بسم الله الرحمن الرحيم

MEAE – Middle East Institute for Alternative Energy

www.temo-ek.de

A member of AECENAR Applied Research Center

www.aecenar.com/institutes/meae

Construction of the cooling system for the condenser

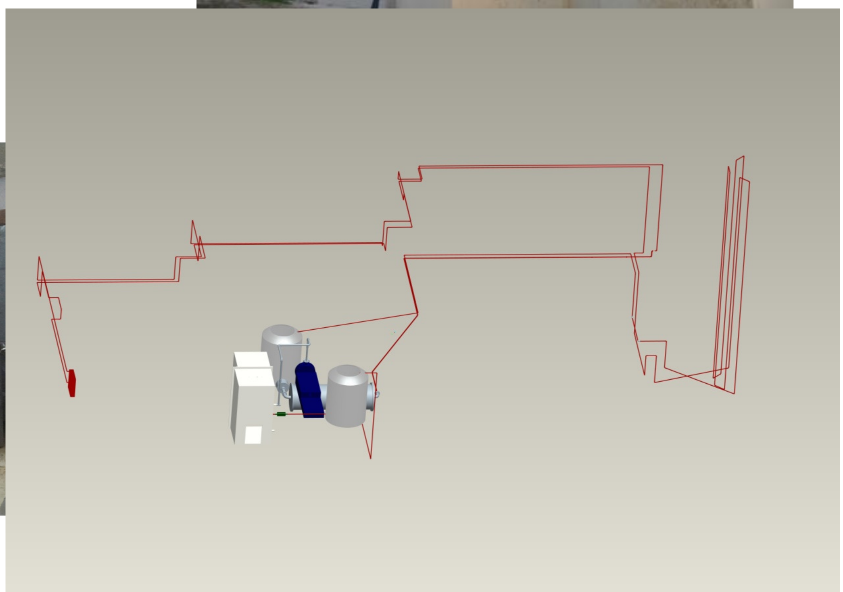
Construction of condensor

Programming and Integration of Process Control System

Further integration of mechanical parts for Demonstration Power Plant

التقرير **الرابع** لمشروع **TEMO-STPP** (المدة من كانون الثاني الى كانون الاول 2013)

TEMO-STPP: **4th** project report (Jan – Dec 2013)



Published by:

AECENAR e.V., **http://www.aecenar.com**

Content in short / المحتوى في شكل موجز

Content / المحتوى

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

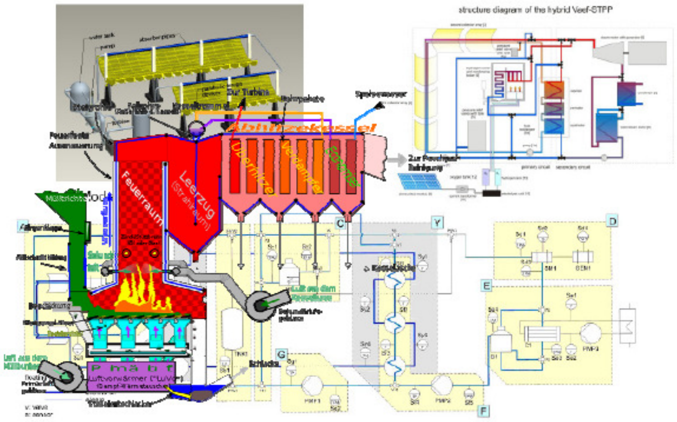
In the Name of God, the Most Merciful

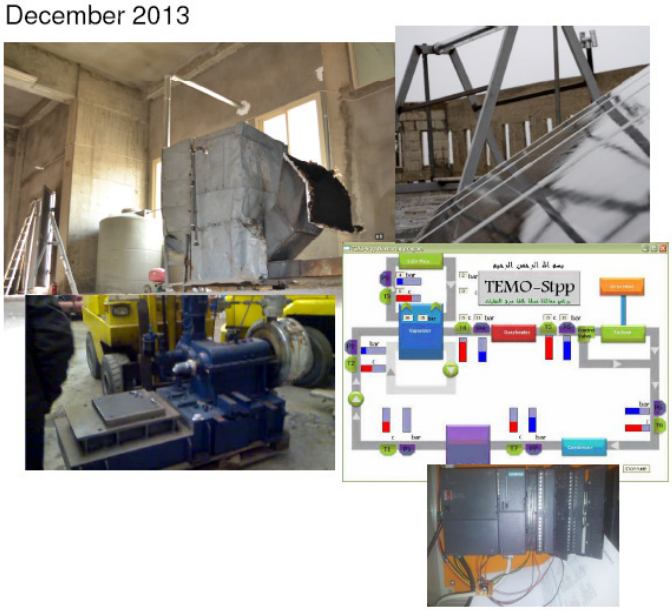
مركز للطاقة البديلة
http://aecenar.com/institutes/meae
بحوث حول انجاز محطات طاقة عن طريق الحرار الشمسية و عن طريق حرق النفايات

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

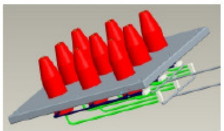
Solarthermal/Incineration Power Plant Technology
TEMO-STPP Test Plant
توليد كهرباء – تدفأة بنايات – حل لمشكلة النفايات و الاستفادة منها – الاستفادة من الطاقة الشمسية لتوليد الكهرباء

Last update: 17 December 2013





Architecture of process control system (sensors and actuators)



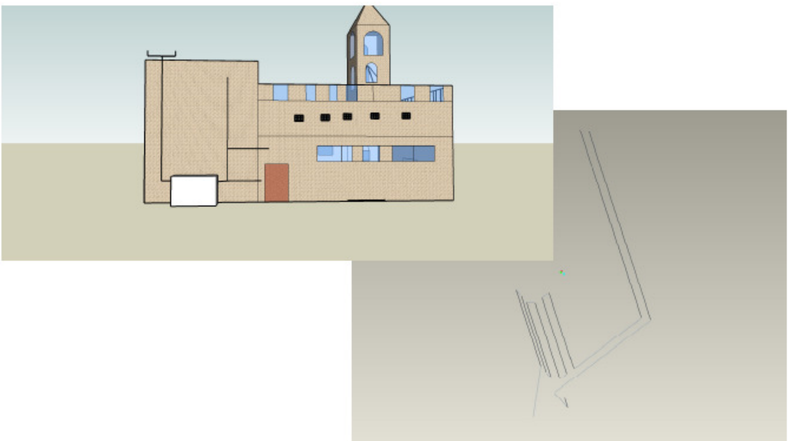
Hydrogen burner

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

Part I

1 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

1.1 Strategic Economical Goals / الأهداف الاستراتيجية الاقتصادية

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.

1.2 Main Working Packages to be done / الأهداف العملية

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)).

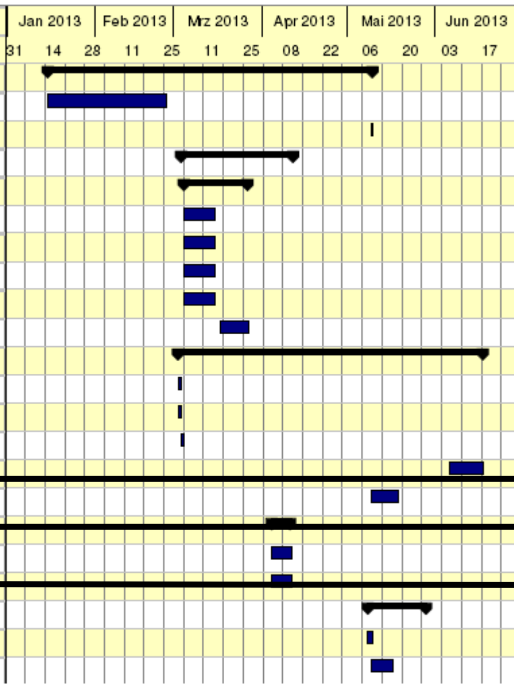
2) تشغيل محطة kW40 في رأسنحاش/لبنان للحصول على مستثمرين لمحطات الطاقة الأخرى

2 إدارة المشروع / Project Management

2.1 الجدول الزمني / Time Schedule

2.1.1 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$**
WinCC work	1st monitoring choise	2 week	2 week (**Stopped** doesn't done because of license end)	
SIMATIC manager work	For controlling	1 week	2 week (**Done** without Profibus)	
Python software	2nd monitoring choise	1 week	1 week (**Done**)	
Integration of mechanical parts:				
Tests				
Test 1	Only water	1 day	1 day (failed) caused 3 days delay	100$
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.

2.1.2 Planned Scedules for the PCS work:

- **Driver built:**

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

- **Analog reading with temp. calculation**

كتابة برنامج الـ LAD على الـ SIMATIC manager ليقوم بإستقبال بيانات Analog من الـ 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 الـ PLC او الـ Velleman board

- **User interface software (GUI)**

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

2.1.3 Mounting overheater with turbine (Sep 13)

Practicant work, Material costs: 100 EUR

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

Costs: ca. 1.600 EUR

2.2 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 €**	

2.3 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)

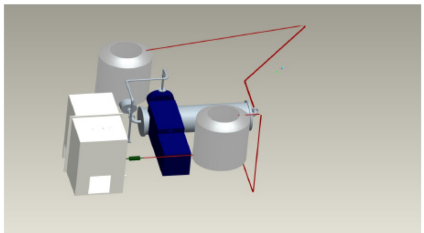
Attachments:

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



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

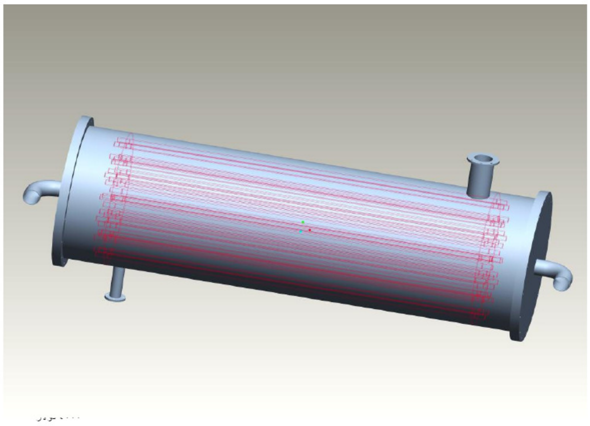
Response of LASER

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

2.4 Condensor Construction Dec 2013

Condensor

Part (القطعة)	Material (المادة) Stainless 304 (ستانلس ٣٠٤)	عدد	Price/Item	All
الجسم الخارجي	الواح ستانلس سماكة ٣ ملم او قسطل	2	$250	$500
	قسطل ١انش ٢٥ ملم سماكة ٣ ملم	12	$60	$720
	فلانش ٣٠سنتم او ٣٤سنتم مع ٢٤ 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



2.4.1 Offer from Naouchi

Materials price

December 22, 2013 at 8:22:35 pm
ورحمة عليكم السلام _ وبركاته
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

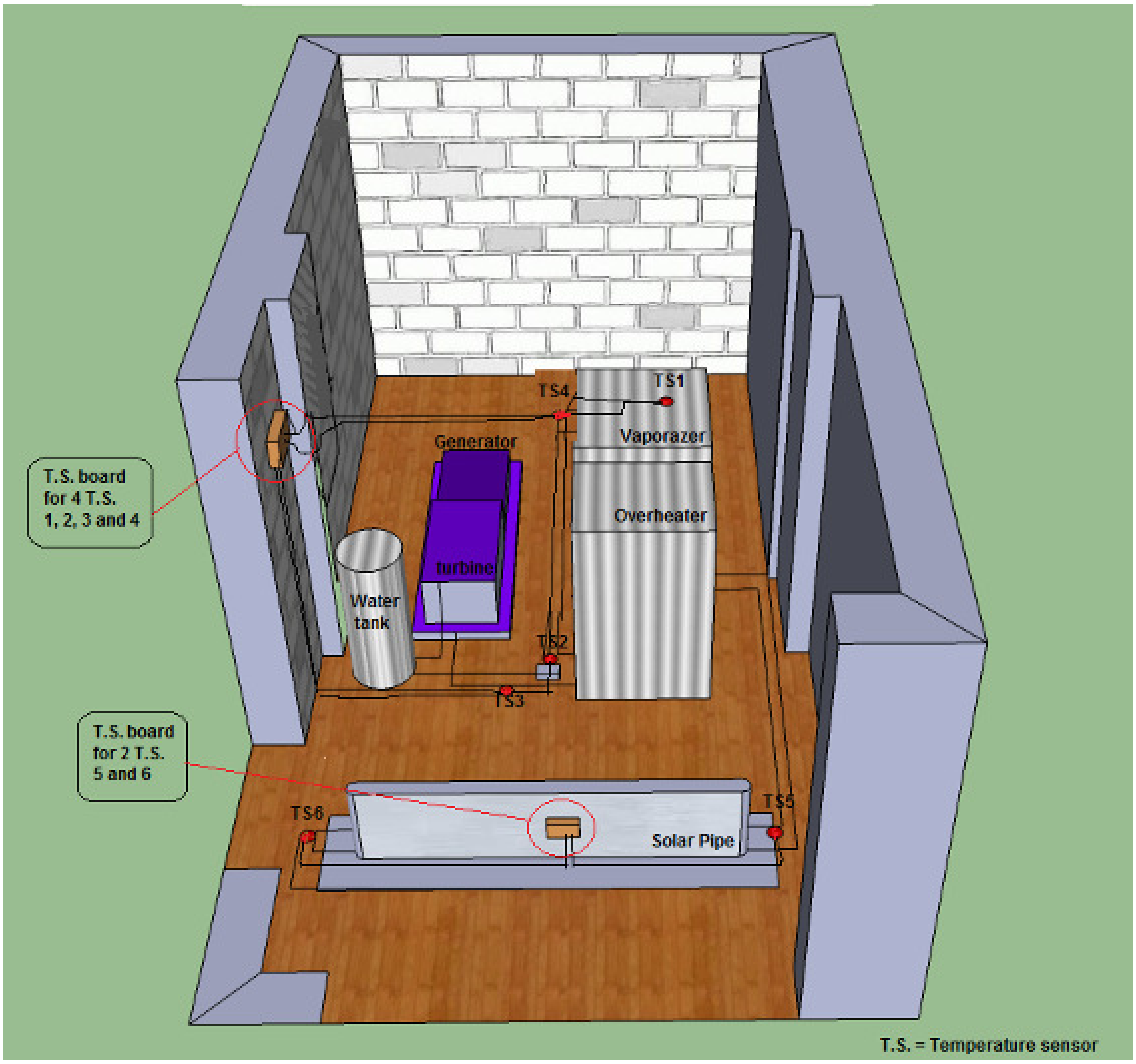
3 Integration of mechanical parts / تجميع القطع الميكانيكية

3.1 (Placing of the main devices) وضع القطع الاساسية في مكانها

3.1.1 At working hall

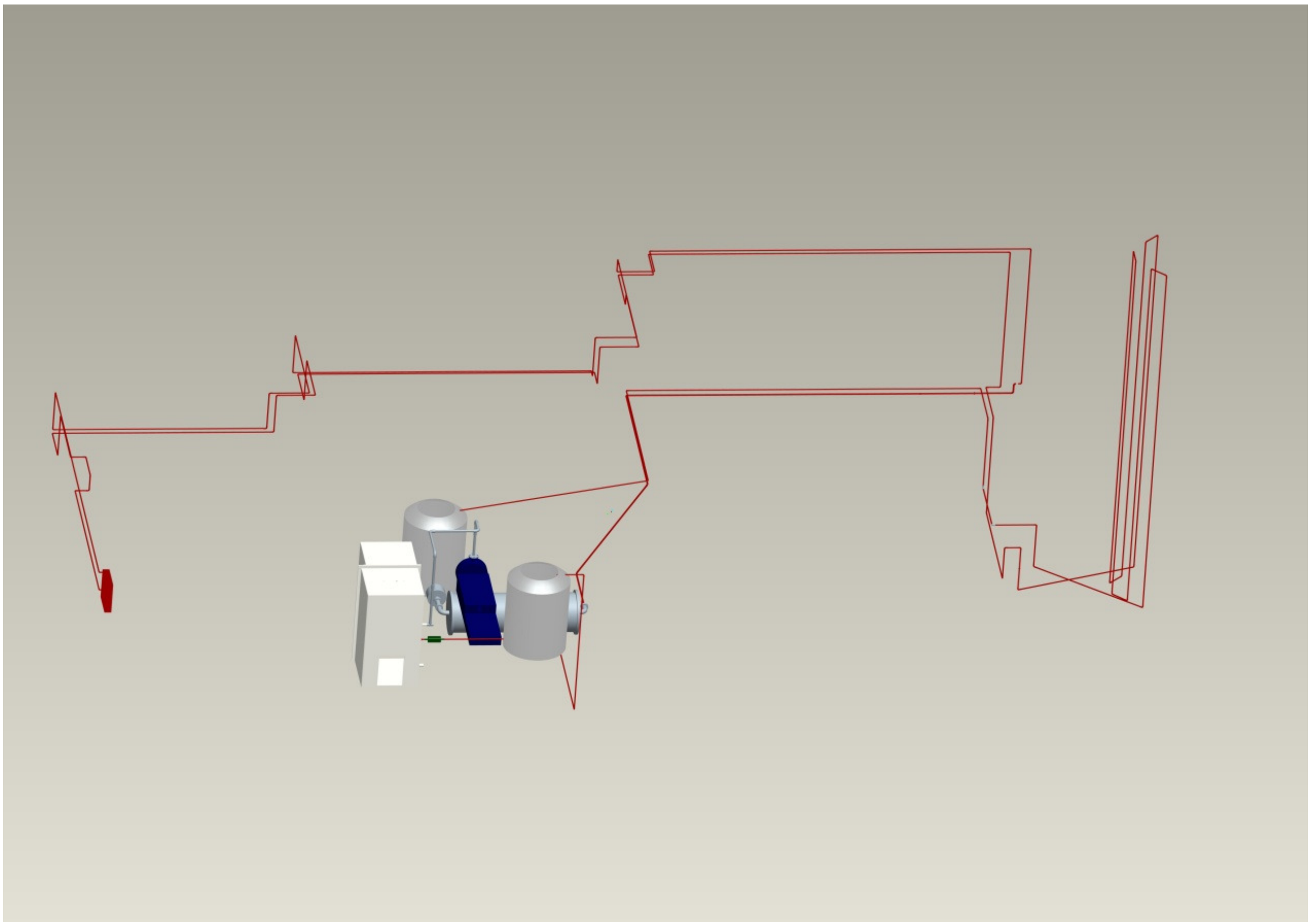
الصورة التالية تبين طريقة جمع محطة الطاقة

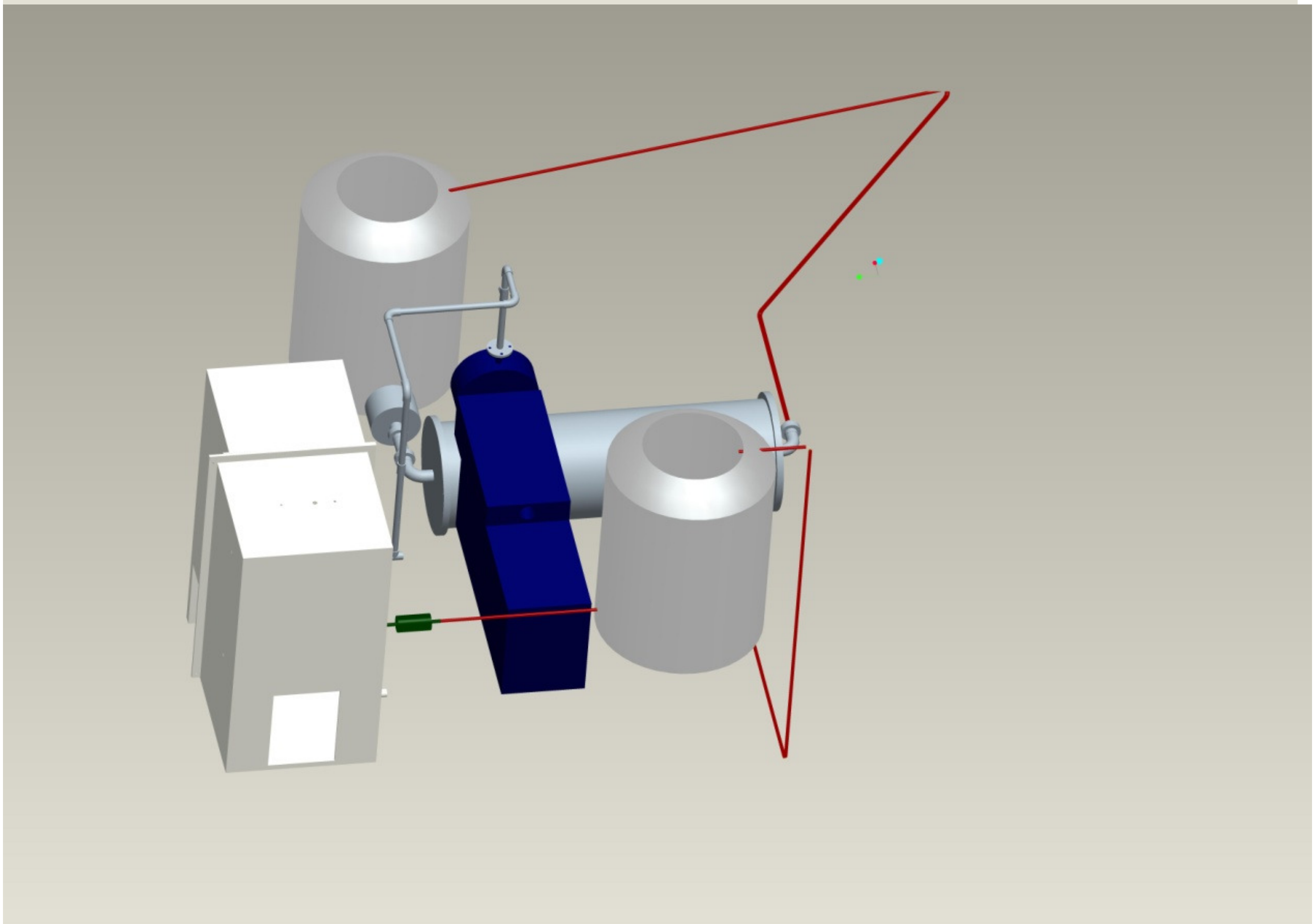
Figure bellow shows us the integration of the mechanical part with sensors.

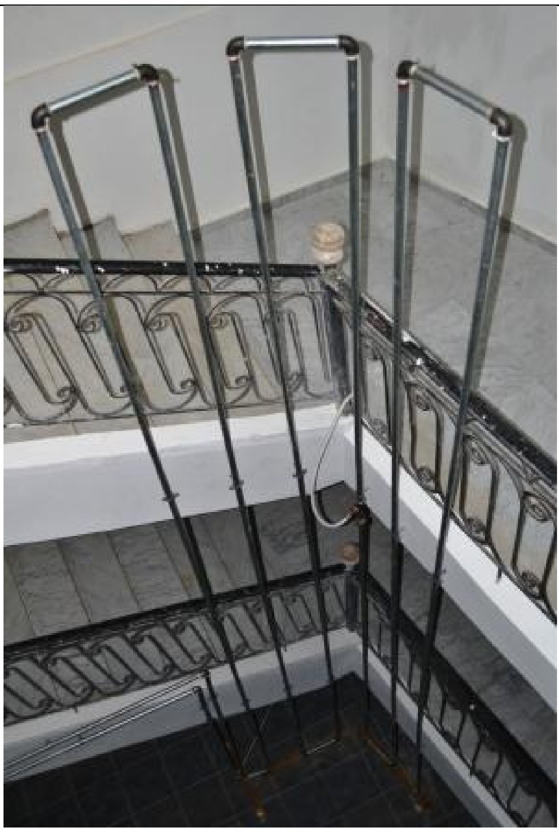


Vaparizor with overheater	Solar pipe	Turbine	Control system
			

3.1.2 At Qubaisi Center

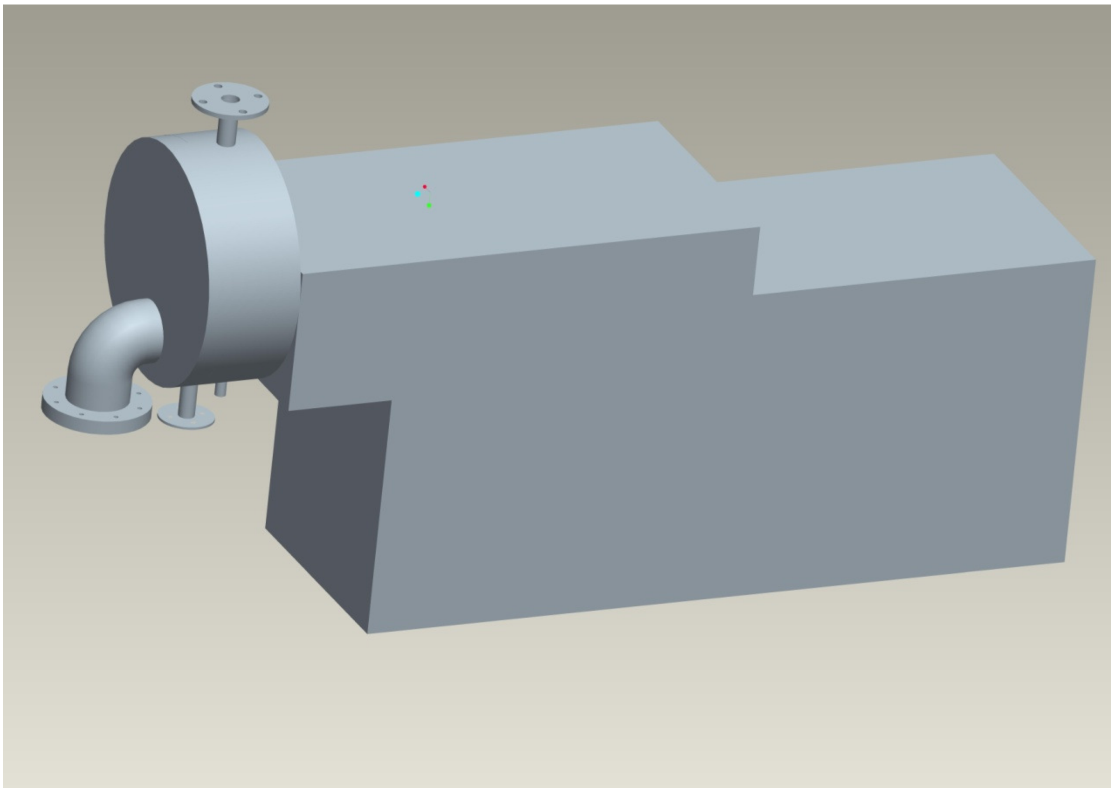






3.2 التربين (turbine)

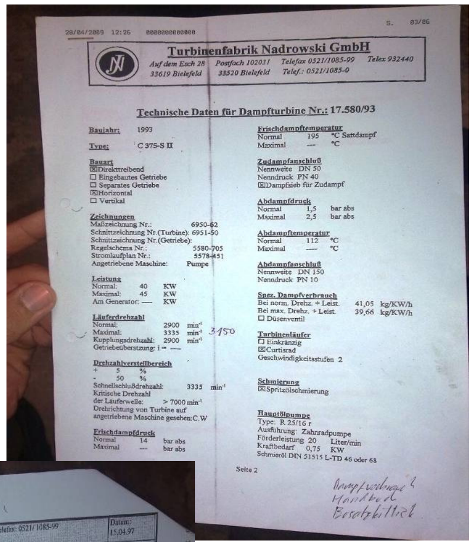
3.2.1 تفحيص التوربين 40 kW (Curtis turbine)



There must put in a fiber as "Dichtung" at the large front end of the turbine.

3.2.2 Technical Data of the turbine

The turbine used is a used Steam turbine Nadrowski Bielefeld (Dresser-Rand) Power 40KW. And have the following specification:


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

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

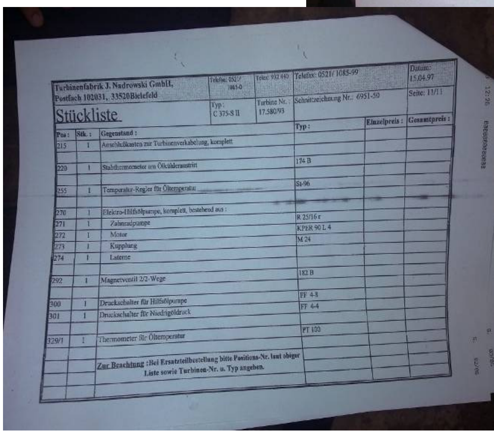
steam release pressure 1.5 bar

steam temperature: 195 ° C

exhaust temperature: 112 ° C

Shaft Diameter 50mm

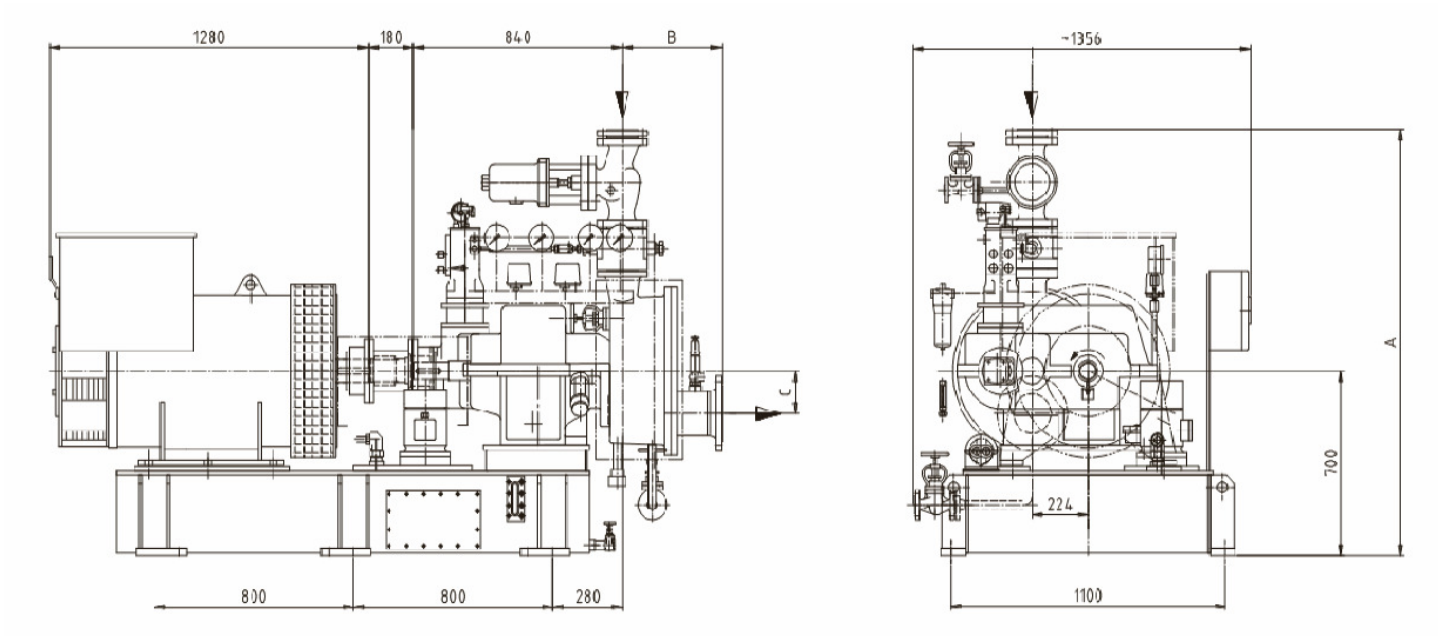
Weight: 1150 kg


Turbinenfabrik J. Nadrowski GmbH, Postfach 102031, 33520 Bielefeld — 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 Ölkühlerausstritt	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.			

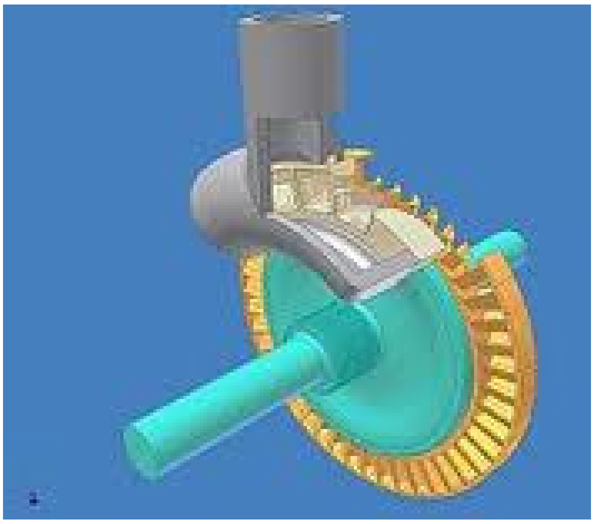
Others qualification:

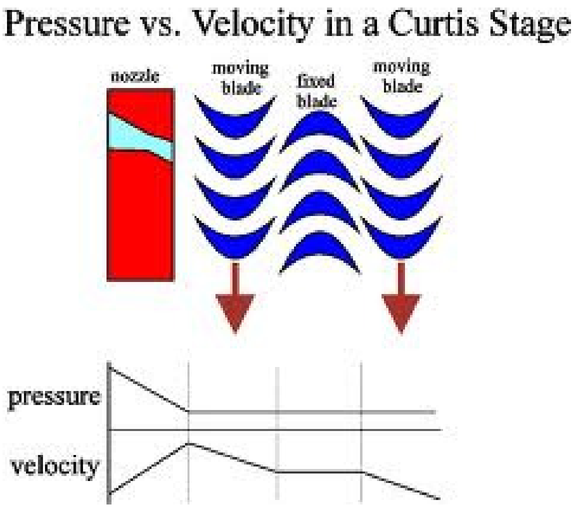


- Curtisrad
- Splash oil lubrication by gear pump 0.75 KW electric auxiliary oil pump remote activation elektisch
- Bearing 2 Rolling local speedometer
- Exhaust steam

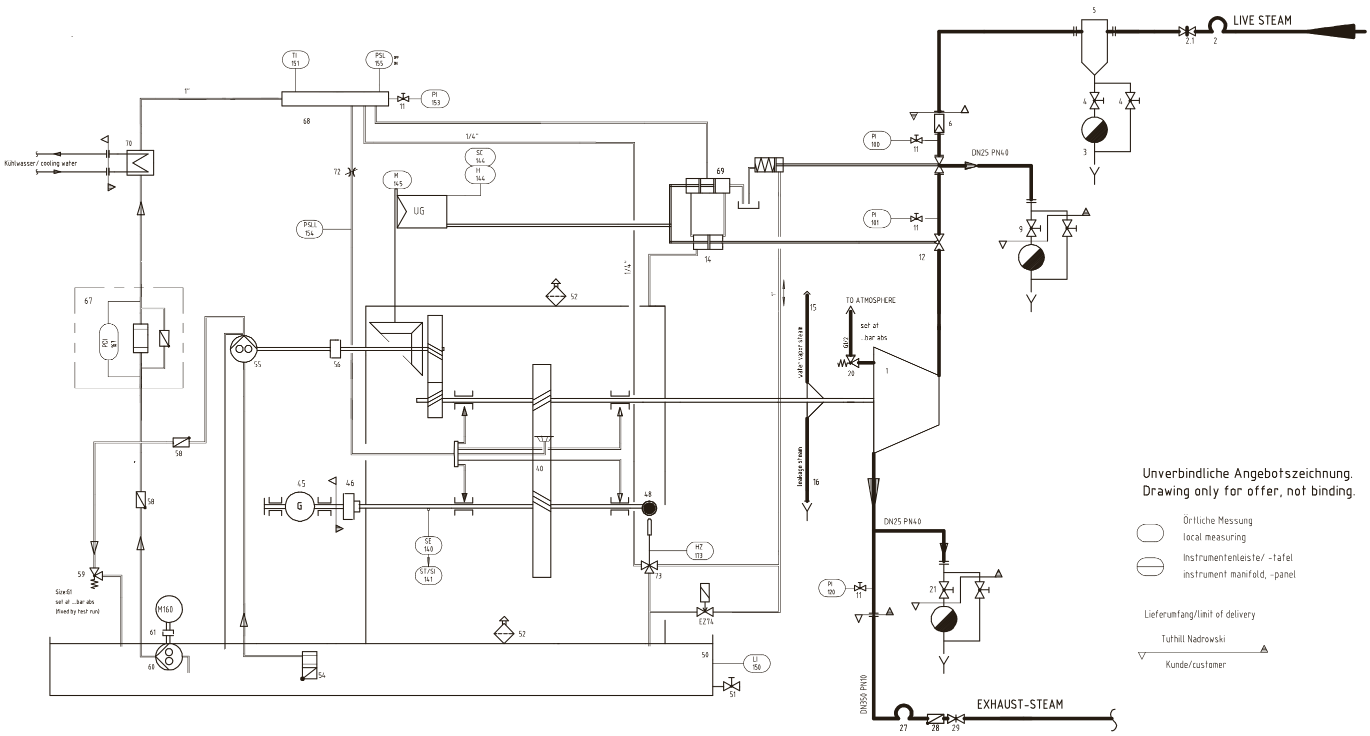
- Warning safety valve housing with thermal insulation
- Labyrinth shaft seal
- Hydraulic speed control
- Speed control electric
- Quick-closing valve with mechanical overspeed

3.2.3 Some CAD data of Curtis turbines





3.2.4 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

3.2.5 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)

3.3 المضخَّه (*The pump*)

This sort of pump (about 4 bar) can only be used for the condenser cooling cycle

3.4 المبرد (The condensor)

3.4.1 Introduction to condensor technology

From Strauss, "Kraftwerkstechnik"

Bei einem vorgegebenem Mengenstrom $\dot{m}_W$ des Kühlwassers und $\dot{m}_D$ des zu kondensierenden Dampfes ergibt sich die Bilanz

$$\dot{m}_W \, c_{p_W} \, (\vartheta_2 - \vartheta_1) = \dot{m}_D \, (h_D - h_K) \, . \qquad (9.1)$$

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 $\dot{m}_D$, h_D und ϑ_1 durch Randbedingungen vorgegeben. Im Grenzfall könnte das Kondensat entweder bis auf $\vartheta_K = \vartheta_1$ 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.

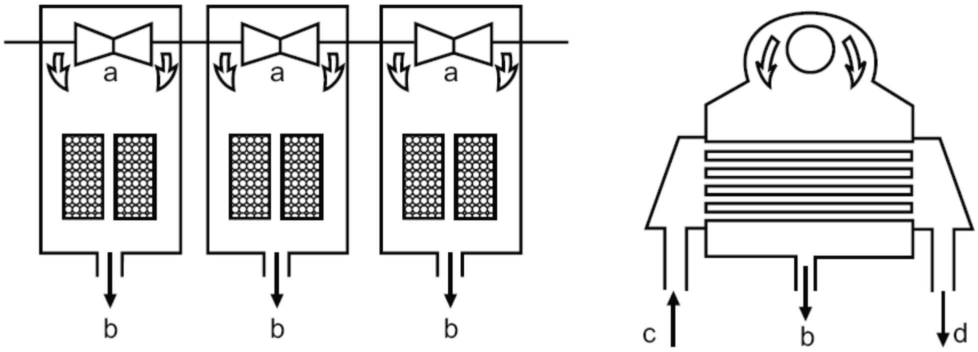
Due to unavoidable leaks in the water / steam cycle also failed condensables in the condenser, which must be continuously removed with special pumps.

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

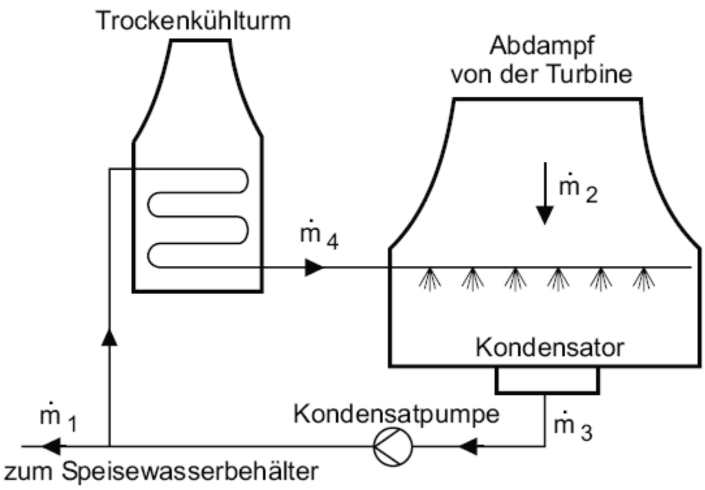


Abbildung 9.2. Schema eines Mischkondensators

$$\dot{m}_2 = \dot{m}_1 \tag{9.2}$$

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.

3.4.2 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.

3.4.3 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:

$$\dot{Q} = kA(T_{warm} - T_{kalt})$$

3-1

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:

$$k = \frac{1}{\sum_i \frac{1}{\alpha_i} + \sum_j \frac{s_j}{\lambda_j}}$$

3-2

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.

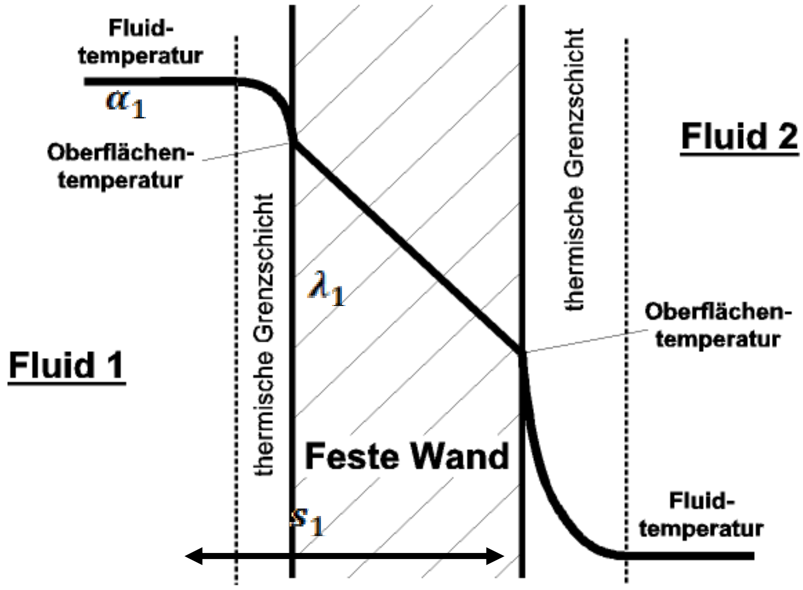


Figure 3 1: Temperature variation with heat transfer through a solid wall (Wikipedia)

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:

$$\Delta T_{log} = \frac{[(T]_{FE} - T_{LA}) - (T_{FA} - T_{LE})}{(\ln \frac{[(T]_{FE} - T_{LA})}{(T_{FA} - T_{LE})}}$$

3-3

The indices are back to the same terms as described in …. Of course, the interchangeability of the terms described above will remain even.

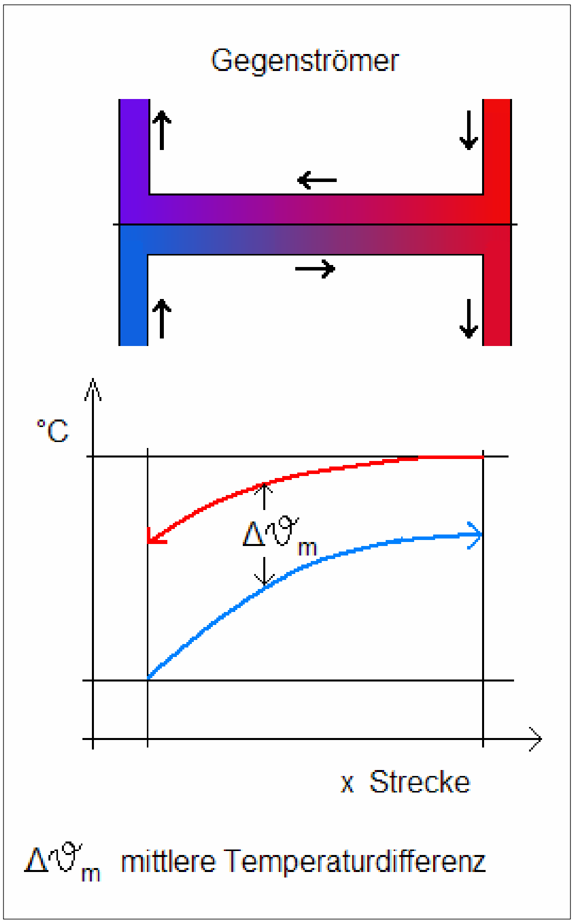


Figure 3 2: The counter-current process (Wikipedia)

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 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.

3.4.3.1 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.

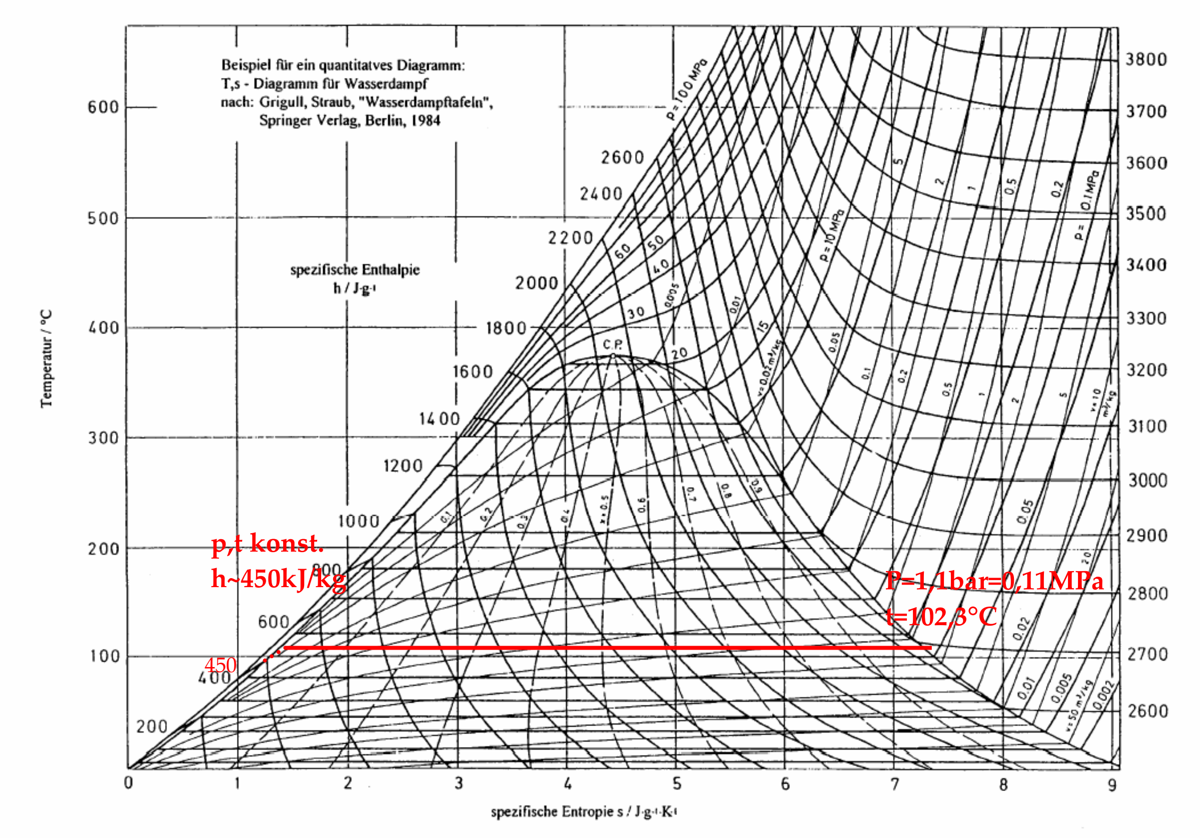


Figure 3 3: Ts diagram (Institute of Technical Thermodynamics, Karlsruhe University)

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

$$\dot{Q}_{kond} = 1{,}0028 \text{ MW}$$

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:

$$\dot{Q}_{kond} = \dot{m}_{KW}\, c_{p,w}\, (T_{aus} - T_{ein})$$

3-4

$$\dot{V}_{KW} = 0,\frac{00346m^3}{\square} \quad \dot{Q}_{kond} = \dot{m}_{KW}\, c_{p,w}\, (T_{aus} - T_{ein}) / \rho_{Wasser}$$

3-5

$$\dot{V}_{KW} = A v_{ström}$$

3-6

Using the information from the table are

$\dot{m}_{KW} = \frac{34,6kg}{\square}$ 15,916 kg/s Mass flow of the cooling water

$\dot{V}_{KW} = \frac{0,00346m^3}{\square}$ 15,916 kg/s / 1000kg/m^3 = 0.015916 $\dot{V}_{KW} = \frac{0,00346m^3}{\square}$ 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.

3.4.3.2 The principle of a condenser tube bundle

In principle, a condenser tube of the tube bundle itself and the housing is disposed about.

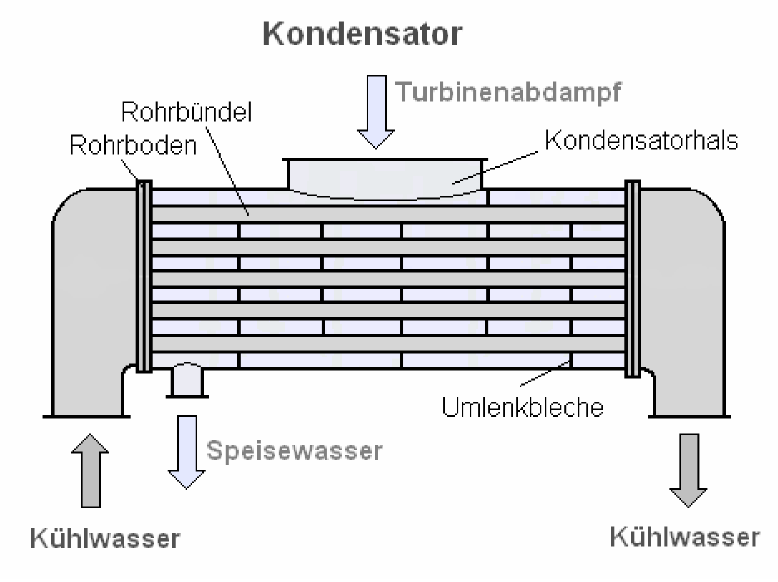
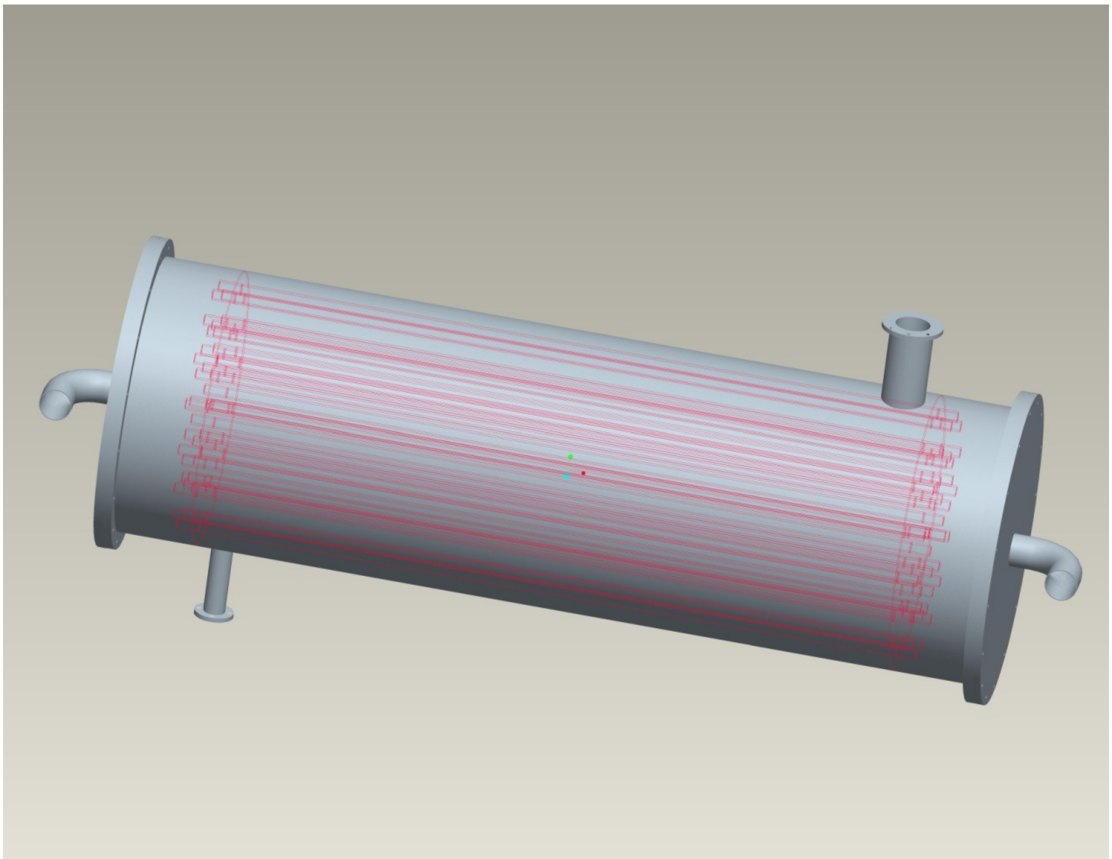


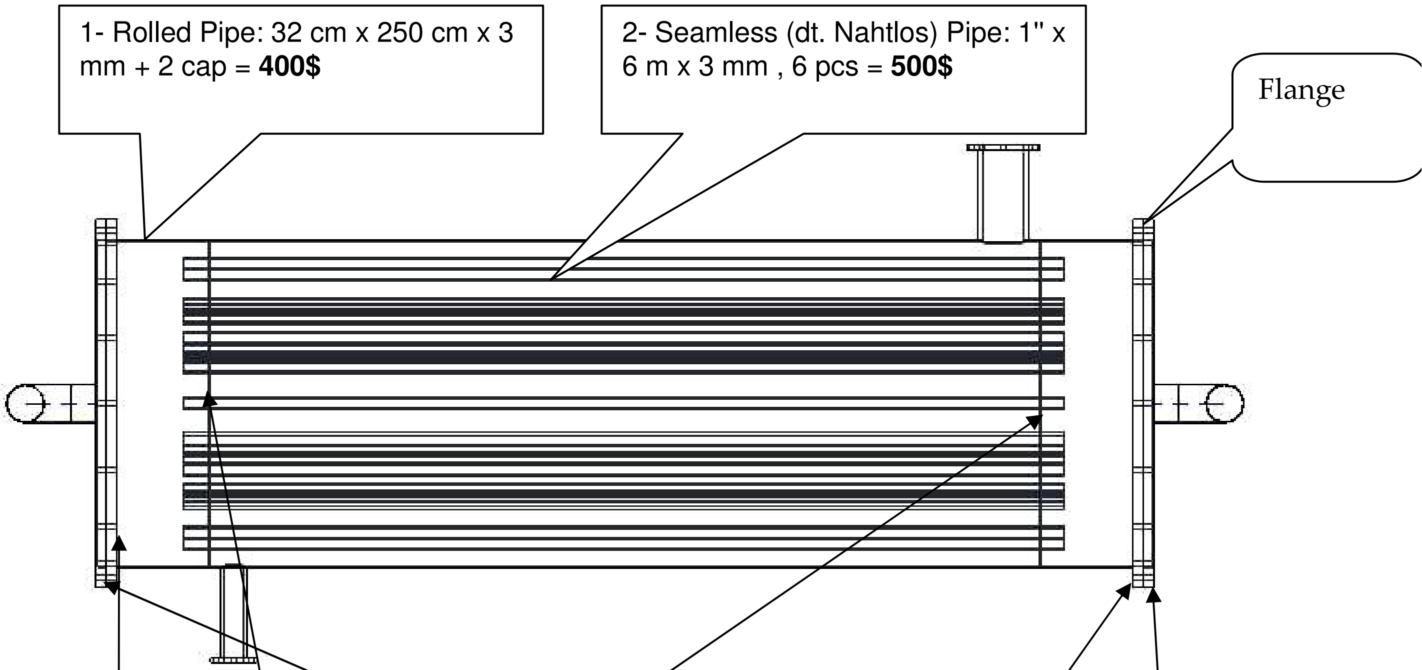
Figure 3 4: Principle structure of a shell and tube condenser (Wikipedia)

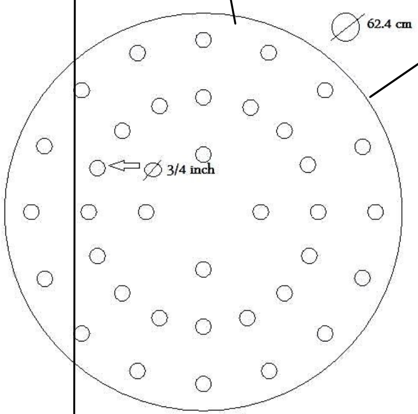
Flows through the housing of the turbine exhaust steam is condensed on the individual tubes of the tube bundle. The condensed water collects at the bottom of the housing and passes over the feedwater outlet from. The baffles ensure that the steam flows around each area of the tube bundle, and thus takes 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.

3.5 Condensor Design of Dec 2014

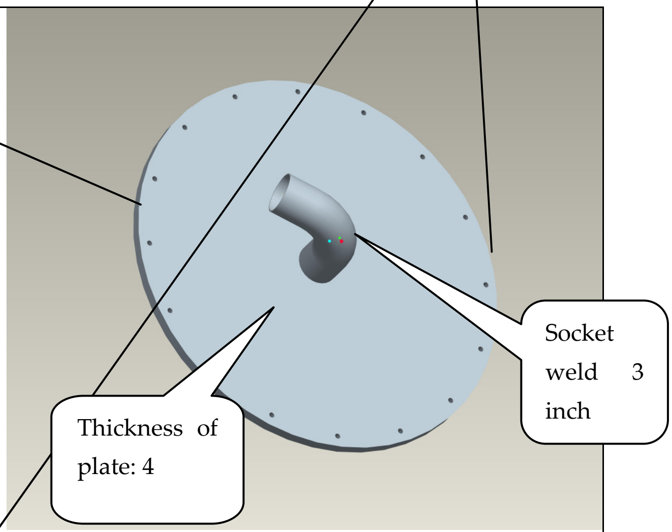




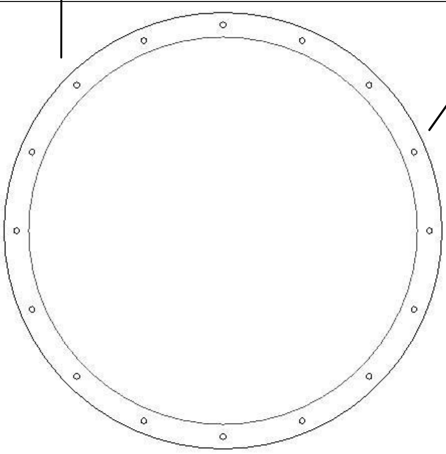


Thickness: 10 or 15 mm

15mm Thickness, 2 pcs = **450$**

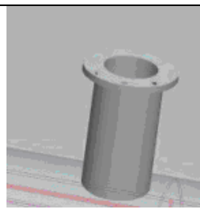


5- Socket weld Flange : 10 mm Thickness, 2 pcs = **450$,** 4- Seamless pipe: 3" x 1 m x 3mm = **48$**



Flange

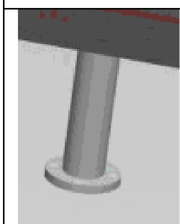
15mm Thickness, 2 pcs = **450$**



Seamless Pipe: 4" x 1 m x 3mm

Socket weld Flange : 4"

6- Socket weld Flange : 4" - 1 pc = **160$**



Socket Weld Flange : 3"

7- Socket Weld Flange : 3" - 1 pc = **140$**

8- Bolts/Nuts & Gaskets = **60$** 9- Argon Gas + welding rods = **200$**	3 day work: **400 USD** **Total: 3260 USD**

3.6 Boiler feed water

3.6.1 From TEMO-STPP 2nd project report (from Nagel, Fabian: Integration and animation of the test stand): Speisewasserkessel

3.6.1.1 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.

3.6.1.2 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.).

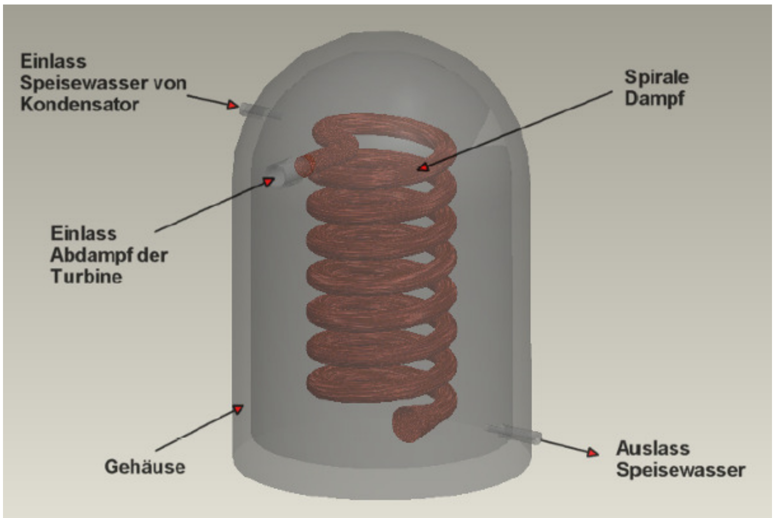


Figure 3 6: ProE model of boiler feed water

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.