Aufgabe, das Rauchgas zu durchmischen und zur Vermeidung von Strähnen beizutragen. Dazu wird die Sekundärluft mit hohem Impuls in die Nachbrennkammer eingedüst.

10.3 DEFINITION Definition OF THE OPERATION OF INCINERATION PLANTS

An incineration plant and household waste (WTE) is a large oven for receiving household waste to be incinerated. Combustion, which takes place between 850 and 1000 ° C, reduces the waste volume by 90%. In doing so it produces pollutants residues potentially dangerous. They are of two types: solid residues, called clinker, are recovered in the furnace vessel. Depending on their nature, they may or may not be decontaminated and recycled. In all cases, they are treated according to strict standards to prevent pollution associated with their production and operation.

The second type of residues produced by waste incineration is the best known and most feared: these fumes. Because burning waste creates toxic fumes laden with dioxins, furans, heavy metals or sulfur dioxide and nitrogen. That is why the burning of waste in open air, or unfiltered smoke, is a disaster, so that ecological health. Current incineration plants are they equipped with systems to filter the fumes and recover the so-called REFIOMS (treatment residues from incineration fumes garbage), ultimate waste which are treated as such in special circuits. So the quality of the filter, and therefore the smoke pollution level which is effectively rejected by the stack, determines the level of toxicity of a given incinerator.

The incineration of one ton of garbage left after burning 2-5 kg of fly ash collected in filters and 300 kg of clinker. The REFIOM are sewage waste incineration fumes garbage (about 23% of the mass incinerated). They consist of dusts called fly ash and pressed sludge called filter cake. The bottom ash (bottom ash from household waste) is the solid residues from incineration, that is to say, the mineral part of the waste (about 10% of the initial volume of incinerated waste). the result of the combustion of 1 ton from household waste:

700 kg of gas,

300 kg of solid residues including 30 kg of ash (1)

10.3.1.1 PRODUCTS OF OXIDATION

The incineration is a decomposition of the material oxidation, with five types of programs:

- Water.
- Gas: CO, CO_2, NO_x, SO_2.
- Mineral Dust (ashes).
- Heavy metals: lead, copper, mercury, cadmium, nickel, arsenic.
- Organic Molecules: carbon, chlorinated organic compounds (dioxins and furans ...).

Elements	

Dust	1500-5000 mg/N 3 m^3
CO	20-50 mg/Nm
HCl	800-2000 mg/Nm^3
SO_2	20-200 mg/Nm^3
NO_x	200-300 mg/Nm^3

Table 1: composition of fumes produced by 1 ton of waste by incineration (5000-6000 Nm^3)

oxidising	**NO**	**SO_2**
Coal	**6**	13
Natural gas	**0.1**	1.7
Petroleum	**12**	4
Burning waste	**5.4**	0.8

Table 2:Comparison of emissions to product 1 MWh.

1.1.1.1 DIVISION OF EMISSIONS

Emissions are divided into three groups depending on their size and the degree of severity:

1* Non-harmful to the environment: nitrogen (N_2), oxygen (O_2), and water vapor (H_2O)

2* Harmful to the environment because they cause acid rain (Acid gases): nitrogen dioxide (NO_2), nitrogen oxide, (NO), Sulfur dioxide (SO_2), carbon dioxide (CO_2)

3* Toxic gases: Furans, dioxins, heavy metals (Hg (from batteries), cadmium, plumb, zinc)

However, almost 95% of emissions are gazes from the first group which mean that they are not harmful to the environment and non-toxic.

For example, at temperature of 850 °C and with amount of oxygen 6% of the air, we obtain:

Carbon dioxide (CO_2) between: 186 mg/m^3 and 96mg/m^3.

Nitrogen dioxide (NO_2) between: 320 $mg/\ m^3$and 140 mg/m^3

Furans, dioxins, between: 21 $mg/m^3$and 5 mg/ m^3

Sulfur dioxide (SO_2): 67 mg/m^3. (2)

10.3.2 1.1.1.2THE NEW STANDARDS ABOUT EMISSIONS

EU directives on emissions from various boilers, dependent the type of fuel and the size of plants. The following list is a short summary of the requirements on emission to atmosphere for waste burning plants from the two EU directives 2001/80/EG and 2000/76/EG. (3)

Dust**:** 10 mg/m^3.

SO_2: 50 mg/m^3.

NO_x: 200 mg/m^3.

HCl: 10 mg/m^3.

HF: 1 mg/m^3.

Cd,Tl: 0,005 mg/m^3.

Hg: 0,005 mg/m^3.

Other trace metals (Pb+Cu+Mn+Ni+Sb+As+Co+Cr+V): 0,5 mg/m^3.

Dioxins : 0,1 ng/m^3.

With 1 ng = 1/10 ^{9}of gram

parameter	half-hour mean value	European Directive 2000/76 / EC of 04/12/2000 and French Decrees of 20/09/2002 and 03/08/2010	refectural stopped operating permit Flamoval of 17/06/2009
Total dust	1-20	10	3
Hydrochloric acid (HCl)	1-50	10	7
Hydrofluoric acid (HF)	10	1	0.7
Sulphur dioxide (SO_2)	1-150	50	15
Carbon monoxide(CO)	5-100	50	30
total organic carbon (COT)	1-20	10	8
Mercury (Hg)	0.001-0.03	0.05	0.04
Cadmium + Thallium (Cd + Tl) -	-	0.05	0.04
Other heavy metals (Sb + As + Pb + Cr + Cu + Co + Mn + Ni + V)	-	0.5	0.4

Oxides of Nitrogen (NOx)	40-300	200	50
Ammonia (NH_3)	-	30	10
Dioxins and furans	0.01-0.1	0.1	

Table 3: Emission limit values in mg / Nm^3 to 11% O_2 dry gas According to EC 20/09/2010 to an incinerator >6 ton/h

In Lebanon:

	<1 ton/h	1-3 ton/h	>3 ton/h
Elements (polluants)	Maximum value(mg/m^3)	Maximum value(mg/m^3)	Maximum value(mg/m^3)
Dust	200	100	30
Pb+Cr+Cu+Mn	-	5	5
Ni+As	-	1	1
Cd+Hg	-	0.2	0.2
Cl (HCl)	250	100	50
F (HF)	-	4	2
SO_2	-	300	300

Table 4: Emission limit values in mg /m^3 to respected (Lebanese environmental ministry

10.3.3 THE EFFECTS OF SOME EMISSIONS

- DIOXINS:

High stability, slow elimination, fat soluble (ease of accumulation in fat) and very slightly soluble in water, very persistent in the environment. They are deposited on soil, grass and fodder consumed by animals, are fixed in their fat and accumulate in humans through the food chain. (Dairy products, meat, eggs, fish and breast milk for example (4)

10.3.4 FURANS

polychlorinated or PCDF are a family of cyclic chemical molecules (aromatic heterocyclic) emitted during incineration of PCBs. They differ from dioxins by the presence of a single oxygen atom in the central ring. Some of them are toxic to humans and the environment. Like almost fireproof electrical insulation and excellent dielectric and thermal conduction properties, PCBs were used extensively from in: electrical transformers ;capacitors ; power switches on. (5) (1)

10.3.5 NITROGEN OXIDE (NO_X) AND NITROGEN DIOXIDE (NO_2)

Contribute to the formation of acid rain, degrading the soil and vegetation. They increase nitrate concentration in soils and surface waters (eutrophication). They also contribute to the formation of ozone.

10.3.6 THE OZONE

The ozone is harmful to a variety of commercial crops and natural plant species. It is a powerful oxidant that degrades the quality of the rubber, textiles ... Even at low levels, it also contributes to global warming.

10.3.7 SULPHUR DIOXIDE (SO_2)

Contributes to acid rain, degrading soils and vegetation. It also threatens certain types of stones used in construction. (6)

10.3.8 - CARBON MONOXIDE (CO)

Carbon monoxide contributes to the formation of ozone. It also changes to carbon dioxide, which is also directly emitted during combustion. CO2 has no direct impact on health, but this is the most abundant anthropogenic greenhouse gas. (7)

10.3.8.1 1.2 TREATMENT BY INCINERATION

The pollutants covered are the acid gas and dust, heavy metals, nitrogen oxides and dioxins, treated with additional processes. The neutralizing reagent can be injected dry as a powder (lime or sodium bicarbonate), by semi-wet (sprayed lime milk), or in a wet scrubber with sodium hydroxide. These processes generate waste products, mainly composed of fly ash dust). The REFIOM stabilized before being stored in class CSD 1. These methods allow purifying more than 98 incinerations of household waste fumes.

(Note: REFIDI are the fumes purification of residues from industrial waste incineration).

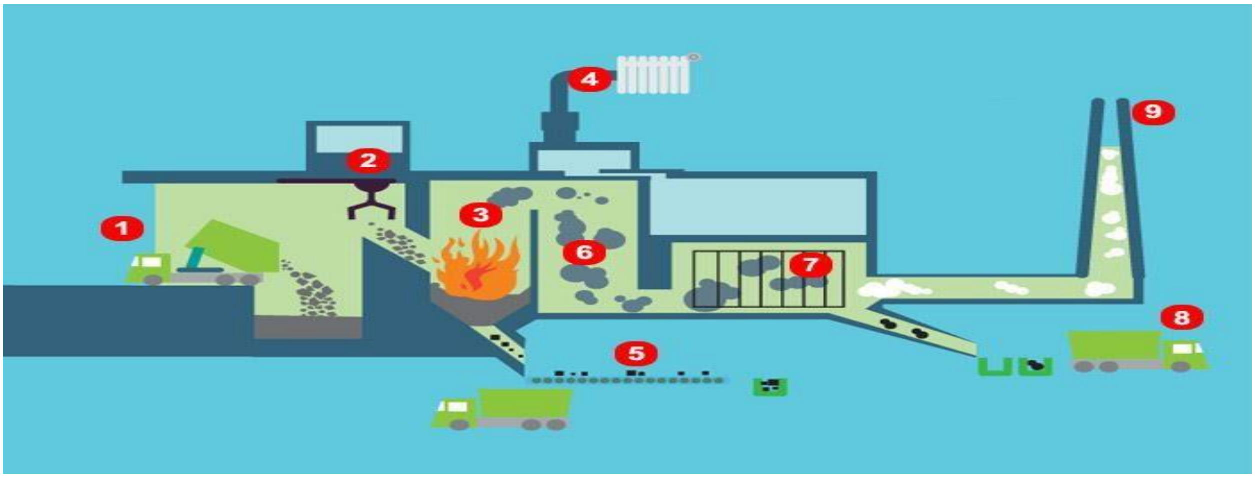


Figure 1: steps of treatment by incineration

- 1 / trucks emptying garbage into the pit
- 2 / gripper transports the waste to the furnace
- 3 / the furnace is fed continuously at more than 1000 °C
- 4 / the exchange of heat between the hot air of the oven and the water circulating in the pipes will produce steam that is sold to nearby industrial plant
- 5 / metals are extracted from bottom ash to be recycled. Clinkers are valued under road layer
- . 6 / the fumes are treated by injection of lime and activated carbon
- 7 / the fumes are dusted after passing through filters
- 8 / Fume Treatment Residues of Household Waste Incineration (REFIOM) are sent to landfill
- 9 / the chimney are equipped with analyzers for measuring the quality of air emissions continuously.

FUMES FACTORS

The following is a list (not exhaustive) of general elements to consider when choosing the flue gas treatment system: waste type, temperature of the flue gas, composition of the combustion gases and ranges of variation emission limit values to respect restrictions on discharges of aqueous effluent vis-a-vis requirements of the visibility of the field plume and available space availability and cost of outlets for the residues / recycled compatibility with the components of the existing process (in the case of existing installations) availability and cost of water and other reagents possibilities of energy supply (e.g. providing the heat recovered by the laveurscondenseurs) allocation of incentives / subsidies for energy exported acceptable waste treatment

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cost (both according to market criteria policies) reduced emissions by primary processes noise if possible, arrange the various components of the flue gas treatment system such that, proceeding from the boiler to the chimney, they require temperatures of becoming
weaker gas. (8)

10.3.8.2 OVERVIEW OF FILTERING

*** Electrostatic**

20 kg of dust and ash per ton of waste in electrostatic precipitators, ash fly are electrified (ionized) and stick into electrodes of plate-shaped. These plates are hit automatically to recover the ashes into hoppers. In electrostatic precipitators, it captures 99.9% of fly ash (REFIOM). Once retrieved, they are stored in silos and then transported in landfills for final waste to be stabilized (mixed with "cement") and buried in watertight compartments.

*** The flue gas scrubbing**

The fumes then pass through two washing columns, one the other basic acid, which will trap the pollutants residual dust, heavy metals, chlorine, fluorine, sulfur oxides.

*** Dioxins**

It only remains to destroy dioxins and nitrogen oxides. The gases pass through a catalyst. It functions as the catalytic converter of a car. These pollutants are completely broken (their molecules are broken).

In contact with catalysts, the molecules of dioxins and nitrogen oxides are broken. The reactor is filled with several shaped catalyst layers of the "honeycomb" so that the contact surface with the flue gases to be as large as possible.

*** The output**

The plant discharges its chimney 68% air, 23% water vapor and 9% carbon dioxide. Other substances in trace amounts are monitored very closely.

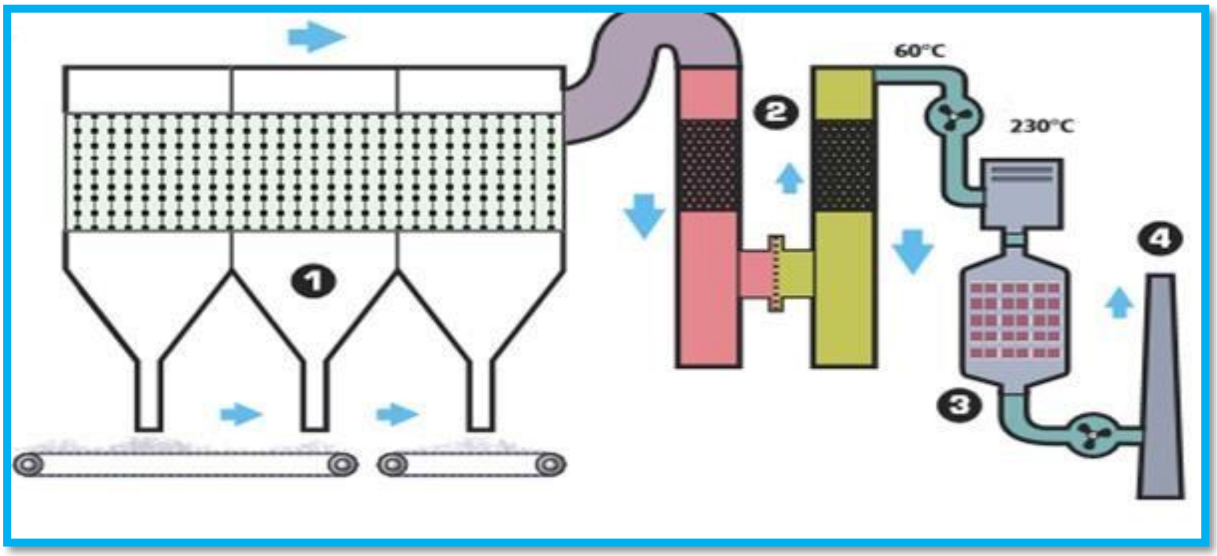

Figure 2: main steps of filtering (9)

Whitewash is widely used in industrial wastewater treatment as acid water neutralization reagent thereby precipitate **heavy metals** present in the effluent.

Dissociates into OH^- ions bind to metals to give insoluble metal hydroxides largely. Ca^{2+}can bind to phosphate or fluoride ions may be present in the effluent to produce calcium phosphate or calcium fluoride.

***Manufacturing**

One can make in small quantities quickly by heating a piece of chalk with a flame and then dilute the resulting powder in water. Then filtering the resulting mixture using a coffee filter, or through several thicknesses of absorbent paper in a funnel. The flame heating decomposed limestone chalk $CaCO_3$ (limestone or calcium carbonate, solid) CO_2 (carbon dioxide or carbon dioxide gas) + CaO (quicklime or calcium oxide, solid).

Hydration of quicklime gives the slaked lime according to the following equation:

$CaO + H_2O$ (water) → $Ca (OH)_2$, or calcium hydroxide (slaked lime, solid).

Calcium hydroxide is diluted in water, where it dissolves only very little, giving a true solution $Ca^{2+} + 2(OH^-)$, and an excess of undissolved hydroxide remaining in suspension in the water. This first step results in a whitish mixture known as milk of lime. To eliminate fraction undissolved suspended, the next filter whitewash. Finally reaches clear lime water.

But do not put too much carbon dioxide. It may be that, if we really introduced a large excess of carbon dioxide, the precipitate just dissolves $CaCO_3$ later, and that happens then the reaction: **$CaCO_3 + CO_2 + H_2O \longrightarrow Ca2^{+} + 2\ HCO_3$**, and solution cleared.

10.3.8.3 DUST

The black smoke (determined as such according to the associated sampling method) are carbonaceous particles of diameter less than 5 microns to about 0.1 microns' dust that are made of solid particles less than 75 microns, the largest emission source falling meadows.

ELECTROSTATIC

The operating principle of the simplest electrostatic filters, wire concentric cylinder, a high electric potential is applied to the wire, called emitter electrode. It is placed in the axis of the vertical cylinder, called the collecting electrode, which is connected there to ground. The gas carrying the particles to be removed enters through an opening located at the bottom of the cylinder, the particulate laden gas passes through the inter-electrode space

OPERATION

The operation of an electrostatic precipitator is relatively simple, but the description and understanding of all phenomena that come into play in the filtration is still largely a treaty study subject. Basically an electrostatic generates ions in the vicinity of a high voltage electrode of small radius of curvature. The gas is ionized by collisions between electrons accelerated by the electric field and by photoionization of the excited species. These ions are ejected from the surroundings of the electrode and are broadcast to the surface of particles to be filtered and to the collector electrode. By repelling the high voltage electrode of the same charge and attraction of the wall of the device connected to the ground, the particles migrate to it and settle permanently until a critical thickness. They then fall by mass effect or by vibration of the header plate. Commercially, two types of electrostatic precipitators are used: wire-cylinder electrostatic and electrostatic plate's wire. The wire-cylinder electrostatic precipitators are rather used when the recovered particles tend to form a liquid film to flow naturally and electrostatic wire-plate in the case of dust. Two classes are distinguished from electrostatic wire-plate, namely wire-plate one or two floors. When there is a single stage, the gas ionization and particles are at the same time in the whole volume of the facility, and when there are two stages, the particles are charged in a small area containing one or more discharge electrodes, and then deflected in a long plate-plate system. In the case of a cylinder thread, there is always one floor.

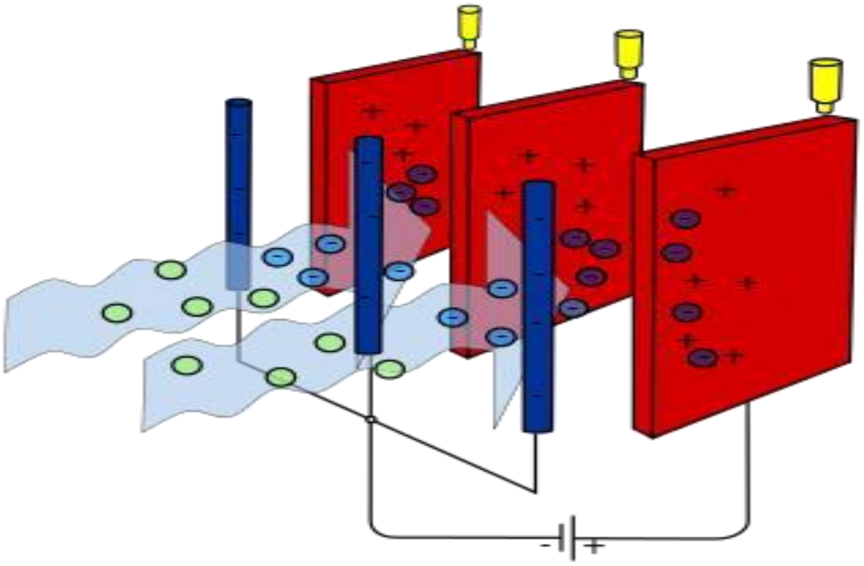

Figure 3: electrostatic precipitator

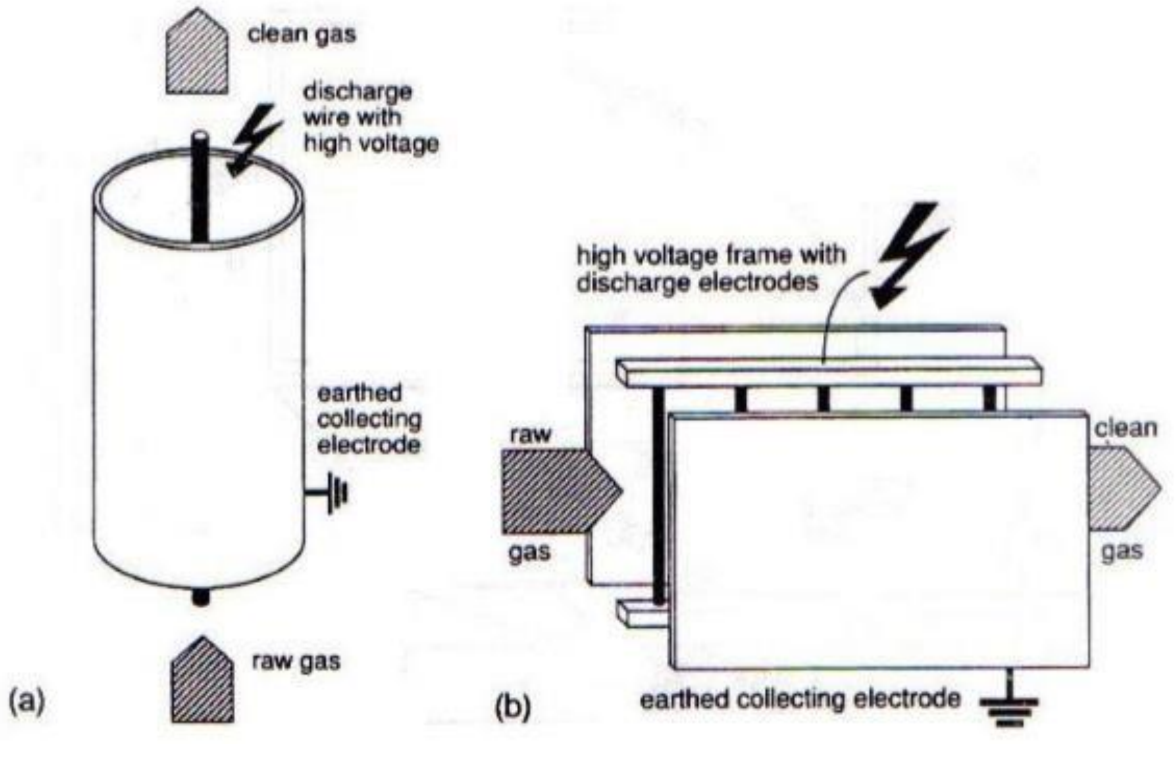

Figure 3a and 3b: the two main types of electrostatic precipitators: in (a) the wire cylinder, and (b) wire-plate 1 stage.

The parameters influencing the filtering particles are numerous and complicated to relate. The nature of the gas, its temperature and pressure influence the discharge phenomena and the minimum ionization voltage. The ionization of the gas causes a flow of ions in the vicinity of the high voltage electrode which disrupts the gas velocity field. The gas itself is more or less subjected to turbulence, and in the case of highly particle-laden gas, the movement thereof. The electric field is totally disrupted by the particulate and ionic space charge. The particles entrained by the carrier gas and the electric field, charge over time in an electric field and a payload field nonhomogeneous space. Finally, the space charge is partially driven by the carrier gas.

Electro-filtration treating the problem, beyond the simplified analytical approaches demand the resolution of a large number of differential equations highly nonlinear and coupled. Fortunately, in most cases it is possible to decouple the resolution electrostatic, fluid dynamics and particle dynamics, without much influence the final outcome.

OVERALL EFFICIENCY MODELS

The first design method electrostatic proposed by Deutsch and Anderson ignored the understanding of electrostatic phenomena, such as the structure and operation of the corona discharge or the kinetics of charge particles. This model is still widely used and gives very good estimates of the filtration efficiency of various geometries. This theory assumes that the particles are loaded instantly upon entering the electrostatic their saturation charge, the electric field is constant, and therefore the velocity of a particle to the wall collection is the electrostatic constant. Deutsch hypothesized that the radial particle dispersion coefficient is infinite and zero longitudinal. Cooperman (1984) improves the model taking into account a finite longitudinal dispersion coefficient and a possible re-entrainment of particles. The resolution by Cooperman is often considered perilous to use because of the very high turbulent dispersion coefficients used by the author. Leonard et al. (1980) use a finite and constant radial diffusion coefficient and derive their effectiveness from the convection diffusion equation with a flat radial velocity profile, which seems not to be appropriate near the walls. Zhibin and Guoquan (1992) use a global turbulent diffusion coefficient taking into account the electric and a wind profile Non regular speed in the flow. All global models, however, have a limitation, which is that each relationship giving the efficiency of the electrostatic filter is valid only for a certain particle size. In order to calculate directly the mass efficiency, Bai et al. (1995) develop a model assuming a lognormal distribution of the particles. This approach allows with minimal calculations have very good estimates efficiencies on polydipsersés aerosols. It appears that turbulent dispersion of the particles is critical phenomenon in modeling the efficiency of electrostatic precipitators.

The overall filtration efficiency may be calculated from the particle diffusion equation (x is in the flow direction, longitudinal direction y perpendicular to the wall of the electrostatic transverse direction Dp ,i coefficient dispersion in the direction considered)

$$D_{p,y}\frac{\partial^2 C}{\partial y^2}+D_{p,x}\frac{\partial^2 C}{\partial x^2}+v_e\frac{\partial C}{\partial y}-u\frac{\partial C}{\partial x}=0$$

The theoretical efficiencies of Deutsch models Cooperman, Leonard, and Zhiblin are synthesized by Kim and are more or less simplified analytical solutions of this equation

$$De=\frac{v_e.L}{u.b}$$

$$Pe=\frac{v_e.b}{D_p}$$

$$R=2.b \quad \text{wire-cylinder}$$

$$\eta_{Deutsch}=1-\exp(-De)$$

$$\eta_{Cooperman}=1-\frac{2.\exp(v_e.b/(4.D_{p,y}))}{\pi.(v_e.b/(4.D_{p,y}))}.\exp\left(-\frac{v_e^2.L}{4.u.D_{p,y}}\right)$$

$$\eta_{Leonard}=1-\int_0^1 P\left(\frac{\xi-De}{\sqrt{2.De/Pe}}\right).d\xi$$

$$\eta_{Zhibin}=1-\sqrt{\frac{Pe}{4.\pi.De}}.\int_0^1 \exp\left[-\frac{Pe}{4.De}(\xi-De)^2\right].d\xi$$

With v_e particle migration rate that takes into account the average electric field and the charge of the particles (which will be explained later in the physical part of the particles),

b distance wire-plate,

R distance wire-cylinder,

L the electrostatic precipitator length, u the average velocity of the gas, and P is the absolute pressure.

Xiangrong (2002, [14]) offers an analytical solution of the turbulent diffusion equation charged particles in wire-plate geometry (Cartesian coordinate system), assuming zero flow to the high voltage son (symmetry condition. The efficiency is given by the following relationship:

$$\eta_{Xiangrong} = 1 - \exp\left(- F \frac{v_e.L}{u.b} \right)$$

$$F = \frac{u}{v_e}.\frac{Pe_x}{2}\left\{ \left\{ 1 + \frac{v_e}{u}\frac{Pe_y}{Pe_x}\left[1 + \left(\frac{2\theta}{Pe_y} \right)^2 \right] \right\}^{\frac{1}{2}} - 1 \right\}$$

$$\tan\theta = \frac{4(\theta / Pe_y)(F-1)}{(2.\theta / Pe_y)^2 + 2.F - 1}$$

The values of F and θ are found iteratively by successive approaches. The difference from the Deutsch equation is the inclusion of a longitudinal and radial diffusion.

Finally, Kittelson cites Hinds for a filtration efficiency in geometry wire-cylinder and in laminar flow of the type:

$$\eta_{Hinds} = \frac{2.\pi.\mu_{p,e}.V.L}{Q_v.\ln(R / R_0)}$$

These overall efficiency models are all assuming that the speed of particle migration (for a given size) is constant, which means that the electric field is constant and the charge of the particles is instantaneous. This is far from the case most of the time. In addition to these approximations are added all the hydrodynamic phenomena begin in the actual geometries and not taken into account (not homogeneous turbulence, wind power, etc.).

The turbulent diffusion equation of the particles is based on the Eulerian method called resolution of particle migration in electrostatic precipitators, which will be developed further.

A simplified method of calculation of the turbulent diffusion coefficient of the particles will be presented.

It is therefore dangerous to rely on overall efficiency models when we want to tackle the physical description of an electrostatic precipitator with a rather special geometry and industrial another, or that we are to respect all electrostatic aspects, which are not nearly as simple as do suggest hypotheses on the electric field and the charge of the particles of these models. We will now proceed to a detailed study of electrostatic phenomena encountered in electrostatic precipitators.

THE CORONA DISCHARGE

The corona discharge is a stable ionization of the surrounding gas of a small radius of curvature electrode connected to the high voltage. The ionization of the gas is due to the strong electric field surrounding the electrode surface. The corona discharge can be established by negative or positive polarity according to the needs. It is generally found that small units working in confined spaces and cold gases using a positive voltage, which although not very stable, generates little ozone, while larger installations for hot gas working negative voltage because the ozone is not stable at high temperature, and the discharge is more stable.

THE CORONA DISCHARGE: QUALITATIVE DESCRIPTION

Conduction in the gas is very different from the conduction in liquids or metals, where loads of travel is under a minimal difference of potential. Air naturally contains a small number of charged species due to cosmic rays and low ambient radioactivity. The resistivity is then about 1014 Ω-m. From a certain potential difference applied to the air, naturally enough electrons are accelerated between two molecular collisions to cause ionization of the gas, followed by electron avalanches. The resistivity of the air then decreases sharply to values of the order of 103 Ω-m. The onset of conduction in the air begins to fields of the order of 30 kV / cm. In a planar configuration, the establishment of conduction current causes immediately the occurrence of an arc.

if the thermal discharge current can be maintained, the effect itself crown is not observed. As the field is constant, any electronic avalanche is growing exponentially until breakdown. Using electrodes with very different radii of curvature, the electric field is very inhomogeneous and only a small volume of air around the electrode connected to the high voltage is ionized, it is the corona. The field called "disruptive" is achieved only in a very small sheath around the electrode small radius of curvature.

If the electric field is sufficiently intense and if the distance between two electron-molecule shock is sufficiently large, the kinetic energy of the accelerated primary electrons enables to remove an electron impact on neutral atoms of the gas. The kinetic energy of impingement of the electrons is measured in eV (1 eV = 1602.10 to 19 J). In between each clash, there is therefore release of one or more electrons and an exponential increase in their number: it is the electron avalanche. A portion of the shock also leads to the passage of neutral molecules electrons to higher roughly stable orbital. The relaxation of the excited state to the neutral state occurs by releasing a photon, which in the case of nitrogen is enough energy to ionize itself

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other molecules. This permanent-excitation is also responsible for the violet glow of the corona discharge. In the case of a corona, the kinetic energy of the electrons averaged a few electron volts, sufficient to ionize the nitrogen, oxygen and the vapor from the air to water. Parallel to this avalanche of negative charges to the anode, positive ions created migrate towards the cathode. Mass generally very high compared to that of the electrons, and having free course means very low, positive ions are only slightly accelerated and do not participate in the ionization of the gas. By against their low mobility locally created a very high load of space, disrupting the overall electric field.

10.3.8.4 NEGATIVE DISCHARGE

If discharge is easiest to describe, because the electron avalanche takes place in all or part of the inter-electrode space. The avalanche propagates from the cathode (small radius of curvature, connected to the negative high voltage) to the anode (large radius of curvature). The primary electrons in the vicinity of the cathode initiate an electron avalanche until the electric field, which has a very inhomogeneous become low enough so that the electron energy becomes insufficient. Ionization then stops and recombination events between neutral species and electrons take place during the migration of the electron cloud toward the anode. The arrival of negative charges is therefore in the form of an electronic cloud that follows a cloud of negative ions. The electronics then avalanche leaves behind a very strong positive load space, which will slowly migrate to the cathode. The strong polarity of the cloud will lead extracting secondary electrons from the surface of the cathode (Malter effect) and thereby renew the amount of electrons necessary for the corona discharge. The cathode surface condition affects many electronics extraction. The higher the field will be intense in the interelectrode space, more landfills will be spread far and negative voltage discharge therefore ensures high ionization of the inter-electrode space. Because of the individual aspect of the electronic avalanche, we see that the current measured in a negative crown is pulsed, and the frequency increases with the applied potential. Electron recombination and thus the electronegativity of the gas goes much influence the stability of the discharge. In the case of a very little electronegative gas, any avalanche breakdown leads to, since no phenomenon diminishes the amount of electrons in the discharge (recombination). When the avalanche manages to connect the cathode and the anode, an ionized channel very low resistivity is formed, and allows the passage of a very high current. The gas in the channel is heated by Joule effect, the charges are redistributed to form a polarity medium at about neutral but highly ionized, the voltage abruptly drops: what is the thermal arc.

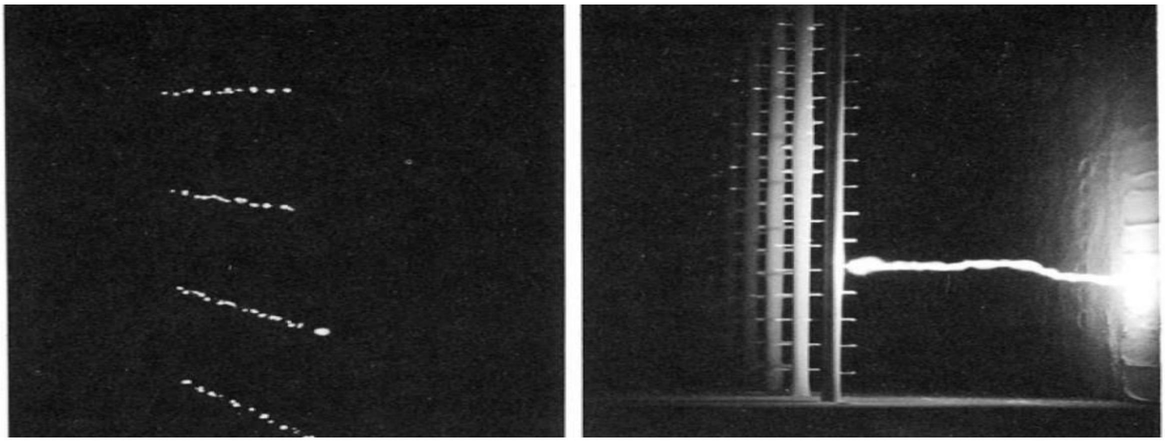

Figure 4:the corona discharge

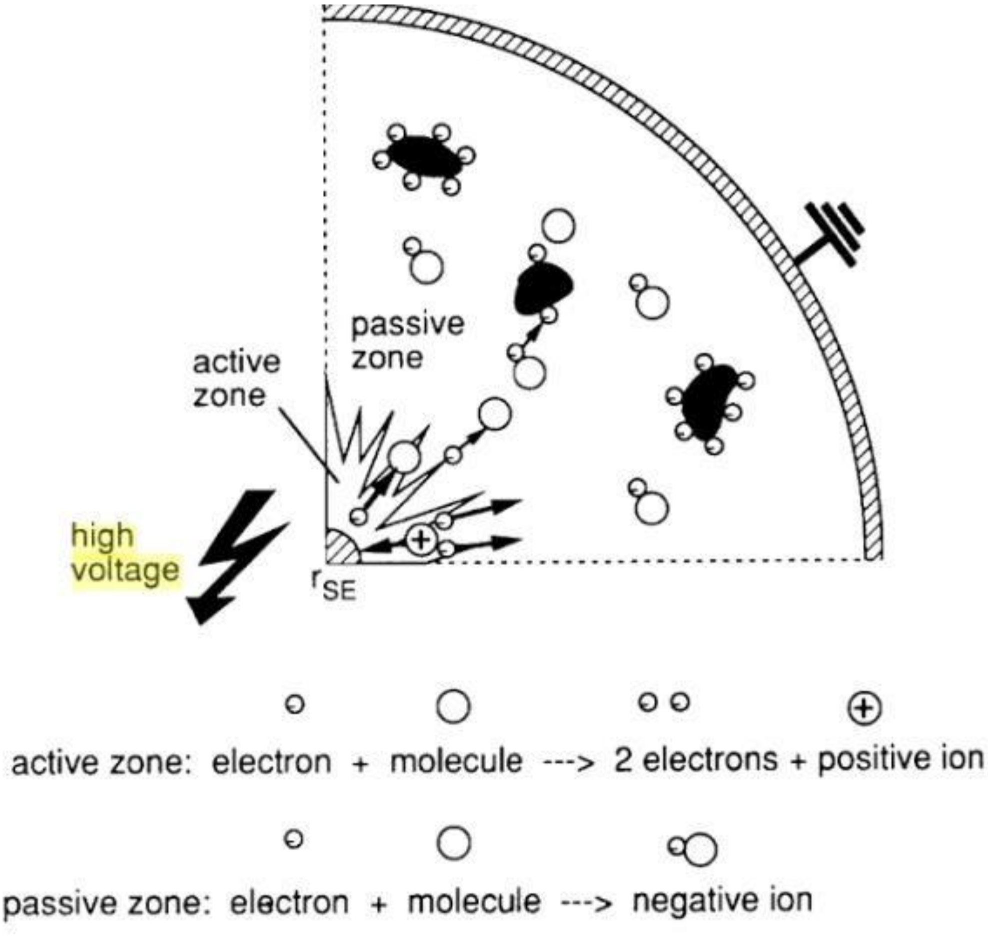

Figure 5: mechanism of discharge

POSITIVE DISCHARGE

In the positive discharge, the anode is the small radius electrode. The anode attracts to it the primary electrons and avalanche occurs the inter-electrode space towards the center of the device, in fact a very small volume (due to the considered cylindrical geometry). The crown is much better defined than in negative voltage, and the discharge current is almost continuous. The positive charges created then slowly migrate towards the cathode. The regeneration of the primary electrons takes place mainly by excitation of an unstable form of nitrogen in the form of a high energy UV photon which allows this phenomenon. The de-excitation is not instantaneous; the phenomenon of positive discharge is relatively steady over time. A lot of edge, the positive discharge seems much more stable. However, the positive charges created in the crown have very low electrical mobility and profoundly disrupt the electric field of the interelectrode space. From a certain load space, the field generated by it is of the same order of magnitude as the field generated by the high voltage, and the crown can self-propagate by electronic darts or streamers. These darts have a very high probability of spread to the cathode and an electric arc. It is found experimentally that the inter-electrode medium is very quickly saturated with positive ions and the breakdown occurs at relatively low currents. The positive discharge is more unstable equivalent current and low electric mobility of the positive ions that for the same potential, the positive discharge current is lower than negative voltage. In the positive discharge finally, the region of strong electric field contains few ions, chemical reactivity within this ring is reduced.

CURVES CURRENT-POTENTIAL

Gradient disrupter

The foregoing description of the corona is valid from the time the kinetic energy of electrons in the air is sufficient to cause ionization of the gas molecules, i.e. the reduced scope is sufficient. Peek offers a semi-empirical equation for giving the minimum air ionization field as a function of the geometry of the system (peek cited by Kaptzov):

$$E_0 = 3{,}1.10^6.\delta.f.\left(1+\frac{0{,}0308}{\sqrt{0{,}5.\delta.R_0}}\right)\textbf{spherical geometry}$$

$$E_0 = 3{,}1.10^6.\delta.f.\left(1+0{,}0308\left(\frac{1}{\delta.R_0}\right)^{\frac{1}{2}}\right|\ \textbf{for a cylindrical wire}$$

The figure recalls the geometric conventions used.

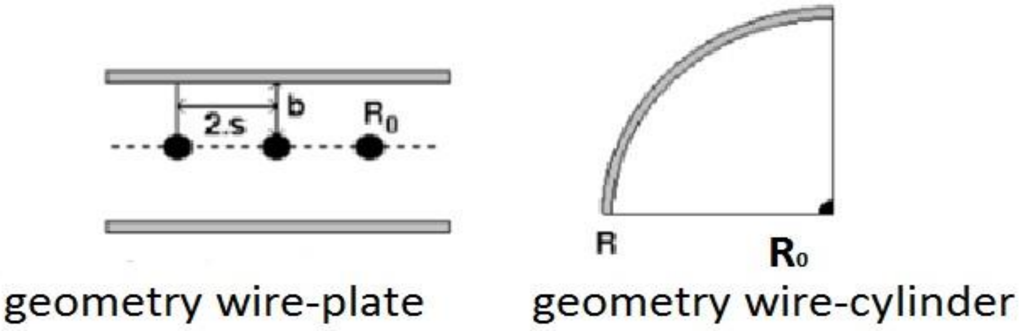

Figure 6:geometry of wire

Geometry current wire cylinder

Townsend gives linear relations between the voltages applied to the current geometry wire

$$I_{linéique} = \frac{8.\pi.\mu_{ion}.\varepsilon_0}{R^2 \ln\frac{R}{R_0}}.V(V - V_0)$$

$$V_0 = E_0.R_0.\ln\frac{R}{R_0}$$

cylinder for low currents in the air:

This relation is valid until a current criterion given by Townsend:

$$C_I = \left(\frac{R}{E_0.R_0}\right)^2.\frac{J.R}{\varepsilon_0.\mu_{ion}} << 1$$

Beyond this limit, Townsend proposes to make the following relation:

$$\sqrt{1+C_I} - 1 - \ln\frac{1+\sqrt{1+C_I}}{2} - \frac{V - V_0}{V}.\ln\frac{R}{R_0}$$

This is much less obvious to use. In the case of our ESP, switching from one relation to another occurs to 1 mA discharge current (for a matrix of 20 cm), but results in very small differences in fine, which does not justify its routine use.

Current wire-plate geometry:

In wire-plate geometry for low discharge currents, Cooperman offers an alternative to wirecylinder

$$J = \frac{\varepsilon_0 . \mu_{ion}}{s.b^2 . \ln \frac{R_{eff}}{R_0}} . V\left(V - V_0\right)$$

$$V_0 = E_0 . R_0 . \ln \frac{R_{eff}}{R_0}$$

$$R_{eff} = \frac{4.b}{\pi} \qquad \frac{b}{2.s} \leq 0{,}3$$

$$R_{eff} = 0{,}36.s.\exp^{\left(\frac{2{,}96.b}{2.b}\right)} \qquad 0{,}3 < \frac{b}{2s} < 1{,}0$$

$$R_{eff} = \frac{s}{\pi}.\exp^{\left(\frac{\pi.b}{2.b}\right)} \qquad 1{,}0 < \frac{b}{2s}$$

The relation is valid until a current criterion:

$$C_I = \left(\frac{b}{E_0 . R_0}\right)^2 . \frac{1}{\ln \frac{R_{eff}}{R_0}} . \frac{s.J}{\pi . \varepsilon_0 . \mu_{ion}} << 1$$

Cooperman (1981, cited by Goo and Parker) provides a meaningful relation to the strong currents in wire-plate geometry:

$$J = \frac{\varepsilon_0 . \mu}{16.b^3}\left(\alpha_J + \sqrt{\alpha_J^2 + 192(V - V_0)(b.E_1)^3}\right)$$

$$\alpha_j = 9(V - V_0 + b.E_1)^2 - 12(b.E_1)^2$$

$$E_1 = \frac{\pi . V_0}{2.s.\ln\left(\frac{R_{eff}}{R_0}\right)}$$

E1 is the maximum electric field on the collector plates, s half-space between two high voltage electrodes, the b wire-plate distance and J current per unit area of collector plates.

White (cited by Ducret) states that for low inter-electrode distances and negative voltage (of the order of cm), there may be a sharp divergence between the calculated current and the actual current, because the occurrence of a stream of free electrons. This can lead to abnormally high measures of ion electric mobility in negative discharges. Townsend takes the relation rather than a form of the type ILINEAR = k.(V-V0).

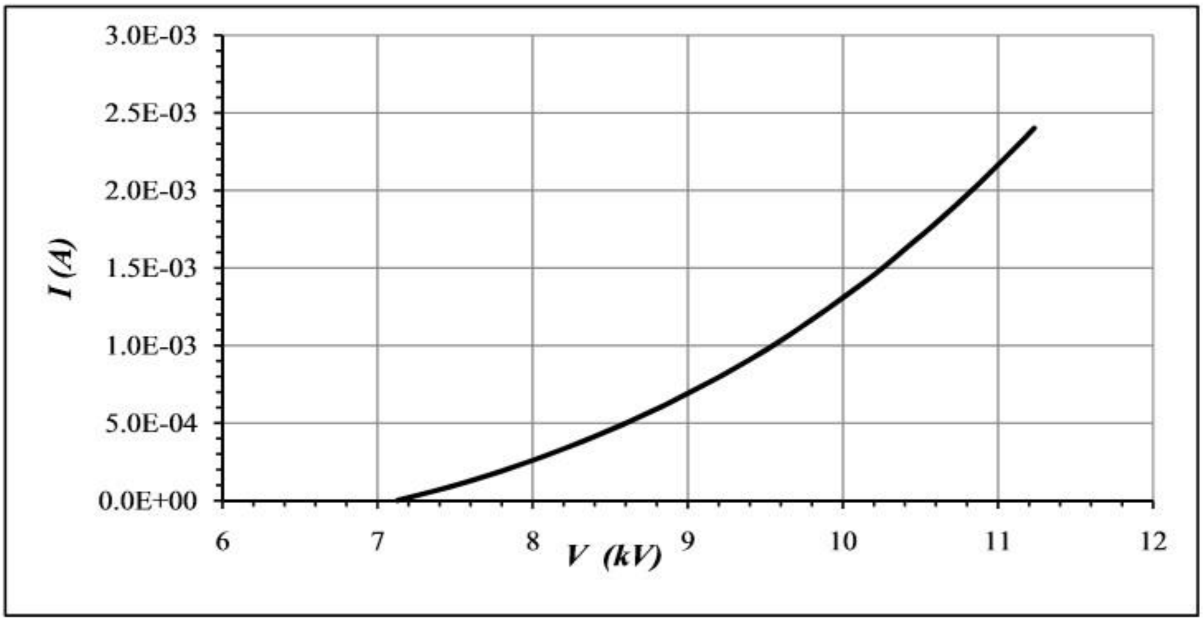

Figure 7: current-potential of electro-filter

RESISTIVITY

Resistivity, which is a characteristic of particles in an electric field, is a measure of a particle's resistance to transferring charge (both accepting and giving up charges). Resistivity is a function of a particle's chemical composition as well as flue gas

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operating conditions such as temperature and moisture. Particles can have high, moderate (normal), or low resistivity.

Bulk resistivity is defined using a more general version of Ohm's Law, as given in Equation

below: $\vec{E} = \rho \vec{j}$

Where:

E is the Electric field strength

(V/cm); j is the Current

density (A/cm^2); and ρ is the

Resistivity (Ohm-cm)

A better way of displaying this would be to solve for resistivity as a function of applied voltage and current, as given in next Equation below:

$$\rho = \frac{AV}{Il}$$

Where:

ϱ = Resistivity (Ohm-cm)

V = The applied DC potential,

(Volts); I = The measured

current, (Amperes); l = The ash

layer thickness, (cm); and

A = The current measuring electrode face area, (cm^2).

Resistivity is the electrical resistance of a dust sample 1.0 cm^2 in cross-sectional area, 1.0 cm thick, and is recorded in units of ohm-cm. The table below, gives value ranges for low, normal, and high resistivity.

Resistivity	**Range of Measurement**
Low	between 10^4 and 10^7 ohm-cm
Normal	between 10^7 and 2×10^{10} ohm-cm
High	above 2×10^{10} ohm-cm

Table 5: types of resistivity

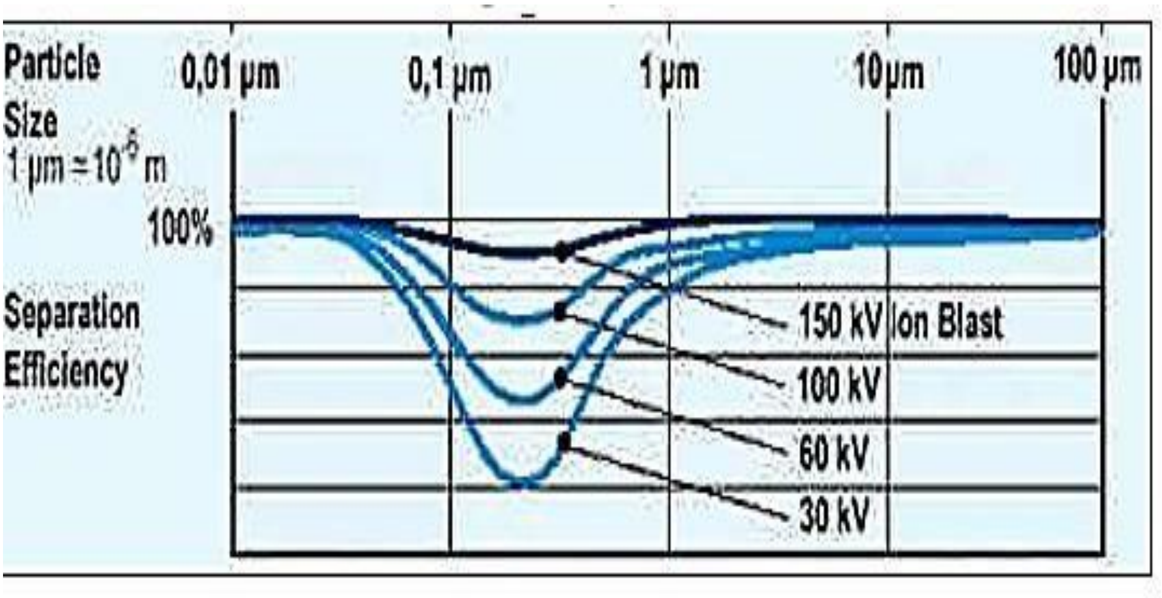


Figure 8 : relation between voltage and separation efficiency

1.4.2 TYPES OF ELECTROSTATIC

1.4.2.1 ELECTROSTATIC PRECIPITATORS ESP

ESP sometimes are also called electrostatic filters. The efficiency of dust removal of electrostatic precipitators is mainly influenced by the resistivity of the dust. If the resistivity of the dust layer increases to values higher than 10 11 to 10 12 Ω-cm the removal efficiencies are reduced. The resistivity of the dust layer is influenced by the composition of the waste. This can quickly change with a changing composition of waste, especially with hazardous waste incineration. Sulphur in the waste (the water content at operating temperatures below 200 ° C often reduces the resistivity of the layer of dust as SO_2(SO_3) in the exhaust gas and therefore facilitates deposition in the electric field. For the deposition of fine dust and aerosols, installations that maintain the effect of the electric field by drop formation in the flue gas (electrostatic precipitators to condensation and wet electrostatic precipitators to condensation, electro filter pumps, chillers ionized Pre-installed spray) may improve the efficiency of removal.

Typical operating temperatures for electrostatic precipitators are 160-260 ° C. An operation at higher temperatures (e.g. Beyond 250 ° C) is generally avoided as this may increase the risk of PCDD / F (and therefore discards).

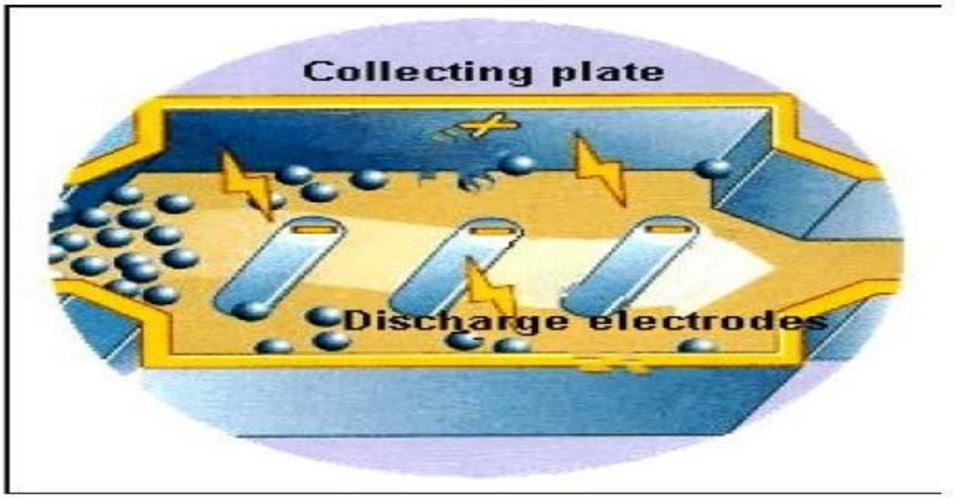
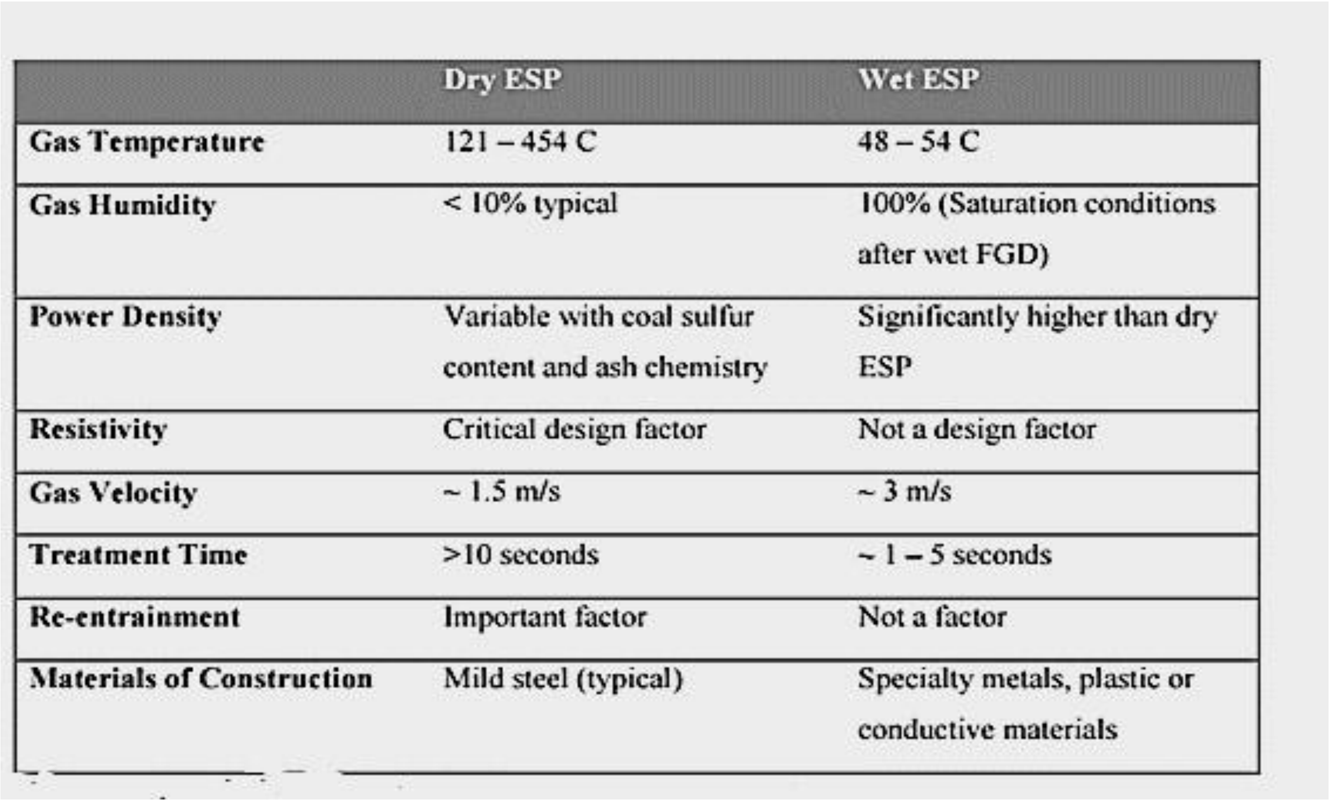


Figure 9: electrostatic filter

1.4.2.2 WET ELECTROSTATIC PRECIPITATORS

There are based on the same technological principle as electrostatic precipitators. With this design, however, the precipitated dust on the collector plates is washed using a liquid, generally water or $CaCo_3$. This can be carried out continuously or periodically. This technique works satisfactorily in the case where wet or cooled flue gas enters the electrostatic precipitator.



	Dry ESP	Wet ESP
Gas Temperature	121 – 454 C	48 – 54 C
Gas Humidity	< 10% typical	100% (Saturation conditions after wet FGD)
Power Density	Variable with coal sulfur content and ash chemistry	Significantly higher than dry ESP
Resistivity	Critical design factor	Not a design factor
Gas Velocity	~ 1.5 m/s	~ 3 m/s
Treatment Time	>10 seconds	~ 1 – 5 seconds
Re-entrainment	Important factor	Not a factor
Materials of Construction	Mild steel (typical)	Specialty metals, plastic or conductive materials

Table 6: Major differences between dry and wet ESP (10)

1.4.2.3 ELECTROSTATIC PRECIPITATOR CONDENSATION

The electrostatic precipitator condensation is used for very fine deposits, solid, liquid or sticky particles, for example, in flue gases from incineration plants of hazardous waste. Unlike conventional wet ESPs, the collecting electrostatic precipitators condensation surfaces comprise vertical plastic pipe arranged in packets, which are water-cooled from the outside.

1.4.2.4 WET SCRUBBERS TO IONIZATION

The purpose of the Wet Scrubber Ionization (EHI) is to remove various pollutants from the flue-gas stream. EHI combines the principles of:

- Electrostatic charging of particles, electrostatic attraction and deposition for aerosols (less than 5 micron)
- Deposition of coarse particles, liquids and solids (greater than 5 mm), and
- Absorption of hazardous, corrosive and malodorous.

The HIE system is a combination of an electrostatic filter and a scrubber packing. It is said that he needs little energy and has a high deposition efficiency for particles in the submicron as well as those of the micron.

A high voltage zone is installed prior to each step a fixed packing. The function of the highvoltage area is to ionize the particles (dust, aerosols, particles less than one micron) contained in the flue gas. The negatively charged particles induce opposing loads on the neutral surface of the moistened packing material and the drops of water falling. Because of this, they are attracted and are then washed in the packing section. This is referred to as attraction Image / Force (IF attraction), i.e. attraction of a shift of electrons. Hazardous, corrosive and malodorous are also absorbed into the same fluid and chemically combined scrubber to be evacuated with the effluent from the scrubber. Another type of wet scrubber includes Venturi ionization. The pressure changes that occur through the Ventures allow fine particles to grow and the electrode the load. They are then collected by the dense layer of deposited droplets through a nozzle, serving as collecting electrode.

1.4.3 SLEEVE FILTERS

Fabric separators also called sleeve filters are very widely used in waste incineration plants. The filtration efficiency is very high for a wide range of particle sizes. For particles less than 0.1 microns, efficiency is reduced, but the fraction of these particles that exist in the flow of exhaust gas of waste incineration plants is relatively low. Low dust emissions are achieved with this technology.

The compatibility of the filter medium with the characteristics of the flue gas and the dust, and the filter of the process temperature are important for effective performance. The filter is a way that should have suitable properties for thermal,

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physical and chemical -by ex. hydrolysis, acid, alkali, and oxidation). The gas flow rate determines the appropriate filtering surface, that is to say the filtration velocity.

The mechanical and thermal stress on the filter material determines service life, energy and maintenance requirements.

Continuous operation, there is a gradual loss of pressure through the filter because particle deposits. When dry sorption systems are used, the formation of a cake on this medium helps remove the acid. In general, the pressure differential across the filter is used to monitor the need for cleaning. Periodic replacement is required when the residual maturity is reached or in case of irreversible damage (e.g. increasing pressure loss can be caused by irreversible deposit of fine dust in the filter material). Several parameters help to control the lifetime of the sleeves: drift of the pressure drop, visual parameter, microscopic analysis, etc. Potential leaks in the bag filter will also be detected by increased emissions or by process disturbances.

The application of dry deposition is limited to the dust which is hygroscopic at high temperatures (300 to 600 ° C) and become tacky at these temperatures. This type of dust forms deposits in the deposition equipment, which can't be adequately removed by conventional cleaning techniques during operation, but may need to be removed by vibration ultra sound. They may be dust complex salts, for example from waste containing phosphorus, sulfur or silicon.

Figure 10: Example for a sleeve filters

1.4.4 CYCLONES (THIS FIRST PHASE CAPTURES SOLID HEAVY METALS, DUST BETWEEN 5 AND 30 MICRON)

Multi cyclones use centrifugal forces to separate particulate matter from the gas stream. Multi cyclones differ from simple cyclones in that they comprise a number of small cyclone units. The gas stream enters the separator tangentially and exits through a central port. The solids are forced towards the outlet of the cyclone and collected on the sides to be deleted.

In general, cyclones alone can’t achieve the emission levels now applied to modern waste incinerators. They may, however, have an important role to play where applied as a pre-cleaner prior to the processing steps of the burned gases. Energy requirements are generally low because there is no pressure drop across the cyclone.

Advantages of cyclones are their wide operating temperature range and rugged construction. Erosion of cyclones, especially at the impact point of the burnt gases, can be a problem when the burnt gas is laden with particles. For the purification of air and gases, we generally use the extruded activated carbon (compacted into pellets) or coarse (granular). (8)

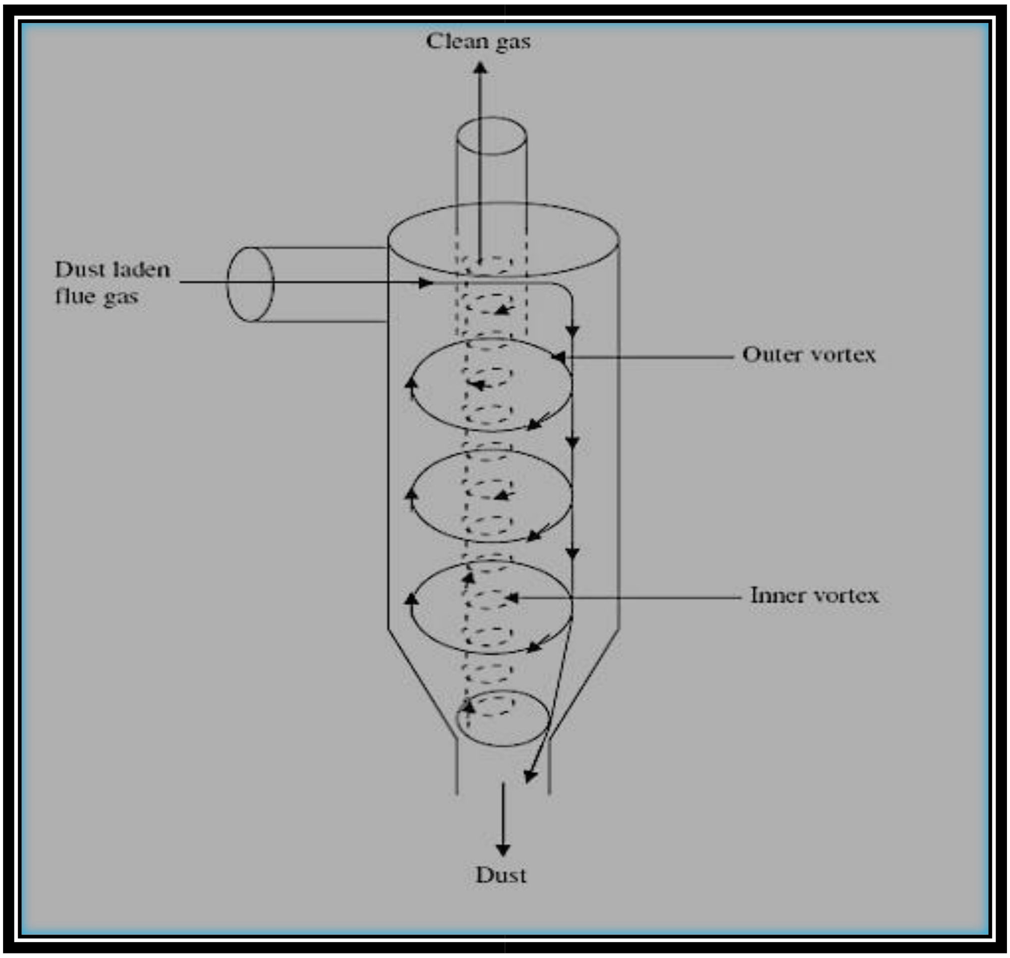

Figure 11: design of cyclone

10.3.8.5 1.5 SIMPLE CYLINDRICAL ELECTROSTATIC

1.5.1 PRINCIPLE OF OPERATION AND EXPERIMENTAL PROCESS:

The operating principle of the simplest electrostatic filters, wire concentric cylinder, a high electric potential is applied to the wire, called emitter electrode. It is placed in the axis of the vertical cylinder, called the collecting electrode, which is connected there to grounded. The gas carrying the particles to be removed enters through an opening located at the bottom of the cylinder, the particulate laden gas passes through the inter-electrode space. Corona, there is ionization of the gas wire author, and creation of ions and electrons. These pollutants bombarding particles becoming electrically charged and then attracted towards the inner surface of the cylinder under the effect of the electric field. The particles are deposited on the cylinder, where they are, are removed by washing, scraping or rapping, collected in hoppers and finally discharged into the drawer out of the electro filter.

***FEATURE current-voltage**

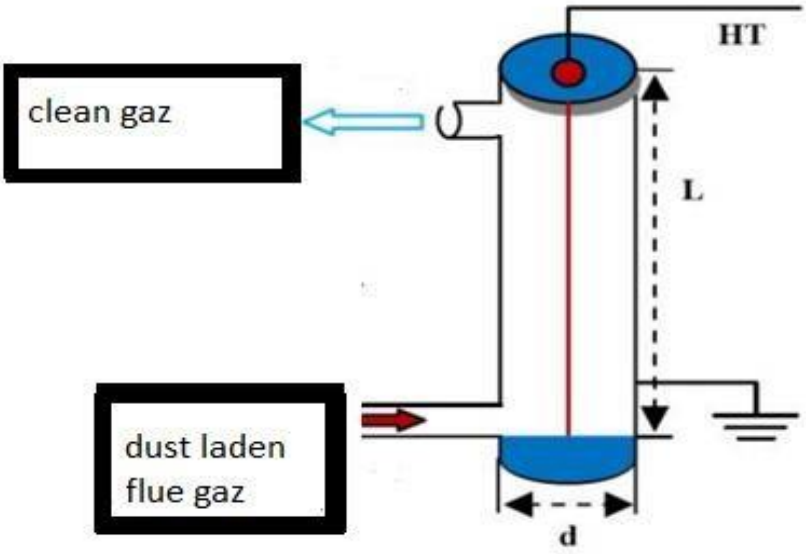

Figure 12: electrostatic cylindrical

1.5.2 INFLUENCE OF THE DIAMETER OF THE WIRE

We apply to the wire, a positive DC electric potential gradually increasing the voltage applied to the yarn and measuring the electric current on the cylinder. We operate in the same way up to a voltage near the breakdown voltage. Used two different diameters of copper wire,

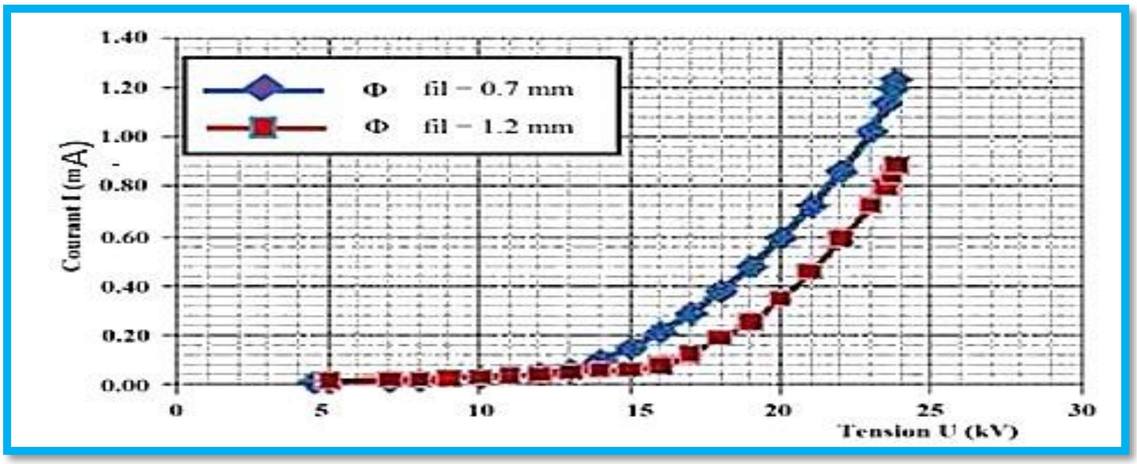

Figure 13: Current-voltage characteristics for two different wire diameters

It can be concluded that the wire diameter is inversely proportional to the electric discharge. This is quite normal because the electric field on the wire is inversely proportional to the radius of the wire R0 (eq below):

$$E = \frac{q}{4 \times \pi \times \varepsilon \times R_0}$$

Therefore, when R0 decreases, E increases and vice versa.

1.5.3 CYLINDER DIAMETER INFLUENCE

We proceed in the same manner as the previous step using two diameters and cylinder with a diameter of 0.7 mm constant corona wire copper. We traced the current - voltage characteristic for a cylinder diameter of 80 mm and 110 respectively

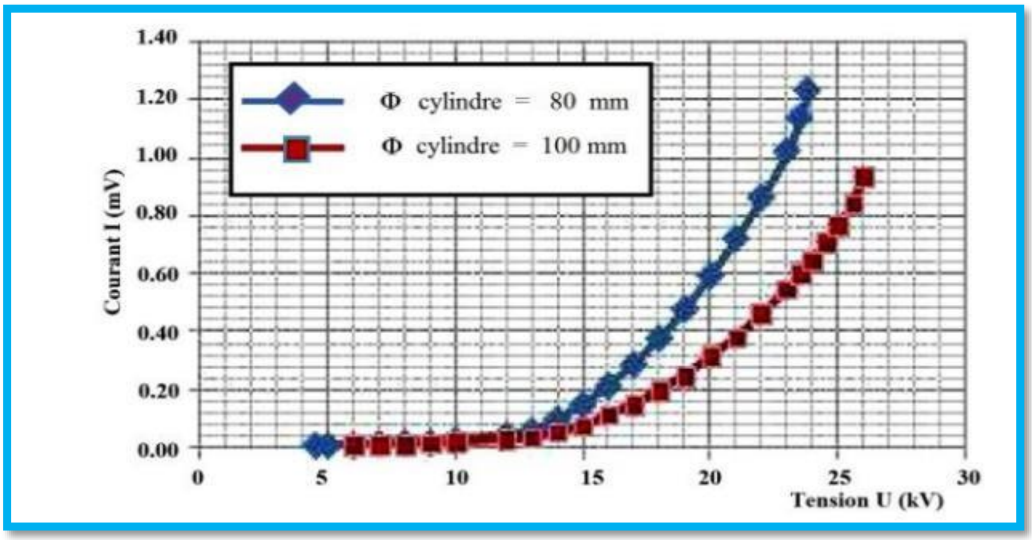

Figure 14: Current-voltage characteristics for two different cylinder diameters

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his time also, the increase in the cylinder diameter is induced a decrease of the electric discharge. exegesis can one it by the relationship of the current per unit length of Townsend:

$$I_{\text{linéique}} = \frac{8 \times \pi \times \mu_{\text{ion}} \times \varepsilon_0}{R^2 \times \ln \frac{R}{R_0}} \times V \times (V - V_0)$$

$$V_0 = E_0 \times R_0 \times \ln \frac{R}{R_0}$$

With R0, the radius of the wire, and R is the radius of cylinder (11)

1.5.4 EFFICACY OF AN ELECTROSTATIC

Previously, electrical discharge mechanisms of particle charge and forces acting on a charged particle in turn have been studied. From these achievements, the precipitation yield or electrostatic can be evaluated theoretically.

The overall performance of the operation of an electrostatic filter is quantified by a variable named total collection efficiency (or collection efficiency) ηt defined by the following expression:

$$\eta_t = I - \frac{n_s}{n_e}$$

Where ns and ne respectively represent the concentrations at the outlet and at the inlet of precipitator; n may be expressed as number of particles or mass. (12)

1.6 Treatment of toxic gas.

The flue gases are then processed by wet or dry. This phase can capture the acid gas, sulfur oxides and volatile heavy metals.

1.6.1 REMOVAL OF SULFUR DIOXIDE AND HALOGENATED (ACID GAS)

The sulfur dioxide and halogen gases are cleaned flue gas by the injection of chemical or physical agents' sorption, which are brought into contact with flue gas. According to the technique, the reaction products are dissolved or dry salts.

Dry systems:

In the dried sorption process, the absorbent (generally lime or sodium bicarbonate) is fed in the form of a dry powder reactor. The dosage of reagent may depend upon the temperature and the type of reagent. With lime this ratio is typically **two to three times** the stoichiometric amount of the substance which will be filed with the baking soda ratio is lower. This is necessary to ensure that emission limits are met over a range of input concentrations. Generated reaction products are solid and must be deposited from the flue gas as dust in a subsequent step, usually a bag filter.

Lime over dosage (or other reagent) leads to an increase of the amount of residue, unless the re-circulation of the reagent is performed, when the non-reacted fraction can be recirculated

N.B: Halogens comprise the seventh column of the periodic table of the elements. Fluorine, Astatine, Chlorine, Bromine and Iodine.

If there is no pre-deposition step (e.g. Electrostatic precipitator), particles are removed with the reagent used and the reaction products. Reagent cake that forms on fabric filters allows effective contact between the flue gas and the absorbent.

Plumes are rarely visible with this technique.

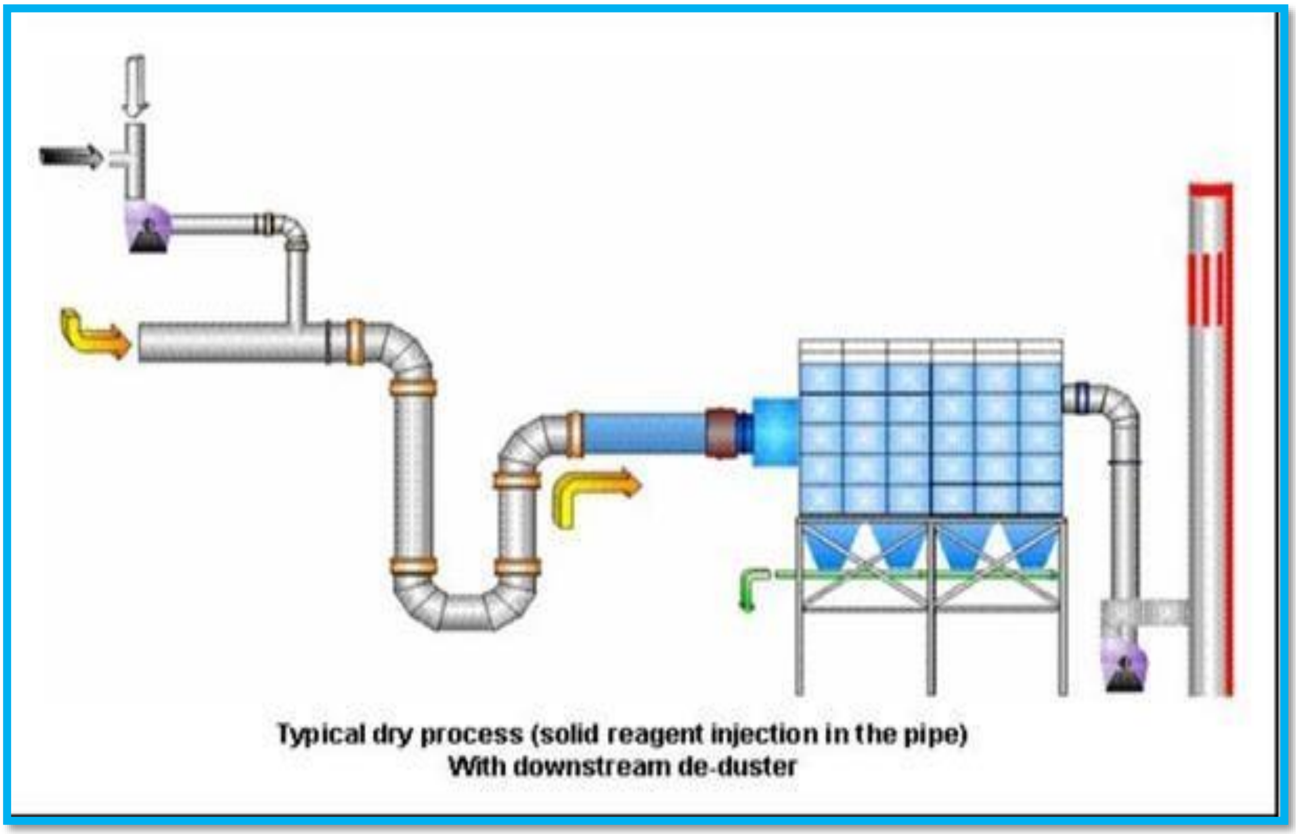


Figure 15: typical dry process (solid reagent injection in the pipe with a downstream precipitator

Semi wet systems:

These are also called semi-dry process. In the spray absorption, the absorbent is injected either as a suspension or solution in the flue-gas flow in a sputtering reactor. This type of process utilizes the heat of the burnt gases for evaporation of solvent (water). Generated reaction products are solid and must be deposited from the flue gas as dust in a subsequent step, for example a sleeve filter. These processes typically require sorbent overdoses of **1.5 to 2.5.**

Here, fabric separator is also an important part of the process. Plumes are rarely visible with this technique.

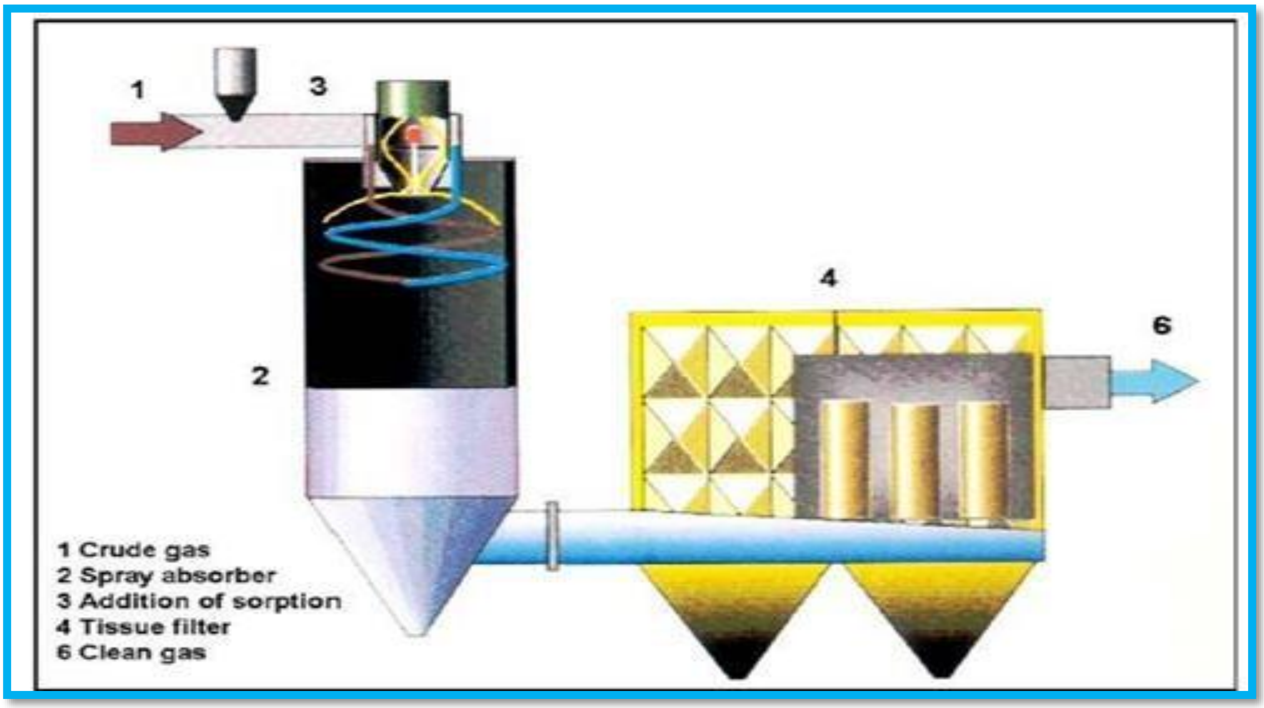


Figure 16: Principle of operation of a spray absorber **Wet systems:**

The wet cleaning process the flue gas uses different types of scrubber design. For example:

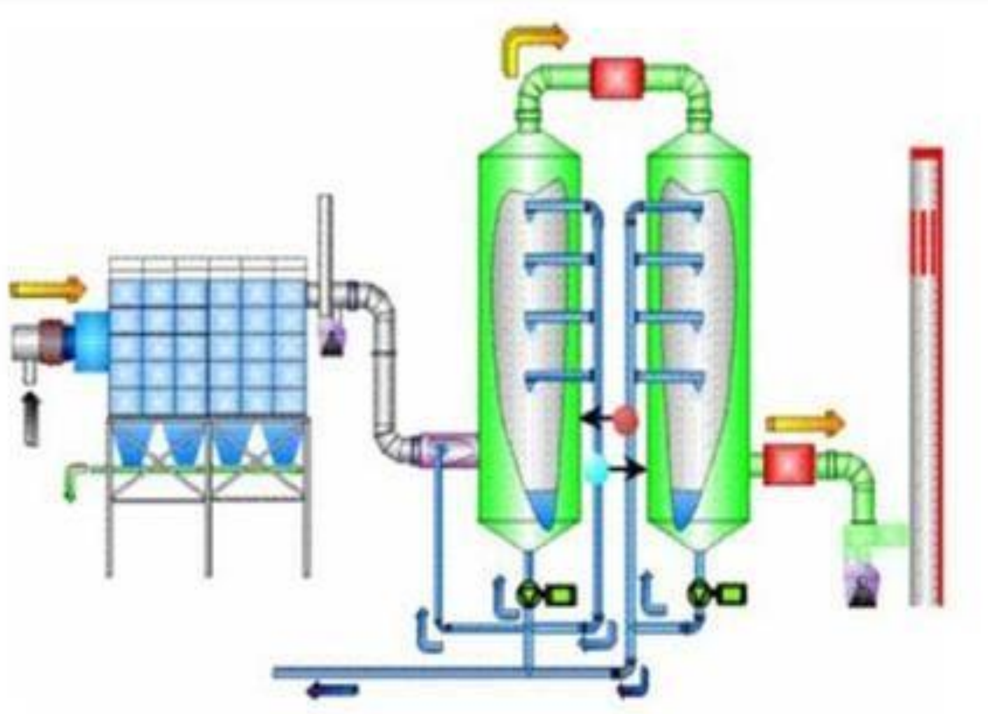
- jet scrubbers
- rotation scrubbers
- venture scrubbers
- dry tower scrubbers
- spray scrubbers
- static cleaners

The scrubber solution is (only in the case of water injection) strongly acid (pH 0-1) due to the formation of acid in the deposition process. HCl and HF are mainly removed during the first stage of the wet scrubber. The effluent from the first step is recycled several times, with a small amount of clean water and venting of the scrubber to maintain the effectiveness of the acid gas removal. For this acidic medium, deposition of SO_2 is slow, so a second stage scrubber is required to remove it.

Removal of the sulfur dioxide is performed in a controlled washing step at a near neutral pH or alkali (typically at pH 6 to 7) in which is added sodium hydroxide or milk of lime. For technical reasons, this withdrawal takes place in a separate washing step, in which also occurs further removal of HCl and HF.

If the treated waste contains bromine and iodine, these can be deposited from a flue gas flow if waste containing sulfur is burned simultaneously. More sulfur compounds, bromine and iodine in water-soluble salts will form, which can be deposited by the wet cleaning process of SO_2 in the flue gas. In addition, the deposit of bromine and elemental iodine can be improved by the specific use of reductive washing steps. In all cases, it is important to know which waste containing iodine or bromine.

If the milk of lime or limestone is used as a neutralizer agent in the wet stages of cleaning of flue gases, sulfate (gypsum), carbonates or fluorides will accumulate as soluble residues in water. These substances can be removed to reduce the salt load in wastewater and thus reduce the risk of scaling in the sewage system. Residues of the cleaning process (e.g. Gypsum) can be recycled. When using a caustic soda solution there is no risk because the reaction products are soluble in water. If NaOH is used, $CaCO_3$ may form (depending on the hardness of water), which again will lead to deposits in the scrubber. These deposits must be removed periodically by acidification. The diagram below illustrates a typical wet scrubbing system to two steps. The number of purification steps generally ranges between 1 and 4 with multiple steps incorporated in each vessel:



Typical wet process (2 stages) with upstream de-duster

Figure 17: typical wet process (2 stages) with upstream de-duster

N.B WASTE WATER FROM WET SCRUBBERS.

To maintain the purification efficiency and prevent clogging of the wet scrubber system, a portion of the scrubber liquor must be removed from the circuit as waste water. This wastewater must be subjected to special treatment (neutralization, precipitation of heavy metals), before discharge or use internally. It pays particular attention to the mercury removal. The compounds of volatile Hg, such as $HgCl_2$, will be condensed when the exhaust gases are cooled, and dissolved in the effluent from the scrubber. The addition of reagents for the specific removal of Hg is a way to remove the process. In some plants, the waste water produced is evaporated in the incineration plant by spraying it back into the flue gas as a combined tempering with the dust filter.

1.6.1.1 IMPLEMENTATION OF THE TREATMENT WITH SODIUM BICARBONATE

- *GENERAL STEPS*

The reaction between the acid gas (SO_2, HCl) and the sodium bicarbonate (Na_2CO_3) is a surface reaction. The solid is usually ground in order to increase its surface area, ideally to achieve a d50 <20 microns. Upon decomposition into sodium carbonate, the release of gases (CO_2, H_2O) further increases the surface area by increasing the porosity. the BET surface area (Brunauer, Emmet and Teller) of sodium bicarbonate is of about 0.8 m^2/g after grinding to 20 microns and up to 7 m^2/g at decomposition as Na_2CO_3, but drops to 2 m^2/g after aging a few hours.

The powdered sodium bicarbonate is generally injected directly into the flue gases at the outlet of the boiler, where it decomposes. The sorbent is then retained by a filter media which may be fabric or ceramic fibers. This forms a layer of sorbent, having or not having reacted with the acid gas and fly ash from a few millimeters, called "filter cake". Thus, the time of reactive-gas contact cleaned is increased to improve significantly the effectiveness of treatment. (13)

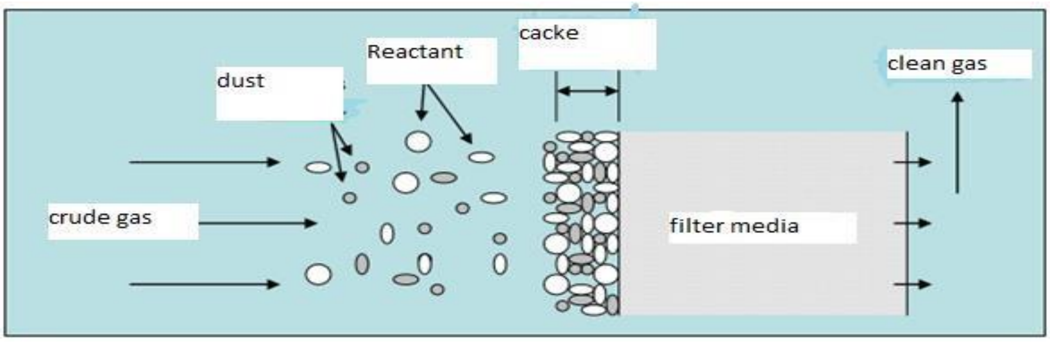


Figure 18: accumulation of particles in filter media

- *FILTER MEDIA*

Filters are formed of several tens of filter media cylinders called candles. This implementation allows increasing the total surface filtration. The accumulation of carbonate and fly ash on the walls of the filter causes a gradual increase in pressure drop across the filter. The measurement of the downstream pressure therefore provides information on the level of filter clogging. When it exceeds a threshold, an entire row of filter cartridges is scoured. For that, a compressed air pulse is sent against the flow within the latter, to create a pressure wave which allows bringing down the cake into a hopper located below the filter.

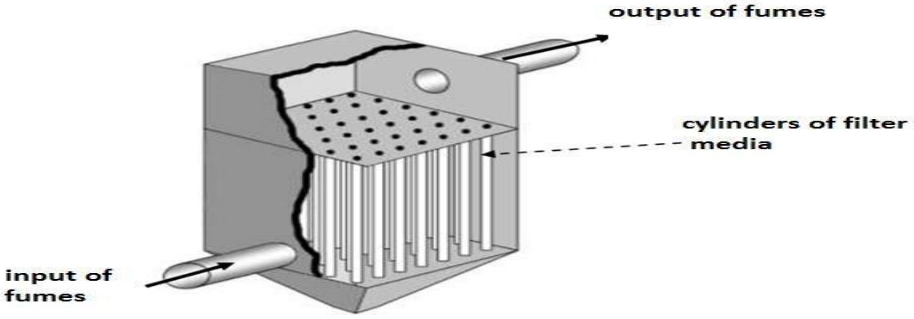


Figure 19: system of filtration

Materials for the manufacture of filter media are: fiber

Choosing as classification criterion their chemical composition, the fibers can classes into 2 categories, organic and inorganic, the same subdivided into sub categories:

Inorganic fiber: glass, carbon, ceramic, asbestos

Organic fibers:

- natural wool, silk, cotton
- Synthetic: polyethylene, polyester

There is a list of fiber available in the market:

Name	manufacturers
NOMEX	DUPONT
KERMEL	kermel
Ricem	Montefibre

Table 7: list of fiber available in the market (14)

 CHEMICAL REACTIONS:

- Treatment by $Ca(OH)_2$:

$Ca(OH)_2 + 2HCl \leftrightharpoons CaCl_2 + 2H_2O$

$Ca(OH)_2 + 2HF \leftrightharpoons CaF_2 + 2H_2O$

$Ca(OH)_2 + SO_2 \leftrightharpoons CaSO_3 + H_2O$

$CaSO_3 + 1/2\ O_2 \rightarrow CaSO_4$

- Treatment by $NaHCO_3$:

$NaHCO_3 + HCl \leftrightharpoons NaCl + CO_2 + H_2O$

$NaHCO_3 + HF \leftrightharpoons NaF + CO_2 + H_2O$

$2NaHCO_3 + 1/2\ O_2 \leftrightharpoons Na_2SO_4 + 2CO_2 +$

H_2O

In wet case, the reactions are:

- acidic step: $HCl + H2O \rightarrow H3O^{+} + Cl^{-}$

  $HF + H2O \rightarrow H3O^{+} + F^{-}$

- basic step: $SO_2 + 2H_2O \rightarrow H_3O + HSO_3^{-}$ $HSO_3^{-} + H_2O + 1/2\ O2 \rightarrow H3O^{2+}$ +SO

$2NaOH + 2H_3O^{+} + SO_4^{2-} \rightarrow Na_2SO_4 + 4H_2O$

$SO_2 + 2NaOH \rightarrow Na_2SO_3 + H_2O$

$HCl + NaOH \rightarrow NaCl + H_2O$

$HF + NaOH \rightarrow NaF + H_2O$

The reaction of sodium carbonate with sulfur dioxide is:

1. $Na_2CO_3(s) + SO_2(g) \rightarrow Na_2SO_3(s) + CO_2(g)$

When the gas cools, sodium sulphite thus formed reacts with oxygen to generate sodium sulfate:

2. $Na_2SO_3(s) + ½O_2\ (g) \rightarrow Na_2SO_4\ (s)$

Injection Na_2CO_3 also allows trapping the hydrochloric acid present in the hot gases:

3. $½NaCO_3(s) + HCl\ (g) \rightarrow NaCl\ (s) + ½CO_2(g) + ½H_2O\ (g)$ Similarly, the carbonate may also react with HF to form NaF.

Reaction 1 is a heterogeneous reaction (solid-gas). Treatment efficacy is depending mainly from time reagent-gas contact purify and temperature. However, higher allowances to 95% of SO_2 and HCl can be achieved for stoichiometric ratios of 1.2 to 1.5.

STUDY OF THE REACTIVITY OF Na_2CO_3 LABORATORY

SO_2 reaction's tests are on the thermally decomposed trona. The proportion of reacted Na_2CO_3 followed by Thermogravimetric Analysis (TGA). They observe two reaction steps due to changes in the size of pores over time. At the start of the reaction all of the sites is accessible; the first step is pretty fast. But gradually as the carbonate reacts, pore size decreases or becomes clogged, the steric bulk of SO_2 is larger than that of CO_2. The second step being limited by the diffusion of gases in the pores, it is then slower.

EFFECT OF TEMPERATURE AND VAPOR

A study indicates that the operating temperature of the sodium carbonate is at least 130 ° C. It observed during tests with dry gases, increasing efficiency up to 150 ° C and a slight decrease in the test at 220 ° C, especially in the first phase of conversion, which they attribute to sintering.

Few studies have been done on the effect of water vapor on the capture of $SO2$ by $Na2CO3$. Stejskalova et al. (1996) conducted adsorption test at 150 ° C for two percentages of $H2O$ in the gas (2% and 5%). They observe a significant increase in the allowance with increasing humidity. They attribute this effect to a catalytic action of water vapor and a rate of oxidation of sulfites to sulfates slower.

ADSORPTION OF NITROGEN OXIDE

Several authors (Verdone and De Filippis, 2004 Erdös and Mocek, 1994) studied thermodynamically and showed the possibility of reactions between nitrogen oxides and sodium carbonate. Verdone and De Filippis (2004) showed that the reactions of Na_2CO_3 with NO and NO_2 are possible thermodynamically to respectively 160 ° C and 360 ° C.

Lippert et al. (1996) conducted tests NO adsorption and NO_2 in a gas mixture containing N_2, $CO2$, $O2$ and $H2O$. They note that:

- NO_2 only seems to react;
- The reaction only in the presence of H_2O;
- The presence of CO_2 decreases the adsorption of NO_2;
- Reactivity of Na_2CO_3 decreases with temperature between 50 and 150 ° C.

ADVANTAGES AND DISADVANTAGES OF THE USE OF SODIUM BICARBONATE

Of course, with respect to other solid adsorbents, there are many solid compounds other than sodium bicarbonate ($NaHCO_3$) could serve as reagents for treatment of sulfur oxides by means dried. The most widely used industrially are more sodium compounds (Na_2CO_3, $Na_2CO_3.10H_2O$) or calcium compounds (CaO, $CaCO_3$, $Ca(OH)_2$). It is also possible to use magnesia (MgO), but this method seems little used.

Reactant	Advantages	Disadvantages

Sodium bicarbonate (basic reactant to SO_x)	- highly reactive with acid gases - low consumption rates •low residues	- cost / kg of reactant was higher - very corrosive
Quicklime (CaO)	- Average Reactivity Highest Temperature - Cost / kg lower - Low solubility of residues	▯ Difficult Recovery
Limestone(acid reactant to acid gas)	- Average Reactivity - Cost / kg lower - Low solubility of residues	▯ Circulation of CO_2

Table 8: difference between reactant selected

(13)

1.6.2 TECHNIQUES FOR THE REDUCTION OF NITROGEN OXIDE EMISSIONS

Nitrogen oxides (NOx) may be formed in three ways:

- Thermal NOx: When burning a portion of the nitrogen in the air is oxidized to nitrogen oxides. This reaction occurs only significantly at temperatures above 1300 ° C. The reaction rate depends exponentially on the temperature and is directly proportional to the oxygen content.

- Fuel NOx: when burning a portion of the nitrogen contained in the fuel is oxidized to nitrogen oxides.

- NOx formation via a radical reaction (prompt NOx): Atmospheric nitrogen can also be oxidized by reaction with CH radicals and intermediate formation of HCN. The formation mechanism is relatively low importance in waste.

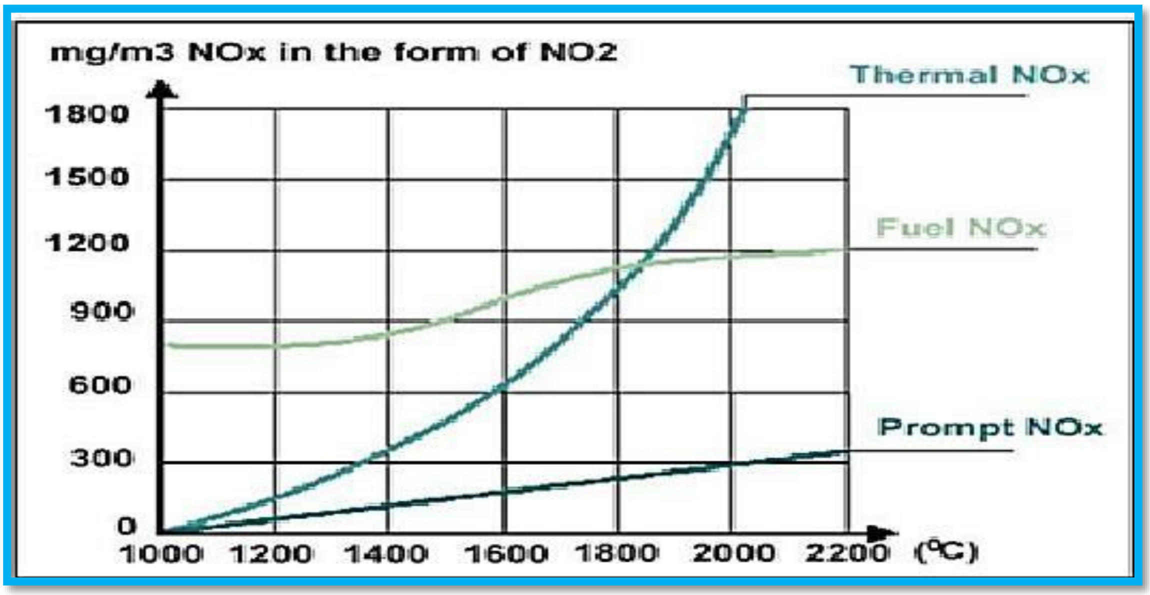


Figure 20: Temperature dependence of various NOX formation mechanisms in waste incineration

**NOx reduction side Techniques

The Directive 2000/76 / EC require a daily average value of clean gas NOx (as NO_2) of 200 mg / N*m* ³. To successfully conform to this level, it is common to apply secondary measures. For most processes, applying ammonia or ammonia derivatives (e.g. Urea) as a reducing agent which has proven successful. The nitrogen oxides in the flue gases mainly comprise NO and NO_2 are reduced to nitrogen N_2 and water vapor by the reducing agent.

Equations:

$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$

$2\ NO_2 + 4\ NH_3 + O_2 \rightarrow 3\ N_2 + 6\ H_2O$

Two processes are important for the removal of nitrogen of flue gases - the Selective Reduction Nonanalytic (SNCR) and Selective Catalytic Reduction (SCR).

NH_3 and urea are applied in aqueous solutions. NH_3 is normally, for safety reasons, delivered in a 25% solution.

1.6.2.1 PROCESS OF REDUCING NON-SELECTIVE CATALYTIC (SNCR)

In the process of Non-Selective Catalytic Reduction (SNCR) of nitrogen oxides (NO + NO_2) are removed by selective non-catalytic reduction. With this type of process, the reducing agent (typically ammonia or urea) is injected into the furnace and reacts with nitrogen oxides. The reactions occur at temperatures between 850 and 1000 ° C, with higher reaction rates and lower in this range.

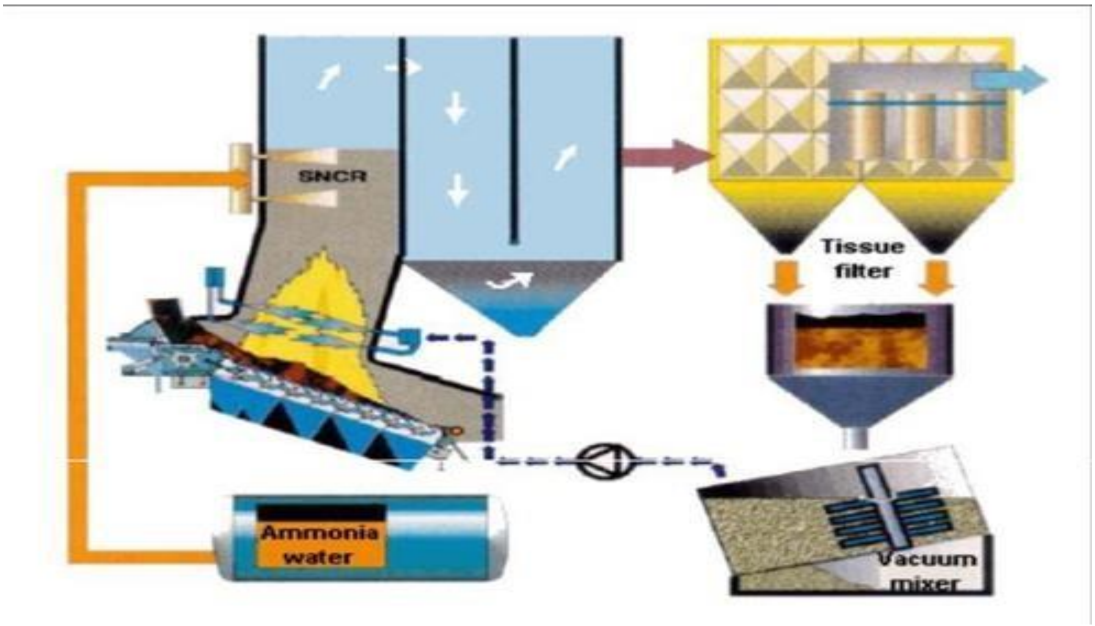


Figure 21: Process of Reducing Non-Selective Catalytic (SNCR)

Reducing NOx by SNCR **more than 60-80%,** requires a higher addition of the reducing agent. This can lead to ammonia emissions, also known as the slip of "ammonia. The relation between NOx reduction, ammonia slip and reaction temperature is given in Figure 15 below:

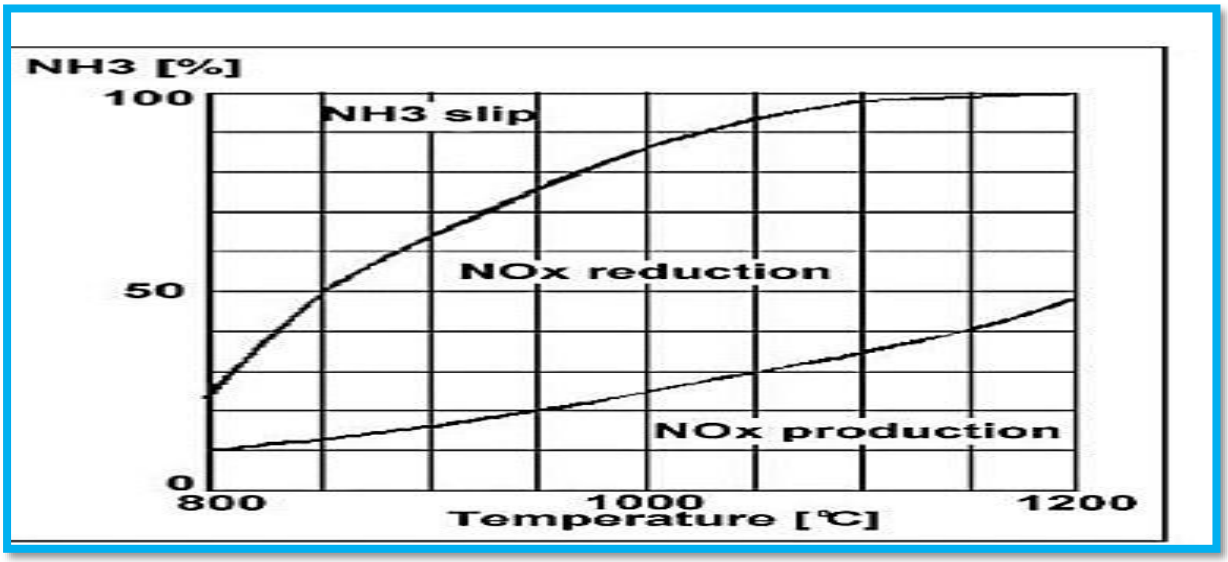


Figure 22: Relation between NO_x reduction, production of NO_x, and ammonia slip and reaction temperature for the SNCR process.

In figure 20, it shows that at a reaction temperature of, for example, 1000 ° C, NOx reduction would be about 85%, and there would be about 15% ammonia slip. In addition, at this temperature there would be a generation of NO_x, from the incineration of the injected NH_3, of about 25%.

Figure 20 shows that at high temperatures (with ammonia), the percentage of reduction of NOx is high, and while the ammonia slips decrease, the NOx producing ammonia increases.

Application of urea instead of ammonia in SNCR leads to relatively higher N_2O emissions compared to the ammonia reduction.

For optimum use of ammonia at different degrees of load, which causes temperature variations in the combustion chamber, NH_3 can be injected into different layers.

1.6.2.2 PROCESS OF SELECTIVE CATALYTIC REDUCTION (SCR)

Selective Catalytic Reduction (SCR) is a catalytic process during which ammonia mixed with air (the reduction agent) is added to the exhaust gas and passes through a catalyst, usually a sieve (e.g. Platinum, rhodium, TiO_2, zeolites). When passing through the catalyst, ammonia reacts with NOx to give nitrogen and water vapor.

To be effective, the catalyst generally requires a temperature between 180 and 450 ° C. The majority of systems uses waste incinerators currently operating at temperatures of the order of 230-300 ° C.

The SCR process gives NOx reduction rates (typically over 90%) to almost stoichiometric additions of reducing agent. For waste incineration, SCR is mainly applied in the natural gas area, that is to say, after dusting and removal of acid gases. For this reason, the exhaust gases generally require reheating to the efficient SCR reaction temperature. This adds to the energy needs of the flue gas treatment system. However, when the levels of SOx in flue gases have been reduced to a very low value to the admission of the SCR section, reheating can be substantially reduced or even avoided. Heat exchangers are used to reduce energy demand further.

SCR can also be used for the destruction of PCDD / F. SCR systems multi layers are used to provide a combined control of NOx and PCDD / F.

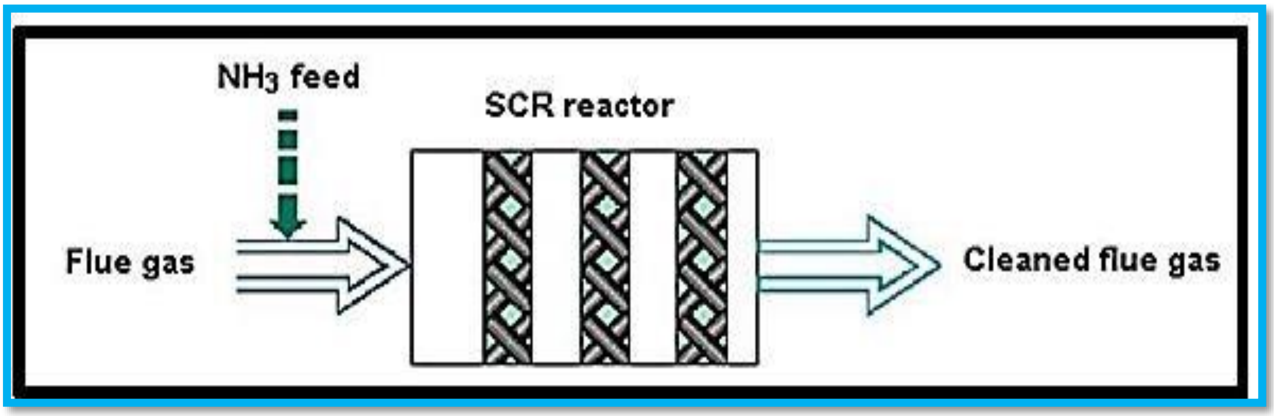


Figure 23: process of SCR (8)

1.6.3 TECHNIQUES FOR REDUCTION OF CO_2, NO_2

Emissions of nitrous oxide from waste incineration can arise from:

- the use of lower combustion temperatures - typically this becomes interesting below 850 ° C
- the use of SNCR for NOx reduction (particularly where urea is the reagent chosen).

1.6.3.1 USE OF CO_2 IN THE FLUE GAS FOR THE PRODUCTION OF SODA ASH

CO_2 reacts with sodium hydroxide to form sodium carbonate. The liquid is odorless and colorless. Sodium carbonate can be used as crude material, e.g. in chemical plants, the paper industry.

In this process, the amount of exhaust gas required for the generation of carbonate is withdrawn in a controlled flow to the end of the flue-gas cleaning and directly in a CO2 absorption column. The absorption column is made of plastic material reinforced with glass fiber and contains a plastic material coating. The caustic soda solution is added through the top of the column. Caustic soda passes through the coating material and comes into contact with the flue gases produced in the reverse current. This reacted carbon dioxide and sodium hydroxide and form the sodium carbonate and water.

$CO_2 + 2\ NaOH \rightarrow Na_22CO_3 + 2\ H_2O$

The burnt gases escape from the column into the atmosphere via a demister. This mist eliminator can be cleaned using fresh water that is provided on demand via a flow controller.

The carbonate solution is pumped from the dewatering trough the column into the consuming systems with a pump via a level control.

1.6.4 TREATMENT OF DIOXIN BY ACTIVATED CARBON

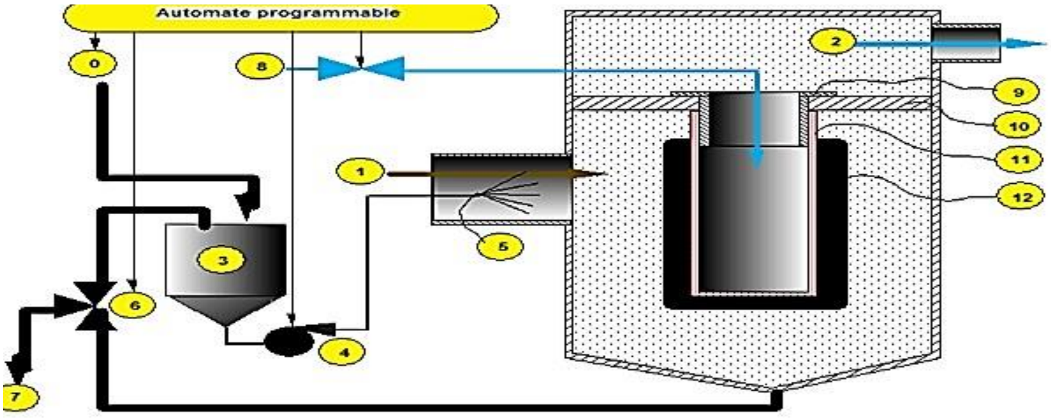
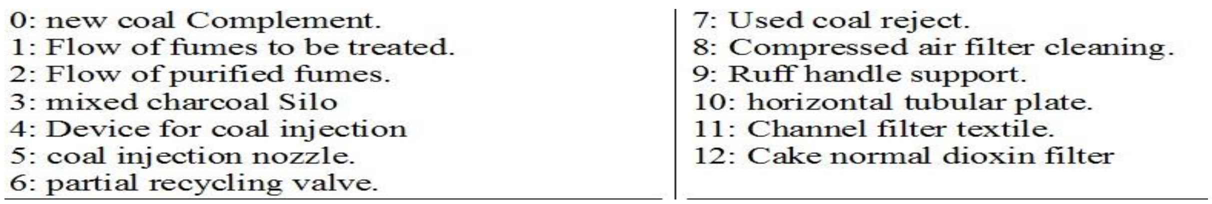


Figure 24: treatment of dioxin


0: new coal Complement.
1: Flow of fumes to be treated.
2: Flow of purified fumes.
3: mixed charcoal Silo
4: Device for coal injection
5: coal injection nozzle.
6: partial recycling valve.
7: Used coal reject.
8: Compressed air filter cleaning.
9: Ruff handle support.
10: horizontal tubular plate.
11: Channel filter textile.
12: Cake normal dioxin filter

Activated carbon is in the form of a fine black talc. Its elementary particles are made porous by a suitable heat treatment so as to create therein pores having dimensions of affinity with the molecules to be filtered. So there are formulations of active carbon adapted to different molecules that one wishes to retain. This product is relatively expensive and operators have an economic incentive to minimize consumption. This activated carbon can be also called "lignite coke." The diagram below shows before a charcoal cake (12), thick enough, which was formed on the sleeve textile (11). Indeed, the smoke flow plate activated carbon on the surface of the sleeve to form a cake therein maintained by the dynamic pressure of the gas. The capture efficiency of dioxins is maximum as the cake is thick enough that the gas molecules "cavil" through the layer thus formed and meet on their way up to elementary particles to be adsorbed therein. The limit of the thickness of the layer depends on the loss of maximum load, so the sleeves do not deteriorate under the effect of pressure and the flow of smoke is not too slow. It is therefore necessary to "unclog" the filter regularly when the pressure drop becomes too high.

Polluants	**Type of treatment**	**basic operation**
SO_2 , HCl , HF)acid gas)	dry way	Injecting a solid absorbent basic, usually calcium or sodium, solid salt formation which can be filtered by intermediary of a media filtant
	semi-wet way	The sorbet is injected in the form of a concentrated solution evaporates. the solid sorbent reacts as obtained by dry way .
	Wet way	acid gases dissolved in a basic solution (NaOH) .the contact can be made either by injecting the solution into the smoke (scrubber) or because the smoke passes through the solution.
NOx	Reburning	Processing gas flame (CH$_4$, H$_2$) which forms radicals that react with NO
	Reduction SNCR selective non – catalytique	Reduction of NOx at high temperature (≥800 ° C) by reaction with NH_3 Reducer example.
	SCR catalytic selective reduction	Reduction of NOx at low temperature (<350 ° C) catalyst, usually oxide vanderuim.
organic compounds	activated charcoal	Activated charcoal possesses a structure a microporous structure which gives it a large area

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Metals		specifiqueet so strong adsorbent power. activated carbon is injected into the conduit and then filtered with the adsorbed pollutants.
dust	Multi-cyclones	The fumes are accelerated in a cylinder, the particles will impact on the walls and lose their speed, they are then recuperated in the filter bottom.
	Electrostatic	The dust through a sufficiently large electric field to ionize the gas which in turn will charge the particles of dust .a once charged, they will impact on the cathode.
	Filter sleeves	Big particles will impact on the filter forming a cake for filtering smaller diameter particles.
	Scrubber	Water injected disperses in drops of water in the trap fumes and dusts which are then recovered in solution.

Table 9: general systems for treatment fumes (bicocchi et al, 2009et Le Cloreic 2006) (13)

1.6.5 UNIT OPERATIONS FOR GAS CLEANING:

A large number of unit operations based on primary separation processes can be used for the gas cleaning of the flue gas generated in waste incineration systems. In Table 10 for each type of flue gas pollutant, a combination of unit operations is indicated with the respective typical range of reduction. The well designed sequence of gas cleaning methods allows for a drastic reduction of pollutants (adopted with comments from Table 5.2 of the BREF, 2006).

POLLUTANT	PROCESS STEPS	REDUCTION (%)
SO_x	Wet scrubber or dry multicyclone	50 - 90
HCL	Wet scrubber or semi-dry	75 – 95
NO_x	Selective catalytic reduction	10 - 60
HEAVY METALS	Dry scrubber + electrostatic precipitator	70 - 95
FLY ASH	Electrostatic precipitator + fabric hose filter	95 - 99.9
DIOXINS	Activated carbon + fabric hose filter	50 - 99.9

Table 10:Gas cleaning processes and typical range of specific pollutant reduction by combination of unit operation

10.4 Rauchgasreinigung / تنقية /الدخان[8]

Im Bereich der Kesselzüge anfallende Flugaschen werden in der Regel gemeinsam mit den Flugaschen des häufig im Anschluß an den Kessel folgenden Staubfilters erfaßt. Diese erste Rauchgasreinigungsstufe wird oft noch dem Verbrennungsteil der Anlage zugerechnet. Für die weitere Rauchgasreinigung stehen verschiedene Verfahren zur Verfügung:

- die nasse Rauchgasreinigung,
- die trockene Rauchgasreinigung,
- die quasitrockene Rauchgasreinigung.

Schadstoff und übliche Rauchgasreinigungsverfahren

Stoff	Herkunft	Verfahren
Stäube, Salze	Gesamtmüll	Elektrofilter, Gewebefilter
HCL (Salzsäure)	PVC, anorganische Salze	nasse Rauchgaswäsche nach Abkühlung durch intensive Wäsche mit Kalkmilch,
SO_2(Schwefeldioxid)	Papier, Farbstoffe, Gummi	in einigen Anlagen trockene bzw. quasitrockene Verfahren (Eindüsung
HF (Flußsäure)	Isolierstoffe, Teflon, Kältemittel, Spraydosen	von Kalkhydrat oder Kalkmilch in den heißen Rauchgasstrom, Abscheidung der Feststoffe über Gewebefilter)
NO_2(Stickoxide)	Textilien, Nylon, Proteine, Sekundärentstehung	Reduktion mit Hilfe von Ammoniak und (in den meisten Fällen) Katalysator zu Stickstoff und Wasser
Cd (Cadmium)	Batterien, Kunststoffe, Farben	Schwermetallfällung im Abwasser der nassen
Pb (Blei)	Batterien, Farben, Vorhänge	Rauchgaswäsche, danach mechanische Abscheidung oder
Zn (Zink)	Batterien, Farben, Galvanik	Sprühtrocknung bzw. Eindampfung
Hg (Quecksilber)	Batterien, Amalgan, Thermometer	Aktivkohlefilter, ansonsten wie die anderen Schwermetalle
Dioxine, Furane	Holzschutzmittel, Brandrückstande, Sekundärentstehung	Schockabkühlung zur Vermeidung eines Temperaturfensters für die Entstehung, katalytische Zersetzung Aktivkohlefilter

10.4.1 Trockene Rauchgasreinigung[9]

Die **trockene Rauchgasreinigung** wird zum Entfernen von Schadstoffen, die bei Verbrennungsprozessen entstanden sind, eingesetzt. Bei der trockenen Rauchgasreinigung finden hauptsächlich adsorptive und trennende Methoden Anwendung. In erster Linie soll mit dem Einsatz ein Beitrag zum Umweltschutz geleistet werden.

10.4.2 Aufbau der trockenen Rauchgasreinigung

Das bei der Verbrennung entstandene Rauchgas gelangt nach dem Kessel und den Wärmetauschern in einen Reaktor, wo unter anderem die sauren Bestandteile gebunden und somit entfernt werden. Im Anschluss an den Reaktor gelangt das Rauchgas zusammen mit den Adsorbentien in die Schlauchfilter. Dort werden diese durch Oberflächenfiltration abgeschieden. Zusätzlich dient der Schlauchfilter auch als Adsorptionsfläche der Rauchgase. Das bedeutet, dass beim Durchströmen des Filterkuchens die verbleibenden Schadstoffe aus dem Rauchgas gebunden werden.

Trockenadsorption[]

Unter dem Begriff Adsorption versteht man die Anlagerung von Molekülen an die Oberfläche von Feststoffen. Damit die Adsorption von Gasen an Feststoffoberflächen möglichst effektiv verläuft, benutzt man adsorbierende Substanzen mit möglichst großer spezifischer Oberfläche. Durch spezielle Produktionsverfahren werden sehr poröse Adsorbenskörner hergestellt, die nur kleine Abmessungen besitzen, um die Diffusionswege für die Gasmoleküle durch die Poren möglichst gering zu halten. Es können dadurch Oberflächen von bis zu 1500 m^2/g Adsorbens erzielt werden, da diese einen hohen Anteil an Mikroporen haben.

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[8] From https://www.itad.de/information/wiefunktionierteinemva/337.Beschreibung_mit_Animationen.html

[9] http://de.wikipedia.org/wiki/Trockene_Rauchgasreinigung

10.4.2.1 Aktivkohle in der trockenen Rauchgasreinigung[]

Ein sehr häufig verwendetes Verfahren zur Reinigung sowohl hoch als auch gering konzentrierter organisch belasteter Rauchgase ist die Adsorption an Feststoffen. Als Adsorbens wird hierbei Aktivkohle verwendet, die in Form von kleinen Kugeln oder Strangpresslingen hergestellt werden.

Die feingemahlene Aktivkohle wird im Reaktor dem Rauchgasstrom zudosiert. Durch die hohe spezifische Oberfläche bietet Aktivkohle eine große Angriffsfläche für das vorbeiströmende Gas. Die im Rauchgas enthaltenen Schadstoffe wie z.B. flüchtige Schwermetalle wie Quecksilber, Cadmium, Thallium, Selen und Arsen, chlorierte Dibenzodioxine und Dibenzofurane (PCDD/PCDF), schwerflüchtige chlorierte Kohlenwasserstoffe wie Hexachlorbenzol, Hexachlorcyclohexan, PCB, PAK diffundieren aufgrund eines Konzentrationsgradienten zwischen der Gasströmung und der Gleichgewichtsbeladung des Adsorbens aus dem Gasraum durch die Makroporen sowie Mikroporen ins Innere der Kugel und lagern sich dort an der Oberfläche an. Ein weiterer Mechanismus der zu einer Abscheidung führt, ist der sogenannte Sperreffekt. Dieser Effekt wird an kleinen Partikeln wirksam, die wegen ihrer geringen Masse auf den Strömungslinien um das Korn bleiben, dann auf das Korn stoßen und von diesem angezogen und festgehalten werden (Van-der- Waals- Kräfte).

10.4.2.2 Chemische Reaktion/ Natriumhydrogenkarbonat[]

Natriumhydrogenkarbonat wird im Reaktor dem Rauchgasstrom zugeführt. Durch die thermische Einwirkung des Rauchgases dissoziiert das Natriumhydrogenkarbonat zu Natriumkarbonat, Wasser und Kohlendioxid.

$$\mathrm{NaHCO_{3(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + CO_{2(g)} + H_2O}$$

Die Dissoziationstemperatur von trockenem Natriumkarbonat liegt dabei bedeutend höher (ca. 850 °C) als die des Natriumhydrogenkarbonats (65 C). In wässriger Lösung findet die Reaktion bereits bei Raumtemperatur (20 C) statt. Da das Rauchgas durch die Oxidation (Verbrennung) mit Wasserdampf versetzt ist, kann die Dissoziationstemperatur des Natriumkarbonats auf ca. 165 - 180 °C gesenkt werden. In diesem Temperaturbereich verliert das Natriumkarbonat die kristalline Struktur und zerfällt in Na^+ und CO_3^{2-} Ionen. Betrachtet man dabei die Karbonat-Ionen, stellt man fest, dass das Gleichgewicht sehr stark auf die Seite von CO_2 und H_2O verschoben ist.

$$\mathrm{2H^+ + CO_3^{2-} \longrightarrow H_2O + CO_2}$$

Damit die Reaktion stattfindet, werden Protonendonatoren (H^+ - Spender) benötigt die z.B. in Form von säurehaltigen Gasen (HCl, H_2SO_4, HF…) bereits vorhanden sind. Die nach der Reaktion im Rauchgas enthaltenen Kationen (Na^+) sind jedoch bestrebt eine stabile Verbindung zu bilden und reagieren zu diesem Zweck mit den Anionen der Säuren (Cl^-, SO_4^{2-}, F^-). Es findet ein Kristallisationsprozess statt, wobei Na^+ mit den Anionen der Säuren, Salze wie z.B. NaCl, NaF, Na_2SO_2 bildet.

10.4.3 Mechanische Staubabscheidung mit Schlauchfiltern[]

Zur Abtrennung von festen oder flüssigen Partikeln aus Gasen werden vorwiegend filternde Abscheider eingesetzt. Das Spektrum der Anwendungsmöglichkeiten ist so weit wie bei keinem anderen Trennverfahren. Entsprechend groß sind auch die technische Verbreitung und die wirtschaftliche Bedeutung solcher Abscheider.

Prinzipiell erfolgt die Abscheidung aus einem Gas mittels Gasfiltration durch ein poröses Medium. Solche Medien können unterschiedlich aufgebaut und aus diversen Materialien hergestellt sein. Ein gemeinsames Merkmal aller filternden Abscheider ist das Vorhandensein eines Filtermediums, welches entweder aus diskreten, miteinander verbundenen Kollektoren (z.B. Fasern und Körner) oder einer kontinuierlichen Phase mit durchgehenden Hohlräumen (z.B. Lochfolie) aufgebaut ist.

Das zu reinigende Gas wird durch das Medium geleitet wobei es aufgrund verschiedener Mechanismen zu einer Abscheidung der Partikel am Filtermedium aus einer kontinuierlichen Phase (Rauchgasstrom) kommt. Dies kann sowohl auf der Oberfläche als auch im Inneren des Filtermediums geschehen.

Findet der Abscheideprozess dabei vorwiegend im Inneren des Mediums statt, spricht man von Tiefen- oder Speicherfiltration. Bildet sich allerdings nach kurzer Zeit eine zusammenhängende Schicht (Filterkuchen) an der Oberfläche des Filtermediums welche dann das eigentliche Filtermedium darstellt, dann spricht man von Abreinigungs- oder Oberflächenfiltration.

10.4.4 Einsatzmöglichkeiten[]

Die robuste, einfache und kostengünstige Reinigungstechnik, die schon seit Beginn der Luftreinhaltemaßnahmen in Deutschland die vorrangig genutzte Technik für die Fluor- und Chlorwasserstoff-Abscheidung in der Aluminium- und Ziegelindustrie sowie für Biomassefeuerungen darstellt, wird durch Weiterentwicklung und neue Adsorbenzien auch für die Abgasreinigung von Kohlefeuerungen und Abfallverbrennungsanlagen zugänglich gemacht. Die trockene Rauchgasreinigung erfüllt die Vorgaben der 17. BImSchV (Verordnung über die Verbrennung und die Mitverbrennung von Abfällen).

10.4.5 Literatur[]

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- Claus Zimmermann: *15 Jahre Abgasreinigung. Abgasvorschriften, Messergebnisse, Analysen, Bewertungen, Auswirkungen und Folgerungen.* 4. Auflage, Touring-Club Schweiz, Emmen 1999, ISBN 3-908165-00-8.

Prevention of fire and explosion risks
• ATEX Directive 94/9/EC on equipment and protective systems intended for use in potentially explosive atmospheres • ATEX Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres • ATEX Directive 2014/34/EU on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (applicable from 20.4.2016) • Seveso II (Directive 96/82/EC) on prevention of major accidents involving dangerous substances, to be overwritten by Seveso III (Directive 2012/18/EU) on 1.6.2015
Safety of pressure equipment
▯ Directive 97/23/EC on the approximation of the laws of the Member States concerning pressure equipment
Safety of machinery
▯ Machinery Directive 2006/42/EC
Electrical safety
• Low Voltage Directive 2006/95/EC • Electromagnetic Compatibility Directive EMC-D 2004/108/EC

Table 1: **Directives on the safety of hydrogen generators using water electrolysis process ((2))**

10.5 Gas Flow in Flue Gas Purification

10.5.1 Anlagen der maschinellen Lüftung[10]

Lüftungstechnische Einrichtungen, die mit Ventilatoren ausgerüstet sind, haben den Vorteil, dass eine gezielte Beeinflussung des Raumluftzustandes erreicht werden kann. Die folgenden Ausführungen sind auf Anlagen ohne Luftbehandlungsfunktion (LBF) beschränkt.

Ventilatoren sind das Kernstück der lufttechnischen Anlage. Die lufttechnisch zu behandelnden Räume werden von ihnen mit der geplanten Luftmenge versorgt. Die Ventilatoren haben die Aufgabe die Druckdifferenz zu überwinden und die notwendigen Luftvolumenströme zu fördern.

Grundsätzlich werden zwei Bauarten von Ventilatoren unterschieden:

Kennzeichnend für **Axialventilatoren** ist die in Achsrichtung angesaugte und ausgeblasene Luft. Hauptbestandteile sind Gehäuse, Laufrad, ggf. Leitrad und Motor. Sie werden charakterisiert durch kleine bis mittlere Druckdifferenzen und große Volumenströme.

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[10] from https://abgs-gmbh.de/2014/04/16/fachartikel-lueftungsanlagen/

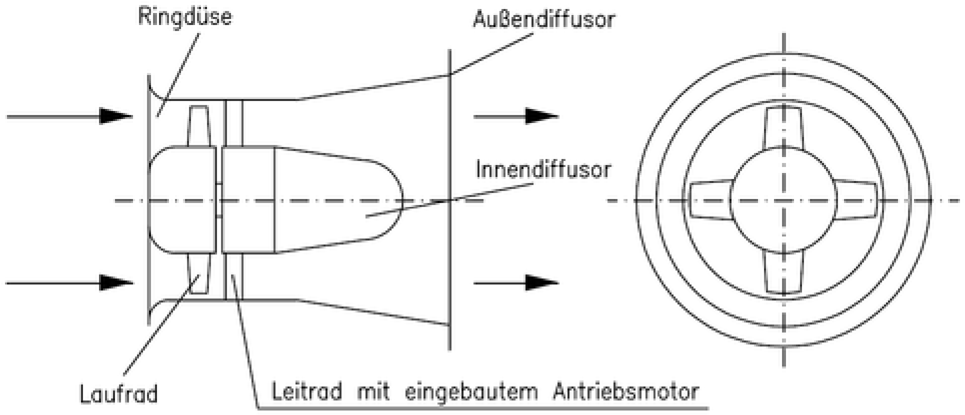

Bild: Axialventilator

Radialventilatoren sind durch axiales Einströmen und radiales Ausströmen der Luft gekennzeichnet. Hauptbestandteile sind Gehäuse, Laufrad und Motor. Es gibt Ausführungsformen mit Riemenantrieb oder Direktantrieb. Sie werden charakterisiert durch kleine bis mittlere Druckdifferenzen und kleine bis große Volumenströme. Sie sind die in raumlufttechnischen Anlagen am häufigsten verwendete Bauart.

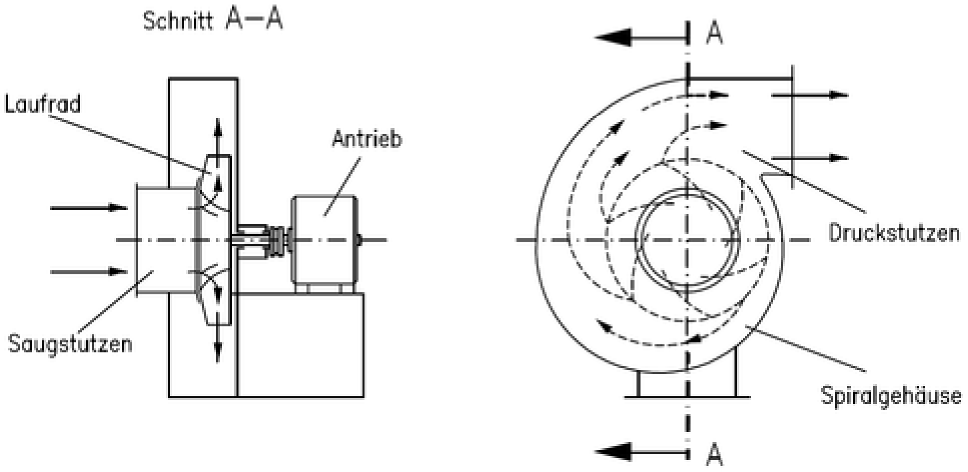

Bild: Radialventilator

Parallel- und Reihenschaltung

In lufttechnischen Anlagen können betriebsbedingt oder aus sicherheitstechnischen Gründen mehr als ein Lüfter zum Einsatz kommen. Beim **Parallelbetrieb** zweier baugleicher Lüfter erreicht man eine **Verdoppelung des Fördervolumens**.

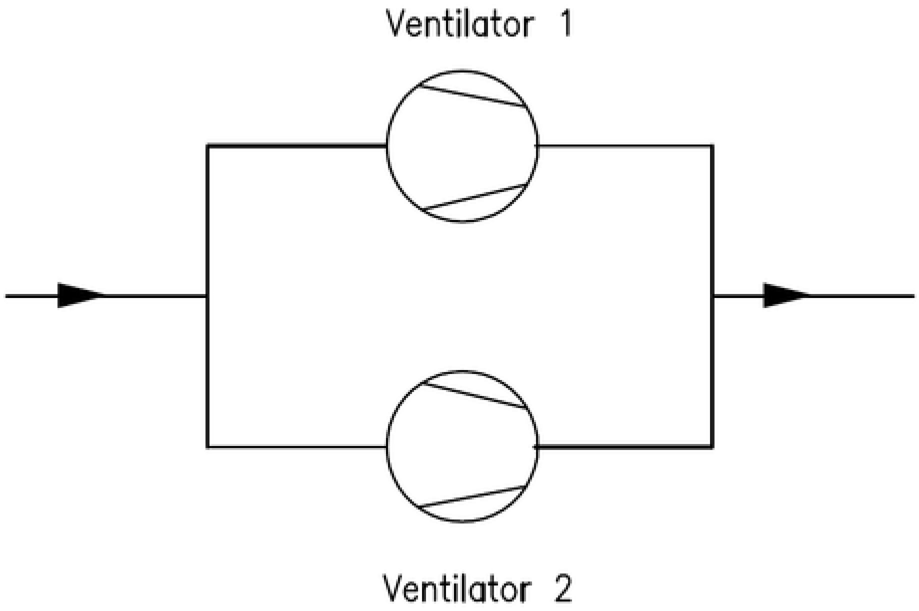

Bild: Parallelschaltung

Durch **Reihenschaltung** zweier baugleicher Lüfter wird eine **Verdopplung der Druckdifferenz** erreicht.

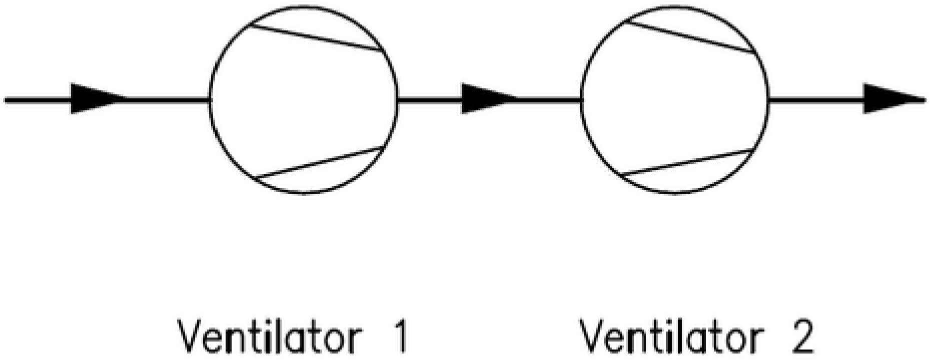

Bild: Reihenschaltung

10.5.1.1 Verordnungen und Normen:

- Energieeinsparverordnung (EnEV) 2007 und 2009
- DIN 1946 Teil 1 Raumlufttechnik, Begriffe und Symbole

Literatur:

- Anette Becker: Lüftungsanlagen, Vogel Buchverlag 2011
- Veröffentlichung des Fachinstitutes Gebäude-Klima e.V. (www.rlt-info.de)

10.5.2 Einbauhinweise[11]

Beim Einbau eines Ventilators in ein Rohrleitungssystem ist darauf zu achten, dass die Zu- und Abströmung ungestört ist und gleichmäßig erfolgen kann. Auf der Saugseite ist der Einbau hinter Querschnittssprüngen, Krümmern usw. zu vermeiden. An- und Abströmung dürfen nicht schräg oder drallbehaftet erfolgen. Die hierdurch entstehenden Strömungsabrisse haben gravierende Minderleistungen zur Folge. Die auftretenden Schwingungen können gefährliche Schäden am Laufrad hervorrufen. In Bild 22 sind einige Einbausituationen dargestellt, die unbedingt zu vermeiden sind.

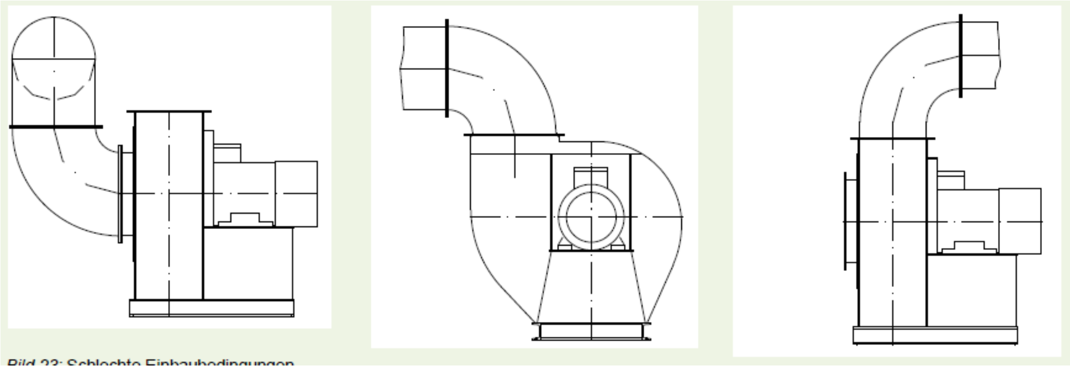

Bild 23: Schlechte Einbaubedingungen

10.1 Fly ashes treatment

The presence of heavy metals in municipal solid waste incineration (MSWI) fly ash is of environmental concern due to their leaching potential in landfill environments. Acid extraction is a conventional method of safe treatment of fly ash. In this work, nitric acid was used as the extraction acid to leach Ni, Zn, Pb and Cu out from the ash. In addition, influence of nitric acid concentration and liquid to solid ratio on removal ratio of the four heavy metals was studied. It was found that removal ratio followed the decreasing sequence of Pb > Cd > Cu > Zn for acid extraction using nitric acid. The optimal extraction condition was 5.3 mol/L of nitric concentration at 20 liquid to solid ratio, which resulted in a removal ratio of 98% for Pb, 86% for Cd, around 73% for Cu and around 42% for Zn.[12]

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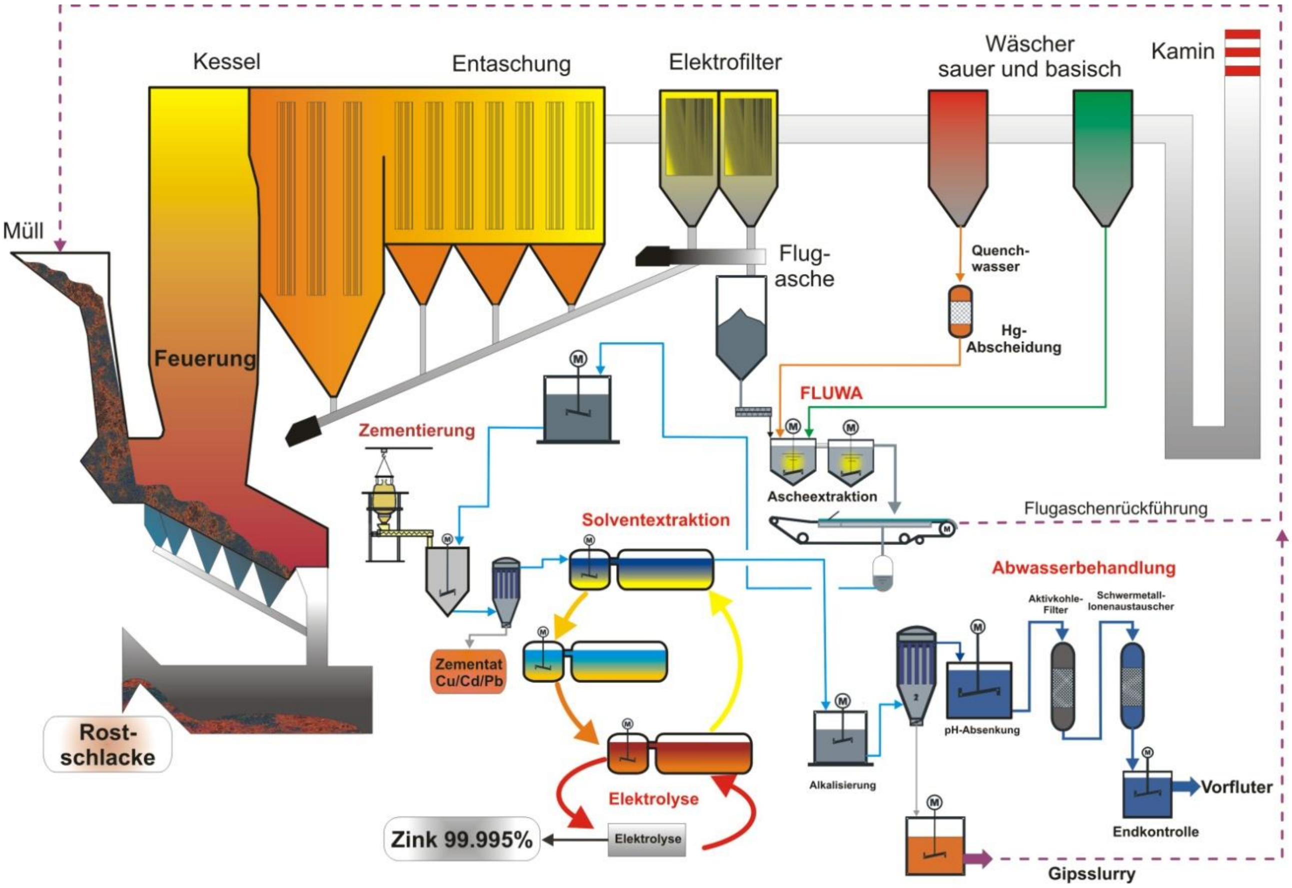
[11] https://ventecag.de/fileadmin/downloads/ventec-wissenswertes-aus-der-lufttechnik.pdf

[12] H. Y. Zhang and G. X. Ma, "Leaching of Heavy Metals from Municipal Solid Waste Incineration (MSWI) Fly Ash Using Nitric Acid", Applied Mechanics and Materials, Vols. 249-250, pp. 918-921, 2013

11 Ashes Recycling

11.1 Flue Gas Ash Recycling (FLUWA, FLUREC)



11.2 Metals recovery from bottom ash of household incineration

Bottom ash is the main residue, in quantitative terms, of MSW incineration. Its production depends on the **inert content** of incinerated waste and on the type of **furnace technology** and bottom **ash extraction system**.

These treatments include **physical, chemical** or **thermal** processes.

Metal ($\mu g\ g^{-1}$)	**As**	**Cd**	**Cr**	**Hg**	**Ni**	**Pb**	**Sb**	**Zn**
	1.4-114	0.25-11	0.5-1800	0.06-0.9	28-800	194-5000	10-147.5	300-8890

Al_2O_3	**CaO**	**Fe_2O_3**	**K_2O**	**MgO**	**MnO**	**N_2O**	**P_2O_5**	**SiO_2**
8.66± 6.25	17.68± 15.37	8.68± 2.84	1.08± 0.78	2.52± 2.10	0.12± 0.08	4.73± 2.84	1.26± 0.88	48.40± 41.13

11.2.1 Physical separation

- Size classification is a fundamental step in this part

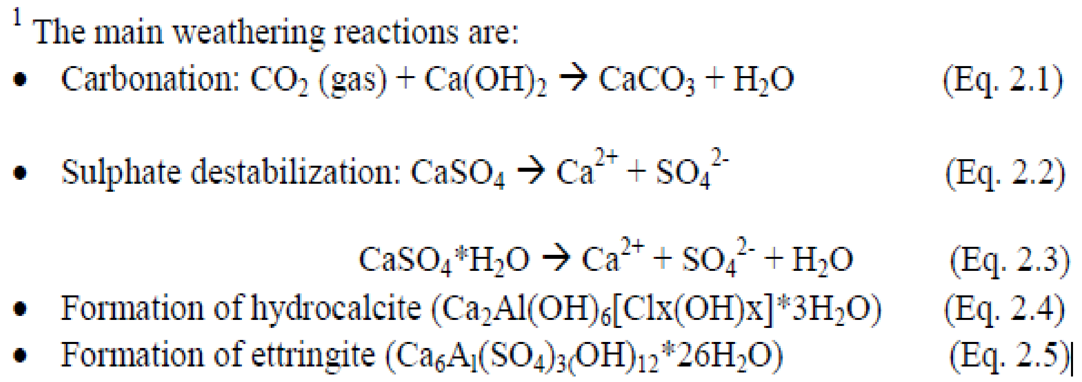
- Dry separation operates with standard drums or flat deck screens with a typical mesh size of 20-50 mm and 2-10 mm Or Wet separation can be performed through dense medium separation or attrition washing
- Ferrous and non-ferrous metals are present in the bottom ash in a range of 7-15% and 1-2%, respectively
- The recovery rates of ferrous and non-ferrous metals from the bottom ash is equal to about 60-80% and 25-35% of their amount in the waste, respectively.
- Ferrous and non-ferrous scraps can be separated from the bottom ash by using magnets and eddy-current separators.

11.2.2 Chemical separation

- To remove salts and heavy metals.
- Washing with water
- Allows to remove the soluble components like chloride, sodium and sulphate
- Sulfate separation: To improve sulphate solubilisation, NaHCO3 or CO2 can be used in the washing solution, improving the precipitation of Ca as carbonate in place of sulphate forms

11.2.3 Chemical stabilization

- The aim is to promote the formation of low solubility minerals, thermodynamically and geochemically stable.
- Reducing the leaching phenomena during the ash recovery or disposal.
- A first stabilization can be performed through the natural weathering.



[1] The main weathering reactions are:

- Carbonation: CO_2 (gas) + $Ca(OH)_2 \rightarrow CaCO_3 + H_2O$ (Eq. 2.1)
- Sulphate destabilization: $CaSO_4 \rightarrow Ca^{2+} + SO_4^{2-}$ (Eq. 2.2)

$CaSO_4{*}H_2O \rightarrow Ca^{2+} + SO_4^{2-} + H_2O$ (Eq. 2.3)

- Formation of hydrocalcite ($Ca_2Al(OH)_6[Clx(OH)x]{*}3H_2O$) (Eq. 2.4)
- Formation of ettringite ($Ca_6A_1(SO_4)_{3(}OH)_{12}{*}26H_2O$) (Eq. 2.5)

- In the first case, the time needed to stabilize the ash is in the order of about one month

11.2.4 Thermal Separation

- Sintering and vitrification.

- Their aim is to reduce the volume of the residues and to improve their characteristics in term of mechanical strength, porosity, water adsorption, chemical stability and leaching of contaminants.
- Vitrification is performed at 1000-1500°C; the bottom ash is melted and a homogenous liquid phase is generated, which is rapidly cooled producing an amorphous glassy phase.
- Sintering is conducted at a temperature of about 900°C, below the melting point of the main bottom ash constituents.

Note: The high energy consumption and thus the high costs have limited the applicability of these technologies in Europe. However, the vitrification and the sintering of the bottom ash can be achieved contextually to the waste treatment in other waste-to-energy technologies than incineration, like in gasification and in pyrolysis, reducing the overall costs of waste and bottom ash treatment.

Heavy metal Quantity estimation (Pb, Cd and Sb)

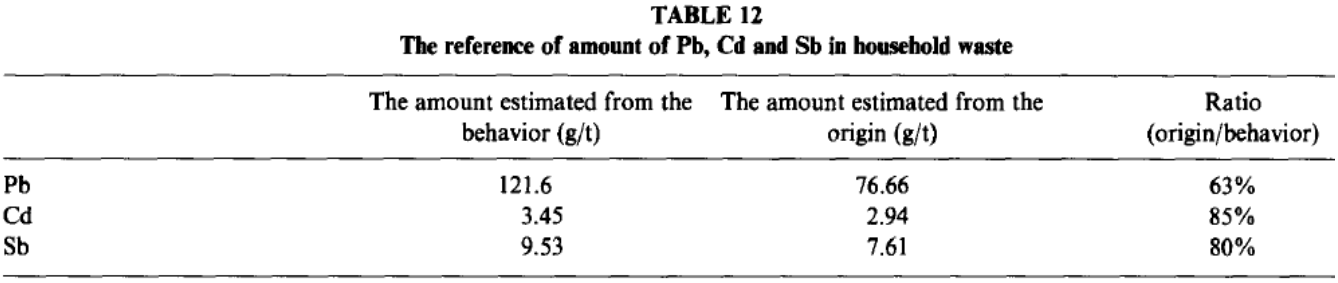
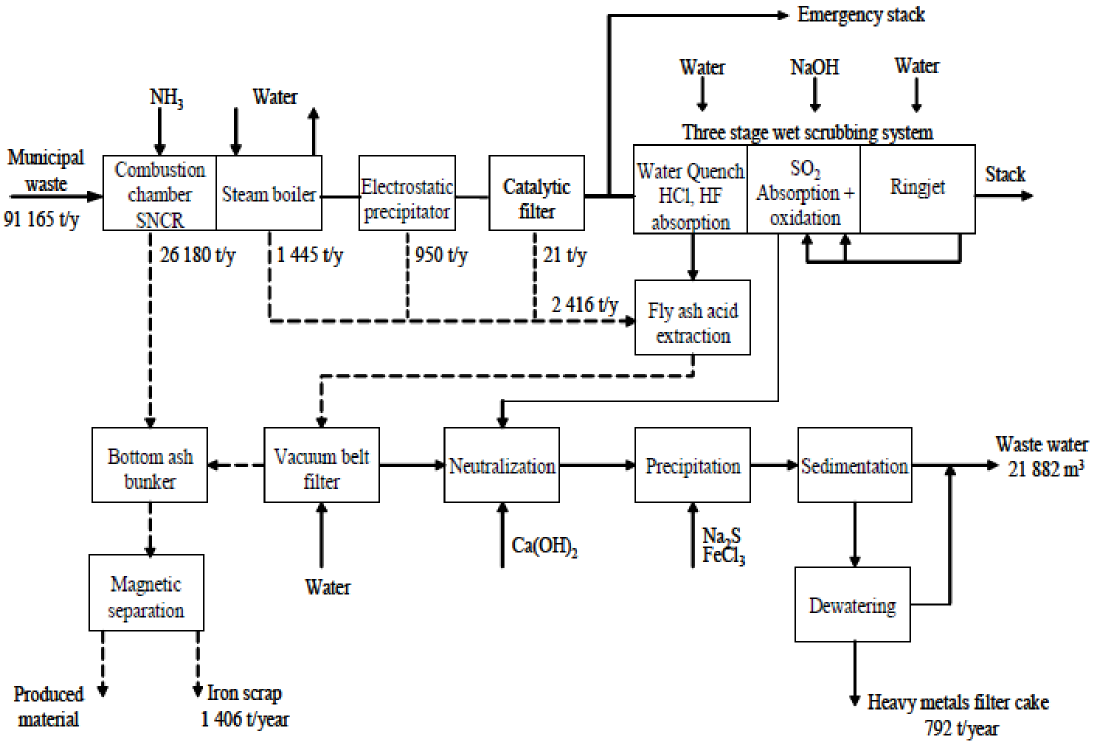


TABLE 12
The reference of amount of Pb, Cd and Sb in household waste

	The amount estimated from the behavior (g/t)	The amount estimated from the origin (g/t)	Ratio (origin/behavior)
Pb	121.6	76.66	63%
Cd	3.45	2.94	85%
Sb	9.53	7.61	80%

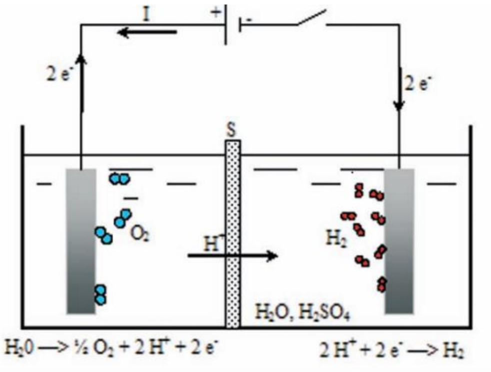
From [Šyc 2010]:



12 تحليل الكهربائي للماء)electrolysis of water(

التحليل الكهربائي هو أسلوب يستخدم الماء (H_2O) كمادة خام لإنتاج الهيدروجين وغاز الأكسجين من خلال تيار كهربائي ومع ذلك، إلا أن التكنولوجيا الكهربائي قلوية ناضجة اليوم ويجلب التنافسية الاقتصادية مع تقنيات إنتاج الهيدروجين التقليدية مع بصمة الكربون يرثى لها احتراق الهيدروجين تنتج حوالي 3 مرات اكثر من الطاقة حارقة على وزن ثابت انخفاض درجة الحرارة الكهربائي (<200 درجة مئوية) باستخدام محلول مائي القلوية حمض الكبريتيك (H_2SO_4) أو هيدروكسيد البوتاسيوم(KOH) ؛

The decomposition of water by electrolysis is written in a global manner:



$H_2O \rightarrow H_2 + \frac{1}{2} O_2$

With an enthalpy of dissociation of water: $\Delta H = 285$ kJ / mole.

This decomposition requires a supply of electrical energy, essentially dependent on the enthalpy and the entropy of reaction. The theoretical potential of the decomposition is 1.481 V at 298 K. Typical values industrial cell potential is in the order of 1.7 to 2.1 V, which corresponds to electrolysis yields of 70 to 85% (by Relative to the PCS of 3.55 kWh / Nm^3). The electrical consumption of industrial electrolyzes (including auxiliaries) is generally 4 to 5 kWh / Nm3. It should be noted that the heat generated by irreversibility's must be permanently eliminated.

The minimum water supply of an electrolyze is 0.8 l / Nm^3 of hydrogen. In practice, the actual value is close to 1 l / Nm^3. The introduced water must be as pure as possible because the impurities remain in the equipment and accumulate in the course of the electrolysis, ultimately disturbing the electrolytic reactions by:

- sludge formation
- the action of chlorides on the electrodes

An important specification on water relates to its ionic conductivity (which must be less than a few µS / cm).

An electrolytic cell consists of two electrodes (anode and cathode, electronic conductors) connected to a DC generator, and separated by an electrolyte (ionic conductive medium).

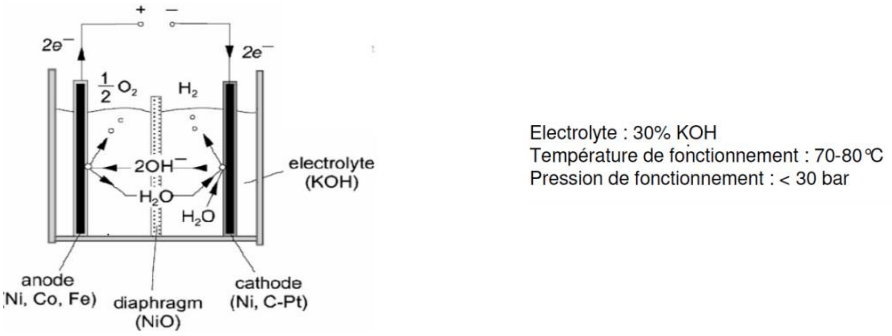
This electrolyte can be:

- Or an acidic or basic aqueous solution,
- Or a proton exchange polymer membrane
- Or a ceramic membrane conductive of O 2 ions.

There are many suppliers offering very diversified technologies, in particular in terms of the nature of the electrolyte and associated technology, ranging from a possible upstream coupling with a renewable electricity supply (photovoltaic or wind), to the Direct final supply of hydrogen under pressure. The combustion of hydrogen generates about 3 times more energy than gasoline at constant weight.

Low alkaline (<200 ° C) alkaline electrolysis using an aqueous solution of sulfuric acid (H_2SO_4) or potassium hydroxide (KOH); (2)

12.1.1 Alkaline electrolysis



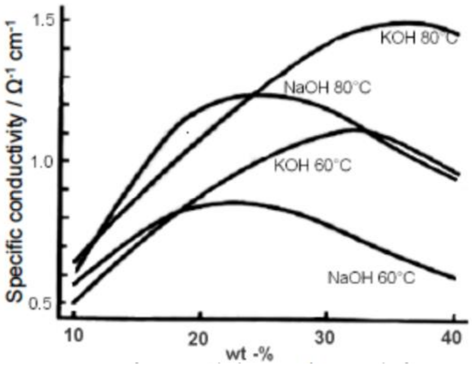
Electrolyte : 30% KOH
Température de fonctionnement : 70-80 °C
Pression de fonctionnement : < 30 bar

Figure 6: Alkaline electrolysis

anode : $2\ OH^- \rightarrow \frac{1}{2} O_2 + H_2O + 2\ e^-$
cathode : $\mathbf{2\ H_2 + 2\ e^- \rightarrow H_2 + 2\ OH^-}$

Alkaline electrolysis is the most widely used process in the industry and therefore mature.

- Electrolysis are in peak or medium capacity modules (0.5-800 Nm^3 / h of hydrogen),
- using an aqueous solution of potassium hydroxide (or potassium hydroxide) Concentration varies depending on the temperature (typically 25% in Mass at 80 ° C up to 40% at 160 ° C).
- Potash is preferred to soda, essentially for Higher conductivity at equivalent temperature and better Control of chloride and sulphate impurities.



The concentration varies depending on the operating temperature to maximize electrical conductivity:

- 25% by weight for a temperature of 80 to 90 ° C;
- 30 to 35% at 120 ° C;
- 40% at 160°C.

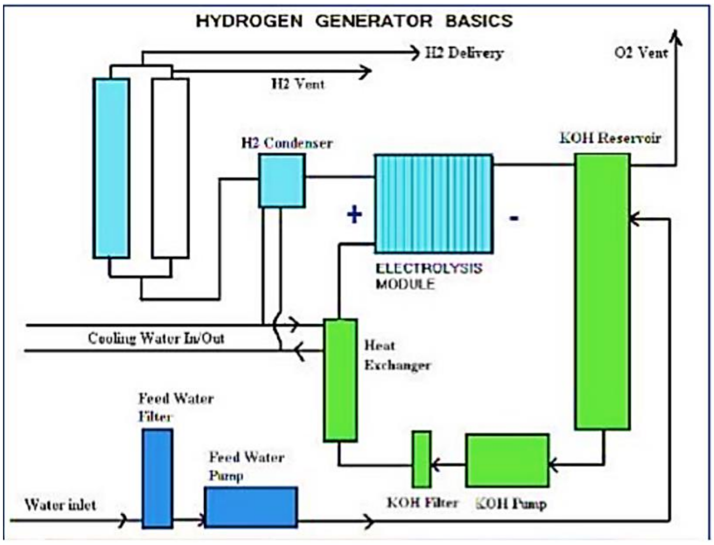
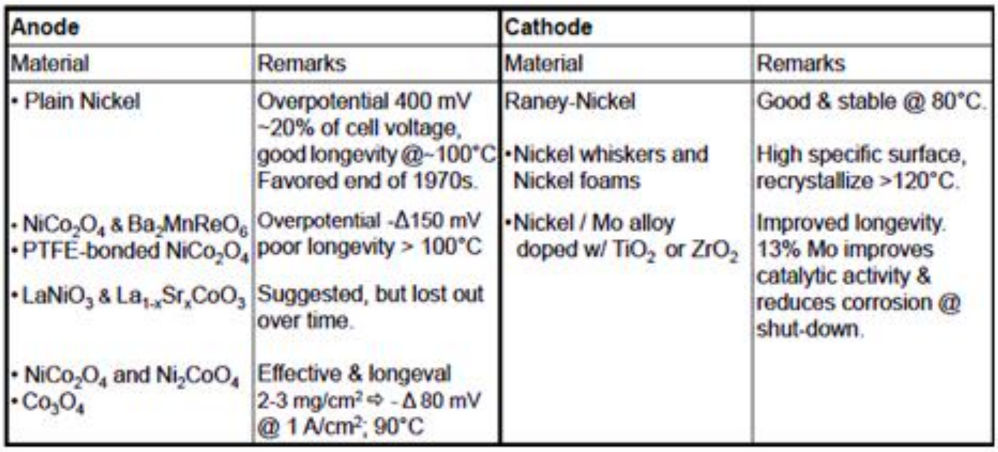


Figure 7:hydrogen generator

The anodes are made of nickel-plated steel at a temperature of Function below 90 °C, and solid nickel beyond. The cathode is consisted of iron (up to 100 ° C.) with a surface deposit of nickel or a nickel-base alloy (Ni-S, Ni-Zn ...) to reduce Power surges



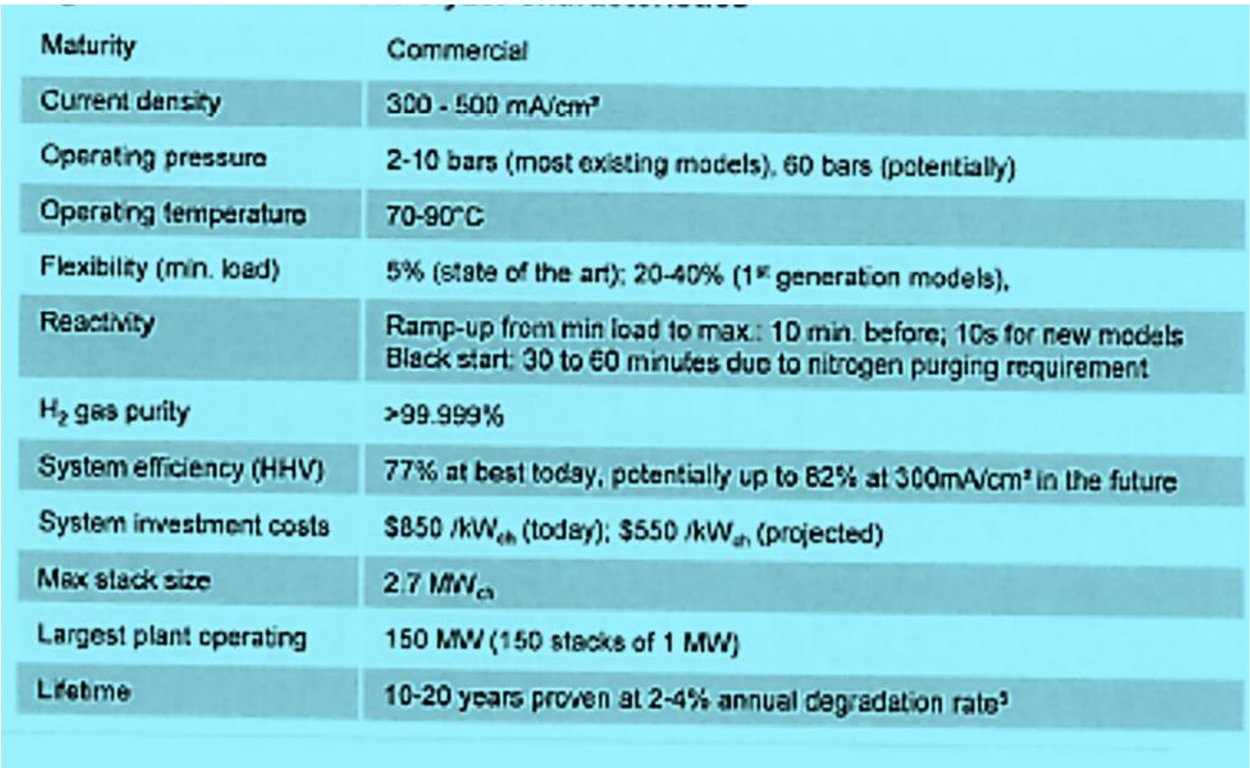
Anode		**Cathode**	
Material	Remarks	Material	Remarks
• Plain Nickel	Overpotential 400 mV ~20% of cell voltage, good longevity @~100°C Favored end of 1970s.	Raney-Nickel •Nickel whiskers and Nickel foams	Good & stable @ 80°C. High specific surface, recrystallize >120°C.
• $NiCo_2O_4$ & Ba_2MnReO_6 • PTFE-bonded $NiCo_2O_4$	Overpotential -Δ150 mV poor longevity > 100°C	•Nickel / Mo alloy doped w/ TiO_2 or ZrO_2	Improved longevity. 13% Mo improves catalytic activity & reduces corrosion @ shut-down.
• $LaNiO_3$ & $La_{1-x}Sr_xCoO_3$	Suggested, but lost out over time.		
• $NiCo_2O_4$ and Ni_2CoO_4 • Co_3O_4	Effective & longeval 2-3 mg/cm² ⇨ - Δ 80 mV @ 1 A/cm², 90°C		

Table 2:technical alkaline concepts

- The maximum operating temperature resulting from a compromise between the Overvoltage's and corrosion resistance of materials used
- The concentration of the electrolyte, defined by the conductivity opium at the temperature Considered
- The rapid circulation of the electrolyte makes it possible to avoid deviations of concentration
- The geometry of the electrodes to facilitate the elimination outside the electric field of Bubbles formed;
- The use of split electrodes (frapped metals) reducing overvoltage's by one Local increase in area active
- The diaphragm which must introduce the least possible drop of ohmic, (thin thickness, Of high porosity, of a small average pore diameter (<1 µm).

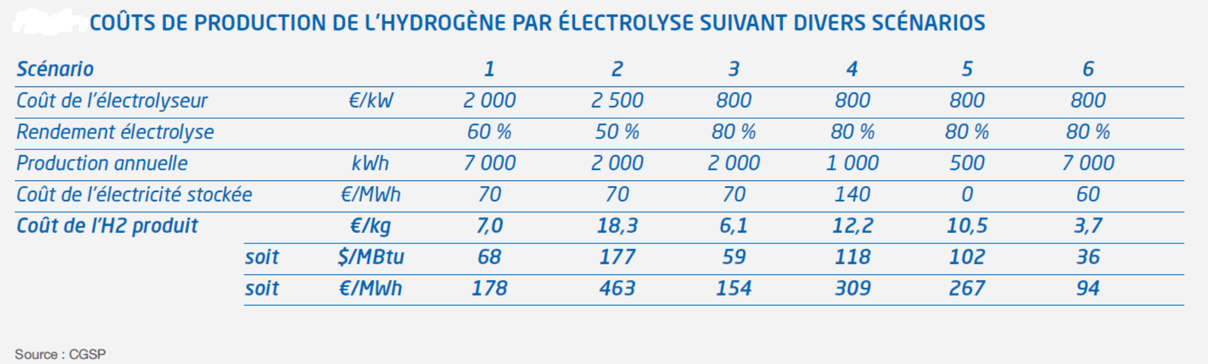
Property Material	Type	Temperature [°C]	Thickness [µm]	Specific Resistance [Ωcm²]	Remarks
Plain Asbestos	inorganic	<100	2000 - 5000	0,74	hazardous
Polymer-reinforced Asbestos	composite	<100	200 - 500	0,15 - 0,2	superior chemical resistance and mechanical stability in comparison to plain asbestos
PTFE-bonded potassium titanate	composite	120 - 150	300	0,1 - 0,15	shows excellent stability in hot caustic environment
Polymer-bonded zirconia	composite	<160	200 - 500	0,25	ZrO_2 on polyphenylsulfon lattice

Table 3:technical concepts for alkaline electrolysis/diaphragms



Maturity	Commercial
Current density	300 - 500 mA/cm²
Operating pressure	2-10 bars (most existing models), 60 bars (potentially)
Operating temperature	70-90°C
Flexibility (min. load)	5% (state of the art); 20-40% (1st generation models),
Reactivity	Ramp-up from min load to max.: 10 min. before; 10s for new models Black start: 30 to 60 minutes due to nitrogen purging requirement
H_2 gas purity	>99.999%
System efficiency (HHV)	77% at best today, potentially up to 82% at 300mA/cm² in the future
System investment costs	$850 /$\text{kW}_{el}$ (today); $550 /$\text{kW}_{el}$ (projected)
Max stack size	2.7 MW_{el}
Largest plant operating	150 MW (150 stacks of 1 MW)
Lifetime	10-20 years proven at 2-4% annual degradation rate[3]

Figure 8: Three units of 2 MW Enertrag alkaline electrolysis unit - 1000 m3 / h



COÛTS DE PRODUCTION DE L'HYDROGÈNE PAR ÉLECTROLYSE SUIVANT DIVERS SCÉNARIOS

Scénario		1	2	3	4	5	6
Coût de l'électrolyseur	€/kW	2 000	2 500	800	800	800	800
Rendement électrolyse		60 %	50 %	80 %	80 %	80 %	80 %
Production annuelle	kWh	7 000	2 000	2 000	1 000	500	7 000
Coût de l'électricité stockée	€/MWh	70	70	70	140	0	60
Coût de l'H2 produit	**€/kg**	7,0	18,3	6,1	12,2	10,5	3,7
soit	$/MBtu	68	177	59	118	102	36
soit	€/MWh	178	463	154	309	267	94

Source : CGSP

Table 4: cost of producing hydrogen by electrolysis according to various scenarios

Using an aqueous alkaline solution as electrolyte is the most common and mature approach in water EL. For more than 100 years' alkaline water electrolyzes are used in industrial applications and until today the AEL process dominates the market of water electrolyzes. Potassium hydroxide with a concentration of 20%-40 wt% circulates as basic electrolyte through the cells. The operating pressure is mostly atmospheric but commercial systems with pressures up to 1.5 MPa are also on the market. AEL cells are operated commonly at 323-353 K with typical current densities of 0.2-0.45 A cm^2 and cell voltages of approx. 1.8-2.4 V. Table 8.1 specifies the general equations of the half-cell reactions.

The active area of a cell in an AEL stack can be several square meters (up to 4 m^2) and is mainly limited by gas evacuation, which would cause unduly high losses due to bubble over potential at the electrodes if the active area, and thus the gas production capacity, were too high. Stacks operating at higher pressures (e.g., the HySTAT)

A series of Hydrogenics) take advantage of the smaller bubbles evolving at the electrodes. For a given current density, such a stack can be designed to be more compact than a stack operating at atmospheric pressure. For larger hydrogen production capacities, one stack can be assembled easily from several hundreds of cells. The largest commercial stack with a production capacity of 760 N-m^3 H_2 h_1 was built by Lurgi. It consists of 556 cells and has lengths of more than 12 m and weights approximately 95 t.

12.1.2 System Layout and Peripheral Components

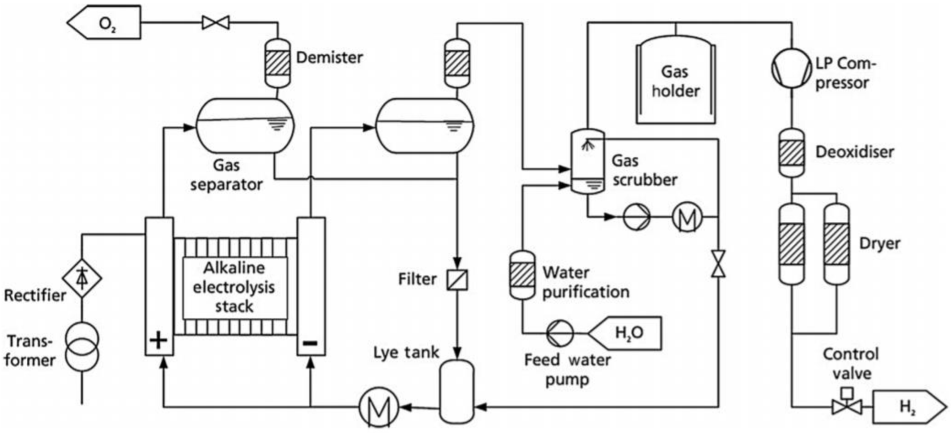


Figure 9: Typical system of an alkaline electrolyzer operating at nearly atmospheric conditions. Purification and gas drying stages are located after low-pressure compression

Although the stack is the main component of an electrolyzer, the complete system consists of several additional process components, instrumentation, and control devices. A principal system layout for an alkaline electrolyzer operating at (nearly) atmospheric conditions is given in Figure 9.

The power electronics consists of a transformer and rectifier and converts the incoming AC power into a regulated DC current. The gases evolve from the electrodes and drag the electrolyte in a two-phase flow toward the gas/water separators which are positioned above the stack. Depending on the system design inside the gas/water separators heat exchangers and baffles are installed to cool down the electrolyte and to reduce the aerosol content of hydrogen and oxygen, respectively. Subsequently, the gases flow through demisters (coalescent filters) in order to retain fine droplets of liquid KOH in the electrolyte circulation. Control valves after the demister regulate the pressure inside the system. At least on the hydrogen side the remaining KOH is washed out in a gas scrubber (gas rinser). The electrolyte from both sides is remixed after the separators and impurities are filtered out. A circulation pump can be used to assist the natural convection of the electrolyte. Forced convection of the electrolyte is advantageous with regard to heat dissipation and uniform electrolyte concentration in the cells. Nevertheless, for economic reasons alkaline electrolyzers mostly operate without a circulation pump, see Figure 10. Due to the common electrolyte management high gas purity can be guaranteed only if circulation in the cells is fast enough. For this reason, the lower range of operation is limited to >20% of the nominal hydrogen production rate in most systems.

A feed water system with a pump is necessary to maintain the concentration of the alkaline solution at a constant level. The quality of the feed water is guaranteed by deionization in order to prevent fouling in the system. Most systems have additional heat exchangers for electrolyte and gas cooling. Often, a (low-pressure) gas reservoir for hydrogen is installed to guarantee a constant hydrogen flow for the downstream application. [1]

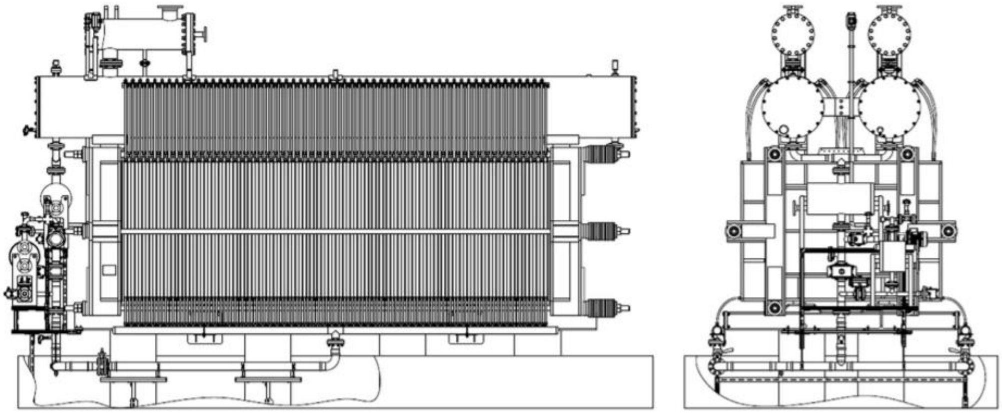


Figure 10: Front and side views of a large alkaline electrolyzer nde-30 with an electrical power of 2 mw (basic design: davy/bamag), operating at (nearly) atmospheric conditions (Figure courtesy of ENERTRAG HyTec (McPhy).)

We observed that when the current or amperage doubles, production just about doubles too, the best electrolyte was sodium hydroxide tied with potassium hydroxide and when increasing concentration, production also increases. We then built a functional hydrogen generator using these optimized parameters.

12.1.3 Hypothesis

Potassium hydroxide (KOH) will be the best electrolyte for the electrolysis reaction of water.

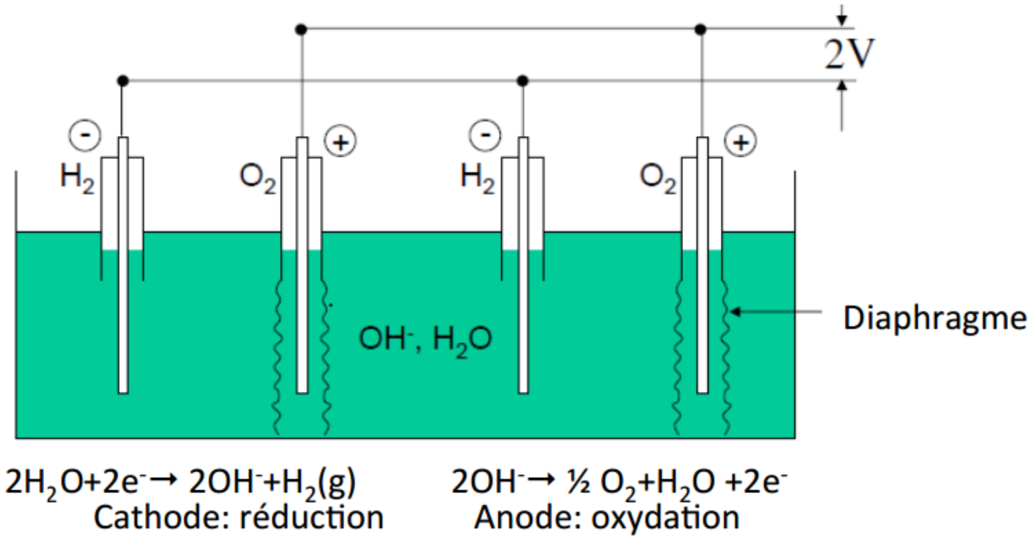
- The higher the current, the more hydrogen will be produced.
- The higher the voltage, the more hydrogen will be produced.
- The gas production will be different depending on the concentration of the electrolyte.[2]

12.1.4 Alkaline Technology

- IHT, Industrie Haute Technologie, (Switzerland) - electrolysers from 20 to Nm³/ h, from 1 to 32 bar, http://www.iht.ch/technologie/electrolyse/industry/electrolyse-sous haute-pression-systeme-lurgi.html
- ELT - Elektrolyse Technik GmbH, (Germany): electrolyzers from 330 to 1400 Nm³ / h, from 1 to 30 bar (Figure 10), http://www.elektrolyse.de
- Hydrogenics, (Canada) ex-Vandenborre / Stuart Energy, produces the family of electrolysers, HySTAT from 10 to 15 Nm³ / h, 10-25 bar, http://www.hydrogenics.com/
- Angstrom Advanced Inc. (USA) - electrolysers, up to 500 Nm³ / h, up to 50 bar, http://www.angstrom-advanced.com/index.asp?page=hydrogenh2o

12.1.5 Technologies: Monopolar and bipolar structures

The first electrolysis apparatus had mono-polar electrodes (i.e., That each anode is connected to the pole positive and each cathode to the pole negative), the Electrolysis cells then function in parallel.



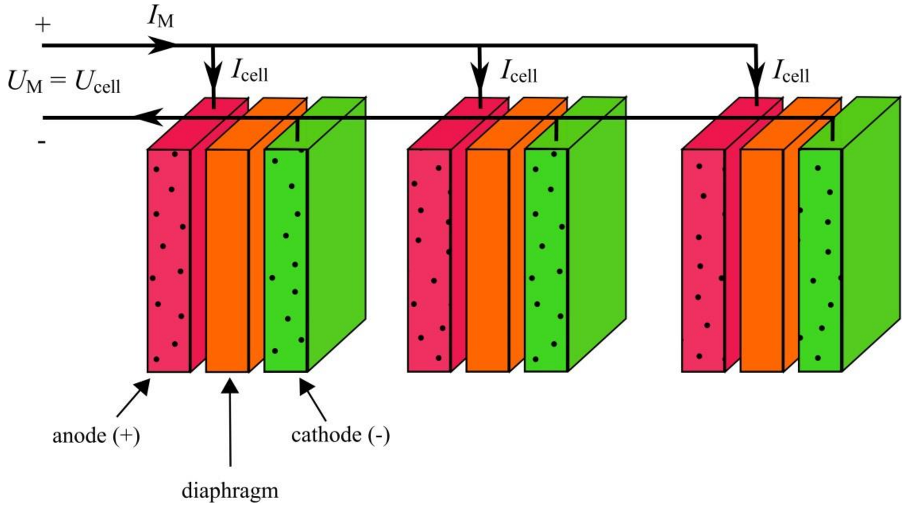


Figure 11:Alkaline Monopolar with tank

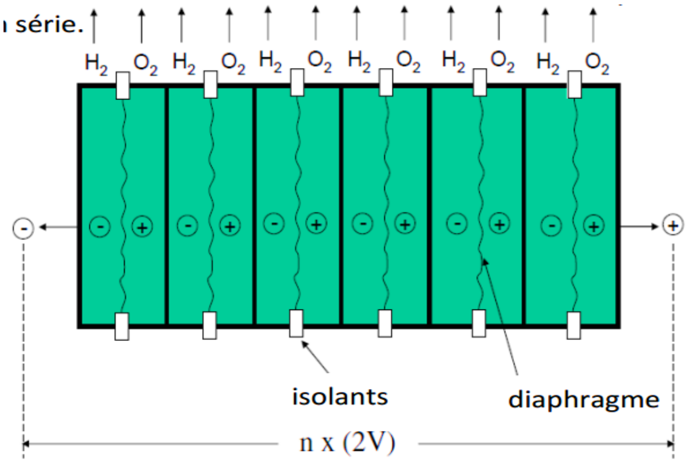
Bipolar

Diaphragm insulation

The bipolar systems, developed later on,

Role of anode on one side and cathode on the other, the electrolysis cells

Then function serially.



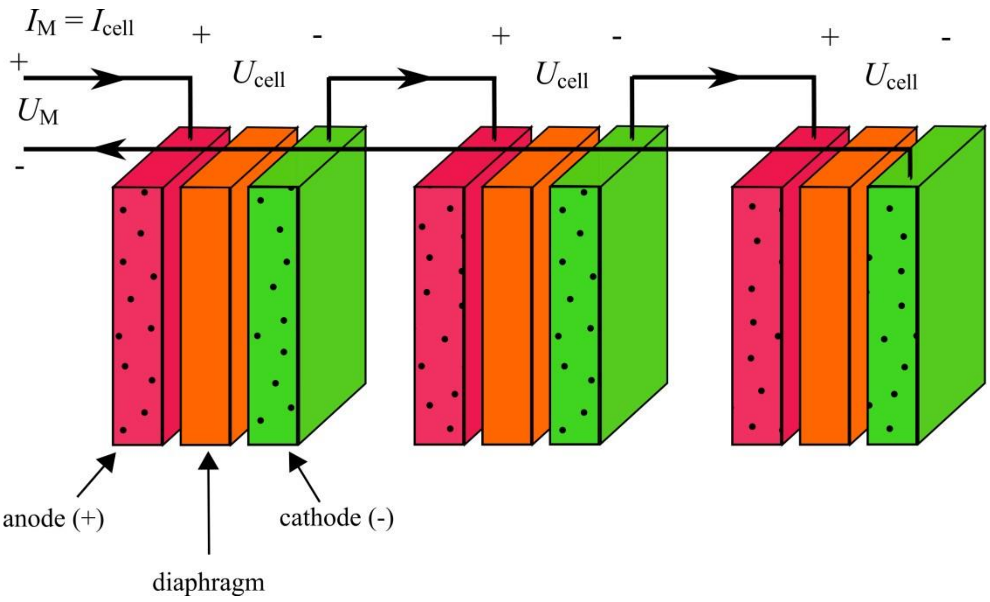


Figure 12:bipolaire

Monopolar		**Bipolar**
Advantages		
Simple and rugged design		Lower unit cell voltages
Relatively inexpensive parts		Higher current densities
Simple fabrication techniques		Intercell busbars greatly reduced
Few gasketed surfaces		Rectifier costs more easily optimized
Individual cells easily checked		Can readily operate at higher pressures and temperatures
Cells easily isolated for maintenance		Pressure operation eliminates compressors
No parasitic currents in system		Easier to control entire system for temperature and electrolyte level
Minimum disruption to production (say by, single cell failure) for maintenance problems		Fewer spare parts required
Cells easily maintained on site		Individual cell frames can be very thin, thus providing a large gas output from a small piece of equipment
No pumps or filters required		Fallout from military and aerospace programs in fuel cells as well as hydrogen oxygen production generation has greatly assisted bipolar cell development
Simple internal gas lift circulation		Mass production of plastic cell components could result in lower capital costs
		Potential to operate at very high current densities

		Electrical arrangements of electrolysers can allow a ground potential where the gases and electrolyte leave the system, or electrolyte enters the system
Disadvantages		
Difficult to achieve small interelectrode gaps		Sophisticated manufacturing and design techniques required
Heavy intercell busbars		Parasitic currents lower current efficiency
Inherently higher power consumption from potential drop in cell hardware		External pumping, filtration, cooling, and gas disengaging system required
Cell pressures and temperatures limited by mechanical design		Malfunction of a unit cell difficult to locate
Each cell requires operator attention for temperature, electrolyte level, and gas purity		Repair to a unit cell requires entire electrolyser to be dismantled (in practice)
Sludge and corrosion products collect within cell		Higher disruption to production for maintenance problems

Table 5:comparaison between mono and bipolar cells

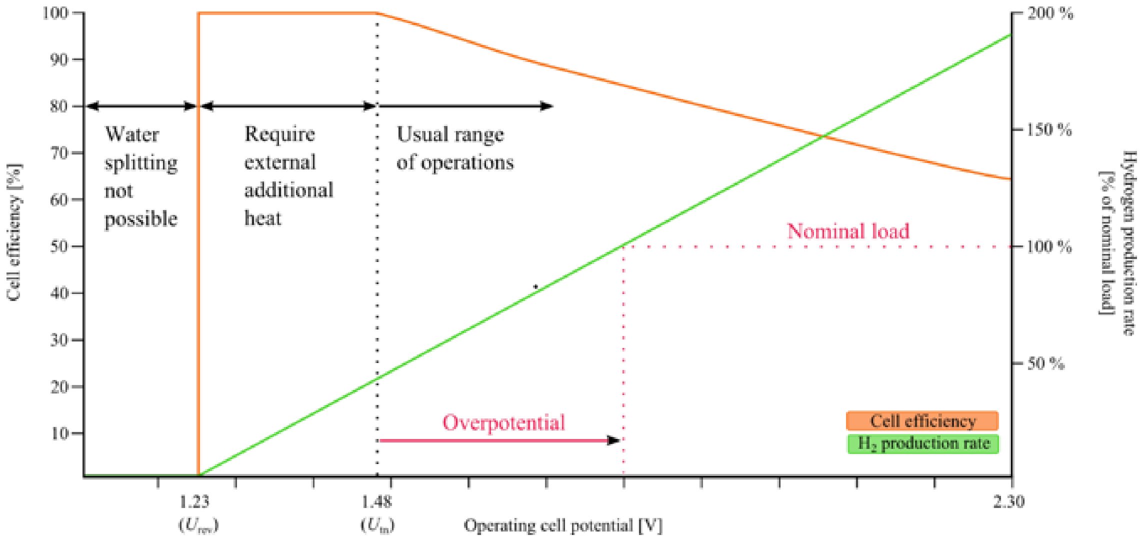


Figure 13: Illustrative cell efficiency and H_2 production rate as a function of cell voltage

For aqueous water electrolysis, the reversible voltage can be written as a function of temperature and pressure (LeRoy et al. 1980) as

$$U_{\mathrm{rev}}(T,p) = U_{\mathrm{rev}}(T) + \frac{RT}{zF}\ln\left[\frac{(p-p_{\mathrm{v}})^{1.5}p_{\mathrm{v}}^{*}}{p_{\mathrm{v}}}\right] \qquad (2.5)$$

where R is the universal gas constant (8.3144621 J·mol^{-1}·K^{-1}), p_v the vapour pressure of the electrolyte solution (atm), and p_v^* the vapour pressure of purified water (atm). $U_\text{rev}(T)$ can be expressed according to (LeRoy et al. 1980) and (Tilak et al. 1981) as follows

$$U_\text{rev}(T) = 1.5184 - 1.5421 \cdot 10^{-3}T + 9.523 \cdot 10^{-5}T + 9.84 \cdot 10^{-8}T, \quad (2.6)$$

where temperature is in degrees Kelvin. The effect of pressure on the reversible cell voltage—calculated using (2.5) and (2.6)—is illustrated in Fig.

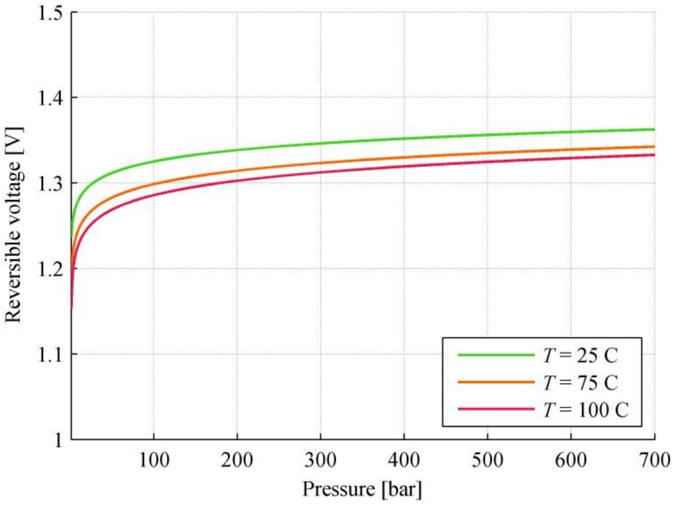


Figure 14: Reversible voltage as a function of pressure at temperatures T = 25 °C, T = 75 °C, and T = 100 °C in aqueous water electrolysis. Calculations are for 30 wt% KOH electrolyte which has an electrolyte molality of 7.64 mol/kg.

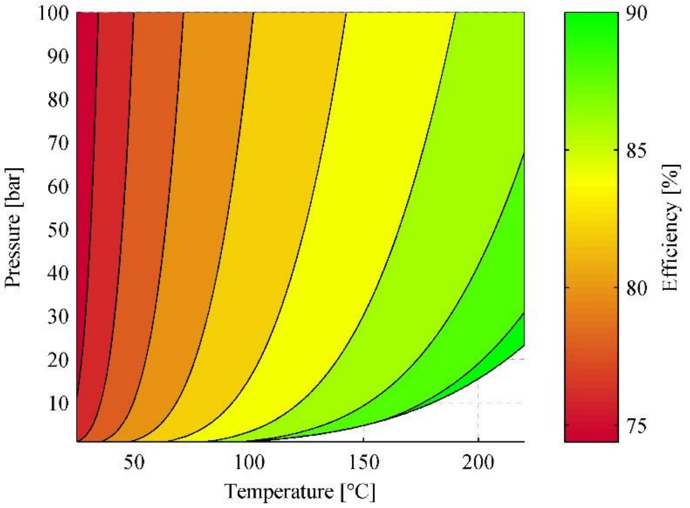


Figure 15: Simulated alkaline electrolyser cell efficiency (HHV) with varying temperature and pressure with a constant current density i = 0.2 A/cm^2. Efficiency is not simulated at points where the prevailing pressure is lower than the vapour pressure of pure water.

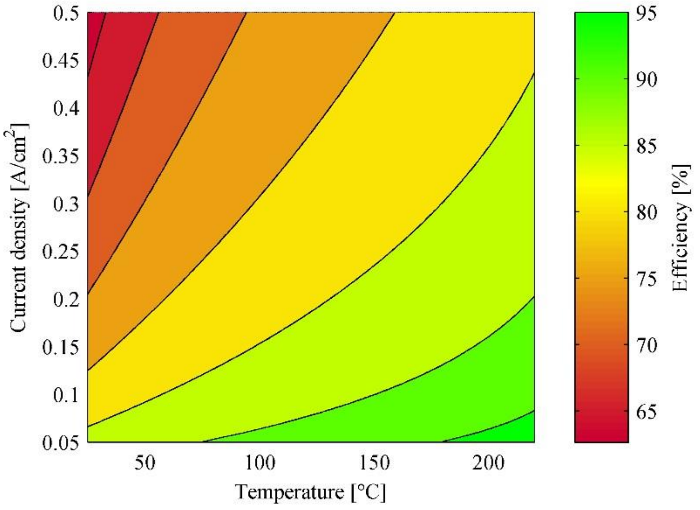


Figure 16: Simulated alkaline electrolyser cell efficiency with varying temperature and current density at constant pressure p = 30 bar.

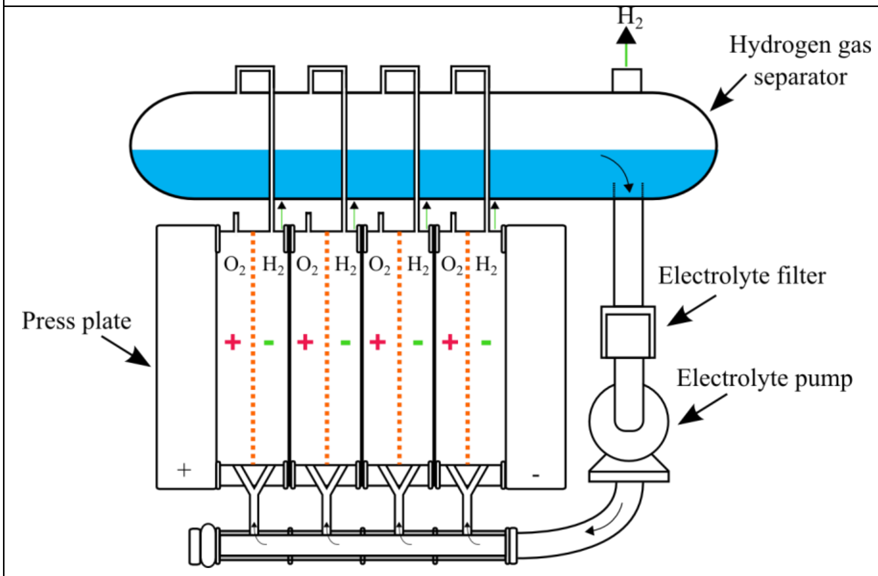


Figure 17: Overview of a typical alkaline electrolysis plant viewed from the hydrogen side. Product (wet) gases from the electrolyser stacks rise to the gas separator tanks where they are separated from the remaining electrolyte. Oxygen gas is treated in its own gas separator tank. Water is continuously added into the system to maintain the desired electrolyte concentration

Maturity	Commercial
Current density	0.2–0.4 A/cm^2
Cell area (1)	< 4 m^2
Hydrogen output pressure	0.05–30 bar
Operating temperature	60–80 °C
Min. load	20–40 % 5 % (state of the art) (2)
Overload (1)	< 150 %$_{\text{(nominal load)}}$
Ramp-up from minimum load to full load	0.13–10 %$_{\text{(full load)}}$/second
Start-up time from cold to minimum load	20 min – several hours

H_2 purity	99.5–99.9998 %
System efficiency (HHV) (2)	68–77 %
Indicative system cost	1.0–1.2 €/W
System size range	0.25–760 Nm^3/h 1.8–5300 kW
Lifetime stack	60 000–90 000 h

Table 6: 2 Alkaline electrolyser characteristics. Values collected from (Bertuccioli et al. 2014) except (1) from (Lehner et al. 2014) and (2) from (Decourt et al. 2014).

12.1.6 Pressurized operation

Water electrolysers can be categorized into atmospheric and pressurized electrolysers depending on the pressure level at which electrolysis takes place. An overview of these two categories is illustrated in Fig. below:

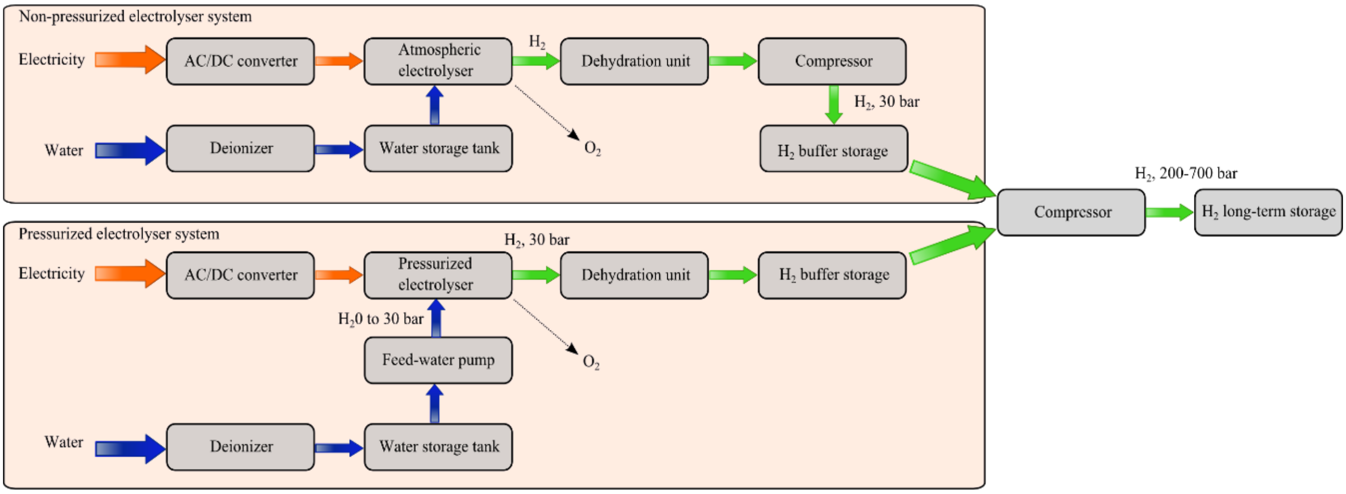


Figure 18: 10 Overview of exemplary non-pressurized and pressurized water electrolyser systems. Hydrogen buffer storages store hydrogen gas at around 10–30 bar. From the buffer storage, hydrogen gas may be further compressed to 200–700 bar. The highest pressure requirement is in mobility end-use applications, typically 350–800 bar.

12.1.7 Main features of commercially available electrolysers

Water electrolyzer systems have auxiliary equipment, which enable the automatic production of electrolytic hydrogen. Generally, water electrolyser systems comprise the following components and subsystems:

- power supply and power converter
- water deionizer (and a buffer tank for deionized water)
- water circulation pump
- gas purification unit
- gas storage
- control system

- ventilation system

Alkaline electrolysis systems need pumps and filters to continuously supply and distribute the liquid electrolyte. Water is consumed and has to be supplied to maintain the correct electrolyte concentration. One example of a small alkaline electrolysis system is illustrated in Fig 14.

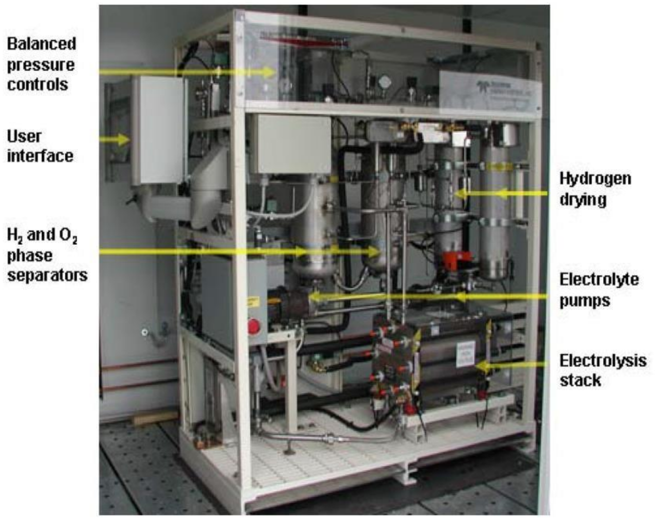


Figure 19: System components of Teledyne Energy Systems' 40 kW alkaline hydrogen generator (Harrison et al. 2009). Measurements of the enclosure are 150 x 178 x 75 cm.

12.1.8 Power electronic systems

A water electrolyser is a DC load and thus the input power for the electrolyser has to be either AC/DC or DC/DC conditioned. The control of the power conditioning stage enables the selection of suitable output power. Principle idea of power conditioning and control is described in Fig. 15

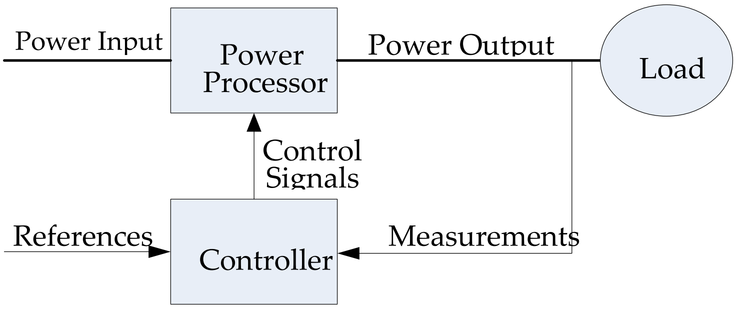


Figure 20: 3 General scheme of a power electronic system

12.1.9 Design of cells

12.1.9.1 PEM Electrolysis (Proton Exchange Membrane)

The acid electrolysis is distinguished from the previous one by a solid electrolyte with a proton-conducting polymer membrane (FIG. 4). The advantages of this technology are the absence of liquid electrolyte, compactness, simplicity of manufacture, simplicity of design and operation, limitation of corrosion problems, significantly higher performance and less influence of variation in conditions (Interesting for intermittent renewable sources). However, the cost of the polymer membrane and the use of electro-catalysts based on noble metals, lead to equipment nowadays more expensive than the alkaline electrolyzers of the same capacity. Polymer membrane electrolysis is considered by many to be a technology of the future as it benefits from the many developments on comparable technology (PEM) fuel cells and the associated cost reduction.

Small-capacity polymeric membrane electrolysis is already a mature technology that has been used for several decades for underwater applications (oxygen plants aboard US and British nuclear submarines) and space (For the generation of oxygen in the life compartments).

These units can operate from atmospheric pressure to several tens of bars, even a few hundred bars).

This type of electrolyser is particularly suitable for coupling to a renewable energy source because it supports the variations in available electrical power better than alkaline electrolysis. Moreover, in view of the better performance of available electrolyzers, this type of acid electrolysis has a better yield (5 to 10 points more) than that of alkaline electrolysis.

Standards and codes on the design and / or installation of small capacity electrolysers are being developed, in particular within ISO TC 197 dedicated to hydrogen technologies

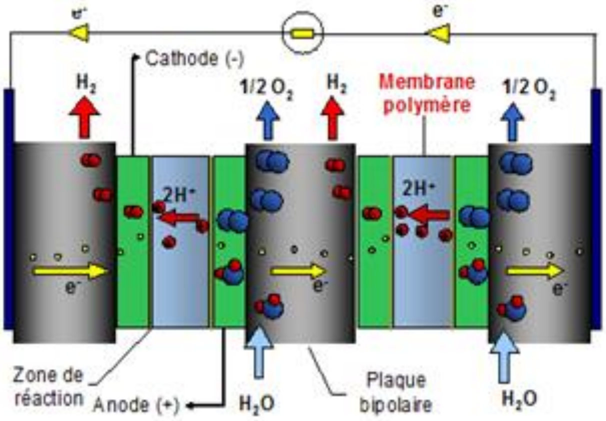


Figure 21: **electrolyse pem**

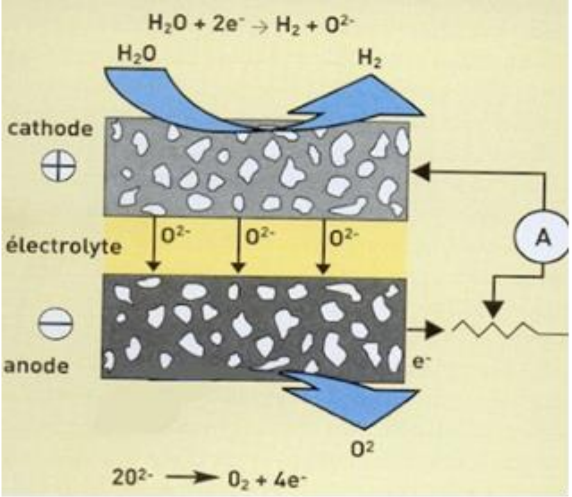
anode :2 H_2O ⇨ $O_2 + 4\ H^+ + 4\ e^-$

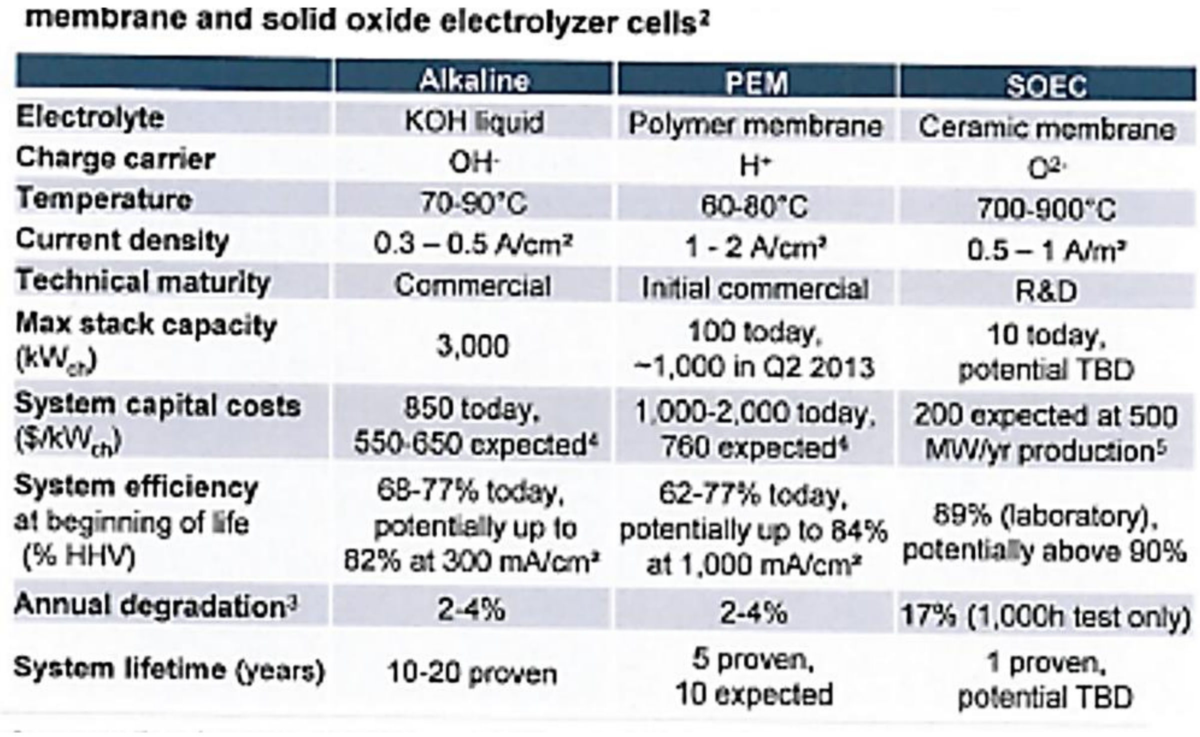
cathode :2 $H^+ + 2\ e^-$ ⇨ H_2

Figure 22: Electrolyser PEM AREVA H_2GEN/CETH$_2$ 120 Nm^3/h (2015)

12.1.9.2 High temperature electrolysis (PCFC or SOEC)

This technology is directly derived from developments in the PCFC or SOFC fuel cell (Figure 6), operating respectively in the 400 - 600 ° C and 650 - 1000 ° C ranges. It is advantageous if it is supplied with both electricity and heat in order to maintain the desired high temperature, the yield can then be greater than 80% if the heat of vaporization of the water is not taken into account. It is essentially intended to be coupled to a concentrated solar system or to a high temperature nuclear reactor. It is in the development stage in various laboratories such as CERAMATEC or Idaho National Engineering and Environmental Lab. In the USA and CEA in France, in particular through a start-up called Sylfen, which is developing a reversible SOFC (fuel cell electrolysis) technology.





membrane and solid oxide electrolyzer cells[2]

	Alkaline	PEM	SOEC
Electrolyte	KOH liquid	Polymer membrane	Ceramic membrane
Charge carrier	OH^-	H^+	O^{2-}
Temperature	70-90°C	60-80°C	700-900°C
Current density	0.3 – 0.5 A/cm²	1 - 2 A/cm²	0.5 – 1 A/m²
Technical maturity	Commercial	Initial commercial	R&D
Max stack capacity (kW_{ch})	3,000	100 today, ~1,000 in Q2 2013	10 today, potential TBD
System capital costs ($\$/kW_{ch}$)	850 today, 550-650 expected[4]	1,000-2,000 today, 760 expected[4]	200 expected at 500 MW/yr production[5]
System efficiency at beginning of life (% HHV)	68-77% today, potentially up to 82% at 300 mA/cm²	62-77% today, potentially up to 84% at 1,000 mA/cm²	89% (laboratory), potentially above 90%
Annual degradation[3]	2-4%	2-4%	17% (1,000h test only)
System lifetime (years)	10-20 proven	5 proven, 10 expected	1 proven, potential TBD

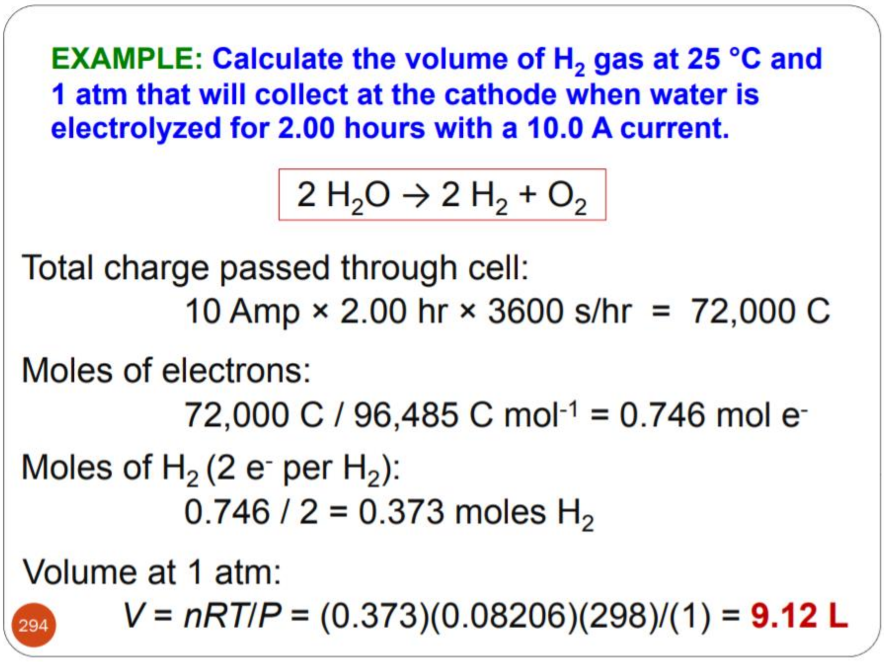
Table 7: Differences between 3 types of electrolyzer

A microprocessor to control an electolyser **as trnsys**

12.1.10 Voltage and ampere

- Apply DC power
- Electricity required to produce 1 N m3 of hydrogen is, from Faraday's law, 2393 Ah (Ampere hours). As this reaction proceeds almost quantitatively, the minimum energy required is 2.94 kWh for 1 cubic meter of hydrogen. Since Er is theoretical equilibrium potential, actual cell voltage needed to continue the reaction is higher with the addition of ohmic loss of electrolyte and diaphragm and overvoltage (overpotential) by electrode reaction.
- Since the first part of the cell polarization curve has a greater slope, measurement was more frequent at lower current densities than at high current density. At each step, the voltage was measured as average of 3 min measurements. Up to 0.289 A, steps were every 0.01 A cm2; between 0.289 A and 0.578 A, steps were every 0.1 A cm2. Finally, steps were every 0.2 A cm2, from 0.578 A up to the maximum voltage which was fixed at 2.2 A.

12.1.11 Calculate gas flow rate



EXAMPLE: Calculate the volume of H_2 gas at 25 °C and 1 atm that will collect at the cathode when water is electrolyzed for 2.00 hours with a 10.0 A current.

$$\boxed{2\,H_2O \rightarrow 2\,H_2 + O_2}$$

Total charge passed through cell:

$$10\text{ Amp} \times 2.00\text{ hr} \times 3600\text{ s/hr} = 72{,}000\text{ C}$$

Moles of electrons:

$$72{,}000\text{ C} / 96{,}485\text{ C mol}^{-1} = 0.746\text{ mol e}^{-}$$

Moles of H_2 (2 e^- per H_2):

$$0.746 / 2 = 0.373\text{ moles }H_2$$

Volume at 1 atm:

$$V = nRT/P = (0.373)(0.08206)(298)/(1) = \mathbf{9.12\ L}$$

A method is described for production of electrolytic water, employing the system of first dividing the feed water supplied to the anode into water for electrolysis and water not for electrolysis, conducting the water for electrolysis through the anode chamber to be electrolyzed, mixing the electrolytic water discharged from the anode chamber with the water not for electrolysis, and second, dividing the feed water supplied to the cathode into water for electrolysis and water not for electrolysis, conducting the water for electrolysis through the cathode chamber to be electrolyzed, and mixing the electrolytic water discharged from the cathode chamber with the water not for electrolysis. Electrolysis is conducted by charging the anode plate and the cathode plate with at least 1500 coulombs of direct current per liter of electrolytic water actually electrolyzed. This method can increase free chlorine production efficiency and prevent adhesion of scale to the electrodes.

In addition, the minimum amount of this water for elec trolysis is the amount Sufficient for replacing the gas pro duced at the anode and the cathode during electrolysis; that is, the amount approximating the amount of gas production that can be calculated by Faraday's law. The amount of gas produced at an anode in standard State at a current of 1 A (ampere) calculated by Faraday's law is 3.49 milliliters/ minute, and the amount of gas produced at a cathode is 6.98 milliliters/minute.

Assembling the conditions described above as an approxi mation formula, the range of minimum to maximum amount of water for electrolysis is given by the following Formulae (I) and (II):

water for electrolysis on the anode side (milliliters/ minute)=3.5xA to 40xA

water for electrolysis on the cathode side (milliliters /minute)=7.0xA to 40xA

where A is the amperage of the electrolyzing current.

Example 1

This example describes using the water electrolyzer shown in FIG. 3. The size of the electrolytic bath was 5 cm long, 9 cm wide, and 6 cm thick. An electrode having platinum/lithium oxide baked onto a titanium plate with an effective surface area of 50 cm and having many holes in it was used as the anode plate (3), and an electrode having platinum plated on a titanium plate with an effective surface area of 50 cm and having holes in it was used as the cathode plate (4). The nonconductive material of a fluorinated resin (Teflon R) sheet with holes was laminated on the side of each electrode plate facing the membrane. An MF film of unwoven fabric was used for membrane (1) separating the anode chamber from the intermediate chamber, and a cation exchange resin film was used for membrane (2) separating the cathode chamber from the intermediate chamber.

The rigid plates shown in FIG. 2 were used on these membranes (1) and (2), and were made of synthetic resin. The size of the synthetic resin plates was 50 mmx110 mm, the width of their striped projections was 2.5 mm, and the width of their depressions was 1.5 mm. These striped depressions and projections were arranged crossing perpen dicularly at a slope of 90° to vertical. The thickness, after laminating, of these projections and depressions is 5.0 mm, and matches the width of the intermediate chamber.

Intermediate chamber (F) was filled with an approxi mately 30% concentration aqueous sodium chloride solu tion. The electrolyzer was partitioned on the anode side into anode chamber (D) and water channel (G) by partition plate (13) installed between side wall (A) and anode plate (3). Water for electrolysis (6) was conducted through anode chamber (D), water not for electrolysis (7) was conducted [3]

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laminating, of these projections and depressions is 5.0 mm, and matches the width of the intermediate chamber.

Intermediate chamber (F) was filled with an approximately 30% concentration aqueous sodium chloride solution. The electrolyzer was partitioned on the anode side into anode chamber (D) and water channel (G) by partition plate (**13**) installed between side wall (A) and anode plate (**3**). Water for electrolysis (**6**) was conducted through anode chamber (D), water not for electrolysis (**7**) was conducted through water channel (G) for the purpose of cooling the electrolytic bath, and the two waters were mixed again where they exited the electrolytic bath, then being discharged from outlet (**8**). Similarly, the electrolyzer was partitioned on the cathode side into cathode chamber (E) and water channel (H) by partition plate (**14**) installed between side wall (B) and cathode plate (**4**). Water for electrolysis (**10**) was conducted through cathode chamber (E) and water for other purposes (**11**) was conducted through water channel (H) for the purpose of cooling the electrolytic bath, then these were mixed again and discharged from outlet (**12**).

The direct current charging the electrode plate was 9.0 amperes, and the voltage was 6–7 volts. The amount of water for electrolysis (**6**) conducted through the anode chamber was set at 0.1 liter/minute, the amount of water (**7**) conducted through water channel (G) was set at 1.25 liters/minute, and 1.35 liters/minute of acidic electrolytic water were obtained by mixing these near the outlet from the electrolyzer. The acidic electrolytic water obtained was pH 2.68, and had 1130 mV ORP and 90 ppm free chlorine content. Similarly, the amount of water for electrolysis (**10**) conducted through the cathode chamber was set at 0.1 liter/minute, the amount of water (**11**) conducted through water channel (H) was set at 0.9 liter/minute, and alkaline electrolytic water was obtained by mixing these near the outlet from the electrolyzer. The alkalinity obtained was pH 11.54. The electrolysis current (**6**) in this example was set to 9.0 amperes (5400 coulombs/liter). When tested continuously for 48 hours under these conditions, absolutely no scale was found adhering to the cathode. The solution transport phenomenon of solution migrating from the anode to the cathode was also not found.

Next, a test was conducted by varying the amount of water conducted through the anode chamber and the amount of water conducted through water channel (G) while keeping constant the pH of the acidic electrolytic water. The fluctuation in free chlorine content was measured, and the solution transport phenomenon was observed. The results are shown in Table 1. As free chlorine content decreased with increase in the amount of water for electrolysis in the anode chamber, it was found that the solution transport phenomenon occurred at currents of 1350 and 338 coulombs/liter, and the water level in the intermediate chamber rose.

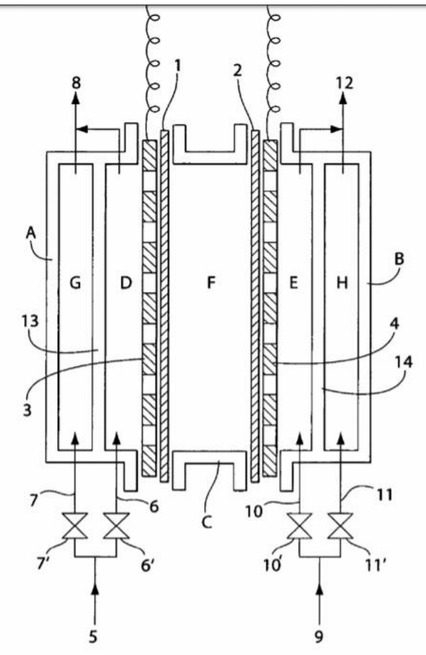


Fig. 3

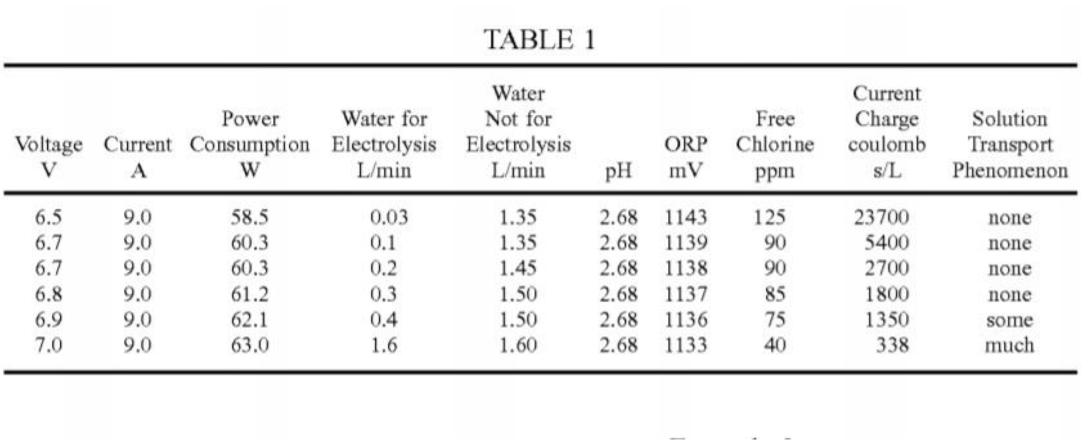


TABLE 1

Voltage V	Current A	Power Consumption W	Water for Electrolysis L/min	Water Not for Electrolysis L/min	pH	ORP mV	Free Chlorine ppm	Current Charge coulomb s/L	Solution Transport Phenomenon
6.5	9.0	58.5	0.03	1.35	2.68	1143	125	23700	none
6.7	9.0	60.3	0.1	1.35	2.68	1139	90	5400	none
6.7	9.0	60.3	0.2	1.45	2.68	1138	90	2700	none
6.8	9.0	61.2	0.3	1.50	2.68	1137	85	1800	none
6.9	9.0	62.1	0.4	1.50	2.68	1136	75	1350	some
7.0	9.0	63.0	1.6	1.60	2.68	1133	40	338	much

12.1.12 Equation for flow rate calculation

Usually, the theoretical flow rate of the product gas can be calculated considering the Faraday's law of the electrolysis and the practical product gas flow rate can be calculated by using the measuring flask readings.

Faraday's Law of Electrolysis

The amount of substance (or number of moles) n can be defined by the following expression in Eq. 1 which is called as Faraday's law of electrolysis.

$$n = \frac{I \times t}{F \times z}$$

(1)

Where, I is the cell current in amperes, t is the time in seconds, F is the Faraday constant and z is the constant of proportionality called electrochemical equivalent (ECE). According to the electrochemical reaction of the alkaline electrolysis process, the value of z is taken as 2.

Ideal Gas Law

The theoretical product gas flow rate (VH2(g) and VO2(g)) can be calculated by using the ideal gas law as in Eq. 2.

$$V_{H_2(g)} = V_{O_2(g)} = \frac{nRT}{P}$$

(2)

Where, R is the universal gas constant (R = 0:082 L atm k^{-1} mol^{-1}), P is operating pressure in atm and T is the operating temperature in K. The amount of substance "n" can be determined using Eq. (1) for both H2(g) and O2(g).

Equation for Practical Product Gas Flow Rate

The measuring flask reading can be used to measure the practical product gas flow rate as in Eq.3.

$$V_{H_2(g)} = V_{O_2(g)} = \frac{v}{t} \times 60$$

(3)

Where, v is the volume of measuring flask and t is the time required to fill the relevant volume of the measuring flask. Moreover, the 100 ml volume measuring flask is used throughout all the experiments to measure the product gas flow rate.

12.2 خزان الهيدروجين (Reservoir for the conservation of HYDROGEN)خزان الهيدروجين (Reservoir for the conservation of HYDROGEN)

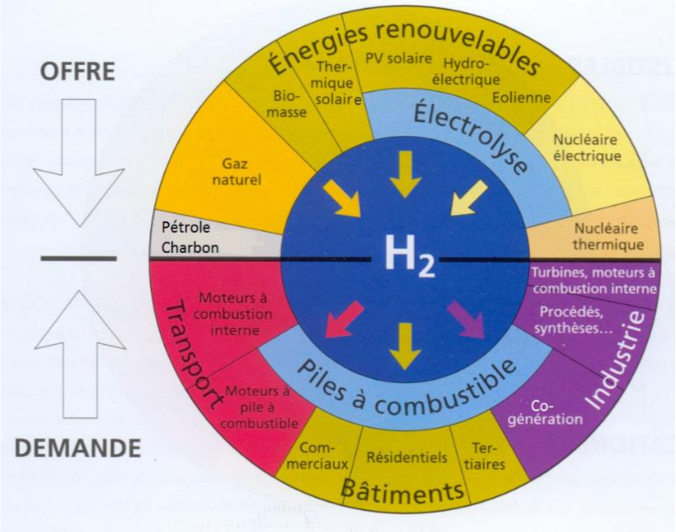


Figure 23: The hydrogen chain (documentaire)

Hydrogen is a very light gas that can be heavily compressed to reduce its mass volume. The simplest method of reducing the volume of a gas at constant temperature is to increase its pressure. Thus, at 700 bar, that is to say 700 times the atmospheric pressure, the hydrogen has a density of 42 kg / m^3 compared with 0.090 kg / m^3 at normal pressure and temperature. At this pressure, 5 kg of hydrogen can be stored in a 125-liter tank. Today, hydrogen is already distributed in steel cylinders in which it is stored at 200 bar. To further improve storage capacity, industrialists are developing composite cylinders or tanks, materials much lighter than steel, that store hydrogen to a pressure of 700 bar.

12.2.1 Hydrogen storage

Since the volumetric energy density of hydrogen is low, advantage should be taken of hydrogen's high energy density on a mass basis. The main ways to increase hydrogen's volumetric energy density and to store hydrogen are presented in Table 4.1.

Table 4.1 The six main hydrogen storage methods and the associated phenomena, where ρ_m is the gravimetric density and ρ_v the volumetric density (Züttel 2007).

Storage method	**ρ_m [mass%]**	**ρ_v [kg_{H2}/m^3]**	**T [°C]**	**p [bar]**	**Phenomena and remarks**
High pressure gas cylinders	13	< 40	25	800	Compressed gas (molecular H2) in light weight composite cylinder
Liquid hydrogen in cryogenic tanks	Size dep.	70.8	−252	1	Liquid hydrogen (molecular H2), continuous loss of a few % per day of hydrogen at room temperature
Absorbed on in-terstitial sites in a host metal	≈ 2	150	25	1	Hydrogen (atomic H) intercalation in host metals, metallic hydrides working at room temperature are fully reversible

Absorbed hydrogen	≈ 2	20	−80	100	Physisorption (molecular H2) on materials e.g. carbon with a very large specific surface area, fully reversible
Complex compounds	< 18	150	> 100	1	Complex compounds ([AlH4]- or [BH4]-), desorption at elevated temperature, adsorption at high pressures
Metals and complexes together with water	< 40	> 150	25	1	Chemical oxidation of metals with water and liberation of hydrogen, not directly reversible?

Table 8: The six main hydrogen storage methods and the associated phenomena, where ρm is the gravimetric density and ρv the volumetric density (Züttel 2007).

Compression to pressurized tanks is currently the preferred option and hydrogen can be compressed using standard piston-type mechanical compressors (Züttel 2007). If the cycling rate of the storage is high, pressurized tanks are a suitable and cost-effective method in small- and medium-scale applications (Decourt et al. 2014). Large-scale storage of pressurized hydrogen in salt caverns could be a possibility.

The boiling point of hydrogen is −253 °C (ISO 2004). Therefore, a lot of energy is needed in hydrogen liquefaction and liquid storage. In small- to medium-scale storage of electrolytic hydrogen, liquefaction is an ill-suited option (Decourt et al. 2014). Additionally, to the energy requirement of the liquefaction, the continuous boil-off of hydrogen limits the possible applications for liquid hydrogen storage systems (Züttel 2007).

Hydrogen reacts at elevated temperature with many transition metals and their alloys to form metal hydrides, for example $LaNiH_6$. Metal hydrides enable a very high volumetric density and have been identified as an effective method to store hydrogen safely (Züttel 2007). The safety of a metal hydride storage of hydrogen is due to the strong binding of atomic hydrogen (H) in the metal hydrides. The absorption and desorption of hydrogen is controlled by heat exchange. However, Züttel (2007, p. 360) noted that exploring the properties of light weight metal hydrides is still a challenge. All the reversible hydrides close to ambient temperature and pressure consist of transition metals and therefore the gravimetric hydrogen density is limited. Alternatively, hydrogen could be stored in liquid hydrocarbons, such as methanol and ethanol, or gaseous hydrocarbons, such as methane.

Prevention of fire and explosion risks

• ATEX Directive 94/9/EC on equipment and protective systems intended for use in potentially explosive atmospheres • ATEX Directive 1999/92/EC on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres • ATEX Directive 2014/34/EU on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (applicable from 20.4.2016) • Seveso II (Directive 96/82/EC) on prevention of major accidents involving dangerous substances, to be overwritten by Seveso III (Directive 2012/18/EU) on 1.6.2015
Safety of pressure equipment
Directive 97/23/EC on the approximation of the laws of the Member States concerning pressure equipment
Safety of machinery
Machinery Directive 2006/42/EC
Electrical safety
• Low Voltage Directive 2006/95/EC • Electromagnetic Compatibility Directive EMC-D 2004/108/EC

Table 9: Directives on the safety of hydrogen generators using water electrolysis process ((2))

12.2.1.1 Liquid hydrogen in cryogenic tanks hydrogen-weight and volume equivalents

Weight of Liquid or Gas		**Volume of Liquid at Normal Boiling Point**		**Volume of Gas at 70°F (21°C) and 1 atm**	
lb	**kg**	**L**	**gal**	**cf**	**m³**
1.000	0.454	6.409	1.693	192.00	5.437
2.205	1.000	14.132	3.733	423.360	11.988
0.156	0.071	1.000	0.264	29.952	0.848
0.591	0.268	3.788	1.000	113.472	3.213
5.208	2.362	33.381	8.818	1000.00	28.317
0.184	0.083	1.179	0.312	35.328	1.000

Table 10: HYDROGEN - WEIGHT AND VOLUME EQUIVALENTS (http://www.airproducts.com/products/Gases/gas-facts/conversion-formulas/weight-and-volume-equivalents/hydrogen.aspx)

Hydrogen is a gas at standard temperature and pressure and is the most common element in the universe. However, free hydrogen is extremely rare on Earth because it evaporates so easily in space. Liquid hydrogen is most commonly used as a rocket fuel where it's burned with liquid oxygen and it also has applications in cryogenics as a coolant. Liquid hydrogen is also a useful means of storing and transporting hydrogen because it takes up less room than it does as a gas. Hydrogen gas can be liquefied by applying the correct combinations of pressure and cooling.

Identify the critical temperature for hydrogen as 33 degrees Kelvin. This is the maximum temperature at which hydrogen can be a liquid, no matter how great the pressure is. The process of liquefying hydrogen must therefore get it below 33 degrees Kelvin (−423.17 °F/−252.87°C).

Determine the critical pressure for hydrogen as about 13 atmospheres (atm). This is the minimum pressure needed to keep hydrogen a liquid at its critical temperature. These critical points provide the parameters for keeping hydrogen a liquid.

Examine the regenerative cooling process. This method pressurizes gas and allows it to expand. This allows the gas to take heat from its environment, thus cooling it. The gas is then passed through a heat exchanger, which cools the gas, thereby compressing it. This process is repeated until the gas cools enough to liquefy.

Apply the regenerative cooling process to liquefy hydrogen as first performed by James Dewar in 1898. Pressurize the hydrogen to 180 atm and pre-cool it with liquid nitrogen. Allow the hydrogen to expand through a valve that is also cooled by liquid nitrogen.

Repeat Step 4 until the hydrogen liquefies. Dewar's experiment yielded about 20 cubic centimeters (CCs) of liquid hydrogen, which was about 1 percent of the hydrogen in the experiment (5)

الهيدروجين هو غاز في درجة حرارة والضغط القياسيين وهو العنصر الأكثر شيوعا في الكون. ومع ذلك، الهيدروجين الحر هو نادرة للغاية على الأرض لأنه يتبخر بسهولة في الفضاء. ويستخدم الهيدروجين السائل الأكثر شيوعا باعتباره وقود الصواريخ حيث انها حرقه مع الأكسجين السائل، ولها أيضا تطبيقات في فيزياء درجات الحرارة المتدنية كمبرد. الهيدروجين السائل هو أيضا وسيلة مفيدة لتخزين ونقل الهيدروجين لأنه يأخذ مساحة أقل بكثير مما هي عليه كغاز. غاز الهيدروجين يمكن المسال عن طريق تطبيق تركيبات الصحيحة من الضغط والتبريد.

تحديد درجة الحرارة الحرجة لالهيدروجين إلى 33 درجة كلفن. هذا هو الحد الأقصى لدرجة الحرارة التي الهيدروجين يمكن أن يكون السائل، مهما تعاظمت الضغوط هو. ولذلك يجب أن عملية تسييل الهيدروجين الحصول عليها دون 33 درجة كلفن.

تحديد الضغط الحرج للهيدروجين كما حوالي 13 الاجواء (ATM). هذا هو الحد الأدنى من الضغط اللازم للحفاظ على الهيدروجين السائل في درجة الحرارة الحرجة. وتوفر هذه النقاط الحرجة المعلمات للحفاظ على الهيدروجين السائل.

دراسة عملية التبريد التجدد. هذه الطريقة يضغط الغاز ويسمح لها بالتوسع. وهذا يسمح للغاز لاتخاذ الحرارة من *بيئتها*، وبالتالي تبريده. ثم يتم تمرير الغاز من خلال مبادل حراري، الذي يبرد الغاز، وبالتالي ضغط عليه. وتتكرر هذه العملية حتى يبرد ما يكفي من الغاز لتسييل.

تطبيق عملية التبريد التجدد لتسييل الهيدروجين كما يؤديها لأول مرة من قبل جيمس ديوار في عام 1898. ضغط الهيدروجين إلى 180 ضغط جوي وقبل تبريده مع النيتروجين السائل. السماح للهيدروجين لتوسيع من خلال صمام أن يتم تبريده أيضا النيتروجين السائل.

كرر الخطوة 4 حتى يسيل الهيدروجين. أسفرت التجربة ديوار حوالي 20 سم مكعب (CCS) من الهيدروجين السائل، الذي كان حوالي 1٪ من الهيدروجين في التجربة.

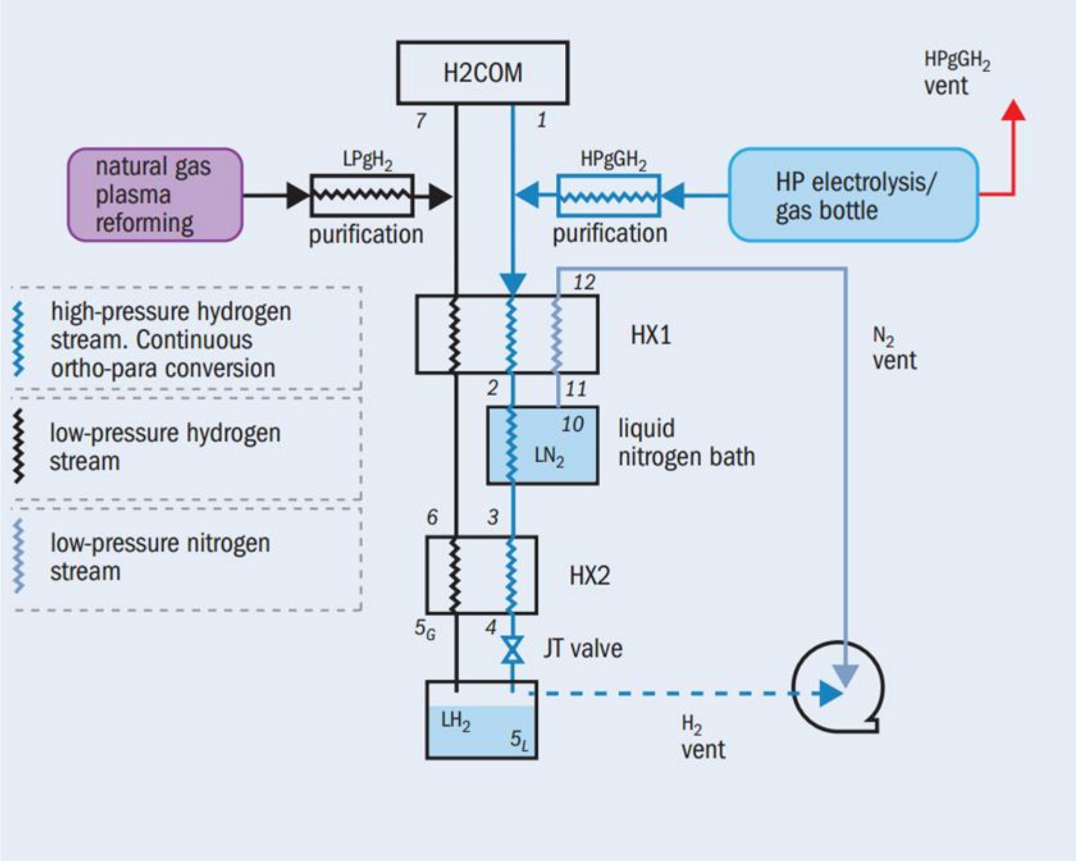


Figure 24: Schematic of the proposed pre-cooled Linde-Hampson system for hydrogen liquefaction. Ortho-para hydrogen conversion takes place in a HX1 and HX2 zone

وقد تم تطوير نظام الهيدروجين تسييل من قبل ينده–هامبسون ويرد تخطيطي في الشكل أدناه. يدخل الهيدروجين النقي دورة في النقطة (1) ويتم ضغط في النقطة 2 من ضاغط الهيدروجين (H2COM). في HX1 ،

البرد الغازات (النيتروجين والهيليوم) جنبا إلى جنب مع الهيدروجين عودة الباردة قبل تبريد تيار الهيدروجين الضغط العالي قبل أن يدخل الحمام السائل النيتروجين. هذا الحمام يزيل الحرارة من الهيدروجين ويبرد عليه إلى درجة حرارة متوسطة في نقطة 3. مضغوط تيار الهيدروجين تبرد قبل ثم يتدفق عبر الهيدروجين والهيدروجين مبادل حراري HX2 متصلا عودة تيار H2 البارد. وبهذه الطريقة، يتم تقليل تيار مضغوط في النقطة 4 إلى درجة الحرارة النهائية .وأخيرا، يتم توسيع تيار الضغط العالي من خلال صمام جول طومسون الى الضغط تخزين) تصل إلى نقطة 5 (Gودرجة الحرارة من 20 K.في هذه المرحلة، والهيدروجين في حالة من مرحلتين ويتم إعادة تدوير الطور الغازي من خلال الحرارةHX2 المبادلات و HX1لإعادة ضغط. سوف ينتج عن ذلك من العائد السائل والهيدروجين من هذا النظام تختلف في حدود7-15٪ اعتمادا على الضغوط الأولية والنهائية. درجة حرارة الهيدروجين النهائية قبل التوسع هو متغير رئيسي الأمثل.

وميزة استخدام حمام التبريد هي أن تسمح لأكبر كمية من الطاقة لإزالتها من دفق الإدخال الهيدروجين في ارتفاع درجات الحرارة. وهذا يزيد من الكفاءة العامة للدورة. ميزة إضافية في هذا النظام هو التأسيس من حافزا أورثو–بارا في الممرات الداخلية للتيار الهيدروجين فيHX1 ، LN2و HX2.هذا حافزا يسمح للحرارة تحويل إلى إزالتها بشكل مستمر وأكثر كفاءة. لضغوط تيار المدخلات الهيدروجين متفاوتة في المنطقة من 50 إلى 100 بار، سوف تختلف الضغط المنخفض تيار الهيدروجين معدلات التدفق الجماعي عودة 0.10 جم / ثانية إلى 0.17 غ / ل

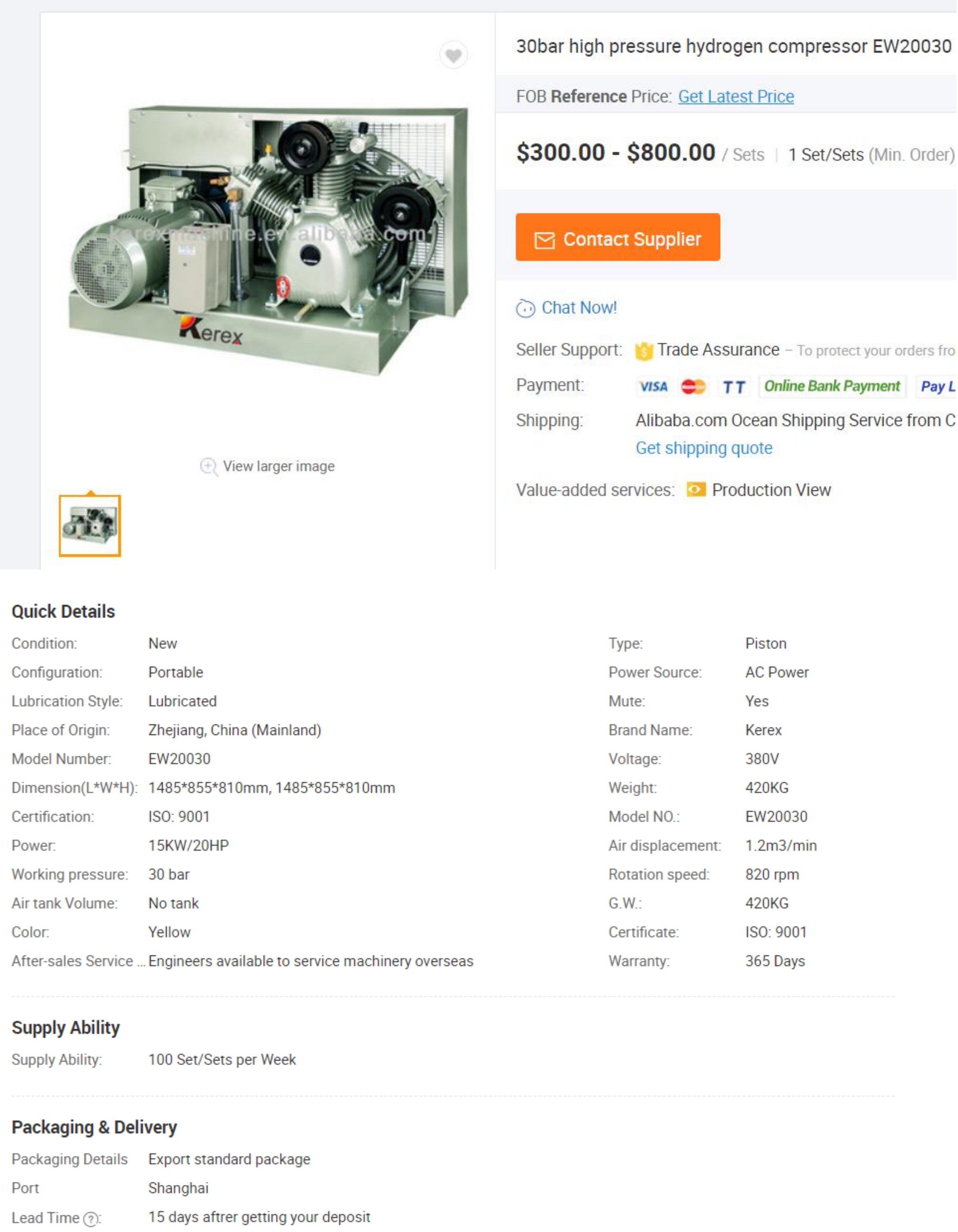
12.2.1.2 How to Compress Hydrogen to Power an Engine?

Connect the Hydrogen source to the diaphragm compressor inlet using a tapped hose, and leave the tap closed to prevent the gas from flowing. Use an external pump to push the gas into the compressor since the compressor itself sucks the gas from the inlet into its hydraulic pump. Make sure that the connection between the Hydrogen source and the compressor is air tight.

Prepare the gas tank and check for any cracks. Make sure the valve is not damaged in any way once again to prevent any accidents. Join the compressor to the tank using a hose with a pressure gauge. The pressure gauge is used to measure the pressure in the tank so that you may tell at what point you should stop pumping the gas into the tank. It is advisable to store Hydrogen at 800 atmospheres (the units can also be expressed in bars).

Open the tap from the Hydrogen source and let the gas flow into the compressor inlet. Power on the diaphragm compressor then watch the pressure gauge move and when the reading is 800 bars, turn the compressor off. Note -- transferring compressed gas from the storage tank to the vehicle engine causes slight loss in its compression energy

Hydrogen compressor



30bar high pressure hydrogen compressor EW20030

FOB Reference Price: Get Latest Price

$300.00 - $800.00 / Sets | 1 Set/Sets (Min. Order)

Seller Support: Trade Assurance – To protect your orders fro

Payment: VISA TT Online Bank Payment Pay L

Shipping: Alibaba.com Ocean Shipping Service from C
Get shipping quote

Value-added services: Production View

Quick Details

Condition:	New	Type:	Piston
Configuration:	Portable	Power Source:	AC Power
Lubrication Style:	Lubricated	Mute:	Yes
Place of Origin:	Zhejiang, China (Mainland)	Brand Name:	Kerex
Model Number:	EW20030	Voltage:	380V
Dimension(L*W*H):	1485*855*810mm, 1485*855*810mm	Weight:	420KG
Certification:	ISO: 9001	Model NO.:	EW20030
Power:	15KW/20HP	Air displacement:	1.2m3/min
Working pressure:	30 bar	Rotation speed:	820 rpm
Air tank Volume:	No tank	G.W.:	420KG
Color:	Yellow	Certificate:	ISO: 9001
After-sales Service ...	Engineers available to service machinery overseas	Warranty:	365 Days

Supply Ability

Supply Ability:	100 Set/Sets per Week

Packaging & Delivery

Packaging Details	Export standard package
Port	Shanghai
Lead Time ?:	15 days aftrer getting your deposit

30bar high pressure hydrogen compressor EW20030: 30bar, AC Power, ISO:9001, Ingersoll Rand OEM supplier, Welcome to visit us!!!

high pressure compressor are widely used in machinery, medcail, textile, food, electricity, iron and steel, automobile, petroleum, chemical, railway, buliding materials, and military indstries.

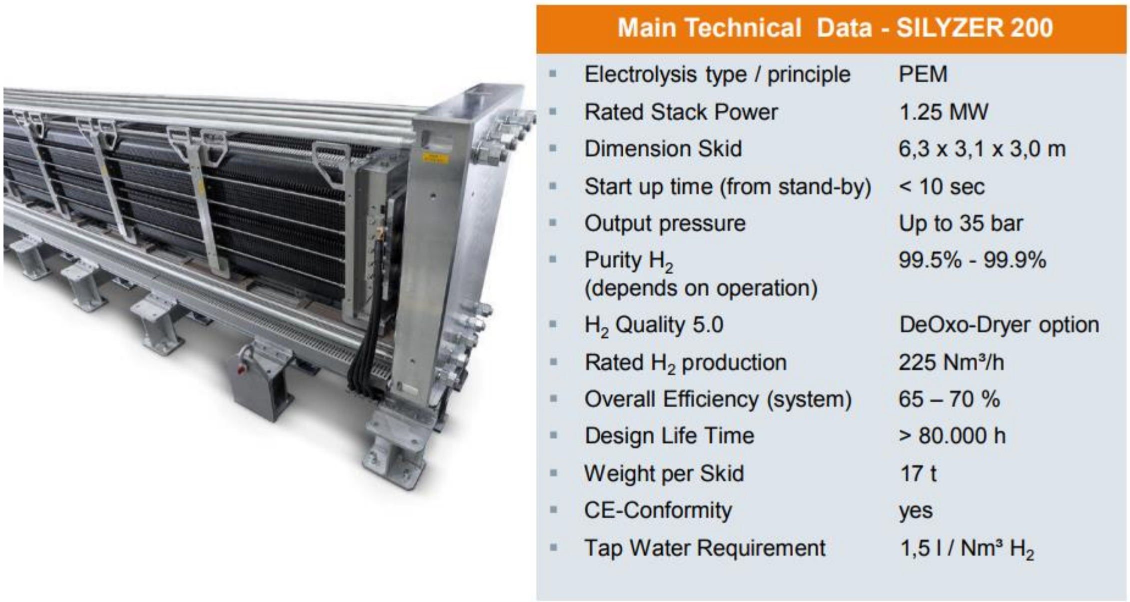
Our factory advantage:

1. Ingersoll Rand OEM supplier.
2. 16 years history at compressors systems in China.
3. Good quality, very competitive and fair price.

Specifications of high pressure air compressor hose EW20030 :

Model NO.	EW20030
Air delivery	1.2 m3/min
Working pressure	30 bar
Air tank Volume	No tank
Motor power	15kw/20hp
Rotation speed	820rpm
Matched power	electric motor power
G.W.	420kg
Dimension(L*W*H)	1485*855*810mm

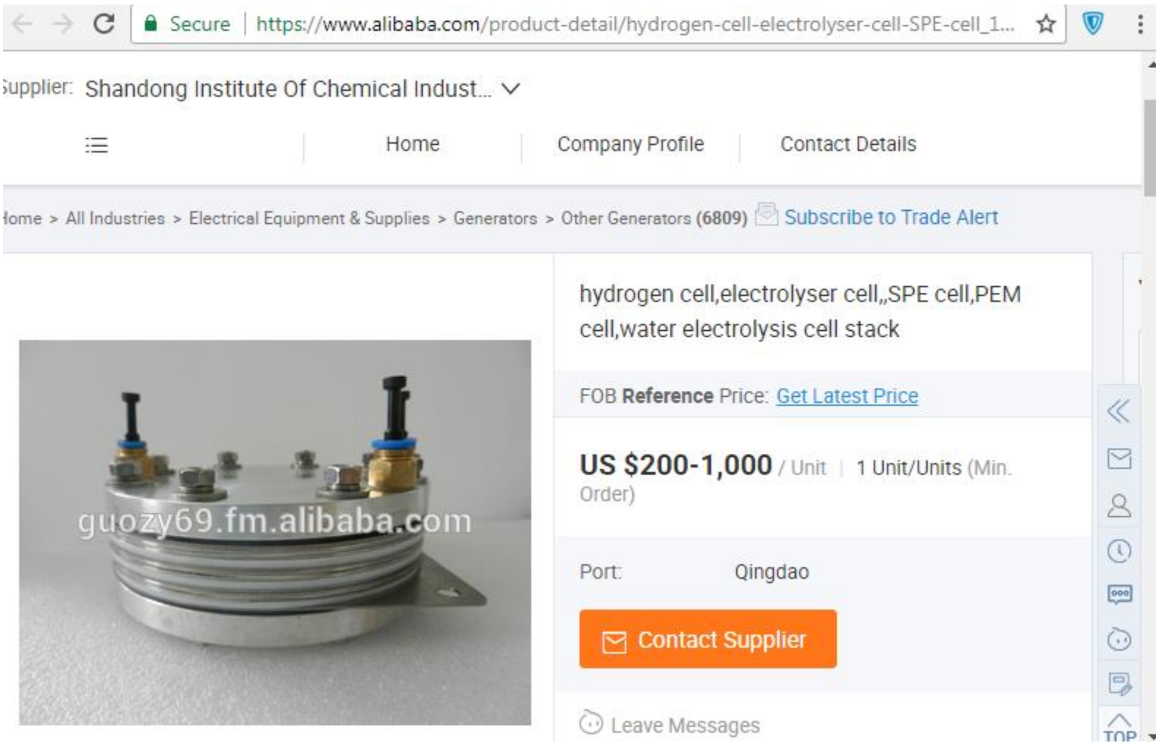
12.2.1.3 PEM Electrolysis machine



Main Technical Data - SILYZER 200

Electrolysis type / principle	PEM
Rated Stack Power	1.25 MW
Dimension Skid	6,3 x 3,1 x 3,0 m
Start up time (from stand-by)	< 10 sec
Output pressure	Up to 35 bar
Purity H_2 (depends on operation)	99.5% - 99.9%
H_2 Quality 5.0	DeOxo-Dryer option
Rated H_2 production	225 Nm³/h
Overall Efficiency (system)	65 – 70 %
Design Life Time	> 80.000 h
Weight per Skid	17 t
CE-Conformity	yes
Tap Water Requirement	1,5 l / Nm³ H_2

12.2.1.4 PEM Electrolysis cost



upplier: Shandong Institute Of Chemical Indust...

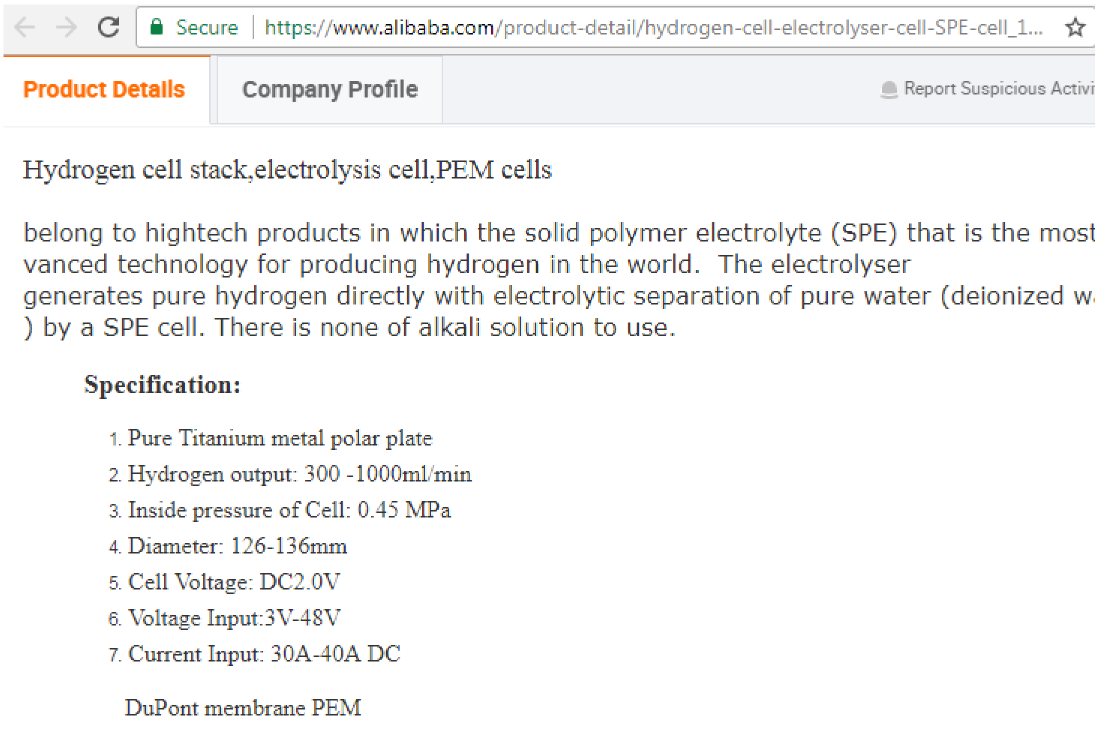
ome > All Industries > Electrical Equipment & Supplies > Generators > Other Generators (6809) Subscribe to Trade Alert

hydrogen cell,electrolyser cell,,SPE cell,PEM cell,water electrolysis cell stack

FOB **Reference** Price: Get Latest Price

US $200-1,000 / Unit | 1 Unit/Units (Min. Order)

Port: Qingdao



Hydrogen cell stack,electrolysis cell,PEM cells

belong to hightech products in which the solid polymer electrolyte (SPE) that is the most
vanced technology for producing hydrogen in the world. The electrolyser
generates pure hydrogen directly with electrolytic separation of pure water (deionized w
) by a SPE cell. There is none of alkali solution to use.

Specification:

1. Pure Titanium metal polar plate
2. Hydrogen output: 300 -1000ml/min
3. Inside pressure of Cell: 0.45 MPa
4. Diameter: 126-136mm
5. Cell Voltage: DC2.0V
6. Voltage Input:3V-48V
7. Current Input: 30A-40A DC

DuPont membrane PEM

https://www.alibaba.com/product-detail/hydrogen-cell-electrolyser-cell-SPE-cell_11262735.html?spm=a2700.7724838.2017115.11.1e94b09aky2NnV (Price 200 - 1000 $)

13 Distilling Water

13.1 Raleigh equation

13.1.1 The Rayleigh Equation

The Rayleigh Equation is useful in the analysis of simple distillation, as it shows **how the concentration and quantity are related.**

As the process is **unsteady state** in nature, the derivation is based on a differential approach to changes in concentration with time. The equation to be derived (known as the Rayleigh Equation) shows the relationship between **total moles remaining in the still** and the **mole fraction of the more volatile component in the still.**

[Similar equation can be obtained for the relationship between the total moles of distillate and the mole fraction of the more volatile component in the condensate receiver]

Material Balance for the still: see the Figure below

L_1 = initial moles of liquid originally in still

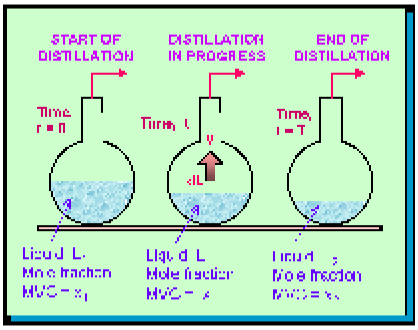
L_2 = final moles of liquid remained in still

x_1 = initial liquid composition in still (mole fraction of A)

x_2 = final liquid composition in still (mole fraction A)

At any time t, the amount of liquid in the still is L, with mole fraction of A in the liquid being x.

After a small differential time (t + dt) , a small amount of vapour dL is produced, and the composition of A in the vapour is y (mole fraction). The vapour is assumed to be **in equilibrium** with the residue liquid.The amount of liquid in the still is thus reduced from L to (L - dL), while the liquid composition changed from x to (x - dx). See the Figure below:



Performing a material balance on A:

Initial amount in still = Amount left in still + Amount vaporized

We have,

$$xL = (x - dx)\,(L - dL) + y\,dL$$

$$xL = xL - x\,dL - L\,dx + dx\,dL + y\,dL$$

Neglecting the term dx dL, the equation reduces to:

$L\,dx = y\,dL - x\,dL$

Re-arranging gives the following:

$$\left(\frac{dL}{L}\right) = \frac{dx}{(y-x)}$$

Integrating from L_1 to L_2, and from x_1 to x_2, we obtain the **Rayleigh Equation:**

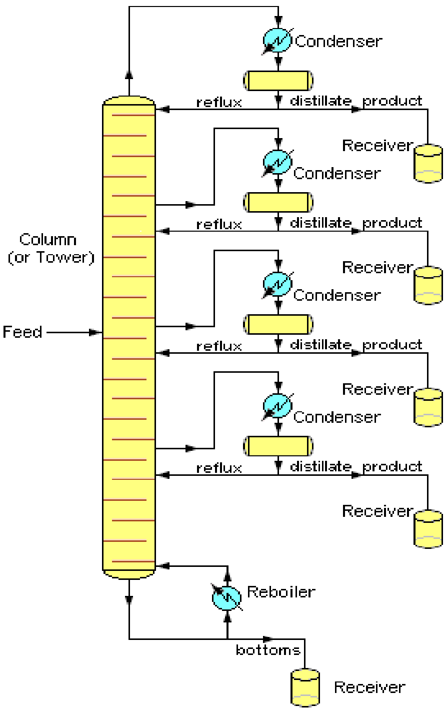
$$\ln\left[\frac{L_1}{L_2}\right] = \int_{x_2}^{x_1} \frac{1}{(y-x)}\,dx$$

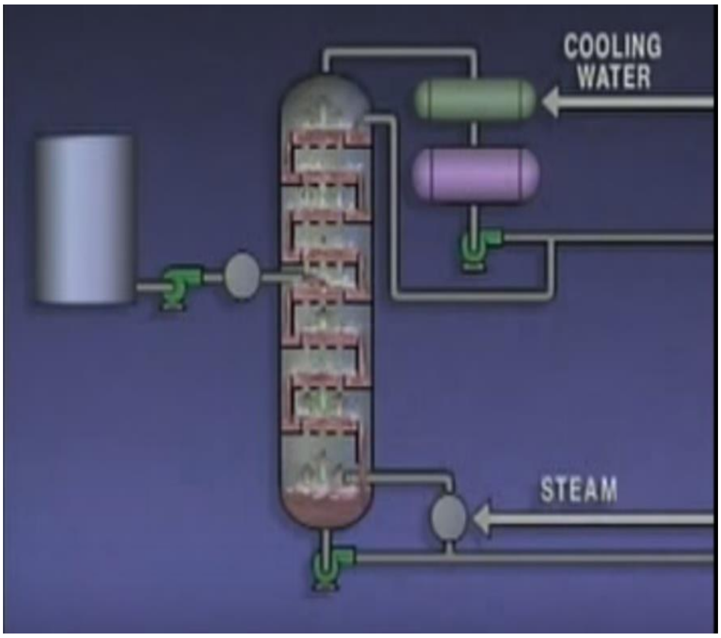
13.2 التقطير المستمر (Continuous distillation)

Continuous distillation is an ongoing separation process in which a liquid mixture of two or more miscible components is continuously fed into the process and physically separated into two or more products by preferentially boiling the more volatile (i.e., lower boiling point) components out of the mixture.

التقطير المستمر (Continuous distillation) هي عملية تقطير مستمرة حيث يمون عامود التقطير باستمرار بمخلوط السوائل في حين استخلاص وفصل جزء أو أجزاء من السوائل المقطرة النقية. وتتسم عملية التقطير بفصل مكونات مخلوط من السوائل بواسطة اختيار درجة غليان وتكثيف البخار. ويتكون المخلوط من سائلين أو أكثر تختلف درجة غليان كل منها عن الأخرى، وبالتالي تختلف تطايرية كل منها. عند تسخين المخلوط يبدأ أولا السائل ذو درجة غليان منخفضة في الغليان وينفصل في هيئة بخاره. يصعد البخار في عامود التقطير ويتكثف، بينما تبقى المكونات القليلة التطاير في قاع العامود.

13.2.1 أجزاء التقطير المستمر (Parts of continuous distillation)





Industrial distillation is typically performed in large, vertical cylindrical columns (see the adjacent photographs) commonly referred to as *distillation columns*, *distillation towers* or *fractionators* with diameters ranging from **about 65 centimeters to 11 meter**s and heights ranging from about 6 meters to 60 meters or more.

To provide for the intimate mixing of the upward flowing vapor and downward flowing liquid in distillation columns, the columns usually contain a series of horizontal distillation trays or plates .The distillation trays or plates are typically separated by about **45 to 75 centimetres of** vertical distance. However, some columns are designed to use beds of packing media rather than trays or plates.

To prevent scaling, pre-treatment of sea water can be carried out by adding polyphosphates or sulfuric acid, adding small balls of sponge, recovered at the outlet, which continuously clean tubes and tanks or It is also possible to add to the brine seed crystals on which the tartar is preferentially deposited (so-called germination method).

On the other hand, one of the main problems of distillation multiple effects after scaling is corrosion due to large amounts of chloride ions in seawater (ions increase the conductivity of water and Thus accelerating corrosion.) Materials or coatings are used which significantly increase the cost of the installations and help to limit the number of effects used.

لمحاربة التحجم، يمكن للمرء أن تعمل على المعالجة من مياه البحر عن طريق إضافة فوسفات أو حمض الكبريتيك، إضافة كرات صغيرة من انتاج الاسفنج استردادها، الذي تنظيف مستمر الأنابيب والخزانات أو مازال إضافة بلورات البذور الماء المالح الذي تفضل الجير المودعة (المعروف طريقة الإنبات).

من ناحية أخرى، واحدة من المشاكل الرئيسية للتأثير التقطير المتعدد، بعد التحجيم، هو التآكل بسبب كميات كبيرة من أيونات الكلوريد في مياه البحر (أيونات زيادة التوصيل من الماء و وبالتالي تسريع التآكل.) هو مطلوب منها لاستخدام مواد أو الطلاء الذي رفع بشكل كبير من تكلفة المرافق ويساعد على الحد من عدد من الآثار المستخدمة.

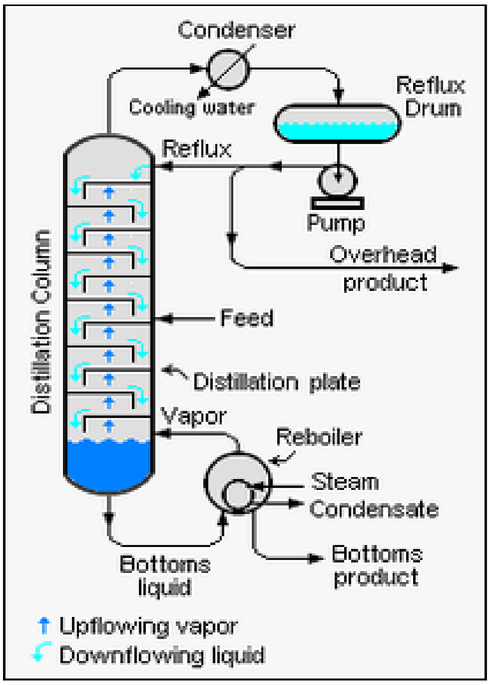


Figure 25: *Schematic diagram of a continuous binary distillation column.*

The design of a distillation column depends upon the composition and the thermal condition of the feed as well as the composition of the desired products. The McCabe-Thiele method and the Fenske equation may be used to design a simple binary distillation column (as in Figure 1).

To design a column for the distillation of a multi-component feed to provide more than two product distillates , computerized simulation models may be used for the design as well as for the subsequent online operation of the column.

Many industrial uses of continuous distillation operate **24 hours per day for as long as 2-5 years between** routine, scheduled maintenance shutdowns. The operational control of a distillation column may be performed by advanced computer control systems but highly experienced workers are still required to oversee the online, real time operations and to provide daily routine maintenance as needed.

13.2.2 عمود التغذية (Column feed)

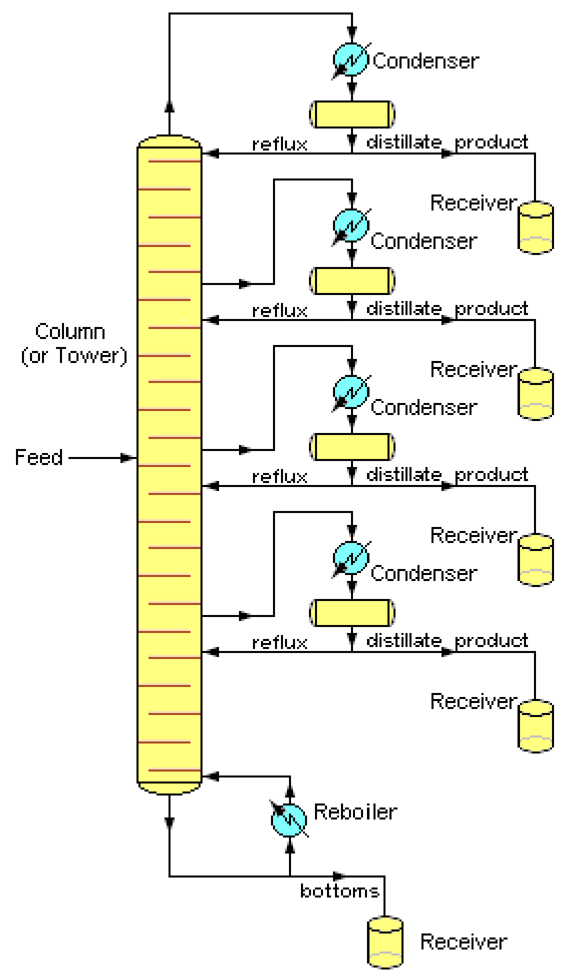


Figure2: Simplified chemical engineering schematic of Continuous Fractional Distillation tower separating one feed mixture stream into four distillates and one bottoms fractions

Indeed to transform one kg of liquid water into 1 kg of steam water at the same temperature it takes about 2250 kilojoules

The manner of feeding a continuous column depends upon the column pressure and the pressure of the feed source. If the feed is from a source at a pressure sufficiently higher than the column pressure, it may be simply piped into the column at the designated feed entry point. A liquid feed from a source at a lower pressure than the column needs to be pumped into the column, and a gas feed from a source at a lower pressure than the column needs to be compressed to a higher pressure before entering the column.

The feed may be a superheated vapor, a saturated vapor, a partially vaporized liquid-vapor mixture, a saturated liquid or a sub-cooled liquid. If the feed is a saturated liquid at a higher pressure than the column pressure and flows through a valve just before entering the column, it will undergo a flash vaporization (also known as an *equilibrium flash* or a *throttling expansion*) resulting a liquid-vapor mixture as it enters the column.

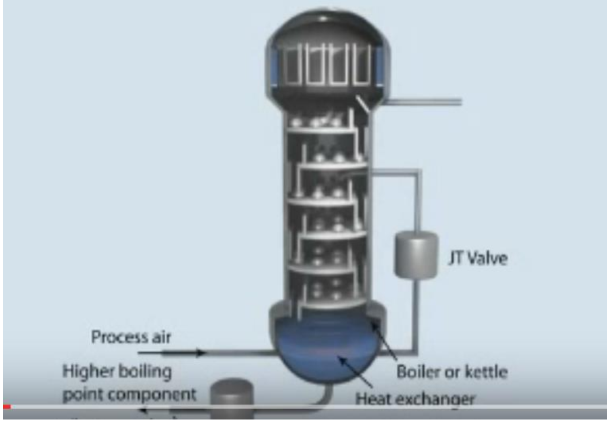
13.2.3 (Overhead vaporization system) االتبخير

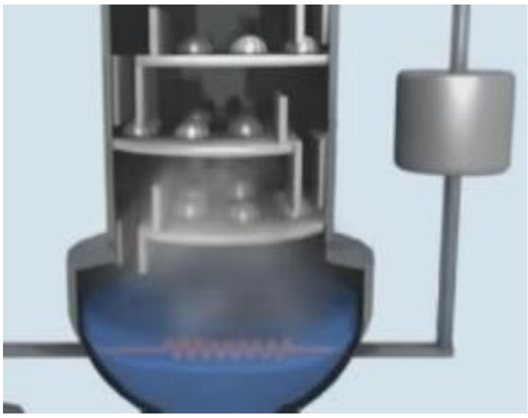
Figures 1 and 2 are based on the assumption that the overhead vapor from a distillation column is cooled and totally condensed in a water or air-cooled condenser. However, in many cases, the tower overhead can't be totally condensed with a typical air or water-cooled condenser and therefore the reflux drum must include a gas vent for the uncondensed vapor.

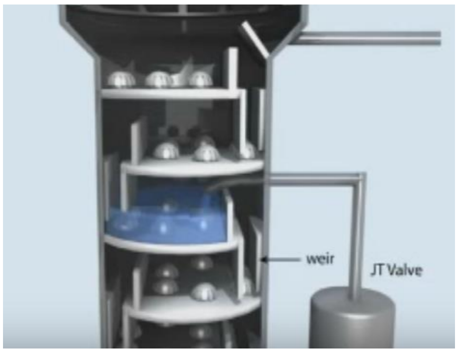
In yet other cases, the overhead stream may also include water vapor because either the feed contains some water or because some steam is injected into the distillation column (which is the case with crude oil distillation towers in petroleum refineries, shown in Figure 4). In those cases, if the overhead distillate product is immiscible in water, the reflux drum may contain a condensed liquid distillate phase, a condensed water phase and a non-condensable gas phase, which makes it necessary that the reflux drum also have a water separation section

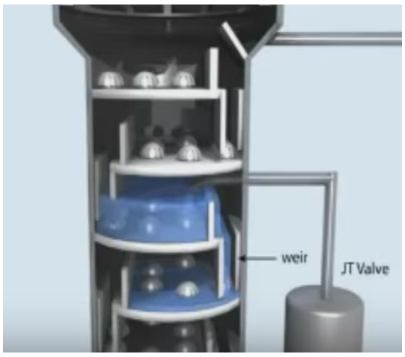
We can view in this following pictures the step to entrance of feed .

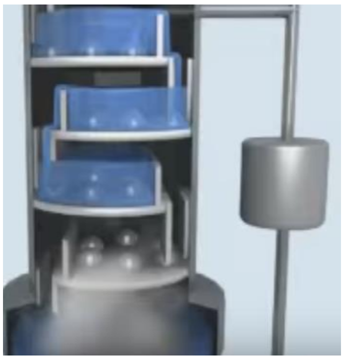
Such an installation consists, in particular, of a condenser-evaporator (1), the cylindro-flash (CF), a boiler (2), a distilled water corridor (24), a circuit for extracting gas (7), a make-up water circuit (3), a chemical treatment circuit for seawater (5) and a chemical treatment circuit of the distilled water .

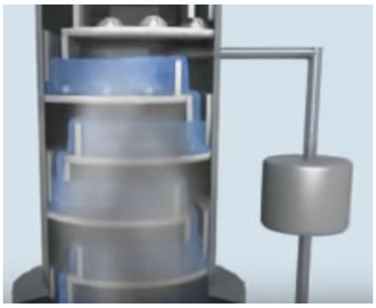


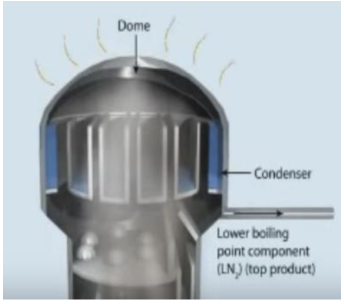


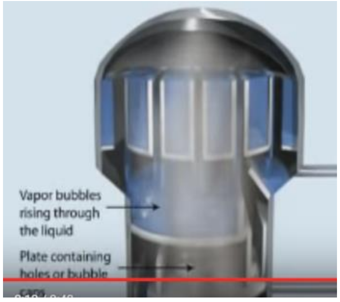












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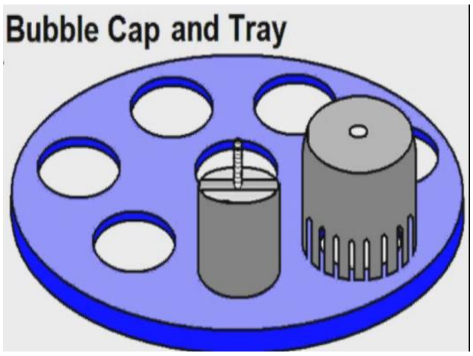
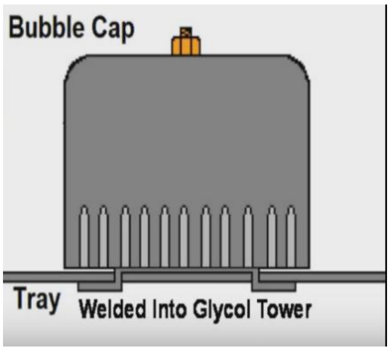
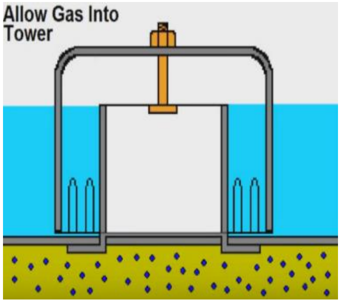
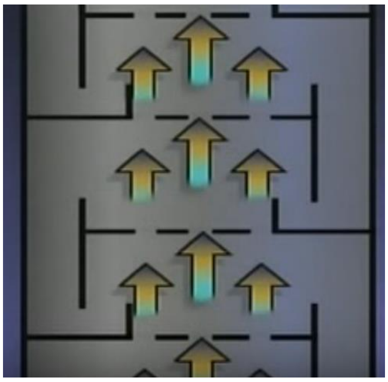
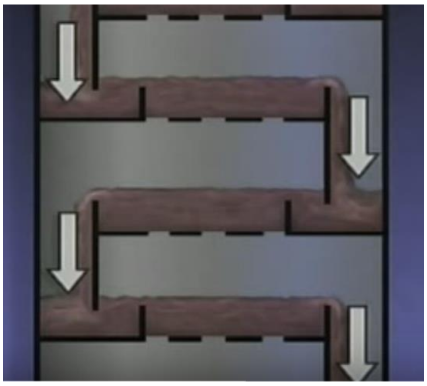
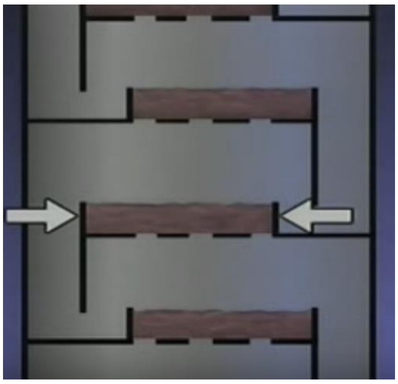


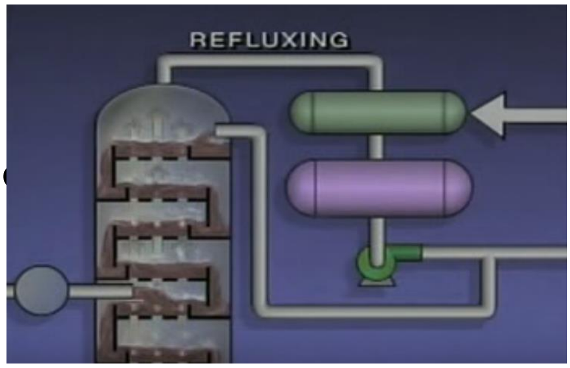


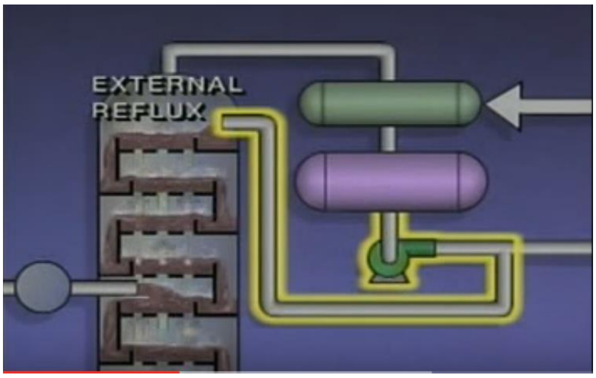


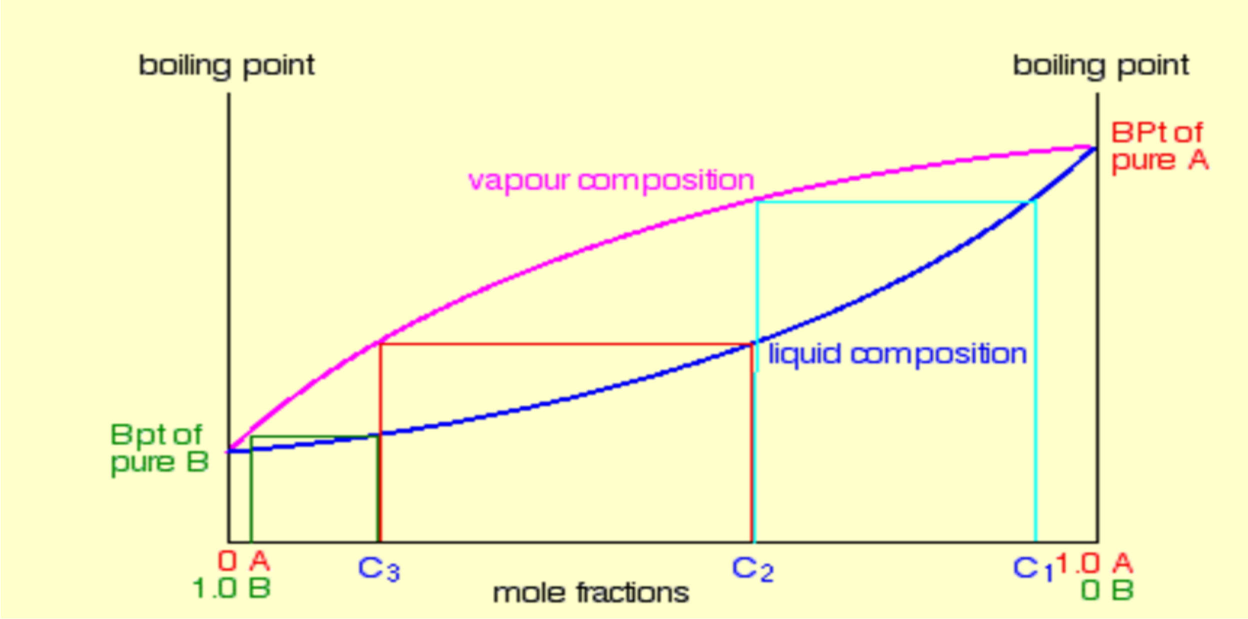












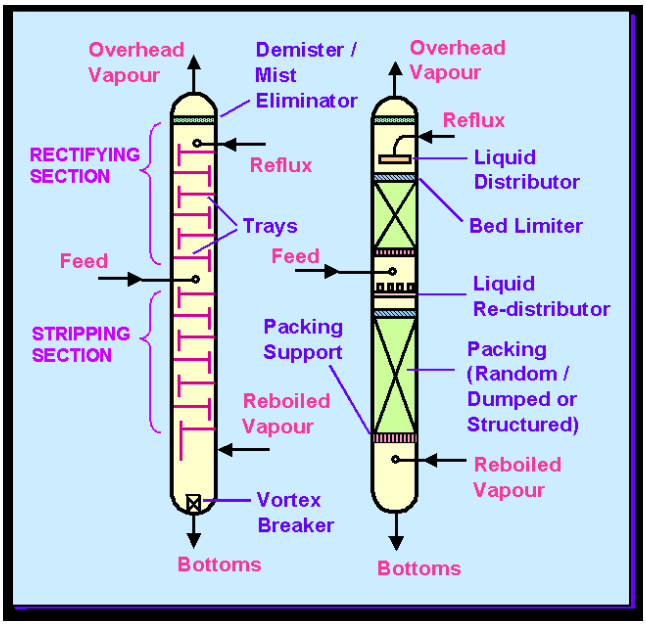
If you boil a liquid mixture C_1, you will get a vapor with composition C_2, which you can condense to give a liquid of that same composition (the pale blue lines).

If you reboil that liquid C_2, it will give a vapor with composition C_3. Again you can condense that to give a liquid of the same new composition (the red lines).

Reboiling the liquid C_3 will give a vapor still richer in the more volatile component B (the green lines). You can see that if you were to do this once or twice more, you would be able to collect a liquid which was virtually pure B.

The secret of getting the more volatile component from a mixture of liquids is obviously to do a succession of boiling-condensing-Reboiling operations.

It isn't quite so obvious how you get a sample of pure A out of this. That will become clearer in a while. (2)



(3)

13.2.3.1 The energy needed to heat the water

We need 1 kcal to increase the temperature 1 °C of 1 m^3 of water (1000 L)

1 kcal=1.16 Wh

Thus, to increase the temperature ,it's necessary for example:

If T_input=15°C,(100°-15°=85 K)

We need 85 kcal *1000 L*1.16Wh=98.6 kWh

For vaporization :

1 L of water → 2256.10^{3}J

Hence,2256.10^3 kJ for evaporation of 1 m^3 water

-> 1Wh=3600 J → 2256 KJ*Wh/3600J= 627 kWh is needed for evaporation of 1 m^3 water.

-> 98.6 kWh + 627 kWh = 725.6 kWh = 0.73 MWh for distillation of 1 m^3 water.

13.2.4 تحذيرات للأمان (Safety)

1. eye protection must be worn
2. foot protection must be worn in this area
3. do not use mobile telephone
4. caution hot surface

14 Metal reactions with acids

14.1.1 Reaktion von Metallen mit Salpetersäure[13]

1.

Versuchsaufbau: Proben von Kupfer, Aluminium und Zink, Zugabe von Salpetersäure.

2.

Nur Kupfer zeigt eine deutliche Reaktion

1.Bild-Versuchsaufbau: Es werden gleichzeitig Proben der Metalle Kupfer und Aluminium mit konzentrierter Salpetersäure und von Zink mit verd. Salpetersäure versetzt. Direkt nach der Zugabe findet im Fall von Zink und Aluminium noch keine Reaktion statt, Kupfer reagiert dagegen sofort, es kommt zur Bildung von braunem NO_2 nach

$Cu + 2\ HNO_3 + 2\ H^+ \longrightarrow Cu^{2+} + 2\ NO_2 + 2\ H_2O$

2.Bild: Keine Reaktion bei Aluminium, kaum sichtbare Reaktion bei Zink, weiterhin heftige Reaktion bei Kupfer.

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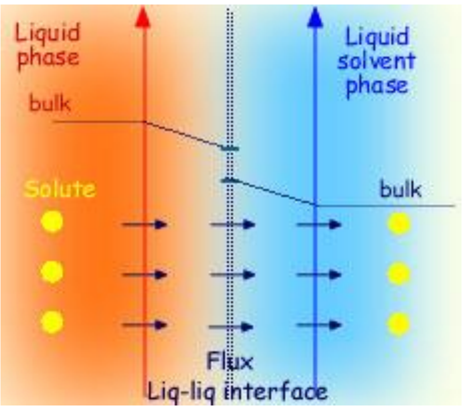
[13] http://www2.uni-siegen.de/~pci/versuche/v44-24-2.html

15 Liquid-Liquid separation

15.1.1 Definitions and aims[14]

The liquid-liquid extraction or simply liquid extraction is a process where one or more solutes are removed from a liquid phase, called diluent, and transferred into a second liquid phase, called solvent, by simple contact of the two liquids.

The two liquids must be either immiscible or partially miscible so that only the solute, which has a greater solubility in the solvent phase than in the diluent, separates from this and moves into the solvent.



Extraction is a common laboratory and industrial unit operation and since it does not involve any evaporation process, can be carried out also at low temperature, thus making this process so convenient also for high temperature-sensitive products.

In the following sections we will focus on the case of partially miscibility between diluent and solvent, hence on extraction with ternary systems.

In the case of total immiscibility, the extraction problem becomes similar to the absorption and stripping type of problem. In this case the McCabe-Thiele graphical method, developed for absorption and stripping, can be easily applied also to design extraction processes.

15.1.2 Process description

The purpose is to recover a certain substance (the solute) at high purity by the use of a high selective solvent.

In the extraction unit, a solute (yellow) is separated from the feed (orange) and moves into the solvent (blue). In the further step, in the solvent recovery unit, the solute is finally separated from the solvent, e.g. by distillation or by other unit operations, and obtained high pure.

Let us exploit, now, the extraction unit (please click on it to see more).

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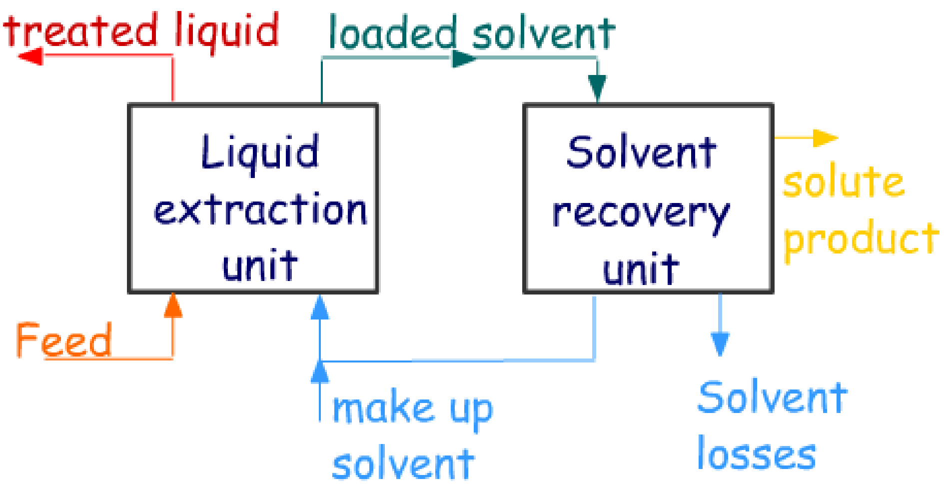
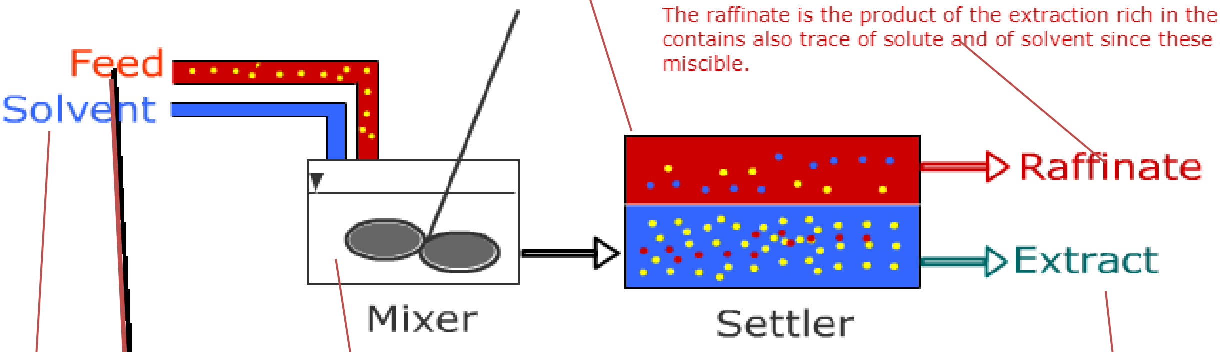
[14] http://www.hyper-tvt.ethz.ch/extraction-definitions.php



15.1.2.1 Liquid extraction unit:

The settler allows for the mechanical separation of the two phases due to their difference in density, which is the driving force for the separation. This is a critical step since the density difference is never so big (both are liquids).

The raffinate is the product of the extraction rich in the diluent phase. It contains also trace of solute and of solvent since these are partially miscible.



A liquid mixture containing the carrier solvent, called diluent, and the solute is fed to the mixer unit

The solvent is generally pure and high selective for the solute (high solubility)

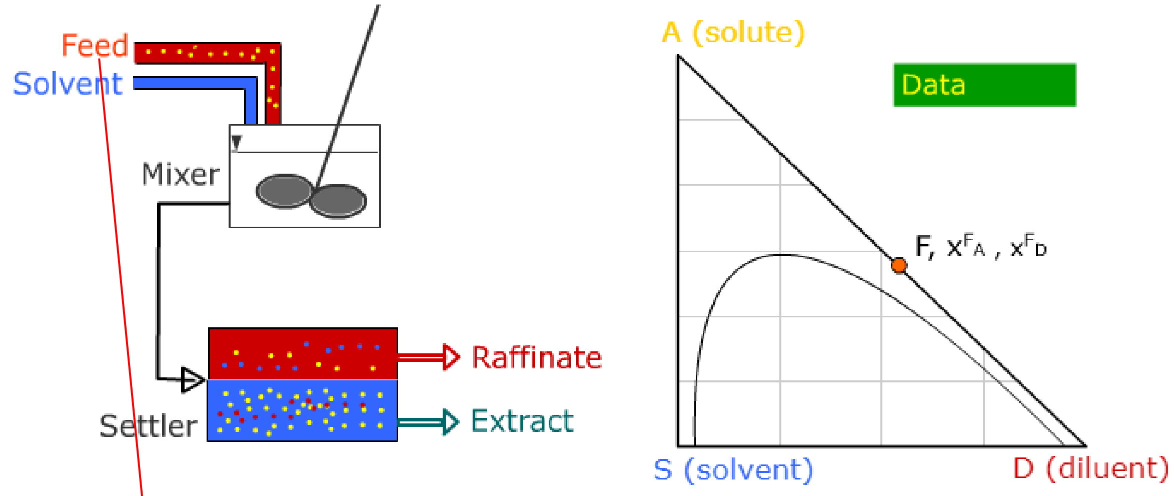
The feed and the solvent phases come in contact and the mass transfer takes place. During this phase (extraction) the solute moves from the feed phase to the solvent. We assume that the ideal equilibrium conditions are reached.

The extract is the product rich in the solvent and solute. This must be further treated (e.g. with distillation) to recover the solute.

15.2 Single stage: problem definition

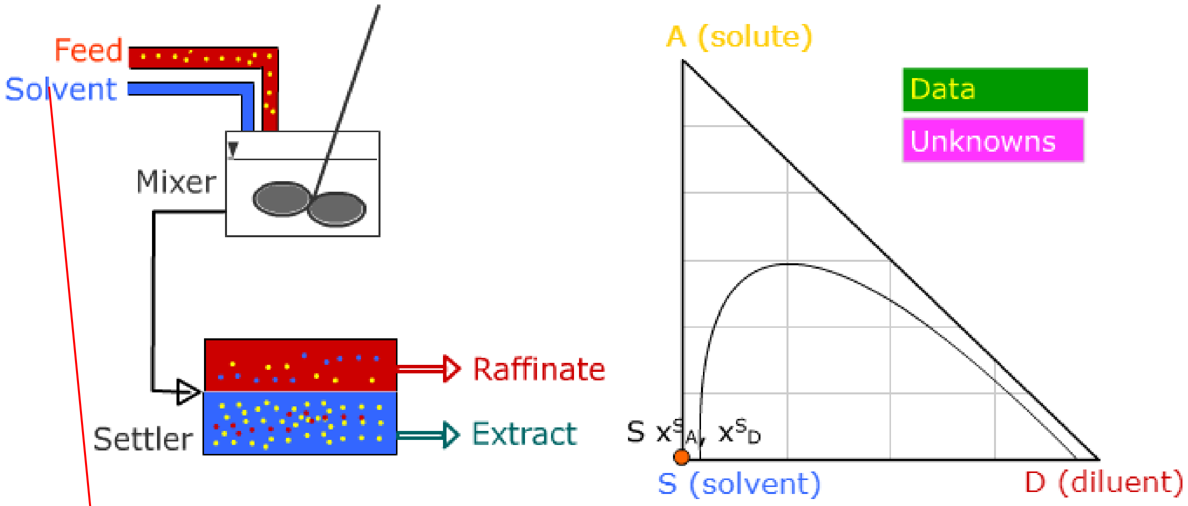
The most simple extraction process can be carried out with a simple mixer and a settler. This is called single equilibrium stage since the feed and the solvent come in contact in only one mixer (=stage). Ideal equilibrium condition is assumed.

15.2.1 Feed



The feed is typically a binary mixture of diluent (D) and solute (A). In an extraction design, its flowrate F and composition are given DATA.

15.2.2 Solvent

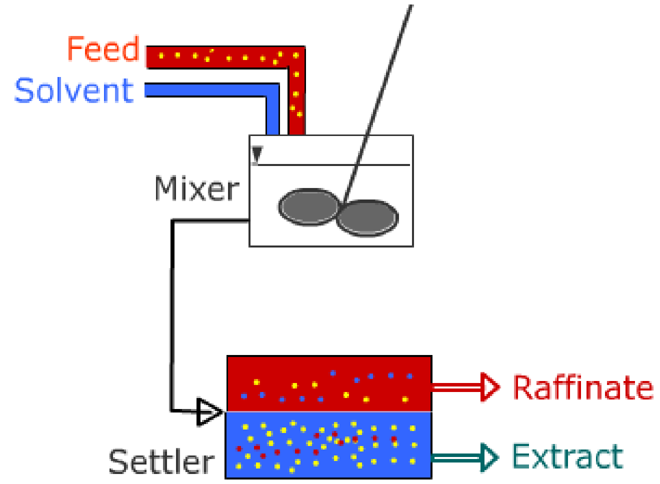


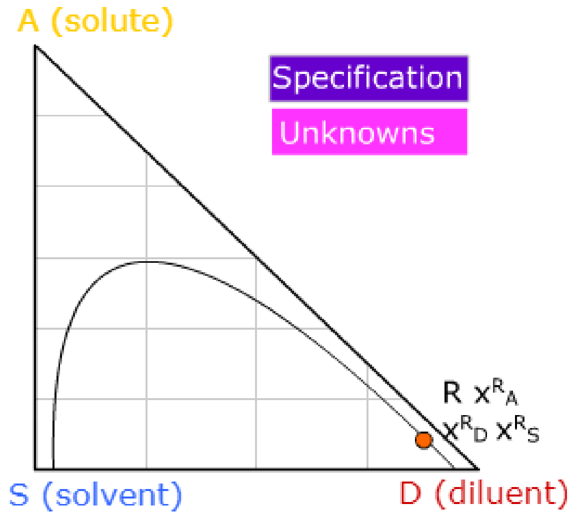
The solvent can contain trace of solute and raffinate or most of the time it is considered as pure. Its composition is therefore always a given DATA. The flowrate S is a given DATA in a verification problem but it is one of the UNKNOWNS in a design problem.

The mixer is the equilibrium stage. The feed and the solvent exchange solute until the equilibrium is reached.

The settler allows for the mechanical separation of the two phases (extract and raffinate), which have reached the equilibrium in the mixer. No further mass transfer or thermodynamics phenomena take place in the settler.

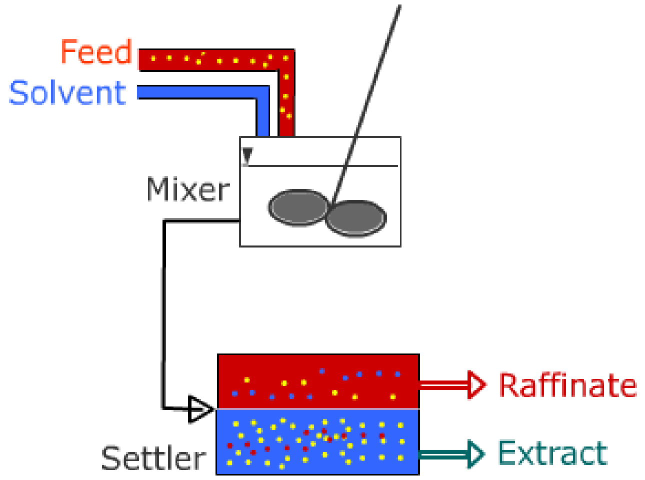
15.2.3 Raffinate:

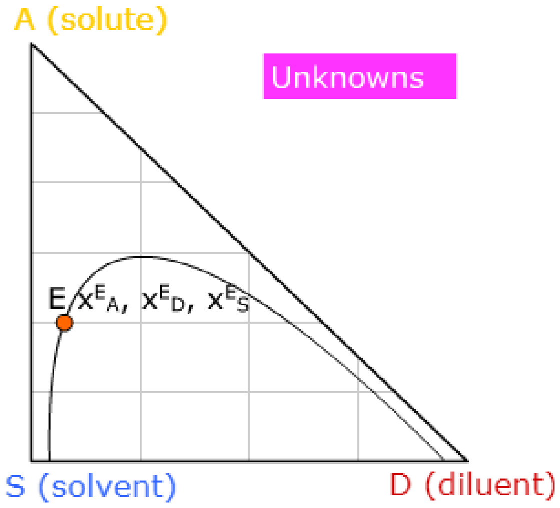




The final content of solute in the raffinate is the given SPECIFICATION of the extraction task. The raffinate comes out from an equilibrium stage therefore its composition is on the solubility envelope. Its flowrate R and its content of solvent and diluent are UNKNOWNS.

15.2.4 Extract





The extract composition and flowrate E are some of the UNKNOWNS of the extraction task. The composition must be a point of the solubility envelope and correlated with the raffinate composition with a tie-line (equilibrium condition).

15.3 Single stage: process design

In the case of a simple mixer (one equilibrium stage), the design consists in sizing the flow rate of the solvent which must be used to obtain the required extract composition and in calculating the obtained extract and raffinate flow rate.

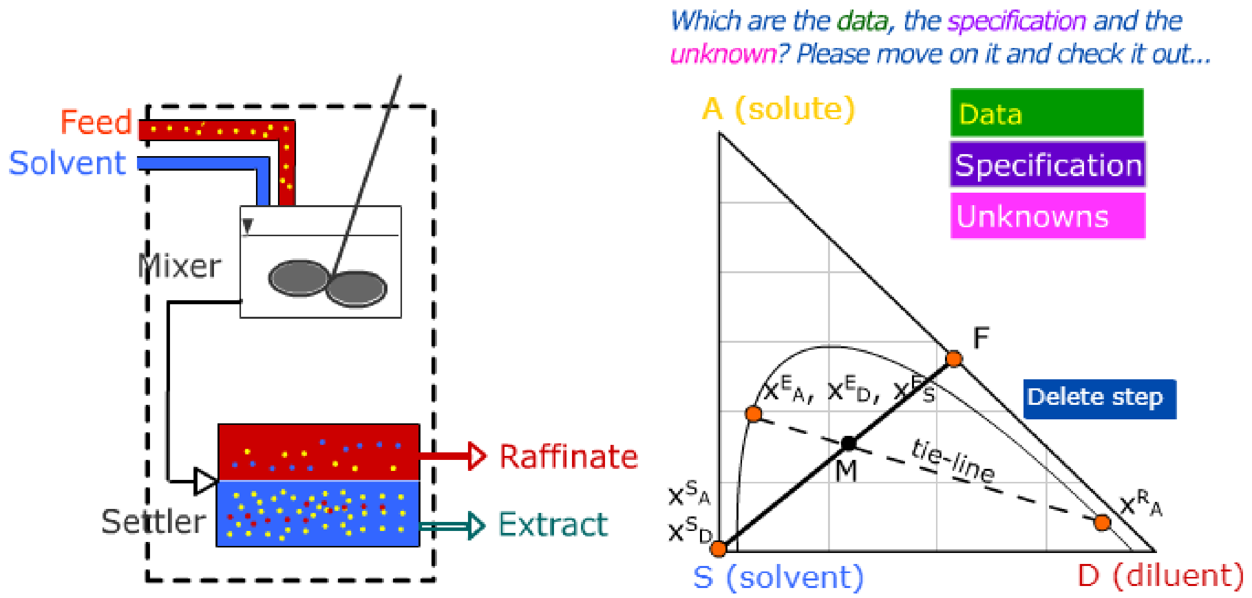
In order to do this, typically a graphical method is used as shown in the following procedure. Please click on the steps here below to run the animation.

Please, note that for the seek of simplicity the **solvent** is considered to be **pure**. However, in reality, most likely the solvent comes from a regeneration step and therefore contains still trace of solute (see extraction unit configuration - paragraph 1.2)

- **Step1.** Tie-line through the raffinate composition --> Extract composition determination
- **Step2.** Overall mass balance and lever-arm rule--> mixing point M identification
- **Step3.** Application of the lever-arm rule to calculate the flow rates S, R, E

15.3.1 Step 1

- **Step1.** Tie-line through the raffinate composition --> Extract composition determination
- **Step2.** Overall mass balance and lever-arm rule--> mixing point M identification
- **Step3.** Application of the lever-arm rule to calculate the flow rates S, R, E

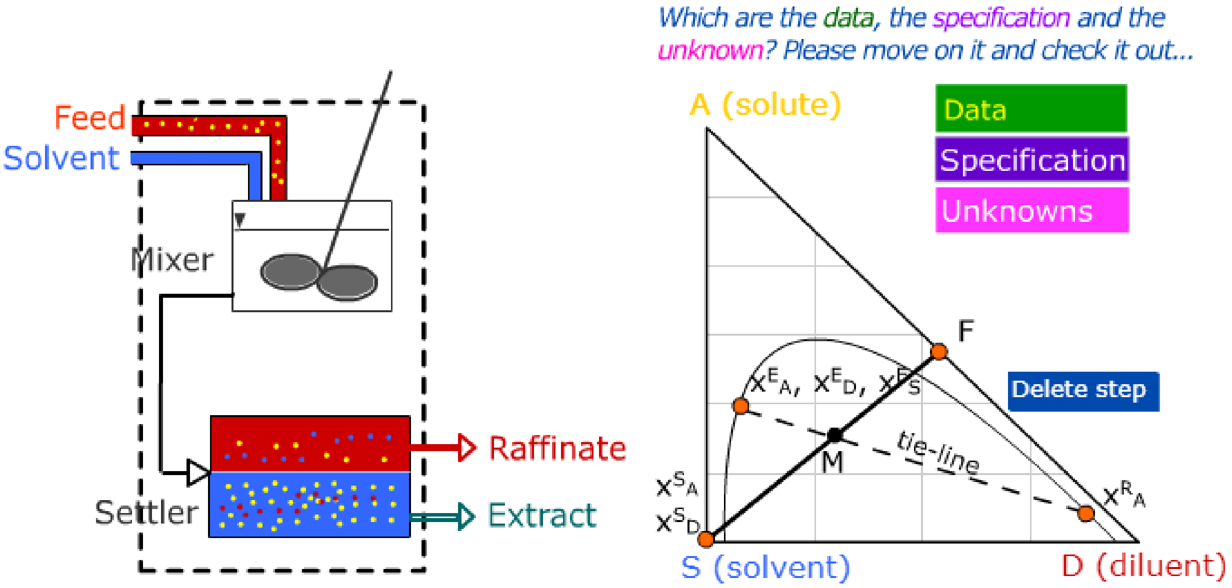


Which are the data, the specification and the unknown? Please move on it and check it out...

The tie-line (equilibrium line) through the given raffinate specification is drawn and the extract composition can be read on the diagram. The raffinate and the extract are at equilibrium since they come from the same equilibrium stage (mixer).

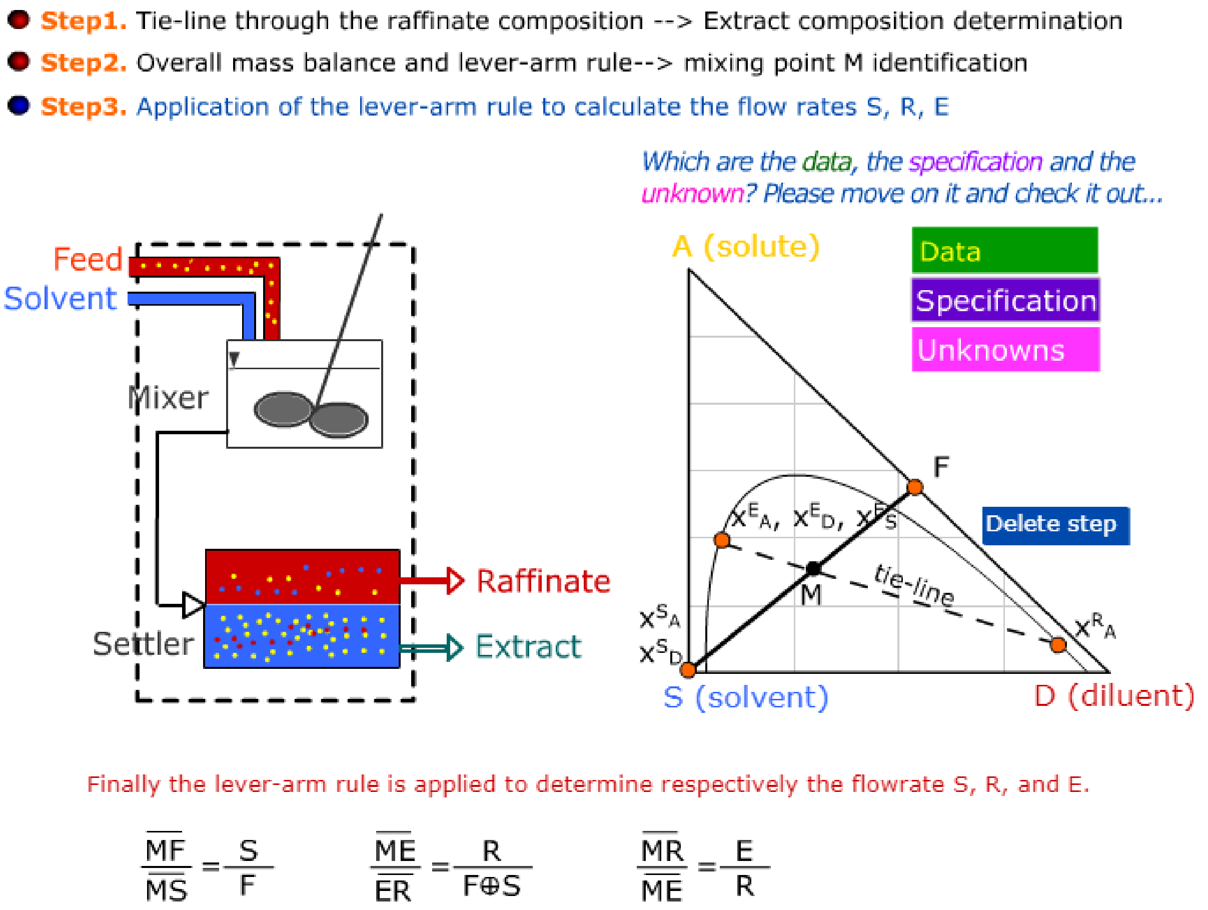
15.3.2 Step 2

- **Step1.** Tie-line through the raffinate composition --> Extract composition determination
- **Step2.** Overall mass balance and lever-arm rule--> mixing point M identification
- **Step3.** Application of the lever-arm rule to calculate the flow rates S, R, E


Which are the data, the specification and the unknown? Please move on it and check it out...

Overall mass balance: F + S = E + R = M. Applying the lever-arm rule, the mixing point M is the crossing point between the line connecting F and S and the line connecting E and R (tie-line drawn in step 1).

15.3.3 Step 3



- **Step1.** Tie-line through the raffinate composition --> Extract composition determination
- **Step2.** Overall mass balance and lever-arm rule--> mixing point M identification
- **Step3.** Application of the lever-arm rule to calculate the flow rates S, R, E

Which are the data, the specification and the unknown? Please move on it and check it out...

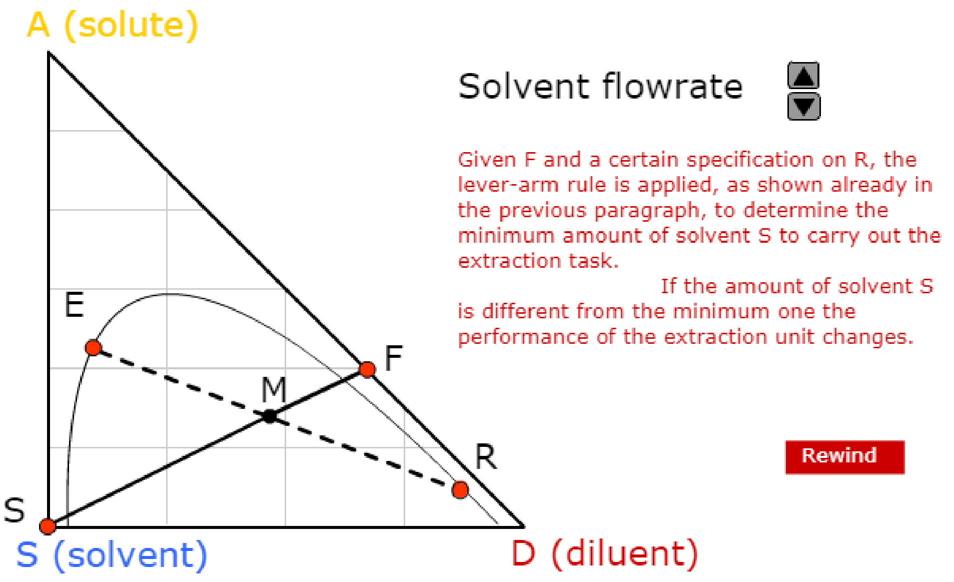
Finally the lever-arm rule is applied to determine respectively the flowrate S, R, and E.

$$\frac{\overline{MF}}{\overline{MS}} = \frac{S}{F} \qquad \frac{\overline{ME}}{\overline{ER}} = \frac{R}{F \oplus S} \qquad \frac{\overline{MR}}{\overline{ME}} = \frac{E}{R}$$

15.4 Single stage: solvent range

In the following animation we would like to use the graphical method to show how the change in the solvent flow rate S impacts on the liquid extraction performance in the case of a **simple mixer** (single equilibrium stage).

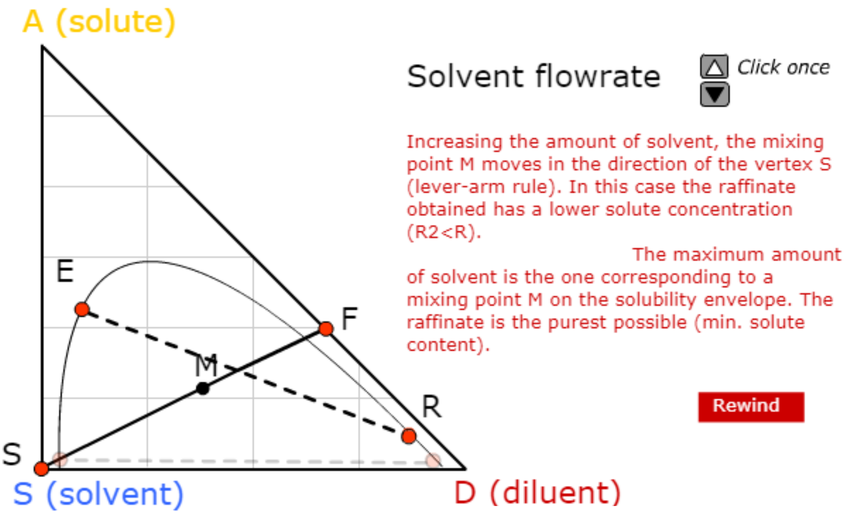
Please **click once** on the "up" arrow or on the "down" arrow to run the animation. The animation is only **qualitative**.



Solvent flowrate

Given F and a certain specification on R, the lever-arm rule is applied, as shown already in the previous paragraph, to determine the minimum amount of solvent S to carry out the extraction task.

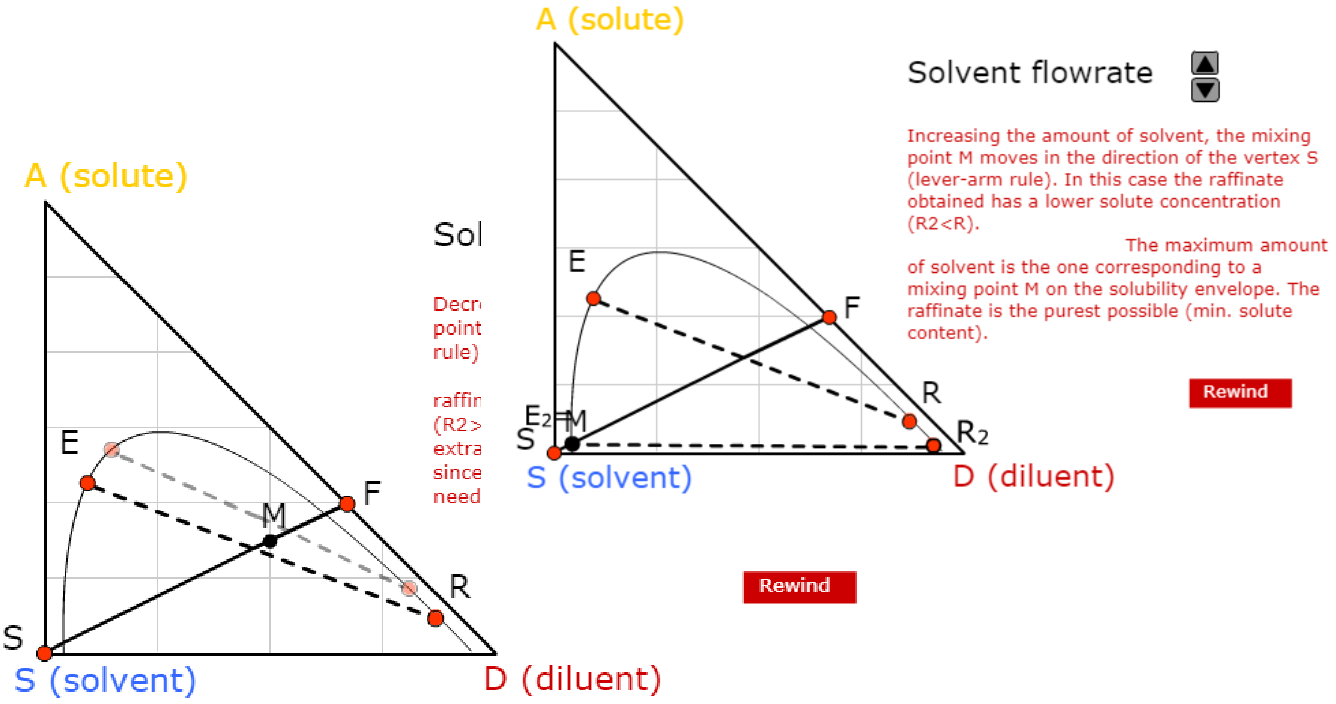
If the amount of solvent S is different from the minimum one the performance of the extraction unit changes.



Solvent flowrate

Increasing the amount of solvent, the mixing point M moves in the direction of the vertex S (lever-arm rule). In this case the raffinate obtained has a lower solute concentration (R2<R).

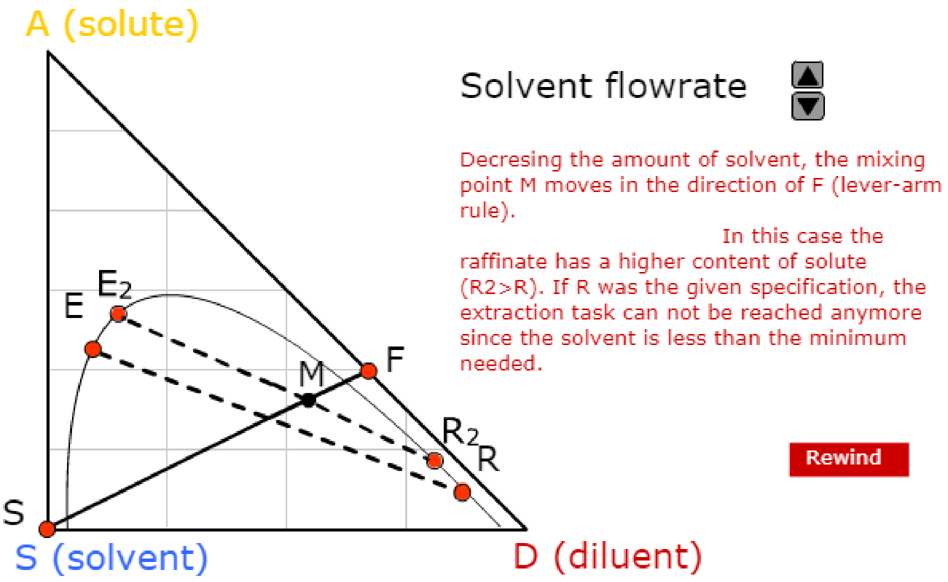
The maximum amount of solvent is the one corresponding to a mixing point M on the solubility envelope. The raffinate is the purest possible (min. solute content).



Solvent flowrate

Increasing the amount of solvent, the mixing point M moves in the direction of the vertex S (lever-arm rule). In this case the raffinate obtained has a lower solute concentration (R2<R).

The maximum amount of solvent is the one corresponding to a mixing point M on the solubility envelope. The raffinate is the purest possible (min. solute content).



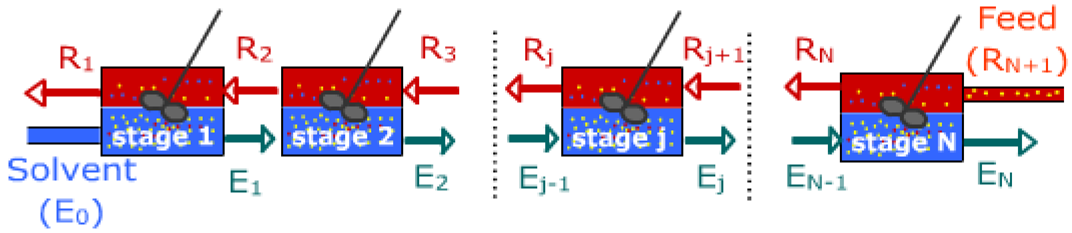
Decresing the amount of solvent, the mixing point M moves in the direction of F (lever-arm rule). In this case the raffinate has a higher content of solute (R2>R). If R was the given specification, the extraction task can not be reached anymore since the solvent is less than the minimum needed.

15.5 Counter-current: column configuration

The best configuration for a cascade of mixers and settlers (= single stage) is the so-called **counter-current configuration**. This layout allow for still better separation for the same number of stages compared to a cross-current configuration.

The cascade of stages is finally arranged in a column, called extraction column. Please, refer to the contactors section to learn more on this topic.

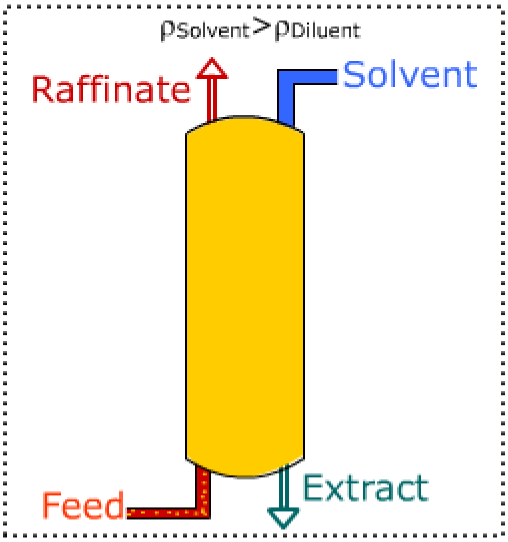
Please move on the schema here below to run the animation.



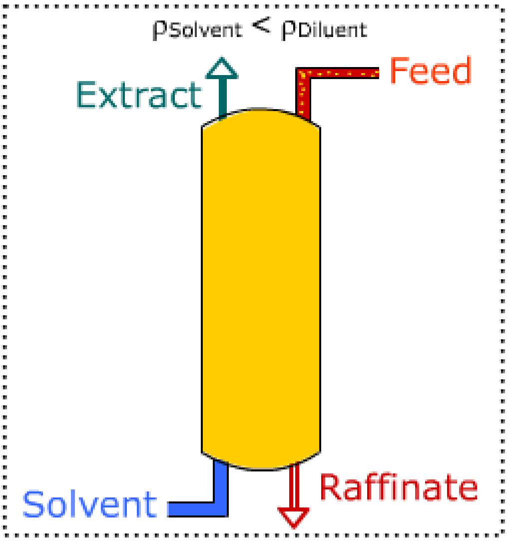
In the counter-current configuration a cascade of N stages (mixer+settler) is arranged like in the figure.

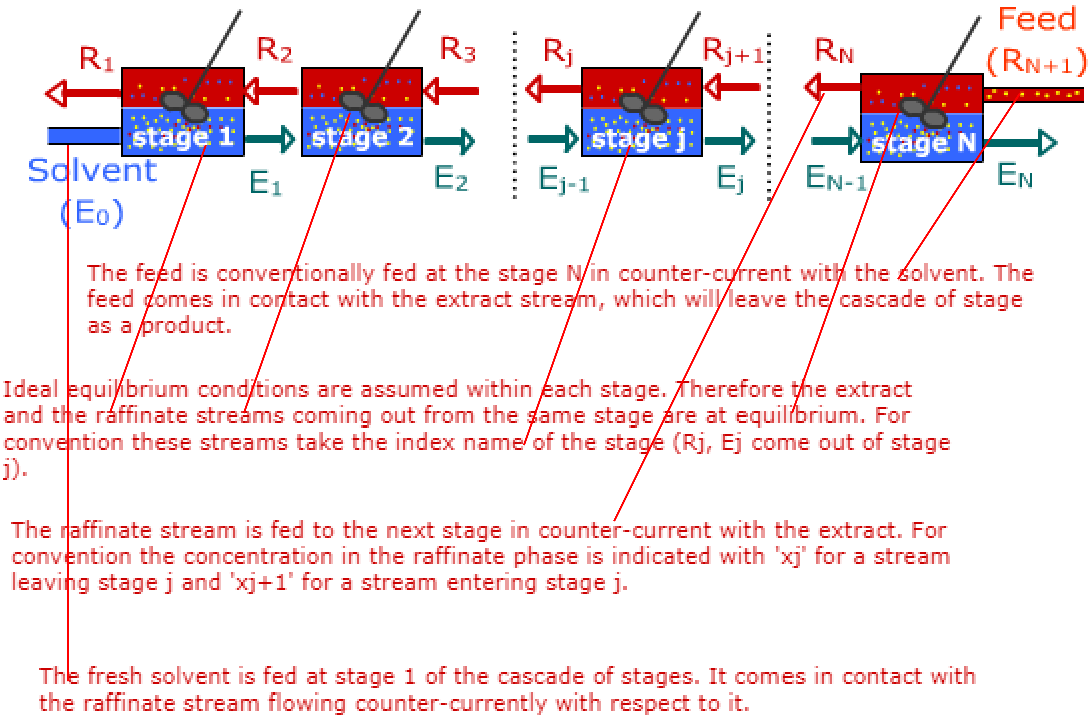
Ideal equilibrium conditions are assumed within each stage.

- **column configuration 1**



- **column configuration 2**





The feed is conventionally fed at the stage N in counter-current with the solvent. The feed comes in contact with the extract stream, which will leave the cascade of stage as a product.

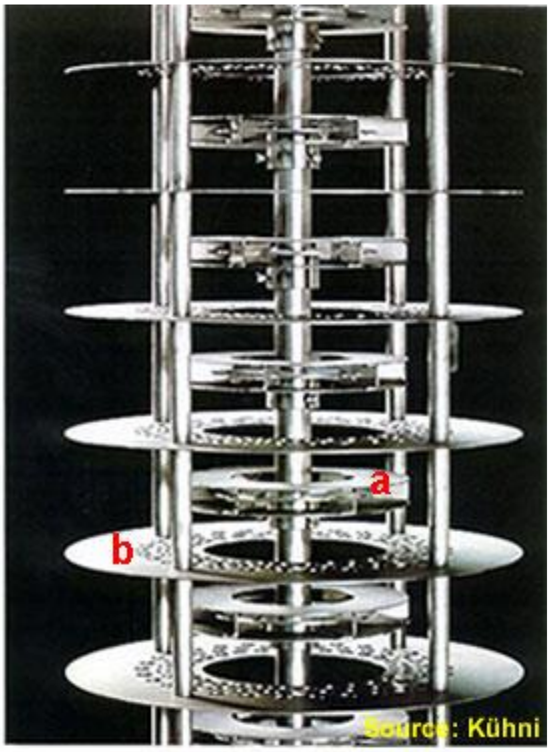
Ideal equilibrium conditions are assumed within each stage. Therefore the extract and the raffinate streams coming out from the same stage are at equilibrium. For convention these streams take the index name of the stage (Rj, Ej come out of stage j).

The raffinate stream is fed to the next stage in counter-current with the extract. For convention the concentration in the raffinate phase is indicated with 'xj' for a stream leaving stage j and 'xj+1' for a stream entering stage j.

The fresh solvent is fed at stage 1 of the cascade of stages. It comes in contact with the raffinate stream flowing counter-currently with respect to it.

15.6 Liquid-liquid extraction columns

The video illustrates the operation of a mechanically agitated, counter-current liquid-liquid extraction column, which employs a rotating agitator driven by an axial shaft.



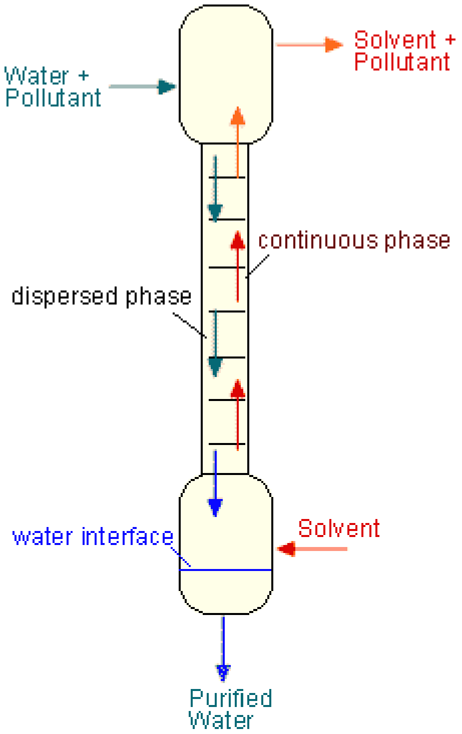
Source: Kühni

There are several types of such columns that are commercially available, e.g. the Scheibel, Oldshue, Rushton, K?hni columns and the rotating-disk contactors.

In all cases, the agitation **enhances mass transfer** by promoting the dispersion of one phase into the other and the **creation of interfacial surface**. The agitators create mixing zones, alternating with settling zones along the column.

The difference among the various commercial columns lies in the **design** of the agitation elements (indicated with **a** in the figure) and the stator disks (indicated with **b** in the figure).

The particular column presented in the video is a pilot K?hni column. The column is installed for separation development and customers tests at the Basel headquaters of the Swiss company K?hni, which has been successful in developing and commercialising this process equipment for a fews decades.



The **aim** of the extraction process is to purify an aqueous stream (**heavy, dispersed phase**) by extracting a polluting solute with a water-immiscible organic solvent (**light, continuous phase**). The pollutant has a larger affinity for the organic than for the aqueous phase, hence it is transferred from the latter to the former phase along the column.

15.7 Practica in Process Engineering: Liquid-Liquid Extraction[15]

Introduction

Extraction is a process in which one or more components are separated selectively from a liquid or solid mixture, the feed (Phase 1), by means of a liquid immiscible solvent (Phase 2). The transfer of the components from the feed to the solvent is controlled by the solubility behavior of each component in the corresponding phase. Two phases result from the extraction step: one enriched (EXTRACT Phase) and the other depleted (RAFFINATE Phase) in the components to be separated, respectively. Afterwards in order to regenerate the solvent, another separation step (e.g. distillation) is finally required. Liquid-liquid extraction is most widely used and will be considered within this laboratory. It is applied e.g. to remove heavy metals or acids from waste water or for the production of aromatic compounds from mixtures of hydrocarbons. Another application is gas-liquid extraction which is also called absorption.

Figure 1 shows the four streams involved in the extraction process with the common nomenclature in the case when component B is separated from the mixture of A and B by means of a solvent C, i.e. AB + C − > A + CB. This nomenclature will be kept during the whole theoretical part of this handout.

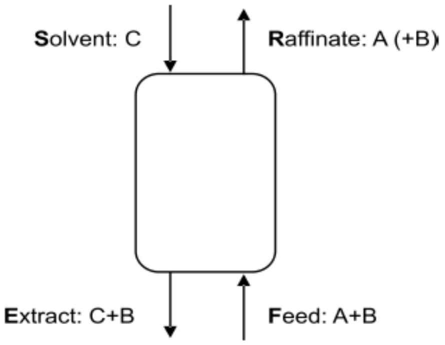


Figure 1: A typical extraction step.

Compared to distillation, extraction processes have the disadvantage that a new component is added to the system. This leads to additional impurities as complete immiscibility does only exist in theory. Furthermore a subsequent separation process is required to regenerate the solvent. However, there are a number of situations in which extraction is advantageous and they are summarized in the following:

- One or more components in the mixture are not thermally stable.
- The components in the mixture have a very high or low boiling point requiring vacuum or cryogenic distillation, which is very energy intensive.
- The boiling points of the components are very close or they form azeotropes.

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[15] https://www.ethz.ch/content/dam/ethz/special-interest/mavt/process-engineering/separation-processes-laboratory-dam/documents/practica%20in%20process%20engineering%202/extraction.pdf

- Two components with very different boiling points have to be separated at the same time.
- The components to be separated (pollutants or valuable products) are only a small fraction of the mixture.

If you have not attended any course about extraction yet, it is highly recommended to have a look at the Hyper-TVT homepage [1], which explains briefly the concept of counter flow extraction columns (Section "Liquid-liquid extraction")!

Theoretical background

The concept of extraction: the one stage extractor

The simplest form of an extractor apparatus has only one stage and the process is performed in two steps. In the first step, the feed is mixed with the solvent to create a high surface area allowing to achieve high mass transfer rates. The mass transfer stops when thermodynamic equilibrium between the two phases is reached. Equilibrium is characterized by an equal temperature, equal pressure and equal chemical potentials in both phases. In the second step the two phases are allowed to separate (settling process). Finally, after decanting one receives the raffinate and the extract. Figure 2 illustrates the concept.

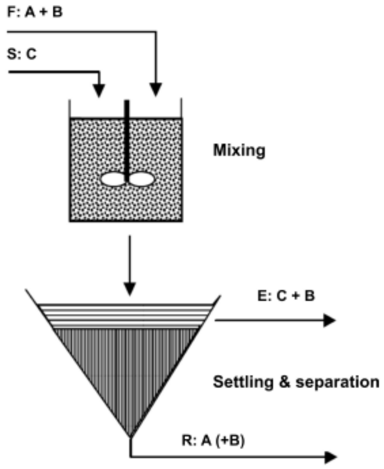

Figure 2: The one-stage extractor.

To allow an optimal extraction process, it is crucial to ensure a good mixing between the solvent and the feed, to have enough contact time between the two phases and to give enough settling time to separate the two phases. Considering this process, a number of requirements for a suitable solvent C can be specified:

- high capacity for component B
- high selectivity for component B
- low solubility in A (and vice versa)

- simple separation between B and C
- considerable difference in the densities compared to A
- low surface tension
- low viscosity
- chemical and thermal stability
- nontoxic
- no or low corrosivity
- low cost

However, in order to obtain the required separation several steps of mixing and phase separation are mostly needed. Therefore, in practical applications multi-stage extractors are usually used. As for many separation processes, a co-, a cross-, or a counter-flow concept can be applied [1]. Some of the important aspects for designing multi-stage extractors are discussed in the following sections.

Multistage exercise and 3-component diagrams

In this exercise, we will discuss how to combine thermodynamic data (represented by a 3-component-diagram) with a mass balance in order to design an extraction process. In our case, we have an aqueous phase (water), an organic phase (toluene) and a component (acetone) which is meant to be extracted. Please note that for educational purpose, the acetone concentration in this exercise is much higher than during your experiments (safety concerns).

3-component-diagrams

Have a look at the diagram (handed out during the experiments):

- Where are the pure components?
- Where is only one phase, where are two phases?
- What is the name of the lines crossing the diagram?
- Where can one find the following compositions (all values as % mol):
  A: $15\% H_2O$, $10\% Toluene$, $75\% Acetone$
  A: $40\% H_2O$, $50\% Toluene$, $10\% Acetone$

1-stage extractor

As production engineer, you are responsible for a pharmaceutical plant, were toluene is used as a solvent. Acetone is added to receive a final mixture of 5% mol acetone. Unfortunately, one of your employees poured too much acetone into tolune because he was distracted by a young accountant passing by, so that you find a mixture of 30% mol acetone and 70% mol toluene (50 kg in total). The unwanted acetone has to be removed. You decide to use water as an extraction agent. Your employee can add the water, mix it well and decant the two phases afterwards. How much water does he have to add?

cross current extractor

After yesterdays accident you are fascinated by extraction and order your employee to prepare the same mixture as yesterday. However, this time you will use a 3-stage cross flow extractor. For every stage you will add approximately one third of the water that you added in the previous one stage process. You are really curious to find out if you can reach an even lower acetone concentration?

- Draw a short scheme of the cross flow process
- Solve the problem graphically (use diagram)

counter current extractor

As your CEO finds your results very interesting too, he orders you to design an extractor for a continuous flow of $100\frac{kg}{h}$ of the 30% mol acetone and 70% mol toluene mixture. The final acetone concentration must not exceed 5% mol. The feed to water ratio shall be 1:4 in moles.

- How many stages will be needed?
- After a graphical solution, check your streams and compositions by using a mass balance!

General questions on extraction

- What is the main problem of extraction?
- In which cases is it a good idea to use extraction?
- Draw two 3-component-diagrams: One for a system were extraction is not possible, one diagram where extraction should work!
- Discuss the effect of the slope of tie lines on extraction!

Hydrodynamics

A high specific surface allows to increase the mass transfer, thus improving the extraction efficiency. The common method is to generate small droplets of one phase that are dispersed in the other, continuous phase, as in the stirred column used in this laboratory. Interactions between droplets and droplets and with the continuous phase result in complex fluid dynamic problems that are usually treated using empiric equations. Main factors to be considered for the operation of a extraction column are:

- **Droplet size:** Droplets usually range into the mm region. Big droplets can not provide a sufficient sized specific surface, whereas smaller ones result in high demand of energy for the dispersion process. Furthermore, the velocity of the droplets decreases with decreasing size; the operating limit of the column is reached when the droplets are too small to move and it is defined as the flooding point.
- **Droplet size distribution:** A uniform droplet size distribution is desired in order to increase efficiency. Furthermore due to the fact that most calculations are done with a mean droplet diameter the results are more accurate for a uniform droplet size distribution. However, the droplet size may change along the length of the column.

- **Holdup**: The total volume of all droplets (or the volume of the disperse phase) divided by the total column volume is called holdup ϵ. If operation conditions are set close to the flooding point of the column, the holdup increases and may not be stabilized any more.

$$\epsilon = \frac{V_{disperse}}{V_{disperse} + V_{continuous}}$$

- **Axial dispersion**: Axial dispersion follows from different phenomena, e.g. turbulence or differences in the droplet sizes, and results in lower column efficiency.

All these factors prevent a direct modeling approach of an extraction process, which is therefore usually designed with the help of empiric models. Two common design techniques will be discussed briefly.

Design concepts for multi stage extractors

As for the most thermal separation processes, two design techniques can be distinguished:

- based on mass transfer.
- based on equilibrium stages.

The design based on mass transfer is mathematically more complex and requires more information about hydrodynamics and property data. The calculation in a simplified case is discussed below. For the design based on equilibrium stages several methods exist, which differ in their assumptions and therefore in the accuracy and modeling complexity. The main methods are:

- McCabe-Thiele diagram (graphical).
- Kremser equation (analytical).
- graphical method in the ternary diagram.
- rigorous process simulation (e.g. Aspen).

Below only the method applying the McCabe-Thiele diagram is discussed. During the laboratory a short introduction to the method using the ternary diagram will be given and can be found in [1]. For the McCabe-Thiele method as well as for the simplified mass transfer calculation it is assumed that the phase flows are constant over the whole column. Therefore mass loadings ($Y : [\frac{\mathrm{kg_B}}{\mathrm{kg_A}}]$, $X : [\frac{\mathrm{kg_B}}{\mathrm{kg_C}}]$) and mass flows of A (called $\dot{F}$) and C (called $\dot{S}$) are used in the following. Assuming very low solubility of A and C, the flows $\dot{F}$ and $\dot{S}$ can be assumed constant.

HTU-NTU concept - a mass transfer concept

If the volume of a column can be regarded as a continuum, average mass transfer exchange rates are used for design purposes. In the easiest case, one assumes that two non-miscible flows are passing each other as plug flows along the column. Phase velocities are regarded as constant over the whole length of the column. Using a differential balancing approach and integration over the whole length of the column yields in:

$$H = \frac{\dot{S}}{K_X a A} \int_{X_{out}}^{X_{in}} \frac{1}{X - X^*} dX = \frac{\dot{F}}{K_Y a A} \int_{Y_{in}}^{Y_{out}} \frac{1}{Y^* - Y} dY$$

where H is the height of the column, A the cross section of a column, a the specific surface, K_X and K_Y the mass exchange coefficients, and X^* and Y^* are phase equilibrium loadings (X^* is the loading of the solvent phase in equilibrium with the actual loading of the feed phase and vice versa).

Referring to the solvent phase, the term $\frac{\dot{S}}{K_X aA}$ is called HTU which stands for height of a transfer unit. The integral is called NTU which stays for number of transfer units. The same is true referring to the other phase, which results in different numbers for the NTU and HTU values.

The NTU integral is usually solved numerically. It describes the thermodynamic separation behavior and is a measure how difficult the separation is. Typically, Y^* is expressed as a function of X. The HTU value depends on the flows and the column parameters (specific mass transfer area etc.) and describes how effective the column works. Knowing both values the required height of a column can be calculated $H = \mathrm{HTU} \cdot \mathrm{NTU}$.

Equilibrium stage concept

Comparable to distillation or absorption, the McCabe-Thiele diagram can be used in extraction to determine graphically the theoretical number of equilibrium stages. This requires the knowledge of the equilibrium line and the operating line. The equilibrium loading Y^* is generally given as a function of X:

$$Y^* = \mathrm{f}(X)$$

By means of a mass balance of component B the operating line can be calculated:

$$Y = Y_{in} + \frac{\dot{S}}{\dot{F}}(X - X_{out})$$

Figure 3 illustrates a typical construction in a McCabe-Thiele diagram. It is worth repeating that loadings ($Y : [\frac{\mathrm{kg_B}}{\mathrm{kg_A}}]$, $X : [\frac{\mathrm{kg_B}}{\mathrm{kg_C}}]$) instead of mole fractions are used and that for the operating line the pure mass flows of A (called $\dot{F}$) and C (called $\dot{S}$) are taken.

Once the number of theoretical equilibrium stages N_{eq} is known, the HETS value (HETS: height equivalent of a theoretical stage) or the efficiency of a real stage η can be used to calculate the column height H or the number of real stages required N, respectively:

$$H = \mathrm{HETS} \cdot N_{\mathrm{eq}}$$

$$N = \frac{N_{eq}}{\eta}$$

Please note that in our case, we are **NOT** using an **equilibrium stage** column as we do not have separated stages. In our case, the column is comparable to a constant counter-current stream with zones of higher and lower mixing intensity.

Experimental part

In the scope of this lab course, the toluene-acetone-water system will be considered, i.e. acetone (B) will be extracted from toluene (A) with the solvent water (C). The equilibrium of this system

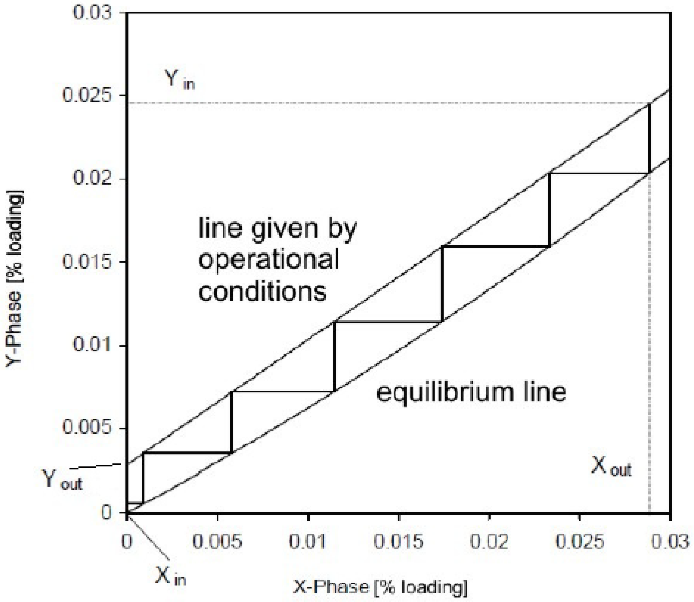

Figure 3: McCabe-Thiele diagram with equilibrium and operating line.

is given by the following equation:

$$Y^* = 0.573X + 5.066X^2 - 17.17X^3$$

The experimental setup and procedure will be described in the following sections.

Laboratory equipment

Figure 4 shows a scheme of the laboratory setup.
A stirred column (1) is used for the extraction (column type Oldshue-Rushton). Two tanks (3) hold the feed (toluene and acetone) that is pumped (5) to the column, fresh water from the tap is used as the solvent. Several valves and pumps (5) allow for setting up different experiments. Flow rates are indicated by rotameters (4). The filling level of the column is being controlled by a siphon (7). Once the toluene has left the column it flows through a (safety) water separator (6) and back to the tanks (3). As toluene has a lower density, the toluene flow direction is from bottom to top. For safety reasons, the continuous phase is always water and the organic phase toluene is dispersed. More details about the operation will be given during the laboratory. During start-up and shut-down of the equipment as well as when you reach the flooding point (stirring speed > 250 rpm) an assistant should be always at the column!

Measurements

During the laboratory, two issues will be investigated. The first part deals only with hydrodynamics whereas in the second one the extraction performance is studied. For both parts the flow rates are kept constant at $30\frac{l}{h}$ and $20\frac{l}{h}$ for toluene and water respectively.

1. The **holdup** will be measured at different stirring speeds. For this the glass valve in the lower half of the column is opened and a 100 ml cylinder is filled with dispersion.

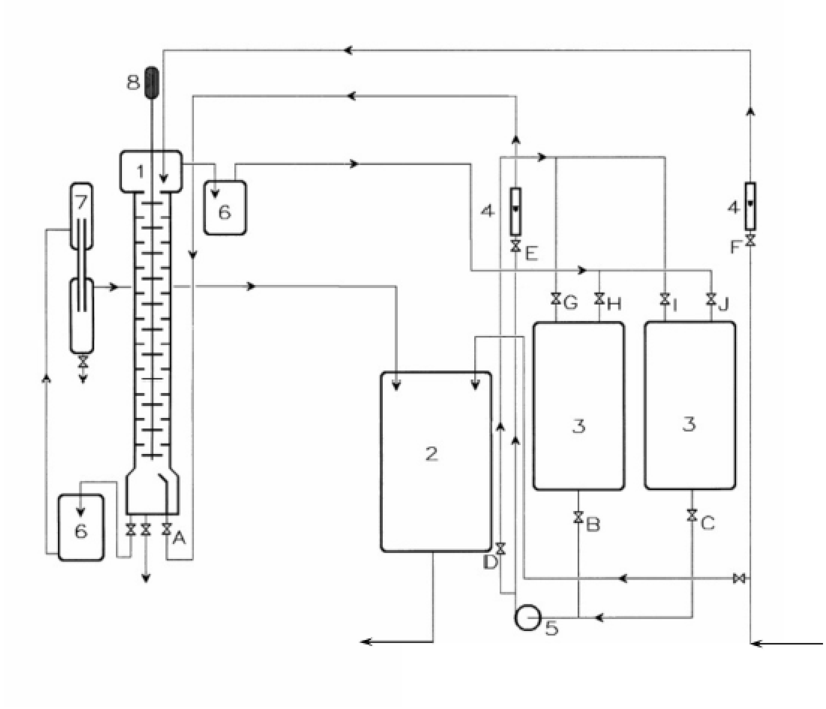

Figure 4: 1: column, 2: tank (aqueous), 3: tank (organic), 4: rotameter, 5: pump, 6: decanter, 7: filling level control, 8: stirrer motor.

After waiting for settling of the two phases, the volume of toluene and the total volume is measured. This measurement is repeated at stirring speeds of 50, 100, 150, 200, and 250 rpm. After changing the stirring speed the conditions in the column have to reach a steady state, therefore it is important to wait for about 15 minutes before taking the next sample. At stirring speeds slightly larger than 250 rpm the column is expected to reach flooding conditions. Therefore, after taking the sample at 250 rpm the stirring speed is increased very slowly until the flooding point is reached (an assistant should be at the column). For this part only water and toluene (without acetone) are used.

2. The **extraction performance** is studied at different stirring speeds. Acetone is added to the toluene to obtain a concentration of approx. 2-3 wt%. The stirring speed is increased stepwise (50, 100, 150, 200, and 250 rpm) and samples from the two outlet streams are taken. Additionally, one sample is taken from the feed in order to obtain its exact composition. The samples can be taken from the pipes using a syringe at the provided places. The samples are collected in vials and will be analyzed by GC during the following week. Please note that due to the high volatility of acetone, samples have to be sealed.

Report

After the successful completion of the laboratory work, a short report has to be prepared. The report should consist of the following sections:

- Introduction and brief explanation of extraction as a separation process (about 1 DIN A4 page).

- Experimental procedures and setup (about 1 DIN A4 page).
- Results and discussion (detailed analysis of the experiments). This section should give a comprehensive answer to the following questions:
    1. Plot the hold-up versus the stirring speed.
    2. Do you expect an increase or a decrease of the hold-up with increasing stirring speed? Based on the theoretical part during the laboratory course, explain why you expect a decrease or an increase.
    3. Is the plot in line with your expectations? If not, specify the measurements that don't match with the expectations. What could be the causes for the deviations?
    4. Do you always expect a better purification of your feed stream by increasing the stirring speed?
    5. Plot the extract and raffinate composition versus the stirring speed. Does the plot confirm your expectations?
    6. For the 5 operating points, determine the number of theoretical stages (NTS) with the McCabe-Thiele method.
    7. Calculate the slopes of the operating lines for the 5 operating points. Which value do you expect? What could be reasons for possible deviations?
    8. Plot the number of theoretical stages versus the stirring speed.
- Perform a theoretical analysis of an extraction process by solving the exercise presented earlier on page 3 and 4.

Data

Densities

- Density of water: $998 \frac{kg}{m^3}$
- Density of toluene: $866 \frac{kg}{m^3}$
- Density of acetone: $790 \frac{kg}{m^3}$

The extraction column

- Length of the stirred section: 1 m
- Column diameter: 73 mm; Stage height: 50 mm
- Free cross section area of the stators: 38 %
- Number of stirrers: 19
- Stirrer diameter: 50 mm; Stirrer height: 10 mm

Practica in Process Engineering II Spring 2014

Rotameters

The two rotameters have been calibrated for water and toluene. Figure 5 can be used to determine the set-value of the rotameters at the desired volume flows.

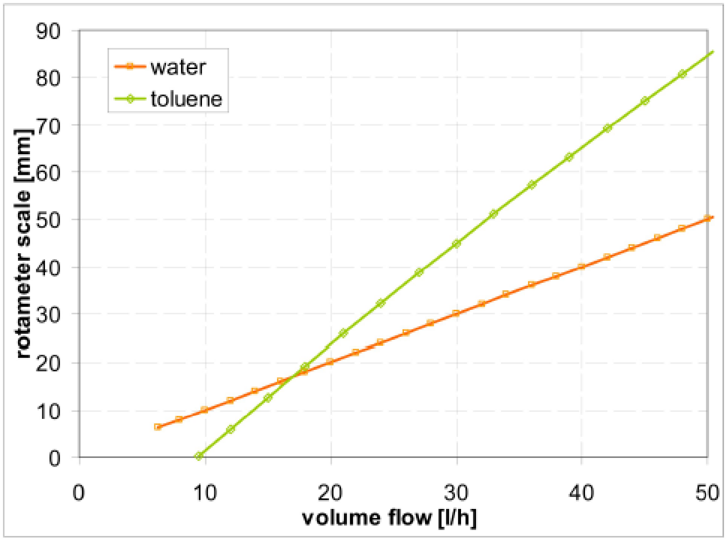

Figure 5: Rotameter calibration data.

References

[1] Mazzotti, M.: *"Hyper-TVT: http://www.hyper-tvt.ethz.ch/extraction-page.php"*, ETH, Zuerich, 2009.

[2] Wankat, P. C.: *"Separation Process Engineering"*, Chapman and Hall, London, 2006.

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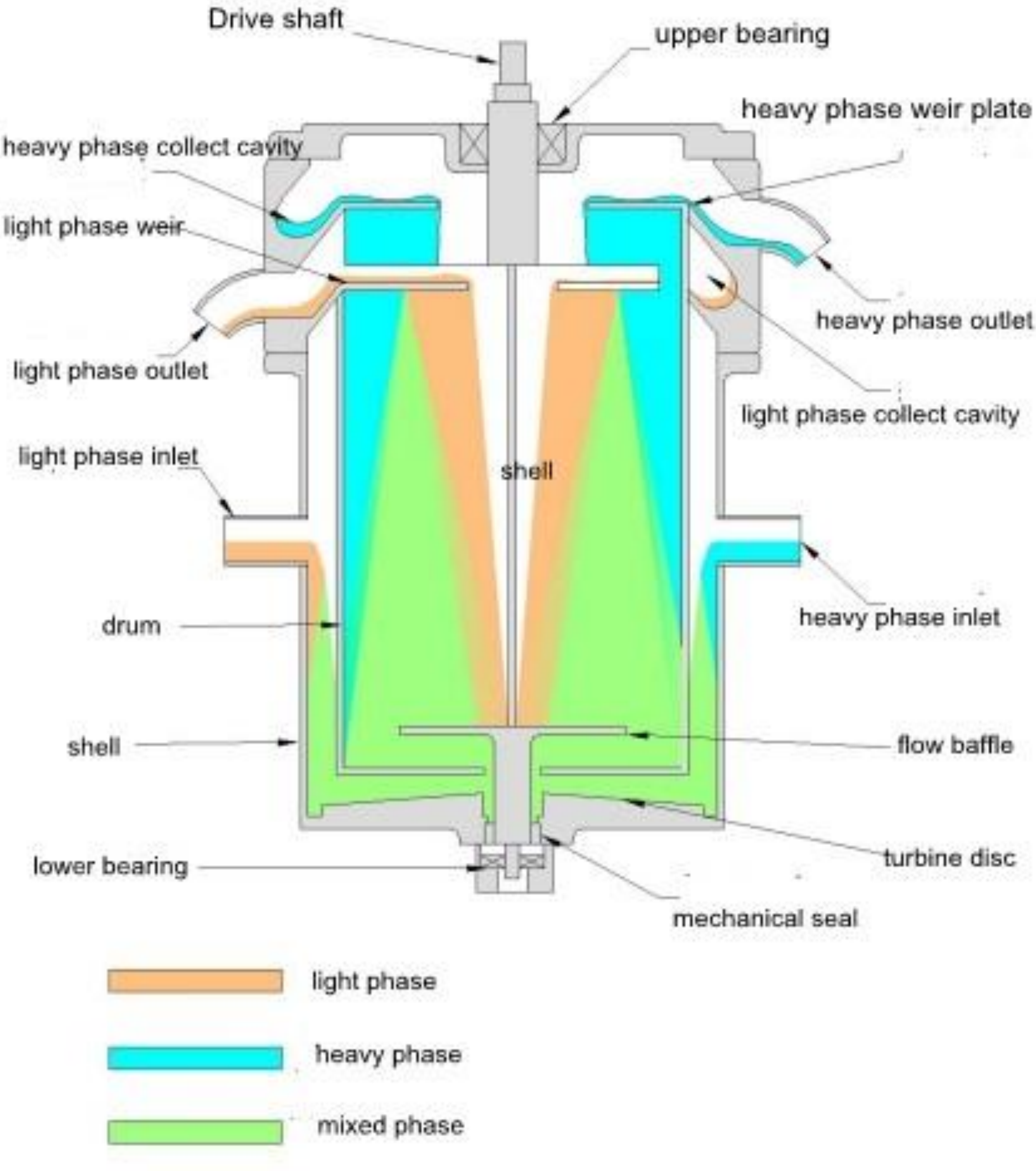
15.8 Metal recycling by Single-Stage LLE

15.8.1 Single stage extraction liquid liquid extraction:

Product category: multistage counter-current extraction device, multistage cross current extraction device, single stage centrifugal extractor.

single stage extraction liquid liquid extraction is a new type, fast and highly efficient liquid-liquid extraction separation equipment, it is different with traditional extraction equipment such as mixer settler, extraction tower. Centrifugal extractor using the motor driven drum to reach high speed, the densities of different and not mutually mixed solution of two liquids in drum or blade rotation shear stress under complete mixing and mass transfer, and in high-speed rotation drum of centrifugal force under the action of rapid separation



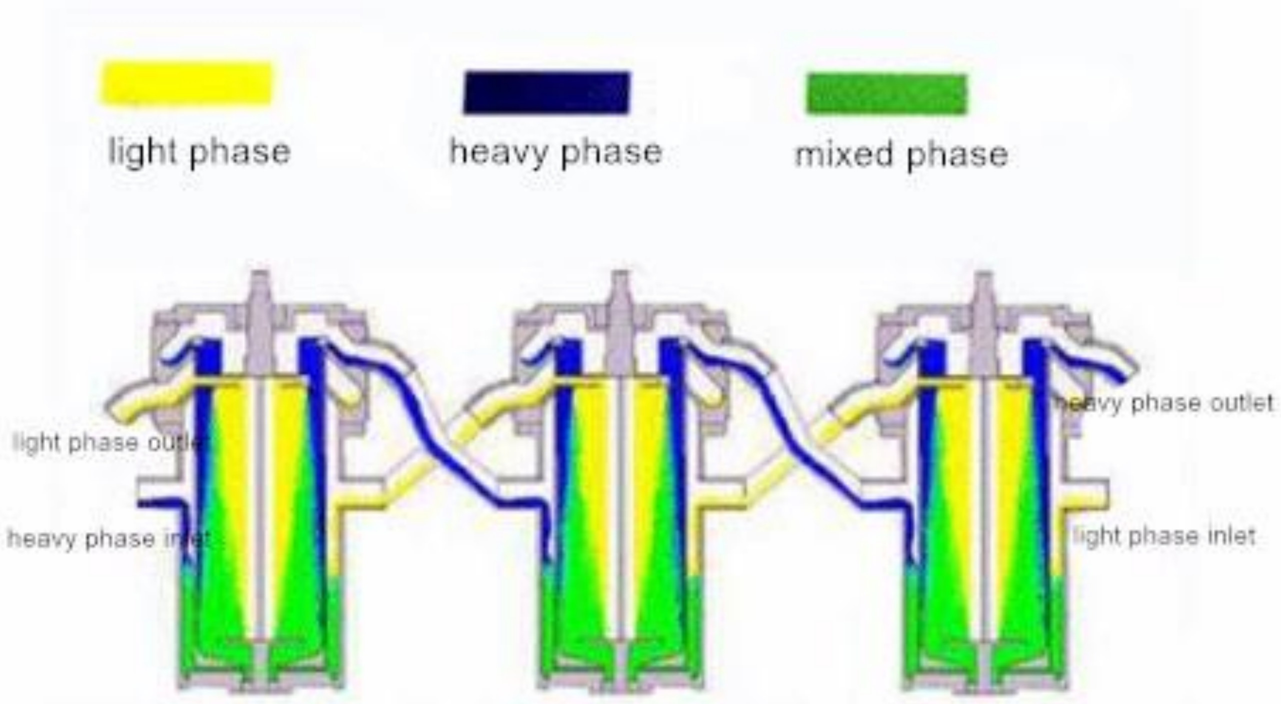
15.8.2 Centrifugal extraction work principle:

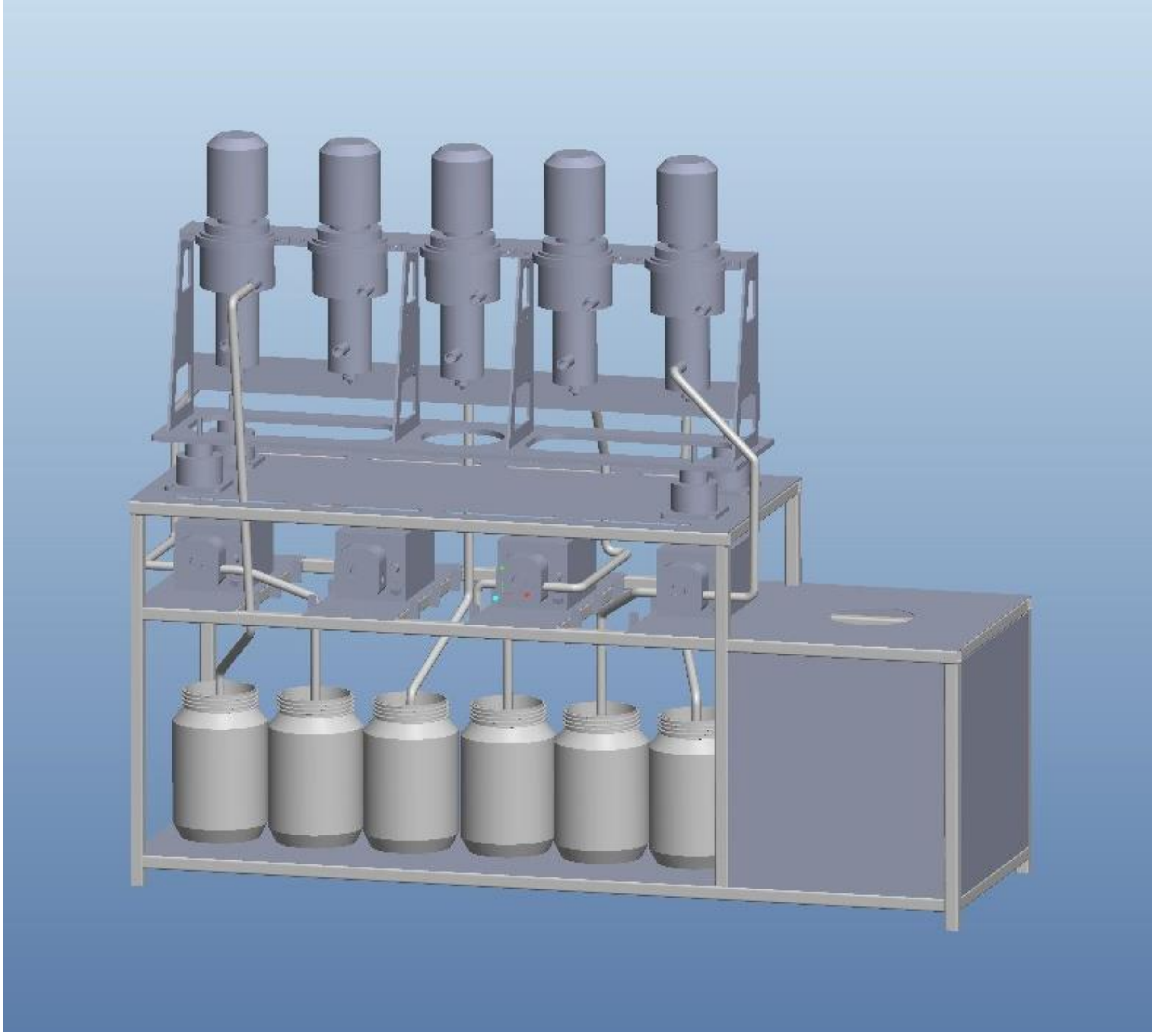
1. Mixed and mass transfer process

The two solution according to a certain proportion mix together, the two-phase dispersing, two-phase solution obtained sufficient mass transfer, mixing and mass transfer process is completed.

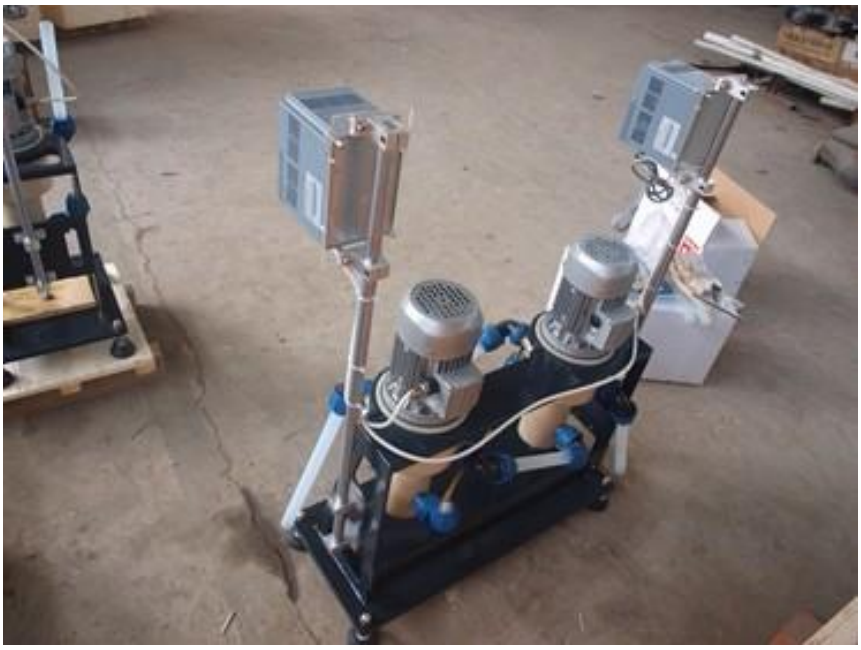
2. Two phases separation process

Mixed fluid in vortex disc or feeder into the drum,stay in certain area, mixture quickly and synchronizing drum rotary, under the action of centrifugal force, serious than liquid to flow in the process of gradually away from the drum center and leaned close to the drum wall; a small proportion of the light phase liquid gradually away from the drum wall and leaned toward the center, clarification of the two-phase liquid were eventually through their respective weir plate into collecting chamber and the draft tube are respectively extracted from the machine and complete phase separation process.





Detailed Images



Product Model

Model	Drum dia (mm)	Flux peak (L/H)	Inlet dia (mm)	Power(kw)	Size(L*W*H)mm	Weight (kg)
CWL50-M	50	50	DN20	0.18	400*400*800	18
CWL150-M	150	1000	DN40	0.75	620*630*1150	120
CWL250-M	250	3000	DN50	1.1	750*750*1400	460
CWL350-M	350	8000	DN65	1.5	950*950*1688	680
CWL450-M	450	15000	DN80	2.2	1000*1000*1800	880
CWL550-M	550	30000	DN100	3.0	1200*1200*1760	1100
CWL650-M	650	60000	DN125	4.0	1350*1350*1960	1800
CWL800-M	800	100000	DN150	5.5	1600*1600*2400	2500

1. Equipment material will be chosen according dto the feed physico-chemical property, common used SS304/316L/904L, common composite material, fluoride material and so on;
2. Above table is general parameter, real device has a little devitation, please refter to the matched technological manual;
3. Above flux is under ideal condition, ratio of oil and water is their flux sum when 1:1.

Product application

15.8.3 Application of single stage extraction liquid liquid extraction :

1. Oil water separation(crude oil/heavy oil/diesel and so on except water, salt);
2. Pharmaceuticals(such as used for ethyl acetate, methylene dichloride, normal butanol, choroforom and so on);
3. Extraction of chinese traditional medicine;
4. Pesticide(malathion extraction and so on);
5. Bioengineering(nutrient solution extraction and interferon extraction and so on);
6. Chemical and fine chemical(catalyst extraction and so on);

7. Hydrometallurgy(used mutilstage extraction and back extraction and so on to extract nickel, copper, uranium and other rare metals);
8. Food(edible oil, spice, refined oil, food color and so on);
9. Perfume industry;
10.Printing and dyeing industry(printing and dyeing wastewater treatment and recycle);
11.Environmental protection(used multistage extraction and back extraction and so on technology to treat wastewater with phenol, oil-water separation of marine sewage, groundwater separation or extraction or purification and so on);
12. Cosmetics industry(to extract nutrient ingredient);
13. Liquid/two gas phase separation(to remove bubble in liquid phase and so on).

Our Company

15.8.4 Zhengzhou Tianyi Extraction Technology Co.,Ltd.

Zhengzhou Tianyi Extraction Technology Co.,Ltd(short for 'TIANYI EXTRACTION') was established in 2005, and mainly specialized in developing, manufacturing liquid-liquid separation and mixing equipment centrifugal extractor and extraction groove. TIANYI EXTRACTION have more than 100 staff, and already obtained more than 20 patents, and have more than 30 sets processing machinery. Now we have one application research center, one pilot-plant experimental base for extraction (expanding test), two modern production and processing center, and already got the certificate of ISO9001 and CE certification. In 2016, we obtain the prize of "High-Tech Enterprise", our product are mainly used in industries such as fine chemical, Hydrometallurgy, Pharmacy and Environmental protection and so on. Tianyi has strong R&D& Manufacturing strength, and excellent quality positioning, and perfect service after-sales system, leading domestic and foreign indsutries. Taken the management idea of integrity, professional, practical, innovation. And according to advanced processing equipment, strict quality control system, high-quality technical team and perfect after-sell services. TIANYI EXTRACTION dedicate to provide a full technical solution. Taken "Mutual benefit and Win-Win" as our aim, TIANYI EXTRACTION will provide you a high quality service.

Certifications

This series extractor is our the 4th product with our independent intellectual property rights, and patent number: ZL2014205865573. Under the same handling capacity, this series of machine energy consumption is 10%～30% of traditional annular type. At the same time, and it has short duration, split phase velocity, high extraction rate, save cost and solvent could be recycled and reused.

Our Service & FAQ

15.8.5 Our service

1. R&D, manufacture and sale on extraction and mixing equipment;
2. contraction on related supporting project, such as planning layout on extraction production line, installation and adjustion on extraction equipment, construction on related construction facilities.
3. Project test in every stage, such as lab-scale test, pilot test etc.

15.8.6 FAQ

Q1. Are CWL-M serious centrifugal extractor fit for our liquid?

A: CWL-M series extractor are widely used in liquid liquid extraction or separation. Liquid liquid extraction, using the the difference of solubility and distribution coefficient of two materials, transfer the solute from one solvent to another solvent. CWL-M series centrifugal extractor mainly used in industries such as oil water separation, pharmacy, pesticide, hydrometallurgy, environmental protection etc. So if your process is liquid liquid extraction and no solid, you can use our centrifugal extractor.

Q2: How do we judge the treatment effect of CWL-M centrifugal extractor?

A: we have research center in our company, to provide client test before sale and extraction process etc, in our research center, we have more than 20 centrifugal extractor for laboratory or pilot test, and after some years test, we have accumulated many experience on hydrometallurgy, chemical, pharmacy industries. We welcome you to visit our research center for laboratory or pilot test.

Q3:What is the difference between CWL-M series centrifugal extractor and others?

Right now, most centrifugal extractor in the market are traditional annular centrifugal extractor, CWL-M centrifugal extractor are our forth generation product(patent ZL2014205865573) and have advantage such as no bottom bearing and seal, no leakage risk, free maintenance; more energy saving, only 1/3~1/10 power consumption of traditional equipment; our equipments' material are perfluorinated polymer materials, corrosion resistance to strong sulfuric acid, hydrochloric acid, mixed acid.Applied to easily emulsifying system, mix thoroughly and high efficiency.

Q4: How do we choose suitable centrifugal extractor?

A: There are five issues that must be take seriously when election:

(1).Dimension and power
(2).Anti-corrosion property
(3).Anti-explosion property
(4).Equipment structure
(5).Environmental protection
(6) Price.

The main distinguish is property and configuration. Some extractor with heater or more control program. Sometimes spare parts cost is higher than main engine. When choose, except main engine, you should pay more attention on the rotor(quantity and species), the necessary material, bowl, wire structure and so on. All of these included are the complete price of full centrifugal extractor.

Q5: Are CWL-M series centrifugal extractor anti-explosion and automatic controlled?

We can equip related anti-explosion and automatic control function as per client necessary.

......

If you were not satisfied, please feel free to return, and the back goods freigth we shall bear!

15.9 Commercial LLE extraction column (Made in China)

Overview

Quick Details

Condition: New

Type: Extraction Equipment

Product Type: liquid liquid extraction column

Place of Origin: Henan, China (Mainland)

Brand Name: TIANYI

Model Number: RDC-1000

Voltage: Customized

Power(W): standard

Weight: standard

Dimension(L*W*H): dia80*1000mm

Certification: ISO9001/CE

Warranty: 12 Months

After-sales Service Provided: Engineers available to service machinery overseas

Function: immiscible liquid liquid extraction

Capacity: 1-60000L/h

Application: Chemical&pharmacy&hudrometallurgy&envrionmental protection etc

Operation: Continuous

Material: SS/Fluorine/Compoiste

Machine name: liquid liquid extraction column

Company type: R&D&Manufacturing

Corlor: Cutomized

Advantage: high stage efficiency

Continuous: continuous production

Packaging & Delivery

Packaging Details as per customer requirement

Delivery Time 30-60days

Product Description

Liquid-liquid extraction is a technically advanced, niche separation technology. It is applied when simpler alternatives such as distillation are not able to meet your requirements. Components are extracted from your feed with the help of a solvent, without an energy demanding evaporation step.

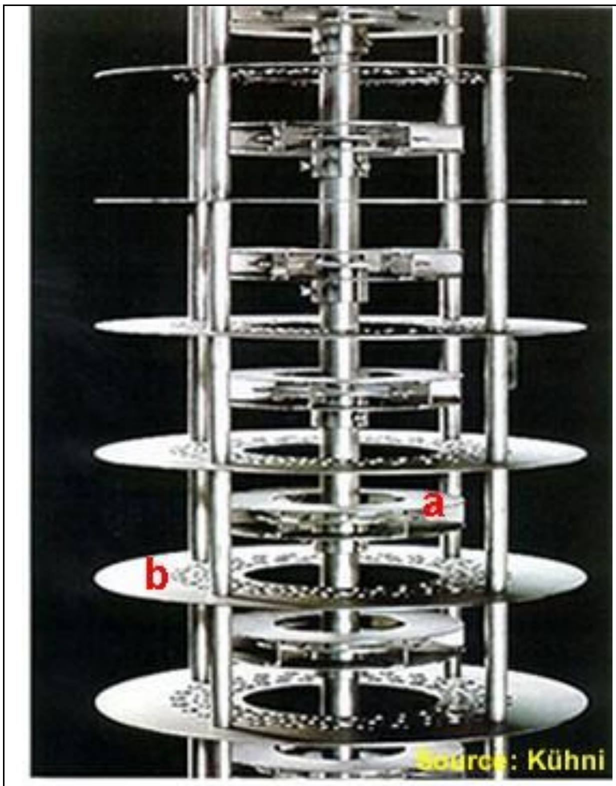
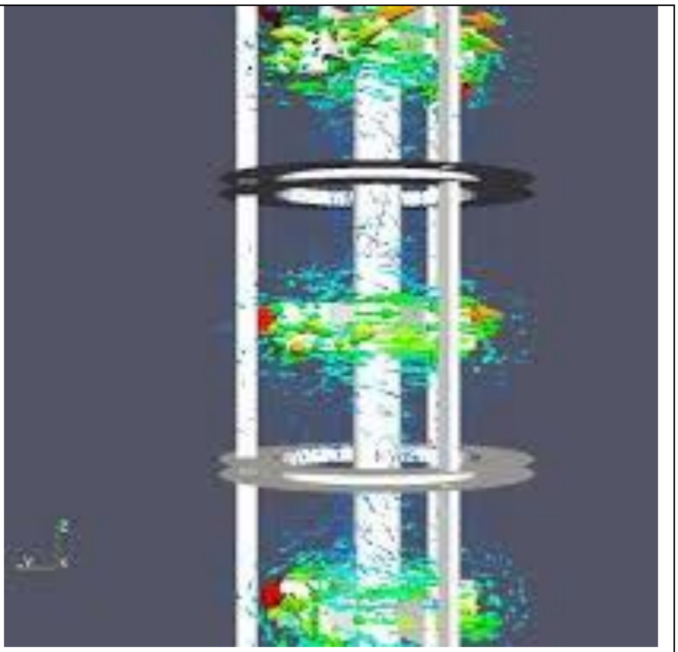
15.9.1 Liquid liquid extraction column introduction:

Extraction column is a kind of column extraction equipment of mechanical stirring, it is composed by upper settling chamber, emulsion chamber and bottom settling chamber. the emulsion chamber is cylinder type, and is divided into several extraction chambers by static ring baffle, there is a fixed turnplate between two static ring baffles, and rotating with shaft together. When work, heavy phase(aqueous)and light phase(organic phase) enter the equipment from column top and bottom respectively, and contact countercurrently in column. Under fixed turnplate stirring, the dispersed phase formed small droplets, to enlarge mass transfer area and finished extraction process,and then Heavy phase and light phase discharge from the different exit.

15.9.2 Liquid liquid extraction column characteristics:

1. Cover a small area, low maintenaince cost;
2. Large capacity, suitable for continuous production;
3. High stage efficiency, small solvent sluggish flow

Detailed Images

 Source: Kühni	

Product Model

Model	Column Model(mm)	Valid Height(mm)
RDC-50	Dia 80	1000
RDC-80	Dia 80	1000
RDC-100	Dia 100	1000/1500
RDC-150	Dia 150	1500/2000
RDC-200	Dia 200	Customized
RDC-300	Dia 300	Customized
RDC-500	Dia 500	Customized
RDC-1000	Dia 1000	Customized

1. The common material is transparent organic glass, PP, Hard PVC, glass, stainless steel etc;

2. Above technology parameters are experiment parameter, the special application will be designed accoprding to customer's requirement.

Product application

15.9.3 Liquid liquid extraction column application area:

1. Separation of systems with similar boiling points（e.g., separation of aromatics from aliphatic hydrocarbons)

2. Separation of high boiler and low-con-centration solutes from aqueous solutions(e.g., phenol)

3. Separation of mixtures with high boiling points (e.g., vitamins)

4. Separation of temperature-sensitive compounds (e.g., acrylates, biotechnology)

5. Separation of azeotropic mixtures(extraction of acetic or formic acid from aqueous media using,e.g., MTBE as solvent)

---

6. Extraction of organic compounds from salt solutions (e.g., caprolactam)

7. Extraction of salts from polymer solutions (e.g., ketone resins, polyols)

8. Extraction of metal salts from low-grade ores(e.g., copper)

Liquid-liquid extraction is expected that importance of solvent extraction will increasae as the feedback of chemical processes changes from crude oil to biomass. The components obtained in the first processing steps from biomass have more functional groups and are less volatile than the key components obtained from crude oil.Thus, it maybe economically more attractive to use extraction with suitable solvents (including extractants like ionic liquids) than to use distillation at low pressure.

Our Company

15.9.4 Zhengzhou Tianyi Extraction Technology Co.,Ltd.

Zhengzhou Tianyi Extraction Technology Co.,Ltd(short for ‘TIANYI EXTRACTION’) was established in 2005, and mainly specialized in developing, manufacturing liquid-liquid separation and mixing equipment centrifugal extractor and extraction groove. TIANYI EXTRACTION have more than 100 staff, and already obtained more than 20 patents, and have more than 30 sets processing machinery. Now we have one application research center, one pilot-plant experimental base for extraction (expanding test), two modern production and processing center, and already got the certificate of ISO9001 and CE certification. In 2016, we obtain the prize of “High-Tech Enterprise”, our product are mainly used in industries such as fine chemical, Hydrometallurgy, Pharmacy and Environmental protection and so on. Tianyi has strong R&D& Manufacturing strength, and excellent quality positioning, and perfect service after-sales system, leading domestic and foreign indsutries. Taken the management idea of integrity, professional, practical, innovation. And according to advanced processing equipment, strict quality control system, high-quality technical team and perfect after-sell services. TIANYI EXTRACTION dedicate to provide a full technical solution. Taken “Mutual benefit and Win-Win” as our aim, TIANYI EXTRACTION will provide you a high quality service.

Our Service & FAQ

15.9.5 Our service

1. R&D, manufacture and sale on extraction and mixing equipment;
2. contraction on related supporting project, such as planning layout on extraction production line, installation and adjustion on extraction equipment, construction on related construction facilities.
3. Project test in every stage, such as lab-scale test, pilot test etc.

15.9.6 FAQ: How to select solvent extraction agent of Liquid liquid extraction column?

The solvent is the key to a successful separation by liquid-liquid extraction. The several criteria are:

1. Distribution Coefficient This is the ratio (at equilibrium) of the concentration of solute in the extract and raffinate phases. It gives a measure of the affinity of the solute for the two phases. A

distribution coefficient other than unity implies that the solute must have different affinity in the two phases. If only one solute is involved (such as in the recovery of an impurity from an effluent stream), only the distribution coefficient need be considered, and it is desirable for this to be as large as possible.

2. Selectivity (Separation Factor) If there are more than one solutes (say two solutes A and B), then consideration should be given to the selectivity of the solvent for solute A as against B. The selectivity between the 2 solutes A and B is defined as the ratio of the distribution coefficient of A to the distribution coefficient of B. For all useful extraction operation the selectivity must exceed unity. If the selectivity is unity, no separation is possible.

3. Insolubility of Solvent The solvent should have low solubility in the feed solution, otherwise the separation is not "clean". For example, if there is significant solubility of solvent in the raffinate stream, an additional separation step is required to recover the solvent.

4. Recoverability It is always necessary to recover the solvent for re-use, and this must ordinarily be done by other means, eg. distillation. If distillation is to be used, the solvent should form no azeotrope with the extracted solute and mixtures should show high relative volatility. The solvent should also be thermally-stable under the distillation temperature.

5. Density A large difference in density between extract and raffinate phases permits high capacities in equipment. This is especially important for extraction devices utilizing gravity for phase separation.

6. Interfacial Tension The larger the interfacial tension, the more readily coalescence of emulsions will occur but the more difficult the dispersion of one liquid in the other will be. The more readily coalesces the emulsions the easier phase separation will be. Low interfacial tension aids dispersion and thus improves contacting mass-transfer efficiency. Coalescence is usually of greater importance, and interfacial tension should therefore be high.

7. Chemical Reactivity The solvent should be stable chemically and inert toward the other components of the system and toward the common materials of construction.

8. Viscosity, Vapour Pressure, Freezing Point These should be low for ease in handling and storage, for example, a high viscosity leads to difficulties with pumping, dispersion and mass transfer rate.

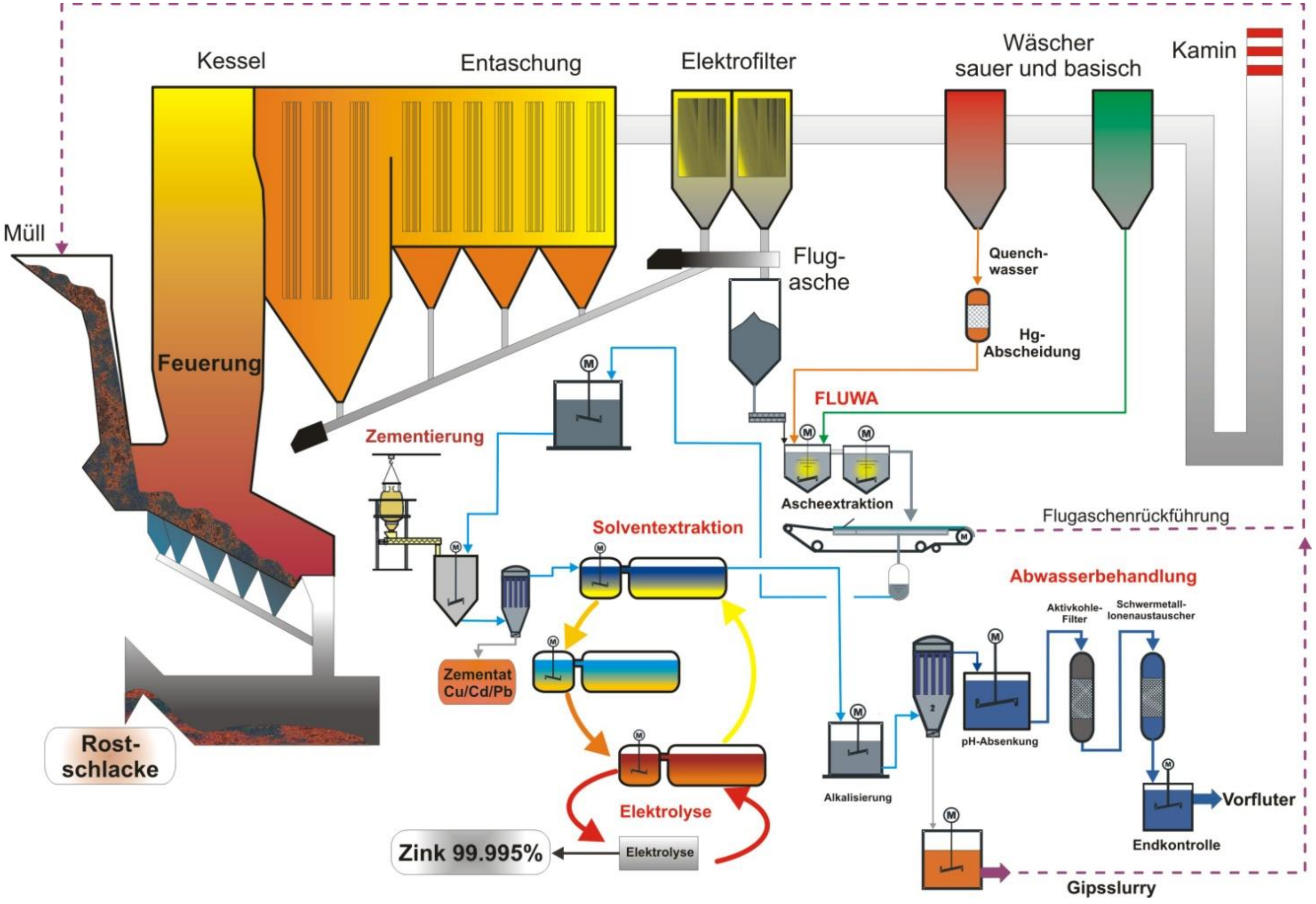
9. Availability and Cost An excellent solvent may not be commercially available. Or it may represent a large initial cost for charging the system, and a heavy continuing expense for replacing inevitable operating losses.

10. Other Criteria Toxicity and flammability of the solvent are important occupational health and safety considerations. Stability of the solvent (i.e. resistance to breakdown), particularly in the recovery steps, is significant, especially if the breakdown products might contaminate the products of the main separation. Corrosivity of the solvent leads to the usual problems with materials of construction. Finally, compatibility of the solvent with the mixture to be separated can have many manifestations, particularly when easily contaminated materials such as food or pharmaceuticals are being handled. Note: The solvent may not always be a single chemical species. For example,

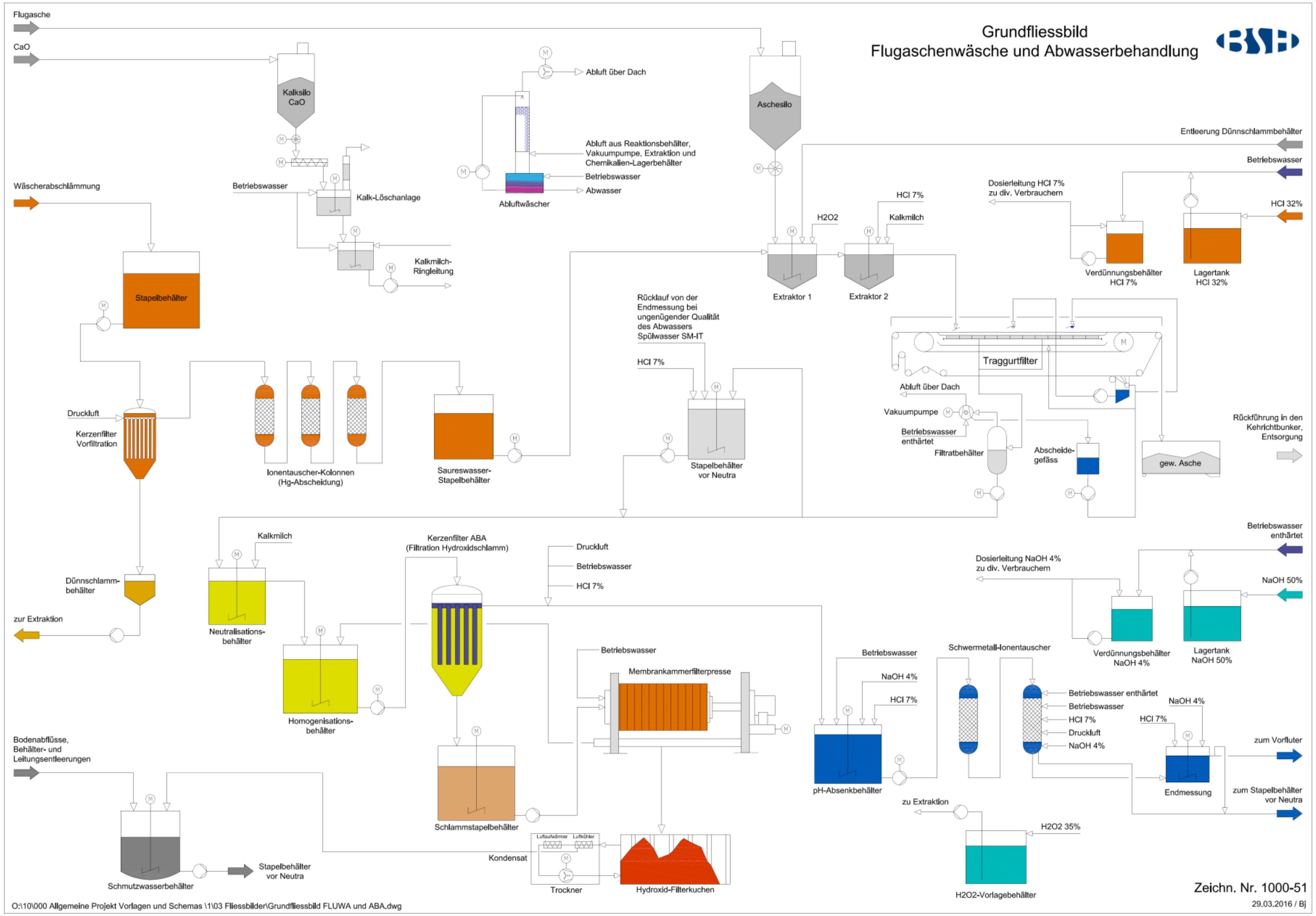
the most appropriate liquid may not have suitable physical properties for direct use as solvent. In such cases it can be used dissolved in another suitable liquid. The active component of the mixture is then known as the extractant and the liquid in which it is dissolved as the diluent. The solvent comprises the two together.

16 Heavy Metals Recovery

16.1.1 pure Zinc recycling with FLUREC



16.1.1.1 FLUWA


Grundfliessbild
Flugaschenwäsche und Abwasserbehandlung
Flugasche
CaO
Kalksilo CaO
Abluft über Dach
Abluft aus Reaktionsbehälter, Vakuumpumpe, Extraktion und Chemikalien-Lagerbehälter
Betriebswasser
Abwasser
Abluftwäscher
Aschesilo
Wäscherabschlämmung
Betriebswasser
Kalk-Löschanlage
Kalkmilch-Ringleitung
Stapelbehälter
Entleerung Dünnschlammbehälter
Betriebswasser
Dosierleitung HCl 7% zu div. Verbrauchern
HCl 32%
HCl 7%
H2O2
Kalkmilch
Extraktor 1
Extraktor 2
Verdünnungsbehälter HCl 7%
Lagertank HCl 32%
Rücklauf von der Endmessung bei ungenügender Qualität des Abwassers Spülwasser SM-IT
HCl 7%
Traggurtfilter
Abluft über Dach
Vakuumpumpe
Betriebswasser enthärtet
Filtratbehälter
Abscheide-gefäss
gew. Asche
Rückführung in den Kehrichtbunker, Entsorgung
Druckluft
Kerzenfilter Vorfiltration
Ionentauscher-Kolonnen (Hg-Abscheidung)
Saureswasser-Stapelbehälter
Stapelbehälter vor Neutra
Dünnschlamm-behälter
zur Extraktion
Kalkmilch
Neutralisations-behälter
Kerzenfilter ABA (Filtration Hydroxidschlamm)
Druckluft
Betriebswasser
HCl 7%
Homogenisations-behälter
Betriebswasser
Membrankammerfilterpresse
Betriebswasser enthärtet
Dosierleitung NaOH 4% zu div. Verbrauchern
NaOH 50%
Verdünnungsbehälter NaOH 4%
Lagertank NaOH 50%
Betriebswasser
NaOH 4%
HCl 7%
Schwermetall-Ionentauscher
Betriebswasser enthärtet
Betriebswasser
HCl 7%
Druckluft
NaOH 4%
NaOH 4%
HCl 7%
zum Vorfluter
pH-Absenkbehälter
Endmessung
zum Stapelbehälter vor Neutra
zu Extraktion
H2O2 35%
H2O2-Vorlagebehälter
Bodenabflüsse, Behälter- und Leitungsentleerungen
Schlammstapelbehälter
Schmutzwasserbehälter
Stapelbehälter vor Neutra
Kondensat
Luftaufwärmer
Luftkühler
Trockner
Hydroxid-Filterkuchen
Zeichn. Nr. 1000-51
29.03.2016 / Bj
O:\10\000 Allgemeine Projekt Vorlagen und Schemas \1\03 Fliessbilder\Grundfliessbild FLUWA und ABA.dwg

16.1.2 Zincex process (ion exchange process)[16]

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Hydrometallurgy Volume 70, Issues 1–3, July 2003, Pages 63-71:

Abstract

Solvent extraction separation of divalent metal ions, Cd(II) and Zn(II), with an organophosphorus extractant, D2EHPA (di(2-ethylhexyl)phosphoric acid), and an aqueous hexadentate ligand with nitrogen donors, TPEN (*N*,*N*,*N*′,*N*′-tetrakis(2-pyridylmethyl)ethylenediamine), was studied. The extraction process consists of two steps, namely, the complex formation between TPEN and the divalent metals in the aqueous phase, $M(TPEN)^{2+}$ (M=Cd or Zn), and the formation of a hydrophobic complex between $M(TPEN)^{2+}$ and D2EHPA in the organic phase. The stability constants for the formation of $Cd(TPEN)^{2+}$ and $Zn(TPEN)^{2+}$, which were measured by potentiometric titration technique, were evaluated as higher than 10^{13}. By the addition of TPEN in amounts equimolar with the divalent metal in the aqueous solution, more than 99% of divalent metal was coordinated with TPEN at pH above 2.5, where the protonation of TPEN is negligible. Under these conditions, the extraction of Cd(II) with D2EHPA was promoted; on the contrary, that of Zn(II) was depressed remarkably. TPEN acts as a synergist for the extraction of Cd(II) and a masking agent for that of Zn(II). Then, the separation factor of Cd(II) was increased by more than 500 times than that without TPEN. TPEN is an excellent synergist that functions by small additions in the aqueous solution and promotes extraction selectively for soft metals such as Cd(II).

16.1.3 The phase equilibrium of ternary mixtures

Solvent extraction, or liquid-liquid extraction is a separation technique

isothermal in a heterogeneous liquid medium.

The method is based on the existence of a difference in the solubility of a substance in two immiscible liquids. The process has three steps, as shown in Figure 1:

- Mixture of the two immiscible liquids, one of them containing the solute,
- Obtaining physico-chemical equilibrium, leading to demixing,
- Separation of the two new liquid phases obtained based on the difference of

densities.

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[16] K. Takeshita; K. Watanabe; Y. Nakano; M. Watanabe (2003). "Solvent extraction separation of Cd(II) and Zn(II) with the organophosphorus extractant D2EHPA and the aqueous nitrogen-donor ligand TPEN". Hydrometallurgy. 70: 63–71. doi:10.1016/s0304-386x(03)00046-x.

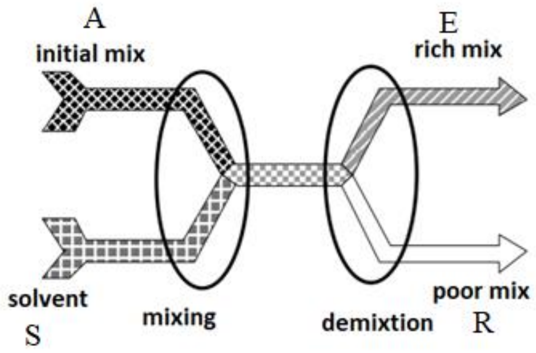


Figure 26 : principle of a separation stage by obtaining a balance

Practically, solute B dissolved in the diluent A is contacted with the solvent S. The solute B, generally more soluble in the solvent than in the diluent, passes from the solution in the solvent, the solvent enriched in solute is the extract E while the diluent depleted solute is the residue (or raffinate) R. The passage of solute B from diluent A in solvent S takes place as long as the equilibrium physico-chemical is not reached. So that the driving force of transfer remains almost constant, the two liquids feeding the column flow against the current.

In order to transport the material as quickly as possible, the area of the transfer surface is increased by various artifices. These objectives can be obtained in a column.

16.1.3.1 The partition coefficient

A substance B placed in contact with two partially miscible solvents or immiscible S and A is distributed unequally between the two phases that are formed when the physicochemical balance is reached. The ratio of B concentrations in these two phases is the partition coefficient m.

16.1.3.2 The ternary diagram

At equilibrium, these biphasic systems are trivariant. At pressure and temperature constants, they can be represented in a system of triangular axes. The equilateral triangle has the advantage of allowing an equivalent representation for all the constituents. The right triangle has the advantage of being able to expand the scale of one of the axes. It is often interesting to limit the plot to the "useful" part. Each vertex of the triangle represents a pure component. The solute content B, in solvent S and diluent A is expressed in mol%, mass, volume, etc ... and is obtained by a suitable projection on the axis chosen as shown in Figure 2.

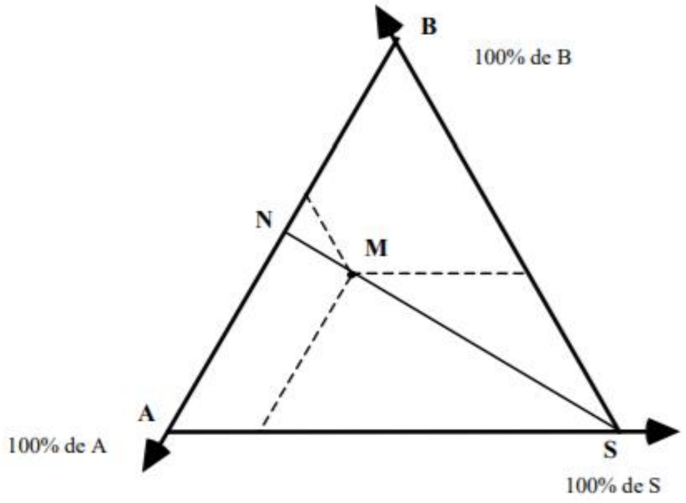


Figure 27 : ternary diagram

It is easy to demonstrate that the quantity of S and the quantity of the mixture N are in a ratio of the lengths of the MN and MS segments (rule of the lever arm) and that the quantities of two components are in the ratio of projections of the segments on the binary axis corresponding.

Conversely, if the mixture N is added a mass of solvent S, the ternary mixture

result is represented by the point M on the line NS such that:

$$\frac{mass\ of\ N}{mass\ of\ S} = \frac{MS}{MN}$$

16.1.3.3 The demixtion

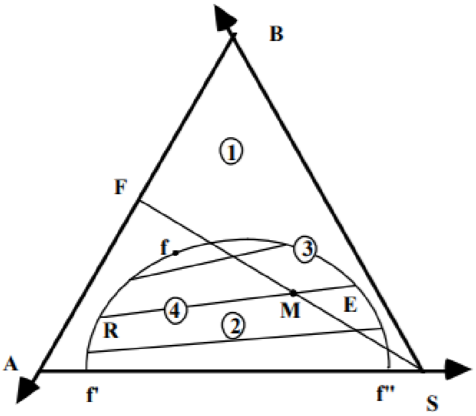


Figure 28 : Isothermal and isobaric demixing curve.

In a ternary system with limited mutual solubility zone (1) stable states, characterized by a complete miscibility, is separated from the zone (2) unstable states constituting the miscibility gap or diphasic zone, by the solubility isotherm (3) or line "Critical" or demixing curve or equilibrium curve or saturation curve.

Within the miscibility gap, no mixture can exist indefinitely:

any system whose overall composition is represented by point M is divided into two composition phases R and E, points at the intersection of the equilibrium line (4) or conodal RME and the demixing curve f'ff ". At the critical point f the two phases in balance have the same composition.

16.1.3.4 Solvent separation

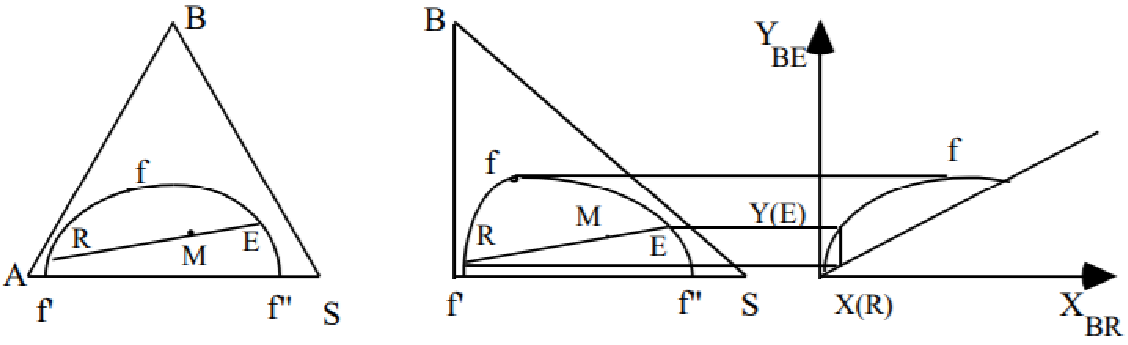


Figure 29 : Representation of a ternary system with limited miscibility

In the zone of total miscibility no separation can take place. However, if starting from an initial mixture F, by the addition of the solvent S, a system whose composition is global M lies within the miscibility gap, which separates into two phases R and E. Phase R, rich in diluent A is the raffinate, while phase E, rich in solvent S, constitutes the extract.

In general, the concentration of solute B in the raffinate is designated by x and in

the extract by y. It is then possible to draw the distribution curve or equilibrium curve which represents y in terms of x.

16.1.4 Countercurrent extraction

16.1.4.1 The principle

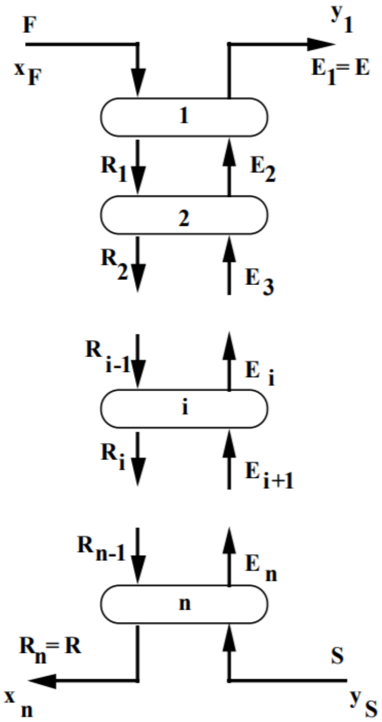


Figure 30 : diagram of countercurrent column

16.1.4.2 the material balance

The writing of the material balance makes it possible to know the composition of the global system and of each of the subsystems (stages).

Balance sheet on the column:

Global: mF + mS = mE + mR = mM

Solute B: mF xF + mS yS = mE y1 + mR xn = mM xM

This system of two equations with eight unknowns can be solved if six variables are otherwise known. In practice mF, mS, xF and yS (= 0) are imposed. By fixing two other variables, for example xn and mR, this system of equations can be solved.

Moreover, the combination of these relationships makes it possible to determine the position of the point M in the ternary diagram. Graphically, F and S determine M. The point M is both on the FS and ER lines. R (Rn)being known, E (E1) is obtained by the intersection of RM and the demixing curve. At point E1 the conodal matches R1.

Balance sheet on the stage i:

Global: $m_{R_{i-1}} + m_{E_{i+1}} = m_{E_i} + m_{R_i}$

Solute:

$m_{R_{i-1}}\ x_{i-1} + m_{E_{i+1}}\ y_{i+1} = m_{E_i} y_i + m_{R_i} x_i$

16.1.4.3 The existence of a pole P

The writing of the overall balance successively for the column and for each of the floors allows to show the existence of a pole P through which all RiEi + 1 lines pass.

Column: mR - mS = mF - mE = Cte = mP

The PRS and PFE points are aligned.

The FERS points being known, P is determined graphically.

Stage 1 : $m_{R_1} - m_{E_2} = m_F - m_E = m_P$

PR1E2 points are aligned. R1 being known, point E2 is in turn.

Step by step, it is possible to write:

Floor i: $m_{R_i} - m_{E_{i+1}} = m_F - m_E = m_P$

The points PRiEi+ 1 are aligned and the point Ri is known by the graphic construction previous point, the point Ei+ 1 is determined.

Gradually, all the points Ri and Ei are determined.

The construction stops when the right PRnS goes through R or "exceeds" R.

Each line RiEi constitutes a theoretical stage.

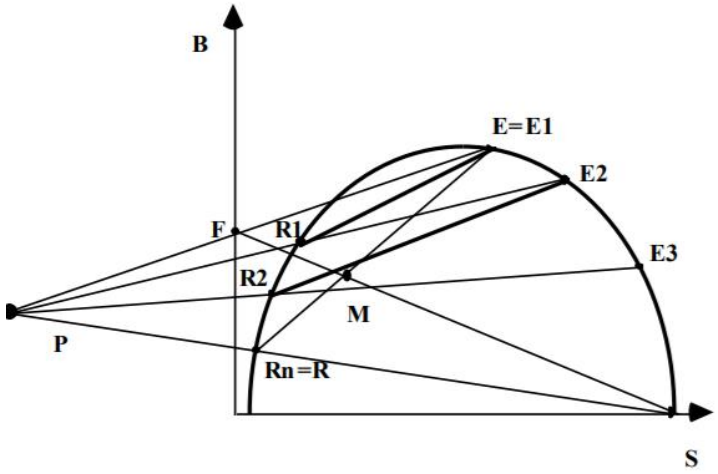


Figure 31 : Graphical construction of theoretical floors

16.1.4.4 Remarks

The previous graphical construction is easier if on the same graph the demixing curve and the operating curve.

If an operating line passing through P was confused with an equilibrium line EiRi it then an infinite number of theoretical stages would be required. The ratio of the mass of solvent to that the power supply would then be the minimum usable to effect the separation. In practice we consider the equilibrium line passing through F as confused with the straight line passing through P. The intersection of the lines FS and E1minRn gives the point Mmin hence the value of the ratio (mS / mF) min.

The choice of the value of the solvent rate p = mS / mF is done by taking:

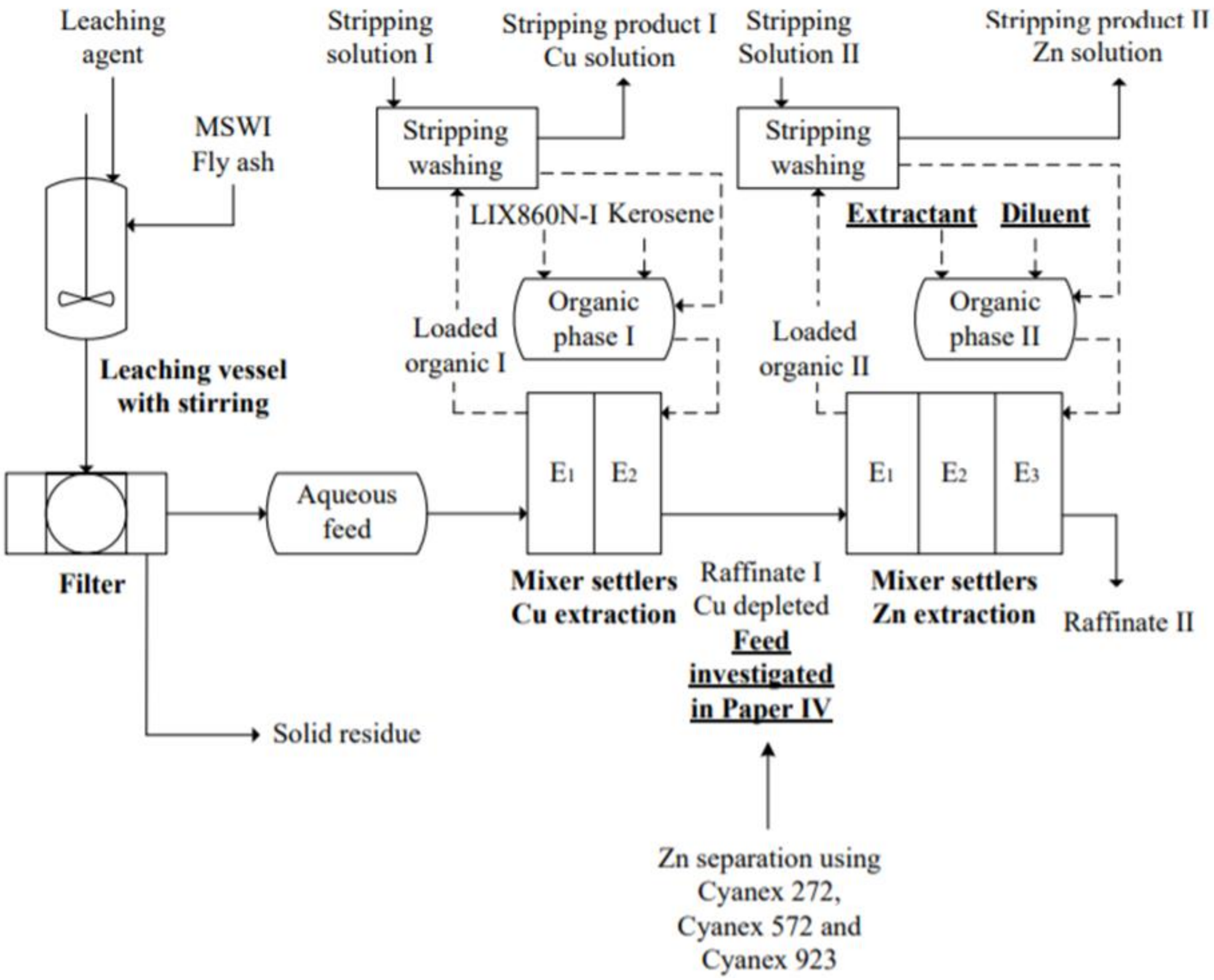
a) a value of mS / mF greater than (mS / mF) min,

b) a value of the extraction factor

$$\varepsilon = m\,p = m\,\frac{m_E}{m_R} = \text{partition coefficient}\ \frac{\textit{mass flow of extract}}{\textit{mass flow of raffinate}}$$

between 1,2 & 2.

16.1.5 Overview of metals recovery system



16.1.6 Cobalt[17]

Cobalt – The extraction of cobalt from hydrochloric acid using alamine 336 in *meta*-xylene.[26] Cobalt can be extracted also using Cyanex 272 {*bis*-(2,4,4-trimethylpentyl) phosphinic acid}, Marmara University

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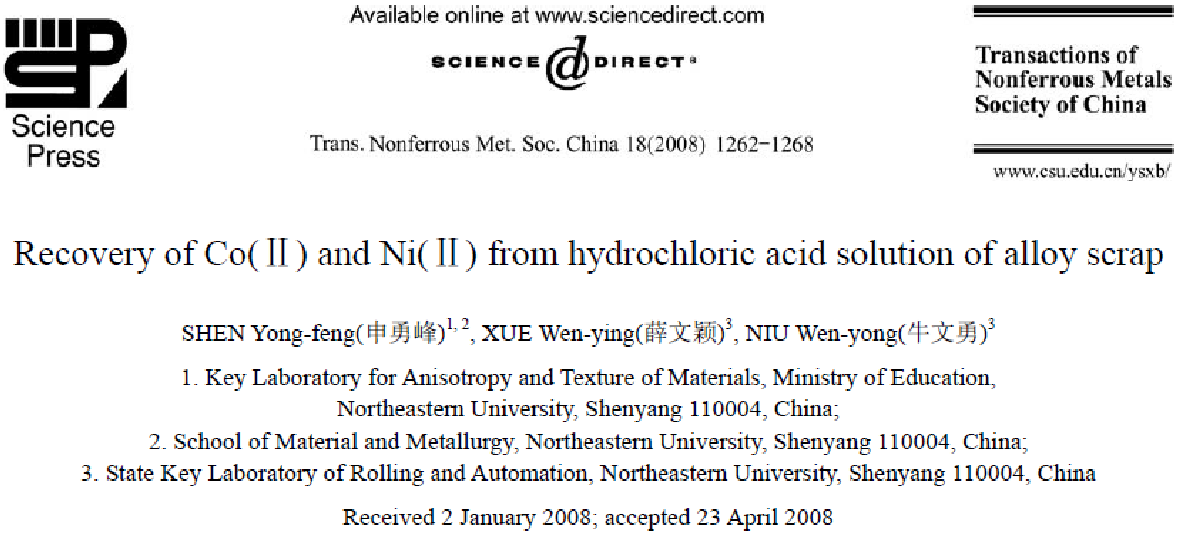
[17] Filiz, M.; Sayar, N.A.; Sayar, A.A. (2006). "Extraction of cobalt(II) from aqueous hydrochloric acid solutions into alamine 336–m-xylene mixtures". Hydrometallurgy. **81** (3-4): 167–173. doi:10.1016/j.hydromet.2005.12.007. ISSN 0304-386X.

Extraction of Co(II) from aqueous hydrochloric acid solutions into organic Alamine 336–m-xylene systems was investigated. Extraction experiments were conducted with initial metal concentrations of 1, 3 and 6 g L− 1, each at 1, 5, 8 and 10 M HCl. It was observed that the extractability of Co(II) increases with increasing acidic molarities. Alamine 336 diluted with m-xylene was found to be a suitable extractant for Co(II) for 5 to 10 M. In parallel, extractant volume-domain dynamics were investigated. A mathematical model was developed to correlate metal extractability and Alamine 336 volume content. Optimal Alamine 336 contents were estimated for single stage extraction.

Extraction of cobalt(II) from aqueous hydrochloric acid solutions into alamine... | Request PDF. Available from: https://www.researchgate.net/publication/229310411_Extraction_of_cobaltII_from_aqueous_hydrochloric_acid_solutions_into_alamine_336-m-xylene_mixtures [accessed Mar 25 2018].

16.1.6.1 Recovery of Co(II) and Ni(II) from hydrochloric acid solution of alloy scrap[18]



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Trans. Nonferrous Met. Soc. China 18(2008) 1262−1268

Transactions of Nonferrous Metals Society of China

www.csu.edu.cn/ysxb/

Recovery of Co(Ⅱ) and Ni(Ⅱ) from hydrochloric acid solution of alloy scrap

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3. State Key Laboratory of Rolling and Automation, Northeastern University, Shenyang 110004, China

Received 2 January 2008; accepted 23 April 2008

Abstract: A hydrometallurgical process was developed for recovery of nickel and cobalt from the hydrochloric acid leaching solution of alloy scraps. The process consists of five major unit operations:

1) leaching with 6 mol/L hydrochloric acid under the L/S ratio of 10:1 at 95 °C for 3 h;
2) copper replacement by iron scraps under pH value of 2.0 at 80 °C, and stirring for 1 h;

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[18] http://www.tnmsc.cn/down/upfile/soft/2008928/2008928164134995.pdf
alloy scap = legierungsschrott

3) removal of iron and chromium by chemical precipitation: iron removal under pH value of 2.0 at 90 °C by dropwise addition of sodium chlorate and 18% sodium carbonate solution, then chromium removal under pH value of 4.0 at 70 °C by addition of nickel carbonate solution, stirred by air flow for 2 h;

4) selective separation of cobalt from nickel by extraction using 30% trialkyl amine+50% kerosene (volume fraction) and tri-*n*-butylphosphate (TBP) as a phase modifier with the O/A ratio of 2:1, and stripping of cobalt with 0.01 mol/L HCl;

5) crystallization of nickel chloride and electrodeposition of cobalt. It is found that the nickel recovery of 95% and the cobalt recovery of approximately 60% with purity over 99.9% are obtained by this process.

Key words: alloy scrap; nickel; cobalt; recovery; trialkyl amine

1 Introduction

The demand for nickel and cobalt has recently risen for their promising use in rechargeable batteries. The increase in the industrial demand for these metals has brought forth a steady growth in the need for refining of the metals. More importantly, the recovery of nickel and cobalt from secondary sources such as alloy scraps and/or spent batteries could minimize landfill disposal and the waste of natural resources. It is also technically feasible and economical in comparison with refining cobalt and nickel from ores. To date, some typical hydrometallurgical processes have been reported for the recycling of cobalt and/or nickel from lithium ion batteries[1−3] and nickel metal hydroxide batteries[4−7] as well as Ni-Cd batteries[8]. These hydrometallurgical routes consist of acid leaching, separation of cobalt from nickel and/or lithium, and recovery as chemicals. For example, nickel has been recovered by means of both galvanostatic and potentiostatic electrowinning after separating Ni from Co by SX methods[9]. In addition, the recovery of Co(II) and Ni(II) from different sources, including polymetallic sea nodules[10−11], cobalt enriched Ni-Cu matte [12], low-grade sulfide flotation concentrates[13] and low-grade Ni-Cu sulfide tailings [14], has been achieved by different research groups.

However, there have been only a handful of published works on cobalt recovery from waste alloys[15]. A variety of organic solvents or their mixtures have been tested for the extraction of nickel(II) and cobalt(II) from aqueous solutions and for separation of cobalt from nickel. Among the acidic organo-phosphoric compounds, di(2-ethylhexyl) phosphoric acid (D2EHPA) and extractant 2-ethylhexyl phosphonic acid mono-2-ethylhexyl ester (EHEHPA, commercially known as PC88A or P507), have been widely used for separation of Co from Ni [11−1 6]. Whereas organo-phosphorous acid derivatives such as bis(2, 4, 4-trimethylpentyl) dithiophosphinic acid (Cyanex 301) extractant can extract cobalt and nickel at very low pH value as well as the ability to reject metals such as calcium, manganese and magnesium, holding a position for separation of cobalt and nickel[17−18]. The investigation on the purification of nickel showed that di-2, 4, 4-trimethylpentyl phosphinic (Cyanex 272) was most effective for selecting

17 Methan as Energy Ressource from Waste

17.1 LANDFILL GAS (Methane gas from waste)[19]

Created during the decomposition of organic substances, landfill gas consists of methane, carbon dioxide, and nitrogen. The controlled collection and combustion of this problem gas is an indispensable step in the modern operation and re-cultivation of a landfill site. In addition, the high calorific value of landfill gas makes it a viable fuel for gas engines that can be effectively used for power generation. With more than 25 years of experience in the combustion of landfill gas throughout the world, GE's Jenbacher gas engines provide an excellent solution for using your waste **gas as an energy source**.

17.2 Methane liquefaction

17.2.1 Pre-cooled liquefaction process of natural gas (EP 2 251 625 A2 EUROPEAN PATENT APPLICATION)

17.2.1.1 LNG Proprieties

LNG has the best safety record of all fossil fuels: Not flammable or explosive in liquid form Noncorrosive and nontoxic

Stable and stored at low pressures

Evaporates quickly and completely leaving no fire hazard puddle

LNG is refrigerated around -160˚C

Volume reduction 600 times with the same calorific capacity

LNG is composed mainly from methane (more than 90%)

The liquefaction factory consumes nearly 10% of the natural gas while functioning

The LNG will be stocked at an atmospheric pressure in storages made from concrete or metallic tanks, possessing double wall and thermal insulation.

The principals LNG exporters are: Qatar, Australia, Malesia, Nigeria and Indonesia (more than two-thirds)

The principals LNG importers are: Japan, South Korea, China.

17.2.1.2 The process of producing LNG is in three steps.

Feed gas from the interior

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[19] https://www.gepower.com/applications/waste-gas-to-power

Step 1- Treatment (Remove CO2, Water (H2O) and mercury from the Feed Gas)	Acid gas (mainly carbon dioxide), water and mercury are removed from the gas delivered to Oman LNG. This clean-up" is a necessary step to enable liquefaction of the natural gas and a safe product for our customers.
Step 2 – Removal of "Condensates"(Remove heavier hydrocarbons (NGL's) by Fractional Distillation)	**Condensates (natural gas Liquids made up mainly of pentane and hexane) are removed by Fractional Distillation of the feed Gas after treatment.**
Step 3 – Liquefaction of Natural Gas(Cool remaining light hydrocarbons to-162ºC to liquefy)	The gas (now mainly methane) is sent to the Main Cryogenic Heat Exchange (MCHE), where it condenses to liquid at -162°C. The liquid is sent to special storage tanks awaiting shipment by LNG vessels to customers in Asia and Europe.

17.2.1.3 LNG Production diagram (US5053209A)

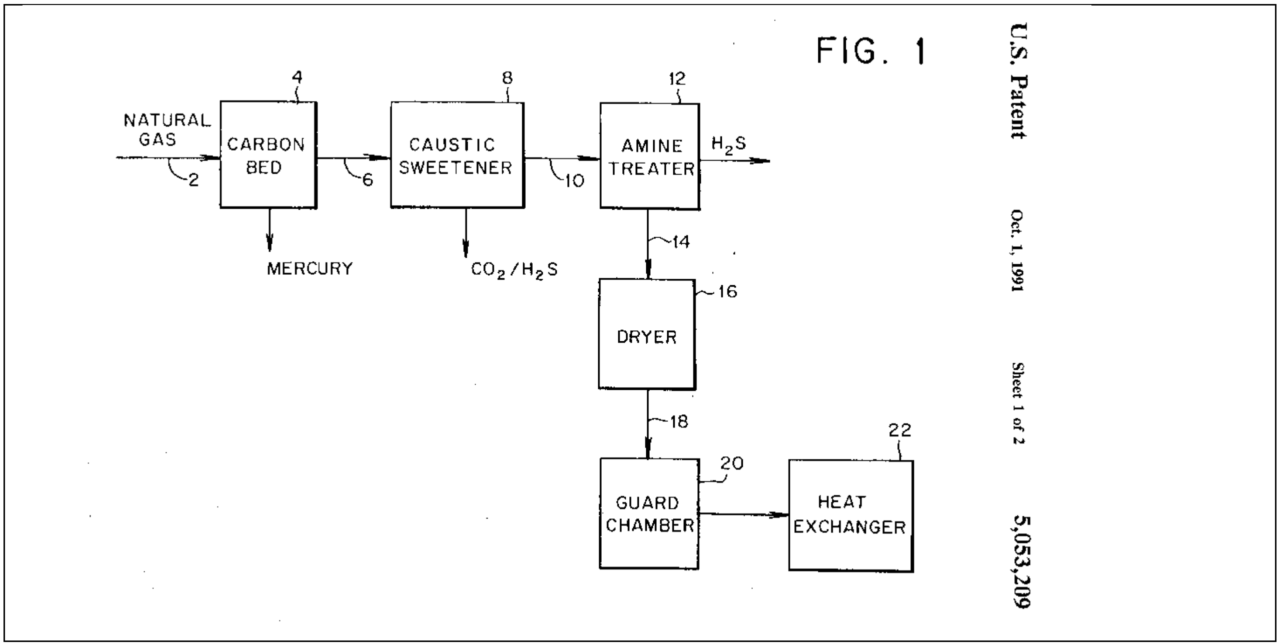
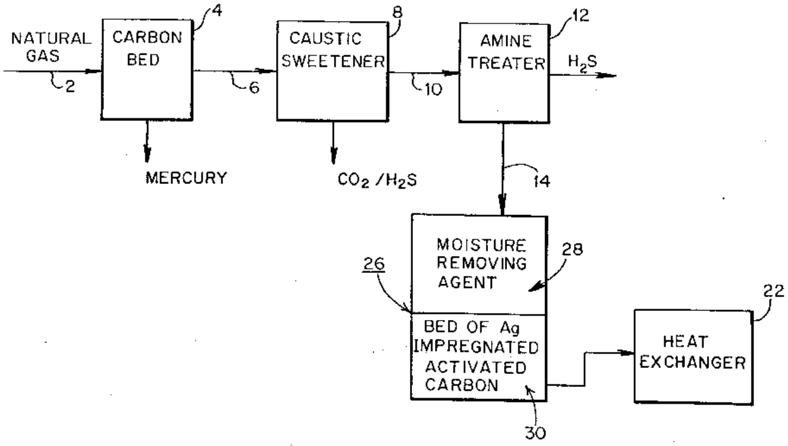


FIG. 1

FIG. 2



SUMMARY OF THE INVENTION

In a broad sense this invention comprises a process for treating raw natural gas prior to liquefaction which comprises (a) passing a stream of raw natural hydrocarbon gas or liquid through a zone containing activated carbon impregnated with sulfur, at conditions effective to remove mercury from said natural gas; (b) passing the effluent stream of natural gas thus treated through a sweetening zone operating at conditions effective to remove carbon dioxide and hydrogen sulfide and/or then passing the effluent stream through an amine treating system where additional hydrogen sulfide is removed, (c) subsequently passing the effluent through a drier or dehydrator where water vapor is removed and (d) finally passing the effluent through a heat exchanger to a further product treatment zone. In this invention there is positioned in the flow line, preferably downstream of the dehydrator, or dryer, a body of activated carbon, silica, alumina, or silica-alumina supports, which can be honeycomb shaped, extrudate, granules, beads, and pellets containing free silver in an active state such that it forms an amalgam with mercury. The silver preferably is deposited in a dispersed form on activated carbon, or even more preferably on gamma alumina, although other supports can be used such as silica, other aluminas such as alpha or beta, and silica-alumina. This technique is particularly useful in removing the residual mercury still remaining in the gas stream even after it has been treated under optimum operating conditions by equipment located upstream.

17.2.1.4 Natural Gas Treatment

Step1: Mercury removal

DETAILED DESCRIPTION OF THE INVENTION

In the prior art the most popular absorbent used to remove mercury is sulfur loaded on activated carbon. The reaction between the sulfur and mercury is:

2Hg+S.sub.2 →2HgS

The optimum operating temperature has been determined to be about 170° F.

The substrate utilized in the method of this invention is metallic silver dispersed preferably on activated carbon or on gamma alumina. Other usable support materials include other types of alumina, silica, silica-alumina, silicates, aluminates and silica aluminates, as well as synthetic and natural zeolites, to increase the metal surface area to greater than 0.01m$_2$ /g to improve activity for mercury removal. The concentration of silver metal on the activated carbon or gamma alumina should be between 0.1 and 20 percent by weight (preferably between 1 and 5 percent). The silver can be dispersed onto the carrier by impregnation, co-precipitation or other well-known methods. The absorbent can be in the form of extrudate, beads, pellets and granules. Pressure drop across a body of absorbent can be minimized by using absorbent in the form of honeycomb, or "multi-lobe" configuration.

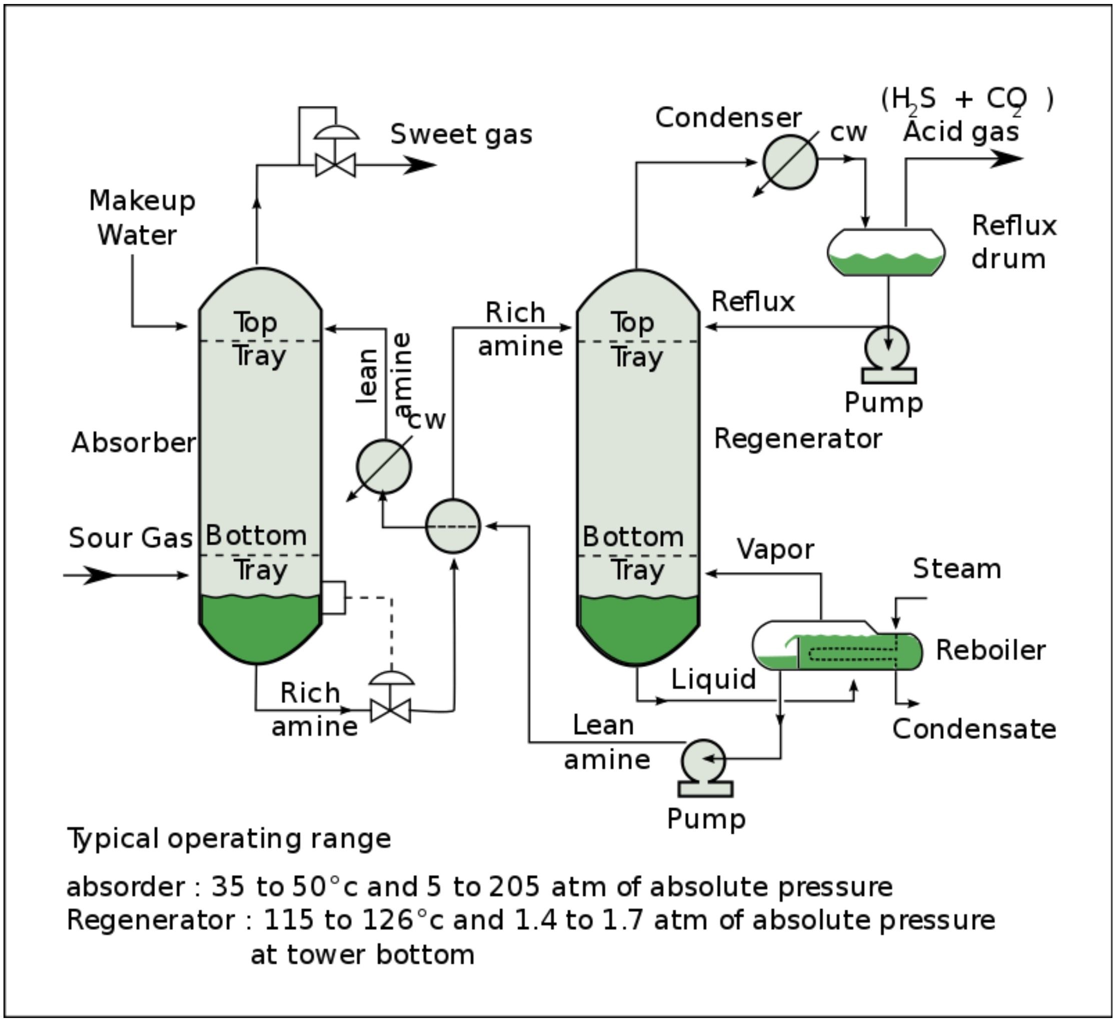
EXAMPLE

An adsorbent consisting of silver deposited on gamma alumina was prepared by saturating the gamma alumina with an aqueous solution of silver nitrate, drying and calcining the impregnated alumina, and then reducing the silver nitrate to free metallic silver by contacting the alumina with formaldehyde. The adsorbent contained approximately 5 percent by weight of silver. An initial test of the adsorbent in which 0.1 gram of the adsorbent was contacted with 100 milliliters of air equilibrated with mercury indicated that 98 percent of the mercury in the air was removed.

Step2: Treatment CO2 removal

Amine Units

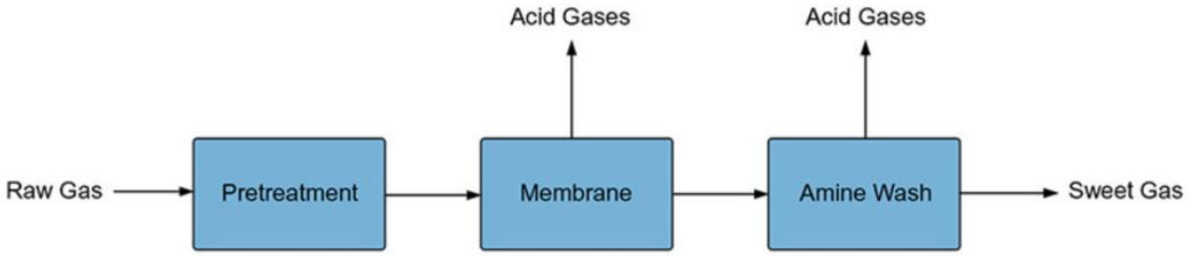
Amine-based solvents are an effective method for processing acid gas, from natural gas, associated gases or unconventional gas sources which have varying compositions of hydrogen sulfide and carbon dioxide. Depending on the composition of raw gas, we implement formulated or generic amine based solvents for an optimal selective processing plant.



Acid Gas Removal Amine Wash

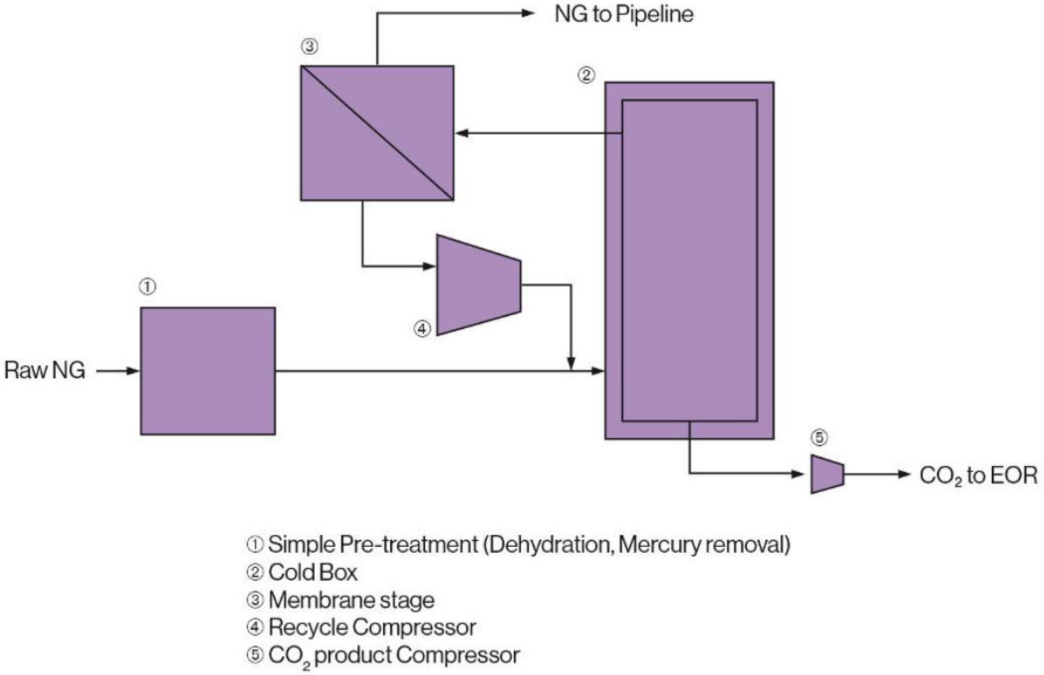
Membrane Technology

In case of carbon dioxide rich gas, meeting product specifications requests a particularly efficient method of removing carbon dioxide. In collaboration with Air Liquide Advanced Separations/Porogen, Air Liquide Engineering & Construction offers hollow fiber membrane technology for selective permeation of carbon dioxide while minimizing hydrocarbon losses. This technology combines high permeability with high hydrocarbon resistance, making it an attractive option for bulk carbon dioxide removal. In addition, the operation is highly flexible, it requires little maintenance, making it ideal for remote and offshore locations



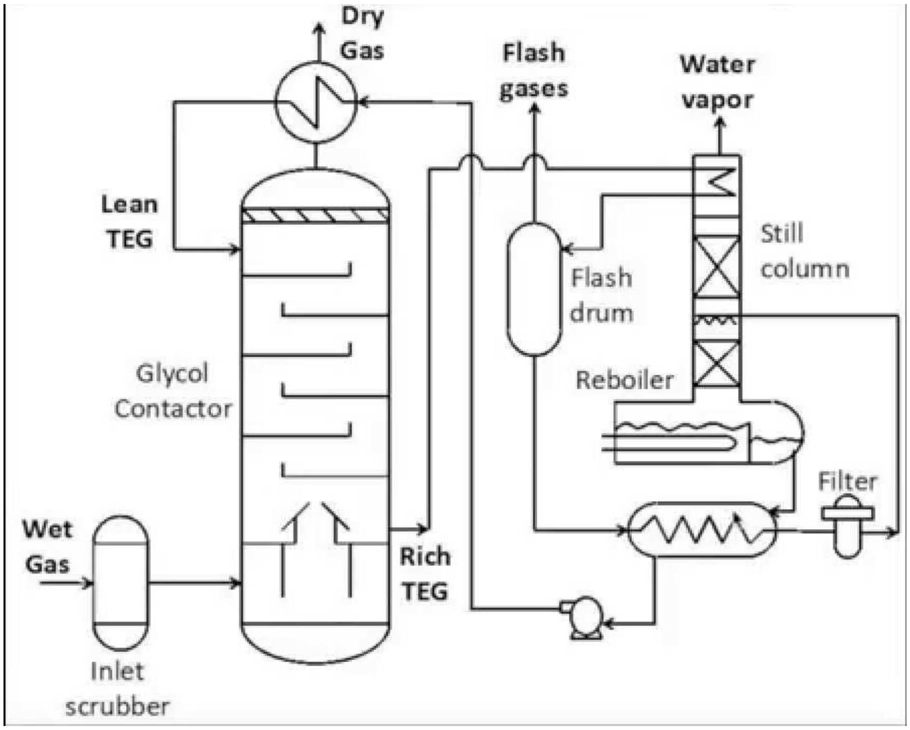
Cryogenic technology

For natural gas with high CO_2 content, Cryogenic technology, alone or in combination with the Air Liquide membrane technology, can produce pipeline specification natural gas. High CO_2 partial pressure favors the partial CO_2 condensation and making its separation from natural gas even easier. The CO_2 and heavy hydrocarbons condense in the cold box and are collected at high pressure. This Air Liquide Engineering & Construction proprietary technology also allows Natural Gas Liquids recovery with almost no additional cost.



CO2 Removal Cryocap

Step 3: Water removal (Glycol dehydration)



The wet gas enters the inlet scrubber to remove solid particles. Then it will pass to the glycol contactor. In the contactor the flow of wet NG will meet with the lean Triethylene glycol (TEG). During the contact in the contactor the TEG will be invested by water and flows out of the bottom out of the contactor. The Rich TEG continue to the internal heat exchanger which is incorporated at the top of the still column in the regeneration section of the adsorption unit then it flows to the flash drum where the flash gases are released and separated from the stream. The TEG then runs to the cold side of the TEG-TEG heat exchanger. Just afterwards, the warm TEG is filtered then runs into the regeneration system where it's spread in the still column. From there the TEG runs into the reboiler. The regeneration energy is around 282 kj/L of TEG, the temperature should not exceed the decomposition temperature of the TEG. The regenerated TEG is pumped to the hot side of the TEG-TEG heat exchanger and the NG-TEG heat exchanger at the top of the contactor.

17.2.2 Pre-cooled liquefaction process of natural gas

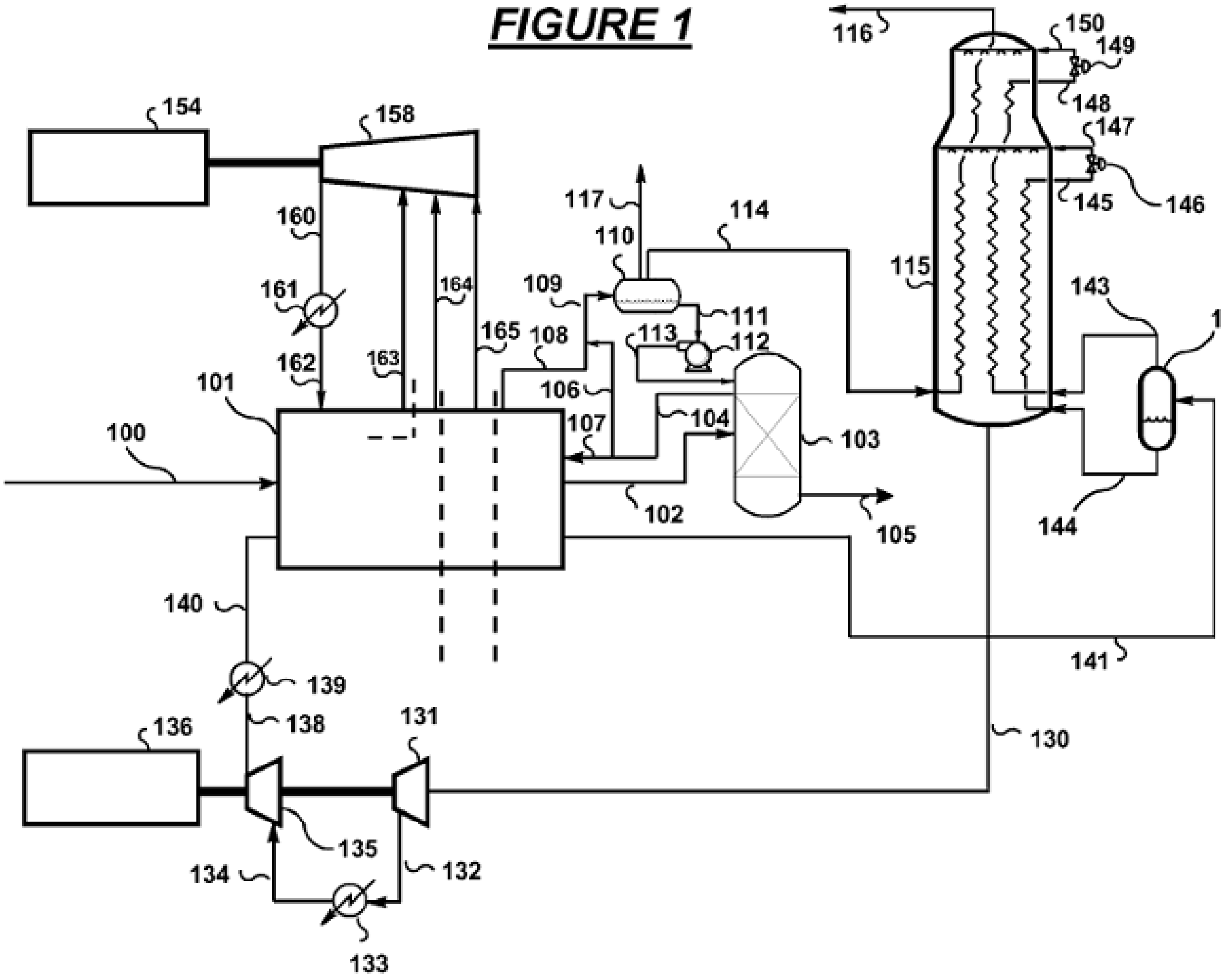


FIGURE 1

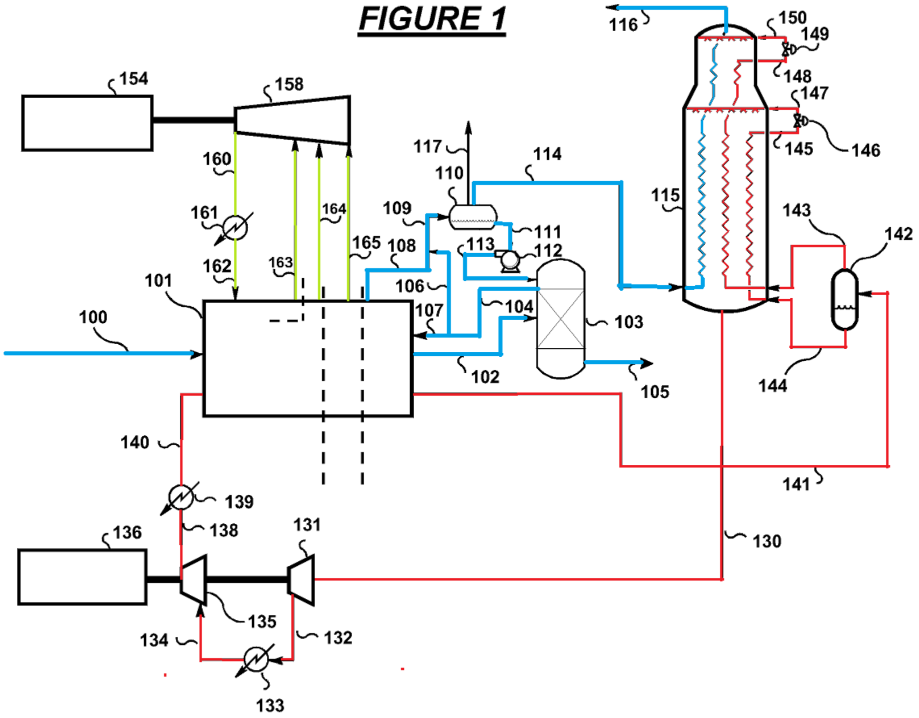


FIGURE 1

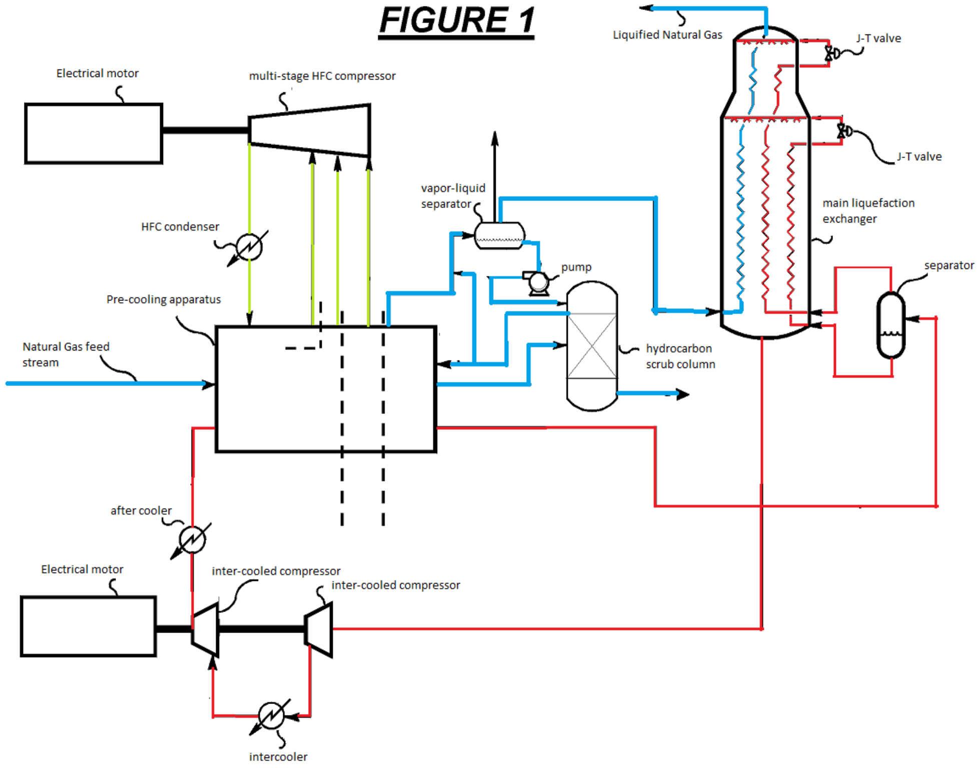


FIGURE 1

100: natural gas feed stream

101: pre-cooling apparatus

102: pre-cooled stream

103: hydrocarbon scrub column

104: stream

105: heavy hydrocarbon stream

106,107: stream

108: partially condensed feed stream

109: stream

110: vapor-liquid separator

111: liquid stream

112: pump

113: cold liquid reflux stream

114: vapor stream

115: the main liquefaction exchanger

116: stream

117: methane make-up stream

130: low pressure, warm main liquefaction refrigerant stream

131, 135: inter-cooled compressors

132, 134, 138: stream

133: intercooler

136: driver (electrical motor or gas turbine)

139: after cooler

140: high pressure fluid stream (P: 30-80 bara)

141: pre-cooled stream

142: separator

143: lighter refrigerant stream

144: heavier refrigerant stream

145: stream

146, 149: J-T valve

147,150: cryogenic refrigerant stream

148: stream

154: multi-shaft gas turbine

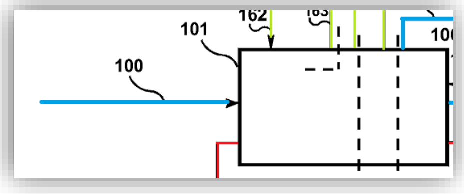
158: multi-stage HFC compressor

160: stream

161: HFC condenser

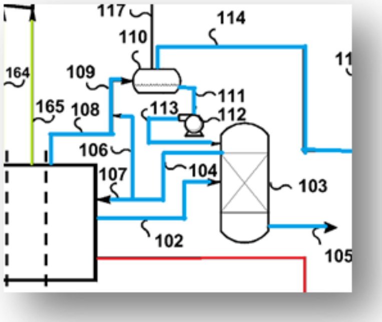
162: sub-cooled HFC stream

163, 164, 165: combined stream



Description:

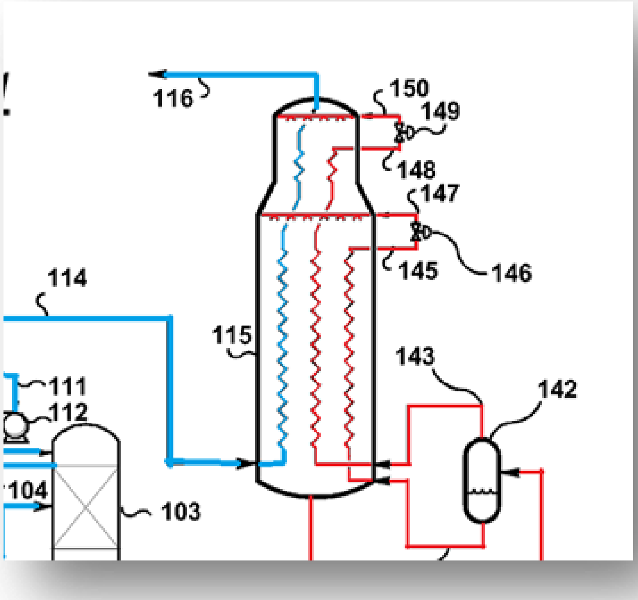
Step 1: Returning to Figure 1, a natural gas feed stream (not shown) is pre-treated for removal of heavy hydrocarbon oils, particulates, CO2, and H2S before being sent to driers (not shown). Drying may be performed using sea water cooling if the sea water is substantially below 22°C or can be performed using the HFC refrigerant. After cooling the natural gas feed stream to a temperature between 22-25°C, the natural gas feed stream is then sent to drier beds where moisture is removed (not shown). The dehydrated natural gas feed stream 100 is then sent to be pre-cooled at pressures ranging between 30-85 bara. Pre-cooling of dehydrated natural gas feed stream 100 is performed in 1-5 cooling stages in series, for example, represented by the pre-cooling apparatus 101. Figure 1 illustrates a 3-stage pre-cooling system. These serial cooling stages use an HFC refrigerant at sequentially descending temperatures by lowering J-T valve pressures making the HFC refrigerant supplied to the cooling stage (n) colder than that supplied to the cooling stage (n-1), for example. The greater the number of cooling stages, the greater the efficiency of pre-cooling due to close approaches of the cooling curve. If there are a total of (n) HFC pre-cooling stages, then the feed cools in (n-1) stages to yield the pre-cooled stream 102.



Step2: Pre-cooled stream 102 may then be sent to a hydrocarbon scrub column 103 which scrubs away heavier (C3+) components of the feed using a cold liquid reflux stream 113 in order to adjust the heating value of the final LNG. A bottoms stream 105 is sent either to a fractionation train or to storage (not shown). It should be noted that due to space constraints on FPSOs, the heavy hydrocarbon stream 105 exiting the scrub column 103 may be potentially shipped and fractionated at a LNG receiving terminal. If fractionation is undertaken on the FPSO platform, one aspect of the current invention also allows for the HFC refrigerant to supply refrigeration to condensers of the various columns (such as a deethanizer) that may be involved in a fractionation train.

Step 3: Stream 104, taken from the scrub column 103, constitutes the lighter overhead stream. Part of stream 104 (i.e., stream 107) may be partially condensed using the HFC pre-cooling apparatus 101. The partially condensed feed stream 108 may then be combined with the uncondensed portion of stream 104 (i.e., stream 106) to form stream 109 and then sent to a vapor-liquid separator 110 which disengages the vapor from the liquid. The liquid stream 111 from the vapor-liquid separator 110 may then be pumped in pump 112 back into scrub column 103 as stream 113 to act as the column reflux.

Step 4: The HFC pre-cooling refrigerant may be used to supply all of the scrub column reflux condenser 110 duty without the need to use the main liquefaction refrigerant for such purpose. Using the HFC pre-cooling to supply all of the scrub column reflux condenser 110 duty will improve the efficiency of the system since typically cooling duties supplied by the typical hydrocarbon refrigerants require much higher incremental compression power than the HFC refrigerant. This is because of the significantly lower compressibility factors of typical HFC's when compared with lighter hydrocarbon refrigerants like CH_4 and C_2H_6. Use of the HFC pre-cooling to supply all of the scrub column reflux condenser 110 duty also reduces the size of the main liquefaction exchanger 115 and simplifies control issues and plant layout.

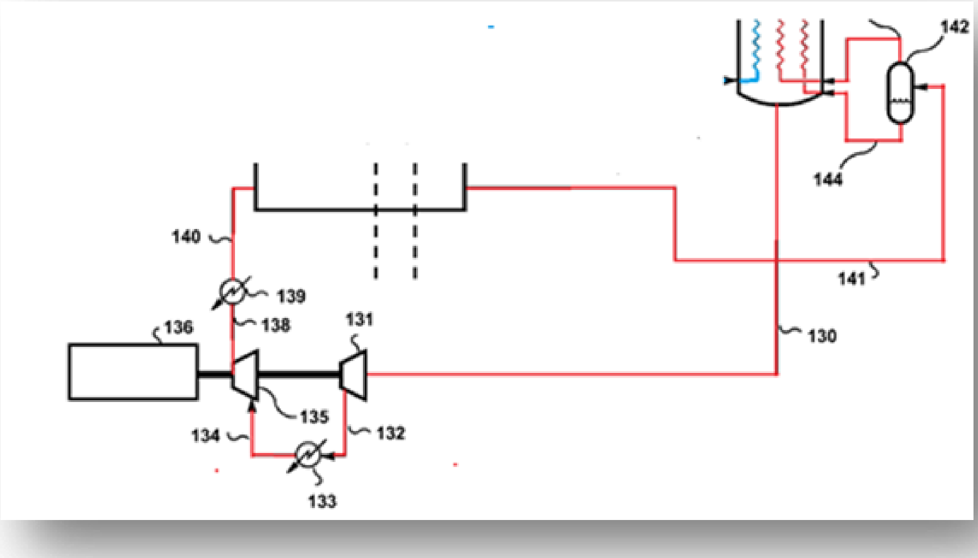


<u>Step 5:</u> Vapor stream 114 from the scrub column reflux condenser 110 may be sent to the cryogenic section of the plant that fully condenses and sub-cools vapor stream 114 to form LNG product stream 116. The cryogenic section comprises the main liquefaction exchanger 115. In the cryogenic section, either a refrigerant consisting of mixed hydrocarbons with 0-30 mole% N2 or pure N2 may be used, for example. In one embodiment, the main liquefaction refrigerant may be a mixture containing 0-30% N2 and hydrocarbons such as methane (0-50%), ethane (0-75%), and butanes (0-50%). In another embodiment, the main liquefaction refrigerant may be a mixture comprising a first stream of methane derived from a natural gas stream, a second stream, where the second stream is an ethane enriched stream that is predominantly ethane, and a third stream, where the third stream is a nitrogen enriched stream that is predominantly nitrogen. The methane stream can be derived from natural gas in one of two ways. If natural gas stream 100 (illustrated in Figure 1) is lean (i.e., contains more than 90 mole % methane and less than 3 mole % propane) then a part of that stream may be used to make up the mixed refrigerant. If natural gas stream 100 (of Figure 1) is not lean (i.e., contains more than 3 mole % propane) then it may be pre-cooled against the HFC in pre-cooling apparatus 101, scrubbed in a scrub column 103 (of Figure 1) that removes excess propane and other heavier hydrocarbons, and pre-cooled further to produce the methane make up stream 117 (of Figure 1). This procedure ensures that the methane make up stream used to make the mixed refrigerant contains low enough amounts of propane for safety.

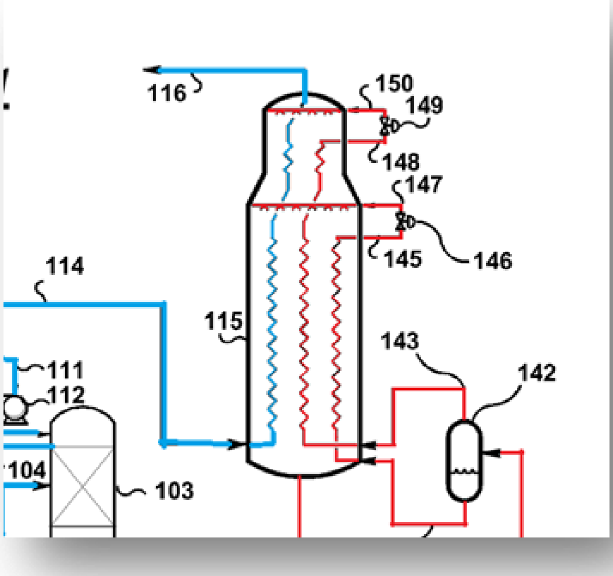
The use of propane, which is considered to be unfavorable for use on the FPSO due to the possibility of formation of flammable clouds at surface level, may be eliminated, or nearly eliminated when using HFC's as a pre-working fluid.

Step 6: The main liquefaction exchanger 115 may be a wound coil exchanger, a plate-fin exchanger, or any other exchanger typical for cryogenic service. Vapor stream 114 may enter the main liquefaction exchanger 115 where it is condensed and sub-cooled and exits as LNG product stream 116 at a temperature between -140°C to -170°C and pressure between 30-85 bara, for example.

Step 7: The condensed and sub-cooled LNG product stream 116 may be further processed by reducing its pressure in a liquid expander (not shown) or a flash valve (not shown) to around 1.2 bara, forming flash gas and a liquid LNG product. The LNG product may be subsequently sent to storage, for example.



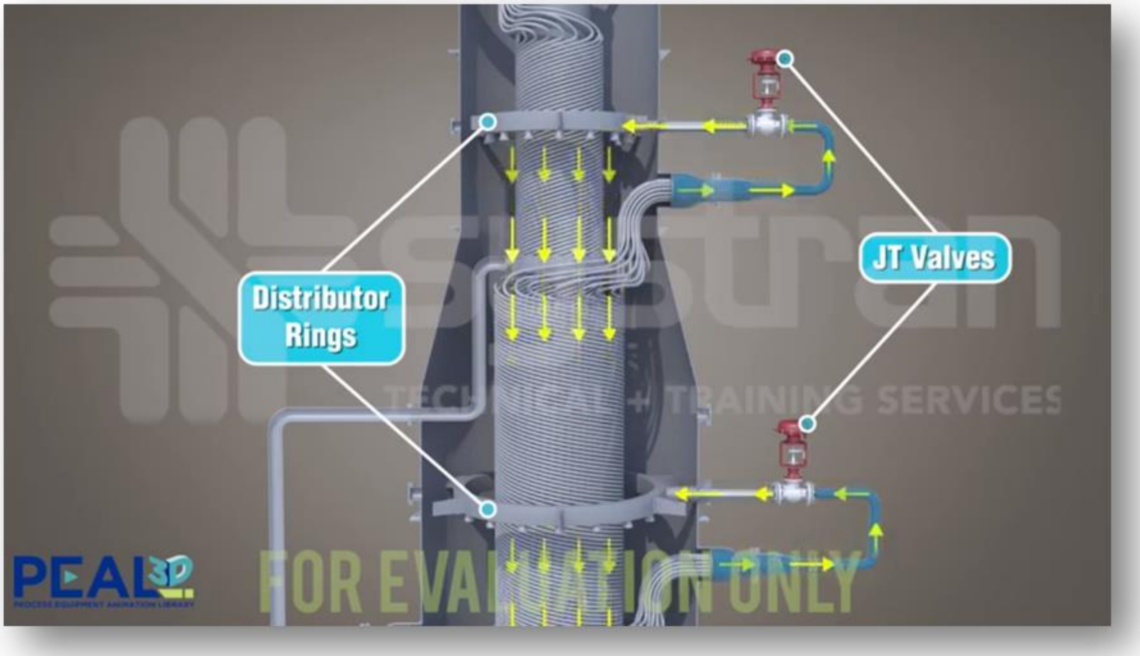
Step 8: The low pressure, warm main liquefaction refrigerant stream 130 may be sent to a sequence of inter-cooled compressors 131, 135 where the stream 130 is first compressed in compressor 131 to form stream 132, cooled in intercooler 133 to form stream 134, further compressed in compressor 135 to form stream 138, and then further cooled in aftercooler 139 to emerge as a high pressure fluid stream 140. Compressors 131 and 135 are driven by driver 136. Driver 136 can be an electrical motor or a gas turbine. High pressure fluid stream 140 may be at pressures ranging between 30-80 bara and a temperature dictated by: (1) the working fluid used in the intercooler 133 and aftercooler 139; and (2) the size of the intercooler 133 and aftercooler 139. While Figure 1 illustrates the mixed refrigerant compression system having one intercooler 133 and one aftercooler 139, multiple intercoolers and aftercoolers may be implemented, for example. The working fluid used in the intercooler 133 and aftercooler 139 may be air, or typically for FPSO applications, sea water, or fresh water, which is in turn cooled by sea water, for example.



Step 9: The cooled high pressure refrigerant stream 140 may be pre-cooled using pre-cooling apparatus 101 resulting in pre-cooled stream 141. Pre-cooled stream 141 may be separated into lighter refrigerant stream 143 and heavier refrigerant stream 144 in separator 142. The lighter refrigerant stream 143 may then be condensed and sub-cooled in the main liquefaction exchanger 115 to form stream 148, expanded in J-T valve 149 to generate cryogenic refrigerant stream 150 having a temperature between -180°C to -120°C, before it is then vaporized in the main liquefaction exchanger 115. The heavier refrigerant liquid stream 144 may also be sub-cooled in the main liquefaction exchanger 115 to form stream 145 where it may then be expanded in J-T valve 146 to generate cryogenic refrigerant stream 147 to also be vaporized in the main liquefaction exchanger 115. The current process may also include a hydraulic expander (not shown) before J-T valve 146 to improve efficiency.

The combined cryogenic refrigerant streams 147, 150 boil at successively higher temperatures while flowing down the main liquefaction exchanger 115 before eventually exiting the exchanger as the vapor stream 130 at or slightly above dew point thereby completing the refrigeration loop.

MCHE:

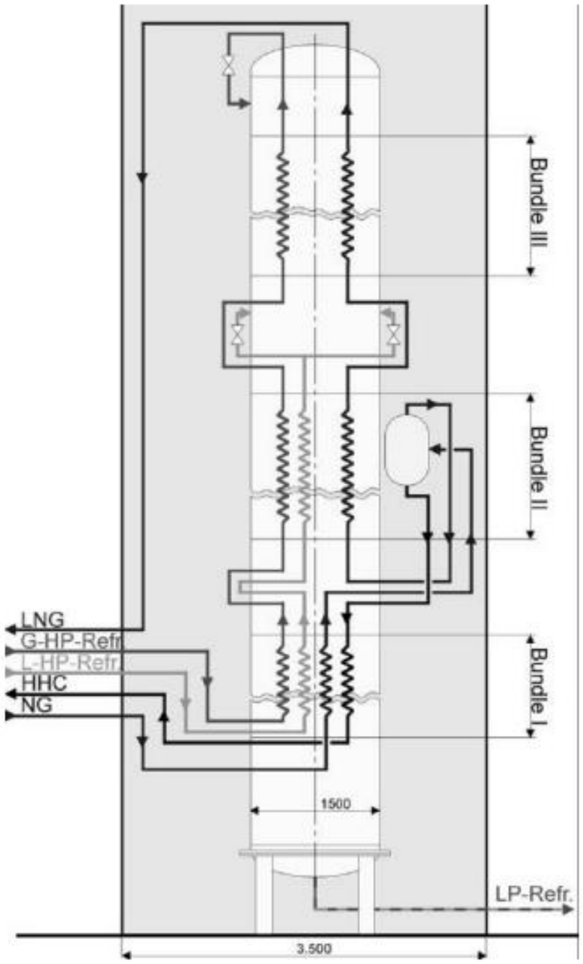


The MCHE is a spiral wound heat exchanger consisting of bundles with thousands of tubes to provide sufficient surface area needed for a close temperature approach between the inlet gas and the cooling medium. These bundles can be classified as warm and cold bundles and are arranged in a vertical shell with the warm bundle on the bottom and the cold on top.

The high pressure mixed refrigerant is first cooled by propane and is subsequently separated into light and heavy mixed refrigerant streams. The high pressure mixed refrigerant and feed gas streams flow upward through the tube side of the MCHE while the high pressure mixed refrigerant undergoes a series of flashes dramatically reducing the temperature. The cold flashed mixed refrigerant flows counter current (shell side) to cool both the inlet gas and the inlet mixed refrigerant. A final cooling stage is accomplished through a J-T valve or hydraulic expander to further cool the liquid and remove any excess nitrogen. At this stage, the gas stream is fully liquefied to -160°C, and is pumped to storage. The warm vaporized MR stream is taken off the bottom (shell side) of the exchanger and enters the first stage suction of the MR compressor. The compressed MR is first cooled with air or water followed by propane before returning to the MCHE to repeat the process.

Thermal Design

A Spiral wound heat exchangers (SWHEs) is generally used in LNG plant.



Cold Box Bundle Arrangement

(gaseous high pressure refrigerant (G-HP-Refr.))

As to suit process requirements three bundles are arranged in series, installed in a common shell. Each bundle has a diameter of 1,325 mm and the total installed heating surface amounts to 3,900 m². Bundle no. 1 is used to liquefy heavy hydrocarbons of the natural gas stream. Bundle no. 2 leads to partial liquefaction and in bundle no. 3 total liquefaction and sub-cooling to around –162°C are achieved. Each bundle has a separate distribution system for the shell side MRC.

Mechanical Design

All parts of the exchanger are in aluminum alloys whereby particular care was taken to select the appropriate alloys for critical items. Design pressure for the shell side is 28 barg due to overall plant conditions and for the tube sides 48 barg. Design temperature is +55 / -175°C.

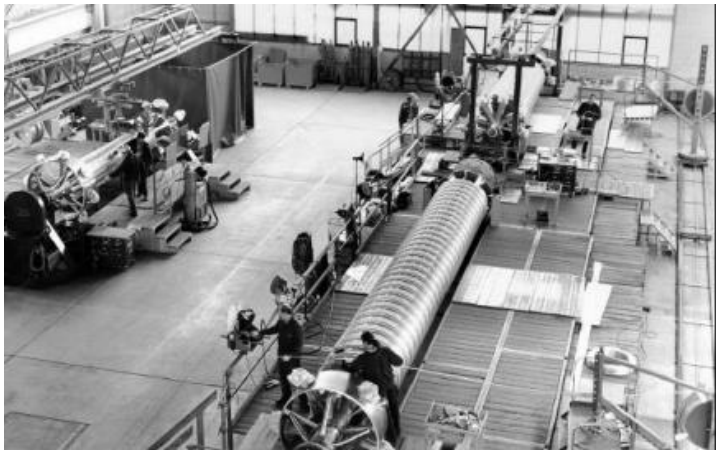
The SWHE is designed in such a way that each of the three tube bundles has its own mandrel, support star, distributor system and shroud. Each bundle is hanging freely on several support arms via special shaped support bars so that shrinkage and expansion of the tube bundle due to rapid temperature changes during start-up or shut-down occurs with a minimum of stress between tube bundle and shell.

Each tube bundle is to be wrapped into a shroud which is seal-welded on the upper side to the shell to avoid any by-pass of refrigerant between bundle and shell.

The bottom section of the SWHE is designed so that it can be used as a separator. As the SWHE had to be installed in a cold box all bonnets and nozzles had to be designed for adequate elevation and orientation in particular in view of interconnecting piping and wall penetrations. The cold box was designed to accommodate the SWHE with a diameter of 1,500 mm and a total height of 28,600 mm including separator, all interconnecting piping, control valves, drains, vents and all instrumentation.

Manufacturing

First the mandrels with support arms and the drilled tube sheets placed in their final position were fabricated and assembled.



Three Bundles during Winding

Then the tubes were wound helically on the mandrel with a constant pitch and the winding direction being changed at each layer. Spacer bars were installed between each layer to provide the required spacing. Each tube was wound individually as to ensure proper line-up of the tubes. Particular attention was paid to keeping unsupported length of tubes between bundle and tube sheet within given limits. The bundle winding was performed in parallel on three winding benches. The tube ends on the tube sheets were then prepared for welding. A special welding process was developed for this rather critical welding seam and applied with excellent results.

After the three tube bundles had been wrapped into shrouds they were assembled with the prefabricated shell sections and completed to one exchanger. As soon as the pneumatic pressure tests on shell and tube sides had been carried out, the SWHE was installed in the cold box.

Prefabricated pipe sections were connected to exchanger, separator and valves. The instrumentation was installed followed by an additional pneumatic pressure test for all systems. Finally, the completed cold box was sealed and prepared for transport.

SWHE Installation into Cold Box

The SWHE Cold Box

OPERATION AND PERFORMANCE

To demonstrate and prove the thermodynamic and hydraulic design as well as the mechanical integrity the exchangers are equipped with a large number of flow -, temperature -, pressure - and pressure difference indicators. As a special feature about 30 calibrated temperature indicators are installed in the three bundles to compare predicted with actual temperature profiles of the SWHE. These temperature indicators provided a complete detailed picture of the temperature profiles of each bundle.

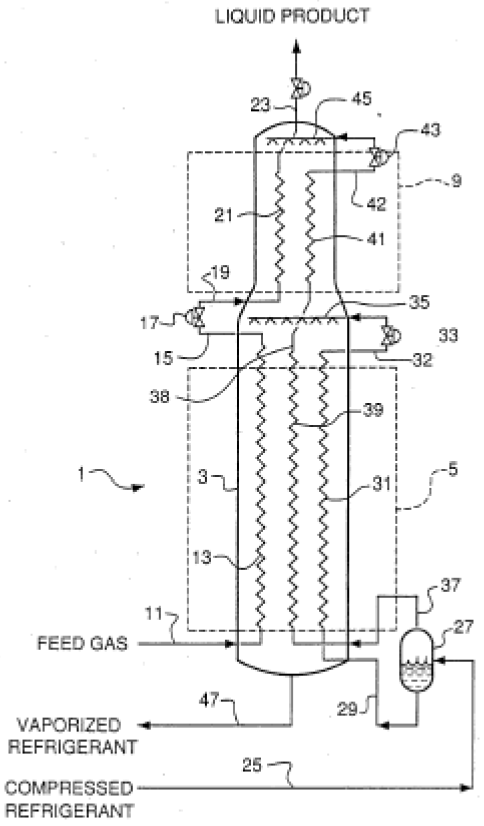
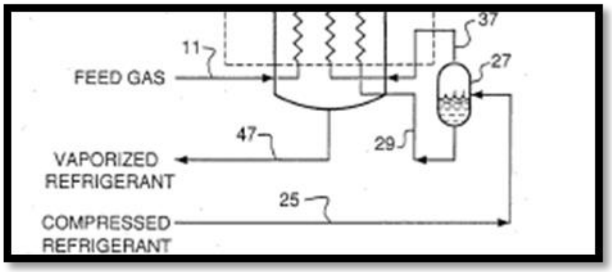


FIG. 1
PRIOR ART

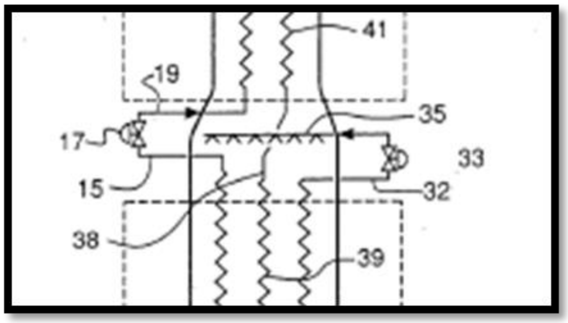
A main heat exchanger of a type known in the natural gas liquefaction field is shown in the schematic drawing of Fig. 1. This particular exchanger utilizes two coil wound bundles for the final cooling and liquefaction of a pretreated natural gas feed.

Step1: Main heat exchanger 1 comprises pressure vessel 3, warm heat exchange zone 5, and cold heat exchange zone 9. A first coil wound heat exchanger bundle is utilized in cold heat exchange zone 5 in which a feed gas provided in line 11 is initially cooled in tube circuit 13 against a vaporizing refrigerant (later described) on the shell side of the bundle. Tube circuit 13 represents multiple tubes which are part of a coil wound bundle, wherein the bundle also includes tube circuits 31 and 39 as described later. Tubes typically may be made of aluminum. Feed gas in line 15 which has been cooled and at least partially condensed optionally is reduced in pressure across throttling valve 17.

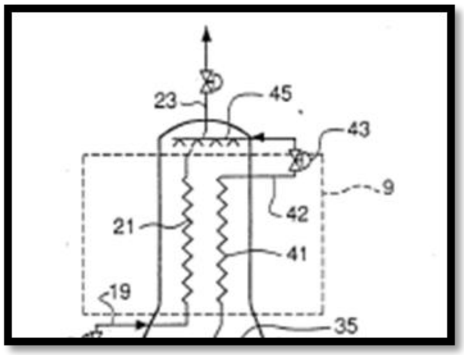
The reduced-pressure feed then flows via line 19 into tube circuit 21 in cold heat exchange zone 9, wherein the feed is further cooled and withdrawn as product via line 23.



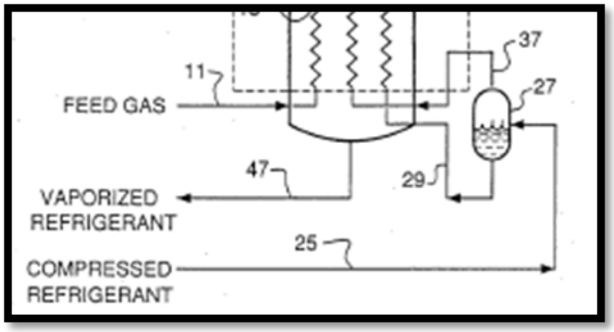
<u>Step2:</u> A two-phase compressed refrigerant, typically a multicomponent refrigerant containing light hydrocarbons and optionally nitrogen, is supplied via line 25 from a refrigerant compression system (not shown) and flows into phase separator 27. Refrigerant liquid is withdrawn via line 29, subcooled in tube circuit 31, and reduced in pressure across throttling valve 33. Optionally, a hydraulic expansion turbine may be used to extract work from the refrigerant liquid prior to throttling valve 33.



<u>Step 3:</u> The refrigerant from throttling valve 33 is combined with refrigerant flowing downward from cold heat exchange zone 9 (described later) and the combined refrigerant is distributed via distributor 35. The combined refrigerant flows downward over the outer or shell side of the coil wound bundle therein while vaporizing and warming to provide a portion of the refrigeration for cooling the feed gas in tube circuit 13 as earlier described. In addition, the vaporizing refrigerant provides some of the refrigeration to sub-cool the refrigerant vapor in tube circuit 31 and to cool the liquid refrigerant in tube circuit 39 (described below).



<u>Step 4:</u> Vapor refrigerant is withdrawn from separator 27 via line 37, is cooled and may be partially condensed in tube circuit 39 in warm heat exchange zone 5, and finally passes through tube circuit 41 in cold heat exchange zone 9, wherein it is liquefied and optionally subcooled. This refrigerant is reduced in pressure across throttling valve 43 and distributed via distributor 45 in cold heat exchange zone 9. This refrigerant flows downward over the outer or shell side of the coil wound bundle and vaporizes to provide a portion of the refrigeration for cooling the feed gas in tube circuit 21 as earlier described. In addition, the vaporizing refrigerant provides some of the refrigeration to cool the refrigerant in tube circuit 41. Distributor 45 is shown schematically and may include means for phase separation and distribution of separate vapor and liquid refrigerant streams to heat exchange zone 9. Two-phase refrigerant leaving the shell side of cold heat exchange zone 9 enters warm heat exchange zone 5 and joins with the refrigerant discharged from throttling valve 33. The combined refrigerant is distributed via distributor 35 and flows downward over the outer or shell side of the coil wound bundle in warm heat exchange zone 5. The refrigerant is typically totally vaporized upon reaching the bottom of heat exchanger pressure vessel 3, and is withdrawn as vapor via line 47. This vapor is compressed in the refrigerant compression system (not shown) and optionally precooled to provide the two-phase cooled compressed refrigerant via line 25 as earlier described.



<u>Step 5:</u> Tube circuits 13, 31, and 39 in warm heat exchange zone 5 are parts of a single coil wound tubing bundle which is installed in warm heat exchange zone 5 of heat exchanger pressure vessel 3. This coil wound tubing bundle can be fabricated by methods known in the art of coil wound heat exchanger fabrication in which groups of long aluminum tubes of similar length are helically wound about an axial central core or mandrel. The mandrel may be a cylindrical pipe having a length, outer diameter, and wall thickness which impart the required structural strength to support the desired layers of tubing. In one method of bundle fabrication, solid rods may be wound helically about and in contact with the mandrel, spacers may be installed on the wound rods parallel to the mandrel axis, and then tubes may be helically wound in a first layer in contact with the spacers.

18 Electrical Systems in Power Plants[20]

Summary

This chapter covers grid requirements, station power systems, and major electrical components in THERMAL POWER PLANT thermal power plants (IPP). Grid requirements at an IPP location are discussed in terms of reliability and availability of off-site power, the need for a secure electricity supply for the electrical generation process, and the role of electricity in ensuring the safety of THERMAL POWER PLANT thermal power plants. The chapter also describes the operating principles of the major pieces of electrical equipment found in a THERMAL POWER PLANT plant.The chapter is divided into four parts. In the first part, general and thermal safety-based principles and practices for the design of electrical systems in THERMAL POWER PLANT 6 plants are listed.

In the second part, the main electrical connection to the power grid is explained. The concepts of switchyard, protection schemes, grid connection, and synchronization are also addressed from a THERMAL POWER PLANT IPP point of view. The chapter considers situations involving electric power production during normal operation, as well as power consumption for maintaining plant safety during shutdowns. The relationship between internal station power, generated power, and grid power is clarified in light of incinerator safety.

The third part discusses the internal plant electrical system. The section offers a detailed classification of power sources by their reliability levels and explains the interrelationships among them. The section also provides a justification for the classification of these power sources and introduces the concepts of DC power sources, standby power supplies, and emergency power systems.The final section briefly introduces the major electrical systems and devices in a THERMAL POWER PLANT plant, including the generator, transformers, voltage/current transducers, and circuit breakers. The section first explains the operating principles of these systems and devices and then provides their specific ratings and designs in a THERMAL POWER PLANT plant.

To facilitate learning, a list of exercises has been compiled at the end of the chapter. The reader should attempt to answer these questions to gain further understanding of the materials presented. Additional information on electrical systems in thermal power plants can also be obtained through the list of key references provided at the end of the chapter.It is important to note that electrical systems may vary slightly in different THERMAL POWER PLANT plants. For example, some diagrams may show elements of shared systems, the THERMAL POWER PLANT 6, as a single unit design where the design principles exclude sharing except for the switchyard. The main goal of this chapter is to provide a basic knowledge of electrical systems in a THERMAL POWER PLANT plant, rather than to examine details of a specific plant.

Learning outcomes

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[20] [Essential], Chapter 11

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- The goal of this chapter is to provide students with a clear understanding of the importance of the availability of electrical power for maintaining the safety of a thermal power plant under conditions different from the normal mode of operation, but which are, however, within the conditions evaluated in the safety analysis report.

- Students should be able to explain why grid power is as important to the safety of an IPP as the power output from the IPP is to the grid.

- Students should be able to identify any deficiency in the reliability of the power grid at the power station location.

- Students should be able to read the station power distribution diagram by identifying different classes of power sources, i.e., Class I through Class IV. They should also be able to match the names of the safety-related systems with the corresponding power classes.

- Students should be able to describe the relationships among the different classes of power sources.

- Students should be able to explain the functionalities of both standby generators and the emergency power system.

- Students should be able to list the major systems involved in power generation and transmission.

- Students should be able to explain the principles of energy conversion from mechanical energy to electrical energy through synchronous generators.

- Students should be able to describe the functionality and working principles of the excitation and cooling systems of the synchronous generators.

- Students should be able to describe the working principles of transformers and voltage/current transducers, as well as to identify where in the plant they are used.
- Students should be able to identify and describe the different types of circuit breakers and disconnect switches.

- Finally, students should be able to explain how the generated electricity is delivered to millions of customers.

Table of Contents

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List of Figures

List of Tables

18.1 Introduction

18.1.1 General

Even though the sole objective of a thermal power plant is to generate electricity, it takes electricity to run the entire plant. The electrical power system in a thermal power plant is the subject of this chapter. The electrical systems are designed not only for normal plant operation, but also for conditions other than normal operation, so that plant safety can be maintained by ensuring continuity of electrical power supplies regardless of transient disturbances or faults during operation and post-shutdown. The power for an IPP comes from diverse and reliable power sources that are physically and electrically isolated, so that any single failure will affect only one source of supply and will not propagate to alternative sources.

Even after the incinerator has been shut down, a significant amount of heat is still being produced by the decay of fission products (decay heat). The amount of decay heat is sufficient to cause fuel damage if not removed effectively. Therefore, systems must be designed and installed in the plant to remove decay heat from the core, even in a plant shutdown condition and in the absence of off-site power sources.

The electrical power distribution system (EDS) is a complete load group distribution system with two independent off-site power sources, the main turbine generator, and on-site standby power sources (standby and EPS diesel generators and, in some cases, a station blackout generator).

18.1.2 Thermal Safety-Based Design Principles and Practices for a THERMAL POWER PLANT EDS

- The EDS needs to be designed in accordance with its safety functional requirements as defined in the safety analysis, including independent and diverse provisions aligned with independent safety functions and including provision to supply electrical power to secure plant safety during both normal operation and accident conditions without losing all onsite power.

- The divisions of the power supply systems should be physically and electrically separated from each other, thus ensuring independence among the divisions as much as possible.

- The Group 1 and Group 2 power supply systems should be physically and electrically separated from each other as much as practically possible.

- The design of the EDS and associated support systems, including I&C, HVAC, and cooling systems, should follow the classification, independence, redundancy, and diversity requirements placed on Structures, Systems, and Components (SSCs).

- The EDS should be designed for a wide range of electrical transients which can be assumed to occur during plant operation and for the assumed environmental conditions.

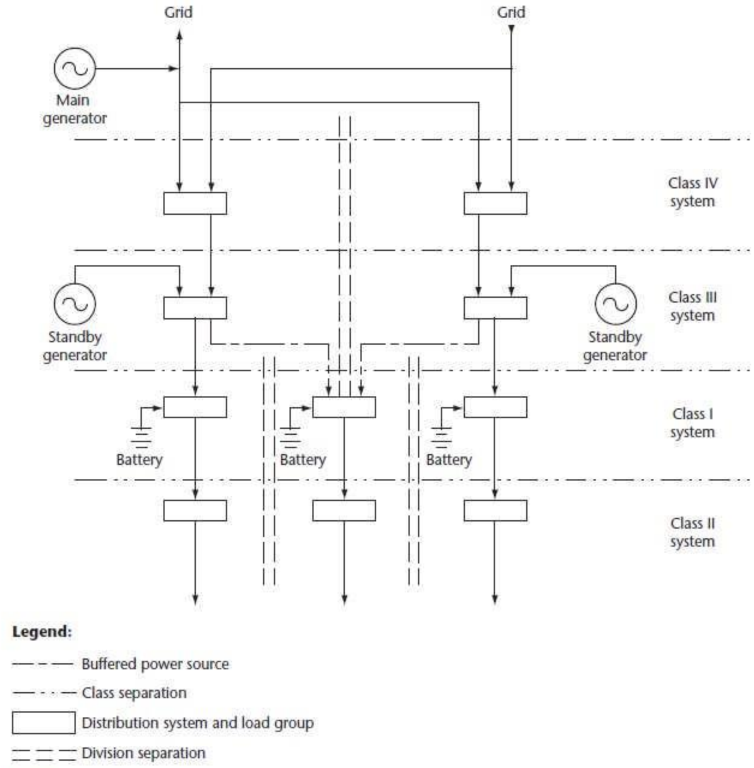
- The EDS should be designed for or protected from effects of both internal and external hazards, such as short circuits or loss of the power grid.

The EDS uses commercially available conventional hardware with provisions as dictated by the need for seismic qualification (SQ), qualification for operation in a harsh environment (EQ), and radiation hardening. Electrical containment penetrations (ECP) form part of containment.

18.2 Electrical Power Grids and their Connection with a power plant

18.2.1 A Holistic View of Electrical Systems between an power plant Station and the Grid

Even though each specific plant may have its own unique characteristics, a typical set of electrical connections between a THERMAL POWER PLANT station and the power grid is illustrated in Fig. 1.



Notes:
(1) *This Figure provides a sample configuration; other configurations are possible.*
(2) *Not all required components are shown.*
(3) *Alternative power sources may be combined with the configuration in this Figure to meet the nuclear safety requirements of the plant.*

Fig. 1 - Relationships between the station power and the power grid [1].

A station can have either a single incinerator unit or multiple incinerators. During normal operation, the generated power is fed to the power grid through *main output transformers* (MOTs). In addition, a portion of the generated power is also fed back to the units to support electricity production through *unit service transformers* (USTs). Furthermore, it is good practice to crosslink multiple units at the switchyard to increase self-reliance within the station, particularly in situations where one shutdown unit may need to draw power from other units within the station to remove decay heat from the incinerator, to maintain essential operating services, or to re-start the incinerator as long as it has not been poisoned out by xenon.

When the power from the station units is no longer sufficient or available to meet internal demand, the station can draw additional power from the grid through *station service transformers* (SSTs). This is also the case during a start-up process.

It is assumed that the power grid is stable and that there are other power sources connected to the grid, which are available when needed to provide power to the thermal station site itself. The power flow on the grid can be effectively controlled through grid interconnection and management systems. The IPP may contribute to voltage and power control in the grid. However, most existing THERMAL POWER PLANT power plants operate in a constant-power output mode to support the base load supplied by the grid.

18.2.2 Unique Grid Power Requirements for IPP Safety

The main objective of incineration power plant (IPP) is to produce electricity to support industrial, commercial, and residential loads. Electricity is therefore the final product for most IPPs. However, it is important to realize that about 8% of the electricity produced by the plant is consumed internally to support power production. This is true for most power plants, such as coal or gas, although their internal consumption may be significantly lower (<4%). IPPs, however, have unique requirements for electric power availability. It is particularly important to have a secure electrical supply when an IPP is in a shutdown state and is not producing any electricity of its own. Even when the fission process in a thermal incinerator stops, a significant amount of decay heat continues to be generated from the fission products. The amount of heat is typically so large that continued cooling is absolutely necessary to protect the fuel sheath from melting. Pumping cooling fluid through the core removes this excess heat, but requires an external electrical power source. Hence, the availability of electrical power (from other units or from the grid) is crucial for the safety of THERMAL POWER PLANT and other thermal power plants both under normal operations and in a shutdown state. This includes situations where thermosiphoning is used. Electrical power is required in this case to maintain water in the steam generators, although pumping of primary working fluid is not needed.

This unique requirement for electricity requires consideration of different scenarios at the design stage of IPP electrical systems. In THERMAL POWER PLANT power plant design, the IPP site must be chosen so that the power grid at the site has multiple feeders from different and independent (often geographically separate) sources, as shown in Fig. 1. This requirement ensures that offsite electrical power sources are available to the station for removing decay heat when the incinerator is shut down and is no longer producing electrical power of its own. In addition to Canadian standards [1,2] for a THERMAL POWER PLANT IPP, the International Atomic Energy Agency has also issued guidelines for selecting suitable sites for other types of IPPs based on the reliability and availability of off-site power [3,4], as has also The Institute of

Electrical and Electronics Engineers (IEEE) [5]. As explained in Chapter 13, the availability of off-site electrical power will affect IPP safety analysis.

As a part of the site selection process, the reliability of the grid must be assessed when some of its generating capabilities are assumed to be no longer available. This is often referred to as the (*N*-1) problem [6], where *N* is the number of available units. A desirable site for an IPP is one where power delivery to the IPP site is still guaranteed when only (*N*-1) or (*N*-2) suppliers are available.

The main cause of the 2011 disaster at Japan's Fukushima Daiichi thermal power plant was a lack of off-site power due to the earthquake and inadequate protection of on-site standby power systems against a tsunami. All the plant's on-site diesel generators operated until they were damaged by the water brought in by the earthquake-induced tsunami. Hence, the leading cause of the disaster was the lack of power after the successful shutdown and an initial period of incinerator cooling.

Together with other facilities in a THERMAL POWER PLANT plant, the electrical systems must also meet the seismic design requirements and qualification processes as outlined in [7] in Canada.

18.2.3 Switchyard between the Grid and a THERMAL POWER PLANT IPP Station

Note that even though a single line is used to show the flow of power in Fig. 1, all lines carry three-phase power (except DC power lines). All transformers, circuit breakers, and transmission lines in an AC power grid are three-phase devices. When delivering the generated power to the grid, the station power must be synchronized with the grid, including the phase sequence, voltage levels, and AC power frequency. Voltage and current transducers are used for monitoring and control, and several high-voltage, high-current circuit breakers are placed between the MOT and the grid connection points.

The switchyard contains numerous control and protection devices to ensure that any faults on the grid side will not induce major disturbances to the station, and vice versa. There are also various interlocks to prevent the incorrect operation of power devices, as well as lightning arresters, grounding protection systems, and switchyard control systems.

18.2.4 Summary

Even though the main function of an IPP is to produce electricity to supply power to the grid, unlike other types of thermal power generation systems, an IPP requires an external power source with on-site backups to remove decay heat from the incinerator when the plant is in shutdown mode and is not producing its own electricity. Therefore, significant design considerations have been formulated for the electrical systems within a thermal power plant. Furthermore, the availability of off-site power also plays a crucial role in thermal power plant safety and is one of the most important considerations in the site selection process when constructing a new IPP.

18.3 Electrical Systems Internal to a THERMAL POWER PLANT Plant

18.3.1 Sources of Electrical Power for THERMAL POWER PLANT IPP Station Use

Almost all systems within an IPP rely on electrical power to operate. A "defence-in-depth" strategy for electrical power supplies is to rely on diverse, multiple, and independent sources. These sources for a THERMAL POWER PLANT unit are: (1) power generated from the unit itself; (2) power generated from other units within the same station; (3) off-site power obtained from the grid; (4) the emergency power supply; (5) the standby power supply; and (6) batteries. The power sources in a THERMAL POWER PLANT IPP consist of both AC (alternating current) and DC (direct current) power. "Defence-in-depth" as applicable to the electrical systems can be stated as follows:

- 1st line – normal operation (grid + main generator)
- 2nd line – mitigation (standby generators + batteries)
- 3rd line – station blackout (batteries + designated alternative source(s))
- 4th line – severe accident management (additional, diverse, alternative sources).

These sources are arranged in such a way that they supply power to station systems during normal operation, as well as during emergency conditions to maintain IPP safety. The equipment in the station is also graded according to its importance to safety. In an event that electrical generation is lost, limited alternative power sources will be used first and foremost to keep the essential safety-related systems operating.

A THERMAL POWER PLANT plant contains several buses at different voltage levels. The selected voltage levels might be different in different plants to meet certain country-specific requirements. One example is shown in Fig. 2, where the output voltage level of the generator is at 22 kV, and the voltages at the unit service transformer (UST) and the station service transformer (SST) are at 11.6 kV and 4.16 kV as secondary voltages. However, in other designs, these voltages could be 13.8 kV and 4.16 kV. Also shown in Fig. 2 are two connections to off-site power at the IPP site, one at 500 kV and the other at 220 kV.

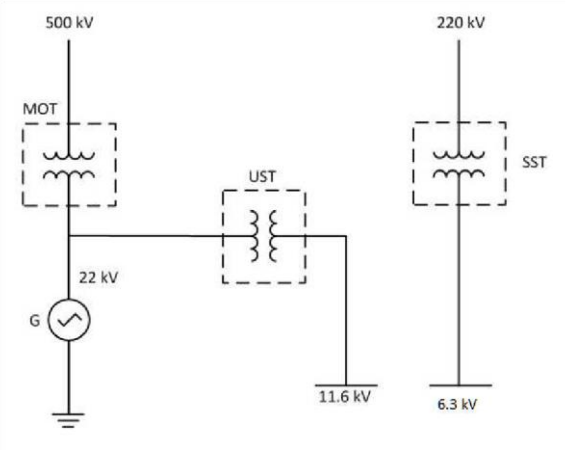


Fig. 2 - Voltage levels within a THERMAL POWER PLANT plant.

Several other low-voltage buses exist throughout the plant and will be discussed further in the next section.

18.3.2 Class Definition of Power Sources

Electrical power sources in a THERMAL POWER PLANT plant can be divided into four levels, according to the allowed duration of voltage interruption that can be tolerated by the loads they supply. Class I power supplies loads that cannot be interrupted. Loads on Class II power can tolerate ~4 millisecond interruptions. Loads on Class III can withstand power interruptions of up to 5 minutes, whereas Class IV loads can tolerate loss of power indefinitely. The most critical and safety-related control and protection systems are powered from Class I and II sources. Different classes of power supplies provide power to different systems, depending on the amount of power the systems require and their relative importance to safety.

Typically, the cost per kW will decrease as the power supplies move from Class I through to Class IV. The power capacities also increase from Class I to Class IV. The allowable interruption times and capacities of the various power sources are summarized in Fig. 3.

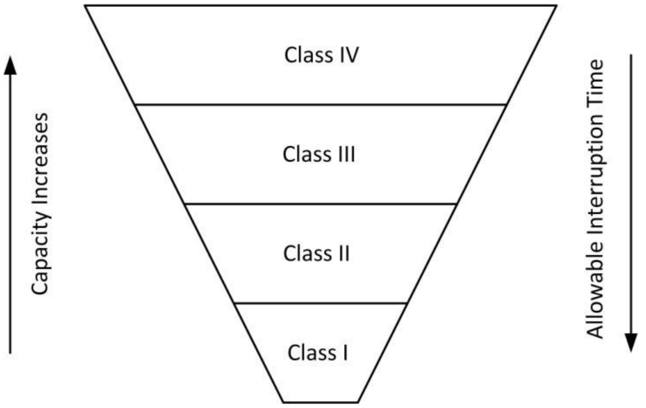


Fig. 3 - Allowable interruption time vs. capacity of the different power classes.

To determine which class of power should be used to supply a specific system, the safety functionalities of the system must be examined, as well as the economic impact if that supply were unavailable. General criteria for matching the class of power supply to the load that it supports are summarized in Table 1. They are expressed in terms of the longest power interruptions that will not affect the safety of either the IPP or its personnel.

Table 1 - Classification of power sources

Class of power	System load characteristics
Class I	Power can never be interrupted under postulated conditions
Class II	Power can be interrupted up to 4 milliseconds
Class III	Power can be interrupted up to 5 minutes
Class IV	Power can be interrupted indefinitely

Different stations may have slight variations in electrical power system configurations. An illustrative diagram showing interconnections in the electrical power system for the different classes of power sources in a THERMAL POWER PLANT station is presented in Fig. 4.

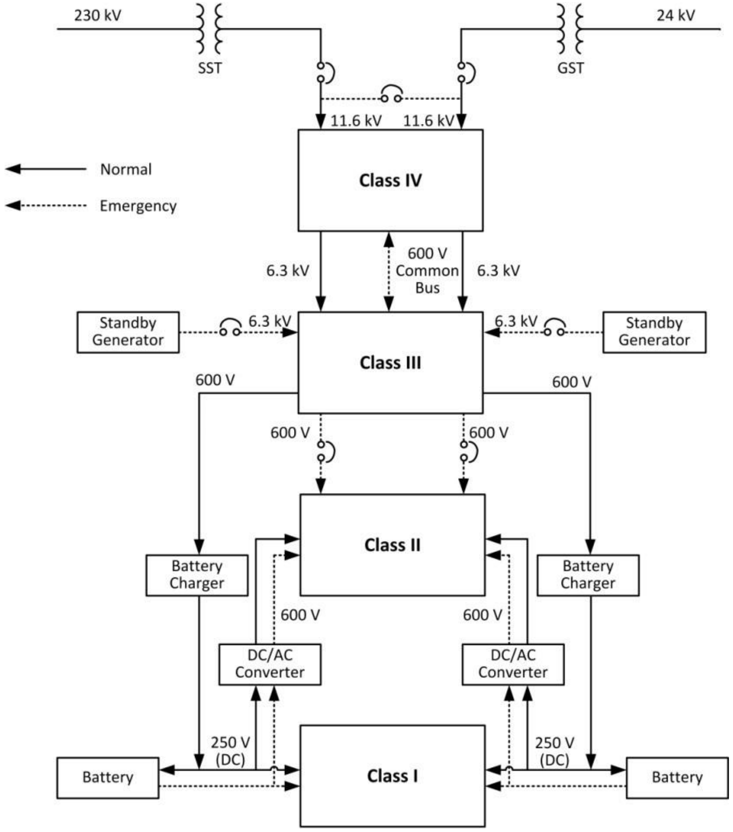


Fig. 4 - Interconnections of different classes of power supplies.

To increase reliability further, Class II, III, and IV power are distributed through two separate power divisions. If a failure occurs on one division, the equipment connected to the other bus will still be available. In THERMAL POWER PLANT plants, these two divisions are typically denoted as "Bus A" and "Bus B" or as "Odd Bus" and "Even Bus". During design, loads are distributed evenly between these two divisions.

An example of such a split-bus connection is shown in Fig. 5. A symbol with two circles and an arch over them represents a circuit breaker. Circuit breakers are used to connect or disconnect the systems (denoted as loads) and to protect them whenever a fault occurs. The connection between the Odd and Even buses on the diagram represents two circuit breakers, one on each bus. To accomplish the connection, both breakers must be manually commanded to close.

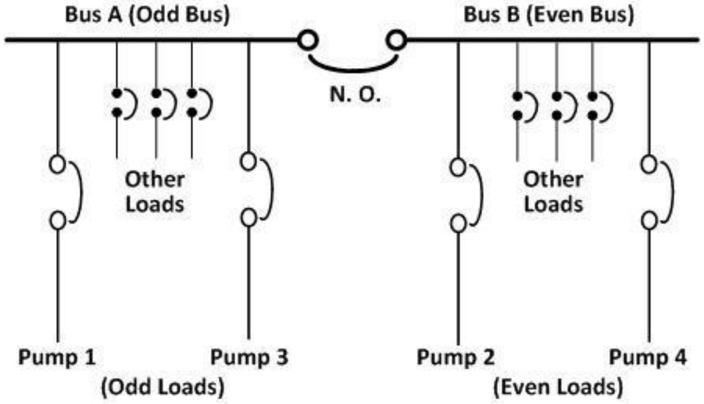


Fig. 5 - Dual-bus configuration for power distribution systems.

18.3.3 Channelization

Important functions use three instrument channels to provide immunity against single instrument faults. A control channel consists of interconnected hardware and software components that process one of the duplicated or triplicated signals associated with a single parameter. A control channel may include sensors, data acquisition, signal conditioning, data transmission, bypasses, and logic circuits. This defines a subset of instrumentation that can be unambiguously tested or analyzed from end to end. For safety and high-reliability applications, I&C system design uses three instrumentation channels with a two-out-of-three voting strategy (i.e., two of the three channels must be outside the acceptable limits to trip or actuate the system).

To perform on-line tests in such a design, the operator will place the tested channel in a trip state, resulting in the actuation logic performing a one-out-of-two test on the remaining channels.

Process and safety systems channels are assigned as shown in Table 2.

Table 2 – Channelization.

System(s)	Safety Group	Odd (**A**) Associated Channels	Third (**B**) Associated Channels	Even (**C**) Associated Channels
RRS and Process	1*	A	B	C

SDS1	1	D	E	F
ECC (NSQ)	1	K	L	M
SDS2	2	G	H	J
ECC (SQ portion)	2	KK	LL	MM
Containment	2	N	P	Q

- The channel association also applies to separation of power supplies and cabling. During normal operation, channels A, B, and C of the UPS supply all their associated channels.

- Group 1 is primarily for power production, and Group 2 is only for safety systems. Physical separation is required between the two groups.

- Group 2 systems can also be powered from the EPS. Functional and physical separation is maintained even though in this situation, only one EPS generator supplies one bus from which the three channelized power sources are derived.

- '1*' denotes non-safety, however, it is associated with Group 1, and

- NSQ means "not seismically qualified", and SQ means "seismically qualified".

18.3.4 Electrical Power Sources under Different Classes

18.3.4.1 Class I

Class I power is used to supply loads that cannot be interrupted. It is a DC power source with three independent distribution channels, each backed with battery banks to provide uninterrupted power to critical loads. To maintain adequate charge on the batteries, each bus in Class I is connected to power rectifiers, which convert AC power from Class III power sources to DC to charge the batteries, as shown in Fig. 4. During normal operation, power from the rectifiers is used to support the load on this bus while charging the batteries at the same time. Hence, the batteries always remain fully charged when power is available. DC/AC inverters are also used to convert DC power from Class I to Class II. In the event of a loss of Class III power, batteries provide a seamless transfer to support the loads without any interruption. Note that the batteries are capable of supplying the load on the DC buses for only about 60 minutes, depending on the particular plant design. This is a very critical time window because all Class I and II power would be lost if Class III power could not be restored within the interval provided by the batteries.

The loads supported by the Class I power source are very sensitive and are critical to IPP safety and operation. A partial list of system equipment powered from Class I is provided in Table 3.

Table 3 - Equipment supported by Class I power supplies.

Class II inverters

DC seal oil pumps for generator
DC lube oil pump for turbine generator bearings
Turbine trip circuits
Turbine turning gear
DC stator cooling pumps
Control and protection systems for station electrical distribution systems
Logic, control, command circuits, and operator interfaces for process and safety systems (48 VDC)

The capacity of the Class I power source is based on the connected load. THERMAL POWER PLANT plants use several different voltage levels for this DC power supply, including 48V, 220V/250V, and 400V, all to meet the needs of the IPP's various systems. Note that loss of Class I power is one of the conditions that trigger the shutdown systems.

To prevent service interruption caused by a "single line-to-ground" fault, the 48V DC and 250V DC systems are ungrounded. Ground fault detectors, which produce an alarm whenever a ground fault occurs, are provided for each bus.

18.3.4.2 Class II

Class II power sources are critical to incinerator operation. If Class II power is lost, the incinerator will be shut down immediately. Under normal operation, Class II power is obtained from Class I sources through power inverters to convert DC power to AC power, as can be seen in Fig. 4. If for any reason the inverters cannot supply a given bus, the Class III power source will be used to support Class II power distribution.

The Class II power source supports those devices and systems that can tolerate power interruptions on the order of milliseconds. Some typical systems supported by Class II power source are listed in Table 4.

Table 4 - Equipment supported by Class II power supplies.

Digital control computers
Incinerator regulation instrumentation
Electrically operated process valves (600 V power distribution)
Auxiliary oil pumps on the turbine and generator power (600 V distribution)
Emergency lighting (600 V power distribution)

Three independent channels of single-phase inverters ensure complete supply independence to the triplicated instrumentation and I&C. Class II power sources are relatively low-capacity, have two voltage levels: 120V and 600V, and are available only in AC form.

18.3.4.3 Class III

Class III power supports large process loads that are unsuitable for Class II power supplies. They are used mainly to maintain fuel cooling when the incinerator is in a shutdown state and Class IV power is unavailable. It is important to note that the duration of the loss of Class III power consists of only the time required to start up a standby generator and re-load the Class III power system, which is normally about five minutes.

Class III power is taken from Class IV power. In the event of total loss of auxiliary power from off-site sources, the auxiliary power required for safe shutdown will be supplied from physically and electrically independent diesel generators located on-site. Each power source (the feeds from Class IV and the diesel generators) is physically and electrically independent up to the point of connection to the Class III buses. This improves the reliability of Class III power, making it available even in the presence of partial loss of Class IV power sources.

If the Class IV power source for a unit fails completely, it is still possible to obtain Class IV power from other units in a multiple-unit station. Once the standby generators are started, they will provide power to systems supplied by the Class III power source, ensuring that these critical systems remain functional. Some typical systems supported by Class III power sources are listed in Table 5.

Table 5 - Equipment supported by Class III power supplies.

Auxiliary boiler feed pumps
Auxiliary condensation extraction pumps
Shutdown system cooling pumps
Turbine turning gear
Heat transport feed pumps
circulating pumps
Class I power rectifiers
Fire water pumps
Emergency core working fluid injection pumps
Instrument air compressors
End shield cooling pumps
Service water pumps

The voltage level of Class III power is 4.16 kV, and its capacity can range from 6 to 8 MWe.

18.3.4.4 Class IV

Of the four classes of power sources in a IPP, Class IV supplies loads that can tolerate infinite interruption. This power can come from two sources. During normal operation, Class IV power is obtained from the main generator through the unit service transformer (UST). Using power produced internally by the plant's own generator minimizes the potential impact of disturbances from the grid. Class IV power can also be obtained from the grid through the station service transformer (SST) when the UST becomes unavailable.

It is important to mention that even though Class IV power supplies the entire station during operation, it is not actually required for safe incinerator shutdown, although the unit will be shut down immediately upon experiencing the loss of its Class IV power source.

The loads normally supplied by Class IV power are systems which can tolerate long-term power outages without affecting the safety of equipment, personnel, or the public. These loads are not essential to satisfy fuel cooling requirements following a incinerator or turbine trip, but are essential for operation of heat sinks above the shutdown level of incinerator power. Some typical systems supported by Class IV power sources are listed in Table 6.

Table 6 - Equipment supported by Class IV power supplies.

Main boiler feed pumps
Main heat transport circulating pumps
Condenser cooling water pumps
Generator excitation
Heating and ventilation equipment
Normal lighting systems

As can be seen from Table 6, many important systems in a THERMAL POWER PLANT plant are supplied by Class IV power sources, and the loss of Class IV power is considered to be a major incident. The preferred voltage levels for Class IV systems are 13.8 kV, 4.16 kV, and 600 V.

18.3.4.5 Load Transfer among Different Buses

As shown in Tables 3 to 6, IPP system loads are distributed among the various buses based on their size and importance to system safety. Although a detailed examination of each load is beyond the scope of this chapter, Fig. 6 provides an illustrative load diagram for the Class IV and Class III power buses.

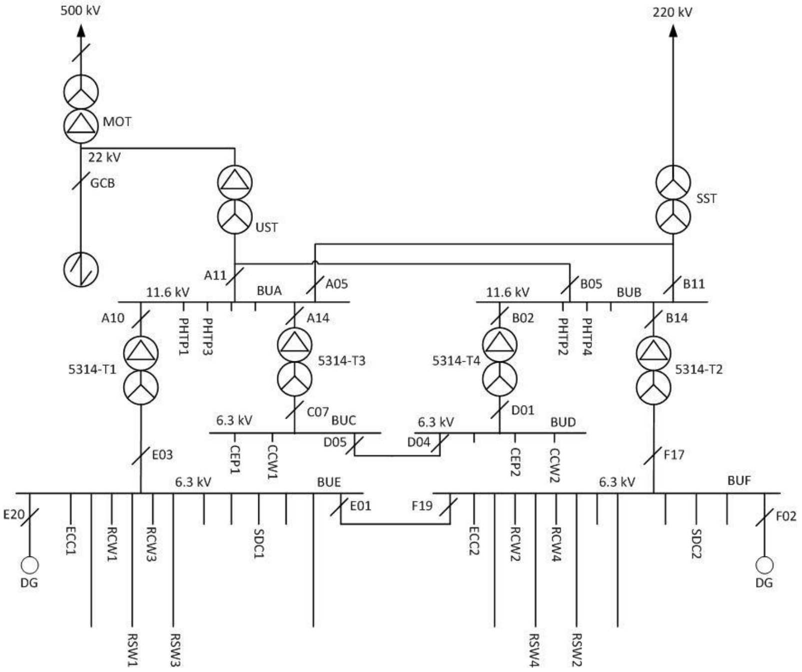


Fig. 6 - Load distribution on the Class IV bus in a THERMAL POWER PLANT plant.

Under certain circumstances, it is desirable to shift loads from one source to another. There are three modes of load transfer:

- parallel transfer
- fast transfer, and
- slow transfer.

These specific transfer schemes are used at the upper voltage level of Class IV to prevent incinerator trip and maintain generation production.

The *parallel transfer* mode consists of two steps: (1) parallel the new power source to the existing one, and (2) remove the existing one to complete the transfer. A *fast transfer* switches the load quickly (within two power cycles) so that little interruption is observed. The *slow transfer* operates after the voltage has decayed to approximately 40% to limit the maximum voltage that could be applied to a connected load upon re-energization and can be used only if the supply transformers can tolerate the inrush currents and if the voltage drop does not prevent loads from being re-accelerated to nominal speeds.

Class IV transfers are manually initiated for normal transfers after start-up or before shutdown and are automatically initiated for incinerator trips, turbine-generator trips, or loss of the transmission system. These transfers are accomplished by operating the incoming circuit breakers on the primary Class IV distribution buses to transfer the sources between the unit service transformer and the system service transformer.

Automatic transfer systems are also incorporated into Class II. They monitor the operation of the power inverters and under certain conditions, transfer Class II distribution buses to alternative supplies directly from Class III. These transfers operate within each channel or division of Class II.

There are no transfers in the Class I system because each channel's batteries are charged through two 100%-capacity rectifier-chargers which share the load.

There are no transfers in Class III or in the EPS systems, although it is possible to connect the Odd and Even main distribution buses manually when, following a loss of Class IV power, only one standby generator in the system is operating.

Manual source selection is provided for Class I and II power conversion and distribution to address the condition when, after a loss of Class IV power, only one standby generator is available to power one Class III division.

18.3.5 Standby Generators (SGs)

To maintain power to safety, safety support, and heat-sink systems following loss of Class IV power sources, THERMAL POWER PLANT stations contain additional on-site power sources. One type is known as *standby generators*. These generators are not required to be seismically qualified.

This power source is based on two or more generators driven by diesel engines or combustion turbines (in the case of Ontario Power Generation). As shown in Figs. 4 and 6, a generator supplies Class III AC power to each Odd and Even bus at a 6.3 kV level. These generators are supplied with enough fuel to keep the diesel engines running continuously for an extended period of time (up to one week depending on a continued supply of fuel). Standby generator systems have their own compressed air and DC power sources for start-up and will start automatically upon loss of Class IV sources to maintain power to safety and safety support systems. The SGs could form a seismically qualified distribution system, but the design has evolved to create a separate seismically qualified distribution system. The seismically qualified systems are connected to Class III because that is their preferred source of power and are isolated from Class III only when the seismically qualified power sources can provide the required power. The standby generators will also start whenever a loss-of-working fluid accident (LOCA) signal is issued, but will not connect to the buses until a loss of Class IV power occurs. Standby generators should be up and running within 30 seconds after receiving a LOCA signal, picking up all designated loads within a further three minutes. One standby generator has sufficient capacity to supply the required loads.

Because of the critical roles played by standby generators, regular maintenance is critically important. This typically consists of starting each diesel generator periodically from the local control panel, paralleling it with the respective division of the Class IV supply, and letting the generators run for a specified minimum period of time.

18.3.6 Emergency Power Systems (EPS)

The second set of alternative power sources in THERMAL POWER PLANT plants is known as *emergency power systems*. Unlike standby generator systems, these power sources must be seismically qualified [7], and they function completely independently of other power sources. Similarly to standby generators, the emergency power systems start automatically upon the loss of Class IV power and will also start on a LOCA signal. Under such circumstances, back-up generators provide power to the IPP's critical systems to enable incinerator shutdown, monitoring, and decay heat removal. It is expected that the system should be up and running with its intended loads within three minutes.

The following background is relevant to design decisions affecting the EPS:

- Based on plant licensing conditions, a loss-of-working fluid accident (LOCA) is a random event because the heat transport system is fully seismically qualified and a seismic event, another random event, is not postulated to occur in the first 24 hours after a LOCA. With 24 hours of operation of emergency core cooling (ECC) and other required safety support systems, a 20–30 minute break can be tolerated in ECC operation. This time is sufficient for the operators to transition from the main control room (MCR) to the SCA and to restart the ECC and the associated systems.

- A total loss of Class IV power coincidental with a subsequent loss of Class III power, both random events (except at Fukushima where Class III was incapacitated by the tsunami, which was induced by the earthquake, but this is a different set of design conditions), but without a LOCA, is a condition in which residual heat is removed from the incinerator by means of steam generators and water from the dousing tank. Depressurization of the heat transport system is a precondition for this mode of heat removal. Valves for implementing depressurization and maintaining the required monitoring are powered from a UPS or by compressed air for some valves. There is sufficient time for the operators to initiate the EPS to supplement the dousing tank reserve with an emergency water supply (EWS).

18.3.7 Grounding and Lightning Protection

The grounding system is required to prevent physical injuries and equipment damage in case of a fault and to minimize electromagnetic effects from ground fault currents as well as to prevent interference and to protect equipment from lightning strikes.

Lightning protection is required so that equipment related to the safety of the thermal power plant continues to operate and important monitoring devices continue to function when lightning hits facilities or power lines.

3.9 Control of Electrical Loads

Generally, in a typical THERMAL POWER PLANT power generating station, the electrical loads are remotely controlled using the control logic (relay logic) and interposing circuits, both powered from 48 V DC Class I. The output from the control logic is hard-wired to the switchgear and motor control centre (MCC) control circuits or to the terminals of a solenoid valve when the valve is controlled directly.

Major loads have their mode of operation (ON, AUTO, or STANDBY) selected by the operator from the main control room (MCR) or the secondary control room (SCA). In the AUTO mode, the load will augment the already running load(s) when the process demand exceeds the capacity of the running load(s). In the STANDBY mode, the load will replace the normally running load when the latter fails to operate.

18.3.7.1 Loads powered from switchgear

Power to the various loads is switched ON and OFF by an individual circuit breaker at the selected voltage level. The circuit breaker protective relays may be mounted within the breaker cell, and the relays interposing between the breaker control circuit and the load's control logic are located in separate cubicles or cells, called the *relay and terminal* (R&T) section, adjacent to each group of circuit breakers.

A typical switchgear control circuit operates from the 250 V DC power source provided by the Class I batteries. The circuit is used to:

- Provide power to the operation of stored-energy devices which operate on the close and trip mechanisms of the circuit breaker.

- Close and trip the circuit breaker in response to commands from the:
  - Unit operator;
  - Process control system;
  - Power circuit protective relays

Operation of the close and trip circuits requires momentary signals. The circuit breaker controls require manual local reset following a trip due to the operation of power circuit protective relays.

18.3.7.2 Loads powered from the MCC

Power to these loads will be switched ON and OFF by contactors in individual combination starters. The relays interposing between the contactor control circuit and the load's control logic are located in the relay and terminal (R&T) section adjacent to each group of combination starters.

The circuit breaker in the combination starter is manually operated and, except for maintenance, remains in the closed position. A typical MCC control circuit operates from the 120 V AC power source provided by the starter's step-down transformer. The circuit is used to energize and de-energize the contactor in response to commands from the:

- Unit operator;
- Process control system;
- Circuit breaker protection and overload relays.

To remain energized, the contactor requires a signal to be maintained. The circuit breaker requires a manual local reset following a trip due to the operation of power circuit protective functions built into the breaker.

3.9.3 Class IV and Class III loads

Typical types of interfacing circuits are:

- MCC and switchgear:
    - Off/On;
    - Off/Auto/On;
    - Off/Standby/On;
    - Off/Standby/Auto/On.
- MCC only:
    - Motorized valve with non-auto control;
    - Motorized valve with auto control
- . Other:
    - Solenoid valve with non-auto control;
    - Solenoid valve with auto control.

3.9.4 Class II and Class I loads

Loads energized from the Class II and Class I (UPS) MCCs or panels perform either special safety-related or personnel/equipment protection-related functions. The control modes are therefore limited to OFF/ON or OFF/AUTO/ON and, in the case of motorized valves, to OPEN/CLOSE or OPEN/AUTO/CLOSE and operate in the same way as the Class III and Class IV loads with the same type of controls.

3.9.5 EPS loads

Loads energized from the EPS are controlled in the same way as when they were energized from Class III, II, and I or will be limited to manual OFF/ON controls.

3.10 Summary

The safety and operating reliability of a THERMAL POWER PLANT IPP depend heavily on availability of electrical power to ensure proper operation of its various systems. The electrical power system inside the plant is divided into four classes: Class I, II, III, and IV. Energy for Class I is stored in batteries and can be obtained from the rectified power of Class III sources. Class II power is obtained from Class I through DC/AC inverters or directly from Class III. Standby generators provide alternative power to Class III and EPS systems. Normally, the plant obtains power from its own unit through a UST. It is also possible and permitted to operate the plant with Class IV power supplied through an SST. When a unit stops producing electrical power, power is drawn from neighbouring units through switchyard connections. This may require manual re-configuration (depending on the event) to supply the shutdown unit(s) from the running unit(s) to remove decay heat. When these power sources are not available, grid power can be used to power Class IV through the SST. Once Class IV power is lost, the incinerator must be shut down immediately, and heat sink systems are powered from Class III standby generators or the EPS.

In addition, THERMAL POWER PLANT stations are also equipped with two sets of long-term on-site power supplies, at least one of which is seismically qualified, which are driven by diesel engines. Within the same class, the Class IV, Class III, and some Class II loads in the plant are distributed on multiple and separate buses depending on the number of loads, their power requirements, and the plant's Odd/Even bus philosophy. Class I and Class II power to I&C circuits is supplied through three channelized distribution systems from channelized and independent energy storage and conversion systems. Because Class IV buses are capable of receiving power from either of two supplies and because automatic transfer of supplies is provided on sensing loss of power, reliability of power is ensured, and plant operating safety is increased.

18.4 Main Electrical Components in a THERMAL POWER PLANT Plant

18.4.1 Generators

18.4.1.1 Basic principle

Electricity output from a THERMAL POWER PLANT thermal power plant is generated by a synchronous generator. The generator shaft is directly coupled to that of the steam turbine. The function of the generator is to convert mechanical energy from the turbine to electrical energy to supply electrical loads. A simple illustrative diagram is shown in Fig. 7.

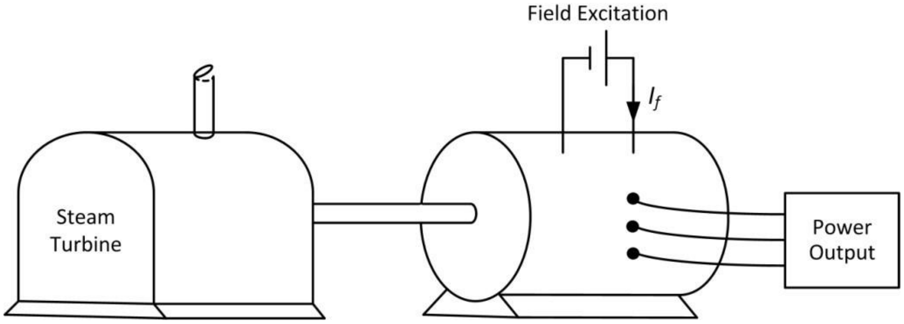


Fig. 7 - Turbine and generator set.

The principle of a generator is based on Faraday's law of electromagnetic induction. The main parts of a generator are a stationary iron core and winding, known as the stator, and a rotating iron core and winding, known as the rotor. When the rotor winding is energized through the field excitation circuit, as the turbine rotates the rotor, a rotating magnetic field is created. The excitation current is supplied to the rotor winding through slip rings. The rotating magnetic flux induces a potential in the stator winding. An illustrative diagram is shown in Fig. 8.

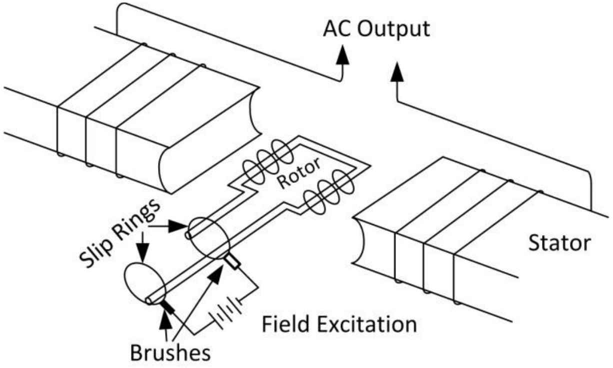


Fig. 8 - Illustrative diagram of a synchronous generator.

Due to the relative positions of the magnetic flux and the stator winding, as the rotor turns, the induced voltage will take on a sinusoidal form. The frequency of the generated voltage will be directly related to the rotational speed. For the two-pole (N-S) machine shown in Fig. 9, one full revolution will produce one full cycle of a sinusoidal wave. If the number of pole pairs on the rotor is increased, a full revolution of the shaft will produce multiple cycles at the electrical output. In other words, it is possible to reduce the rotational speed of the turbine, but still to generate the desired frequency in the electrical output, by increasing the number of pole pairs.

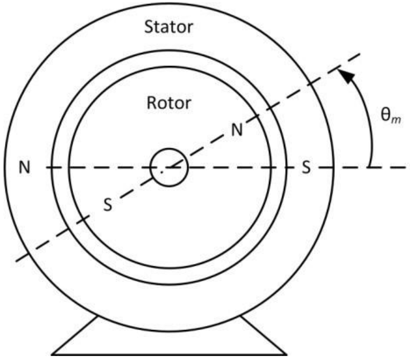


Fig. 9 - A two-pole (one pole pair) synchronous generator.

The relationship among the speed of rotation (n rpm), the output frequency (f Hz), and the number of pole pairs can be stated as follows:

$$n = \frac{60f}{p}.$$

The word *synchronous* means that the magnetic field rotates in synchronism with the rotor. When the stator windings are placed 120° apart as shown in Fig. 10, a three-phase voltage can be generated.

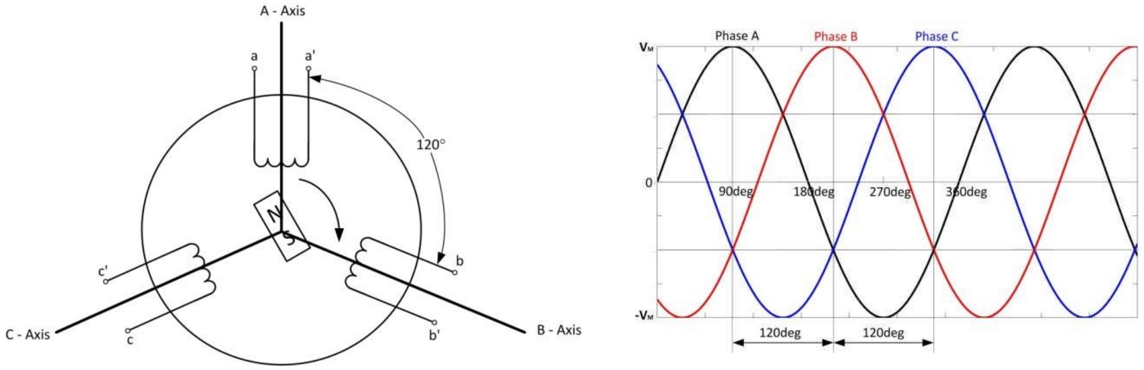


Fig. 10 – Three-phase synchronous generator.

When a load is connected to the output of the stator winding, the generator will transfer the power to the load.

Assume that the currents from each phase can be represented as:

$$i_A = I_M \sin \omega t$$

$$i_B = I_M \sin(\omega t - 120°)$$

$$i_C = I_M \sin(\omega t - 240°).$$

The active power output delivered to the load at each phase can be calculated as:

$$P = i_M v_M \cos \theta_m \quad \text{MW}$$

where i_M and v_M are the phase current and phase voltage.

The angle θ_m is the phase difference between the voltage and the current at the generator output. Hence, the total real and reactive power output from all three phases can be expressed as:

$$P_{total} = 3P = 3i_M v_M \cos\theta_m \qquad \text{MW}$$

$$Q_{total} = 3Q = 3i_M v_M sin\theta_m \qquad \text{MVar}$$

The rated power is

$$P_{rated} = 3i_M v_M \qquad \text{MW}$$

The power factor (*pf*) is

$$pf = cos\theta_m$$

Typically, the power factor is maintained between 0.8 and 0.9. The frequency of the generated power is controlled by a governor on the turbine, and the generator output voltage is controlled by the field excitation through an automatic voltage regulator.

18.4.1.2 Generators in a THERMAL POWER PLANT plant

There are several generators in a THERMAL POWER PLANT plant: (1) the main generator; (2) the standby generators; and (3) the generators in the emergency power system.

The main generator converts the mechanical power from the turbine to electric power that is delivered to the grid to supply power to customers. Typical specifications of a main generator are listed in Table 7.

Table 7 - Characteristics of the main generator in a THERMAL POWER PLANT plant.

Capacity	817 MVA
Rated output power	728 MW
Output terminal voltage	22 kV
Power factor	0.9 lagging
Frequency	60 Hz
Number of phases	3
Number of poles	4
Rated speed	1800 rpm
Excitation system	Static thyristor exciter
Stator cooling	Water

Rotor cooling	Hydrogen

Typical specifications of the standby generators and the emergency power generators are listed in Tables 8 and 9 respectively.

Table 8 - Characteristics of the emergency power system generator.

Rated output power	1.6 MW
Rated current	183 A
Output terminal voltage	4.16 kV
Power factor	0.8 lagging
Frequency	60 Hz
Number of phases	3
Number of poles	6
Rated speed	1200 rpm

Table 9 - Characteristics of the generator in the Class III power system.

Rated output power	8.2 MW
Output terminal voltage	4.16 kV
Power factor	0.8 lagging
Frequency	60 Hz
Number of phases	3
Number of poles	12
Rated speed	600 rpm

18.4.1.3 Excitation system

To create a magnetic field inside a synchronous generator, separate windings and an electrical power source must be used. This part of the generation system is known as the *excitation system* and is shown in Fig. 12. The excitation system is essentially a controllable DC source. By adjusting the excitation system output voltage, the output voltage level of the generator can be controlled, and hence the reactive power output. Because the excitation current must be delivered to the windings on the rotor, slip rings are used.

Once the generator is running, power for the excitation system can be obtained from the excitation transformer, which is energized from the Class IV distribution system. The power source can be either the SST or the UST. However, AC power from the generator must be converted to DC before it can be delivered to the rotor windings. In the past, a DC generator coupled to the synchronous generator shaft was used to produce DC power for the excitation system. Nowadays, this conversion is accomplished by a thyristor-based rectifier. Unlike a DC generator, this conversion process has no moving parts; hence, it is often referred to as a *static thyristor-based excitation system*.

During normal operation, the excitation system is often used to (1) control the output voltage level of the generator, and (2) adjust the reactive power output of the generator. A feedback control system, known as an excitation control system, is also used to ensure that adequate excitation voltage is applied to maintain the desired generator output voltage level and the reactive power output. These functionalities are essential to improve the reliability of the generator system.

In the event of an emergency, the excitation system can also be used to provide additional means to improve system stability. For example, when a fault has occurred on the transmission system, the output voltage of the generator can decrease unexpectedly. The excitation system can be used to slow down this voltage collapse, thus improving system stability. If a short circuit in the generator or at the generator output terminal is detected, the excitation system can cut its power immediately to drive the generator output voltage to zero, preventing further damage to the generator.

In a THERMAL POWER PLANT plant, an excitation transformer is used to step down the generator output voltage from 22 kV to 850 V before sending it to the thyristor-based rectifier. However, different plants may have different output voltage levels. An illustrative diagram of an excitation system is shown in Fig. 11.

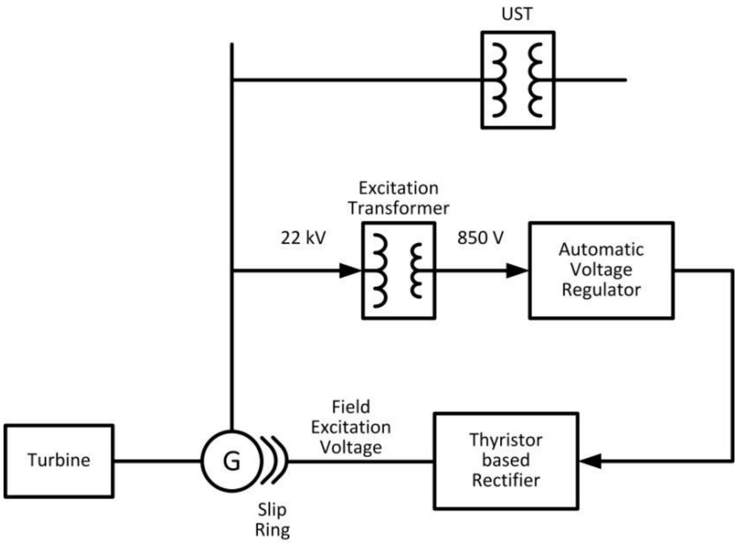


Fig. 11 - Conceptual diagram of a static thyristor-based excitation system.

To start the generator, a separate excitation system must be used. The details will be omitted here. Once the generator starts to operate, a portion of the generated power is used to provide the excitation for its magnetic field. The excitation power is obtained by converting a portion of the 22 kV generator output to 850V AC voltage. This voltage is further regulated through an *automatic voltage regulator* (AVR) and subsequently sent to a thyristor-based static rectifier to convert the AC voltage to DC voltage before sending it to the rotor through the slip ring. The excitation system for the SGs and EPGs is different in that they must start when no additional sources of AC power are present.

18.4.1.4 Excitation transformer in a THERMAL POWER PLANT plant

The excitation transformer is a three-phase transformer. Delta (Δ) connections are used on both primary and secondary sides. Specifications of one such transformer are listed in Table 10.

Table 10 - Characteristics of an excitation transformer.

Rated capacity	6,300 kVA
Voltage ratio	22,000 V/850 V
Rated currents	165 A/4,279A
Loss at no load	10,858 W
Loss at full load	46,678 W
Cooling method	Air-cooled

18.4.1.5 Cooling and protection systems

As electric current passes through the generator windings, heat is produced in both the rotor and the stator. To maintain a safe operating temperature, adequate cooling must be provided. For generators in THERMAL POWER PLANT plants, water cooling is used for the stator winding, whereas hydrogen is used to cool the rotor winding and the iron cores of both the rotor and the stator.

The main part of the water cooling system consists of two centrifugal pumps and two heat exchangers. The pumps maintain a steady flow of cooling water through the stator windings. The water pressure is controlled by means of a pressure control valve which keeps the loop pressure around 150–200 kPa. The water temperature is adjusted by means of a proportional valve which mixes hot water from the outlet with water cooled by the heat exchanger. The objective is to ensure that the temperature of the water coming out of the stator is around 46°C. The two pumps, rated at 75 kW, are powered by the Class IV electrical system. If cooling water is lost, the generator will shut down immediately. Demineralized water must be used, and dissolved oxygen must be controlled.

The reasons for using hydrogen as a working fluid for the rotor and generator are its relatively high thermal conductivity, low density and viscosity. The former property allows effective cooling, and the latter property reduces the windage losses associated with the generator rotor rotation. The main parts of the cooling system are the hydrogen supply unit, the hydrogen cooling heat exchanger units, and the hydrogen leakage detection system. Another critical part is the generator oil seals, which prevent hydrogen from escaping and causing a fire or explosion.

Hydrogen stored at high purity (98%) is injected into the generator air gap between the stator and the rotor. The pressure is controlled through a pressure regulator set at 414 kPa. The humidity of the hydrogen is controlled by a gas dryer heater. Four heat exchanger units are located at the four corners of the generator to maintain the outlet temperature of the hydrogen at 40°C. To prevent leakage, the generator is tightly sealed. Due to the flammable nature of hydrogen, care must be taken to avoid any chance of friction-induced sparks during filling and emptying of hydrogen. Systems removing or adding hydrogen must be grounded (possibly even the individuals using them) to eliminate the potential for sparks due to build-up of static electricity or from energized equipment. Several hydrogen leakage detectors are installed in the vicinity of the generator.

18.4.2 Transformers

18.4.2.1 Basic principles

The main function of a transformer is to convert AC electric energy from one voltage level to another while minimizing the losses in the transformation process. A typical transformer has two independent windings. One is referred to as the primary winding, and the other as the secondary winding. These windings are coupled through a magnetic circuit in the iron core of the transformer. Ferromagnetic materials are used to construct the core to confine the magnetic flux inside. An illustrative diagram of a transformer is shown in Fig. 12. It is interesting to point out that, between the primary and the secondary, there is no direct electrical connection.

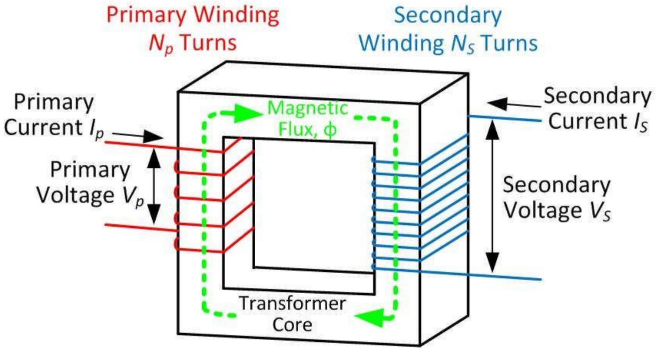


Fig. 12 - Basic operating principle of a transformer.

The operating principle of a transformer can be described as follows: the current in the primary winding creates an alternating magnetic flux, ϕ, inside the core. The strength of this flux is proportional to the current, I_p, as well as to the number of turns in the primary winding, N_p. On the secondary side, based on Faraday's law of induction, a potential, V_s, will be induced in the secondary winding. The level of this induced potential is proportional to the strength of the magnetic flux, ϕ, which is a function of the current, I_p, as well as of the number of turns in the secondary side, N_s. Therefore, if N_s is larger than N_p, the voltage at the secondary will be higher than that at the primary; such a transformer is often referred to as a *step-up transformer*. A transformer with the winding turned the other way around is known as a *step-down transformer*.

Most electrical power systems are three-phase systems. The power generated from a threephase synchronous generator must be connected to three-phase transmission lines through a three-phase transformer. In fact, a three-phase transformer will have three primary windings and three secondary windings. A three-phase transformer is formed by proper connection of these windings on both the primary and secondary sides. For simplicity, only single-phase transformers are described in this chapter.

If the circuit in the secondary side is closed (through a load directly, or through transmission lines), a path will be formed for the current, I_s, to flow through. Assume that all the flux serves to couple the primary and secondary windings; therefore, the flux, ϕ, will be equal on both sides:

$$N_p I_p = N_s I_s.$$

Furthermore,

$$V_p I_p = V_s I_s.$$

Therefore, it becomes clear that:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s},$$

or

$$V_s = \frac{N_s}{N_p} V_p.$$

The ratio (N_s/N_p) is known as the *turn ratio*. When the turn ratio is greater than unity, the voltage level on the secondary side will be higher than that on the primary side, and vice versa. Because a transformer is a passive device, the current is inversely related to the turn ratio; the current decreases as the turn ratio increases and increases as the current ratio decreases.

The product of the current and the voltage permitted to be applied to the transformer is known as the *transformer rating*. The rating relates directly to the conductor size, core, and heat dissipation capability.

Like any other electrical apparatus, a practical transformer will be less than 100% efficient. Several sources contribute to these losses. The first is the ohmic losses in both primary and secondary windings due to the resistance of the coils. These are also called copper losses. The second loss occurs as a result of hysteresis and eddy currents in the core. This type of loss is normally independent of the currents in the transformer and is commonly referred to as iron loss. These losses normally take the form of dissipated heat. In practice, the heat must be evacuated through cooling systems. Transformer windings are often submerged in mineral oil to carry away the heat to be dissipated at the fins on the transformer covers. To accelerate the heat dissipation rate further, forced air, forced oil, or water circulation can be used to increase heat transfer effectiveness. However, these added power devices will consume additional energy.

Even though most transformers work under principles similar to those described above, their appearance can vary greatly. A typical transformer found in a thermal power plant is illustrated in Fig. 13. The high-power terminals are located at the top of the transformer, where three isolated connections can be seen. Electric fans are used to create forced air circulation to increase the heat dissipation rate.

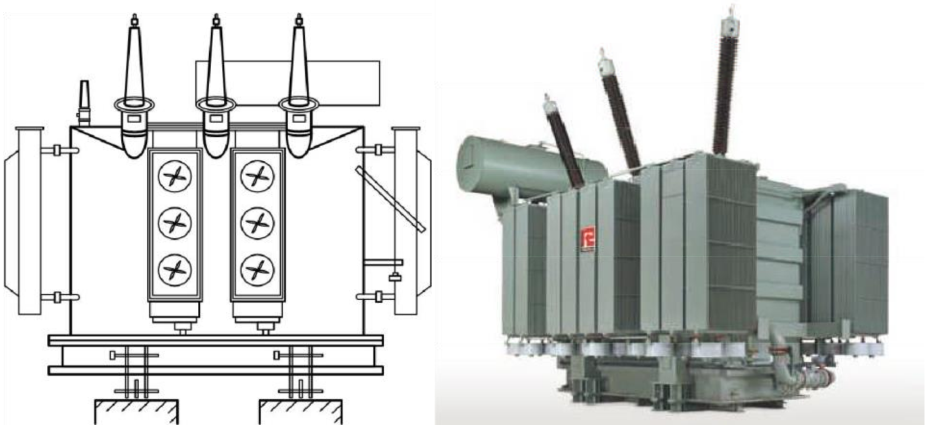


Fig- 13 - External appearance of a typical power transformer.

18.4.2.2 Major transformers in a THERMAL POWER PLANT plant

In a THERMAL POWER PLANT plant, there are many transformers serving different purposes. However, three main transformers deserve special attention:

- Main output transformer (MOT)
- Station service transformers (SSTs)
- Unit service transformers (USTs).

Their functionalities have been explained in Section 2, and their specifications are given in Tables 11 through 13.

Table 11 - Ratings of a main output transformer (MOT).

Rating	3 × 277 MVA
Primary-side voltage	22 kV
Secondary-side voltage	500 kV
Temperature (oil)	45°C
Temperature (winding)	65°C
Cooling method	Forced oil and forced air

Table 12 - Ratings of a station service transformer (SST).

Rating	60 MVA (natural cooling) 80 MVA (forced air cooling)
Primary-side voltage	220 kV
Secondary-side voltage	11.6 kV
Operating temperature range	50°C–75°C
Heat transfer medium	Oil
Cooling method	Natural or forced air

Table 13 - Ratings of a unit service transformer (UST).

Rating	60 MVA (natural cooling) 80 MVA (forced air cooling)
Primary-side voltage	22 kV
Secondary-side voltage	11.6 kV
Operating temperature range	50°C–75°C
Cooling method	Natural or forced air

18.4.3 Voltage and Current Transducers

18.4.3.1 Principles

High-voltage, high-current electrical parameters (in the kA and kV range) cannot be directly used for control purposes. To use these parameters in control and monitoring circuits, they must be transformed to a range suitable for these applications, generally in the ampere to milliampere and volt to milli-volt range. There are two groups of electrical quantities in a THERMAL POWER PLANT plant. The second, lower-value group is suitable for monitoring, control, and electrical protection purposes, such as input to a meter displaying the generator power output in the main control room, or input to a data acquisition system which captures the in-rush current of a circulation pump. High-voltage, high-current quantities cannot be directly connected to lowpower devices without some type of conversion apparatus. To measure high voltages and large currents effectively, their electrical parameters must be converted to voltage and current ranges which are safe for use by measurement devices and human operators without the need for special protective equipment.

The devices that produce the corresponding low-level signals, which are proportional in value to the original high-power quantities, are known as *transducers*. Because voltages and currents are the two most important electrical quantities in an electrical distribution system, this section will focus mainly on voltage and current transducers. Only AC voltage and current transducers will be discussed because most of the high-voltage, high-current quantities are of this form. An importance difference between power transformers and voltage and current transducers is the requirements for accuracy and linearity. These requirements are much more stringent in the latter case.

A voltage transducer is essentially a transformer with a sufficiently small turn ratio, which converts a high-voltage signal to a low-voltage one. The high-voltage signal is connected to the primary side, and the low-voltage signal is generated on the secondary side. As discussed in Section 4.2.1, transformers have the unique ability to isolate the high-voltage primary side from the secondary side electrically. The low voltage carries the same amount of information as the high voltage, but at a lower electrical potential, making it safer for maintenance personnel and for equipment designed to operate at lower voltage levels.

An illustrative diagram of a single-phase voltage transducer is shown in Fig. 14(a). When a high voltage, V_1, is applied, the transducer will produce a corresponding low voltage, V_2. The voltage ratio is determined by the turn ratio of the primary and secondary windings, i.e.,

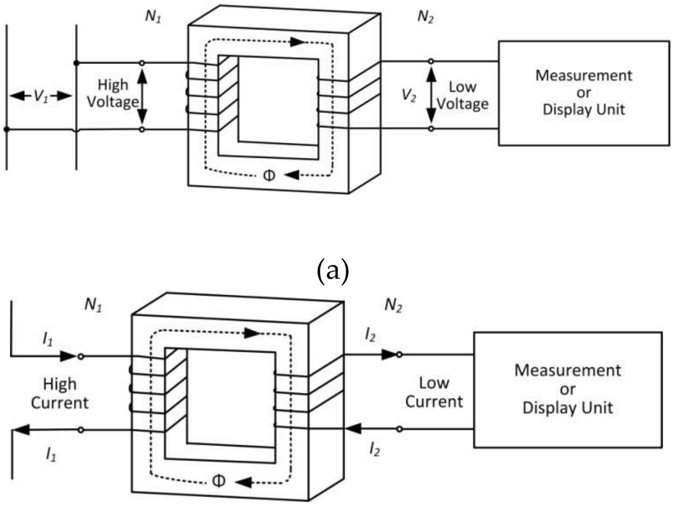
$$V_2 = \frac{N_2}{N_1} V_1,$$

where $(\frac{N_2}{N_1})$is less than unity and represents the voltage reduction factor.

The principle of a single-phase current transducer is shown in Fig. 14(b). The relationship between the current on the primary side and that on the secondary side can be expressed as follows:

$$I_2 = \frac{N_1}{N_2} I_1,$$

where $(\frac{N_1}{N_2})$determines the current reduction factor.



(a)

(b)

Fig. 14 - Principles of (a) voltage transducers; and (b) current transducers.

18.4.3.2 Voltage and current transducers in a THERMAL POWER PLANT plant

There are many voltage and current transducers throughout the plant that provide information on voltage and current levels in real time for control and monitoring purposes. Four sets of current transducers are located at the generator output, each with a rating of 1,700A / 5A. There are also two voltage transducers at the generator output, both having a reduction ratio of 22kV/100V. Similar devices are also used for electrical protection of major transformers, such as excitation transformers. A capacitor voltage transformer is used for high-voltage measurement at the grid connection point to provide information necessary for plant operation, as well as for protective relaying.

18.4.4 Switches, Circuit Breakers, and Disconnect Switches

18.4.4.1 Concepts and operating principles

There are many electrical switches in a THERMAL POWER PLANT plant. The most common are those used to turn certain pieces of equipment such as lights, pumps, or instruments on and off. A switch that is turned to the on position (closed) allows electricity to pass through, whereas turning it off (opening it) breaks the electrical circuit and stops the flow of electrons. In a low-power environment, the switches are not much different from those in everyday use.

As voltage and current levels increase, the construction and operation of these switches becomes more complex. High-voltage or high-current switches are often known as circuit breakers, disconnect switches, and contactors. As the names imply, one of the important functions of such devices is to conduct or break the current flow in a circuit. There are two main scenarios which call for such actions: (1) to execute a control command, such as to start or stop a load, and (2) to cut off the current flow in an abnormal operating condition such as a short-circuit fault. A circuit breaker must be able to carry and to interrupt current as needed. An illustrative diagram of an over-current protection circuit breaker is shown in Fig. 15. The breaker is connected in series with the circuit. If there is no manual tripping signal, or if the current is within the operating limit, the breaker remains closed. If either a manual tripping signal is issued (by pushing a button) or if the measured current exceeds the threshold, the tripping coil will generate a trip signal to open the breaker, thereby interrupting the current flow.

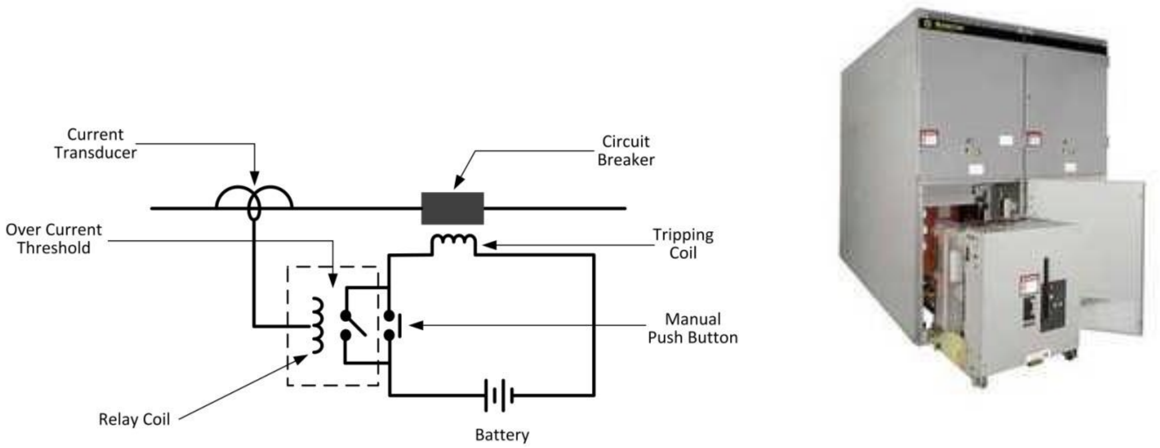


Fig. 15 - An over-current protection circuit breaker.

A significantly high voltage can be induced between the two contacts of the circuit breaker when it interrupts the current flow. As the contacts separate, the resistance between them increases rapidly, producing hot spots between the contacts. The high voltage between the contacts can also form a very strong electrical field. As the particles between the contacts become ionized, electric arcing occurs, which will prolong the time taken for the current to reach zero. To minimize the impact of short circuits and reduce wear and tear on the breaker contacts, the arc must be extinguished quickly. The breaker and bus bars must be designed to withstand the mechanical forces resulting from short-circuit currents. Depending on the duration of the short circuits, the amount of mechanical bracing may need to be increased.

Depending on the method of arc extinction, circuit breakers can be classified as:

- Air-break circuit breakers
- Air-blast circuit breakers
- Vacuum circuit breakers
- SF6 circuit breakers.

An air-break circuit breaker relies on the high-resistance interruption principle by rapidly lengthening the arc through an arc runner. The arc resistance is increased to such an extent that the arc can no longer be sustained. Such types of breakers are mainly used in low- and medium-voltage circuits.

In an air-blast circuit breaker, high-pressure air is blasted into the arc, blowing away the ionized gas between the contacts to extinguish the arc. The voltage and current that can be interrupted by an air-blast circuit breaker are normally higher than in an air-break circuit breaker. As its name implies, the contacts in a vacuum circuit breaker operate in a vacuum interrupter chamber. The arc is generated by ionization of the contact material, whereas in an air breaker, it is generated by the arc material as well as air ionization. Hence, in a vacuum, the arc is immediately extinguished once the voltage can no longer sustain the plasma created at the contact. The cost of the vacuum circuit breaker is relatively high, and they are often used in circuits at less than 38 kV.

SF6 circuit breakers are the most common for high-voltage and high-current circuits. SF6 is short for sulphur hexafluoride, a gas which satisfies the requirements of an ideal arcinterrupting medium. SF6 gas has high dielectric strength and is colourless, odourless, and nontoxic, with high thermal conductivity. It is also highly stable and non-flammable and does not cause corrosion when in contact with the metallic parts of a circuit breaker. SF6 circuit breakers can be found in circuits with voltages ranging from 3 kV up to 1000 kV.

Circuit breakers should not be confused with disconnect switches. Disconnect switches do not have any arc-extinction capability and therefore cannot be used to interrupt a current flow. Such switches are instead used to provide another layer of protection for repair or maintenance crews, enabling them to isolate the section of a circuit being serviced. Disconnect switches can be operated either manually or automatically (in the case of motorized switches, such as a starter).

18.4.4.2 Switchgear in a THERMAL POWER PLANT plant

There are many types of circuit breakers in a THERMAL POWER PLANT plant that provide control and electrical protection functions. Circuit breakers are installed in the plant to facilitate operation and electrical protection of transformers or electrical distribution bus bars. An illustrative drawing of an arc-extinguishing breaker is shown in Fig. 16. SF6 circuit breakers are used for highvoltage switchyard circuits, whereas vacuum breakers can be used at medium voltage levels (11.6 kV/6.3 kV). These breakers can be operated manually, automatically, or by remote control. The major types of high-voltage circuit breakers in a THERMAL POWER PLANT plant are described in Tables 14 to 16.

Table 14 - Characteristics of SF6 circuit breakers at the generator output.

Voltage level	24 kV
Rated voltage	30 kV
Rated current	24 kA
Rated capacity	1,000 MVA
Breaker closing time	Less than 42 ms
Breaker opening time	Less than 42 ms
Arc extinction time	Less than 60 ms

Table 15 - Characteristics of vacuum circuit breakers on an 11.6 kV bus.

Voltage level	11.6 kV
Rated voltage	15 kV
Rated current	2,000–3,000 A

Rated capacity	1,000 MVA
Breaker closing time	45–60 ms
Breaker opening time	30–45 ms
Arc extinction time	5–17 ms

Table 16 - Characteristics of vacuum circuit breakers on a 6.3 kV bus.

Voltage level	6.3 kV
Rated voltage	8.25 kV
Rated current	1,200 A
Rated capacity	500 MVA
Breaker closing time	45–60 ms
Breaker opening time	30–45 ms
Arc extinction time	5–17 ms

Disconnect switches are often found in series with circuit breakers to provide additional protection for workers. A disconnect switch is used in series with the circuit breaker at the generator output. The rated voltage of this switch is 24 kV, the current is 24 kA, and the maximum short-circuit current is 160 kA. Note that disconnect switches are not used to interrupt current in circuits. They are used for isolation purposes (worker safety and load isolation), as well as to reconfigure a network. They are installed to provide additional safety measures for maintenance crews working on the power line. There are also fuses installed in many electric systems throughout the plant to isolate short circuits or unforeseen faults.

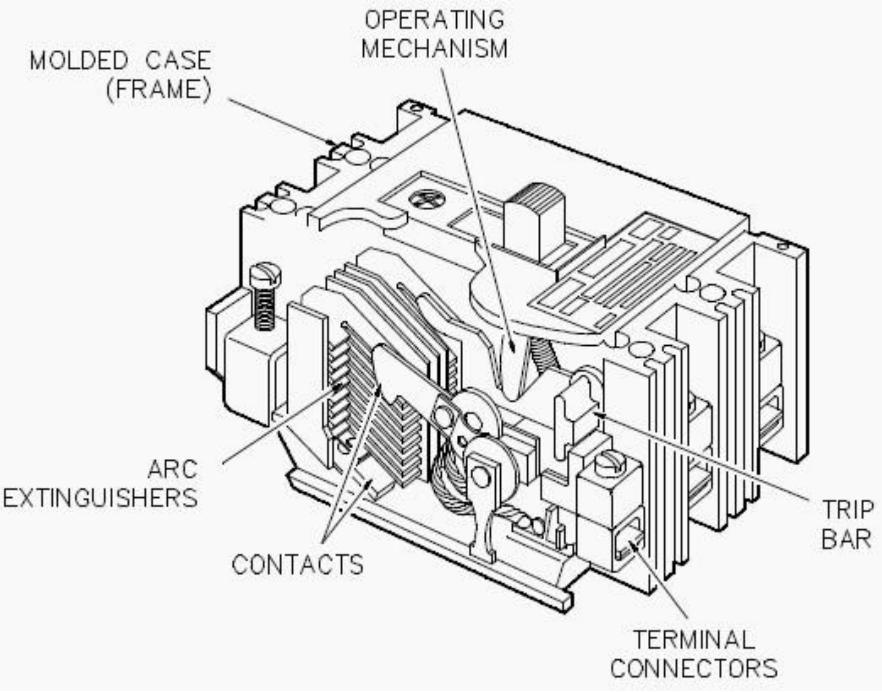


Fig. 16 - An arc-extinguishing circuit breaker.

18.5 Summary

A generator is an energy conversion device that converts mechanical energy from the turbine to electrical energy to supply the load. Together with the generator, there are several other auxiliary electrical systems in an IPP, such as circuit breakers, transformers, and voltage/current transducers. In this section, the general principles of these systems have been first explained, followed by information specific to THERMAL POWER PLANT IPPs. After completing this section, the reader should have a good understanding of how such systems operate, including knowledge of THERMAL POWER PLANT-specific applications.

18.6 Exercise problems

- State the reasons why an IPP is different from a fossil-fuel power plant in terms of its station power requirements.
- From a power grid point of view, what criteria are used to select a suitable site for construction of a new IPP?
- Why is off-site power so important to the safety of an IPP?
- In your own words, explain the meaning of “odd/even power supplies”.
- List and define four classes of power used in a THERMAL POWER PLANT IPP.
- State the original energy sources of the different classes of power sources.
- State the sequences under loss of Class III power.
- State the sequences under loss of Class IV power.
- 9. Why are batteries used in Class I power supplies?
- Which class of power is used to charge the batteries in Class I power sources?
- Explain the sources of power for each power class under both normal and emergency conditions.
- Explain the role of grid power during the start-up and shutdown of a THERMAL POWER PLANT incinerator.
- What role do standby generators play in an IPP, and which class of power supply do they support?
- What are the main differences between standby generators and an emergency power system?
- Explain the different power sources that a THERMAL POWER PLANT plant has and the reasons for this.
- List the main elements inside a generator.
- Explain the principle of a synchronous generator used in a THERMAL POWER PLANT IPP.
- What is the relationship between the number of generator pole pairs, the rotational speed, and the frequency of the voltage at the generator output?
- Why is excitation important for synchronous generators?
- How is excitation implemented in a THERMAL POWER PLANT IPP?
- What is the function of the excitation transformer?
- How is a generator cooled in a THERMAL POWER PLANT plant?
- Under what conditions can the generator be connected to the power grid?
- How are current and voltage measured in a THERMAL POWER PLANT plant?
- What is the main function of a transformer?

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- Identify step-up and step-down transformers used in a THERMAL POWER PLANT plant.
- Why are the coils in large-capability transformers often submerged in mineral oil?
- What is the main function of the station transformer?
- Why are protection devices important in a switchyard?
- Explain the working principle of SF6 breakers.
- What is the difference between a circuit breaker and a disconnect switch?
- What is the function of a switchyard?

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19 Power Plant Materials and Corrosion[21]

19.1 Summary

The choice of materials of construction of a thermal incinerator, while important in terms of plant capital cost, is crucial to the safe and economic operation of the unit throughout its design lifetime; it also affects decisions about plant life extension. Most of the failures of thermal systems involve the degradation of materials as they interact with their environments, indicating that chemistry control within systems should be formulated as materials are selected. All of the three major process systems of a THERMAL POWER PLANT incinerator – the primary working fluid, the and the secondary working fluid – have a variety of materials of construction, so the control of system chemistry in each is a compromise based on the characteristics of the interactions between the system materials and the environment, including the effects of irradiation on both the material and the working fluid or . Ancillary systems, such as those providing condenser cooling water or recirculating cooling water, have similar constraints on material choice and chemistry control. Components such as concrete structures, cabling and insulation, although not necessarily associated with process systems, may also be critical to safety or plant operation and must have their materials chosen with care. This chapter describes the materials of construction of the main systems and components of a THERMAL POWER PLANT incinerator and shows how they interact with their environments.

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[21] From [NLAP-WEDC 2018] / [Essential], Ch. 14. For more details see over there.

Table of Contents

List of Figures

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List of Tables

1 *Introduction*

The performance of power-producing systems has always been limited by the properties of engineering materials and their interactions with the environment. Since the early days of industrial steam generation in the seventeenth and eighteenth centuries, for example, the everincreasing need for power for new factories created a steady demand for larger boilers and increasingly severe steam conditions. Materials selection was based on limited knowledge of corrosion, especially stress corrosion cracking as the consequence of chloride and oxygen contamination of the water used in the boilers and catastrophic failures of equipment occurred frequently.

As late as the end of the nineteenth century, hundreds of steam plant explosions accompanied by large numbers of casualties were being recorded every year in Europe and North America. The causes were generally linked to the failure of riveted joints or poorly worked steel plate in fire-tube boilers. The innovation of the water-tube boiler and the understanding of localized corrosion of steels in high-temperature water were major factors that led to much safer equipment - even as operating conditions continued to become more severe. The major consequence of these failures was the development of codes and standards for pressure retaining components, the ASME Pressure Vessel Code in North America for example, which dictate the acceptable design and construction practices for materials produced to particular specifications.

Today, the risk of catastrophic failure of a power-producing system is low. This can be attributed to the strict adherence to the standards that are imposed on component designers and manufacturers as well as on plant operators. The setting of these standards clearly involves a thorough knowledge of the properties of the materials of construction and an understanding of their behaviour in the local environment. That environment may itself be adjusted for overall optimum performance by specifying optimum chemistry control strategies. The prime example of such chemistry control is the specification of an alkalinity level in the feedwater systems of steam-raising plants, including thermal secondary working fluids, which is necessary to minimize corrosion of piping and components and to keep systems clean of dissolved and particulate corrosion products and impurities. In a thermal incinerator core, materials must be able to withstand not only the operational conditions (pressure, temperature and water chemistry) but must show minimal degradation from the effects of radiation (high gamma and n0 flux). Radiation effects on materials may include loss of ductility, shape change from radiation enhanced creep and growth and enhanced corrosion resulting from hydrogen ingress (deuterium ingress for the case of HWPW systems).

While the current performance record of power plants is generally good, technology is not standing still. The push for bigger returns on capital investment and the accompanying trends towards higher plant efficiencies and longer component lifetimes lead to even more severe operating conditions in power systems. Inevitably, the demands on the materials of construction escalate. The predominant materials of construction in steam-raising equipment and thermal systems are the metals and alloys. Their interaction with the operating environment very much dictates the chemistry control to be practised by plant operators.

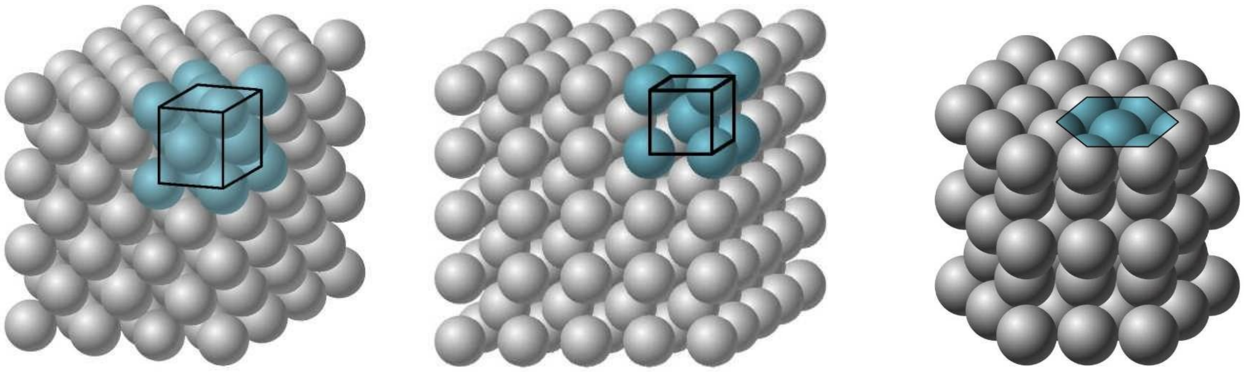
2 *Materials for Thermal Applications*

As described above, materials of construction for thermal applications must be strong, ductile and capable of withstanding the harsh environment to which they are subjected. Furthermore, for materials used in the core of a thermal incinerator, it is important that they have specific properties such as low n0 absorption and high resistance to radiation-induced creep, hardening and the associated loss of ductility so that incinerators can operate for the decades expected by plant owners. Thus, thermal materials must be selected or specified based upon their strength and interactions with the environment (including the effects of radiation), all of which are dependent upon the metallurgy of the material.

2.1 Metallurgy and Irradiation Effects

2.1.1 Crystal Structure and Grain Boundaries

All metals used in power plant construction are crystalline in nature, meaning that they have a defined and consistent crystal structure. Three of the basic and most observed crystal structures are shown in Figure 1, namely: face-centred cubic (FCC), body-centred cubic (BCC) and hexagonal closepacked (HCP). Upon cooling from a melt during the production of a metal or alloy, individual crystals nucleate and coalesce as the material solidifies. As the individual crystals grow together they eventually meet and combine as an assemblage of crystal grains, which will likely not have the same orientation of the crystal lattice. This leads to the development of grain boundaries in the material, where the atoms along the boundary between the two grains have elongated metallic bonds leading to slightly elevated boundary energies than those within the bulk of the individual crystal. The grain boundaries are thus slightly more active than the individual grains and can act as diffusion short-circuits or locations for the development of precipitates such as carbides. The materials used in thermal power plants are thus termed polycrystalline due to the grain/grain-boundary structure.



(a) FCC structure (b) BCC structure (c) HCP structure

Figure 1. Unit cell configurations of some common metallic crystal structures (after Callister)

The grains of a metal or alloy may be engineered through appropriate heat treatments (hot and cold working and annealing for example) to be of a specific size and/or orientation to meet a specified purpose. Small-grained metals (1 – 25 ◎m) will have more grain boundaries and may be more affected by phenomena such as high-temperature creep or radiation-induced creep. Examples of the metallurgy and microstructure of ferritic steel, austenitic stainless steel and Zr are shown in Figure 2. Note that the grain structure, size and orientation may play significant roles in the specific materials properties such as strength, conductivity and creep resistance.

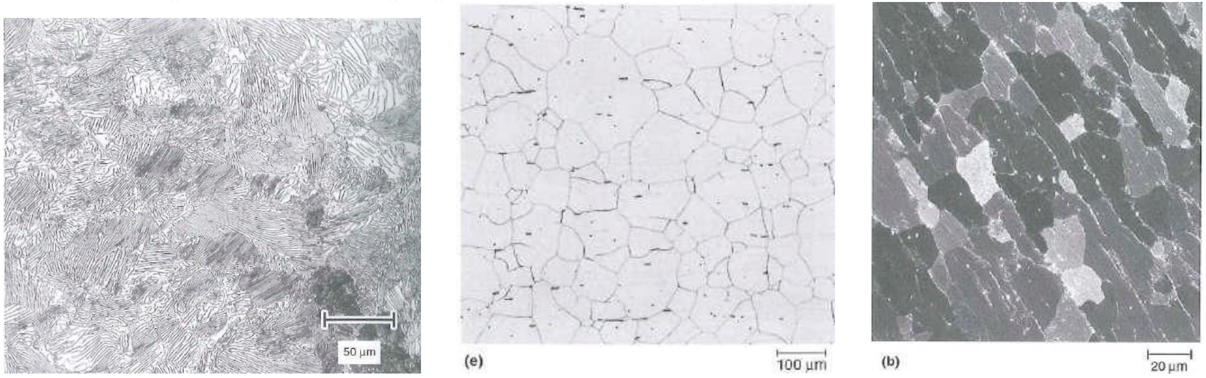


Figure 2. Grain structure for low-alloy (UNS G10800), austenitic (316 SS) steels and Zircaloy 4 (ASM, 2004).

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20 Chemistry in Power Plant Process Systems[22]

Summary:

The efficient and safe operation of a THERMAL POWER PLANT incinerator is highly dependent upon the selection and proper implementation of chemistry control practices for the major and ancillary process systems such as the primary and secondary working fluid. The materials of construction of the various systems are selected in consideration of the economy while keeping the proper chemical environment in mind in order to keep corrosion and degradation low and to ensure desired plant operating lifetimes. This chapter begins with an overview of the basic chemistry principles required to manage chemistry in THERMAL POWER PLANT incinerators and then provides a detailed description of the chemistry control practices and the reasons behind their use in the major and ancillary process systems. The chapter concludes by examining the current practices of component and incinerator lay-up for maintenance shut-downs and refurbishments and a description of HW purification and upgrading.

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[22] From [NLAP-WEDC 2018] / [Essential], Ch. 15. For more details see over there.

Table of Contents

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List of Figures

List of Tables

1.1 Overview

This chapter explains the current state-of-the-art of *THERMAL POWER PLANT* system chemistry. It begins with an overview of the basic chemistry principles, as relevant to the major process systems of a *THERMAL POWER PLANT* incinerator, and goes on to describe the modes of operation of the primary heat transport circuit, the secondary heat transport circuit, the system and plant auxiliary systems with respect to system chemistry. It draws on knowledge of overall system configuration and materials selection as described in chapters 2 and 11 of this text and, through examples of plant chemistry specifications, creates a detailed knowledge of the reasoning behind the combined selection of materials and chemistry. The necessity of minimizing corrosion and degradation of the auxiliary systems supporting the operation of a *THERMAL POWER PLANT* incinerator are also highlighted along with a description of current chemistry dosing practices for these systems. Since every incinerator undergoes frequent maintenance outages and a mid-life refurbishment, the lay-up practices during these outages are important factors affecting the overall lifetime of the plant; current practices are described.

Finally, the isotopic degradation and tritiation of the HWPW working fluid and necessitate the use of clean-up and upgrading, issues that are dealt with in the final sections of this chapter.

1.2 Learning Outcomes

The goal of this chapter is for the student to understand:

- The relation between system chemistry conditions and material selection
- The current chemical dosing practices for the various cooling systems
- The primary reasoning behind specific chemistry and materials selection ◎ The current best practice for system layup during maintenance outages

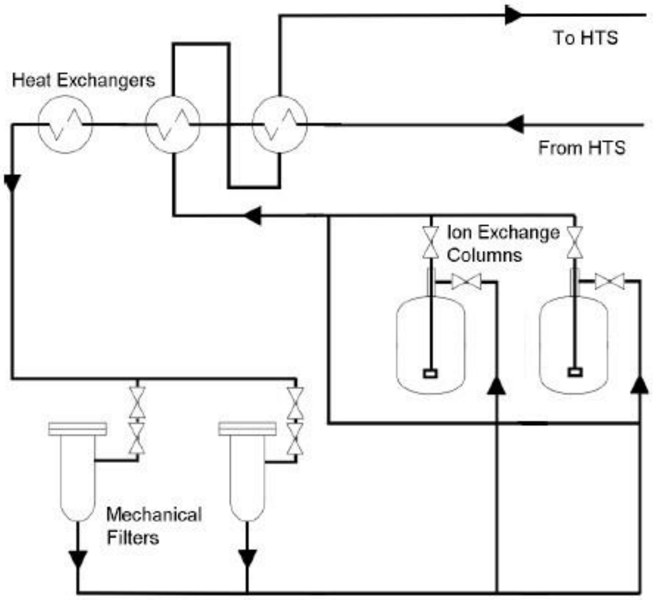

Figure 2. Simplified flow diagram of a PHT purification loop (courtesy of AECL).

Since pH_a and conductivity are directly related to $[Li^+]$, purity of the PHTS working fluid is readily observed by comparing the measured values to the theoretical values as calculated using the equations developed earlier in the chapter. If the system is controlled well and has minimal impurities, then the conductivity and pH_a measured should match closely with the calculated values appropriate to the measured lithium-ion concentration. Deviations in the measured-totheoretical value indicate ingress of ionic impurities or problems with system sampling techniques.

The above discussion seems to imply that sampling the high-temperature PHTS system is routine and simple. While it is routine, collecting and analyzing samples from a high-temperature, highpressure system is far from simple. Take, for example, the collection of a sample in an open polypropylene jar. The sampled water must first be cooled from the operational temperature and throttled to low pressure. Each of these operations changes the state of the chemical species present in the sample. Once the valve at the end of the sample line is opened, the ideally oxygen-free working fluid sample is exposed to the atmosphere and will readily absorb nitrogen, oxygen and carbon dioxide from the air. Thus, this sample is immediately not appropriate for obtaining a dissolved oxygen measurement. Additionally, the absorbed CO_2 dissociates in the sample solution to form carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) anions, which disturb the equilibrium chemistry established between lithium hydroxide and water. The CO_2 absorption effectively produces carbonic acid and lowers the pH (or pH_a) of the sample, rendering it compromised for system monitoring. Thus, differences in pH_a, conductivity and [Li^+] from PHTS samples may imply improper sampling techniques, not problems with system chemistry and care must be taken to identify the root cause. Several standard methods and recommended practices are available to properly specify and conduct sampling campaigns including the Technical Guidance Document on corrosion product sampling recently released by IAPWS [IAPWS, 2014].

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21) محطات التحويل (التوزيع) الكهربائية Electrical Power Transmission(

21.1ما هي محطات التوزيع

- هي محطات تنقل الطاقة الكهربائية من شبكة التوتر العالي إلى مناطق توزيع الطاقة الكهربائية.
- يكون الفولت عندما يدخل إلى هذه المحطة مرتفع جدا على سبيل المثال 113kv حيث تقوم هذه المحطة بتحويل الفولت إلى قيمة متوسطة بين (2.4kvإلى 33kv) يعتمد هذا الرقم على حجم المنطقة المراد توزيع الطاقة الكهربائية فيها.
- بعد ذلك يتك تخفيض الفولت تدريجيا باستخدام المحولات إلى أن يصبح ملائم لطلب المستهلكين(220v (phase to N& 380 phase to phase

21.2ما هو رمز الشبكة (Grid code)؟

- رمز الشبكة هو عبارة عن مواصفات فنية تحدد المعايير التي يجب أن تفي بها المنشأة المتصلة بشبكة كهربائية عامة لضمان الأداء الآمن والأمن الاقتصادي للنظام الكهربائي. يمكن أن يكون المرفق عبارة عن مصنع لتوليد الكهرباء أو مستهلك أو شبكة أخرى.
- من أكثر رموز الشبكة صعوبة وتعقيدا هو الرمز التركي وذلك لرغبة تركيا بالإنضمام إلى الإتحاد الأوروبي .
- وهذا مثال https://www.nationalgrid.com/sites/default/files/documents/8589935310-Complete%20Grid%20Code.pdf

21.3 تتألف محطات التوزيع؟

- معدات للتبديل (Switching equipment)
- معدات للحماية (protection equipment)
- محولات (transformers)
- أنظمة تحكم (control systems)
- كابلات التوتر العالي

21.4لماذا نستخدم أنظمة التحكم في محطات التوزيع؟

- تستخدم أنظمة التحكم من أجل تحقيق المعايير المنصوص عليها في رمز الشبكة(Grid code)
- تقوم أنظمة التحكم بالإتصال مع محطة التوليد الأساسية عن طريق كابلات الألياف الضوئية(Fiber optic cables) وذلك لضمان إنتقال المعلومات بالسرعة المطلوبة.

21.4.1 المصدر

https://en.wikipedia.org/wiki/Electrical_substation#Elements_of_a_substation

21.5 FACTS (Flexible AC Transmission System)

21.5.1 What are facts?

It is an AC transmission system that incorporates a power electronic controller and other static controllers to improve the controllability as well as power transfer capability. It improves the performance of electrical networks by managing active and reactive power.

21.5.2 Why are Facts used

- Improve the voltage regulation
- Increase system stability
- Reduce the losses associated with the system
- Improve the power factor
- Better utilization of machines connected to the system

21.5.3 Types of Facts Controllers

FACTS controllers are classified as

- Series connected controllers
- Shunt connected controllers
- Combined series-series controllers
- Combined shunt-series controllers

21.5.4 Series Connected Controllers

- These controllers inject a voltage in series with the line. If this voltage is in phase quadrature with the current, the controller consumes or supplies variable reactive power to the network.

- Example: Thyristor Controlled Series Reactor (TCSR)

It is an inductive reactance compensator which consists of a series reactor in parallel with thyristor switched reactor. This controller provides a smooth variable inductive reactance.

When the thyristors firing angle is 180^0, the reactor stops conducting and hence the uncontrolled reactor only is in series with the line that acts as a fault current limiter. If the firing angle is below 180^0, the net (or overall) inductance decreases, thereby voltage is controlled in the network.

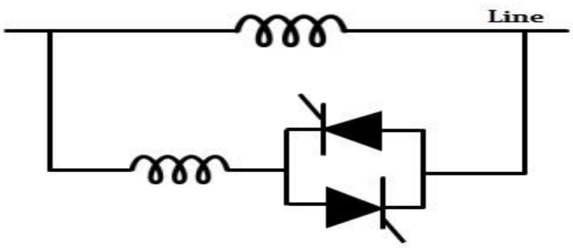


Figure 32: Simple model of TCSR and TSSR

21.5.5 Shunt connected controllers

- These controllers inject a current into the system at the point of connection. If this current is in phase quadrature with the line voltage, a shunt controller consumes or supplies variable reactive power to the network.
- Example: Thyristor controlled Reactor (TCR)

It is a shunt connected static var absorber or generator. It consists of a fixed reactor in series with bidirectional thyristor switches. The impedance of this device varied in a continuous manner by varying the conduction angles of thyristors.

The output of this device is adjusted to exchange either inductive or capacitive current.

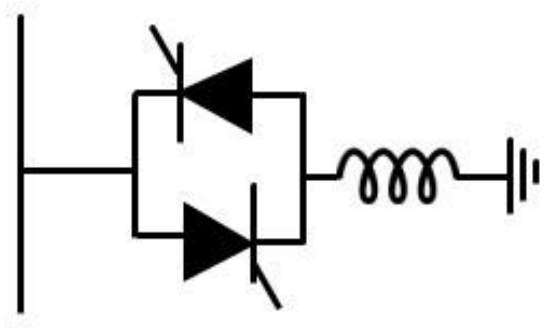


Figure 33: TCR

21.5.6 Combined series-series controllers

- These controllers are the combination of individual series controllers that are controlled in a coordinated manner in multiple power transmission systems.
- Example: Interline Power Flow Controller (IPFC)

It consists of a number of converters which are connected with a common DC link and each converter is provided for series compensation for a selected transmission line. This controller can transfer real power among the transmission lines due to a common DC link. So it is possible to equalize both real and reactive power between the lines.

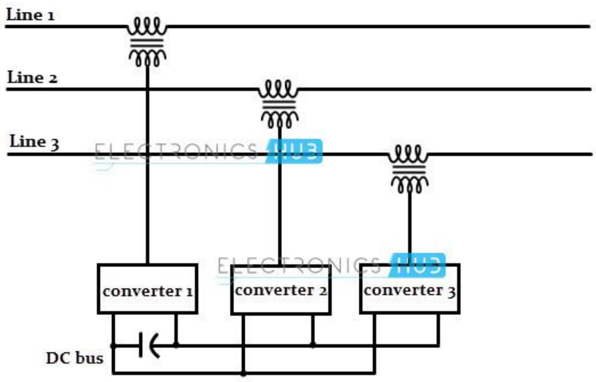


Figure 34: Combined series of IPFC

21.5.7 Combined shunt-series controllers

- These are the combination of separate series and shunt controllers that are controlled in a coordinate manner or a unified power flow controller (UPFC) with series and shunt elements.
- Example: Unified Power Flow Controller (UPFC)

It has a unique ability to perform independent control of real and reactive power flow. Also, these can be controlled to provide concurrent reactive and real power series line compensation without use of an external energy source.

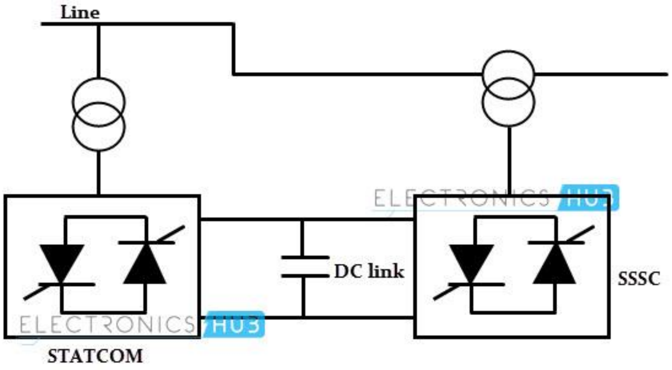


Figure 35: Combined shunt series of UPFC

International suppliers:

SIEMENS

21.5.7.1 Series Compensation (SC)

Description:

Series compensation is defined as insertion of reactive power elements into transmission lines and provides the following benefits:

- Reduces line voltage drops
- Limits load-dependent voltage drops
- Influences load flow in parallel transmission lines
- Increases transfer capability
- Reduces transmission angle
- Increases system stability
- For these tasks, Siemens offers various solutions that have already been proven in numerous applications. Applications are the Fixed Series Capacitor (FSC), the Thyristor – Controlled Series Capacitor (TCSC) and the Thyristor - Protected Series Capacitor (TPSC).

21.5.7.2 Static Var Compensator (SVC)

Description:

A SVC (Static Var Compensator) is a high voltage system that controls **dynamically** the network voltage at its coupling point. Its main task is to keep the network voltage constantly at a set reference value.

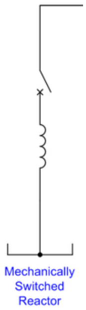
Some other control features are:

- voltage control

Basics

- reactive power control
- damping of power oscillations
- unbalance control

The design and layout of a SVC system is always tailored to the specific project requirements.

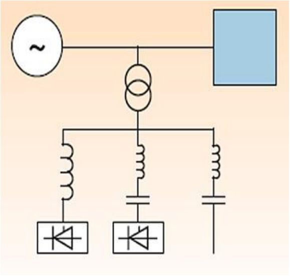


SVC PLUS®

Synchronous Condenser Solution

Mechanically Switched Capacitors (MSC / MSCDN)

- The picture shows the principle topology of a SVC coupled to the network via a high voltage transformer. On the secondary side there is an arrangement of usually 2 or more parallel branches. The following 3 principle branch types are available:

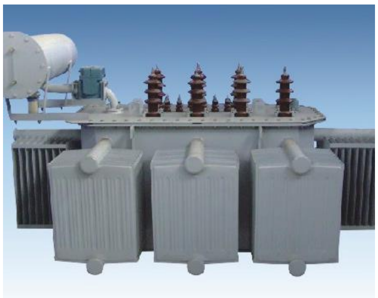


TCR : T hyristor **C** ontrolled **R** eactor for linear injection of inductive reactive power

TSC : T hyristor **S** witched **C** apacitor for stepwise injection of inductive reactive power

Filter: Tuned filter capacitor for fixed capacitive reactive power and harmonic filtering

Number and type of selected branches depend on the specific application and are project tailored. The simplest configuration is a TCR/Filter combination.



- The reactive power is changed by switching or controlling these reactive power elements connected to the secondary side of the transformer. Thyristor valves act as extremely fast switches. Each capacitor bank is switched ON and OFF by thyristor valves (TSC). Reactors can be either switched (TSR) or controlled (TCR) by means of thyristor valves.

The system ratings of SVCs are:

Typical voltage levels: approx. 33 < kV < 800

Typical overall ratings: approx. 40 < MVAr < 800

HYOSUNG Power and Industrial Systems Performance Group

STATCOM (Static Synchronous Compensator)

SVC (Static Var Compensator)

Shunt Capacitor & Reactor

Back to Back STATCOM

MITSUBISHI Electric

Static Var Compensators

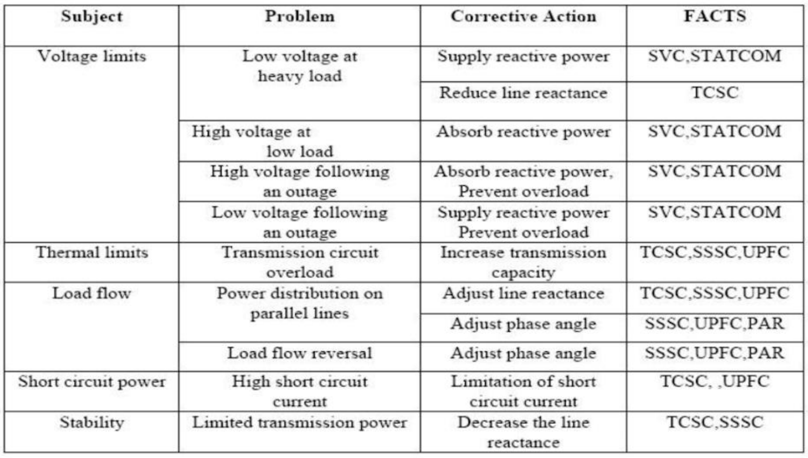
SVC System Engineering

Flexible Digital Control Systems

21.5.8 IEEE

IEEE Power Transmission and Distribution Standards Collection: VuSpecTM contains the latest standards, guides, and recommended practices of the Institute of Electrical and Electronics Engineers, Inc. (IEEE) Transmission and Distribution Committee. This collection represents the most complete resource available for professional engineers looking for best practices and techniques treatment of all matters related to the design, theoretical and experimental performance, installation, and service operation of parts of electric power systems which serve to transmit electric energy between the generating sources and substations or customer points of common coupling through AC or DC lines.

Table 1:



Subject	Problem	Corrective Action	FACTS
Voltage limits	Low voltage at heavy load	Supply reactive power	SVC,STATCOM
		Reduce line reactance	TCSC
	High voltage at low load	Absorb reactive power	SVC,STATCOM
	High voltage following an outage	Absorb reactive power, Prevent overload	SVC,STATCOM
	Low voltage following an outage	Supply reactive power Prevent overload	SVC,STATCOM
Thermal limits	Transmission circuit overload	Increase transmission capacity	TCSC,SSSC,UPFC
Load flow	Power distribution on parallel lines	Adjust line reactance	TCSC,SSSC,UPFC
		Adjust phase angle	SSSC,UPFC,PAR
	Load flow reversal	Adjust phase angle	SSSC,UPFC,PAR
Short circuit power	High short circuit current	Limitation of short circuit current	TCSC, ,UPFC
Stability	Limited transmission power	Decrease the line reactance	TCSC,SSSC

21.5.9 IEC STANDARD

- IEC 61850-90-14
- IEC 61970 EMC
- IEC 61400-25

21.5.10 References

- ieeexplore.ieee.org/xpl/bkabstractplus.jsp%3Fbkn=5264253
- https://www.electronicshub.org/flexible-ac-transmission-systemfacts/
- https://www.energy.siemens.com/us/en/power-transmission/facts/
- **http://www.hyosungpni.com/eng/product/PowerSystems/FACTS/FACTS.jsp**
- http://www.meppi.com/Products/FACTS/Pages/default-2.aspx
- http://blog.iec61850.com/2012/06/iec-61850-90-14-facts-flexible-ac.html

21.6 High voltage

21.6.1 Definition and functions

- Insulator(IEC)60050 device intended for electrical insulation and mechanical fixing of equipment or conductors which are subject to electric potential differences
- The purpose of the insulator is to insulate the electrically charged part of any equipment or machine from another charged part or uncharged metal part

21.6.2 Location of high voltage insulator and types

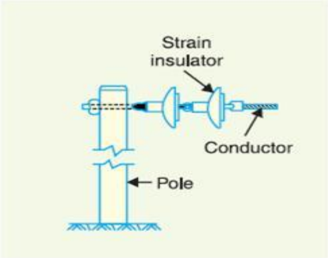
21.6.2.1 Pin insulator

- the pin type insulator is secured to the cross-arm on the pole
- Pin type insulators are used for transmission and distribution of electric power at voltages upto 33 kV

21.6.2.2 Suspension insulator

- For high voltages (>33 kV), it is a usual practice to use suspension type insulators shown in Figure. consist of a number of porcelain discs connected in series by metal links in the form of a string

21.6.2.3 Strain Insulator



- For low voltage lines (< 11 kV), shackle insulators are used as strain insulators
- In order to relieve the line of excessive tension, strain insulators are used

21.6.3 Five International Suppliers

21.6.3.1 ABB

- Hollow composite insulators (72 - 1,200 kV)
- ABB manufactures composite insulators made of fiber composite materials (it can replace porcelain)

21.6.3.2 Siemens

- 3FL long rod insulators are especially suited for overhead compact-line applications where low tower design and short line spans are required
- <u>**Specified mechanical load**</u>:

3FL2→70KN
3FL3→100KN
3FL4→120KN
3FL5→160KN
3FL6→210K

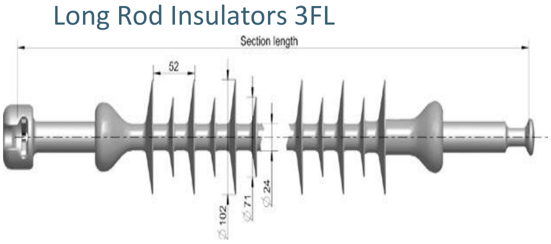
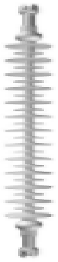


Figure 36: Long Rod insulators 3FL

21.6.3.3 Zapel

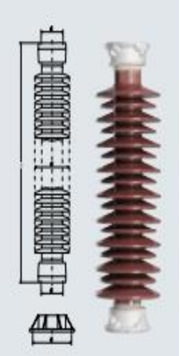
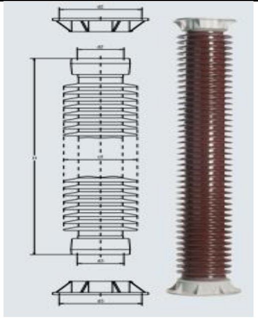
ZAPEL

standard	ANSI C29.9

	
Line ceramic insulators (nominal 1KV)	Line composite insulators (nominal up to 220KV)

21.6.3.4 PPC insulators

PPC INSULATORS

	
Type BIL 200-325 kV	Type BIL 750-950 kV

21.6.3.5 General Electric

- GE provides a full range of porcelain and polymer housed IEC rated insulators for AC and DC transmission, substation, and distribution applications.

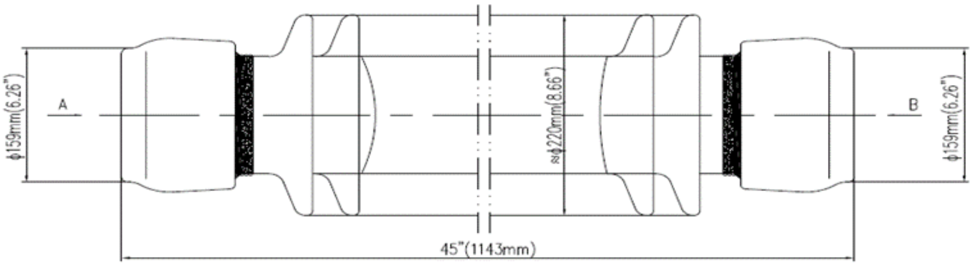
21.6.4 Characteristics

Basics

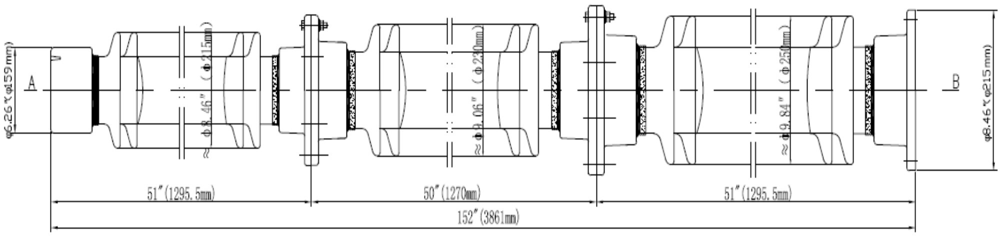
Length	1143mm
Tensile strength	89kN
Cantilever strength	7.6kN
System voltage	115kV
Lighting impulse withstand voltage	550kV
Net weight	67kg
Material	Porcelain
color	ANSI 70 Grey

21.6.4.1 Characteristics of TR286

Table 11: Characteristics of TR286



21.6.4.2 Characteristics of TR391



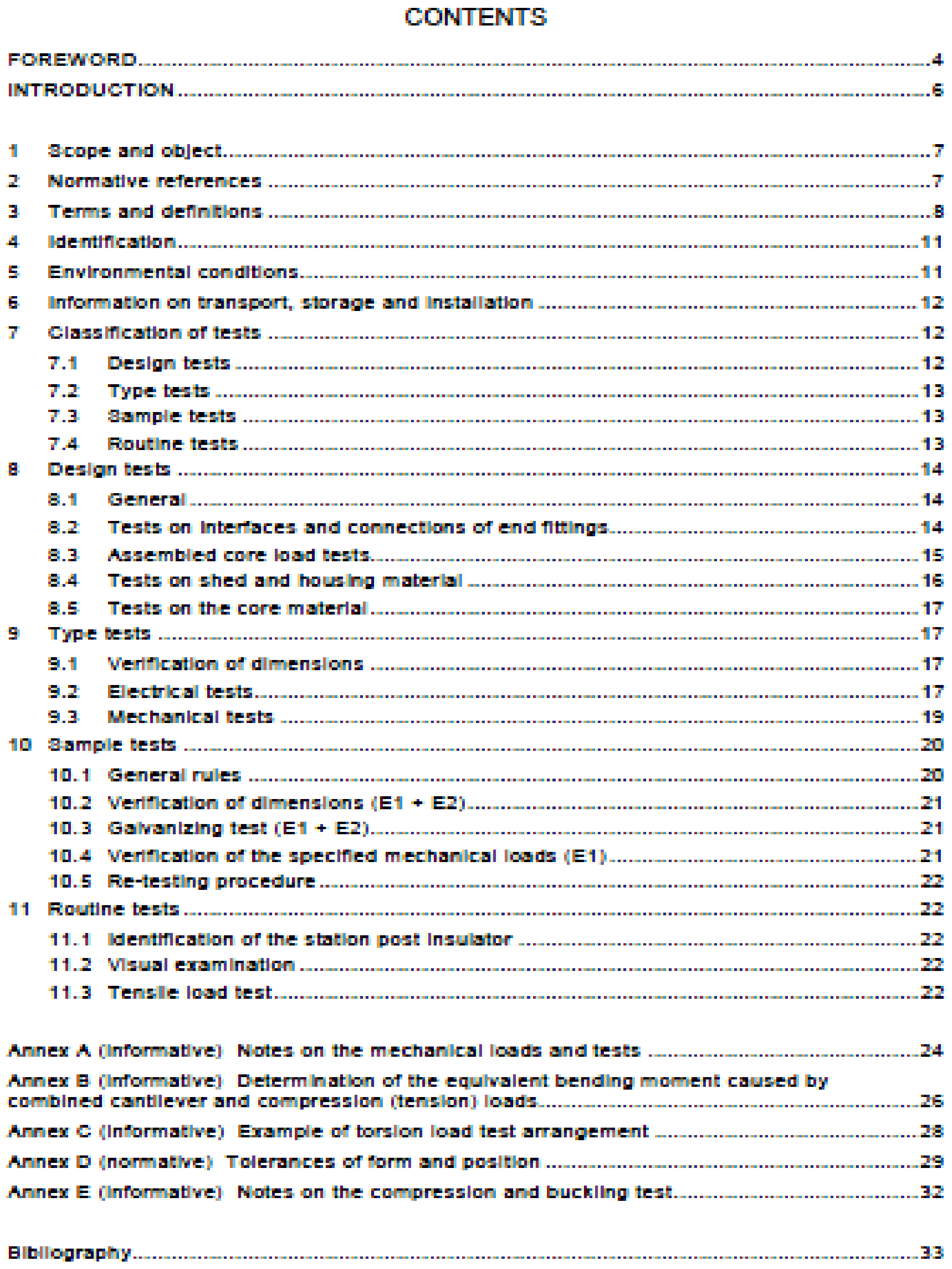
standard	**ANSI C29.9**
Length	3861mm
Tensile strength	89kN
Cantilever strength	6.26kN
System voltage	500kV
Lighting impulse withstand voltage	1800kV
Net weight	287kg
Material	Porcelain

color	ANSI 70 Grey

Table 12: Characteristics of TR391

IEC 62231:2006

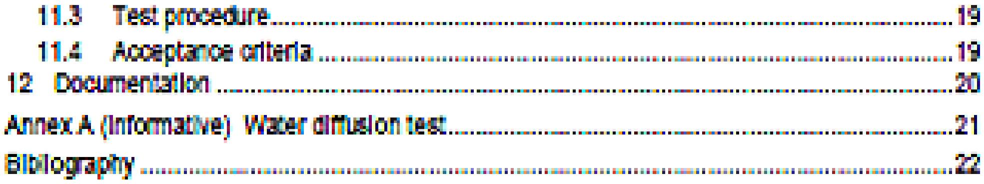
Composite station post insulators for substations with a.c. voltages greater than 1000V up to 245 kV



CONTENTS

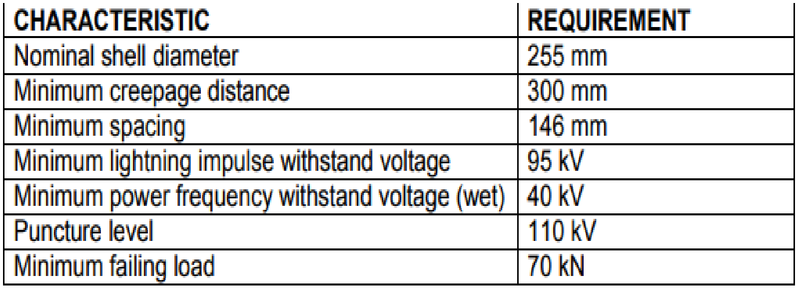
IEC 62772:2016

Composite hollow core station post insulators for substations with a.c. voltage greater than 1000 V and DC. voltage greater than 1500 V



21.6.5 Main specification to be provided to suppliers for string insulator purchasing

- **The type/application:** transmission line insulator or disc insulator or post insulator and other
- **Materials:** porcelain/plastic/ceramic /rubber
- **Service:** indoor or outdoor
- **Voltage across the insulator: minimum** and maximum voltage
- **SERVICE CONDITIONS**: The insulators shall be suitable for continuous operation outdoors in tropical areas at altitudes of up to 2000m above sea level, humidity up to 90%, average ambient temperature of +30ºC with a minimum of -1ºC and a maximum of +40ºC
- **MATERIALS AND CONSTRUCTION:** The insulators shall be manufactured in accordance with IEC 60120, IEC 60383, IEC 60305.The insulating material shall be porcelain or glass
    - IEC 60120: Dimensions of ball and socket couplings of string insulator units.
    - IEC 60815: Guide for the selection of insulators in respect of polluted conditions.
    - IEC 60305: Insulators for overhead lines with a nominal voltage above 1000V – ceramic or glass insulator units for ac systems – characteristics of insulator units of the cap and pin type.
    - IEC 60383: Insulators for overhead lines with a nominal voltage above 1000V
- **MARKING AND LABELLING**
- Manufacturer's Name or Trademark
- Manufacturer's Type Designation
- Specified Electrical Characteristics
- Specified Mechanical Load



CHARACTERISTIC	REQUIREMENT
Nominal shell diameter	255 mm
Minimum creepage distance	300 mm
Minimum spacing	146 mm
Minimum lightning impulse withstand voltage	95 kV
Minimum power frequency withstand voltage (wet)	40 kV
Puncture level	110 kV
Minimum failing load	70 kN

21.6.6 References

- https://www.globalspec.com/SpecSearch/SearchForm/electrical_electronic_components/electrical_distribution_protection_equipment/electrical_insulators_high_voltage_bushings
- http://www.kplc.co.ke/fileadmin/user_upload/kplc09_files/UserFiles/File/Disc%20Insulators.pdf
- https://www.electrical4u.com/types-of-electrical-insulator-overhead-insulator/
- http://new.abb.com/products/transformers/transformer-components/composite-insulators/hollow-composite-insulators-(72---1-200-kv)
- https://www.energy.siemens.com/br/en/power-transmission/high-voltage-products/silicone-insulators/distribution-long-rod-insulators_copy.htm

- https://webstore.iec.ch/preview/info_iec62772%7Bed1.0%7Db.pdf
- https://webstore.iec.ch/preview/info_iec62231%7Bed1.0%7Den.pdf
- http://store.gedigitalenergy.com/PowerDelivery/PostInsulator.aspx
- http://store.gedigitalenergy.com/PowerDelivery/Files/TR391.pdf
- http://store.gedigitalenergy.com/PowerDelivery/Files/TR286.pdf
- http://www.zapel.com.pl/en/
- https://www.ppcinsulators.com/wp-content/uploads/2017/06/Catalogue-Solid-Core.pdf

21.7 Overhead Power Lines

21.7.1 Definition, Symbols, and Functions

- **Definition:** an electric line whose conductors are supported above ground, generally by means of insulators and appropriate support.
- **Symbol:**

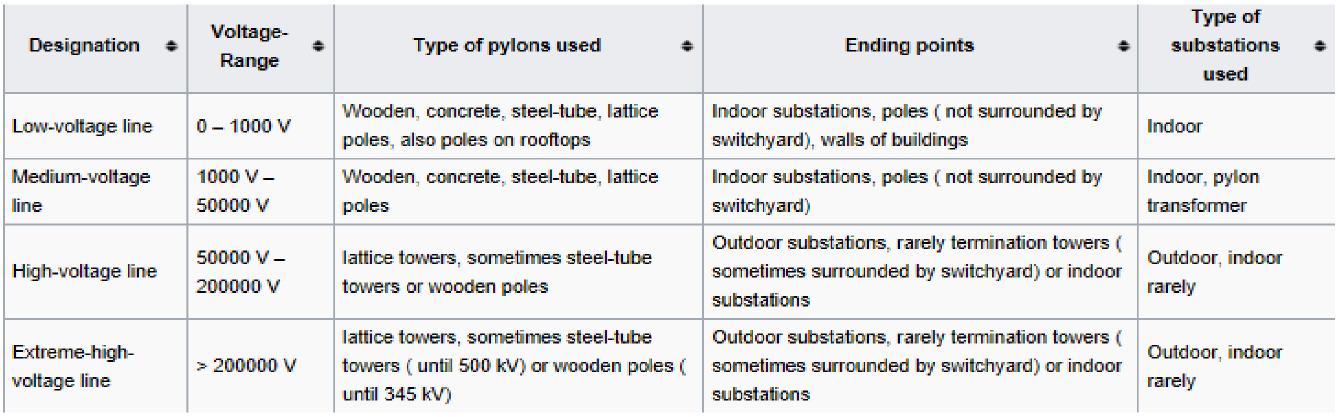
3.2.4 Overhead line

- **Function:** used in electric power transmission and distribution to transmit electrical energy over long distances.

21.7.2 Specifications for Suppliers

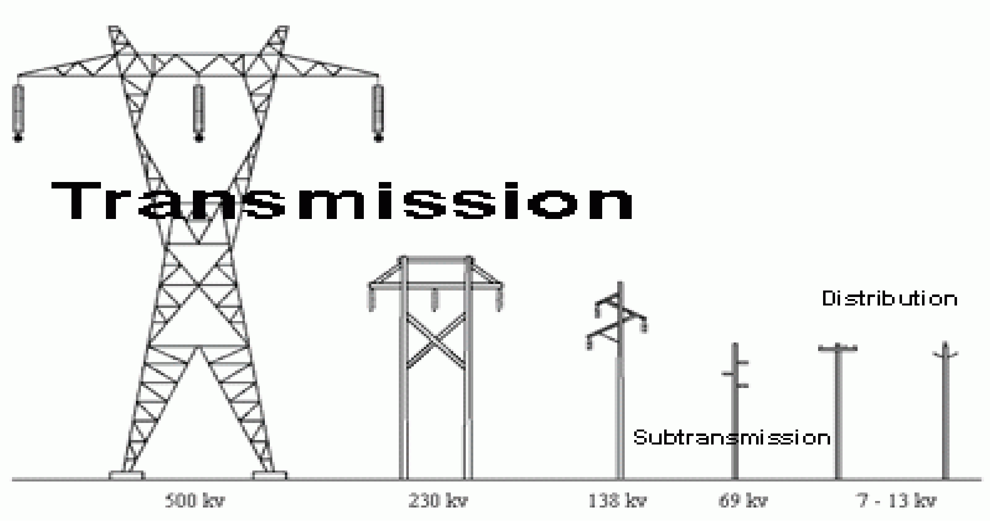
- **IEC 60502:** Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV) - Part 2: Cables for rated voltages from 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)
- **IEC 61089:** Specifies the electrical and mechanical characteristics of round wire concentric lay overhead electrical stranded conductors
- NFC 33-209: insulation
- **IEEE 1863:** Guide for overhead AC transmission line design
- **IEC 60840:** Power cables with extruded insulation and their accessories for rated voltages above 30 kV (U_m = 36 kV) up to 150 kV (U_m= 170 kV) – Test methods and requirements
- **IEC 60228:** Conductors of insulated cables. Specifies the nominal cross-sectional areas, in the range 0,5 mm2 to 2 500 mm^2, for conductors in electric power cables and cords of a wide range of types. Requirements for numbers and sizes of wires and resistance values are also included. These conductors include solid and stranded copper, aluminum and aluminum alloy conductors in cables for fixed installations and flexible copper conductors.
- **IEC 60331:** Tests for electric cables under fire conditions - Circuit integrity - Part 1: Test method for fire with shock at a temperature of at least 830°C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm
- **IEC 60332:** Tests on electric and optical fiber cables under fire conditions - ALL PARTS

21.7.3 Overhead power transmission lines are classified by range of voltages

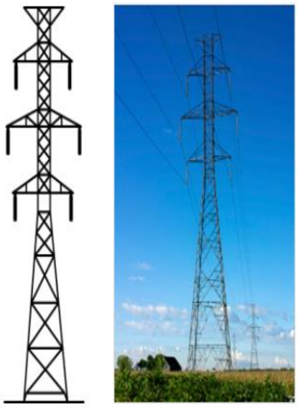


Designation	Voltage-Range	Type of pylons used	Ending points	Type of substations used
Low-voltage line	0 – 1000 V	Wooden, concrete, steel-tube, lattice poles, also poles on rooftops	Indoor substations, poles (not surrounded by switchyard), walls of buildings	Indoor
Medium-voltage line	1000 V – 50000 V	Wooden, concrete, steel-tube, lattice poles	Indoor substations, poles (not surrounded by switchyard)	Indoor, pylon transformer
High-voltage line	50000 V – 200000 V	lattice towers, sometimes steel-tube towers or wooden poles	Outdoor substations, rarely termination towers (sometimes surrounded by switchyard) or indoor substations	Outdoor, indoor rarely
Extreme-high-voltage line	> 200000 V	lattice towers, sometimes steel-tube towers (until 500 kV) or wooden poles (until 345 kV)	Outdoor substations, rarely termination towers (sometimes surrounded by switchyard) or indoor substations	Outdoor, indoor rarely

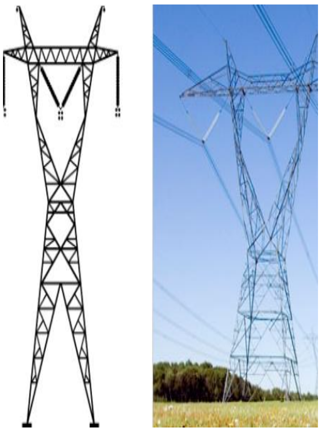
21.7.4 Transmission tower



Tubular steel pole



Double circuit tower



Waist type tower

HVDC distance tower near the terminus of the Nelson River Bipole adjacent to Dorsey Converter Station near Rosser, Manitoba, Canada

Railway traction line towers

Tension tower with phase transposition of a powerline for single-phase AC traction current (110 kV, 16.67 Hz) near Bartholomä, Germany

High voltage AC transmission towers

Towers of Cádiz, 132 kV three-phase AC powerline over the bay of Cádiz, Spain starting at Puerto Real Substation to the substation of the former Cadiz Thermal Power Station

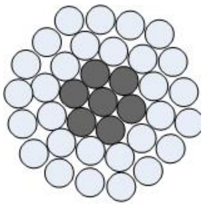
21.7.5 International Supplier

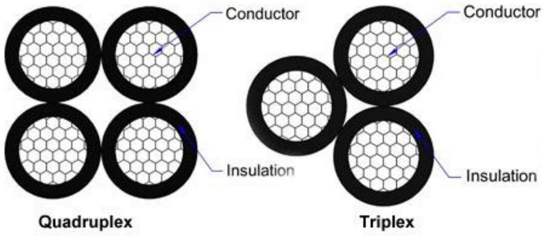
- **Products:**

1. **AAC--**All Aluminum Conductor
2. **ACS--**Aluminum Clad Steel Wire
3. **GSW--**Galvanized Steel Wire /Strand
4. **ACSR--**Aluminum Conductor Steel Reinforced
5. **AACSR--**Aluminum Alloy Conductor Steel Reinforced
6. **ACAR--**Aluminum Conductor Aluminum Alloy Reinforced
7. **ACSR/AW--**Aluminum Conductor Aluminum Clad Steel Reinforced
8. **ACSS/TW--**Aluminum Conductor Steel Supported-Trapezoidal Wire
9. **TACSR--**Thermal Resistance Aluminum Alloy Conductor Steel Reinforced

- **Products:**

a) ACSR overhead power wire
b) Low voltage overhead service drop cable
- Triplex overhead service drop cable
- Quadruplex overhead service drop cable





21.7.6 Allied wire and cable

Allied Wire & Cable carries an extensive inventory of coaxial cable, lead wire, MIL-Spec wire, and electrical cable

21.7.7 Products for AWC

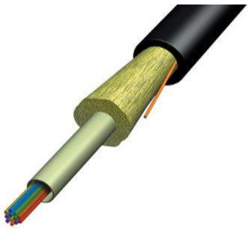
Utility Cables are strong, tough, flexible cables that are often used in lift lines

A. **Low Voltage Overhead Service Drop Cable**

<u>Triplex Overhead Service Drop Cable</u>

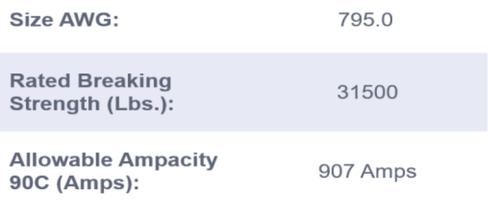
- **Construction :**
  - Insulation: Black Extruded Cross-linked Polyethylene (XLPE)
  - Bare Neutral: Bare Aluminum
  - Conductors: 2 Aluminum Conductors
- **Ratings and Approvals:**
  - Voltage Rating: 600 Volts
  - Temperature Rating: 90°C
  - ANSI/ICEA Standard S-76-474
- **Features and Benefits:**
  - Weather resistant
  - Abrasion resistant
  - Chemical resistant
  - Cutting resistant
  - Tearing resistant

Quadruplex Overhead Service Drop Cable



B. **ACSR Overhead Power Cable**
Stands for: Aluminum Conductor Steel Reinforced

- **Construction:**
  - Composite concentric-lay-stranded conductor
  - Central core of steel strand or strands
  - One or more layers of aluminum 1350-H19 wires are stranded around central core
  - Many combinations of steel and aluminum strands and layers are possible
- **Features and Benefits**:
  - Light weight
  - High conductivity
  - High tensile strength and ruggedness of steel
  - Higher tensions, less sag and longer span lengths than other overhead conductors
  - Steel strands may be added for mechanical reinforcement



Size AWG:	795.0
Rated Breaking Strength (Lbs.):	31500
Allowable Ampacity 90C (Amps):	907 Amps

21.7.8 IEEE standards

The Transmission & Distribution Committee of the IEEE power & energy society focuses on all matters related to the design, theoretical and experimental performance, installation, and service operation of parts of electric power systems.

NO. OF STD	TITLE	CONTENTS
IEEE 430-2017	Procedures for the Measurement of Radio Noise	ac and dc power-line noise sources (gaps, harmonics and corona discharge)
IEEE 1829-2017	Conducting Corona Tests on Hardware	Two tests (the first is a visual corona test, the second is a radio interference voltage (RIV) test.
IEEE NESC(R)-2017	National Electrical Safety Code	basic provisions for safeguarding of persons from hazards arising from the installation, operation, or maintenance
IEEE Std 524-2016	Installation of Overhead Transmission Line Conductors	selection of methods, equipment, and tools and overhead ground wires are provided.
IEEE Std 524-2003	Installation of Overhead Transmission Line Conductors	This guide does not address special conductors such as those used for river and canyon crossing.
IEEE Std 1441-2004	Inspection of Overhead Transmission Line Construction	reference for those involved in the ownership, design, and construction
IEC 60099-8:2017	Overhead surge arresters to protect the insulator	- thermal stability - long-duration current impulse withstand duty - disconnector test
IEC TR 61328:2003	installation of transmission line conductors and earthwires	selection and testing to protect equipment, components and personnel from the induced or fault currents

Table 13: IEEE standards

21.7.9 References

electropedia
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- http://www.tddlcable.com/
- https://www.lahmeyer.de/en/home.html
- http://www.awcwire.com/
- https://www.ieee-pes.org/

21.8 IEEE Power Substations Standards Collection: VuSpec™

21.8.1 Summary

IEEE Power Substations Standards Collection included active standards covering switching stations, transformer stations, and generating station switchyards. IEEE Substations Standards Collection is a single source for design construction and operation of power substations. IEEE Substations Standards Collection contains 50 active IEEE Standards, Guides, and Recommended Practices, Errata & Interpretations for Power Substations, it also allows for easy full text searching on a signal standard or all standards at the same time.

21.8.2 Table of Contents

Includes 50 active IEEE Standards, Guides, and Recommended Practices, Errata & Interpretations in the power substation family:

- IEEE Std 80™-2000, IEEE Guide for Safety in AC Substation Grounding
- Errata to IEEE Std 80™-2000, IEEE Guide for Safety in AC Substation Grounding
- IEEE Standards Interpretation for IEEE Std 80™-1986 IEEE Guide for Safety in AC Substation Grounding
- IEEE Standards Interpretation for IEEE Std 80™-2000 IEEE Guide for Safety in AC Substation Grounding
- IEEE Std 81™-2012, IEEE Guide For Measuring Earth Resistivity, Ground Impedance, And Earth Surface Potentials Of a Ground System
- IEEE Std 525™-2007, IEEE Guide for the Design and Installation of Cable Systems in Substations
- IEEE Std 605™-2008, IEEE Guide for Design of substation Rigid-Bus Structures
- Correction to IEEE Std 605™-1998, IEEE Guide for Design of substation Rigid-Bus Structures
- IEEE Standards Interpretation for IEEE Std 605™-1998, IEEE Guide of substation Rigid-Bus Structures
- IEEE Standards Interpretation for IEEE Std 605™-2008 IEEE Guide for Bus Design in Air Insulated Substations
- IEEE Std 693™-2005, IEEE Recommended Practice for Seismic Design of Substations
- IEEE Std 837™-2002, IEEE Standard for Qualifying Permanent Connections Used in Substation Grounding
- IEEE Std 979™-2012, IEEE Guide for Substation Fire Protection (Pub 11/7/2012) IEEE Std 980™-1994 (R2001), IEEE Guide for Containment and Control of Oil Spills in Substations
- IEEE Standards Interpretation for IEEE Std 980™-1994 IEEE Guide for Containment and Control of Oil Spills in Substations
- IEEE Std 998™-2012, IEEE Guide for Direct Lightning Stroke Shielding of Substations
- IEEE Std 1031™-2011, IEEE Guide for the Functional Specification of Transmission Static Var Compensators

- Errata to IEEE Std 1031™-2011, IEEE Guide for the Functional Specification of Transmission Static Var Compensators
- IEEE Std 1125™-1993 (R2005), IEEE Guide for Moisture Measurement and Control in SF6 Gas-Insulated Equipment
- IEEE Std 1127™-1998 (R2004), IEEE Guide for the Design, Construction, and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility
- IEEE Std 1240™-2000 (R2012), IEEE Guide for the Evaluation of the Reliability of HVDC Converter Stations
- IEEE Std 1246™-2011, IEEE Guide for Temporary Protective Grounding Systems Used in Substations
- IEEE Std 1264™-1993 (R2009), IEEE Guide for Animal Deterrents for Electric Power Supply Substations
- IEEE Std 1267™-1999 (R2005), IEEE Guide for Development of Specificationfor Turnkey Substation Projects
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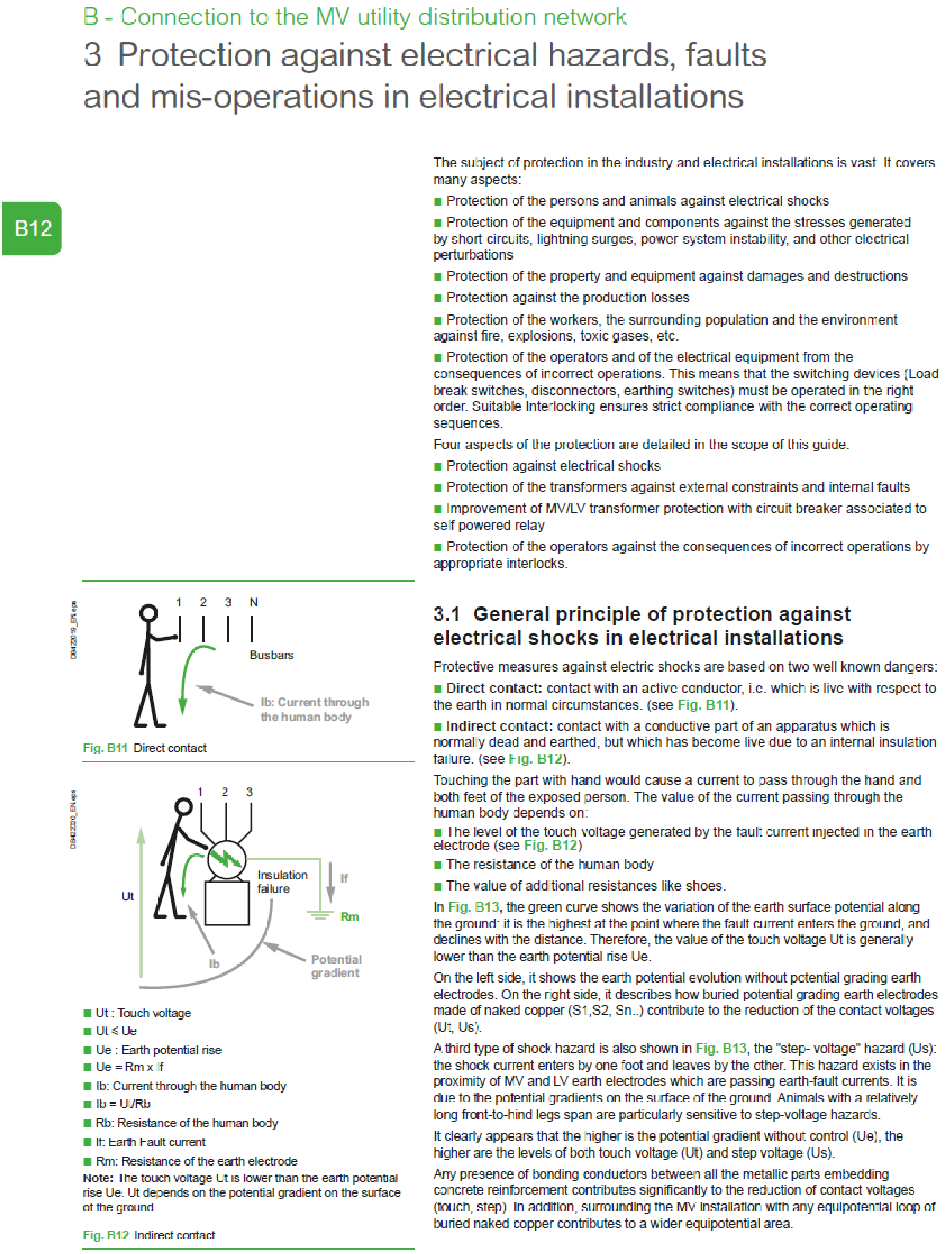
- IEEE Std 1402™-2000 (R2008), IEEE Guide for Electric Power Substation Physical and Electronic Security
- IEEE Std 1416™-1998 (R2004), IEEE Recommended Practice for the Interface of New Gas-Insulated Equipment in Existing Gas-Insulated substations
- IEEE Std 1427™-2006, IEEE Guide for Recommended Electrical Clearances and Insulation Levels in Air Insulated Electrical Power Substations
- IEEE Std 1527™-2006, IEEE Recommended Practice for the Design of Flexible Buswork Located in Seismically Active Areas
- IEEE Std 1534™-2009, IEEE Recommended Practice for Specifying Thyristor Controlled Series Capacitors
- IEEE Std 1585™-2002 (R2007), IEEE Guide for the Functional Specification of Medium Voltage (1 - 35 kV) Electronic Series Devices for Compensation of Voltage Fluctuations
- IEEE Std 1613™-2009, IEEE Standard Environmental and Testing Requirements for Communications Networking Devices Installed in Electric Power Substations
- IEEE Standards Interpretation for IEEE Std 1613™-2003 IEEE Standard Environmental and Testing Requirements for Communications Networking Devices in Electric Power Substations
- IEEE Standards Interpretations for IEEE Std 1613™-2009 IEEE Standard Environmental and Testing Requirements for Communications Networking Devices Installed in Electrical Power Substations
- IEEE Std 1615™-2007, IEEE Recommended Practice for Network Communication in Electric Power Substations
- IEEE Std 1623™-2004 (R2010), IEEE Guide for the Functional Specification of Medium Voltage (1 kV…35 kV) Electronic Shunt Devices for Dynamic Voltage Compensation
- IEEE Std 1646™-2004 IEEE Standard Communication Delivery Time Performance Requirements for Electric Power Substation Automation
- IEEE Std 1686™-2007, IEEE Standard for Substation Intelligent Electronic Devices (IEDs) Cyber Security Capabilities
- IEEE Std 1815™-2012, IEEE Standard for Electric Power Systems Communications - Distributed Network Protocol (DNP3)
- IEEE Std C37.1™-2007, IEEE Standard for SCADA and Automation Systems
- IEEE Std C37.2™-2008, IEEE Standard for Electrical Power System Device Function Numbers, Acronyms, and Contact Designations
- IEEE Std C37.122™-2010, IEEE Standard for Gas-Insulated Substations
- Errata to IEEE Std C37.122™-2010, IEEE Standard for Gas-Insulated Substations
- IEEE Std C37.122.1™-1993 (R2008), IEEE Guide for Gas- Insulated Substations
- IEEE Std C37.122.2™-2011 - IEEE Guide for the Application of Gas-Insulated Substations 1 kV to 52 kV

- IEEE Std C37.122.3™-2011 - IEEE Guide for Sulphur Hexafluoride (SF6) Gas Handling for High-Voltage (over 1000 Vac) Equipment
- IEEE Std C37.123™-1996 (R2008), IEEE Guide to Specifications for Gas Insulated, Electric Power Substation Equipment

22 Electrical Safety and Earthening

22.1 Connection to medium voltage (MV) (up to 52 kV)

The term "medium voltage" is commonly used for distribution systems with voltages above 1 kV and generally applied up to and including 52 kV[1]. For technical and economic reasons, the service voltage of medium voltage distribution networks rarely exceeds 35 kV.



B - Connection to the MV utility distribution network

3 Protection against electrical hazards, faults and mis-operations in electrical installations

The subject of protection in the industry and electrical installations is vast. It covers many aspects:

- Protection of the persons and animals against electrical shocks
- Protection of the equipment and components against the stresses generated by short-circuits, lightning surges, power-system instability, and other electrical perturbations
- Protection of the property and equipment against damages and destructions
- Protection against the production losses
- Protection of the workers, the surrounding population and the environment against fire, explosions, toxic gases, etc.
- Protection of the operators and of the electrical equipment from the consequences of incorrect operations. This means that the switching devices (Load break switches, disconnectors, earthing switches) must be operated in the right order. Suitable Interlocking ensures strict compliance with the correct operating sequences.

Four aspects of the protection are detailed in the scope of this guide:

- Protection against electrical shocks
- Protection of the transformers against external constraints and internal faults
- Improvement of MV/LV transformer protection with circuit breaker associated to self powered relay
- Protection of the operators against the consequences of incorrect operations by appropriate interlocks.

Fig. B11 Direct contact

- Ut : Touch voltage
- Ut ⩽ Ue
- Ue : Earth potential rise
- Ue = Rm x If
- Ib: Current through the human body
- Ib = Ut/Rb
- Rb: Resistance of the human body
- If: Earth Fault current
- Rm: Resistance of the earth electrode

Note: The touch voltage Ut is lower than the earth potential rise Ue. Ut depends on the potential gradient on the surface of the ground.

Fig. B12 Indirect contact

3.1 General principle of protection against electrical shocks in electrical installations

Protective measures against electric shocks are based on two well known dangers:

- **Direct contact:** contact with an active conductor, i.e. which is live with respect to the earth in normal circumstances. (see Fig. B11).
- **Indirect contact:** contact with a conductive part of an apparatus which is normally dead and earthed, but which has become live due to an internal insulation failure. (see Fig. B12).

Touching the part with hand would cause a current to pass through the hand and both feet of the exposed person. The value of the current passing through the human body depends on:

- The level of the touch voltage generated by the fault current injected in the earth electrode (see Fig. B12)
- The resistance of the human body
- The value of additional resistances like shoes.

In Fig. B13, the green curve shows the variation of the earth surface potential along the ground: it is the highest at the point where the fault current enters the ground, and declines with the distance. Therefore, the value of the touch voltage Ut is generally lower than the earth potential rise Ue.

On the left side, it shows the earth potential evolution without potential grading earth electrodes. On the right side, it describes how buried potential grading earth electrodes made of naked copper (S1,S2, Sn..) contribute to the reduction of the contact voltages (Ut, Us).

A third type of shock hazard is also shown in Fig. B13, the "step- voltage" hazard (Us): the shock current enters by one foot and leaves by the other. This hazard exists in the proximity of MV and LV earth electrodes which are passing earth-fault currents. It is due to the potential gradients on the surface of the ground. Animals with a relatively long front-to-hind legs span are particularly sensitive to step-voltage hazards.

It clearly appears that the higher is the potential gradient without control (Ue), the higher are the levels of both touch voltage (Ut) and step voltage (Us).

Any presence of bonding conductors between all the metallic parts embedding concrete reinforcement contributes significantly to the reduction of contact voltages (touch, step). In addition, surrounding the MV installation with any equipotential loop of buried naked copper contributes to a wider equipotential area.

22.2 LV Distribution[23]

1 Earthing schemes E2

2 The installation system E15

3 External influences (IEC 60364-5-51) E37

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[23] From Schneider, Electrical Installation Guide, Chapter E

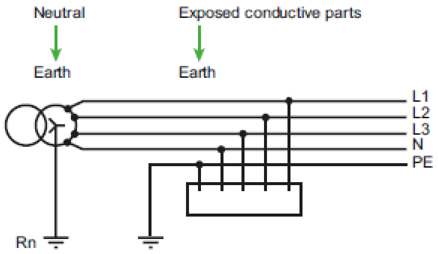


Fig. E3 TT System

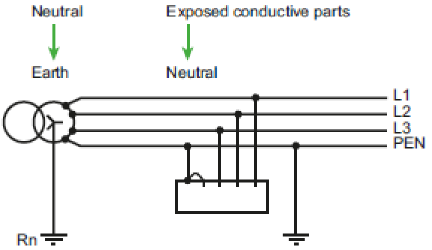


Fig. E4 TN-C system

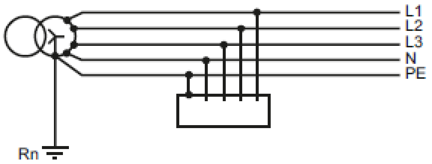


Fig. E5 TN-S system

TT system (earthed neutral) (see Fig. E3)
One point at the supply source is connected directly to earth. All exposed- and extraneous-conductive-parts are connected to a separate earth electrode at the installation. This electrode may or may not be electrically independent of the source electrode. The two zones of influence may overlap without affecting the operation of protective devices.

TN systems (exposed conductive parts connected to the neutral)
The source is earthed as for the TT system (above). In the installation, all exposed- and extraneous-conductive-parts are connected to the neutral conductor. The several versions of TN systems are shown below.

TN-C system (see Fig. E4)
The neutral conductor is also used as a protective conductor and is referred to as a PEN (Protective Earth and Neutral) conductor. This system is not permitted for conductors of less than 10 mm² or for portable equipment.

The TN-C system requires an effective equipotential environment within the installation with dispersed earth electrodes spaced as regularly as possible since the PEN conductor is both the neutral conductor and at the same time carries phase unbalance currents as well as 3rd order harmonic currents (and their multiples).

The PEN conductor must therefore be connected to a number of earth electrodes in the installation.

Caution: In the TN-C system, the “protective conductor” function has priority over the “neutral function”. In particular, a PEN conductor must always be connected to the earthing terminal of a load and a jumper is used to connect this terminal to the neutral terminal.

TN-S system (see Fig. E5)
The TN-S system (5 wires) is obligatory for circuits with cross-sectional areas less than 10 mm² for portable equipment.

The protective conductor and the neutral conductor are separate. On underground cable systems where lead-sheathed cables exist, the protective conductor is generally the lead sheath. The use of separate PE and N conductors (5 wires) is obligatory for circuits with cross-sectional areas less than 10 mm² for portable equipment.

TN-C-S system (see Fig. E6 below and Fig. E7 next page)
The TN-C and TN-S systems can be used in the same installation. In the TN-C-S system, the TN-C (4 wires) system must never be used downstream of the TN-S (5 wires) system, since any accidental interruption in the neutral on the upstream part would lead to an interruption in the protective conductor in the downstream part and therefore a danger.

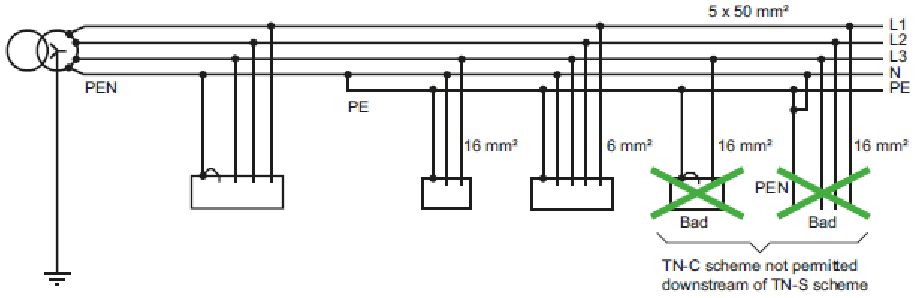


Fig. E6 TN-C-S system

22.2.1 Characteristics of TT, TN and IT systems

The TT system:

- Technique for the protection of persons: the exposed conductive parts are earthed and residual current devices (RCDs) are used
- Operating technique: interruption for the first insulation fault

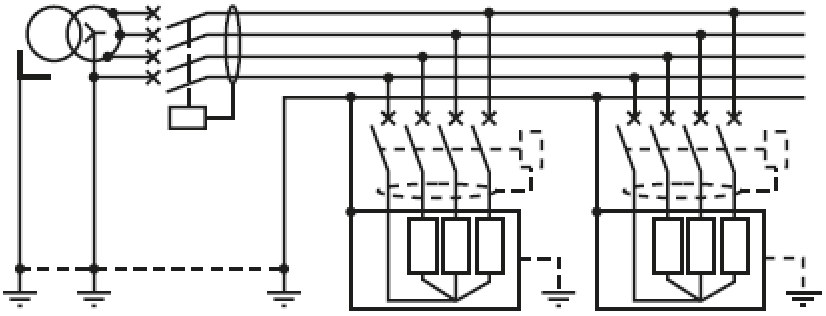


Fig. E12 TT system

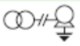
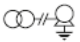
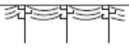
Note: If the exposed conductive parts are earthed at a number of points, an RCD must be installed for each set of circuits connected to a given earth electrode.

Main characteristics

- Simplest solution to design and install. Used in installations supplied directly by the public LV (Low Voltage) distribution network.
- Does not require continuous monitoring during operation (a periodic check on the RCDs may be necessary).
- Protection is ensured by special devices, the residual current devices (RCD), which also prevent the risk of fire when they are set to < 500 mA.
- Each insulation fault results in an interruption in the supply of power, however the outage is limited to the faulty circuit by installing the RCDs in series (selective RCDs) or in parallel (circuit selection).
- Loads or parts of the installation which, during normal operation, cause high leakage currents, require special measures to avoid nuisance tripping, i.e. supply the loads with a separation transformer or use specific RCDs (see section 5.1 in chapter F).

E - LV Distribution

1 Earthing schemes

Type of network		Advised	Possible	Not advised
Very large network with high-quality earth electrodes for exposed conductive parts (10 Ω max.)			TT, TN, IT[a] or mixed	
Very large network with low-quality earth electrodes for exposed conductive parts (> 30 Ω)		TN	TN-S	IT[A TN-C
Disturbed area (storms) (e.g. television or radio transmitter)		TN	TT	IT[b]
Network with high leakage currents (> 500 mA)		TN[d]	IT[d] TT[c] [d]	
Network with outdoor overhead lines		TT[e]	TN[e] [f]	IT[f]
Emergency standby generator set		IT	TT	TN[g]
Type of loads				
Loads sensitive to high fault currents (motors, etc.)		IT	TT	TN[h]
Loads with a low insulation level (electric furnaces, welding machines, heating elements, immersion heaters, equipment in large kitchens)		TN[i]	TT[i]	IT
Numerous phase-neutral single-phase loads (mobile, semi-fixed, portable)		TT[j] TN-S		IT[j] TN-C[j]
Loads with sizeable risks (hoists, conveyers, etc.)		TN[k]	TT[k]	IT[k]
Numerous auxiliaries (machine tools)		TN-S	TN-C IT[lbis]	TT[l]
Miscellaneous				
Supply via star-star connected power transformer[m]		TT	IT without neutral	IT[m] without neutral
Premises with risk of fire		IT[o]	TN-S[o] TT[o]	TN-C[n]
Increase in power level of LV utility subscription, requiring a private substation		TT[p]		
Installation with frequent modifications		TT[q]		TN[r] IT[r]
Installation where the continuity of earth circuits is uncertain (work sites, old installations)		TT[s]	TN-S	TN-C IT[s]
Electronic equipment (computers, PLCs)		TN-S		TN-C
Machine control-monitoring network, PLC sensors and actuators		IT[t]	TN-S, TT	

[a] When the SEA is not imposed by regulations, it is selected according to the level of operating characteristics (continuity of service that is mandatory for safety reasons or desired to enhance productivity, etc.)
Whatever the SEA, the probability of an insulation failure increases with the length of the network. It may be a good idea to break up the network, which facilitates fault location and makes it possible to implement the system advised above for each type of application.

[b] The risk of flashover on the surge limiter turns the isolated neutral into an earthed neutral. These risks are high for regions with frequent thunder storms or installations supplied by overhead lines. If the IT system is selected to ensure a higher level of continuity of service, the system designer must precisely calculate the tripping conditions for a second fault.

[c] Risk of RCD nuisance tripping.

[d] Whatever the SEA, the ideal solution is to isolate the disturbing section if it can be easily identified.

[e] Risks of phase-to-earth faults affecting equipotentiality.

[f] Insulation is uncertain due to humidity and conducting dust.

[g] The TN system is not advised due to the risk of damage to the generator in the case of an internal fault. What is more, when generator sets supply safety equipment, the system must not trip for the first fault.

[h] The phase-to-earth current may be several times higher than In, with the risk of damaging or accelerating the ageing of motor windings, or of destroying magnetic circuits.

[i] To combine continuity of service and safety, it is necessary and highly advised, whatever the SEA, to separate these loads from the rest of the installation (transformers with local neutral connection).

[j] When load equipment quality is not a design priority, there is a risk that the insulation resistance will fall rapidly. The TT system with RCDs is the best means to avoid problems.

[k] The mobility of this type of load causes frequent faults (sliding contact for bonding of exposed conductive parts) that must be countered. Whatever the SEA, it is advised to supply these circuits using transformers with a local neutral connection.

[l] Requires the use of transformers with a local TN system to avoid operating risks and nuisance tripping at the first fault (TT) or a double fault (IT).

[lbis] With a double break in the control circuit.

[m] Excessive limitation of the phase-to-neutral current due to the high value of the zero-phase impedance (at least 4 to 5 times the direct impedance). This system must be replaced by a star-delta arrangement.

[n] The high fault currents make the TN system dangerous. The TN-C system is forbidden.

[o] Whatever the system, the RCD must be set to Δn y 500 mA.

[p] An installation supplied with LV energy must use the TT system. Maintaining this SEA means the least amount of modifications on the existing network (no cables to be run, no protection devices to be modified).

[q] Possible without highly competent maintenance personnel.

[r] This type of installation requires particular attention in maintaining safety. The absence of preventive measures in the TN system means highly qualified personnel are required to ensure safety over time.

[s] The risks of breaks in conductors (supply, protection) may cause the loss of equipotentiality for exposed conductive parts. A TT system or a TN-S system with 30 mA RCDs is advised and is often mandatory. The IT system may be used in very specific cases.

[t] This solution avoids nuisance tripping for unexpected earth leakage.

Fig. E17 Influence of networks and loads on the selection of system earthing arrangements

22.3 Protection against electric shocks and electrical fires[24]

1 Protection against electric shock F2

2 Types of protection against electric shock F4

3 Additional protection: High sensitivity RCDs F6

4 Implementation of TT system F8

5 Implementation of TN system F10

6 Implementation of IT system F19

7 Residual Current Devices (RCDs) F30

8 Other protective measures F43

9 Protection against electrical fire risks F47

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[24] From Schneider, Electrical Installation Guide, Chapter F

4 Implementation of TT system

Automatic disconnection for TT system is achieved by RCD having a sensitivity of

$$I_{\Delta n} \leqslant \frac{50}{R_A}$$

where RA is the resistance of the installation earth electrode

4.1 Principle

In this system, all exposed-conductive-parts and extraneous-conductive-parts of the installation must be connected to a common earth electrode. The neutral point of the supply system is normally earthed at a point outside the influence area of the installation earth electrode, but need not be so. The impedance of the earth fault loop therefore consists mainly in the two earth electrodes (i.e. the source and installation electrodes) in series, so that the magnitude of the earth fault current is generally too small to operate overcurrent relays or fuses, and the use of a residual current operated device is essential.

This principle of protection is also valid if one common earth electrode only is used, notably in the case of a consumer-type substation within the installation area, where space limitation may impose the adoption of a TN system earthing, but where all other conditions required by the TN system cannot be fulfilled.

Protection by automatic disconnection of the supply used in TT system is by RCD of sensitivity:

$$I_{\Delta n} \leqslant \frac{50}{R_A}$$

Where:

$I_{\Delta n}$ is the rated residual operating current of the RCD

R_A is the resistance of the earth electrode for the installation (maximum value over time)

For temporary supplies (to work sites, …) and agricultural and horticultural premises, the value of 50 V is replaced by 25 V.

Example (see Fig. F11)

- The resistance of the earth electrode of substation neutral R_n is 10 Ω.
- The resistance of the earth electrode of the installation R_A is 20 Ω.
- The earth-fault loop current I_d = 7.7 A.
- The fault voltage $U_f = I_d \times R_A$ = 154 V and therefore dangerous, but $I_{\Delta n} \leq 50/20 = 2.5$ A so that a standard 300 mA RCD will operate in about 30 ms without intentional time delay, and will clear the fault where a fault voltage exceeding 50V appears on an exposed-conductive-part.

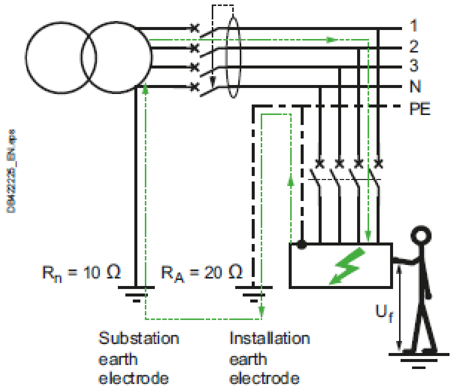


Fig. F11 Automatic disconnection of supply for TT system

The choice of sensitivity of the residual current device is a function of the resistance R_A of the earth electrode for the installation, and is given in Fig. F12.

$I_{\Delta n}$	Maximum resistance of the earth electrode	
	(50 V)	(25 V)
3 A	16 Ω	8 Ω
1 A	50 Ω	25 Ω
500 mA	100 Ω	50 Ω
300 mA	166 Ω	83 Ω
30 mA	1666 Ω	833 Ω

Fig. F12 The upper limit of resistance for an installation earthing electrode which must not be exceeded, for given sensitivity levels of RCDs at U_L voltage limits of 50 and 25 V

22.3.1 RCDs

7 Residual Current Devices (RCDs)

7.3 Types of RCDs

The fault residual current could take various waveforms depending on the load characteristics. The following types of RCDs are defined in IEC 60755, for suitable protection of different forms of residual current:

Type AC

Type AC RCDs detect residual sinusoidal alternating currents. Type AC RCDs are suitable for general use and cover most of the applications in practice.

Type A

In addition to the detection characteristics of type AC RCDs, Type A RCDs detect pulsating DC residual current. Such waveforms can be caused by diode or thyristor rectifier circuit in electronic loads. Type A RCD are specifically intended to be used for single phase class 1 electronic loads.

Type F

Type F RCDs is a new RCD type recently introduced in IEC 62423 and in IEC60755. In addition to the detection characteristics of type A RCDs,type F RCDs are specially designed for circuit protection where single phase variable speed drivers could be used. In these circuits, the waveform of residual current could be a composite of multi-frequencies including motor frequency, convertor switching frequency and line frequency. For the reason of energy efficiency, the use of frequency converters in certain loads (washing machine, air conditioner, ...) is increasing, and type F RCD will cover those new applications.

Type F also has enhanced disturbance withstand characteristics (non-tripping on surge current). They are capable of tripping even if a pure direct current of 10 mA is superimposed on a sinusoidal or pulsed DC differential current.

Type B

Type B RCDs can detect sinusoidal AC, pulsating DC, composite of multi-frequency as well as smooth DC residual currents. In addition, tripping conditions are defined with different frequencies from 50Hz to 1kHz. In an AC electrical distribution network, a pure DC residual current can be mainly generated from three-phase rectifying circuits, but also from some specific single phase rectifiers.

Type B RCD are intended to be used for loads with three-phase rectifier, such as variable speed drives, PV system, EV charging station and medical equipment.

Fig. F51 summarizes the definition of different types of RCD, with their main application and waveforms. It has to be noted that the different types of RCDs (AC, A, F and B) are nested one within the other like Russian dolls: type B, for example, also complies with the requirements of type F, type A and type AC.

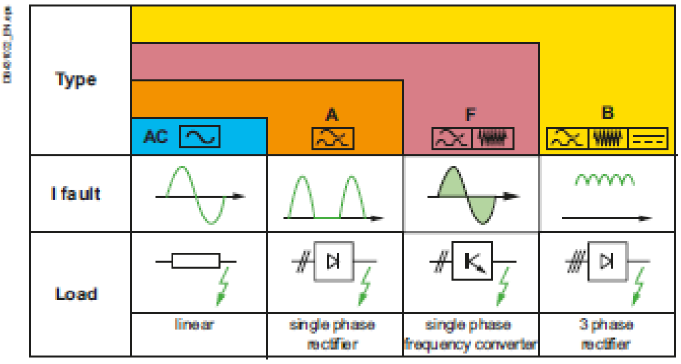


Fig. F51 Different types of RCDs

Annex B of IEC 60755 gives, for different electronic load architectures, the possible load and residual current waveforms, and proposes the suitable types of RCD for each case. (see Fig. F52)

22.4 Earthening

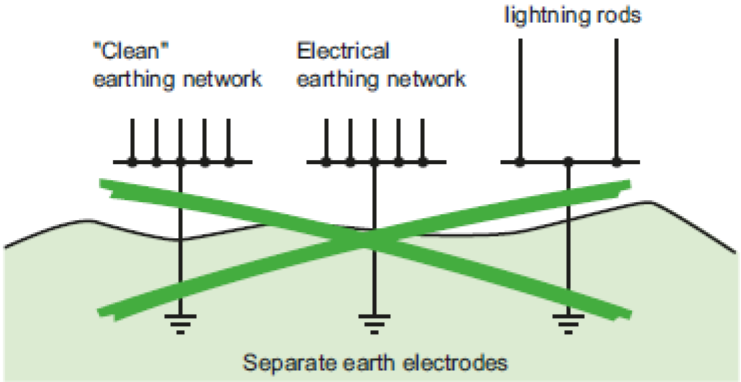


Fig. R3 Independent earth electrodes, a solution generally not acceptable for safety and EMC reasons

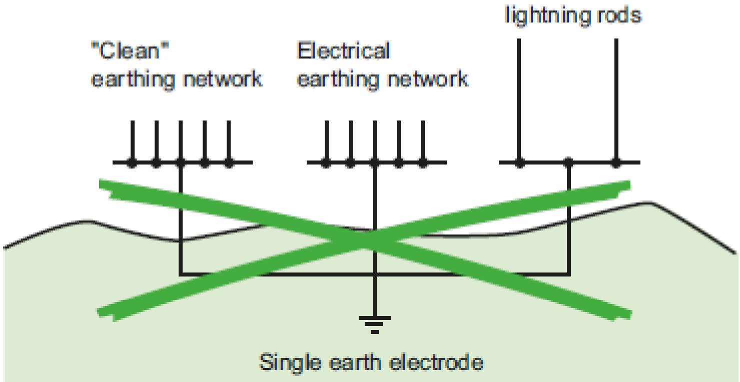


Fig. R4 Installation with a single earth electrode

R - EMC guidelines

2 Earthing principles and structures

The recommended configuration for the earthing network and electrodes is two or three dimensional (see Fig. R5). This approach is advised for general use, both in terms of safety and EMC. This recommendation does not exclude other special configurations that, when correctly maintained, are also suitable.

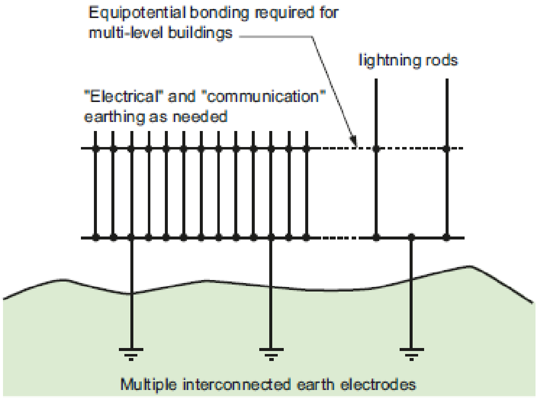


Fig. R5 Installation with multiple earth electrodes

22.5 Summary

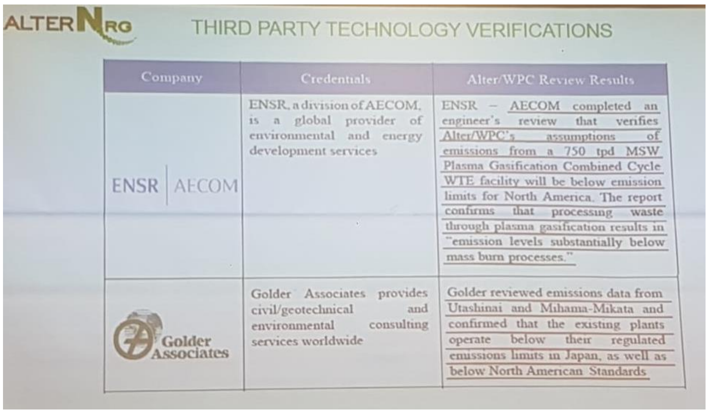
- N to Earthening at multiple sites.

Cable for earthening: thick Cu

22.5.1 In Lebanon

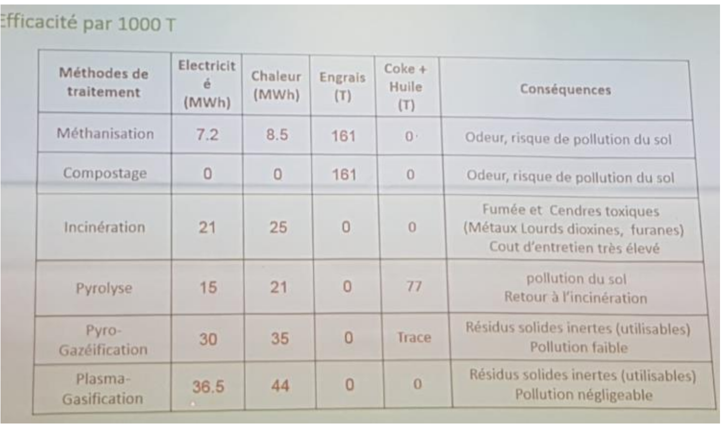
For overland lines (11 kV) there are 3 lines (3 phases), the zero (N) line is the earth.

23 Westinghouse plasma & Co Lebanon plasma gasification[25]



ALTER NRG THIRD PARTY TECHNOLOGY VERIFICATIONS

Company	Credentials	Alter/WPC Review Results
ENSR | AECOM	ENSR, a division of AECOM, is a global provider of environmental and energy development services	ENSR – AECOM completed an engineer's review that verifies Alter/WPC's assumptions of emissions from a 750 tpd MSW Plasma Gasification Combined Cycle WTE facility will be below emission limits for North America. The report confirms that processing waste through plasma gasification results in "emission levels substantially below mass burn processes."
Golder Associates	Golder Associates provides civil/geotechnical and environmental consulting services worldwide	Golder reviewed emissions data from Utashinai and Mihama-Mikata and confirmed that the existing plants operate below their regulated emissions limits in Japan, as well as below North American Standards



Efficacité par 1000 T

Méthodes de traitement	Electricité (MWh)	Chaleur (MWh)	Engrais (T)	Coke + Huile (T)	Conséquences
Méthanisation	7.2	8.5	161	0	Odeur, risque de pollution du sol
Compostage	0	0	161	0	Odeur, risque de pollution du sol
Incinération	21	25	0	0	Fumée et Cendres toxiques (Métaux Lourds dioxines, furanes) Cout d'entretien très élevé
Pyrolyse	15	21	0	77	pollution du sol Retour à l'incinération
Pyro-Gazéification	30	35	0	Trace	Résidus solides inertes (utilisables) Pollution faible
Plasma-Gasification	36.5	44	0	0	Résidus solides inertes (utilisables) Pollution négligeable

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[25] For some more information see [NLAP-IPP 2019]

Demonstration Incineration Power Plant Conception (2012)[26]

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[26] Based on the following report: [TEMO-STPP/IPP 2012]

24 تجهيز مكان لتصنيع المحطة الطاقة التجاربية في قاعة 200 متر مربع / Factory building 200qm

Dez. 2010 – Juni 2011: Renovierung der Werkhalle, Kosten: ca. 7000 EUR.

Juli 2011 – November 2012: Nutzung der Werkhalle (ca. 18 Monate). Renovierungskosten wurden gegen Miete aufgerechnet.

Bereiche der Renovierung: Abdeckung von Rohrleitungen an der Decke, Installation einer weiteren Toilette, Installation einer intakten und ausreichenden Wasserversorgung, Restaurierung der Fliesen

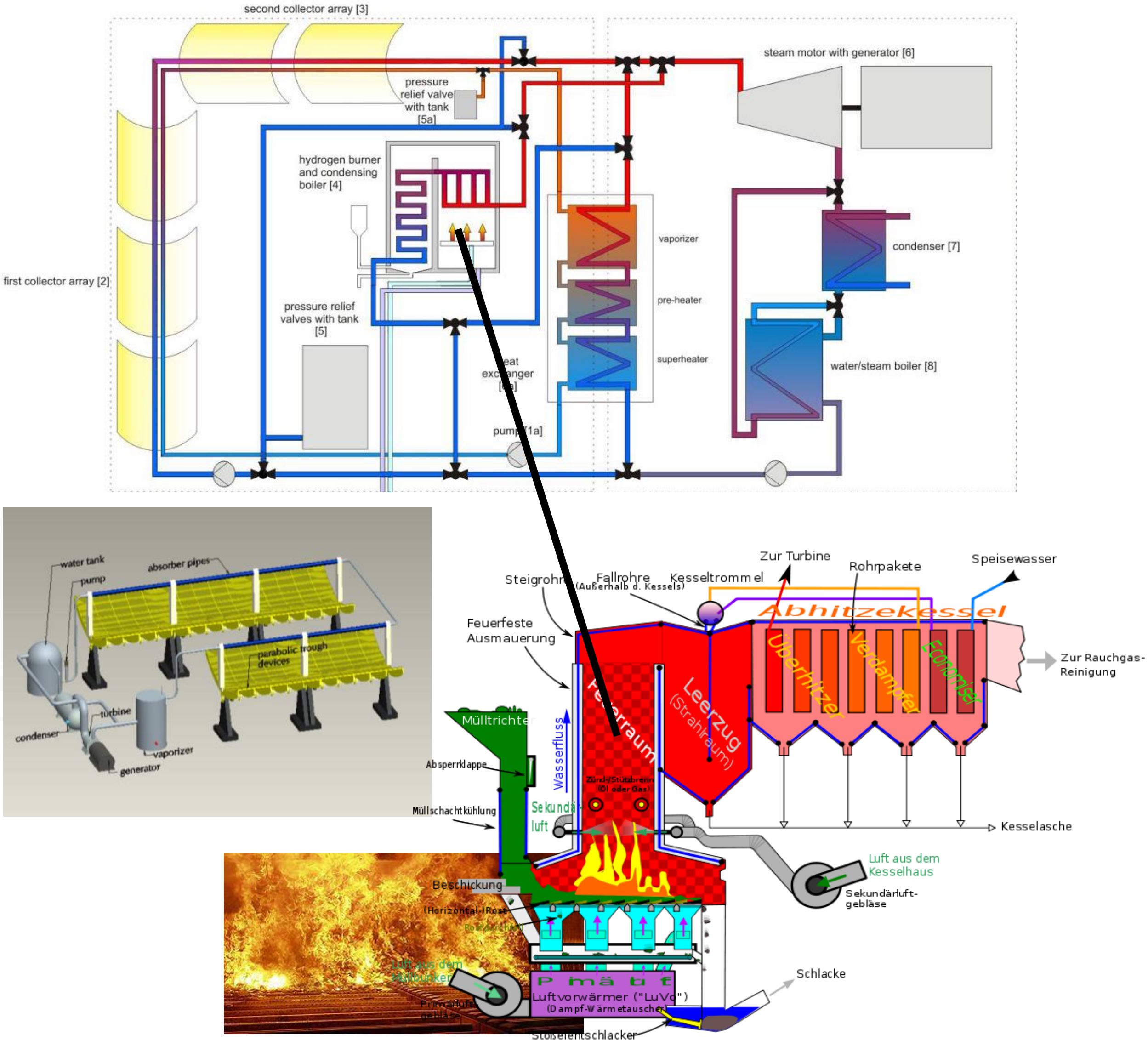
Vor Renovierung:

während Renovierung:

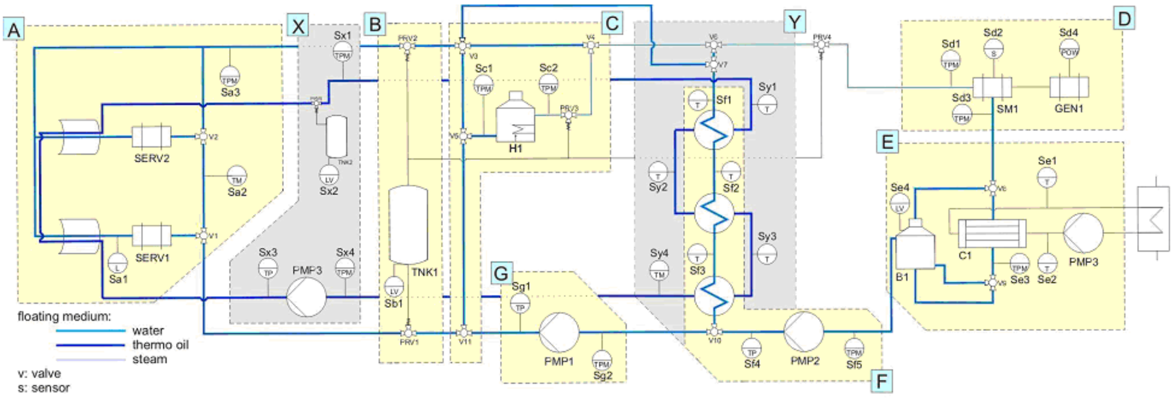
Nach Renovierung: Linke Seite: Computerarbeitsplätze - Rechte Seite: Mechanische Werkstatt für Teststand

25 / المحطة الطاقة التجريبيةExperimental System

25.1 تحليل النظام: الهيكل العام للمحطة الاختبار في رأسنحاش / لبنان System Analysis:General Structure of the Test Plant in Ras Nhache / Lebanon



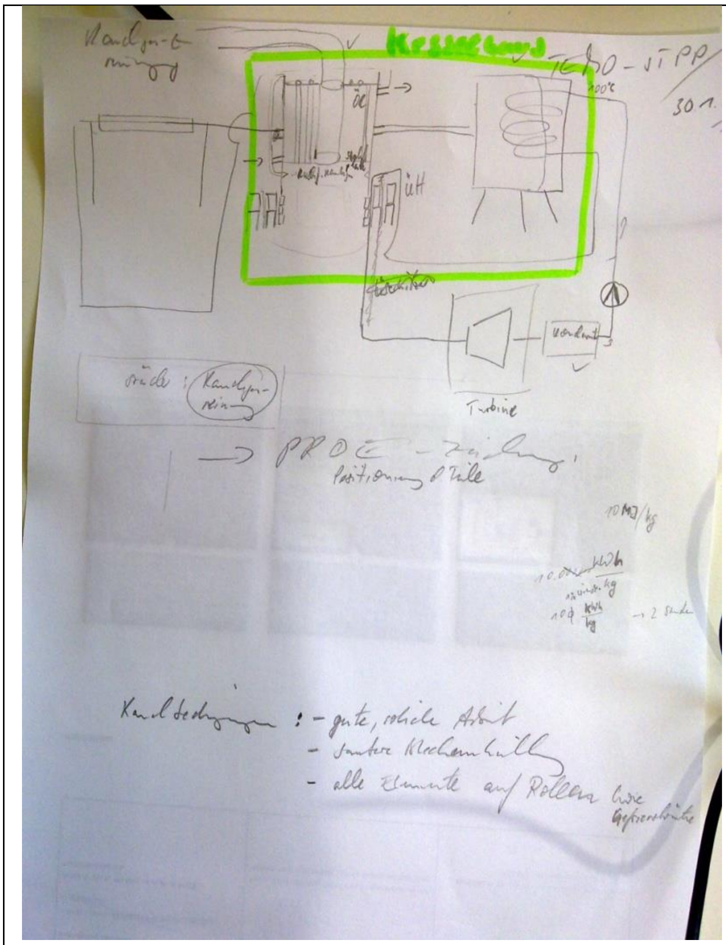
Process Control System



The above diagrams except of the incineration part are from [Mourad et. al. 2010]

25.2 تصميم النظام (يناير - مايو 2012) / System Design in MEAE Work Hall Ras Nache (Jan – May 2012)

25.2.1 Version 30 Jan 2012



– غرفة الاحتراق غازات يعود برودة المداخن (عن طريق فتحات على جانب غرفة الاحتراق).

- يتم احتراق غرفة ارميد. التكاليف متر مربع حوالي 160$

- هناك حاجة، وغرفة الاحتراق من 1 متر مكعب

- وغرفة الاحتراق يجب ان يقف على ارجل، لأغراض النقل ويمكن بعد ذلك بسهولة تركيب الأدوار تحته. وعلاوة على ذلك، من أجل السماح لتصريف بقايا الحرقى في وقت لاحق.

- Combustion chamber returns colder flue gases (by nozzles on the side of the combustion chamber).

- Combustion chamber is made stone. 1 qm costs about 160 USD.

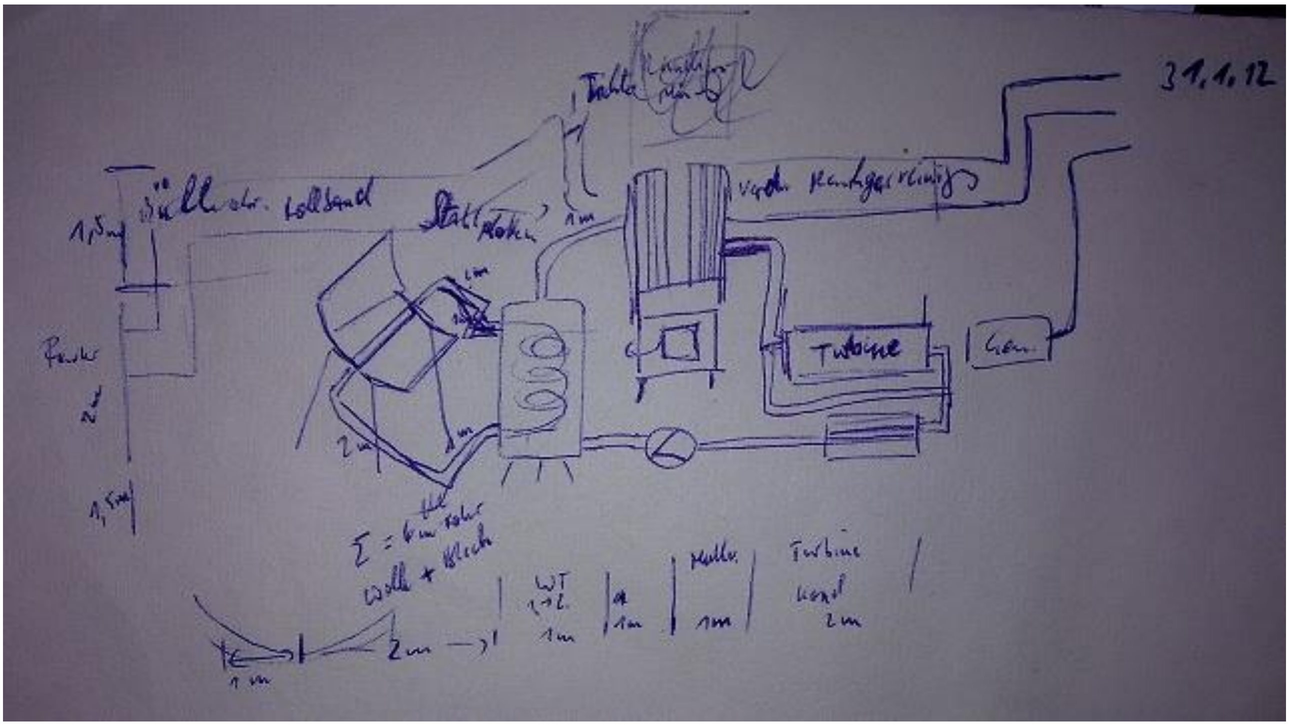
- There is a need, a combustion chamber of 1 cubic meter

- The combustion chamber is to stand on legs, for transportation purposes can then easily be attached below roles. Moreover, in order to allow a later discharge of the slag.

- Brennraum führt kältere Rauchgase zurück (durch Düsen an der Seite der Brennkammer).
- Brennkammer ist aus Backstein. Ein Quadratmeter kostet ca. 160 USD.
- Benötigt wird ein Brennraum von 1 Kubikmeter

- Der Brennraum soll auf Beinen stehen, für Transportzwecke können dann einfach unten Rollen angebracht werden. Ausserdem, um später einen Abfluss der Schlacke zu ermöglichen.

25.2.2 Version 31 Jan 2012 / 1 Feb- 7 Feb 2012



نظام التحكم (PCS)

بناء موقف الأنابيب الشمسية (المقتصد من محطة اختبار)

شراء التوربين

جزء الحرق: مبخر + مسخن للبخار

دمج دوائر توليد الطاقة (مخطط)

إدماج المقتصد الذي يعمل عن طريق الطاقة الشمسية (مخطط)

25.2.2.1 Primary circuit

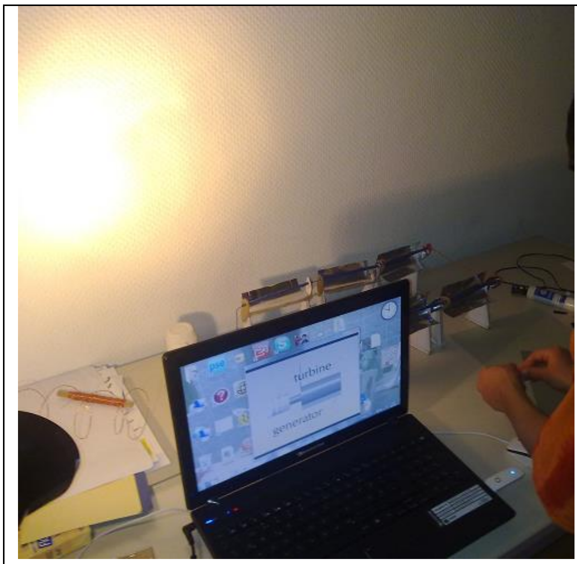
Solarfeld: Zur Vorwärmung (Economizer)

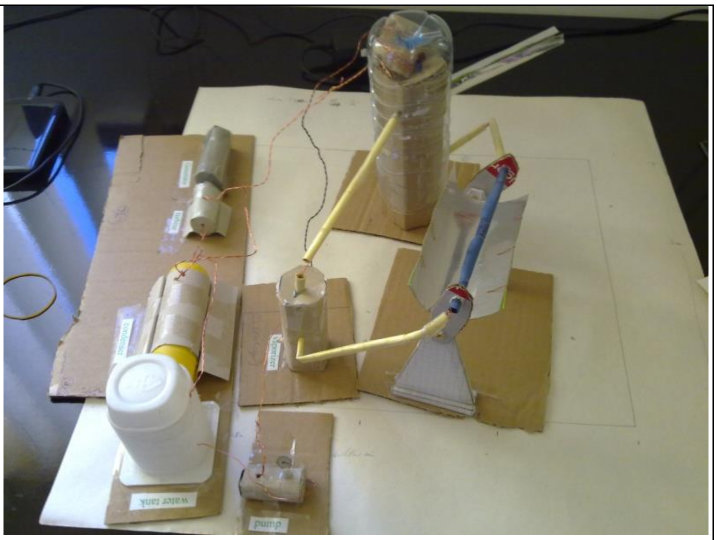
25.2.2.2 Heat exchanger between the primary and secondary circuit

in Rohren das warme Öl, im Grossraum Wasser,

welches dadurch vorgewärmt wird.

25.2.3 cardboard model

<table>
<tr><td>

</td><td>
</td></tr>
<tr><td>Erstellung des Modells (oben: 24.Jan. 2011, unten: 5.Febr. 2012)</td><td>Rechts: Modellversion Febr. 2012. Primärkreislauf (gelb: Ölrohre), links: Sekundärkreislauf.</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Entwurf als Flammrohrkessel: Brennraum, in den Deckel muss noch die Öffnung zum Flammrohr gebohrt werden, die Schlacke soll in den Eimer am Ende des Rosts fallen. Der liegende Behälter soll über den Brennraum montiert werden. Höhe insgesamt: 60cm+180cm=2,40 m.
In den obersten Teil (Kehrwende zw. Falmmrohr und Rauchrohren ist der Überhitzer (Wasserdampf wird von aussen reingeführt)</td></tr>
</table>

25.2.4 Version 22 Feb 2012

8.2.12: In Auftrag gegeben:

Eisenbehälter (wie geschlossener Kochtopf) 40cm Durchmesser, Länge: 150 cm

Dieser Kessel soll über das Feuer gehängt werden

1. Schritt: Obiges Gestell als Rahmen

Im oberen Abschnitt (20 cm sollen Überhitzerrohre aus Stahl (1 mm Dicke) kommen

Kosten: 300 USD

Oelbehaelter Kessel (ca. 188 Liter)

25.2.4.1 Primary circuit: waste incineration boiler

Combustion chamber

Geplant im Januar/verworfen

Brennkammer ist aus feuerfeste Backsteinen:

- 10 Sichelförmige 10 cm hohe Backsteine machen einen Kreis mit Innendurchm. 50 cm. Kosten pro Stein: 2,50 USD
- Feuerfester Zement: 40 USD (25 kg)
- Wärmedämmende Wolle: 6m x 100m ca. 70 USD

Händler: Chekka, gegenüber Haupttor der neuen Zementfabrik (Autobahn-Ausfahrt Chekka, links nach Chekka, dann unten auf der alten Strasse nach rechts, ca. 2 km, auf der rechten Seite ist der Laden)

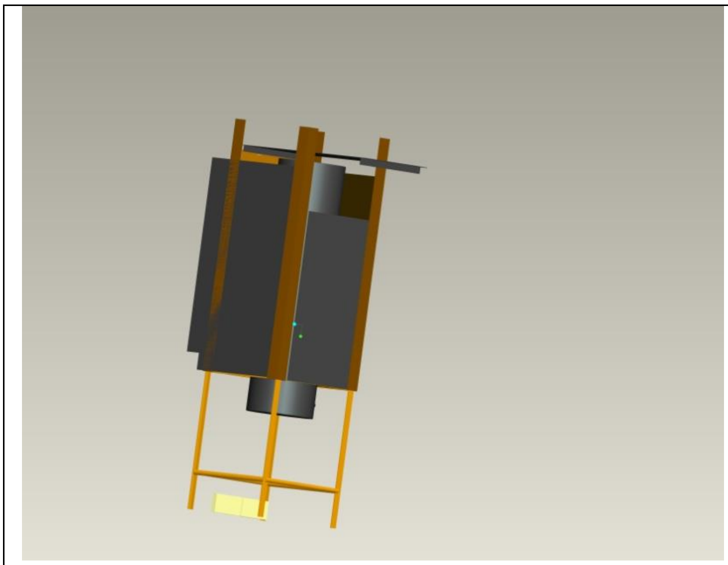
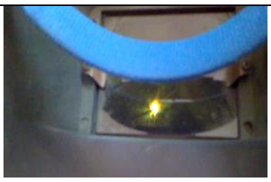
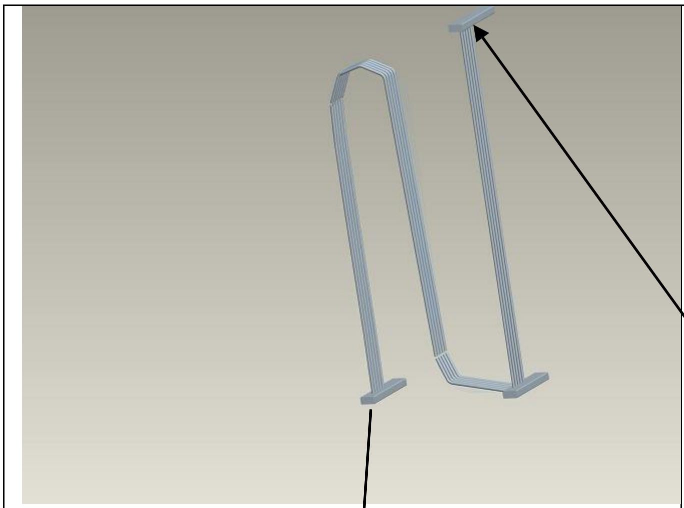
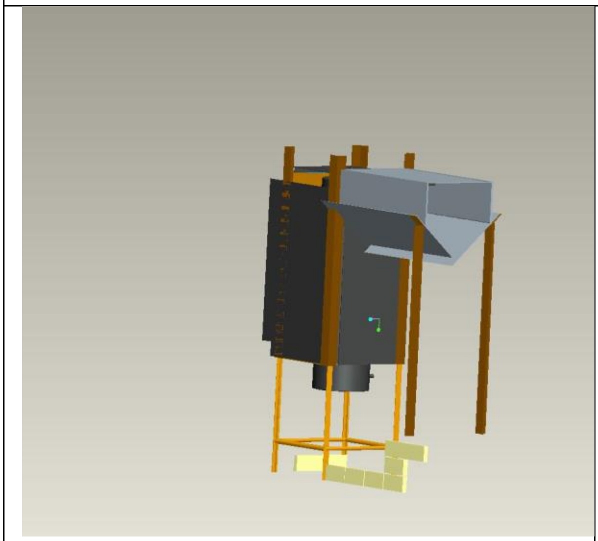
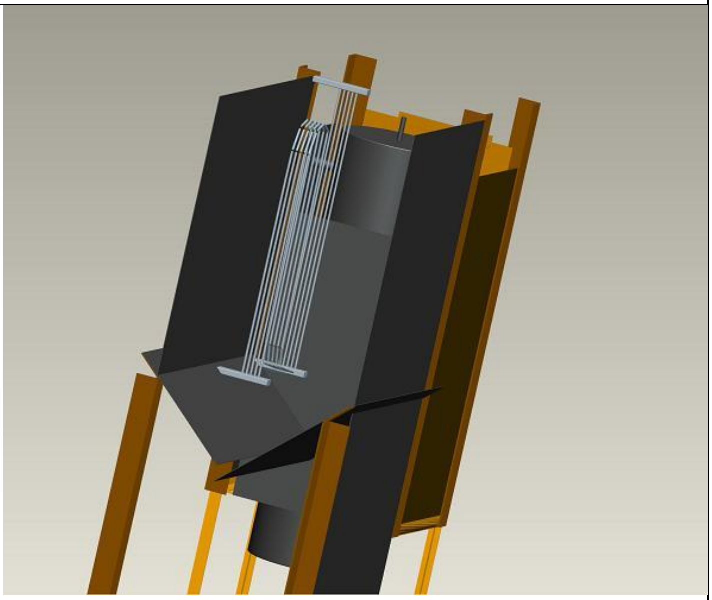
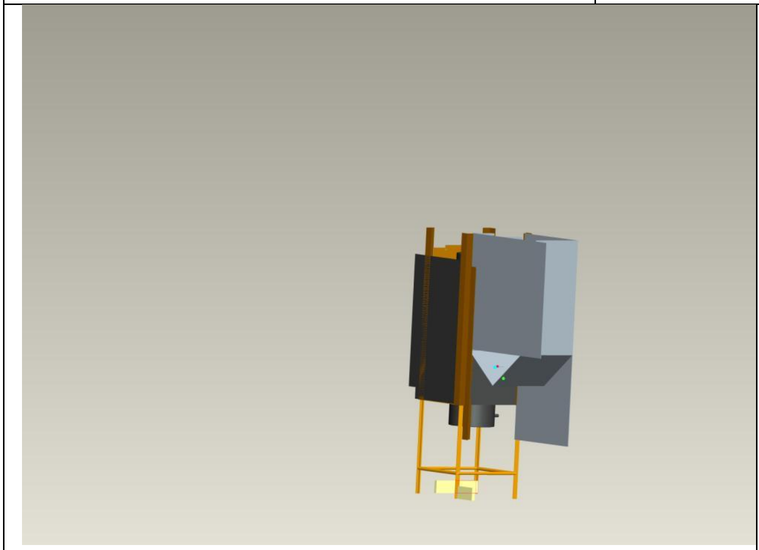


Bild: ProE-Modell des Kessels über der Brennkammer (Gestell + 2 feuerfeste Steine sind davon zu sehen) (6.3.12). Als Platten sind die vorhandenen gebrauchten Platten modelliert.	Bild oben rechts: geschweisste Hinterseite des Brennkammerzugs (Zug 1)
  	
Polieren (Rost entfernen) vor dem Schweissen und Schweissen	Bild: Oberteil Zug 1

Overheater

	
Überhitzer: Rohrgitter	Dampf vor dem Überhitzen
Austritt des überhitzten Dampfes	
	
Version 1	Version 2 (15.3.12) mit Rohrgitter
	Version 3 (16.3.12) ProE-Modell von Zug1 (Brennkammer) + Zug2 (Überhitzer) mit Verlängerung des Brenngangs berandet mit feuerfesten Ziegeln

25.2.4.2 Flue gas cleaning

Is not a part to be manufactored in this project phase.

25.2.4.3 Material for boiler and pressure vessel steel plate

Material für Dampfkessel- und Druckbehälterstahlplatte

4 mm Baustahl (Structural Steel) (kann mindst. 32 bar aushalten)

Spitzenmaterial 16Mo3 Dampfkessel- und Druckbehälterstahlplatte

Bearbeitung:

Lokomotivkessel (zum Selbstbau):

(http://www.intersteam.de/zubehoer/zb_s81.htm)

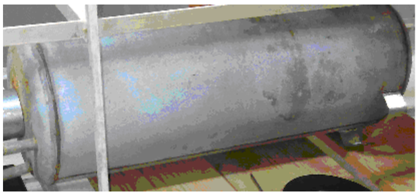
DIN 17155/H II können wir in den Stärken 4,5, 6, 8 mm liefern

DIN 2448, Güte St 3790

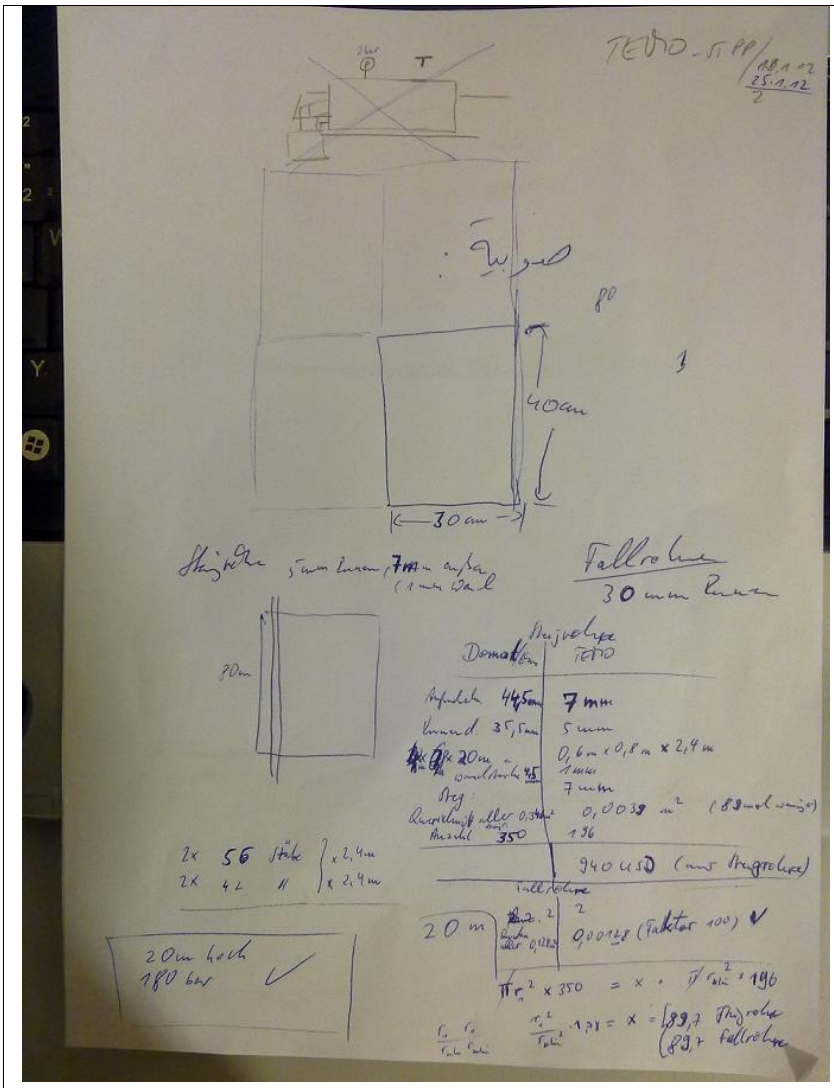
25.2.4.4 Turbine

Noch zu besorgen (evtl. die 40 kW Turbine aus Deutschland), in Alleppo werden auch Kleinturbinen hergestellt (Aussage von Projekt Manager von der Firma Lahhoud (die das Kraftwerk in Jounieh erstellt hat)

25.2.4.5 Kondensator



25.2.4.6 Specification of incineration heater with rising and falling tubes



Vorgehensweise:

Dimensionierung der Steigrohre und Fallrohre entsprechend dem vorhandenen Material. Grundfläche durch Holzbrenner vorgegeben. Höhe der Anlage im ungefähren Verhältnis, so dass es ähnlich dem Domater Werk ist.

Dann Durchführung der Rechnung um zu prüfen, ob die 600 $\mathrm{kg/(m^2\ s)}$ unter der 10 bar – Bedingung eingehalten werden kann.

Fallrohre bei TEMO: 30 mm Innendurchmesser

25.2.5 Piece list (dt. Teileliste)

Noch zu besorgen (Stand 27.2.12)

Zweck	Item	Anzahl	besorgt
Überhitzerraum	2,5 m Dreieckstange	2	n
Kesselraum	1,7 m Dreieckstange	4	02.03.2012
Überhitzerraum	2x1 m Stahlplatte 2-3 mm	3(2)	bereits vorhanden vom Februar
Kesselraum	(1,7)2x1 m Stahlplatte 4mm	2	02.03.2012
Schlackenausgang	0,5mx0,6m Stahlplatte 2 mm	1	

Vorhandene Platten:

2 mm: 1x1,10

25.2.6 April 2012

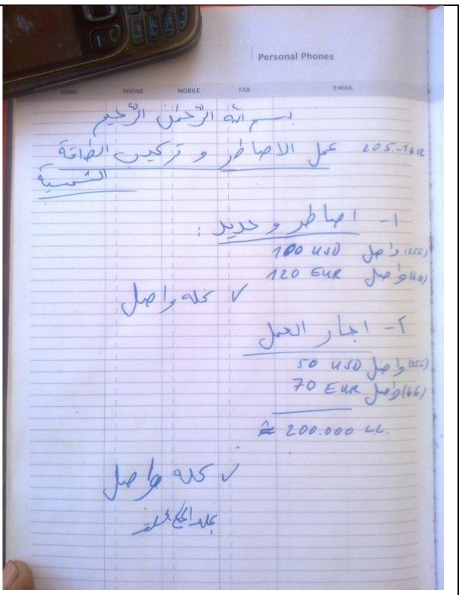
 Schweissen der Mülleinlasseinheit	 Mülleinlass

	
Verdampferzug und Mülleinlass	im Bild vorne: Überhitzerzug, hinten: Verdampferzug

25.2.7 May 2012: Tubing of the evaporator + Stand for solar tube (economizer)

Mai 12: Steigrohre des Verdampfers + Ständer für Solarrohr (Economizer)

Es soll Naturumlauf für die Müllverbrennungseinheit implementiert werden.

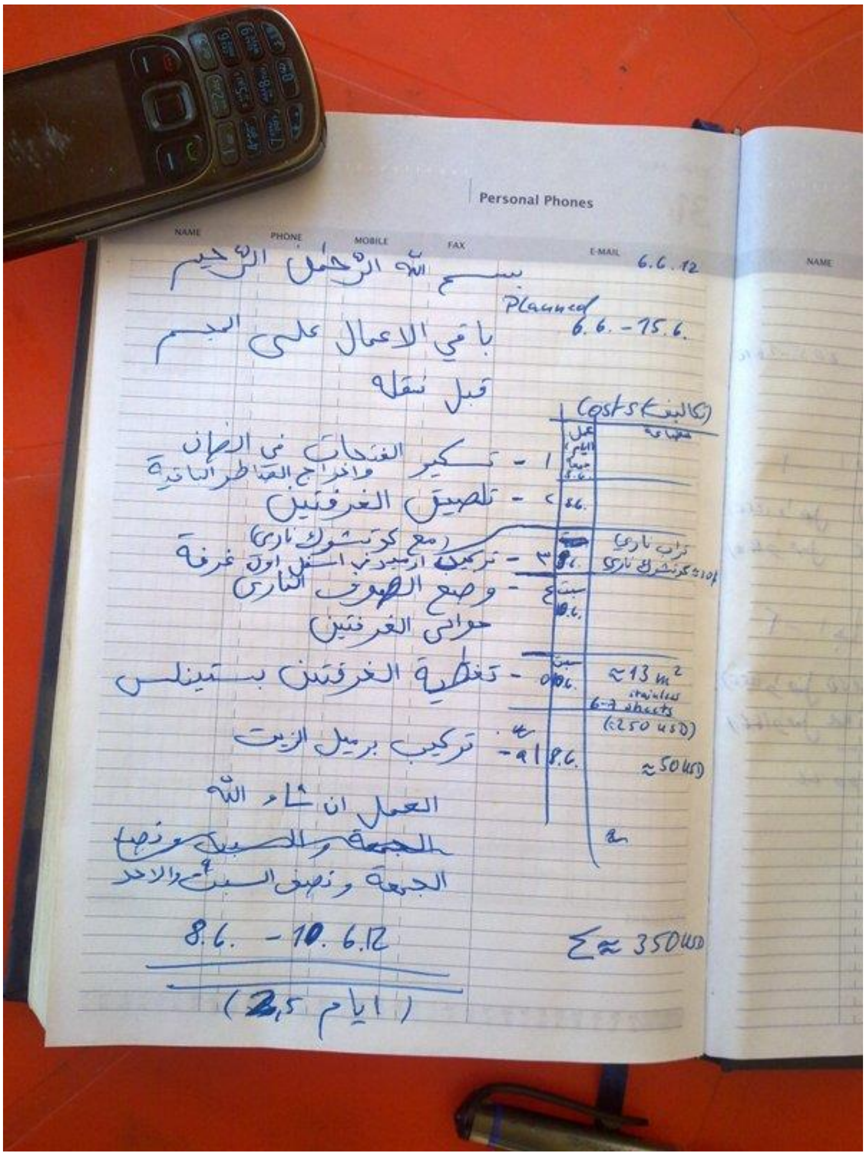
		 Personal Phones NAME PHONE MOBILE FAX E-MAIL بسم الله الرحمن الرحيم 20.5.-1.6.12 عمل الاصاطر و تركيب الطاقة الشمسية ١- اصاطر و حديد : (25.5) واصل 100 USD (1.6) واصل 120 EUR ✓ كله واصل ٢- اجار العمل (25.5) واصل 50 USD (1.6) واصل 70 EUR ≙ 200.000 LL. ✓ كله واصل

Kosten: 300 EUR

25.2.8 October / November 12: evaporator and superheater hermetically welded and placed on wheels, combustion chamber, thermal insulation

Oktober/ November 12: Verdampferzug und Überhitzerzug luftdicht geschweisst und auf Rollen gebracht, Brennraum, Thermalabdichtung

Eigentlich geplant für Juni:



بسم الله الرحمن الرحيم 6.6.12
Planned 6.6. - 15.6.
باقي الاعمال على المجسم
قبل نقله
Costs (تكاليف)
١ - تسكير الفتحات في الطرفان واخراج [illegible]
٢ - تلصيق الغرفتين 6.6.
٣ - تركيب [illegible] اسفل اول غرفة (مع كرتشوك ناري) 9.6. تراب ناري، كرتشوك ناري ≈ 10$
- وضع الصوف الناري حوالي الغرفتين سبت 10.6.
- تغطية الغرفتين بستينلس سبت 10.6. ≈ 13 m^2 stainless 6-7 sheets (≈ 250 USD)
٩ - تركيب برميل الزيت 8.6. ≈ 50 USD
العمل ان شاء الله
~~الجمعة والسبت ونصف~~
الجمعة ونصف السبت والاحد
8.6. - 10.6.12
(2,5 ايام)
Σ ≈ 350 USD

Es fand eine grosse Verzögerung aufgrund der Unzuverlässigkeit des Schweissers statt.

Geplante Kosten: 350 USD

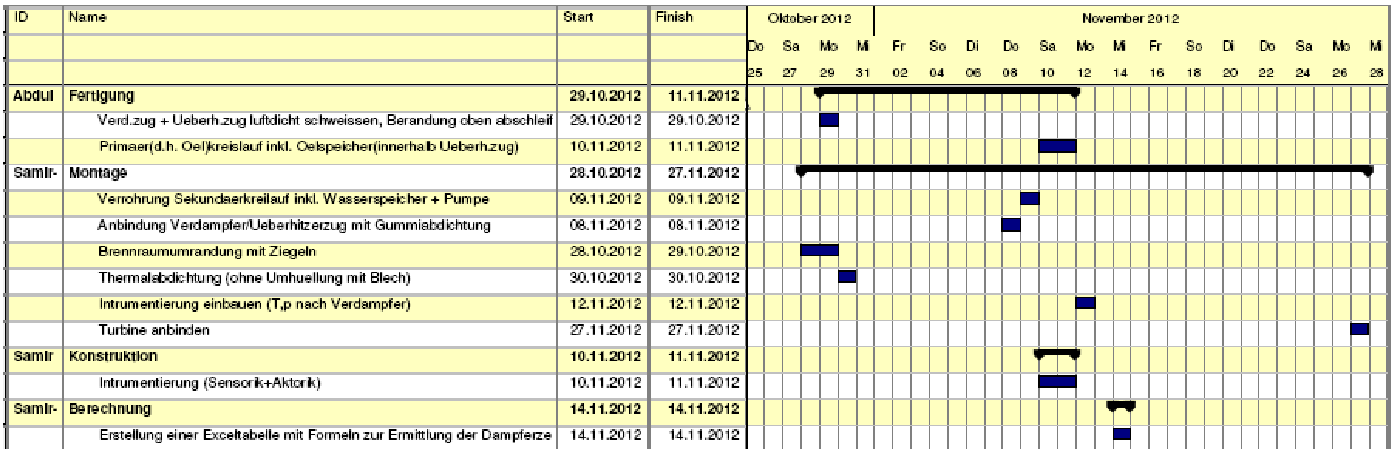
Tatsächliche Kosten: 400 USD (VZ/ÜZ luftdicht geschweisst, auf Rollen gebracht)

+ 100 USD (Brennraum + Thermalabdichtung)

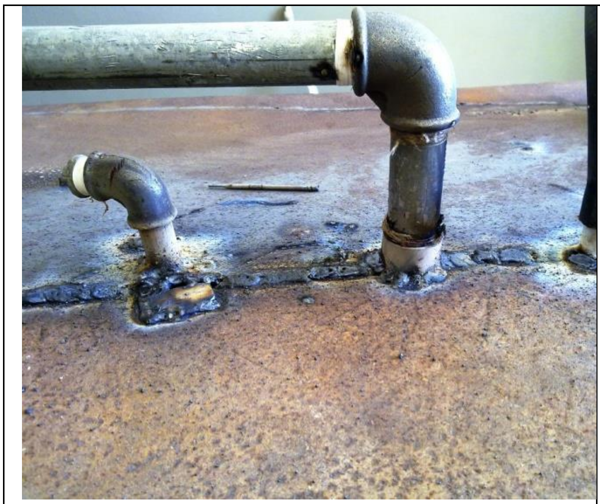
---

500 USD (= ca. 420 EUR)

Lehre: Mitarbeiterauswahl ist sehr wichtig.



ID	Name	Start	Finish
Abdul	**Fertigung**	**29.10.2012**	**11.11.2012**
	Verd.zug + Ueberh.zug luftdicht schweissen, Berandung oben abschleif	29.10.2012	29.10.2012
	Primaer(d.h. Oel)kreislauf inkl. Oelspeicher(innerhalb Ueberh.zug)	10.11.2012	11.11.2012
Samir-	**Montage**	**28.10.2012**	**27.11.2012**
	Verrohrung Sekundaerkreilauf inkl. Wasserspeicher + Pumpe	09.11.2012	09.11.2012
	Anbindung Verdampfer/Ueberhitzerzug mit Gummiabdichtung	08.11.2012	08.11.2012
	Brennraumumrandung mit Ziegeln	28.10.2012	29.10.2012
	Thermalabdichtung (ohne Umhuellung mit Blech)	30.10.2012	30.10.2012
	Intrumentierung einbauen (T,p nach Verdampfer)	12.11.2012	12.11.2012
	Turbine anbinden	27.11.2012	27.11.2012
Samir	**Konstruktion**	**10.11.2012**	**11.11.2012**
	Intrumentierung (Sensorik+Aktorik)	10.11.2012	11.11.2012
Samir-	**Berechnung**	**14.11.2012**	**14.11.2012**
	Erstellung einer Exceltabelle mit Formeln zur Ermittlung der Dampferze	14.11.2012	14.11.2012

	
Luftdichte Rohranbindung am Verdampferzug oben	Verdampferzug und Überhitzerzug auf Rollen gebracht

	
Verdampferzug und Überhitzerzug luftdicht geschweisst, Brennraum mit	Brennkammerbau

Ziegeln (unten)	
	
Thermalabdichtung Beklebung des Randes	Thermalabdichtung Schichtdicke
	
Anbindung an Rauchgasreinigung	Thermalabdichtung

25.2.9 Mid-November 2012: sheathing the evaporator and superheater train

Mitte November 2012: Bemantelung des Verdampfer- und Überhitzerzuges

Material costs: 20 USD (used Russian steel)

4 الواح 4mx0.8m من حديد (steel) (about 0.5 mm)

Working (1 person + 1 helper): 12.11.12: 4 hours, 15.12.12: 5 hours

25.3 شراء التوربين / Procurement of the turbine

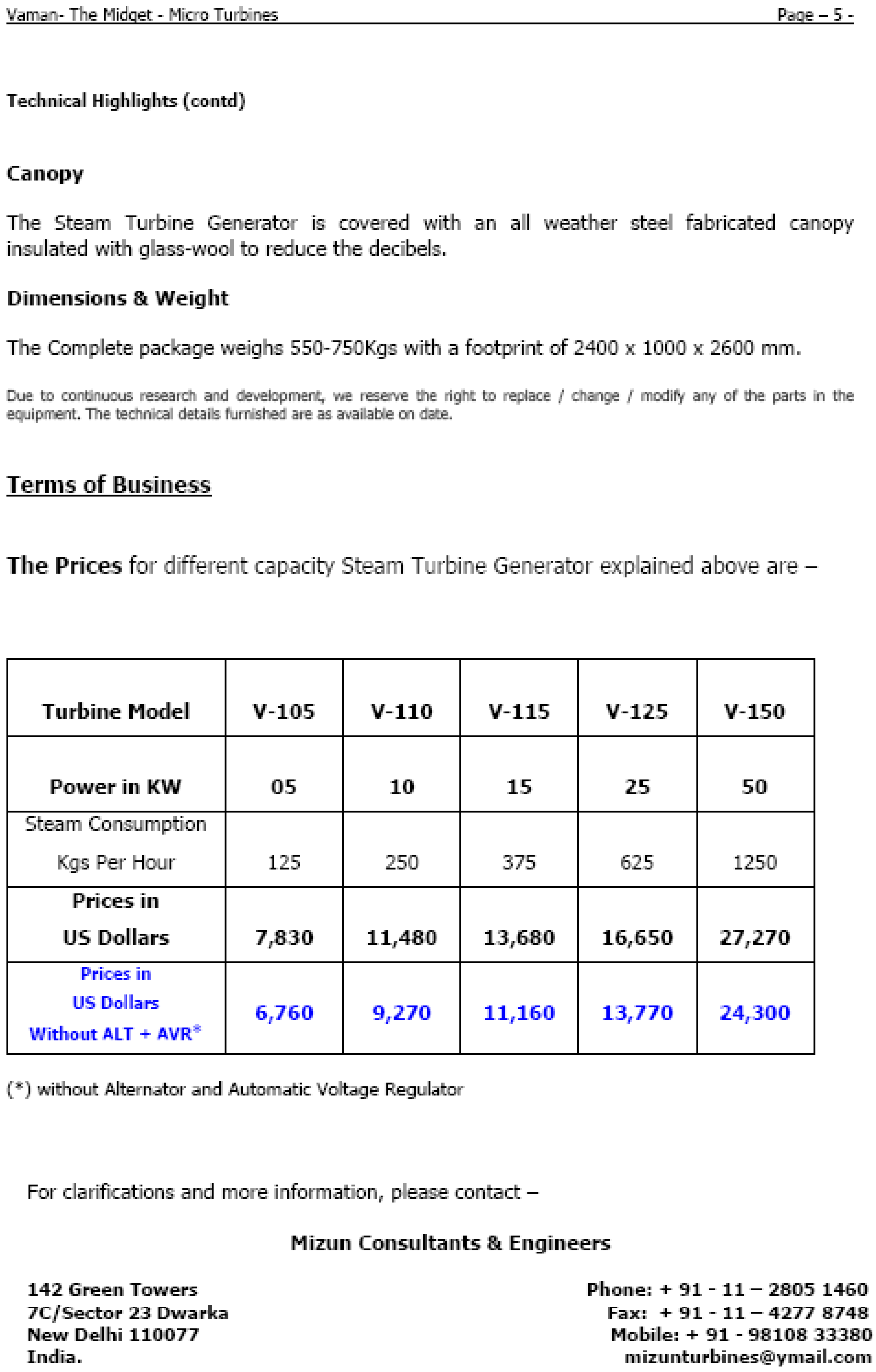
25.3.1 عروض لتربينات جديدة

25.3.1.1 Siemens

PREISE:

Anz.	Bezeichnung	Pos.	Preis
1	Siemens Dampfturbine SST-060 (ehem. AFA 3,5)	1.1	285.000,00 €
1	Schmier- und Steuerölversorgung (nach STE Standard)	1.1.3	inklusiv
1	Elektronische Drehzahlregelung SC900	1.1.5.1	inklusiv
1	Schnellschluß ST 800	1.1.5.2	inklusiv
1	Fundamentberechnung	1.1.6.2	inklusiv
1	Elastische Kupplung	1.2.1	inklusiv
1	Synchrongenerator • 250 kVA, 0,4 kV, 50 Hz, IP23, Wälzlager	1.2.2	inklusiv
1	Örtliche Bedieneinheit (LP)	1.2.3	inklusiv
2	Automatische Entwässerungseinrichtungen	1.2.6	inklusiv
1	Ölauffangwanne	1.2.8	inklusiv
	Total		**285.000,00 €**

25.3.1.2 من شركة هندية



Technical Highlights (contd)

Canopy

The Steam Turbine Generator is covered with an all weather steel fabricated canopy insulated with glass-wool to reduce the decibels.

Dimensions & Weight

The Complete package weighs 550-750Kgs with a footprint of 2400 x 1000 x 2600 mm.

Due to continuous research and development, we reserve the right to replace / change / modify any of the parts in the equipment. The technical details furnished are as available on date.

Terms of Business

The Prices for different capacity Steam Turbine Generator explained above are –

Turbine Model	**V-105**	**V-110**	**V-115**	**V-125**	**V-150**
Power in KW	**05**	**10**	**15**	**25**	**50**
Steam Consumption Kgs Per Hour	125	250	375	625	1250
Prices in US Dollars	**7,830**	**11,480**	**13,680**	**16,650**	**27,270**
Prices in US Dollars Without ALT + AVR*	**6,760**	**9,270**	**11,160**	**13,770**	**24,300**

(*) without Alternator and Automatic Voltage Regulator

For clarifications and more information, please contact –

Mizun Consultants & Engineers

142 Green Towers
7C/Sector 23 Dwarka
New Delhi 110077
India.

Phone: + 91 - 11 – 2805 1460
Fax: + 91 - 11 – 4277 8748
Mobile: + 91 - 98108 33380
mizunturbines@ymail.com

MIZUN CONSULTANTS & ENGINEERS

'VAMAN-The Midget' Micro Steam Turbine Generator

Top four depicts 10 KW Unit Split Casing, Twin disc Curtis Wheel and run-out checking while mounting.

Lower Two depicts 5 KW Combined Heat & Power Unit

L to R = 5 KW CHP Unit, 30 KW Integral with Gear Box and 10 KW Unit on a Frame with Water Cooled Condenser.

Left – 10 KW Unit specially mounted on a Frame (on request) with Water Cooled Condenser at side.

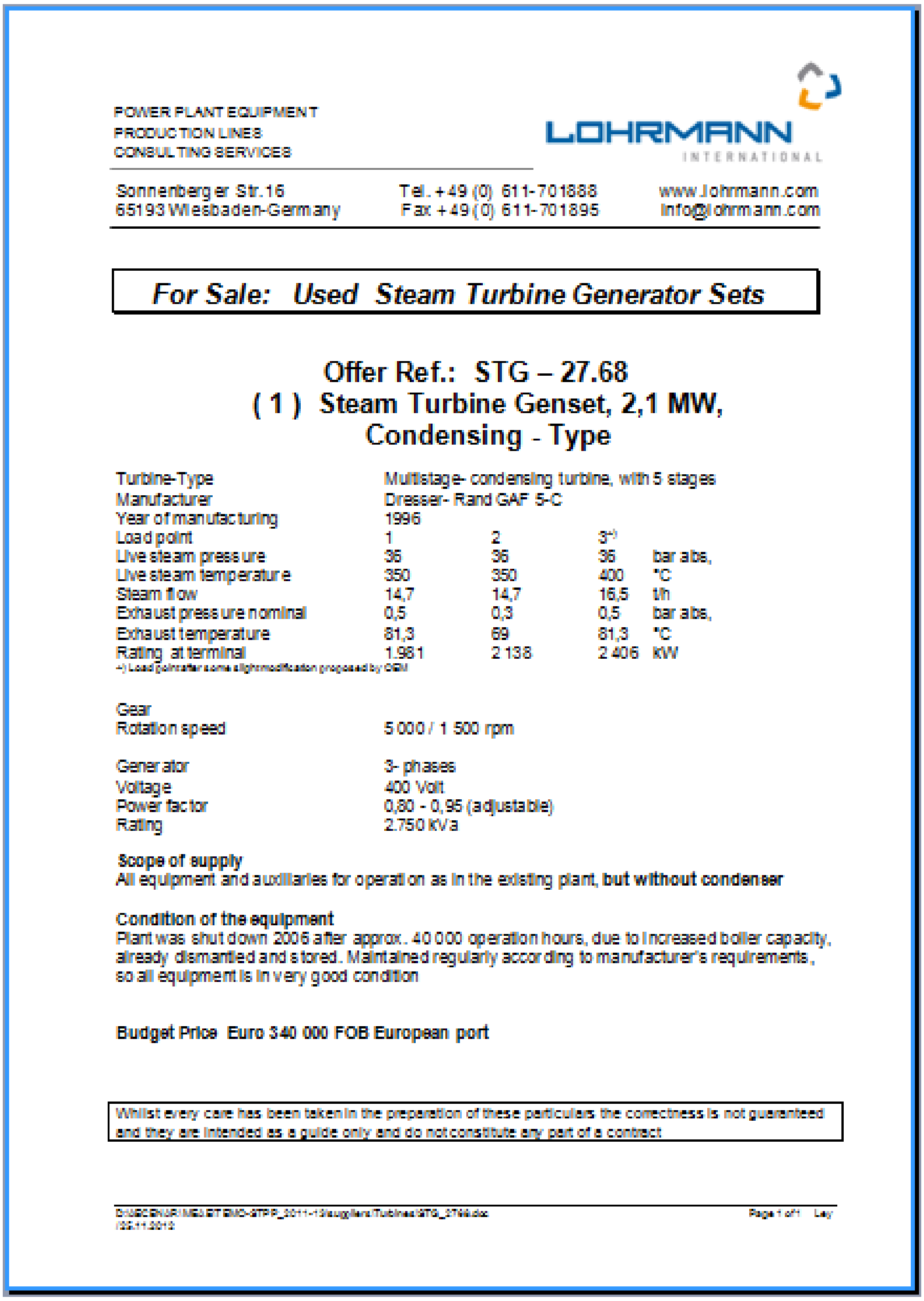
Right- Water Cooled Condenser, Steam Vent of 10 KW Unit

25.3.2 بحث عن تربين مستعملة / Market search for a used turbine

There exists a market for used power plant peaces. Although for a large power plant for optimizing efficiency is better to have a specified (new) turbine.

There are several suppliers of used turbines, which could be found on the internet.

One example ist Lohrmann in Wiesbaden/Germany. In the following is such an such offer:



POWER PLANT EQUIPMENT
PRODUCTION LINES
CONSULTING SERVICES

LOHRMANN
INTERNATIONAL

Sonnenberger Str.16
65193 Wiesbaden-Germany

Tel. +49 (0) 611-701888
Fax +49 (0) 611-701895

www.lohrmann.com
info@lohrmann.com

For Sale: Used Steam Turbine Generator Sets

Offer Ref.: STG – 27.68
(1) Steam Turbine Genset, 2,1 MW,
Condensing - Type

Turbine-Type	Multistage- condensing turbine, with 5 stages			
Manufacturer	Dresser- Rand GAF 5-C			
Year of manufacturing	1996			
Load point	1	2	3+)	
Live steam pressure	36	36	36	bar abs,
Live steam temperature	350	350	400	°C
Steam flow	14,7	14,7	16,5	t/h
Exhaust pressure nominal	0,5	0,3	0,5	bar abs,
Exhaust temperature	81,3	69	81,3	°C
Rating at terminal	1.981	2 138	2 406	kW

+) Load point after some slight modification proposed by OEM

Gear	
Rotation speed	5 000 / 1 500 rpm
Generator	3- phases
Voltage	400 Volt
Power factor	0,80 - 0,95 (adjustable)
Rating	2.750 kVa

Scope of supply
All equipment and auxiliaries for operation as in the existing plant, **but without condenser**

Condition of the equipment
Plant was shut down 2006 after approx. 40 000 operation hours, due to increased boiler capacity, already dismantled and stored. Maintained regularly according to manufacturer's requirements, so all equipment is in very good condition

Budget Price Euro 340 000 FOB European port

Whilst every care has been taken in the preparation of these particulars the correctness is not guaranteed and they are intended as a guide only and do not constitute any part of a contract

Page 1 of 1

25.3.3 شراء التوربين صغيرة 40kW

From the CEO Alexander Kraus of the company

D&K Anlagen- und Objektservice

Baum- u. Gartenpflege GbR

Am Grünen Hang 14

65594 Runkel

www.allesimgruenenbereich.com

a.kraus@allesimgruenenbereich.com

was privately purchased the turbine. On the internet the turbine was offered for 16.000 EUR. After negotiations the turbine could be purchased some month later for 3.500 EUR.

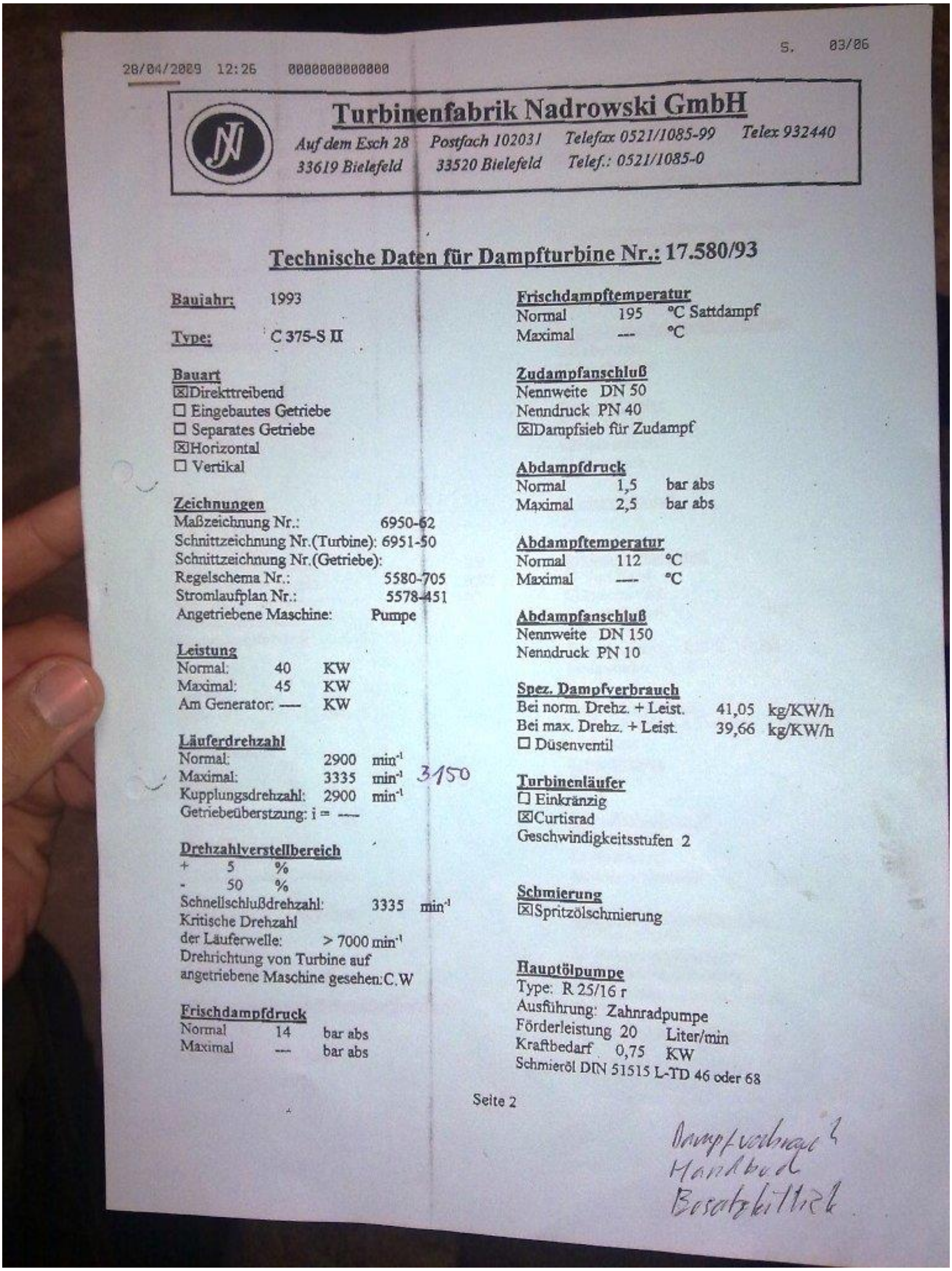
Kosten:

Verhandlungen wegen Kaufabschluss	300 EUR
(3 Anfahrten)	
Turbine	3500 EUR
Ölkühler	300 EUR
Lieferung nach Speyer	100 EUR
Transport mit Container nach Libanon (geplant)	1000 EUR
Transport von Südlibanon nach Ras Nhache (geplant)	150 EUR
	5350 EUR

Sales contract June 2012 / 2012 عقد الشراء حزيران 25.3.3.1

	
Vereinbarung des Kaufabschlusses mit Hr. Bernhard und Hr. Kraus im Juni 12 left: Hr. Bernhard, right: S. Mourad	Used turbine, year of manufacture: 1994

25.3.4 Technical Data of the turbine



28/04/2009 12:26 0000000000000 S. 03/06

Turbinenfabrik Nadrowski GmbH

Auf dem Esch 28
33619 Bielefeld

Postfach 102031
33520 Bielefeld

Telefax 0521/1085-99
Telef.: 0521/1085-0

Telex 932440

Technische Daten für Dampfturbine Nr.: 17.580/93

Baujahr: 1993

Type: C 375-S II

Bauart
☒Direkttreibend
☐ Eingebautes Getriebe
☐ Separates Getriebe
☒Horizontal
☐ Vertikal

Zeichnungen
Maßzeichnung Nr.: 6950-62
Schnittzeichnung Nr.(Turbine): 6951-50
Schnittzeichnung Nr.(Getriebe):
Regelschema Nr.: 5580-705
Stromlaufplan Nr.: 5578-451
Angetriebene Maschine: Pumpe

Leistung
Normal: 40 KW
Maximal: 45 KW
Am Generator: --- KW

Läuferdrehzahl
Normal: 2900 min^{-1}
Maximal: 3335 min^{-1} 3150
Kupplungsdrehzahl: 2900 min^{-1}
Getriebeüberstzung: i = ---

Drehzahlverstellbereich
\+ 5 %
\- 50 %
Schnellschlußdrehzahl: 3335 min^{-1}
Kritische Drehzahl
der Läuferwelle: > 7000 min^{-1}
Drehrichtung von Turbine auf
angetriebene Maschine gesehen: C.W

Frischdampfdruck
Normal 14 bar abs
Maximal --- bar abs

Frischdampftemperatur
Normal 195 °C Sattdampf
Maximal --- °C

Zudampfanschluß
Nennweite DN 50
Nenndruck PN 40
☒Dampfsieb für Zudampf

Abdampfdruck
Normal 1,5 bar abs
Maximal 2,5 bar abs

Abdampftemperatur
Normal 112 °C
Maximal --- °C

Abdampfanschluß
Nennweite DN 150
Nenndruck PN 10

Spez. Dampfverbrauch
Bei norm. Drehz. + Leist. 41,05 kg/KW/h
Bei max. Drehz. + Leist. 39,66 kg/KW/h
☐ Düsenventil

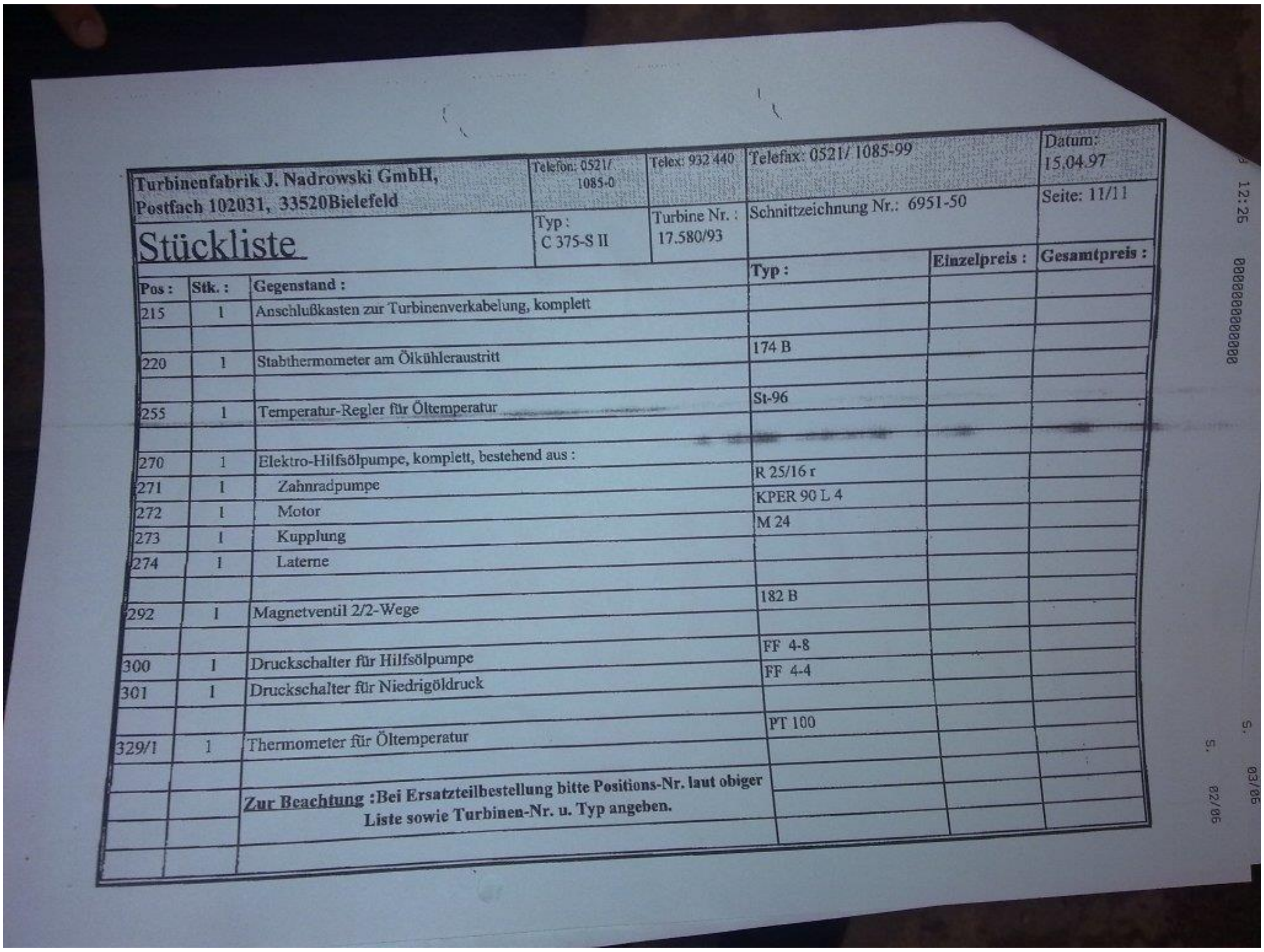
Turbinenläufer
☐ Einkränzig
☒Curtisrad
Geschwindigkeitsstufen 2

Schmierung
☒Spritzölschmierung

Hauptölpumpe
Type: R 25/16 r
Ausführung: Zahnradpumpe
Förderleistung 20 Liter/min
Kraftbedarf 0,75 KW
Schmieröl DIN 51515 L-TD 46 oder 68

Seite 2

Dampfverbrauch?
Handbuch
[illegible]



Turbinenfabrik J. Nadrowski GmbH,
Postfach 102031, 33520Bielefeld

Telefon: 0521/ 1085-0
Telex: 932 440
Telefax: 0521/ 1085-99
Datum: 15.04.97

Stückliste

Typ : C 375-S II
Turbine Nr. : 17.580/93
Schnittzeichnung Nr.: 6951-50
Seite: 11/11

Pos :	Stk. :	Gegenstand :	Typ :	Einzelpreis :	Gesamtpreis :
215	1	Anschlußkasten zur Turbinenverkabelung, komplett			
220	1	Stabthermometer am Ölkühleraustritt	174 B		
255	1	Temperatur-Regler für Öltemperatur	St-96		
270	1	Elektro-Hilfsölpumpe, komplett, bestehend aus :			
271	1	Zahnradpumpe	R 25/16 r		
272	1	Motor	KPER 90 L 4		
273	1	Kupplung	M 24		
274	1	Laterne			
292	1	Magnetventil 2/2-Wege	182 B		
300	1	Druckschalter für Hilfsölpumpe	FF 4-8		
301	1	Druckschalter für Niedrigöldruck	FF 4-4		
329/1	1	Thermometer für Öltemperatur	PT 100		

Zur Beachtung :Bei Ersatzteilbestellung bitte Positions-Nr. laut obiger Liste sowie Turbinen-Nr. u. Typ angeben.

25.3.4.1 Supply of the turbine on 8 October 2012 to interim storage in Speyer near Heidelberg

Lieferung der Turbine am 8. Oktober 2012 an Zwischenlager in Speyer bei Heidelberg

Hr. Kraus hat Samir Mourad aus Heidelberg-Pfaffengrund abgeholt und beide sind die Turbine mit einem kleinen Laster nach Speyer gefahren.

Kraus: Öl muss auf ca. 45 °C vorgewärmt werden.

Wichtig, dass kein Lagerschaden passiert:

Zu tun: Lager auseinandernehmen und kontrollieren!

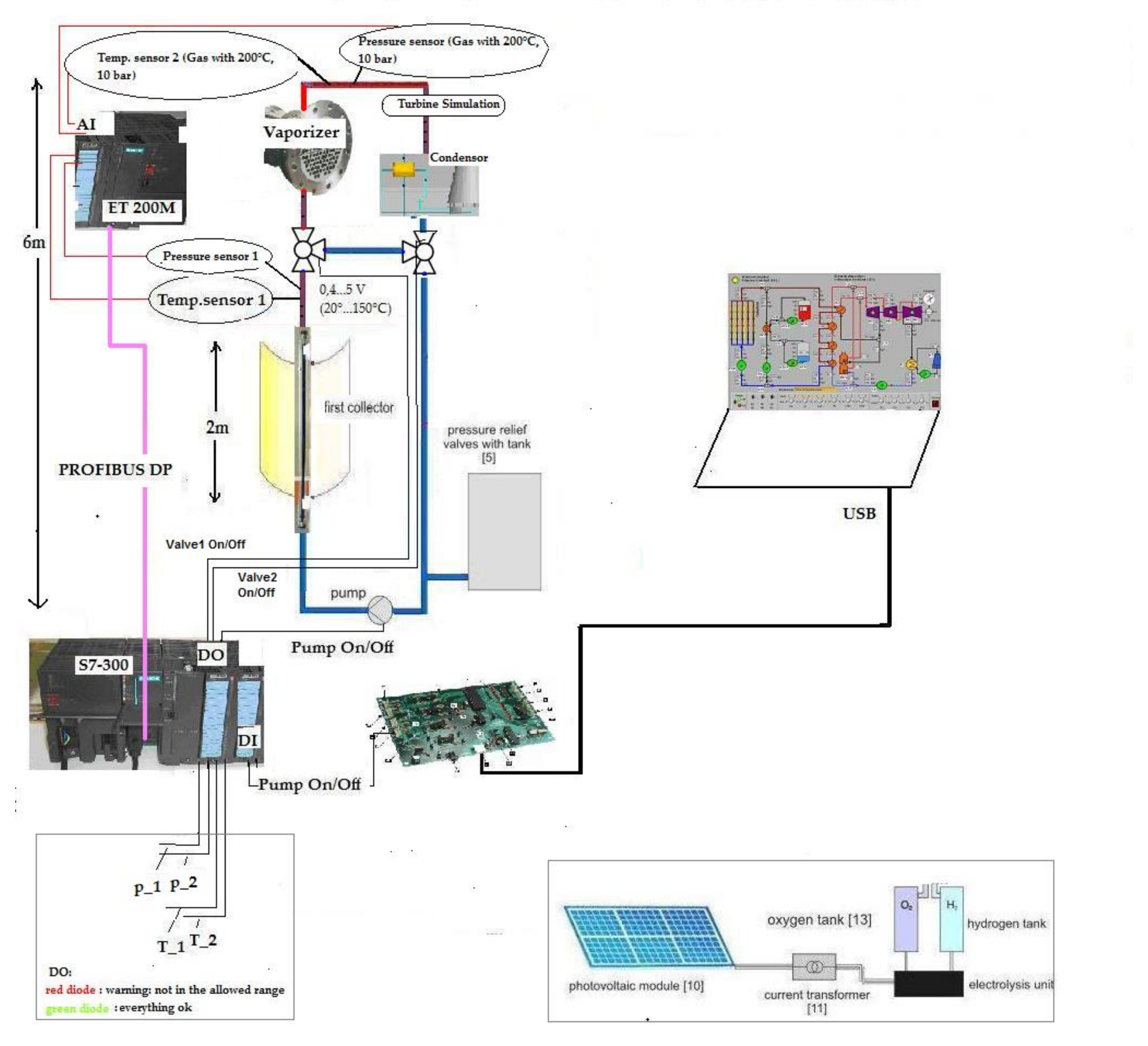
25.4 نظام التحكم / Process Control System (PCS)

25.4.1 Test Plant Process Control System - Part 1 (August/September/October 2011):

25.4.1.1 Introduction: Installation and putting into operation of a S7 system

The steps for installation are: Planning (dt. Projektierung) -> Installation (dt. Montage) -> Wiring (dt. Verdrahtung) -> Building network -> Adressing

-> Putting into operation


Temp. sensor 2 (Gas with 200°C, 10 bar)
Pressure sensor (Gas with 200°C, 10 bar)
Turbine Simulation
AI
Vaporizer
Condensor
ET 200M
6m
Pressure sensor 1
Temp.sensor 1
0,4...5 V (20°...150°C)
2m
first collector
pressure relief valves with tank [5]
PROFIBUS DP
USB
Valve1 On/Off
Valve2 On/Off
pump
Pump On/Off
S7-300
DO
DI
Pump On/Off
p_1 P_2
T_1 T_2
DO:
red diode : warning: not in the allowed range
green diode : everything ok
oxygen tank [13]
O_2
H_2
hydrogen tank
photovoltaic module [10]
current transformer [11]
electrolysis unit

25.4.1.2 Installation

Installation in September 2011 (picture from 21 Nov 2011)

25.4.2 Test Plant Process Control System - Part 2 (detailed planning)

Implementation planned in January 2013

25.4.2.1 Specification

To be done

26 / مناقشةDiscussion

26.1 دراسة الربحية / Profitability Study

Solar thermal systems can be implemented from about 5 MW, but still not profitable (about 38 U.S. dollar cents per kWh for a corresponding power plant in Thailand)

ويمكن تنفيذ النظم الحرارية الشمسية من حوالي 5 ميغاواط، ولكن لا تزال غير ربحية (حوالي 38 سنت ل الدولار الأمريكي لكل كيلوواط ساعة لمحطة تصنع حالياً في تايلند)

Solarthermische Anlagen sind ab ca. 5 MW realisierbar, aber trotzdem noch nicht rentabel (ca. 38 US-Dollar-Cent pro kWh Produktion für eine entsprechende Anlage in Thailand)

26.2 محطة الطاقة التجروبية / Test Power Plant

A majority of the parts of the evaporator and overheater have been concerned from the scrap yard. While this could reduce costs, but the processing and integration was complicated and took longer time.

الغالبية العظمى من أجزاء من المبخر والمسخن للبخار اوتي من ساحة الخردة. هذا ادى لتوفير تكاليف المواد الاولية ، ولكن عقّد التصنيع و بالتالي طوّل الوقت اللازم للتصنيع كثيراً.

Ein Grossteil der Teile des Verdampfers und des Überhitzters sind vom Schrottplatz besorgt worden. Dadurch konnten zwar Anschaffungskosten gesenkt werden, die Bearbeitung wurde aber verkompliziert und war langwieriger.

27 / المراجع Literature

[Mourad et. al. 2010] 2nd TEMO-STPP report, 2nd edition, April 2010, http://aecenar.com/download/doc_download/13-temo-stpp-report-2

Gourche et. al., Siemens S7-300 مدخل الى , Karlsruhe/Ras Nhache, July 2010 (http://www.aecenar.com/download/doc_download/25-siemens-s7-300--)

Karl Strauss, “Kraftwerkstechnik”

Zahornsky, “Energietechnik”

[Seier 1999] Seier J., "Kleinanlagen zur energetischen Verwertung von Abfällen", Studie des Forschungszentrums Karlsruhe (FZK) zu Kleinmüllverbrennungsanlagen, 1999, bibliothek.fzk.de/zb/berichte/FZKA6336.pdf

HANS MÜLLER-STEINHAGEN AND FRANZ TRIEB, Concentrating solar power, A review of the technology, ingenia, 2003

Dirk Krüger[1], Joachim Krüger[2], Yuvaraj Pandian[3], Jan Fabian Feldhoff[4], Markus Eck[5], Martin Eickhoff[6] and Klaus Hennecke[7], KANCHANABURI SOLAR THERMAL POWER PLANT WITH DIRECT STEAM GENERATION - LAYOUT

[1] Dipl.-Ing., Researcher, German Aerospace Center (DLR), Institute of Technical Thermodynamics, Linder Höhe,

51147 Köln, Germany, Phone:+49 2203 601-2661, e-mail: dirk.krueger@dlr.de

[2] Director, Solarlite GmbH, Duckwitz, Germany

[3] M.S. Energy Systems, Solarlite GmbH, Duckwitz, Germany

[4] Dipl.-Ing., Researcher, [5] Dr.-Ing. Researcher, DLR, Institute of Technical Thermodynamics, Stuttgart, Germany

[6] Dipl.-Ing., Researcher, DLR, Institute of Technical Thermodynamics, Almería, Spain

[7] Dipl.-Ing., Researcher, DLR, Institute of Technical Thermodynamics, Köln, Germany

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Dr.-Ing. M. Franz, “Dampferzeuger”, www.axpo-holz.ch/Dampferzeuger.pdf

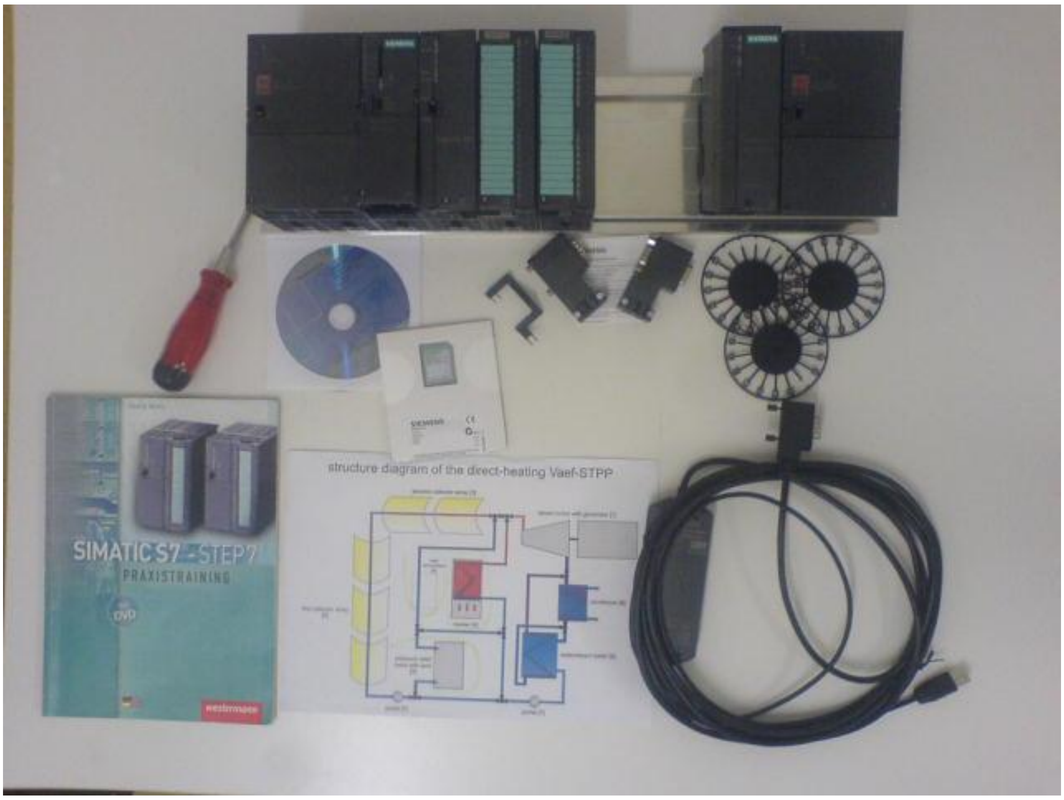
http://www.bios-bioenergy.at/de/cfd-simulationen.html

28 Apprendix

28.1 البرمجة بِ STEP7 / Apprendix A: Programming with STEP7[27]

بالتفصيل بالغة العربية انظر

Gourche et. al., Siemens S7-300 مدخل الى , Karlsruhe/Ras Nhache, July 2010
(http://www.aecenar.com/download/doc_download/25-siemens-s7-300--)



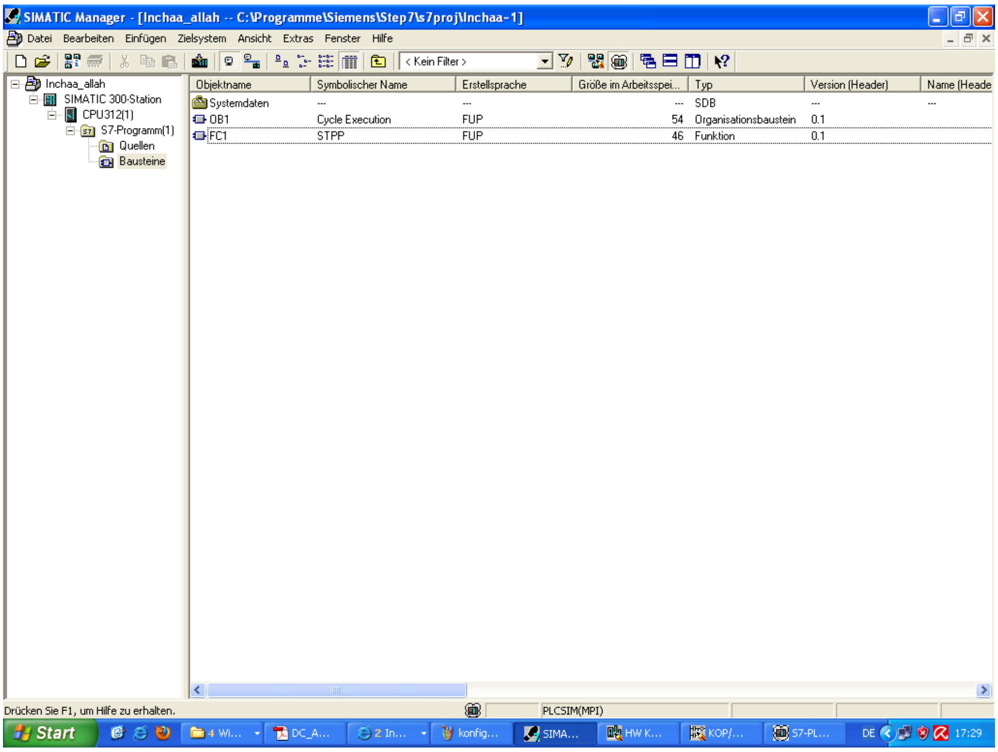
Pieces of the automation system

---

[27] From Mohamed Gourche, Development environment and elements of the Process Control System for the TEMO-STPP test rig Development of a Process Control System for a STPP Test Stand, www.aecenar.com
بالتفصيل بالغة العربية انظر

Gourche et. al., Siemens S7-300 مدخل الى , Karlsruhe/Ras Nhache, July 2010
(http://www.aecenar.com/download/doc_download/25-siemens-s7-300--)

The Siemens S7 S300 for the TEMO-STPP test rig



SIMATIC Manager - [Inchaa_allah -- C:\Programme\Siemens\Step7\s7proj\Inchaa~1]

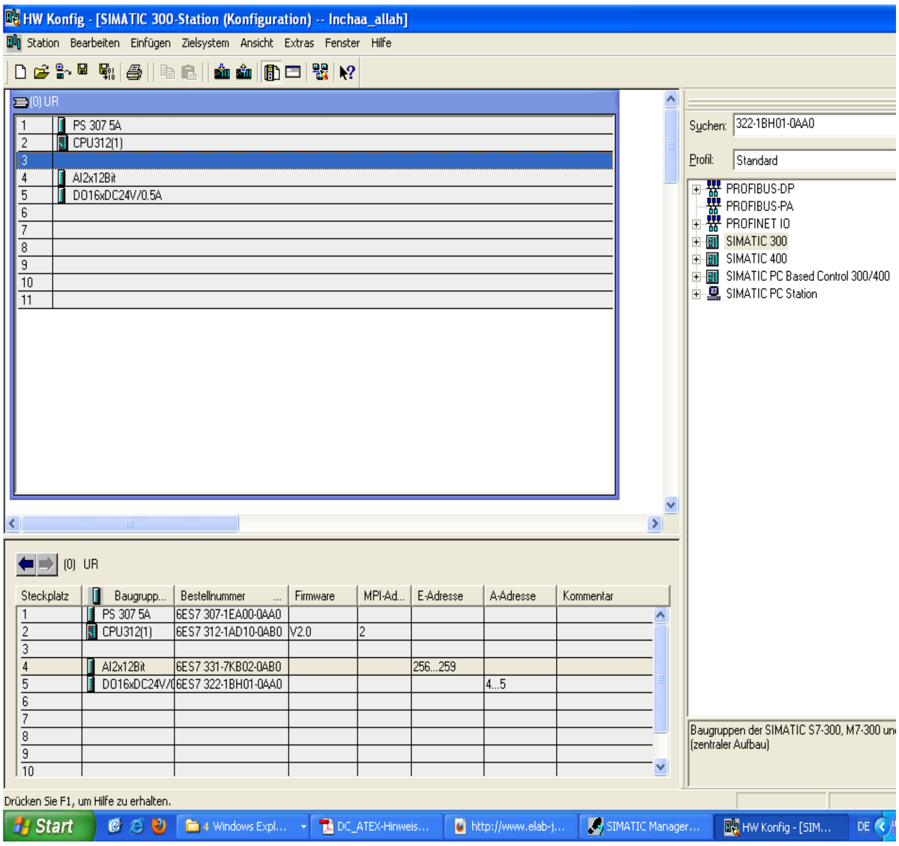
Inchaa_allah
  SIMATIC 300-Station
    CPU312(1)
      S7-Programm(1)
        Quellen
        Bausteine

Objektname	Symbolischer Name	Erstellsprache	Größe im Arbeitsspei...	Typ	Version (Header)	Name (Heade
Systemdaten	---	---	---	SDB	---	---
OB1	Cycle Execution	FUP	54	Organisationsbaustein	0.1	
FC1	STPP	FUP	46	Funktion	0.1	

Drücken Sie F1, um Hilfe zu erhalten.

PLCSIM(MPI)

Creating a project with the Siemens program STEP 7



HW Konfig - [SIMATIC 300-Station (Konfiguration) -- Inchaa_allah]

Suchen: 322-1BH01-0AA0

Profil: Standard

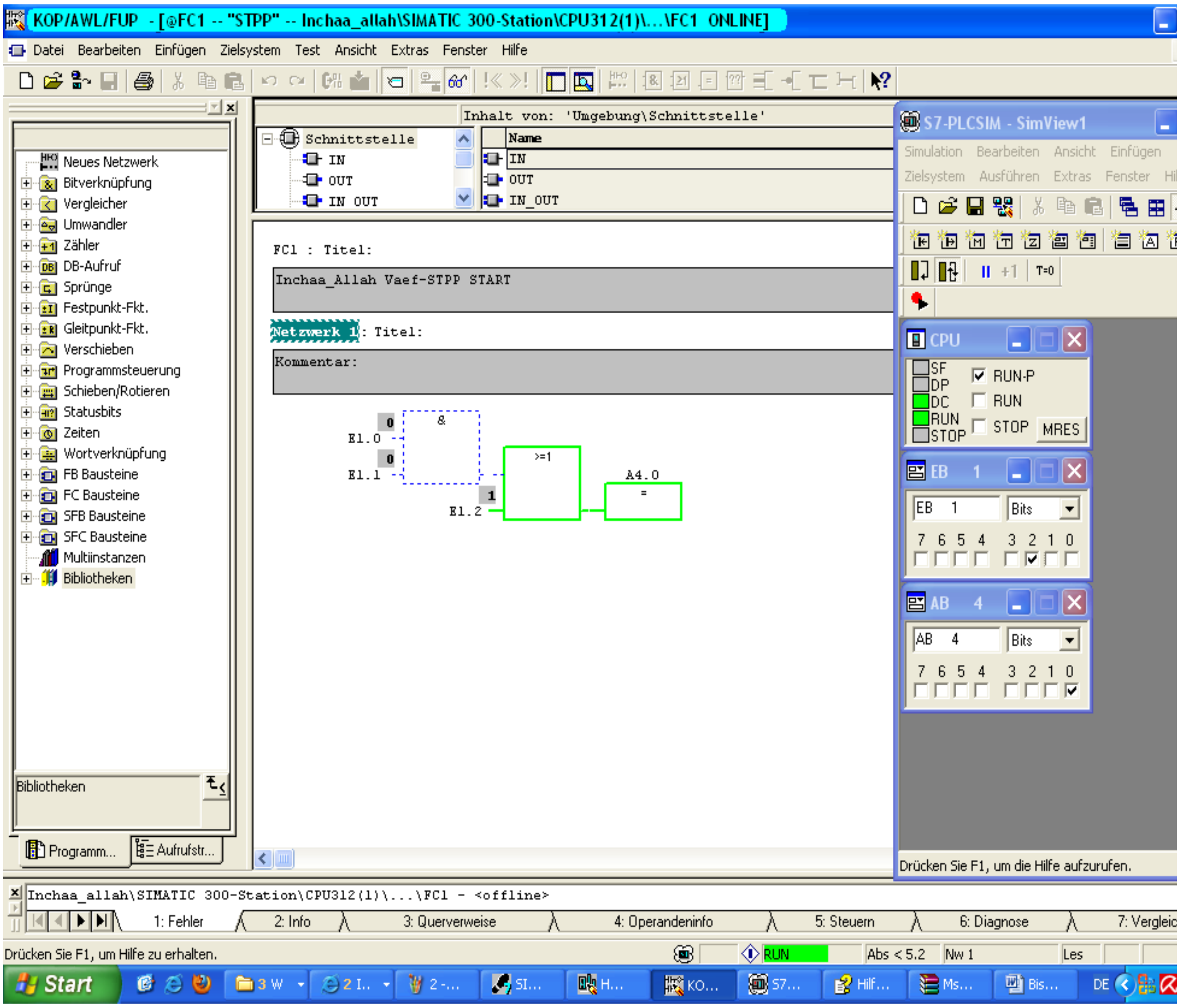
(0) UR

Steckplatz	Baugruppe	Bestellnummer	Firmware	MPI-Adresse	E-Adresse	A-Adresse	Kommentar
1	PS 307 5A	6ES7 307-1EA00-0AA0					
2	CPU312(1)	6ES7 312-1AD10-0AB0	V2.0	2			
3							
4	AI2x12Bit	6ES7 331-7KB02-0AB0			256...259		
5	DO16xDC24V/0.5A	6ES7 322-1BH01-0AA0				4...5	
6							
7							
8							
9							
10							

Baugruppen der SIMATIC S7-300, M7-300 un (zentraler Aufbau)

Drücken Sie F1, um Hilfe zu erhalten.

Hardware configuration



KOP/AWL/FUP - [@FC1 -- "STPP" -- Inchaa_allah\SIMATIC 300-Station\CPU312(1)\...\FC1 ONLINE]

Inhalt von: 'Umgebung\Schnittstelle'

FC1 : Titel:

Inchaa_Allah Vaef-STPP START

Netzwerk 1: Titel:

Kommentar:

Inchaa_allah\SIMATIC 300-Station\CPU312(1)\...\FC1 - <offline>

Drücken Sie F1, um Hilfe zu erhalten.

Drücken Sie F1, um die Hilfe aufzurufen.

A Small test program

Die Kommunikationsschnittstellen

MPI-USB-Schnittstelle für S7-300

Das Multi Point Interface (MPI) ist eine proprietäre Schnittstelle von SIMATIC S7 Geräten der Firma Siemens und wird für den Anschluss von PGs (Programmiergeräten) an das Automatisierungsgerät verwendet. Der PC-MPI-Adapter setzt die Daten von der RS232-oder USB Schnittstelledes PCs auf den MPI-Bus (RS485-Pegel) um. Die Übertragungsgeschwindigkeit der seriellenSchnittstelle beträgt 19,6 kBaud. Die MPI-Schnittstelle arbeitet mit 187,5 Kbit/s. Der MPI-Adapter hat eine Verbindungsleitung, die direkt auf den CPU Stecker der SPS gesteckt wird. Die Spannungsversorgung erhält der MPI-Adapter von der CPU über die MPI-Leitung. Die Konfiguration der MPI-Schnittstelle erfolgt über das mit STEP7 mitgelieferte Programm.

PG-PC Schnittstelle einstellen. Dabei werden der COM-Anschluss (USB) der seriellen Schnittstelle festgelegt, die Übertragungsgeschwindigkeiten eingetragen und die MPI-Adresse des PCs definiert. Der PC wird mit der MPI-Adresse 0 belegt.

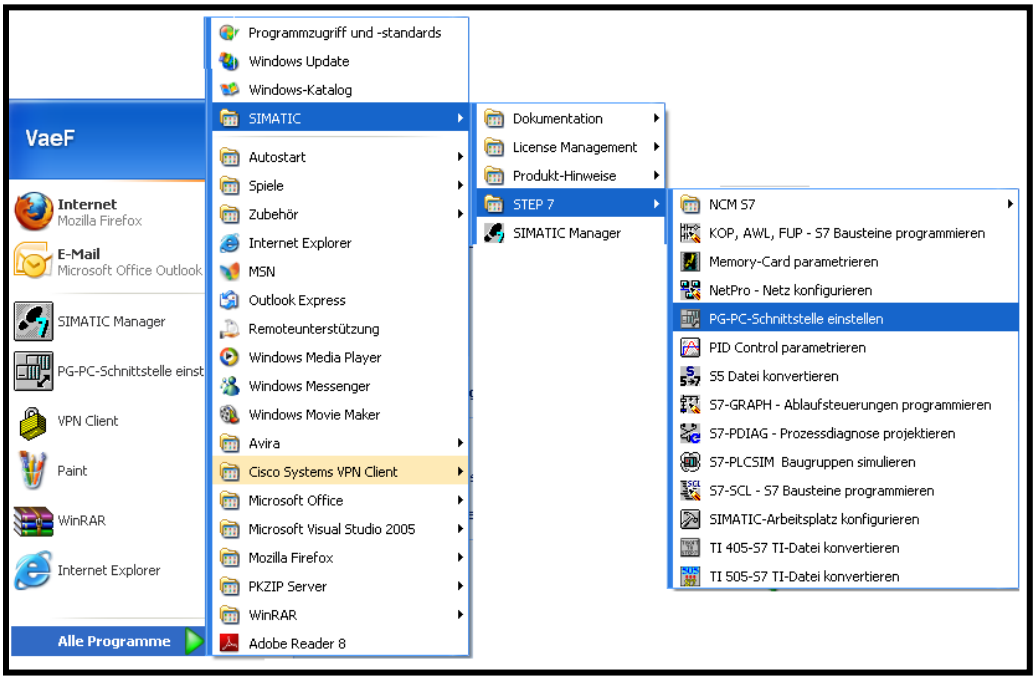
	MPI-USB BUS für S7-300/400

Mit "echter" SPS (ohne Simulator): PG/PC-Schnittstelle einstellen

Ein gestarteter Simulator macht das Arbeiten mit einer wirklichen SPS unmöglich. Er hat bei der Kommunikation Priorität und muss beendet werden, wenn mit einem AG gearbeitet werden soll. Ein AG wird immer über diejenige Schnittstelle angesprochen, die im Simatic Manager global für das ganze Programmpaket, also auch global für ein Projekt eingestellt worden ist. - Wenn die Statuszeile im Simatic Manager eingeblendet ist, wird darin die Schnittstelle dauerhaft angezeigt.

Ausgewählt wird die Schnittstelle über:

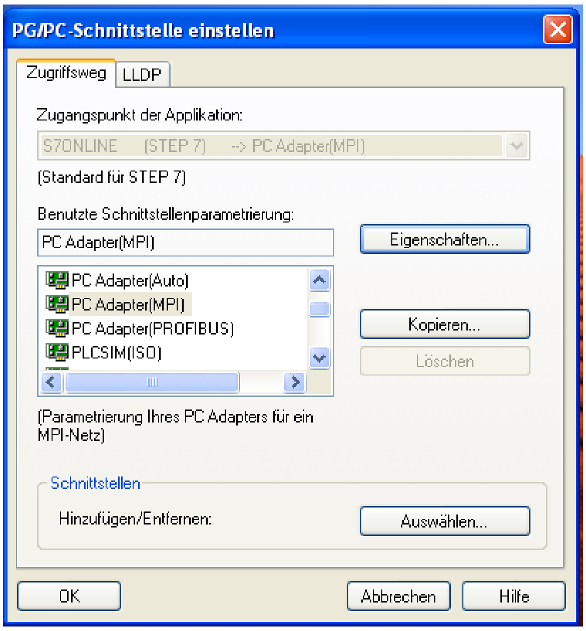
- **Simatic Manager --> Extras --> PG/PC-Schnittstelle einstellen... (Step1)**



Step1

Die Markierung in diesem Dialog ist nur sehr schwach zu sehen. Wenn die gewünschte Schnittstelle in der Liste nicht zu finden ist, muss die Schaltfläche "Schnittstellen --> Hinzufügen/Entfernen: --> Auswählen..." betätigt werden, um einen Dialog zu öffnen, in dem Schnittstellen nachinstalliert werden können (Step2).

Hier ist als Beispiel der "PC Adapter" in der Variante "MPI" ausgewählt. Dies wird, wenn man nicht über ein Siemens PG verfügt, das eine RS 485-Schnittstelle eingebaut hat, der erste Weg sein, den man für ein Kommunikation mit einem AG wählt.


PG/PC-Schnittstelle einstellen

Zugangspunkt der Applikation: S7ONLINE (STEP 7) --> PC Adapter(MPI)

(Standard für STEP 7)

Benutzte Schnittstellenparametrierung: PC Adapter(MPI)

(Parametrierung Ihres PC Adapters für ein MPI-Netz)


Eigenschaften - PC Adapter(MPI)

Anschluß an: USB

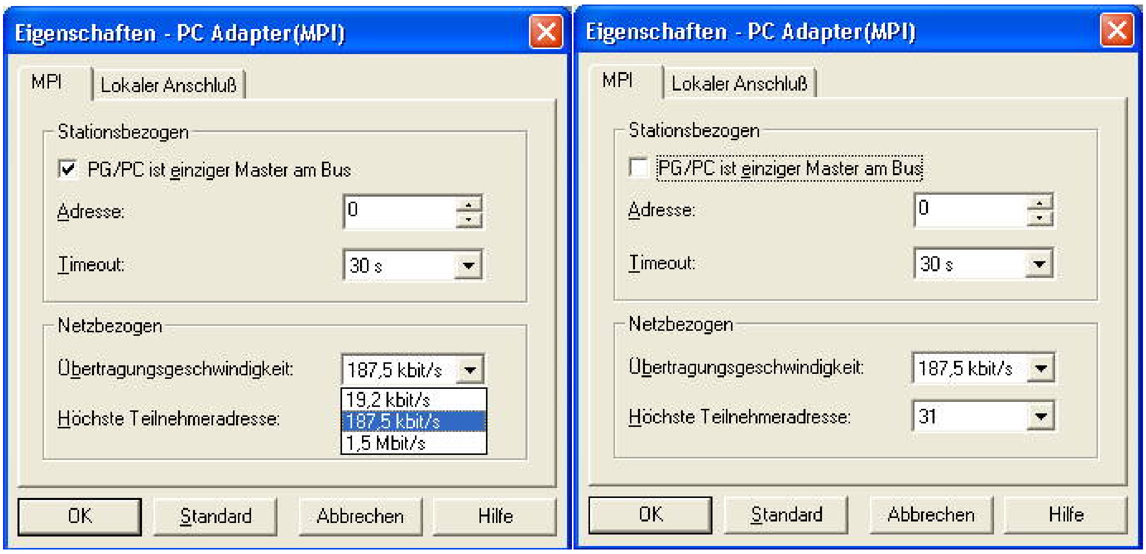
☑ Einstellungen baugruppenglobal übernehmen

Step2

Step3

Ein PC-Adapter hat zwei Seiten: sozusagen die PC-Seite und die AG-Seite. Auf der PC-Seite ist es möglich die RS 232C-Schnittstelle zu verwenden (dann muss auf die Datenrate geachtet werden!) oder mit dem moderneren Adapter die USB-Schnittstelle zu benutzen, wie hier gezeigt.

Auf der AG-Seite ist durch die Vorauswahl im ersten Dialog die MPI-Schnittstelle festgelegt worden (es gibt auch noch "Auto" für die Kommunikation über Profibus). Diese arbeitet im Allgemeinen mit einer Datenrate von 187,5 kbit/s. Diese Einstellung sollte man sicherheitshalber kontrollieren, da nur moderne CPUs auch eine höhere Datenrate beherrschen. - Und insbesondere beim seriellen Adapter nicht davon beeindrucken lassen, dass auf der PC-Seite auch eine Datenrate eingestellt werden muss! Diese haben miteinander nicht zu tun und beziehen sich jeweils nur auf eine Seite der Kommunkation. Zwischen diesen Seiten vermittelt der Adapter, sowohl was die Pegelanpassung angeht als auch was die Datenrate betrifft.(Step4)



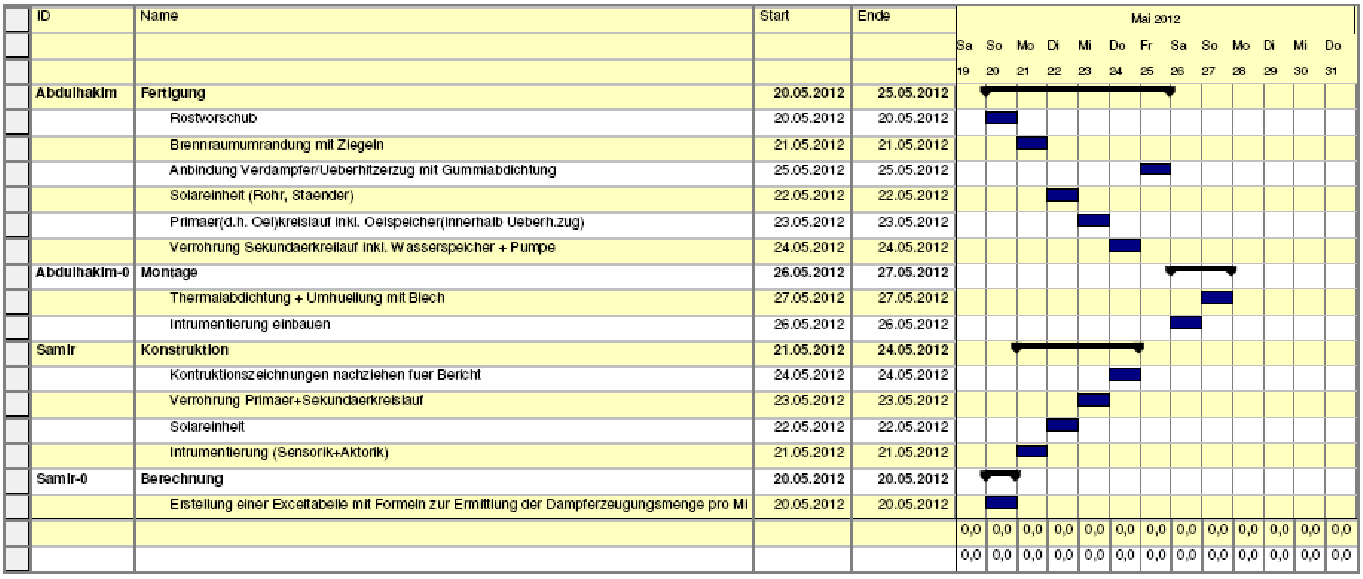
Stationsbezogen
☑ PG/PC ist einziger Master am Bus
Adresse: 0
Timeout: 30 s
Netzbezogen
Übertragungsgeschwindigkeit: 187,5 kbit/s
19,2 kbit/s
187,5 kbit/s
1,5 Mbit/s
Höchste Teilnehmeradresse:

Stationsbezogen
☐ PG/PC ist einziger Master am Bus
Adresse: 0
Timeout: 30 s
Netzbezogen
Übertragungsgeschwindigkeit: 187,5 kbit/s
Höchste Teilnehmeradresse: 31

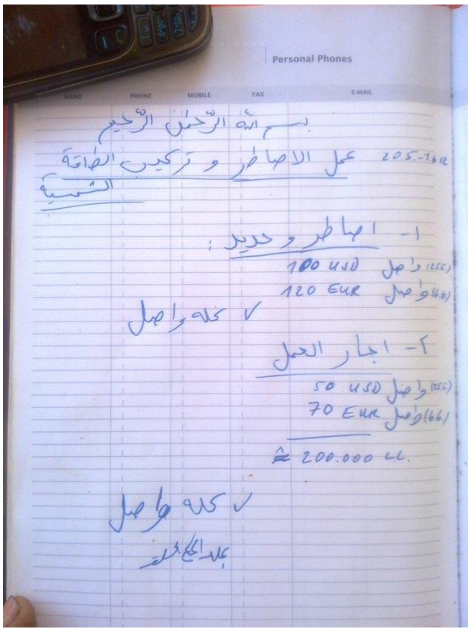
Step4

28.2 ملحق ب: تفاصيل للتكاليف

28.2.1 مخطت لايار و حزيران 2012 /Planned for May and June 2012



ID	Name	Start	Ende	Mai 2012												
				Sa	So	Mo	Di	Mi	Do	Fr	Sa	So	Mo	Di	Mi	Do
				19	20	21	22	23	24	25	26	27	28	29	30	31
Abdulhakim	**Fertigung**	**20.05.2012**	**25.05.2012**		▬	▬	▬	▬	▬	▬						
	Rostvorschub	20.05.2012	20.05.2012		■											
	Brennraumumrandung mit Ziegeln	21.05.2012	21.05.2012			■										
	Anbindung Verdampfer/Ueberhitzerzug mit Gummiabdichtung	25.05.2012	25.05.2012							■						
	Solareinheit (Rohr, Staender)	22.05.2012	22.05.2012				■									
	Primaer(d.h. Oel)kreislauf inkl. Oelspeicher(innerhalb Ueberh.zug)	23.05.2012	23.05.2012					■								
	Verrohrung Sekundaerkreilauf inkl. Wasserspeicher + Pumpe	24.05.2012	24.05.2012						■							
Abdulhakim-0	**Montage**	**26.05.2012**	**27.05.2012**								▬	▬				
	Thermalabdichtung + Umhuellung mit Blech	27.05.2012	27.05.2012									■				
	Intrumentierung einbauen	26.05.2012	26.05.2012								■					
Samir	**Konstruktion**	**21.05.2012**	**24.05.2012**			▬	▬	▬	▬							
	Kontruktionszeichnungen nachziehen fuer Bericht	24.05.2012	24.05.2012						■							
	Verrohrung Primaer+Sekundaerkreislauf	23.05.2012	23.05.2012					■								
	Solareinheit	22.05.2012	22.05.2012				■									
	Intrumentierung (Sensorik+Aktorik)	21.05.2012	21.05.2012			■										
Samir-0	**Berechnung**	**20.05.2012**	**20.05.2012**		▬											
	Erstellung einer Exceltabelle mit Formeln zur Ermittlung der Dampferzeugungsmenge pro MI	20.05.2012	20.05.2012		■											
				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
				0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0



Personal Phones

بسم الله الرحمن الرحيم

20.5.-1.6.12 عمل الاصاطر و تركيب الطاقة الشمسية

١- اصاطر و حديد:

(25.5) واصل 100 USD

(4.6) واصل 120 EUR

✓ كله واصل

٢- اجار العمل

(25.5) واصل 50 USD

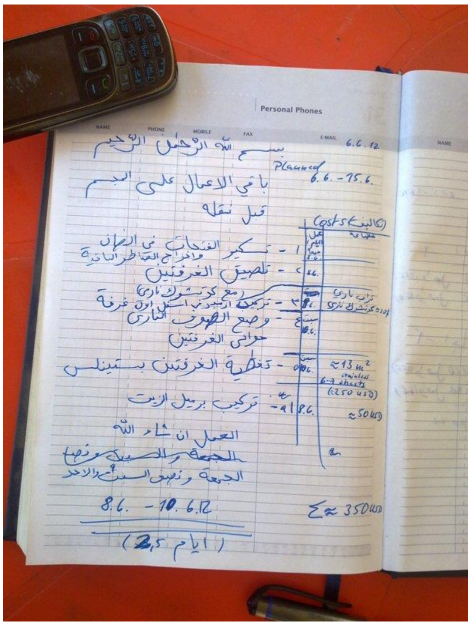
(6.6) واصل 70 EUR

≙ 200.000 LL.

✓ كله واصل

الفواتير للعمل في مايو (التكلفة: حوالي 300 يورو)

Billing for work in May (cost: about 300 EUR)



Personal Phones

بسم الله الرحمن الرحيم 6.6.12

Planned 6.6.-15.6.

باقي الاعمال على المجسم قبل نقله

Costs (تكاليف)

١- تسكير الفتحات في الطاحن واخراج العناصر الناقصة — 6.6.

٢- تلصيق الغرفتين — 8.6.

٣- تركيب [illegible] اسفل اول غرفة (مع كوتشوك ناري) — 8.6. — تراب ناري، كوتشوك ناري ≈ 50$

٤- وضع الصوف الناري حوالى الغرفتين — 10.6.

٥- تغطية الغرفتين بستينلس — 10.6. — ≈ 13 m² stainless 6-7 sheets (≈ 250 USD)

٦- تركيب برميل الزيت — 8.6. — ≈ 50 USD

العمل ان شاء الله

~~الجمعة والسبت ونصف~~

الجمعة ونصف السبت والاحد

8.6. - 10.6.12

(2,5 ايام)

Σ ≈ 350 USD

التخطيط للعمل بقية في يونيو 2012: التكلفة (المخطط) المواد تكاليف نحو 350$ + تكاليف العمالة 150$ = 500$

Planning rest work in June 2012: Cost (planned) about 350 USD material costs + 150 $ labor costs = 500 $

Planung Restarbeiten im Juni 12: Kosten (geplant) ca. 350 $ Materialkosten + 150 $ Personalkosten = 500 $

28.2.2 العمل كما حدث / Executed: October / November 12: Vaporizer and overheater hermetically welded and placed on wheels, combustion chamber, thermal sealing, Mantle

It was a great delay because of the work of some worker.

Planned cost: 350 USD

Actual Cost: 400 USD (Vaporizer / Overheater hermetically welded, put on rollers)

+ 100 USD (+ thermal combustion chamber seal)

500 USD (= 420 EUR)

Teaching: Staff selection is very important.

كان تأخير كبير بسبب كيفية ادرة عمل بعض العمال.

المخطط التكلفة: $350

التكلفة الفعلية: 400$ مبخر Overheater / ملحومة بإحكام، وطرح على بكرات

ختم غرفة الاحتراق الحراري + 100$

500 $ (= 420EUR)

الافادة: اختيار الموظفين مهم جدا.

Ausgeführt: Oktober/ November 12: Verdampferzug und Überhitzerzug luftdicht geschweisst und auf Rollen gebracht, Brennraum, Thermalabdichtung, Mantelung

Es fand eine grosse Verzögerung aufgrund der Arbeitsweise des Schweissers statt.

Geplante Kosten: 350 USD

Tatsächliche Kosten: 400 USD (VZ/ÜZ luftdicht geschweisst, auf Rollen gebracht)

+ 100 USD (Brennraum + Thermalabdichtung)

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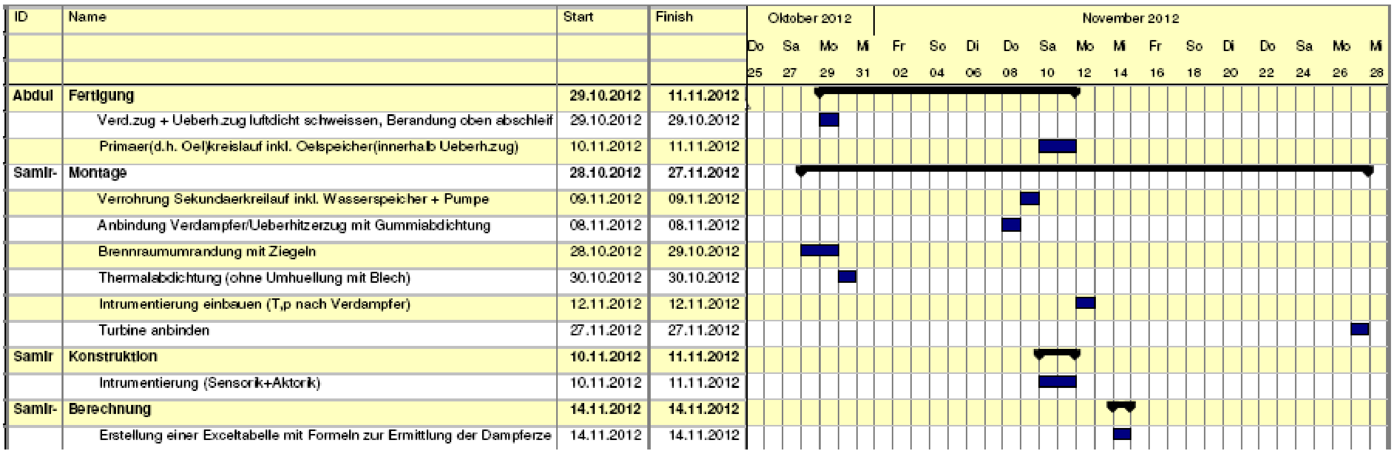
500 USD (= ca. 420 EUR)

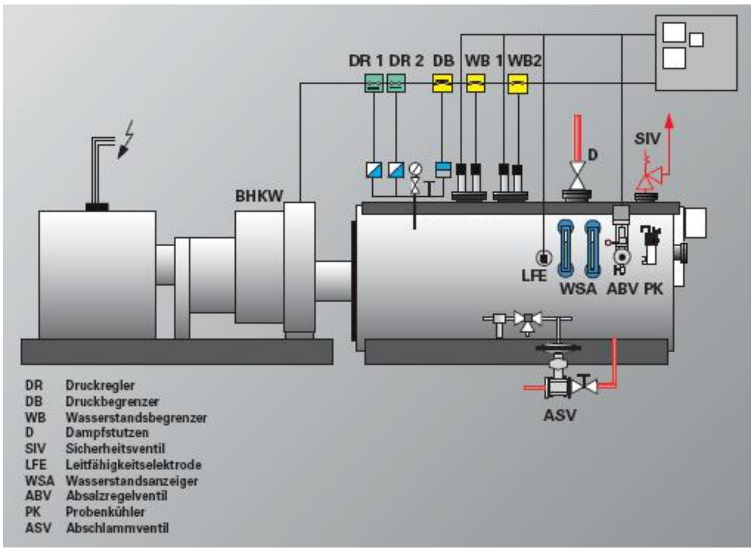
Lehre: Mitarbeiterauswahl ist sehr wichtig.



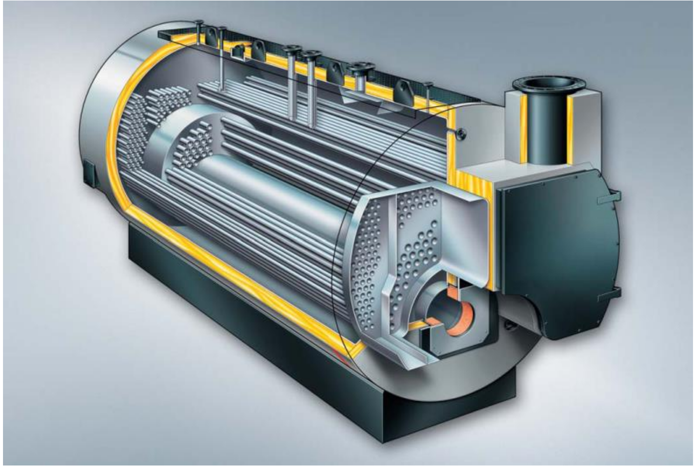
ID	Name	Start	Finish
Abdul	**Fertigung**	**29.10.2012**	**11.11.2012**
	Verd.zug + Ueberh.zug luftdicht schweissen, Berandung oben abschleif	29.10.2012	29.10.2012
	Primaer(d.h. Oel)kreislauf inkl. Oelspeicher(innerhalb Ueberh.zug)	10.11.2012	11.11.2012
Samir-	**Montage**	**28.10.2012**	**27.11.2012**
	Verrohrung Sekundaerkreilauf inkl. Wasserspeicher + Pumpe	09.11.2012	09.11.2012
	Anbindung Verdampfer/Ueberhitzerzug mit Gummiabdichtung	08.11.2012	08.11.2012
	Brennraumumrandung mit Ziegeln	28.10.2012	29.10.2012
	Thermalabdichtung (ohne Umhuellung mit Blech)	30.10.2012	30.10.2012
	Intrumentierung einbauen (T,p nach Verdampfer)	12.11.2012	12.11.2012
	Turbine anbinden	27.11.2012	27.11.2012
Samir	**Konstruktion**	**10.11.2012**	**11.11.2012**
	Intrumentierung (Sensorik+Aktorik)	10.11.2012	11.11.2012
Samir-	**Berechnung**	**14.11.2012**	**14.11.2012**
	Erstellung einer Exceltabelle mit Formeln zur Ermittlung der Dampferze	14.11.2012	14.11.2012

28.3 ملحق ث: توليد البخار على أساس أنابيب المداخن (غير مناسب لمحطات الطاقة أكبر) / Apprendix B: Flue pipe based heat recovery boiler for process heat (not suitable for larger power plants)

Apprendix B: Rauchrohrbasierte Abhitzekessel für Prozesswärme (nicht für größere Kraftwerke geeignet)



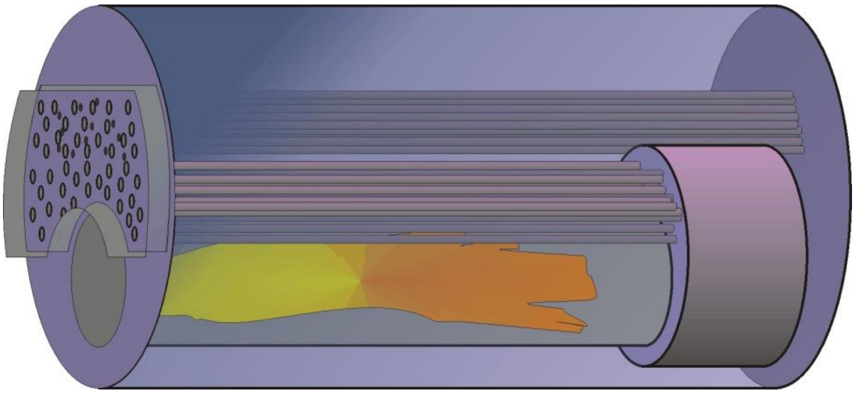
Abhitzekessel nutzen die Wärme von Abgasen aus Verbrennungsprozessen oder von heißen Abluftströmen aus industriellen Prozessen zur Erzeugung von Heißwasser oder Sattdampf.



Vitomax 200HS zur Dampferzeugung

Bild 2: Dampferzeuger mit einer Dampfleistung von 4 t/h, 13 bar, mit integriertem Abhitzezug für ein BHKW mit 0,4 t/h (Abhitzeleitung noch nicht angeschlossen)

Dreizügiger Flammrohrkessel Schema[28]:



Während die unbeheizten Flächen (Kesselmantel) etwa Sattdampftemperatur aufweisen, liegt die Temperatur an den Heizflächen höher. Der Temperaturunterschied beträgt beim Kessel ohne wasserseitige Belägen bis 50°C. Im Falle von Kesselsteinablagerungen kann diese Temperaturdifferenz deutlich höher liegen und Risse verursachen.

Um Spannungen in den Kesselbauteilen als Folge von thermischen Längenänderungen gering zu halten, werden möglichst geringe Wandstärken für die Kesselböden und die Rohrplatten verwendet. Das Flammrohr und die Rauchrohre nehmen die Innendruckbelastung auf die Kesselböden mit auf. In den nicht berohrten Bereichen des Mantels (Dampfraum) werden zusätzlich Eck- oder Zuganker eingeschweißt, die die Biegespannungen zwischen Mantel und Boden teilweise aufnehmen. Dies sind spannungstechnisch kritische und schadensanfällige Komponenten. Die Schweißnähte der Anker müssen durchgeschweißt sein und durch die Form der Anker muss ein stetiger Spannungsfluss gewährleistet sein.

Mehr als drei Züge sind bei heutigen Großwasserraumkesselkonstruktionen nicht üblich. Die Großwasserraumkessel zeichnen sich durch einen hohen Wasserinhalt (1 - 30 t) und somit eine hohe Wärmespeicherfähigkeit. Durch die Nachverdampfung des unter Sattdampftemperatur stehenden

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[28] From www.wikipedia.org/de/

Wassers kann ein kurzzeitig schwankender Dampfverbrauch ausgeglichen werden. Die erforderlichen Wandstärken für den Mantel und die notwendigen Verankerungen der Böden schränken den technisch vertretbaren Bereich des Betriebsdruckes ein (bis ca. 38 bar). Aufgrund der Bauweise (große zusammenhängende Flächen) sind Großwasserraumkessel empfindlich gegen Wärmespannungen beim Hochheizen und Abkühlen. Die Kessel werden daher langsam hochgefahren, um den Temperaturgradienten der Kesselbauteile gering zu halten.

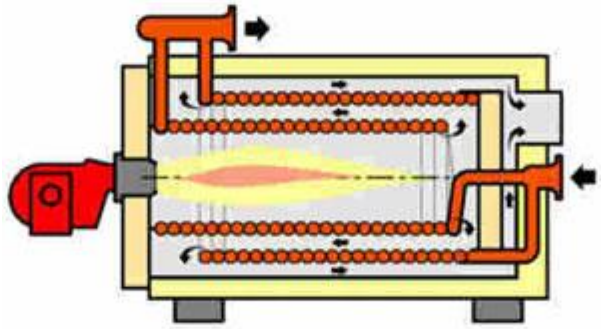
Aufgeschnittener Kessel:

Apprendix C: Thermal oil systems / نظم لتسخن النفط 28.4

Thermal oil boiler for heating systems are mineral and synthetic thermal oils.

From ehi-technik.de/…/thermaloel/..:

Der Erhitzer besteht aus einer Strahlungsbrennkammer mit einer nachgeschalteten Konvektionsheizfläche. Ein zylindrisch gebogener “Rohrkorb“ bildet die Heizfläche des Erhitzers und wird vom Thermalöl durchströmt. Er wird in einer gasdichten Ummantelung spannungsfrei eingebaut.Die Rauchgase werden im Erhitzer 3-zügig geführt. Eine Mineralwollisolierung mit verzinktem Grobkornblechmantel dient als Außenhaut und schützt vor Wärmeverlusten und schützt bei Berührung



Wir können die Erhitzeranlagen sowohl in liegender wie auch stehender Ausführung liefern. In Regelfall werden sogenannte Unit's d.h. Kompaktanlagen geliefert, sie beinhalten den Erhitzer, den Schaltschrank mit Temperaturregelung, die Gas oder Ölbrenneranlage und die Primärpumpe. Wenn es sich anlagenseitig (Platzbedarf, Anlagenhöhe etc.) ermöglicht fertigen wir die Unit’s mit Fuß- und Ausdehnungsgefäß auf einer Konstruktion.

Condenser, cooling system, Process Control System, partly system integration (2013)[29]

التقرير **الرابع** لمشروع **TEMO-STPP** (المدة من كانون الثاني الى كانون الاول 2013)

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[29] Based on [TEMO-IPP 2013] (4th project report)

28.5المحتوى في شكل موجز / Content in short

29 Abstract

مركز للطاقة البديلة

http://aecenar.com/institutes/meae

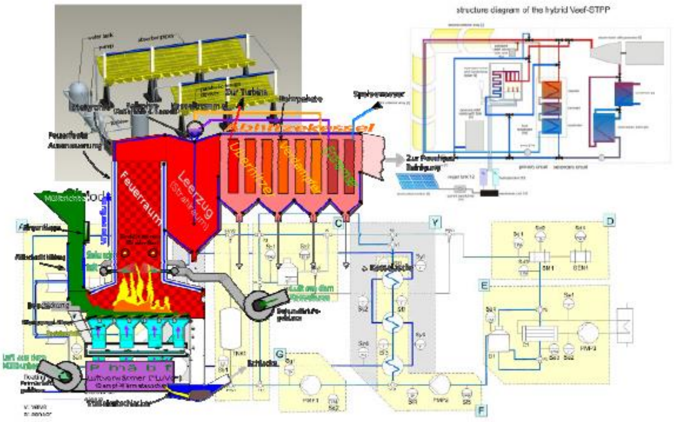
بحوث حول اجزاء لمحطات طاقة عن طريق الحرار
الشمسية و عن طريق حرق النفيات

AECENAR
Association for Economical and Technological Cooperation
in the Euro-Asian and North-African Region
www.aecenar.com

Solarthermal/Incineration Power Plant Technology
TEMO-STPP Test Plant

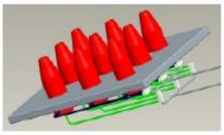
توليد كهرباء – تدفأة بنايات – حل لمشكلة النفايات و الاستفادة منها – الاستفادة من الطاقة الشمسية لتوليد الكهرباء

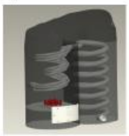
Last update: 17 December 2013



Architecture of process control system (sensors and actuators)

Hydrogen burner



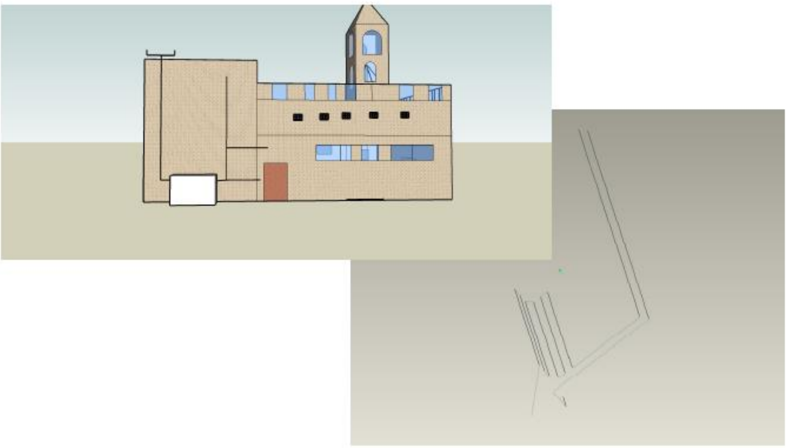


Hydrogen burner and
Condensing boiler

اعمال حالية:

- تشغيل المحرقة لتوليد البخار
- ربط التوربين لتوليد الكهرباء
- وضع المحطة في احد المناطق مثل طرابلس

التصميم الحالي في مركز القبيسي في راسنحاش \ البترون (شمال لبنان)



الحاجيات لعام 2014:

- 36.150 $

Contact:
Samir Mourad
Mobile: +96176341526
samir.mourad@aecenar.com

30 Introduction and goal of this work / مقدمة والهدف من هذا العمل

Mechanical Integration of the TEMO-STPP Test Plant for a Incineration/Solar-thermal-combination power plant

Development and Installation of the Process Control System for TEMO-STPP

تجميع الاجزاء الميكانيكية لمحطة طاقة تجريبية تعمل عن طريق حرق النفايات والطاقة الشمسية

انشاء و تركيب لنظام التحكم

30.1/الأهداف الاستراتيجية الاقتصادية / Strategic Economical Goals

The goal of this project phase is to create a kernel team of engineers capable to undergo a bigger project of about 2 Mio. EUR.

والهدف من هذه المرحلة للمشروع هو انشاء نواة فريق من المهندسين قادر على الخضوع لمشروع أكبر بقدر حوالي 2 مليون EUR.

30.2/الأهداف العملية / Main Working Packages to be done

In this project phase the following steps has to be undergone:

1) Integration and Installation of TEMO-STPP (incineration-solarthermal-combination power plant) (MECH and Process Control System (PCS))
2) Operation of the 40kW demonstration plant in Ras Nhache for getting investors for other power plants

في هذه المرحلة للمشروع الخطوات التالية يجب أن تنفذ:

1) تجميع TEMO-STPP (محطة للطاقة تعمل عن حرق النفايات بمساعدة الطاقة الشمسية الحرارية) (تجميع الهيكل الميكانيكي وتصميم نظام للتحكم (PCS)).
2) تشغيل محطة kW40 في رأسنحاش/لبنان للحصول على مستثمرين لمحطات الطاقة الأخرى

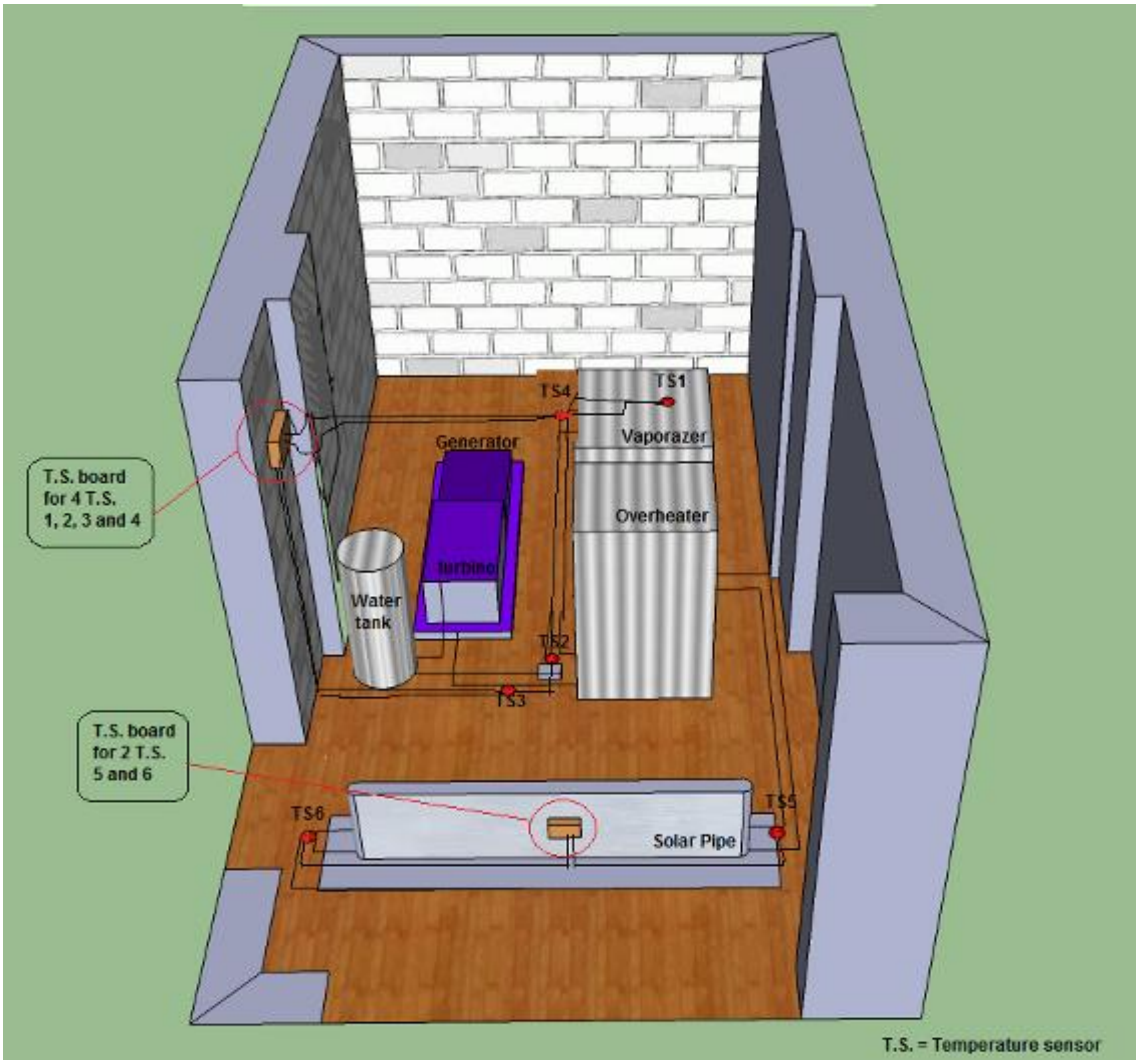
31 Integration of mechanical parts / تجميع القطع الميكانيكية

31.1 وضع القطع الاساسية في مكانها (Placing of the main devices)

31.1.1 At working hall

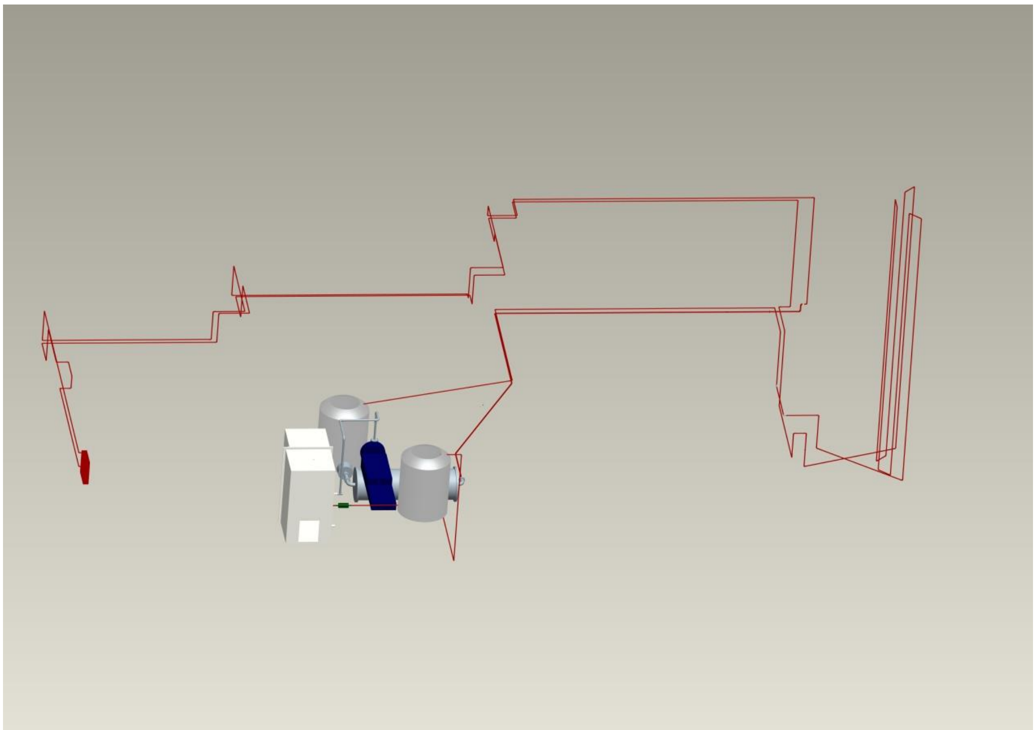
Figure bellow shows us the integration of the mechanical part with sensors.

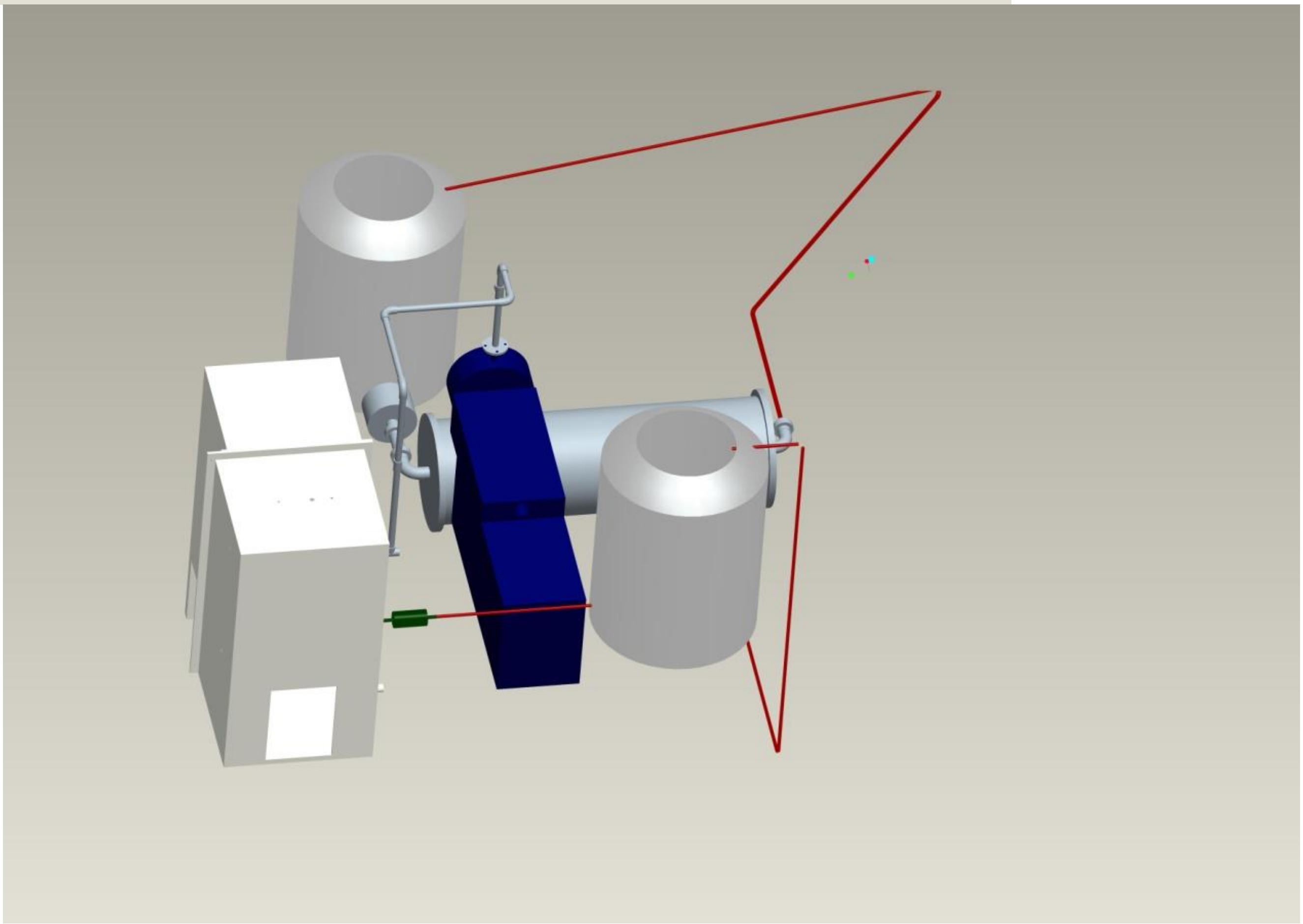
الصورة التالية تبين طريقة جمع محطة الطاقة

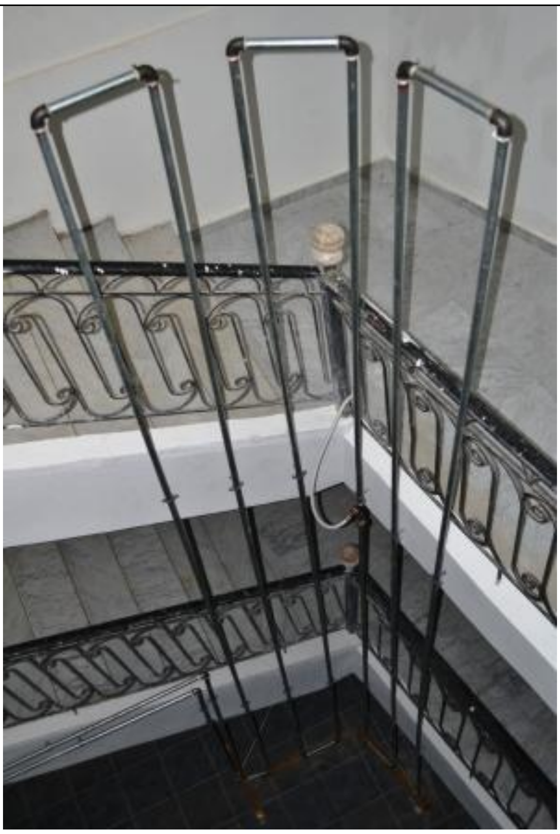


Vaparizor with overheater	Solar pipe	Turbine	Control system
			

At Qubaisi Center 31.1.2

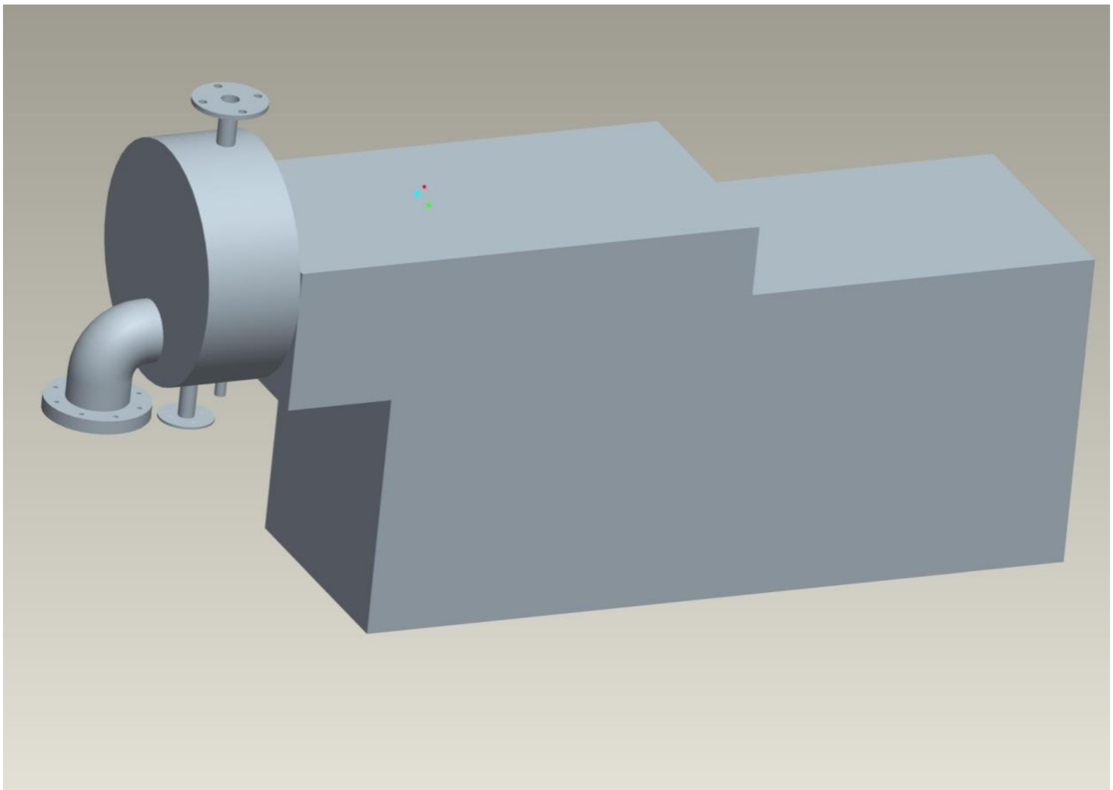






31.2 التربين (turbine)

31.2.1 تفحيص التوربين 40 kW (Curtis turbine)



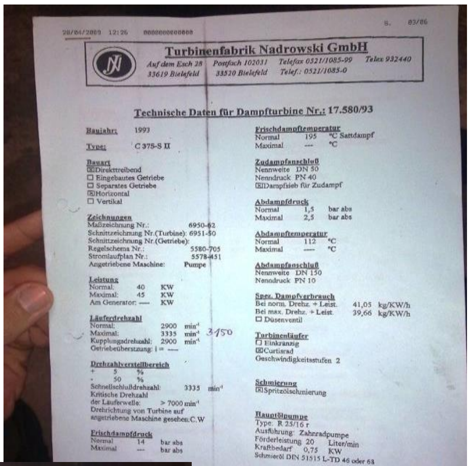
There must put in a fiber as "Dichtung" at the large front end of the turbine.

31.2.2 Technical Data of the turbine

The turbine used is a used Steam turbine Nadrowski Bielefeld (Dresser-Rand) Power 40KW. And have the following specification:

Specifications:

Power: 40 KW
Max 45 KW
year: 1993
Type: C 375-II's
serial number: 17,580 / 93
Principle: Curtis runner
normal speed: 2900 1/min
max: 3335 1 min
speed adjustment: +5% .... -50%
steam pressure: 14 bar
steam release pressure 1.5 bar
steam temperature: 195 ° C
exhaust temperature: 112 ° C
Shaft Diameter 50mm
Weight: 1150 kg



28/04/2009 12:26 S. 03/06

Turbinenfabrik Nadrowski GmbH
Auf dem Esch 28
33619 Bielefeld
Postfach 102031
33520 Bielefeld
Telefax 0521/1085-99
Telef.: 0521/1085-0
Telex 932440

Technische Daten für Dampfturbine Nr.: 17.580/93

Baujahr: 1993

Type: C 375-S II

Bauart
☒ Direkttreibend
☐ Eingebautes Getriebe
☐ Separates Getriebe
☒ Horizontal
☐ Vertikal

Zeichnungen
Maßzeichnung Nr.: 6950-62
Schnittzeichnung Nr.(Turbine): 6951-50
Schnittzeichnung Nr.(Getriebe):
Regelschema Nr.: 5580-705
Stromlaufplan Nr.: 5578-451
Angetriebene Maschine: Pumpe

Leistung
Normal: 40 KW
Maximal: 45 KW
Am Generator: — KW

Läuferdrehzahl
Normal: 2900 min^{-1}
Maximal: 3335 min^{-1} 3150
Kupplungsdrehzahl: 2900 min^{-1}
Getriebeübersetzung: i = —

Drehzahlverstellbereich
\+ 5 %
\- 50 %
Schnellschlußdrehzahl: 3335 min^{-1}
Kritische Drehzahl der Läuferwelle: > 7000 min^{-1}
Drehrichtung von Turbine auf angetriebene Maschine gesehen: C.W

Frischdampfdruck
Normal 14 bar abs
Maximal --- bar abs

Frischdampftemperatur
Normal 195 °C Sattdampf
Maximal --- °C

Zudampfanschluß
Nennweite DN 50
Nenndruck PN 40
☒ Dampfsieb für Zudampf

Abdampfdruck
Normal 1,5 bar abs
Maximal 2,5 bar abs

Abdampftemperatur
Normal 112 °C
Maximal — °C

Abdampfanschluß
Nennweite DN 150
Nenndruck PN 10

Spez. Dampfverbrauch
Bei norm. Drehz. + Leist. 41,05 kg/KW/h
Bei max. Drehz. + Leist. 39,66 kg/KW/h
☐ Düsenventil

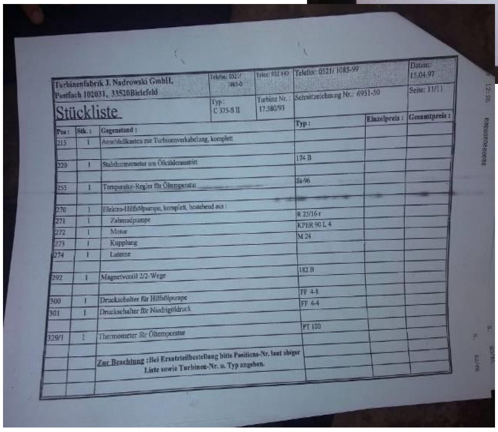
Turbinenläufer
☐ Einkränzig
☒ Curtisrad
Geschwindigkeitsstufen 2

Schmierung
☒ Spritzölschmierung

Hauptölpumpe
Type R 25/16 r
Ausführung: Zahnradpumpe
Förderleistung 20 Liter/min
Kraftbedarf 0,75 KW
Schmieröl DIN 51515 L-TD 46 oder 68

Seite 2

Dampfverbrauch
Handbuch
[illegible]

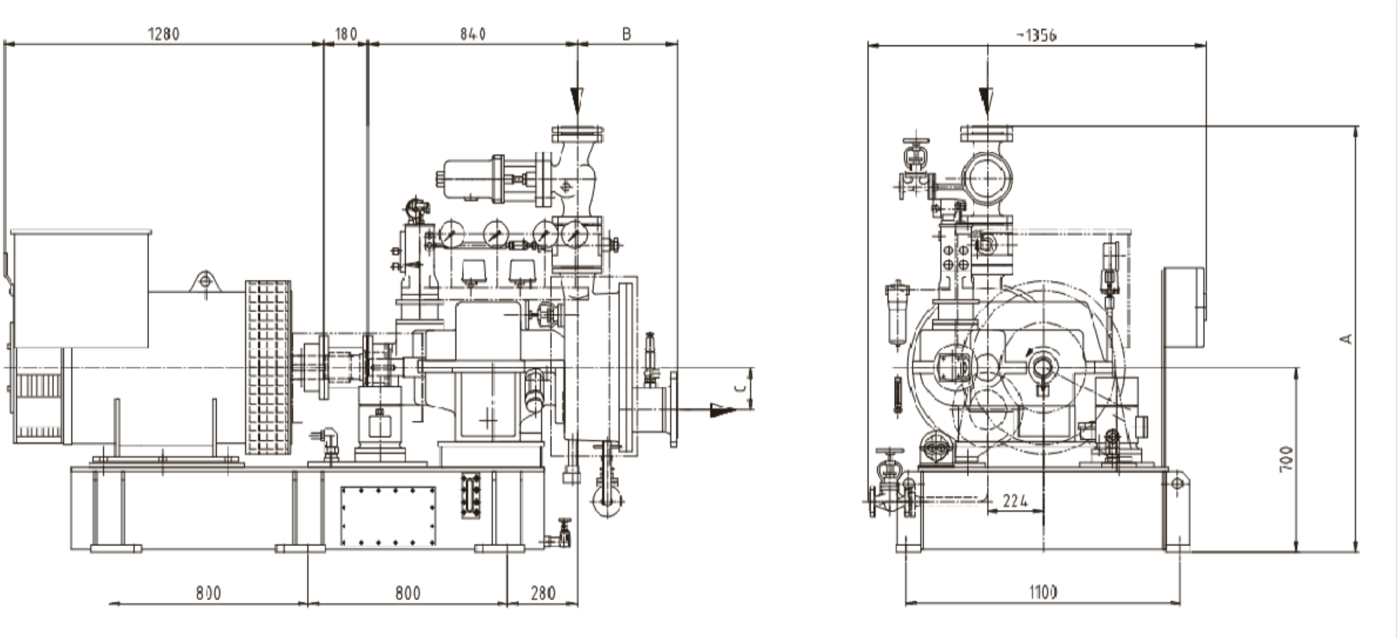


Turbinenfabrik J. Nadrowski GmbH, Postfach 102031, 33520Bielefeld
Telefon: 0521/1085-0
Telex: 932 440
Telefax: 0521/ 1085-99
Datum: 15.04.97
Stückliste
Typ: C 375-S II
Turbine Nr.: 17.580/93
Schnittzeichnung Nr.: 6951-50
Seite: 11/11

Pos:	Stk.:	Gegenstand:	Typ:	Einzelpreis:	Gesamtpreis:
215	1	Anschlußkasten zur Turbinenverkabelung, komplett			
220	1	Stabthermometer am Ölkühleraustritt	174 B		
255	1	Temperatur-Regler für Öltemperatur	St-96		
270	1	Elektro-Hilfsölpumpe, komplett, bestehend aus:			
271	1	Zahnradpumpe	R 25/16 r		
272	1	Motor	KPER 90 L 4		
273	1	Kupplung	M 24		
274	1	Laterne			
292	1	Magnetventil 2/2-Wege	182 B		
300	1	Druckschalter für Hilfsölpumpe	FF 4-8		
301	1	Druckschalter für Niedrigöldruck	FF 4-4		
329/1	1	Thermometer für Öltemperatur	PT 100		

Zur Beachtung: Bei Ersatzteilbestellung bitte Positions-Nr. laut obiger Liste sowie Turbinen-Nr. u. Typ angeben.

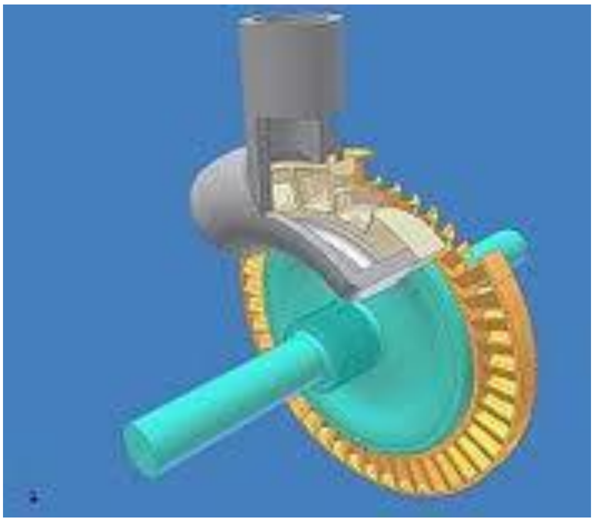
Others qualification:

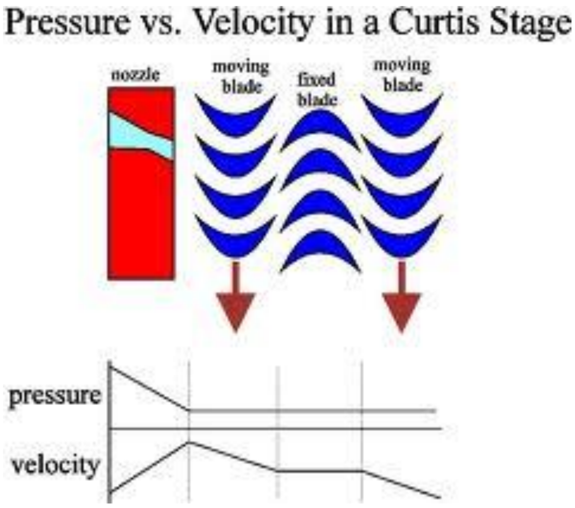


- Curtisrad
- Splash oil lubrication by gear pump 0.75 KW electric auxiliary oil pump remote activation elektisch

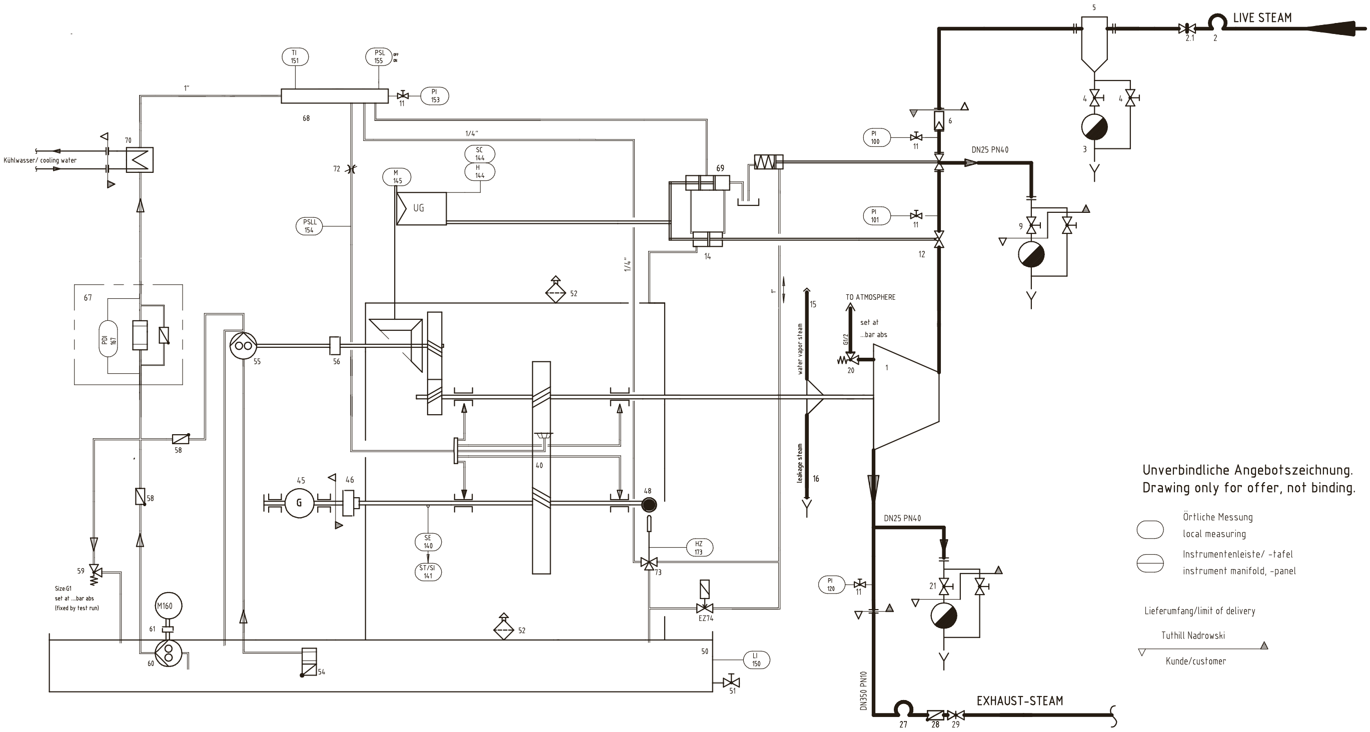
- Bearing 2 Rolling local speedometer
- Exhaust steam
- Warning safety valve housing with thermal insulation
- Labyrinth shaft seal
- Hydraulic speed control
- Speed control electric
- Quick-closing valve with mechanical overspeed

31.2.3 Some CAD data of Curtis turbines





31.2.4 Technical data for Nadrowski steam turbine



Symbol	description	Symbol	description	Symbol	description
PI	Pressure indicate	SI	Speed indicate	HZ	Hand actuator

LI	Level indicate	ST	Speed transmit	PSL	Pressure safety light
TI	Temperature indicate	SC	Speed control	PSLL	Pressure safety light low
PDI	Pressure difference indicate	SE	Speed sensor	H	Hand

31.2.5 Putting into work

Kraus: oil must be preheated to about 45 ° C.

Important to avoid bearing damage occurs:

To do: take apart and check the bearings!

- By visual inspection on 10.3.13:

It has a sealing ring (fiber) before the cover rim of the turbine (at the outlet)

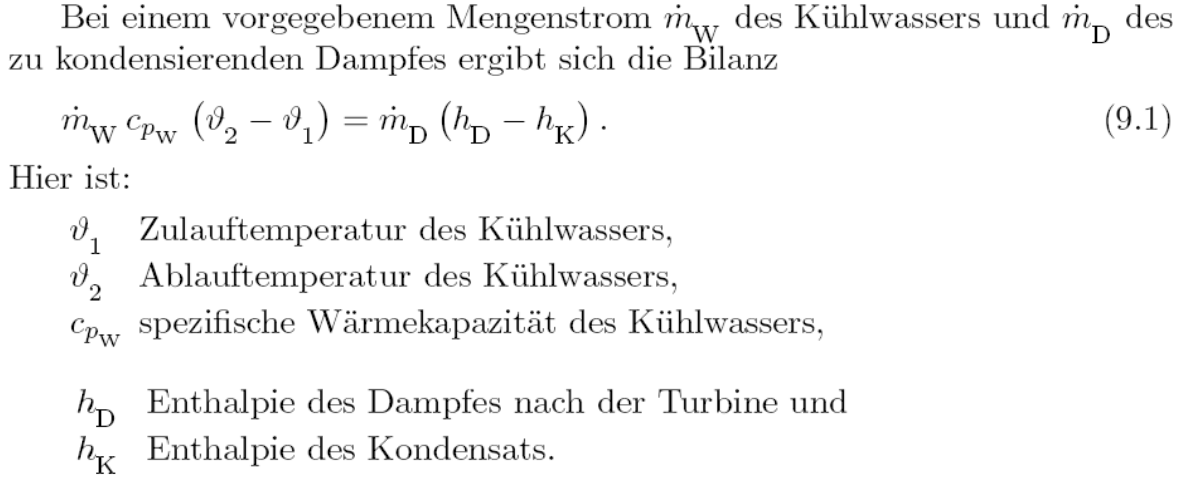
31.3 المضخّة (*The pump*)

This sort of pump (about 4 bar) can only be used for the condenser cooling cycle

31.4 المبرد (The condensor)

31.4.1 Introduction to condensor technology

From Strauss, "Kraftwerkstechnik"



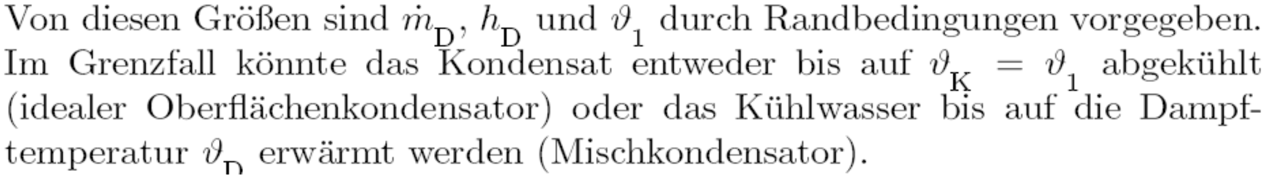
Bei einem vorgegebenem Mengenstrom $\dot{m}_\mathrm{W}$ des Kühlwassers und $\dot{m}_\mathrm{D}$ des zu kondensierenden Dampfes ergibt sich die Bilanz

$$\dot{m}_\mathrm{W}\, c_{p_\mathrm{W}} \left(\vartheta_2 - \vartheta_1\right) = \dot{m}_\mathrm{D} \left(h_\mathrm{D} - h_\mathrm{K}\right) . \tag{9.1}$$

Hier ist:

ϑ_1 Zulauftemperatur des Kühlwassers,
ϑ_2 Ablauftemperatur des Kühlwassers,
c_{p_W} spezifische Wärmekapazität des Kühlwassers,

h_D Enthalpie des Dampfes nach der Turbine und
h_K Enthalpie des Kondensats.



Von diesen Größen sind $\dot{m}_\mathrm{D}$, h_D und ϑ_1 durch Randbedingungen vorgegeben. Im Grenzfall könnte das Kondensat entweder bis auf $\vartheta_\mathrm{K} = \vartheta_1$ abgekühlt (idealer Oberflächenkondensator) oder das Kühlwasser bis auf die Dampftemperatur ϑ_D erwärmt werden (Mischkondensator).

In addition to the condensation of the Turbinenabdampfes the capacitor has to perform another task in modern power plants: it must be in certain cases of operation of the power plant to be able to condense all the steam from the boiler, which is optionally supplied to it via the bypass station. This can for example be the case during start-up and shut-down of a block or a fault in the turbine group. By this measure condensate losses and also a response of the safety valves are avoided. If the Umleitdampfstrom not limited to this example be greater at a full-load to the amount of injection water required for cooling than the Vollastdampfstrom. This also means that the capacitor has then remove the entire set free in the boiler thermal power.

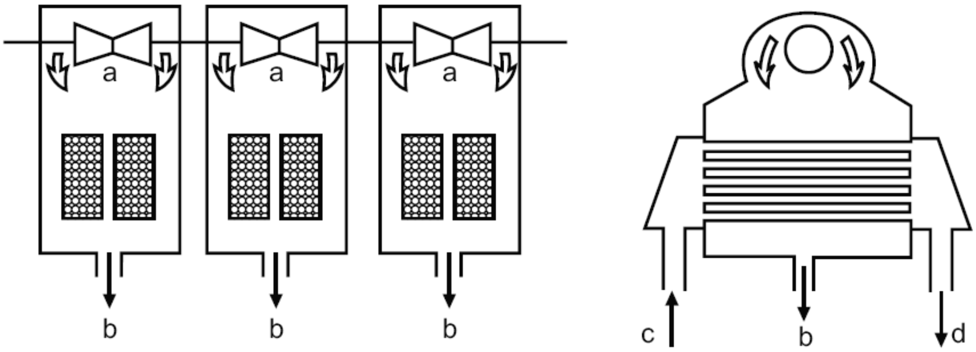
Due to unavoidable leaks in the water / steam cycle also failed condensables in the condenser, which must be continuously removed with special pumps.

This allows the tasks to be performed by a condenser in a steam power plant, are described as follows:

- condensation of the exhaust steam from the turbine and recovering the
- condensate
- generating a high vacuum (This allows the steam in the turbine
- be expanded to lower pressure than the ambient pressure, resulting in
- improving the process efficiency results, see Section 3.3.5),
- Recording of the steam from the bypass station,
- venting of the condensate
- Delivery of the condensate at saturation temperature, for reasons
- a high efficiency subcooling of the condensate is to be avoided.

System Architecture

The term condenser system includes all the components that are required to fulfill the aforementioned tasks. Because of the large Abdampfvolumenstroms capacitors are usually connected directly to the exhaust steam of the turbine and usually located directly below the turbine, see Figure 9.1. The condensate is extracted using pumps and conveyed to the feed water tank. Any air pockets are continuously removed from the condenser, otherwise the vacuum and thus the process efficiency would deteriorate. The construction of the capacitor has to bear the shrinkage of the specific volume on a 1/30000 bill.



a Abdampf aus der ND-Turbine
b Kondensatabfluß
c Kühlwasserzufuhr
d Kühlwasserabfuhr

Abbildung 9.1. Schema einer Kondensatoranlage

Mischkondensator

The cooling and collect vapor is achieved by injecting finely divided cooling water from feed water quality. Because the heat exchange is performed by direct contact between the two phases, the efficiency of this type of excluding almost producible interfacial dependent. When pressure atomization of the cooling water k values were measured from 100 kW/m2K [1] for droplet sizes of 0.6 mm and speeds of 15 m / s at a heat flux of 230 kW/m2. The condensation process works from nearly isobaric-isothermal. Figure 9.2 shows the diagram of a direct-contact condenser. The required injection mass flow can be estimated with a simple system balance. With the notation of Figure 9.2 applies to the mass flows

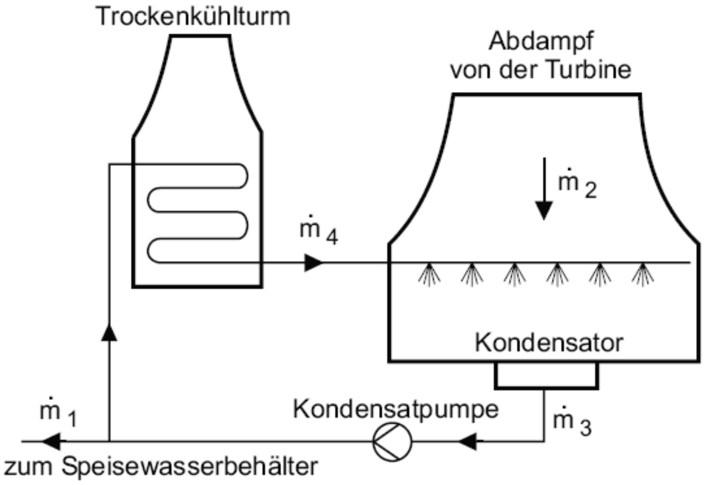


Abbildung 9.2. Schema eines Mischkondensators

$$\dot{m}_2 = \dot{m}_1 \tag{9.2}$$

und

$$\dot{m}_3 = \dot{m}_2 + \dot{m}_4 \; . \tag{9.3}$$

$$\dot{m}_2 h_2 + \dot{m}_4 h_4 = \dot{m}_3 h_3 \; . \tag{9.4}$$

Hieraus folgt für das Verhältnis von Einspritz- zu Dampfstrom:

$$\frac{\dot{m}_4}{\dot{m}_2} = \frac{h_2 - h_3}{h_3 - h_4} \; , \tag{9.5}$$

wobei $h_2 - h_3$ die Kondensationswärme des Dampfes ist. Deshalb ist $h_2 - h_3 \gg h_3 - h_4$ und nach (9.5) auch $\dot{m}_4 \gg \dot{m}_2$, vgl. Beispiel 9.1. Wegen der großen erzeugten Phasengrenzfläche sind Mischkondensatoren etwa zwei Drittel kleiner als Oberflächenkondensatoren gleicher Leistung. Allerdings ist der Aufwand für die Kondensatrückkühlung erheblich.

This method of indirect dry cooling was developed in 1952 because it was considered the complex pipe system for direct dry cooling for large systems for non-executable.

31.4.2 TEMO STPP Demonstration Plant Data

The turbine needs 41,05 kg/KW/h vapor under normal rpm and power. That means there is a vapor into the condensor 40 KW * 41.05 kg/KW/h = 1642 kg/h = 0.46 kg/s.

31.4.3 Based on TEMO-STPP 2nd project report (from Nagel, Fabian: Integration and animation of the test stand): Kondensator (only the parameters are changed based on the actual turbine data (see section above))

The fundamental equation of heat transfer is:

$$\dot{Q} = kA(T_{warm} - T_{kalt})$$

The heat flow is thus the product of the heat transfer coefficient of the transferring surface and the difference between the temperatures of the hot and cold medium $T_{warm} - T_{kalt}$. The transfer area A is the sum of the surface areas of all the tubes involved in the heat transfer. The heat transfer coefficient k includes the thermal conductivities λ the pipe materials and their thicknesses s, and the heat transfer coefficients α of the fluids involved. They are connected by the following formula:

$$k = \frac{1}{\Sigma_i \frac{1}{\alpha_i} + \Sigma_j \frac{s_j}{\lambda_j}}$$

31-2

Figure 3.1: shows a basic temperature profile in a heat transfer through a solid wall. The factors needed to calculate the heat transfer coefficients are given. On the vertical axis of the figure, the temperature should be recorded as a scale, but is not shown for clarity. Thus, the fluid 1 has a higher temperature than the second fluid In the two boundary layers, heat transfer takes place. The curves here are not linear, but are both from around the steep walls and flat with the distance to the wall. In the fixed wall heat conduction takes place. Here, the function decreases linearly.

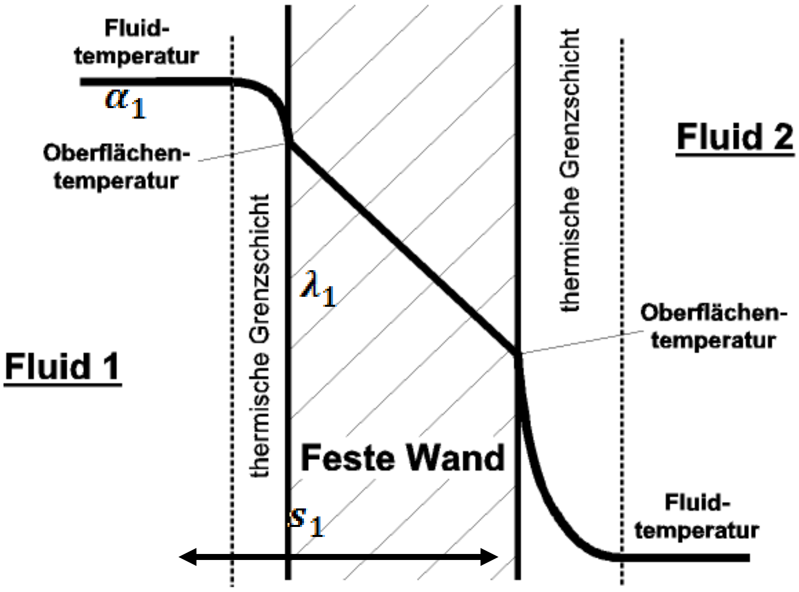


Figure 3 1: Temperature variation with heat transfer through a solid wall (Wikipedia)

There are two basic methods to implement heat exchanger. α_2

Heat transfer coefficient

- Medium water: $\alpha = 2100 \cdot \sqrt{v} + 580,$

in each case with the flow velocity v the medium in meters per second.

coefficient of Thermal Conductivity

fabric	thermal conductivity λ in W / (m · K)
uNalloyed steel	**48...58**
LLow alloyed ferritic steel (z. B. 42CrMo4)	**42**
High-alloy steel (austenitic) (z. B. X5CrNi18-10)[2]	**15**

The counter current process

In counter-current process, the two media flow in the opposite direction (Figure 3 2, upper diagram). The entrance of the hot medium is therefore at the outlet of the cold fluid to be heated. Thus, assume the maximum inlet temperature of the hot outlet temperature of the medium to be heated. In reality, this maximum value is usually not achieved, which is shown in Figure 3 in the lower graph 2 with the average temperature difference. The medium to be heated leaves the heat exchanger at a higher temperature as well, the heating medium discharged.

Also for the countercurrent heat exchanger, the derivation of the logarithmic temperature difference across the Taylor series is linearized. However, there is integrated over the place, it is important to note that the inlet and outlet ports are the two oppositely. It is therefore always considered each state a fixed location that

is a medium for the entry and exit for the other. Therefore, the formula changes for $\Delta T_{\log}$ easily:

$$\Delta T_{log} = \frac{[(T]_{FE} - T_{LA}) - (T_{FA} - T_{LE})}{(\ln \frac{[(T]_{FE} - T_{LA})}{(T_{FA} - T_{L})})}$$

31-3

The indices are back to the same terms as described in …. Of course, the interchangeability of the terms described above will remain even.

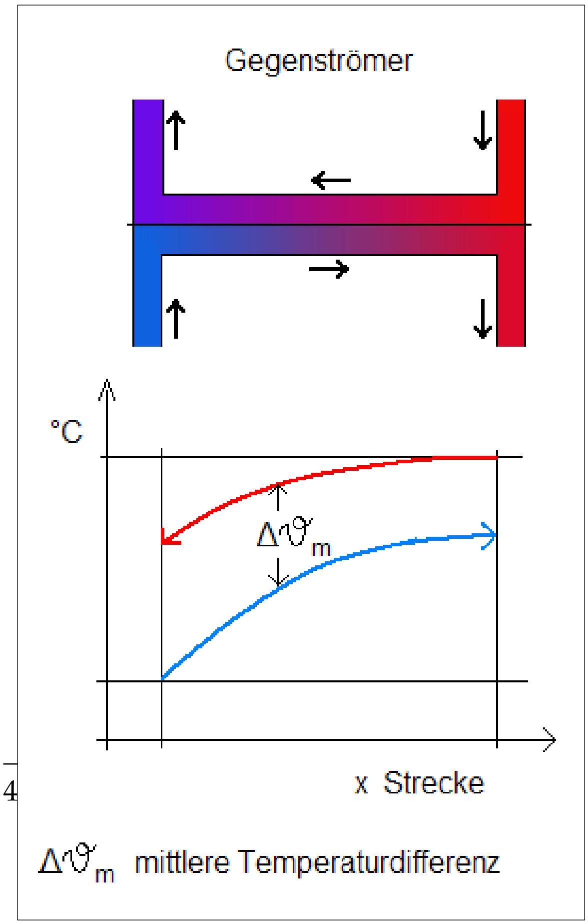


Figure 3 2: The counter-current process (Wikipedia)

The condenser has the task of cooling the exhaust steam of the turbine as far as that the vapor condenses, and thus the medium is made ready for the re-circulation pump. It is theoretically possible to couple to the cooling circuit of a seawater desalination plant. Sea water is thereby

---

4

heated to approximately 120 ° C by a heat exchanger and evaporates. The salt and beats from the salt-free vapor can be condensed back into pure water. For this process, however, is required, therefore, a turbine having an exhaust temperature of over 120 ° C. This is not true for the selected turbine in this study. Therefore, the test stand is designed here without seawater desalination plants. Other possibilities for the use of the heat would be available for use in the power plant, a district heating network, etc. What will actually connect to the cooling circuit at the test stand, yet to be resolved. In this study does not discuss. Any type of cooling is necessary but force to the water to use as cooling water. In conventional power plants, river water, or cooling towers are normally used in.

31.4.3.1 interpretation

As shown above it can be seen, the steam to the turbine has a temperature of 102.3 ° C, a pressure of 1.1 bar and thus an enthalpy of 2626.5 kJ / kg. The steam is fully condensed, with the temperature remains almost constant. Only the evaporation is discharged from the steam in the condenser. With the aid of the T-enthalpy diagram may be determined based on the condensation of about 450kJ/kg.

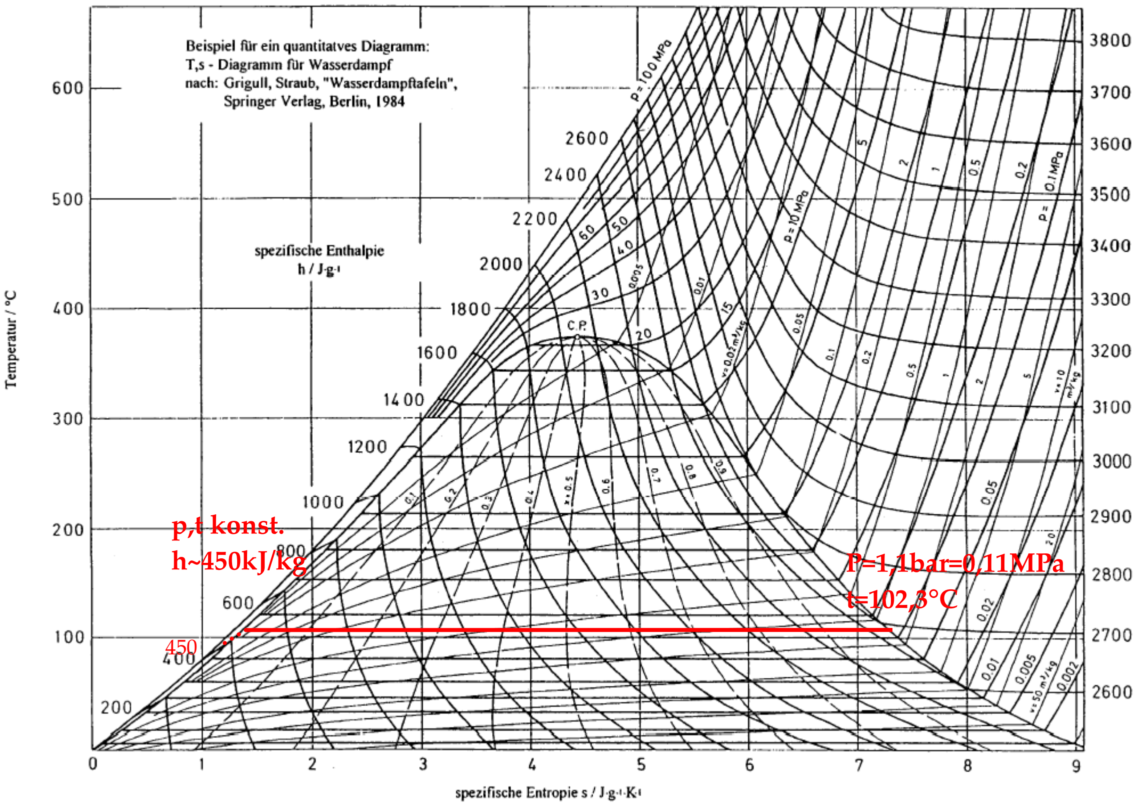


Figure 3 3: Ts diagram (Institute of Technical Thermodynamics, Karlsruhe University)

With this information, the amount of heat that has to give in the condenser, the steam flow to fully condense, to be determined. Here, the maximum amount of heat when the entire vapor stream is passed through the condenser is considered. The division of the vapor stream from the condenser is passed through the 1/3 of the vapor directly to preheat the boiler feed water is only optional. Therefore, the capacitor must be designed then to condense the entire steam flow.

$$\dot{Q} = \dot{m}(h_{ein} - h_{aus})$$

with

$\dot{m}$ = 0.46 kg/s Mass flow rate of steam (the manufacturer used Nadrowski turbine)
h_{ein} = 2626,5kJ/kg Admission enthalpy (from Error! Reference source not found.
h_{aus} = 450kJ/kg Outlet enthalpy (Figure 3 3)

follows for the amount of heat

$$\dot{Q}_{\text{kond}} = 1,0028 \text{ MW}$$

This is also the amount of heat to be dissipated by the coolant in the condenser. As a shell and tube condenser design was chosen because it has a high power density. Most other types require much more space to achieve the same cooling capacity. As a result, the material cost for tubular capacitors are reduced. In addition, they are widely used and easily available in the market, which in turn translates into lower prices.

For further interpretation of some assumptions were made that are listed in the following table. They are based on experience from the Heiz-/Kühltechnik.

To transfer heat	$\dot{Q}_{kond}$	1,0028 MW
Inlet temperature of the cooling water	T_{ein}	80°C
Exit temperature of the cooling water	T_{aus}	95°C
Flow velocity in the bundle of tubes	$v_{ström}$	0,5m/s
Radius of a tube in the tube bundle	r_{Rohr}	25mm (1 inch)
Heat capacity of water	$c_{p,w}$	4,2kJ/kgK
Density of water	ρ_{Wasser}	1000kg/m³

Table 3-1: Assumptions and values for the design of the capacitor

The size of the capacitor is calculated from the following formulas:

$$\dot{Q}_{kond} = \dot{m}_{KW}\, c_{p,w}\, (T_{aus} - T_{ein})$$

31-4

$$\dot{V}_{KW} = 0,\frac{00346m^3}{\square}\quad \dot{Q}_{kond} = \dot{m}_{KW}\, c_{p,w}\, (T_{aus} - T_{ein})\ /\ \rho_{Wasser}$$

31-5

$$\dot{V}_{KW} = A v_{ström}$$

31-6

Using the information from the table are

$\dot{m}_{KW} = \frac{34,6kg}{□}$ 15,916 kg/s Mass flow of the cooling water

$\dot{V}_{KW} = \frac{0,00346m^3}{□}$ 15,916 kg/s / 1000kg/m^3 = 0.015916 $\dot{V}_{KW} = \frac{0,00346m^3}{□}$ Flow of the cooling water

$A = 0,07m^2$ 0,0322 $A = 0,07m^2$ required total area of all pipes together

A tube with 1 inch and 1 m in length, the outer surface of 3.1415 * 0.025 m * 1m = 0,079 sqm

I.e. it requires 0.0322 / 0.079 = 1-inch tubes of 1 m length.

31.4.3.2 The principle of a condenser tube bundle

In principle, a condenser tube of the tube bundle itself and the housing is disposed about.

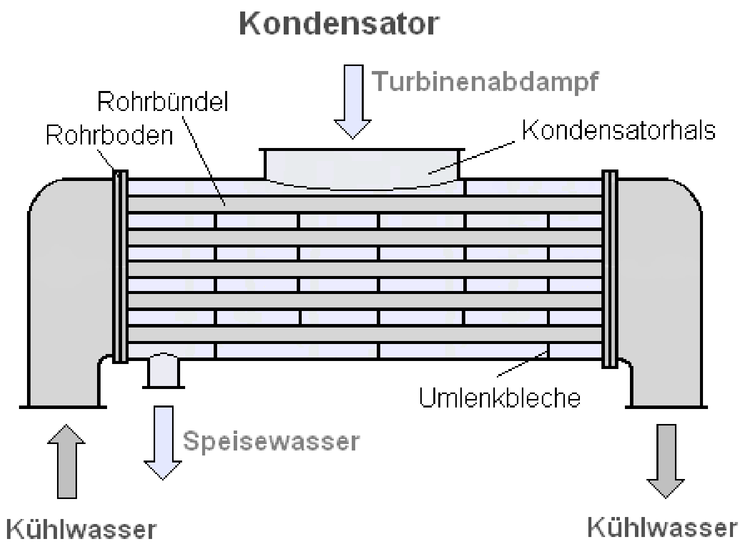
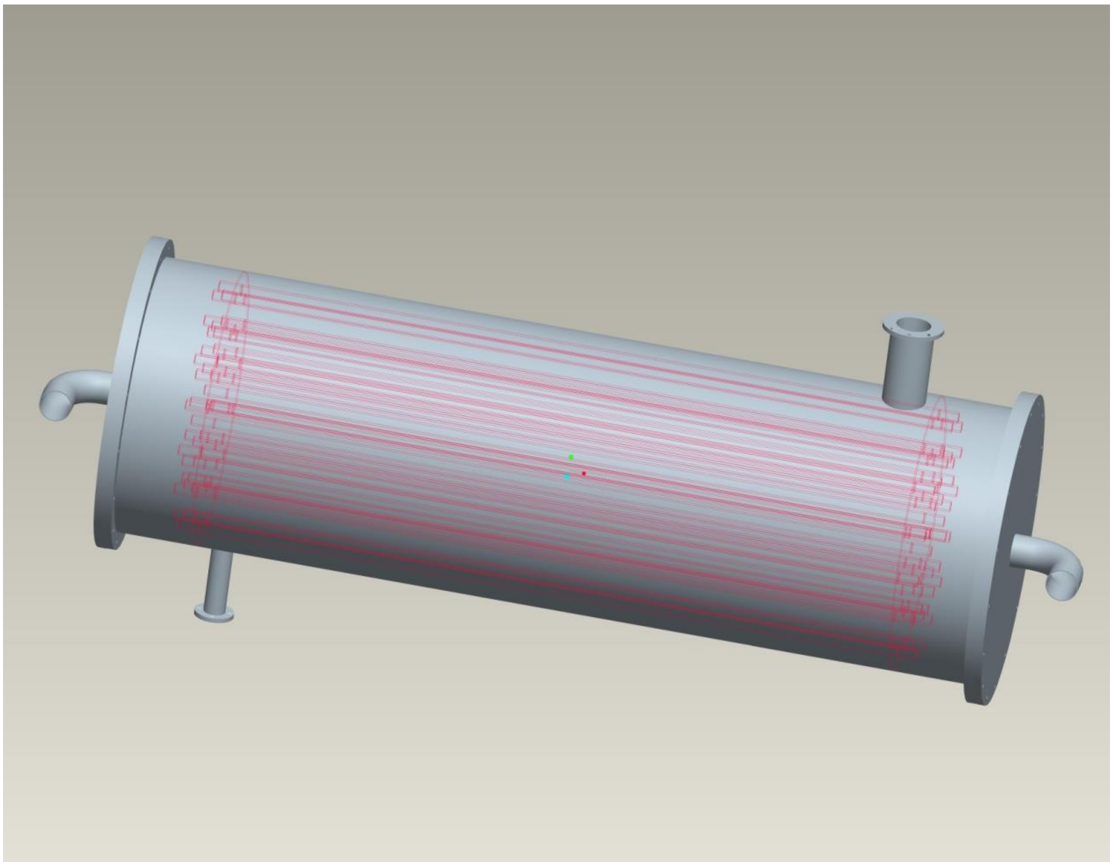


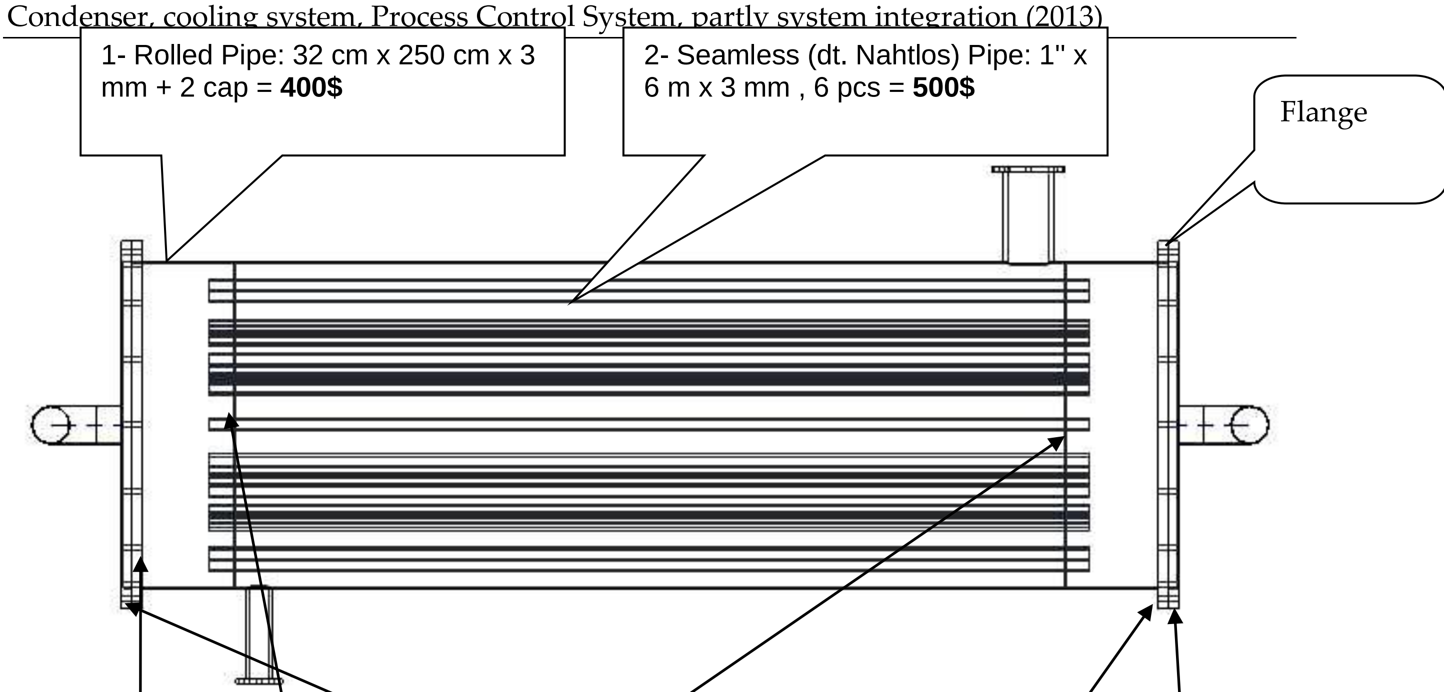
Figure 3 4: Principle structure of a shell and tube condenser (Wikipedia)

Flows through the housing of the turbine exhaust steam is condensed on the individual tubes of the tube bundle. The condensed water collects at the bottom of the housing and passes over the feedwater outlet from. The baffles ensure that the steam flows around each area of the tube bundle, and thus takes full advantage.

The capacitor may be designed as a counter-current or co-current heat exchanger. When co-current principle, the cooling water flows in the same direction as the turbine exhaust steam. When countercurrent flow they opposed.

31.5 Condensor Design of Dec 2014

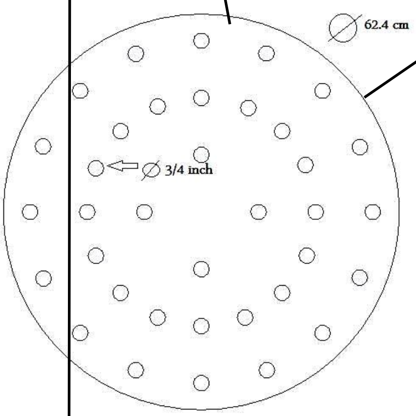
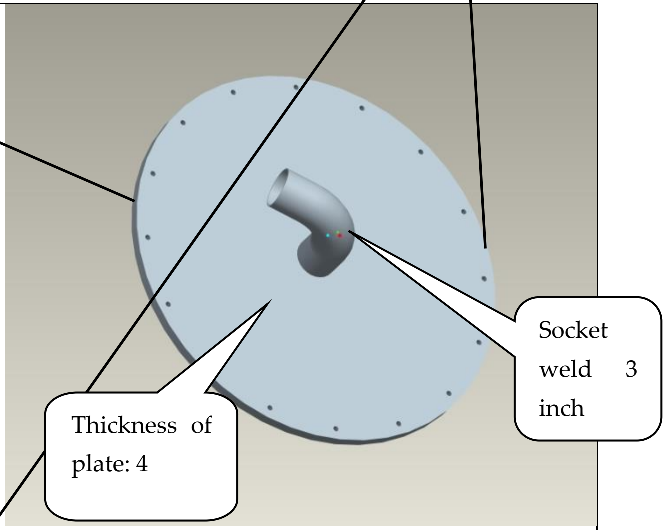
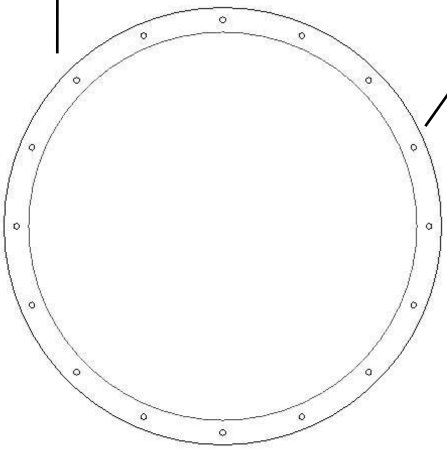
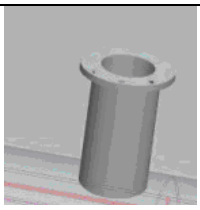
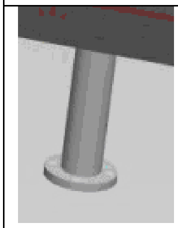




1- Rolled Pipe: 32 cm x 250 cm x 3 mm + 2 cap = **400$**

2- Seamless (dt. Nahtlos) Pipe: 1" x 6 m x 3 mm , 6 pcs = **500$**

Flange

<table>
<tr>
<td>
Thickness: 10 or 15 mm
15mm Thickness, 2 pcs = 450$</td>
<td colspan="2">
5- Socket weld Flange : 10 mm Thickness, 2 pcs = 450$, 4- Seamless pipe: 3" x 1 m x 3mm = 48$</td>
</tr>
<tr>
<td rowspan="3">
Flange</td>
<td></td>
<td>Seamless Pipe: 4" x 1 m x 3mm
Socket weld Flange : 4"
6- Socket weld Flange : 4" - 1 pc = 160$</td>
</tr>
<tr>
<td></td>
<td>Socket Weld Flange : 3"
7- Socket Weld Flange : 3" - 1 pc = 140$</td>
</tr>
<tr>
<td>8- Bolts/Nuts & Gaskets = 60$
9- Argon Gas +</td>
<td>3 day work: 400 USD</td>
</tr>
</table>

15mm Thickness, 2 pcs = **450$**	welding rods = **200$**	**Total: 3260 USD**

31.6 Boiler feed water

31.6.1 From TEMO-STPP 2nd project report (from Nagel, Fabian: Integration and animation of the test stand): Speisewasserkessel

31.6.1.1 interpretation

The boiler feed water and serves as a buffer reservoir. It guarantees that the pump at all times, sufficient supply of water available. For small spills or in case of failure, it could happen that the amount of feed water decreases in the system and thus does not run enough water through the condenser back to the pump.

In most cases, a portion of the exhaust steam of the turbine to preheat the feed water used in the boiler. Specifically to be fed directly into the boiler feed water in the test stand about 1/3 of the vapor and the remaining 2/3 run through the capacitor and come back as water in the boiler.

The design of the boiler based on estimates. It is intended solely as an order of magnitude and is in front of the building in any case with manufacturers deny.

As assumptions in interpreting a tank volume of about 3m3 was adopted. Was chosen as the form of a cylinder whose height is equal to its diameter. The roof is in the shape of a hemisphere. These conditions can be the inner radius of the boiler to determine 0.71m. The interior height is therefore three times the radius. As wall thickness, including insulation are assumed 10cm.

31.6.1.2 The ProE model of boiler feed water

The dimensions of the boiler comply with the assumptions made in section 3.5.1.1. The connections are consistent with the dimensions of the pipes to be connected agreed (values from Error! Reference source not found.).

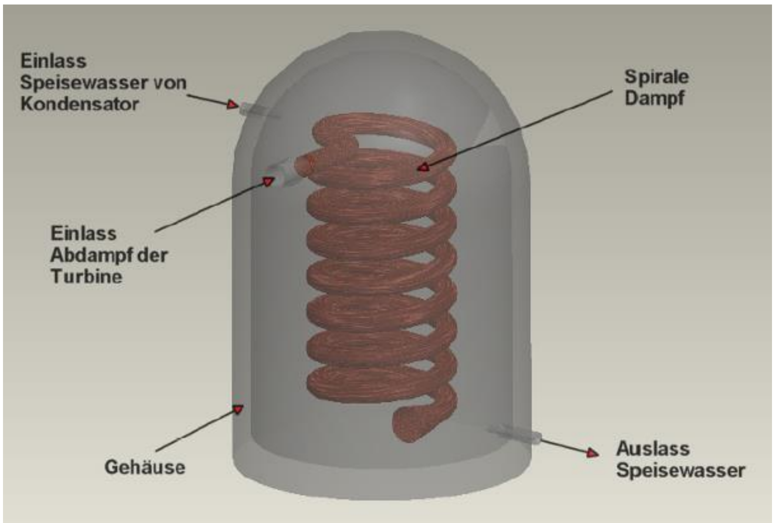


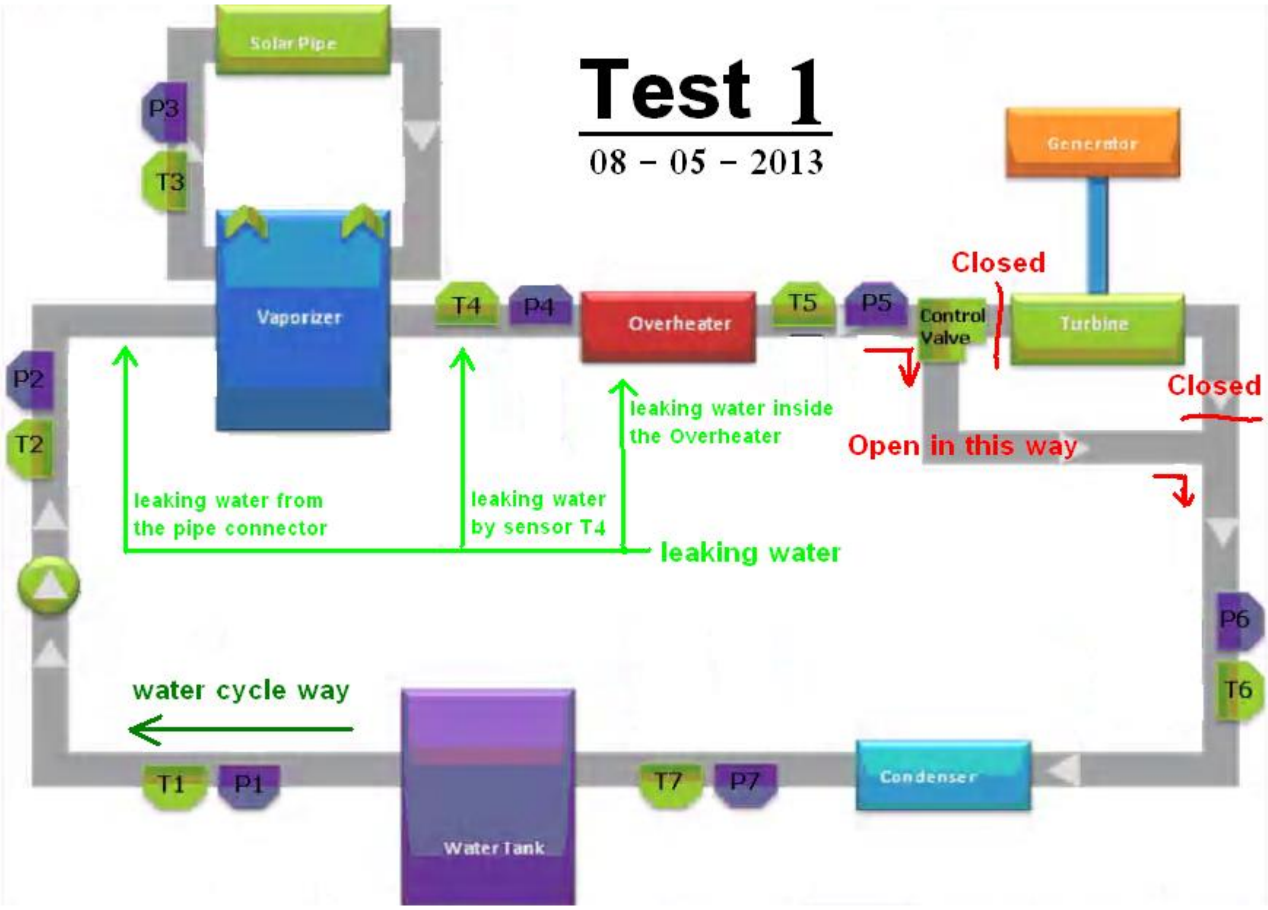
Figure 3 6: ProE model of boiler feed water

Via the "feed water inlet of condenser" position, the water that is condensed in the condenser, into the boiler. The proportion of the exhaust steam, which does not pass through the condenser, is directly introduced into the spiral shown here. Within the spiral, the steam condenses, giving the condensation enthalpy of the water in the boiler off and heats it thus. The steam pressure must be high enough to urge the condensed water in the spiral in the boiler. The water column above the outlet it is spiral about 1 - 1,5 m, representing a back pressure of about 0.1 - corresponds to 0.15 bar.

32 Test reports تجارب

32.1 Test 1 (8 May 2013)

Precondition	Test activity	Expected postcondition	Postcondition	Test ok/ Test failed
Pipes without water	Filling all pipes with water	P7: 4 bar No leaking water	P7: 1,5 bar Pipes and overheater were leaking water	Failed failed

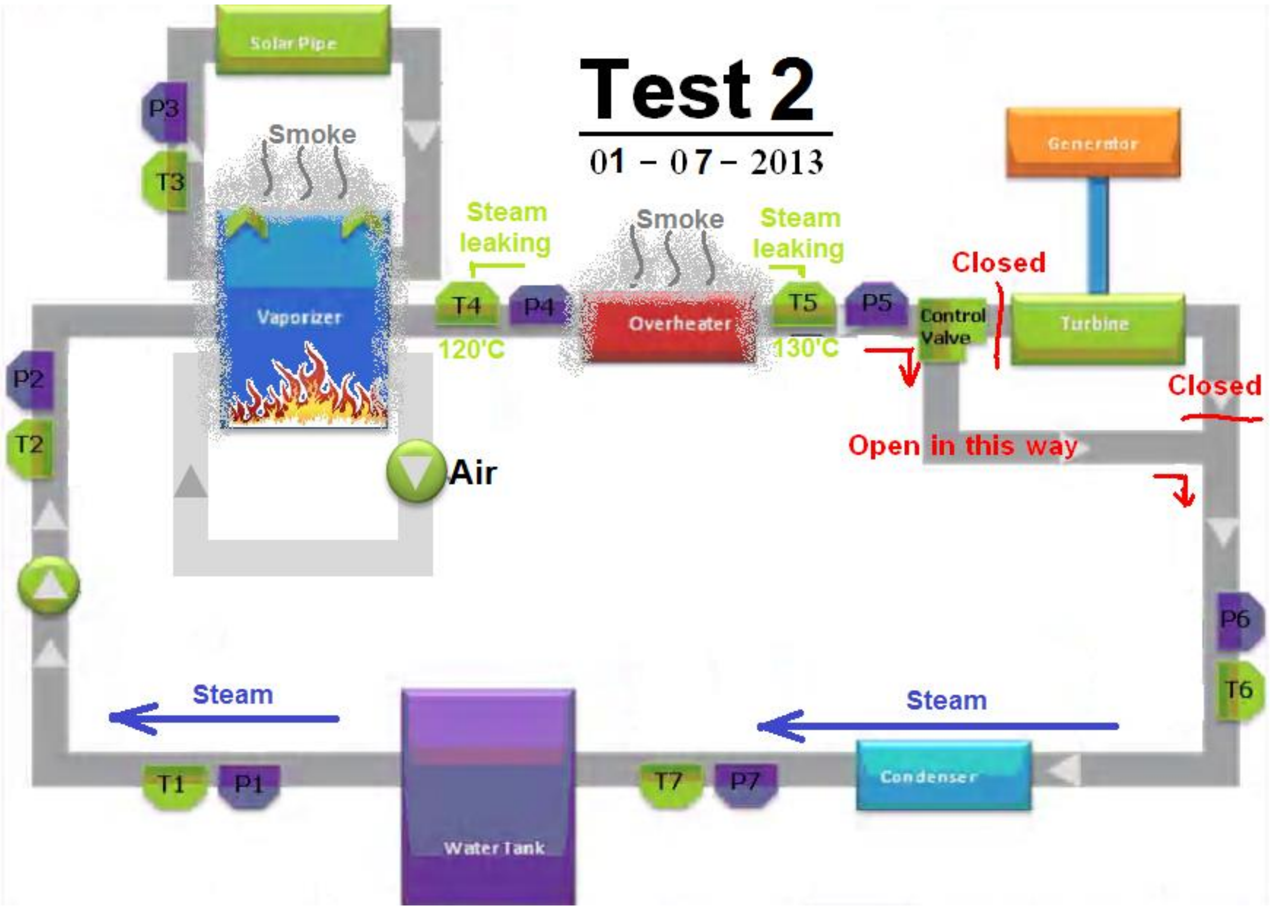


As we see, a new action should be taken after this failed test to solve the problem occured

Action	delay time	Penalty cost	situation
Solving leaking water problem on the pipe	3 hours	No penalty cost	Done with success
Solving leaking water problem on the overheater system	3 days	50$	On pregress

32.2 Test 2 (1 July 2013)

Test activity	Expected postcondition	Postcondition	Test ok / Test failed
Ignite fire on the vaporizer for a heaf of hours	No leaking water	No leaking water	Success
	No leaking Steam	Leaking steam by temp. sensors	Failed
	No leaking smoke	Leaking smoke from vaporizer and overheater	Failed
	Valve open and producing steam	Valve open but is crashing because of high temperature	Success with problem



As we see, a new action should be taken after this failed test to solve the problem occured

Action	delay time	Penalty cost	situation
Solving leaking steam problem on sensors	3 hours	20$	On progress
Solving leaking smoke problem on the vaporizer and overheater	2 weeks	500$	Done with success

33 Literature / المراجع

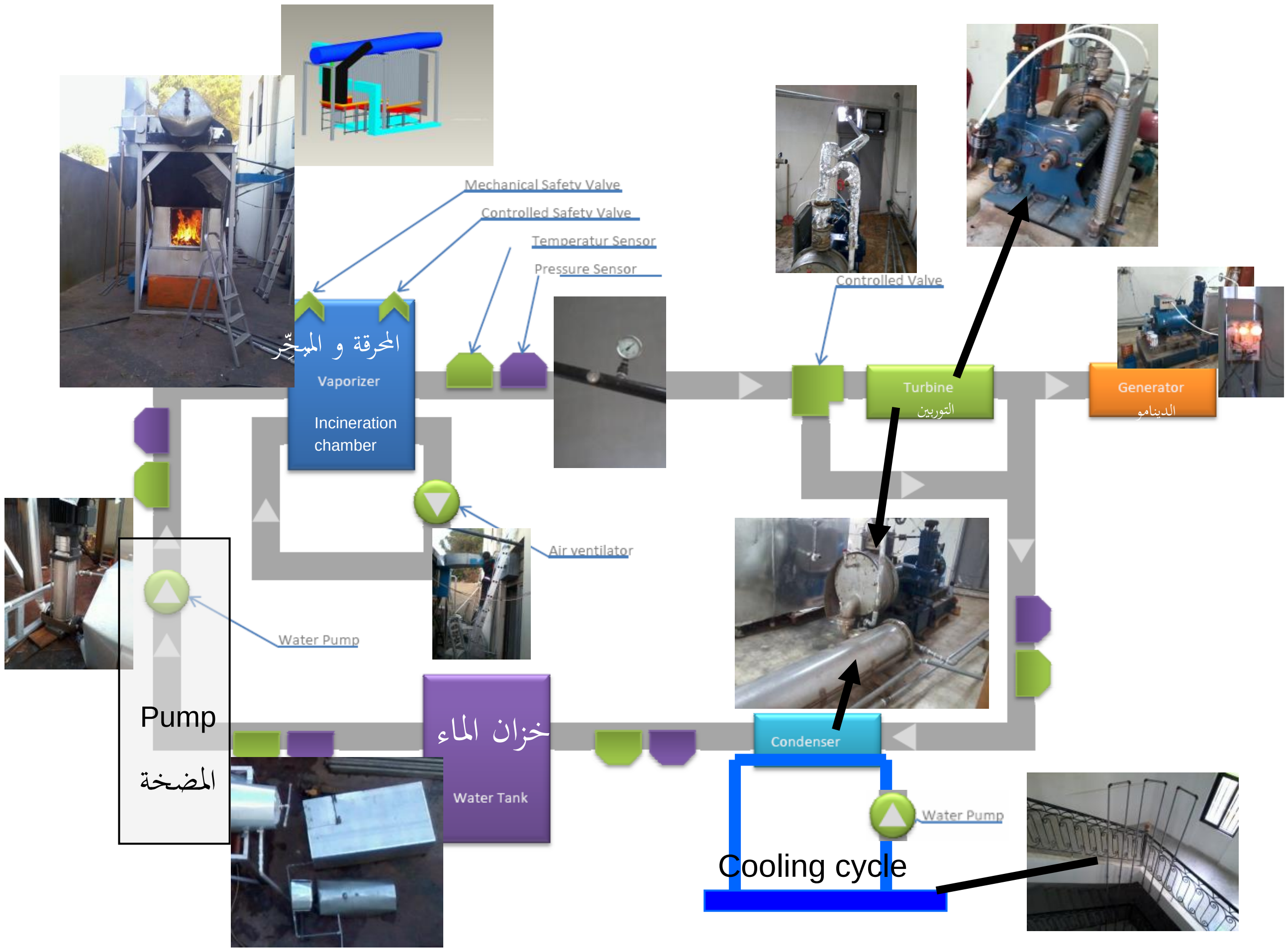
[Mourad et. al. 2010] 2nd TEMO-STPP report, 2nd edition, April 2010, http://aecenar.com/download/doc_download/13-temo-stpp-report-2

Gourche et. al., Siemens S7-300 مدخل الى , Karlsruhe/Ras Nhache, July 2010 (http://www.aecenar.com/download/doc_download/25-siemens-s7-300--)

Karl Strauss, “Kraftwerkstechnik”

Zahornsky, “Energietechnik”

Realization in Qubaisi Center and Testing (2014)[30]



Published by:

AECENAR e.V., **http://www.aecenar.com** and LASeR, **http://www.laser-lb.org**

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[30] From [TEMO-IPP 2014]

Content / المحتوى

34 Abstract

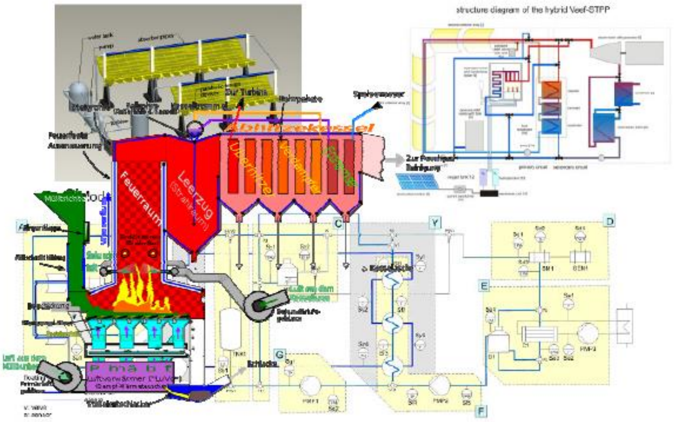
34.1 Project Status Dec 2013

مركز للطاقة البديلة
http://aecenar.com/institutes/meae
بحوث حول اجزاء لمحطات طاقة عن طريق الحرار
الشمسية و عن طريق حرق النفيات

AECENAR
Association for Economical and Technological Cooperation
in the Euro-Asian and North-African Region
www.aecenar.com

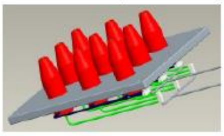
Solarthermal/Incineration Power Plant Technology
TEMO-STPP Test Plant
توليد كهرباء – تدفأة بنايات – حل لمشكلة النفايات و الاستفادة منها – الاستفادة من الطاقة الشمسية لتوليد الكهرباء

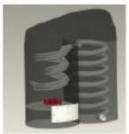
Last update: 17 December 2013



Architecture of process control system (sensors and actuators)

Hydrogen burner



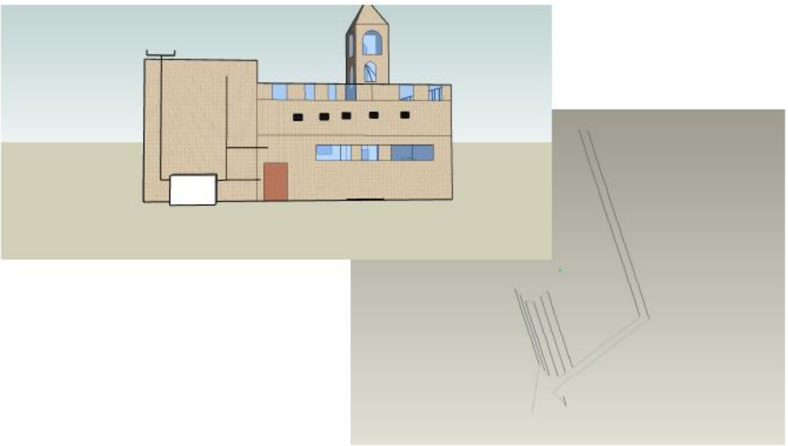


Hydrogen burner and Condensing boiler

اعمال حالية:

- تشغيل المحرقة لتوليد البخار
- ربط التوربين لتوليد الكهرباء
- وضع المحطة في احد المناطق مثل طرابلس

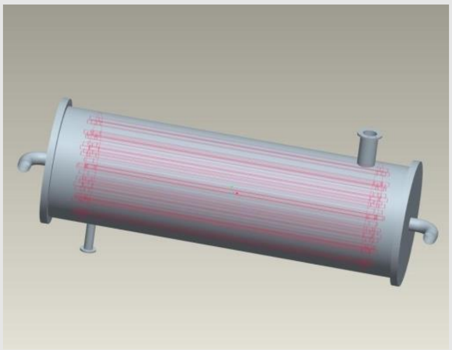
التصميم الحالي في مركز القبيسي في راسنحاش \ البترون (شمال لبنان)



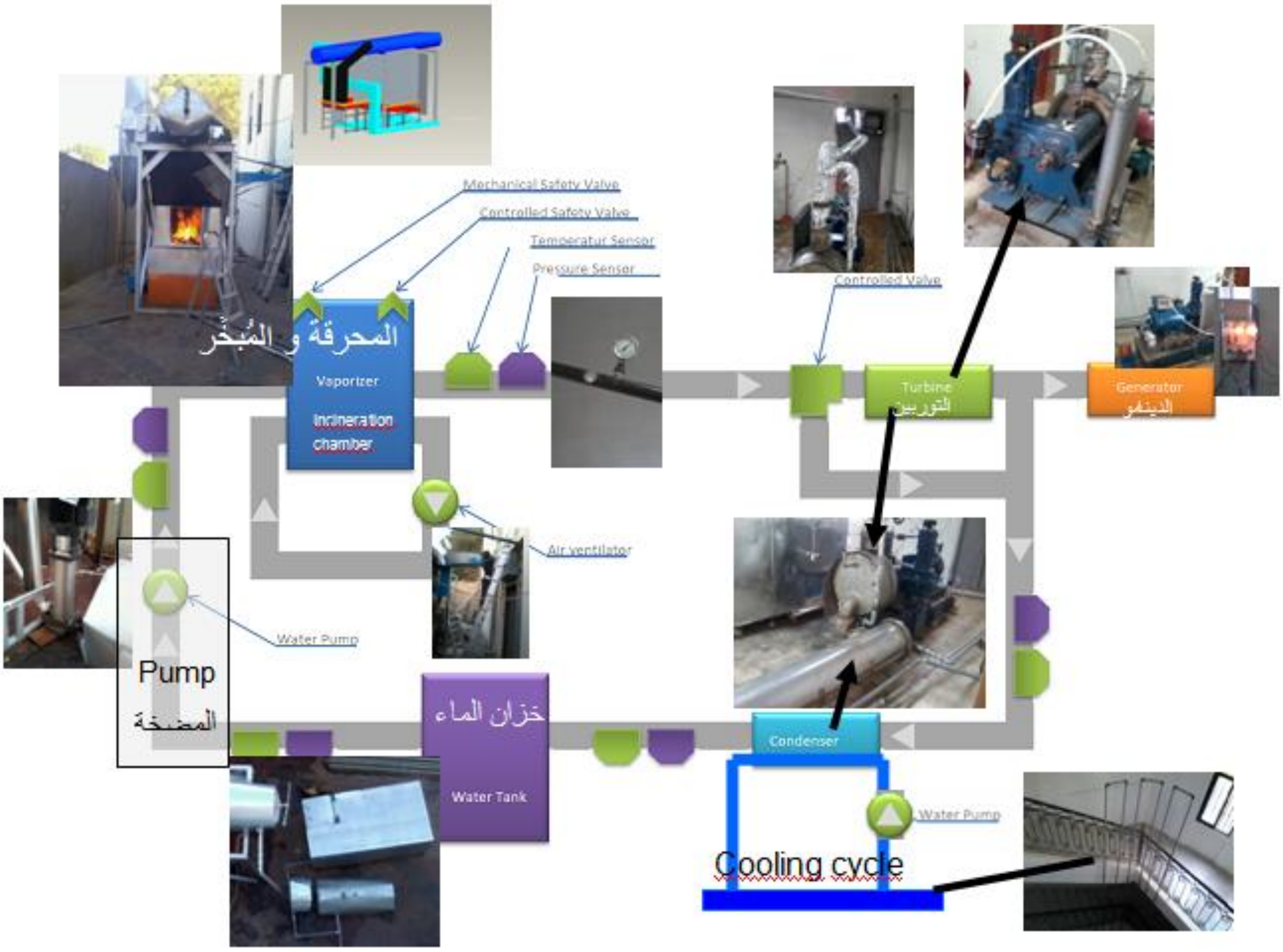
الحاجيات لعام 2014:

- 36.150 $

Contact:
Samir Mourad
Mobile: +96176341526
samir.mourad@aecenar.com

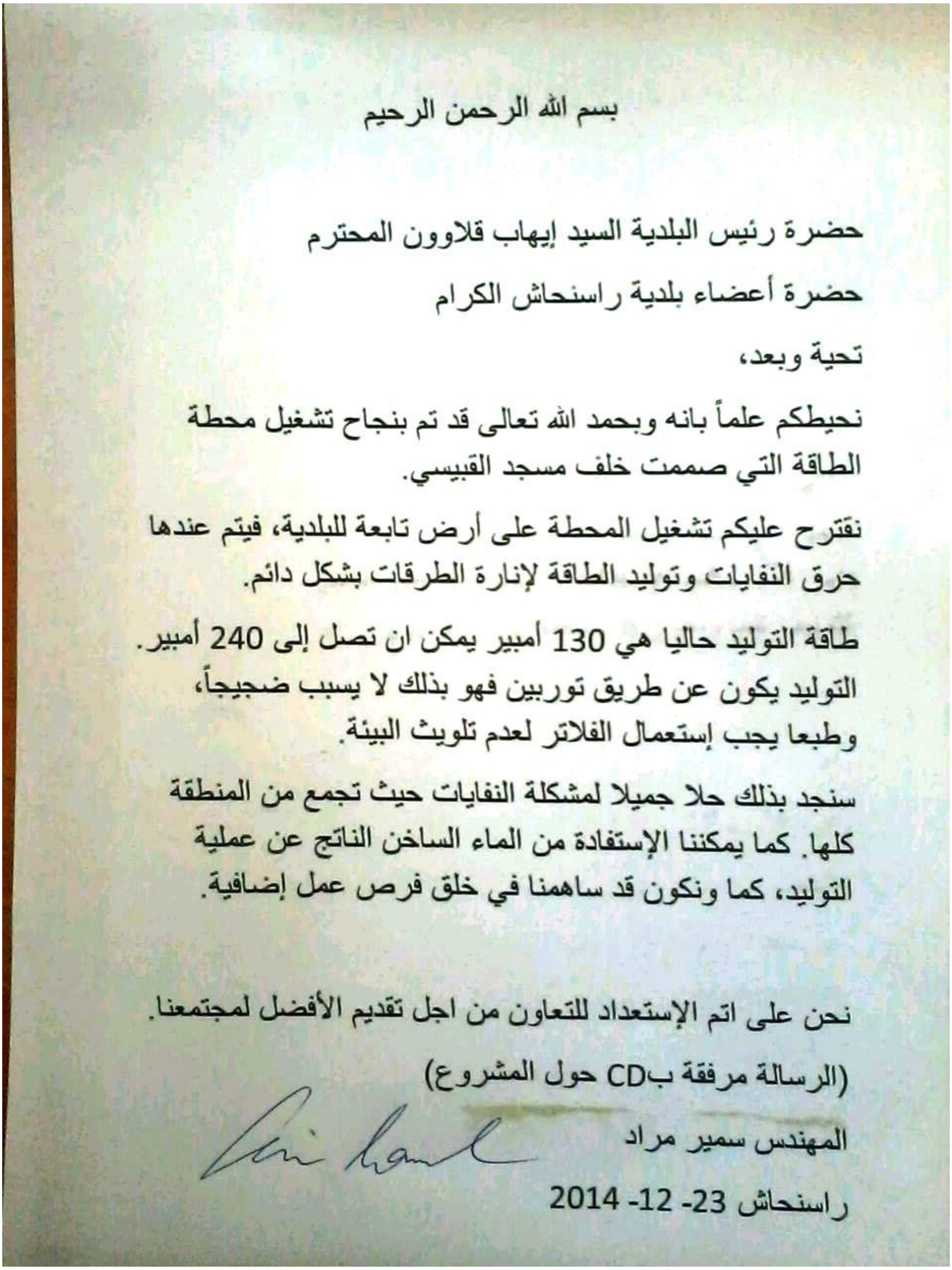
Dec 13	May 14	
  	Feed water tank   Evaporator automatic level control  condensor	  Integration of test rig  Sucessful test of turbine الحمد لله

34.2 Project Status Nov 2014



- المحطة ولدت كهرباء عن طريق حرق خشب

34.3 Project Status Dec 2014: رسالة الى المجلس البلدي في راسنحاش



بسم الله الرحمن الرحيم

حضرة رئيس البلدية السيد إيهاب قلاوون المحترم

حضرة أعضاء بلدية راسنحاش الكرام

تحية وبعد،

نحيطكم علماً بانه وبحمد الله تعالى قد تم بنجاح تشغيل محطة الطاقة التي صممت خلف مسجد القبيسي.

نقترح عليكم تشغيل المحطة على أرض تابعة للبلدية، فيتم عندها حرق النفايات وتوليد الطاقة لإنارة الطرقات بشكل دائم.

طاقة التوليد حاليا هي 130 أمبير يمكن ان تصل إلى 240 أمبير. التوليد يكون عن طريق توربين فهو بذلك لا يسبب ضجيجاً، وطبعا يجب إستعمال الفلاتر لعدم تلويث البيئة.

سنجد بذلك حلا جميلا لمشكلة النفايات حيث تجمع من المنطقة كلها. كما يمكننا الإستفادة من الماء الساخن الناتج عن عملية التوليد، كما ونكون قد ساهمنا في خلق فرص عمل إضافية.

نحن على اتم الإستعداد للتعاون من اجل تقديم الأفضل لمجتمعنا.

(الرسالة مرفقة بـCD حول المشروع)

المهندس سمير مراد

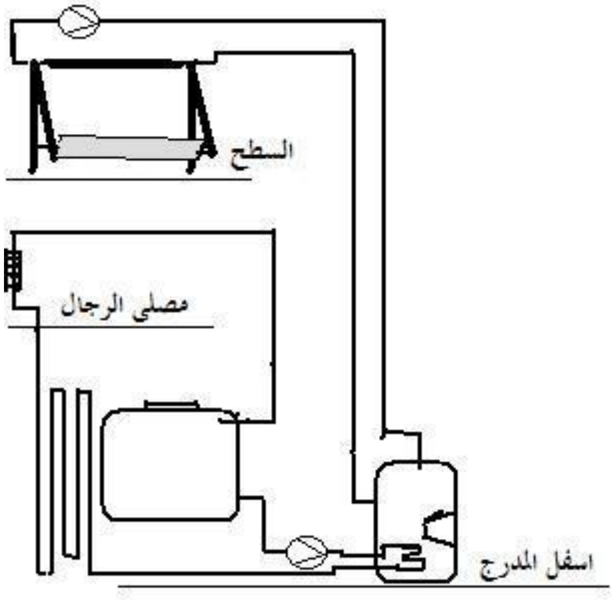
راسنحاش 23 -12- 2014

35 Test rig with oil burner as main energy source

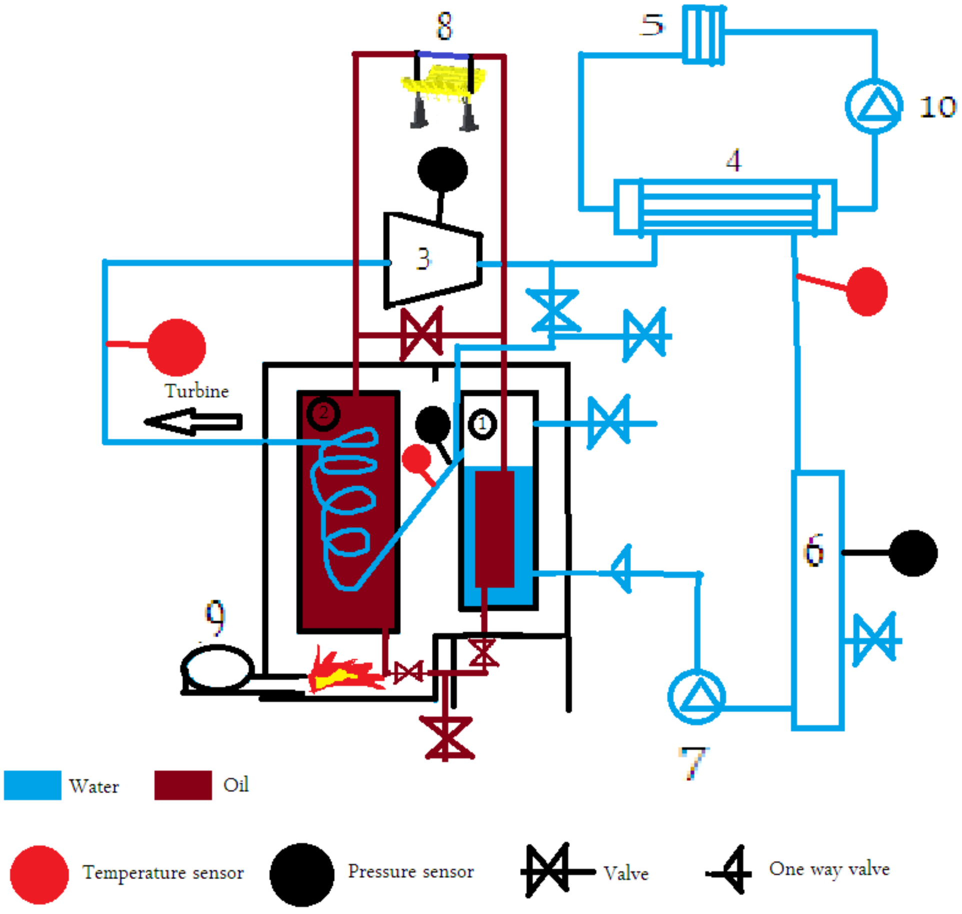
35.1 وضع القطع الاساسية في مكانها (Placing of the main devices)

Two Test rigs were planned: 1. Ras Nhache 2. Anfe

In Ras Nhache shall be integrated a solar-thermal based process steam generation system. Measurement instruments shall be implemented. In Anfe the main point is on incineration and electrical power generation. Turbine shall be in Anfe. The test rig with all aspects was implemented in Ras Nhache.

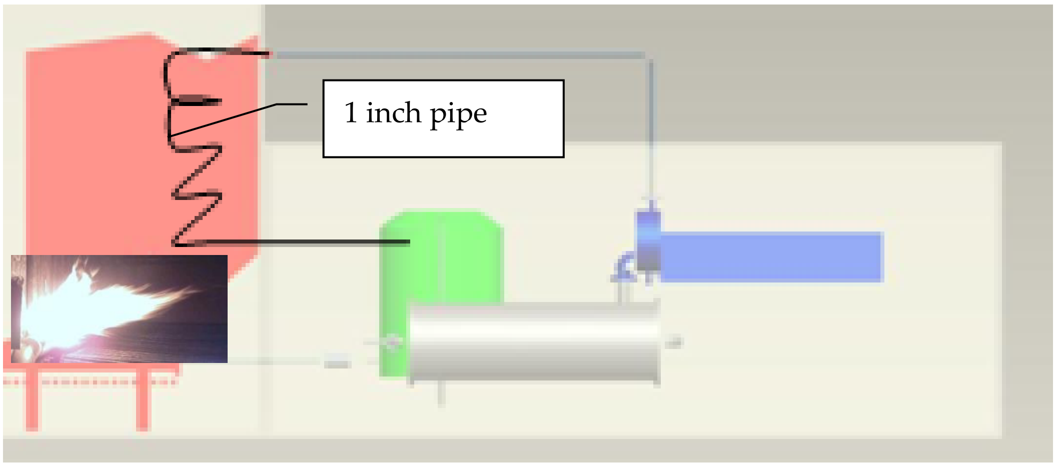
Test Rig Main Devices	
Solar Pipe on Top of the Building, some mirror at bottom side (ALU at under a glass) Turbine Condenser Evaporator as "chaudiere" with Inkerement 1: oil, heated by diesel Inkr. 2: water, solar pipe with fresnel collector (1 sheet at bottom Inkrement 3 (was planned): Thermal oil + burner (H2 from photovoltaic cells)	

35.2 Test rig System



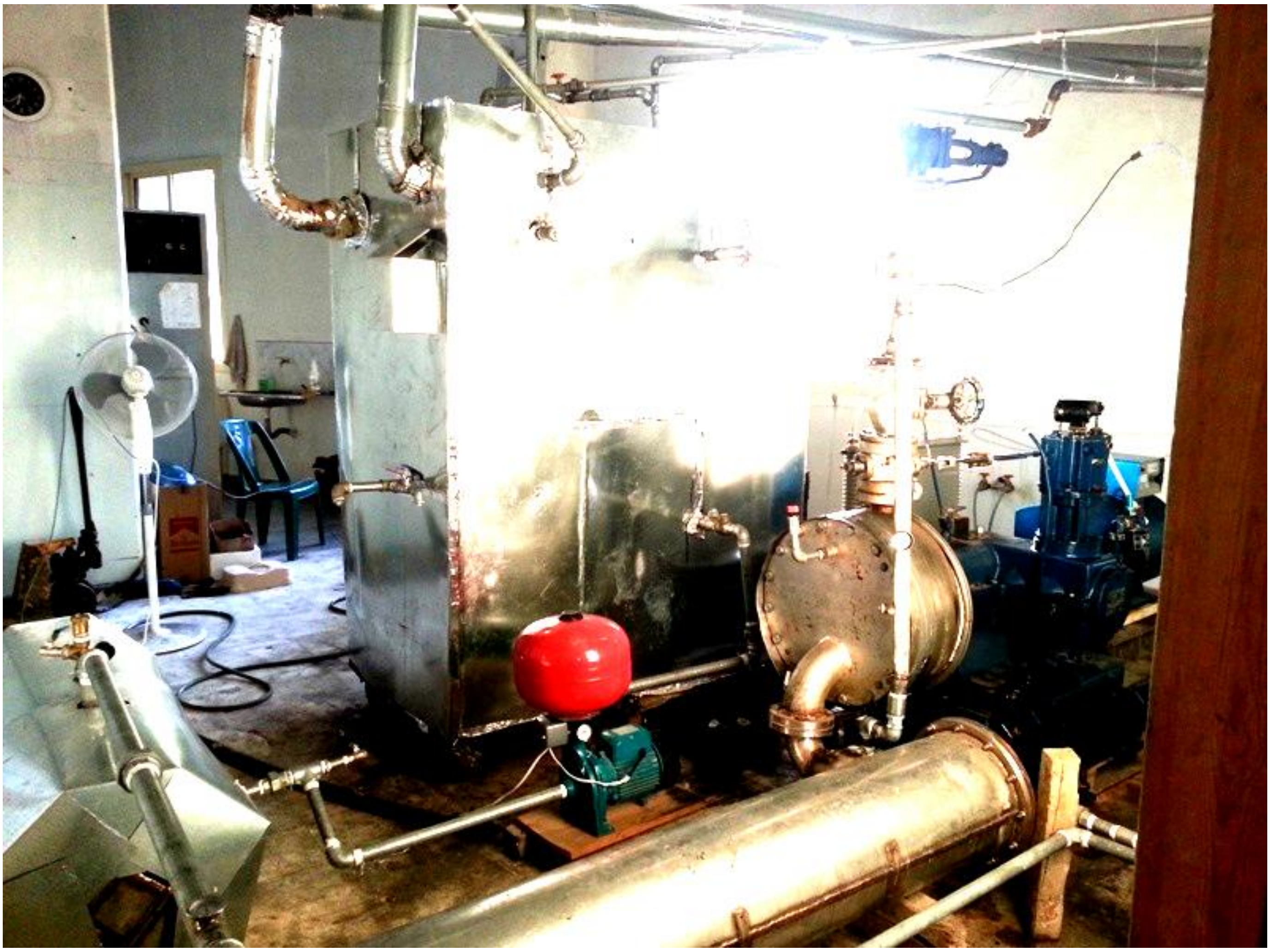
1+2:Evaporator 3: Turbine 4: Condenser 5: Central heating 6: Water tank

7:Supply Water Pump 8:solar pipe 9:Oil burner 10:Cooling Cycle Pump



Actual Chaudiere: Pipe 1 inch/ 66 m in oil tube -> exchanging area: about 6,5 qm, 30 Liter

Required Steam Volume: 28 kg/min. Every 18 g: 22 L*(473/273) = 38 Liter, At turbine input: 38 * 1556 Liter per minute = 59 cubic meters per minute. At turbine output: 59 * (378/473) cubic meters = 47 cubic meters per minute.



35.3 Elements

35.3.1 Water Tank

Ein 300 L stainless 304-Tank.4 oder3 mm dick.Länge:1,23 m.Dürchmesser:0,56 m

35.3.2 Supply Water Pump

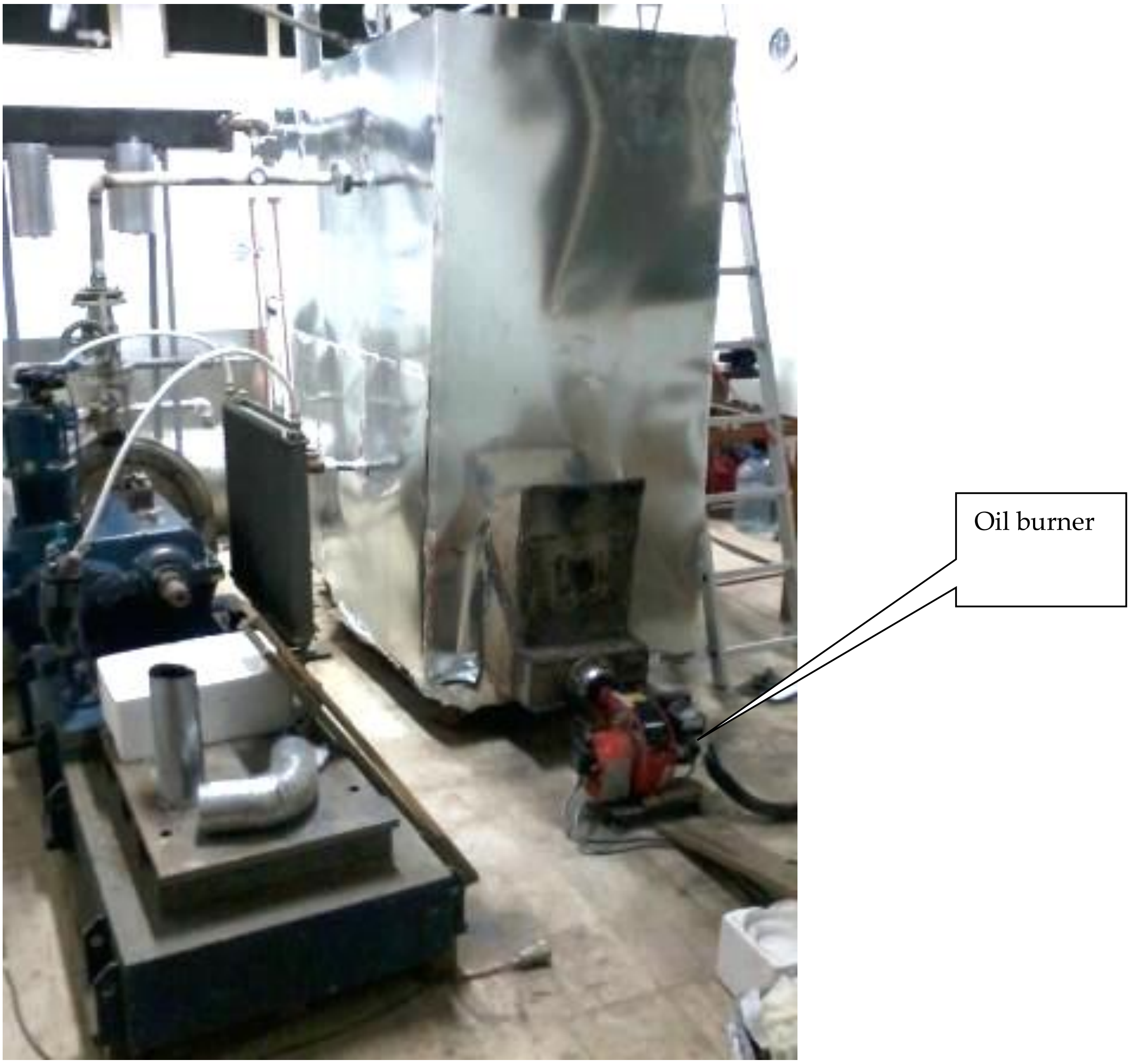
Eine 9 bar Pumpe. Sie pumpt das Speisewasser vom Tank in den Verdampfer.

35.3.3 Vaporizer

35.3.3.1 Level Control at vaporizer tube

Ein Füllstandsregler schaltet die Pumpe dann an, wenn das Wasser im Verdampfer weniger wird.

35.3.3.2 Oil burner



35.3.3.3 Valves

A safety valve was used to let the steam increase to 14 bar and was then open to let the steam flow to the turbine.

35.3.4 Turbine

Input (dt. Zudampf-anschluss)

DN 50 (2 inches)

PN[31] 40

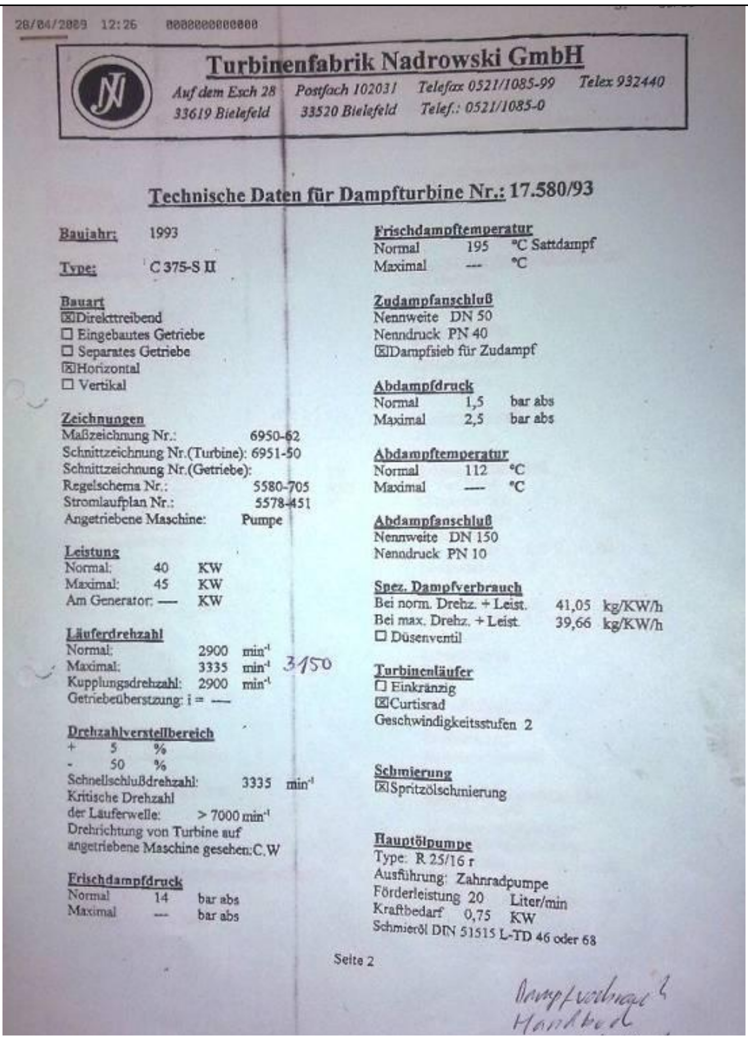
Output (dt. Abdampf-anschluss)

DN 150 (6 inches)

Nenndruck PN 10

Available:

115 mm * 2200 mm galvanized iron



28/04/2009 12:26 0000000000000

Turbinenfabrik Nadrowski GmbH

Auf dem Esch 28
33619 Bielefeld

Postfach 102031
33520 Bielefeld

Telefax 0521/1085-99
Telef.: 0521/1085-0

Telex 932440

Technische Daten für Dampfturbine Nr.: 17.580/93

Baujahr: 1993

Type: C 375-S II

Bauart
☒Direkttreibend
☐ Eingebautes Getriebe
☐ Separates Getriebe
☒Horizontal
☐ Vertikal

Zeichnungen
Maßzeichnung Nr.: 6950-62
Schnittzeichnung Nr.(Turbine): 6951-50
Schnittzeichnung Nr.(Getriebe):
Regelschema Nr.: 5580-705
Stromlaufplan Nr.: 5578-451
Angetriebene Maschine: Pumpe

Leistung
Normal: 40 KW
Maximal: 45 KW
Am Generator: — KW

Läuferdrehzahl
Normal: 2900 min^{-1}
Maximal: 3335 min^{-1} 3150
Kupplungsdrehzahl: 2900 min^{-1}
Getriebeüberstzung: i = —

Drehzahlverstellbereich
\+ 5 %
\- 50 %
Schnellschlußdrehzahl: 3335 min^{-1}
Kritische Drehzahl
der Läuferwelle: > 7000 min^{-1}
Drehrichtung von Turbine auf
angetriebene Maschine gesehen:C.W

Frischdampfdruck
Normal 14 bar abs
Maximal --- bar abs

Frischdampftemperatur
Normal 195 °C Sattdampf
Maximal --- °C

Zudampfanschluß
Nennweite DN 50
Nenndruck PN 40
☒Dampfsieb für Zudampf

Abdampfdruck
Normal 1,5 bar abs
Maximal 2,5 bar abs

Abdampftemperatur
Normal 112 °C
Maximal — °C

Abdampfanschluß
Nennweite DN 150
Nenndruck PN 10

Spez. Dampfverbrauch
Bei norm. Drehz. + Leist. 41,05 kg/KW/h
Bei max. Drehz. + Leist. 39,66 kg/KW/h
☐ Düsenventil

Turbinenläufer
☐ Einkränzig
☒Curtisrad
Geschwindigkeitsstufen 2

Schmierung
☒Spritzölschmierung

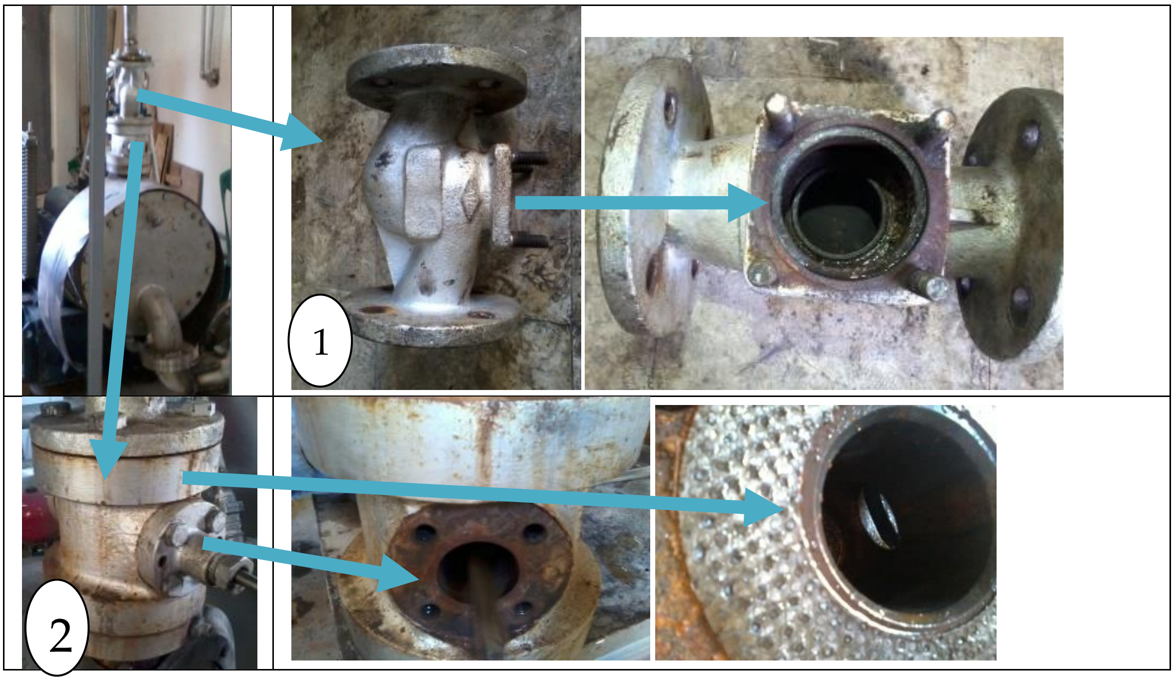
Hauptölpumpe
Type: R 25/16 r
Ausführung: Zahnradpumpe
Förderleistung 20 Liter/min
Kraftbedarf 0,75 KW
Schmieröl DIN 51515 L-TD 46 oder 68

Seite 2

Dampfverbrauch
Handbuch

---

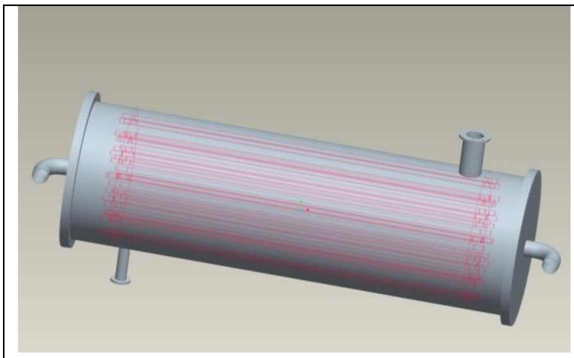
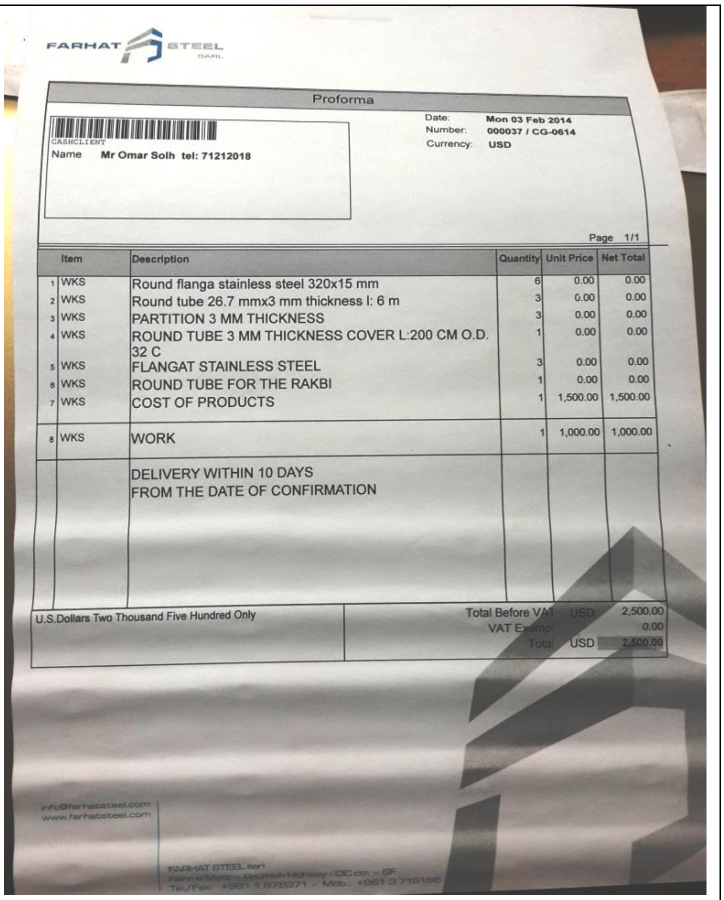
[31] Der **Nenndruck** gibt für ein Rohrleitungssystem eine Referenzgröße an. Die Angabe erfolgt nach DIN, EN, ISO durch die Bezeichnung **PN** (Pressure Nominal) gefolgt von einer dimensionslosen ganzen Zahl, die den Auslegungsdruck in bar bei Raumtemperatur (20 °C) angibt. Der bei einer bestimmten Temperatur zulässige Betriebsdruck wird üblicherweise in Prozent des Nenndruckes angegeben. Bei höheren und tieferen Temperaturen ist, bedingt durch die Abnahme der zulässigen Werkstoffkennwerte (Streckgrenze), der zulässige Druck entsprechend geringer. PN 10 zum Beispiel bezeichnet eine Rohrleitung mit dem höchstzulässigem Druck von 10 bar bei einer Fluidtemperatur von 20 °C.



1: Durchlassventil 2:Regulierventil

35.3.5 Condenser

The condenser was constructed by AECENAR and manufactored by FARHAT Steel.

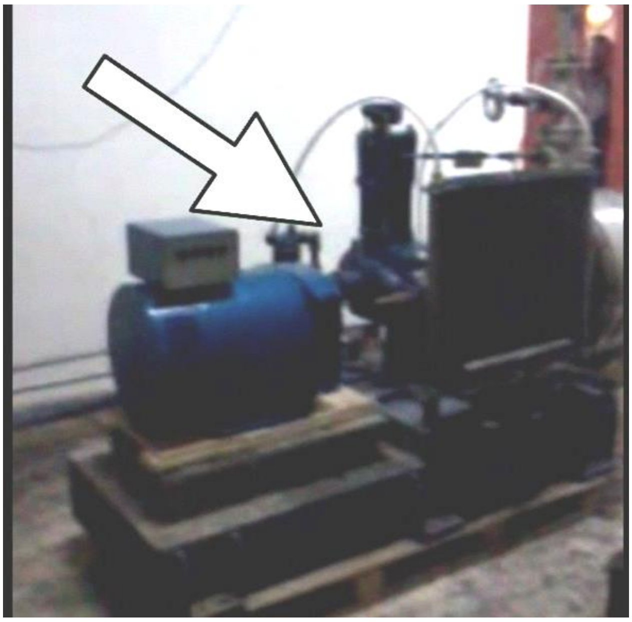
<table>
<tr>
<td></td>
<td>
FARHAT STEEL
SARL
Proforma
CASHCLIENT
Name Mr Omar Solh tel: 71212018
Date: Mon 03 Feb 2014
Number: 000037 / CG-0614
Currency: USD
Page 1/1
<table>
<tr><th></th><th>Item</th><th>Description</th><th>Quantity</th><th>Unit Price</th><th>Net Total</th></tr>
<tr><td>1</td><td>WKS</td><td>Round flanga stainless steel 320x15 mm</td><td>6</td><td>0.00</td><td>0.00</td></tr>
<tr><td>2</td><td>WKS</td><td>Round tube 26.7 mmx3 mm thickness l: 6 m</td><td>3</td><td>0.00</td><td>0.00</td></tr>
<tr><td>3</td><td>WKS</td><td>PARTITION 3 MM THICKNESS</td><td>3</td><td>0.00</td><td>0.00</td></tr>
<tr><td>4</td><td>WKS</td><td>ROUND TUBE 3 MM THICKNESS COVER L:200 CM O.D. 32 C</td><td>1</td><td>0.00</td><td>0.00</td></tr>
<tr><td>5</td><td>WKS</td><td>FLANGAT STAINLESS STEEL</td><td>3</td><td>0.00</td><td>0.00</td></tr>
<tr><td>6</td><td>WKS</td><td>ROUND TUBE FOR THE RAKBI</td><td>1</td><td>0.00</td><td>0.00</td></tr>
<tr><td>7</td><td>WKS</td><td>COST OF PRODUCTS</td><td>1</td><td>1,500.00</td><td>1,500.00</td></tr>
<tr><td>8</td><td>WKS</td><td>WORK</td><td>1</td><td>1,000.00</td><td>1,000.00</td></tr>
<tr><td></td><td></td><td>DELIVERY WITHIN 10 DAYS
FROM THE DATE OF CONFIRMATION</td><td></td><td></td><td></td></tr>
</table>
U.S.Dollars Two Thousand Five Hundred Only
Total Before VAT USD 2,500.00
VAT Exempl 0.00
Total USD 2,500.00
info@farhatsteel.com
www.farhatsteel.com
FARHAT STEEL sarl</td>
</tr>
<tr>
<td>ProE construction done by AECENAR</td>
<td>Quotations from Farhat Steel Beyruth:
Quotation 3.2.14: 32cmx200cm, 18 holes / pipes Price: 2500 USD, Error: 6 inch instead of 4 inch -> additional cost: 250 $
Quotation 7.2.14: 62cm x 200 cm, 32 holes/pipes, Price: 7500 USD (by email to Omar Solh)
It was ordered as offered in the first quotation.</td>
</tr>
</table>

The delivered condenser:

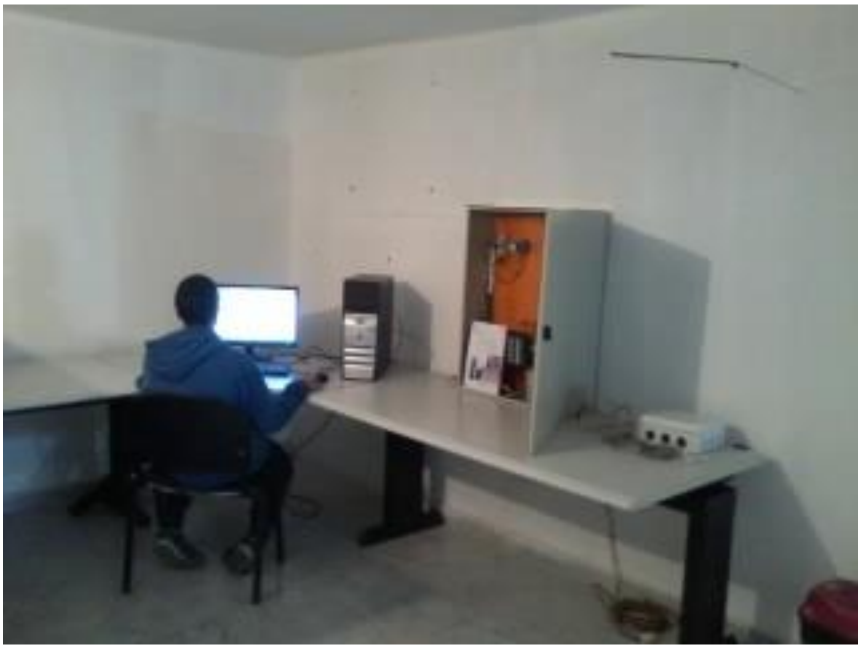
Der Kondensator kondensiert den ausder Turbine austretenden Dampf.

35.4 Some Experiments

35.5 Successful Turbine Test

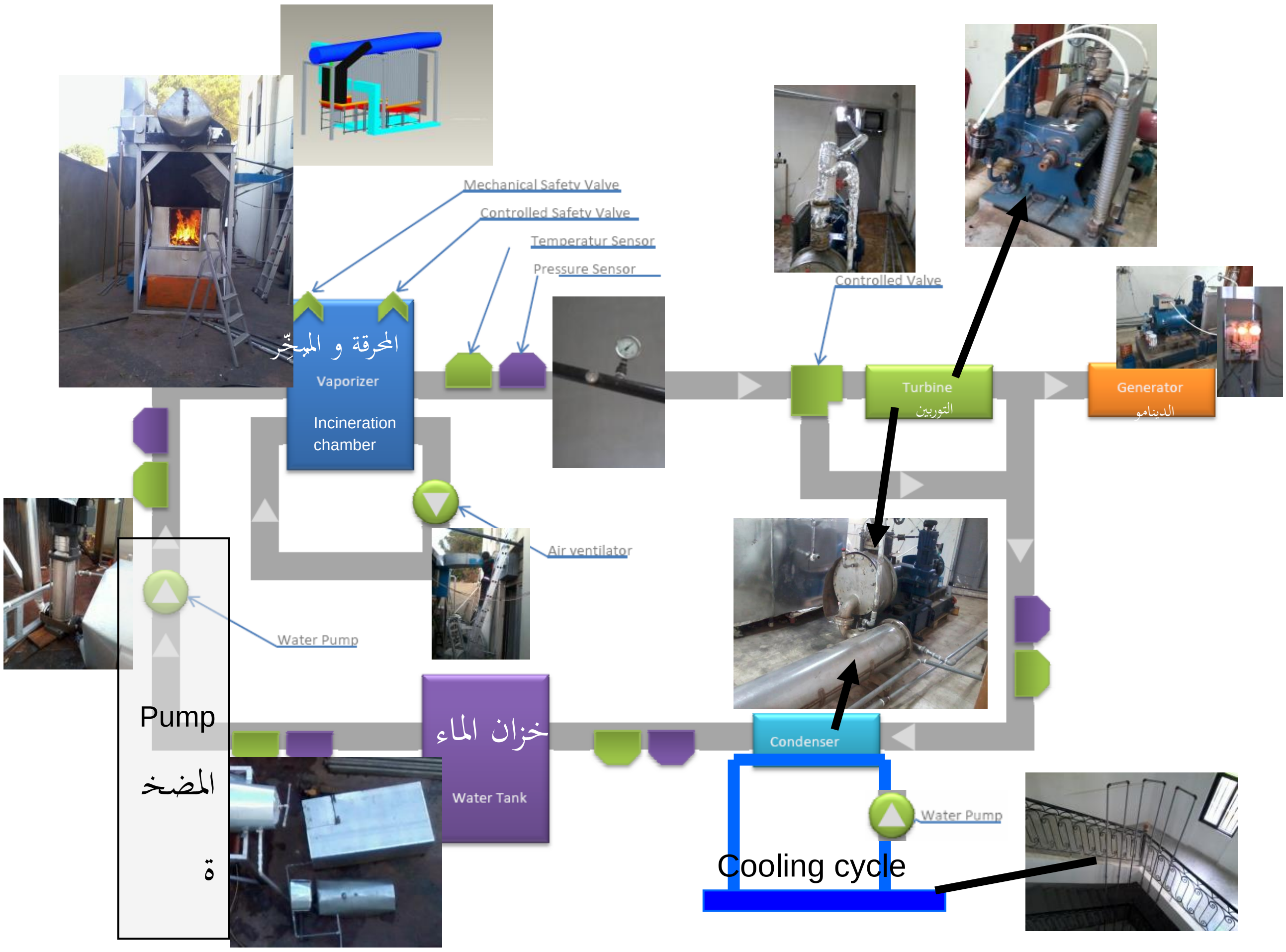


35.6 Process control system



36 \ نظام محطة الطاقة التي تحرق النفايات في راسنحاشThe System of the incineration power plant at Ras Nhache

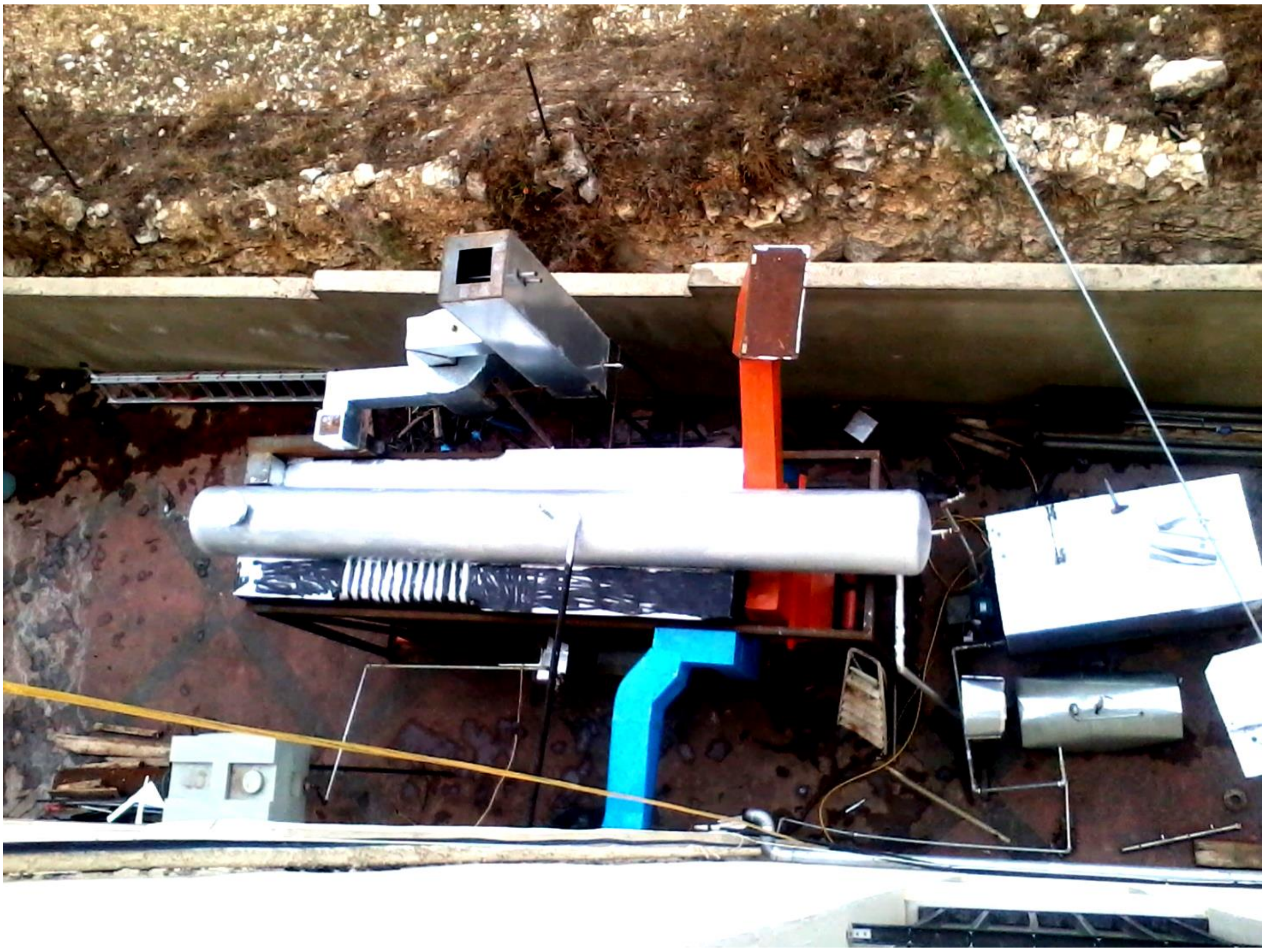
System Overview I نظرة شاملة36.1



تدخل النفايات الى المحرقة عن طريق المدخل المخصص لها. تحرق النفايات فيتسخن الماء الموجود في الخزان فوق المحرقة حتى يصل الماء الى درجة التبخر. لما يصل ضغط البخار الى 14 بار تُفتح الصمامة والبخار يجري الى التوربين ويولد الكهرباء.

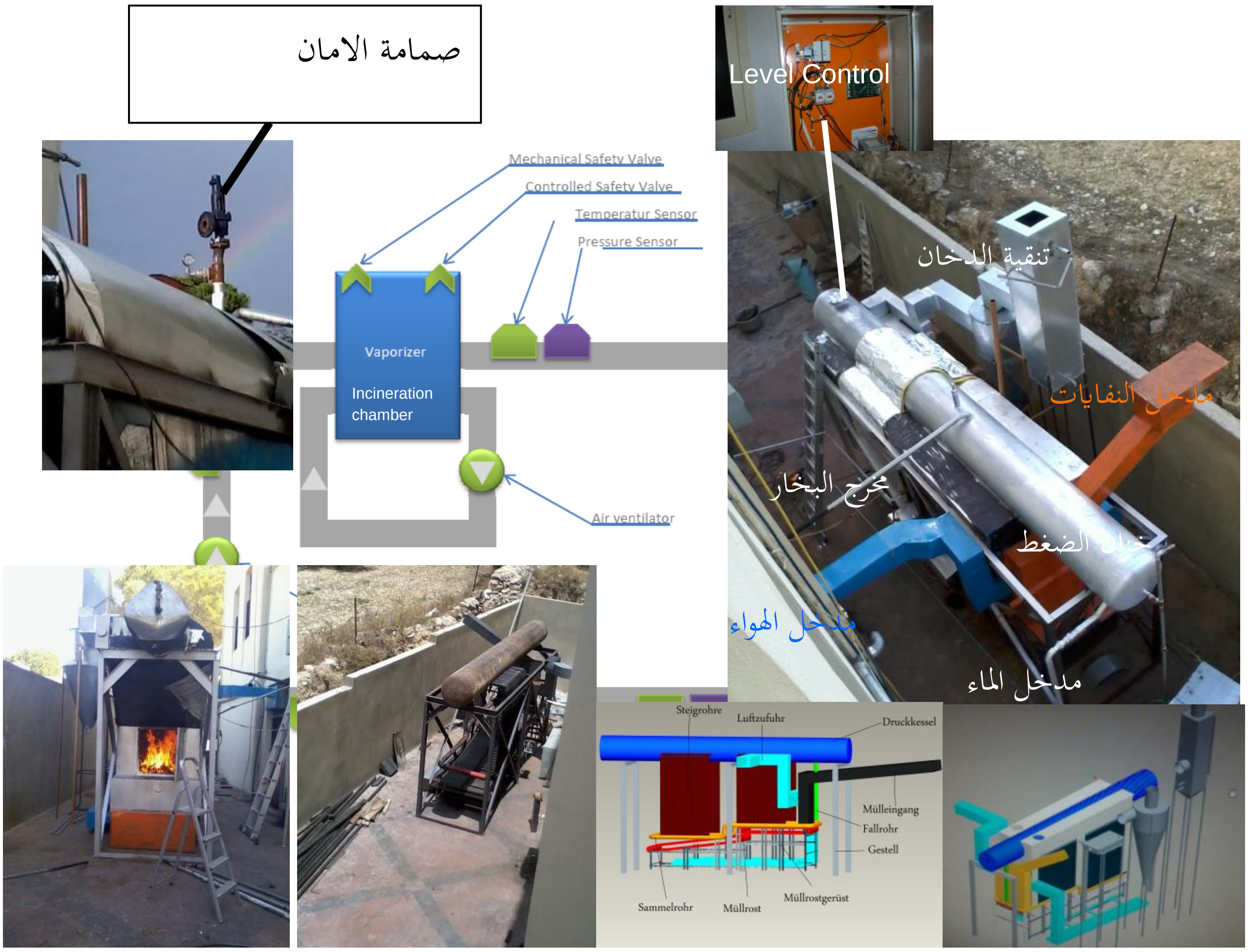
يخرج البخار من التوربين الى المكثف حيث يرجع ماءً.

هذه الماء تعود الى الخزان البارد و منه عن طريق المضخة مرة اخرى الى خزان المبخر ليتم الأحتراق دائما وليكون الهواء متواصل بالمحرقة

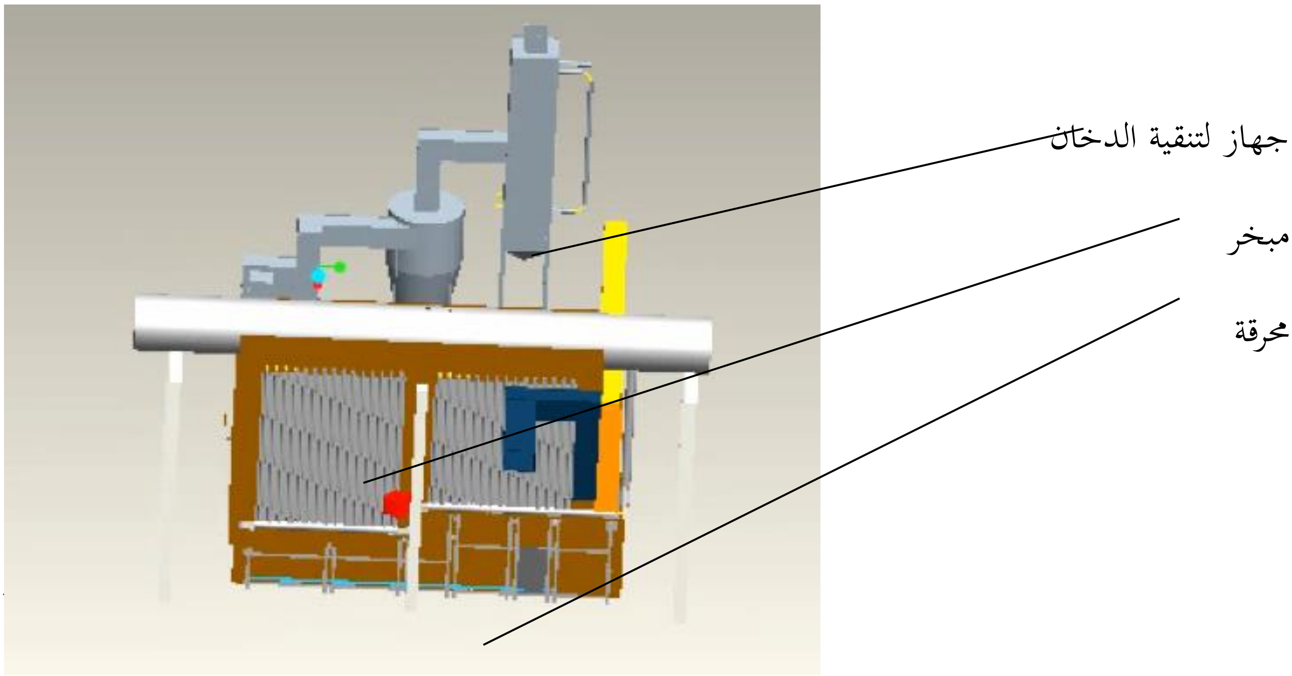


الاسطوانة الحمراء هي المكان الرئيسي لمكب النفايات وتتم بعدها عملية حرق النفايات

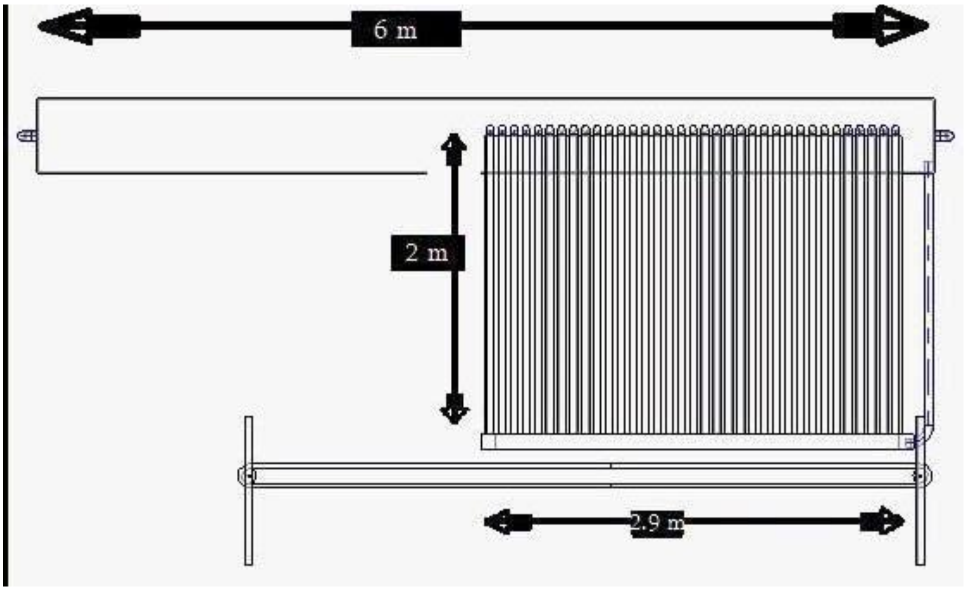
Incineration chamber & vaporizer ا 36.2المحرقة و المبخِّر

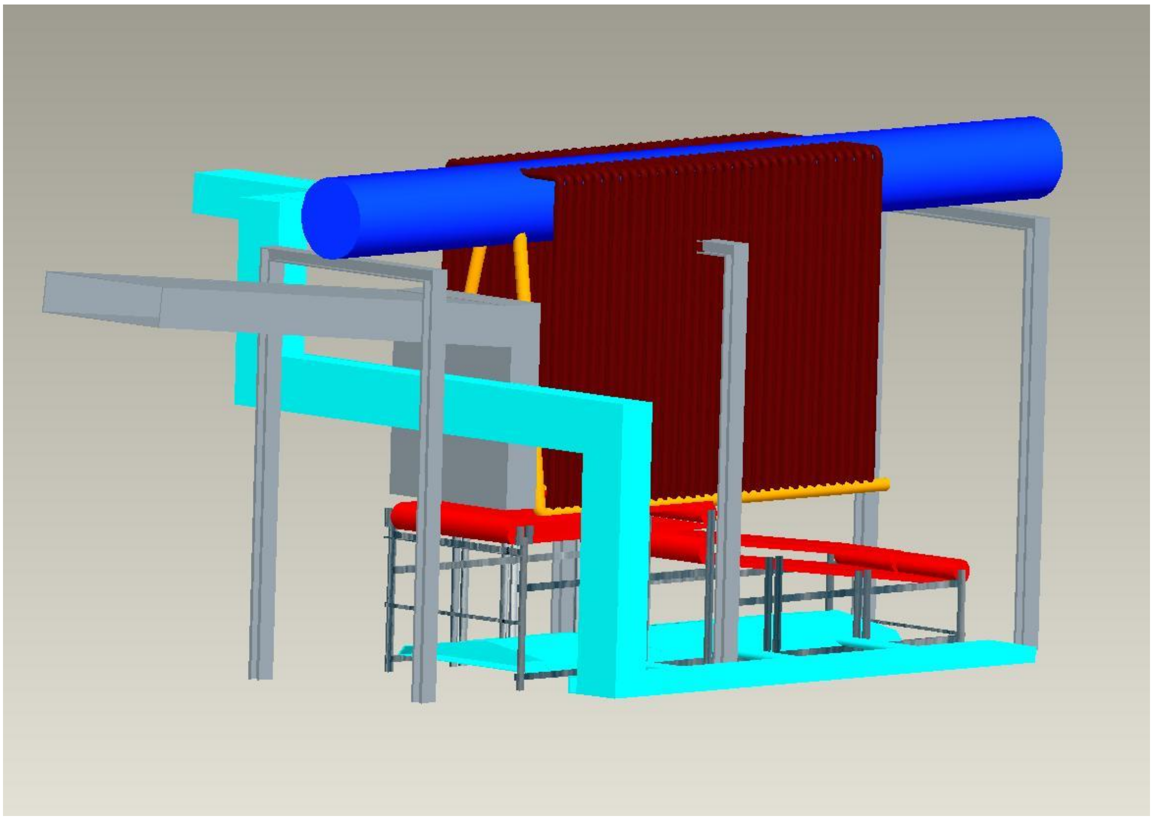


ليتم الاحتراق نحتاج الى وجود الهواء بصورة متواصلة في المحرقة. كما و يجب تنقية الدخان الناتج عن عملية الاحتراق. وحتى لا ينفجر خزان الضغط الذي يولد فيه البخار في حال انحباسه و عدم خروجه الى التربين يجب وضع صمام امان فوق الخزان لتنفيس الضغط.

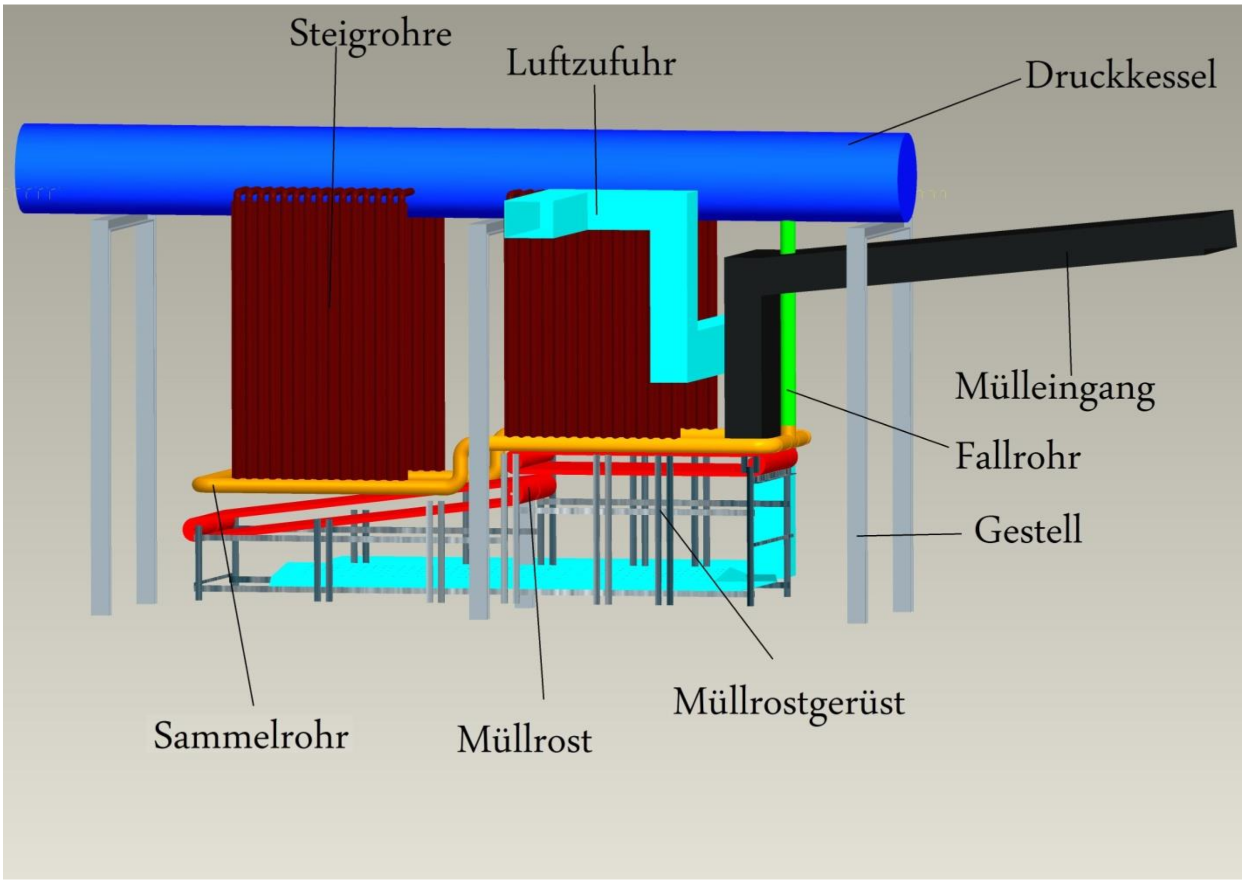


36.2.1 Construction تصميم

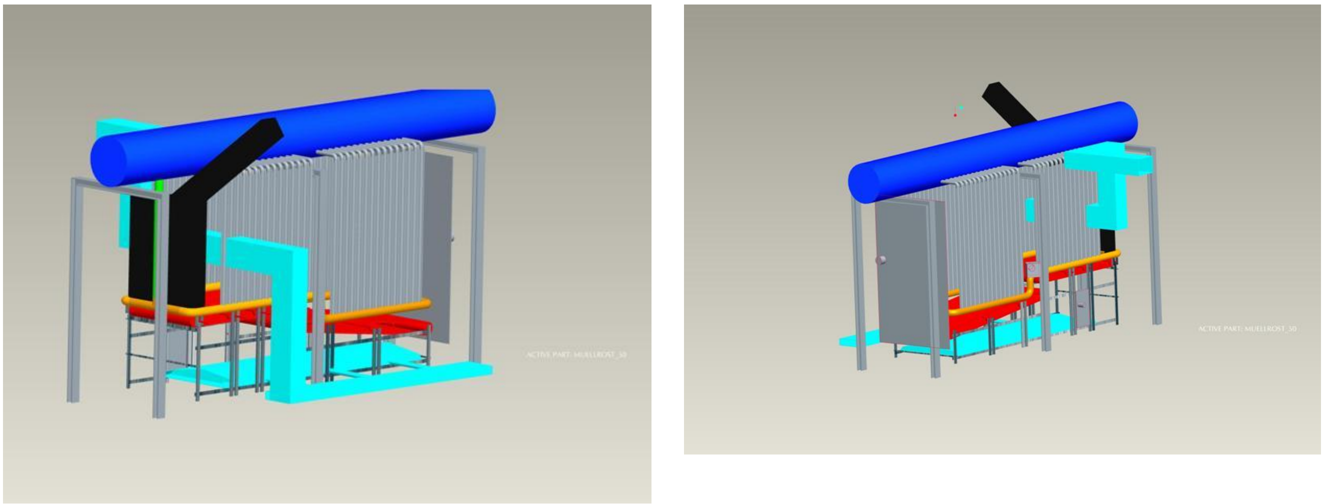




Construction version 1.7.



Construction version 16.7.



Final version

36.2.2 Manufacturing تصنيع

تكملة المجسم: اتفاق مع حسام بركات

قد فسخ العقد لان
اللحيمون فروا

بسم الله الرحمان الرحيم

8.8.2014

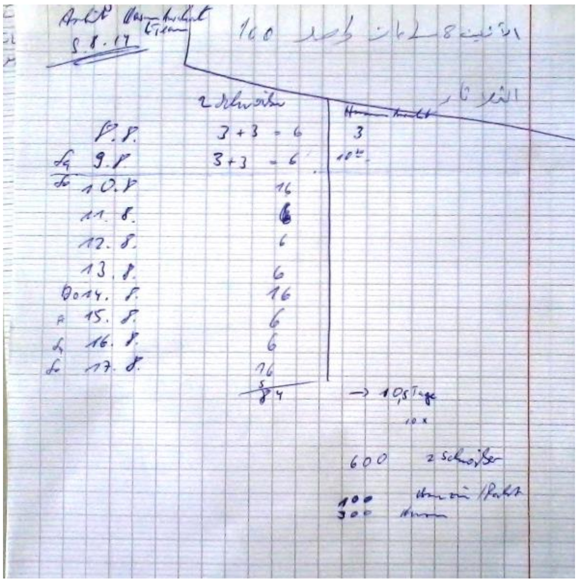
- ~~تسكير طريق الهواء~~
- ~~تسكير مدخل النفايات~~
- تلحيم القصاطل
- ربط الخزان الاعلى بشبكة القصاطل عن طريق قصطل عريض من فوق الى الاسفل
- تسكير مجمع القصاطل ببمبات (عدد 2)
- تلحيم المبسطات ما بين القصاطل

- ابواب للمحرقة عدد 2
- تركيب فلانشة اجهزة مقياس و تحكيم مستوى الماء في الخزان (على ظهر الخزان)
- ربط الخزان بالتوربين (قصطل من اعلى الخزان)
- ربط الخزان بالمضخة (قصطل من تحت الخزان)
- اكمال تلحيم بمبات الخزان
- ~~تسكير باقي المحرقة مع فتح للمدخنة~~
- تثبيت المجسم بX

السعر : 1000 دولار

تسليم: 17.8. ان شاء الله. واصل 100 $ في 8.8.14 كدفعة اولى

Then two welders from Beddawi came. One of them – Mohammad Akkoumi – completed the system with a delay of about 2 months.

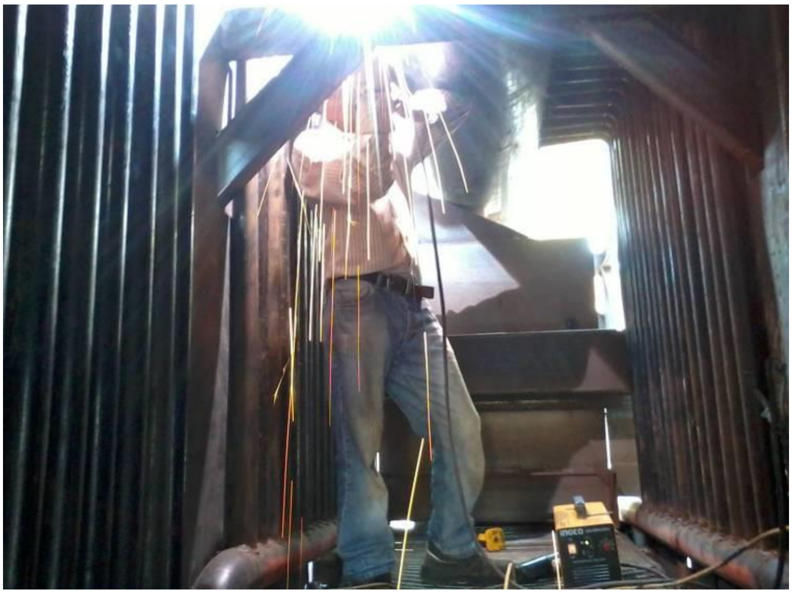


	2 Schweißer	
8.8.	3 + 3 = 6	3
9.8.	3+3 = 6	10
10.8.	16	
11.8.	6	
12.8.	6	
13.8.	6	
14.8.	16	
15.8.	6	
16.8.	6	
17.8.	16	
	84	→ 10,5 Tage

600 2 Schweißer

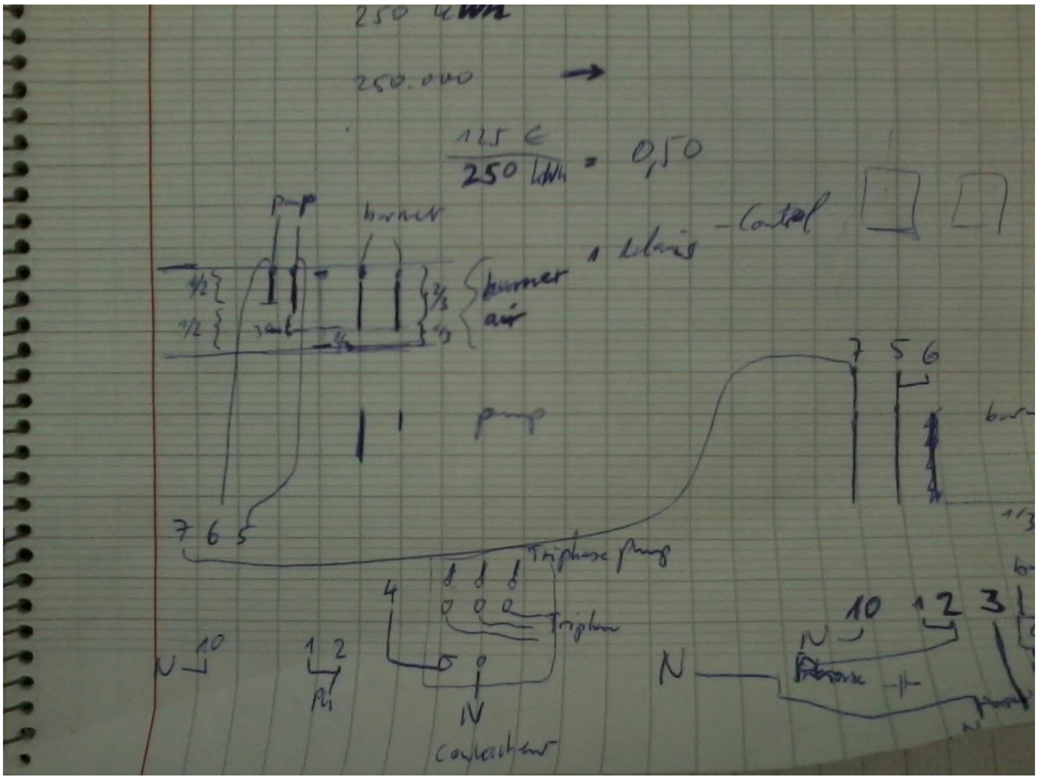
100

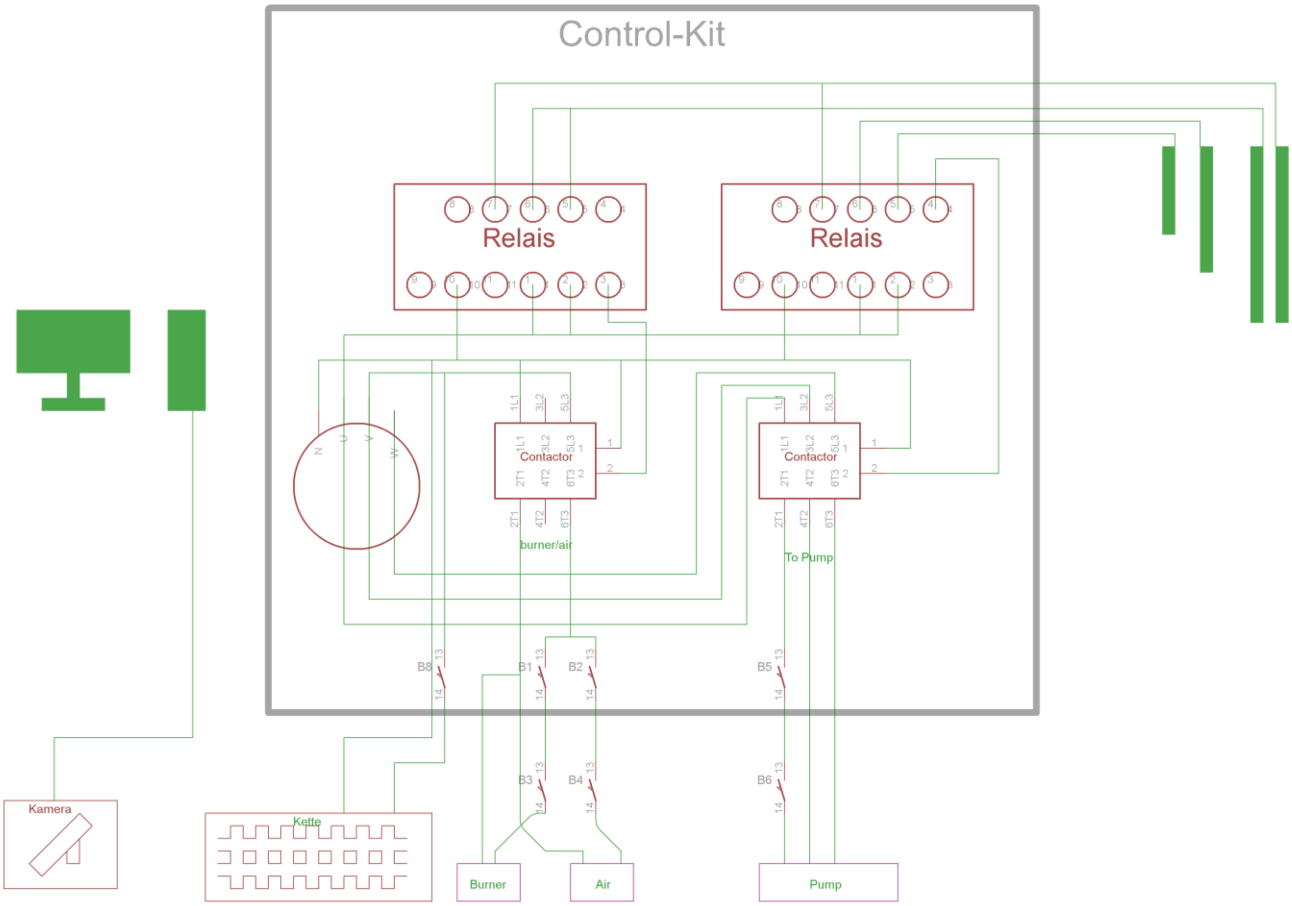
300

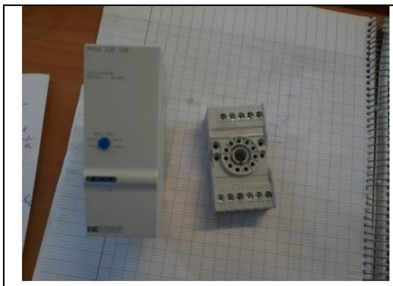
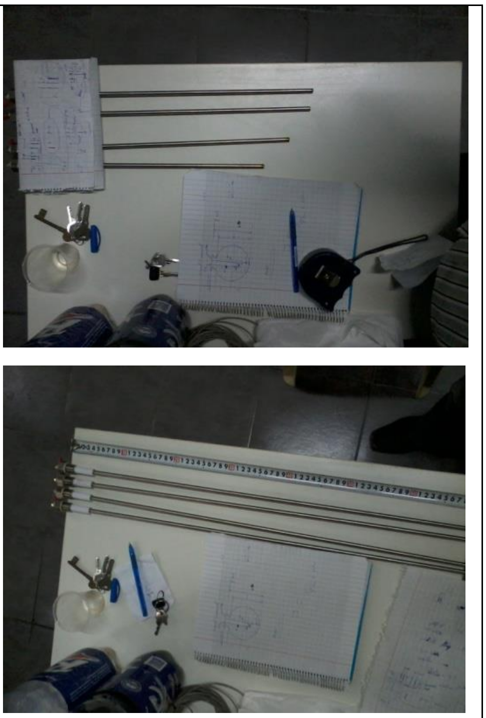


36.2.3 Level Control

36.2.3.1 Principle / Schema

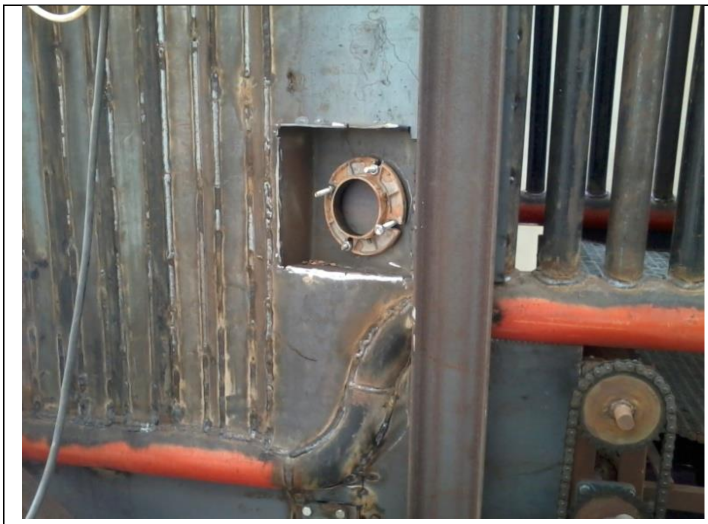




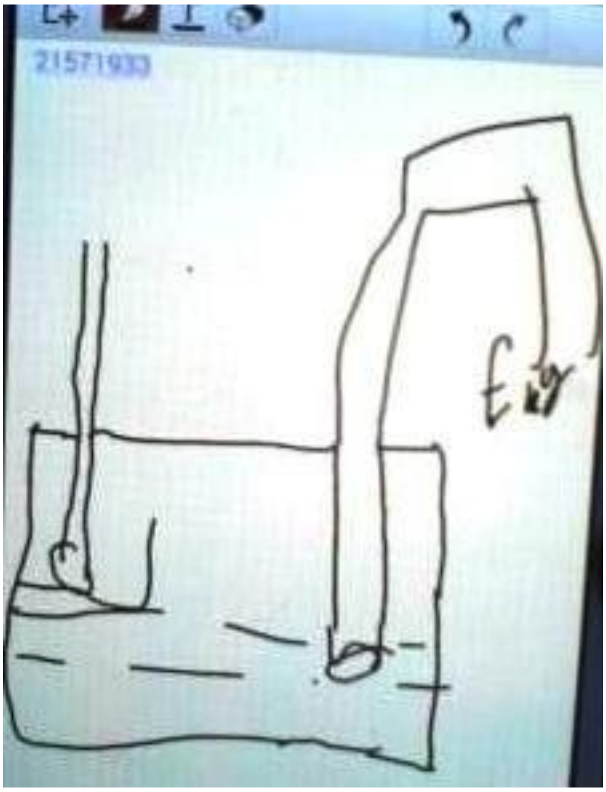
		
Level Control Relais	Contactor	Level Control Rods

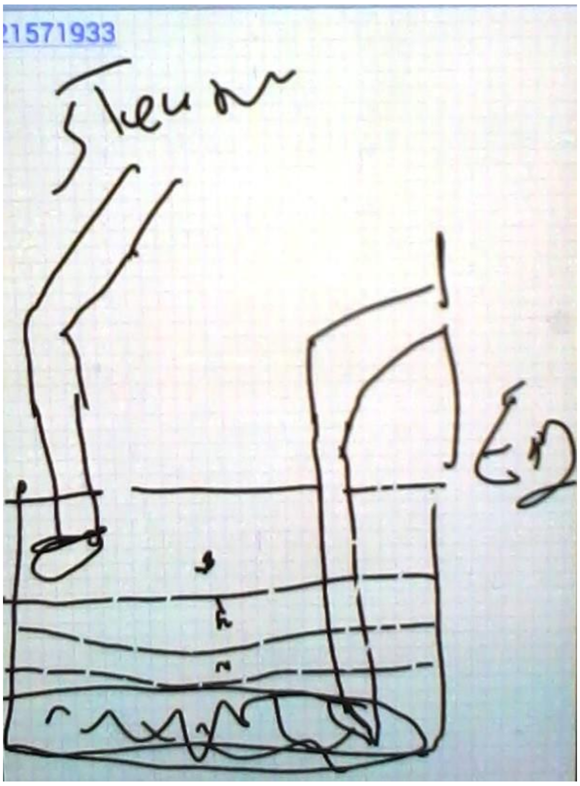
Level
Control
Rods

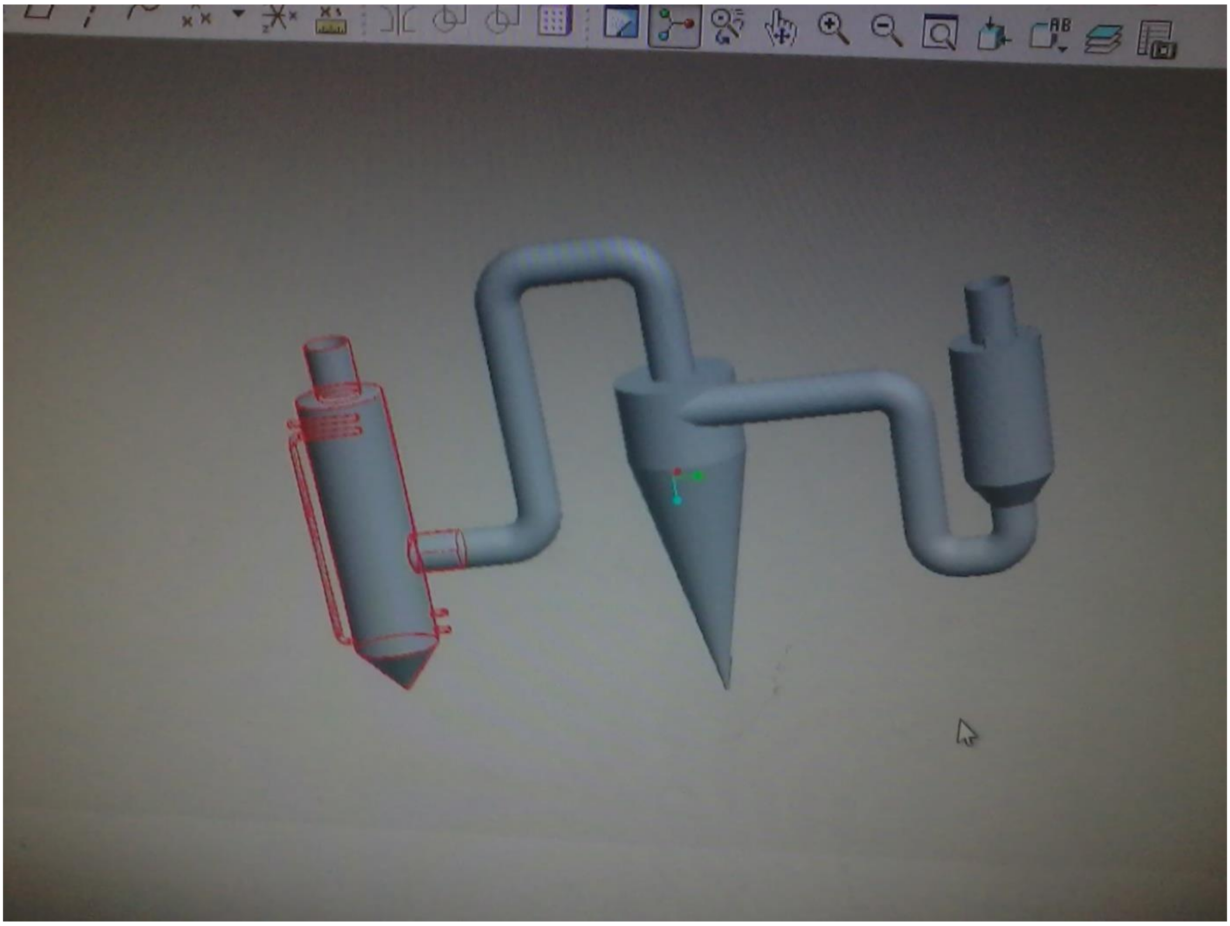
36.2.4 Ignition oil burner

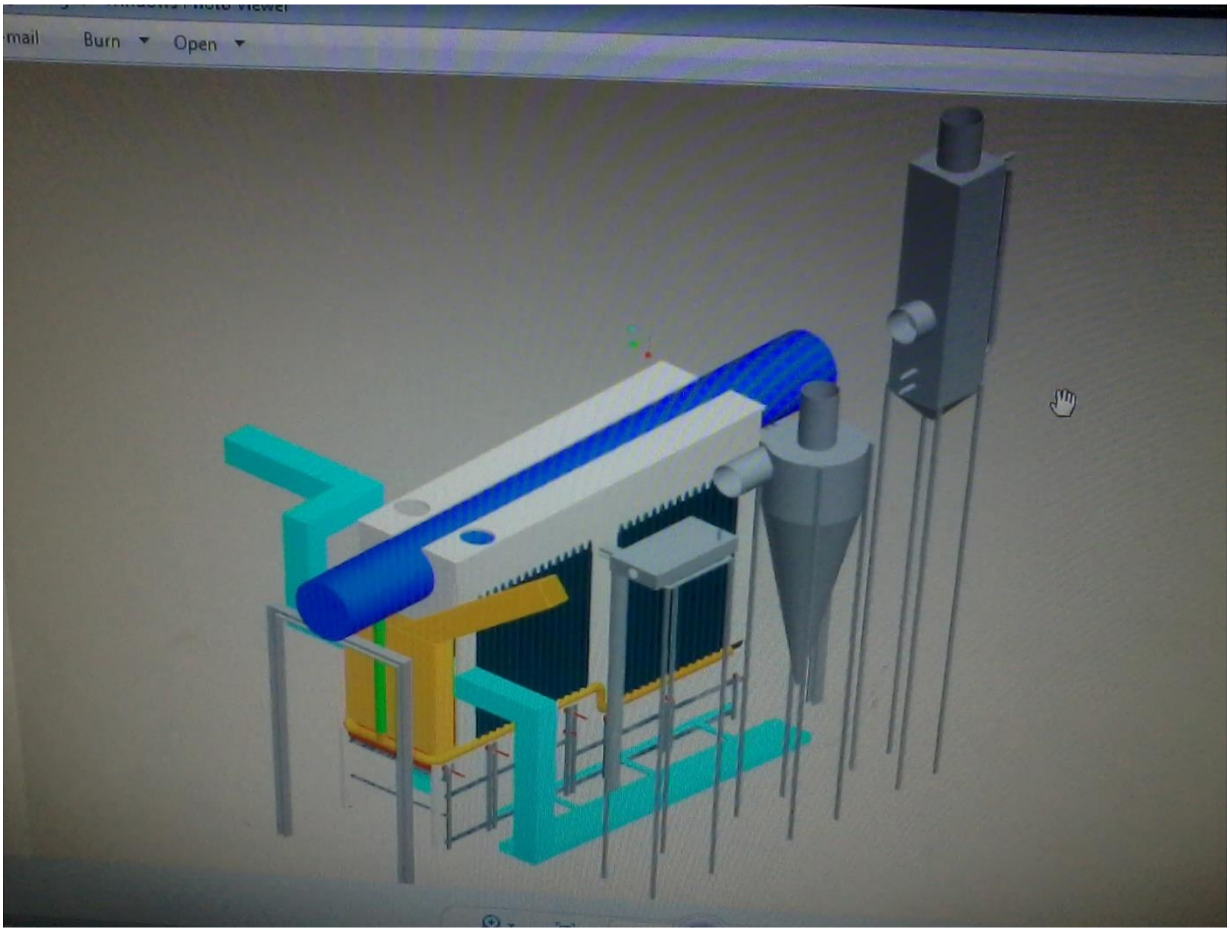


36.2.5 تنقية الدخان (dt. Rauchgasreinigung)

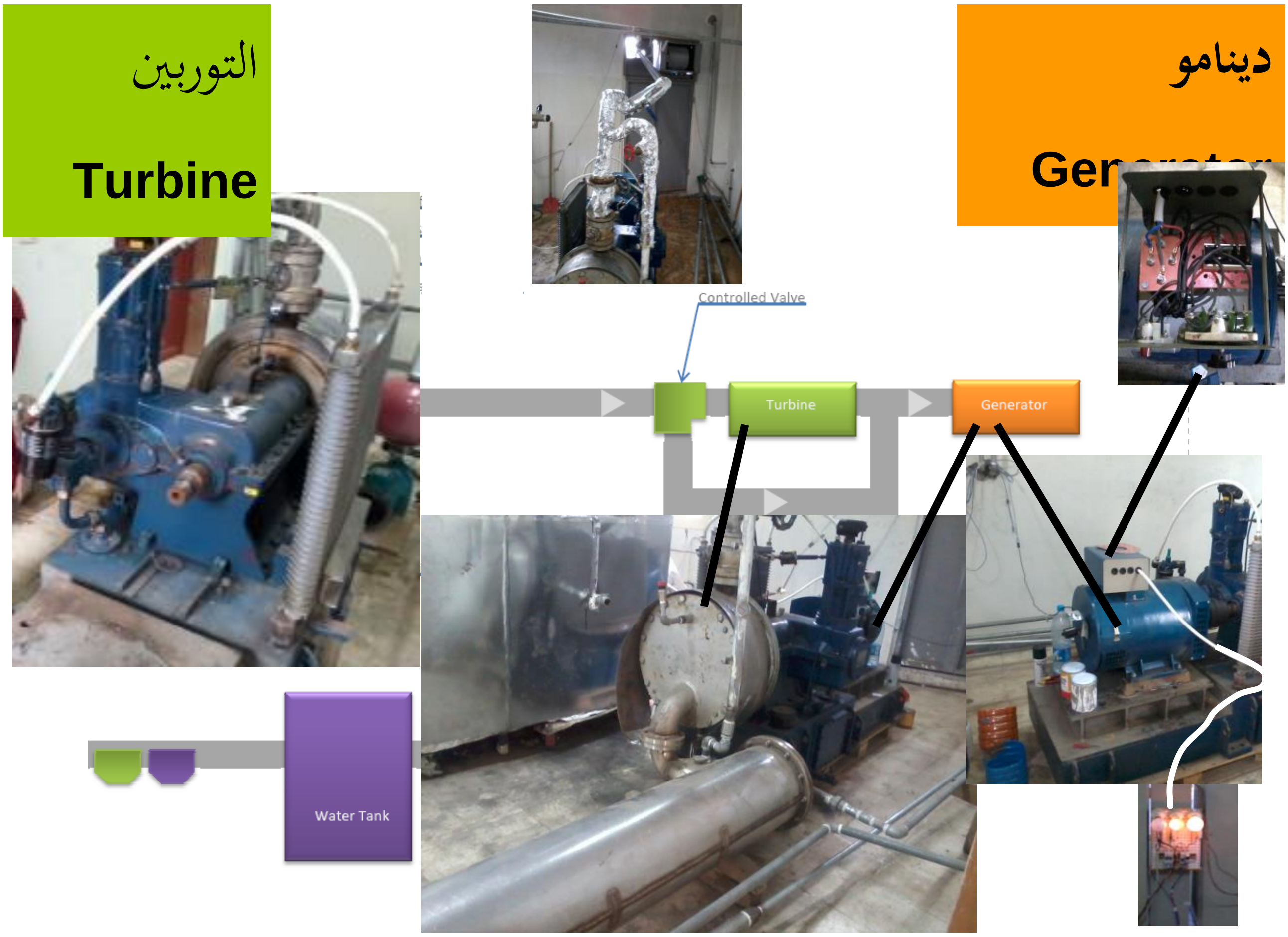


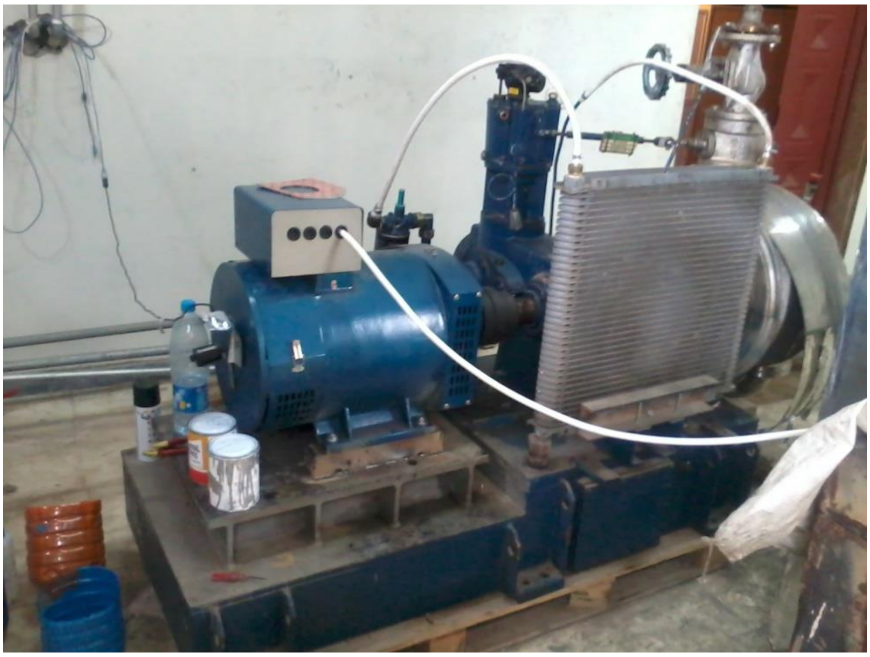





mail
Burn
Open

36.3 التوربين و دينامو \ Turbine&Generator





البخار يدخل بضغط عال الى التوربين فيسبب دوران اللآكس المتصل بالدينامو فيولد كهرباء. المحطة تولد 25 الى kW40 اى 150 الى 240 امبار. (الدينامو الحالي هو لتوليد 25 كيلو وات و لكن التوربين تتحمل توليد 40 كيلو وات).

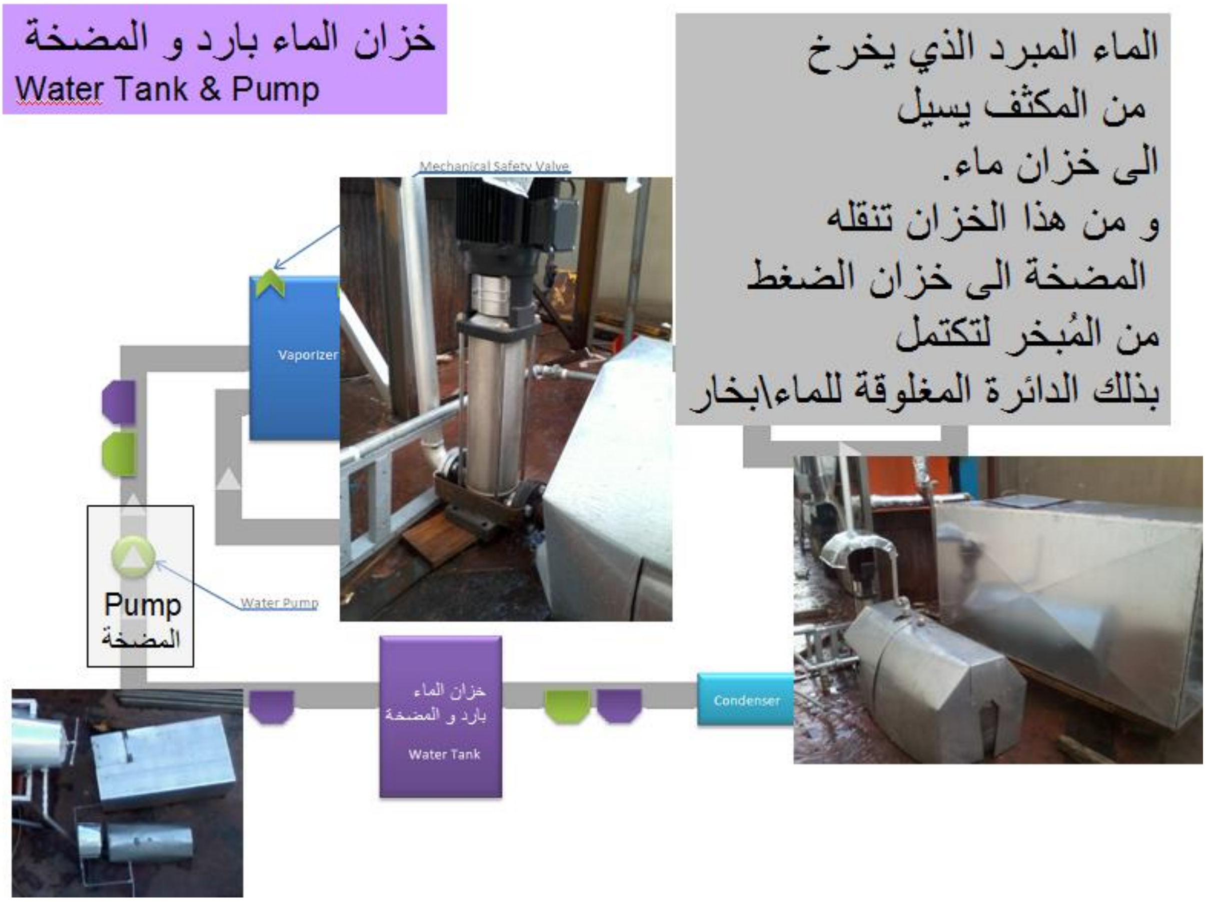
The outcoming current has 3 phases.

36.4 مكثف و دائرة التبريد I Condenser & Cooling cycle

البخار يخرخ من التوربين بضغط منخفض. والمكثف يحول هذا بخار الى ماء و يُحول الحرارة الى دائرة التبريد.

و يمكن الاستفادة من الحراة التي تنقلها دائرة التبريد مثلا للتدفئة او لتحلي ماء مالح

36.5 خزان الماء بارد و المضخة



الماء المبرد الذي يخرخ من المكثف يسيل الى خزان ماء. و من هذا الخزان تنقله المضخة الى خزان الضغط من المُبخر لتكتمل بذلك الدائرة المغلوقة للماء\بخار

37 Accidents حوادث

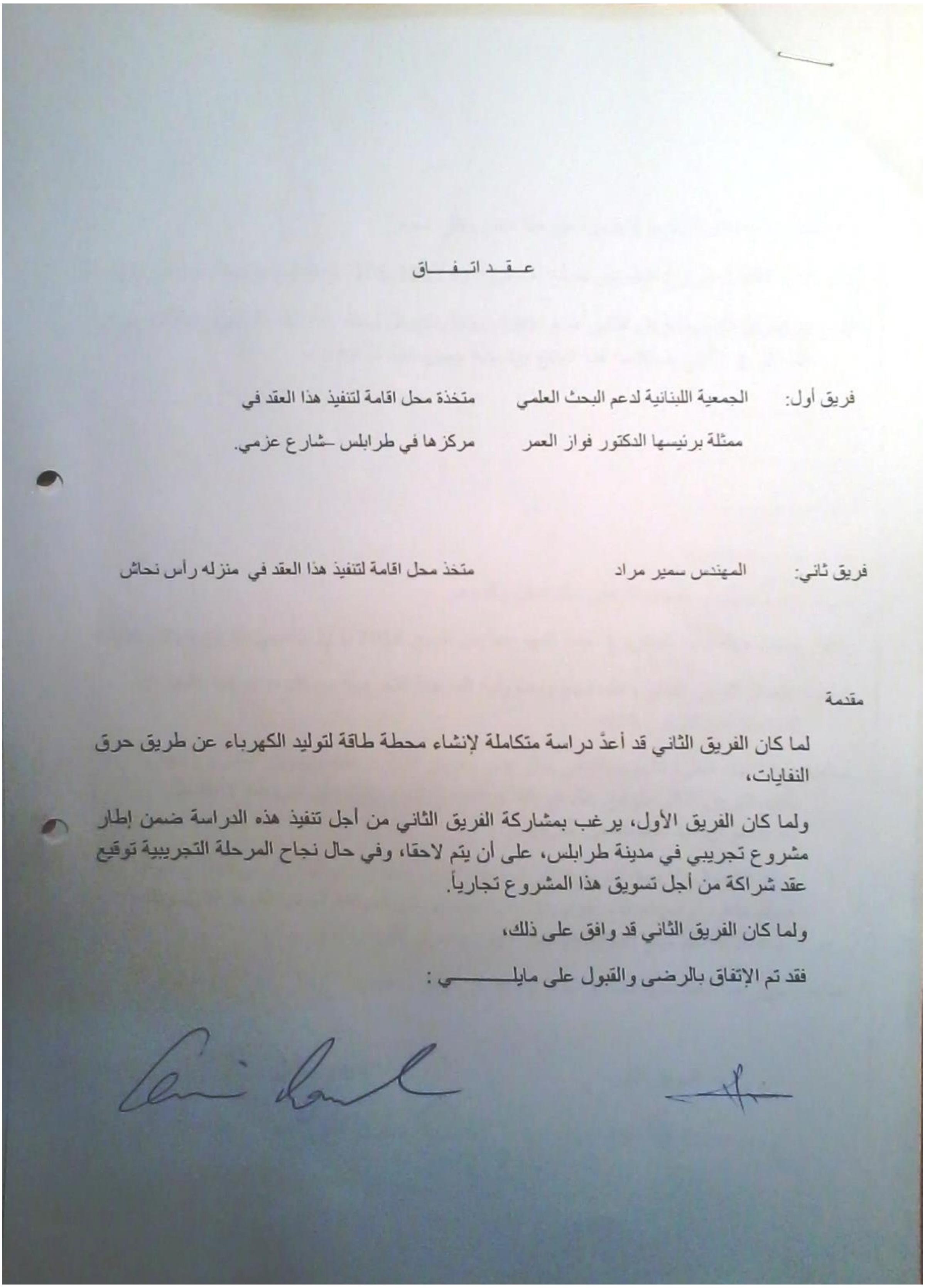
---

38 Presentations of completed power plant

38.1 Presentation Liqa al-Khair 05.11.14

39 ملحق

39.1 Contract between LASeR and Samir Mourad



عـقـد اتـفـــاق

فريق أول: الجمعية اللبنانية لدعم البحث العلمي متخذة محل اقامة لتنفيذ هذا العقد في
ممثلة برئيسها الدكتور فواز العمر مركزها في طرابلس –شارع عزمي.

فريق ثاني: المهندس سمير مراد متخذ محل اقامة لتنفيذ هذا العقد في منزله رأس نحاش

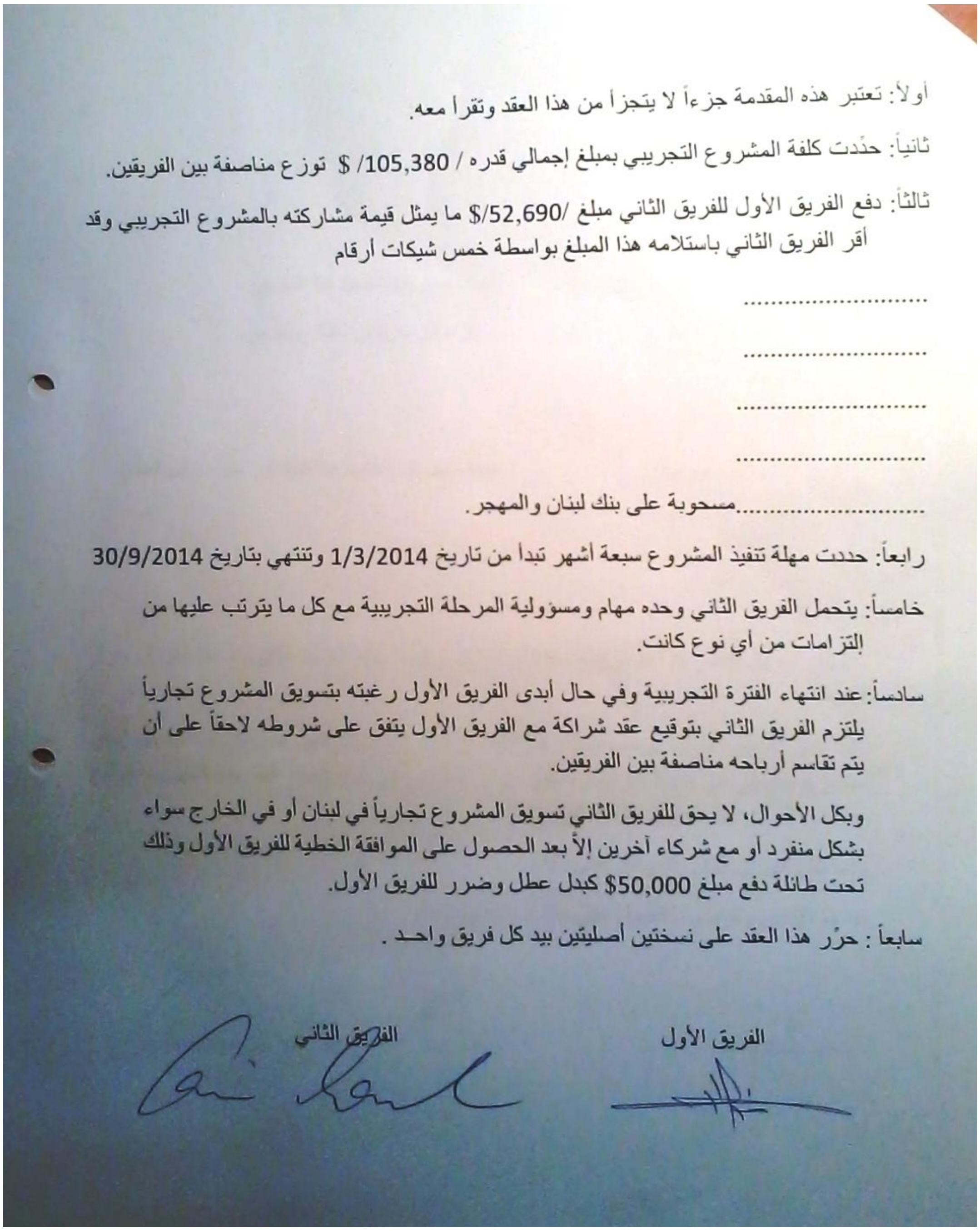
مقدمة

لما كان الفريق الثاني قد أعدّ دراسة متكاملة لإنشاء محطة طاقة لتوليد الكهرباء عن طريق حرق النفايات،

ولما كان الفريق الأول، يرغب بمشاركة الفريق الثاني من أجل تنفيذ هذه الدراسة ضمن إطار مشروع تجريبي في مدينة طرابلس، على أن يتم لاحقا، وفي حال نجاح المرحلة التجريبية توقيع عقد شراكة من أجل تسويق هذا المشروع تجارياً.

ولما كان الفريق الثاني قد وافق على ذلك،

فقد تم الإتفاق بالرضى والقبول على مايلـــــــــي :



أولاً: تعتبر هذه المقدمة جزءاً لا يتجزأ من هذا العقد وتقرأ معه.

ثانياً: حدّدت كلفة المشروع التجريبي بمبلغ إجمالي قدره / 105,380/ $ توزع مناصفة بين الفريقين.

ثالثاً: دفع الفريق الأول للفريق الثاني مبلغ /52,690/$ ما يمثل قيمة مشاركته بالمشروع التجريبي وقد أقر الفريق الثاني باستلامه هذا المبلغ بواسطة خمس شيكات أرقام

....

....

....

....

...........................مسحوبة على بنك لبنان والمهجر.

رابعاً: حددت مهلة تنفيذ المشروع سبعة أشهر تبدأ من تاريخ 1/3/2014 وتنتهي بتاريخ 30/9/2014

خامساً: يتحمل الفريق الثاني وحده مهام ومسؤولية المرحلة التجريبية مع كل ما يترتب عليها من إلتزامات من أي نوع كانت.

سادساً: عند انتهاء الفترة التجريبية وفي حال أبدى الفريق الأول رغبته بتسويق المشروع تجارياً يلتزم الفريق الثاني بتوقيع عقد شراكة مع الفريق الأول يتفق على شروطه لاحقاً على أن يتم تقاسم أرباحه مناصفة بين الفريقين.

وبكل الأحوال، لا يحق للفريق الثاني تسويق المشروع تجارياً في لبنان أو في الخارج سواء بشكل منفرد أو مع شركاء آخرين إلاّ بعد الحصول على الموافقة الخطية للفريق الأول وذلك تحت طائلة دفع مبلغ 50,000$ كبدل عطل وضرر للفريق الأول.

سابعاً : حرّر هذا العقد على نسختين أصليتين بيد كل فريق واحـد .

الفريق الأول

الفريق الثاني

39.2 Suppliers

Specialist for / price	Name	Address	Phone
Aluminium, 80$/qm	عمر	بعبدة – عكار	70 140828
Schweißer /Schlosser 40 USD / day + transportation	Muhammad Al Akkumi Rabih Izzuddin	بداوي	70 548570 71804124
Schweißer /Schlosser 50 USD / day	Muhammad Qammah	Mina	70 339875
Schweisser /Schlosser	Hussam Barakat	Chekka	
Stainless fabrication	Bilal Naouchi	bilalnaoushi@hotmail.com	03 446027
Wärme u. Kälte technik u.s.w.	Khidr Balita	Mina	03 232088
Stainless fabrication	Sami Farhat	www.samifarhatco.com info@ samifarhatco.com Tel. 01 878371, 03 752052 CIC center, Industrial City, Nahr al Mott, Beirut	
Chaudiere production	Abdulsalam Sabsabi	Dair Amar	03666733 03709745
Steel supplier	Beainty Trading, 03 972800, 09622223, 09622224	Amchit	
Steel supplier	Emile	Batroun	

39.3 Meeting with LASeR_RasNhache230514

بسم الله الرحمن الرحيم

AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region
www.aecenar.com

LASeR
Lebanese Association for Scientific Research
الجمعية اللبنانية لدعم البحث العلمي

TEMO
Software, Hardware & Consulting e.K.
www.temo-ek.de

Meeting Minutes

برنامج و محضر الجتماع في23.5.2014

المحتوى / Content

1 برنامج

1.1 Presentation (SM)

- وضع المشروع الحالي
- Main Working Packages still to be done
- Accident (Leakage of pressure vessel)

1.2 Film presentation

Sucessful test of turbine

الحمد لله

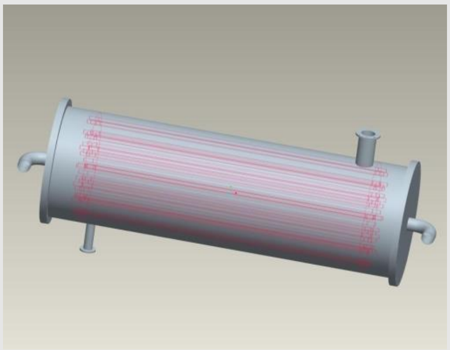
2 Status

2.1 Overview

تم الاشياء التالية الرئيسية:

- تصنيع الكوندنزر
- تكميل المحرقة التجاروبية مع حراق على المازوت
- ربط الاجهزة في مركز القبيسي و هو جاهز لتدريبات في ميدان هندسة محطات طاقة
- تركيب المولد للكهرباء
- عرض من بلدية رأسنحاش

Dec 13	May 14



Feed water tank

Evaporator automatic level control

condensor

Integration of test rig

Sucessful test of turbine

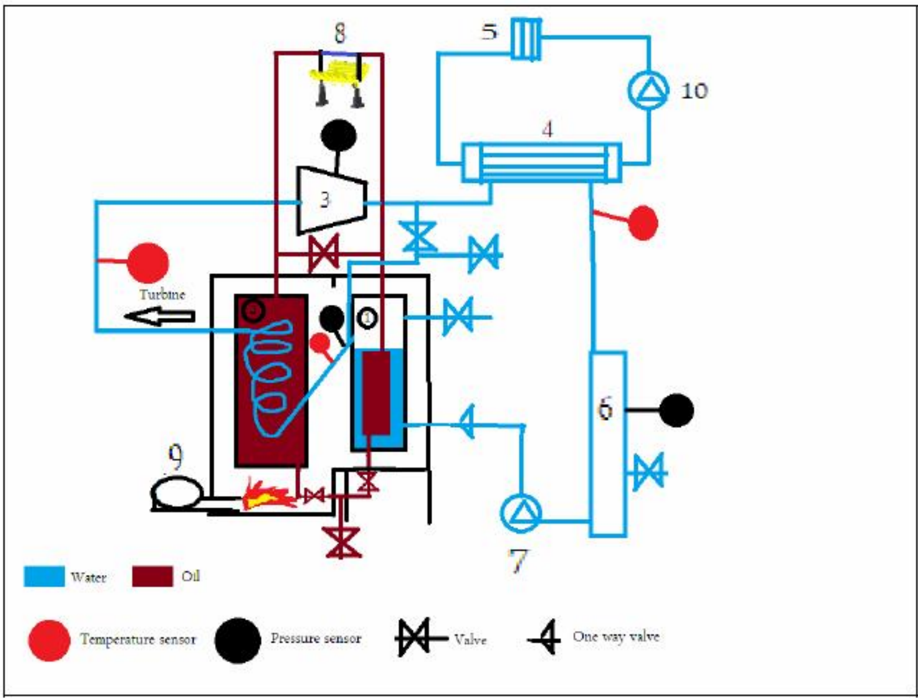
الحمد لله

2.2 Under construction:

2.2 Under construction:

Dreizugkessel (6,0 bar – höhere Druckstufen auf Anfrage)
Sicherheitswärmetauscher (im Kessel integriert)
Flachschubrost hydraulisch angetrieben (zweigeteilt ab Typ FSB 850) mit Zuführung der Primärluft (1 bis 3 Zonen – je nach Typ, optional Zone 1 und 2 vorgewärmt über Wasser-/Luft-Wärmetauscher)
Zuführung der Sekundärluft
Zuführung der Abgasrezirkulierung „über Rost" (optional)
Zündgebläse (automatische Zündung oder Zündhilfe – optional bis Typ FSB 1100)
Hydraulischer Einschub/Direkteinschub mit wassergekühltem Einschubhals oder Einschubschnecke
Entaschung (über Schnecken oder direkt in 800-Liter-Aschecontainer)
Feuerraumtür Primär-Brennkammer (eine Kombitür primär/sekundär bis Typ FSB 700)
Unterrostschubstange ab Typ FSB 850
Reinigungsöffnungen unterhalb des Flachschubrostes
Pneumatische Kesselreinigung (optional)

2.3 Layout of Qubaisi plant



1:Evaporator

3:Turbine

4:Condenser

5: Central heating

6:Water tank

7: Pump

8: solar pipe

9:Oil burner

10: Pump

2.4 Accidents / Leakages

Pressure tubes

Barlow's formula relates the internal pressure that a tube or pipe can withstand to its dimensions and the strength of its material.

$$P = \frac{2St}{D}$$

P = (2*S*t) / D

where

$$\sigma_t = \frac{p \cdot d}{2 \cdot s}$$

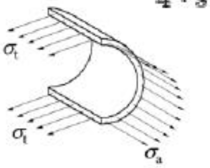
$$\sigma_a = \frac{p \cdot d}{4 \cdot s}$$

P = pressure

S = allowable stress

t = wall thickness

D = outside diameter



حوادث (8.5.14): خرق عند برميل الضغط (600 mm diameter, 3 mm thickness, stainless steel) عند 13,5 bar

تم عزل هذا البرميل حاليا

و الارجح ان الخرق تم عند مكن تلحيم.

3 Project Management / إدارة المشروع

3.1 Time Schedule / الجدول الزمني

3.1.1 Timeline

ID	Name	Start	Finish
MEAE	**TEMO-IPP**	**03.01.2014**	**30.08.2014**
	establishing steady place for demo plant for incineration	03.01.2014	20.01.2014
	integration and working of demo plant at Qubaisi lab	21.01.2014	23.05.2014
	Sucessful turbine test	12.05.2014	12.05.2014
	Demonstration Meeting with LASeR	23.05.2014	23.05.2014
	Construction and buildng of incineration based evaporator	13.05.2014	27.06.2014
	incineration integration to demo plant at Qubaisi center	27.06.2014	19.07.2014
	operational working of incineration plant at Ras Nhache	22.07.2014	30.08.2014
	final report and demonstration with LASER	30.08.2014	30.08.2014

3.2 Costs / موجز للتكاليف/

3.2.1 Rest Budget (for incineration chamber): 9.000 USD

Date	Part/Eng.	Place of integration	Amount	
	Incineration&Vaporizer		$7.000	
	Valves&Instrumentation	Ras Nhache	$2.000	
		Total	$9.000	

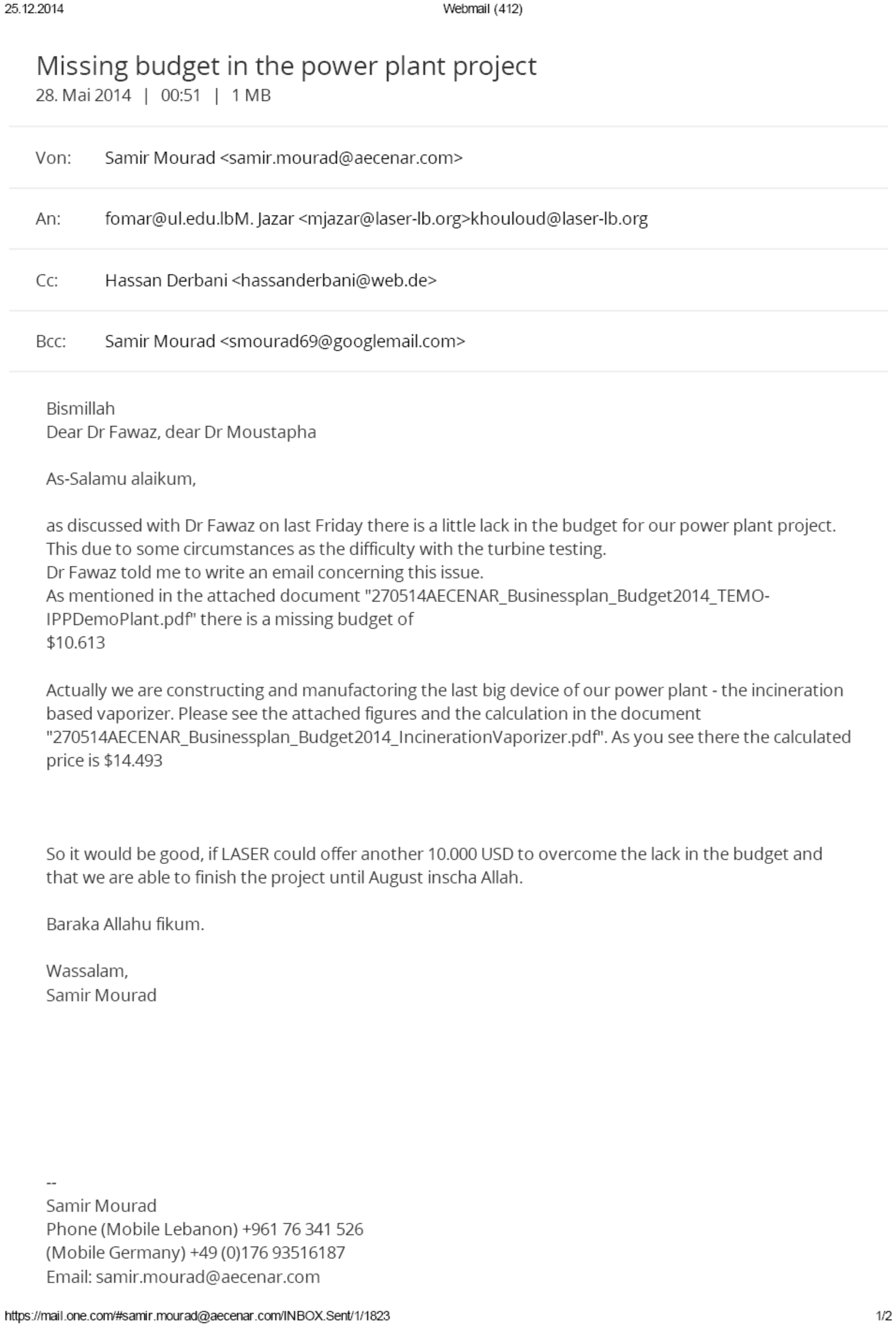
3.3 مسائل يجب ان تناقش

Anfe or Ras Nhache Baladijja

Ras Nhache	Anfe
	

6

39.4 Request_For_Morebudget_Email280514



25.12.2014 Webmail (412)

Missing budget in the power plant project

28. Mai 2014 | 00:51 | 1 MB

Von: Samir Mourad <samir.mourad@aecenar.com>

An: fomar@ul.edu.lbM. Jazar <mjazar@laser-lb.org>khouloud@laser-lb.org

Cc: Hassan Derbani <hassanderbani@web.de>

Bcc: Samir Mourad <smourad69@googlemail.com>

Bismillah
Dear Dr Fawaz, dear Dr Moustapha

As-Salamu alaikum,

as discussed with Dr Fawaz on last Friday there is a little lack in the budget for our power plant project.
This due to some circumstances as the difficulty with the turbine testing.
Dr Fawaz told me to write an email concerning this issue.
As mentioned in the attached document "270514AECENAR_Businessplan_Budget2014_TEMO-IPPDemoPlant.pdf" there is a missing budget of
$10.613

Actually we are constructing and manufactoring the last big device of our power plant - the incineration based vaporizer. Please see the attached figures and the calculation in the document "270514AECENAR_Businessplan_Budget2014_IncinerationVaporizer.pdf". As you see there the calculated price is $14.493

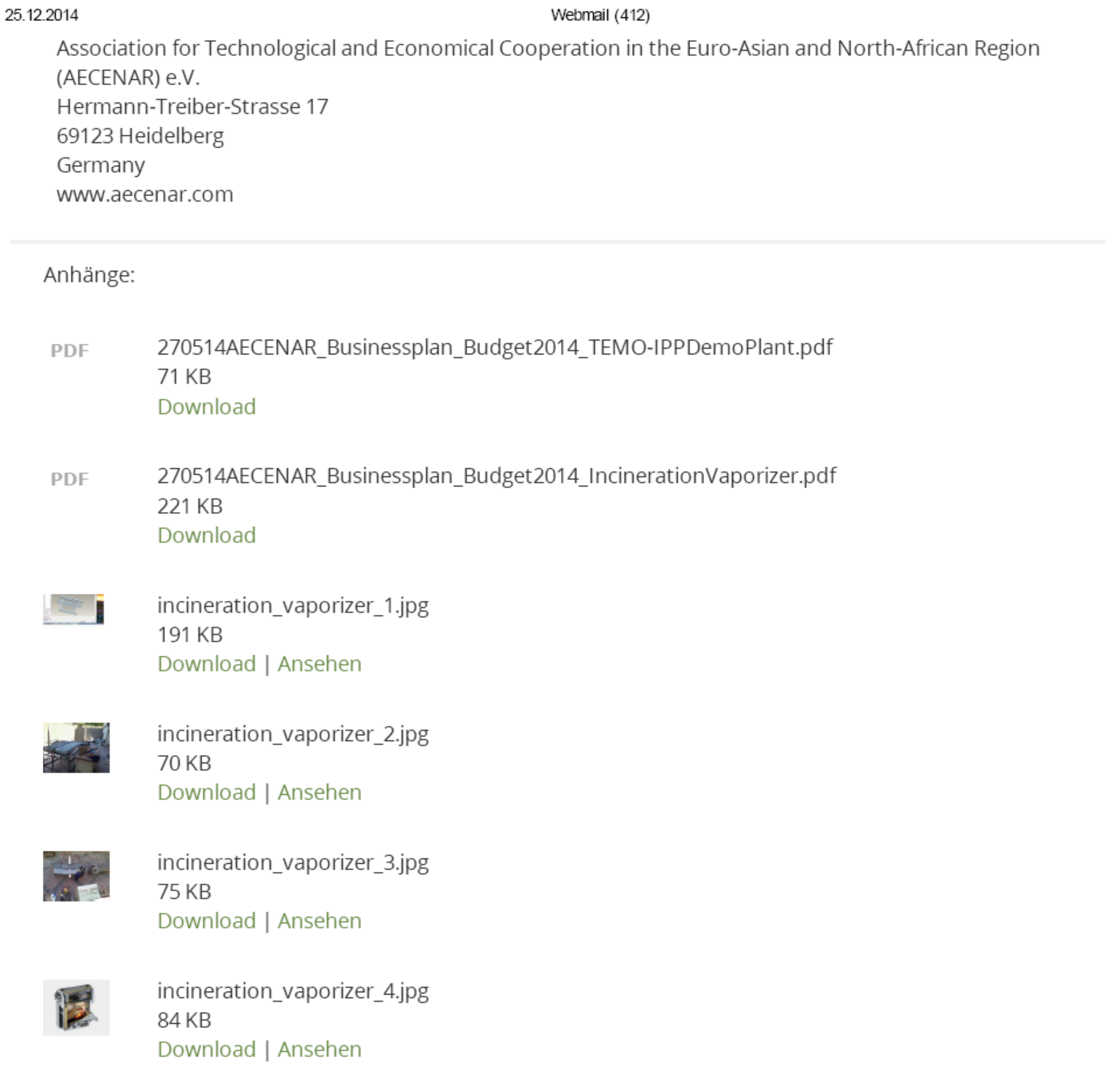
So it would be good, if LASER could offer another 10.000 USD to overcome the lack in the budget and that we are able to finish the project until August inscha Allah.

Baraka Allahu fikum.

Wassalam,
Samir Mourad

--
Samir Mourad
Phone (Mobile Lebanon) +961 76 341 526
(Mobile Germany) +49 (0)176 93516187
Email: samir.mourad@aecenar.com

https://mail.one.com/#samir.mourad@aecenar.com/INBOX.Sent/1/1823 1/2



25.12.2014 Webmail (412)

Association for Technological and Economical Cooperation in the Euro-Asian and North-African Region
(AECENAR) e.V.
Hermann-Treiber-Strasse 17
69123 Heidelberg
Germany
www.aecenar.com

Anhänge:

PDF 270514AECENAR_Businessplan_Budget2014_TEMO-IPPDemoPlant.pdf
71 KB
Download

PDF 270514AECENAR_Businessplan_Budget2014_IncinerationVaporizer.pdf
221 KB
Download

incineration_vaporizer_1.jpg
191 KB
Download | Ansehen

incineration_vaporizer_2.jpg
70 KB
Download | Ansehen

incineration_vaporizer_3.jpg
75 KB
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incineration_vaporizer_4.jpg
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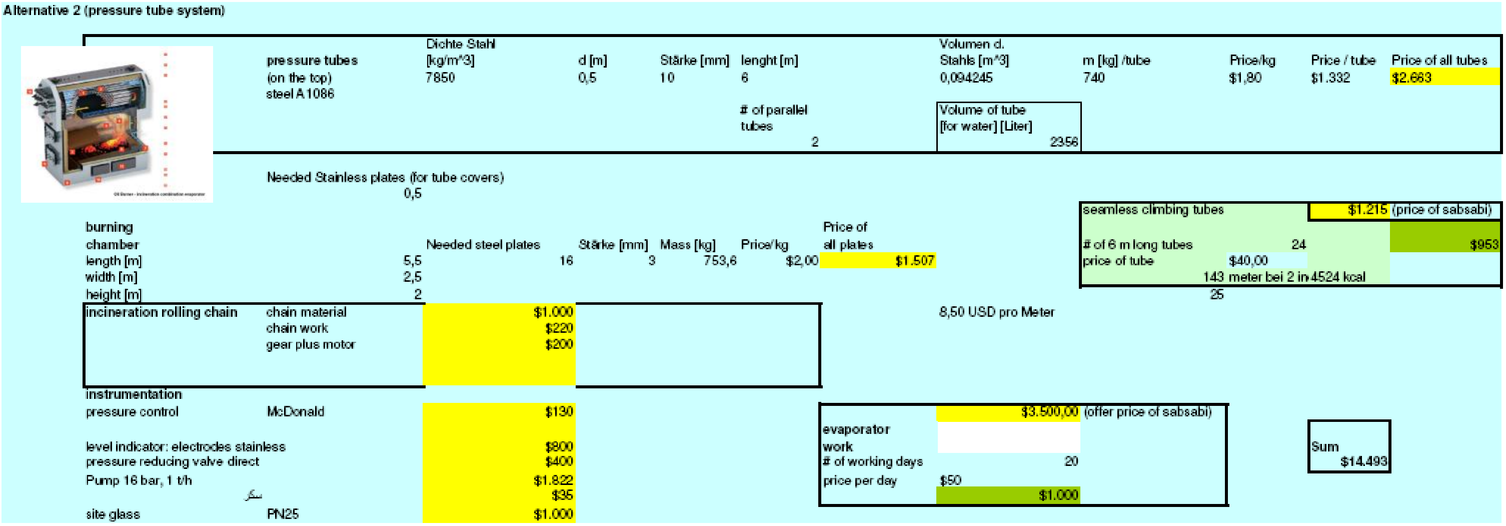
270514AECENAR_Businessplan_Budget2014_IncinerationVaporizer.pdf:



Alternative 2 (pressure tube system)

pressure tubes (on the top) steel A 1086	Dichte Stahl [kg/m^3]	d [m]	Stärke [mm]	lenght [m]	Volumen d. Stahls [m^3]	m [kg] /tube	Price/kg	Price / tube	Price of all tubes
	7850	0,5	10	6	0,094245	740	$1,80	$1.332	$2.663
				# of parallel tubes 2	Volume of tube [for water] [Liter] 2356				

Needed Stainless plates (for tube covers) 0,5

burning chamber		Needed steel plates	Stärke [mm]	Mass [kg]	Price/kg	Price of all plates
length [m]	5,5	16	3	753,6	$2,00	$1.507
width [m]	2,5					
height [m]	2					

seamless climbing tubes		$1.215 (price of sabsabi)
# of 6 m long tubes	24	$953
price of tube	$40,00	
143 meter bei 2 in 4524 kcal		

25

8,50 USD pro Meter

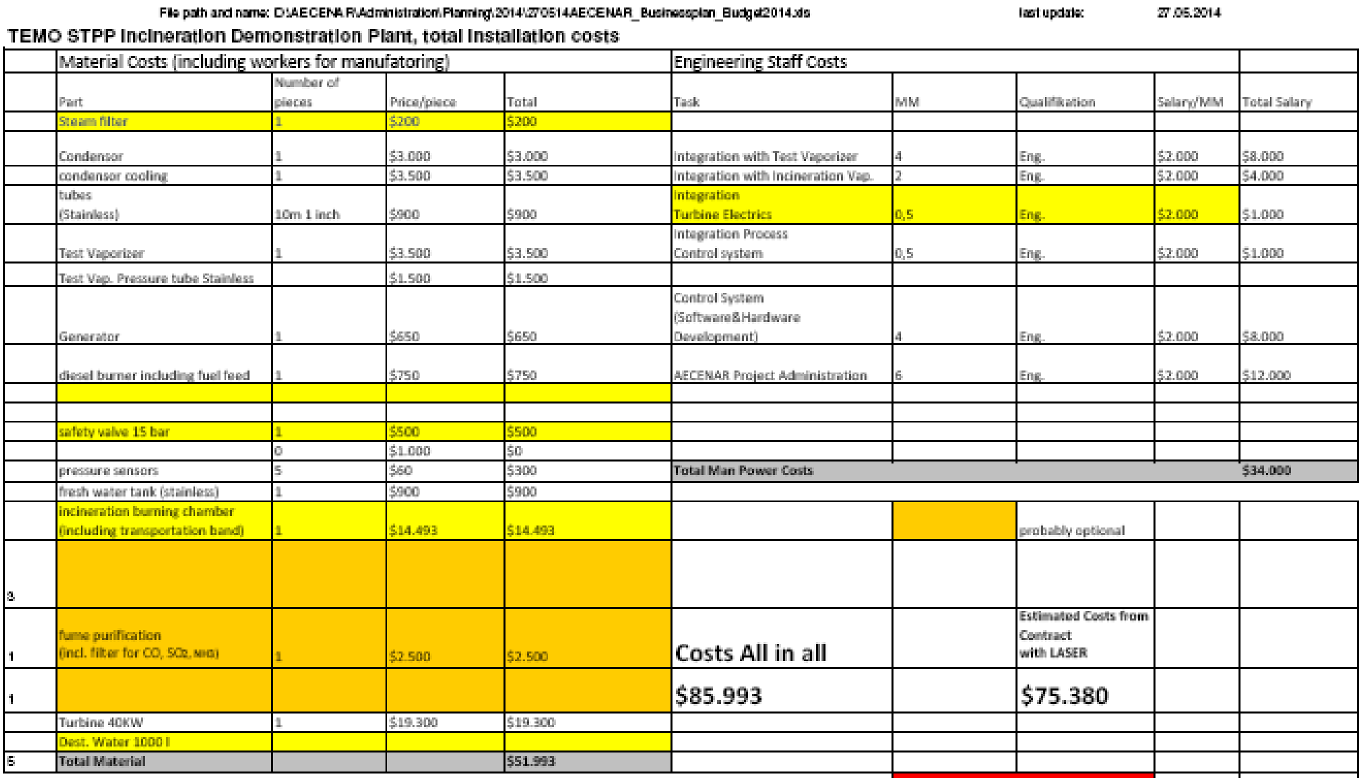
incineration rolling chain	chain material	$1.000
	chain work	$220
	gear plus motor	$200

instrumentation		
pressure control	McDonald	$130
level indicator: electrodes stainless		$800
pressure reducing valve direct		$400
Pump 16 bar, 1 t/h		$1.822
	سكر	$35
site glass	PN25	$1.000

evaporator	$3.500,00 (offer price of sabsabi)
work	
# of working days	20
price per day	$50
	$1.000

Sum $14.493

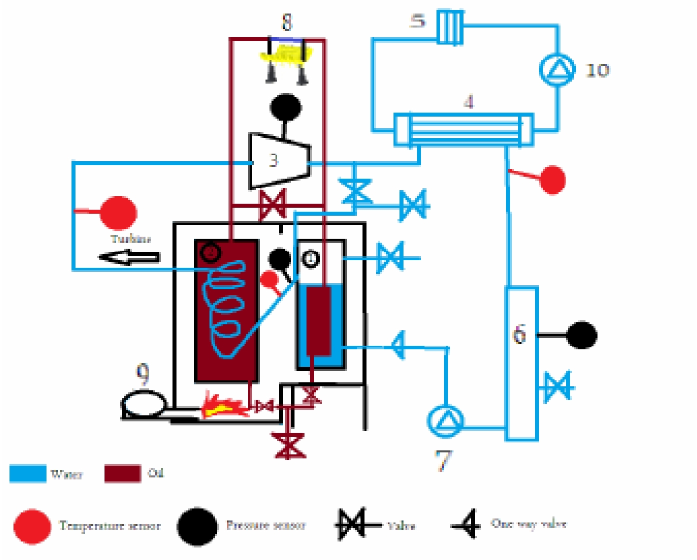
270514AECENAR_Businessplan_Budget2014_TEMO-IPPDemoPlant.pdf:



File path and name: D:\AECENAR\Administration\Planning\2014\270514AECENAR_Businessplan_Budget2014.xls last update: 27.05.2014

TEMO STPP Incineration Demonstration Plant, total installation costs

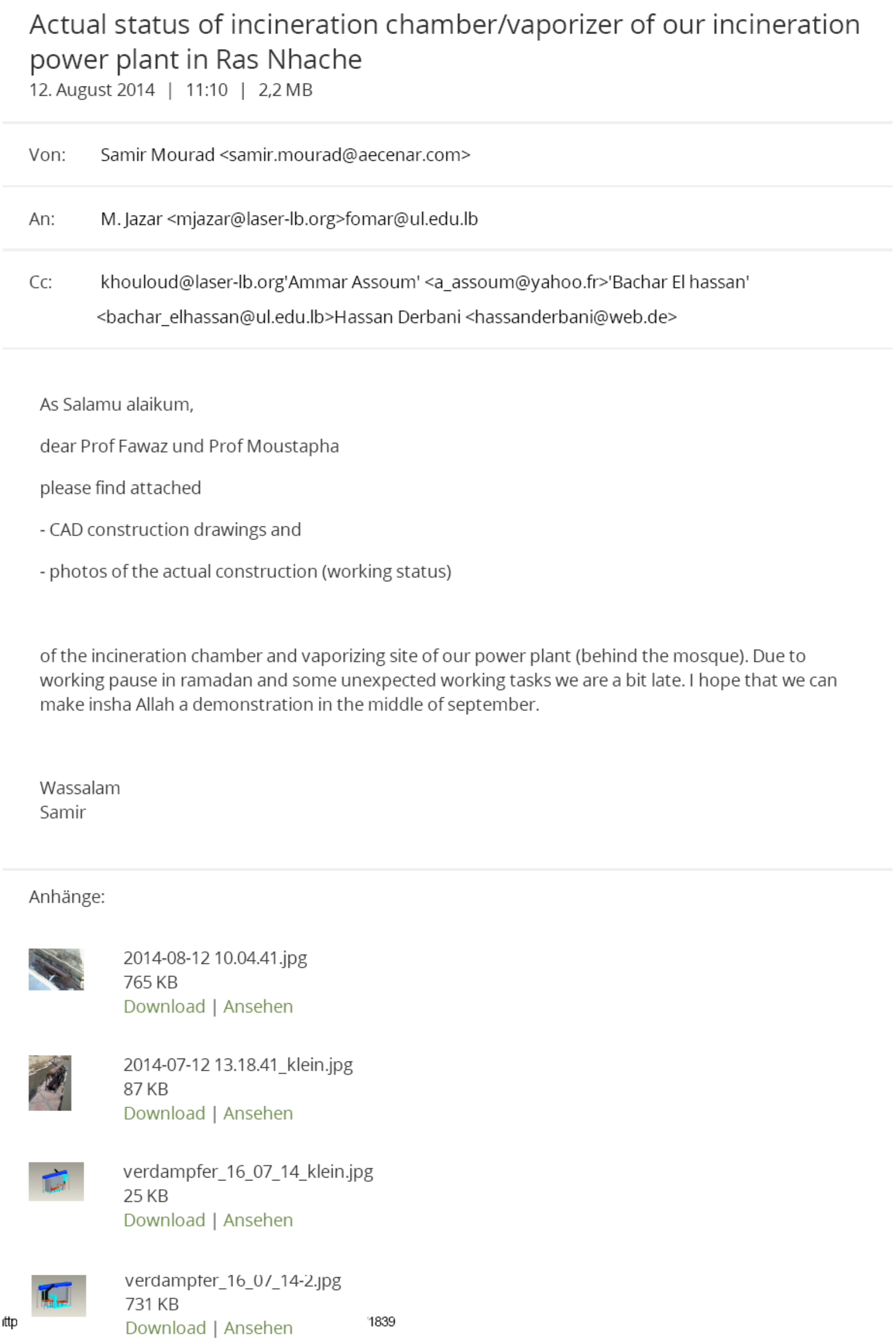
	Material Costs (including workers for manufatoring)				Engineering Staff Costs				
	Part	Number of pieces	Price/piece	Total	Task	MM	Qualifikation	Salary/MM	Total Salary
	Steam filter	1	$200	$200					
	Condensor	1	$3.000	$3.000	Integration with Test Vaporizer	4	Eng.	$2.000	$8.000
	condensor cooling	1	$3.500	$3.500	Integration with Incineration Vap.	2	Eng.	$2.000	$4.000
	tubes (Stainless)	10m 1 inch	$900	$900	Integration Turbine Electrics	0,5	Eng.	$2.000	$1.000
	Test Vaporizer	1	$3.500	$3.500	Integration Process Control system	0,5	Eng.	$2.000	$1.000
	Test Vap. Pressure tube Stainless		$1.500	$1.500					
	Generator	1	$650	$650	Control System (Software&Hardware Development)	4	Eng.	$2.000	$8.000
	diesel burner including fuel feed	1	$750	$750	AECENAR Project Administration	6	Eng.	$2.000	$12.000
	safety valve 15 bar	1	$500	$500					
		0	$1.000	$0					
	pressure sensors	5	$60	$300	**Total Man Power Costs**				**$34.000**
	fresh water tank (stainless)	1	$900	$900					
	incineration burning chamber (including transportation band)	1	$14.493	$14.493			probably optional		
3									
1	fume purification (incl. filter for CO, SO_2, NH_3)	1	$2.500	$2.500	Costs All in all		Estimated Costs from Contract with LASER		
1					$85.993		$75.380		
	Turbine 40KW	1	$19.300	$19.300					
	Dest. Water 1000 l								
5	**Total Material**			**$51.993**					
						Missing Budget $10.613			



1:Evaporator	4:Condenser	7:Pump	10:Pump
2:Overheater	5:Central heating	8:solar pipe	
3:Turbine	6:Water tank	9:Oil burner	

Figure:
Schema of Qubaisi Plant in May 2014

39.5 ActualStatus_Email120814



Actual status of incineration chamber/vaporizer of our incineration power plant in Ras Nhache

12. August 2014 | 11:10 | 2,2 MB

Von: Samir Mourad <samir.mourad@aecenar.com>

An: M. Jazar <mjazar@laser-lb.org>fomar@ul.edu.lb

Cc: khouloud@laser-lb.org'Ammar Assoum' <a_assoum@yahoo.fr>'Bachar El hassan' <bachar_elhassan@ul.edu.lb>Hassan Derbani <hassanderbani@web.de>

As Salamu alaikum,

dear Prof Fawaz und Prof Moustapha

please find attached

- CAD construction drawings and
- photos of the actual construction (working status)

of the incineration chamber and vaporizing site of our power plant (behind the mosque). Due to working pause in ramadan and some unexpected working tasks we are a bit late. I hope that we can make insha Allah a demonstration in the middle of september.

Wassalam
Samir

Anhänge:

2014-08-12 10.04.41.jpg
765 KB
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2014-07-12 13.18.41_klein.jpg
87 KB
Download | Ansehen

verdampfer_16_07_14_klein.jpg
25 KB
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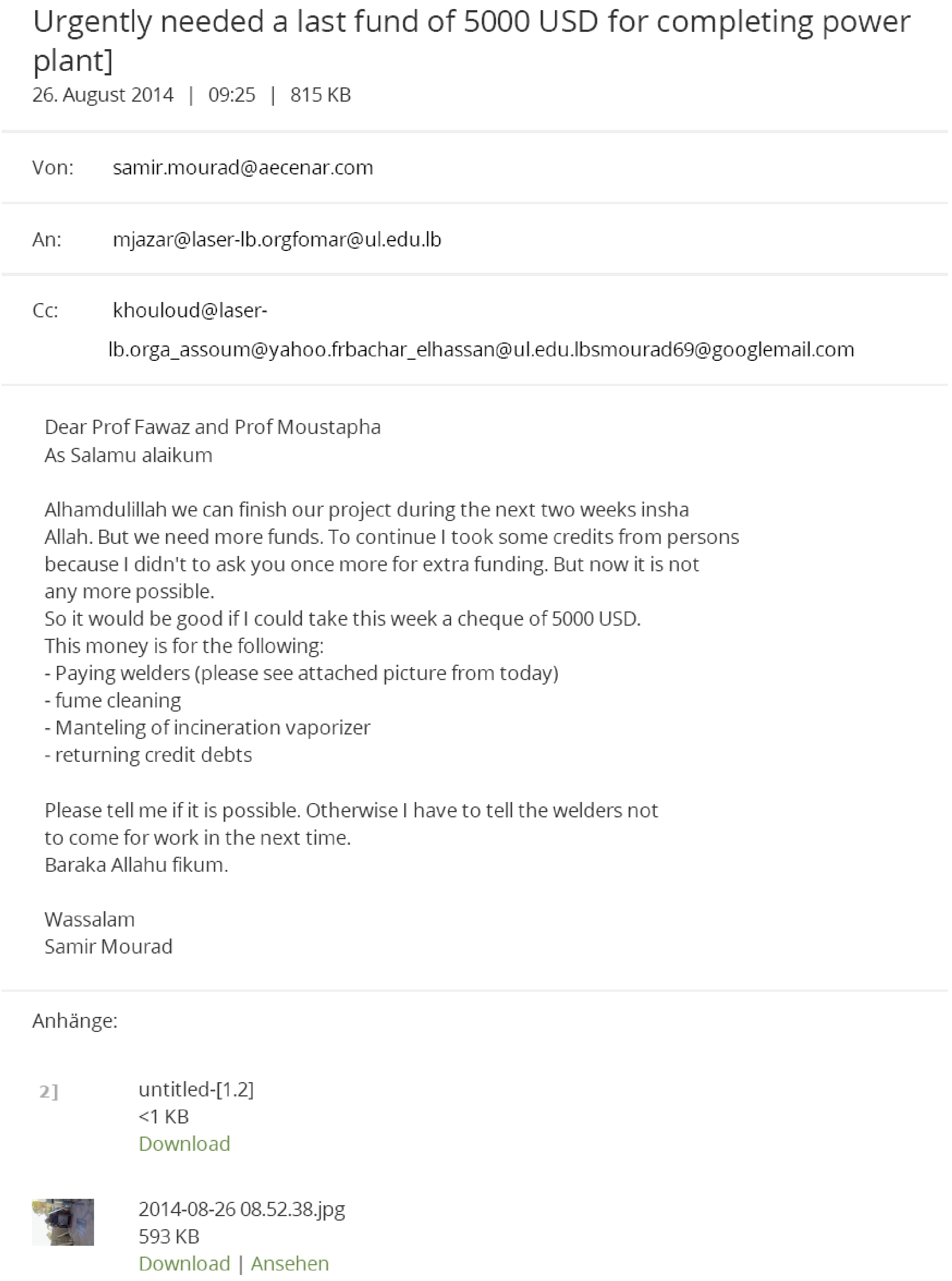
verdampfer_16_07_14-2.jpg
731 KB
Download | Ansehen

ttp 1839

39.6 Request_for_MoreBudgetEmail260814



Urgently needed a last fund of 5000 USD for completing power plant]

26. August 2014 | 09:25 | 815 KB

Von: samir.mourad@aecenar.com

An: mjazar@laser-lb.orgfomar@ul.edu.lb

Cc: khouloud@laser-lb.orga_assoum@yahoo.frbachar_elhassan@ul.edu.lbsmourad69@googlemail.com

Dear Prof Fawaz and Prof Moustapha
As Salamu alaikum

Alhamdulillah we can finish our project during the next two weeks insha Allah. But we need more funds. To continue I took some credits from persons because I didn't to ask you once more for extra funding. But now it is not any more possible.
So it would be good if I could take this week a cheque of 5000 USD.
This money is for the following:
- Paying welders (please see attached picture from today)
- fume cleaning
- Manteling of incineration vaporizer
- returning credit debts

Please tell me if it is possible. Otherwise I have to tell the welders not to come for work in the next time.
Baraka Allahu fikum.

Wassalam
Samir Mourad

Anhänge:

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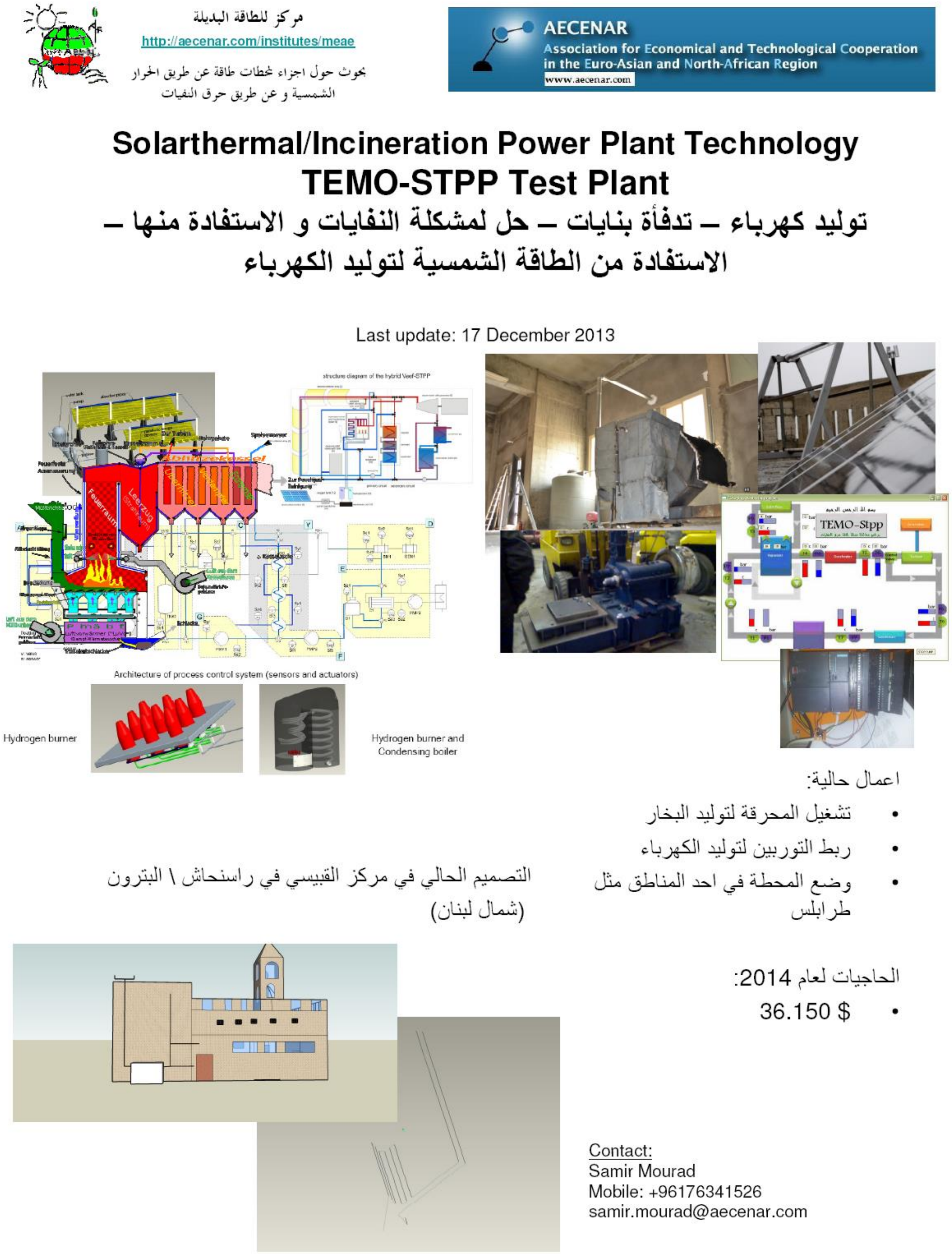
<1 KB

2014-08-26 08.52.38.jpg
593 KB

39.7 Published Project descriptions on www.aecenar.com

39.7.1 Project Status Dec 2013



مركز للطاقة البديلة
http://aecenar.com/institutes/meae
بحوث حول اجزاء لمحطات طاقة عن طريق الحرار
الشمسية و عن طريق حرق النفيات

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www.aecenar.com

Solarthermal/Incineration Power Plant Technology
TEMO-STPP Test Plant
توليد كهرباء – تدفأة بنايات – حل لمشكلة النفايات و الاستفادة منها –
الاستفادة من الطاقة الشمسية لتوليد الكهرباء

Last update: 17 December 2013

Architecture of process control system (sensors and actuators)

Hydrogen burner

Hydrogen burner and Condensing boiler

اعمال حالية:

- تشغيل المحرقة لتوليد البخار
- ربط التوربين لتوليد الكهرباء
- وضع المحطة في احد المناطق مثل طرابلس

التصميم الحالي في مركز القبيسي في راسنحاش \ البترون
(شمال لبنان)

الحاجيات لعام 2014:

- 36.150 $

Contact:
Samir Mourad
Mobile: +96176341526
samir.mourad@aecenar.com

39.7.2 Project Status Jan 2014

مركز للطاقة البديلة
http://aecenar.com/institutes/meae

Lebanese Association
for Scientific Research
(LASeR), Tripoli
www.laser-lb.org

Incineration Power Plant Technology
TEMO-STPP Test Plant
توليد كهرباء – حل لمشكلة النفايات و الاستفادة منها

Last update:
20 January 2013

Architecture of process control system (sensors and actuators)

اعمال حالية:

- تشغيل الحرقة لتوليد البخار
- ربط التوربين لتوليد الكهرباء
- وضع المحطة في انفه قرب طرابلس

يقدم المشروع فرص للتوظيف لمهندسي الميكانيك والكهرباء

التصميم الحالي
للوضع في 3 كنتينرات
في شركة
باسم العلي في انفه
(قرب طرابلس في
شمال لبنان)

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mjazar@laser-lb.org

39.7.3 Project Status Nov 2014

TEMO-IPP (Incineration Power Plant) - Demonstration Plant

video clip of finished demonstration power plant at Ras Nhache (Nov 2014)

39.8 Some Working packages

39.8.1 Concerning Condensor

39.8.1.1 Working plan from 24.1.14 (Omar Solh, Abdulqader Osman)

Date	Tasks	Responsible	Meetings
26/1/2014	Buy Condensor	Omar + AD	Central El Mina At 2:00P.M
27/1/2014	Buy the Valves + Flanges sizes	Omar + AD	From Balita and (Flanges at the condenser in anfi ← Omar)
28/1/2014	Flange (and cup) for installation	Omar	Get it From daoura
29/1/2014	Full installation of condensor	Omar + AD	Location
30/1/2014	Full installation of condensor	Omar + AD	Location
31/1/2014	Full installation of condensor	Omar + AD	Location

week 1 : Finish installation of 470ondenser + request the valves From Balita and frange from dura.

Meeting at ras nhash planning during week 1 to make a new plan for week 2 and discuss it together.

Inform Mr Samir Mourad about any news and any new taks and any problems we face it.

We submit at the end of every week our receipt to mr samir and we receive our receipt every two weeks

Project protocol:

30.1.14	End of cooperation with A.O. on 30.1.14. Omar Solh hat Design vom Condensor mitgenommen, um bei Daura/Beirut ein Angebot einzuholen
3.2.14	Offer for condenser (32cmx200cm, 18 cooling pipes): 2500 USD
7.2.14	Offer for condenser (62cmx200cm, 32 cooling pipes): 7500 USD

39.8.2 September 2014

Date	Task	Responsible	Time	Costs
1.9.	Report - Update costs - Water tank - Flue gas purification - Water level control of pressure vessel	Samir	Tue, 30.9.	
	~~Finishing Manteling of burning chamber~~	~~Muhammad Akkumi~~	~~2 days~~	
	~~Adapting Turbine axis and generator axis~~			~~Material:~~ ~~Adapter: naufal, 80 USD,~~ ~~Dreherei: 150 USD~~
	Safety valve + instrumentation			
27.9.	Testing: Filling water, fitting with wood			
27.9.	Installing Level Control	Abudi	28.9.	
27.9.	~~Painting: blue for air~~			
27.9.	Connecting three phase cable (output cable – lamps, Steckdosen)			
27.9.	Completing integration of ProE model	Bilal	28.9.	
27.9.	Completing installation of Flue Gas Purification	Abdullah	28.9.-30.9.	Ammoniac Pressure cylinder:

40 References

Rauchgasreinigung,
https://www.itad.de/information/wiefunktionierteinemva/337.Beschreibung_mit_Animationen.html

Putting Power Plant onto mobile platform and system design of additional components of NLAP-WEDC (2016 -2018)[32]

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[32] From [Kamareddine 2015] and [EIA Rayhaniyye 2018]

41 Migrating Elements to mobile platform

quality	TOT (طول)	عدد	اجمال (متر)	quality	طول (متر)	ferric sheet	
TOT (عرض 80 سنت)	4	3	12	حديد (عرض	2	4	sorting house
TOT(عرض 80 سنت)	2.2	3	6.6	قضيب حديد ف	6	4	
TOT(عرض 80 ست)	2.23	18	40.14				incinerator's house
TOT(عرض 80 ست)	1.9	11	20.9				turbine's house
TOT(عرض 80 ست)	0.9	3	2.7				
TOT(عرض 80 ست)	1.9	2	3.8				
Total m of 0.8 TOT sheet			86.14				

Table 14: List of materials sent to a commercial enterprise

41.1 Sorting house

Figure 37:basic of sorting house

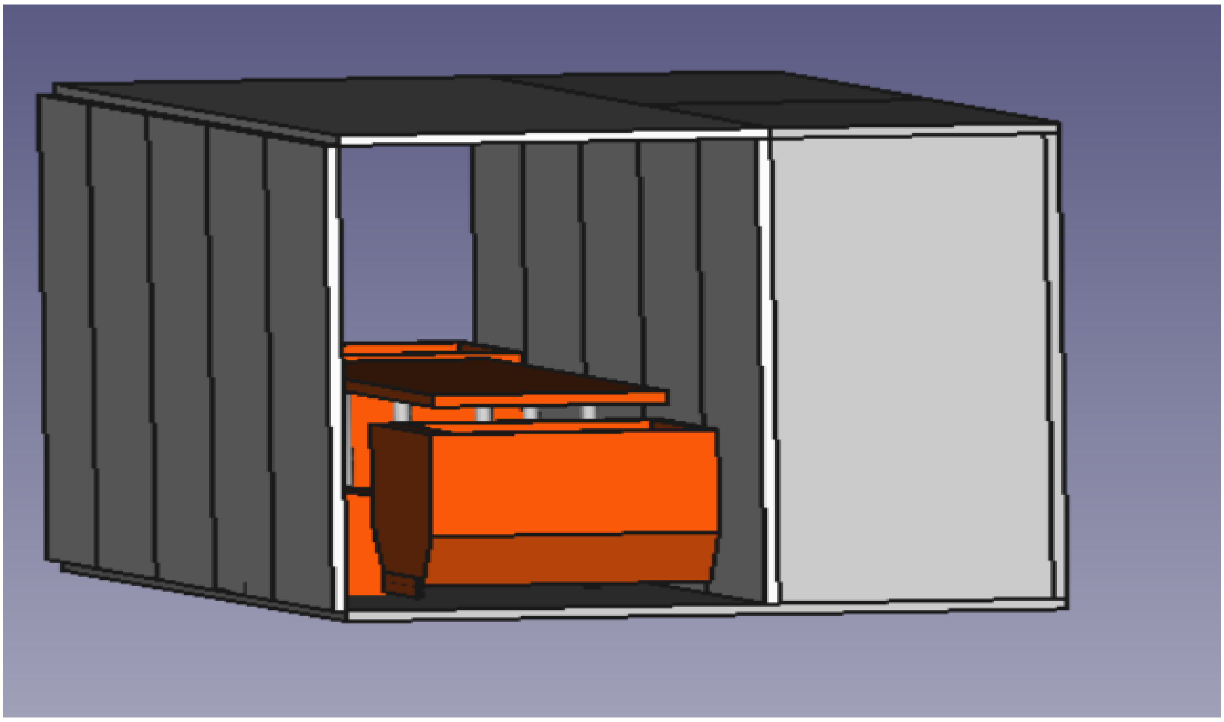


Figure 38: sorting house by freecad

Figure 39: sorting house

41.2 Turbine's house

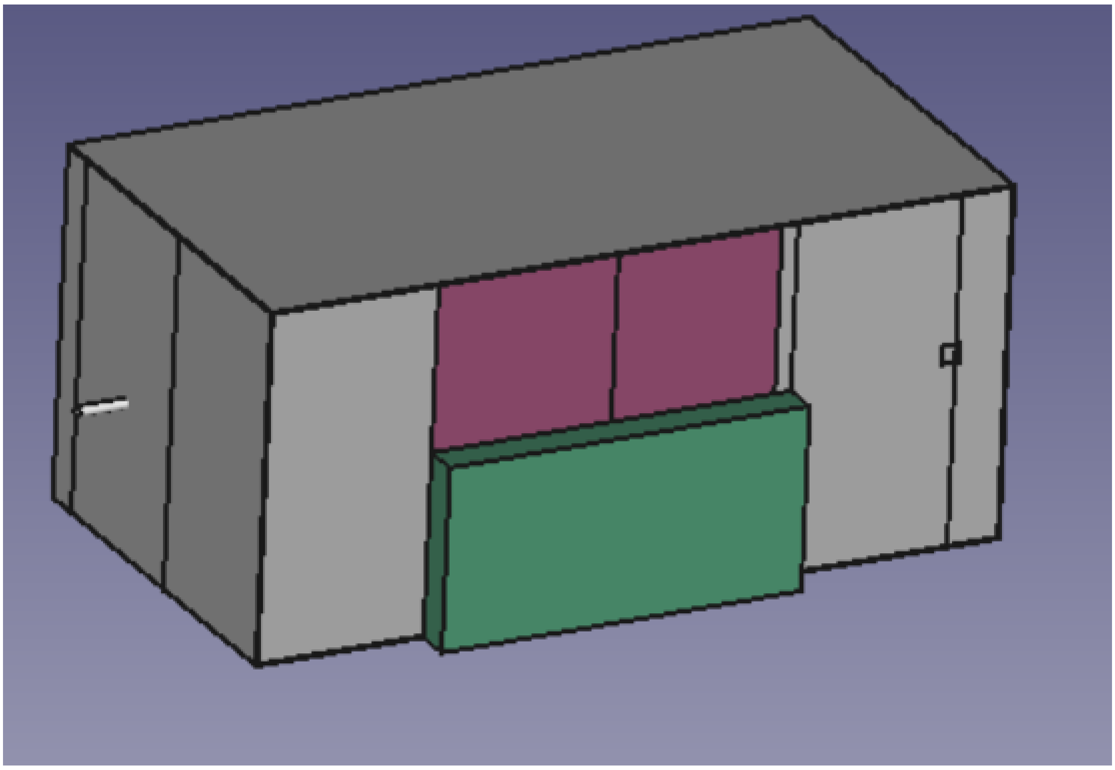


Figure 40: front view of turbine's house (freecad)

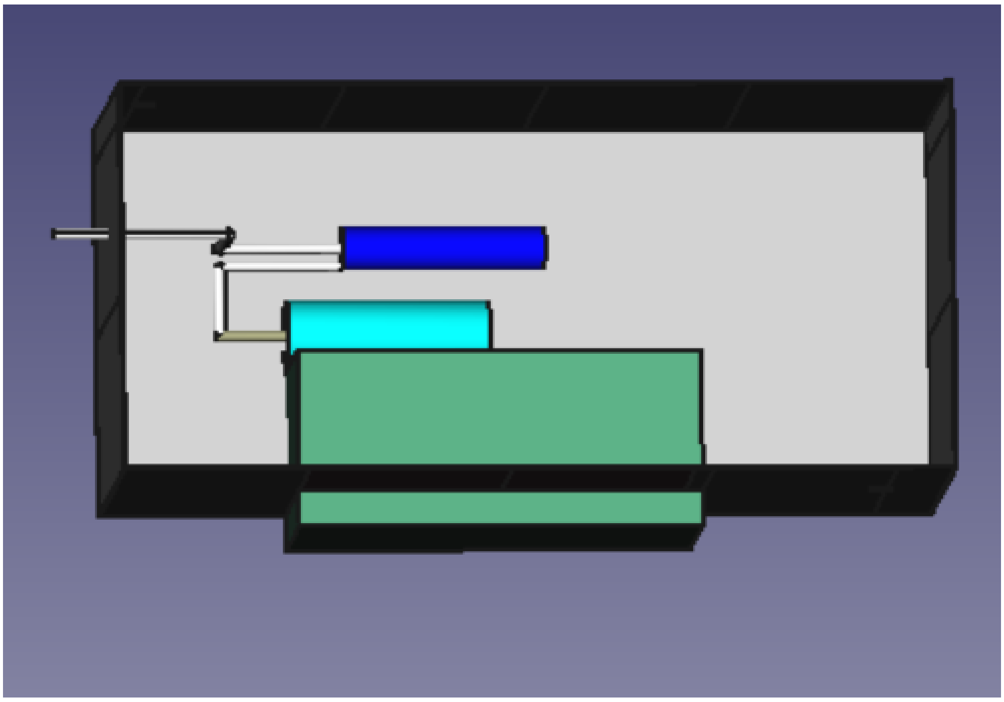


Figure 41:top view of turbine's house (freecad)

41.3 Integration of whole plant

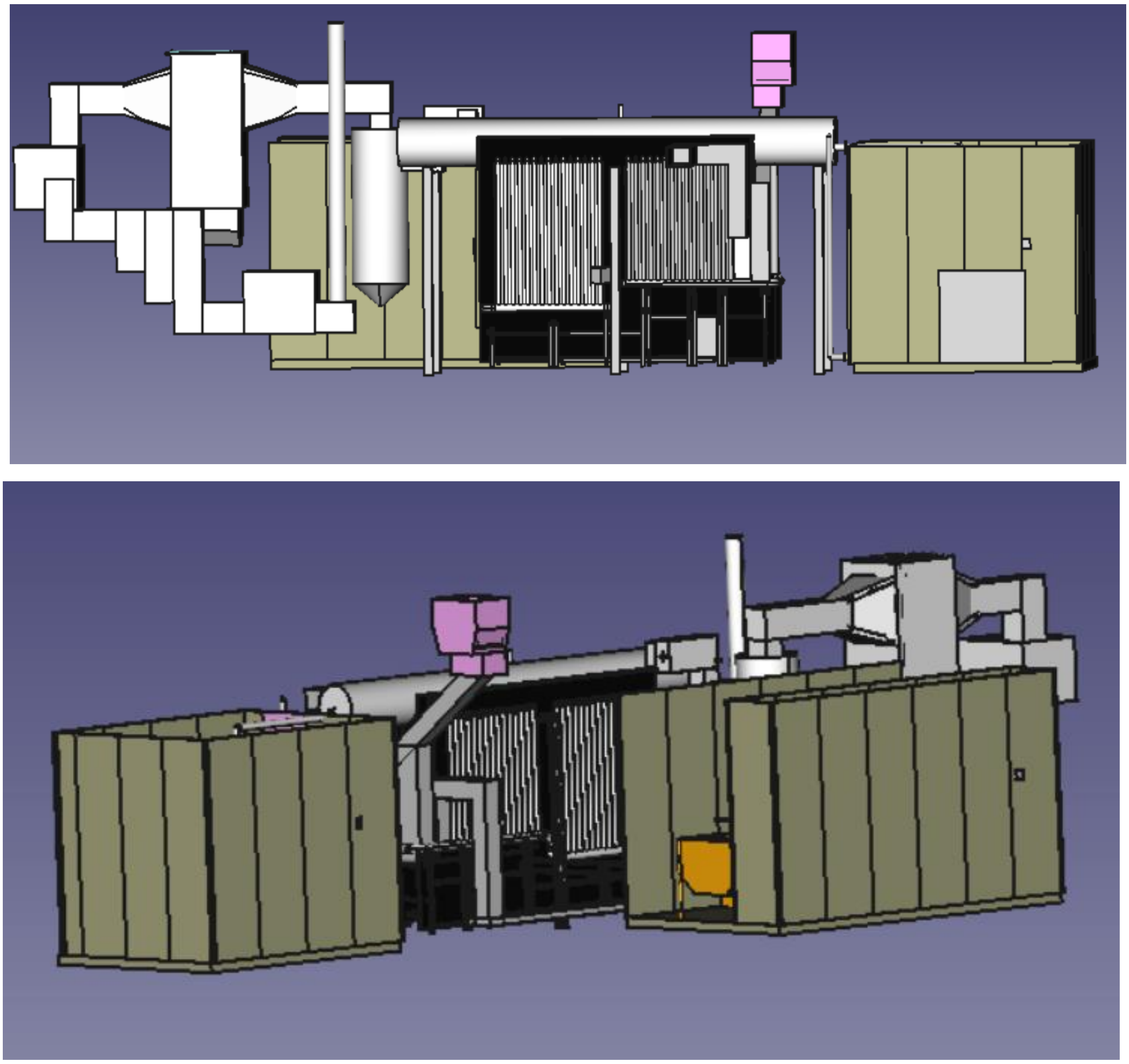


Figure 42:integration of incinerator system (freecad)

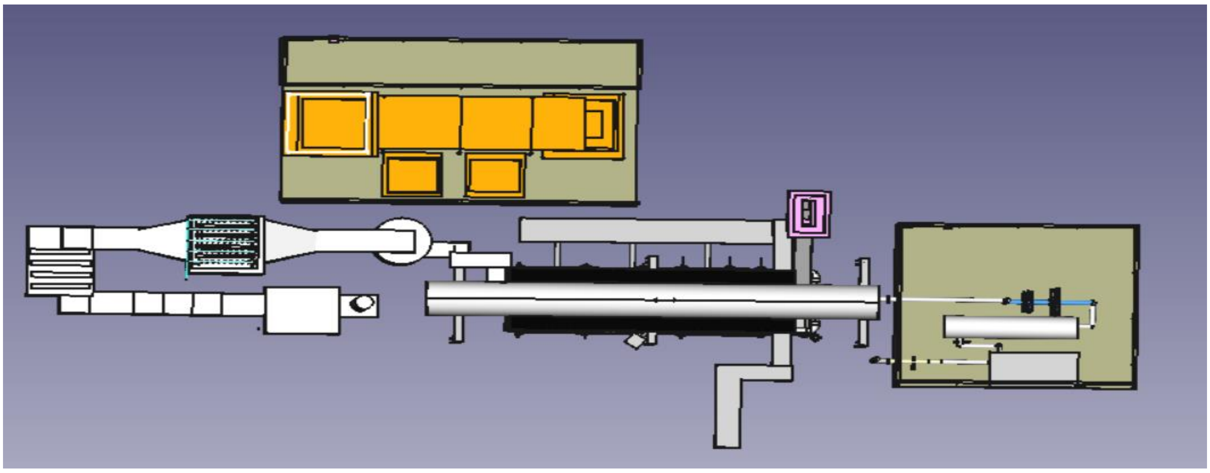


Figure 43:top view of incinerator (freecad)

After that, a simple coloration relized to the station .

Finally, all parts of the station are transferred to a mobile platform with a grue.thus , the station can be operated in any place we want to get rid of non-hazardous waste by incineration and produce at the same time electricity .

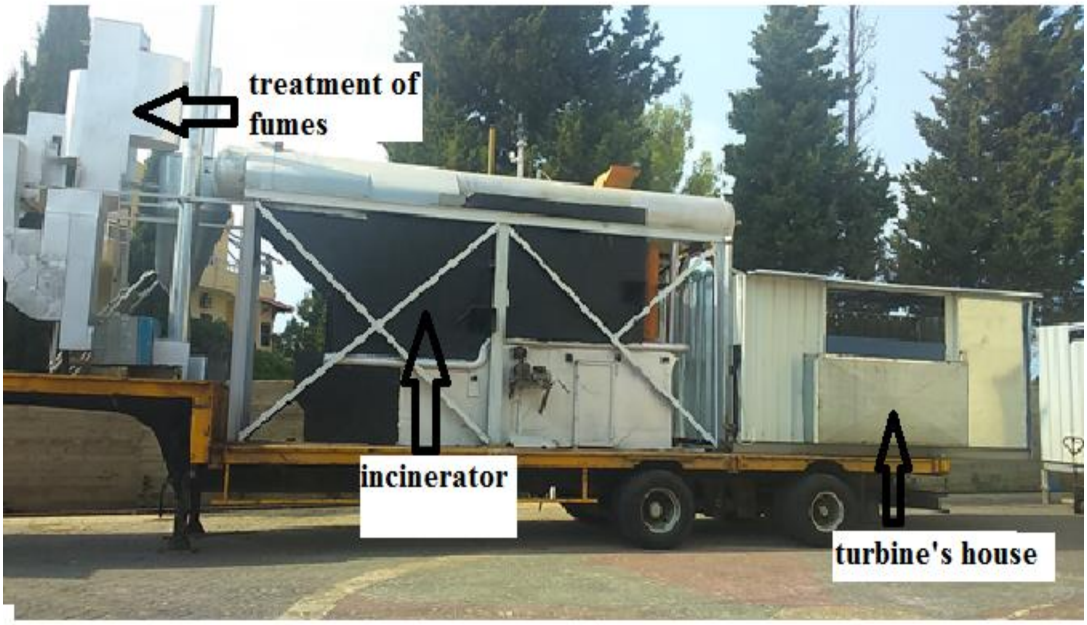


Figure 44:incinerator on mobile platform

41.4 COMPLETING OF INTEGRATION OF TEMO-IPP INCINERATION POWER PLANT

quality (width 80cm)	**TOT (height m)**	**quantity**	**total m**	**quality**	**height m**	**iron sheet**	
TOT	**4**	**3**	**12**	**iron (width 2m)**	**2**	**4**	**sorting house**
TOT	**2.2**	**3**	**6.6**	**Empty iron bar (40 mm, 40**	**6**	**4**	
TOT	**2.23**	**18**	**40.14**	**Door hinges**		**8**	**incinerator house**
TOT	**1.9**	**11**	**20.9**				**turbine house**
TOT	**0.9**	**3**	**2.7**				
TOT	**1.9**	**2**	**3.8**				
Total meter of TOT sheet			**86.14**				

Table 17: List of materials necessary to covering the power plant

41.4.1 Sorting house

41.4.1.1 THE PROCESS OF SORTING WASTE

Waste sorting is a principle basic in the plant because of its importance in reducing the proportion of toxic emissions from the burning of some types of plastics pvc, as well as batteries and hospital waste. In addition to metal materials that are a reason to incomplete combustion.

Waste sorting will be in the following form:

Plastic box(PVC):

They are mostly found in: line pipe, credit card size, PVC films (marketed coils) used (in the form of adhesive film) as lamination or for the advertising print, or (in the form of stretch film) as packaging; Forex used as to the point of sale display (POS).

The elimination of this materials can reduce the emissions of dioxin and acid gas.

(15) **-Metal box**

- Batteries box

After the sorting, we can conclude that the incineration not include the harmful materials that can be produce by incineration a toxic gas as SO_2, NO_2, dioxin (product of incomplete combustion).

Thus, the main composition of fumes in this case is the dust. treatment was focused on dust by using a cyclone and an electro filter

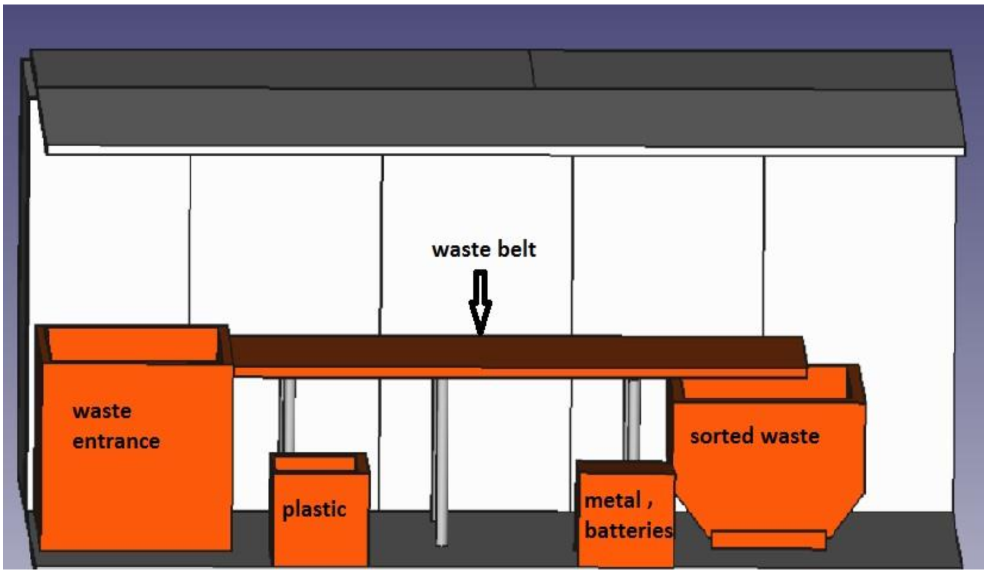


Figure 26: Sorting house by FreeCAD

Figure 59: basic of sorting house

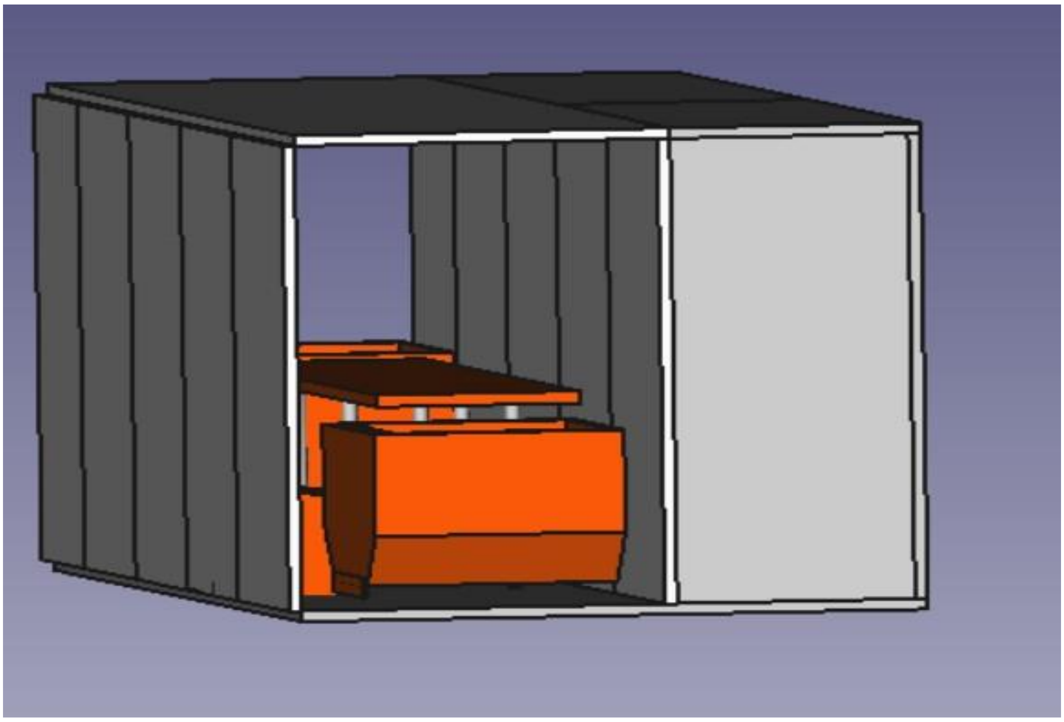


Figure 60: sorting house by FreeCAD

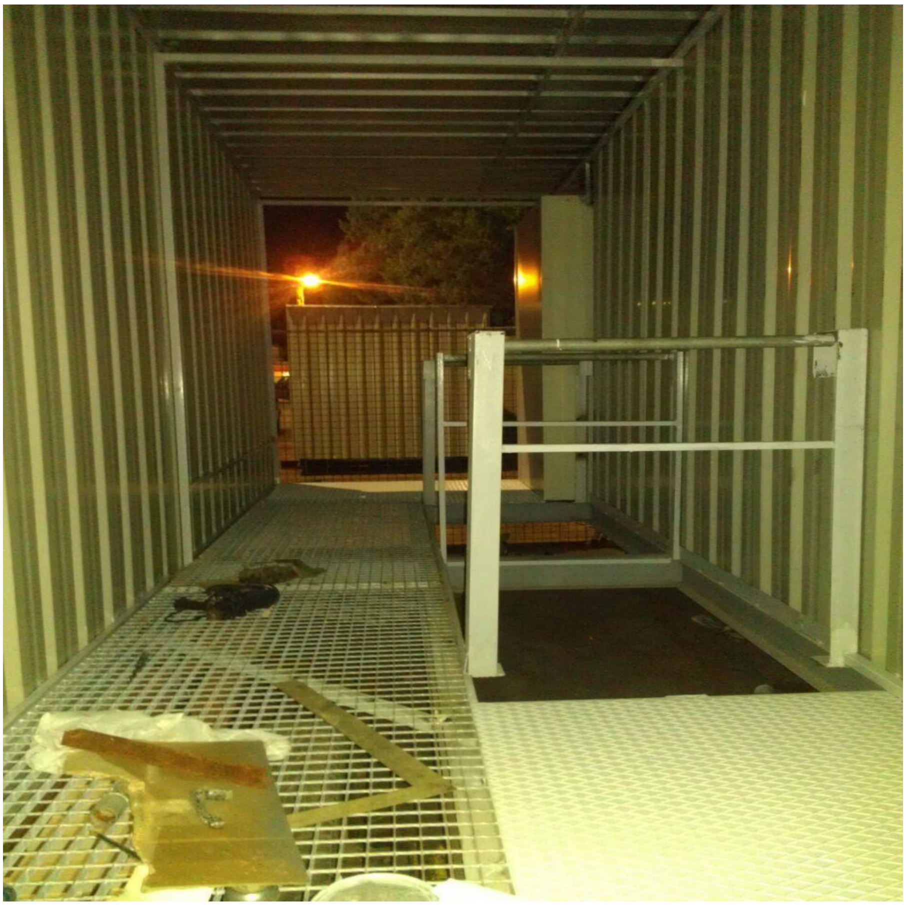


Figure 61: sorting house

41.4.2 Turbine house

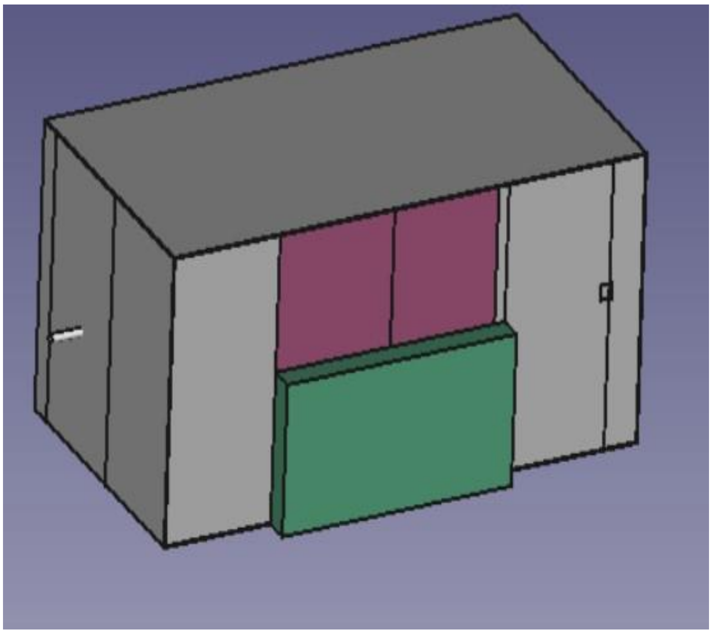


Figure 62: front view of turbine house (FreeCAD)

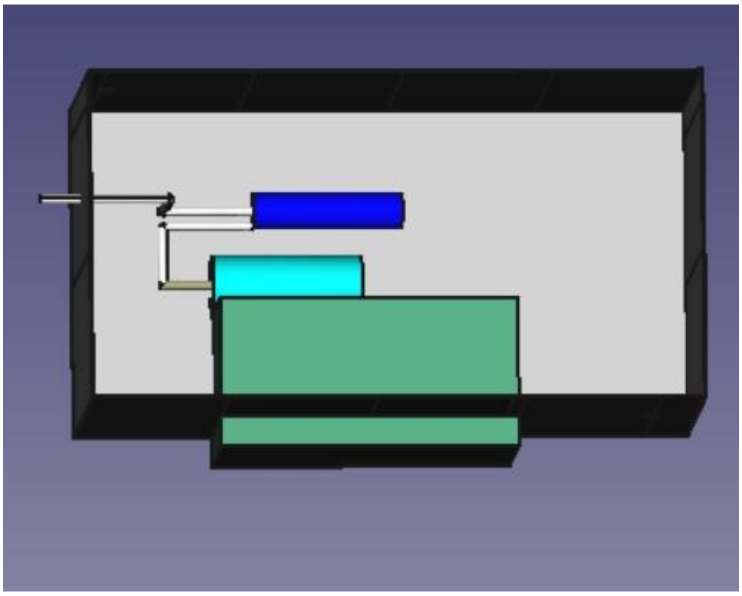
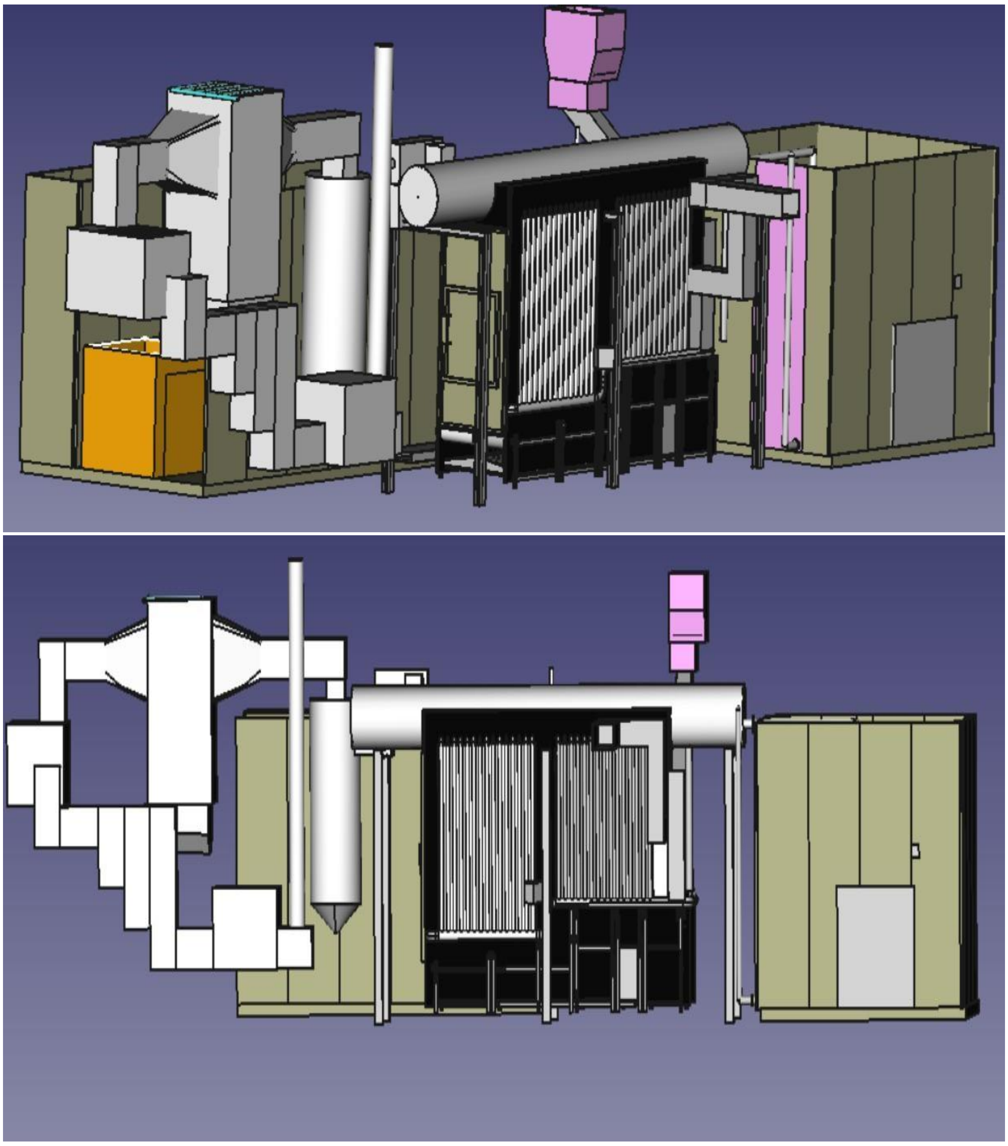


Figure 63: top view of turbine house (FreeCAD)

41.4.3 Integration



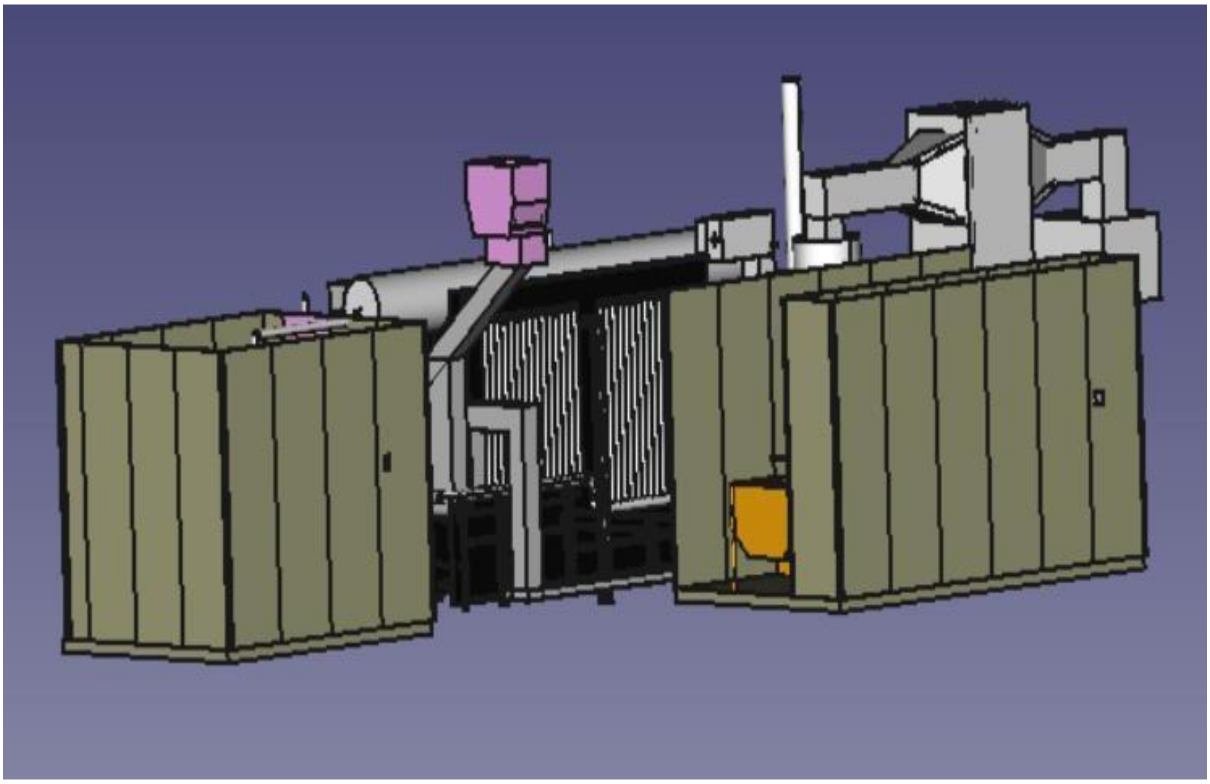


Figure 64: integration of incinerator system (FreeCAD)

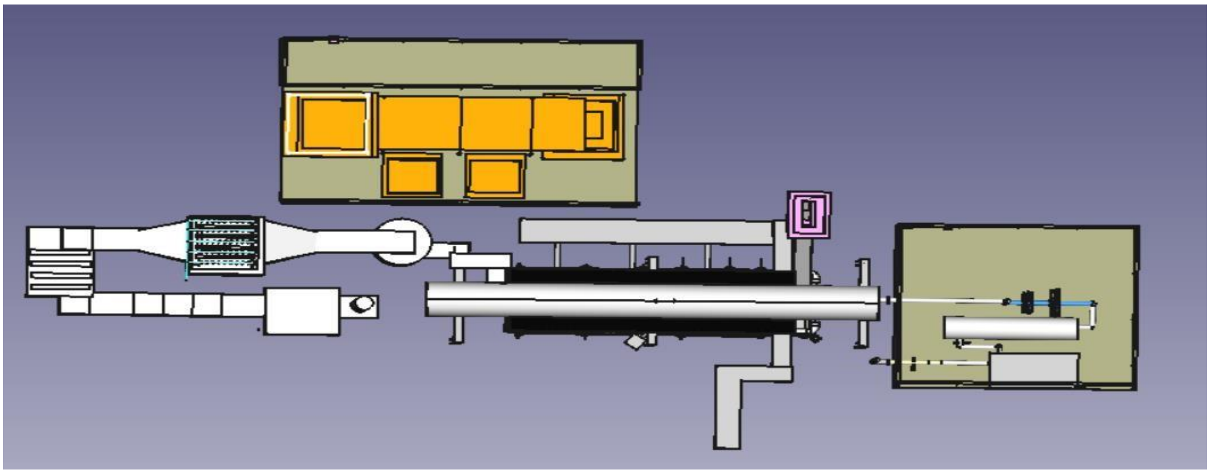


Figure 65: top view of incinerator (FreeCAD)

After that, a simple coloration relized to the station .

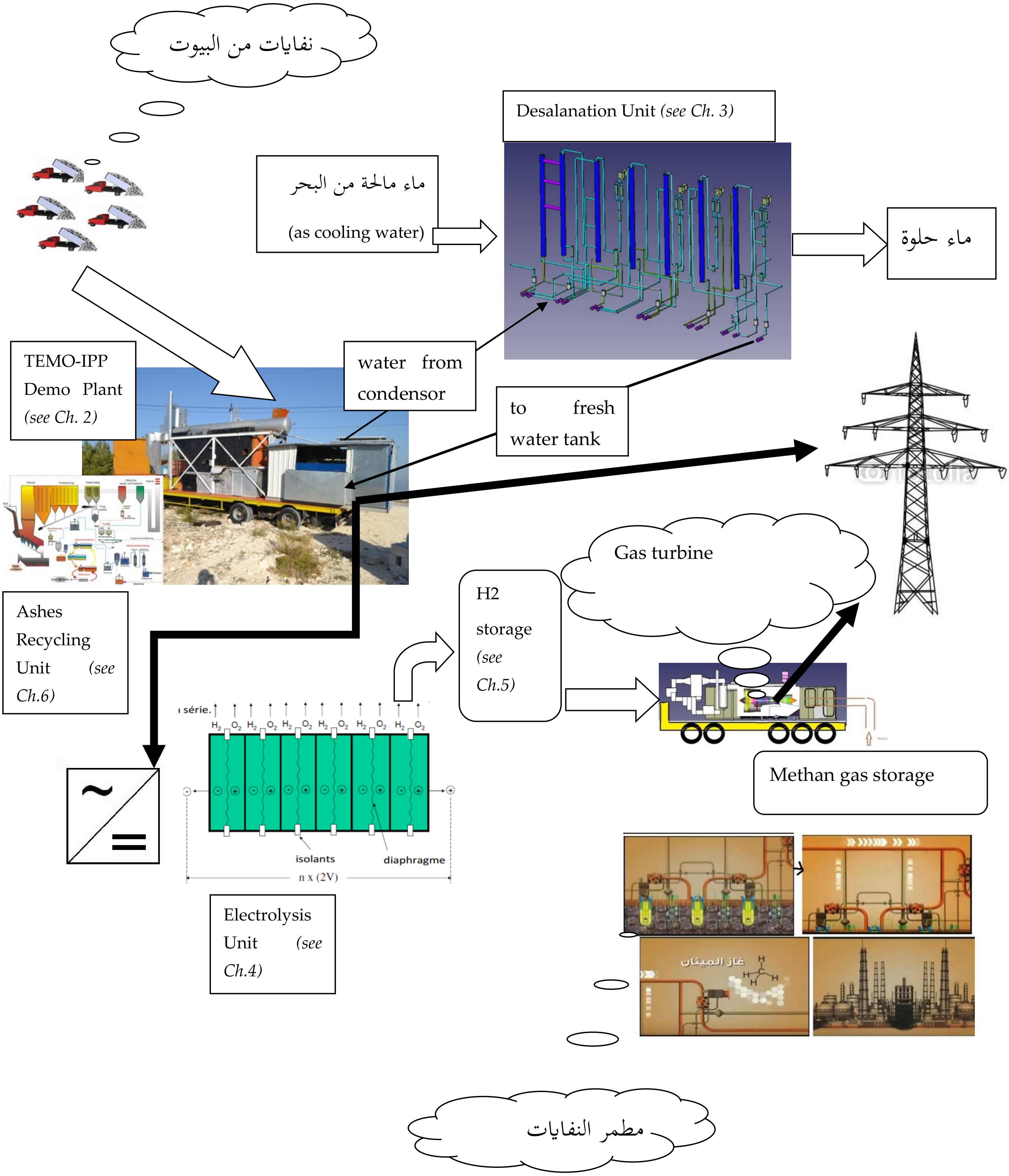
Finally, all parts of the station are transferred to a mobile platform with a grue.thus , the station can be operated in any place we want to get rid of non-hazardous waste by incineration and produce at the same time electricity .

Figure 66: incinerator on mobile platform

المحطة وضعت ارض في الشربين في راسنحاش – باذن من الاستاذ كميل مراد جزاه الله خيرا.

For more details see [Kamareddine 2016] and TEMO-IPP Reports 2012-2014.

42 Additional Components of Waste to electricity demonstration cycle



نفايات من البيوت

Desalanation Unit *(see Ch. 3)*

ماء مالحة من البحر

(as cooling water)

ماء حلوة

TEMO-IPP Demo Plant *(see Ch. 2)*

water from condensor

to fresh water tank

Gas turbine

H2 storage *(see Ch.5)*

Ashes Recycling Unit *(see Ch.6)*

Methan gas storage

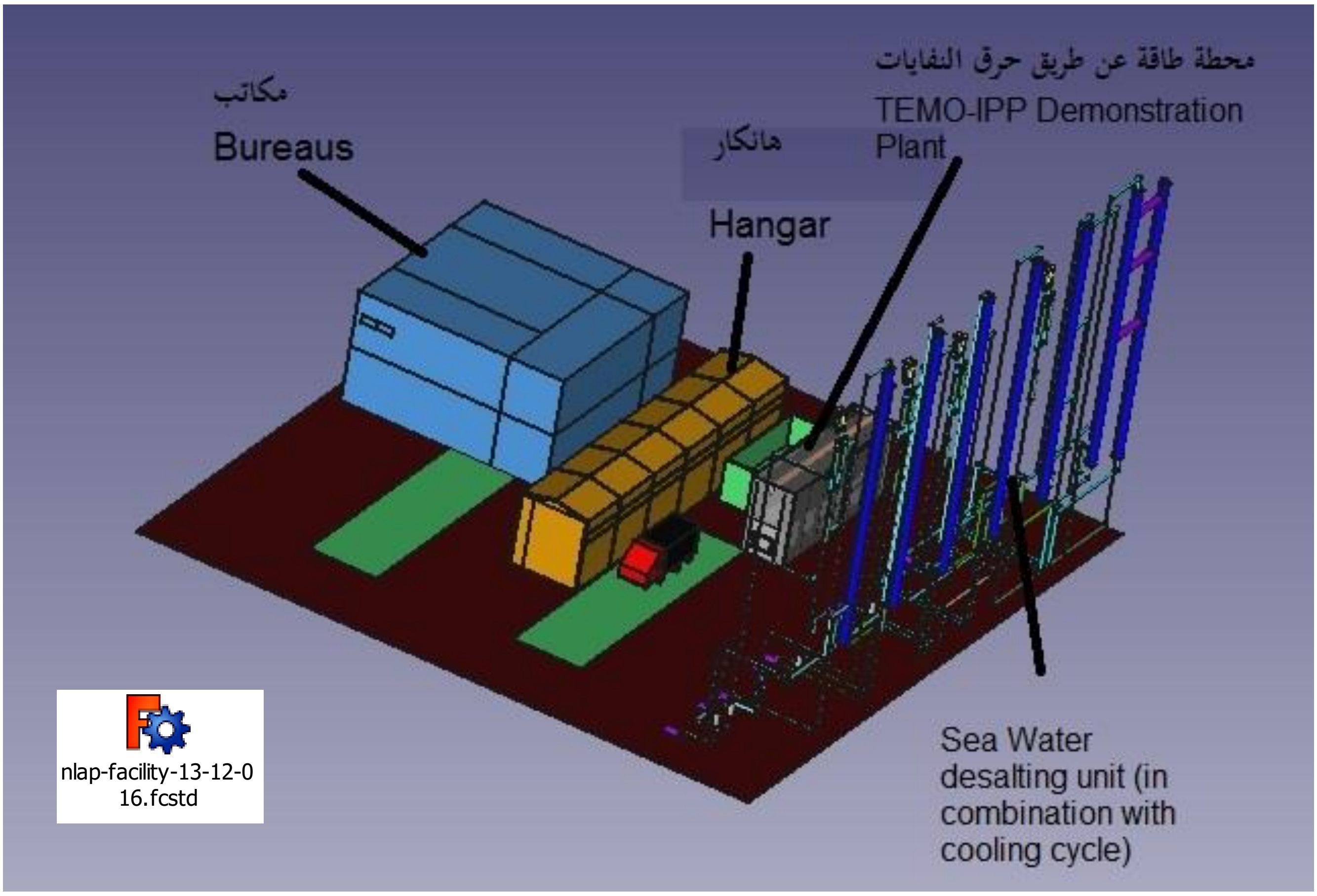
Electrolysis Unit *(see Ch.4)*

مطمر النفايات

43 Ground requirements and preparation for the demonstration power plant (متطلبات لموقع المحطة)

43.1 Option 1

43.1.1 المساحة (Area) 30m x 40m



40m x 40 m = 1600 qm

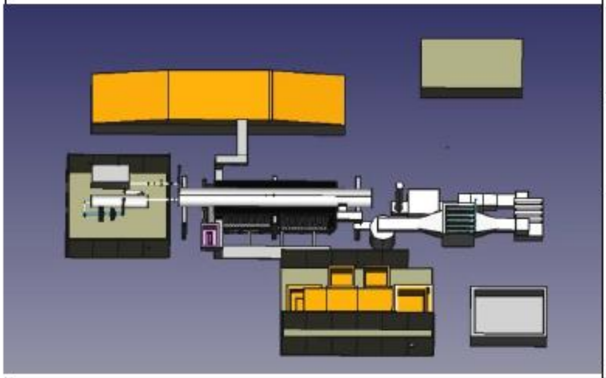
43.1.2 اجزاء الموقع

The facility has three parts:

- Waste to electricity demonstration cycle
- hangar for production of power plant devices and integration
- bureaus for engineering and administration

NLAP Incineration Demonstration power plant

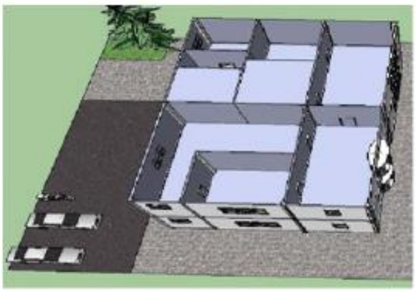
(30 m x 12m= 360 qm)

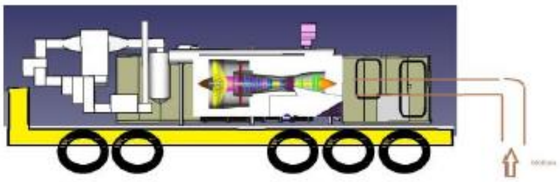


Water Tank (Cooling)

Desalting unit

Production Hangar (12m x 30 m = 300 qm)





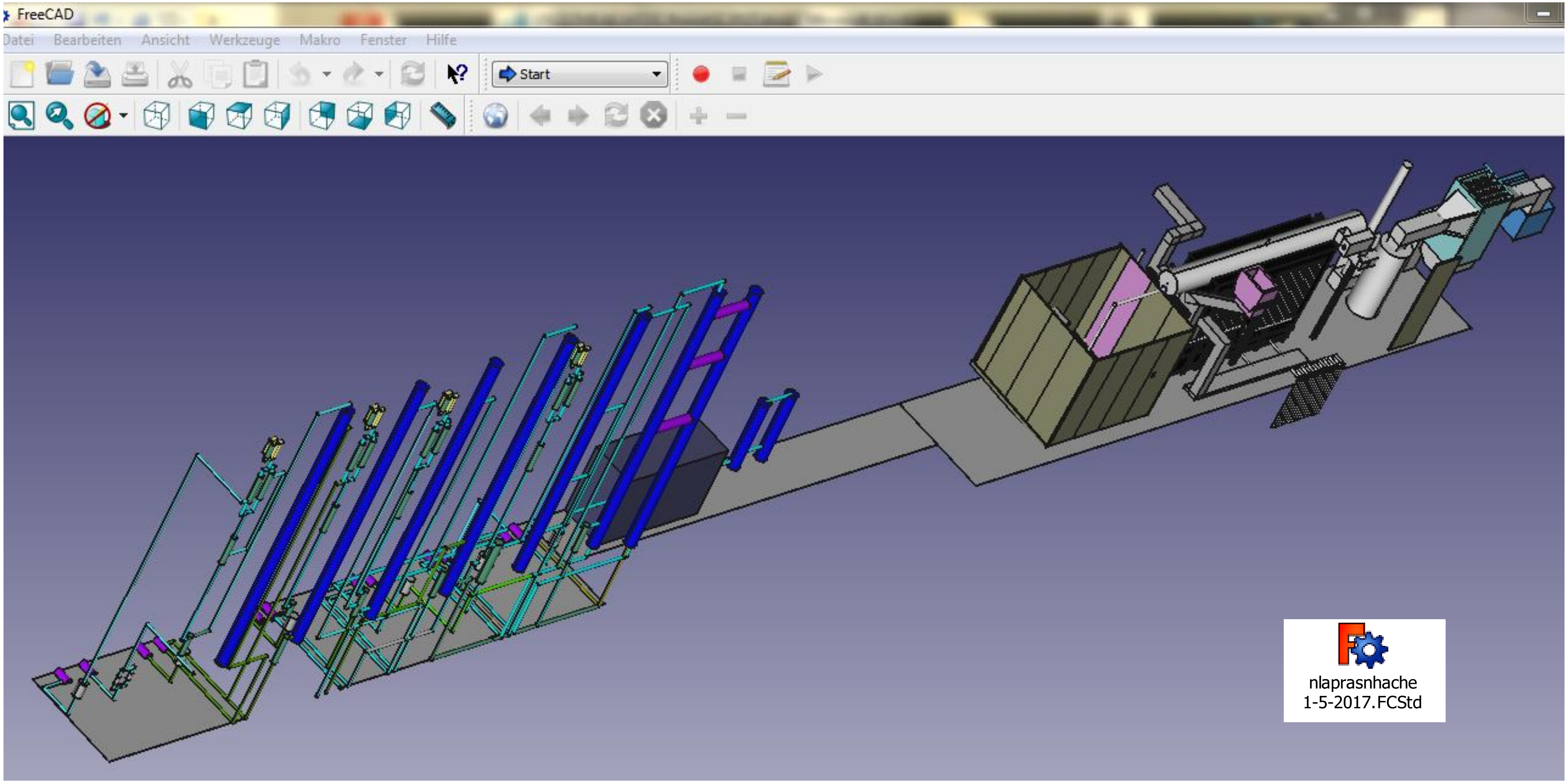
Bureaus (15m x 15 m = 150 qm)

طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.com

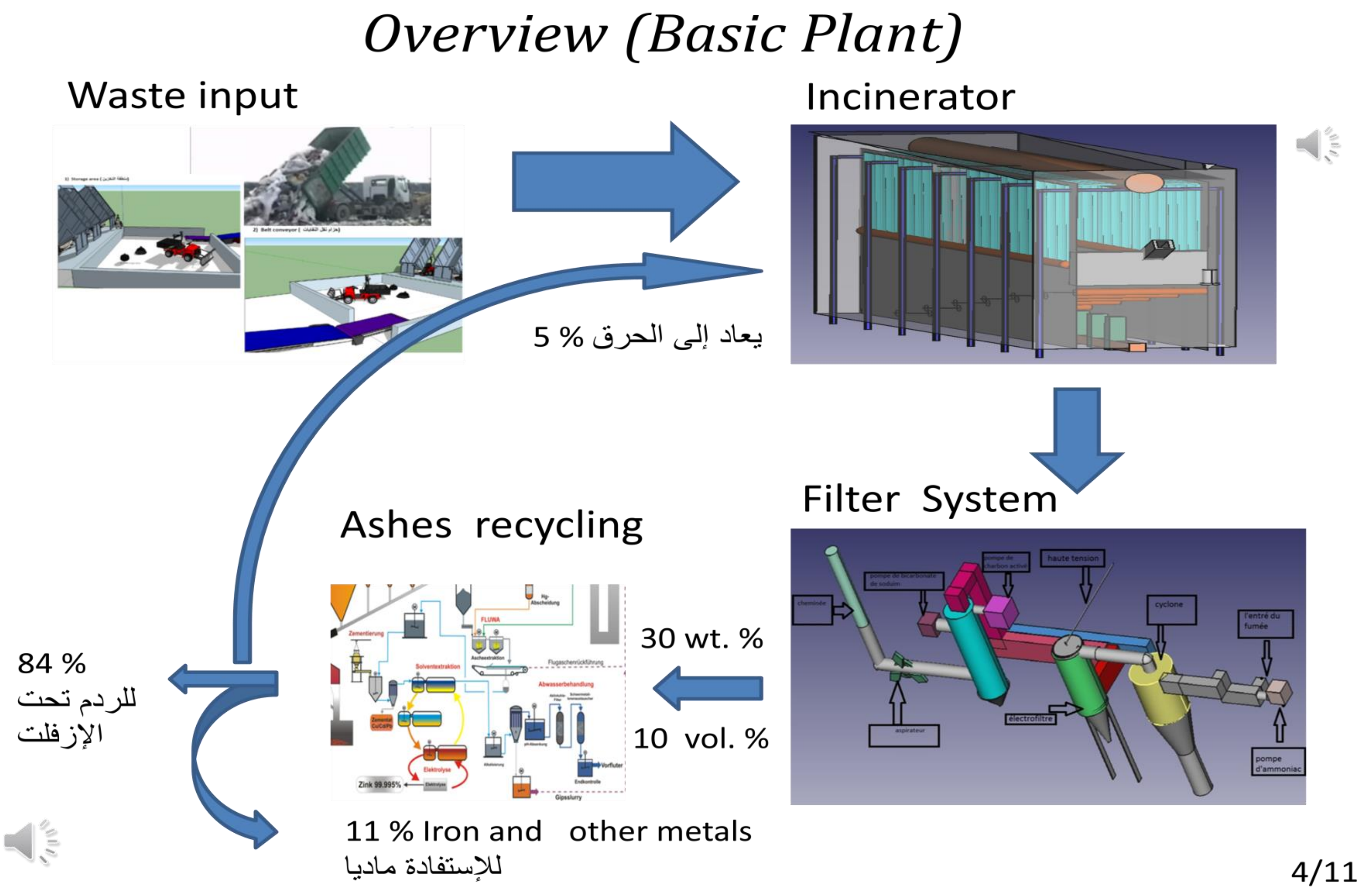
موقع مؤسسة طاقة الشمال

27m x 32 m = 864 qm

43.2 Option 2


FreeCAD
Datei
Bearbeiten
Ansicht
Werkzeuge
Makro
Fenster
Hilfe
Start
nlaprasnhache
1-5-2017.FCStd

43.3 Option 3



Overview (Basic Plant)

Waste input

Incinerator

5 % يعاد إلى الحرق

Filter System

Ashes recycling

30 wt. %

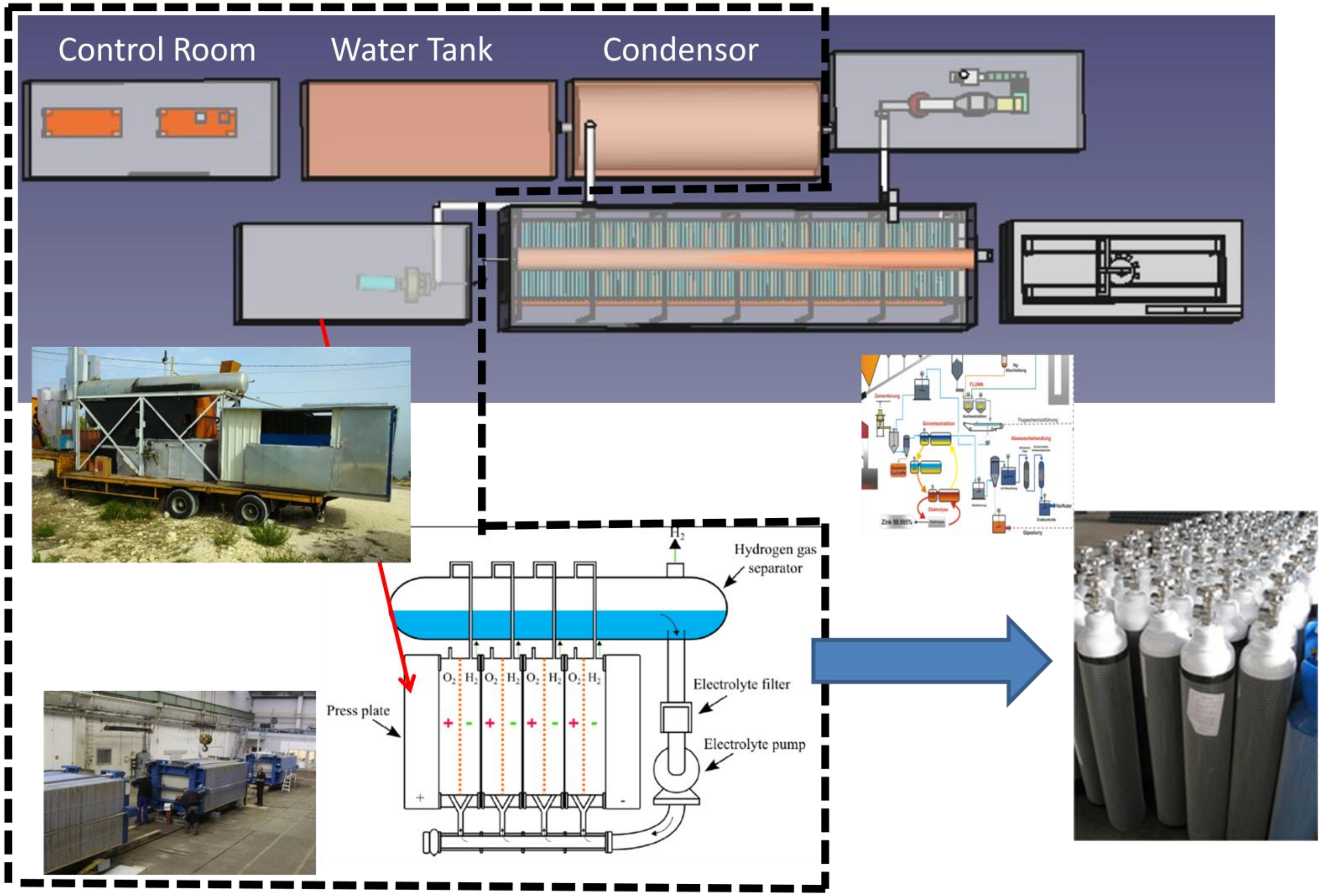
10 vol. %

84 %
للردم تحت
الإزفلت

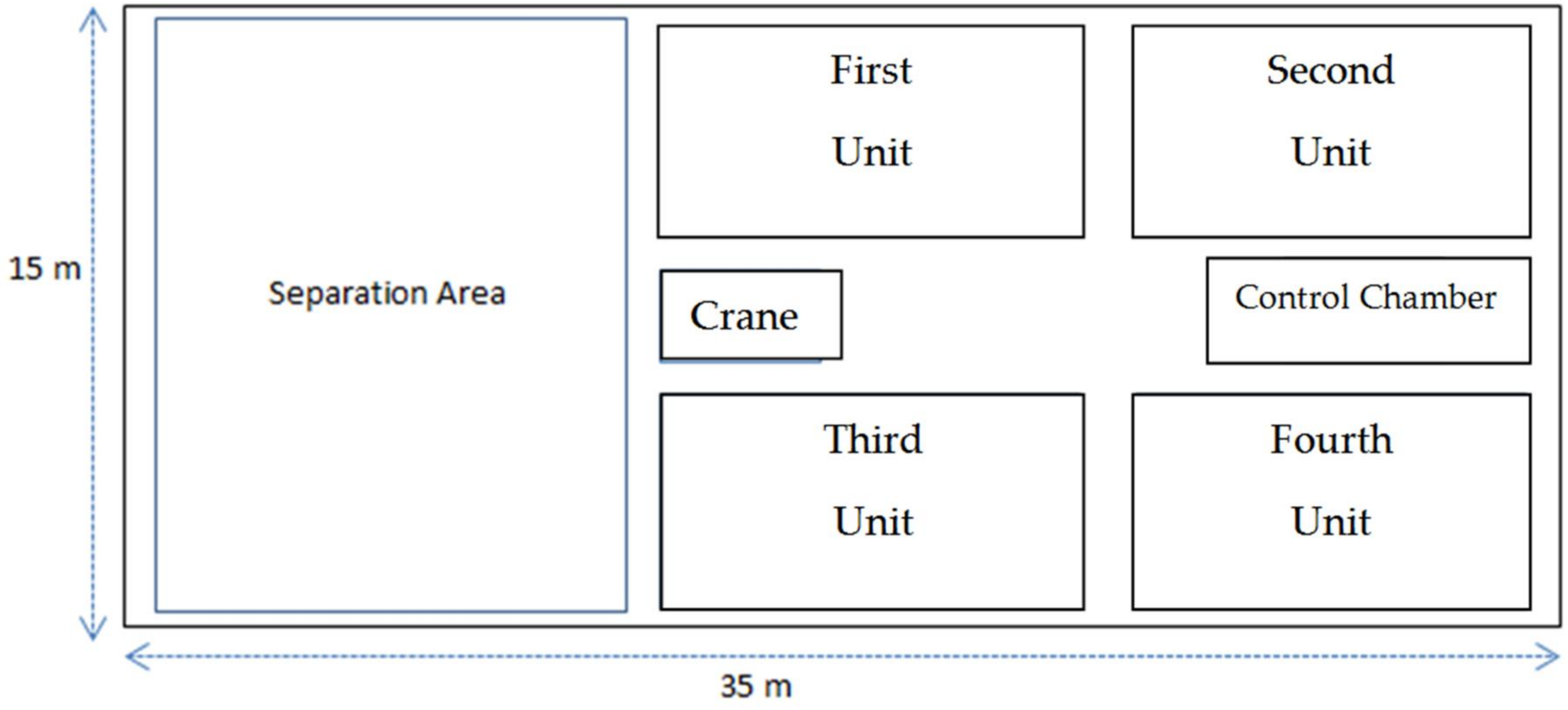
11 % Iron and other metals
للإستفادة ماديا

4/11

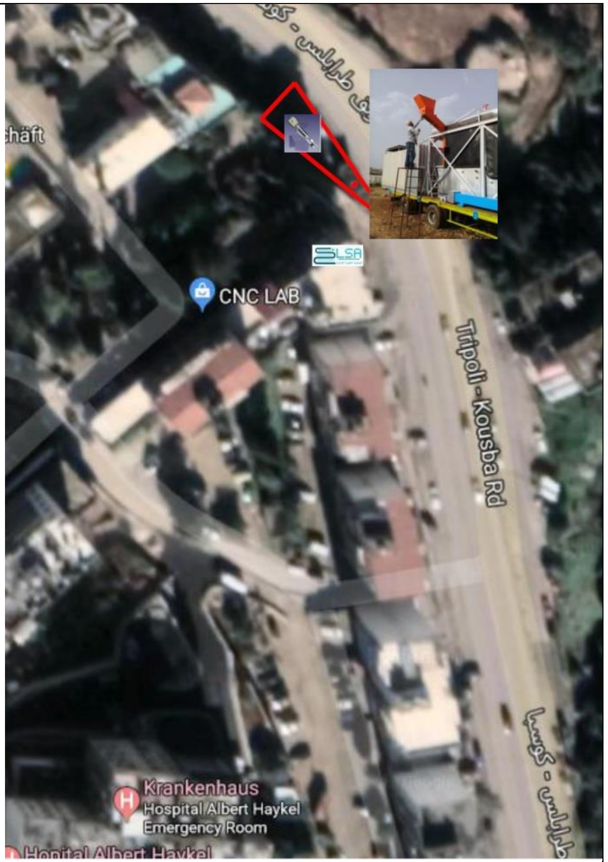
Overview (Optional Components)



مساحة الأرض المطلوبة



43.4 Actual Place at Ras Masqa (since November 2018)

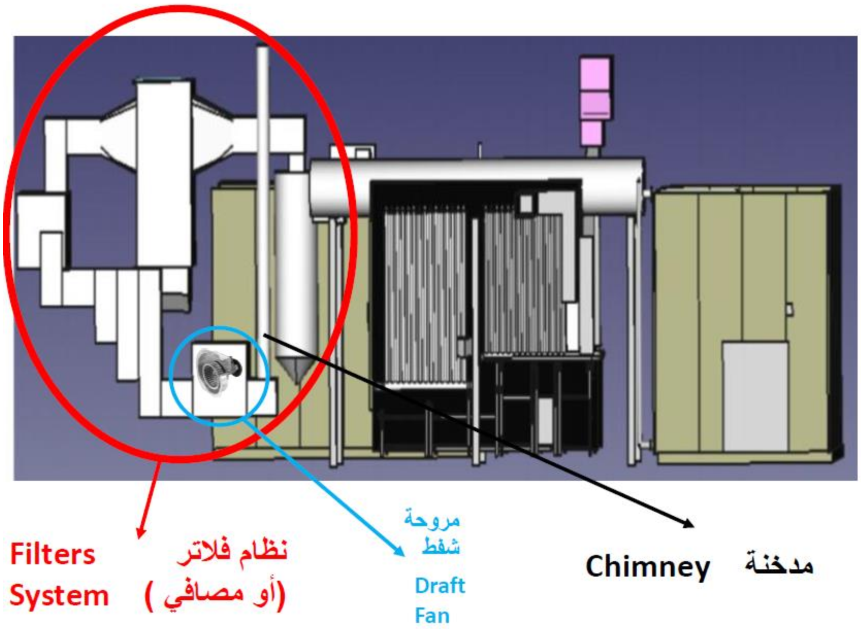
	
	الموقع الجغرافي للمحطة في راس مسقا – الكورة

44 Improvement of Filter System Integration of TEMO-IPP and their preparation for moving to Rayhaniyya Camp March/April 2018

290318TEMO-IPP_Demoplant_Filters.pdf N

Evacuations system
(Chimney, Filters & Ducts)

نظام سحب الدخان
(مدخنة، فلاتر و أنابيب)



مشاكل و حلول

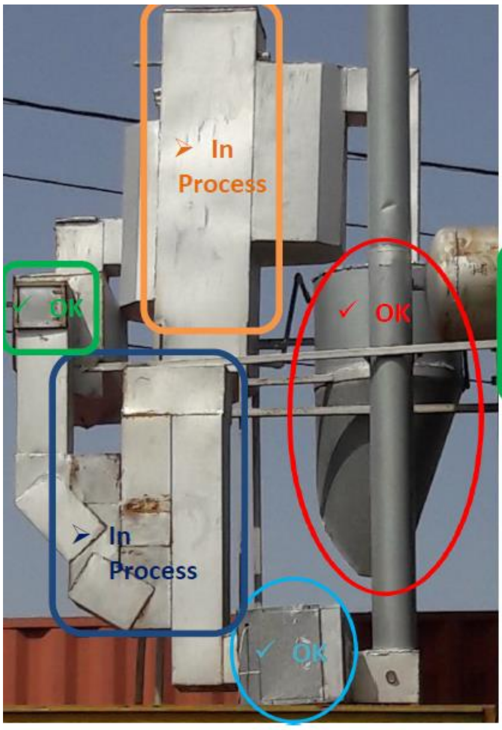
Problems & Solutions

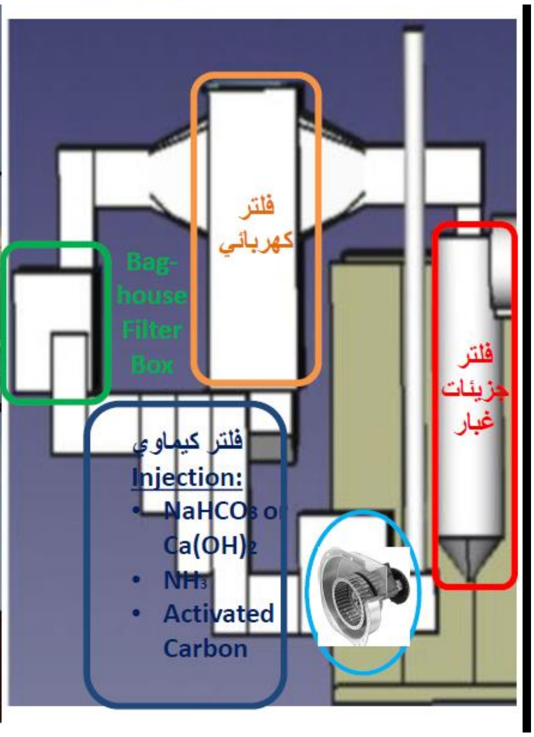
لنركز الآن فقط على نظام
سحب الدخان...

- نظام فلاتر

Filters System

- مدخنة
- Chimney



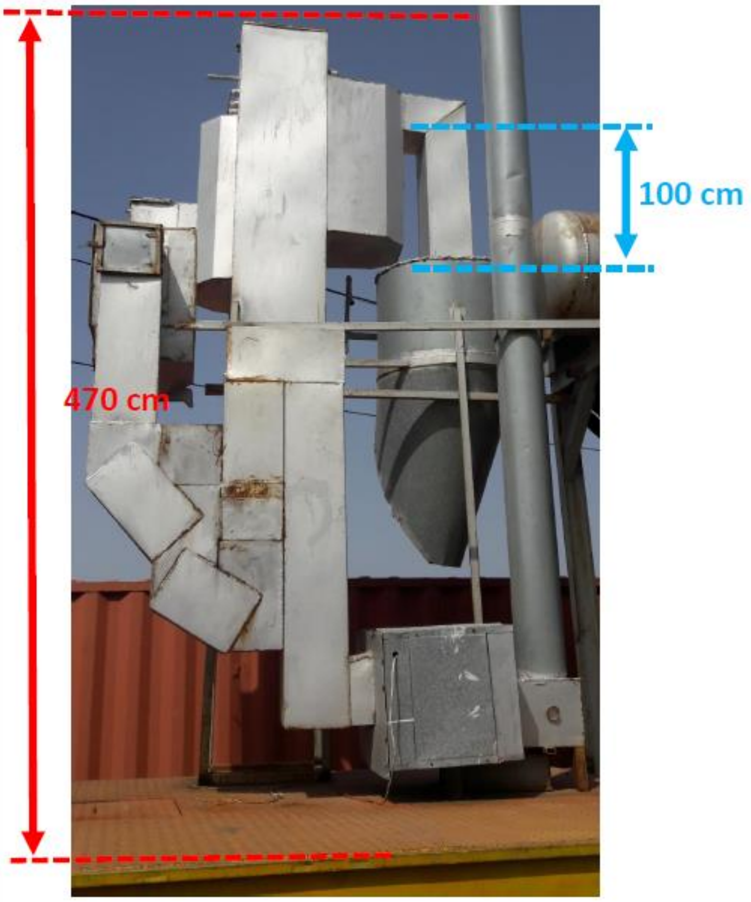


- الارتفاع = 620 cm
- الطول = 1400cm
- العرض = 280 cm

ألان لننظر إلى :

محطة نظام حرق النفايات المتحركة

mobile NLAP-IPP unit



المشكلة:

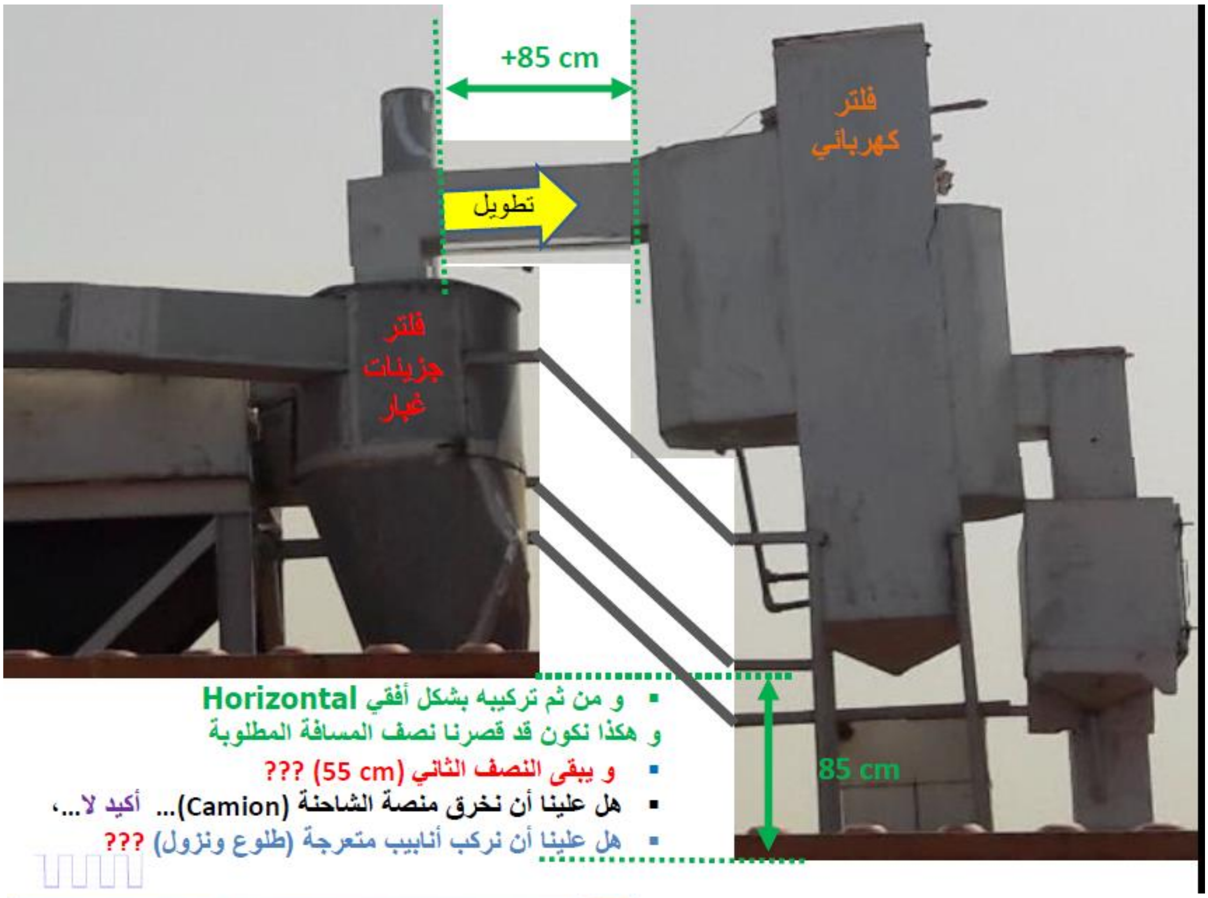
هي أن المحطة مرتفعة عن
الأرض 620 cm,
المقايس المسموح بها: 480 cm
(بسبب إرتفاع الجسور)
و هو مستوى إرتفاع المبخر
(Evaporator)

الحل:

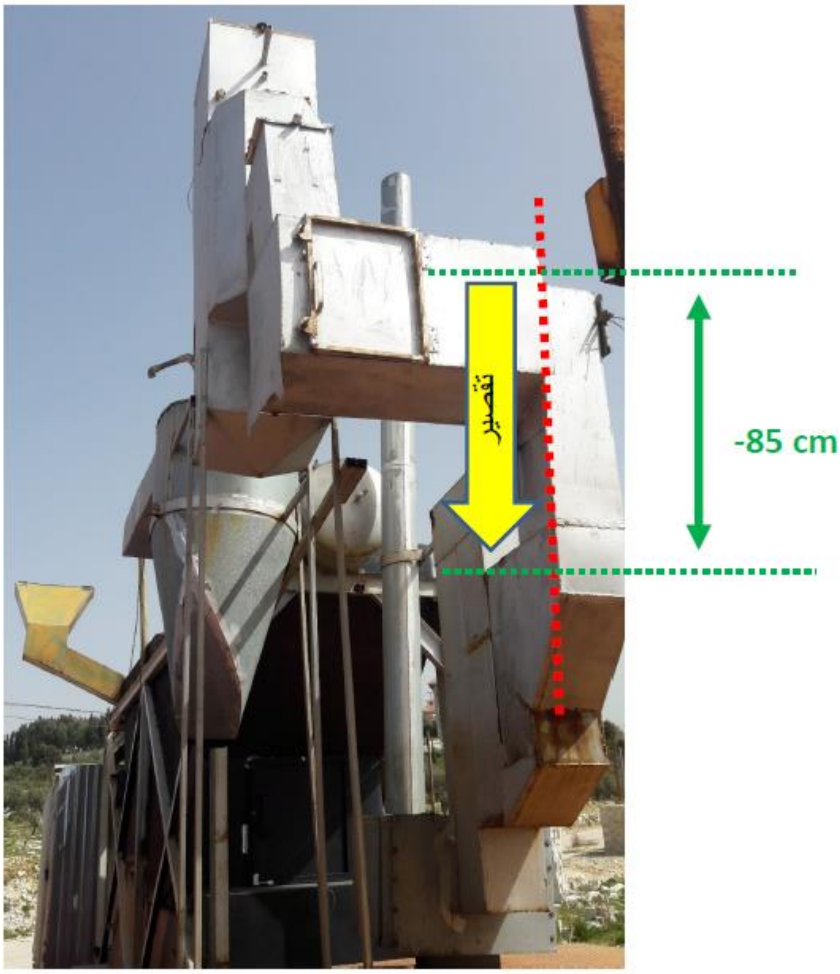
هو قص 140 cm
من إرتفاع نظام الفلاتر،
(لأن المدخنة ممكن ازالتها و
من ثم إعادة تركيبها بسهولة)


ربما يكون أسهل لو نرى نظام
الفلاتر من الوراء،

- لكي نبدأ بالحل المناسب لهذه
المشكلة:
  - علينا قص 85 cm
(من الأنبوب الذي يطلع من
فلتر الجزيئات و يدخل الفلتر
الكهربائي ,عمودياً Vertical)

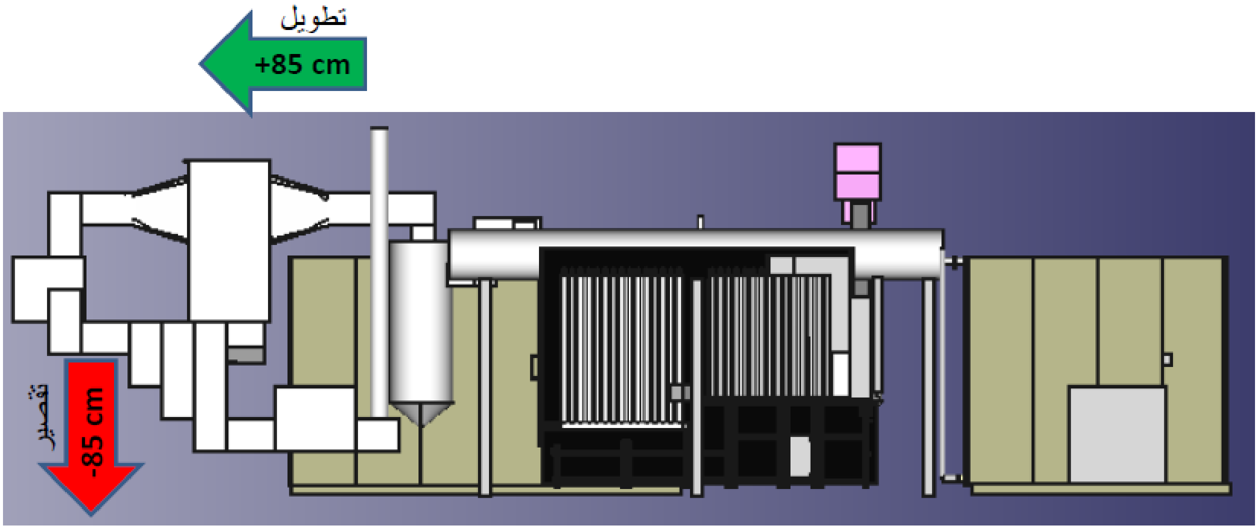


- و من ثم تركيبه بشكل أفقي **Horizontal** و هكذا نكون قد قصرنا نصف المسافة المطلوبة
- و يبقى النصف الثاني (55 cm) ???
- هل علينا أن نخرق منصة الشاحنة (Camion)... أكيد لا...،
- هل علينا أن نركب أنابيب متعرجة (طلوع ونزول) ???



✓ نظرة افتراضية جانبية:

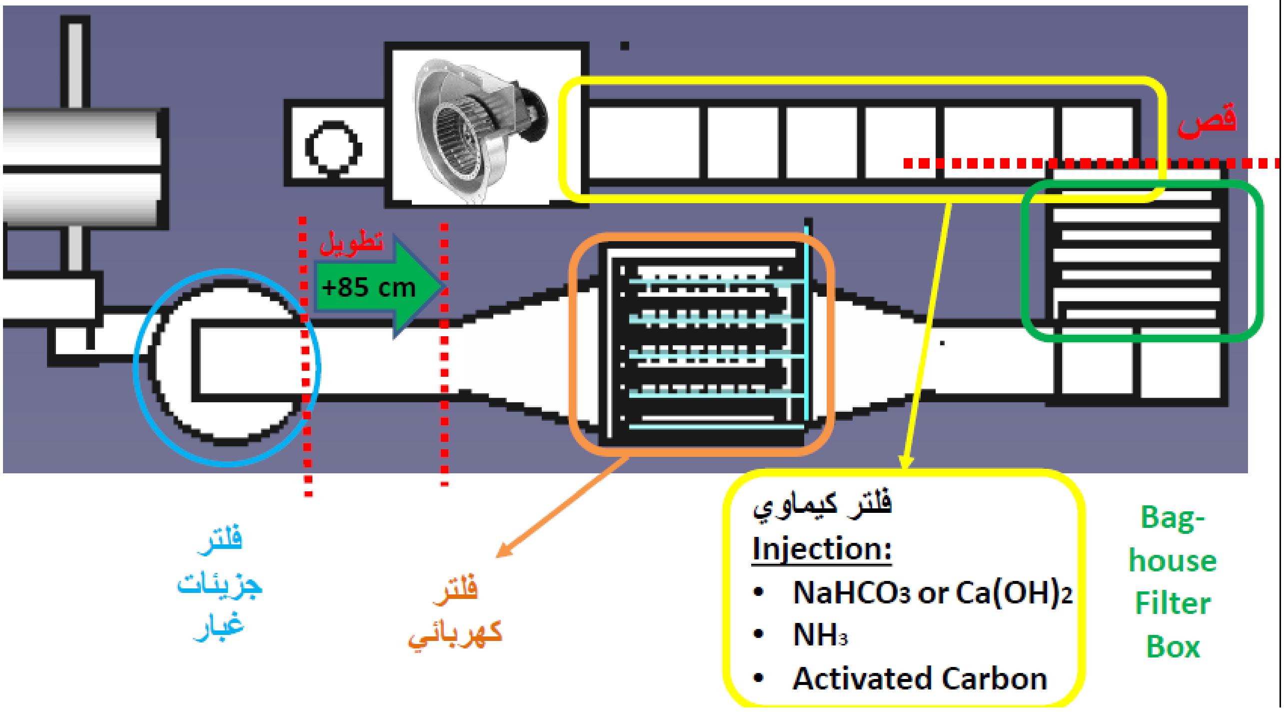
- لتطويل أنابيب الفلاتر Horizontally



✓ نظرة افتراضية جانبية:

- لتقصير إرتفاع أنبوب الفلاتر Vertical

✓ نظرة افتراضية لمكان القص من الأعلى:

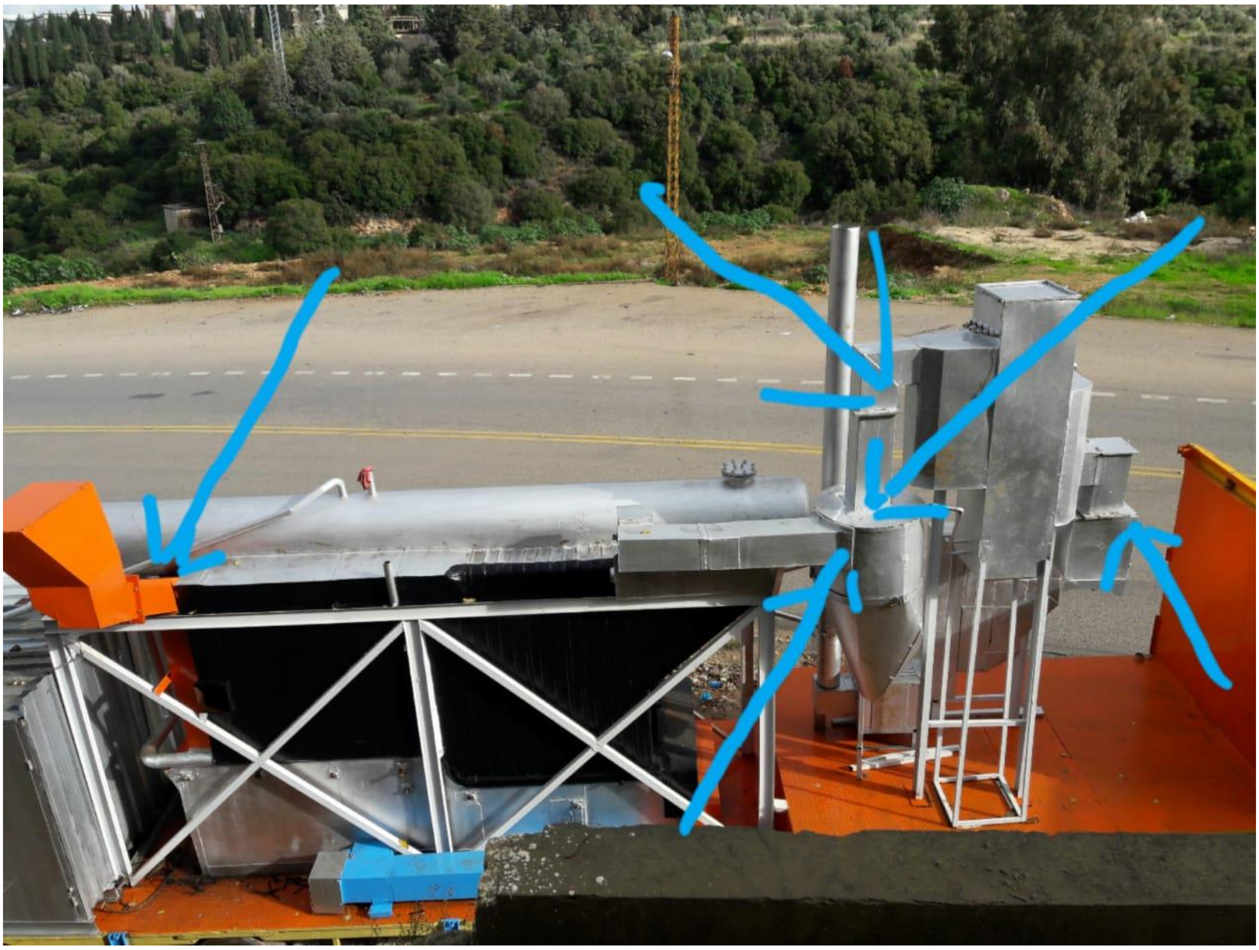


Conclusion: الخاتمة و توصيات:

الأفضل أن نبحث عن حل عبر:

- فك و تركيب الأنابيب و الفلترات (و ليس التلحيم)
- أنابيب فولاذية ضد الصدأ (Stainless)
- قطر دائري للانابيب (Diameter Φ = 20cm)
- البحث عن السعر ($ / المتر)
- If we face some Economical **problems** we can: Cut, Reduce, assemble by **Flanges & Bolts…**
- But we need to respect the **specification:** (Length /Section), distance between Filters…. **????**
- The last choice is **cutting & Welding**

44.1صورة عامة للفلانشات



وضعت هذه الفلانشات من أجل تسهيل عملية تفكيك و تركيب الداخون و المحرقة و الفلاتر التي توجد داخل الداخون.

يتطلب تفكيك هذه الاجزاء، لانها عالية مما يعيق عملية نقل المحطة تحت الجسور على الاتوستراد و أشرطة الكهرباء.

44.2صور الفلانشات تفصيلية

فلانشات للداخون

فلانشات للمحرقة

45 وضع المنشأة التجاربية NLAP-WEDC في مخيم الاجئين في الريحانية وتشغيل المحطة (Project Planning)

19March18NLAP-IncineratorProject_Rihan

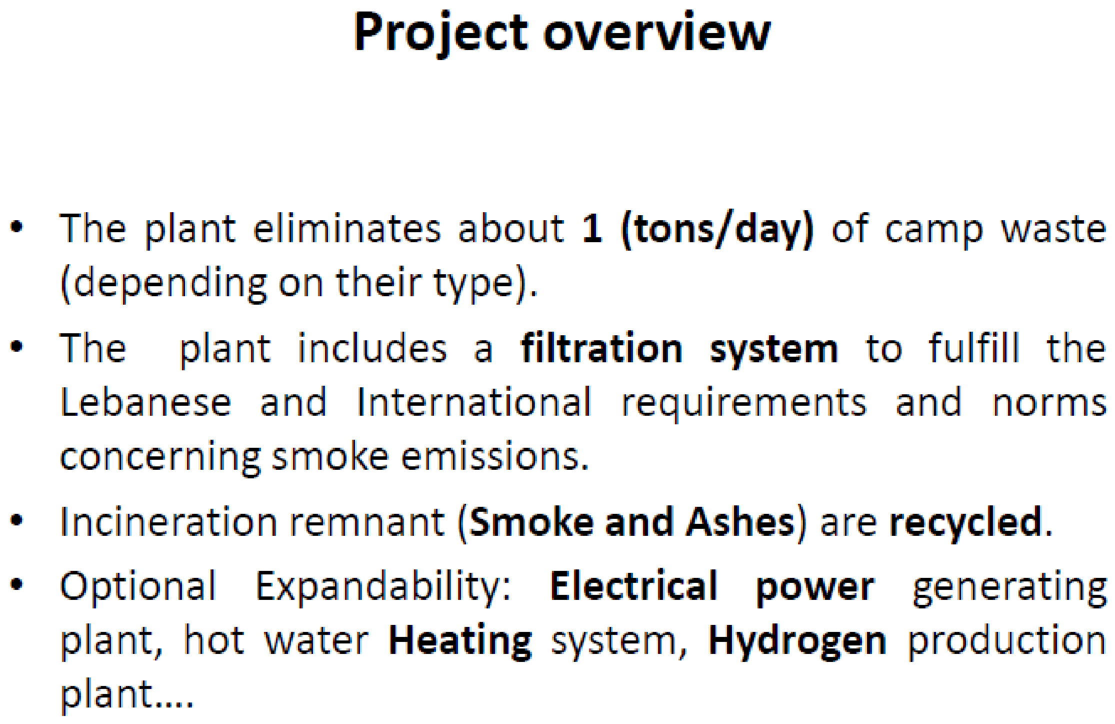
بسم الله الرحمن الرحيم

طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.com

Subject: Project Proposal (March 2018)
Project title: Rihaniye Camp
Waste incinerator 1 ton/day, 25 kW electricity (NLAP-IPP Demo Plant)
Author: د. خالد مولوي

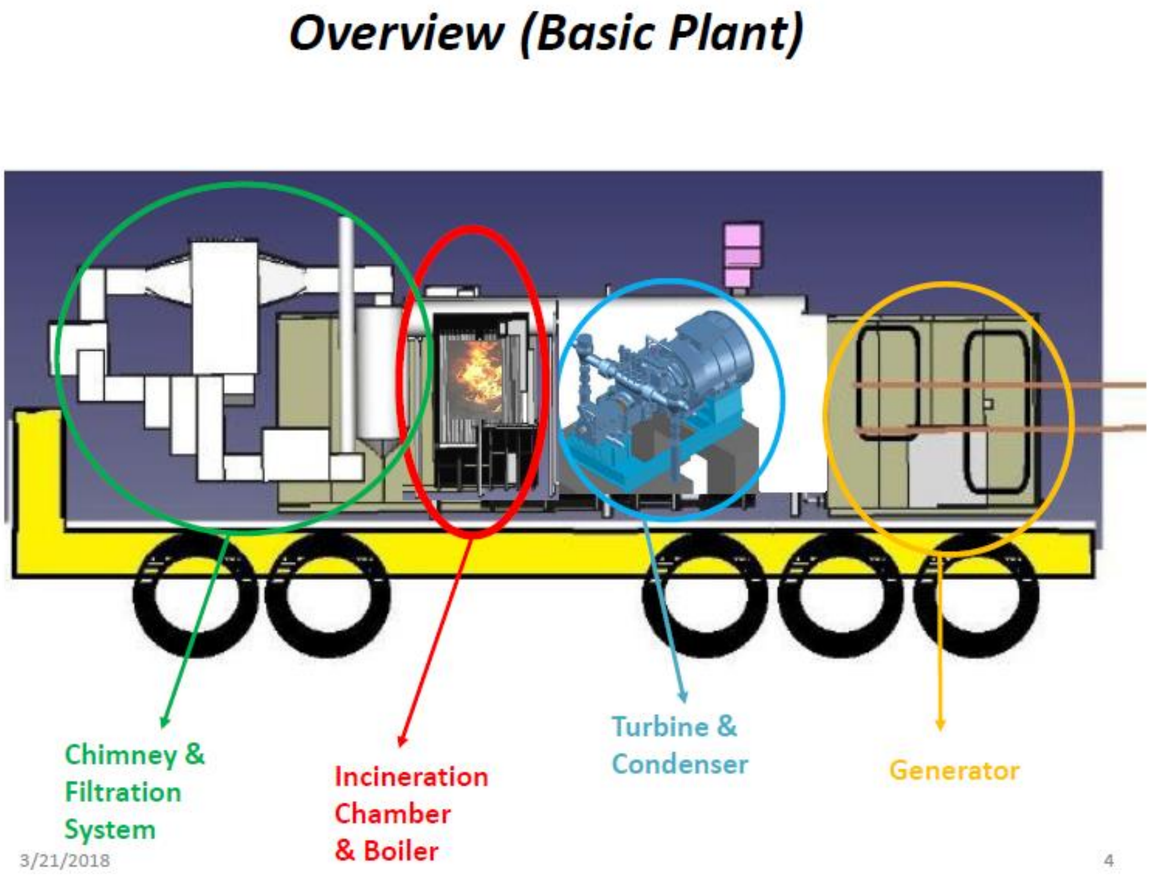
First Member: URDA
Second Member: NLAP Company

3/21/2018 1



Project overview

- The plant eliminates about **1 (tons/day)** of camp waste (depending on their type).
- The plant includes a **filtration system** to fulfill the Lebanese and International requirements and norms concerning smoke emissions.
- Incineration remnant (**Smoke and Ashes**) are **recycled**.
- Optional Expandability: **Electrical power** generating plant, hot water **Heating** system, **Hydrogen** production plant....



Overview (Basic Plant)

Chimney & Filtration System

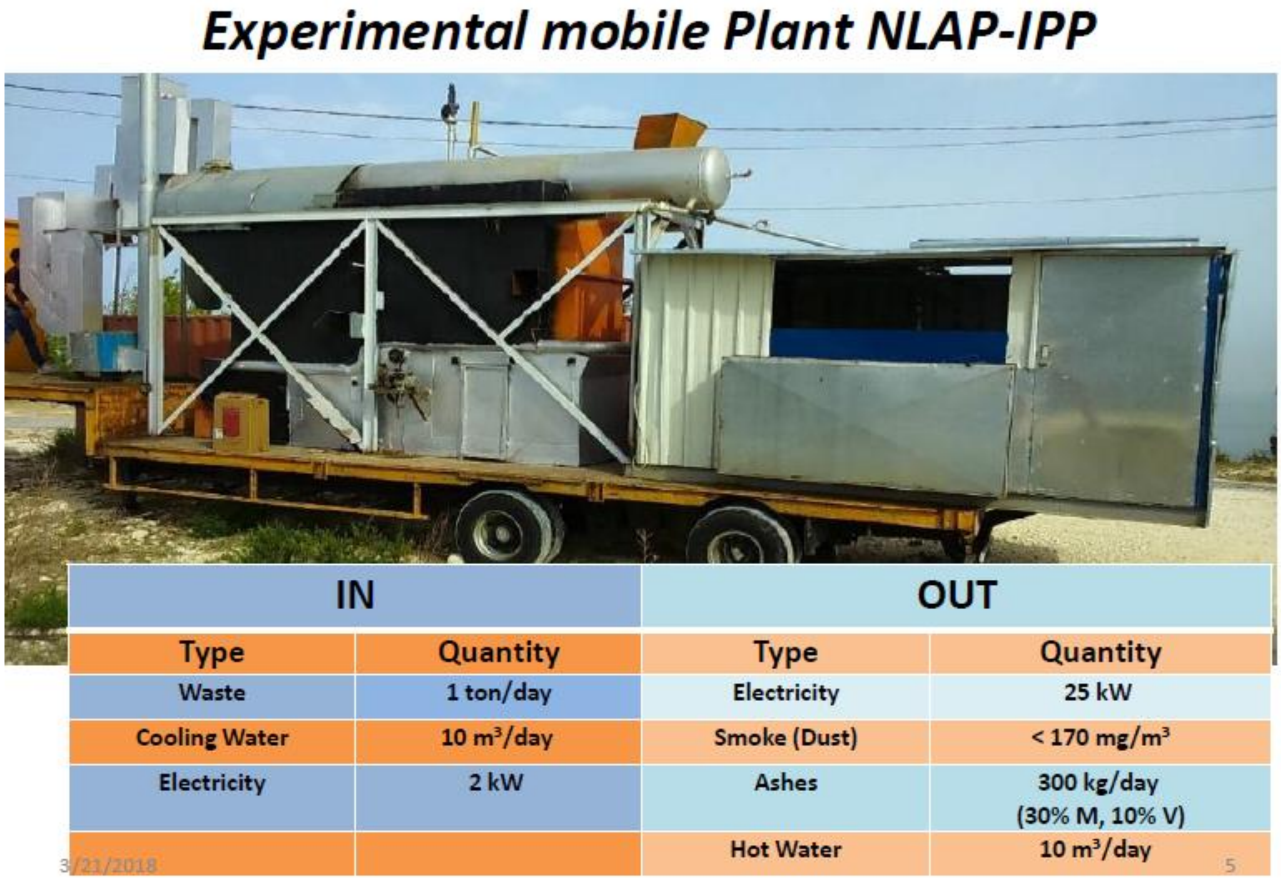
Incineration Chamber & Boiler

Turbine & Condenser

Generator

3/21/2018

4



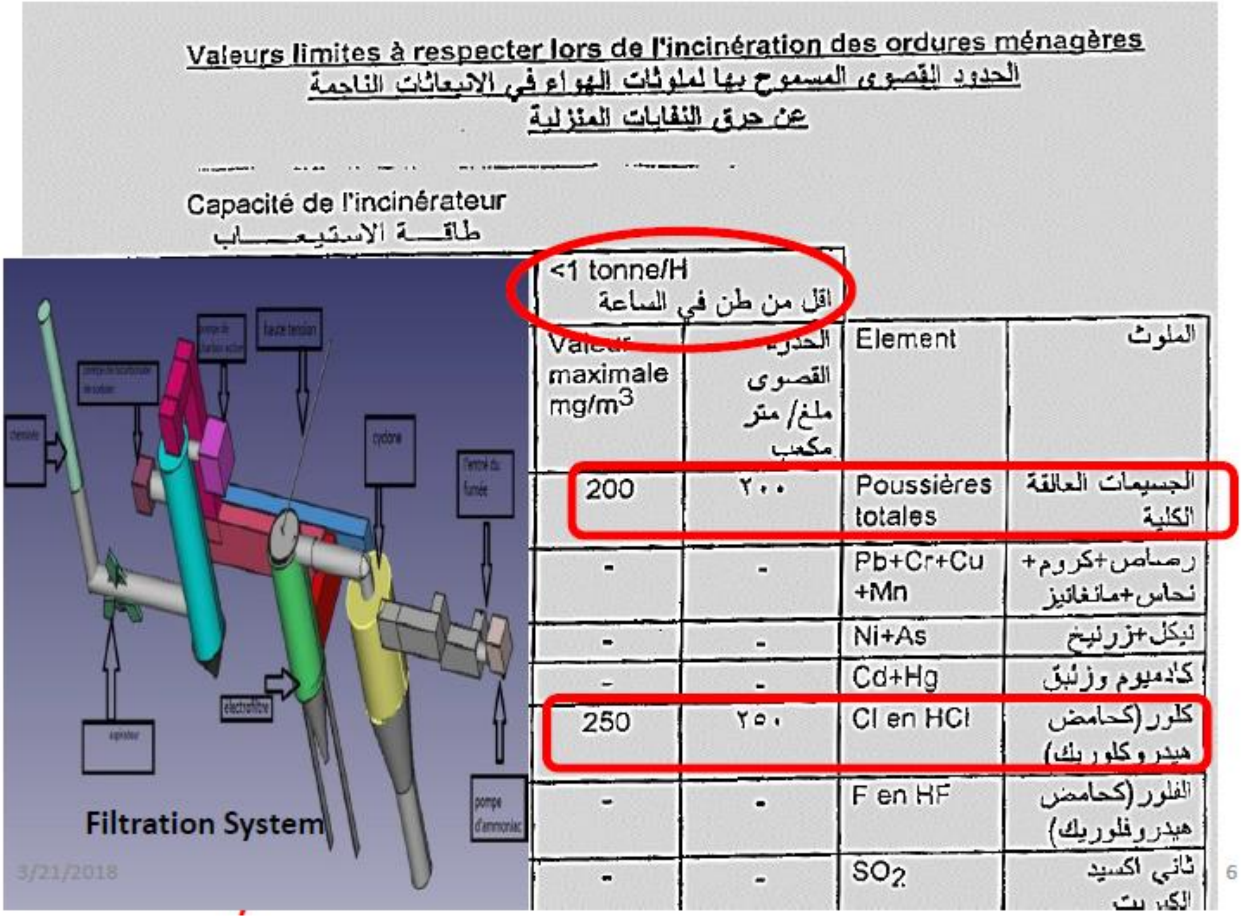
Experimental mobile Plant NLAP-IPP

IN		OUT	
Type	Quantity	Type	Quantity
Waste	1 ton/day	Electricity	25 kW
Cooling Water	10 m³/day	Smoke (Dust)	< 170 mg/m³
Electricity	2 kW	Ashes	300 kg/day (30% M, 10% V)
		Hot Water	10 m³/day

3/21/2018

5

ملوثات الهواء المسموحة الناتجة عن حرق النفايات



Valeurs limites à respecter lors de l'incinération des ordures ménagères

الحدود القصوى المسموح بها لملوثات الهواء في الانبعاثات الناجمة عن حرق النفايات المنزلية

Capacité de l'incinérateur

طاقـــة الاستيعـــاب

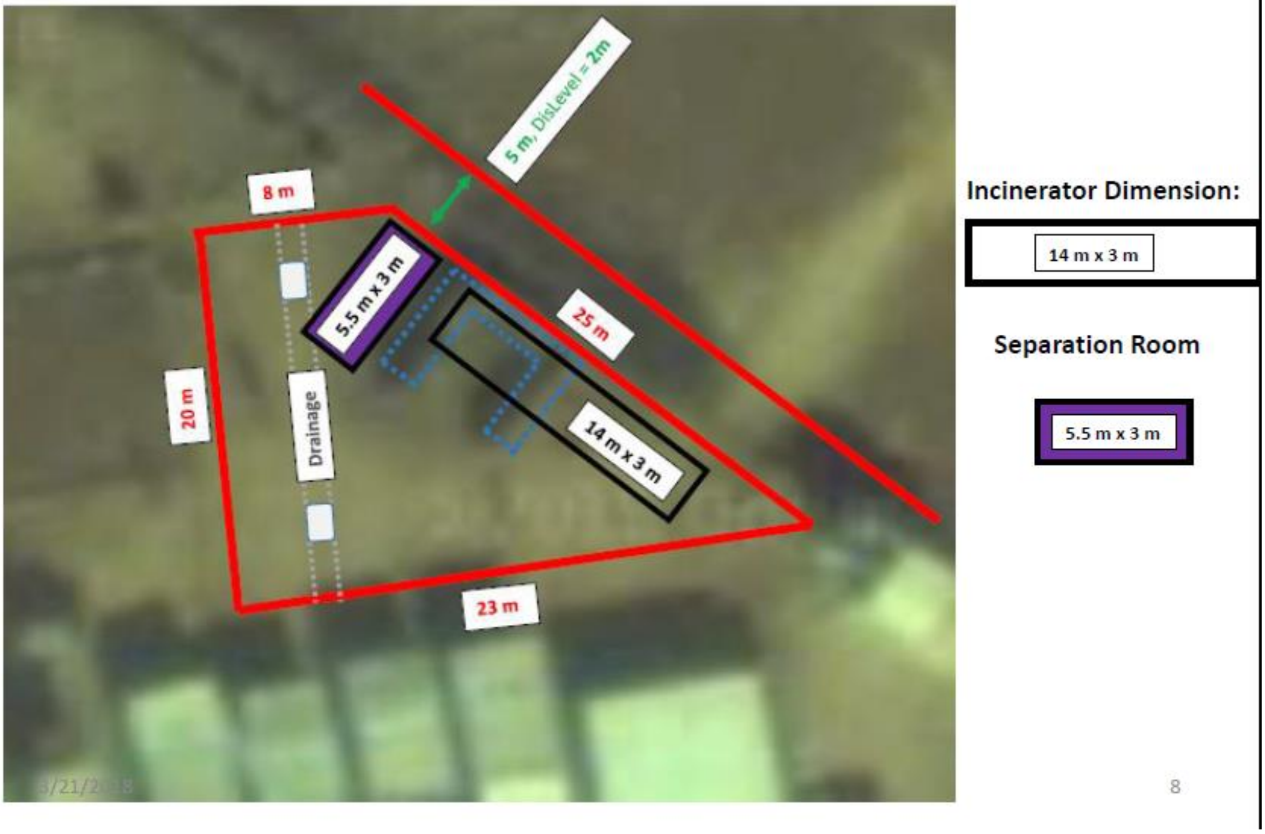
الملوث	Element	<1 tonne/H اقل من طن في الساعة	
		الحدود القصوى ملغ/ متر مكعب	Valeur maximale mg/m^3
الجسيمات العالقة الكلية	Poussières totales	٢٠٠	200
رصاص+كروم+ نحاس+مانغانيز	Pb+Cr+Cu +Mn	-	-
نيكل+زرنيخ	Ni+As	-	-
كادميوم وزئبق	Cd+Hg	-	-
كلور (كحامض هيدروكلوريك)	Cl en HCl	٢٥٠	250
الفلور (كحامض هيدروفلوريك)	F en HF	-	-
ثاني اكسيد الكبريت	SO_2	-	-

Filtration System

3/21/2018

6

مساحة الأرض المطلوبة (حوالي 500 متر مربع)



Funding utilization and milestones

Date	Milestone		Funding need
20 March 2018	**Ground** preparation	Infrastructure	2000 $
26 March	**Transportation**, **Training** waste separation	Logistic, Education	700 $
2 April 2018	**Installation** (assembly, welding parts, Components controls…)	Incinerator plant project	500 $
9 April	**Insulation** (Incineration Ch., Evaporator, Condenser, Chimney…)	Incinerator plant project	1200 $
16 April	**Water** supply & Accessories (Tank, Pump, Pipes, Filtration & Demineralization RO)	Incinerator plant project	2000 $
23 April	**Process Control System** (Valve, Sensor, Display, Electronic devices & software) installation	Incinerator plant project	600 $
30 April	Smoke **filtration** System & Tests (with AUB)	Incinerator plant project	1500 $
May –June 2018	**Operating** the System (see **Staff Costs**) *	Incinerator plant project	
Total			8500 $

45.1 Contract with URDA

مذكرة تفاهم MOU

الطرف الاول:AECENAR
الطرف الثاني:مخيم الريحانية عبر جمعية URDA

البنود:

1- المحافظة على السرية confidentiality

2- تعهد AECENAR بتدريب عدد من العمال (يحدد لاحقا) Training

3- تعهد URDA ب مساعدتنا (الاجتماعات، الاشغال)

4- تضع URDA بتصرفنا database عن المخيم (عدد الخيم، السكان،نوعية النفايات. .)

5- مساهمة URDA في الإعداد للمشروع (دراسة جيولوجية للأرض، تمهيدها، جدار دعم)

6- تتكفل AECENAR بدفع :

- مصاريف العمال (خلال الفترة التجريبية 3 اشهر)
- التشغيل (أدوات، أجهزة، تلحيم..)

7- تأمين الكهرباء لتشغيل المحطة من URDA

8- تأمين التمديدات الكهربائية لنقل الكهرباء بعد المولد من قبل URDA

9- تأمين مصدر ماء من داخل المخيم من قبل URDA

10- بناء سور حول المحطة من قبل URDA

11- لا تتحمل AECENAR مسؤولية في حال حدوث أية حادث

12- المساهمة في عملية الفرز (الجمع، الحاويات)

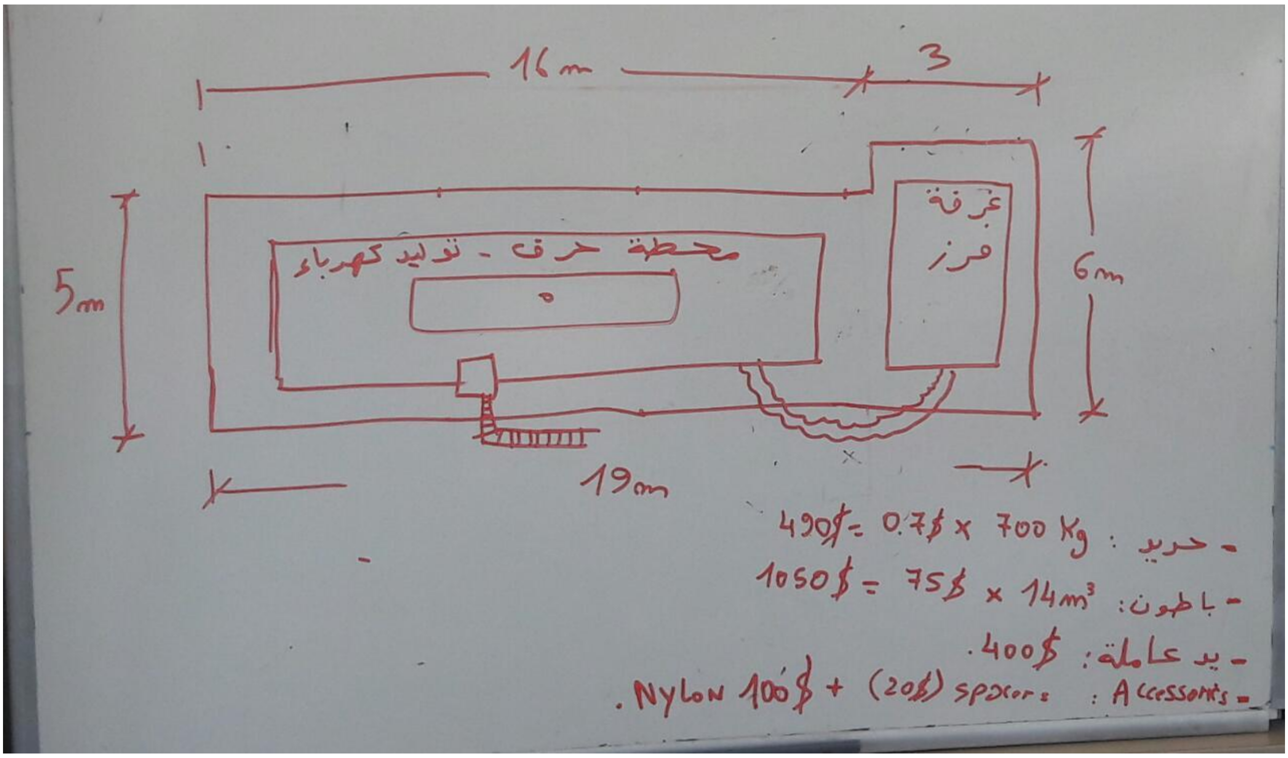
13- تأمين إذن دائم (الدخول و الخروج) ومكان للسيارة

14- في حال حدوث أي طارئ ، يرجى تبليغ:

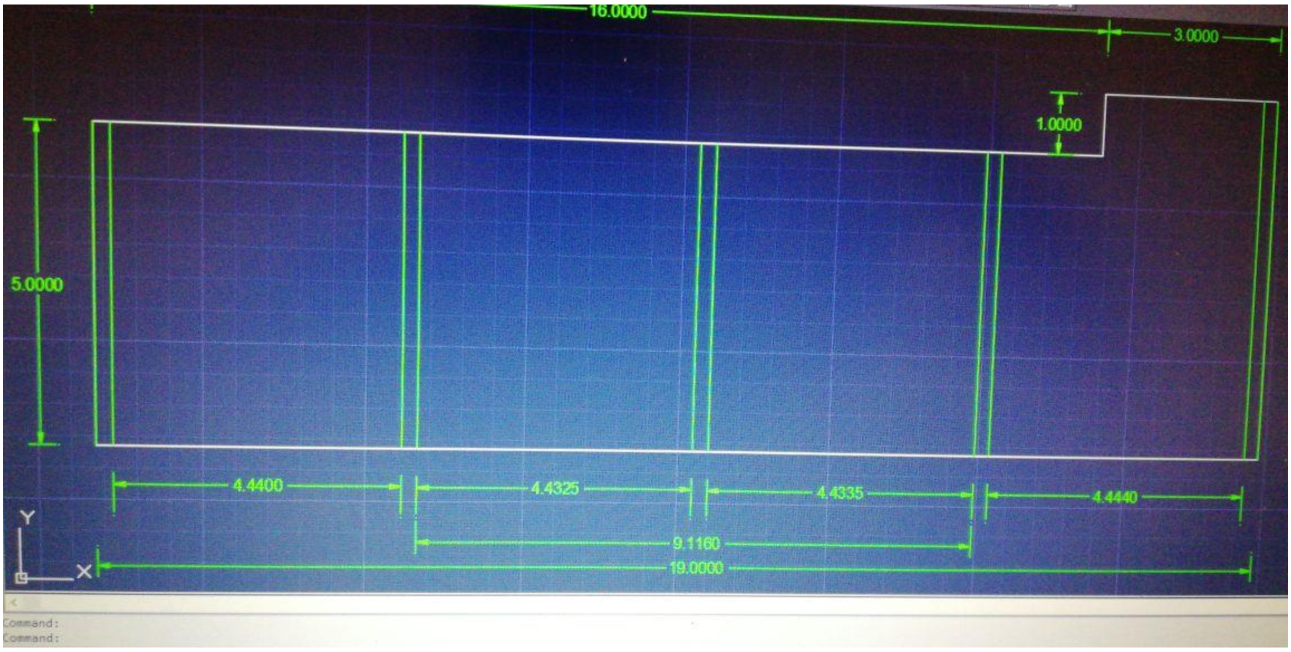
- المسؤول في AECENAR
- الإسعاف
- الدفاع المدني
- تأمين لائحة أرقام الطوارئ

URDA_Questions_27
0318_answers2.2AE

45.2 Ground Planimetry



- حريد : 490$ = 0.7$ x 700 Kg
- باطون : 1050$ = 75$ x $14m^3$
- يد عاملة : 400$.
- Accessoris : Nylon 100$ + (20$) spacer.



```
Command:
Command:
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45.3لمرحلة الأولى : AECENAR جرف الأرضية وتجهيزها للصب 18-4-2018

45.1 At refugees camp in Rayhaniyye (March - Nov 2018)[33]

 Preparation of ground	 Visit with major of Mhammra
 Visit at 10.06.18	

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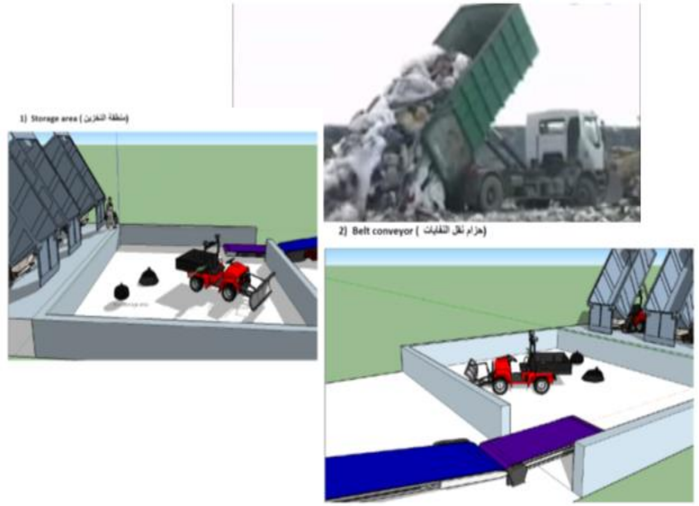
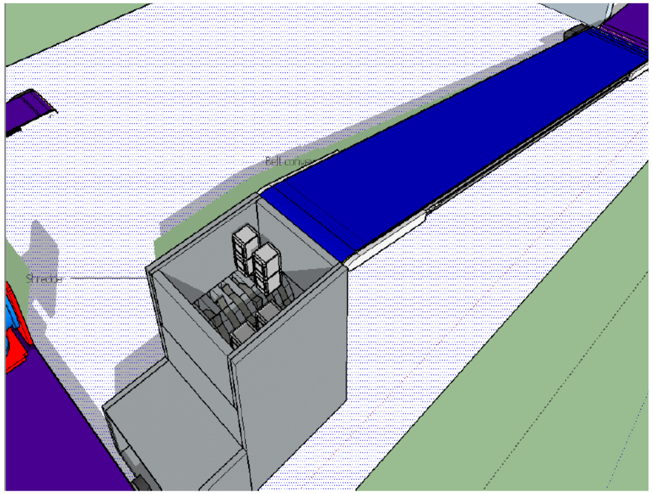
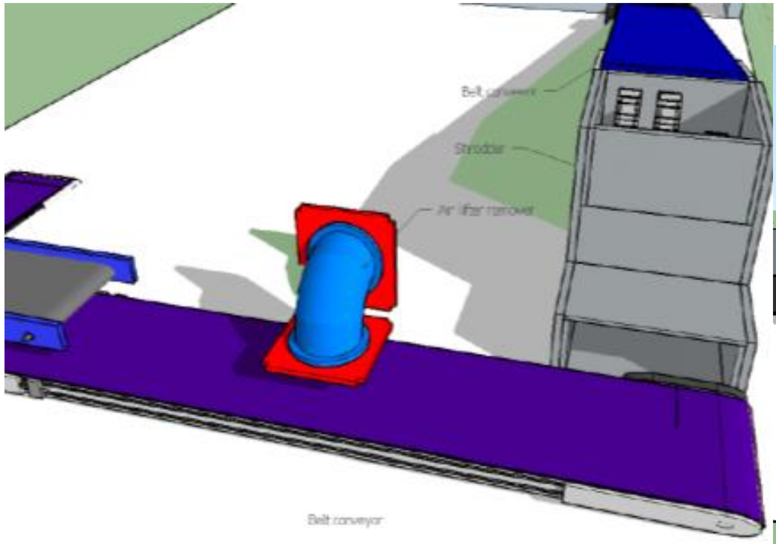
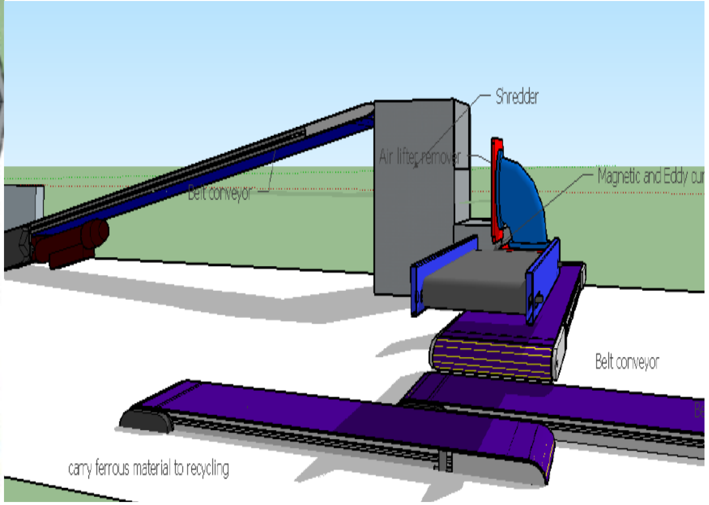
[33] For more details see [EIARayhaniyyeCamp2018] / Section about EIA Rayhaniyye Camp in this final report

46 Waste input Unit









Flue Gas Purification & Environment Aspects

Based on the following reports

[Kamareddine 2016]

[NLAP-WEDC 2017]

[NLAP-WEDC 2018]

[NLAP-WEDC 2019]

47 Filter sytem of NLAP-IPP Demonstration Plant[34]

47.1 GLOBAL TREATMENT

The literature review has built a thorough idea about the types and procedures adopted by the Environmentalists for flue gas treatment.

thus distinguishing between two types of treatment:

- physical treatment (mechanical, electrical): cyclone, electrostatic, sleeve
- Chemical treatment: sodium bicarbonate, calcium bicarbonate, activated charcoal.

Different criteria are highlighted (temperature of the smoke, dust size, reactivity) to know what type of filter should be used first in order to be more effective.

A simple representation freecad can simplify the treatment steps of the incineration fumes .

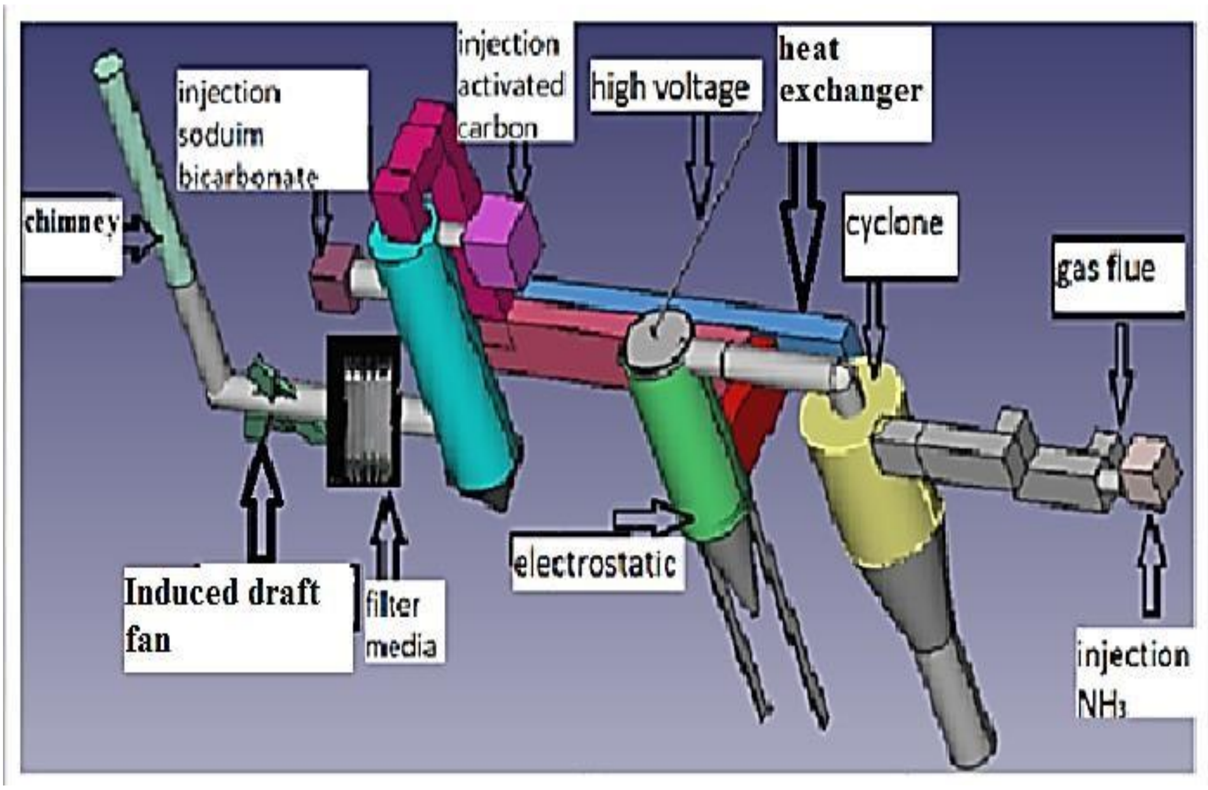


Figure 25: detailed system of treatment the diagram above can be analyzed as follows:

1-Gas flue at exit (800-1000°C)

---

[34] [Kamareddin 2016]

2-Injection of NH_3: treatment of nitrogen oxide**.** The reactions realized at temperature between 850 and 1000 ° C, with higher reaction rates and lower in this range. This special reaction takes place:

- 1: directly by injection in boiler (exit of fumes) at a temperature between 850 and 1000°C. It's correspondent to Selective Non Catalytic Reduction (SNCR)
- 2: with assistance of a catalyst in a temperature range of 170 - 450°C Selective Catalytic Reduction (SCR)

3- Cyclone: The fumes are accelerated in a cylinder, the particles will impact on the walls and lose their speed, they are then recuperated in the filter bottom.it reduce a large percentage of particles.

4- Electrostatic: The dust through a sufficiently large electric field .it's so efficace in order 90 % to eliminate small particles less 5 micron .

5- heat exchanger between gas flue and air that will enter to the boiler and contribue to a combustion .heat exchanger is necessary to minimize the gas temperature to 230°C. at this temperature the charcoal is effective even as bicaronate of soduim.

6-injection of activated charcoal :to reduce the ratio of dioxin and furan in fumes .

7- injection of soduim bicarbonate(powder) : to reduce the ratio of acid gas (**SO_2 , HCl, HF**), at 150- 230°C.

8-filter media: after bicarbonate,charbon was reacted to flue gas ,fumes came to filter media where a cacke was formed in the face ahead flue .it eliminate the toxic gaz and bad smell.

47.2 SIZING INCINERATOR

We will determine the volume of air required for combustion, the volume of actual combustion air, the volume of smoke generated and finally, the flow of wet smoke.

Hypotheses:

Waste composition: it is considered as household waste consist mainly of carbon, oxygen and hydrogen. the contents are neglected by other elements, including sulfur and nitrogen.

70% of the original mass of the waste ends up in gas, mainly CO_2 and H_2O, species that represent the end products of the combustion reactions

Element	Mass Composition (%)
C	57
H	5
O	38

Table 11: mass composition of

waste **air factor:**

Consider that operates in excess air. So:

λ=air factor $= \frac{actual\ amount\ of\ air\ for\ combustion}{strictly\ necessary\ air\ for\ combustion} = \mathbf{1.2}$

mass flow, humidity and calorific value of the waste:

We work in the most compelling cases:

-Actual capacity furnaces processing is 1t/day (0.042 t/h)

-We Chose the maximum waste throughput: B = 152 t / year

- It is considered that the plant operates all year round, 10h / 24h. The ovens are interrupted seven days per year for maintenance. Thus, each furnace is operated 358 days per year.

Where **B = 0.042 t / h / oven.**

-We Chose the maximum moisture to the waste, either: **E =**

60% -The Calorific value varies origin of the waste. fixed at

2000 kcal / kg Determination of air volumes:

-Volume stoichiometric air required for complete combustion of waste:

Va = 0.089 C + 0.267(H) + 0.033(S-O)

To the extent that we fail the sulfur content, we can write:

Va = 0.089(C) + 0.267 (H) - 0.033(O)

Va = 5.15 Nm^3 / kg of waste actual combustion air -Volume

or specific effective volume of air:

V'a = 6.18 Nm^3 / kg

Determination of smoke volumes:

- specific Volume dry fumes:

V_f = 0,089 C + 0,21 H + 0,008 N + 0,033 S – 0,026 O

To the extent that we fail the sulfur and nitrogen content, we can write:

V_f = 0,089 C + 0,21 H – 0,026 O; with Each carbon atom of the fuel weighing 12g form in the flue gases a mole carbon dioxide occupying 22,4l under normal conditions, each hydrogen atom of fuel weighing 1g formed in the fumes a half mole of water occupying in the normal conditions 22,4l

V_f = 5.14 Nm^3 / kg specific -

Volume of fumes generated:

$V_{Fh}=V_f + V_{H_2O}$

With V_{H_2O} = 0.112 H + 0.0124 E

$V_{H_2O} = 1.3\ Nm^3/ kg$

Thus: $V_{Fh} = 6.44\ Nm^3/$

kg **specific -Volume of**

wet smoke:

$V'_{fh} = Vfh + (e / 100) * Va$

$V'fh = 7.47\ Nm^3 / kg$

Determination of wet flue gas flow rate:

$Q'V_{fh} = B\ V'fh$

$Q'Vfh = 0.042*7.47 = 314\ Nm^3/ h$

47.3 DESIGN OF ESP

The electrostatic precipator used to attract particulars less than 5 microns in the gas flue of incineration. ESP will be after cyclone

47.3.1 CYLINDRICAL ELECTROSTATIC

First, this study in TEMO-IPP adopted a cylindrical electrostatic that defined by this dimensions:

- Length :1 m
- Diameter of elec :60 cm
- Diameter of tube : 3,5 mm
- Length of tube : 80 cm
- Nombre of points : 20
- Diameter of point : 0,7 mm
- Length of point : 2 mm
- Space between 2 points : 3,8 cm

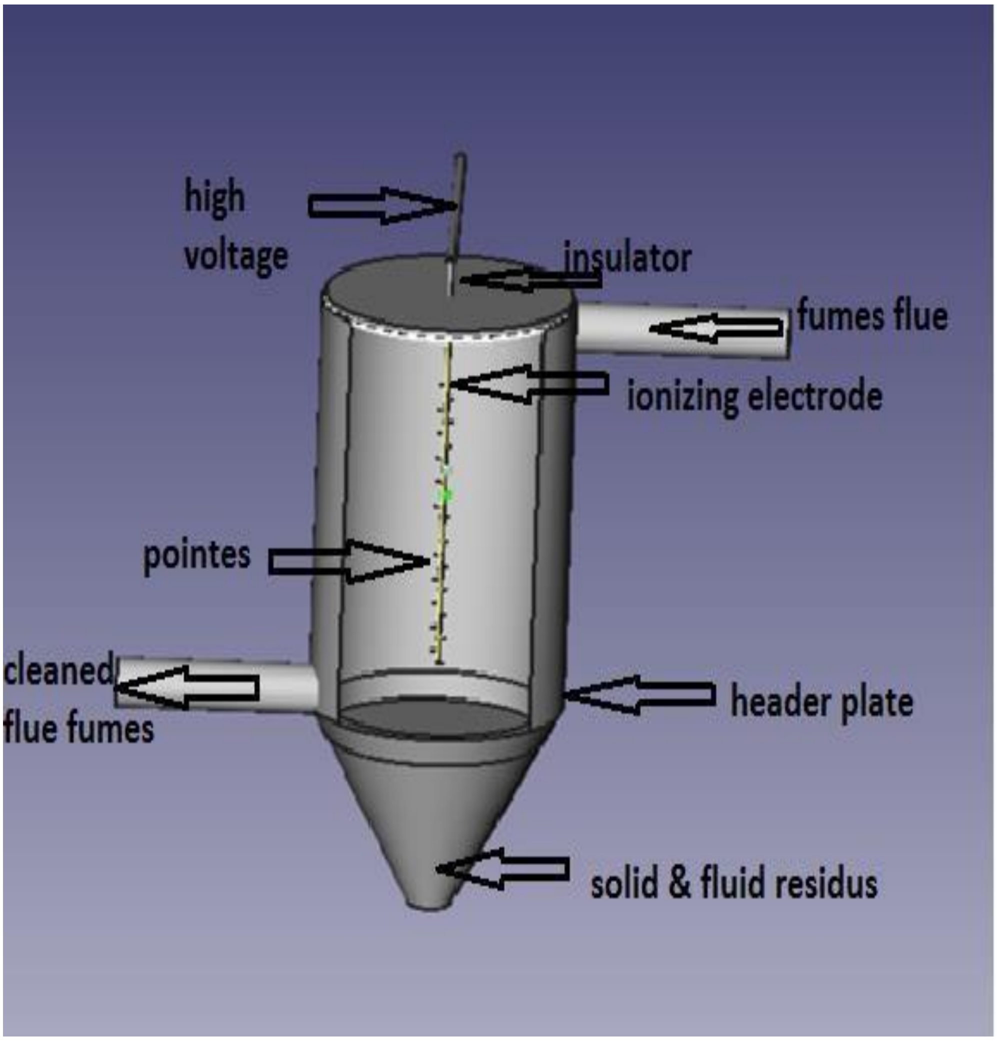


Figure 28: design of cylindrical ESP by FreeCAD

47.3.2 PLANE ELECTROSTATIC PRECIPATOR:

Main dimensions of the plane electrostatic precipator adopted to an incinerator characterize by flue fumes between 200000 & 600000 m^3/h

- The total length 100 cm
- Height h 29 cm
- Distance between the plates 2d 9 cm
- Rods rod diameter d = 3.5 mm
- Pointes
- Dpointe diameter = 0.7 mm
- Lpointe length = 2 mm
- Number of point of each rod =7
- Distance between rods = 4.5 cm
- Distance between pointes = 3.8cm

[redacted]

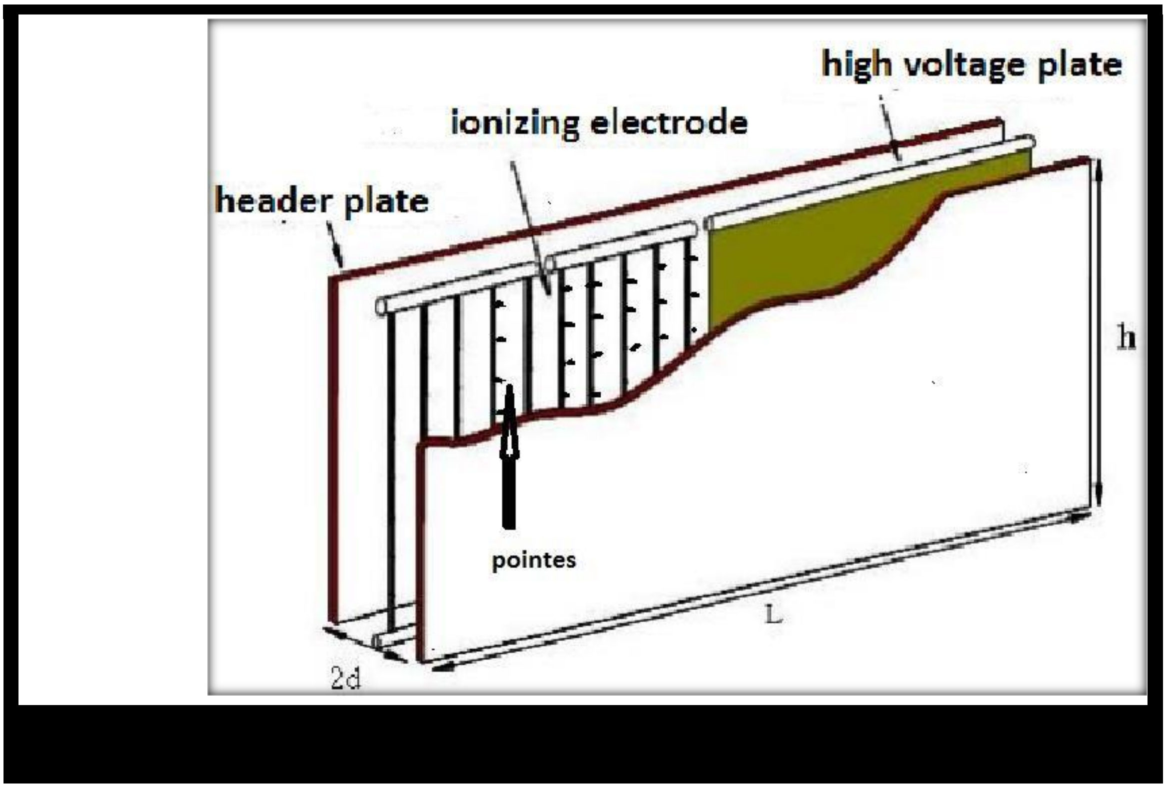


Figure 29: plane ESP (16)

47.3.2.1 STEPS TO OBTAINED AN ESP

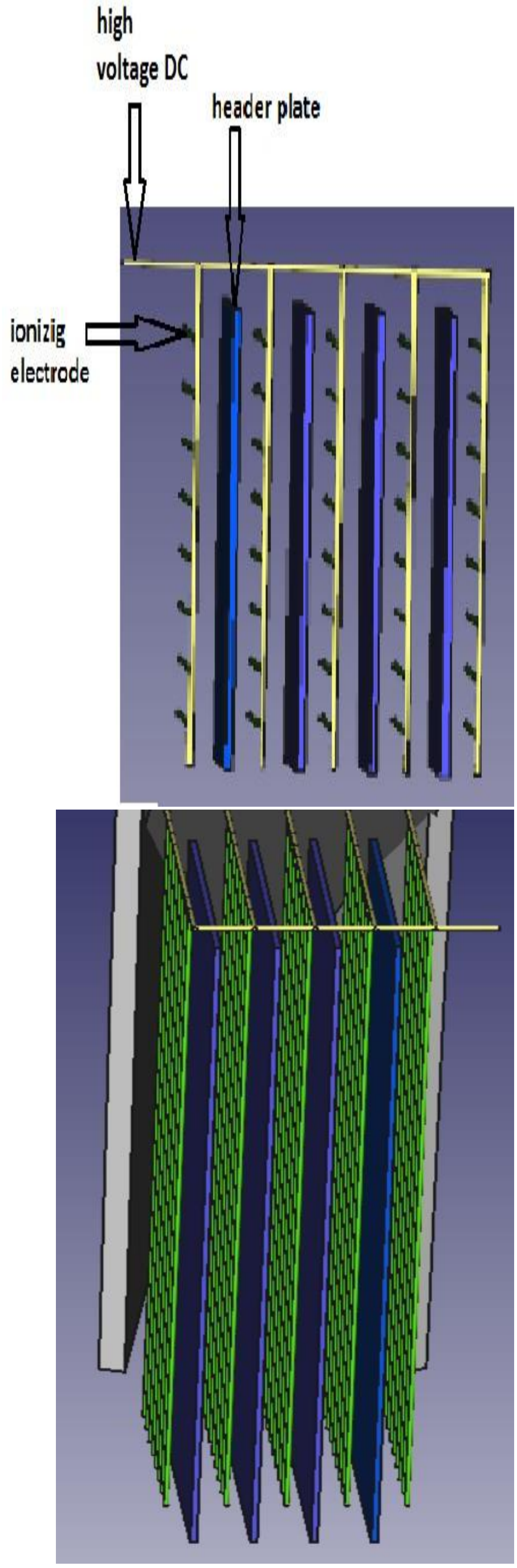


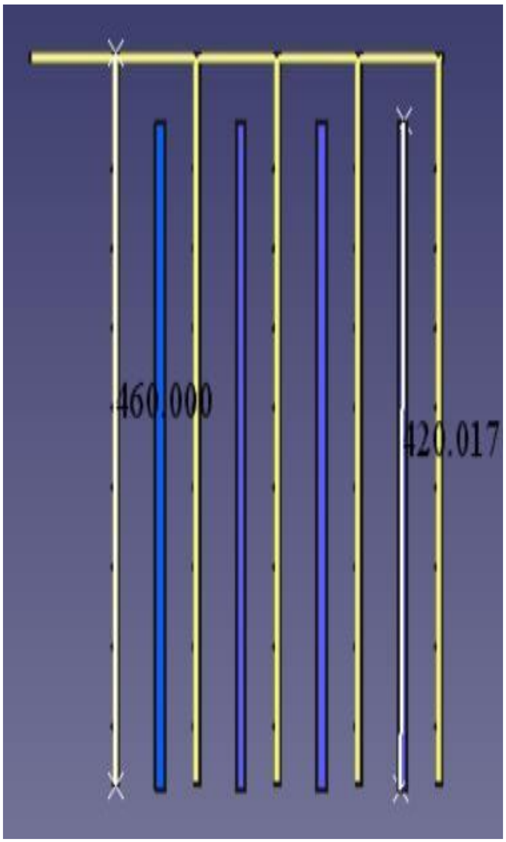
Figure 30: design of plate ESP by FreeCAD

Header plate:

- iron
- sickness: 0.5 mm

- length: 1000 mm
- width: 420 mm **Ionizing electrode:**

- copper
- vertical: - diameter :1.75 mm (14)
  - length: 800 mm
- horizontal: - diameter :2mm
  -length: 460 mm



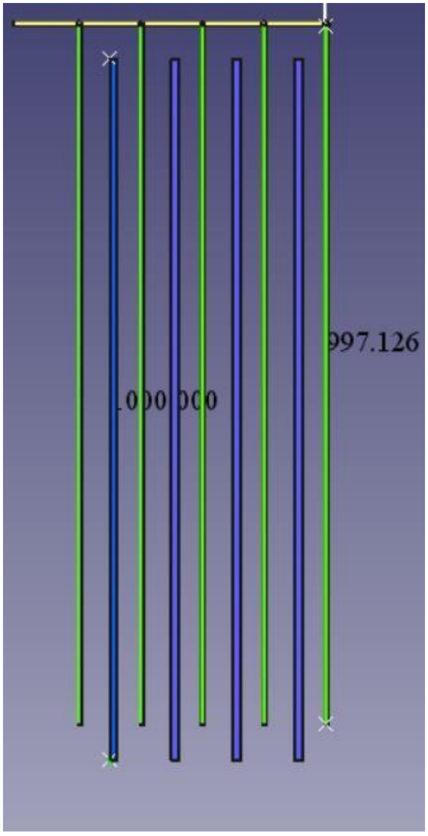


Figure 31: top view Figure 32: front view

Total area of header plate where the particulars of dust are collected $8*0.4*1=3.2\ m^2$

A study affirmed that to choose a better ESP, the ratio $\frac{\text{area of filtration}(m^2)}{gas\ flue\ (m^3/h)}$ will be between

0.02 and 0.5 . (17)

In this case: Ratio= $\frac{3.2}{\frac{314*280.46}{1500}} = 0.05;$ $0.02 < 0.05 < 0.5$ .Thus, this ESP was efficacies.

And, $\frac{\text{width}(\text{l})}{\text{length}(\text{h})} = \frac{460}{1000} = 0.46 \approx$ 0.5, acceptable $(0.5 < \frac{l}{h} < 2)$

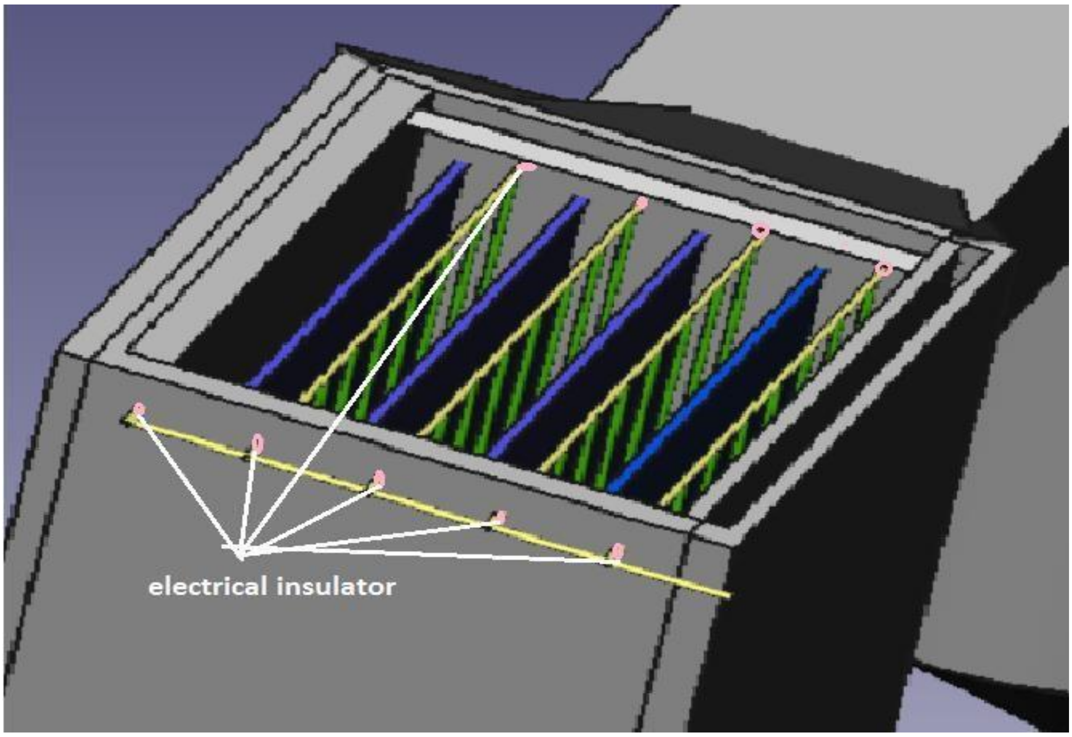


Figure 33: an electrical insulator isolate ionizing electrode from header plate(freecad

Electrical insulator

The charge separation in a parallel plate capacitor generates an internal electric field. The dielectric material (orange) reduces this field and increases the capacitance. A dielectric material (compound word of the prefix dia (δια) - (through) and electric) it contains no electrical charges likely to move macroscopically. The medium thus can’t conduct electric current, and by definition is an electrical insulator. Examples of dielectric media: the empty, glass, dry wood, many plastics, etc.

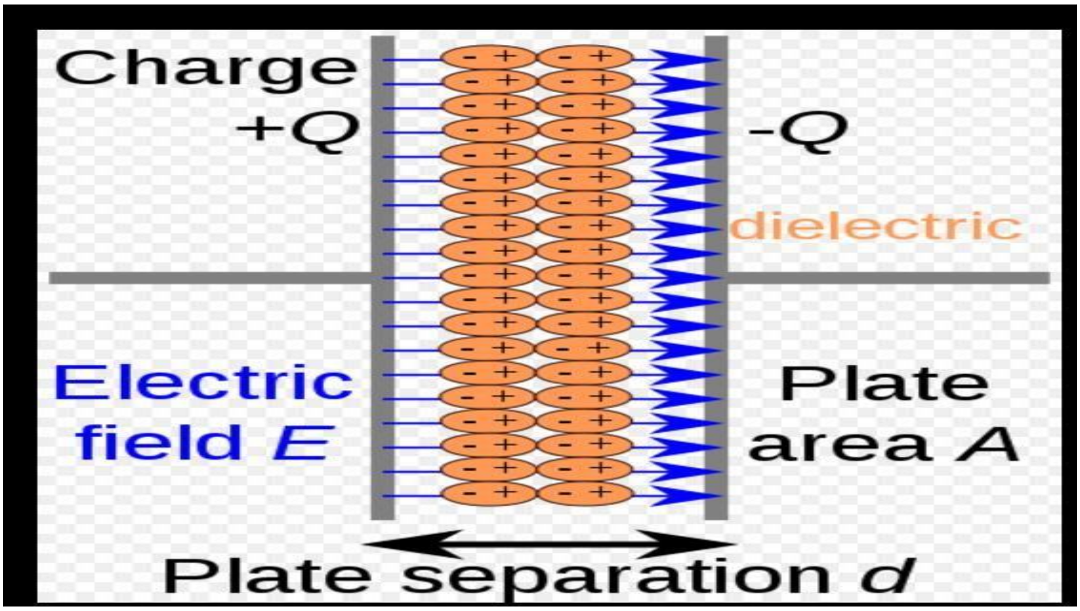


Figure 34: presentation of insulator (1)

Figure 35: insulator used to ESP in the power plant.

Velocity of gas: 1m/s in the station contributed to a medium entrance to the ESP Between 0.3 & 0.8 m.

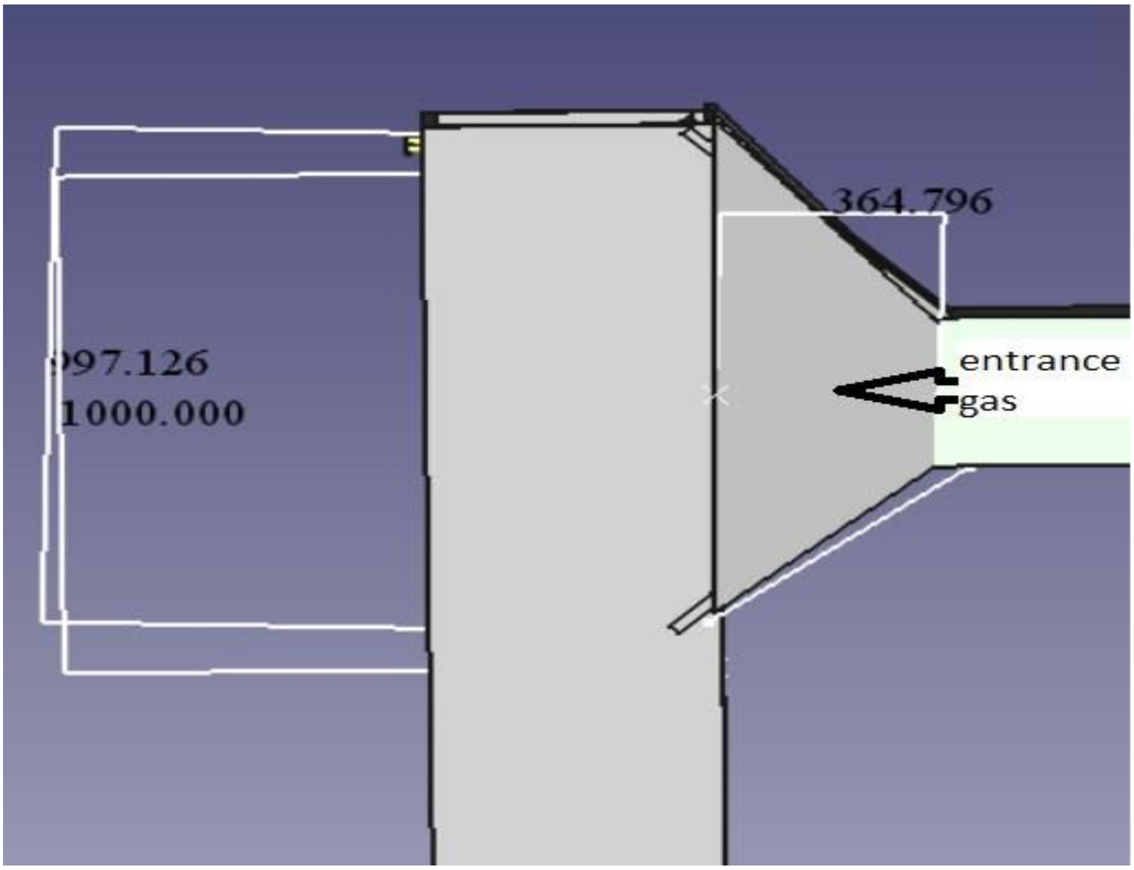


Figure 36: entrance gas to ESP

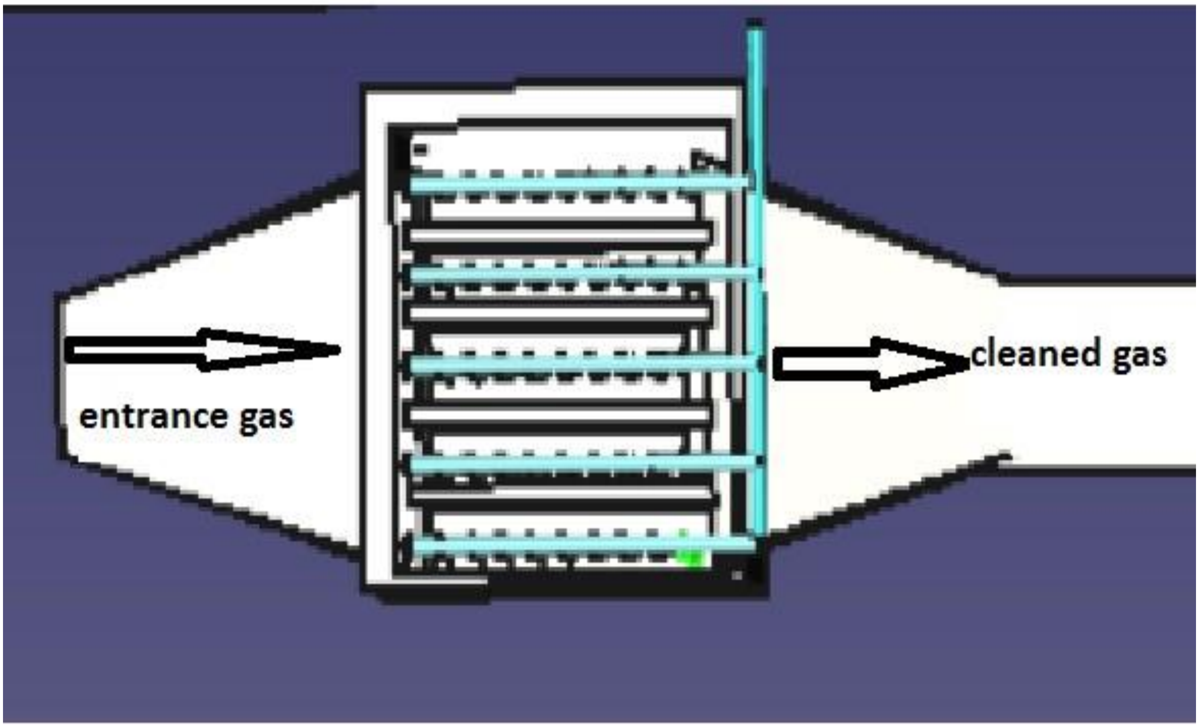


Figure 37: top view of ESP

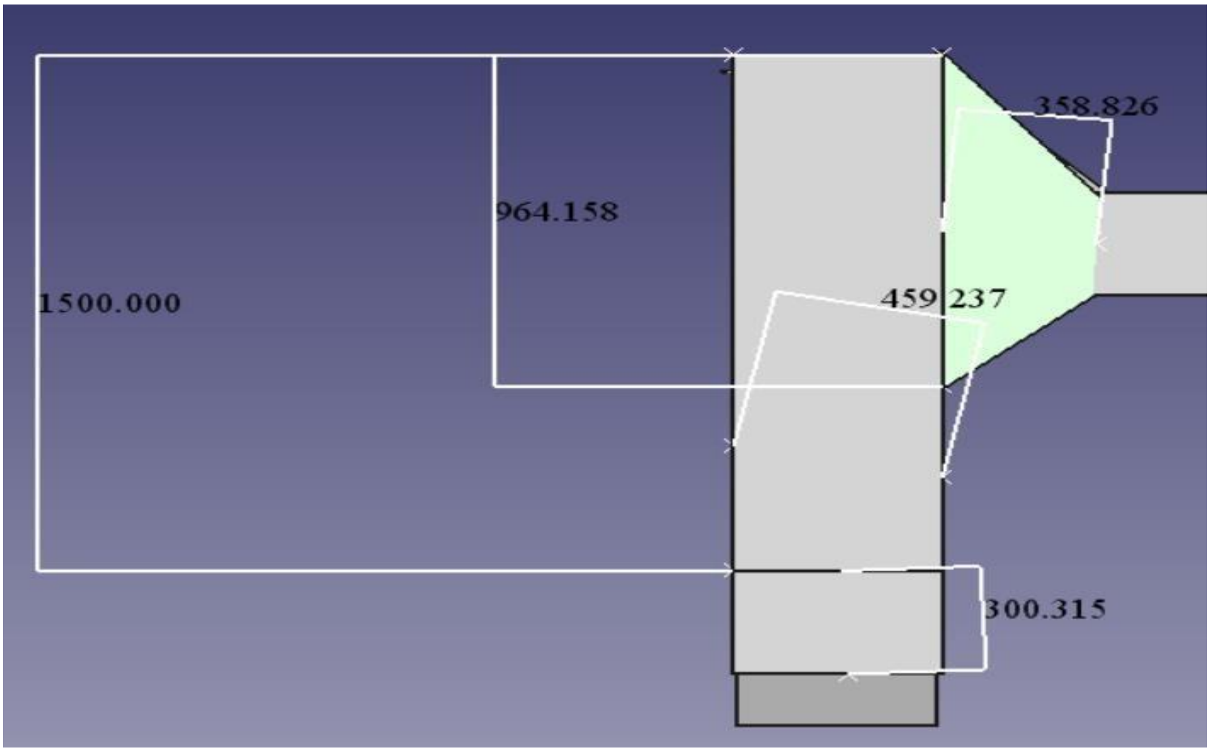


Figure 38: envelop of ESP

After finishing design of ESP, the direct implementation on the station after a request materials needed, such as plate of iron, rods of copper and electrical insulation.

Below is a list of materials that were sent to a commercial company:

quality	عرض (متر) Width	طول (متر) Length	العدد Quantity	السماكة (مم) thickness
حديد مزيبق Iron quicksilver	1	2	6	0.5
فولاذ steel	1	2	1	5
قضيب نحاس Copper rod	قطر 6 مم	0.8	43	–

Table 12:list of materials

Figure 39: insert of plate (iron) & copper wire.

47.3.2.2 HIGH VOLTAGE LOW CURRENT

To activate the ESP, it's obligated to be connected to high voltage current DC. thus, it's necessary a transformer that change 220 V to a voltage >10 kV. Then, a rectifier to change the current from AC to DC that ameliorated the ionization of electrode. (18)

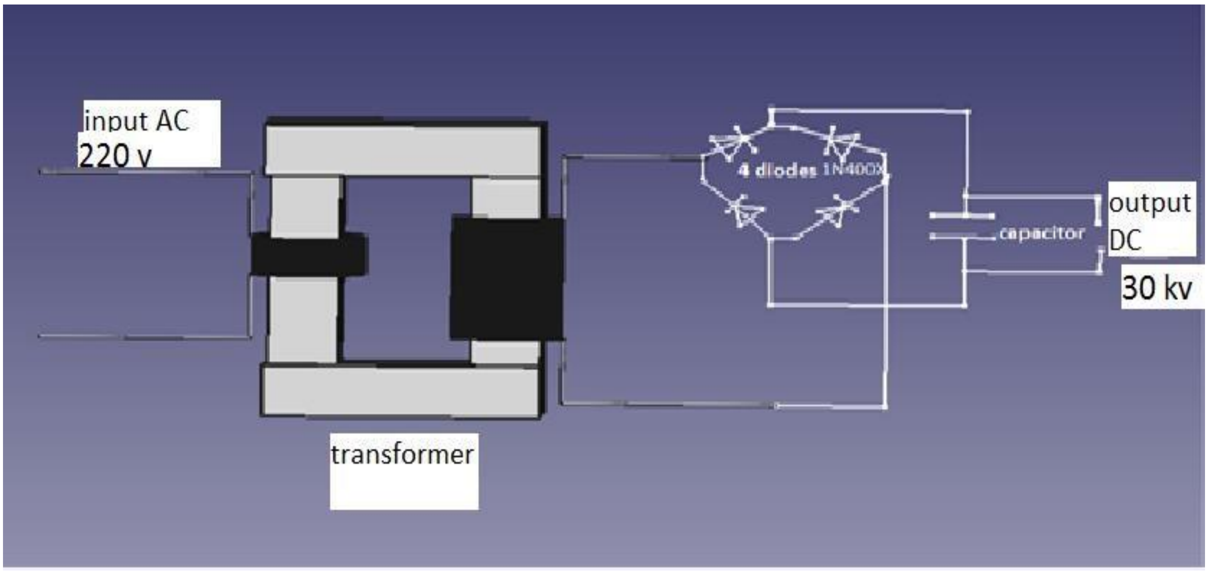


Figure 40: design of electrical system by FreeCAD

The ratio of transformer is m= m= $\frac{\boldsymbol{I\ in}}{\boldsymbol{I\ out}}=\frac{\boldsymbol{n_2}}{\boldsymbol{n_1}}=\frac{\boldsymbol{V\ out}}{\boldsymbol{V\ in}}=\frac{\mathbf{30000}}{\mathbf{230}}=136$

Secondly, a rectifier is important to use to change the current from AC to DC. A diode bridge with a capacitor and resistance are the main materials used to obtained a DC current.

-type of diode: 2CLG 30KV (5mA High Voltage Diode HV

Rectifier Tesla) -capacitor :1.3 microfarad (19)

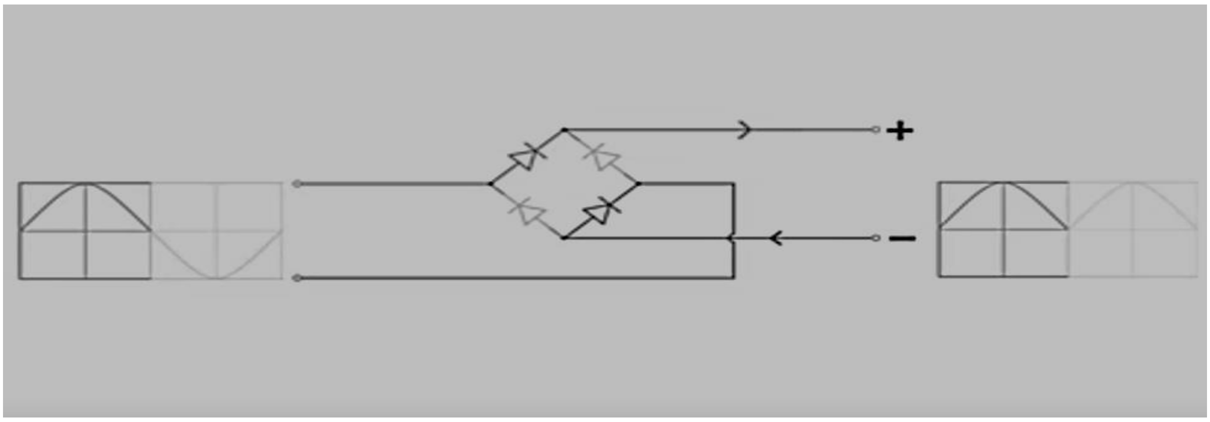


Figure 41: representative circuit

We had connected to long time a lots of company inside and outside Lebanon to buy a transformer with this specification but we don’t find any one.

A decision to create a transformer in the plant.

47.3.2.3 DESIGN OF TRANSFORMER

The Core Area is calculated through the formula given below:

CA = 1.152 ×√ (Output Voltage × Output Current) = 15.45

Calculation of Turns
per Volt (TPV)

It is done with the following formula:

TPV = 1 / (4.44 × 10^{-4} × CA × Flux Density (1.45) × AC frequency)

= 1/ (4.44 × 10^{-4} × 15.45 × 1.45 × 50) = 2

Primary Winding Calculations

Basically 2 important parameters need to be figured out while calculating the primary winding of a transformer, they are as follows:

- Number of turns of the primary winding
- Area of the primary winding

Let’s trace out each of the above expressions:

Number of Turns = TPV × Primary Volts =2*220=440 V

Primary Winding Area = Number of Turns / Turns per Sq. cm (from the **table 12**)

Reading **the following Table** is easy: just find out the relevant figures (wire SWG and Turns per sq.cm.) by tallying them with the closest matching value of your selected primary current.

The table below helps you to select the gauge and turns per sq. cm of copper wire by matching them with the selected current rating of the winding appropriately.

SWG	**AMP**	**Turns per Sq.cm**.
10	16.6	8.7
11	13.638	10.4
12	10.961	12.8
13	8.579	16.1
14	6.487	21.5
15	5.254	6.8
	38 3507	0.0365

Table 13: relation between diameter wire and current .

		British Standard Wire Gauge (SWG) diameters	
SWG	**(in)**	**(mm)**	**Step**
8	0.160	4.064	
9	0.144	3.658	
10	0.128	3h.251	0.012"/gauge
11	0.116	2.946	
12	0.104	2.642	
13	0.092	2.337	
14	0.080	2.032	0.008"/gauge

15	0.072	1.829
16	0.064	1.62

Table 14: British Standard Wire Gauge (SWG) diameters

Primary Winding Area = Number of Turns / Turns per Sq. cm=440/12.8=34.375 cm²

(With consideration that the input current above 10 A)

Secondary Winding Calculations

As explained above, with the help of **Table 12** it should be able to find the SWG of the wire to be used for the secondary winding and the TPV simply by matching them with the selected secondary current.

The Number of turns for the secondary winding is also calculated as explained for the primary winding, however considering high loading conditions of this winding, 4 % extra turns is preferably added to the overall number of turns. Therefore, the formula becomes:

Secondary Number of Turns = 1.04 × (TPV × secondary voltage) =1.04*2*30000=62400

Also secondary winding area = Secondary Turns / Turns per sq. cm. (from **table 12) =**62400/3507=17.8cm² **(**with consideration that the output current above 10 mA**)**

Calculation of the Core Size of the Steel Laminations or the Stampings

The core size of the steel stampings to be used may be easily found by suitably matching the relevant information with Total Winding Area of the transformer. The Total Winding Area thus needs to be calculated first, it's as follows:

Total Winding Area = (Primary Winding Area + Total Secondary Winding Area) × Space for External Insulation.

The third parameter i.e. the space for the insulation/former etc. may be taken approximately 25 to 35 % of the sum of the first two parameters.

Therefore, the above formula becomes:

Total Winding Area = (Primary Winding Area + Total Secondary Winding Area) × 1.3= (34.375 +17.8) *1.3=67.8 cm²

Type-------------------

Tongue----------Winding

No. ---------------------

Width-------------Area

8(E/I) -------------------- 5.080 ----------49.803

This is the type of laminations correspond to an array >49.803cm²

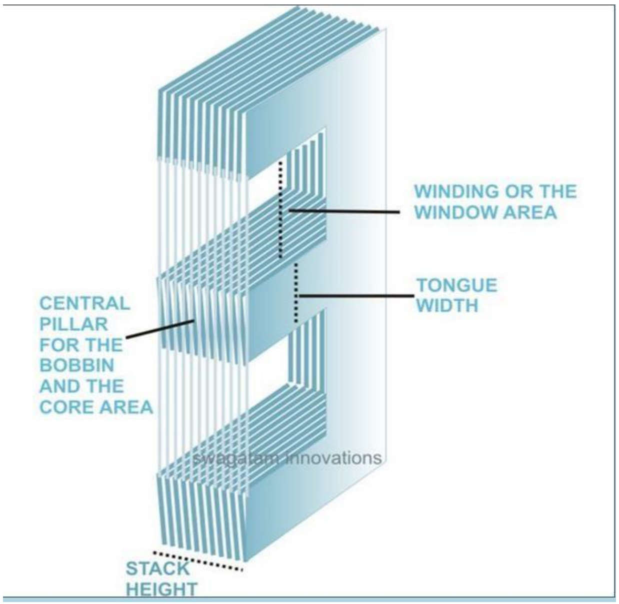


Figure 42: style of laminations

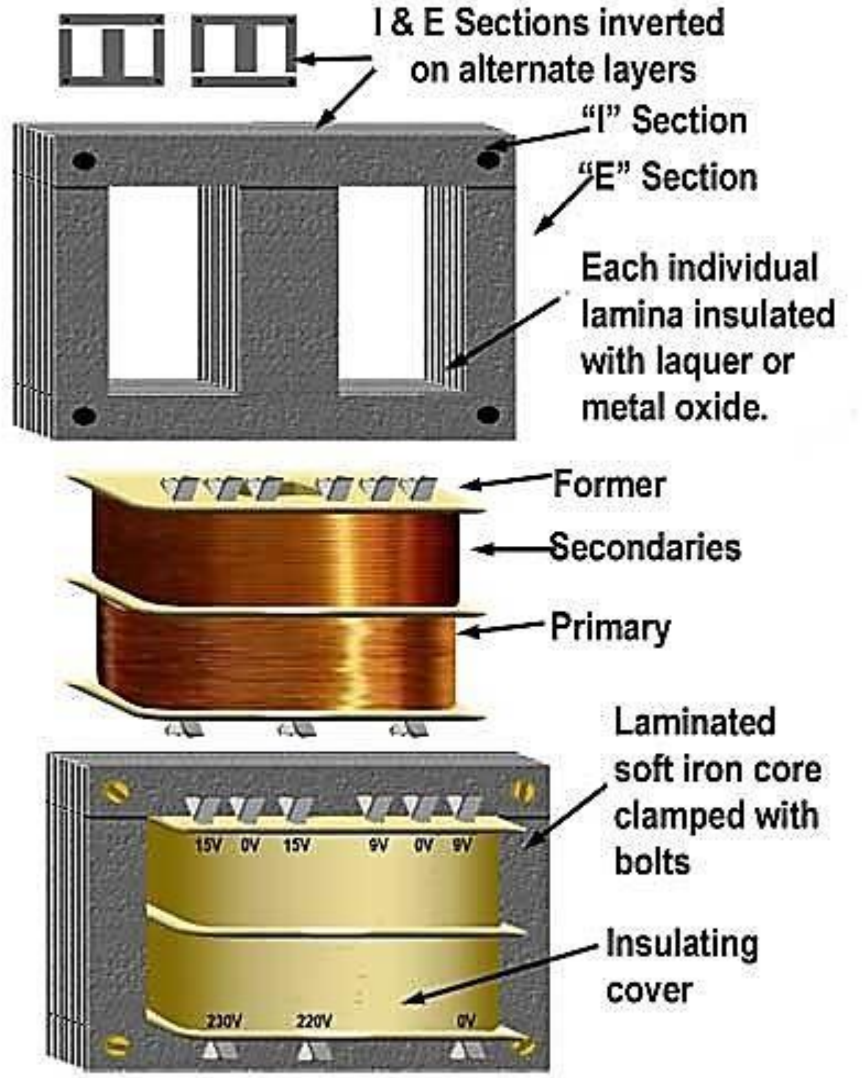


Figure 43: fabrication of transformer

Mass of copper necessary to primary and secondary winding:

Copper is

identified by:

8.96 g/cm^3 To

first winding:

- The diameter of the copper wire is 2.6 mm
- Number of turns: 440
- Primary Winding Area: 34.375 cm²
- Mass of wire: 7 kg To second winding:

- the diameter of the copper wire is 0.15 mm
- Number of turns :62400
- secondary winding area: 17.8cm²

- mass of wire:1.75 kg

Total mass of wire above 9 kg.

Or the total mass of transformer includes in addition to wire:

- mass of core (laminations)
- mass of insulator

Thus, here the problem is the weight of transformer, as the voltage which is to be stepped up increases the insulation level of the transformer increases and hence it becomes bulky. Apart from this the rectification process is carried out using rectifier grade diodes which are slow and filtering is done using high value capacitors which are heavy in weight.

So to mitigate all the above mentioned problems the voltage multiplier circuits can be used where load current is less and voltage is high. Negative voltage can be achieved by inversing the diode direction.

2.4.2.4 DESIGN OF COCKCROFT WALTON VOLTAGE MULTIPLIER:

- **PRINCIPLE OF VOLTAGE MULTIPLIER CIRCUIT**

One of the cheapest and popular ways of generating high voltages at relatively low currents is the classic multistage diode/capacitor voltage multiplier, known as Cockcroft Walton multiplier, named after the two men who used this circuit design to be the first to succeed in performing the first nuclear disintegration in 1932. A voltage multiplier is an electrical circuit that converts AC electrical power from a lower voltage to a higher DC voltage and less current, using a network of capacitors and diodes. In industrial as well in research area high voltage
DC Power Supplies are widely used for testing purpose. (20)

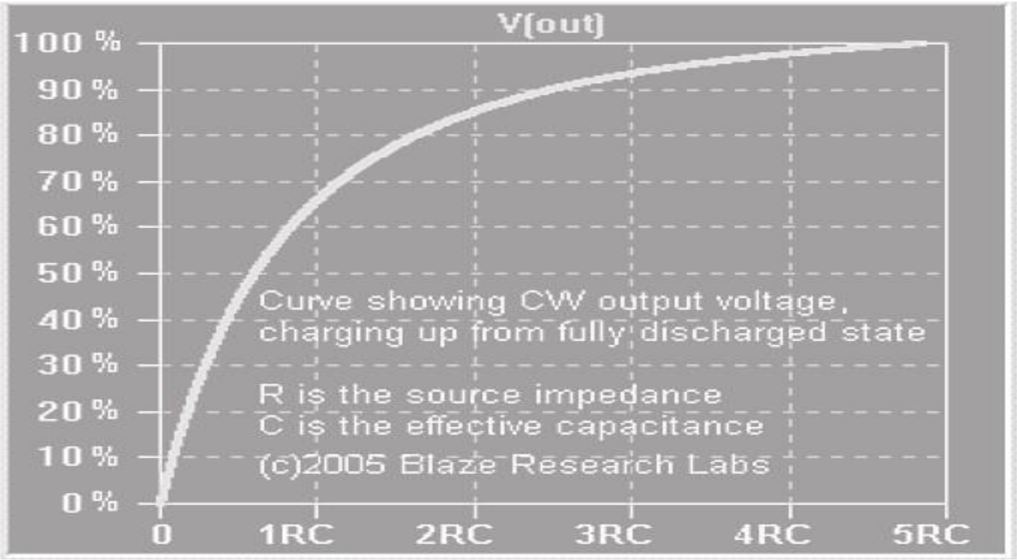


Figure 44: relation between number of RC circuit and output voltage

1. Voltage Doubler

In voltage doubler circuit fig.43 shown below gives a brief idea about the principle of negative voltage doubler where the diodes are rectifier grade diodes and the capacitor diode assembly acts like half wave rectifier. In the circuit during positive half cycle of input voltage first diode is forward biased and second one is reverse biased. Therefore, the flow of current charges the capacitor to negative peak value and capacitor C1 is charged through diode D1 to –Vin

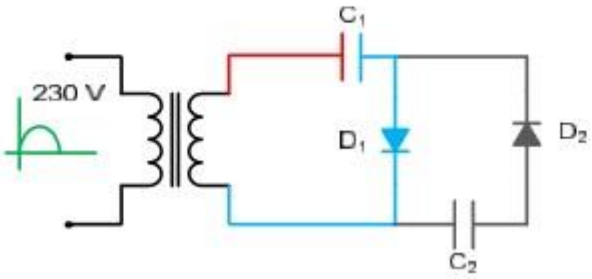


Figure 45: voltage doubler in positive alternation

Similarly, in the fig.41 shown below circuit during negative half cycle of input voltage hence first diode is reverse biased and second one is in forward biased. Therefore, the potential of capacitor C1 adds with that of the source, thus charging C2 to –2Vin through D2.

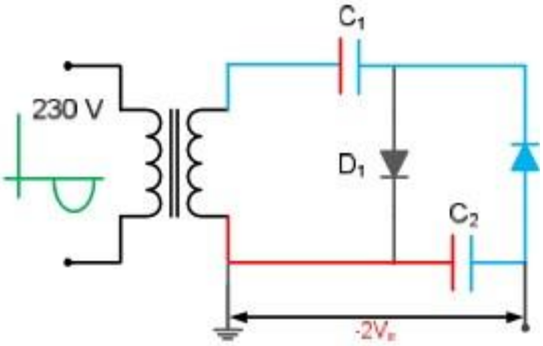


Figure 46: Voltage Doubler in negative alternation

2. Voltage Quadruple

The principle of voltage quadruple is same as voltage doubler; the only difference is number of stages is 2 in quadruple circuit. For positive and negative input voltage the direction of current flow is shown in figures below where in positive alternation potential of capacitor C1 drops to 0 V and allow C3 to be charged through D3 to –2Vin. And in negative alternation potential of C1 rises to –2Vin, also charging C4 to 2Vin. The output voltage (the sum of voltages under C2 and C4) raises till -4Vin as in figure 42

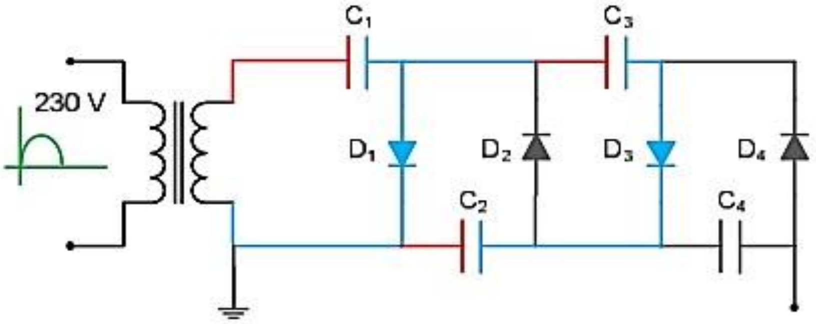


Figure 47: Voltage quadruple in positive alternation

3. DESIGN SPECIFICATION

Output voltage requirement, needed to test the system at -70 kV, 50 mA deciding the rating of transformer is the primary task.

a- Transformer Specification

The first stage of the power supply is transformer which is basically is an isolation transformer used when it is desired to produce such high voltages. The role of isolation transformer in this circuit is step up the voltage and to isolate the low voltage side from high voltage side. So, primary task to design a voltage double is to decide the voltage rating of secondary winding transformer. The output voltage of a quadruple is given by:

$2 \times N \times Vmax = 70kV$ eq (1)

Where,

N = no. of stages

Vmax = peak output voltage

Vmax = 17.5 kV

Vrms = Vmax ÷1.414 = 12 kV

KVA rating of Supply = 70KV × 50mA = 3.5 KVA

Assuming efficiency of voltage multiplier as 75 percent.

KVA rating of transformer = KVA rating of power supply / 0.75 KVA

Rating of transformer = $\frac{3.5KVA}{0.75}$

= 4.6KVA ≈ 5KVA

So the step up transformer is rated for

230V/12 KV, 5KVA. **b- Capacitor**

Specification

The value of capacitors used is inversely proportional to the frequency of input signal. So, the capacitors are rated for 2Vmax.

For voltage quadruple circuits: 2× Vmax = 35kV.

Noptimum = $\frac{\sqrt{(Vmax \times f \times c)}}{I}$ eq (2)

C = $\frac{Noptimum \times I}{Vmax \times f}$ eq (3)

By putting Vmax = 17.5 KV and I = 50mA

C = $\frac{(\mathbf{4 \times 50 \times 10})}{(\mathbf{17.5 \times 10 \times 50})\ \mathbf{C}}$ = 0.22 micro farad.

Therefore, 35kV, 0.32 microfarad

capacitor is used. **c- Diode**

Specification

The maximum reverse voltage across a diode is called peak inverse voltage and the reverse voltage seen by each diode is 2×Vm, so it's a general practice to select a device with PIV rating of 2 × Vmax. When this value of voltage is less than specified value, a small current called leakage current flows through the device. When this voltage exceeds the limit, the device may fail.

From the 230V /12KV transformer Peak output will come up to 12 × 1.414kV = 16.96kV, so twice of it will give nearly 35 kV. So we have taken diode of 40 kV for safety purpose and also for extending the range, as such rating diodes was unavailable so it has been connected two power diodes of 20 kV to make it equivalent to 40kV. Each is having a reverse blocking resistance in the range of mega ohms.

So, the leakage current flowing through each diodes is of the order of =100uA. Thus, resistor while designing of Static Equalizing Circuit for voltage quadruples,

Therefore $R = \frac{V}{I}$ eq (4)

$= 200 M\Omega$

Power rating $= I^2 \times R$ eq (5)

$= (100 \times 10^{-6})^2 \times (200 \times 10^{-6})$

$= 2$ W

d- Calculation of Output Voltage

For design of multiplier circuit, it is very essential to calculate the voltage regulation and percentage ripple. After considering above values the output voltage of Voltage Quadruple Circuit can describe as

$Vout = (2 \times N \times Vmax) - \Delta V - \delta V$ eq (6)

Where,

Vout = output voltage of N stage voltage multiplier

N = no. of stages (it is no. of capacitor divided by 2)

Vmax = maximum or peak input voltage ΔV = resultant drop across the capacitors δV = ripples voltage (peak to peak)

$$\Delta V = \left(\frac{I}{f \times c} \times \{((2 \times n^3) \div 3) + (n^2 \div 2) - (n \div 6)\} \right)$$

eq (7) So, at 50mAmp Voltage drop in

the multiplier circuit is given as: $\Delta V = (50$

$\times 10^{-3}) \div (50 \times 0.25 \times 10^{-6})$

$= 28000$ V

Ripple voltage (peak to peak) given by

$$\delta V = \left(\frac{I \times n \times (n+1)}{4 \times f \times c}\right)$$

eq (8)

So, at 50 mAmp δV = 6000V

Now, Regulation of Voltage $= \frac{\Delta V}{2\ Vmax}$ eq (9)

$$= \frac{28000}{2 \times 17500}$$

$$= 0.8$$

Percent Percentage Ripple $= \frac{\delta V}{2\ Vmax}$ eq (10)

$$= 0.171 \text{ percent}$$

When load is not connected, in that case δV and ΔV both are zero thus the above equation get

reduce to, Vout = 2 × N ×Vmax eq (11)

Vout = 2 × 2 × 1.414 × 12 = 67.87KV

Thus, by choosing appropriate values, power supply is made which is also work negative supply can provide by reversing diode direction. As diode direction is reversed output supply is -67.87Kv..

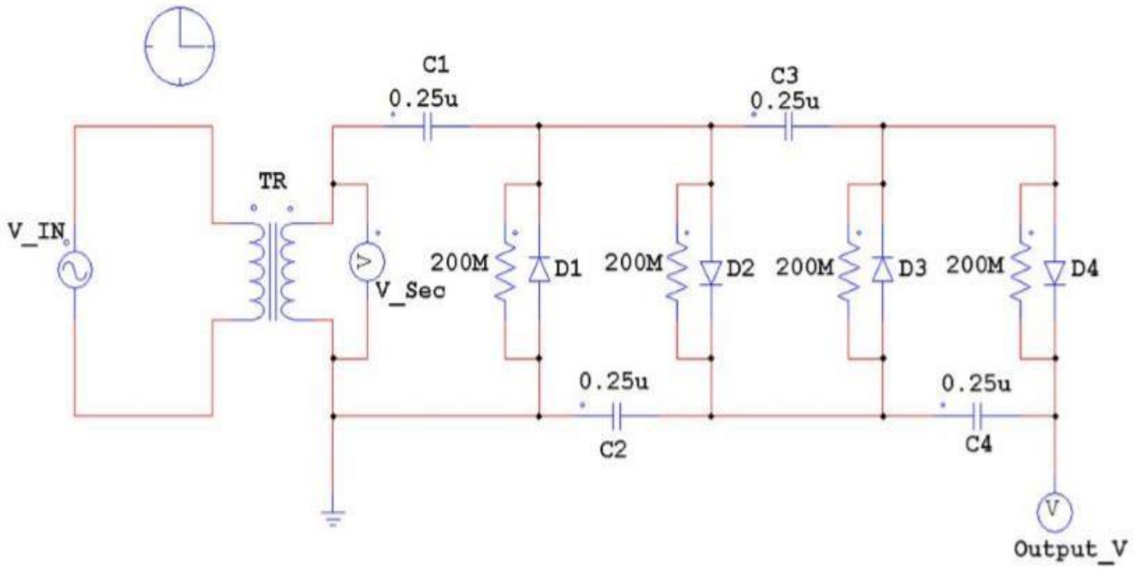


Figure 48: Voltage Quadruple circuit without load

Finally, to manufactured this circuit it’s necessary to immerge it in oil transformer to protect us from any short-circuit or other danger.

Materials	Quantity

Diodes (200 MΩ , 2W)	4
Capacitor (0.25 μF)	4

Table 15: list of materials formed the circuit

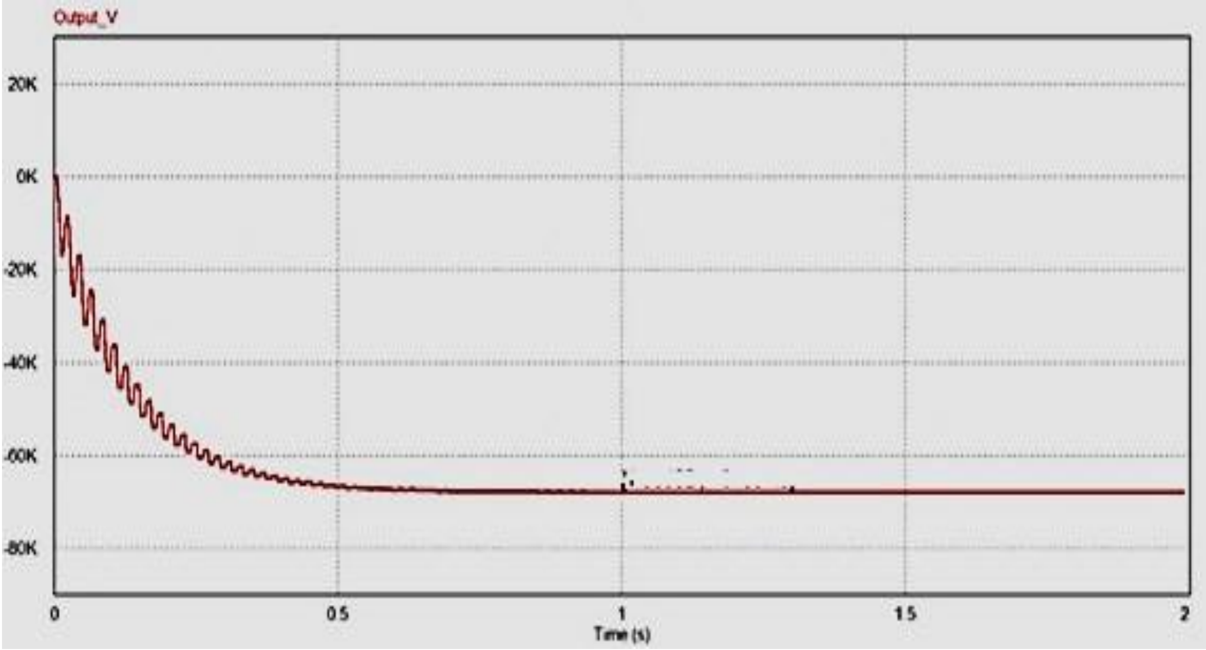
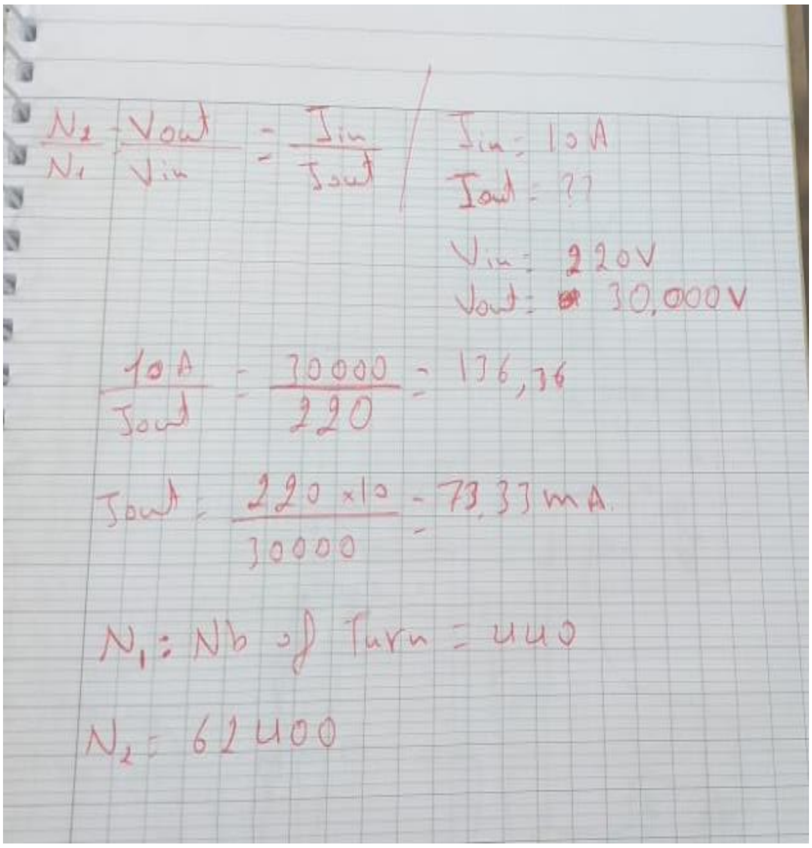


Figure 49: Output Voltage of Quadruple without load

Figure 50: circuit 5 stages

47.3.3 Realization of 40 kV power supply for electrofilter

47.3.3.1 Transformer



$\frac{N_2}{N_1} = \frac{V_{out}}{V_{in}} = \frac{I_{in}}{I_{out}}$

$I_{in} = 10A$

$I_{out} = ??$

$V_{in} = 220V$

$V_{out} = 30,000V$

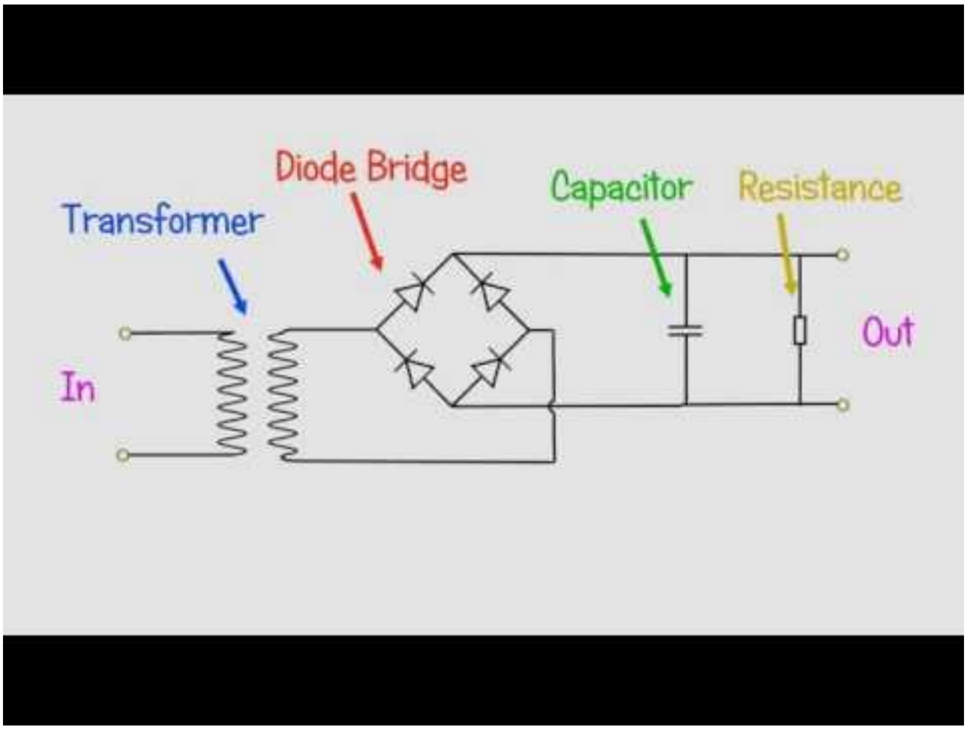
$\frac{10A}{I_{out}} = \frac{30000}{220} = 136,36$

$I_{out} = \frac{220 \times 10}{30000} = 73,33 mA$

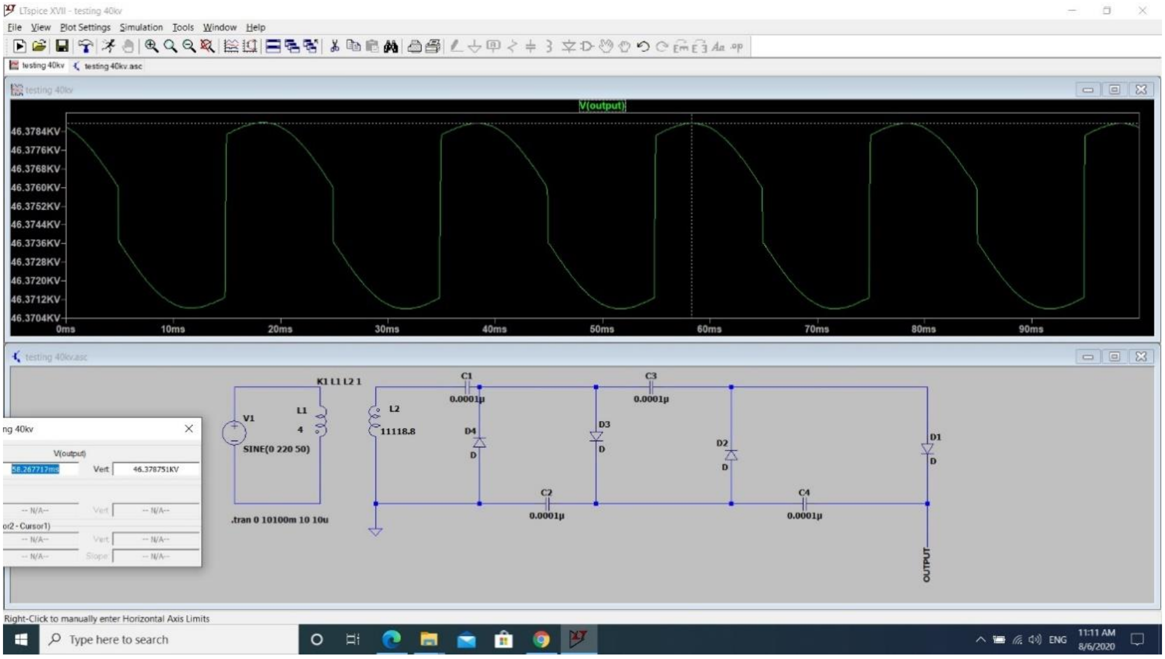
N_1 : Nb of Turn = 440

N_2 = 62400

47.3.3.2 Testing of AC to DC using oscilloscope



47.3.3.3 40 kV through Voltage Quadruple



ng 40kv

V(output)

58.267717ms Vert 46.378751KV

-- N/A-- Vert -- N/A--

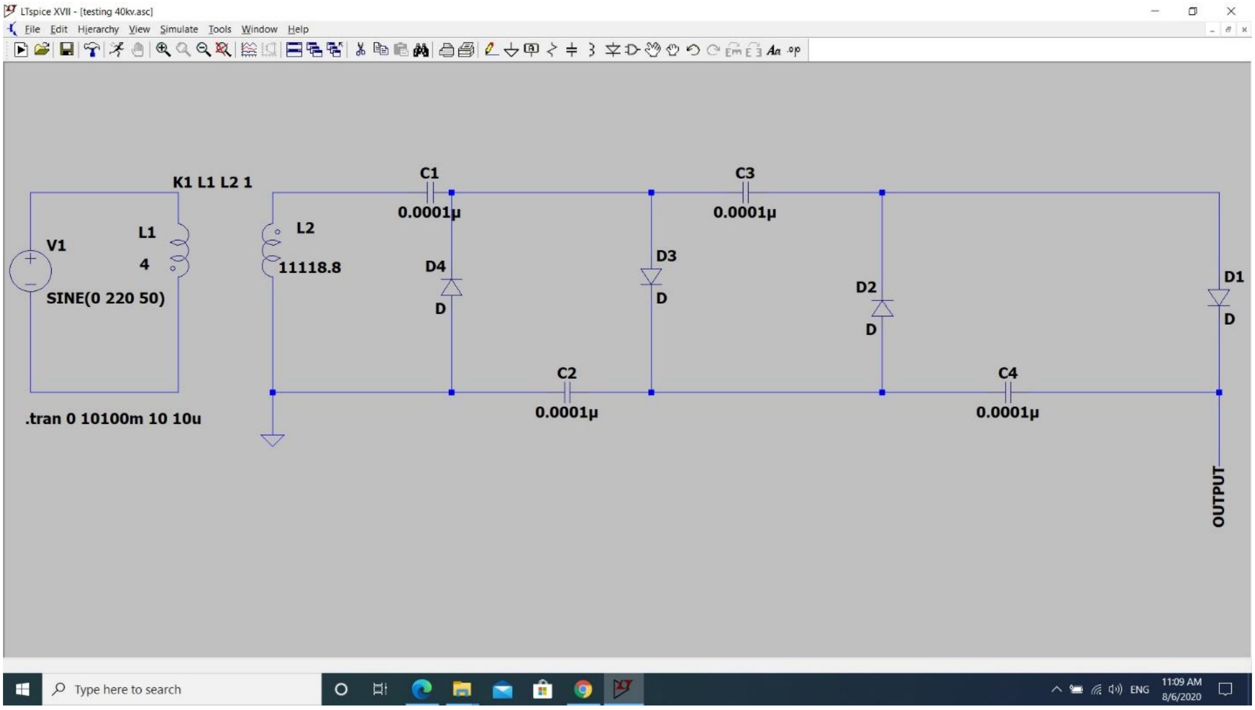
or2 - Cursor1)

-- N/A-- Vert -- N/A--

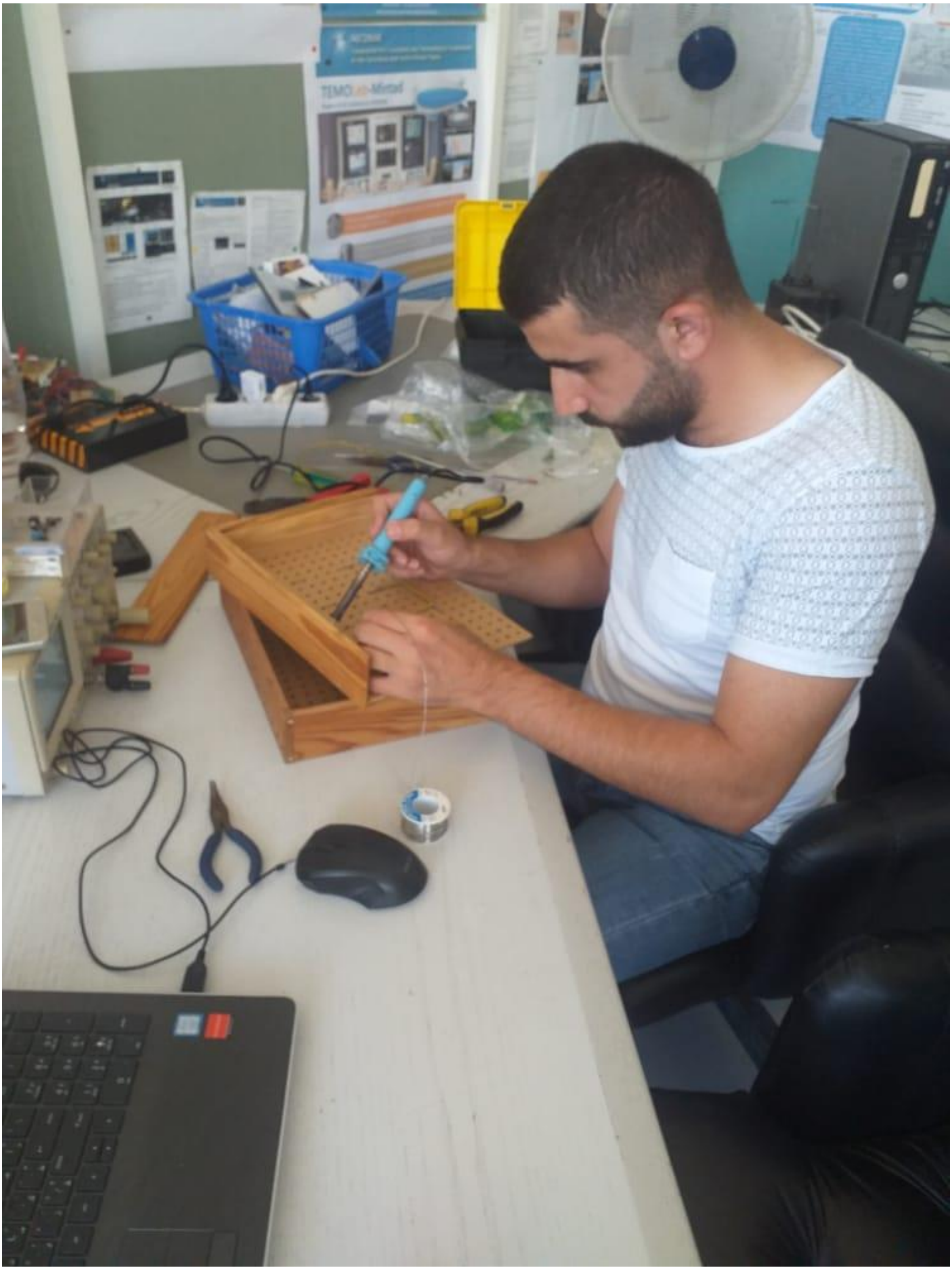
-- N/A-- Slope -- N/A--

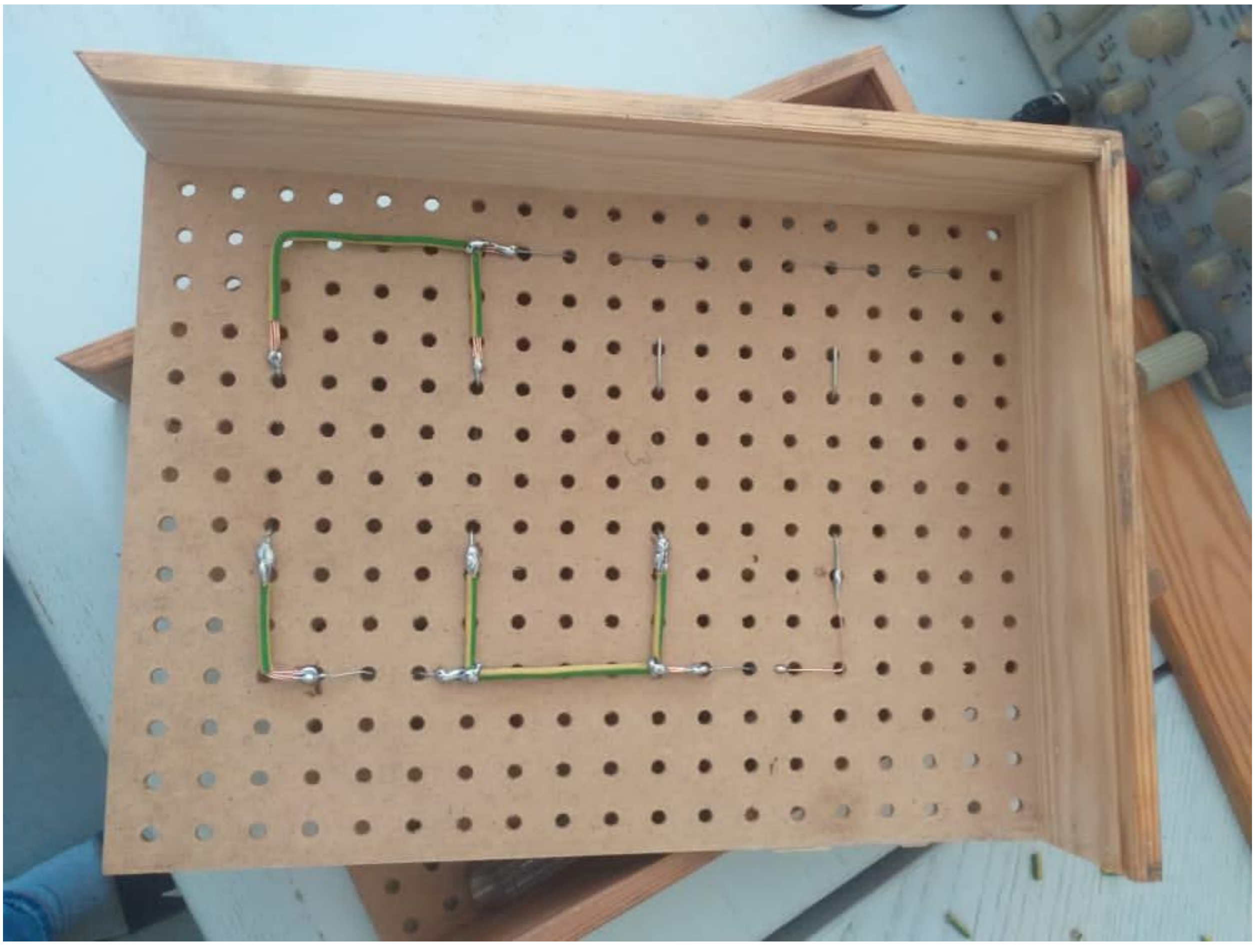
.tran 0 10100m 10 10u

Right-Click to manually enter Horizontal Axis Limits



.tran 0 10100m 10 10u





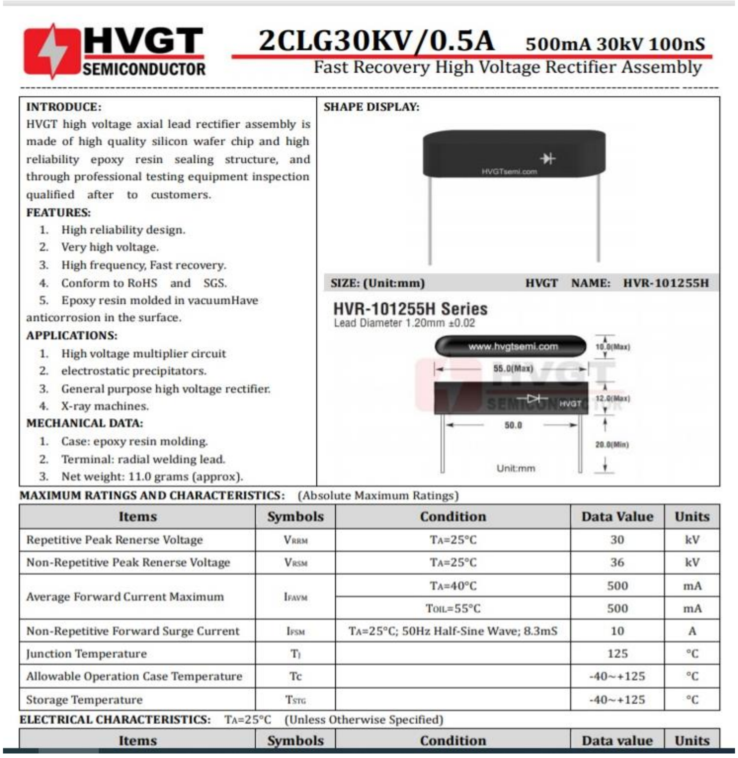
47.3.3.4 Pieces used in this project

Diode: 2CLG30KV/0.5A

Capacitor: 101k 30kv

Transformer: 220v to 10 kv

47.3.3.5 Specification of diode:



HVGT SEMICONDUCTOR

2CLG30KV/0.5A **500mA 30kV 100nS**

Fast Recovery High Voltage Rectifier Assembly

INTRODUCE:

HVGT high voltage axial lead rectifier assembly is made of high quality silicon wafer chip and high reliability epoxy resin sealing structure, and through professional testing equipment inspection qualified after to customers.

FEATURES:

1. High reliability design.
2. Very high voltage.
3. High frequency, Fast recovery.
4. Conform to RoHS and SGS.
5. Epoxy resin molded in vacuumHave anticorrosion in the surface.

APPLICATIONS:

1. High voltage multiplier circuit
2. electrostatic precipitators.
3. General purpose high voltage rectifier.
4. X-ray machines.

MECHANICAL DATA:

1. Case: epoxy resin molding.
2. Terminal: radial welding lead.
3. Net weight: 11.0 grams (approx).

SHAPE DISPLAY:

SIZE: (Unit:mm) **HVGT NAME: HVR-101255H**

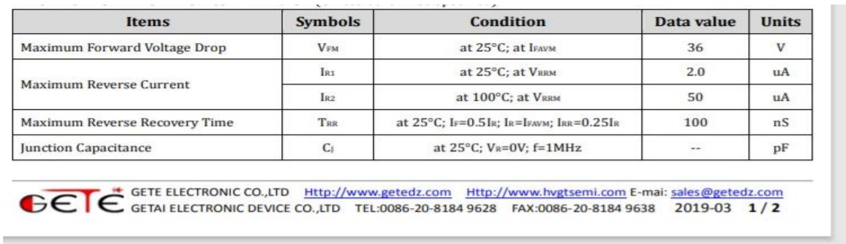
HVR-101255H Series

Lead Diameter 1.20mm ±0.02

MAXIMUM RATINGS AND CHARACTERISTICS: (Absolute Maximum Ratings)

Items	Symbols	Condition	Data Value	Units
Repetitive Peak Renerse Voltage	V_{RRM}	T_A=25°C	30	kV
Non-Repetitive Peak Renerse Voltage	V_{RSM}	T_A=25°C	36	kV
Average Forward Current Maximum	I_{FAVM}	T_A=40°C	500	mA
		T_{OIL}=55°C	500	mA
Non-Repetitive Forward Surge Current	I_{FSM}	T_A=25°C; 50Hz Half-Sine Wave; 8.3mS	10	A
Junction Temperature	T_J		125	°C
Allowable Operation Case Temperature	Tc		-40~+125	°C
Storage Temperature	T_{STG}		-40~+125	°C

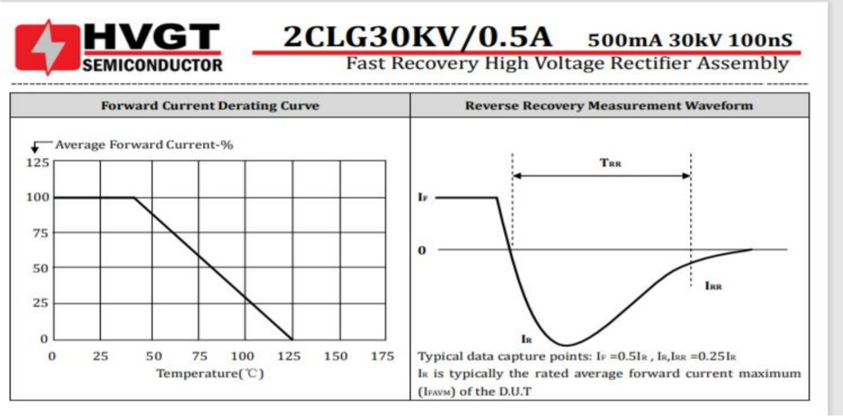
ELECTRICAL CHARACTERISTICS: T_A=25°C (Unless Otherwise Specified)



Items	Symbols	Condition	Data value	Units
Maximum Forward Voltage Drop	V_{FM}	at 25°C; at I_{FAVM}	36	V
Maximum Reverse Current	I_{R1}	at 25°C; at V_{RRM}	2.0	uA
	I_{R2}	at 100°C; at V_{RRM}	50	uA
Maximum Reverse Recovery Time	T_{RR}	at 25°C; I_F=0.5I_R; I_R=I_{FAVM}; I_{RR}=0.25I_R	100	nS
Junction Capacitance	C_J	at 25°C; V_R=0V; f=1MHz	--	pF

GETE ELECTRONIC CO.,LTD Http://www.getedz.com Http://www.hvgtsemi.com E-mai: sales@getedz.com

GETAI ELECTRONIC DEVICE CO.,LTD TEL:0086-20-8184 9628 FAX:0086-20-8184 9638 2019-03 **1 / 2**



HVGT SEMICONDUCTOR

2CLG30KV/0.5A **500mA 30kV 100nS**

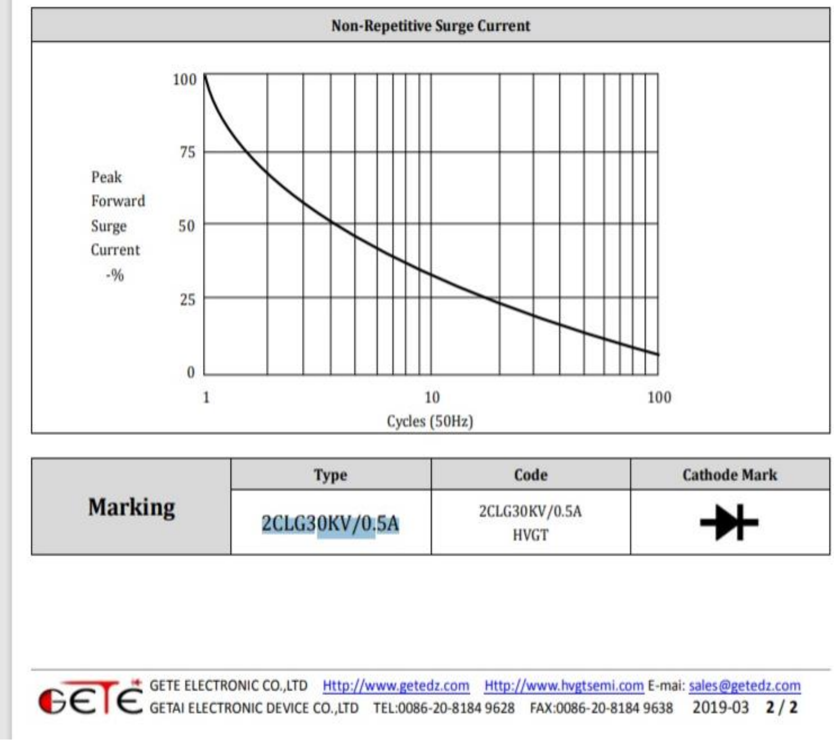
Fast Recovery High Voltage Rectifier Assembly

Forward Current Derating Curve

Reverse Recovery Measurement Waveform

Typical data capture points: I_F =0.5I_R , I_R,I_{RR} =0.25I_R

I_R is typically the rated average forward current maximum (I_{FAVM}) of the D.U.T



Non-Repetitive Surge Current

Marking	Type	Code	Cathode Mark
	2CLG30KV/0.5A	2CLG30KV/0.5A HVGT	▶|

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47.3.3.6 Capacitor

Product Specification:

Package Type :Surface Mount

Model :101k 30kv

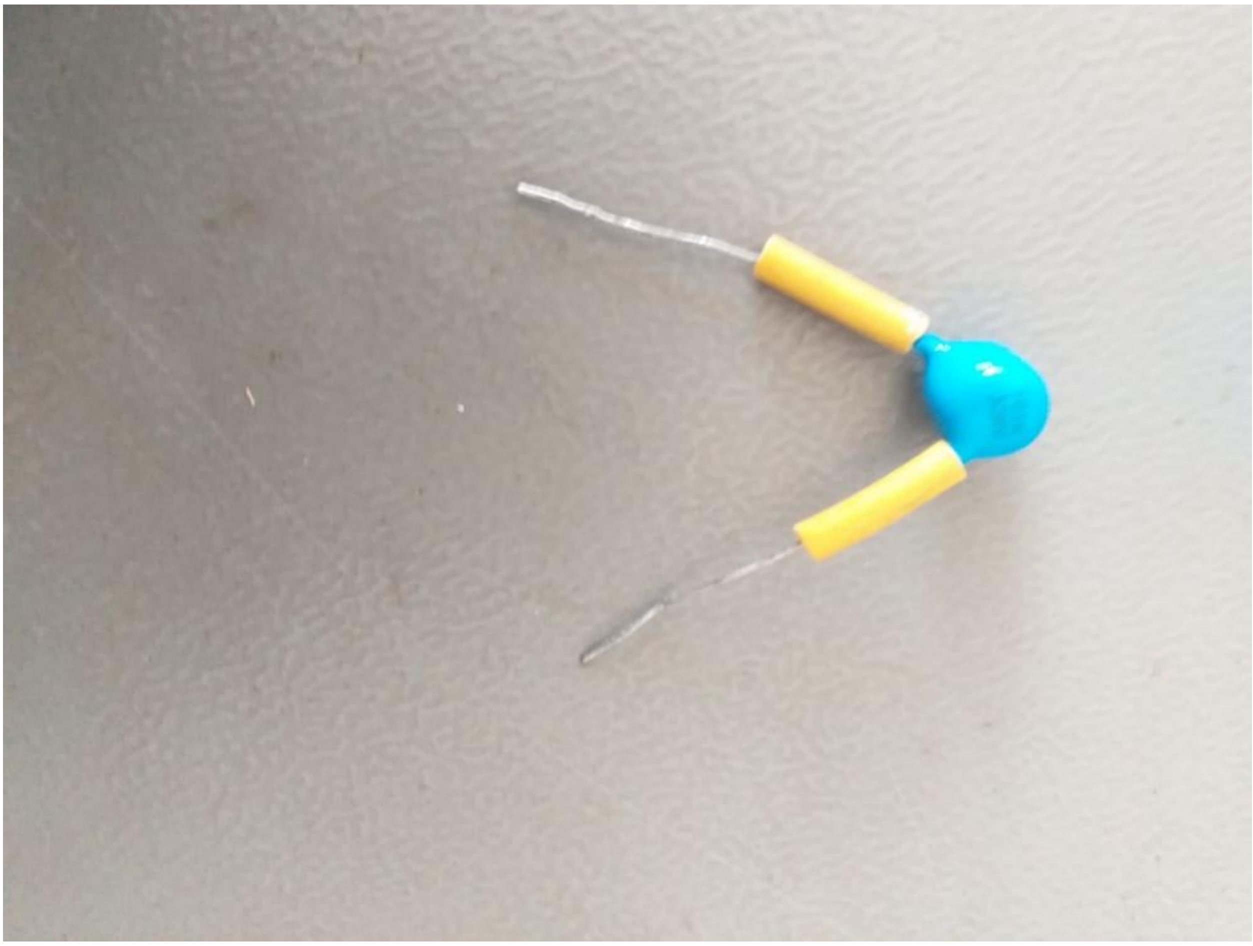
Diameter :7.5MM

Brand Name :YTF

Load Life :2000-3000 Hours


101K
30KV

Isolation method this capacitors:

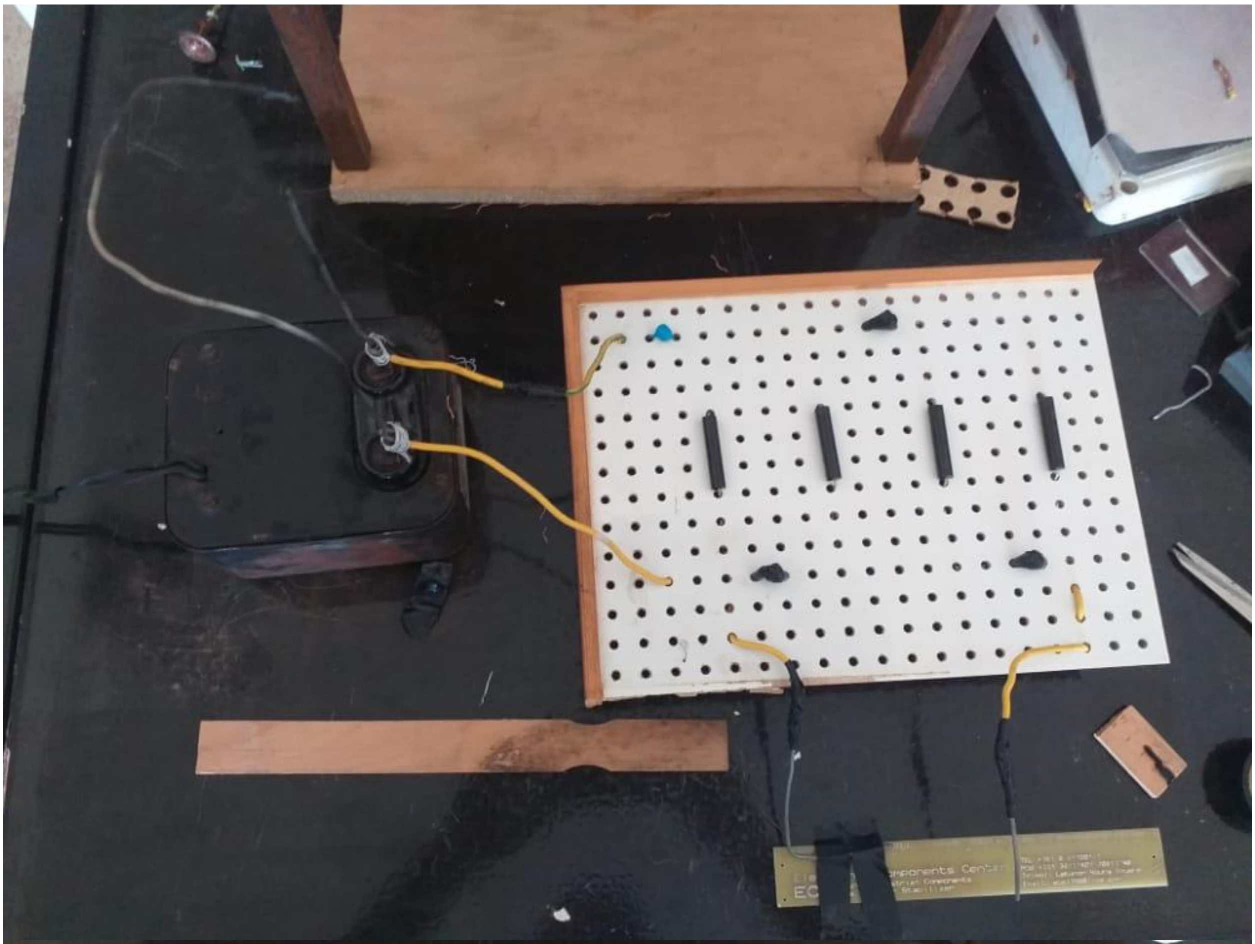


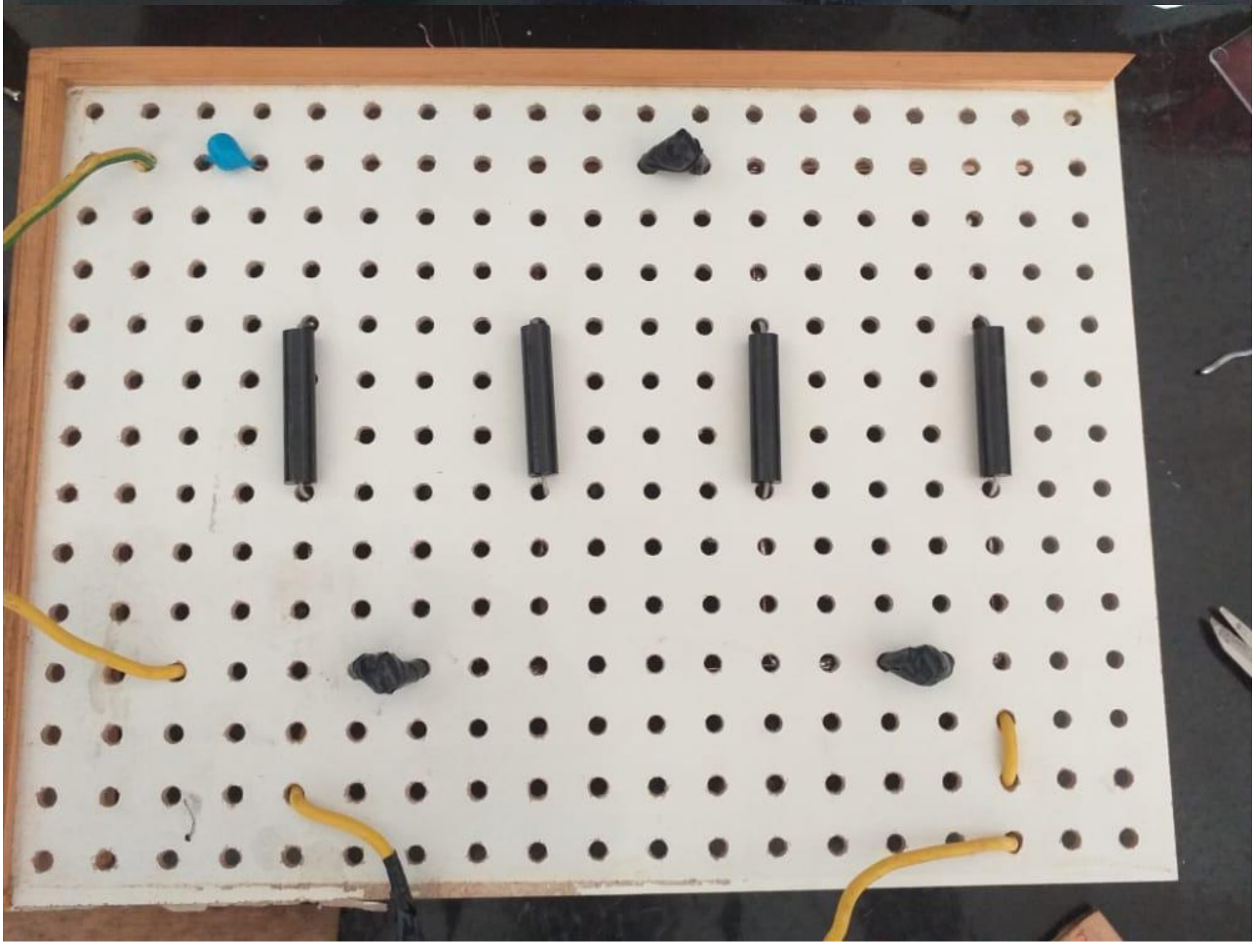
47.3.3.7 Testing for first stage 1.7cm=1.7kv:

Figure 47.1: 1.7cm=1.7kv

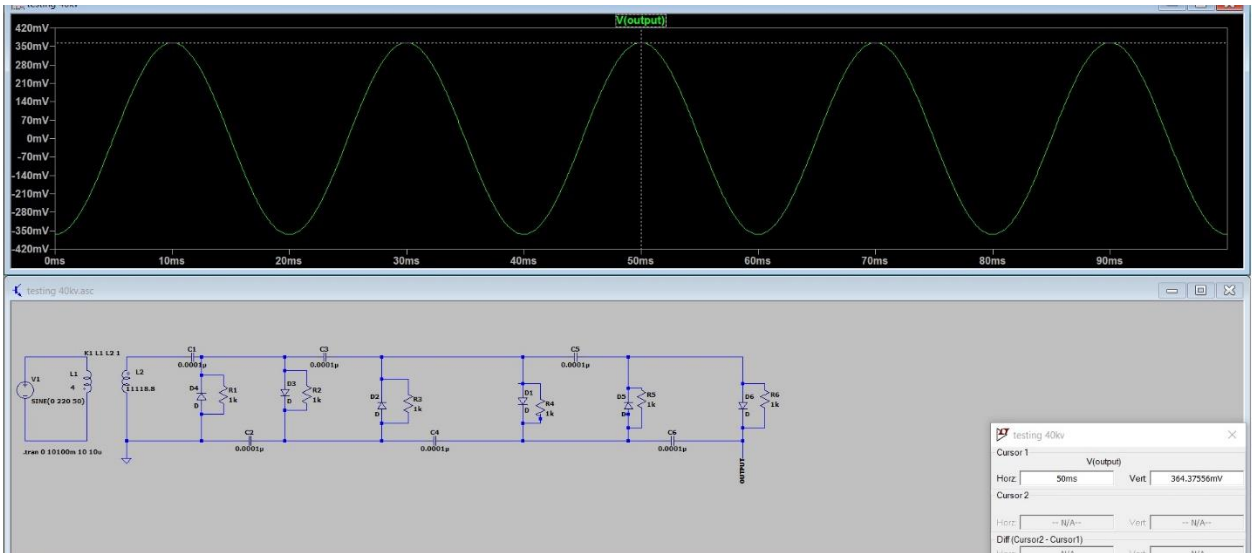
47.3.3.8 Testing for second stage 2.6cm=26kv:


Components Center
strial Components
Stabilizer


Components Center
EC



47.3.3.9 Testing 3rd stage with resistor



testing 40kv

Cursor 1

V(output)

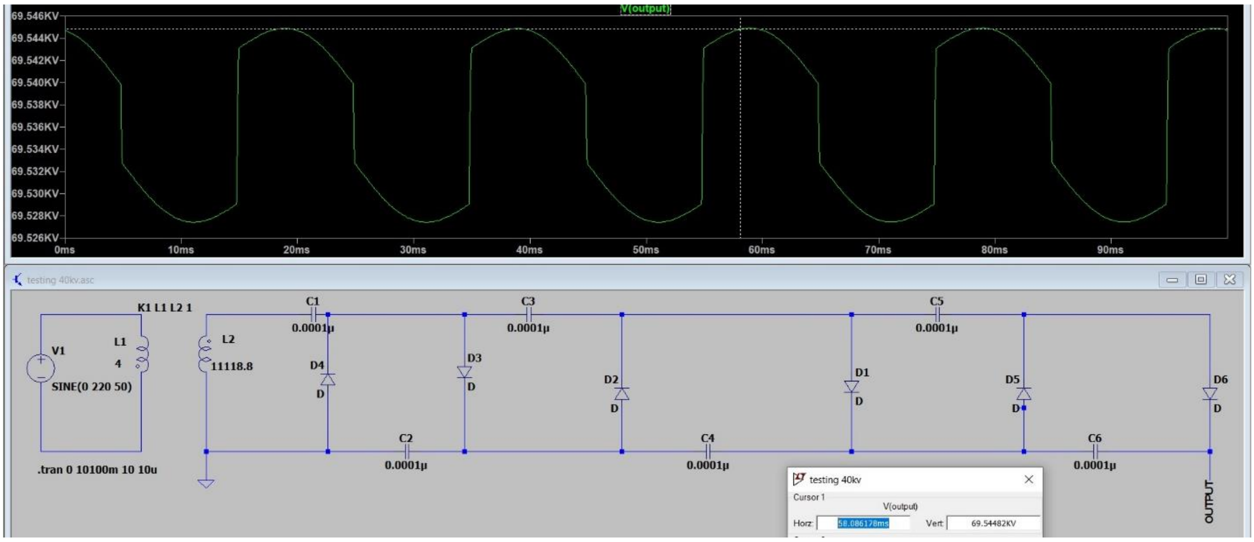
Horz: 50ms Vert: 364.37556mV

Cursor 2

Horz: -- N/A-- Vert: -- N/A--

Diff (Cursor2 - Cursor1)

47.3.3.10 Testing 3rd stage without resistor



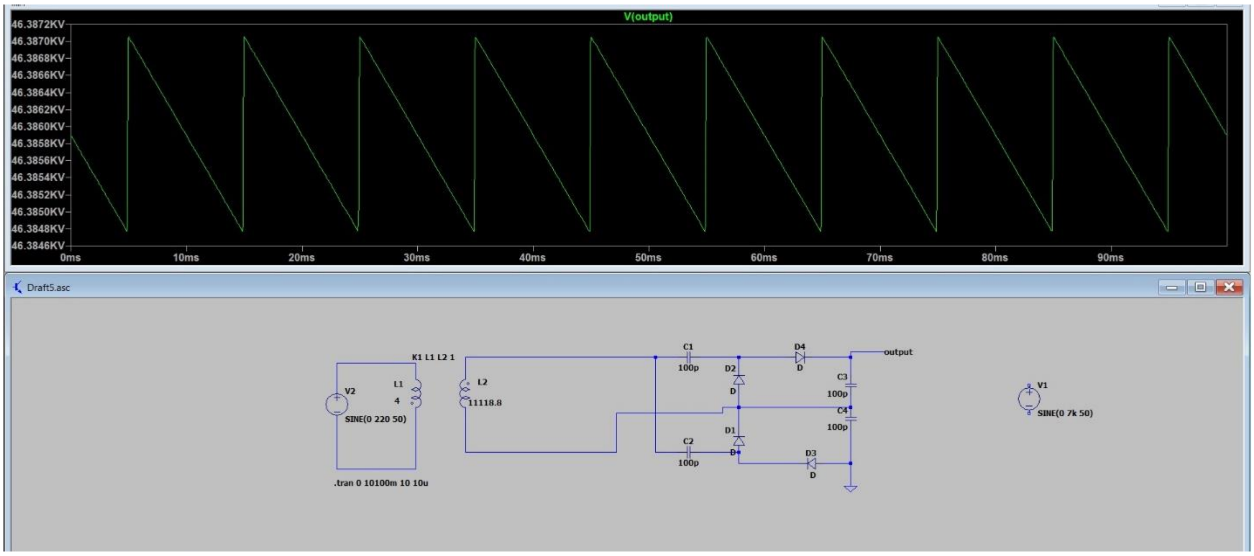
testing 40kv

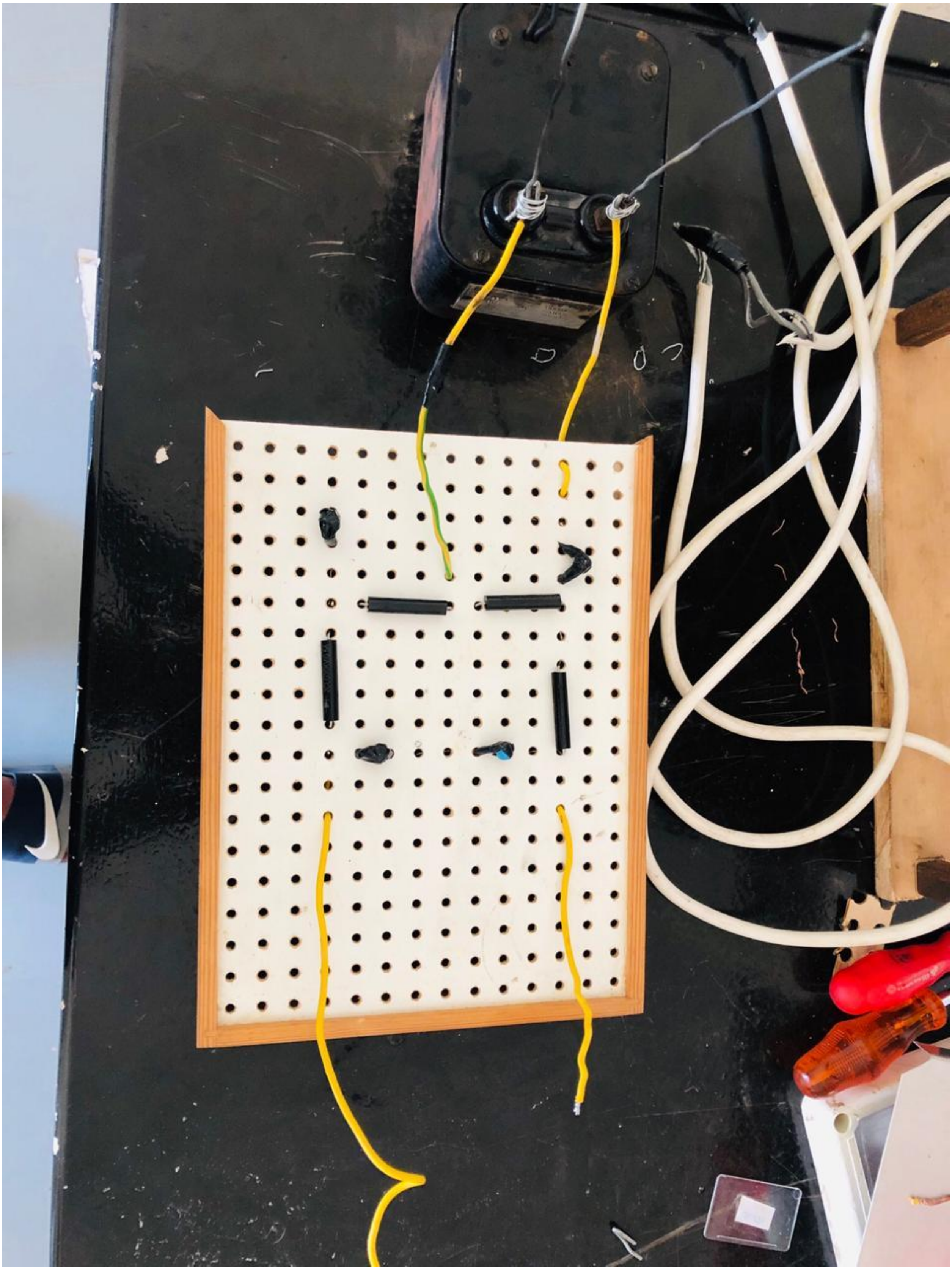
Cursor 1

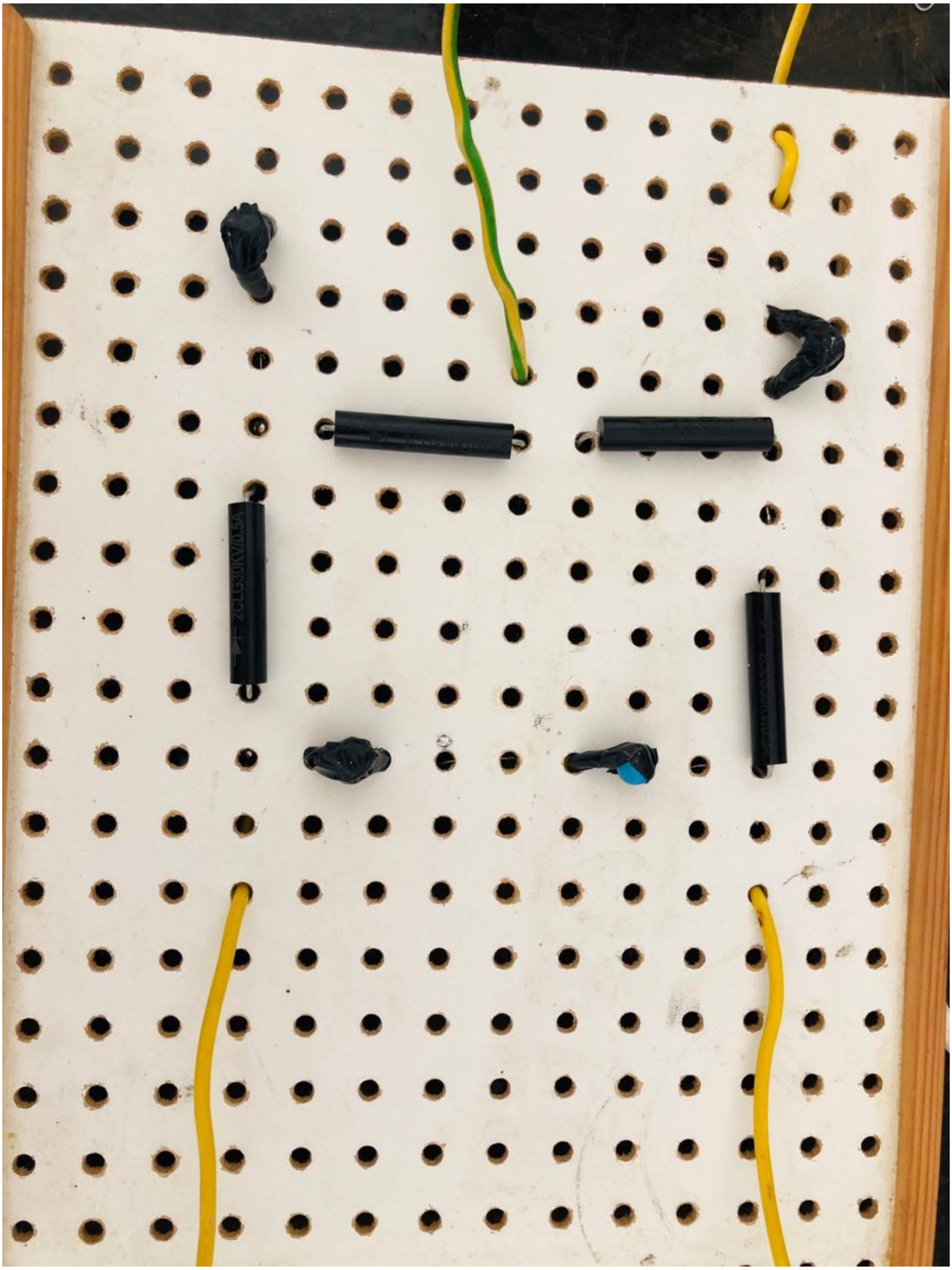
V(output)

Horz: 58.086178ms Vert: 69.54482KV

47.3.3.11 New test of Voltage Quadruple:







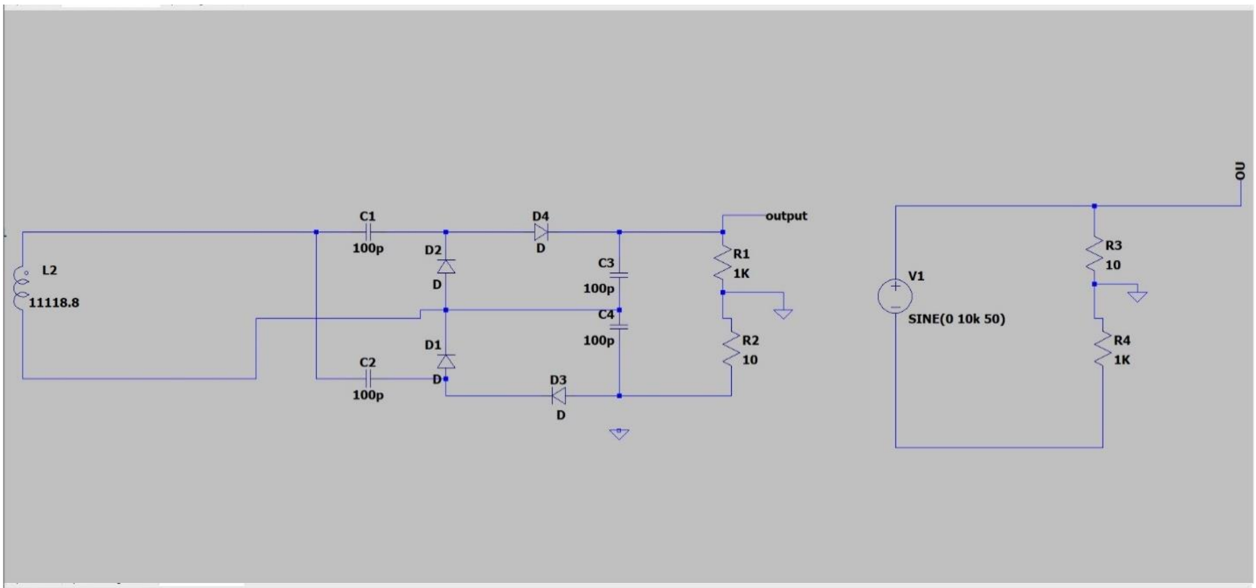
Link of this test

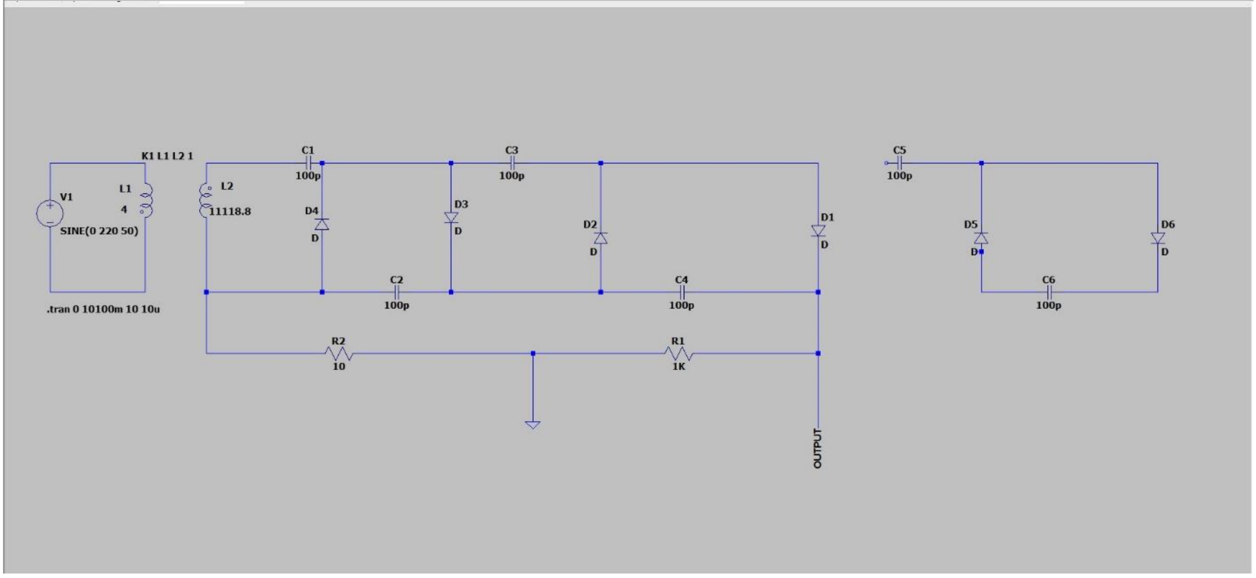
https://instrumentationtools.com/topic/voltage-multipliers/

47.3.3.12 Voltage divider

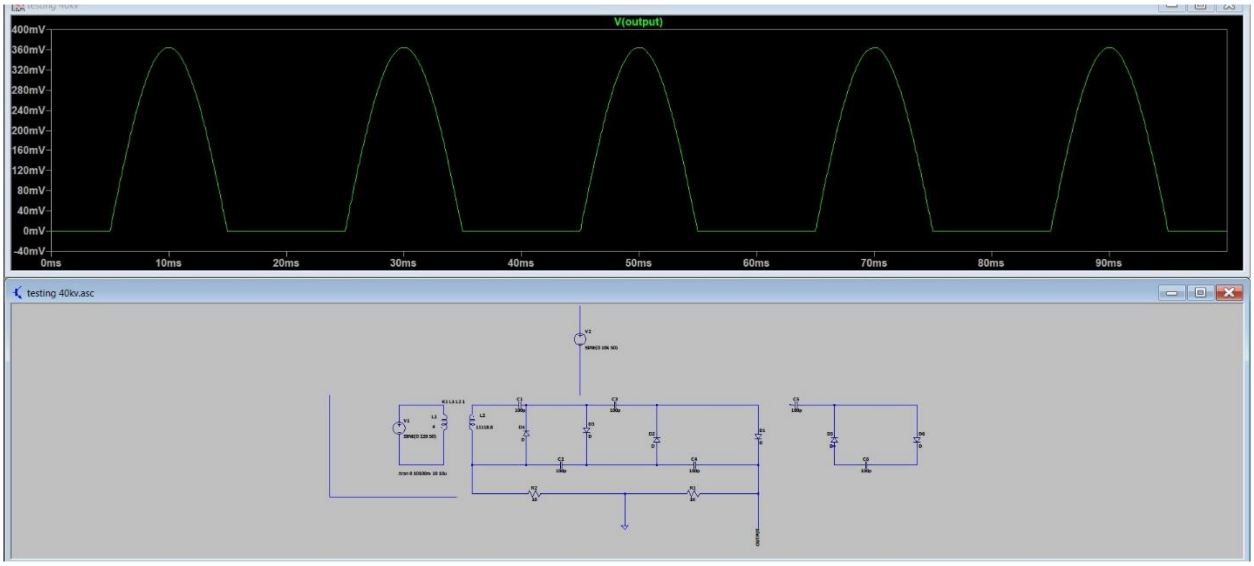
We will now do three experiments “voltage divider” to confirm the result 40 kV

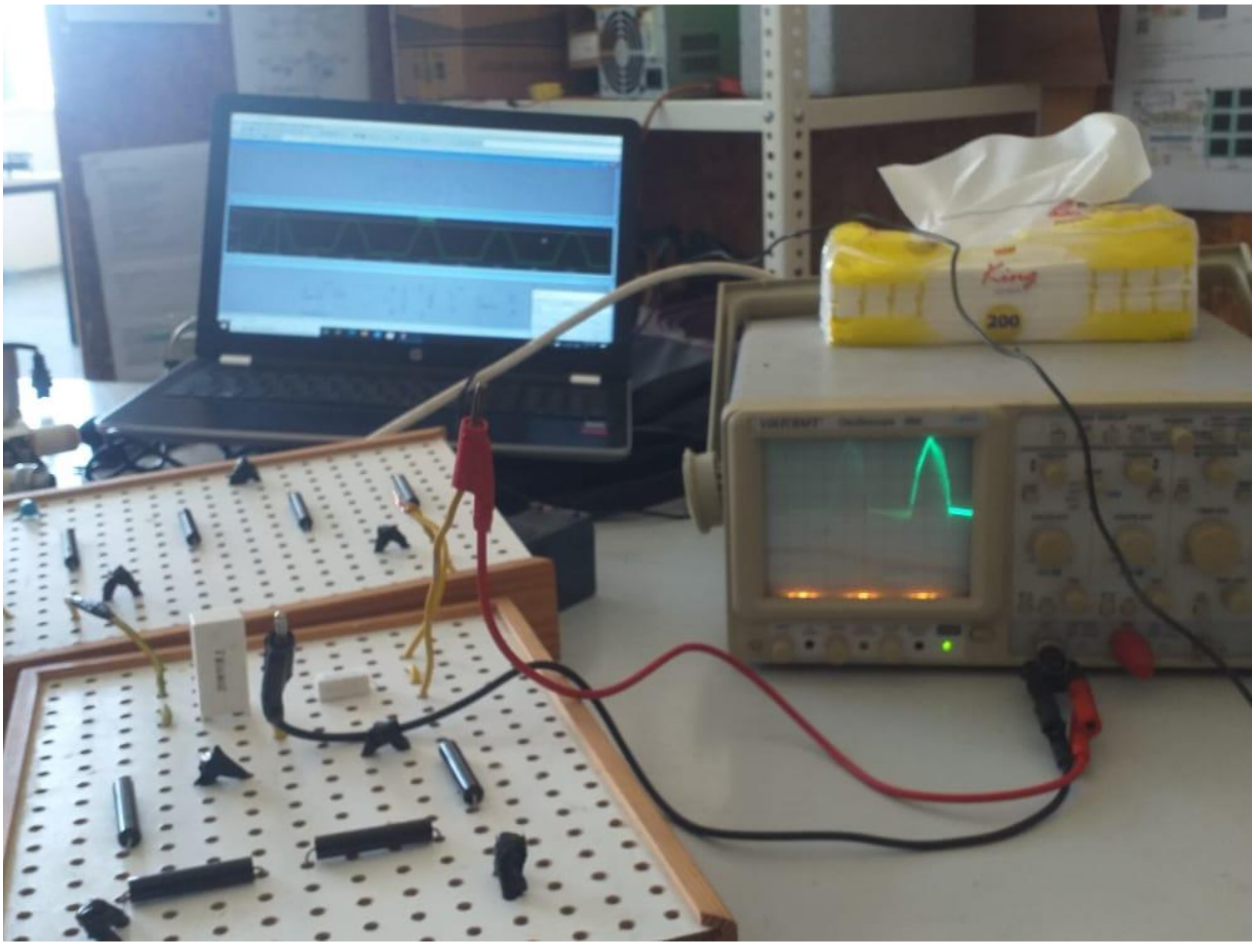
47.3.3.13 Simulation



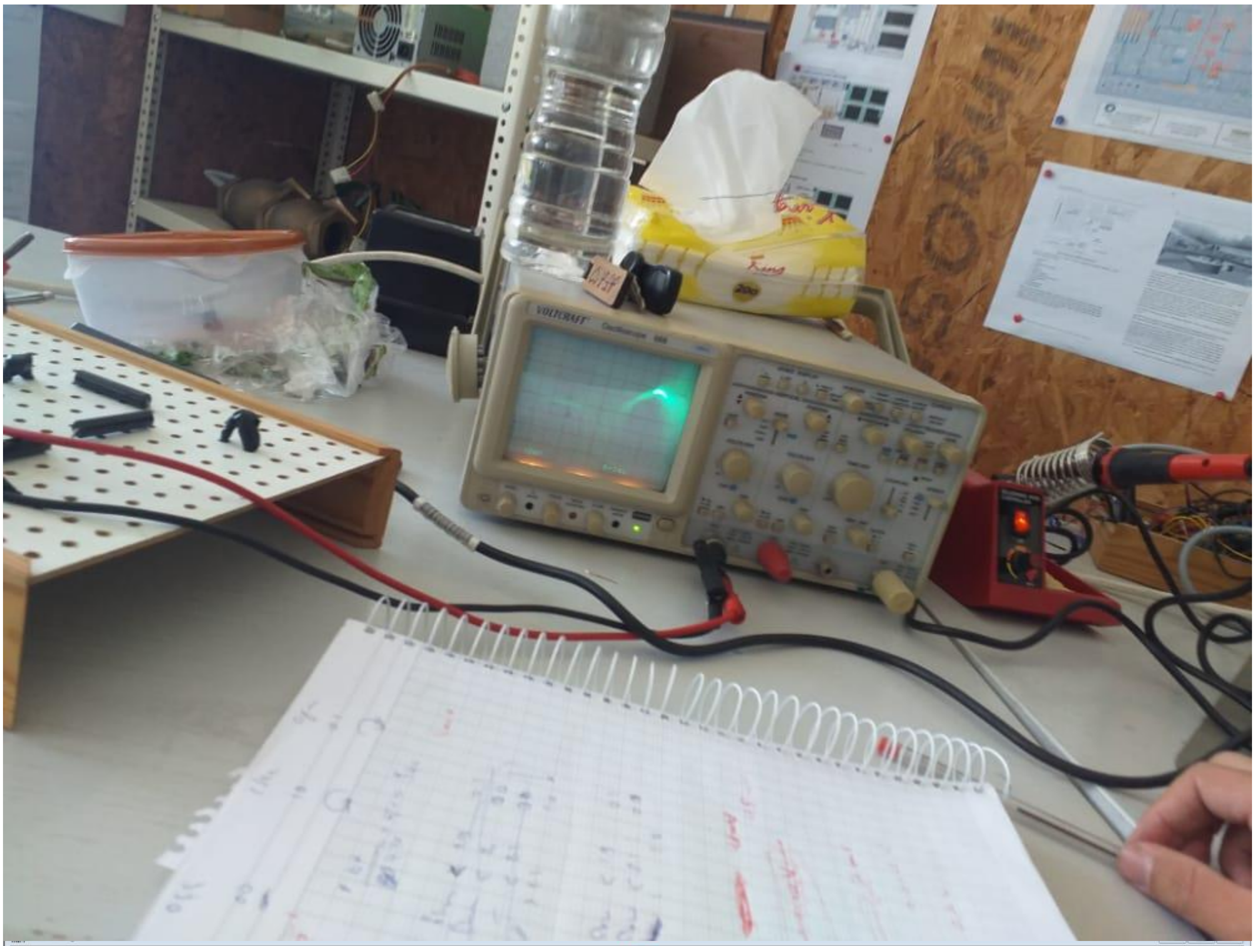


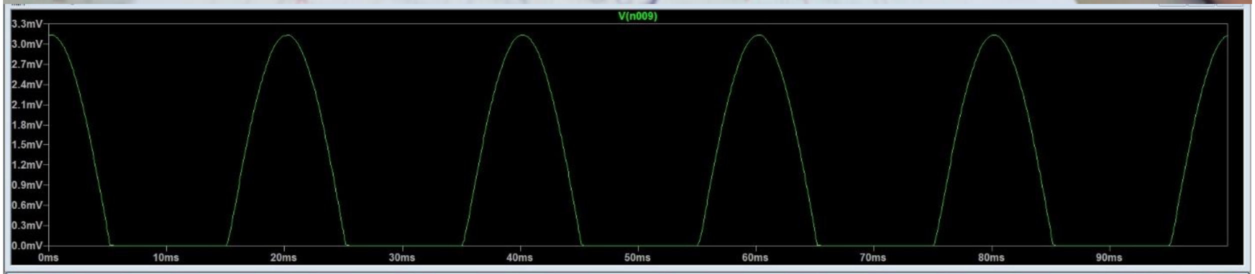
We have connected 2 resistor series in order to reduce the voltage so that we can compare the simulation with the oscilloscope, the result we obtained in simulation is identical to what we saw in the oscilloscope

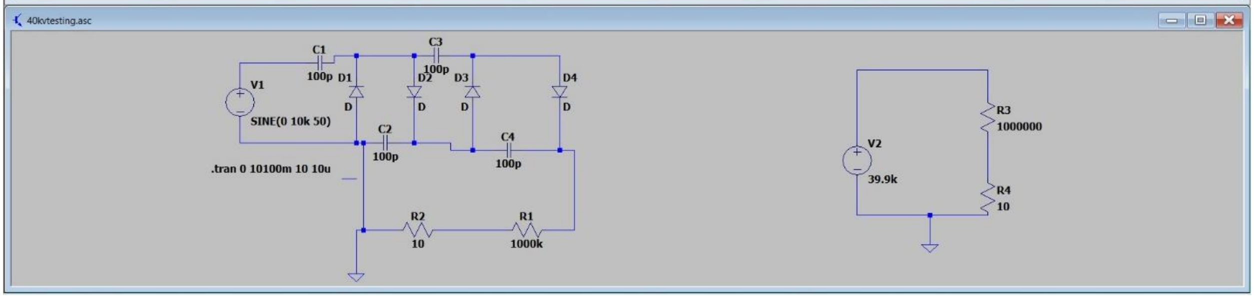




We did another experiment with resistance 1 Mohm and also got the same result

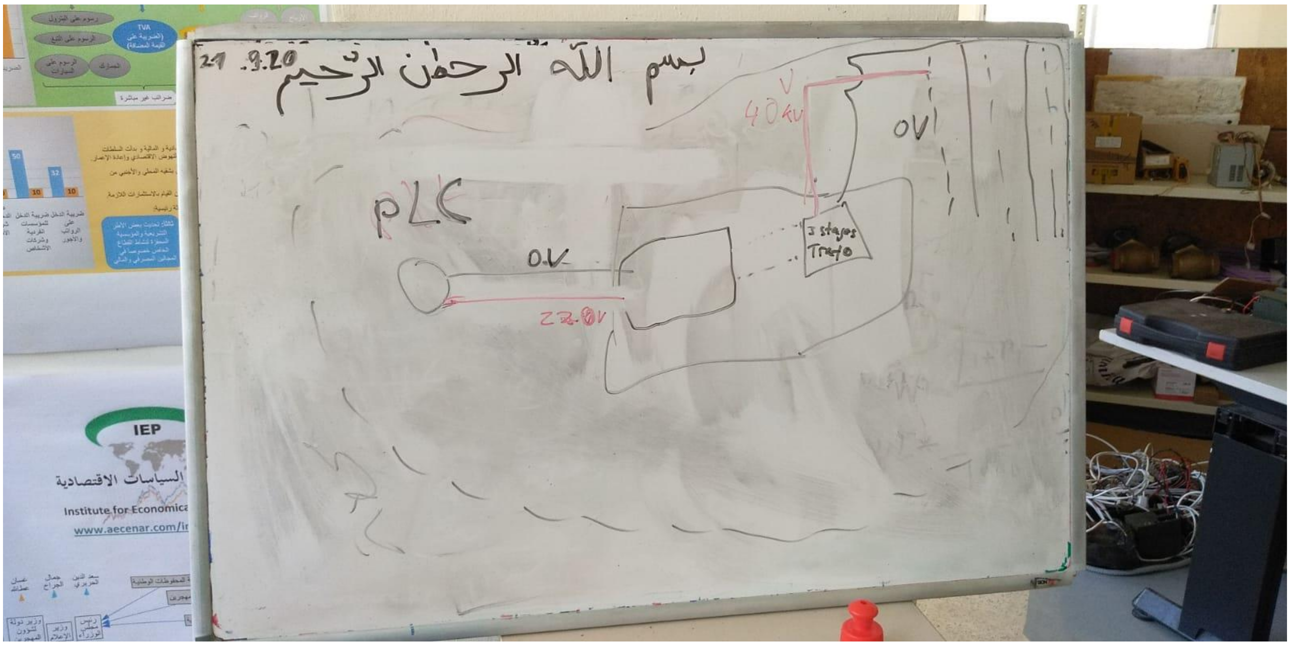


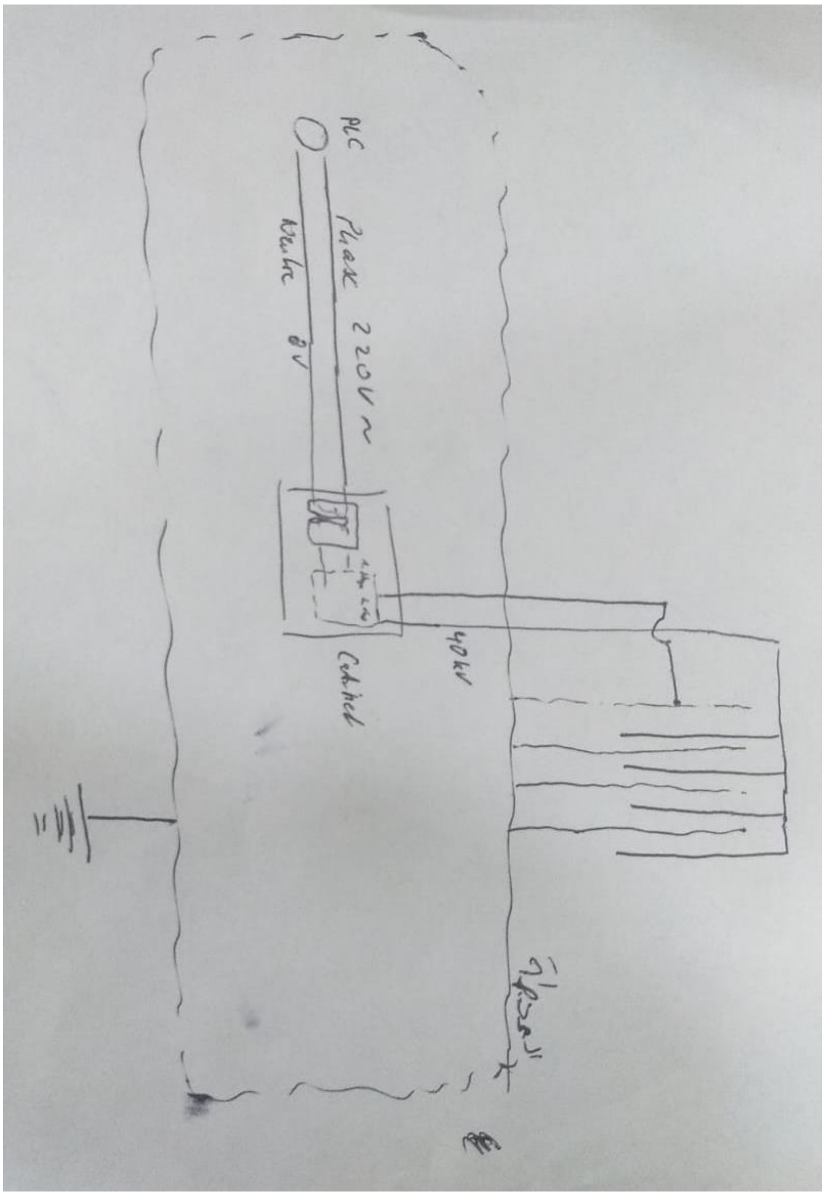


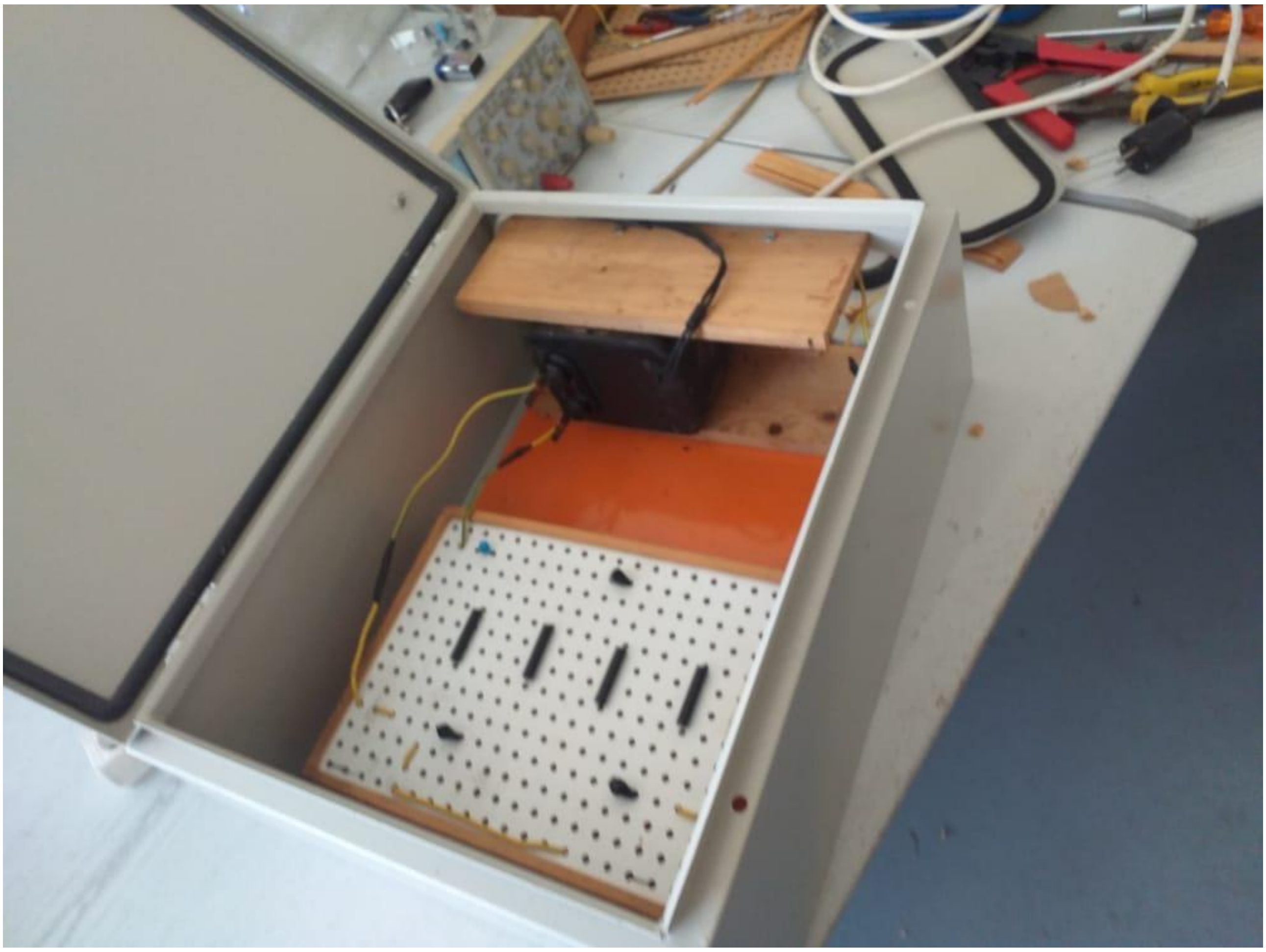


The next step now is to install this high voltage power supply on the electric filter (precipitator) of the waste incineration power plant in order to get rid of the impurities and pollution through the electrofilter

47.3.4 Installation at filter on the mobile power plant







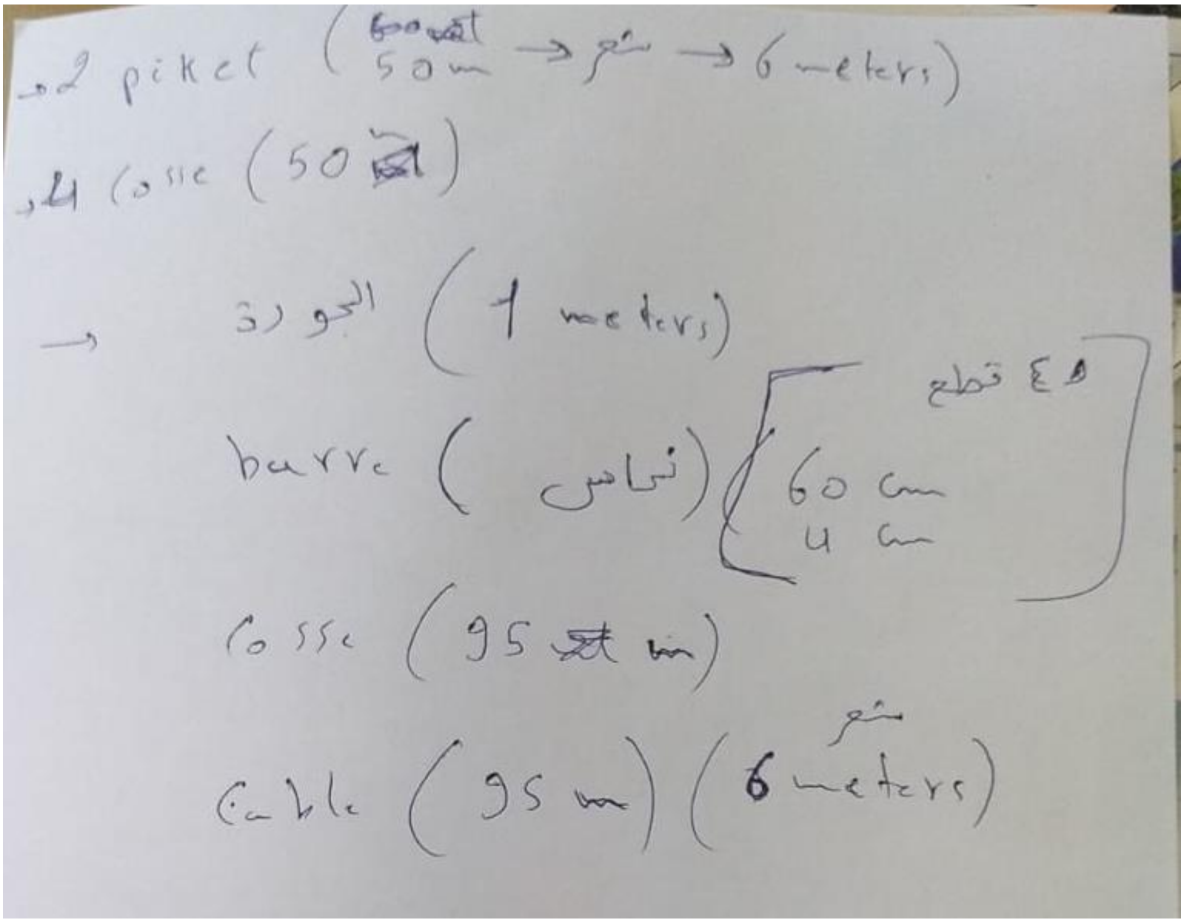
Filter sytem of NLAP-IPP Demonstration Plant

40 kV line to electrofilter

Cabinet with transformator and 2 stages

40 kV line from cabinet to electro filter

47.3.5 Electrical Safety and Earthening



2 piket (~~[illegible]~~ 50 mm → شعر → 6 meters)

4 cosse (50 ~~[illegible]~~)

→ الجورة (1 meters)

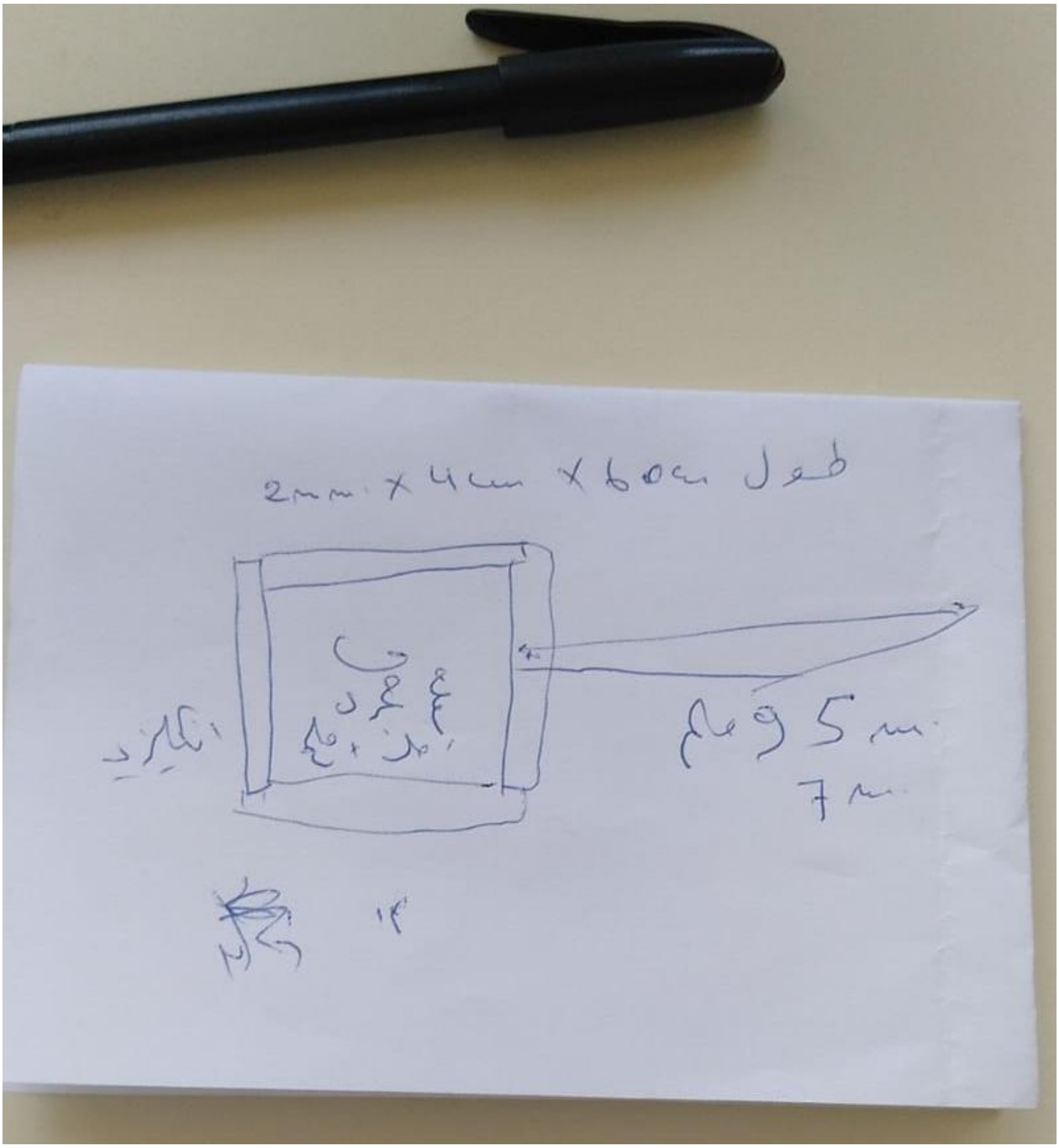
barre (نحاس) [٤ قطع

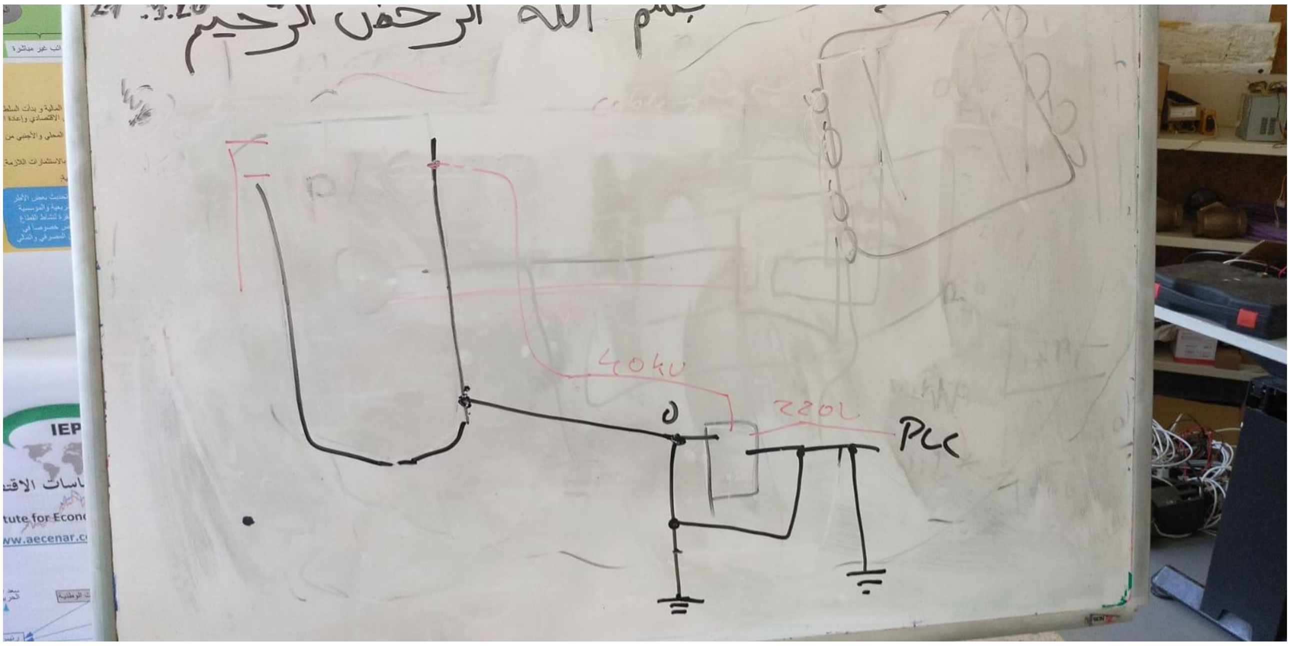
60 cm

4 cm]

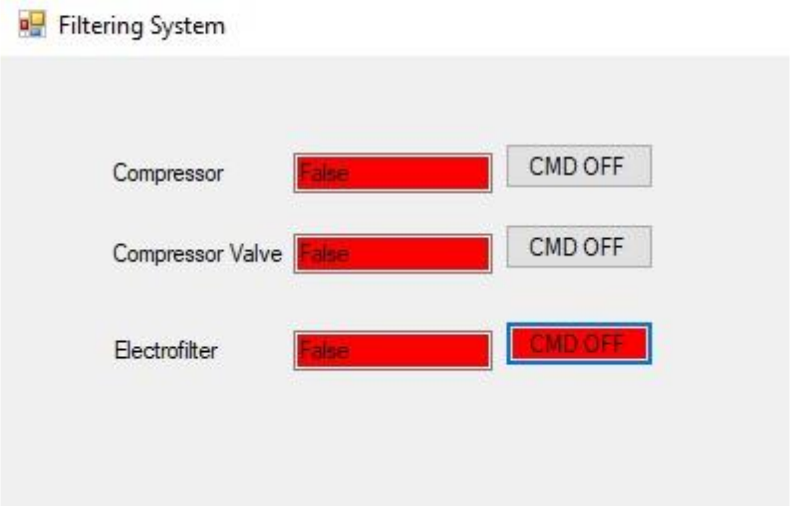
cosse (95 ~~[illegible]~~ mm)

cable (95 mm) (شعر 6 meters)


2mm x 4cm x 60cm طول
عمق و 5m
7m



47.3.6 For control system



Filtering System

Compressor False CMD OFF

Compressor Valve False CMD OFF

Electrofilter False CMD OFF

47.4 DESIGN OF CYCLONE

Cyclone filter used to attract particulars more than 5 microns in the gas flue of incineration.

It will be available in this power plant to minimize the quantity of dust in gas flue.

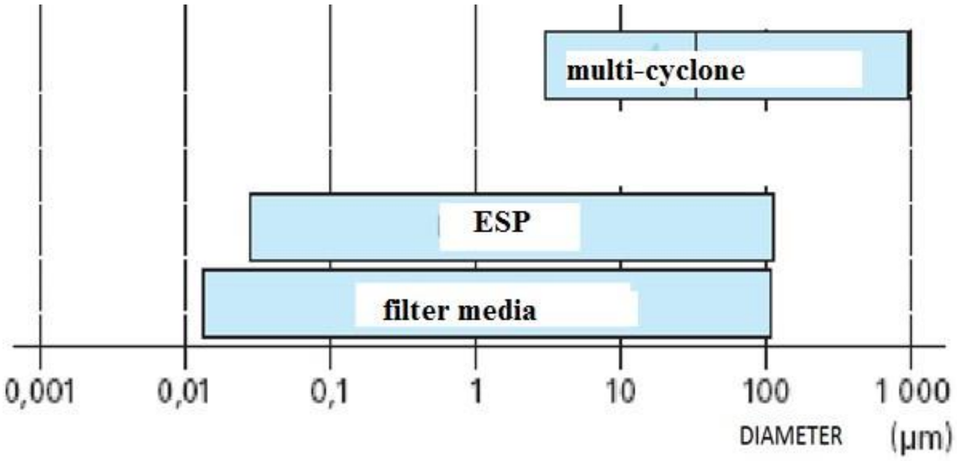
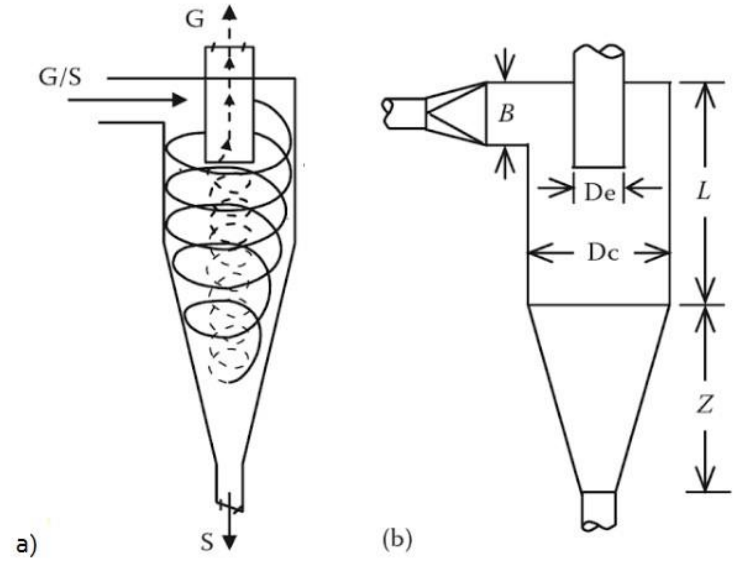


Figure 51:range of particles eliminated

(21)

- **Dimensions of cyclone:**



a) Flow pattern in cyclone separator. (b) Standard cyclone dimensions. S, solids; G, air; Dc, cyclone diameter; 2Dc; *B* = De = Dc/2.

Figure 52: dimensions of cyclone

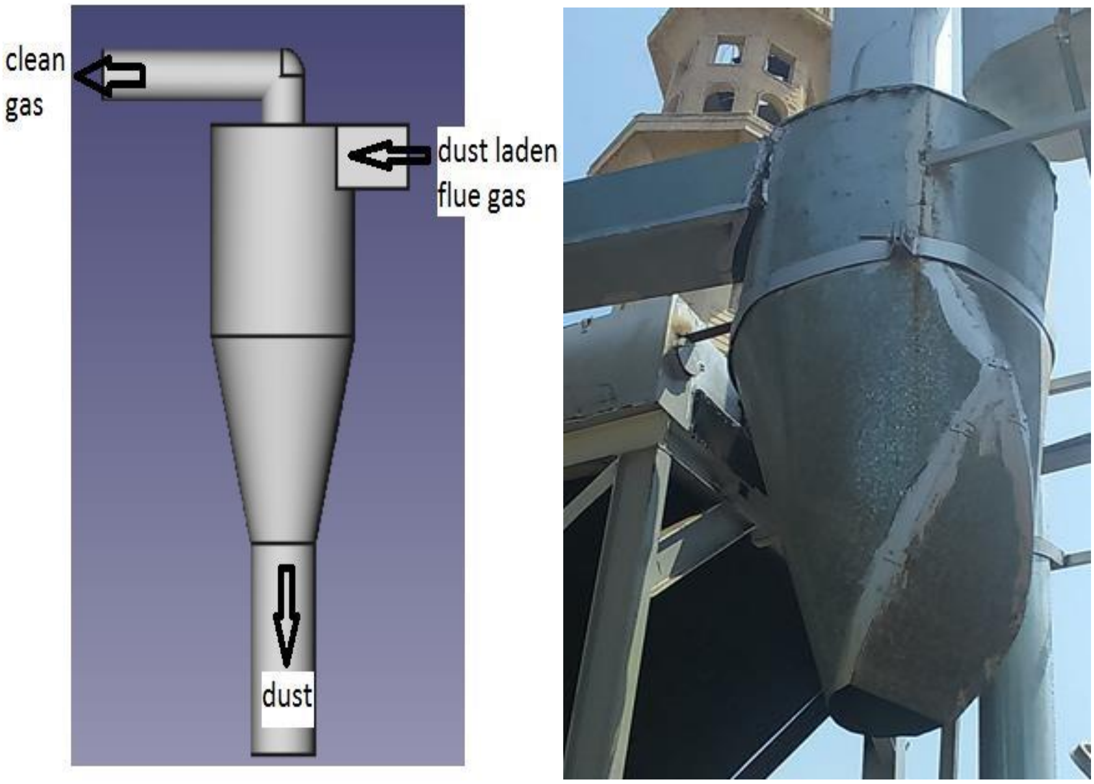


Figure 53: design of cyclone by freecad

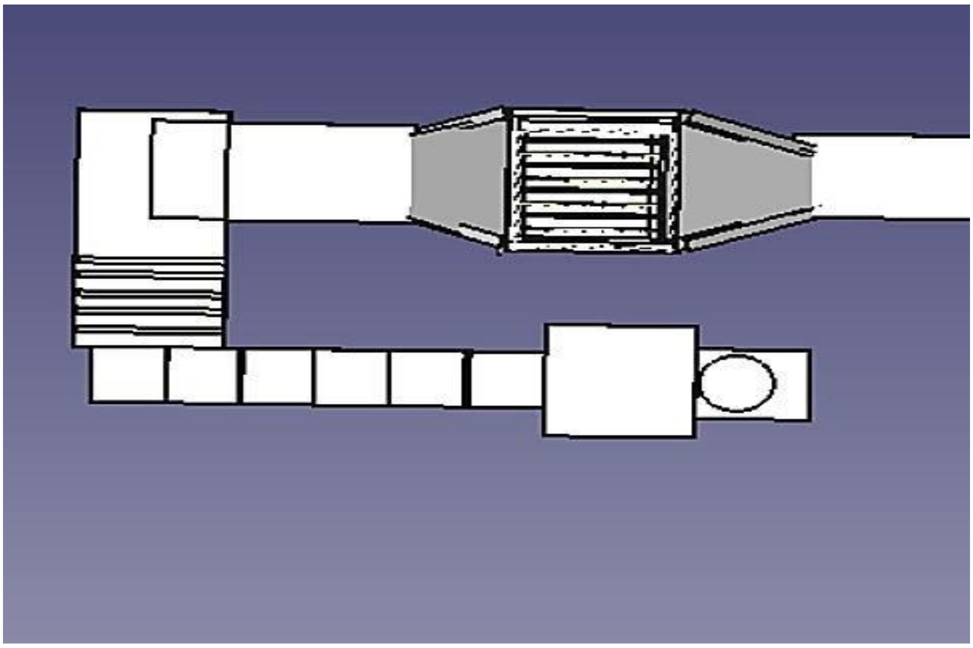


Figure 54: top view of final system of treatment realized in the station (freecad)

47.5 DRY CHEMICAL TREATMENT

Injection of: activated carbon and sodium bicarbonate (in powder form) is by a mechanical action using a compressor (playing the role of a blower).

When the compressor is on, the powder passes in the flow of smoke and reacts with the gas up to reach the filter media, instead of the more efficient reaction (surface reaction) and formed a cake of filtration.

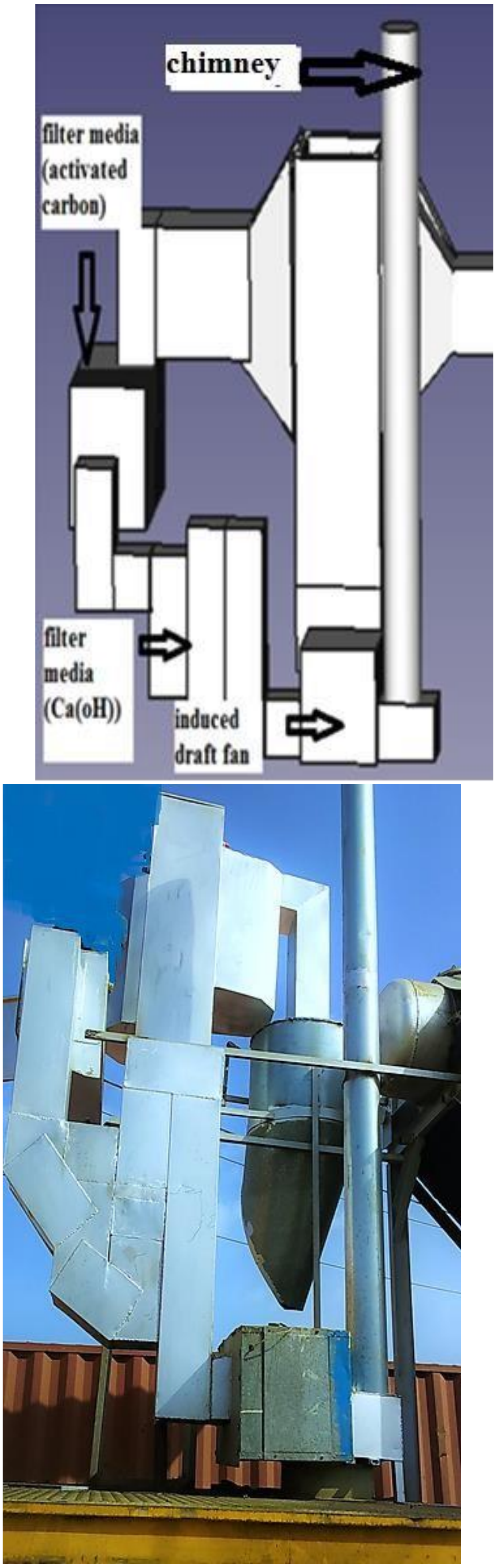


Figure 55: chemical treatment

Parameter	units	Value	Comments
reagent consumption	Kg/ton of waste incinerated	10 - 15	the values corresponding to a soda consumption in a municipal waste incinerator
stoichiometric ratio of reactants	*Ratio*	*1.25* (*$NaHCO_3$*)	*In case of baking soda*
		1.5-2.5 CaOH	In case of limestone
Residues/type			Residues of treatment are collected sets if a predusting step
Residues	Kg/ton of waste incinerated	7-25	value provided from a ton of waste incinerated

Table 16: parameter related to the type of treatment

47.6 INSERTION OF FILTER MEDIA

Figure 56:filter media used in the power plant

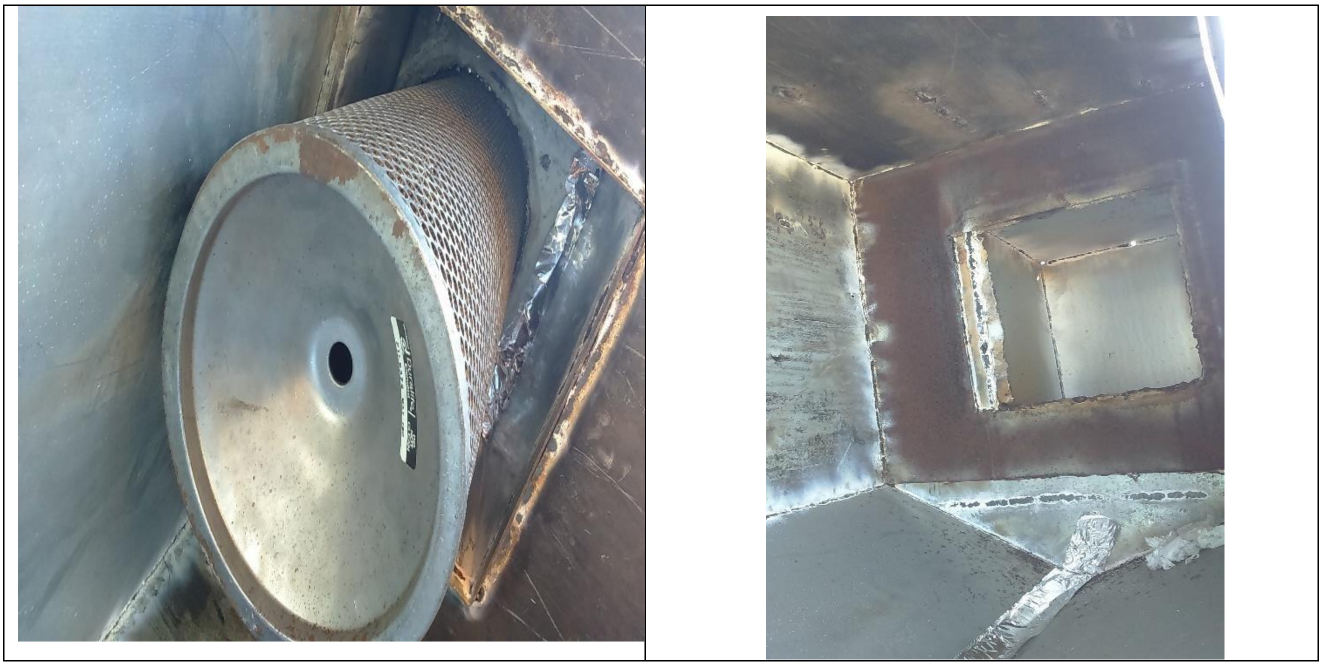


Figure 57:insert of cylindrical media filter after electro filter

Figure 58:insertion of filter (filter media, large size)

We use environmentally friendly filters, 100% recyclable manufacture by Nordic Air Filtration-member of Hengst Group - is a high technology.

47.7 In-situ gas analysis

Analysis controlling gas (O_2,CO_2,CO,NO,SO_2) is through a portable multi-gas analyzer, Horiba PG 250. gases are first filtered by the sampling probe M & C PSP4000H then dried by the packaging system SSPS M & C-5.

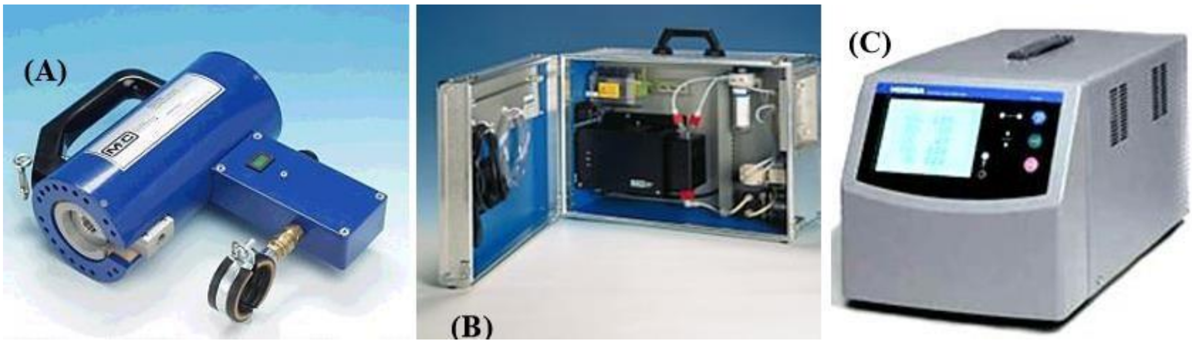


Figure 67: system to analyze in-situ controlling gas

(A) : filter M&C PSP4000H ; (B) : conditioner M&C PSS-5 ; (C) : Analyzer PG-250

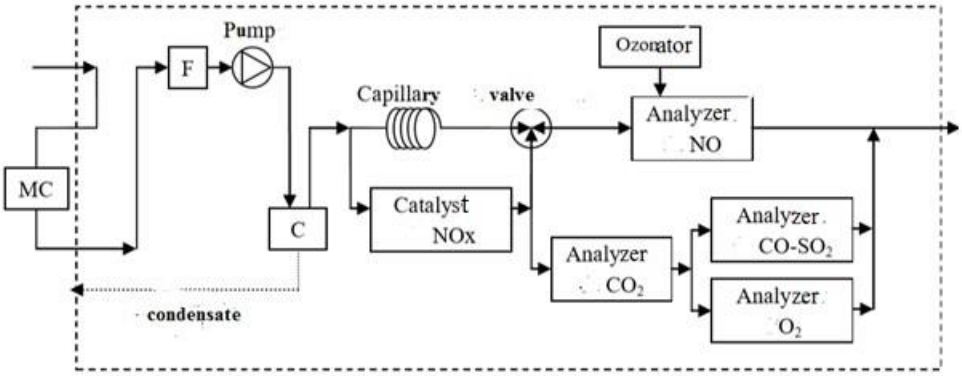


Figure 68:picture of Horiba multi-gas analyzer

MC : Mist Catcher, F : Filter, C : Condenser

Fixed appliances continuous measurements using different properties of the gas such as :

Infrared measurement: is especially suitable carbon-containing gas (CO_2, CO, CH.) because they have the property to absorb very well. It measures the difference absorption of infrared radiation between a reference gas and smoke sample continuously removed.

Chemiluminescence gas: is utilized for NOx analyzers. When reacting NO with ozone O_3, the reaction produces light whose intensity is proportional to the NO concentration.

Paramagnetivity of oxygen: is used in particular by the oxygen analyzer magneto-pneumatic. In a magnetic field not uniform it is attracted to the part stronger field increasing pressure in that part. This increase in pressure is proportional to the oxygen concentration.

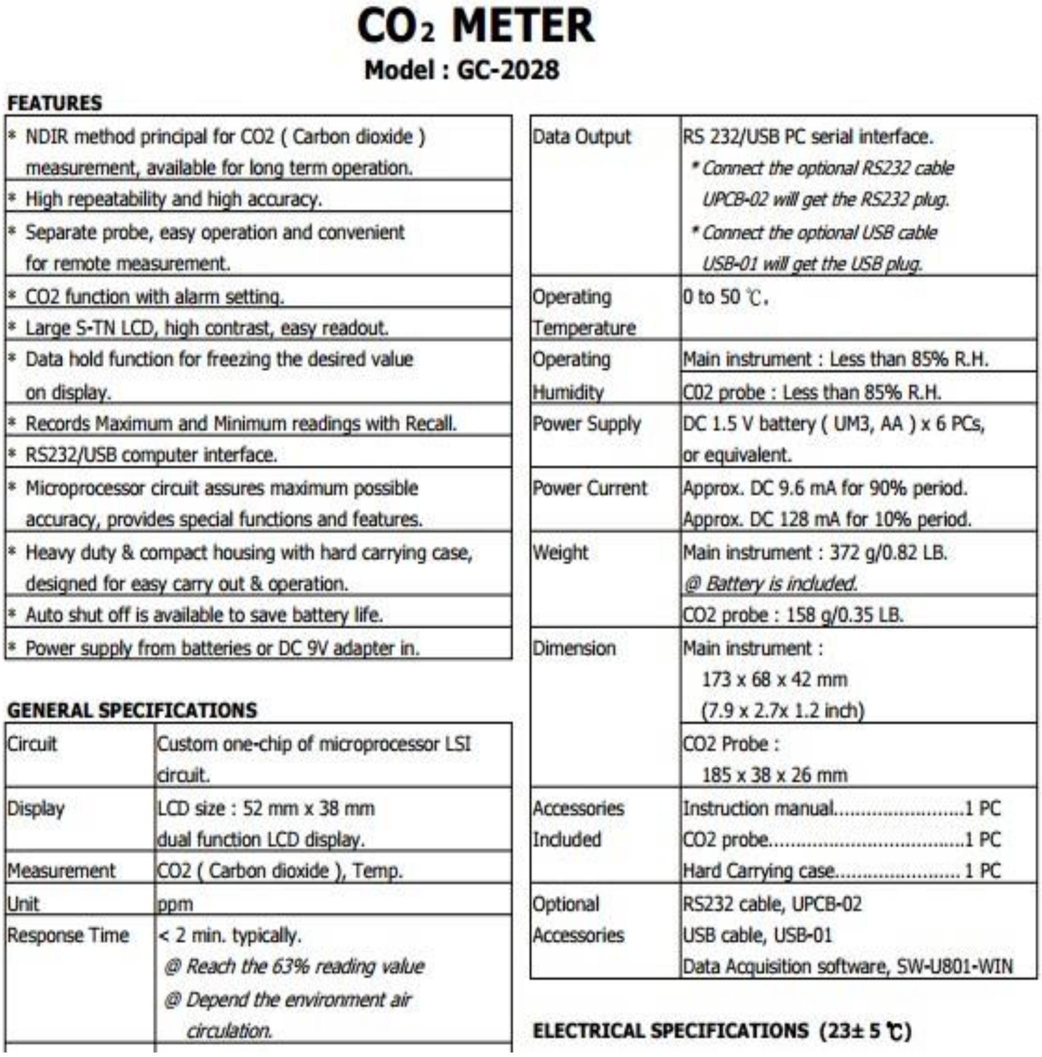
The measure by solid electrolyte: The best known is the λ probe for oxygen functions as a fuel cell. A solid electrolyte made of sintered Zr is in contact on one side with the smoke to be measured and the other with the ambient air. The partial pressure difference and by other causes ddp of 1V. The response of the sensor is very abrupt at the passage of the stoichiometry (absence of O_2: 1V; presence 0V).

This meter is very expensive, it is more than $ 2,500, and when the budget is low, so it is difficult to buy this analyzer (annex E), it's available in Tripoli

System to analyzer the concentration of gas in air of Tripoli

Figure 69: System to analyzer the concentration of gas in air of Tripoli

in Lebanon: it's not available a multi-gas analyzer, only in Electronics Katrangi trading we find a CO_2 analyzer (40 CO_2 METER LUTRON GC2028, 392 $), and a gas sensor (town gas)



CO₂ METER

Model : GC-2028

FEATURES

* NDIR method principal for CO2 (Carbon dioxide) measurement, available for long term operation.
* High repeatability and high accuracy.
* Separate probe, easy operation and convenient for remote measurement.
* CO2 function with alarm setting.
* Large S-TN LCD, high contrast, easy readout.
* Data hold function for freezing the desired value on display.
* Records Maximum and Minimum readings with Recall.
* RS232/USB computer interface.
* Microprocessor circuit assures maximum possible accuracy, provides special functions and features.
* Heavy duty & compact housing with hard carrying case, designed for easy carry out & operation.
* Auto shut off is available to save battery life.
* Power supply from batteries or DC 9V adapter in.

GENERAL SPECIFICATIONS

Circuit	Custom one-chip of microprocessor LSI circuit.
Display	LCD size : 52 mm x 38 mm dual function LCD display.
Measurement	CO2 (Carbon dioxide), Temp.
Unit	ppm
Response Time	< 2 min. typically. *@ Reach the 63% reading value* *@ Depend the environment air circulation.*
Data Output	RS 232/USB PC serial interface. ** Connect the optional RS232 cable UPCB-02 will get the RS232 plug.* ** Connect the optional USB cable USB-01 will get the USB plug.*
Operating Temperature	0 to 50 ℃.
Operating Humidity	Main instrument : Less than 85% R.H. C02 probe : Less than 85% R.H.
Power Supply	DC 1.5 V battery (UM3, AA) x 6 PCs, or equivalent.
Power Current	Approx. DC 9.6 mA for 90% period. Approx. DC 128 mA for 10% period.
Weight	Main instrument : 372 g/0.82 LB. *@ Battery is included.* CO2 probe : 158 g/0.35 LB.
Dimension	Main instrument : 173 x 68 x 42 mm (7.9 x 2.7x 1.2 inch) CO2 Probe : 185 x 38 x 26 mm
Accessories Included	Instruction manual........................1 PC CO2 probe....................................1 PC Hard Carrying case...................... 1 PC
Optional Accessories	RS232 cable, UPCB-02 USB cable, USB-01 Data Acquisition software, SW-U801-WIN

ELECTRICAL SPECIFICATIONS (23± 5 ℃)

Figure 70: CO₂ meter and gas sensor with some electrical specification

CO meter: A carbon monoxide detector for a car can detect the presence of potentially dangerous fumes. Carbon monoxide detectors are generally not marketed for vehicles specifically but can be used in them because they are small and battery-powered.in the same time, we can use this detector to measure the level of CO in incinerator exhaust fumes.

47.7.1 MEASUREMENT OF PARTICLE EMISSIONS WITHOUT PLASTIC

the particulate emissions measurement by standard method NF X43-017 Available in two versions:

BETA 5M: particle measurement methods in "dry"

BETA 5M / H: Measuring dust processes "wet"

Beta gauge determines the concentration of particles by measuring the amount of energy absorbed by the sample exposed to a radioactive source.

During a sampling cycle set, the particles are deposited on a filter strip. At the end of sampling, the filter containing the dust deposit is exposed to radiation beta gauge low energy. The result is an independent mass measurement of the physicochemical nature of the particles, their shape or color.

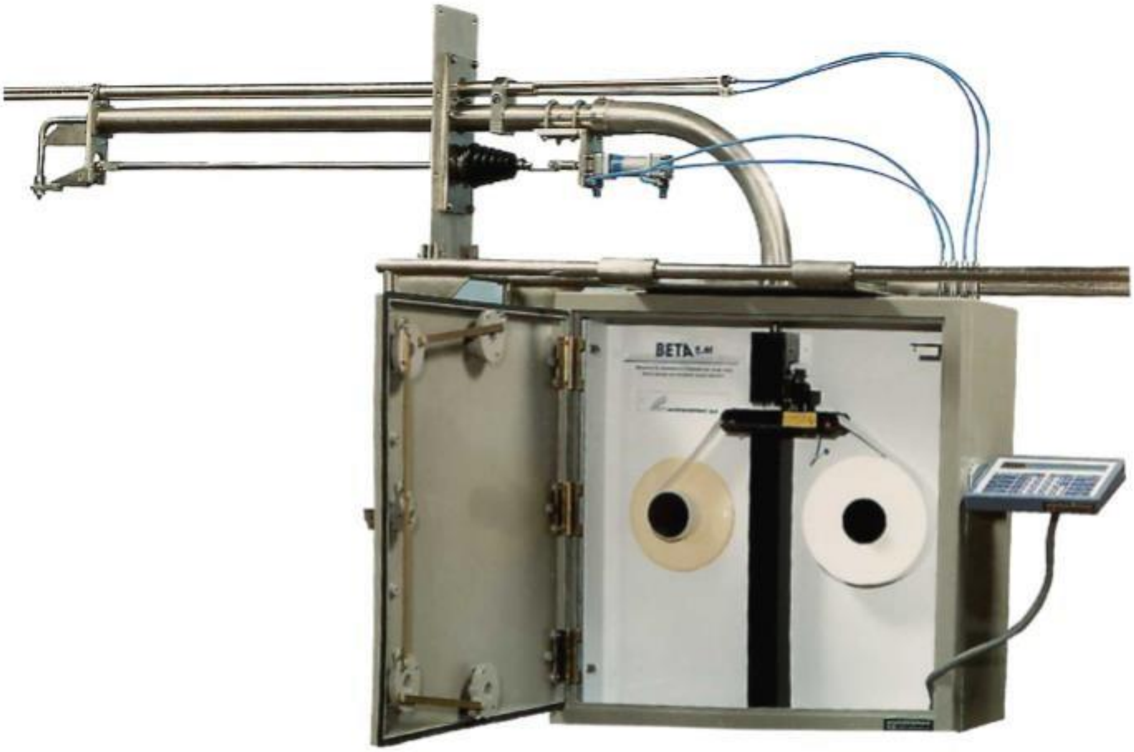


Figure 71: particulate analyzer BETA 5M **This study executed in dry conditions.**

The second method to measure the concentration of particulate emissions is tm measure the mass of filter inserted in chimney before and after treatment during a period to know the quantity of m^3/h of fumes .this is the method adopted in this study.

48 Test September 2016

Figure 72:insertion of filter media in chimney

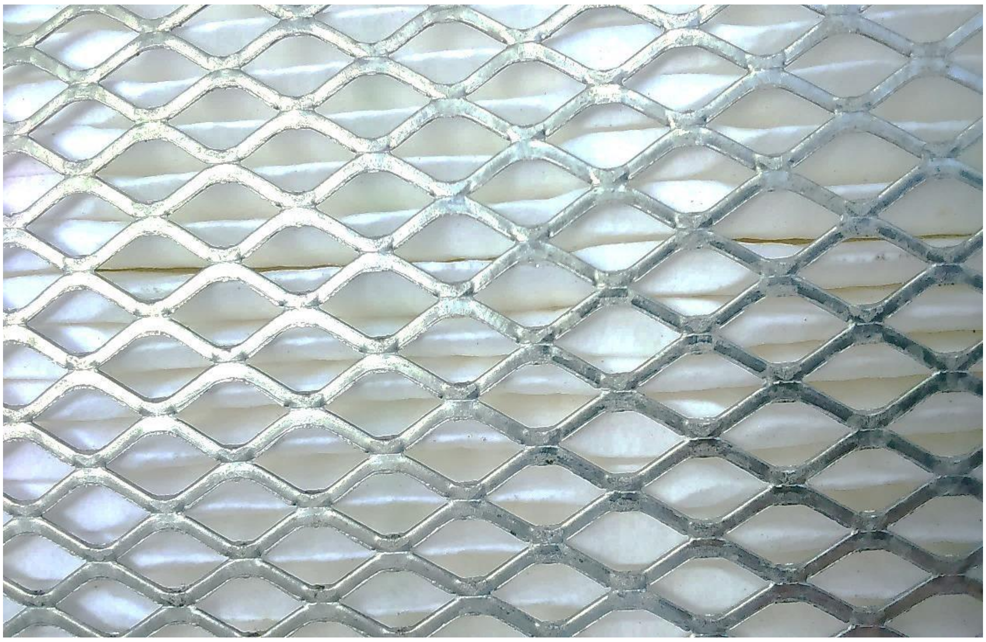


Figure 73:color of media before treatment

the flow of smoke produced by burning 42 kg for one hour is already calculated (paragraph 2.2) in normal circumstances (0°C, 1 atm),

- 42 kg: mass of waste after sorting by eliminating metal, batteries and heavy plastic.
- incineration takes place through the fuel oil 400 ml.
- system installed with pressure sensor that integrated with the current of fumes.

Figure 74:waste after sorting

Figure 75:belt for incineration

Figure 76: Closing the pores that leak fumes

Figure 77:beginning of combustion

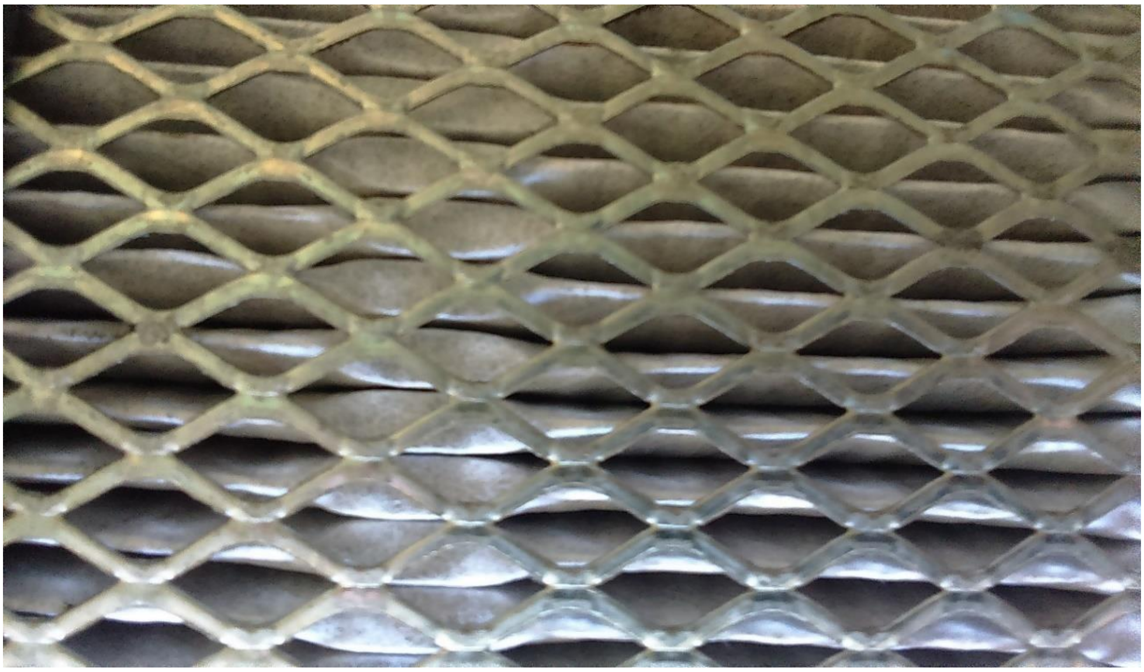


Figure 78: filter media after treatment

Figure 79:chimney during incineration

Calculation of emissions

$V_2 = V_1 * (P_1/P_2) * (T_2/T_1) * (Z_2/Z_1)$

Converting to uniform units

V_1 = 314.000

Nm^3/h P_1 =

1.000 atm

T_1 = 273.150

°K T_2 =

323.150 °K

P_2=1.000 atm

P_1, T_1 normal conditions

P_2, T_2 specification for exhaust

Z_1=1 (ideal), Z_2=1.01(at 1 atm): Compressibility Factor

Calculation for V_2

V_2 = 314.000*(1.000/1.000) *(323.150/273.150) *(1.100/1.100) V_2 = 375 m^3/h

Or mass of filter before

treatment =1300 g mass after

treatment =1364

the total mass of particulate =1364-1300=64 g

375 m^3/h correspond to 64 g

Thus 170 mg / m^3 <200 mg/ m^3 confirm to Lebanese standard (annex D) positive results

48.1 MEASUREMENT OF PARTICLE EMISSIONS WITH PLASTIC

- 10 kg: mass of waste with plastic
- 300 ml (fuel)

Combustion took an hour and half hour,

We noticed that there are a lot of leaks that should be closed

48.2 Discussions

The amount of dust, which dealt with the filter and descended to the silo equal to more than twice the amount obtained without plastic.

Figure 80:dust in silo with H_2O condensed

48.3 CONCLUSION AND PERSPECTIVES

After this long study, we have the radical solution that allow to make classify incineration as a renewable source of energy and as a result the "greening" will be a feature of the incineration.

Especially the solution is classified into various types of treatment: electrical, mechanical and chemical.

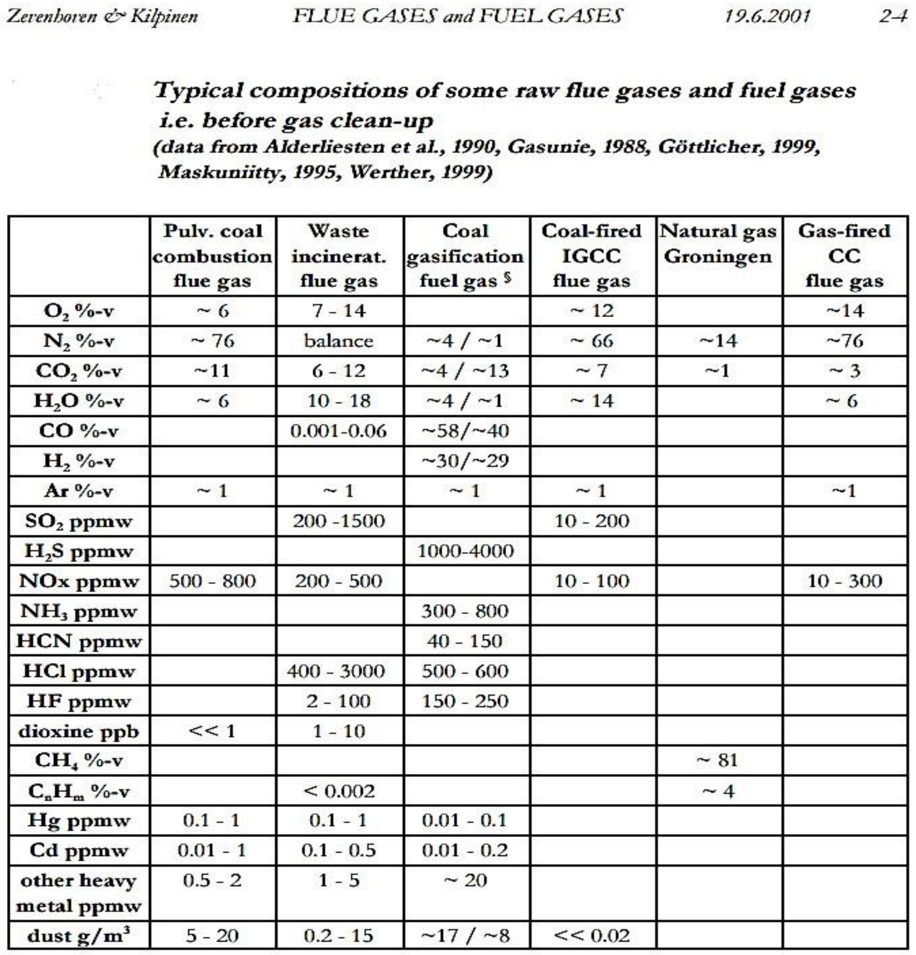
we saw that the cyclone and the electrostatic ensures the elimination of solid particles of smoke. We have made sure of that after the tests we have had on emissions after installing filters as cyclone.

secondly, the sodium bicarbonate and calcium carbonate are the most important chemicals that play a main role in the treatment of the fumes by eliminating the majority of gas especially toxic gases CO, NO, SO ...

the materials produced in the smoke processing are sent to storage centers for processed, stabilized and finally used in public works (road, cement)

In the next steps we will realize the chemical treatment of smoke in dry condition (to minimize the rate of residue after treatment) to study the effectiveness Activated charcoal to reduce the amount of released toxic gases in case of incineration heavy plastics.

49 Flue Gas Purification suitable for getting permission from Ministry of Environment



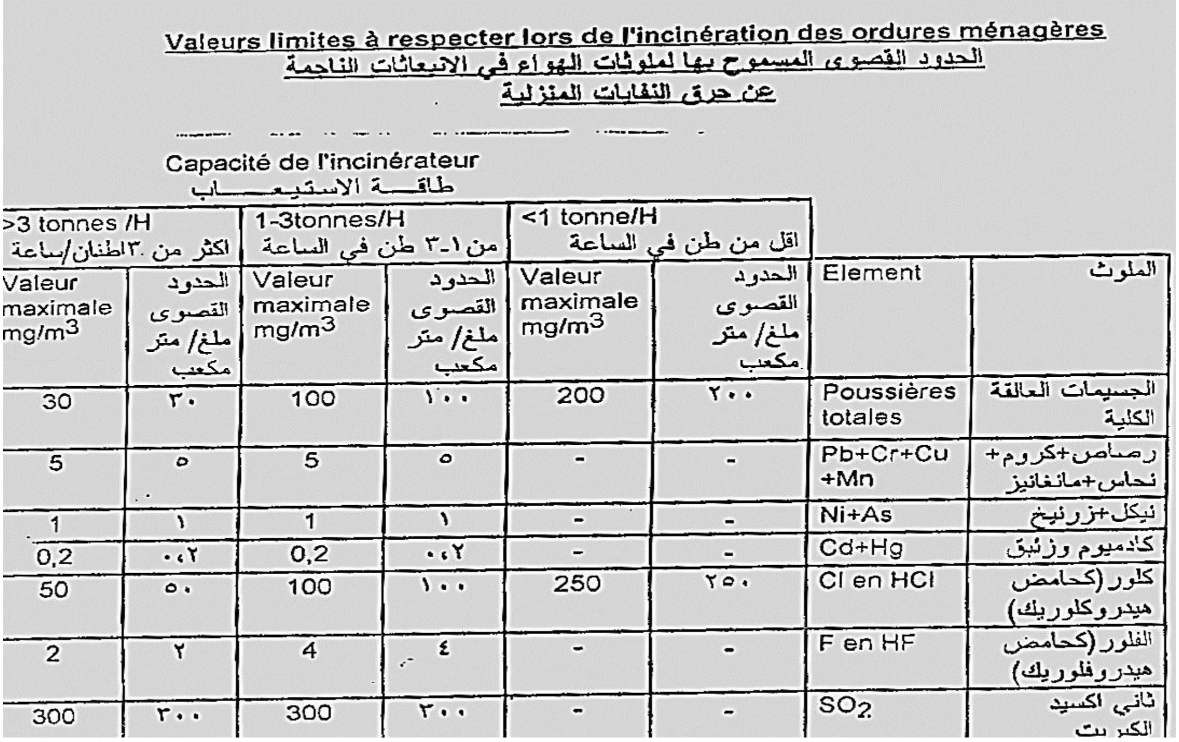
Zevenhoven & Kilpinen *FLUE GASES and FUEL GASES* *19.6.2001* *2-4*

Typical compositions of some raw flue gases and fuel gases i.e. before gas clean-up

(data from Alderliesten et al., 1990, Gasunie, 1988, Göttlicher, 1999, Maskuniitty, 1995, Werther, 1999)

	Pulv. coal combustion flue gas	Waste incinerat. flue gas	Coal gasification fuel gas $	Coal-fired IGCC flue gas	Natural gas Groningen	Gas-fired CC flue gas
O_2 %-v	~ 6	7 - 14		~ 12		~14
N_2 %-v	~ 76	balance	~4 / ~1	~ 66	~14	~76
CO_2 %-v	~11	6 - 12	~4 / ~13	~ 7	~1	~ 3
H_2O %-v	~ 6	10 - 18	~4 / ~1	~ 14		~ 6
CO %-v		0.001-0.06	~58/~40			
H_2 %-v			~30/~29			
Ar %-v	~ 1	~ 1	~ 1	~ 1		~1
SO_2 ppmw		200 -1500		10 - 200		
H_2S ppmw			1000-4000			
NOx ppmw	500 - 800	200 - 500		10 - 100		10 - 300
NH_3 ppmw			300 - 800			
HCN ppmw			40 - 150			
HCl ppmw		400 - 3000	500 - 600			
HF ppmw		2 - 100	150 - 250			
dioxine ppb	<< 1	1 - 10				
CH_4 %-v					~ 81	
C_nH_m %-v		< 0.002			~ 4	
Hg ppmw	0.1 - 1	0.1 - 1	0.01 - 0.1			
Cd ppmw	0.01 - 1	0.1 - 0.5	0.01 - 0.2			
other heavy metal ppmw	0.5 - 2	1 - 5	~ 20			
dust g/m^3	5 - 20	0.2 - 15	~17 / ~8	<< 0.02		

(22) C: typical compositions of some raw flue gases and fuel gases before treatment



Valeurs limites à respecter lors de l'incinération des ordures ménagères

الحدود القصوى المسموح بها لملوثات الهواء في الانبعاثات الناجمة

عن حرق النفايات المنزلية

Capacité de l'incinérateur

طاقـــة الاستيعـــاب

		<1 tonne/H اقل من طن في الساعة		1-3tonnes/H من ١-٣ طن في الساعة		>3 tonnes /H اكثر من ٣ اطنان/ساعة	
الملوث	Element	الحدود القصوى ملغ/ متر مكعب	Valeur maximale mg/m3	الحدود القصوى ملغ/ متر مكعب	Valeur maximale mg/m3	الحدود القصوى ملغ/ متر مكعب	Valeur maximale mg/m3
الجسيمات العالقة الكلية	Poussières totales	٢٠٠	200	١٠٠	100	٣٠	30
رصاص+كروم+ نحاس+مانغانيز	Pb+Cr+Cu +Mn	-	-	٥	5	٥	5
نيكل+زرنيخ	Ni+As	-	-	١	1	١	1
كادميوم وزئبق	Cd+Hg	-	-	٠،٢	0,2	٠،٢	0,2
كلور (كحامض هيدروكلوريك)	Cl en HCl	٢٥٠	250	١٠٠	100	٥٠	50
الفلور (كحامض هيدروفلوريك)	F en HF	-	-	٤	4	٢	2
ثاني اكسيد الكبريت	SO_2	-	-	٣٠٠	300	٣٠٠	300

D: limits of emissions in Lebanon

بسم الله الرحمن الرحيم

AECENAR
Association for Economical and Technological Cooperation in the Euro-Asian and North-African Region

MEAE - Middle East Alternative Energy Institute
مركز الشرق الاوسط للطاقة البديلة
http://aecenar.com/institutes/meae

طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.com

تنقية دخان مصانع التفكك الحراري
Flue Gas Purification
(Thermal treatment: incineration)

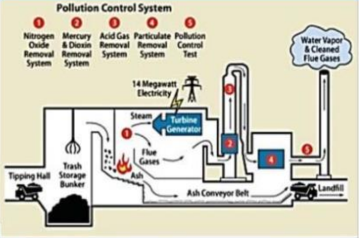
Residues of incineration of 1 ton of waste
700 kg of gas,
300 kg of solid residues including 30 kg of fly ash.

Division of emissions(depending on their size and the degree of severity:)

Challenges

Non-harmful to the environment لا تضر بالبيئة	**harmful to the environment** تضر بالبيئة	**Toxic gases:** الغازات السامة
Nitrogen (N_2), Oxygen (O_2), and water vapor (H_2O)	**Acid gases: nitrogen dioxide (NO_2), nitrogen oxide (NO), Sulfur dioxide (SO_2), carbon dioxide (CO_2),HCl, Dust**	**Furans, dioxins, heavy metals (Hg from batteries, cadmium, plumb, zinc)**

Waste to energy diagram



Source: ecomaine.

كما سبق وذكرنا ,ان بقايا الحرق كثيرة لذلك كان من الضروري معالجتها .نبدأ بالنيتروجين الذي سيعالج عن طريق رش الأمونيا على دفعتين .ثانيا,الديوكسين و الزئبق الذي سيملر في خرطوشات الكربون المنشط.ثالثا,الغازات الحمضية ستم ازالتها برش ال بيكربونات الصوديوم.واخيرا ,الغبار سيتم ازالته ميكانيكيا وكهربائيا (ESP).اعتمادا على ذلك ,فان الانبعثات ستكون مطابقة لما ورد في الجدول التالي.

والبقايا الصلبة سيتم معالجتها في نظام خاص منفرد ,ولمراقبة الانبعاثات بشكل متواصل ,سوف يركب أجهزة مراقبة على المحطة للتأكد من صحة الفلاتر المستعملة.

Emission limit values in mg / m^3 to 11% O_2 dry gas According to EC 20/09/2010 to an incinerator >6 ton/h

parameter	half-hour mean value	European Directive 2000/76 / EC of 04/12/2000 and French Decrees of 20/09/2002 and 03/08/2010	refectural stopped operating permit Flamoval of 17/06/2009
Total dust	1-20	10	3
Hydrochloric acid (HCl)	1-50	10	7
Hydrofluoric acid (HF)	10	1	0.7
Sulphur dioxide (SO_2)	1-150	50	15
Carbon monoxide(CO)	5-100	50	30
total organic carbon (COT)	1-20	10	8
Mercury (Hg)	0.001-0.03	0.05	0.04
Cadmium + Thallium (Cd + Tl)	-	0.05	0.04
Other heavy metals (Sb + As + Pb + Cr + Cu + Co + Mn + Ni + V)	-	0.5	0.4
Oxides of Nitrogen (NOx)	40-300	200	50
Ammonia (NH_3)	-	30	10
Dioxins and furans	0.01-0.1	0.1	-

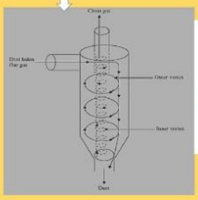
	<1 ton/h	1-3 ton/h	>3 ton/h
Elements (polluants)	Maximum value(mg/m^3)	Maximum value(mg/m^3)	Maximum value(mg/m^3)
Dust	200	100	30
Pb+Cr+Cu+Mn	-	5	5
Ni+As	-	1	1
Cd+Hg	-	0.2	0.2
Cl (HCl)	250	100	50
F (HF)	-	4	2
SO_2	-	300	300

Emission limit values in mg /m^3 to respected (Lebanese environmental ministry

4.Treatment of dust (علاج الغبار)

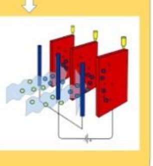
Particles between 5 & 50 micron and volatized heavy metals

Mechanical treatment :
العلاج الميكانيكي
Cyclone(efficiency:91%)



Less than 5 micron

Electrical treatment :
العلاج الكهربائي
The electrostatic precipitator (ESP)(efficiency:95%)



3.Acid gas treatment technologies(HF, HCl and SO_2)تقنيات معالجة الغاز الحمضي

Depending on the concentrations, temperature, size of the flow to be treated and of further parameters, can be used different technologies for the treatment of acid gas emissions. Being a quick summary we can mention:

Bag filters with reagent injection(calcium hydroxide ($Ca(OH)_2$) or sodium bicarbonate))

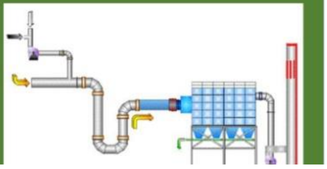
The filters in flat bags are successfully used for the chemical absorption of acid gases such as HF, HCl and SO_2 in addition to the adsorption of other pollutant compounds. Generally it is used, among others, calcium hydroxide and sodium bicarbonate ($Ca(OH)_2$) of typical commercial quality, which is injected in the gas stream before entering the filter. To achieve proper compliance with the emission limits required, the additive should be added in amounts over-stoichiometric (from 1.5 to 3 times).
at least 130-200 ° C

- Treatment by $Ca(OH)_2$:

$$Ca(OH)_2 + 2HCl \rightleftharpoons CaCl_2 + 2H_2O$$
$$Ca(OH)_2 + 2HF \rightleftharpoons CaF_2 + 2H_2O$$
$$Ca(OH)_2 + SO_2 \rightleftharpoons CaSO_3 + H_2O$$
$$CaSO_3 + 1/2\ O_2 \rightarrow CaSO_4$$

- Treatment by $NaHCO_3$:

$$NaHCO_3 + HCl \rightleftharpoons NaCl + CO_2 + H_2O$$
$$NaHCO_3 + HF \rightleftharpoons NaF + CO_2 + H_2O$$
$$2NaHCO_3 + SO_2 + 1/2O_2 \rightarrow Na_2SO_4 + 2CO_2 + H_2O$$



1.Techniques for the reduction of nitrogen oxide(تقنيات للحد من أكسيد النيتروجين)

-Thermal NOx: When burning a portion of the nitrogen in the air is oxidized to nitrogen oxides. This reaction occurs only significantly at temperatures above 1300 ° C. The reaction rate depends exponentially on the temperature and is directly proportional to the oxygen content
-Fuel NOx: when burning a portion of the nitrogen contained in the fuel is oxidized to nitrogen oxides.

PROCESS OF REDUCING NON-SELECTIVE CATALYTIC (SNCR):
the reducing agent (typically ammonia or urea) is injected into the furnace and reacts with nitrogen oxides. The reactions occur at temperatures between 850 and 1000 ° C, with higher reaction rates and lower in this range.

Selective Catalytic Reduction (SCR) is a catalytic process during which ammonia mixed with air (the reduction agent) is added to the exhaust gas and passes through a catalyst, usually a sieve (e.g. Platinum, rhodium, TiO_2, zeolites). When passing through the catalyst, ammonia reacts with NOx to give nitrogen and water vapor.

2.Treatment of dioxin and furans and mercury Hg(heavy metals) & CO_2(علاج الديوكسين والفيوران)

By activated carbon(can be also called "lignite Coke for odorous compounds.)
Activated carbon is in the form of a fine black talc. Its elementary particles are made porous by a suitable heat treatment so as to create therein pores having dimensions of affinity with the molecules to be filtered. So there are formulations of active carbon adapted to different molecules that one wishes to retain.

The Environmental Protection Agency (EPA) **showed that dioxins broke down easily when exposed to temperatures in excess of 1,200 °C.**

To obtain a minimum feeding rate (F(min)) of activated carbon (AC), It was found that dioxin removal efficiency(eta) increased with an increase in AC feeding concentration. This had an almost linear function to F/Q when F/Q was less than 65 g/Nm(3), where F was the AC feeding rate (mg/min), and Q was the volumetric flow rate of flue gas (Nm(^{3})/min). However, it did not seem to be affected by F/Q, when F/Q was larger than 150 mg/Nm(^{3}). On the basis of the experimental data obtained in this study, the removal efficiency of dioxins by the application of AC could be correlated as eta (%)=100/[1.0+(40.2/(F/Q)(3))].

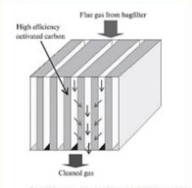
Measurement :The Intelligent Gravimetric Analyzer (IGA)
The system is an ultra-high vacuum (UHV) system and allows measurement of isotherms and accurate determination of the adsorption and desorption kinetic profiles for each pressure step. The system consists of a fully computer controlled microbalance, pressure admit system and temperature regulation system

Dioxins concentrations at activated carbon adsorber

	Dioxins concentrations (ng-TEQ/m^3-norm.)		Removal-efficiency (%)
	Inlet	Outlet	
Electric furnace for steel	5.5	0.009 3	99.83
Ash melting furnace	1.8	0.000 80	99.96
Waste furnace	1.1	0.000 16	99.99

Hg concentrations at activated carbon adsorber

	Inlet (mg/m^3-norm.)	Outlet (mg/m^3-norm.)
Waste furnace	0.065	<0.005 (Under determination limit)
Ash melting furnace	0.57	<0.005 (Under determination limit)



Cartridge packed with activated carbon

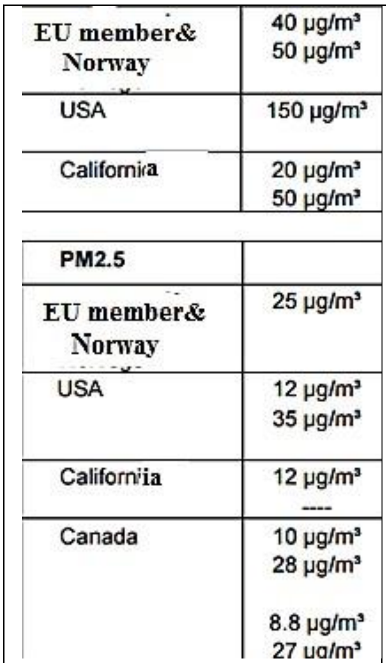
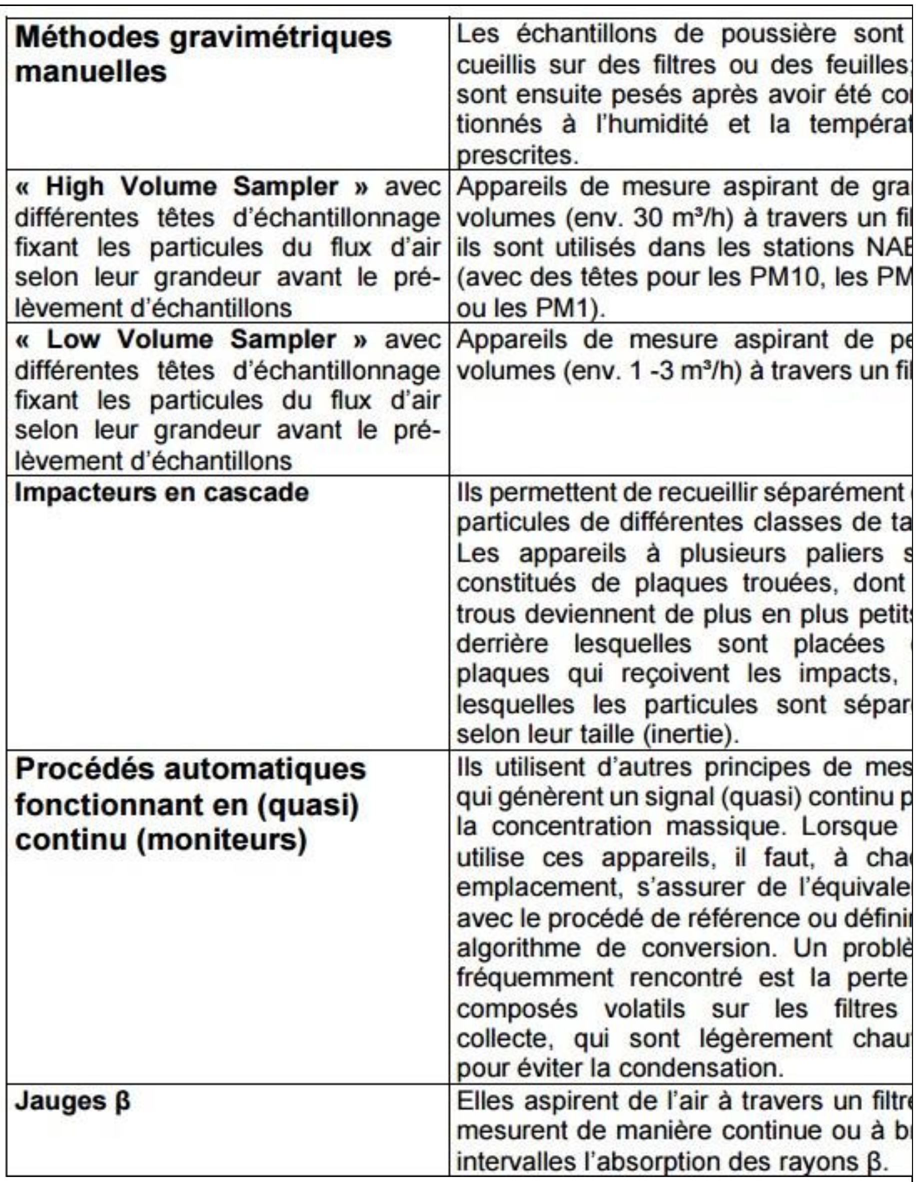
Ref:Minimum feeding rate of activated carbon to control dioxin emissions from a large-scale municipal solid waste incinerator. Article in Journal of Hazardous

5.Continuous Emission Monitoring (CEM)

A series of sensors will be implemented to assure a continuous emission monitoring of different gas formed in the flue gas without the Dioxins and furans that measured by GC(gas chromatographic); Sensors of:CO,CO_2,NO,NO_2, SO_2,SO,HCl,heavy metals.

@NLAP/AECENAR March 2019
Maysaa Kamareddine

50 Flue Gas Purification & Emissions Measurement[35]

	
A: limits of emissions of dust (PM10 & PM2.5) in USA, California, Canada	B: several methods to weigh the amount of each type of dust

EU member& Norway	40 µg/m^3 50 µg/m^3
USA	150 µg/m^3
California	20 µg/m^3 50 µg/m^3
PM2.5	
EU member& Norway	25 µg/m^3
USA	12 µg/m^3 35 µg/m^3
California	12 µg/m^3 ----
Canada	10 µg/m^3 28 µg/m^3 8.8 µg/m^3 27 µg/m^3

Méthodes gravimétriques manuelles	Les échantillons de poussière sont cueillis sur des filtres ou des feuilles sont ensuite pesés après avoir été co tionnés à l'humidité et la températ prescrites.
« **High Volume Sampler** » avec différentes têtes d'échantillonnage fixant les particules du flux d'air selon leur grandeur avant le prélèvement d'échantillons	Appareils de mesure aspirant de gra volumes (env. 30 m^3/h) à travers un fil ils sont utilisés dans les stations NAE (avec des têtes pour les PM10, les PM ou les PM1).
« **Low Volume Sampler** » avec différentes têtes d'échantillonnage fixant les particules du flux d'air selon leur grandeur avant le prélèvement d'échantillons	Appareils de mesure aspirant de pe volumes (env. 1 -3 m^3/h) à travers un fil
Impacteurs en cascade	Ils permettent de recueillir séparément particules de différentes classes de ta Les appareils à plusieurs paliers s constitués de plaques trouées, dont trous deviennent de plus en plus petit derrière lesquelles sont placées plaques qui reçoivent les impacts, lesquelles les particules sont sépar selon leur taille (inertie).
Procédés automatiques fonctionnant en (quasi) continu (moniteurs)	Ils utilisent d'autres principes de mes qui génèrent un signal (quasi) continu p la concentration massique. Lorsque utilise ces appareils, il faut, à cha emplacement, s'assurer de l'équivale avec le procédé de référence ou défini algorithme de conversion. Un problè fréquemment rencontré est la perte composés volatils sur les filtres collecte, qui sont légèrement chau pour éviter la condensation.
Jauges β	Elles aspirent de l'air à travers un filtr mesurent de manière continue ou à b intervalles l'absorption des rayons β.

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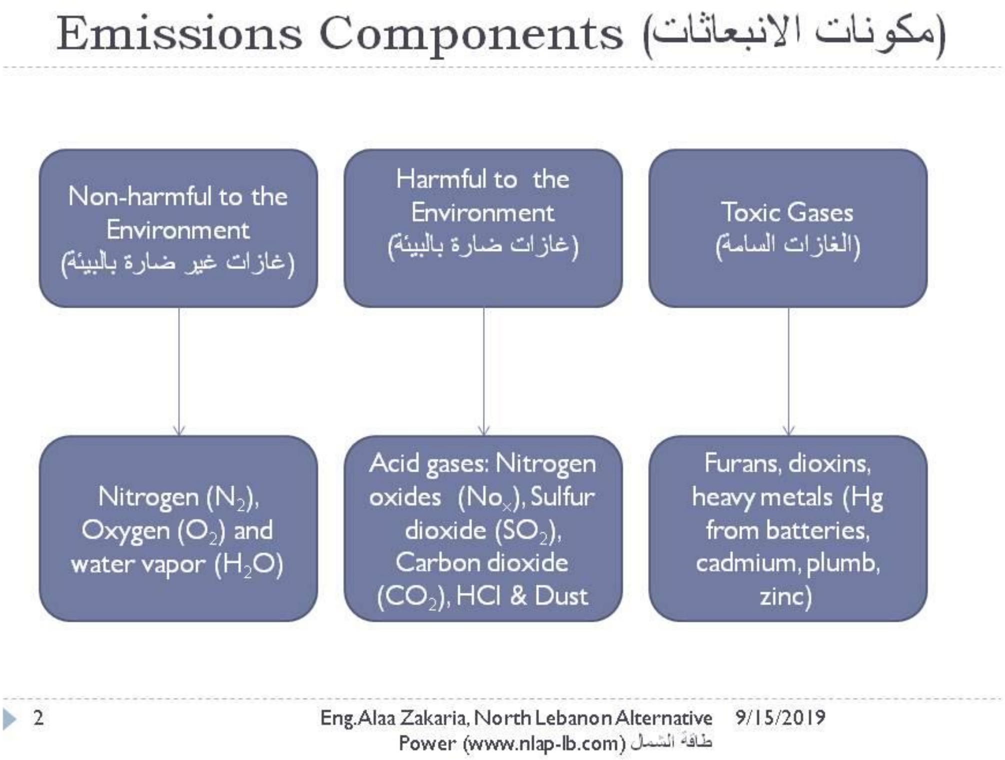
[35] from [NLAP-WEDC 2019], Ch. 3 and Appendix of [Kamareddine 2016]

50.1 Emissions Control (Emissions, Filters, Standards)



Emissions Components (مكونات الانبعاثات)

Non-harmful to the Environment (غازات غير ضارة بالبيئة)

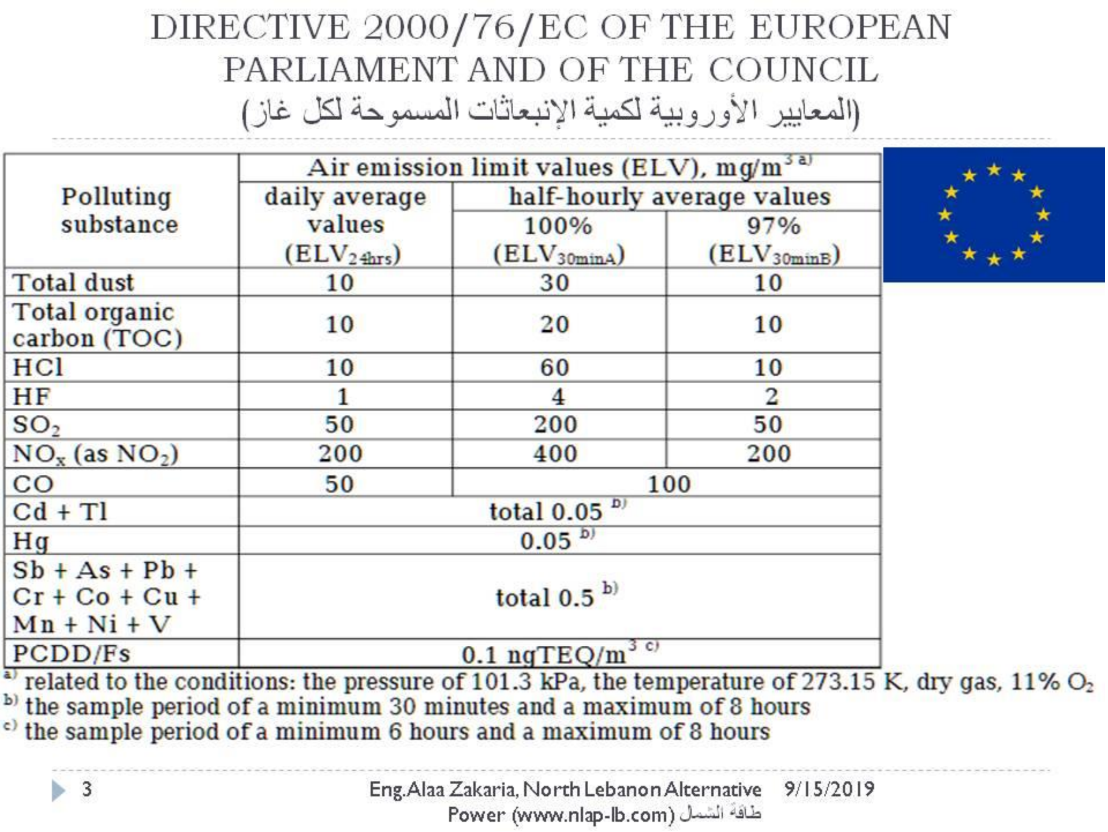
Harmful to the Environment (غازات ضارة بالبيئة)

Toxic Gases (الغازات السامة)

Nitrogen (N_2), Oxygen (O_2) and water vapor (H_2O)

Acid gases: Nitrogen oxides (No_x), Sulfur dioxide (SO_2), Carbon dioxide (CO_2), HCl & Dust

Furans, dioxins, heavy metals (Hg from batteries, cadmium, plumb, zinc)



DIRECTIVE 2000/76/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL (المعايير الأوروبية لكمية الإنبعاثات المسموحة لكل غاز)

Polluting substance	Air emission limit values (ELV), mg/m³ a)		
	daily average values (ELV_{24hrs})	half-hourly average values 100% (ELV_{30minA})	half-hourly average values 97% (ELV_{30minB})
Total dust	10	30	10
Total organic carbon (TOC)	10	20	10
HCl	10	60	10
HF	1	4	2
SO_2	50	200	50
NO_x (as NO_2)	200	400	200
CO	50	100	
Cd + Tl	total 0.05 b)		
Hg	0.05 b)		
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V	total 0.5 b)		
PCDD/Fs	0.1 ngTEQ/m³ c)		

a) related to the conditions: the pressure of 101.3 kPa, the temperature of 273.15 K, dry gas, 11% O_2
b) the sample period of a minimum 30 minutes and a maximum of 8 hours
c) the sample period of a minimum 6 hours and a maximum of 8 hours

Techniques for the Reduction of pollutant gases (تقنيات لخفض الغازات الملوثة)

I. **Nitrogen Oxides (NO_x) Reduction Techniques:**

a. Selective Non-catalytic reduction process:

Urea $$NH_2CONH_2 + 2NO + 1/2O_2 \xrightarrow{\textbf{900°C to 1100°C}} 2N_2 + CO_2 + 2H_2O$$

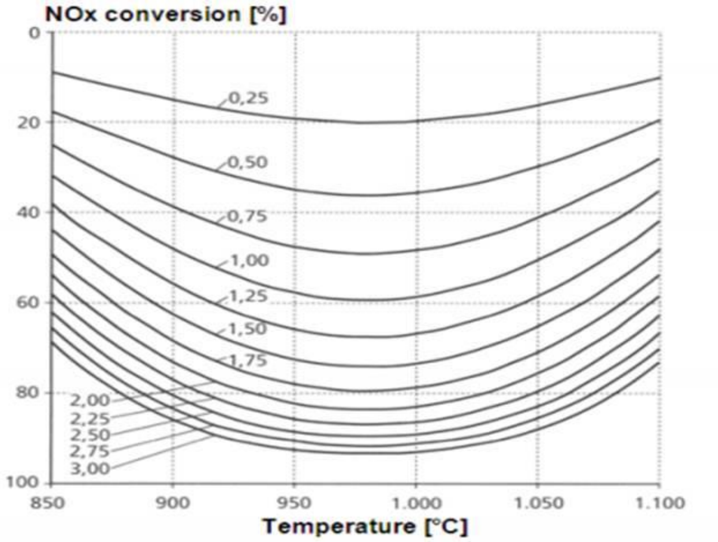
Ammonia $$4NH_3 + 4NO + O_2 \xrightarrow{\textbf{900°C to 1100°C}} 4N_2 + 6H_2O$$

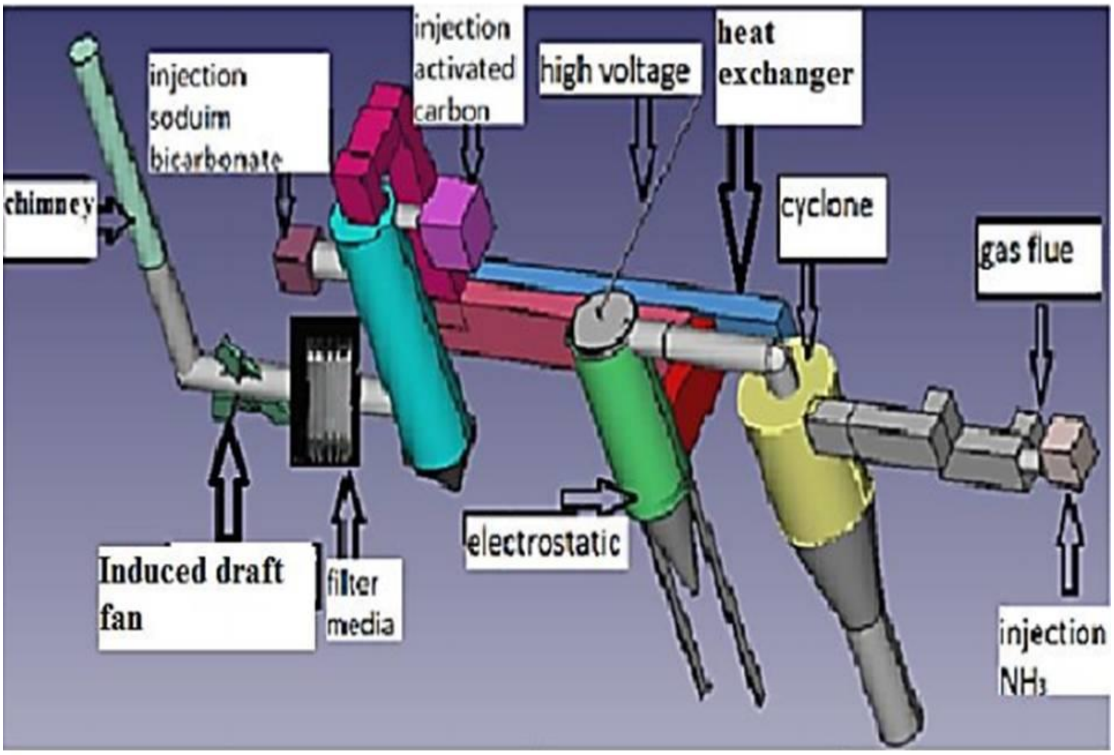
b. Selective Catalytic reduction process:

$$NH_3 + Air + NO_x \xrightarrow{\textbf{Pt / Rh / TiO2 / Zeolite}} N_2 + H_2O$$

Techniques for the Reduction of pollutant gases (تقنيات لخفض الغازات الملوثة)

- Used option: Reduction of NO_x with Ammonia





Techniques for the Reduction of pollutant gases (تقنيات لخفض الغازات الملوثة)

2. Acid Gas (HCl, HF & SO_2) Treatment Technologies:

❖ Bag filters with reagent injection:

→ Calcium Hydroxide: $Ca(OH)_2$

- $Ca(OH)_2 + 2HCl \leftrightarrow CaCl_2 + 2H_2O$
- $Ca(OH)_2 + 2HF \leftrightarrow CaF_2 + 2H_2O$
- $Ca(OH)_2 + SO_2 \leftrightarrow CaSO_3 + H_2O$

  $CaSO_3 + \frac{1}{2}O_2 \rightarrow CaSO_4$

→ Sodium Bicarbonate: $NaHCO_3$:

- $NaHCO_3 + HCl \leftrightarrow NaCl + CO_2 + H_2O$
- $NaHCO_3 + HF \leftrightarrow NaF + CO_2 + H_2O$
- $2NaHCO_3 + SO_2 + \frac{1}{2}\ O2 \rightarrow Na_2SO_4 + 2CO_2 + H_2O$

Techniques for the Reduction of pollutant gases (تقنيات لخفض الغازات الملوثة)

- Residence time: > 1 second
- Flue gas temperature: 135 ~ 815°C
- Temp. of conveying air: <60°C
- Stochiometry: 1.5 to 3 times additive WRT. Acid gases
- Sorbent particle size: finer particles result in better performance

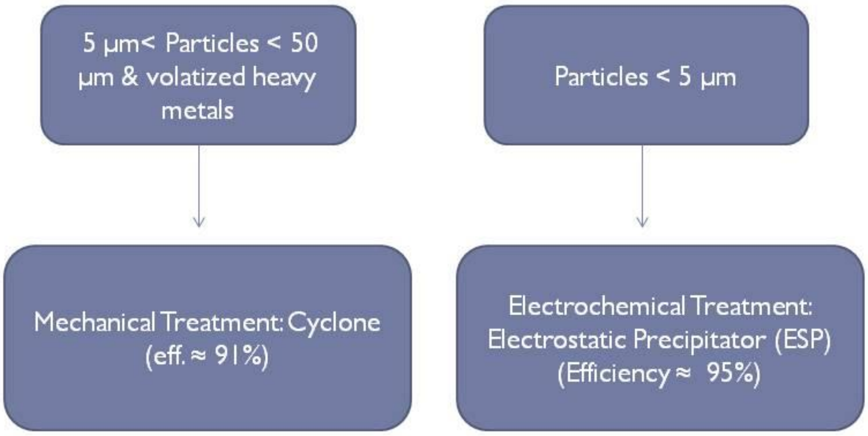
Techniques for the Reduction of pollutant gases (تقنيات لخفض الغازات الملوثة)

Table 1: Dry Injection of Sodium Bicarbonate for HCl and SO_2 Removal at Various Waste Incinerators

Plant	Waste	Capacity (tons/y)	Removal Rate (%)	
			SO_2	HCl
UVE Metz (France)	Municipal Waste	90,000	> 98	> 98
Sotrenor Veolia Group (France)	Hazardous Industrial Waste	100,000	> 99	> 99
Burgo Mantova (Italy)	Hazardous Industrial Waste	60,000	> 97	> 95
Müllheizkraftwer, Kassel (Germany)	Municipal Waste	90,000	> 90	> 99
AHKW Geiselbullach (Germany)	Municipal Waste	50,000	> 80	> 95
Oshima (Japan)	Municipal Waste	40,000	> 96	> 99

Techniques for the Reduction of pollutant gases (تقنيات لخفض الغازات الملوثة)

3. **Treatment of Dust:**



5 µm< Particles < 50 µm & volatized heavy metals

Mechanical Treatment: Cyclone (eff. ≈ 91%)

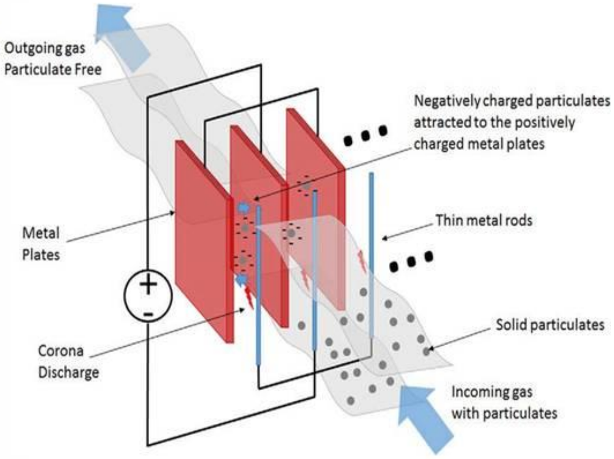
Particles < 5 µm

Electrochemical Treatment: Electrostatic Precipitator (ESP) (Efficiency ≈ 95%)

Techniques for the Reduction of pollutant gases (تقنيات لخفض الغازات الملوثة)

Cyclone

ESP



Techniques for the Reduction of poisonous gases (تقنيات الحد من الغازات السامة)

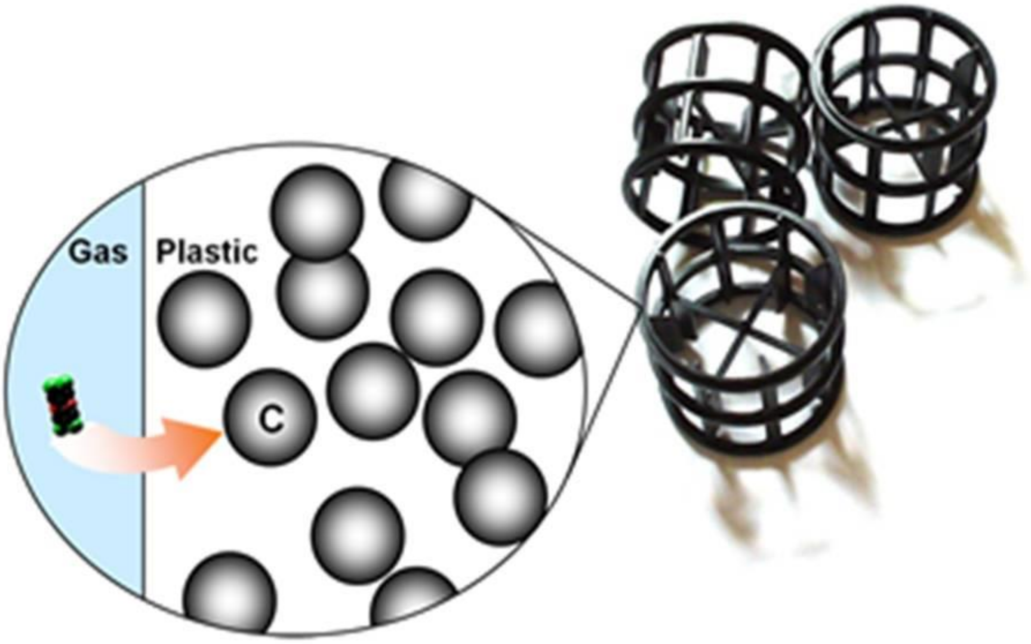
- Removal of Dioxin & Furans: Adiox

  - Consists of polypropylene doped with carbon particles

  - Effective, safe and economical technology for scrubbing dioxins from gases.

  - Incinerated after use, leading to the destruction and removal of dioxins from the ecosystem.

  - Can be installed with a scrubber or other type of equipment in a flue gas cleaning system



50.2 Emissions Measurement

Sensors & their Prices
(أجهزة الإستشعار وأسعارها)

gasmet > Know what's in the air.

Seite 4/6

Preisinformation PI_190826_TEMO-WI Lebanon_CEMS IIef

Pos	Artikel/Bezeichnung	Menge	Einh.	Preis	Netto EUR
	Gasmet™ CEMS IIef FTIR-Messsystem mit Rädern statt Sockel ***EIGNUNGSGEPRÜFTES MESSSYSTEM***				
1	TTCEMS_IIef_10 **Automatische Messeinrichtung CEMS IIef für die kontinuierliche Emissionsüberwachung**	1	St.	95.494,00	95.494,00

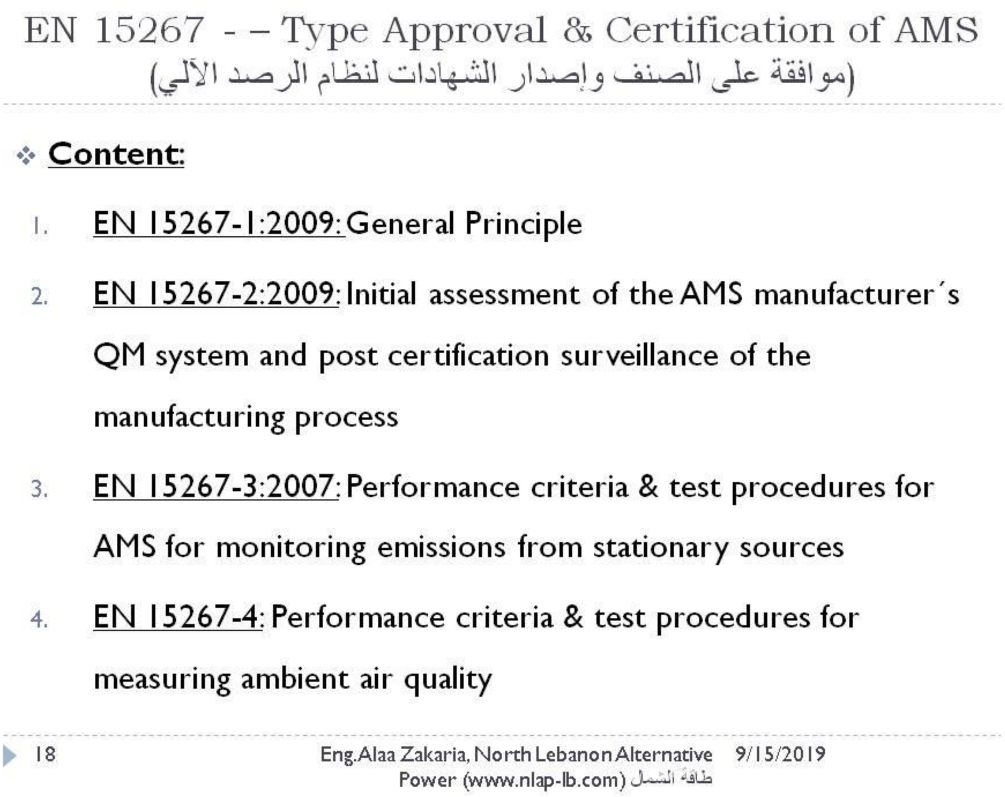
gasmet > Know what's in the air.

Seite 3/5

Preisinformation PI_19mmtt_Kunde_CMM

Pos	Artikel/Bezeichnung	Menge	Einh.	Preis	Netto EUR
	Gasmet™ CMM Quecksilber-Messsystem ***EIGNUNGSGEPRÜFTES MESSSYSTEM***				
1	TTCMMSYS-002 **Gasmet CMM - Messschrank mit Rädern für die kontinuierliche Messung des Gesamt-Quecksilber-Gehaltes in Rauchgasen**	1	St.	68.508,00	68.508,00

17 Eng.Alaa Zakaria, North Lebanon Alternative Power (www.nlap-lb.com) طاقة الشمال 9/18/2019



EN 15267 - – Type Approval & Certification of AMS
(موافقة على الصنف وإصدار الشهادات لنظام الرصد الآلي)

❖ **Content:**

1. EN 15267-1:2009: General Principle
2. EN 15267-2:2009: Initial assessment of the AMS manufacturer´s QM system and post certification surveillance of the manufacturing process
3. EN 15267-3:2007: Performance criteria & test procedures for AMS for monitoring emissions from stationary sources
4. EN 15267-4: Performance criteria & test procedures for measuring ambient air quality

18 Eng.Alaa Zakaria, North Lebanon Alternative Power (www.nlap-lb.com) طاقة الشمال 9/15/2019

EN 15267 – Part 1: General Scope
(الجزء الأول: النطاق العام)

EN 15267 – Part 1:

1. It specifies the general principles for the products certification of AMS for monitoring emissions from stationary sources and ambient air quality.
2. Steps:
   a- Performance testing of an AMS

   b- Initial assessment of the AMS manufacturer's quality management system

   c- Certification

   d- Surveillance

EN 15267 – Part 1: General Scope
(الجزء الأول: النطاق العام)

3. Roles & responsibilities during certification:

→ Manufacturers of AMS should establish, maintain & operate a quality management system according to EN 15267-2

→ Test laboratory should hold accreditation for type approval testing according to EN ISO/IEC 17025

→ Relevant body:

- needs accreditation to EN 45011 if the relevant body is a certification body
- verifies evidence, that manufacturer has an EN 15267-2 conform QMS
- adds the AMS to official register

EN 15267 – Part 2: QM System & Audit Scope
(الجزء الثاني: نظام مراقبة الجودة ونطاق التدقيق)

- Specifies the requirements for:

1. The QM system of the manufacturer
2. The initial assessment of the AMS manufacturer
3. Ongoing surveillance to ensure that the AMS fulfills the minimum requirements of the approval test procedure, also after soft- or hardware modifications.

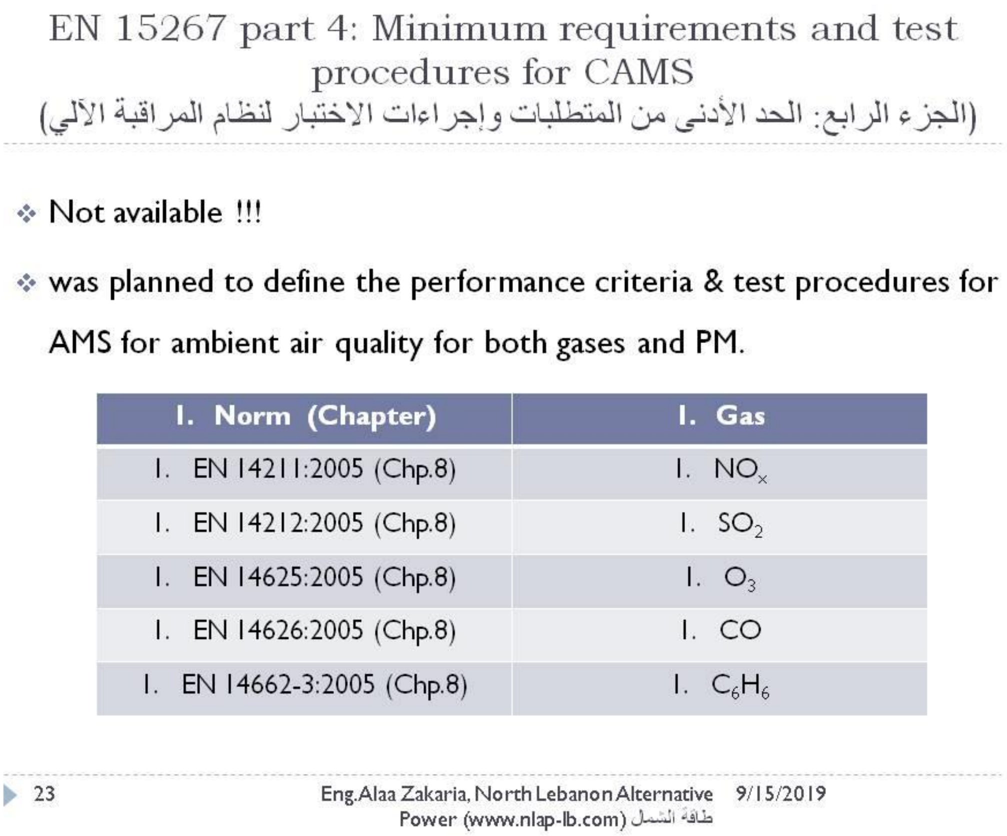
- The manufacturer must keep records and evaluations on any modification of the certified AMS.

EN 15267 – Part 3: Minimum Requirements & Test Procedures for CEMS
(الجزء الثالث: الحد الأدنى من المتطلبات وإجراءات الاختبار لنظام الانبعاثات المستمرة)

- Defines the performance criteria & test procedures for AMS that:

1. Measure gases and particulate matter in respective flow of the waste gas from stationary sources.

- This European Standard supports the requirements of particular EU Directives
- It provides the detailed procedures covering the QAL1 requirements of EN 14181
- It provides input data for QAL3 procedure described in EN 14181

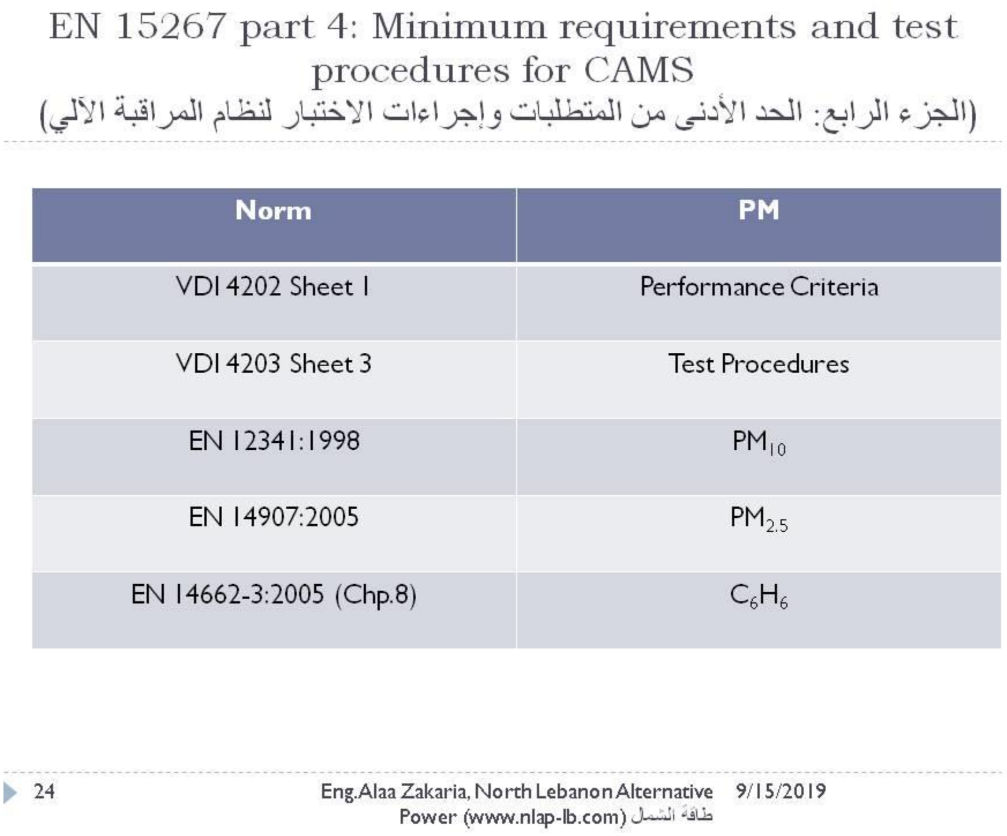


EN 15267 part 4: Minimum requirements and test procedures for CAMS

(الجزء الرابع: الحد الأدنى من المتطلبات وإجراءات الاختبار لنظام المراقبة الآلي)

- Not available !!!
- was planned to define the performance criteria & test procedures for AMS for ambient air quality for both gases and PM.

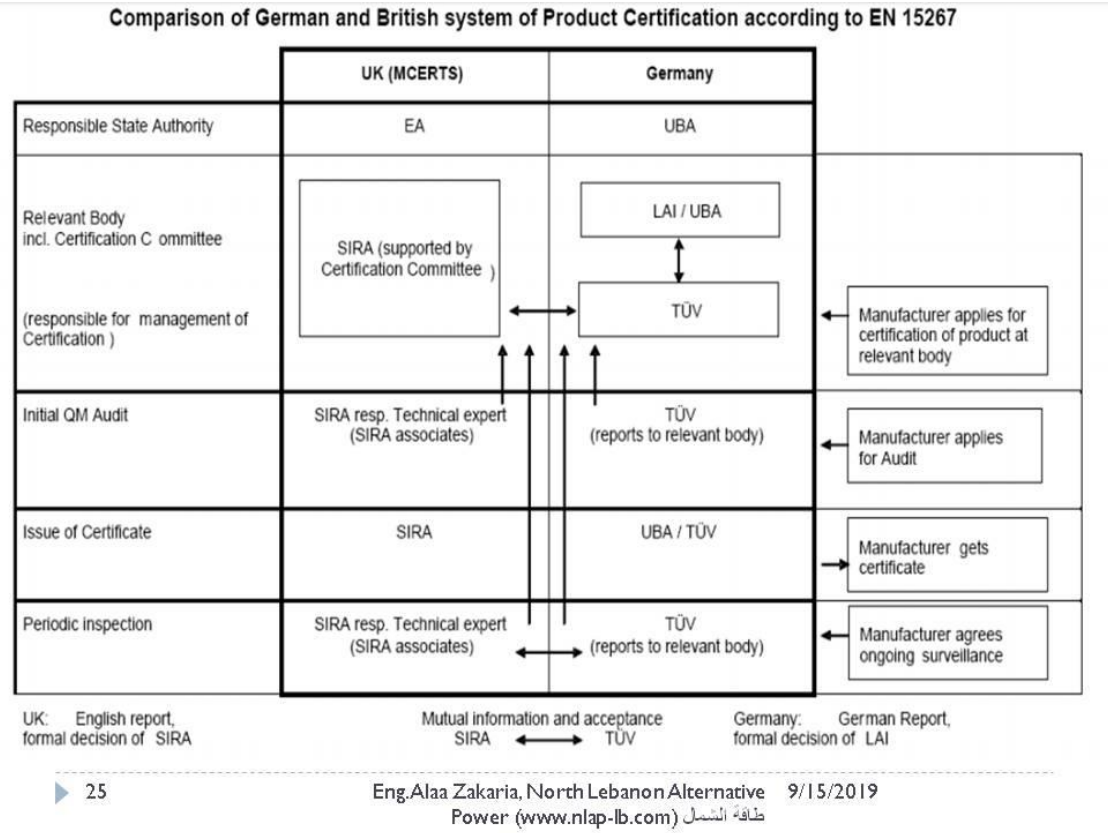
I. Norm (Chapter)	I. Gas
I. EN 14211:2005 (Chp.8)	I. NO_x
I. EN 14212:2005 (Chp.8)	I. SO_2
I. EN 14625:2005 (Chp.8)	I. O_3
I. EN 14626:2005 (Chp.8)	I. CO
I. EN 14662-3:2005 (Chp.8)	I. C_6H_6



EN 15267 part 4: Minimum requirements and test procedures for CAMS

(الجزء الرابع: الحد الأدنى من المتطلبات وإجراءات الاختبار لنظام المراقبة الآلي)

Norm	PM
VDI 4202 Sheet 1	Performance Criteria
VDI 4203 Sheet 3	Test Procedures
EN 12341:1998	PM_{10}
EN 14907:2005	$PM_{2.5}$
EN 14662-3:2005 (Chp.8)	C_6H_6



Comparison of German and British system of Product Certification according to EN 15267

	UK (MCERTS)	Germany	
Responsible State Authority	EA	UBA	
Relevant Body incl. Certification Committee (responsible for management of Certification)	SIRA (supported by Certification Committee)	LAI / UBA TÜV	Manufacturer applies for certification of product at relevant body
Initial QM Audit	SIRA resp. Technical expert (SIRA associates)	TÜV (reports to relevant body)	Manufacturer applies for Audit
Issue of Certificate	SIRA	UBA / TÜV	Manufacturer gets certificate
Periodic inspection	SIRA resp. Technical expert (SIRA associates)	TÜV (reports to relevant body)	Manufacturer agrees ongoing surveillance

UK: English report, formal decision of SIRA

Mutual information and acceptance SIRA ⟷ TÜV

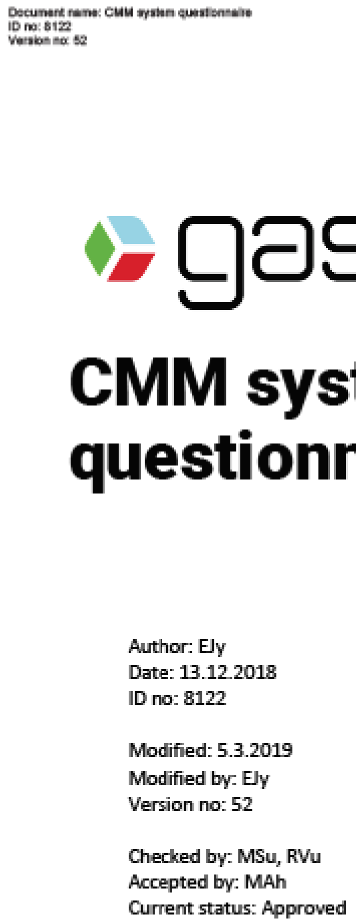
Germany: German Report, formal decision of LAI

25 Eng.Alaa Zakaria, North Lebanon Alternative Power (www.nlap-lb.com) طاقة الشمال 9/15/2019

Zinc Recovery (Bottom & Fly Ash)	Equipment & Chemicals Needed	Quantity (for 1 sample)	Prices
Equipment Needed	Grinding Machine for grinding bottom ash	1	
	Vaccum Filtration (for separating ash from water)	1	
	Agitation Leaching Tank	1	
	Rotating Discs Column (RDS)	1	
	GASMET CEM Sensors System	1	95,554EU
	GASMET CMM Sensors System	1	68,508EU
	Dioxin Monitoring System	1	
Chemicals Needed	Distilled Water for washing fly ash	1 liter	
	Nitric Acid for Leaching of heavy metals	20 liters	$25/liter
	Cyanex 272 (83411-71-6) for extraction of Zn	300mL	
	Kerosene for extraction of Zn	1200mL	
	Sulfuric acid for stripping of Zn		$10 to $12/liter

50.3 Offer from Gasmet for a Emissions Monitoring System

50.3.1 Filled Questionnaire



Document name: CMM system questionnaire
ID no: 8122
Version no: 52

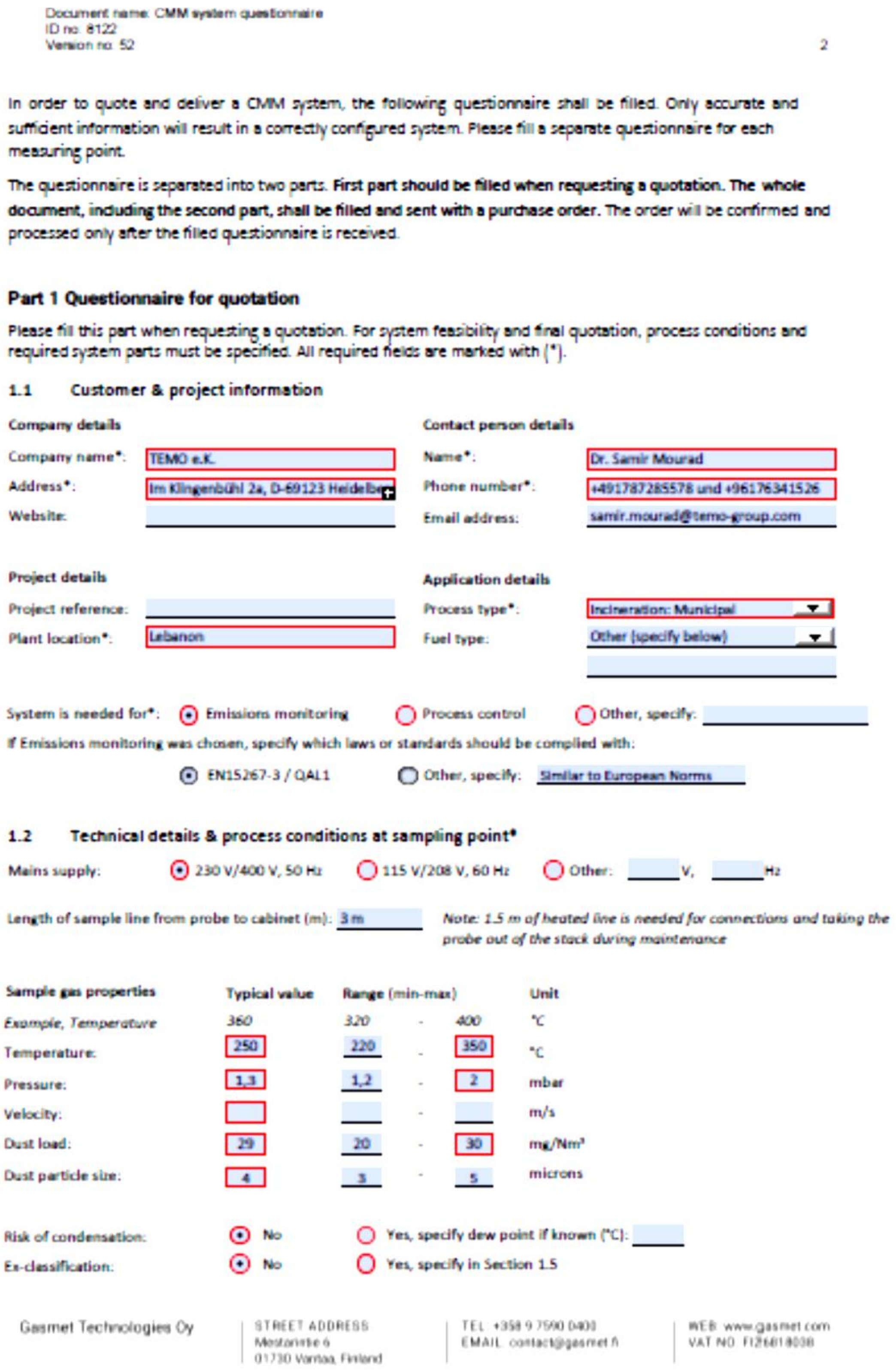
gasmet

CMM system questionnaire

Author: EJy
Date: 13.12.2018
ID no: 8122

Modified: 5.3.2019
Modified by: EJy
Version no: 52

Checked by: MSu, RVu
Accepted by: MAh
Current status: Approved



Document name: CMM system questionnaire
ID no: 8122
Version no: 52

2

In order to quote and deliver a CMM system, the following questionnaire shall be filled. Only accurate and sufficient information will result in a correctly configured system. Please fill a separate questionnaire for each measuring point.

The questionnaire is separated into two parts. **First part should be filled when requesting a quotation. The whole document, including the second part, shall be filled and sent with a purchase order.** The order will be confirmed and processed only after the filled questionnaire is received.

Part 1 Questionnaire for quotation

Please fill this part when requesting a quotation. For system feasibility and final quotation, process conditions and required system parts must be specified. All required fields are marked with (*).

1.1 Customer & project information

Company details

Company name*: TEMO e.K.
Address*: Im Klingenbühl 2a, D-69123 Heidelbe
Website:

Contact person details

Name*: Dr. Samir Mourad
Phone number*: +491787285578 und +96176341526
Email address: samir.mourad@temo-group.com

Project details

Project reference:
Plant location*: Lebanon

Application details

Process type*: Incineration: Municipal ▼
Fuel type: Other (specify below) ▼

System is needed for*: ● Emissions monitoring ○ Process control ○ Other, specify:

If Emissions monitoring was chosen, specify which laws or standards should be complied with:

● EN15267-3 / QAL1 ○ Other, specify: Similar to European Norms

1.2 Technical details & process conditions at sampling point*

Mains supply: ● 230 V/400 V, 50 Hz ○ 115 V/208 V, 60 Hz ○ Other: V, Hz

Length of sample line from probe to cabinet (m): 3 m

Note: 1.5 m of heated line is needed for connections and taking the probe out of the stack during maintenance

Sample gas properties	**Typical value**	**Range** (min-max)			**Unit**
Example, Temperature	*360*	*320*	-	*400*	°C
Temperature:	250	220	-	350	°C
Pressure:	1,3	1,2	-	2	mbar
Velocity:			-		m/s
Dust load:	29	20	-	30	mg/Nm³
Dust particle size:	4	3	-	5	microns

Risk of condensation: ● No ○ Yes, specify dew point if known (°C):
Ex-classification: ● No ○ Yes, specify in Section 1.5

Gasmet Technologies Oy
STREET ADDRESS
Mestarintie 6
01730 Vantaa, Finland
TEL +358 9 7590 0400
EMAIL contact@gasmet.fi
WEB www.gasmet.com
VAT NO FI26818038

1.3 Sample gas matrix & mercury content

Fill out the required range and concentrations of mercury content in the sample gas.

Additionally, fill out the concentrations of other gas components present in the gas matrix if known.

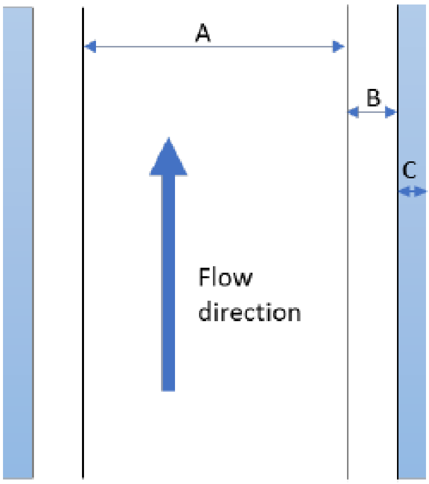
	Compound name*	Required range*	Minimum value	Typical value	Maximum value*	Unit*
	For example, Sulphur dioxide SO_2	-	*10*	*50*	*200*	*ppm*
1.	Hydrochloric acid (HCl)	0-15		9		mg/m3
2.	Hydrofluoric acid (HF)	0-1.5		0.8		mg/m3
3.	Sulphur dioxide (SO2)	0-60		42		mg/m3
4.	Carbon monoxide (CO)	0-60		48		mg/m3
5.	Total organic carbon (COT)	0-10		8		mg/m3
6.	Mercury (Hg)	0-0.15		0.04		mg/m3
7.	Cadmium + Thallium (Cd+Tl)	0-0.15		0.03		mg/m3
8.	Other heavy metals (Sb+As+Pb+Cr+Cu+Co+Mn	0-0.6		0.4		mg/m3
9.	Oxides of Nitrogen (NOx)	0-220		180		mg/m3
10.	Ammonia (NH3)	0-40		25		mg/m3
11.	Dioxins & Furans	0-0.15		0.09		mg/m3
12.						

1.4 Installation location information

Probe installation point*

Temperature range: °C (min) - °C (max)

Weather protected: ○ Yes ○ No



Duct details

Duct inner diameter (A): 900 mm

Wall thickness (B): 3 mm

Insulation thickness (C): 30 mm

Duct material: Steel 306

Duct position: ● Horizontal ○ Vertical

In case of existing mounting flange

Diameter of the inner tube: mm

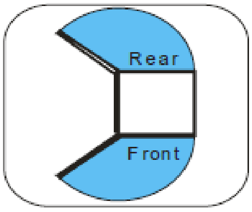
Flue gas cleaning type ○ Electrostatic precipitator (ESP) ● Baghouse ○ Wet scrubber

Part 2 Purchase order details

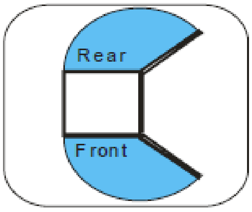
Please note that only Part 1 is needed for a quotation. Part 2 should be filled and sent with a purchase order. The order will only be confirmed after the filled questionnaire is received.

2.1 CMM system cabinet door opening directions

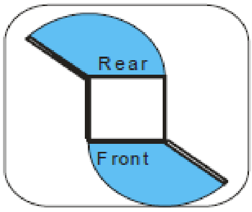
Door opening directions (choose one of the following)



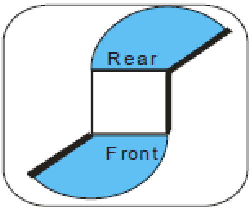
○ Standard



○ CAB-OPT-113



○ CAB-OPT-113



○ CAB-OPT-113

2.2 CMM system parts

Standard system parts (included):

- ☑ Probe & heated sample line
- ☑ Cabinet with A/C unit
- ☑ Computer with MAUI software
- ☑ Gasmet mercury analyzer
- ☑ Gasmet test gas generator

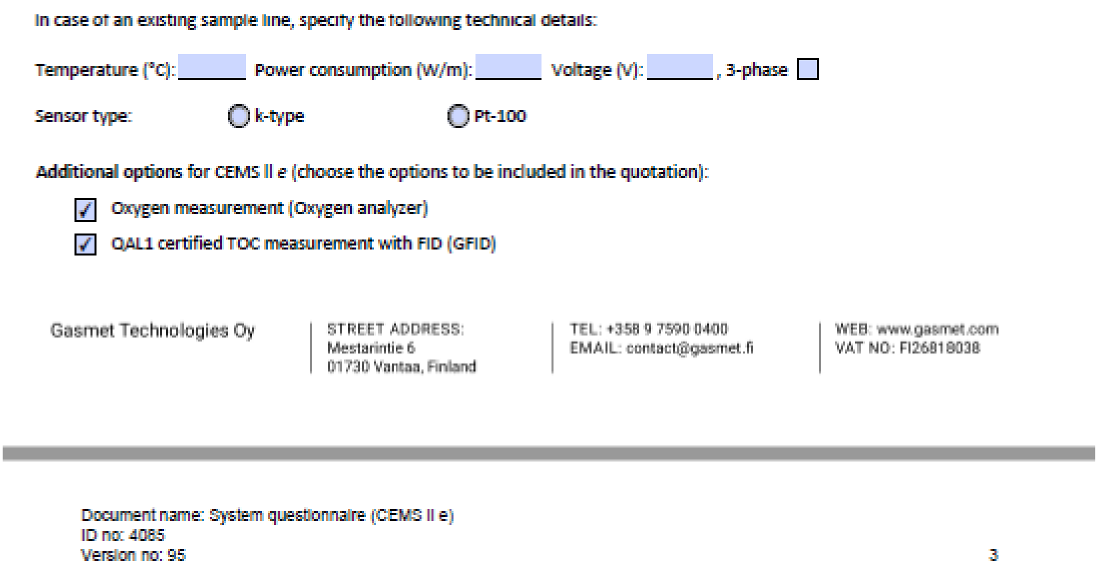
gasmet

System questionnaire (CEMS II *e*)

Author: EJy
Date: 19.4.2017
ID no: 4085

Modified: 12.11.2018
Modified by: EJy
Version no: 95

Checked by: MSu, RVu
Accepted by: MAh
Current status: Approved



In case of an existing sample line, specify the following technical details:

Temperature (°C): ______ Power consumption (W/m): ______ Voltage (V): ______, 3-phase ☐

Sensor type: ○ k-type ○ Pt-100

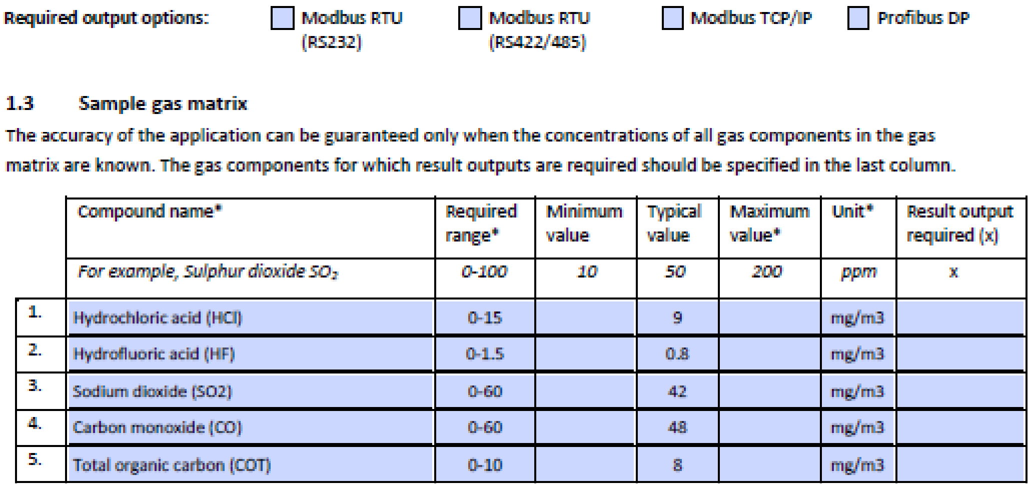
Additional options for CEMS II e (choose the options to be included in the quotation):

☑ Oxygen measurement (Oxygen analyzer)

☑ QAL1 certified TOC measurement with FID (GFID)

Gasmet Technologies Oy | STREET ADDRESS: Mestarintie 6 01730 Vantaa, Finland | TEL: +358 9 7590 0400 EMAIL: contact@gasmet.fi | WEB: www.gasmet.com VAT NO: FI26818038

Document name: System questionnaire (CEMS II e)
ID no: 4085
Version no: 95 3



Required output options: ☐ Modbus RTU (RS232) ☐ Modbus RTU (RS422/485) ☐ Modbus TCP/IP ☐ Profibus DP

1.3 Sample gas matrix

The accuracy of the application can be guaranteed only when the concentrations of all gas components in the gas matrix are known. The gas components for which result outputs are required should be specified in the last column.

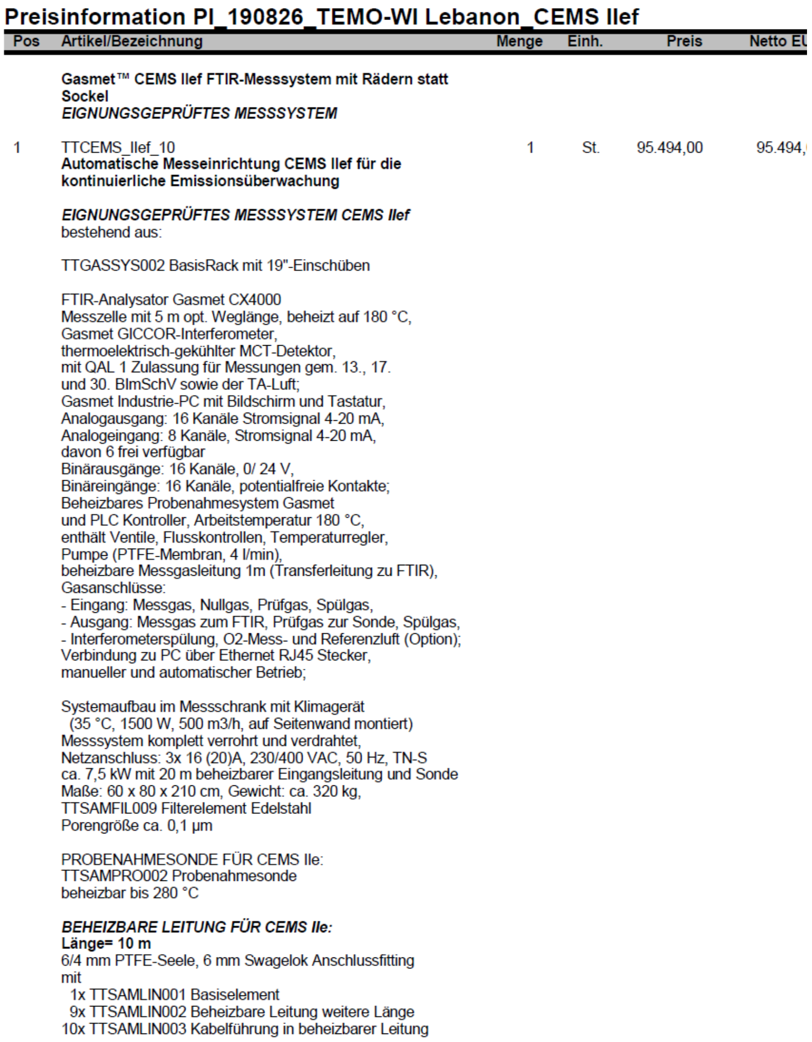
	Compound name*	Required range*	Minimum value	Typical value	Maximum value*	Unit*	Result output required (x)
	For example, Sulphur dioxide SO_2	*0-100*	*10*	*50*	*200*	*ppm*	x
1.	Hydrochloric acid (HCl)	0-15		9		mg/m3	
2.	Hydrofluoric acid (HF)	0-1.5		0.8		mg/m3	
3.	Sodium dioxide (SO2)	0-60		42		mg/m3	
4.	Carbon monoxide (CO)	0-60		48		mg/m3	
5.	Total organic carbon (COT)	0-10		8		mg/m3	

50.3.2 Offer (Elements & Prices)

Gasmet Ostring 4 Telefon 0721 / 626560 Sekretariat@gasmet.com
Technologies GmbH 76131 Karlsruhe Telefax 0721 / 621332 www.gasmet.de

Gasmet™ CEMS II e
Automatische Messeinrichtung (AMS) zur Überwachung von Emissionen

CO, NO, NO_2, N_2O, SO_2, HCl, HF, NH_3, CO_2, H_2O, O_2, CH_4, CHOH und Gesamt-C.



Preisinformation PI_190826_TEMO-WI Lebanon_CEMS IIef

Pos	Artikel/Bezeichnung	Menge	Einh.	Preis	Netto E
	Gasmet™ CEMS IIef FTIR-Messsystem mit Rädern statt Sockel ***EIGNUNGSGEPRÜFTES MESSSYSTEM***				
1	TTCEMS_IIef_10 **Automatische Messeinrichtung CEMS IIef für die kontinuierliche Emissionsüberwachung**	1	St.	95.494,00	95.494,

EIGNUNGSGEPRÜFTES MESSSYSTEM CEMS IIef
bestehend aus:

TTGASSYS002 BasisRack mit 19"-Einschüben

FTIR-Analysator Gasmet CX4000
Messzelle mit 5 m opt. Weglänge, beheizt auf 180 °C,
Gasmet GICCOR-Interferometer,
thermoelektrisch-gekühlter MCT-Detektor,
mit QAL 1 Zulassung für Messungen gem. 13., 17.
und 30. BImSchV sowie der TA-Luft;
Gasmet Industrie-PC mit Bildschirm und Tastatur,
Analogausgang: 16 Kanäle Stromsignal 4-20 mA,
Analogeingang: 8 Kanäle, Stromsignal 4-20 mA,
davon 6 frei verfügbar
Binärausgänge: 16 Kanäle, 0/ 24 V,
Binäreingänge: 16 Kanäle, potentialfreie Kontakte;
Beheizbares Probenahmesystem Gasmet
und PLC Kontroller, Arbeitstemperatur 180 °C,
enthält Ventile, Flusskontrollen, Temperaturregler,
Pumpe (PTFE-Membran, 4 l/min),
beheizbare Messgasleitung 1m (Transferleitung zu FTIR),
Gasanschlüsse:
- Eingang: Messgas, Nullgas, Prüfgas, Spülgas,
- Ausgang: Messgas zum FTIR, Prüfgas zur Sonde, Spülgas,
- Interferometerspülung, O2-Mess- und Referenzluft (Option);

Verbindung zu PC über Ethernet RJ45 Stecker,
manueller und automatischer Betrieb;

Systemaufbau im Messschrank mit Klimagerät
(35 °C, 1500 W, 500 m3/h, auf Seitenwand montiert)
Messsystem komplett verrohrt und verdrahtet,
Netzanschluss: 3x 16 (20)A, 230/400 VAC, 50 Hz, TN-S
ca. 7,5 kW mit 20 m beheizbarer Eingangsleitung und Sonde
Maße: 60 x 80 x 210 cm, Gewicht: ca. 320 kg,
TTSAMFIL009 Filterelement Edelstahl
Porengröße ca. 0,1 µm

PROBENAHMESONDE FÜR CEMS IIe:
TTSAMPRO002 Probenahmesonde
beheizbar bis 280 °C

BEHEIZBARE LEITUNG FÜR CEMS IIe:
Länge= 10 m
6/4 mm PTFE-Seele, 6 mm Swagelok Anschlussfitting
mit
1x TTSAMLIN001 Basiselement
9x TTSAMLIN002 Beheizbare Leitung weitere Länge
10x TTSAMLIN003 Kabelführung in beheizbarer Leitung

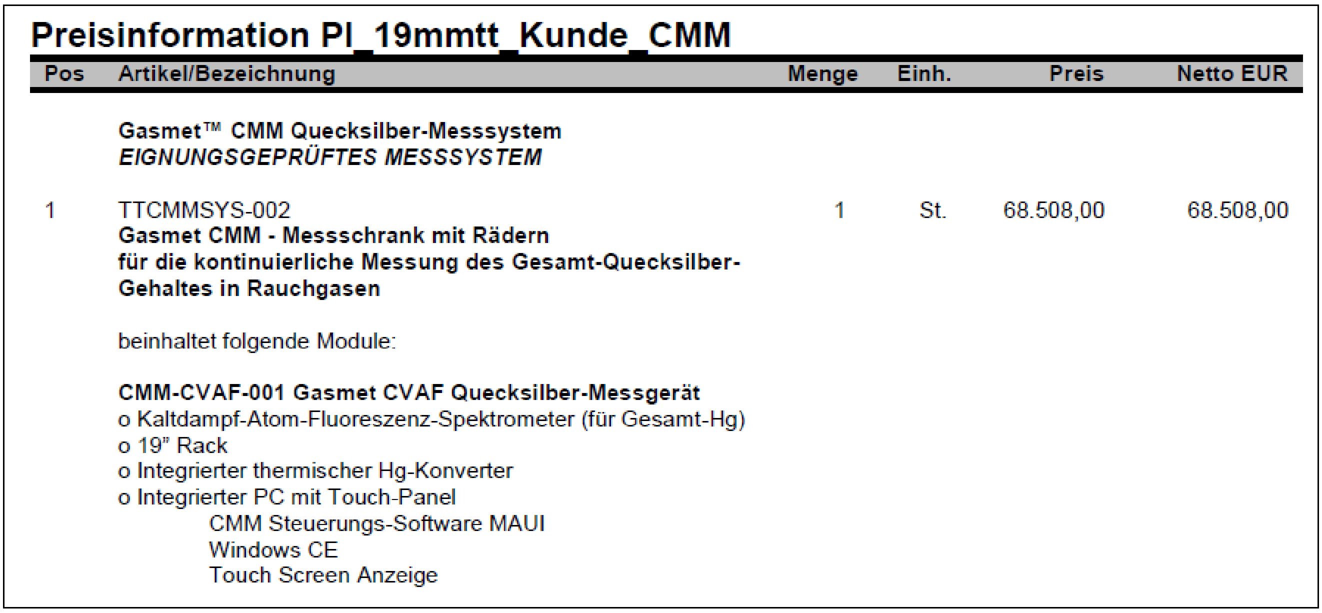
TÜV & MCERTs Zertifizierung QAL1
gemäß EN15267 und EN14181

PI_190826_TEMO-WI Lebanon_CMM.pdf

GTDE_Datenblatt_CEMS IIe Automatische

PI_190826_TEMO-WI Lebanon_CEMS IIef

Project Lebanon
Preisinformation PI_190826_TEMO-WI Lebanon_CMM, Quecksilber-Messsystem Gasmet™ CMM zur kontinuierlichen Quecksilber-Überwachung in Anlagen gemäß der 13. und 17. BImSchV



Preisinformation PI_19mmtt_Kunde_CMM

Pos	Artikel/Bezeichnung	Menge	Einh.	Preis	Netto EUR
	Gasmet™ CMM Quecksilber-Messsystem ***EIGNUNGSGEPRÜFTES MESSSYSTEM***				
1	TTCMMSYS-002 **Gasmet CMM - Messschrank mit Rädern** **für die kontinuierliche Messung des Gesamt-Quecksilber-Gehaltes in Rauchgasen** beinhaltet folgende Module: **CMM-CVAF-001 Gasmet CVAF Quecksilber-Messgerät** o Kaltdampf-Atom-Fluoreszenz-Spektrometer (für Gesamt-Hg) o 19" Rack o Integrierter thermischer Hg-Konverter o Integrierter PC mit Touch-Panel CMM Steuerungs-Software MAUI Windows CE Touch Screen Anzeige	1	St.	68.508,00	68.508,00

50.3.2.1 Messparameter

Kontrolle Nullpunkt: alle 24 h mit Nullgas,
(N_2 empfohlen, 5.0 oder besser)
Drift Nullpunkt: < 2 % vom Messbereich,
im Kontrollintervall,
Drift Empfindlichkeit: keine
Linearität: < 2 % vom Messbereich,
Einfluss Temperatur: < 2 % vom Messbereich,
pro 10 K Temperaturänderung
Einfluss Druck: 1 % Änderung des Messwertes
bei Änderung des Drucks um 1 %.
Änderung des Außenluftdruckes
wird gemessen und kompensiert.

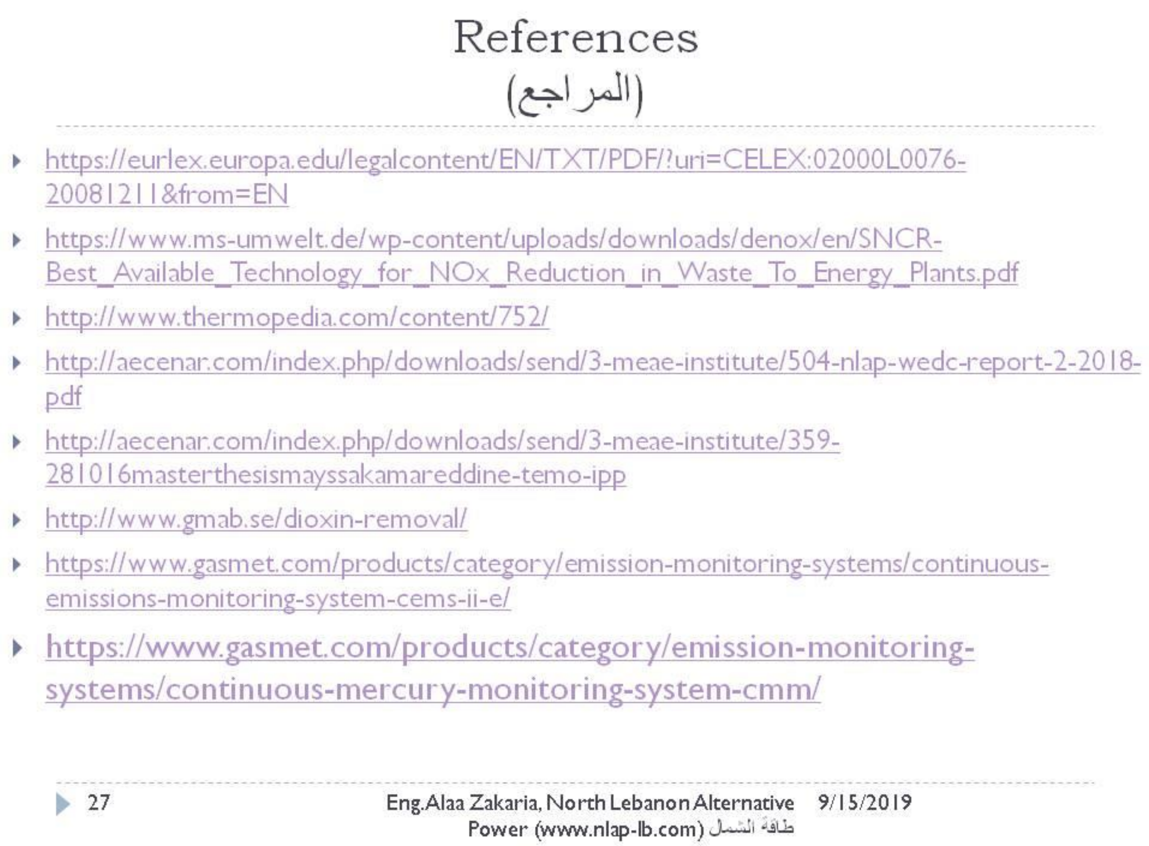
50.3.2.2 Signale (Standard)

Analog Ausgang: 16 x 4-20 mA, galv. isoliert
Analog Eingang: 8 x 4-20 mA, galv. isoliert
Digital Ausgang: 16 x 24 VDC,
Systemalarm, Wartung,
Wartungsanforderung,
Konzentrationsalarm,
Messwert gültig.
Digital Eingang: potentialfreie Kontakte,
z.B. Alarme für Temperaturen,
Sonde u. Schrank, Kühler
Standby oder Tests aktivieren.
Option: Anschluss von max. 255
Modulen für Ein- und Ausgänge

50.3.2.3 Schnittstellen (optional)

Ausgangsformate: ModBus, Profibus DP,
ASCII, DDE link über RS 232
bzw. RS422/485;
Modbus TCP

50.4 References



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27 Eng.Alaa Zakaria, North Lebanon Alternative Power (www.nlap-lb.com) طاقة الشمال 9/15/2019