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مركز الشرق الاوسط للطاقة البديلة
http://aecenar.com/institutes/meae

NLAP-WEDC Waste to Electricity Demonstration Cycle - Project Report 3 (2019)

Basics:

- Public Electricity supply over distance

Detailed Design & Construction for:

- Methan Liquification Unit
- Fuel burner
- Electrolysis
- Metals Recycling (8 species)
- Purification of Water and De-oxidation (Deaerator)
- Emission Measurement System (Norms)

Other issues:

- Operational Test for TEMO-IPP

Authors:

Siham Aisha, Samir Mourad (Editors)

With contributions of: Maysaa Kamareddine, Alaa Zakaria, Samer Youssef, MMJZ

Initial Document: Jan 2019

Last update: 13. Jan. 2020 / الإثنين، 18 جمادى الأولى، 1441

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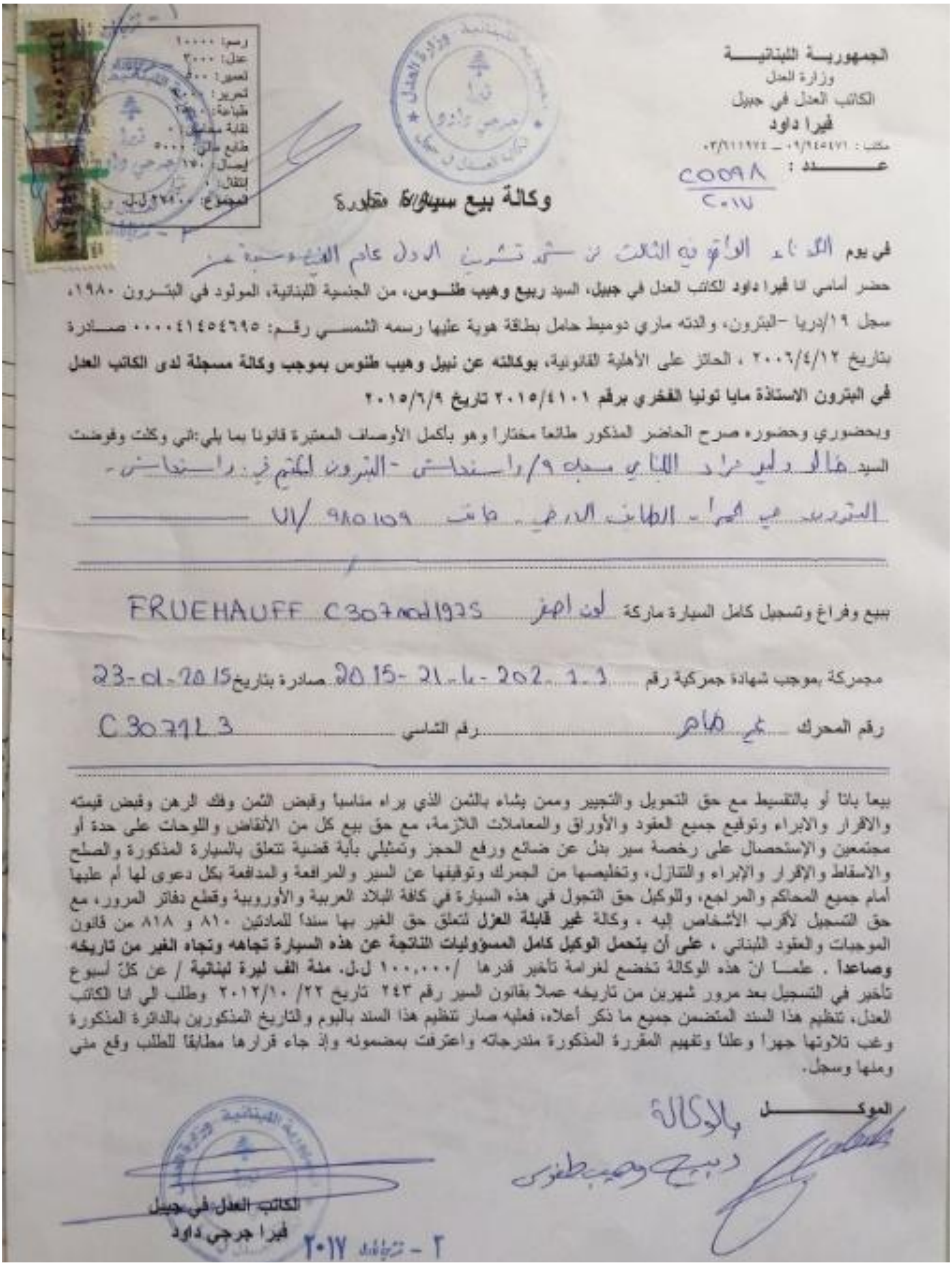
1 NLAP-WEDC Demonstration Cycle Facility

1.1 أوراق حمالة محطة حرق النفايات



الجمهورية اللبنانية
وزارة العدل
الكاتب العدل في جبيل
فيرا داود
مكتب: ٠٩/٩٤٥٤٧١ - ٠٣/٦١١٩٧٤
عدد: ٥٠٠٩٨ / ٢٠١٧

رسم: ١٠٠٠٠
عدل: ٣٠٠٠
تصوير: ٥٠٠
تحرير: ٠
طباعة: ٠
نقابة محامين: ٠
طابع مالي: ٥٠٠٠
إيصال: ١٧٥٠
إنتقال: ٠
المجموع: ٢٧٧٥٠ ل.ل.

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 طنوس**، من الجنسية اللبنانية، المولود في البترون ١٩٨٠، سجل ١٩/دريا -البترون، والدته ماري دوميط حامل بطاقة هوية عليها رسمه الشمسي رقم: ٠٠٠٠٤١٤٥٤٦٩٥ صادرة 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 مبنى الحمرا - الطابق الارضي . هاتف ٩٨٥١٠٩ /٧١

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

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

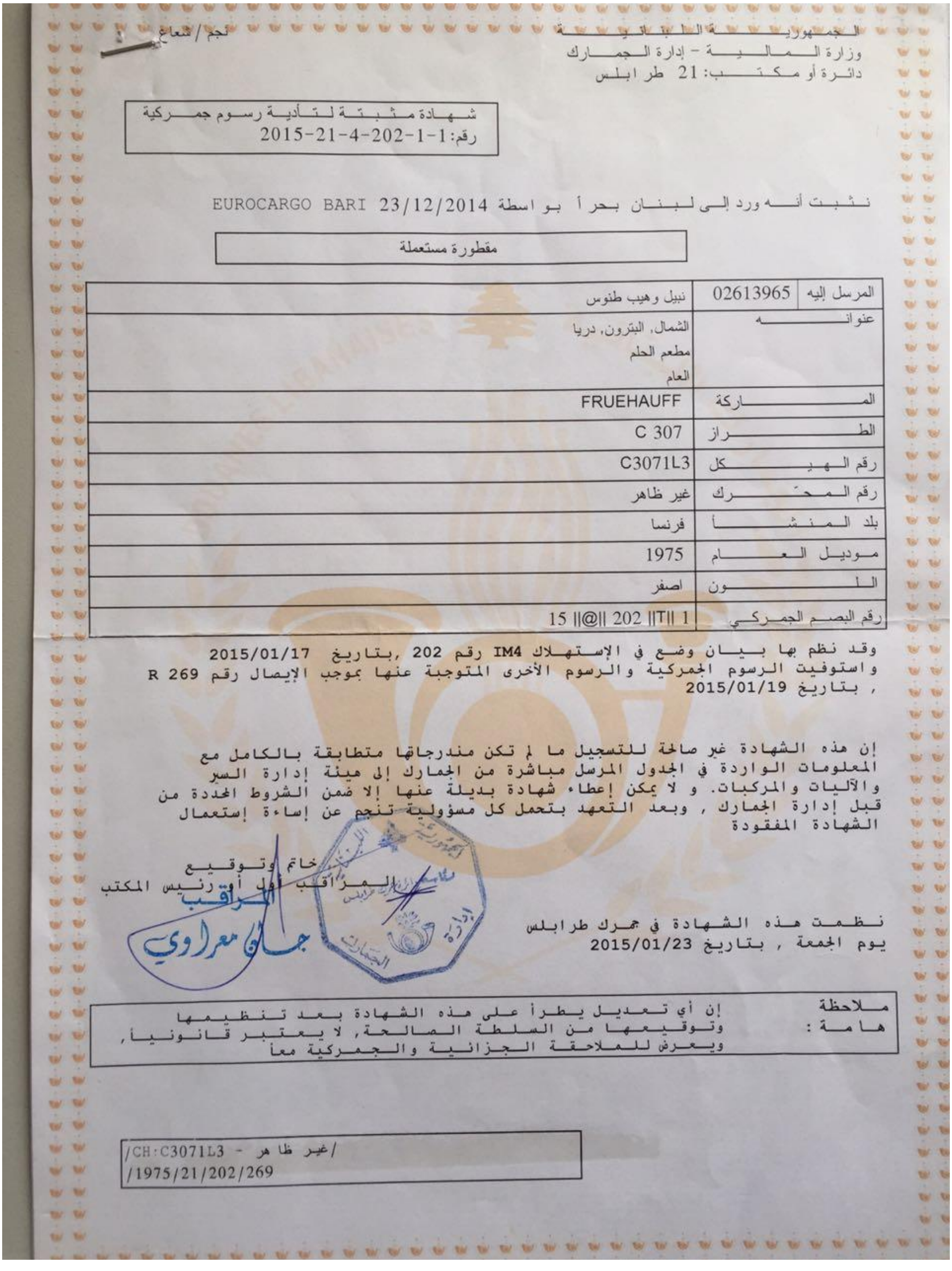
رقم المحرك غير ظاهر رقم الشاسي C30771L3

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 وصاعداً** . علما 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 وعُب تلاوتها جهرا وعلنا وتفهيم المقررة المذكورة مندرجاته واعترفت بمضمونه وإذ جاء قرارها مطابقا للطلب وقع مني ومنها وسجل.

الموكل
بالوكالة
ربيع وهيب طنوس

الكاتب العدل في جبيل
فيرا جرجي داود

٢ - تشرين 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 EUROCARGO BARI 23/12/2014

مقطورة مستعملة

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

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

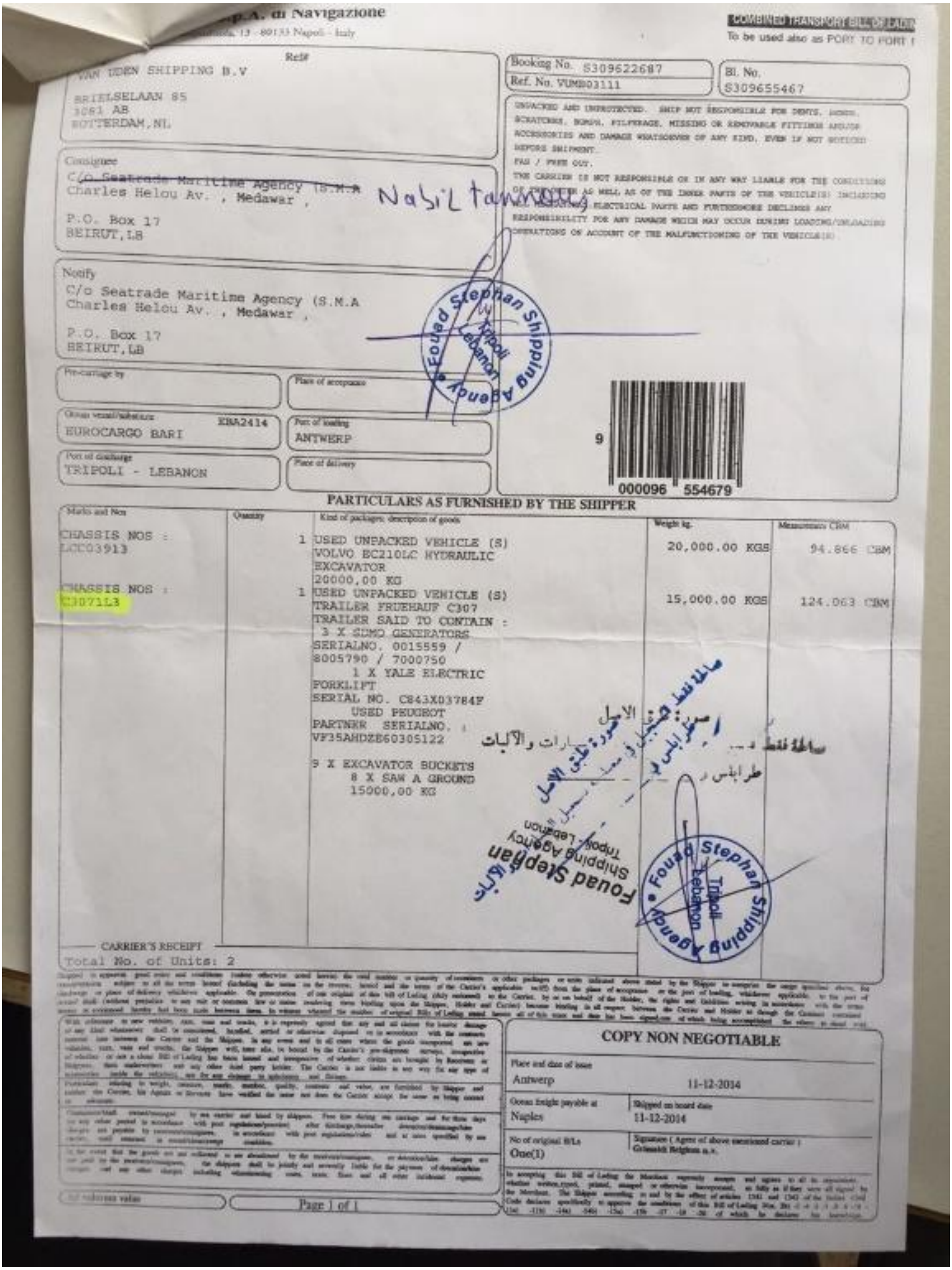
خاتم وتوقيع
المراقب أول أو رئيس المكتب

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 LADING

To be used also as PORT TO PORT B

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, [illegible] SCRATCHES, [illegible] 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 [illegible] AS WELL AS OF THE INNER PARTS OF THE VEHICLE(S) INCLUDING [illegible] 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 tammous
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: EUROCARGO BARI — EBA2414

Port of loading: ANTWERP

Port of discharge: TRIPOLI - LEBANON

Place of delivery

9 000096 554679

PARTICULARS AS FURNISHED BY THE SHIPPER

Marks and Nos	Quantity	Kind of packages; description of goods	Weight kg.	Measurement 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 : C3071L3	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. VF35AHDZB60305122 9 X EXCAVATOR BUCKETS 8 X SAW A GROUND 15000,00 KG	15,000.00 KGS	124.063 CBM

صورة طبق الأصل

طرابلس

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

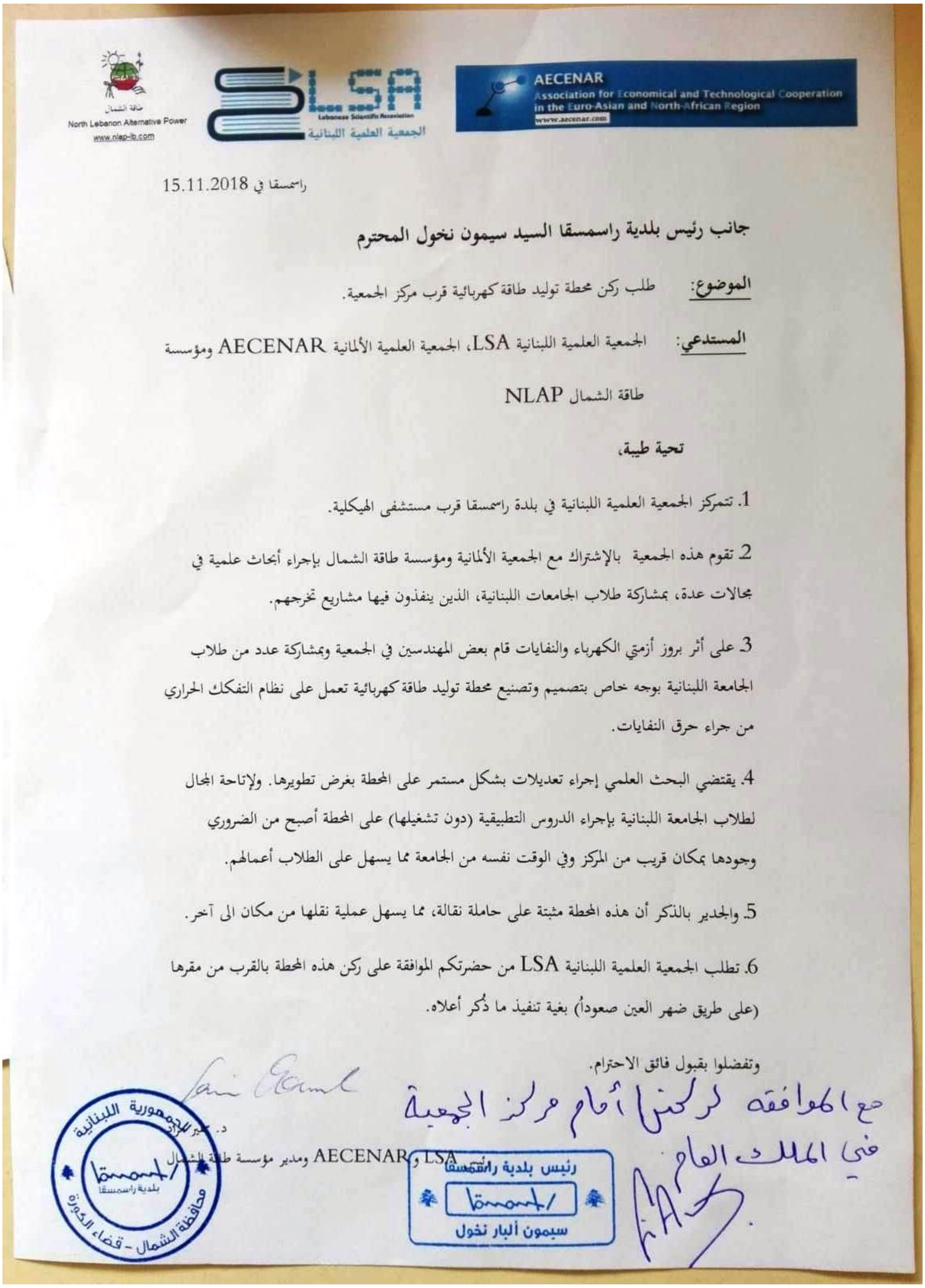
Shipped on board date: 11-12-2014

No of original B/Ls: One(1)

Signature (Agent of above mentioned carrier): Grimaldi Belgium n.v.

Page 1 of 1

1.2 أوراق ادارية بخصوص الموقع في راسمقا



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LSA
Lebanese Scientific Association
الجمعية العلمية اللبنانية

طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.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 صعوداُ) بغية تنفيذ ما ذُكر أعلاه.

وتفضلوا بقبول فائق الاحترام.

Sami Kamal

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
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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.

بلـدية راسمسقا
تاريخ الورود ١٩/٨/٢٧
رقم ٦٩٤

وتفضلوا بقبول فائق الاحترام.

د. سمير مراد
LSA, AECENAR ومدير مؤسسة طاقة الشمال

مع الموافقة دون أي مسؤولية مترتبة على البلدية

رئيس بلدية راسمسقا
سيمون نخول

2 Basics (أساسيات)

2.1 محطات التحويل (التوزيع) الكهربائية

2.1.1 ما 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)

2.1.2 ما 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

2.1.3 تتألف محطات التوزيع؟

- معدات للتبديل (Switching equipment)
- معدات للحماية (protection equipment)
- محولات (transformers)
- أنظمة تحكم (control systems)
- كابلات التوتر العالي

2.1.4 لماذا 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.

2.1.5 المصدر

https://en.wikipedia.org/wiki/Electrical_substation#Elements_of_a_substation

2.2 FACTS (Flexible AC Transmission System)

2.2.1 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.

2.2.2 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

2.2.3 Types of Facts Controllers

FACTS controllers are classified as

- Series connected controllers
- Shunt connected controllers
- Combined series-series controllers
- Combined shunt-series controllers

2.2.4 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.

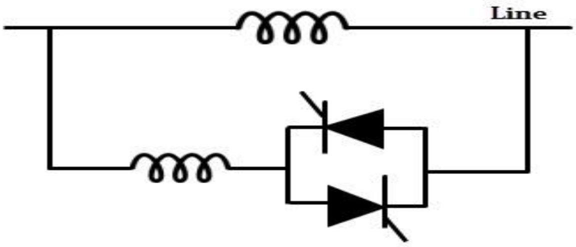


Figure 1: Simple model of TCSR and TSSR

2.2.5 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.

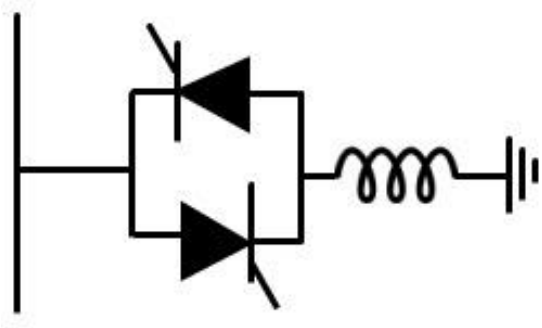


Figure 2: TCR

2.2.6 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.

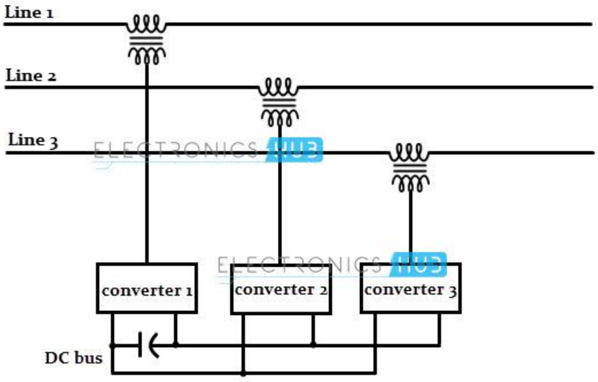


Figure 3: Combined series of IPFC

2.2.7 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.

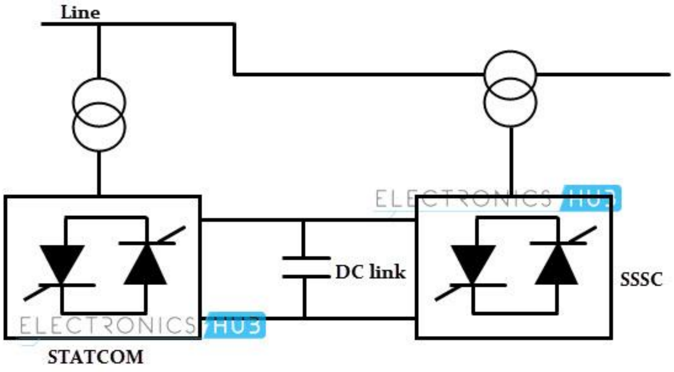


Figure 4: Combined shunt series of UPFC

2.2.8 International suppliers

SIEMENS

2.2.8.1 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).

2.2.8.2 Static Var Compensator (SVC)

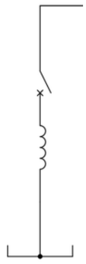
Description:

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:

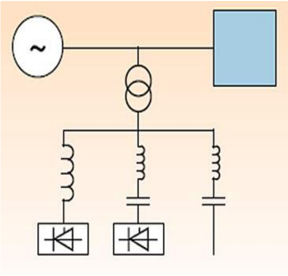
- voltage control
- reactive power control
- damping of power oscillations
- unbalance control

The design and layout of a SVC system is always tailored to the specific project requirements.



Mechanically Switched Reactor

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

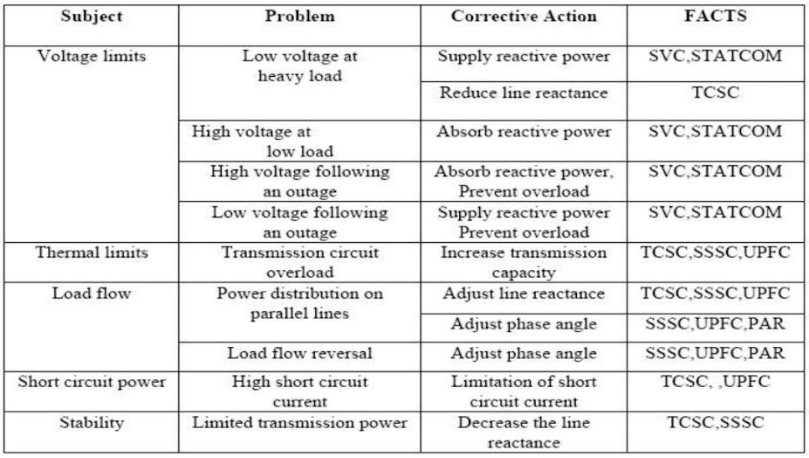
MITSUBISHI Electric

Static Var Compensators
SVC System Engineering
Flexible Digital Control Systems

2.2.9 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

2.2.10 IEC STANDARD

- IEC 61850-90-14
- IEC 61970 EMC
- IEC 61400-25

2.2.11 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

2.3 High voltage

2.3.1 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

2.3.2 Location of high voltage insulator and types

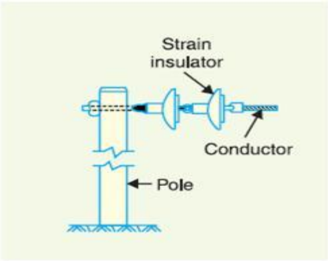
2.3.2.1 Pin insulator

- 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

2.3.2.2 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

2.3.2.3 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

2.3.3 Five International Suppliers

2.3.3.1 ABB

- Hollow composite insulators (72 - 1,200 kV)
- ABB manufactures composite insulators made of fiber composite materials (it can replace porcelain)

2.3.3.2 Siemens

- 3FL long rod insulators are especially suited for overhead compact-line applications where low tower design and short line spans are required

- **Specified mechanical load**:

3FL2→70KN
3FL3→100KN
3FL4→120KN
3FL5→160KN
3FL6→210K

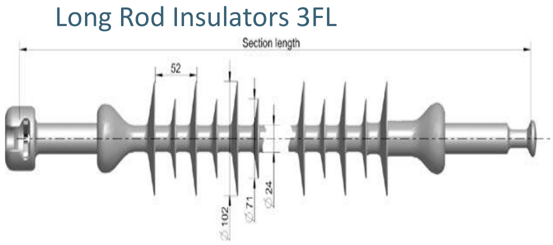
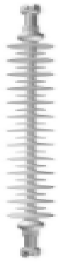


Figure 5: Long Rod insulators 3FL

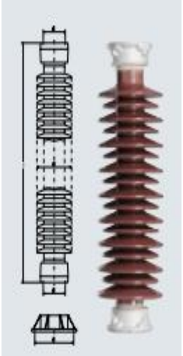
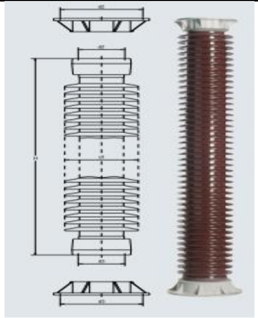
2.3.3.3 Zapel

ZAPEL

	
Line ceramic insulators (nominal 1KV)	Line composite insulators (nominal up to 220KV)

2.3.3.4 PPC insulators

PPC INSULATORS

	
Type BIL 200-325 kV	Type BIL 750-950 kV

2.3.3.5 General Electric

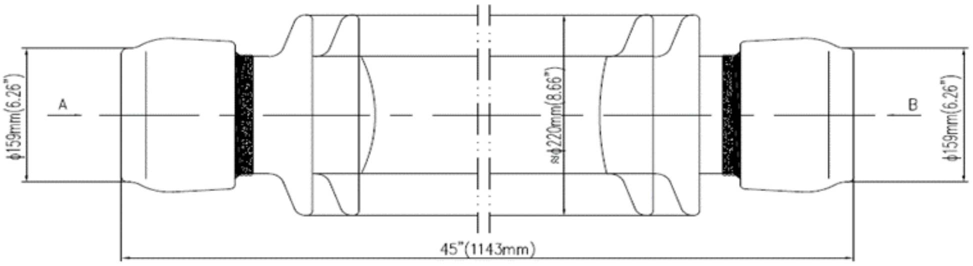
- GE provides a full range of porcelain and polymer housed IEC rated insulators for AC and DC transmission, substation, and distribution applications.

2.3.4 Characteristics

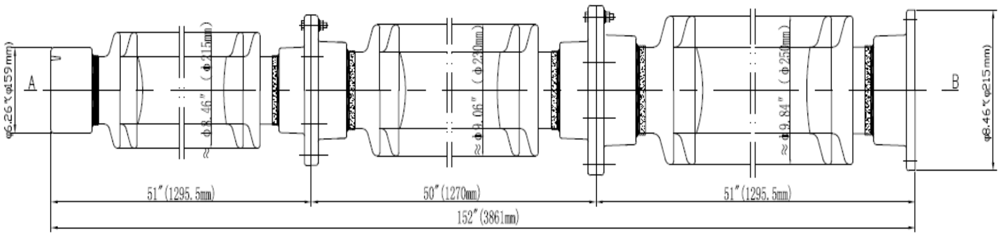
2.3.4.1 Characteristics of TR286

Table 1: Characteristics of TR286

standard	ANSI C29.9
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



2.3.4.2 Characteristics of TR391



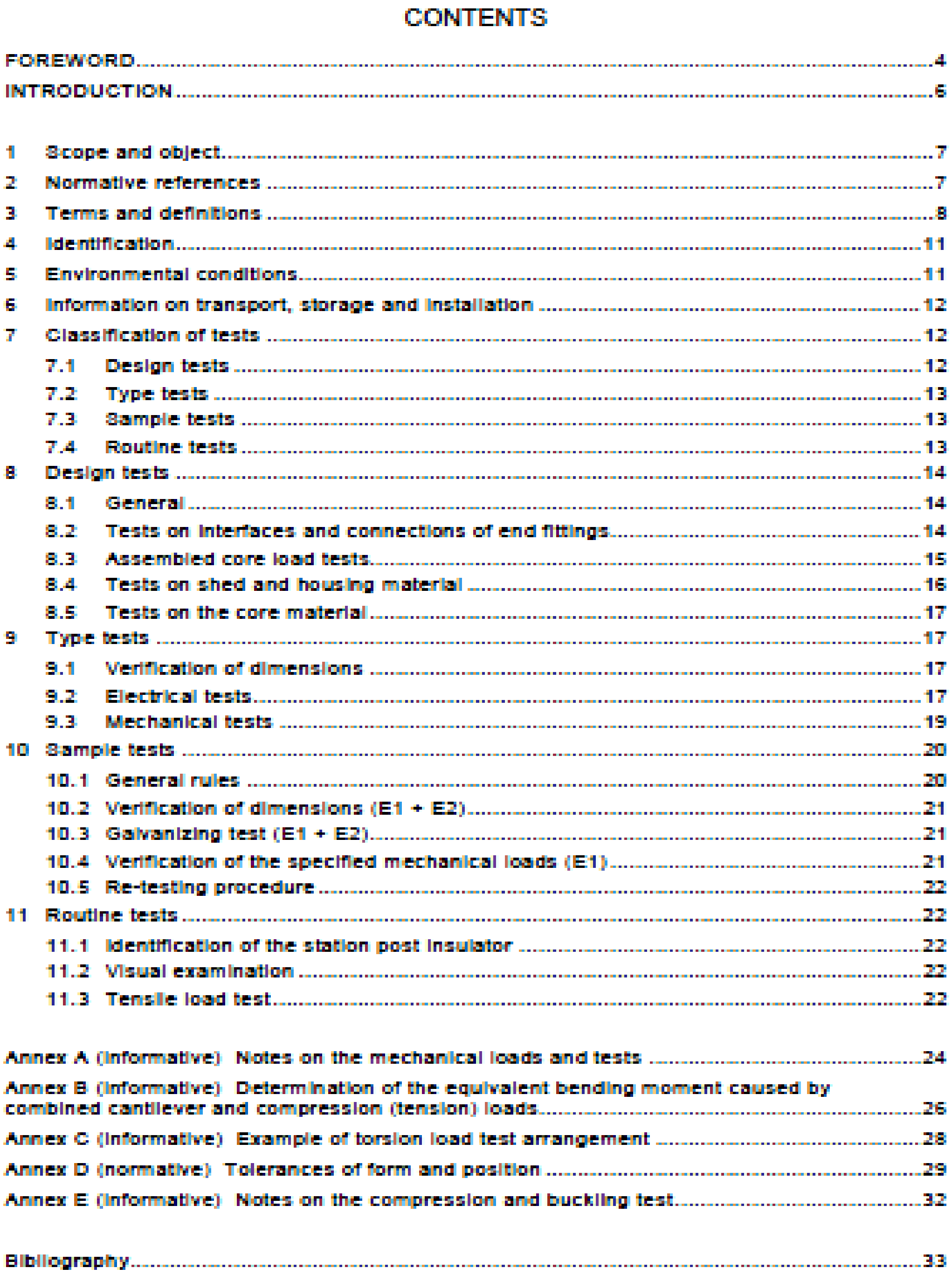
standard	ANSI C29.9
Length	3861mm
Tensile strength	89kN
Cantilever strength	6.26kN
System voltage	500kV
Lighting impulse withstand voltage	1800kV

Net weight	287kg
Material	Porcelain
color	ANSI 70 Grey

Table 2: Characteristics of TR391

IEC 62231:2006

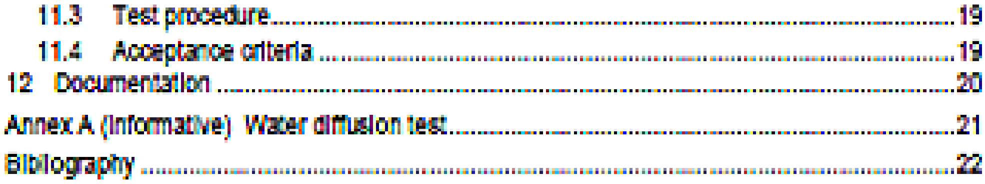
Composite station post insulators for substations with a.c. voltages greater than 1000V up to 245 kV



CONTENTS

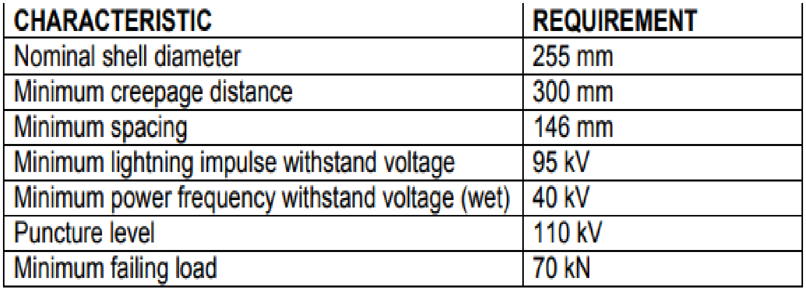
IEC 62772:2016

Composite hollow core station post insulators for substations with a.c. voltage greater than 1000 V and DC. voltage greater than 1500 V



2.3.5 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

2.3.6 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

2.4 Overhead Power Lines

2.4.1 Definition, Symbols, and Functions

- **Definition:** an electric line whose conductors are supported above ground, generally by means of insulators and appropriate support.
- **Symbol:**

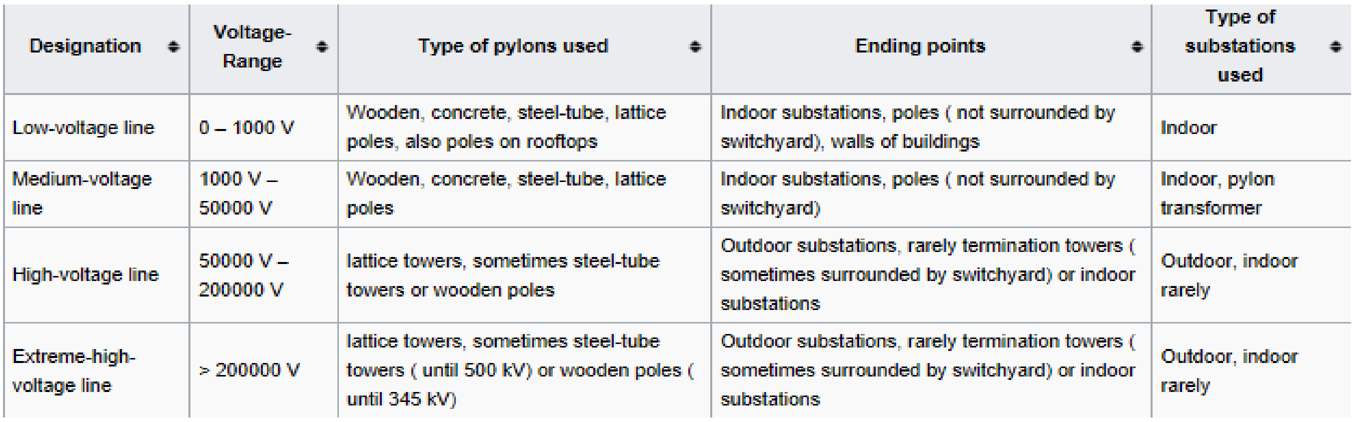
3.2.4 Overhead line

- **Function:** used in electric power transmission and distribution to transmit electrical energy over long distances.

2.4.2 Specifications for Suppliers

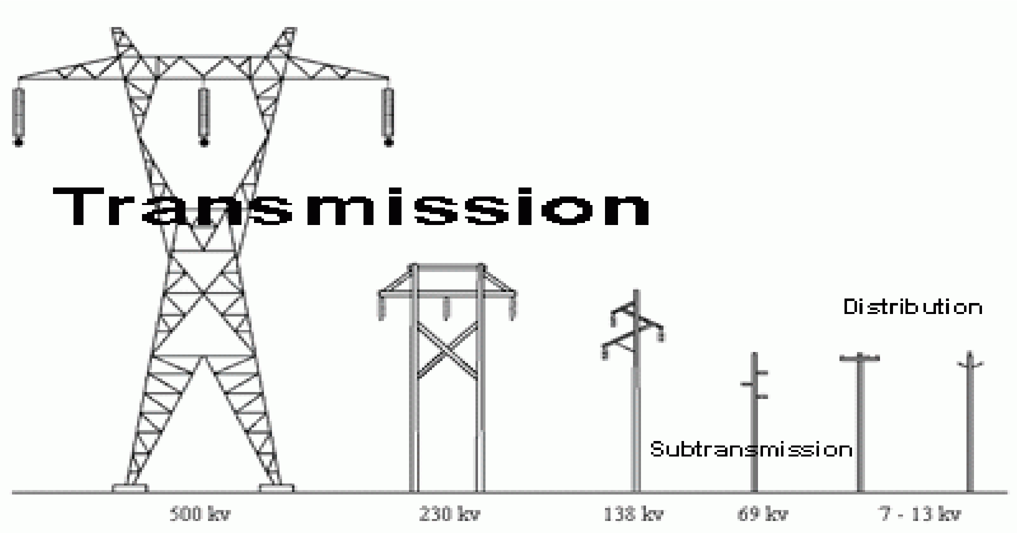
- **IEC 60502:** Power cables with extruded insulation and their accessories for rated voltages from 1 kV (U_m = 1,2 kV) up to 30 kV (U_m = 36 kV) - Part 2: Cables for rated voltages from 6 kV (U_m = 7,2 kV) up to 30 kV (U_m = 36 kV)
- **IEC 61089:** Specifies the electrical and mechanical characteristics 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

2.4.3 Overhead power transmission lines are classified by range of voltages

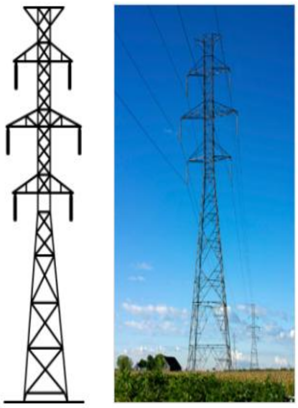


Designation	Voltage-Range	Type of pylons used	Ending points	Type of substations used
Low-voltage line	0 – 1000 V	Wooden, concrete, steel-tube, lattice poles, also poles on rooftops	Indoor substations, poles (not surrounded by switchyard), walls of buildings	Indoor
Medium-voltage line	1000 V – 50000 V	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

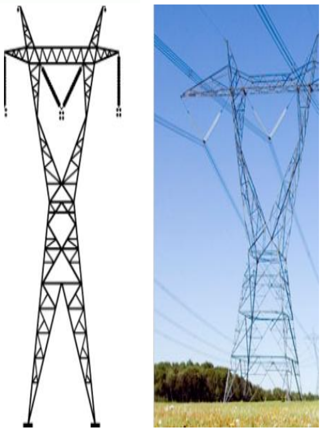
2.4.4 Transmission tower



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

2.4.5 International Supplier

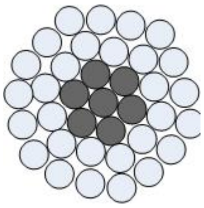
- **Products:**

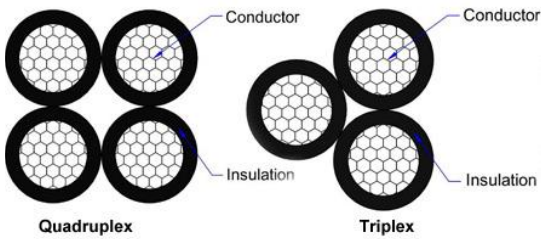
1. **AAC--**All Aluminum Conductor
2. **ACS--**Aluminum Clad Steel Wire
3. **GSW--**Galvanized Steel Wire /Strand
4. **ACSR--**Aluminum Conductor Steel Reinforced
5. **AACSR--**Aluminum Alloy Conductor Steel Reinforced
6. **ACAR--**Aluminum Conductor Aluminum Alloy Reinforced
7. **ACSR/AW--**Aluminum 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





2.4.6 Allied wire and cable

Allied Wire & Cable carries an extensive inventory of coaxial cable, lead wire, MIL-Spec wire, and electrical cable

2.4.7 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**

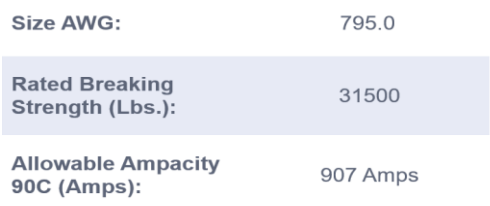
Stands for: Aluminum Conductor Steel Reinforced

➢ **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

2.4.8 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 3: IEEE standards

2.4.9 References

electropedia
Power System Analysis –Hadi Saadat
Standards.ieee.org
Webstore.iec.ch

Libancables.com.lb
Wikipedia.org
Wiki.openstreetmap.org/wiki/Classification_of_Powerlines

- www.hydroquebec.com/learning/transport/types-pylones.html
- http://www.tddlcable.com/
- https://www.lahmeyer.de/en/home.html
- http://www.awcwire.com/
- https://www.ieee-pes.org/

2.5 IEEE Power Substations Standards Collection: VuSpec™

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.

Table of Contents

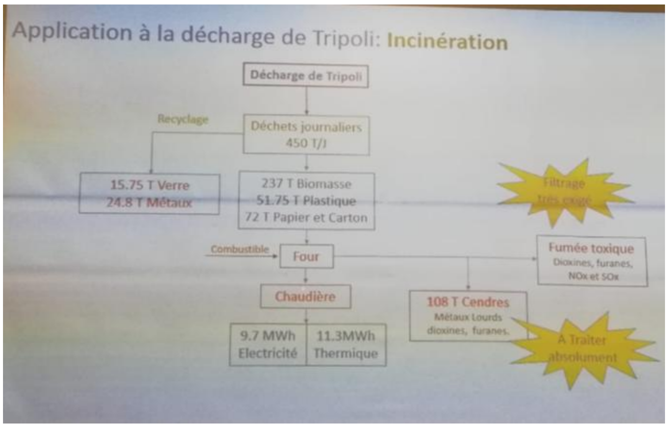
Includes 50 active IEEE Standards, Guides, and Recommended Practices, Errata & Interpretations in the power substation family:

- 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

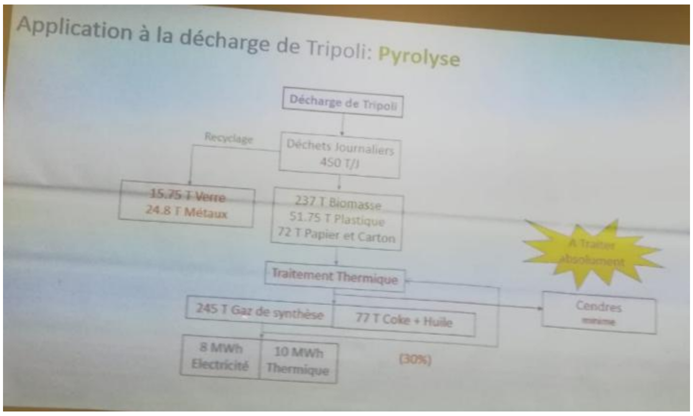
- Errata to IEEE Std 1031™-2011, IEEE Guide for the Functional Specification of Transmission Static Var Compensators
- IEEE Std 1125™-1993 (R2005), IEEE Guide for Moisture Measurement and Control in SF6 Gas-Insulated Equipment
- IEEE Std 1127™-1998 (R2004), IEEE Guide for the Design, Construction, and 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
- IEEE Std 1268™-2005, IEEE Guide for Safety in the Installation of Mobile Substation Equipment
- IEEE Std 1303™-2011, IEEE Guide for Static var Compensator Field Tests
- IEEE Std 1378™-1997 (R2002), IEEE Guide for Commissioning High- Voltage Direct-Current (HVDC) Converter Stations and Associated Transmission Systems
- IEEE Std 1379™-2000 (R2006), IEEE Recommended Practice for Data Communications Between Remote Terminal Units and Intelligent Electronic Devices in a Substation
- 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

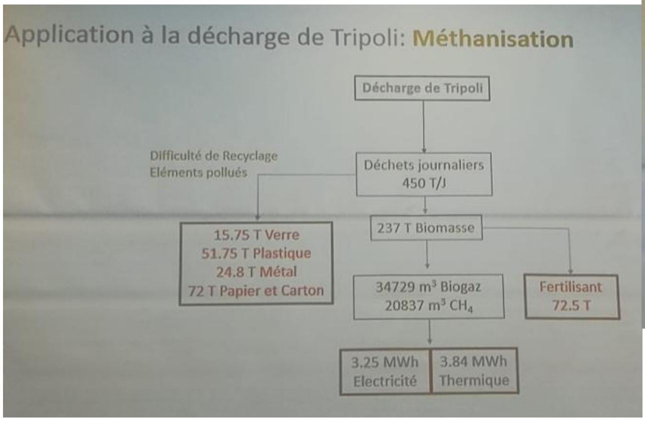
2.6 Westinghouse plasma & Co Lebanon plasma gasification


Application à la décharge de Tripoli: **Incinération**

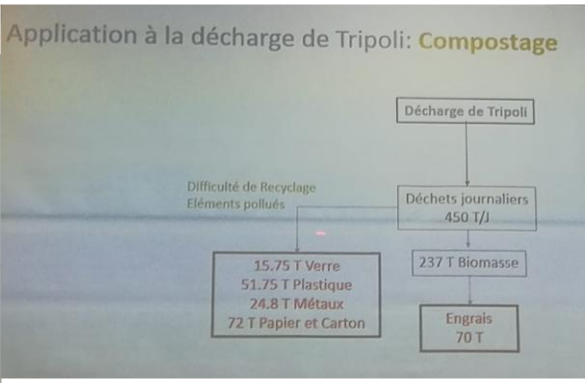
Décharge de Tripoli
Recyclage
Déchets journaliers 450 T/J
15.75 T Verre
24.8 T Métaux
237 T Biomasse
51.75 T Plastique
72 T Papier et Carton
Filtrage très exigé
Combustible
Four
Fumée toxique
Dioxines, furanes, NOx et SOx
Chaudière
108 T Cendres
Métaux Lourds dioxines, furanes.
9.7 MWh Electricité
11.3MWh Thermique
A Traiter absolument


Application à la décharge de Tripoli: **Pyrolyse**

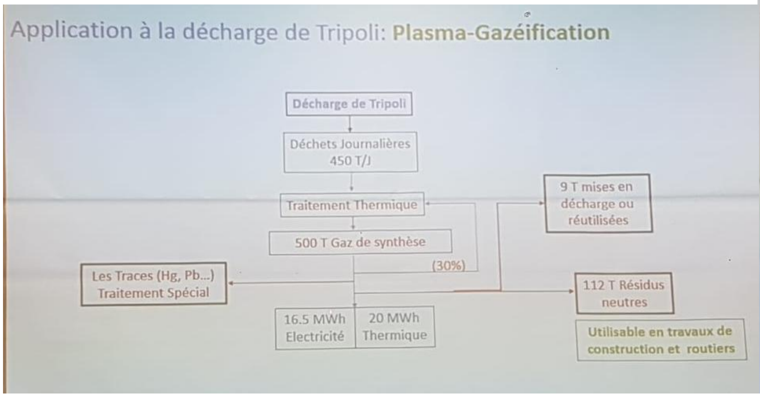
Décharge de Tripoli
Recyclage
Déchets Journaliers 450 T/J
15.75 T Verre
24.8 T Métaux
237 T Biomasse
51.75 T Plastique
72 T Papier et Carton
A Traiter absolument
Traitement Thermique
245 T Gaz de synthèse
77 T Coke + Huile
Cendres minime
8 MWh Electricité
10 MWh Thermique
(30%)


Application à la décharge de Tripoli: **Méthanisation**

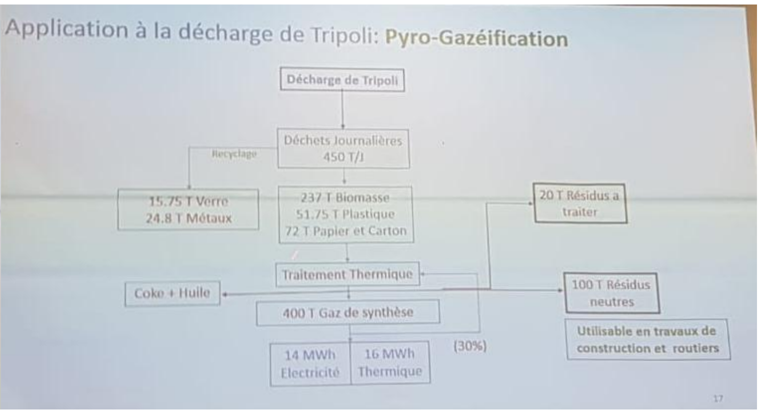
Décharge de Tripoli
Difficulté de Recyclage
Eléments pollués
Déchets journaliers 450 T/J
15.75 T Verre
51.75 T Plastique
24.8 T Métal
72 T Papier et Carton
237 T Biomasse
34729 m³ Biogaz
20837 m³ CH_4
Fertilisant 72.5 T
3.25 MWh Electricité
3.84 MWh Thermique


Application à la décharge de Tripoli: **Compostage**

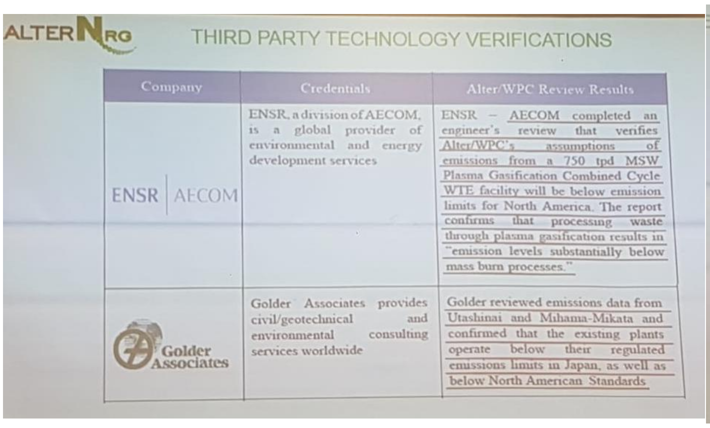
Décharge de Tripoli
Difficulté de Recyclage
Eléments pollués
Déchets journaliers 450 T/J
15.75 T Verre
51.75 T Plastique
24.8 T Métaux
72 T Papier et Carton
237 T Biomasse
Engrais 70 T


Application à la décharge de Tripoli: **Plasma-Gazéification**

Décharge de Tripoli
Déchets Journalières 450 T/J
Traitement Thermique
9 T mises en décharge ou réutilisées
500 T Gaz de synthèse
(30%)
Les Traces (Hg, Pb…) Traitement Spécial
112 T Résidus neutres
16.5 MWh Electricité
20 MWh Thermique
Utilisable en travaux de construction et routiers


Application à la décharge de Tripoli: **Pyro-Gazéification**

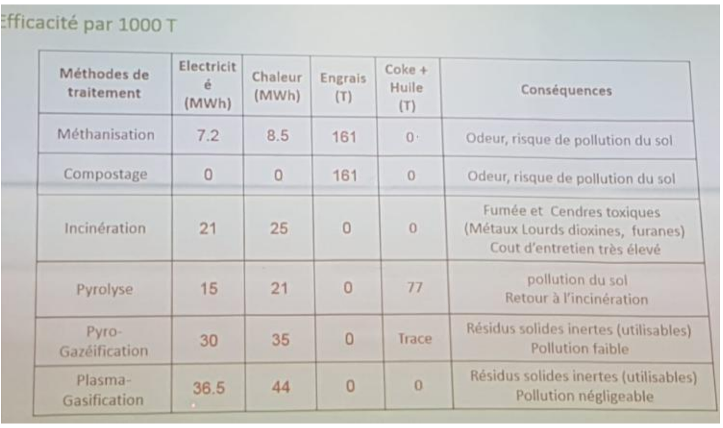
Décharge de Tripoli
Déchets Journalières 450 T/J
Recyclage
15.75 T Verre
24.8 T Métaux
237 T Biomasse
51.75 T Plastique
72 T Papier et Carton
20 T Résidus a traiter
Traitement Thermique
Coke + Huile
100 T Résidus neutres
400 T Gaz de synthèse
Utilisable en travaux de construction et routiers
14 MWh Electricité
16 MWh Thermique
(30%)
17



ALTERNRG

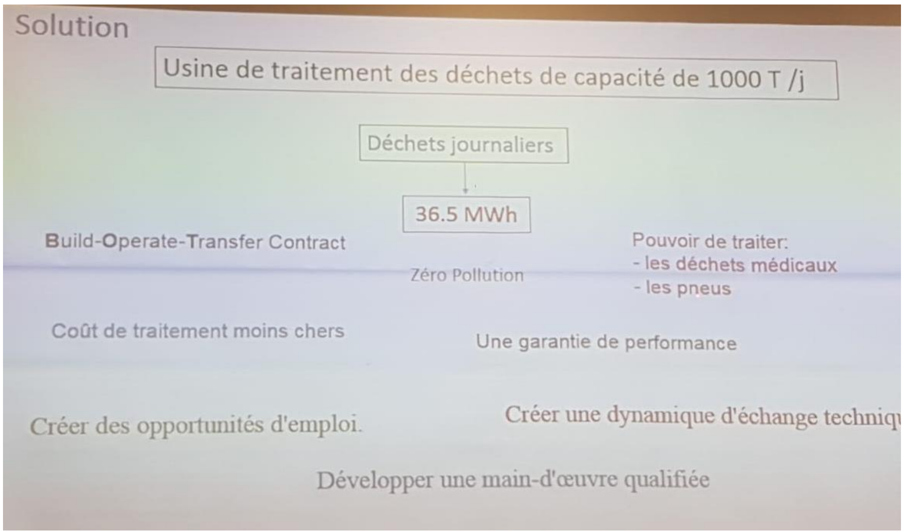
THIRD PARTY TECHNOLOGY VERIFICATIONS

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



Solution

Usine de traitement des déchets de capacité de 1000 T /j

Déchets journaliers

36.5 MWh

Build-Operate-Transfer Contract

Zéro Pollution

Pouvoir de traiter:
- les déchets médicaux
- les pneus

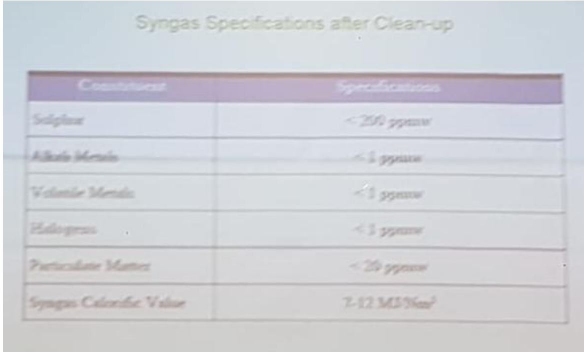
Coût de traitement moins chers

Une garantie de performance

Créer des opportunités d'emploi.

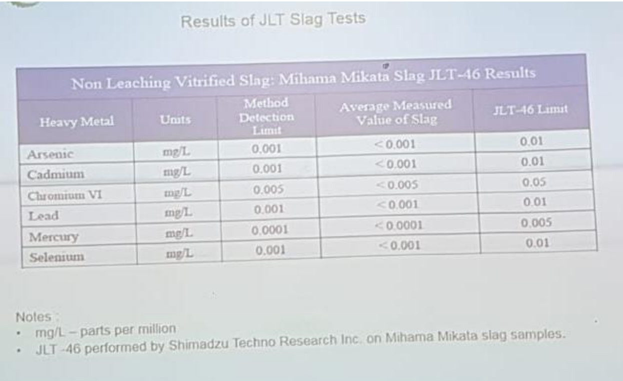
Créer une dynamique d'échange techniq

Développer une main-d'œuvre qualifiée



Syngas Specifications after Clean-up

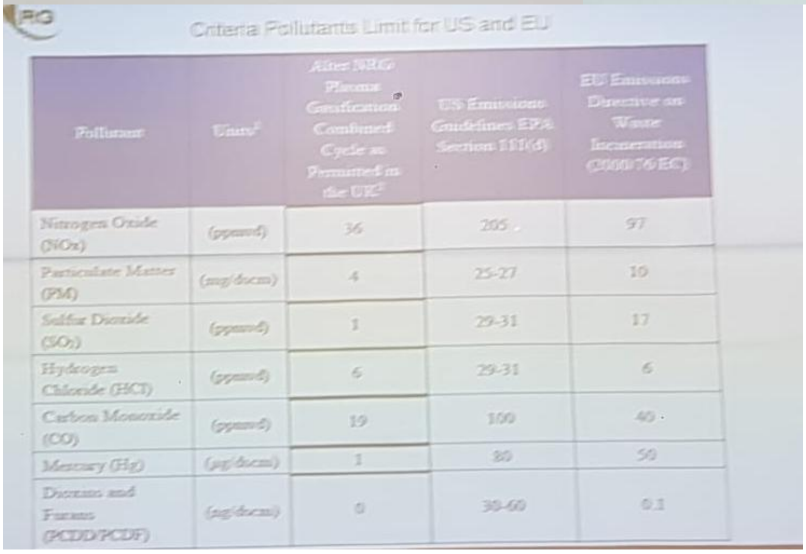
Constituent	Specifications
Sulphur	< 200 ppmw
Alkali Metals	< 1 ppmw
Volatile Metals	<1 ppmw
Halogens	< 1 ppmw
Particulate Matter	< 20 ppmw
Syngas Calorific Value	7-12 MJ/Nm³



Results of JLT Slag Tests

Non Leaching Vitrified Slag: Mihama Mikata Slag JLT-46 Results				
Heavy Metal	Units	Method Detection Limit	Average Measured Value of Slag	JLT-46 Limit
Arsenic	mg/L	0.001	< 0.001	0.01
Cadmium	mg/L	0.001	< 0.001	0.01
Chromium VI	mg/L	0.005	< 0.005	0.05
Lead	mg/L	0.001	< 0.001	0.01
Mercury	mg/L	0.0001	< 0.0001	0.005
Selenium	mg/L	0.001	< 0.001	0.01

Notes :
- mg/L – parts per million
- JLT -46 performed by Shimadzu Techno Research Inc. on Mihama Mikata slag samples.



NRG

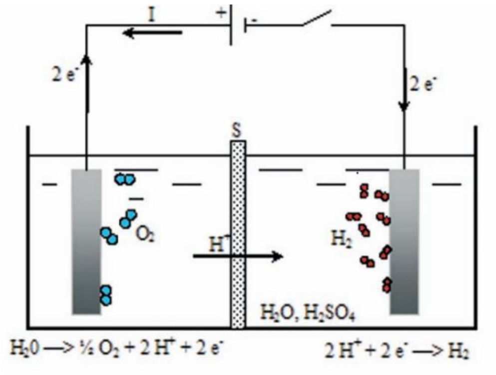
Criteria Pollutants Limit for US and EU

Pollutant	Units¹	Alter NRG Plasma Gasification Combined Cycle as Permitted in the UK²	US Emissions Guidelines EPA Section 111(d)	EU Emissions Directive on Waste Incineration (2000/76/EC)
Nitrogen Oxide (NOx)	(ppmvd)	36	205	97
Particulate Matter (PM)	(mg/dscm)	4	25-27	10
Sulfur Dioxide (SO₂)	(ppmvd)	1	29-31	17
Hydrogen Chloride (HCl)	(ppmvd)	6	29-31	6
Carbon Monoxide (CO)	(ppmvd)	19	100	40
Mercury (Hg)	(µg/dscm)	1	80	50
Dioxins and Furans (PCDD/PCDF)	(ng/dscm)	0	30-60	0.1

2.7 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).

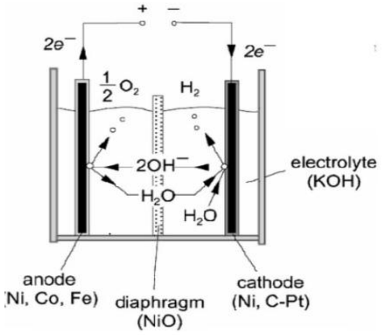
This electrolyte can be:

- 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)

2.7.1 Alkaline electrolysis



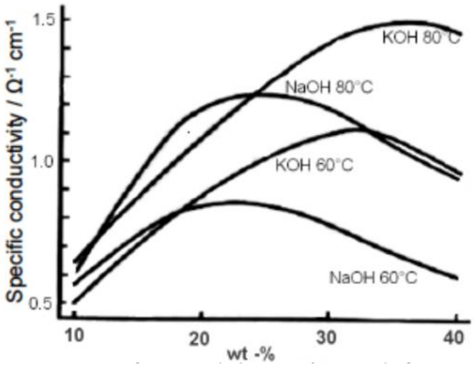
Electrolyte : 30% KOH
Température de fonctionnement : 70-80 °C
Pression de fonctionnement : < 30 bar

Figure 6: Alkaline electrolysis

anode : 2 OH- → ½ O2 + H2O + 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.

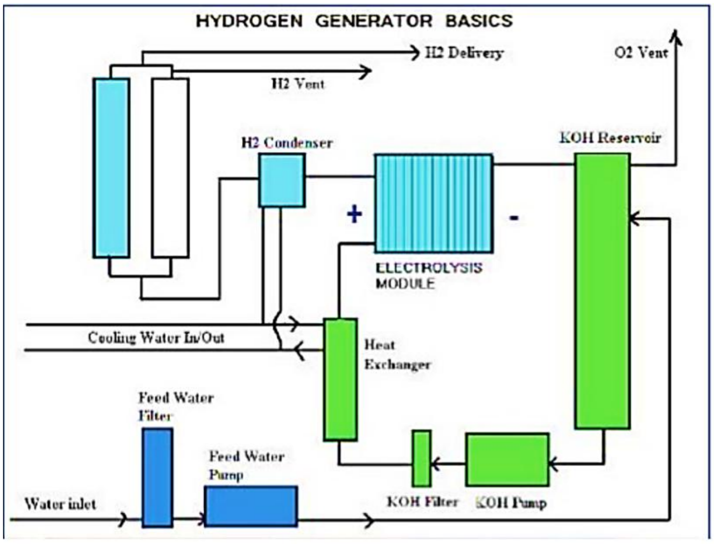
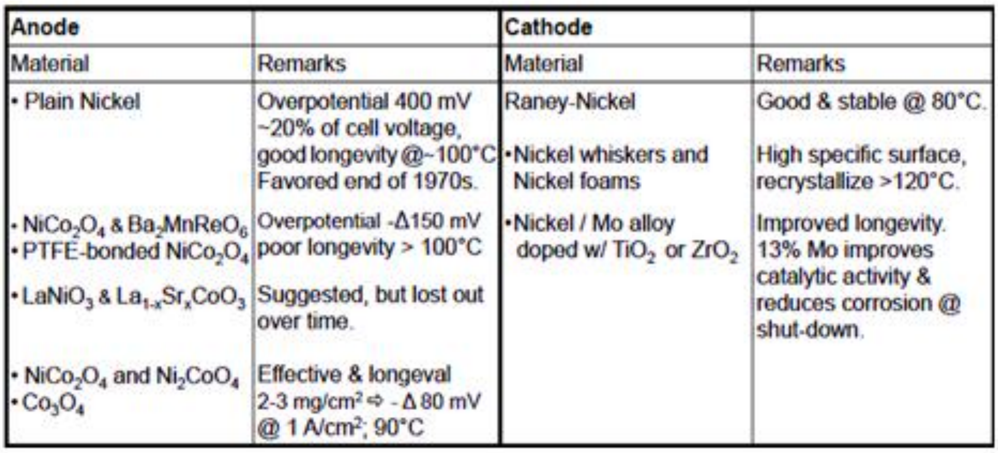


Figure 7:hydrogen generator

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

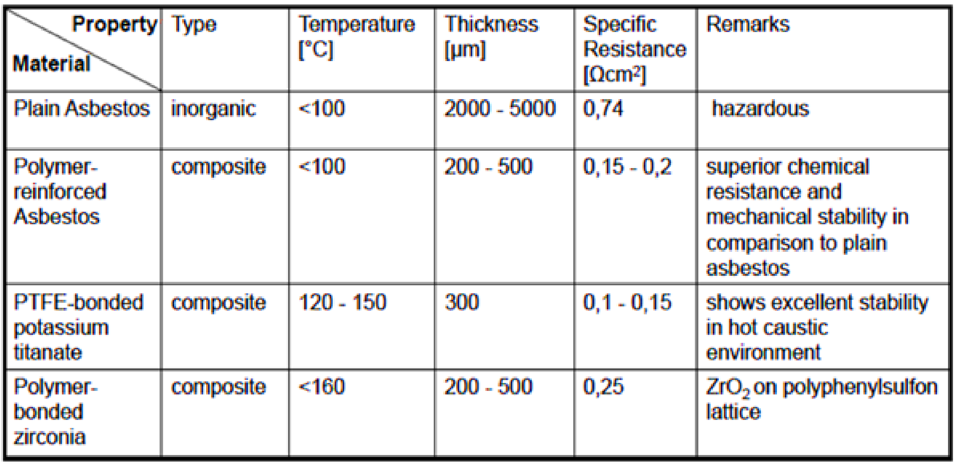


Anode		**Cathode**	
Material	Remarks	Material	Remarks
• Plain Nickel	Overpotential 400 mV ~20% of cell voltage, good longevity @~100°C Favored end of 1970s.	Raney-Nickel •Nickel whiskers and Nickel foams	Good & stable @ 80°C. High specific surface, recrystallize >120°C.
• $NiCo_2O_4$ & Ba_2MnReO_6 • 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 4:technical alkaline concepts

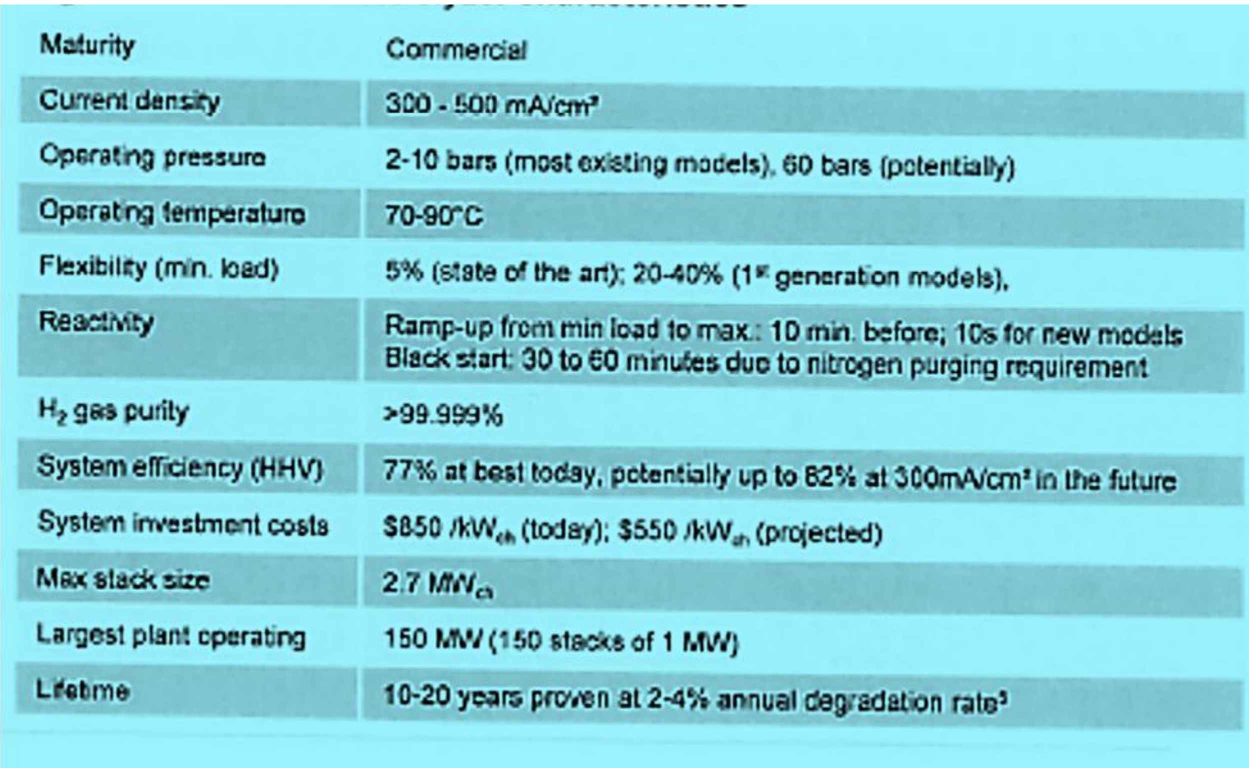
- The maximum operating temperature resulting from a compromise between the Overvoltage's and corrosion resistance of materials used
- The concentration of the electrolyte, defined by the conductivity opium at the temperature Considered
- The rapid circulation of the electrolyte makes it possible to 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).



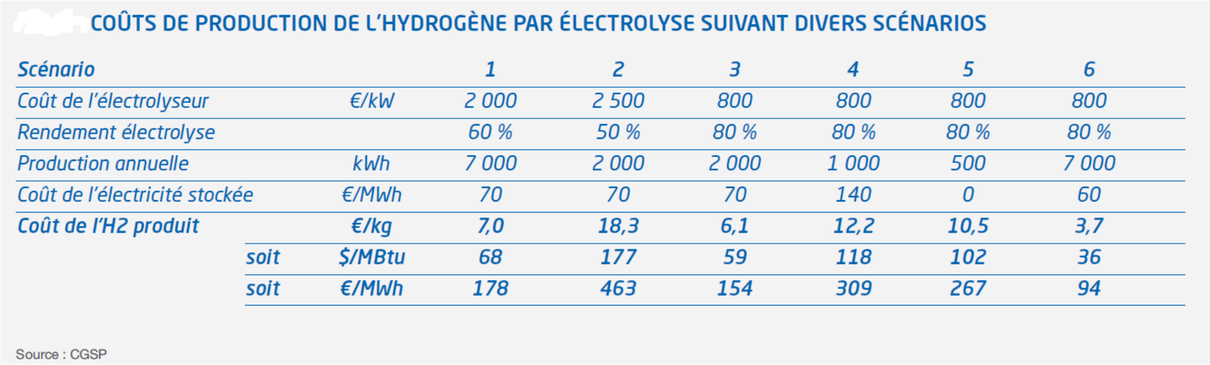
Property Material	Type	Temperature [°C]	Thickness [µm]	Specific Resistance [Ωcm²]	Remarks
Plain Asbestos	inorganic	<100	2000 - 5000	0,74	hazardous
Polymer-reinforced Asbestos	composite	<100	200 - 500	0,15 - 0,2	superior chemical resistance and mechanical stability in comparison to plain asbestos
PTFE-bonded 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 5: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	$850 /$kW_{el}$ (today); $550 /$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 6: 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.

2.7.2 System Layout and Peripheral Components

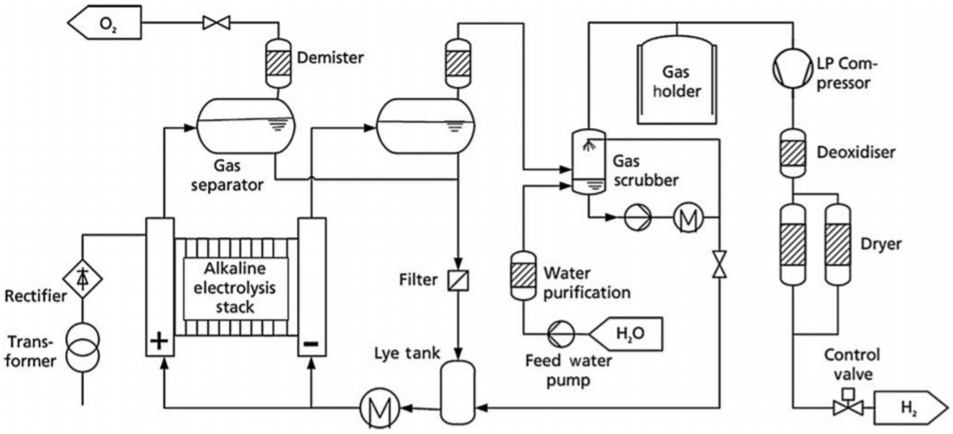


Figure 9: Typical system of an alkaline electrolyzer operating at nearly atmospheric conditions. Purification and gas drying stages are located after low-pressure compression

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]

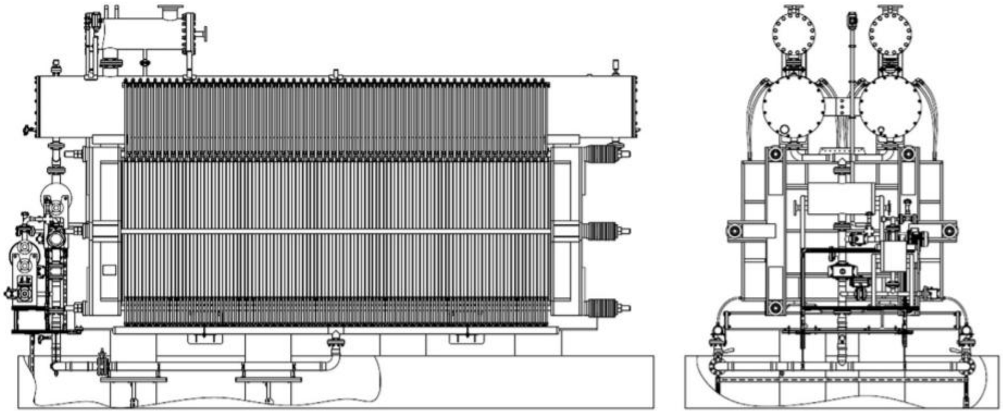


Figure 10: Front and side views of a large alkaline electrolyzer nde-30 with an electrical power of 2 mw (basic design: davy/bamag), operating at (nearly) atmospheric conditions (Figure courtesy of ENERTRAG HyTec (McPhy).)

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.

2.7.3 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]

2.7.4 Alkaline Technology

- IHT, Industrie Haute Technologie, (Switzerland) - electrolysers from 20 to Nm^3/ 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 Nm^3 / 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 Nm^3 / h, 10-25 bar, http://www.hydrogenics.com/
- Angstrom Advanced Inc. (USA) - electrolysers, up to 500 Nm^3 / h, up to 50 bar, http://www.angstrom-advanced.com/index.asp?page=hydrogenh2o

2.7.5 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.

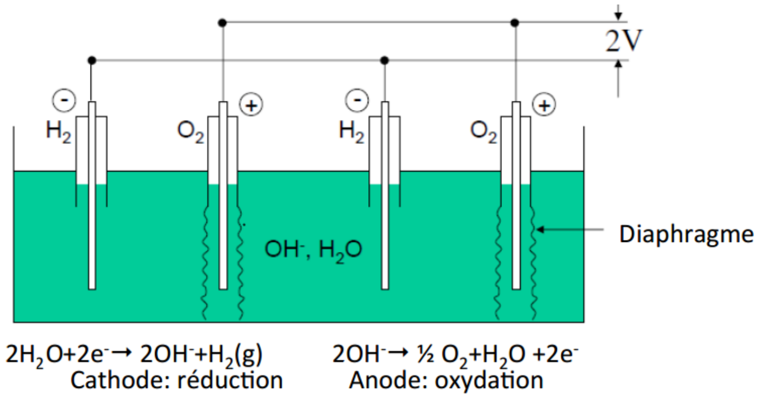


Figure 11 Monopolar electrolysis

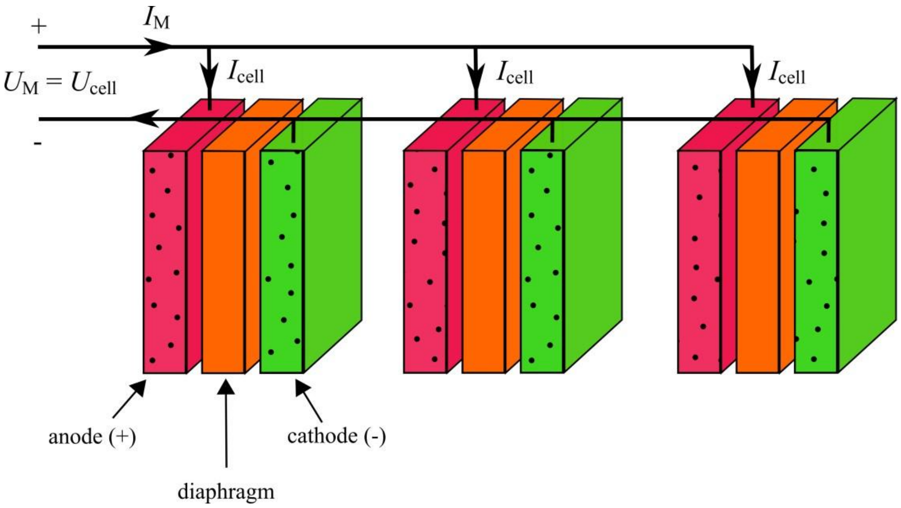


Figure 12:Alkaline Monopolar with tank

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.

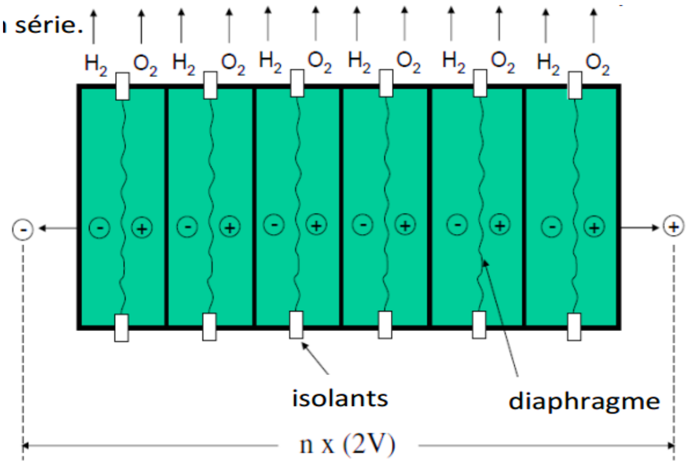


Figure 13: Bipolar electrolysis

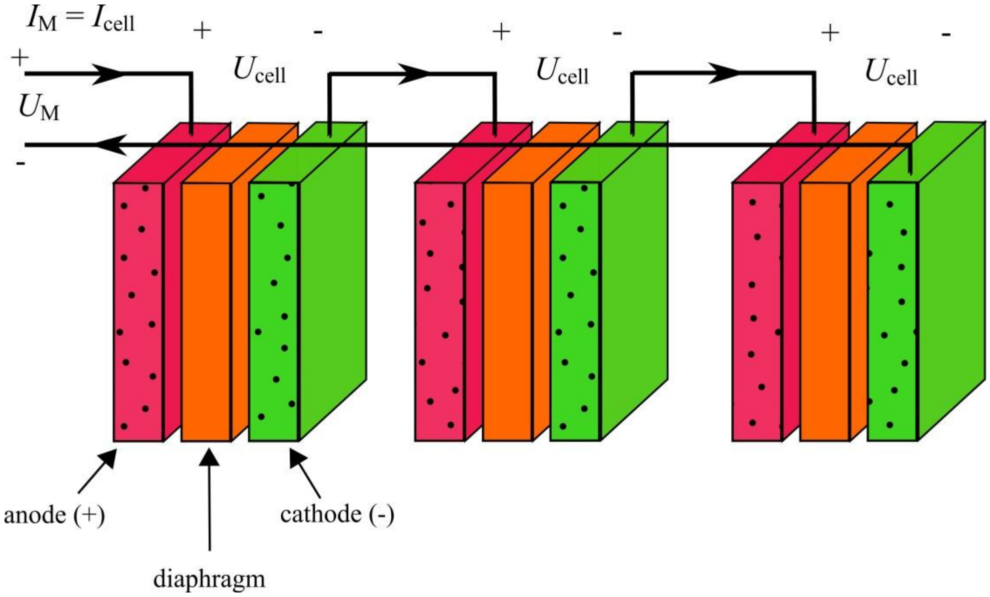


Figure 14:bipolare

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 7:comparaison between mono and bipolar cells

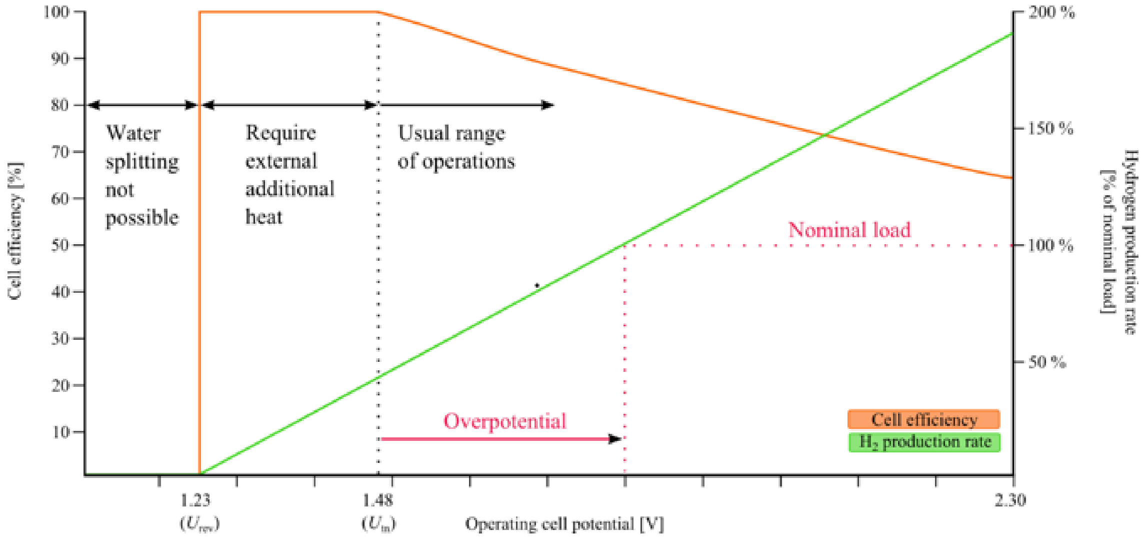


Figure 15: Illustrative cell efficiency and H_2 production rate as a function of cell voltage

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

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

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). $U_{rev}(T)$ can be expressed according to (LeRoy et al. 1980) and (Tilak et al. 1981) as follows

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

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.

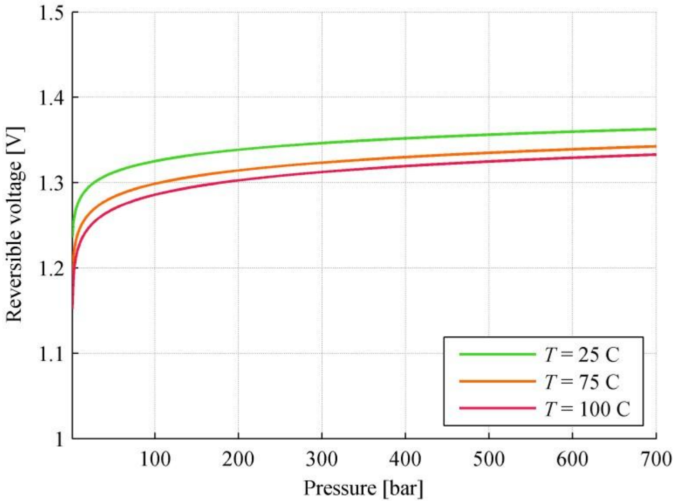
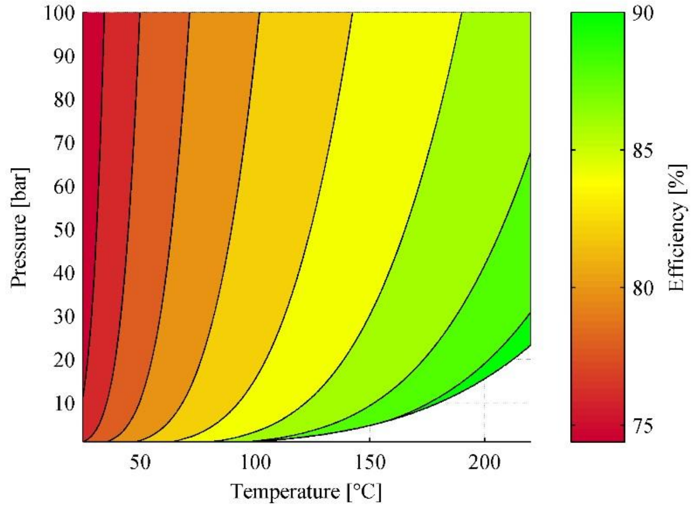
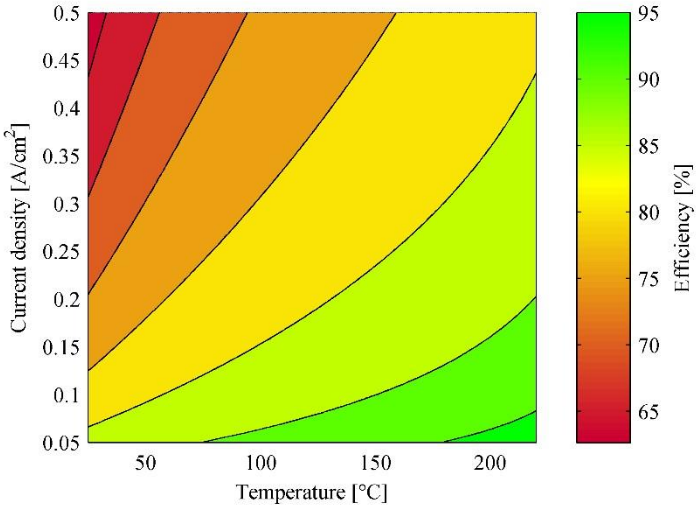
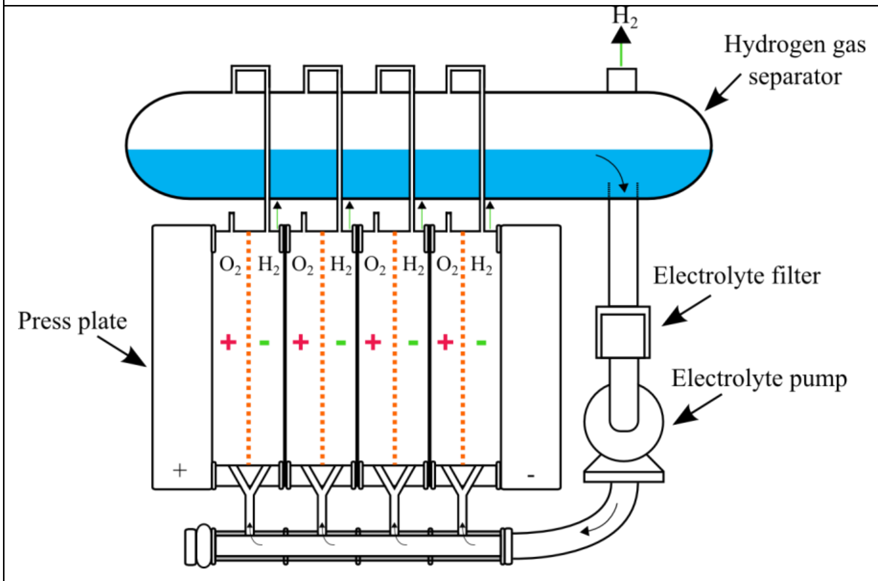


Figure 16: Reversible voltage as a function of pressure at temperatures T = 25 ,T= 75, and T= 100 in aqueous water electrolysis.

Calculations are for 30 wt% KOH electrolyte which has an electrolyte molality of 7.64 mol/kg.

	*Figure 17: 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 18: Simulated alkaline electrolyser cell efficiency with varying temperature and current density at constant pressure p = 30 bar.*
	*Figure 19: 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 8: 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).

2.7.6 Pressurized operation

Water electrolysis can be categorized into atmospheric and pressurized electrolysis depending on the pressure level at which electrolysis takes place. An overview of these two categories is illustrated in Fig. 20:

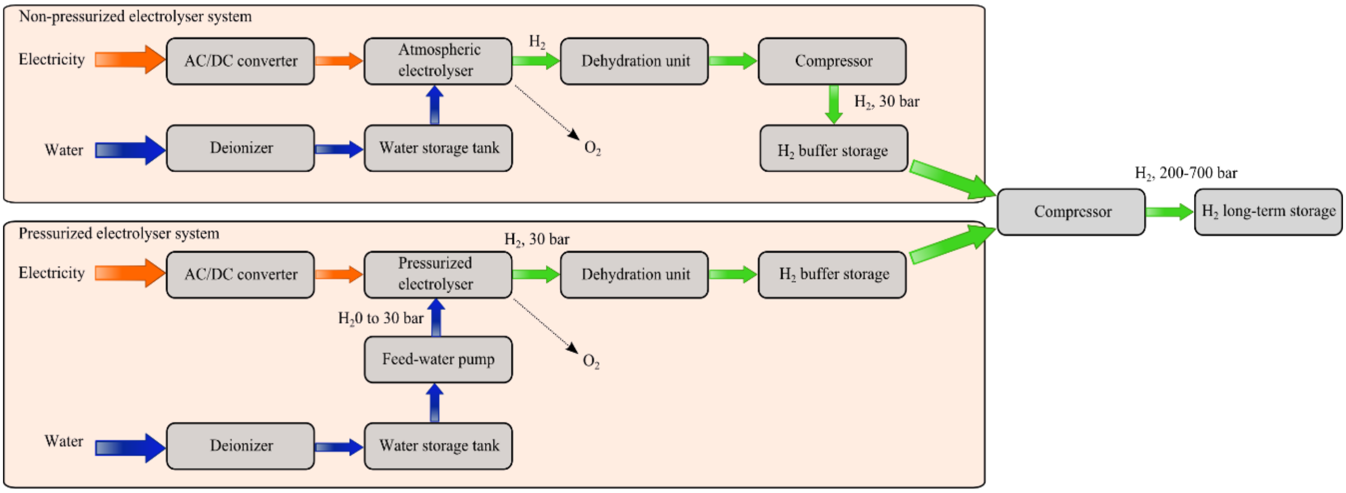


Figure 20: 10 Overview of exemplary non-pressurized and pressurized water electrolyser systems. Hydrogen buffer storages store hydrogen gas at around 10–30 bar. From the buffer storage, hydrogen gas may be further compressed to 200–700 bar. The highest pressure requirement is in mobility end-use applications, typically 350–800 bar.

2.7.7 Main features of commercially available electrolysis

Water electrolyze systems have auxiliary equipment, which enable the automatic production of electrolytic hydrogen. Generally, water electrolyze 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.

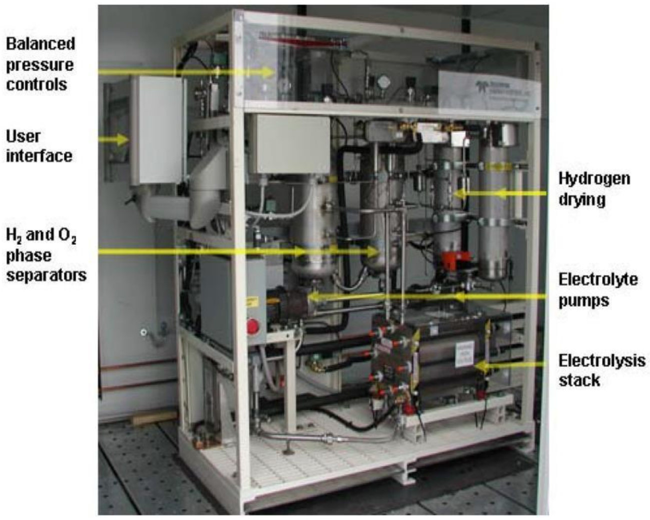


Figure 21: System components of Teledyne Energy Systems' 40 kW alkaline hydrogen generator (Harrison et al. 2009). Measurements of the enclosure are 150 x 178 x 75 cm.

2.7.8 Power electronic systems

A water electrolyze is a DC load and thus the input power for the electrolyze 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

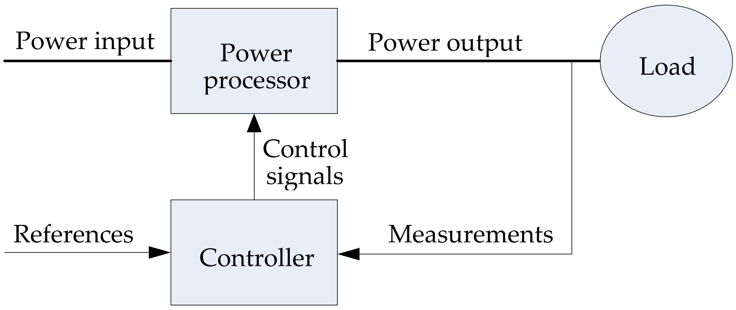


Figure 22 :3 General scheme of a power electronic system

2.7.9 Design of cells

2.7.9.1 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 electrolyzes 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

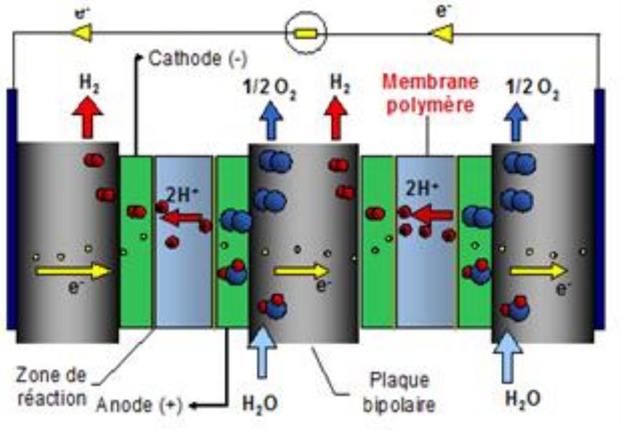


Figure 23 :electrolyze PEM

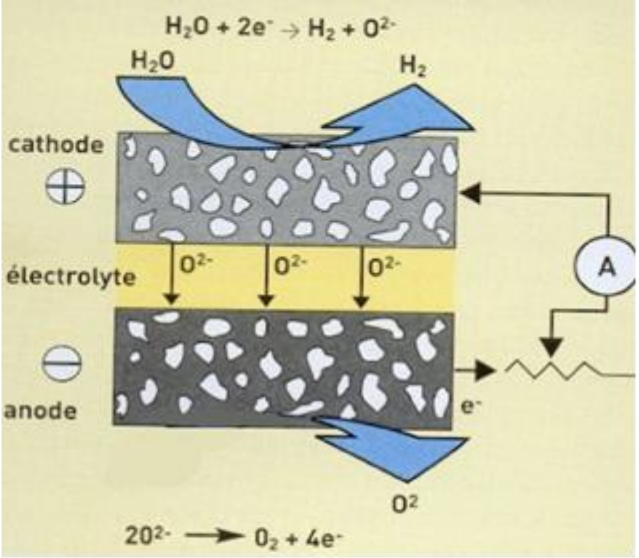
anode :2 H_2O ⇨ O_2 + 4 H^+ + 4 e^-

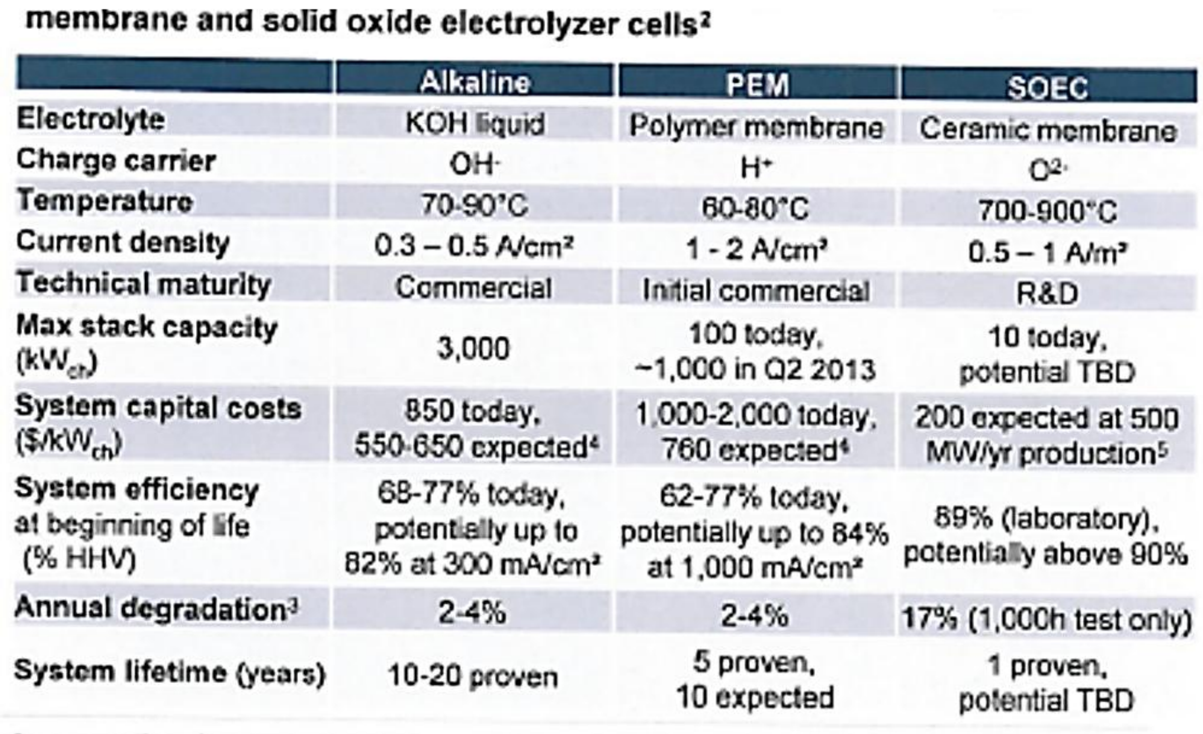
cathode :2 H^+ + 2 e^- ⇨ H_2

Figure 24: Electrolyser PEM AREVA H_2GEN/CETH$_2$ 120 Nm^3/h (2015)

2.7.9.2 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 9: Differences between 3 types of electrolyzer

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

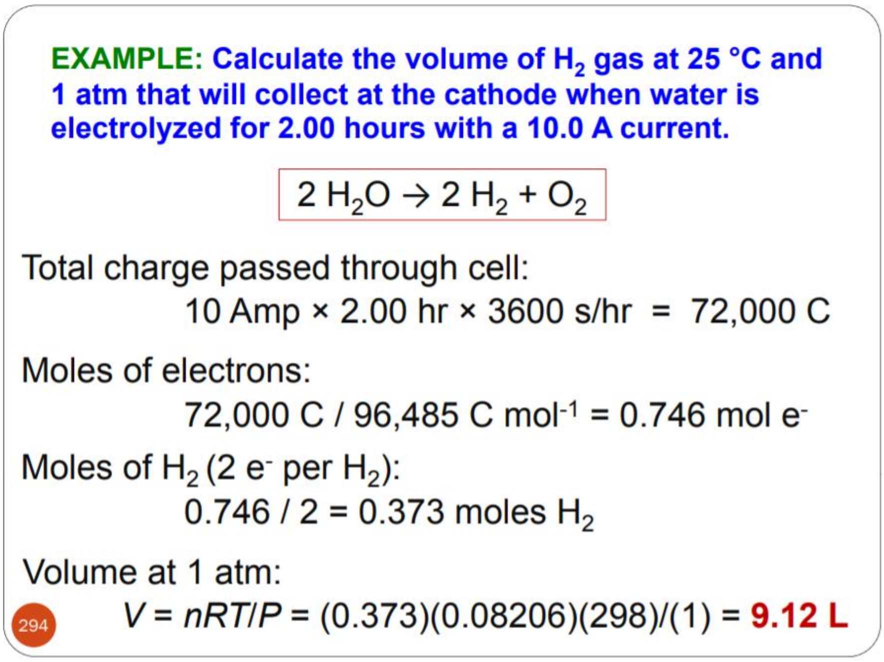
2.7.10 Voltage and ampere

- 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.

2.7.11 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.

$$2\,H_2O \rightarrow 2\,H_2 + O_2$$

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:

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

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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] 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.

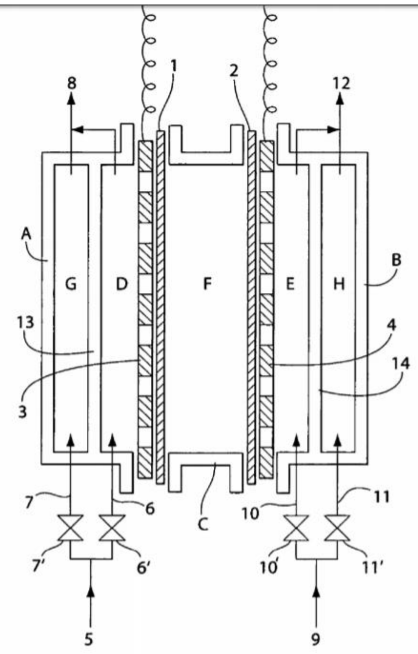


Fig. 3

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

2.7.12 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.

$$n = \frac{I \times t}{F \times z} \quad (1)$$

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.

$$V_{H_2(g)} = V_{O_2(g)} = \frac{nRT}{P} \quad (2)$$

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.

$$V_{H_2(g)} = V_{O_2(g)} = \frac{v}{t} \times 60 \quad (3)$$

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.

2.7.13 خزان الهيدروجين (Reservoir for the conservation of HYDROGEN)

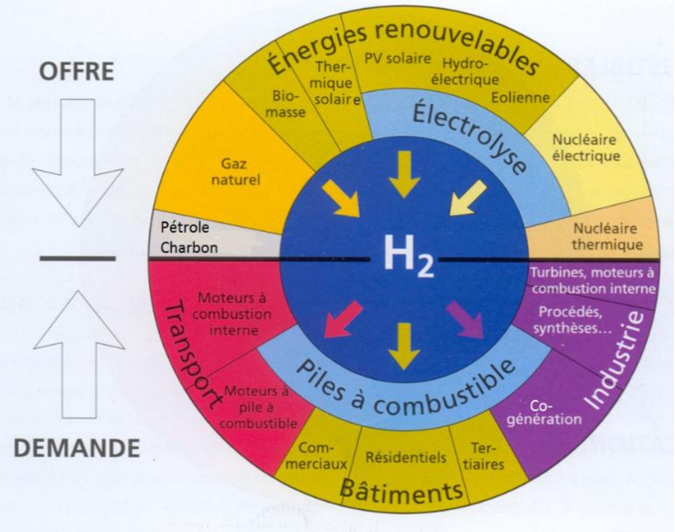


Figure 25: The hydrogen chain (documentaire)

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 / m³ compared with 0.090 kg / m³ 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.

2.7.14 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	≈ 2	150	25	1	Hydrogen (atomic H) intercalation in host metals, metallic hydrides working at room temperature are fully

host metal					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 10: The six main hydrogen storage methods and the associated phenomena, where pm is the gravimetric density and pv 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 11: Directives on the safety of hydrogen generators using water electrolysis process ((2))

2.7.14.1 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 12: 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 لاالهيدروجين 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.

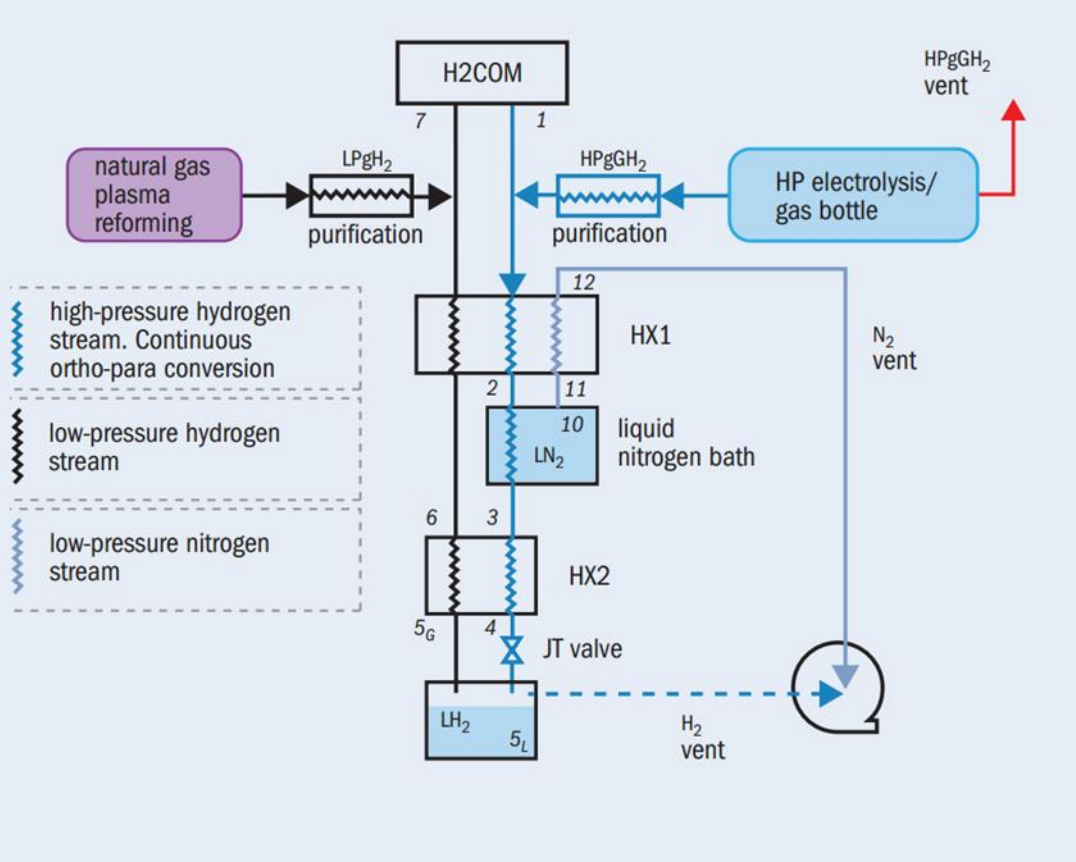


Figure 26: Schematic of the proposed pre-cooled Linde-Hampson system for hydrogen liquefaction. Ortho-para hydrogen conversion takes place in a HX1 and HX2 zone

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) فيHX1 ، 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 .Kفي 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 حدود15-7٪ 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 ، وLN2 .HX2هذا 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

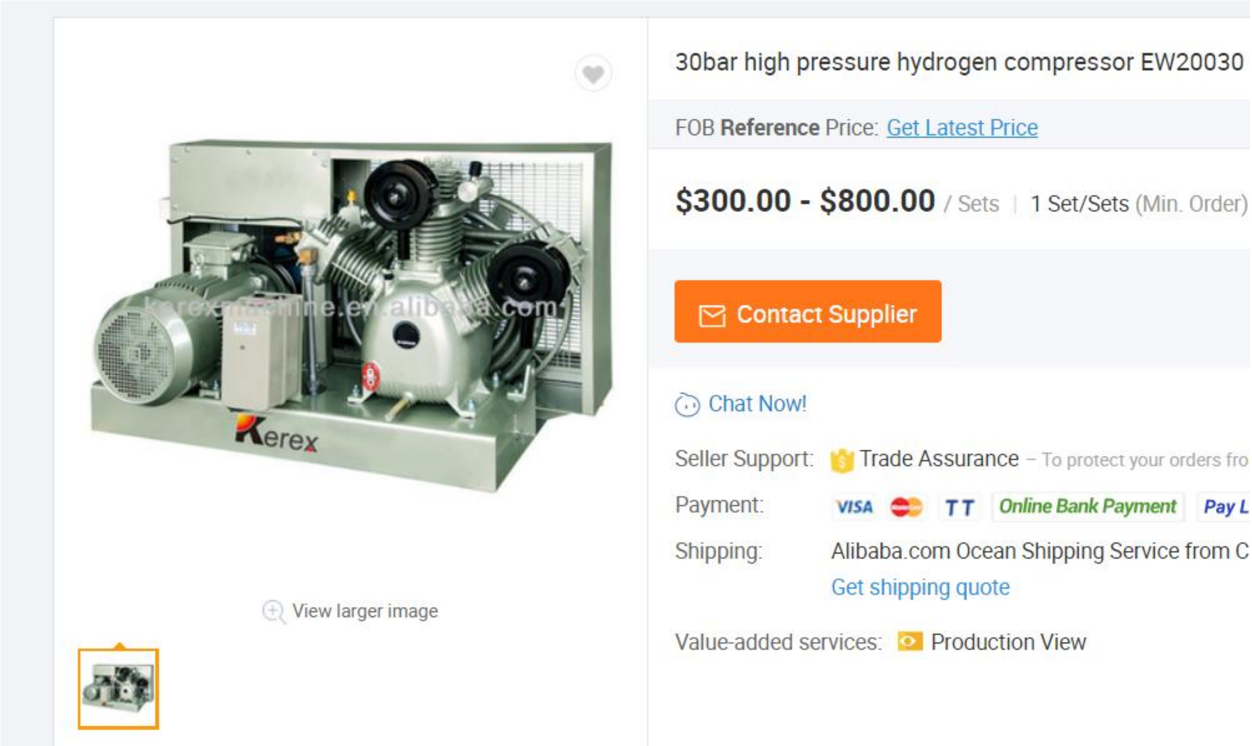
2.7.14.2 How to Compress Hydrogen to Power an Engine?

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)

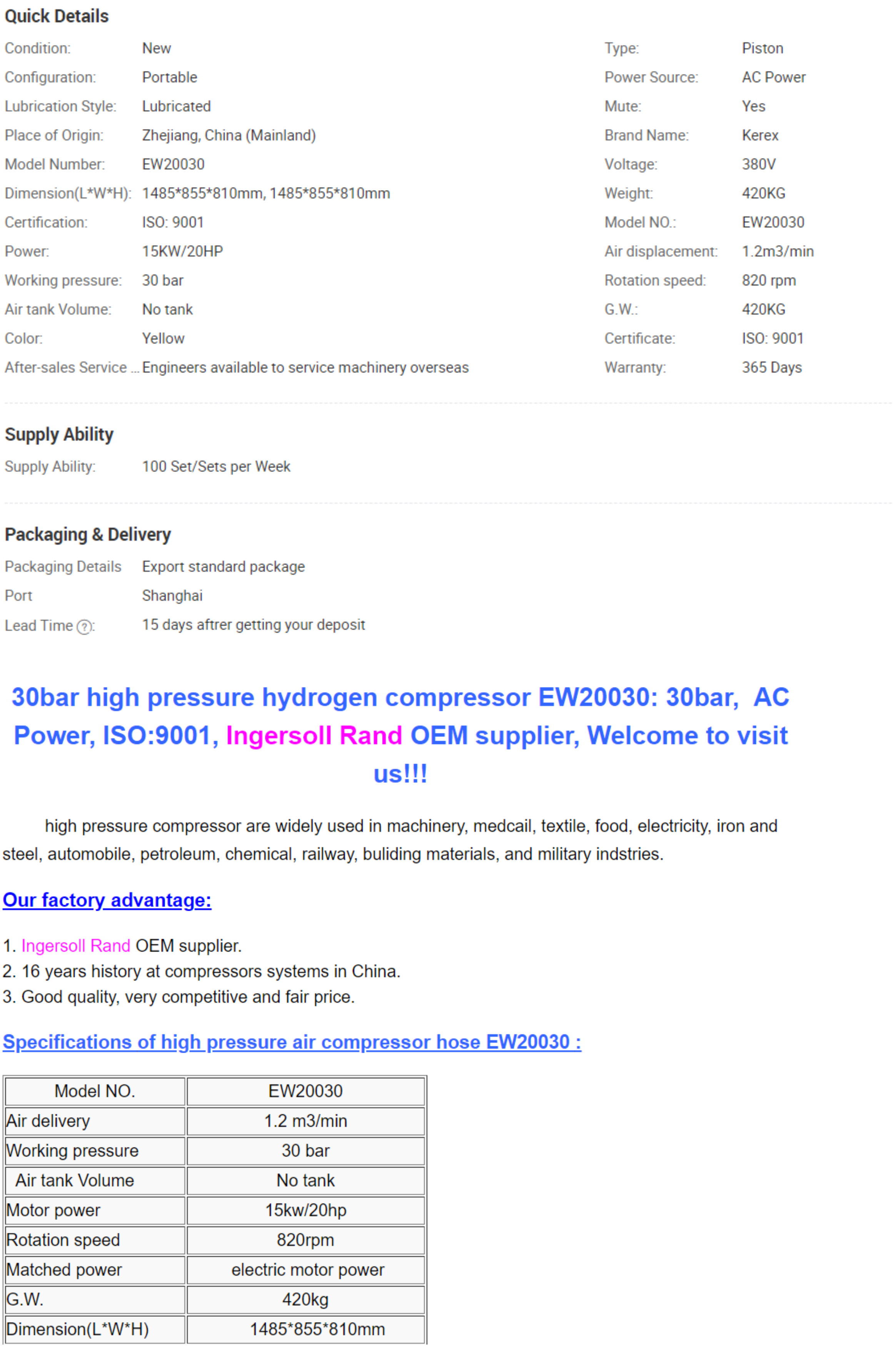
Seller Support: Trade Assurance – To protect your orders fro

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

2.8 Flue Gas Purification (Gas Flow)

2.8.1 Anlagen der maschinellen Lüftung[1]

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.

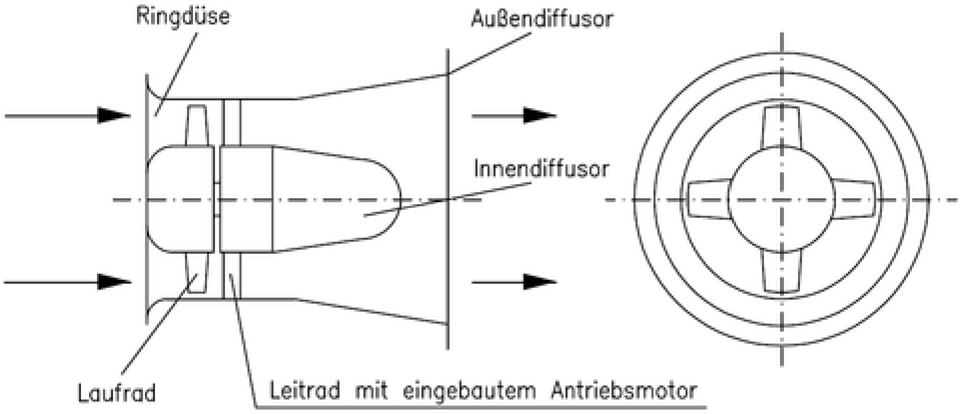


Bild: Axialventilator

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

---

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

Volumenströme. Sie sind die in raumlufttechnischen Anlagen am häufigsten verwendete Bauart.

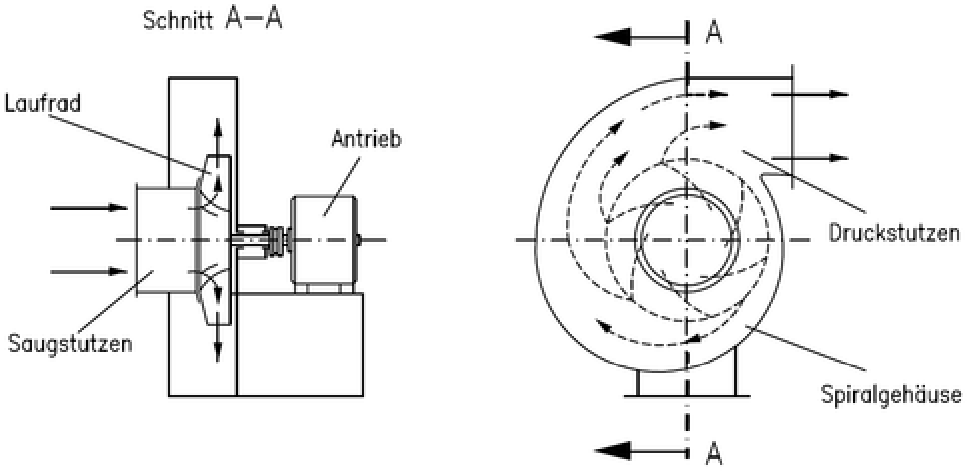


Bild: Radialventilator

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**.

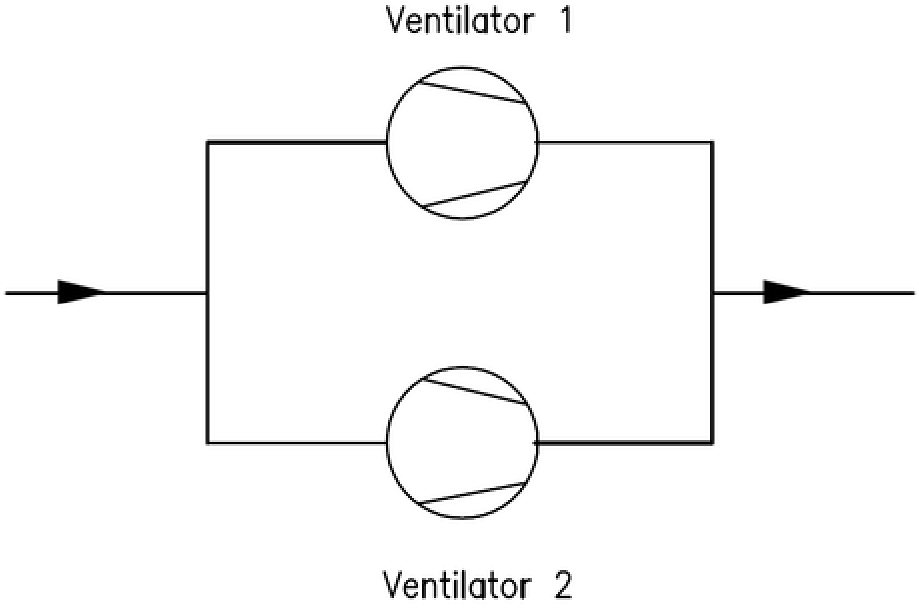


Bild: Parallelschaltung

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

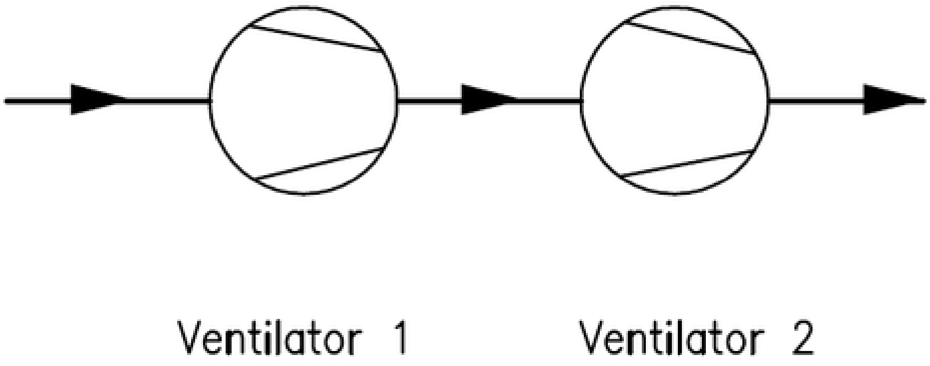


Bild: Reihenschaltung

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)

2.8.2 Einbauhinweise[2]

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.

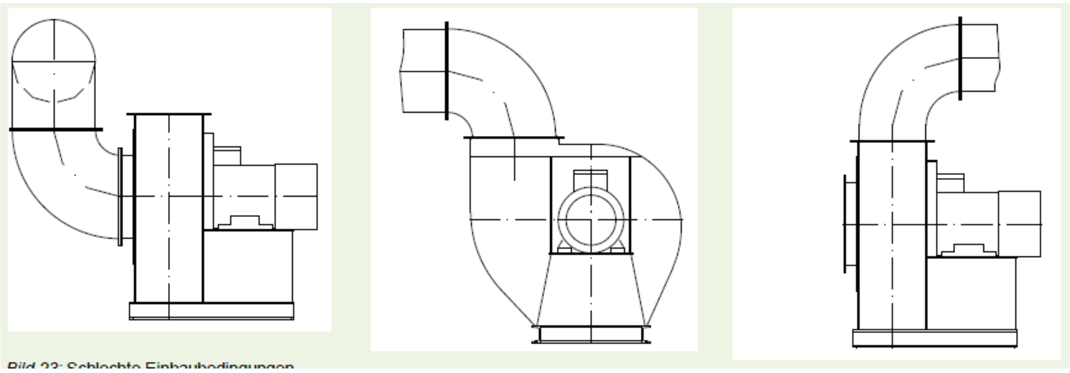


Bild 23: Schlechte Einbaubedingungen

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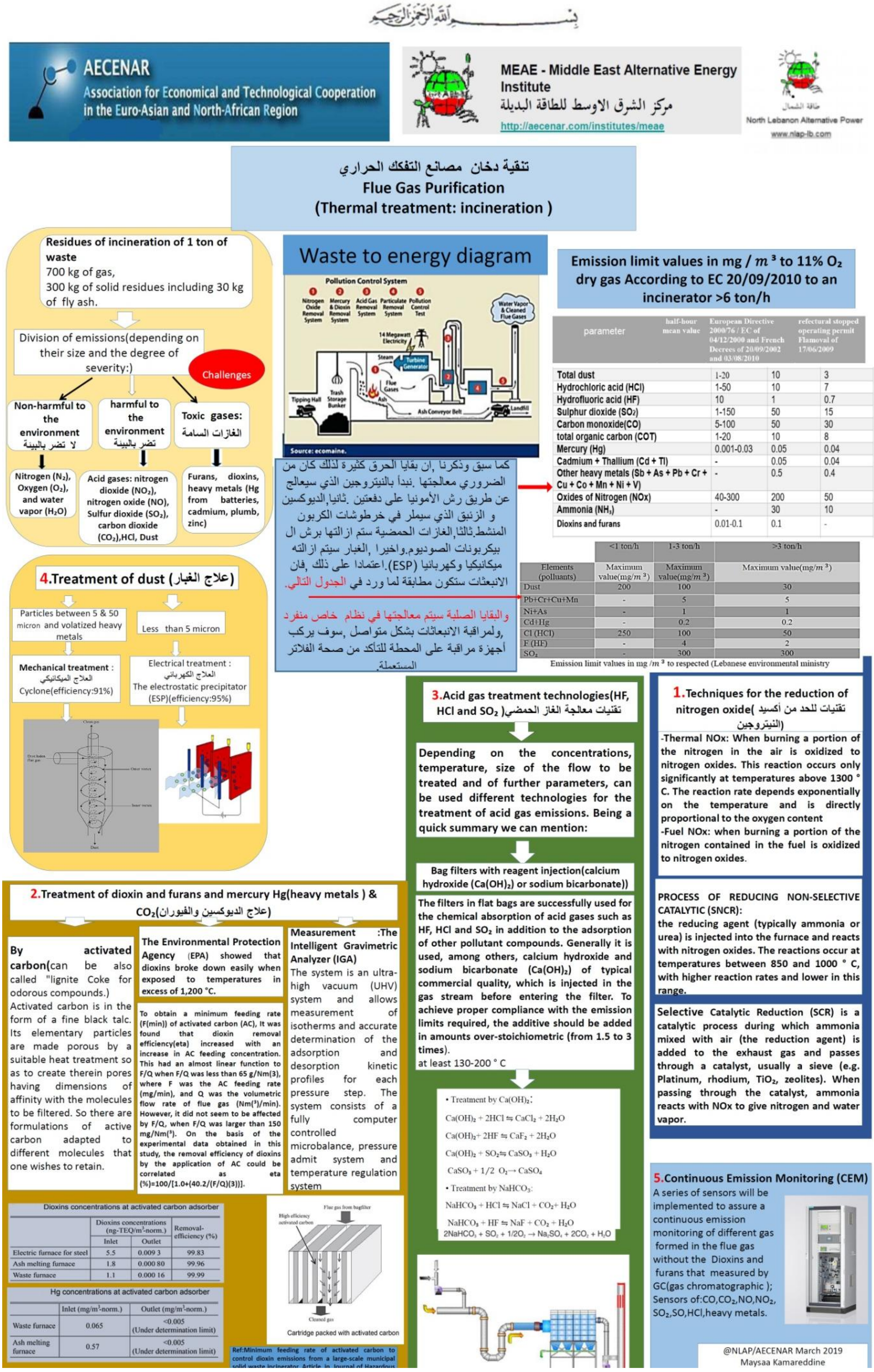
[2] https://ventecag.de/fileadmin/downloads/ventec-wissenswertes-aus-der-lufttechnik.pdf

3 Flue Gas Purification & Emissions Measurement



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 الانبعاثات 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	Less than 5 micron
Mechanical treatment : العلاج الميكانيكي Cyclone(efficiency:91%)	Electrical treatment : العلاج الكهربائي The electrostatic precipitator (ESP)(efficiency:95%)

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

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 $Ca(OH)_2$:

$$Ca(OH)_2 + 2HCl \leftrightharpoons CaCl_2 + 2H_2O$$
$$Ca(OH)_2 + 2HF \leftrightharpoons CaF_2 + 2H_2O$$
$$Ca(OH)_2 + SO_2 \leftrightharpoons CaSO_3 + H_2O$$
$$CaSO_3 + 1/2\ O_2 \rightarrow CaSO_4$$

- Treatment by $NaHCO_3$:

$$NaHCO_3 + HCl \leftrightharpoons NaCl + CO_2 + H_2O$$
$$NaHCO_3 + HF \leftrightharpoons NaF + CO_2 + H_2O$$
$$2NaHCO_3 + SO_2 + 1/2O_2 \rightarrow Na_2SO_4 + 2CO_2 + H_2O$$

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.

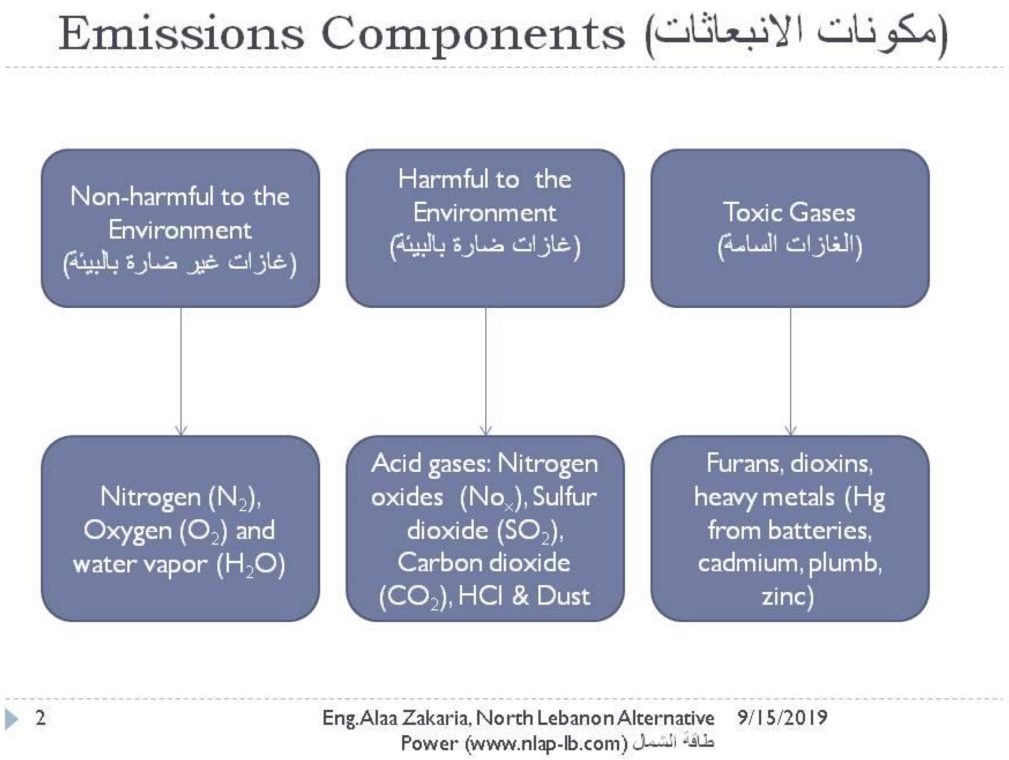
Selective Catalytic Reduction (SCR) is a catalytic process during which ammonia mixed with air (the reduction agent) is added to the exhaust gas and passes through a catalyst, usually a sieve (e.g. Platinum, rhodium, TiO_2, zeolites). When passing through the catalyst, ammonia reacts with NOx to give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

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

3.1 Emissions Control (Emissions, Filters, Standards)



Emissions Components (مكونات الانبعاثات)

Non-harmful to the Environment (غازات غير ضارة بالبيئة)

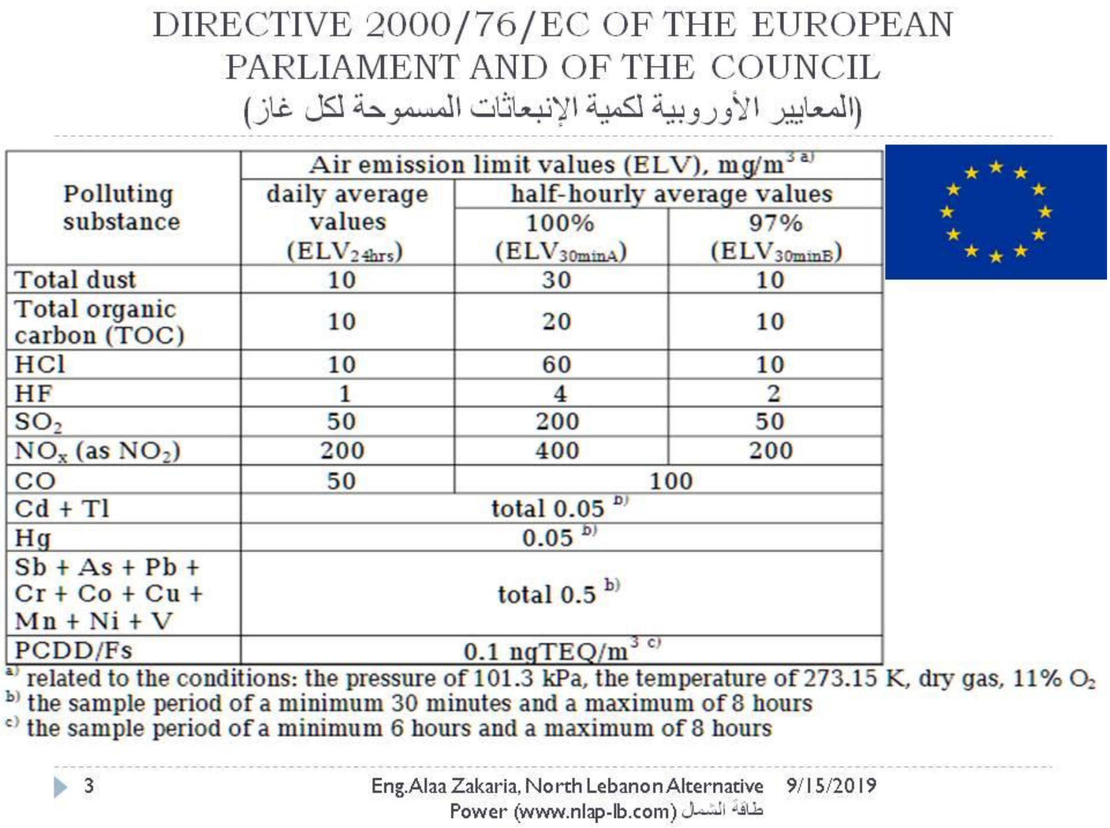
Harmful to the Environment (غازات ضارة بالبيئة)

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	half-hourly average values	
	(ELV_{24hrs})	100% (ELV_{30minA})	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)

1. Nitrogen Oxides (NO_x) Reduction Techniques:

a. Selective Non-catalytic reduction process:

Urea $NH_2CONH_2 + 2NO + 1/2O_2 \xrightarrow{900°C\ to\ 1100°C} 2N_2 + CO_2 + 2H_2O$

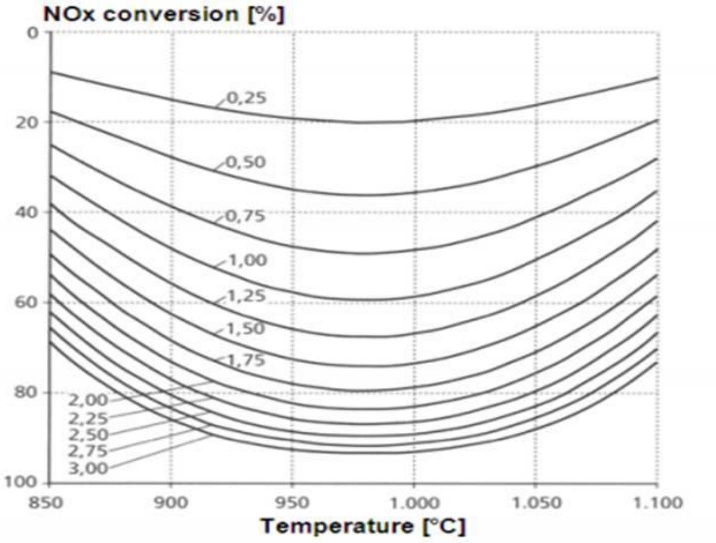
Ammonia $4NH_3 + 4NO + O_2 \xrightarrow{900°C\ to\ 1100°C} 4N_2 + 6H_2O$

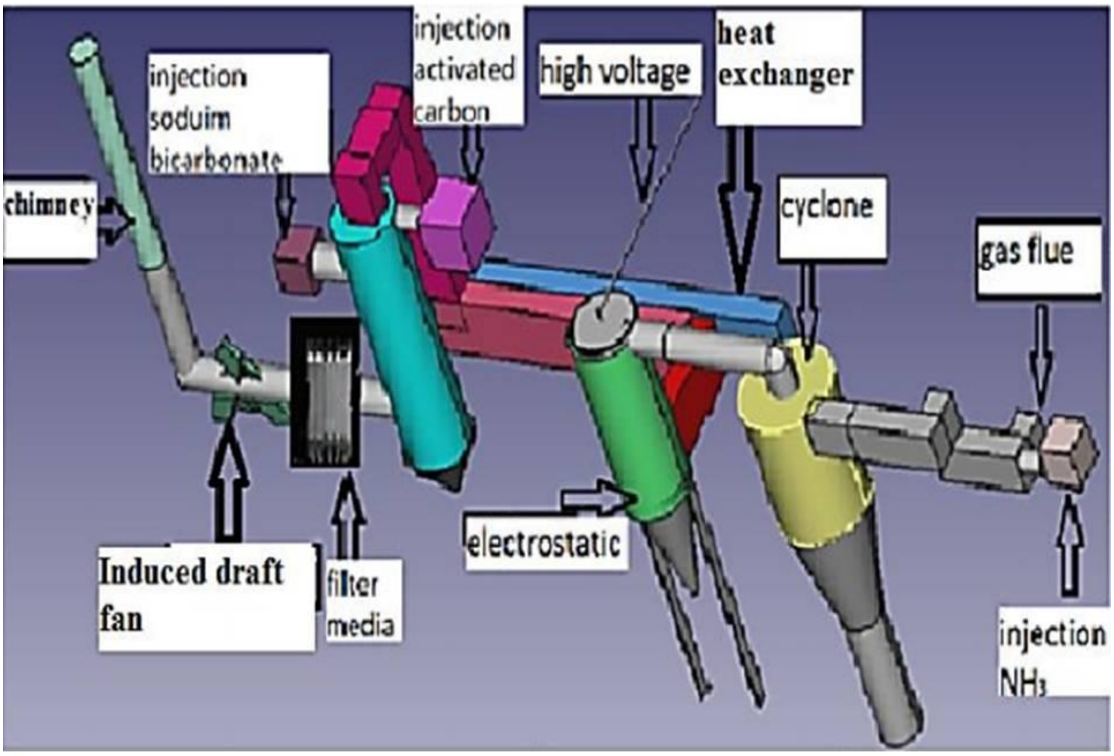
b. Selective Catalytic reduction process:

$NH_3 + Air + NO_x \xrightarrow{Pt / Rh / TiO2 / Zeolite} N_2 + H_2O$

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)

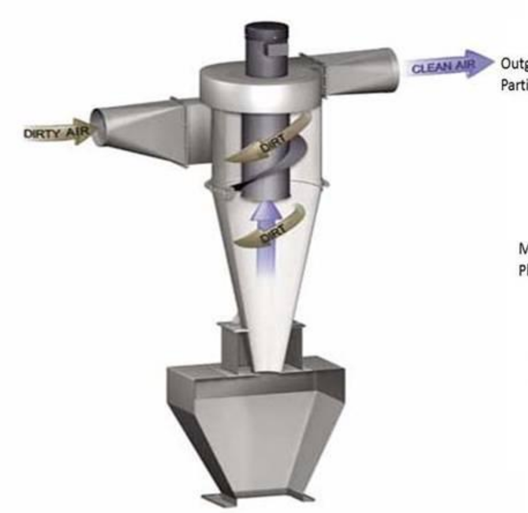
3. **Treatment of Dust:**

5 µm< Particles < 50 µm & volatized heavy metals → Mechanical Treatment: Cyclone (eff. ≈ 91%)

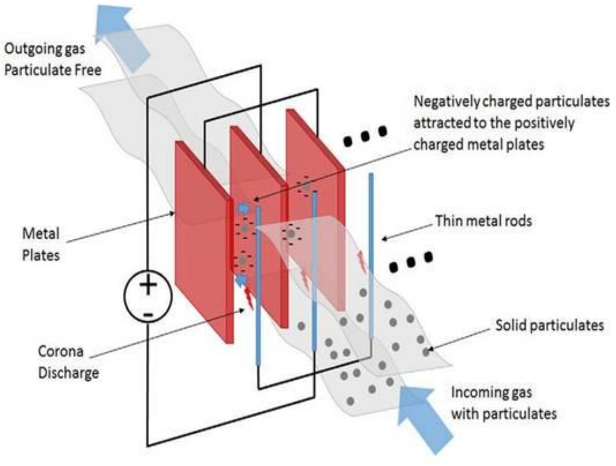
Particles < 5 µm → Electrochemical Treatment: Electrostatic Precipitator (ESP) (Efficiency ≈ 95%)

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)

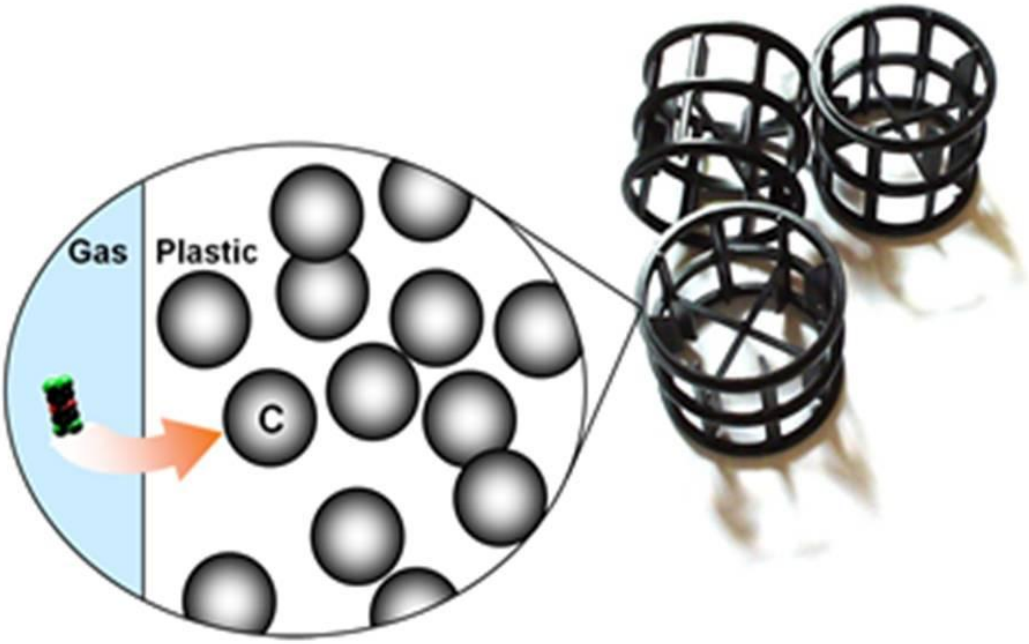
- Removal of Dioxin & Furans: Adiox

- Consists of polypropylene doped with carbon particles

- Effective, safe and economical technology for scrubbing dioxins from gases.

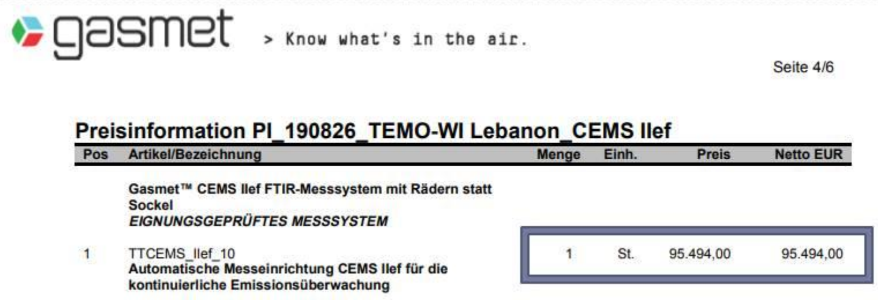
- Incinerated after use, leading to the destruction and removal of dioxins from the ecosystem.

- Can be installed with a scrubber or other type of equipment in a flue gas cleaning system



3.2 Emissions Measurement

Sensors & their Prices
(أجهزة الإستشعار وأسعارها)

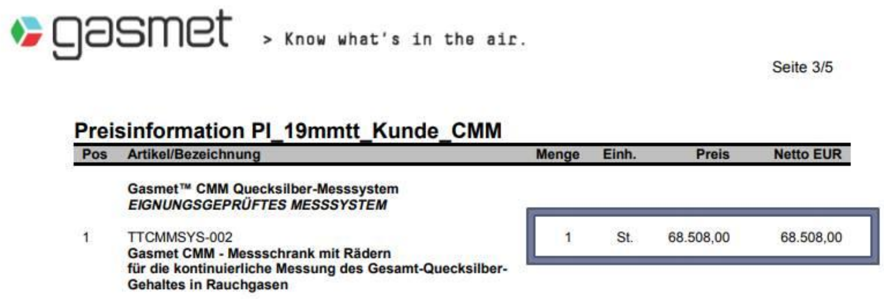


gasmet > Know what's in the air.

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

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

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)

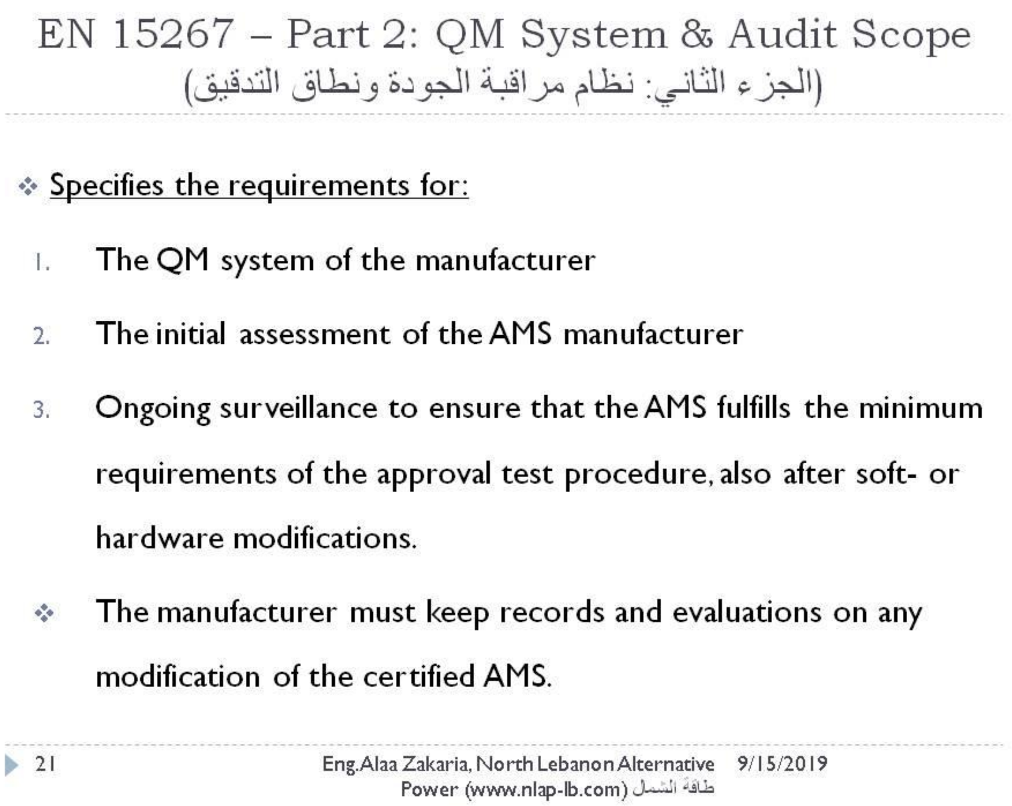
3. Roles & responsibilities during certification:

→ 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

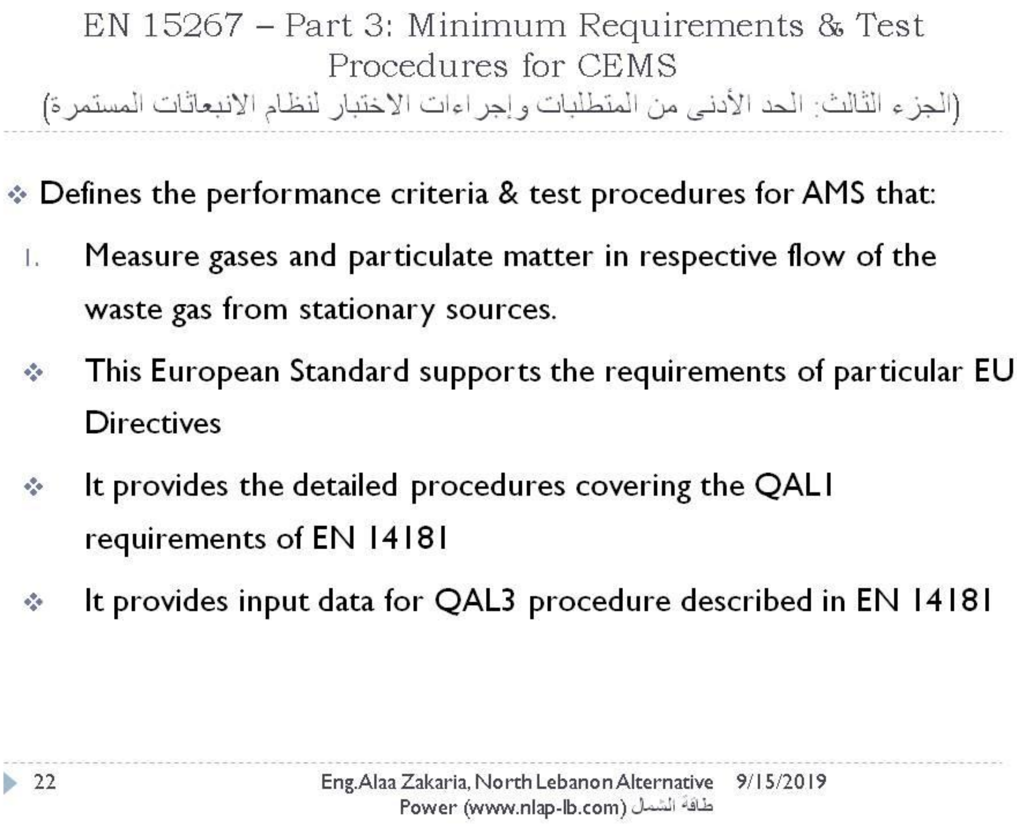


EN 15267 – Part 2: QM System & Audit Scope
(الجزء الثاني: نظام مراقبة الجودة ونطاق التدقيق)

- 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

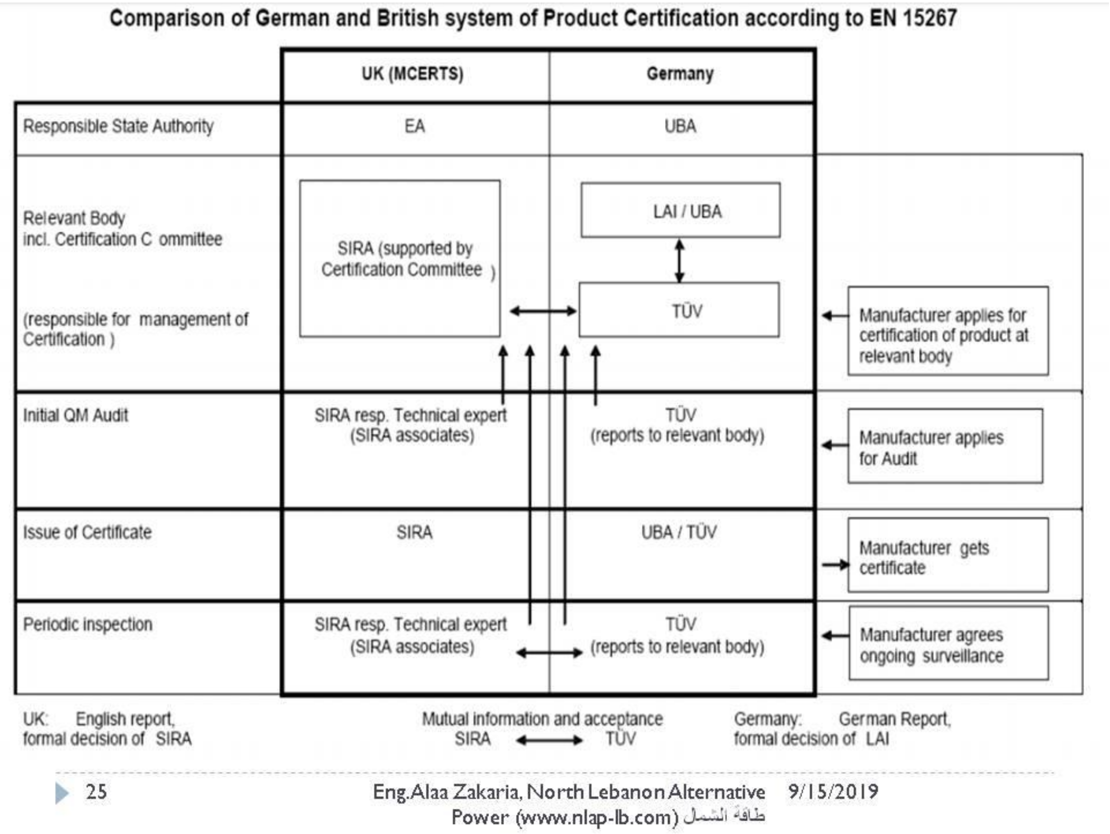
EN 15267 part 4: Minimum requirements and test procedures for CAMS
(الجزء الرابع: الحد الأدنى من المتطلبات وإجراءات الاختبار لنظام المراقبة الآلي)

- 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

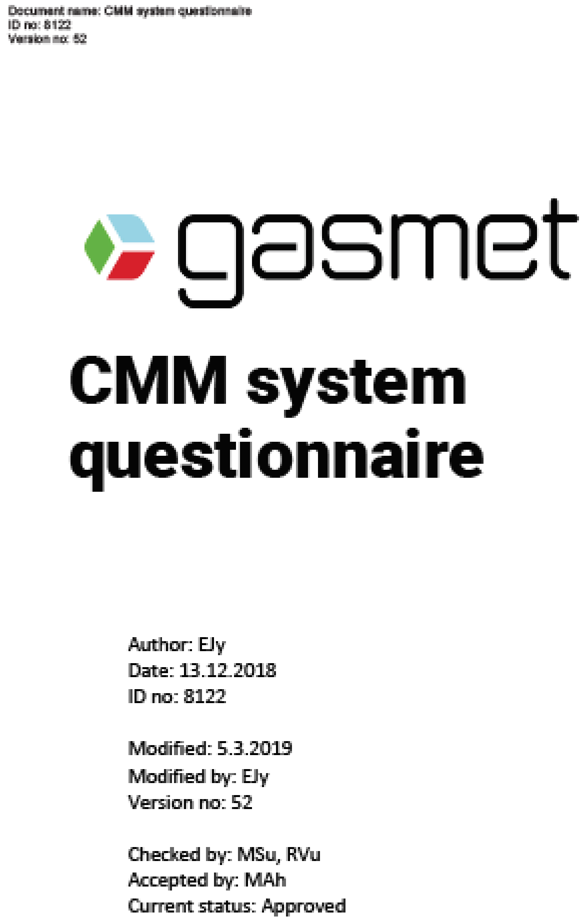
Germany: German Report, formal decision of LAI

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

3.3 Offer from Gasmet for a Emissions Monitoring System

3.3.1 Filled Questionnaire



Document name: CMM system questionnaire
ID no: 8122
Version no: 52

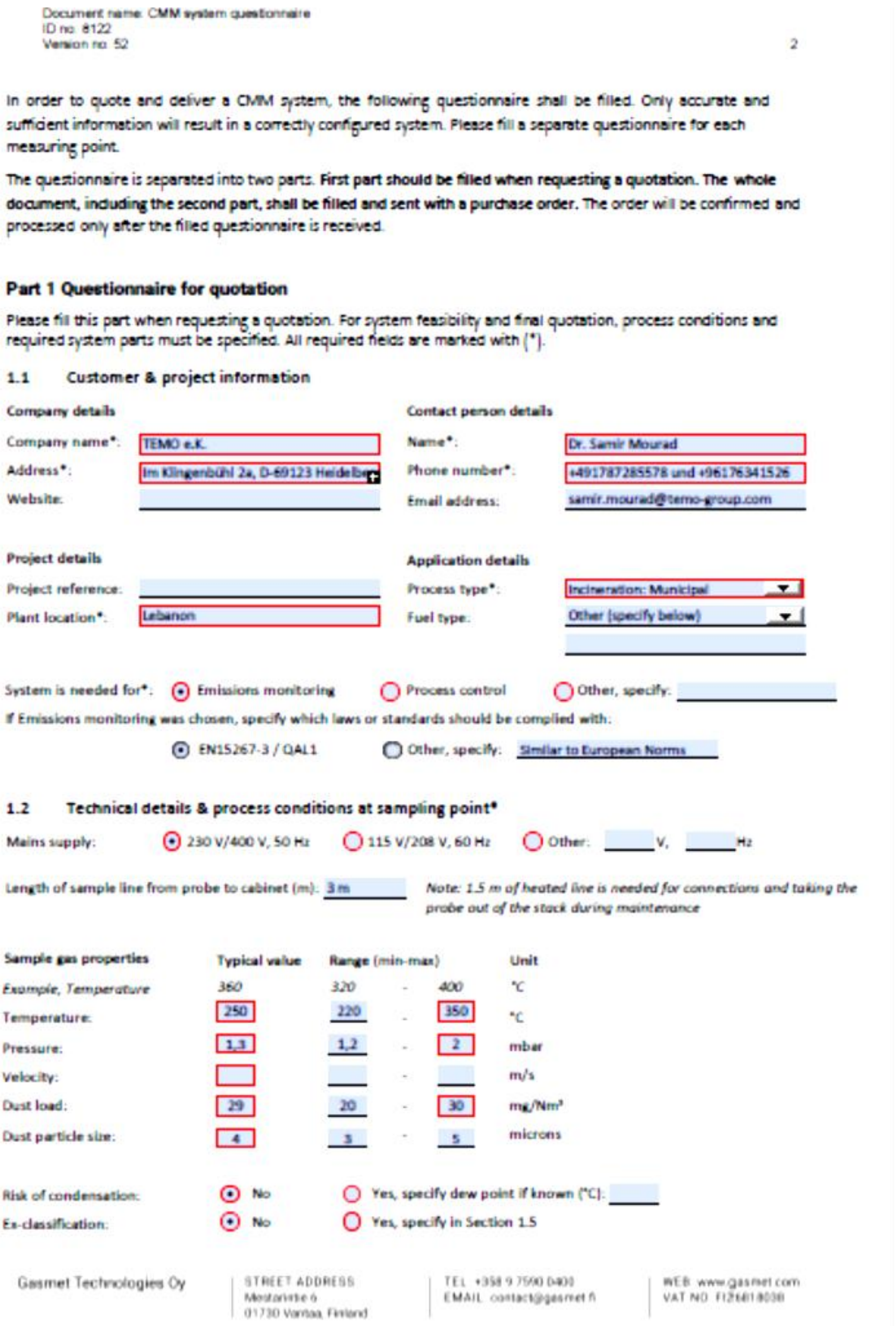
gasmet

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

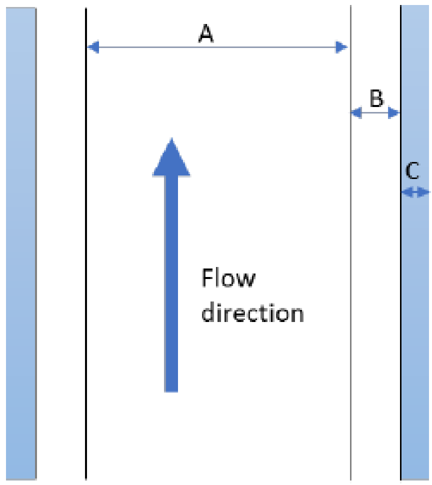
Duct inner diameter (A): 900 mm

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

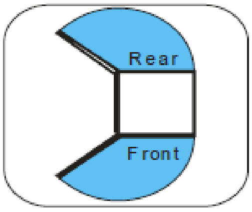
Flue gas cleaning type ○ Electrostatic precipitator (ESP) ● Baghouse ○ Wet scrubber

Part 2 Purchase order details

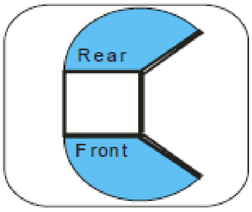
Please note that only Part 1 is needed for a quotation. Part 2 should be filled and sent with a purchase order. The order will only be confirmed after the filled questionnaire is received.

2.1 CMM system cabinet door opening directions

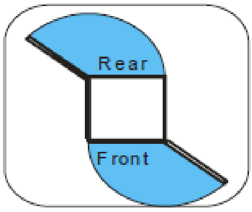
Door opening directions (choose one of the following)



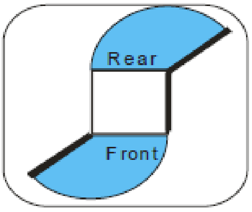
○ Standard



○ CAB-OPT-113



○ CAB-OPT-113



○ CAB-OPT-113

2.2 CMM system parts

Standard system parts (included):

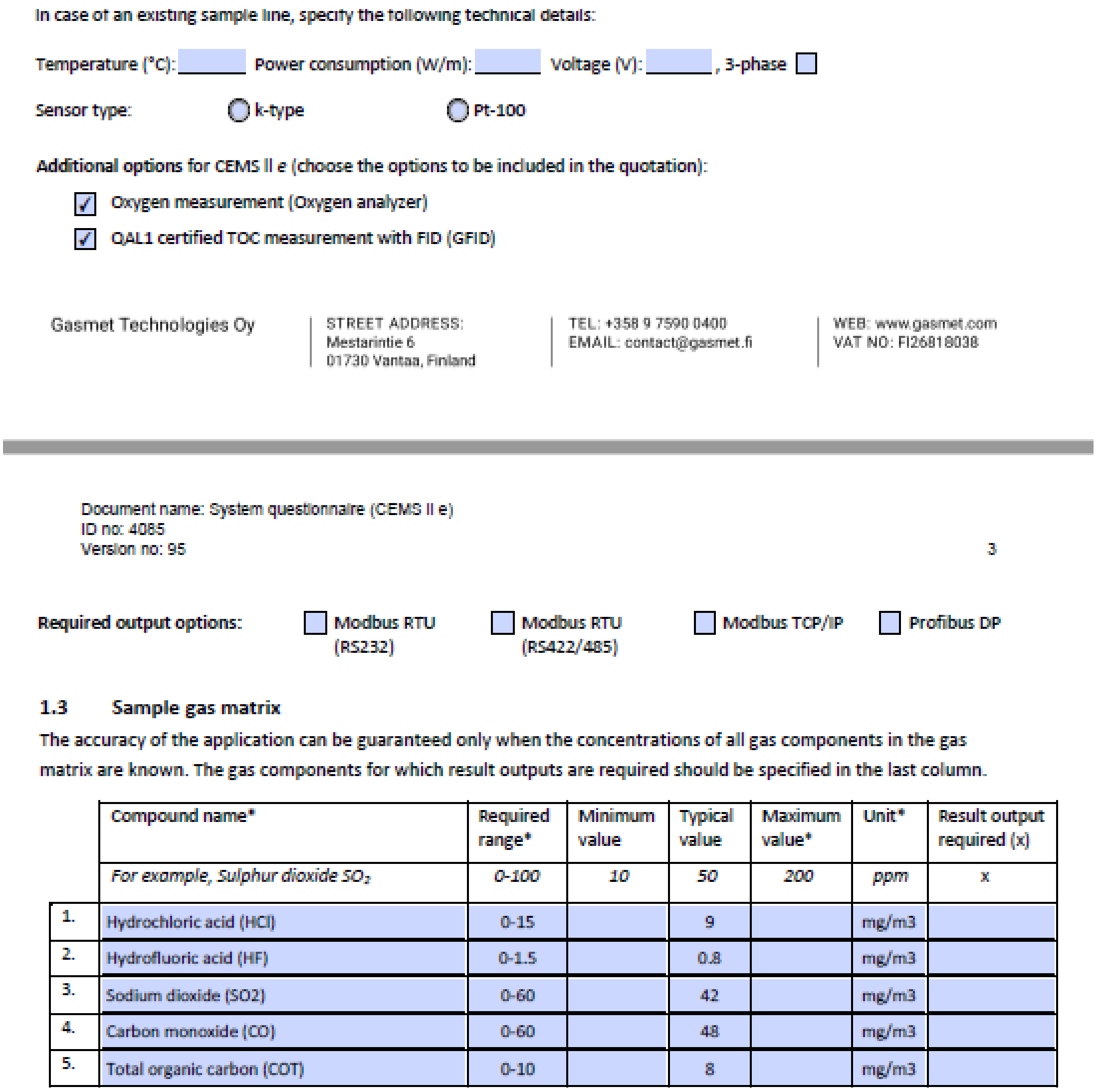
- ☑ Probe & heated sample line
- ☑ Cabinet with A/C unit
- ☑ Computer with MAUI software
- ☑ Gasmet mercury analyzer
- ☑ Gasmet test gas generator

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

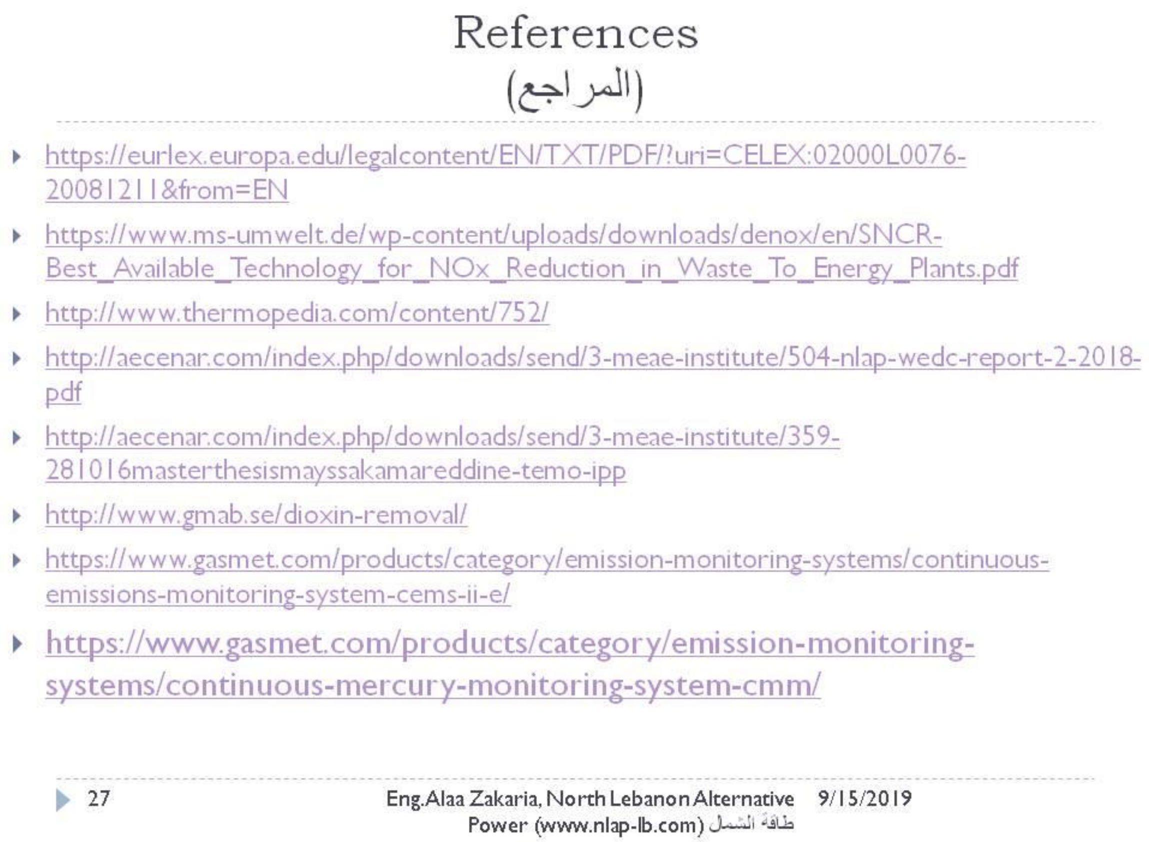
1.3 Sample gas matrix

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	

3.3.2 Offer (Elements & Prices)

3.4 References



References
(المراجع)

- https://eurlex.europa.edu/legalcontent/EN/TXT/PDF/?uri=CELEX:02000L0076-20081211&from=EN
- https://www.ms-umwelt.de/wp-content/uploads/downloads/denox/en/SNCR-Best_Available_Technology_for_NOx_Reduction_in_Waste_To_Energy_Plants.pdf
- http://www.thermopedia.com/content/752/
- http://aecenar.com/index.php/downloads/send/3-meae-institute/504-nlap-wedc-report-2-2018-pdf
- http://aecenar.com/index.php/downloads/send/3-meae-institute/359-281016masterthesismayssakamareddine-temo-ipp
- http://www.gmab.se/dioxin-removal/
- https://www.gasmet.com/products/category/emission-monitoring-systems/continuous-emissions-monitoring-system-cems-ii-e/
- https://www.gasmet.com/products/category/emission-monitoring-systems/continuous-mercury-monitoring-system-cmm/

27 Eng.Alaa Zakaria, North Lebanon Alternative Power (www.nlap-lb.com) طاقة الشمال 9/15/2019

4 Fuel burner unit

4.1 FreeCAD Design

4.1.1 Holder of fuel burner

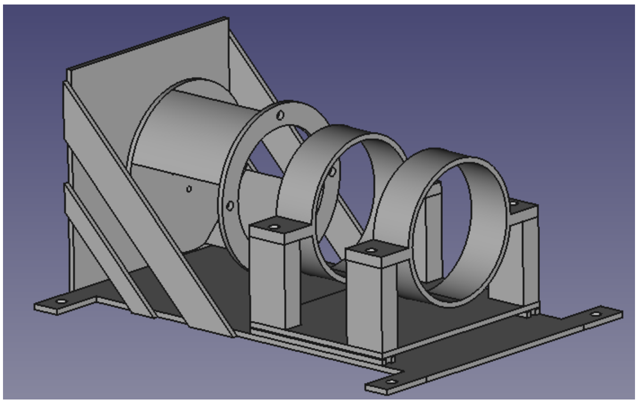
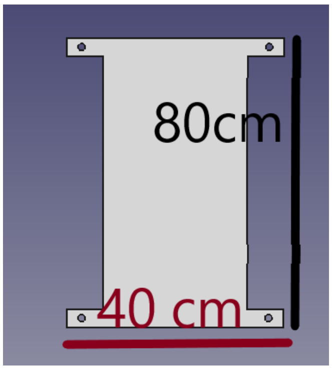
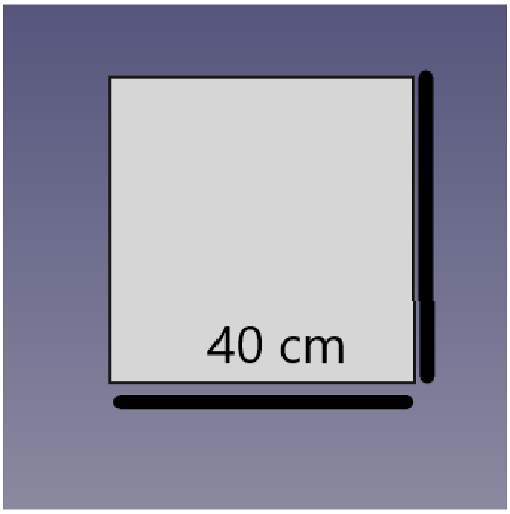


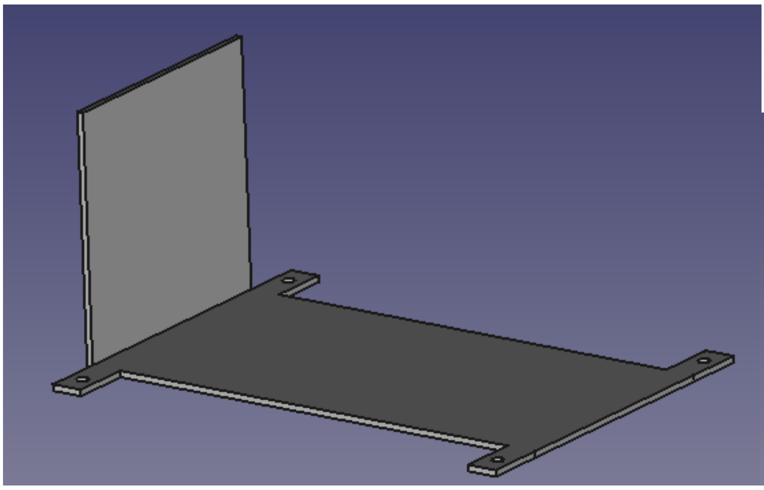
Figure 27: FreeCad holder of fuel burner

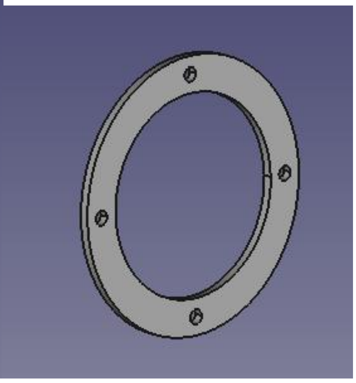


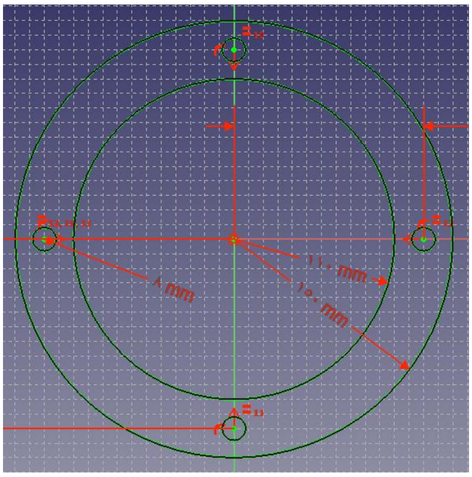


thickness: 10 mm

diameter of holes: 20 mm



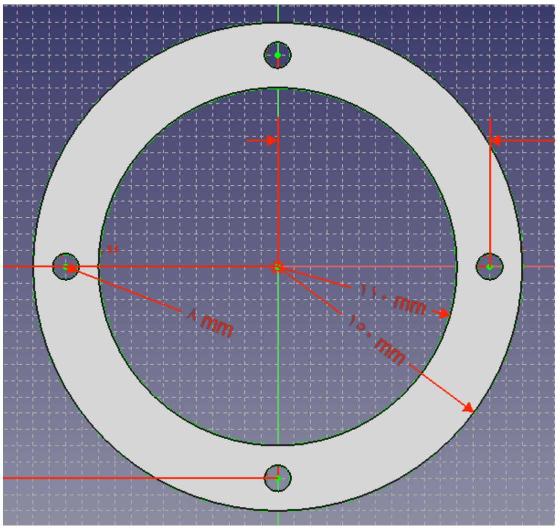




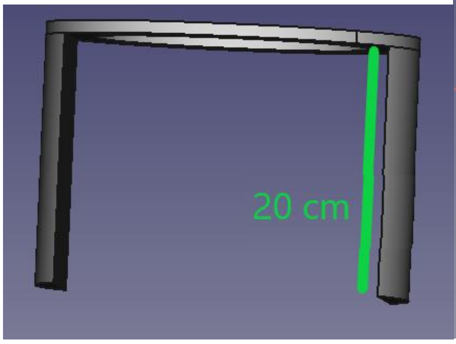
Int diametre: 22 cm

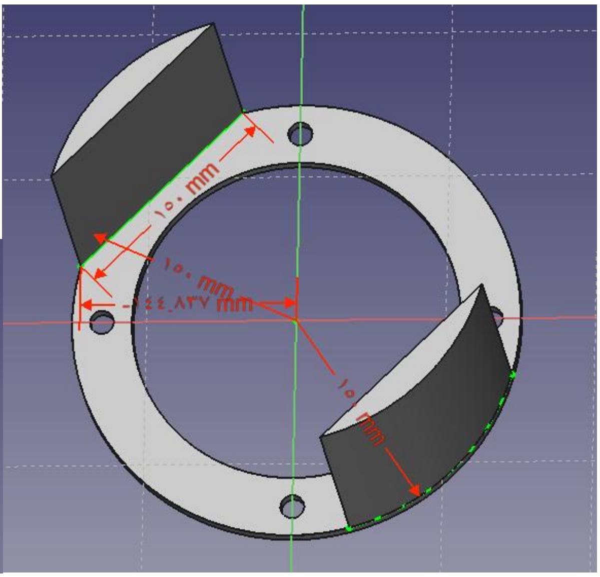
Ext diameter: 30 cm

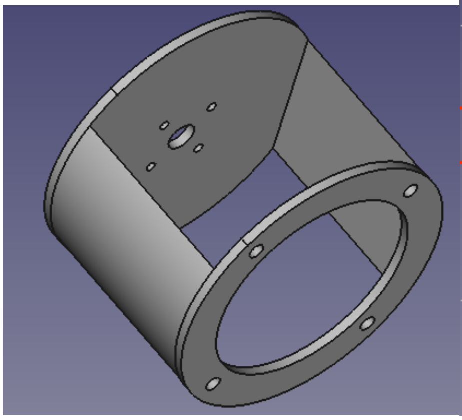
Diam of holes : 16 mm

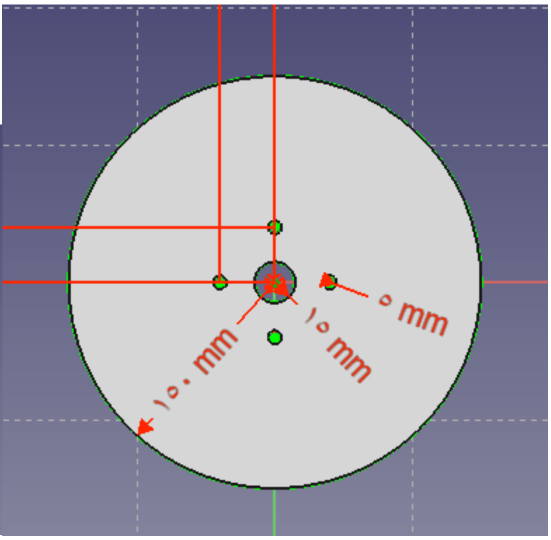


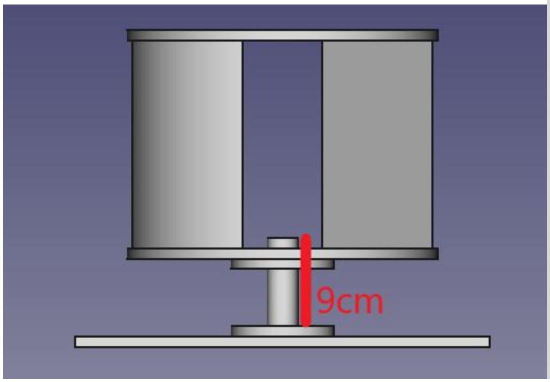
Thibkness : 10 mm

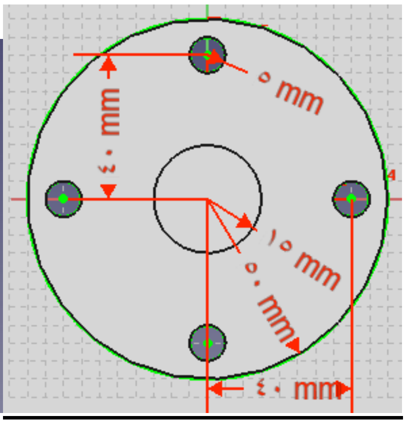

20 cm

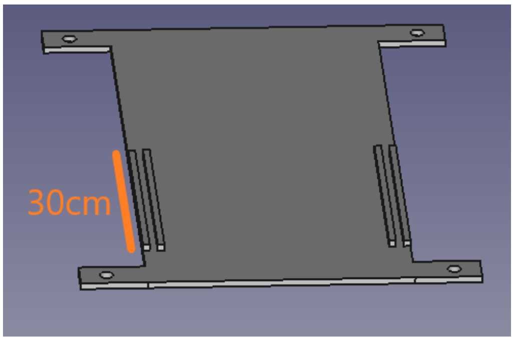

١٥٠ mm
١٥٠ mm
-١٤٤.٨٣٧ mm
١٥٠ mm

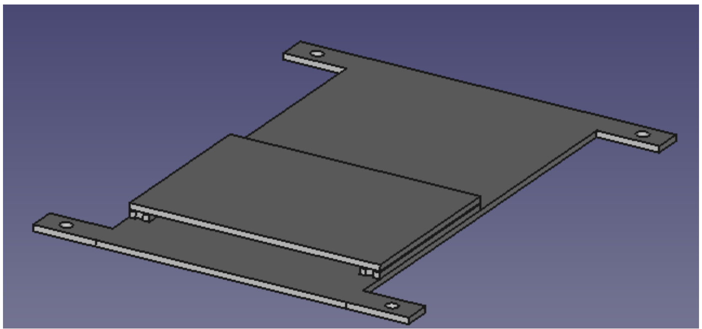


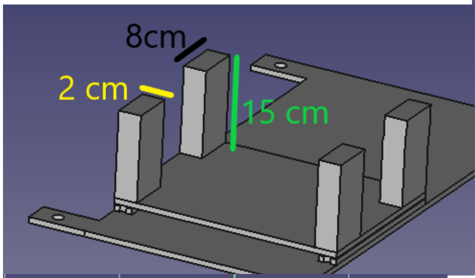

٥ mm
١٥ mm
١٥٠ mm

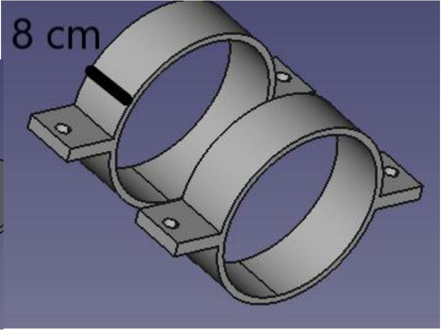

9cm

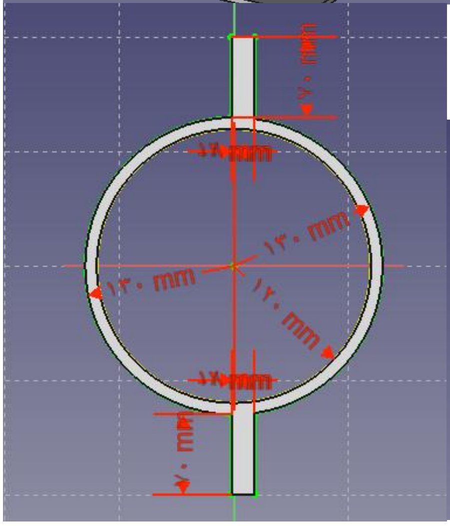

٥ mm
٤٠ mm
١٥ mm
٥٠ mm
٤٠ mm

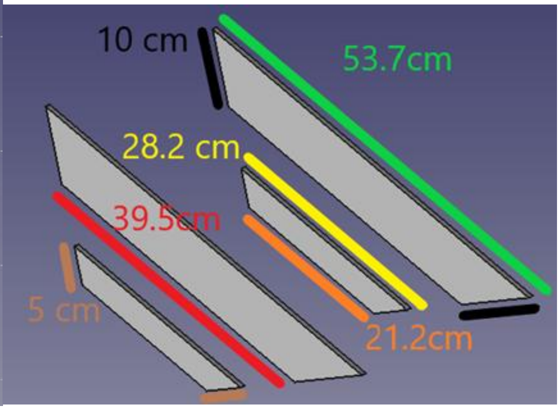

30cm




8cm
2 cm
15 cm


8 cm


٧٠ mm
١٣٠ mm
١٣٠ mm
١٢٠ mm
٧٠ mm


10 cm
53.7cm
28.2 cm
39.5cm
5 cm
21.2cm

4.2 Manufactoring







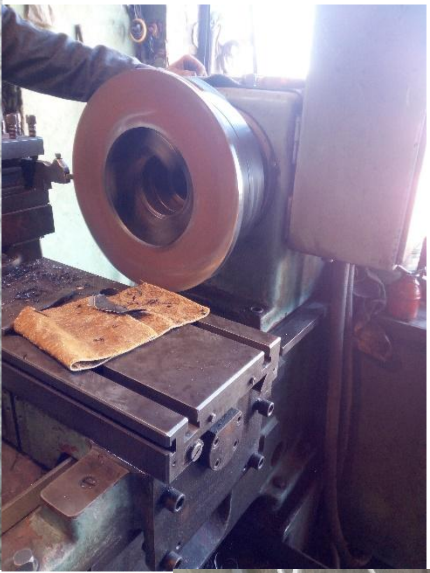


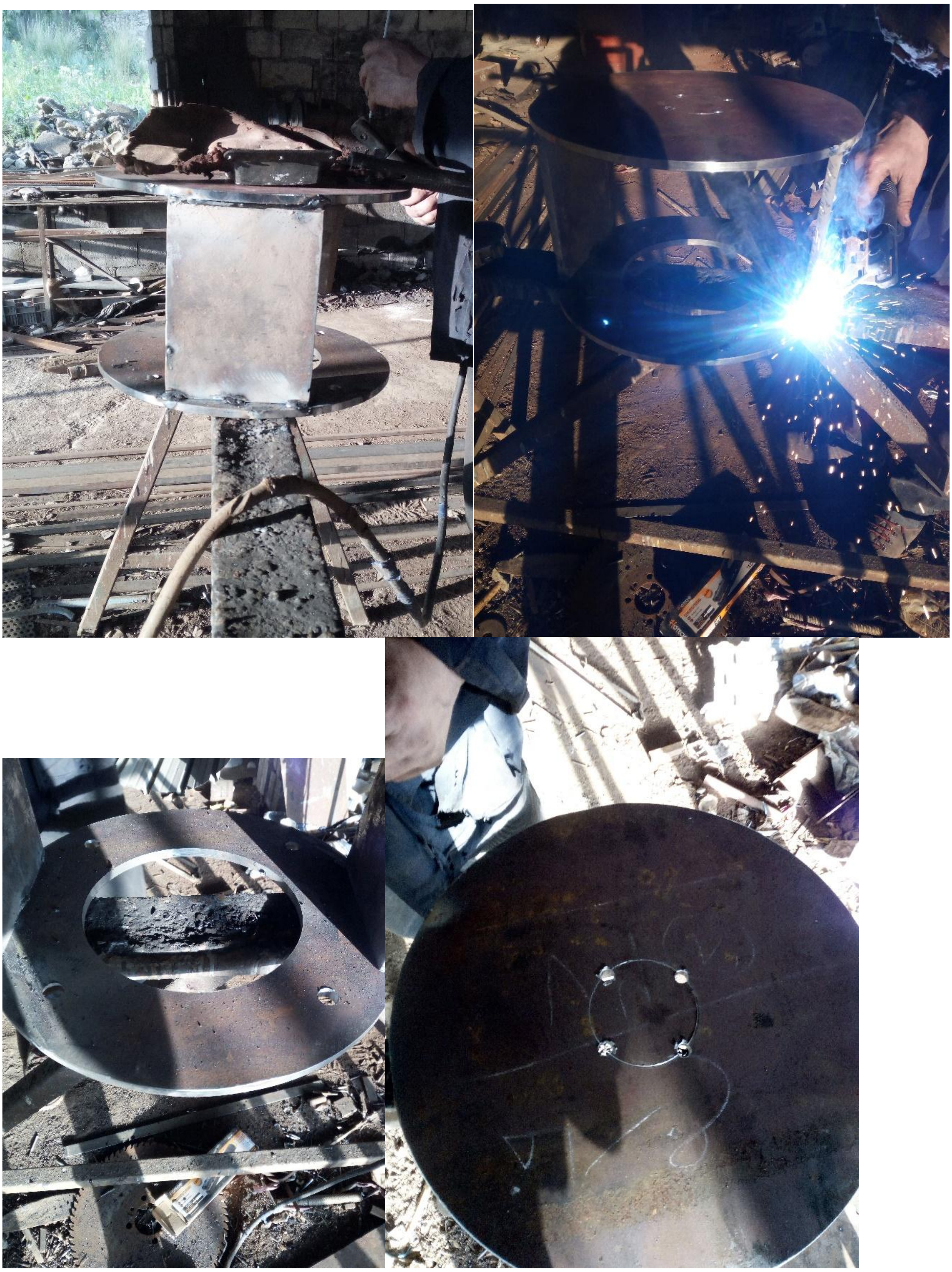












4.2.1 Integration

5 Alkaline Electrolysis of Water Unit

5.1 Overview

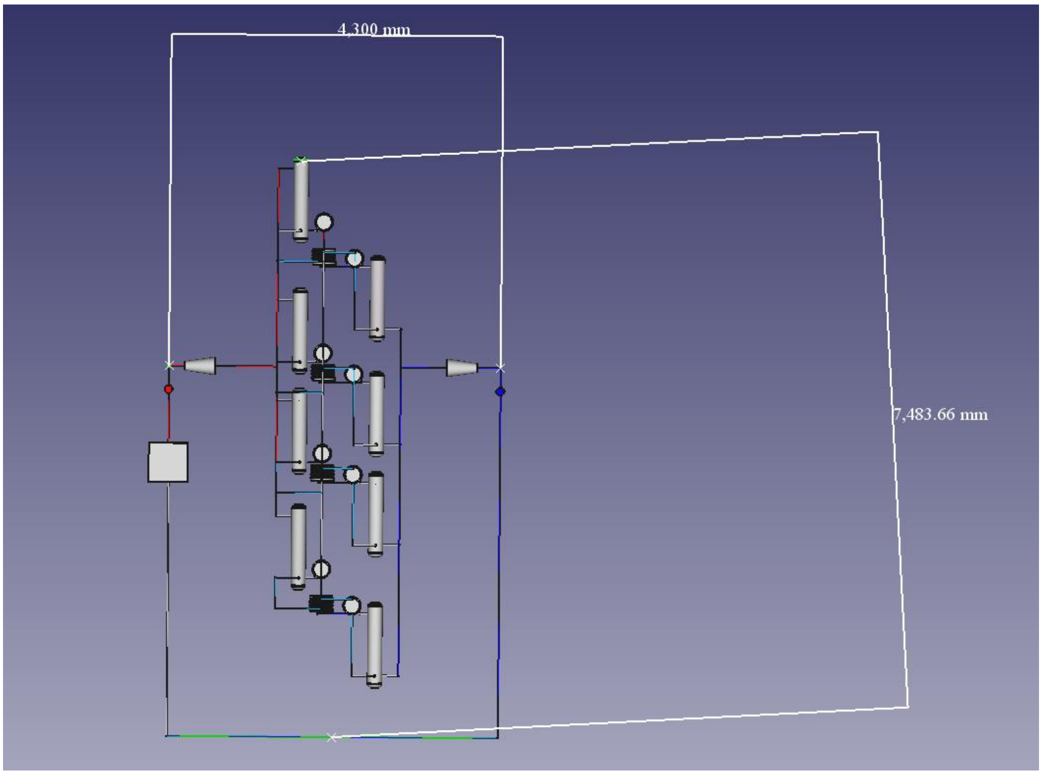


Figure 28: Plant of electrolysis (FreeCAD)

Specification	
Voltage	8 volt
Current	300 Ampere
Power	2.4 KW
KOH	5.7 Kg
Gas flow rate Hydrogen all stacks	2.27 $L.min^{-1}$
Gas flow rate Oxygen all stacks	1.13 $L.min^{-1}$
Dimensions	Electrode (Radius: 15 cm / thickness: 2cm) Stainless 304 Stack (Radius: 15 cm/ Thickness: 16 cm)

Table 13: Specification of electrolysis

8 Volt/ 300 Ampere

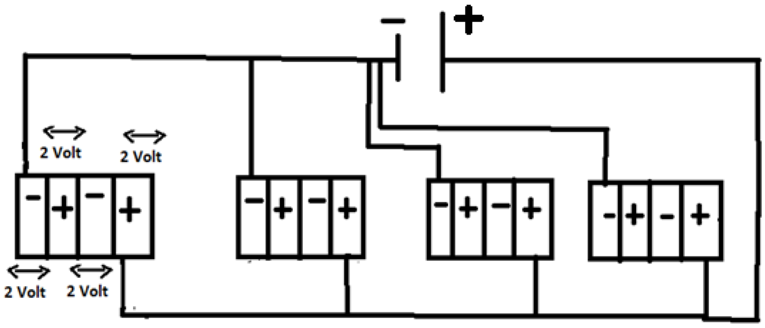


Figure 29:Multistack Amperage/Voltage

Each stack has 4 serial cells (2+2+2+2 = 8 Volt / 75 Ampere)

4 stack parallel (8 Volt/ 75 Ampere*4 = 300 Ampere)

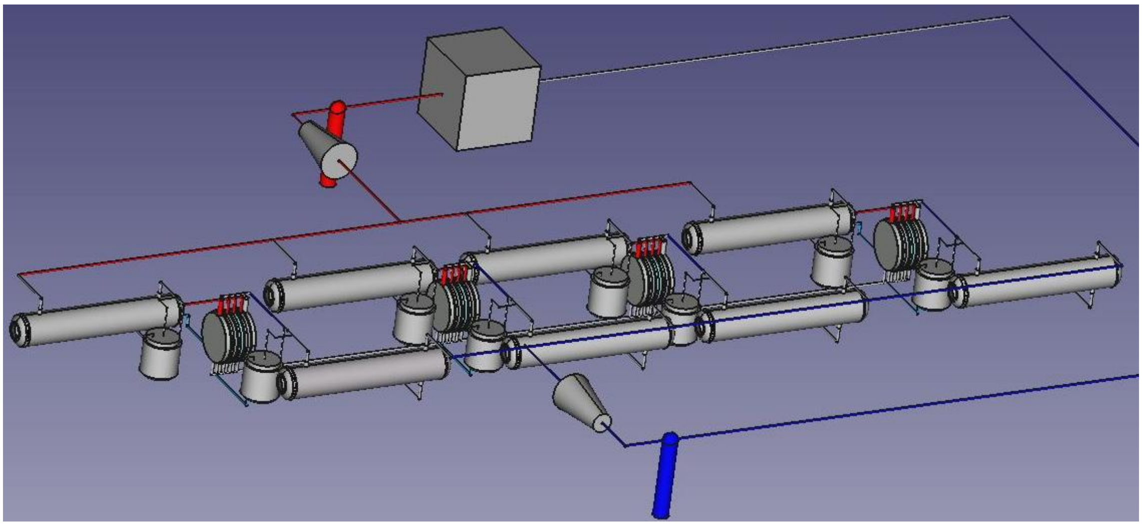
- Each electrode has thickness 2 cm: 166.6 g (KOH)

We have 30 electrodes (2 cm) => 30 * 166.6 = 5000 g (KOH)

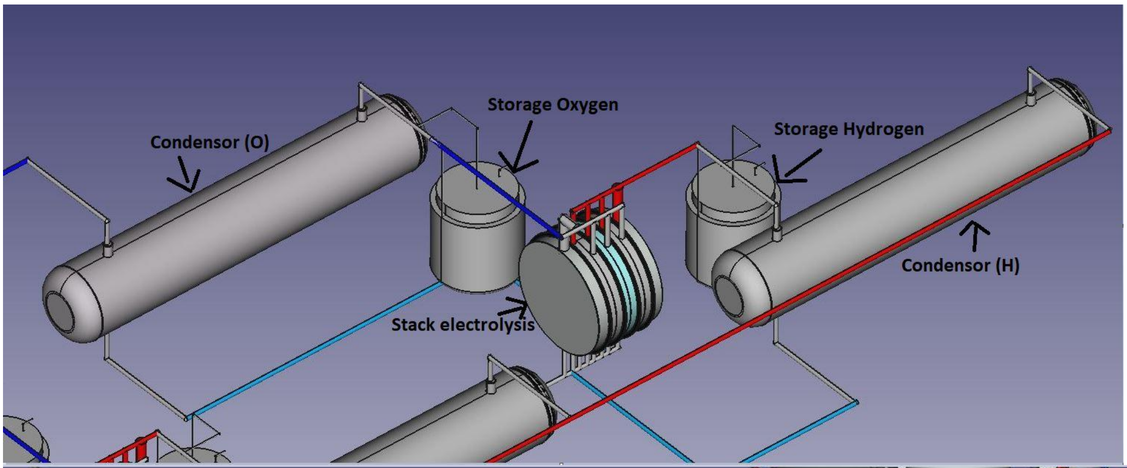
- Electrode has thickness 4 cm: 333.3 g (KOH)

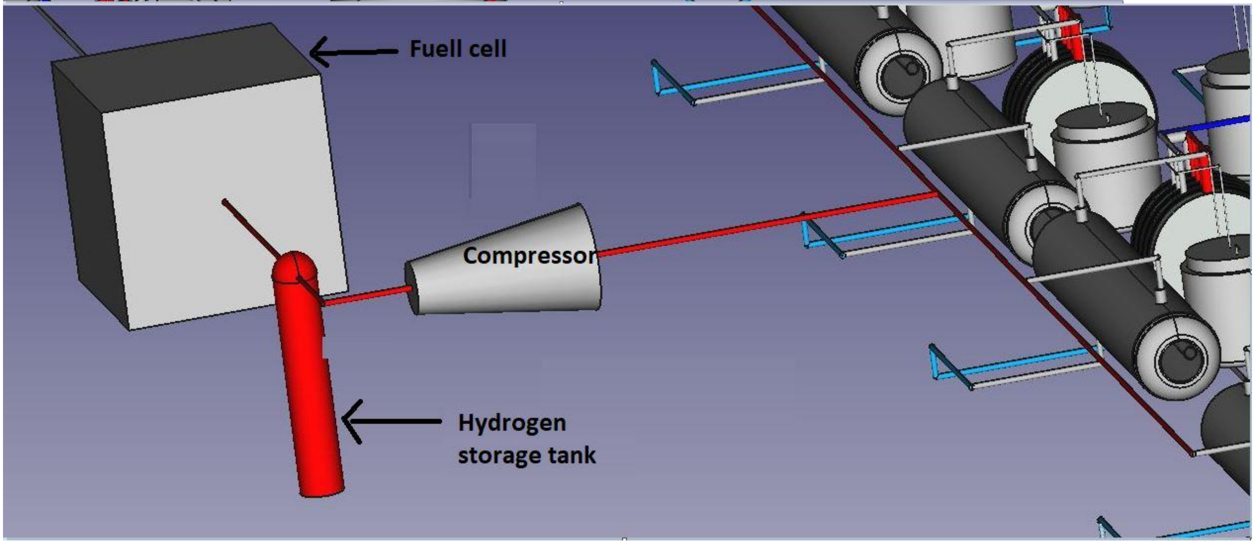
We have 2 electrodes (4 cm) => 2 * 333.33 = 666.6 g (KOH)

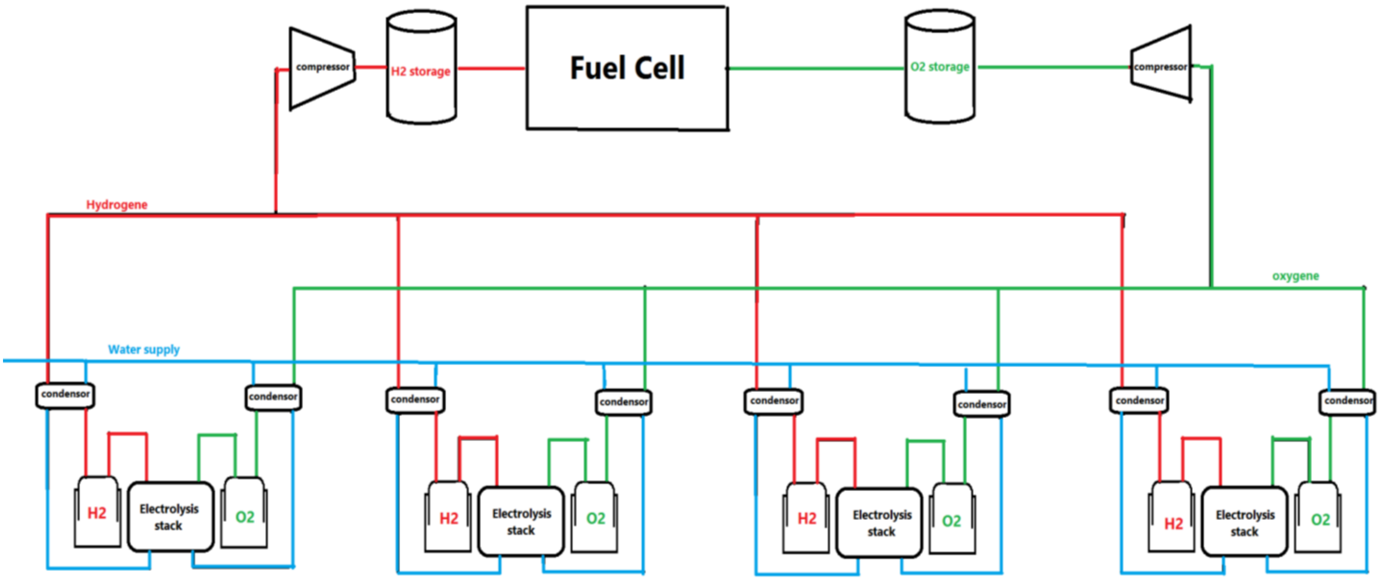
5.2 Design FreeCad



160319_electrolysis_
multistack.FCStd


Storage Oxygen
Condensor (O)
Storage Hydrogen
Condensor (H)
Stack electrolysis


Fuell cell
Compressor
Hydrogen
storage tank


compressor
H2 storage
Fuel Cell
O2 storage
compressor
Hydrogene
oxygene
Water supply
condensor
condensor
H2
Electrolysis stack
O2
condensor
condensor
H2
Electrolysis stack
O2
condensor
condensor
H2
Electrolysis stack
O2
condensor
condensor
H2
Electrolysis stack
O2

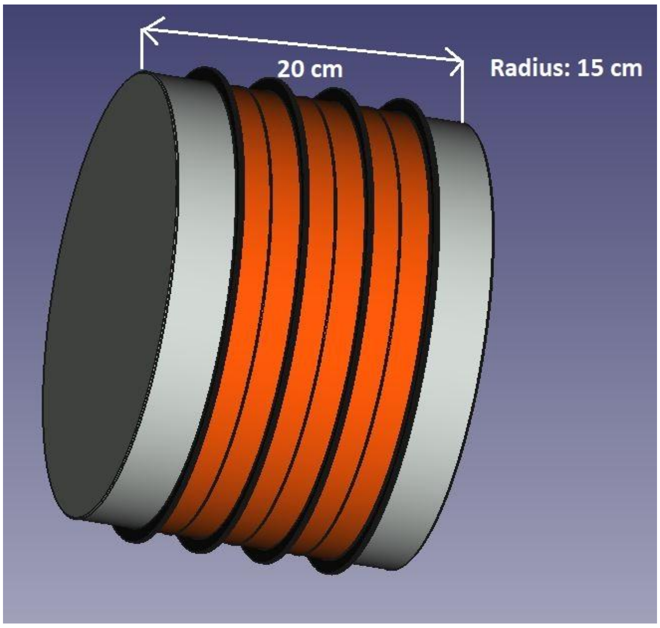
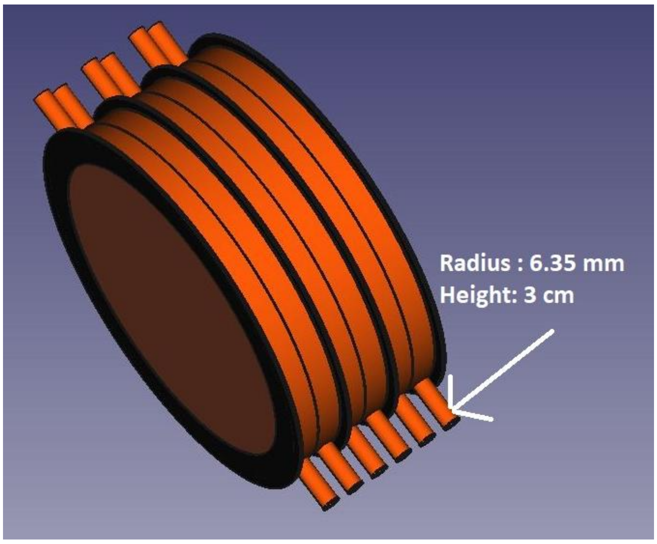


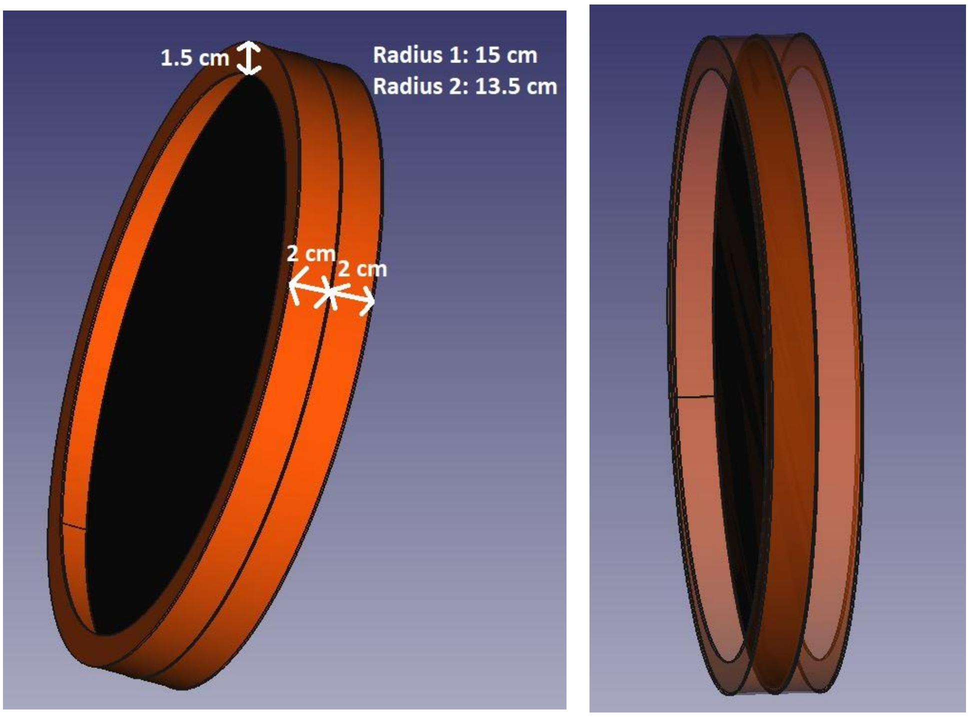
Figure 30: Serial stack

180319_Stack_electrolysis.FCStd

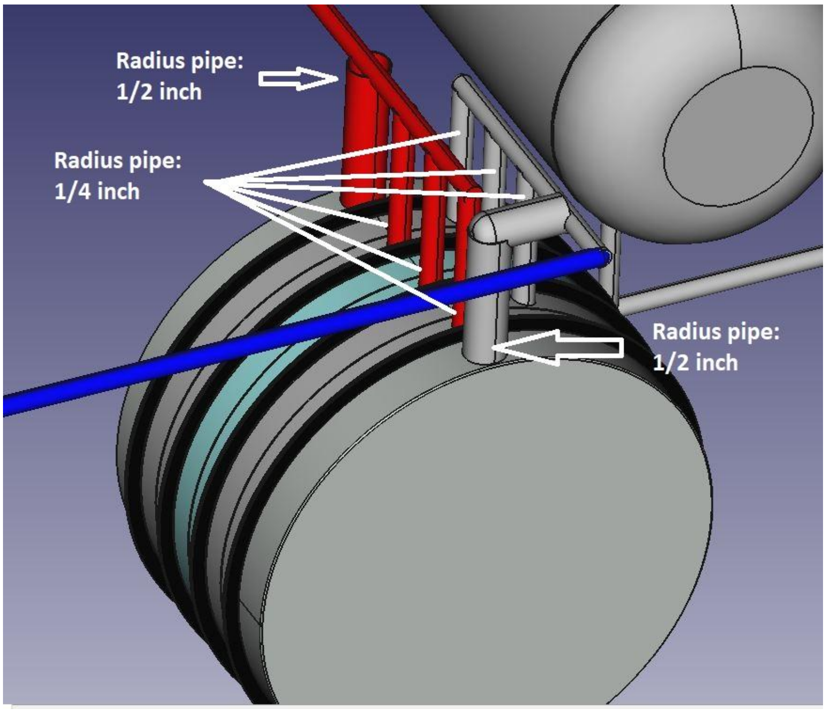
Stack



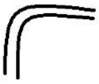
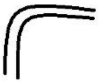
180319_baseplate_electrolysis.FCStd

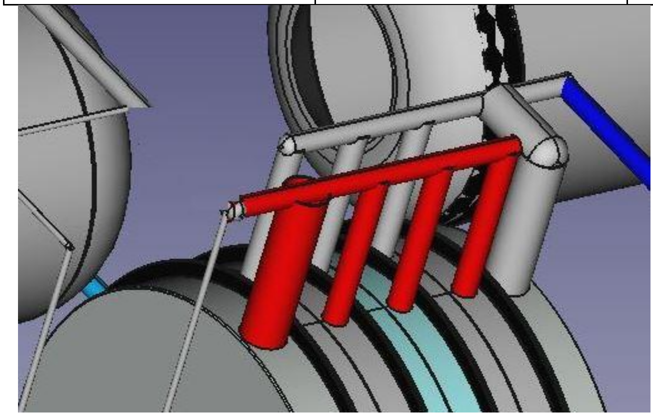


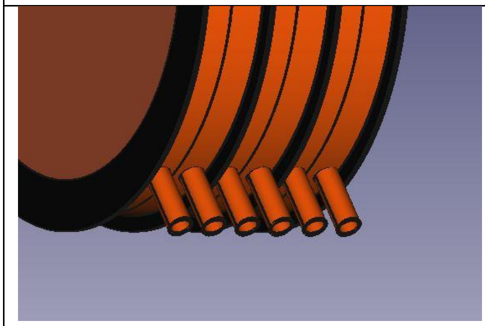
Base plate

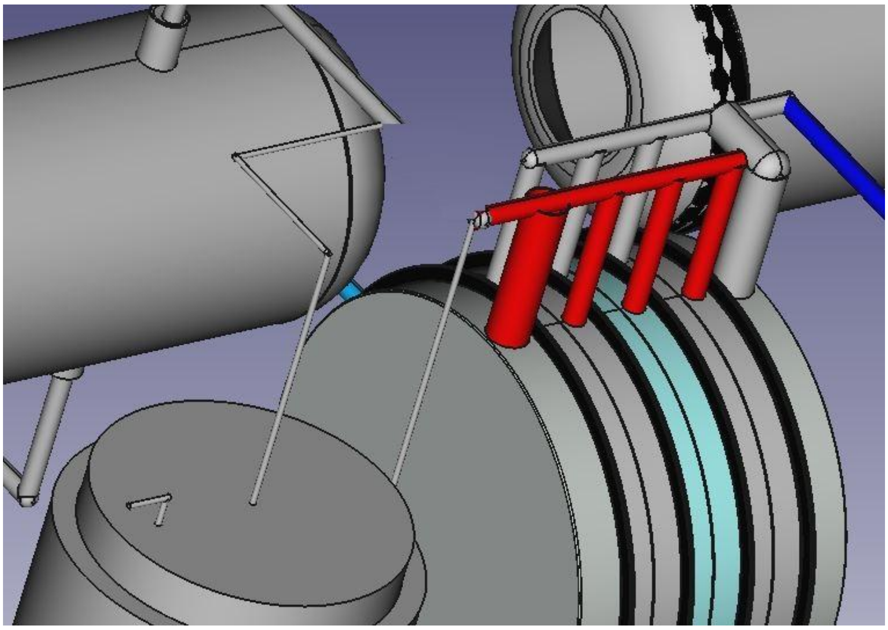


مواد	عدد	المقاس	الشكل
قسطل	6	¼ انش طول 10 سنتمتر	
محول	2	من ½ الى ¼	

كوع	1	½ انش	
كوع	4	¼ انش	
	4	¼ انش	



مواد	عدد	المقاس	الشكل
قسطل	6	¼ انش طول 10 سنتمتر	
	5	¼ انش	



5.3 Calculation of the amount of water and KOH

$V=\prod.R^2.h$

Radius: 15 cm

H_1 : 4 cm H_2 = 2 cm

$V_1=\prod.R^2.h_1$

$= \prod. 0.15^2 . 0.04$

$= 2.82* 10^{-3}$ m³

$= 2.82* 10^{-3}.10^6$ cm³

$=2.82*10^3$ cm³

=2.82 liter

$V2 =\prod.R^2.h_2$

$= \prod. 0.15^2 . 0.02$

$= 1.41* 10^{-3}$ m³

$= 1.41* 10^{-3}.10^6$ cm³

$=1.41*10^3$ cm³

=1.41 liter

The cell can contain 2.82 liter and 1.41 liter but in reality we want fell cell a)1 liter and b) 0.5 liter respectively

KOH

A. *The electrolysis need 25 % KOH in 1000 ml so 75 % is water*

250 g → 750 ml

??   <--1000 ml

Amount of KOH in one cell end plate electrode $= \frac{1000\,ml*250\,g}{750\,ml} = 333.33\,g$

We have 2 electrodes end plate: 2*333.3 g = 666.6 g

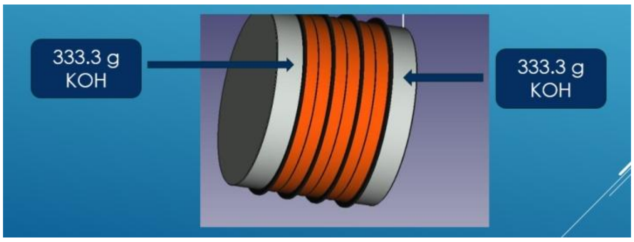


Figure 31: Amount of KOH

B. *The electrolysis need 25 % KOH in 500 ml so 75 % is water*

125 g → 375 ml

??   <--500 ml

Amount of KOH in one cell base plate $= \frac{500\,ml*125\,g}{375\,ml} = 166.66\,g$

We have 30 electrodes base plate: 30 * 166.66 g= 5000 g

5.4 Calculate gas flow rate

The maximum cell current value of 75 A is selected for the calculation. Faraday constant (F= 96485 C.mol^{-1} or C: coulomb (1C = 1A.s)). Moreover, Eq. 1 is used to calculate the number of hydrogen moles as follows.

$$n_{(H_2)} = \frac{I*t}{2F} = \frac{75\,(A)*60(s)}{2(electrons)*96485\,C.mol^{-1}} = 0.0233\,mol/min$$

Considering Eq. 2, assuming the pressure of 1 atm and the operating temperature of 25°C, the theoretical $V_{H2(g)}$ can be determined as,

$$V_{H_{2(g)}} = \frac{n_{H_2}RT}{P} = \frac{0.0233\,mol/\min*0.082\,Latm\,K^{-1}mol^{-1}*298\,K}{1\,atm}$$

$$V_{H_2} = 0.569\,L.\,min^{-1}$$

Each stack produce 0.569 L.min^{-1} => 4 stack produce = 0.569 L.min^{-1} * 4 (stack) = 2.279 L.min^{-1}

For oxygen:

The amount of substance for O_2 (g) can be determined by using either Eq. 5.1 or the electrochemical reaction of the alkaline electrolysis cell. According to the electro chemical reaction, the number of

O_2(g) moles should be half of H_2(g) moles. Hence, the number of O_2(g) moles can be easily determined as in Eq.

$$n_{O_2} = \frac{n_{H_2}}{2}$$

$$n_{O_2} = 0.0116\, mol/min$$

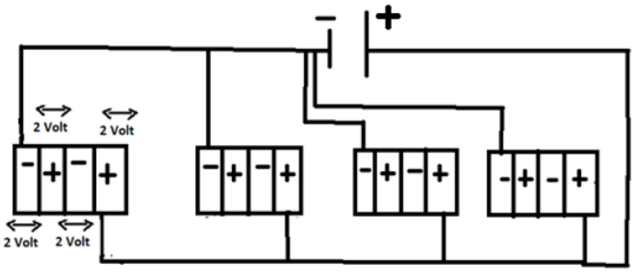
$$V_{O_{2(g)}} = \frac{n_{O_2}RT}{P} = \frac{0.0116\, mol/\min * 0.082\, Latm\, K^{-1}mol^{-1} * 298\, K}{1\, atm}$$

$$V_{O_2} = 0.284\, L.min^{-1}$$

Each stack produce 0.284 L.min^{-1} => 4 stacks produce = 0.284 $L.min^{-1}$ * 4 (stacks)= 1.138 L.min^{-1}

Other https://www.editions-petiteelisabeth.fr/calculs_electrolyse_3.php

5.5 Power supply



- Density current for electrolysis: 0.2 – 0.4 A/cm²
- Our cell contains 0.5 liter = 250 cm²
- Current apply for each cell $= \frac{250\, cm^2 * 0.3\, A/cm^2}{1 cm^2} = 75\, A$
- Voltage apply for each cell is 2V
- Each stack has 4 serial cell => voltage = 4*2 = 8 V
  Current = 75A
- The total is 4 parallel stack => voltage = 8 V
  Current = 4 * 75 = 300 A
- Power apply: Power = voltage x Current = 8 Volt x 300 Ampere = 2.4 KW

5.6 Simplified Design[3]

5.6.1 Level Control System

tubes=12.5mm,6mm

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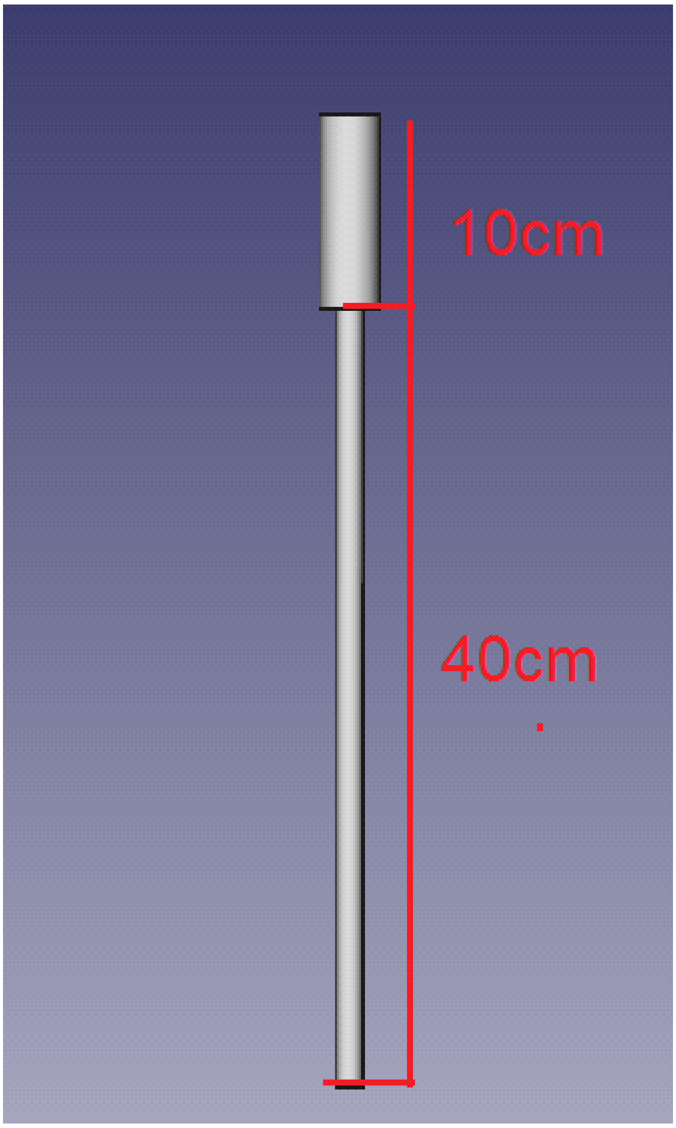
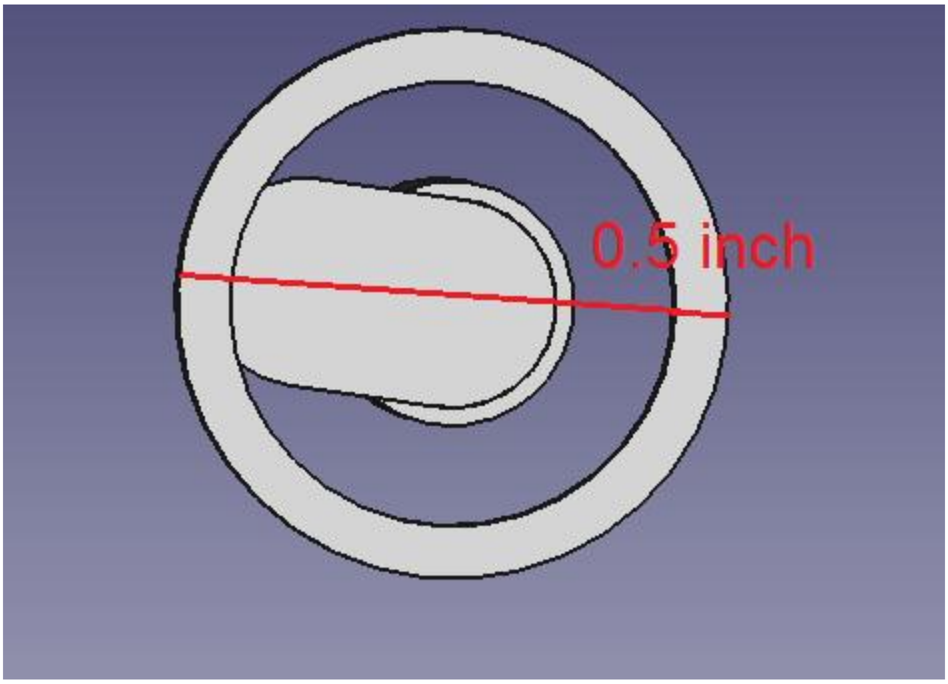
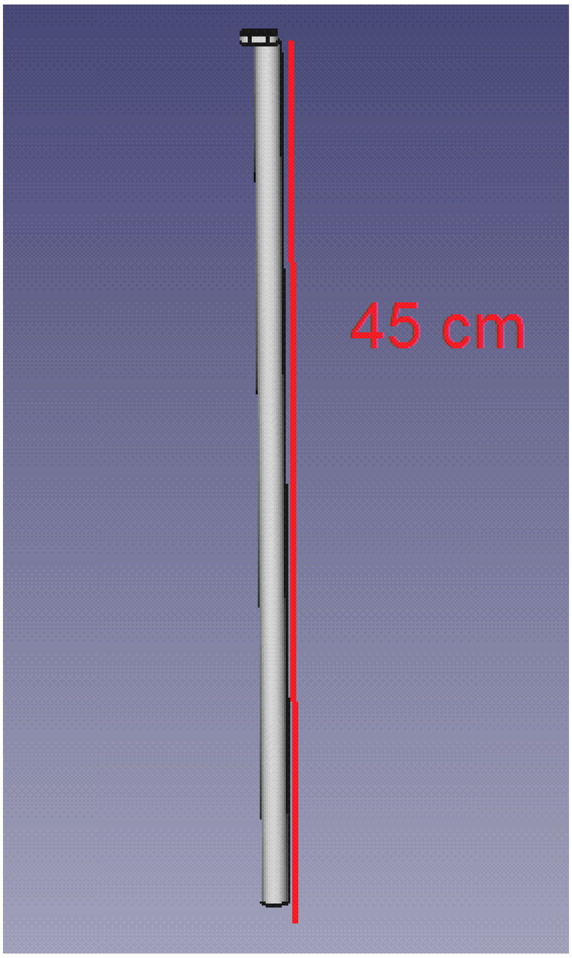
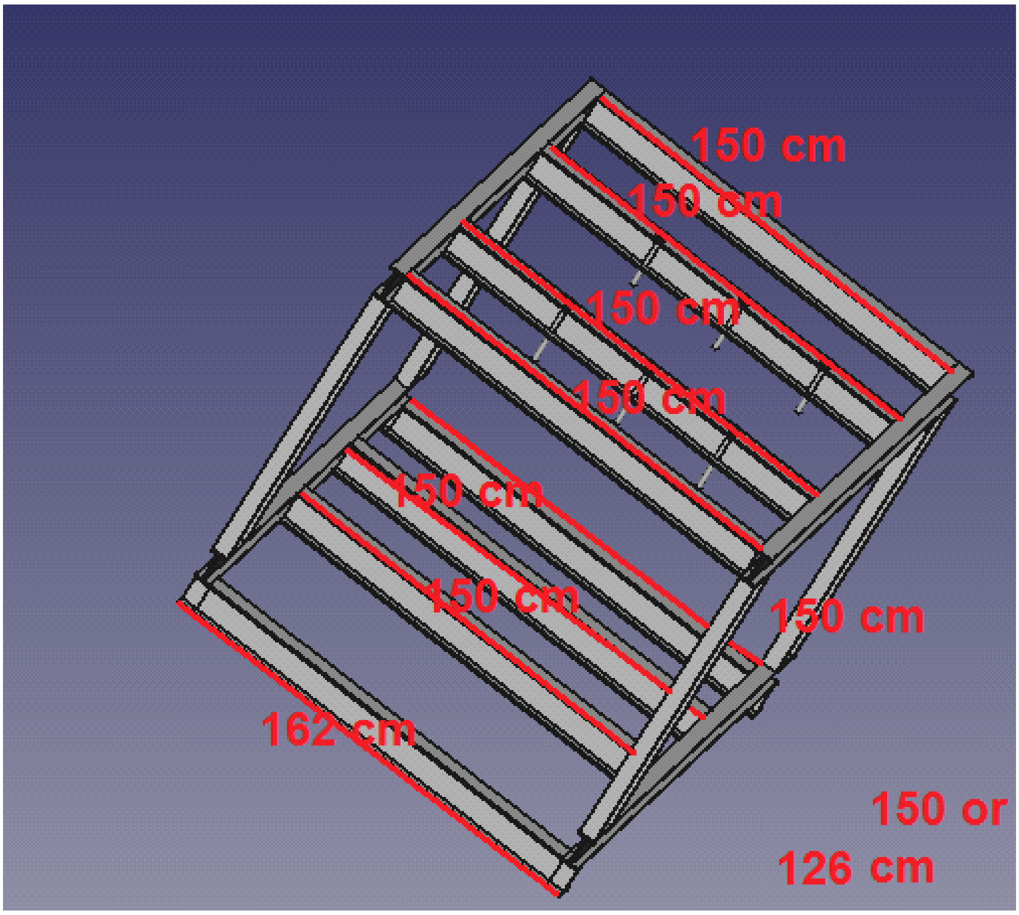
[3] Samer Youssef, July/Aug 2019

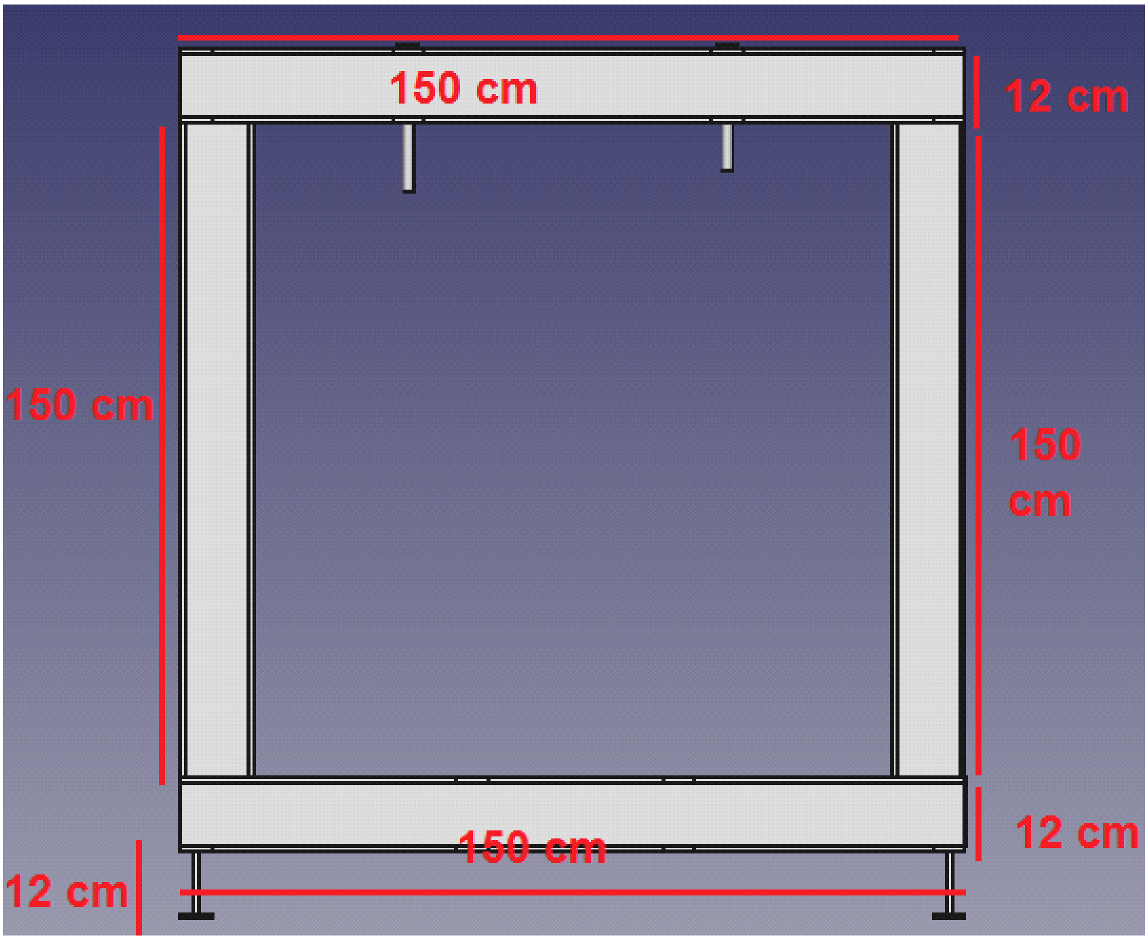

10cm
40cm

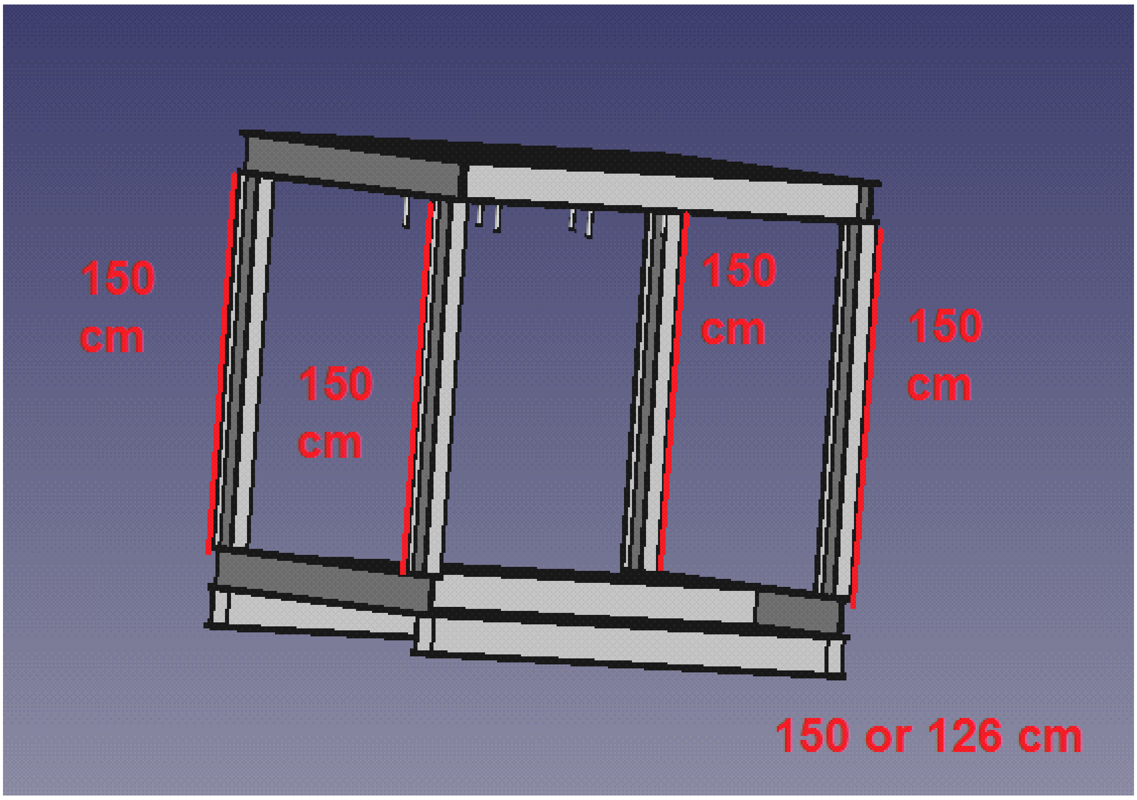

0.5 inch


45 cm

5.6.2 Electrolyser Container

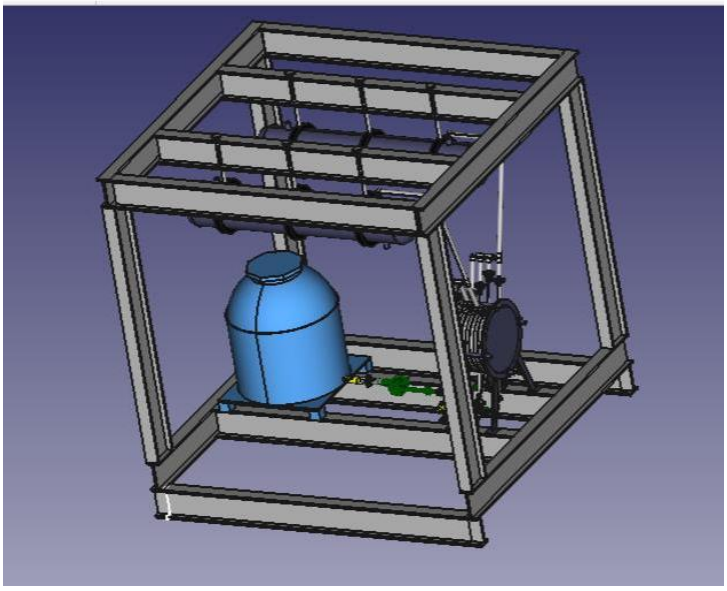






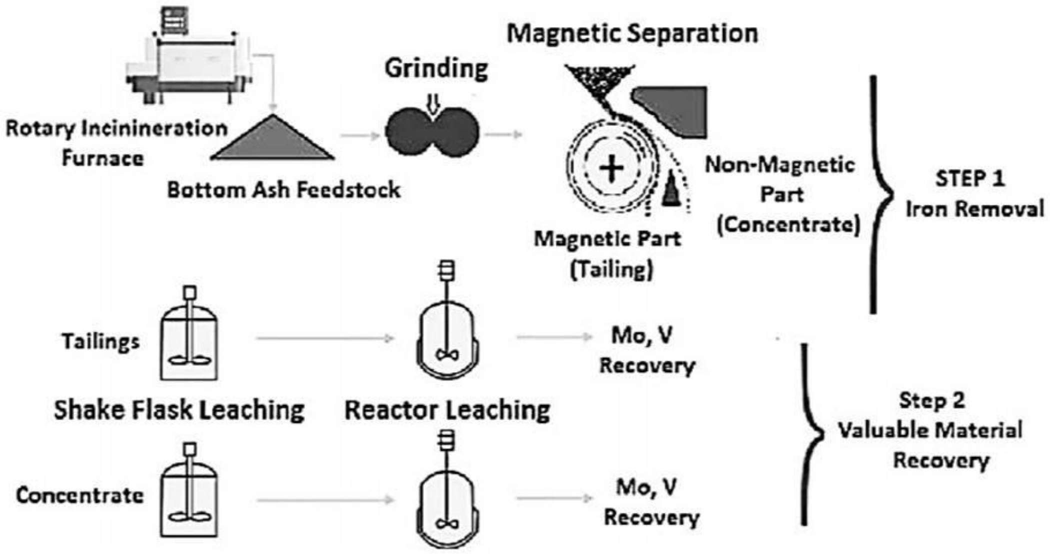
numbers of columns : 2-(162)cm
14-(150)cm.. or.. 12(126)cm
2(150)cm.

5.6.3 Integration

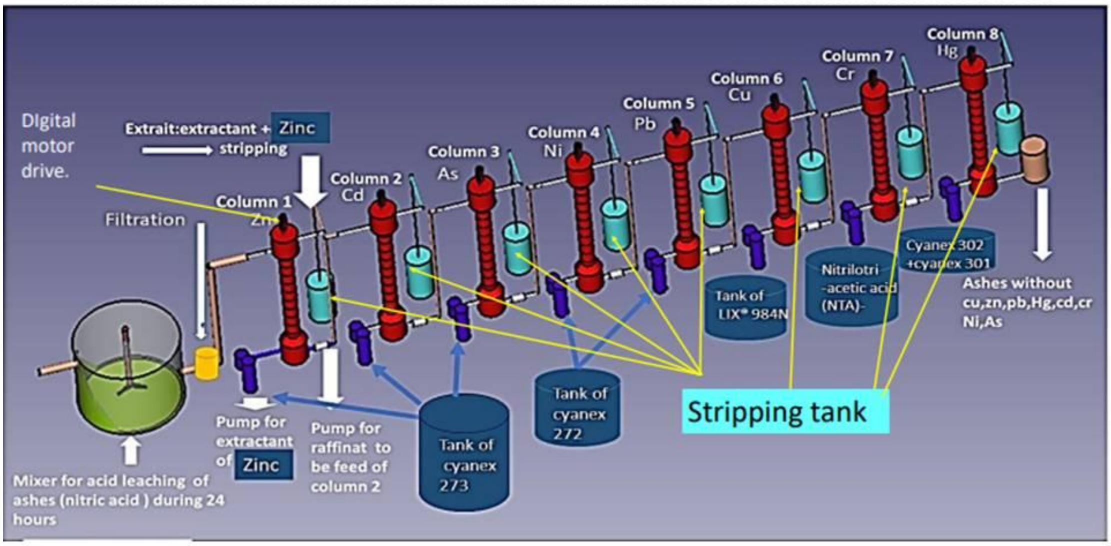
	110619NLAP-WEDC_ElectrolysisUnit.FCStd

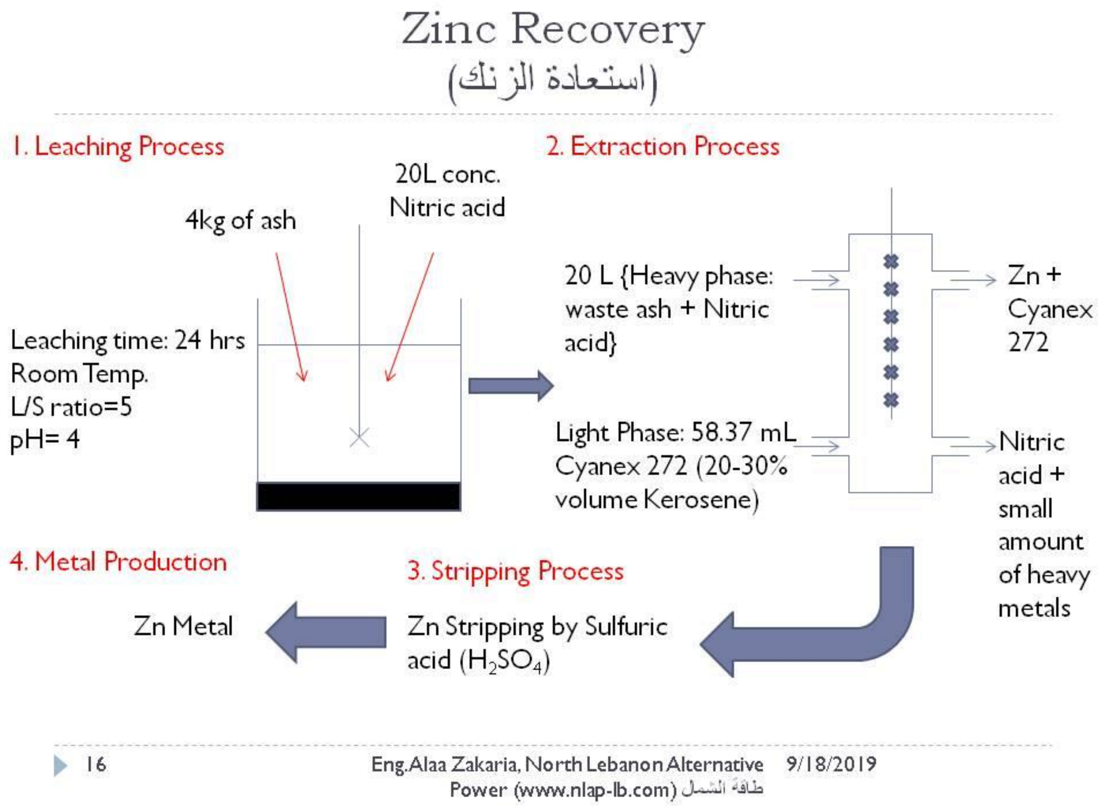
6 Heavy Metals Recycling: Overview

Heavy Metals Recycling Unit
(وحدة إعادة تدوير المعادن الثقيلة)



Heavy Metals Recycling Unit
(وحدة إعادة تدوير المعادن الثقيلة)





Zinc Recovery

(استعادة الزنك)

1. Leaching Process

4kg of ash

20L conc. Nitric acid

Leaching time: 24 hrs
Room Temp.
L/S ratio=5
pH= 4

2. Extraction Process

20 L {Heavy phase: waste ash + Nitric acid}

Light Phase: 58.37 mL Cyanex 272 (20-30% volume Kerosene)

Zn + Cyanex 272

Nitric acid + small amount of heavy metals

3. Stripping Process

Zn Stripping by Sulfuric acid (H_2SO_4)

4. Metal Production

Zn Metal

16 Eng.Alaa Zakaria, North Lebanon Alternative Power (www.nlap-lb.com) طاقة الشمال 9/18/2019

7 Heavy Metals Recycling Unit (for Cu, Zn, As, Hg, Cd, Cr, Ni, Pb) for 0,8 tons of waste per hour (for 2 MW incineration power plant)

Table of figures

In order to built a complete system of heavy metals recovery , we deliver this document to indicate the process used ,operation,instruments and their cost.

7.1 Introduction

Waste-to-energy is an environmentally sound method for reducing the mass and volume of non-recyclable refuse that would otherwise require landfilling. Combustion typically reduces the volume of the refuse by 90% and reduces the solid mass by 70-80%. The resulting ash, while largely inert, can contain concentrations of heavy metals that require treatment in order to comply with regulations, meet standards for producing a usable product, and to provide for long-term stability of the metals when the ash is exposed in the environment. Heavy metals such as lead and cadmium can be toxic to biological systems when present in high enough concentrations.

The bottom ashes, produced by the industrial incinerators, are an essential secondary raw material resource which has been drawing attention to recover economically important metals.

7.1.1 Overview of the system of recycling

Fresh bottom ash samples from the burning incineratorswere collected and dried at 25°C. The unburnt parts such as the screw, wire, plastics were separated manually. Prior to leaching tests (discussed in the next section), the sample was reduced to a size of 500 microns with a roll crusher in order to remove the magnetic content (iron removal). the bottom ash samples (tailings and concentrates) were subjected to leaching tests in order to notice the amenability of the samples for metal recovery along with optimization ofnparameters. The step wise experimental procedure adopted is shown in Figure 1 and the following sections details the methodology. It is important to reduced the size to 500 microns with a roll crusher in order to remove the magnetic contents. the solution is leached and enteres in a series of column when the liquid mixes with a suitable liquid extractants to separate the metals from the solution.

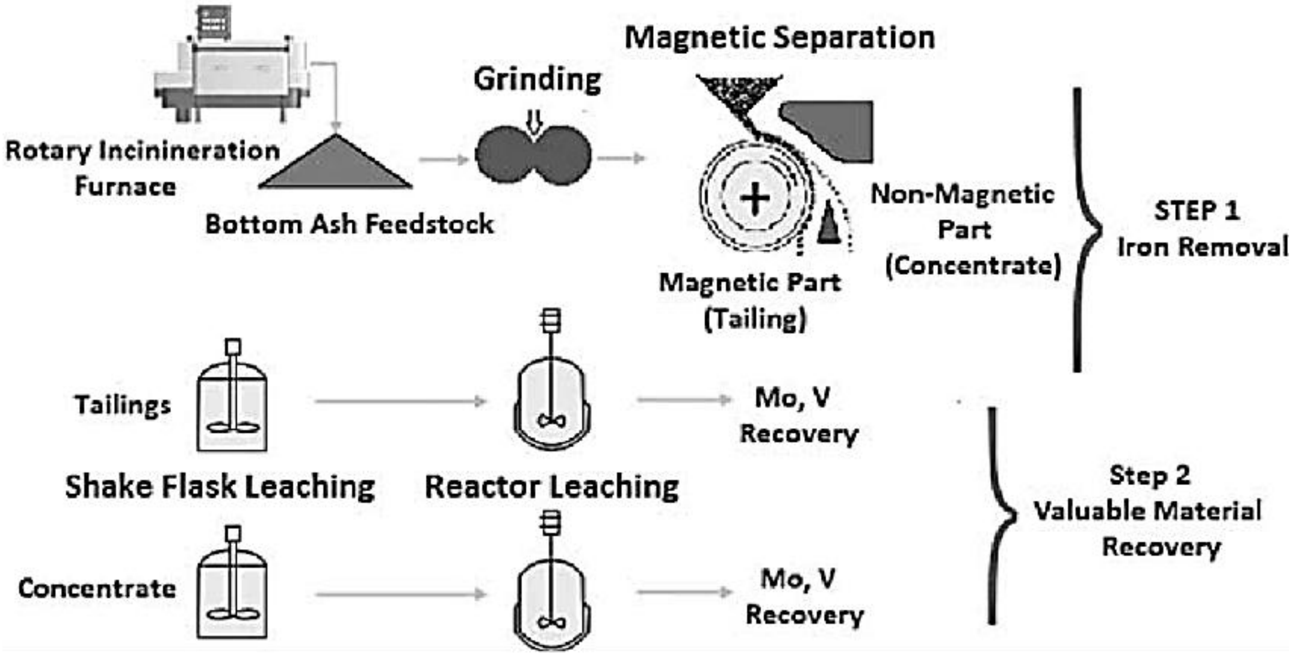


Figure 32: Stepwise experimental procedure adopted for leaching of bottom ash.

7.2 Technology of separation

7.2.1 Principle

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.

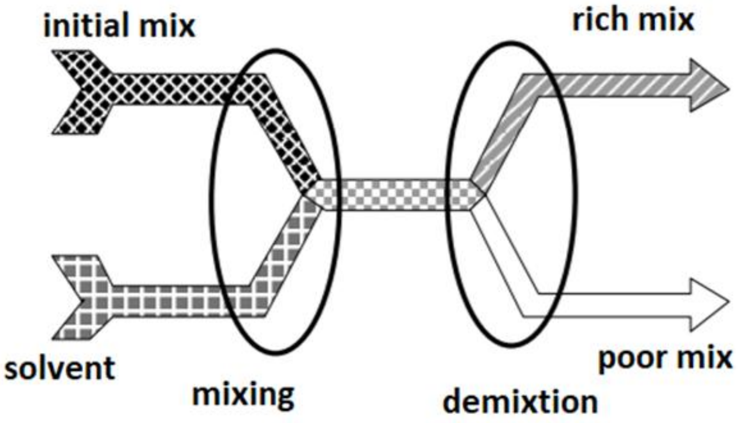


Figure 33: principle of a separation stage by obtaining a balance

Practically, the feed solution F containing 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.

7.2.1.1 The phase equilibrium of ternary mixtures

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.

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 3.

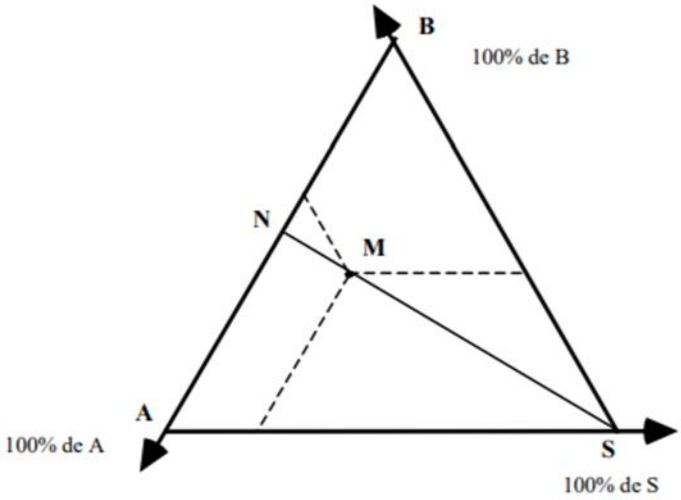


Figure 34:ternary diagram

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:

(mass of N)/(mass of S)=MS/MN

The demixtion

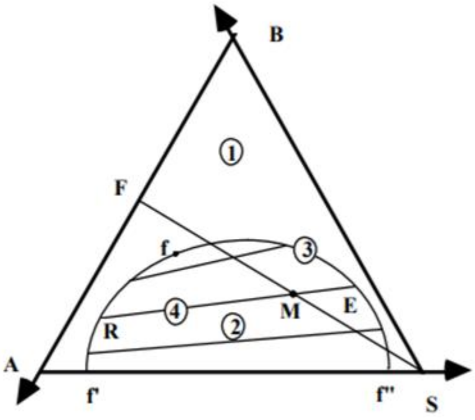


Figure 35:Isothermal and isobaric demixing curve.

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.

Solvent separation

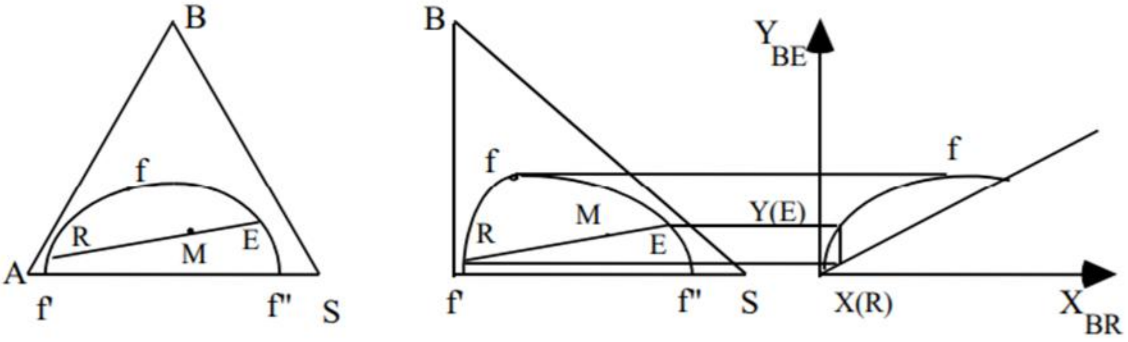


Figure 36:Representation of a ternary system with limited miscibility

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.

7.2.2 Rotating discs column (RDC)

In a rotating discs column (RDC-column) the central shaft equipped with fixed discs is rotating. In addition to that annular rings, so called stators are placed on the inside of the column always in the middle of the distance between two discs. These stators can either be made of metal and inserted into the column or can be integrated in column made of borosilicate glass. The discs have a smaller diameter than inner diameter of the stators so that the shaft can be easily dismantled. Diameters and distances have to be adapted to the process. During operation only the rotating speed can be altered beside the throughput.(https://www.dedietrich.com/en/solutions-and-products/extraction/liquid/liquid-extraction/extraction-columns

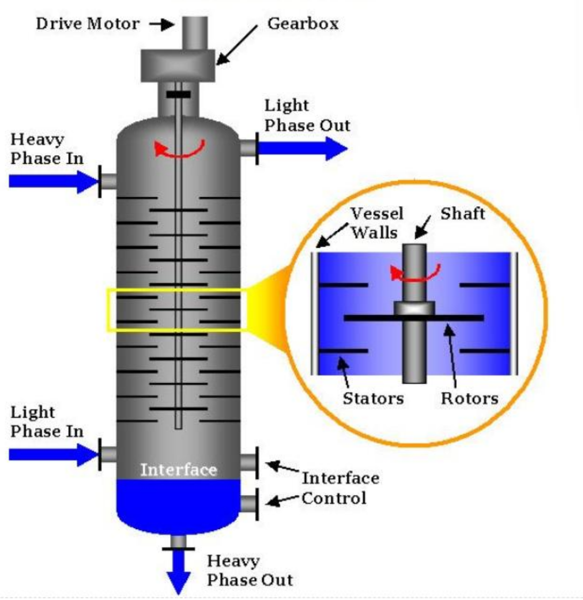
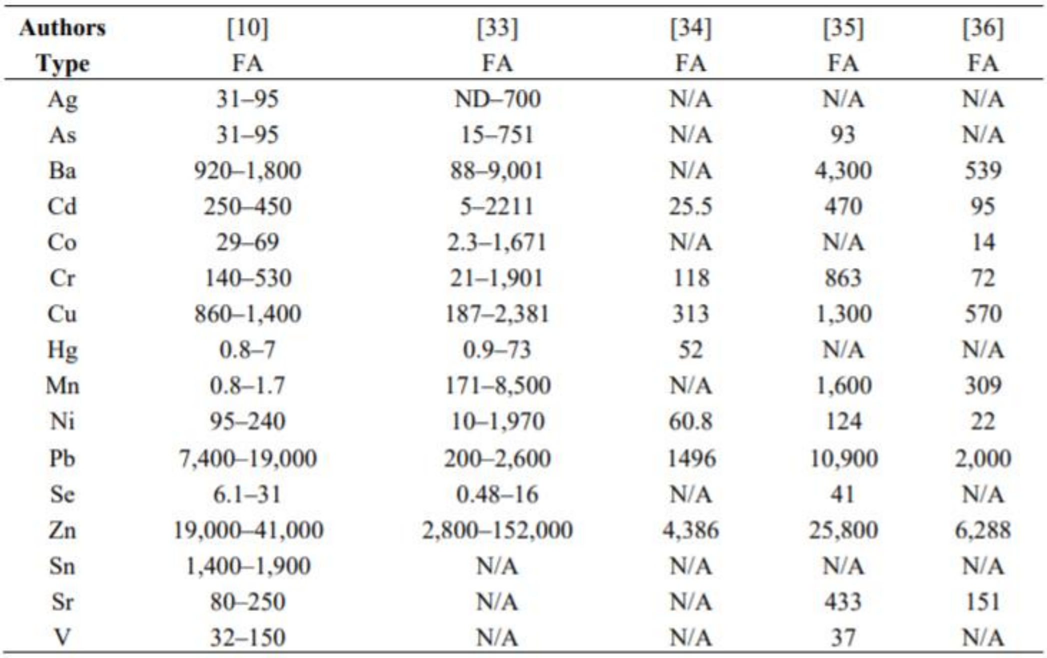


Figure 37: RDC column (https://kochmodular.com/liquid-liquid-extraction/extraction-column-types/rdc/)

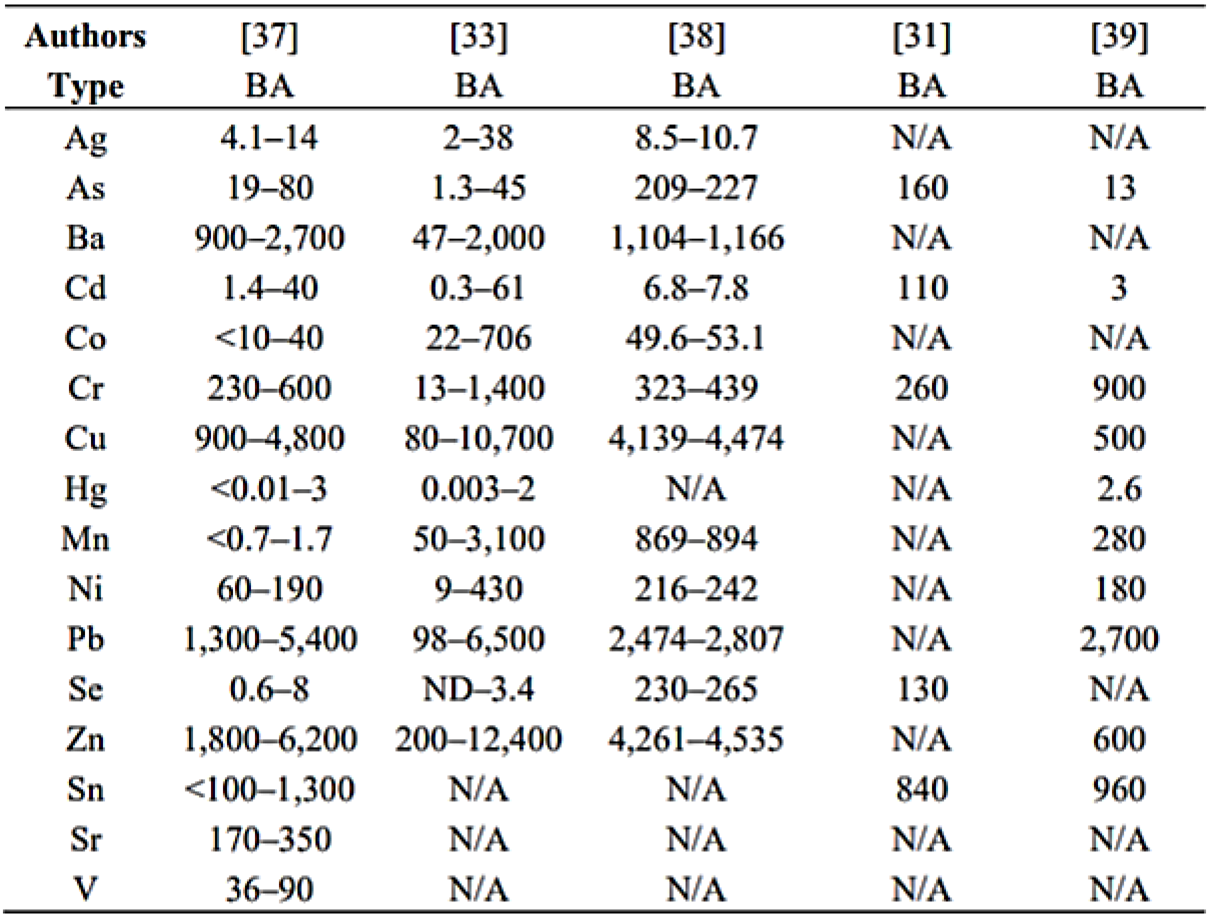
7.2.3 Quantities of heavy metals in ashes from different plants

7.2.3.1 Fly ash



Authors Type	[10] FA	[33] FA	[34] FA	[35] FA	[36] FA
Ag	31–95	ND–700	N/A	N/A	N/A
As	31–95	15–751	N/A	93	N/A
Ba	920–1,800	88–9,001	N/A	4,300	539
Cd	250–450	5–2211	25.5	470	95
Co	29–69	2.3–1,671	N/A	N/A	14
Cr	140–530	21–1,901	118	863	72
Cu	860–1,400	187–2,381	313	1,300	570
Hg	0.8–7	0.9–73	52	N/A	N/A
Mn	0.8–1.7	171–8,500	N/A	1,600	309
Ni	95–240	10–1,970	60.8	124	22
Pb	7,400–19,000	200–2,600	1496	10,900	2,000
Se	6.1–31	0.48–16	N/A	41	N/A
Zn	19,000–41,000	2,800–152,000	4,386	25,800	6,288
Sn	1,400–1,900	N/A	N/A	N/A	N/A
Sr	80–250	N/A	N/A	433	151
V	32–150	N/A	N/A	37	N/A

7.2.3.2 Bottom ash



Authors	[37]	[33]	[38]	[31]	[39]
Type	BA	BA	BA	BA	BA
Ag	4.1–14	2–38	8.5–10.7	N/A	N/A
As	19–80	1.3–45	209–227	160	13
Ba	900–2,700	47–2,000	1,104–1,166	N/A	N/A
Cd	1.4–40	0.3–61	6.8–7.8	110	3
Co	<10–40	22–706	49.6–53.1	N/A	N/A
Cr	230–600	13–1,400	323–439	260	900
Cu	900–4,800	80–10,700	4,139–4,474	N/A	500
Hg	<0.01–3	0.003–2	N/A	N/A	2.6
Mn	<0.7–1.7	50–3,100	869–894	N/A	280
Ni	60–190	9–430	216–242	N/A	180
Pb	1,300–5,400	98–6,500	2,474–2,807	N/A	2,700
Se	0.6–8	ND–3.4	230–265	130	N/A
Zn	1,800–6,200	200–12,400	4,261–4,535	N/A	600
Sn	<100–1,300	N/A	N/A	840	960
Sr	170–350	N/A	N/A	N/A	N/A
V	36–90	N/A	N/A	N/A	N/A

Figure 39: Heavy metals found in MSWI bottom ash (BA) (mg/kg).

7.2.4 Extractants (light phase)

Many heavy metlas are essentil trac elements for humans,animals and plamt in small amounts.

In larger amounts cause acute and chronic toxicity. There are Linked to learning disabilities,cancers and even death .Some of this metals are :**As, Cd, Cr, Hg, Ni, Pb, Zn, Cu.** At low pH, i.e. below 3 there is high release of Cu, Mn, Zn, Al, Fe but as the pH is increased the major metals Al, Fe and Si are usually less soluble.

Metals	**Extractants**
As	Phosphoric Acid (cyanex273)
Cd	Chloride solution - cyanex273
Cr	nitrilotriacetic acid (NTA)- Sulfuric acid, Hydrochloric acid, Nitric acid were at 500^0C and the range of extraction is from 263 to 222 mg/L. All of them were of industrial grades.
Ni	Versatic acid - cyanex 923 and cyanex 272 (Bis(2,4,4-trimethylpentyl)phosphinic acid)

Pb	Chloride solution- Cyanex 272(Bis(2,4,4-trimethylpentyl)phosphinic acid)
Zn **(Nitric acid 0.6-3M)/ pH= 4**	Phosphonic acid (cyanex273 is the best) – tri octyl phosphine oxide (cyanex 921) and Tributyl phosphate (TBP) dissolved in kerosene. - EDTA
Cu	- LIX® 984N (mixture of 2-hydroxy-5-nonylacetophenone oxime and 5-nonylsalicylaldoxime in a high flash diluent), - Acorga® M5640, - LIX® 622N) – - **Cupromex-3302** the maximum net transfer of copper will be about 10g/l,ph=1.2. - ethylendiaminetetraacetate (EDTA), or diethylenetriaminepentaacetate (DTPA) with concentration 3.0% at the pH range 3-9.
Hg **(liquid at ordinary temperature)**	- Chloroform (OAP,Ph=9.5) - By Cyanex 301 (Bis(2,4,4-trimethylpentyl)dithiophosphinic acid) and cyanex 302(Bis(2,4,4-trimethylpentyl)thiophosphinic acid) from hydrochloric acid media

7.2.4.1 Leaching tests

The prewashed sample was vacuum dried at 75°C over-night and subjected to acid leaching tests. Typically,1.00 g of the prewashed sample of fly ash was mixed with different weights of solid citric acid in 50 ml deionized water while the pH was kept constant at a selected value by adjusting with concentrated HNO_3 or NaOH solution.The effect of citric acid concentration was examined in the concentration range from 0.01 to 0.40 M (=mol/L),and the effect of liquid/solid ratio was examined at 10:1,20:1, and 50:1 (ml:g). After stirring for 1 h, the suspension was filtered and the clear solution was sent for heavy metal content analysis by means of ICP/AES. The leaching time was varied from 5 to 250 min, and the temperature was also varied from 25°C to 60°C for examination of the temperature effect. Nitric acid, sulfuric acid, hydrochloric acid, DL-malic acid, oxalic acid, and acetic acid were also examined to compare their leaching performance.

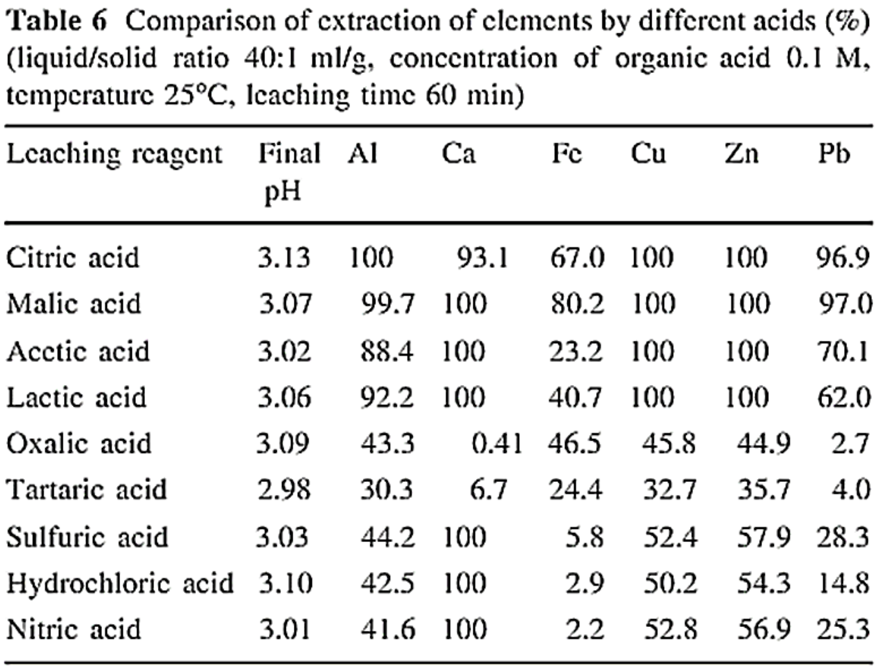
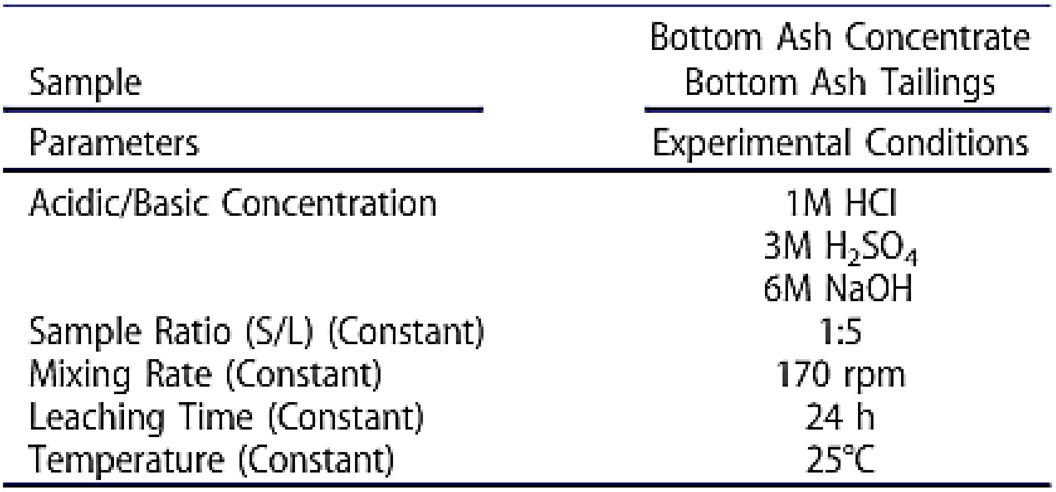


Table 6 Comparison of extraction of elements by different acids (%) (liquid/solid ratio 40:1 ml/g, concentration of organic acid 0.1 M, temperature 25°C, leaching time 60 min)

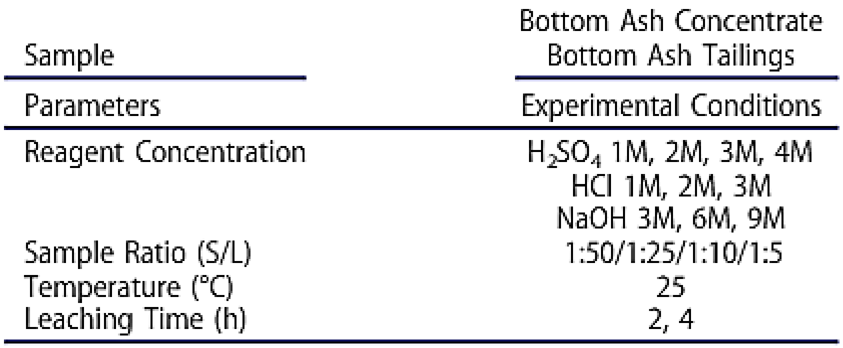
Leaching reagent	Final pH	Al	Ca	Fe	Cu	Zn	Pb
Citric acid	3.13	100	93.1	67.0	100	100	96.9
Malic acid	3.07	99.7	100	80.2	100	100	97.0
Acetic acid	3.02	88.4	100	23.2	100	100	70.1
Lactic acid	3.06	92.2	100	40.7	100	100	62.0
Oxalic acid	3.09	43.3	0.41	46.5	45.8	44.9	2.7
Tartaric acid	2.98	30.3	6.7	24.4	32.7	35.7	4.0
Sulfuric acid	3.03	44.2	100	5.8	52.4	57.9	28.3
Hydrochloric acid	3.10	42.5	100	2.9	50.2	54.3	14.8
Nitric acid	3.01	41.6	100	2.2	52.8	56.9	25.3

Experimental conditions of leaching (preliminary and main)



Sample	Bottom Ash Concentrate Bottom Ash Tailings
Parameters	**Experimental Conditions**
Acidic/Basic Concentration	1M HCl 3M H_2SO_4 6M NaOH
Sample Ratio (S/L) (Constant)	1:5
Mixing Rate (Constant)	170 rpm
Leaching Time (Constant)	24 h
Temperature (Constant)	25°C

Figure 40: Experimental conditions of preliminary leaching tests.



Sample	Bottom Ash Concentrate Bottom Ash Tailings
Parameters	Experimental Conditions
Reagent Concentration	H_2SO_4 1M, 2M, 3M, 4M HCl 1M, 2M, 3M NaOH 3M, 6M, 9M
Sample Ratio (S/L)	1:50/1:25/1:10/1:5
Temperature (°C)	25
Leaching Time (h)	2, 4

Figure 41: Experimental conditions of main leaching test

Note :6 M = 6mol/L

7.2.5 Fly ash

A portion of the fly ash was prewashed with distilled water.A 10-g sample of dried fly ash as-received was mixed together with distilled water at varying liquid/solid ratios[5–50:1 (ml:g)] in a beaker and stirred at room temperature of around 25°C. The suspension was sampled at different time intervals up to 16 h. After vacuum filtration, the metallic elements in the leachate were analyzed by using the ICP/AES spectrometre.

Table 1 Concentration of metal ions (mg/L) and pH in water after varying times of water washing (liquid/solid ratio 5:1 ml/g)

	5 min	10 min	30 min	1 h	2 h	16 h
pH	12.25	12.26	12.23	12.23	12.22	12.26
Na	7.99×10^3	8.09×10^3	6.77×10^3	5.68×10^3	5.05×10^3	4.81×10^3
K	1.92×10^3	1.44×10^3	1.77×10^3	1.46×10^3	1.13×10^3	1.33×10^3
Ca	5.23×10^3	5.23×10^3	4.72×10^3	4.29×10^3	3.87×10^3	2.79×10^3
Mg	0	0	0	0	0	0
Al	3.58	3.41	2.86	2.53	2.58	2.34
Zn	2.31	1.87	0.98	0.33	0	0
Pb	37.91	44.22	25.32	14.19	4.51	0.40
P	1.29	1.31	1.29	1.09	1.09	0.92
Cu	0	0.043	0.017	0	0	0
Fe	0	0.11	0	0	0	0

Table 2 Concentration of metal ions (mg/L) and pH in water after varying times of water washing (liquid/solid ratio 10:1 ml/g)

	5 min	10 min	30 min	1 h	2 h	16 h
pH	12.27	12.29	12.31	12.29	12.27	12.33
Na	3.93×10^3	3.86×10^3	3.69×10^3	3.50×10^3	3.36×10^3	3.31×10^3
K	0.85×10^3	0.54×10^3	0.73×10^3	0.81×10^3	0.48×10^3	0.42×10^3
Ca	3.37×10^3	3.39×10^3	3.27×10^3	3.20×10^3	3.03×10^3	2.58×10^3
Mg	0	0	0	0	0	0
Al	2.28	2.29	2.67	2.27	1.98	1.32
Zn	1.76	0.68	0.23	0.29	0	0
Pb	12.00	8.14	5.74	11.44	4.00	2.77
P	1.29	0.92	0.93	0.91	0.89	0.83
Cu	0	0	0	0	0	0
Fe	0	0	1.77	1.45	0	0

Table 3 Concentration of metal ions (mg/L) and pH in water after varying times of water washing (liquid/solid ratio 20:1 ml/g)

	5 min	10 min	30 min	1 h	2 h	16 h
pH	12.37	12.41	12.42	12.39	12.35	12.39
Na	1.95×10^3	1.96×10^3	1.90×10^3	1.89×10^3	1.87×10^3	1.91×10^3
K	0.66×10^3	0.63×10^3	0.54×10^3	0.68×10^3	0.56×10^3	0.67×10^3
Ca	2.29×10^3	2.22×10^3	2.20×10^3	2.23×10^3	2.15×10^3	2.10×10^3
Mg	0	0	0	0	0	0
Al	2.47	1.43	1.39	1.62	1.55	1.29
Zn	2.13	0.34	0	0	0	0
Pb	5.77	3.12	0.84	0.88	0.91	0.78
P	0.76	0.74	0.77	0.76	0.74	0.70
Cu	0	0	0	0	0	0
Fe	0	0	0	0	0	0

7.2.6 Recovery of Copper (Cu)

Copper is widely used because it has several essential properties for different technological applications, such as applications in electrical materials and construction, transportation and industrial machinery parts, petroleum refining and brass manufacture.

In view of the industrial and economic importance of this metal, there is a great need to separate and recover copper ions using cost effective commercial extractants. Literature review indicates that **hydroxyoximes** are now used widely as extractants for copper . The extraction of copper from aqueous sulfate solution with new extractant Cupromex-3302 (active substance is the 5-nonylsalicylaldoxime) using a rotating disc contactor (RDC) was investigated. It was observed from batch experiments that the best results were obtained with the initial aqueous pH and concentration of Cupromex-3302 of 1.9 and 10% (v/v) respectively.

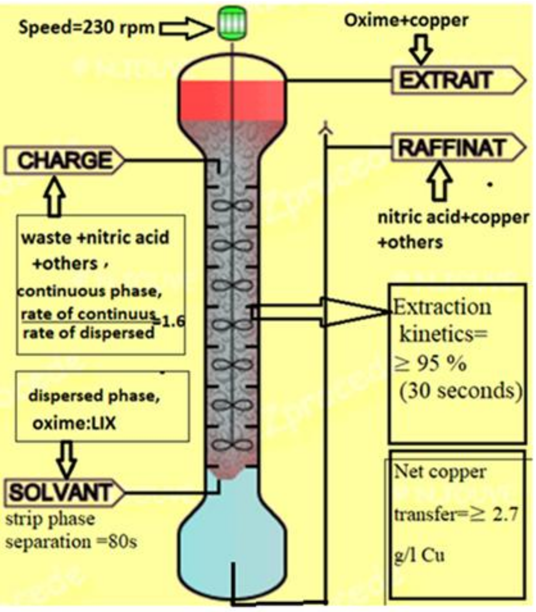


Figure 42:process of separation of copper

The maximum extraction efficiency was equal to 87.44% when the values of rotor speed, Qc and Qd were 375 rpm, 1.83×10^{-6} m^3/s and 2.33×10^{-6} m^3/s respectively. With

- Qc: continuous phase flow rate,
- Qd:dispersed phase flow rate.

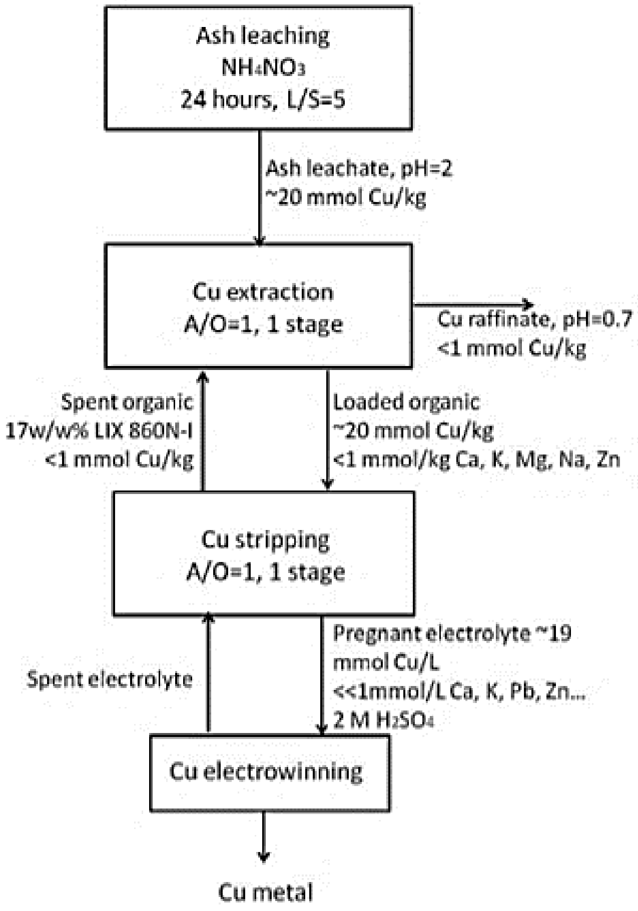


Figure 43: Flow sheet of the proposed recovery method developed for Cu from fly ash

7.2.7 Recovery of zinc

Nitric acid 0.6-3M was used for the ash leaching. The solvent extraction of Zn(II) from acid leachates was carried out using three extraction ligands that have been reported in the literature to be effective in separation of Zn from other metal ions in acid solutions. The ligands used were di-(2,4,4- tri methylpentyl) phosphinic acid (CYANEX 272), tri octyl phosphine oxide (CYANEX 921) and Tributyl phosphate (TBP) dissolved in kerosene and the extractions were carried out at initial pH 2, 3, 4 and 5. A special problem in these extractions is the separation between Zn(II) and Fe(III) from ash leachates. Leaching at pH 4 gives the lowest levels of iron in the leachate and may thus be a good starting point for the solvent extraction step since all tested ligands bind Fe(III) as well as Zn(II). CYANEX 272 gave the best results extracting about 90% of the Zn(II) in the ash leachates to the organic phase. For the fly ash leachate a ligand concentration of 30 vol% in kerosene was needed and for the bottom ash leachate the corresponding concentration was 20 vol%. The other two ligands gave significantly lower extraction results. Literature data indicate that their performance can be much better in a chloride rich media. Thus, they can be interesting to test if ash is leached with hydro chloric acid instead of nitric acid. Based on the results CYANEX 272 is indicated as a suitable extractant for the recovery of zinc from MSWI plant ashes.

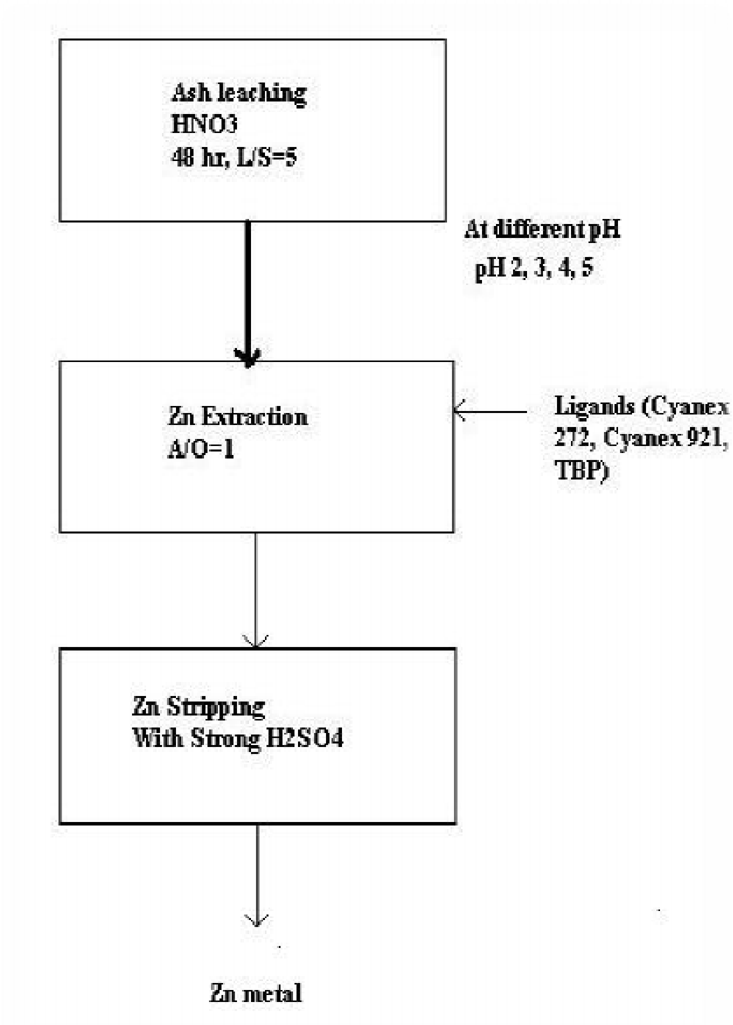


Figure 44:process flow chart

7.2.8 Zinc and copper recovery by Cyanex 272

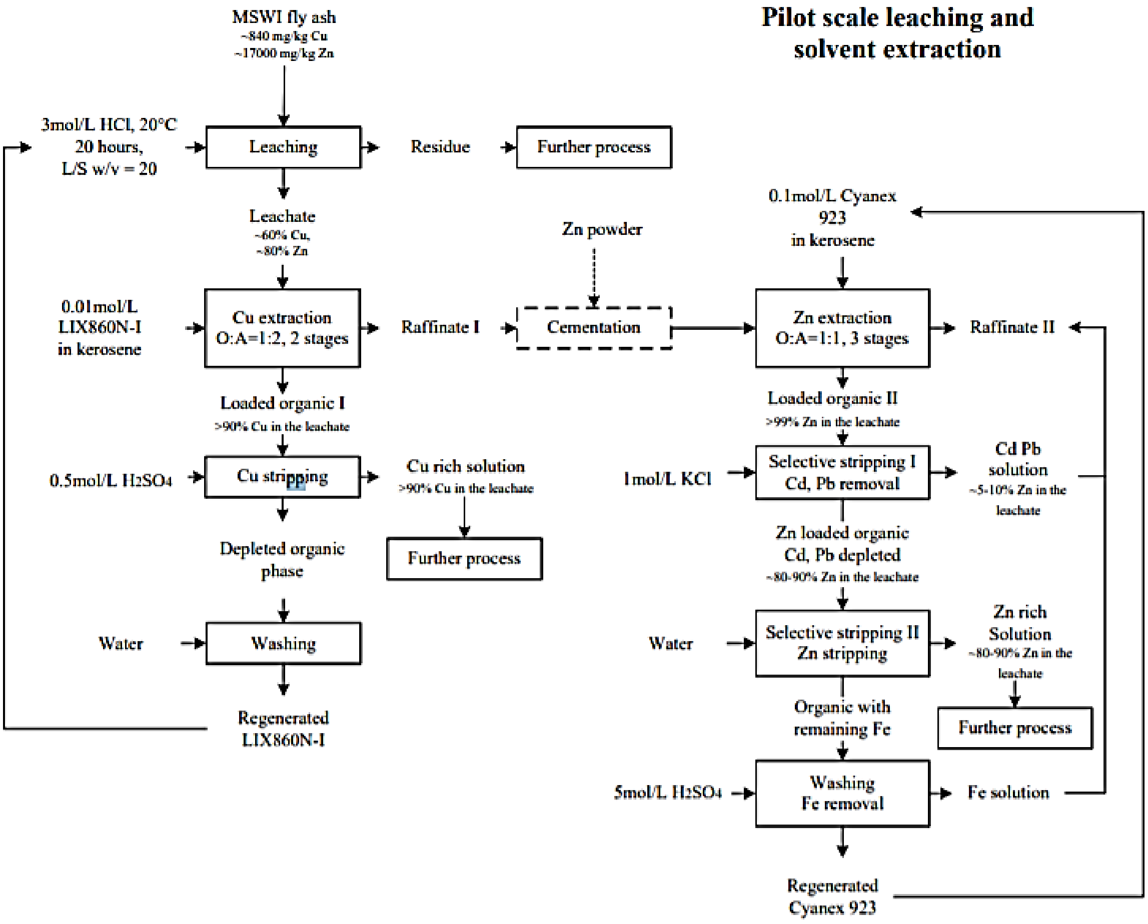
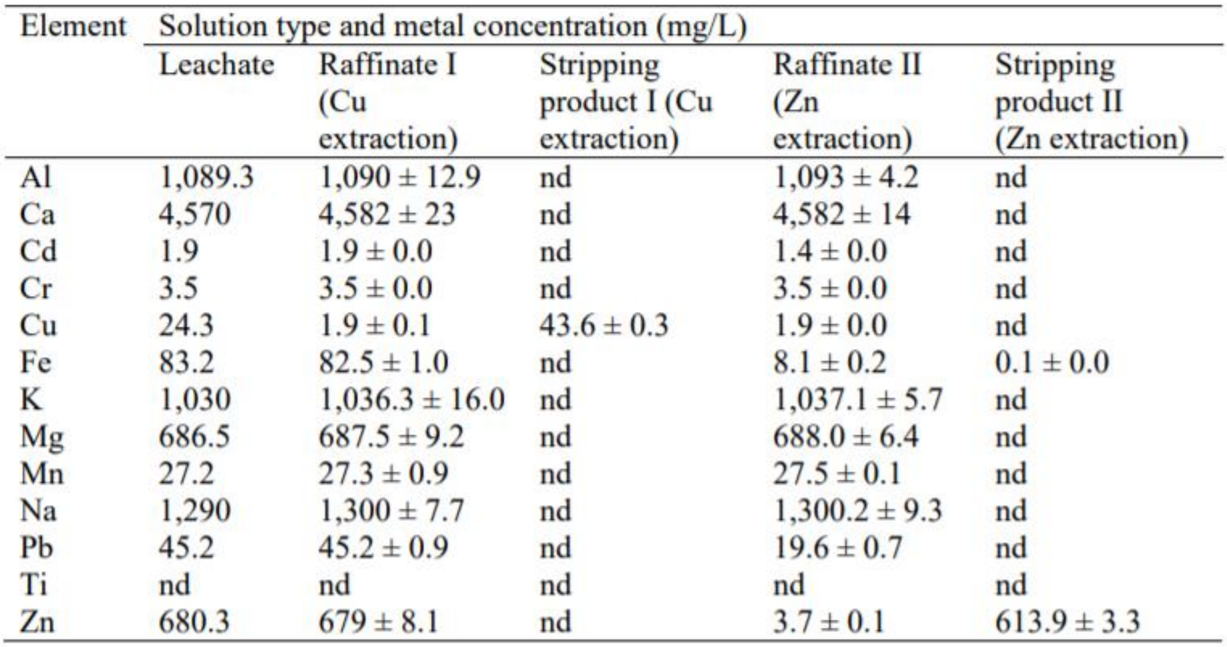


Figure 45: . Mass flowscheme of the leaching-extraction process

7.2.9 Efficiency of leaching



Element	Solution type and metal concentration (mg/L)				
	Leachate	Raffinate I (Cu extraction)	Stripping product I (Cu extraction)	Raffinate II (Zn extraction)	Stripping product II (Zn extraction)
Al	1,089.3	1,090 ± 12.9	nd	1,093 ± 4.2	nd
Ca	4,570	4,582 ± 23	nd	4,582 ± 14	nd
Cd	1.9	1.9 ± 0.0	nd	1.4 ± 0.0	nd
Cr	3.5	3.5 ± 0.0	nd	3.5 ± 0.0	nd
Cu	24.3	1.9 ± 0.1	43.6 ± 0.3	1.9 ± 0.0	nd
Fe	83.2	82.5 ± 1.0	nd	8.1 ± 0.2	0.1 ± 0.0
K	1,030	1,036.3 ± 16.0	nd	1,037.1 ± 5.7	nd
Mg	686.5	687.5 ± 9.2	nd	688.0 ± 6.4	nd
Mn	27.2	27.3 ± 0.9	nd	27.5 ± 0.1	nd
Na	1,290	1,300 ± 7.7	nd	1,300.2 ± 9.3	nd
Pb	45.2	45.2 ± 0.9	nd	19.6 ± 0.7	nd
Ti	nd	nd	nd	nd	nd
Zn	680.3	679 ± 8.1	nd	3.7 ± 0.1	613.9 ± 3.3

Figure 46: Concentration of metals at each stage: after leaching, in the raffinates after copper and zinc extraction, as well as in the stripping products. nd = not detected.

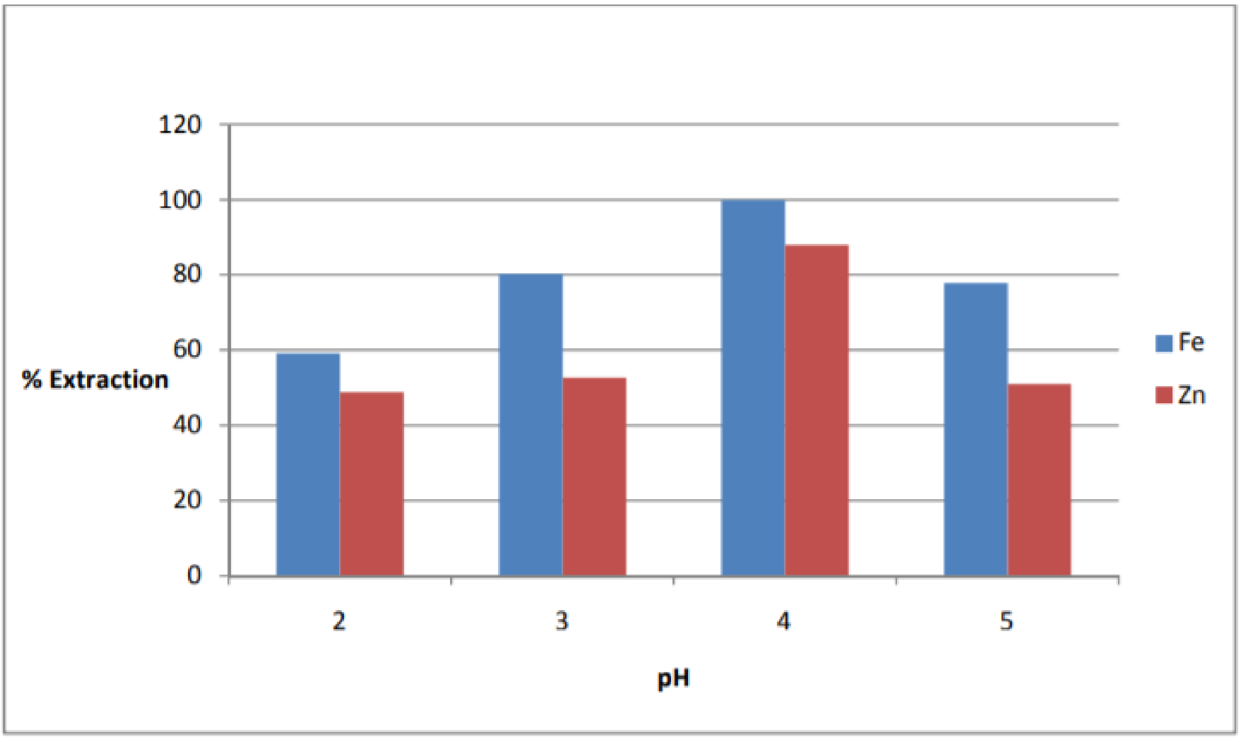


Figure 47: Percentage Extraction of Zn and Fe with 30 vol % Cyanex 272 from bottom ash leachates

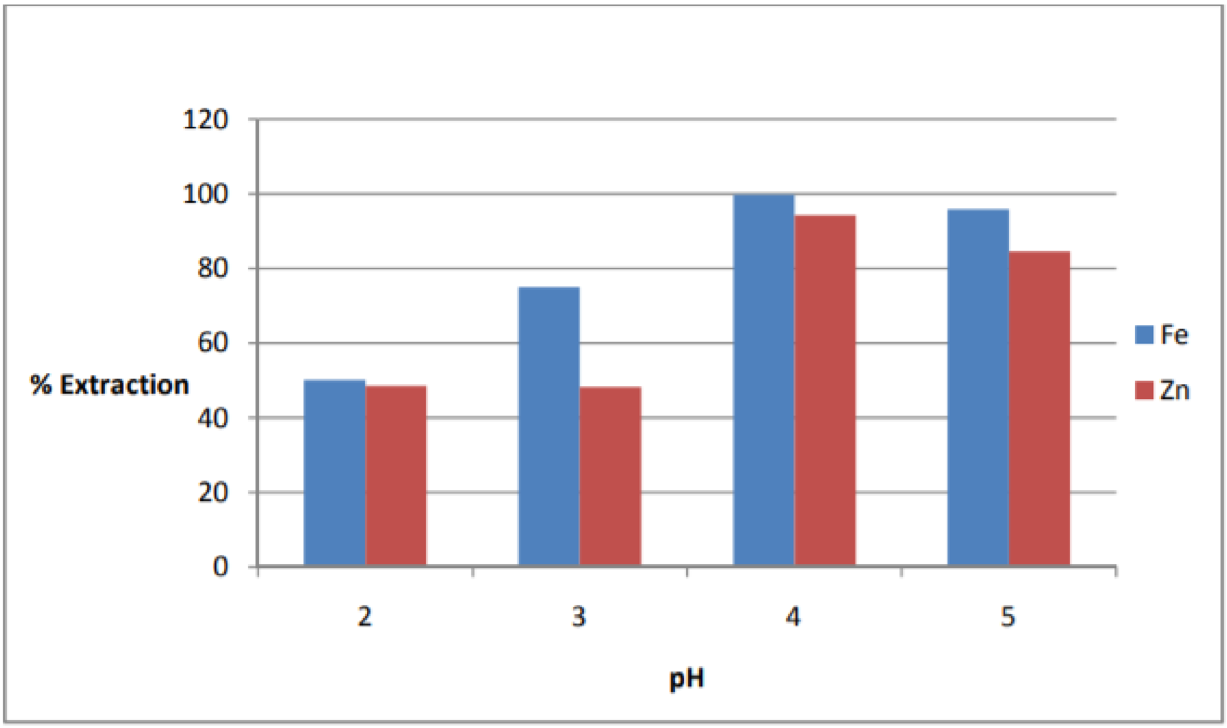


Figure 48: : Percentage extraction of Zn and Fe with 20 vol % Cyanex 272 from bottom ash leachates

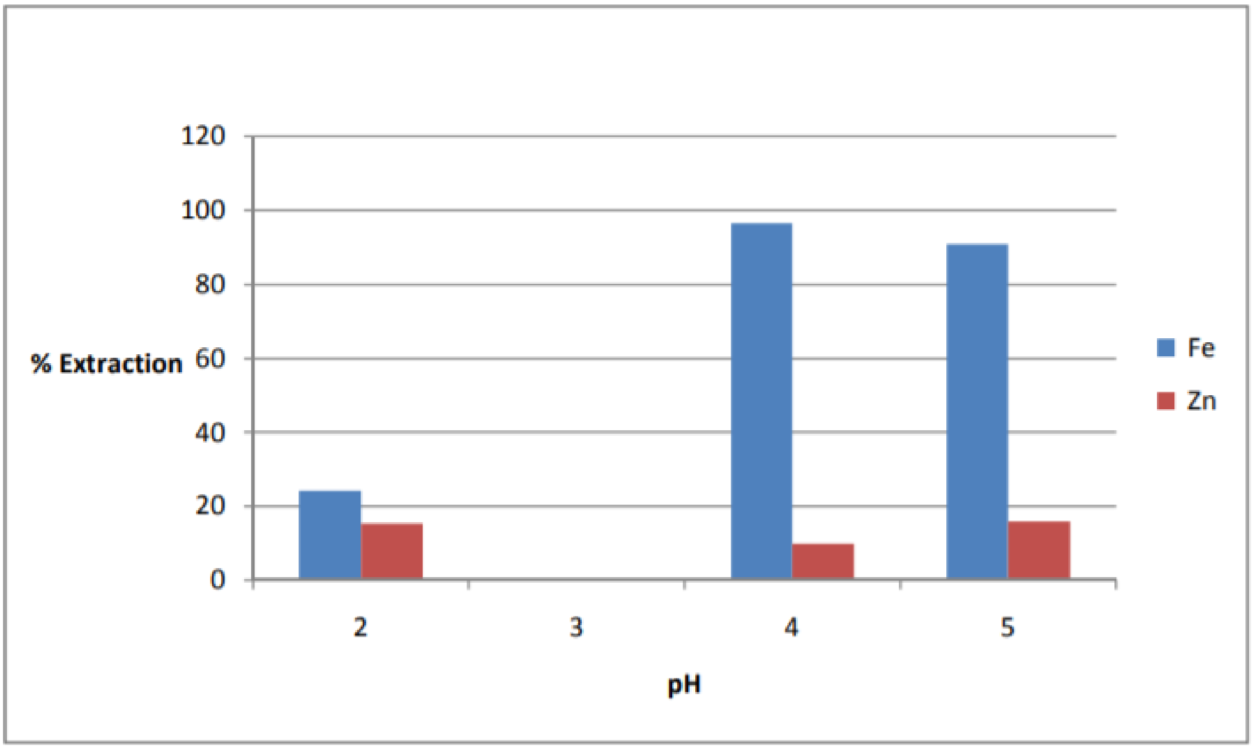


Figure 49: Percentage extraction of Zn and Fe with Cyanex 921 from fly ash leachates

7.3 Contribution

7.3.1 Flow rate of ashes

The the percentage of the residues of incineration change from 20 to 30 %.Then,to calculate the mass of nitric acid that will be used in leaching the ashes ,we should determine the flow rate of ashes.the total mass of residues is **338kg** after incineration of 800 kg of waste **during 1 hour .**

Metals	Quantity in ash(mg/kg)
Cu	2678
Zn	7378
Pb	7760
Ni	1906
Cd	56.6
Cr	1512
As	253.35
Hg	6.67

The ash was extracted at a liquid-to-solid ratio (L/S)=5 correspond to 5L of nitric acid to leach 1 kg of ash .

7.3.2 Nitric acid for leaching

As we mentionned that the nitric acid is a suitable acid for our case .It is important to be concentrated (15.8 mol/L-1.42 g/cm³) to avoid the leaching of Fe that will be extracted mechanically . Metals such as nickel Ni, cobalt Co, copper Cu, mercury Hg, zinc Zn and cadmium Cd dissolve in nitric acid..See below some physical and chemical properties of HNO_3 - H_2O at 20 °C & 1,013 bar :

Gew % HNO_3	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
volumetric mass (g/cm³)	1,00	1,05	1,12	1,18	1,25	1,31	1,37	1,42	1,46	1,48	1,513
Viscosity (mPa·s)	1,00	1,04	1,14	1,32	1,55	1,82	2,02	2,02	1,84	1,47	0,88
T_{fus} (°C)	0	–7	–17	–36	–30	–20	–22	–41	–39	–60	–42
$T_{éb}$ (°C)	100,0	101,2	103,4	107,0	112,0	116,4	120,4	121,6	116,6	102,0	86,0

p(HNO_3) (mbar)	0,0	0,0	0,0	0,0	0,0	0,3	1,2	3,9	14,0	36,0	60,0
p(H_2O) (mbar)	23,3	22,6	20,2	17,6	14,4	10,5	6,5	3,5	1,2	0,3	0,0
Molarity (mol/l)	0	1,7	3,6	5,6	7,9	10,4	13,0	15,8	18,5	21	24,01

Considerring that each hour 800 kg of waste will be incinerate which forms 338 kg of ashes (bottom ash and fly ash), this quantity needs :

- Each hour, 1690 L of acid,
- During 10 hours of incineration , the quantity of ash becomes: 338*10=3380 kg,
- In 10 hour, the amount of acid that we need is 16900 L.

7.3.3 Preparation of solution

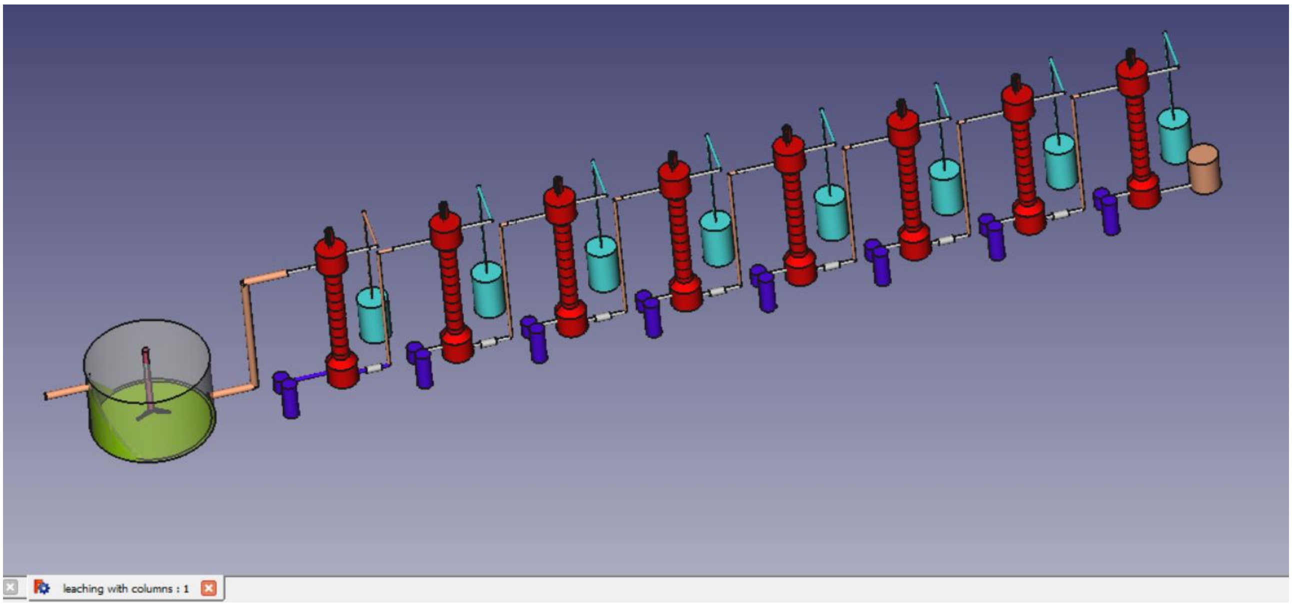
Eash 1 kg of ash needs 5 L of nitric acid .In the mixer then 338 kg grinded of waste is added to 1690 L of acid of 15.8 mol/l of concentration .

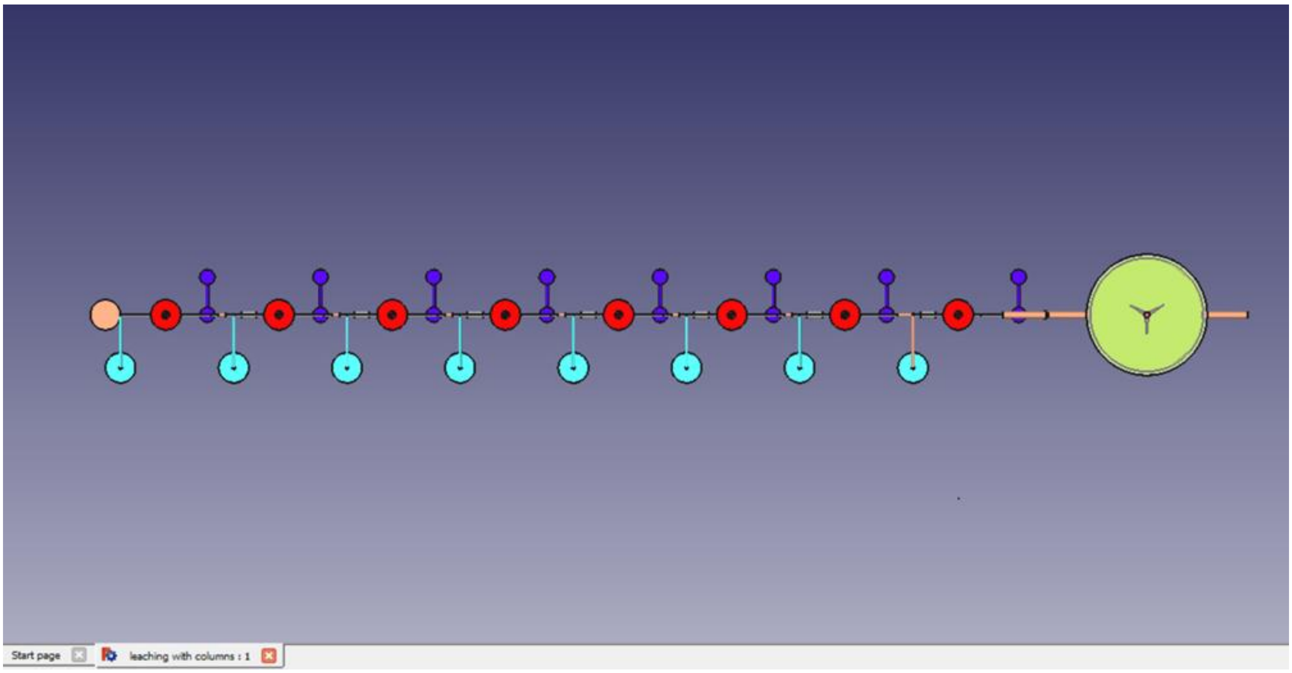
The input of the column 1 is 70.432 l of this mixture leached .

metals	g/kg of ash	338 kg of ashes	metals in 338 of ash(g)	Percentage of metals in 70 L of mixed =4.414, the amount of metals(g)	NOUNS OF extractants	The amount of extractant (ml)
Cu	2.678	338	905.164	37.4737896	LIX® 984N (mixture of 2-hydroxy-5-nonylacetophenone oxime and 5-nonylsalicylaldoxime in a high flash diluent),	74.9475792
Zn	7.3	338	2467.4	102.15036	Cyanex273(Phosphonic acid)	204.30072
Pb	7.76	338	2622.88	108.587232	Cyanex 272(Bis(2,4,4-trimethylpentyl)phosphinic acid)	217.174464
Ni	1.9	338	642.2	26.58708	Cyanex 272(Bis(2,4,4-	53.17416

					trimethylpentyl)phosphinic acid)	
Cd	0.056	338	18.928	0.7836192	Cyanex273(Phosphonic acid)	1.5672384
Cr	1.51	338	510.38	21.129732	nitrilotriacetic acid (NTA)-	42.259464
As	0.253	338	85.514	3.5402796	Cyanex273(Phosphonic acid)	7.0805592
Hg	0.00676	338	2.28488	0.094594032	By Cyanex 301 (Bis(2,4,4-trimethylpentyl)dithiophosphinic acid) and cyanex 302(Bis(2,4,4-trimethylpentyl)thiophosphinic acid	0.189188064

7.3.4 Freecad design

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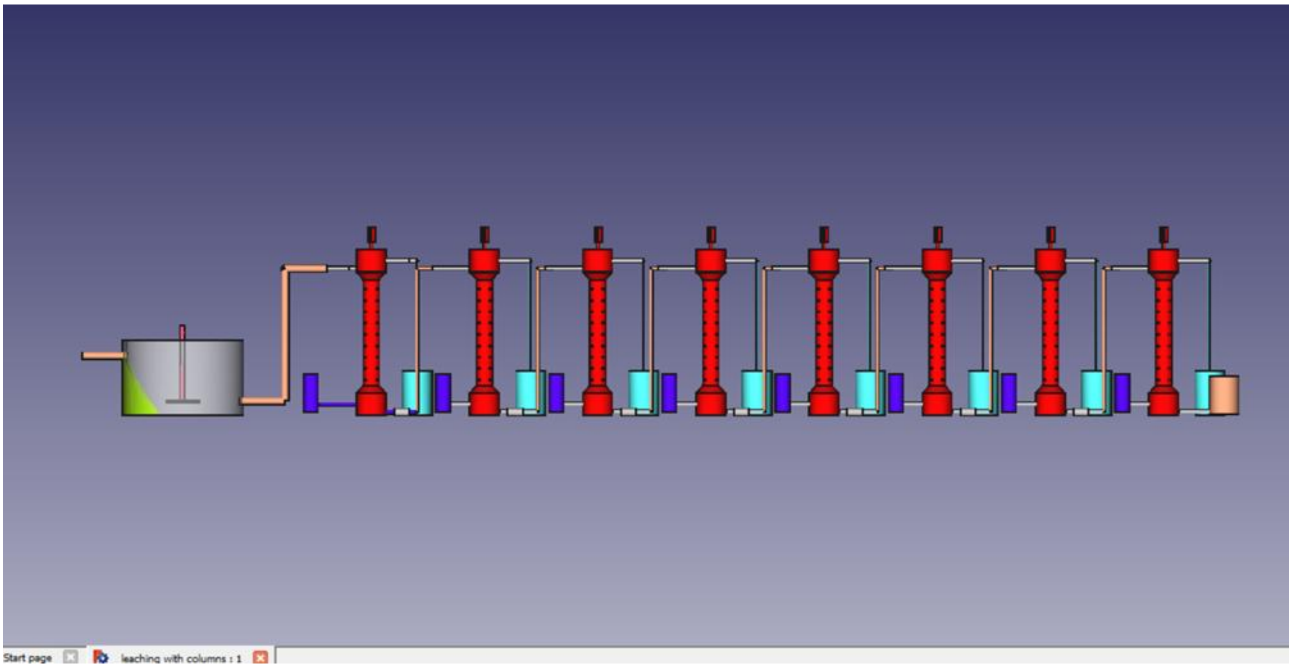
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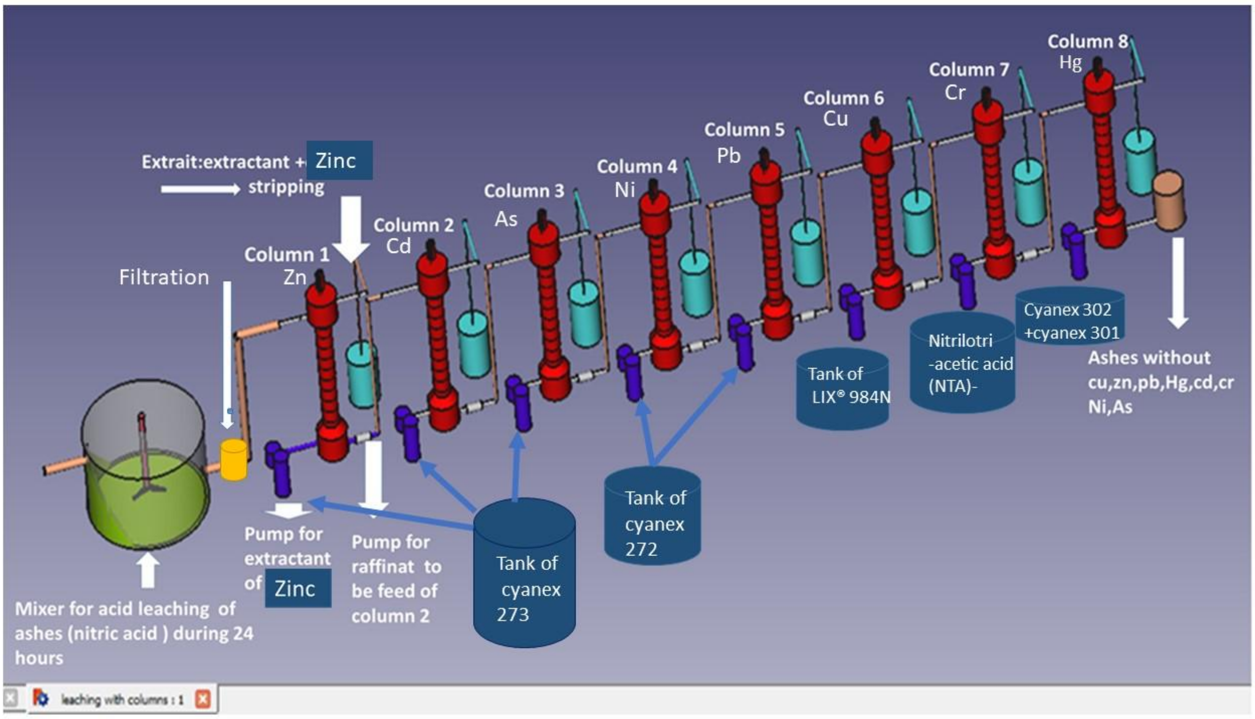
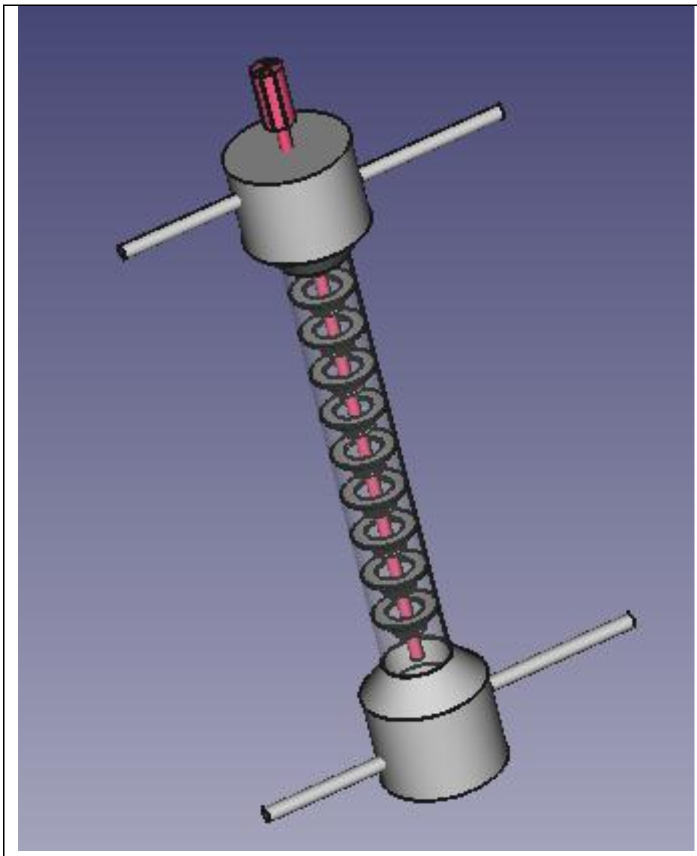
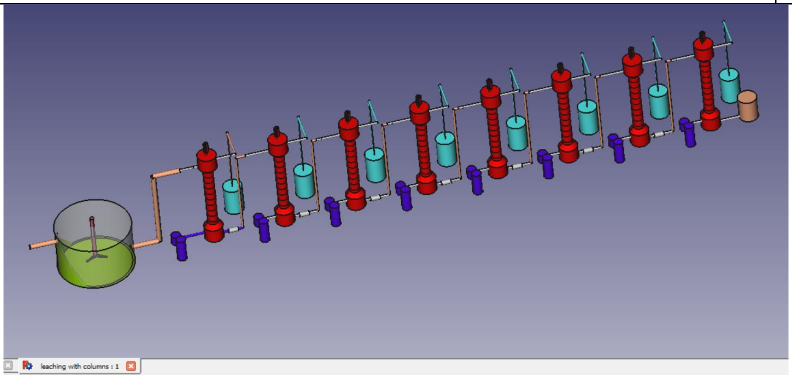


amount of extractant (ml)	extractant	metals
74.9475792	LIX® 984N (mixture of 2-hydroxy-5-nonylacetophenone oxime and 5-nonylsalicylaldoxime in a high flash diluent),	Cu
204.30072	Cyanex273(Phosphonic acid)	Zn
217.174464	Cyanex 272(Bis(2,4,4-trimethylpentyl)phosphinic acid)	pb
53.17416	Cyanex 272 (Bis(2,4,4-trimethylpentyl)phosphinic acid)	Ni
1.5672384	Cyanex273(Phosphonic acid)	Cd
42.259464	nitrilotriacetic acid (NTA)-	Cr
7.0805592	Cyanex273(Phosphonic acid)	As
0.189188064	By Cyanex 301 (Bis(2,4,4-trimethylpentyl)dithiophosphinic acid) and cyanex 302(Bis(2,4,4-trimethylpentyl)thiophosphinic acid)	Hg

	column of hevy metals recycling100419.FC
	leaching with columns100419.FCStd

7.3.5 Operating the Column

- Open the pump and reach the column with 44 l of ash mixed with nitric acid
- When the liquid level in the column reaches the top right nozzle (turn the feed flowrate down to the desired set point.
- Turn on and set the extractant flowrate to the desired set point by adjusting the pump speed.
- Close the extrait out rotameter when the liquid level reaches the top left (extrait out) nozzle.
- Allow the interface to form between the top mesh and the top left nozzle (extrait out). The interface appears as an immiscible layer between acid and extractant with droplets
- Once the interface is formed in the desired location, open the extrait out rotameter slowly until there are flowrates out of the column.

- Adjusting this rotameter is used to control the interface level. Opening the rotameter causes the interface to rise, while closing it causes the interface to drop.
- The optimum setting of this rotameter will allow for a semi-stable interface and give a minimal amount of drift in the interface level.
- Small adjustments should be made in order to keep the interface constant.
- Set the stirrer speed to a setting of 5 using the dial on the top right of the lab equipment panel. Make sure the motor is powered with the top center switch on the right power panel.
- Allow the column to run until steady state is achieved (about hour).

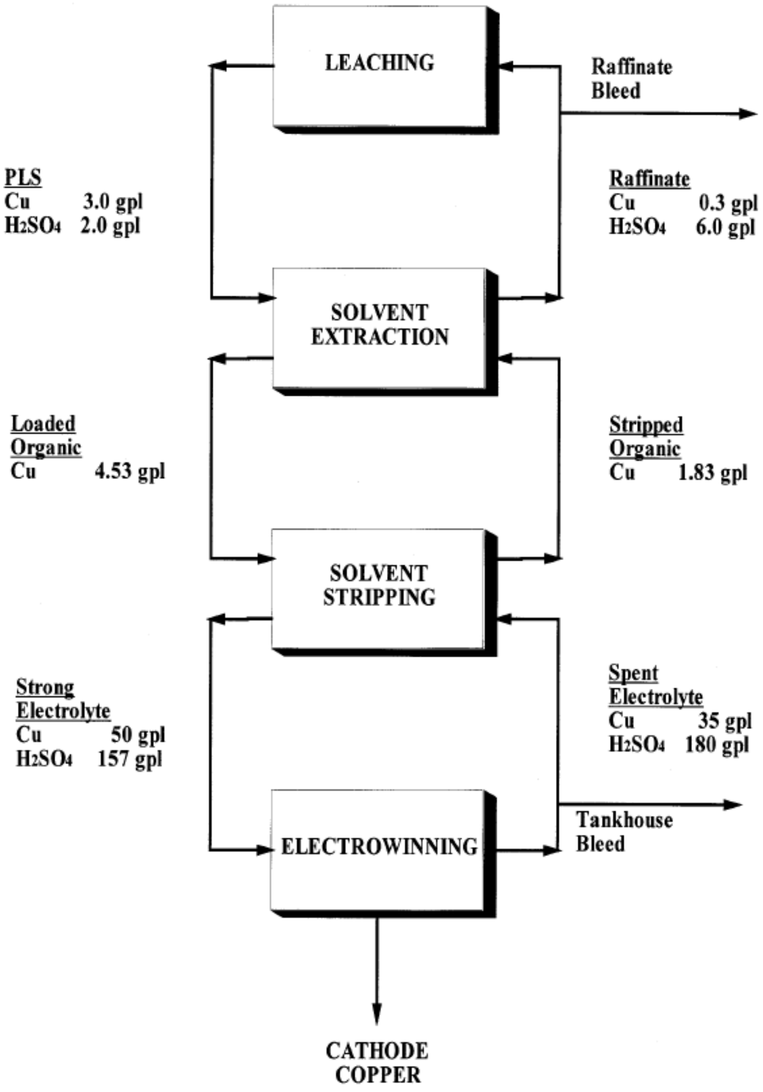
To feed the column in our case with extractant,we need 9890 cm³ (9.89 Liter extractant per batch load). Wotking time about 1 hour.

7.3.5.1 Shutdown Procedure

1. Once the experiments are complete, turn off the agitator and main power switch.
2. Close the feed and solvent ball valves, leaving the raffinate and extract ball valves open.

7.3.5.2 Stripping

The liquid rich in metals sorted from the sovent extraction column should be the input to the stripping tank where it is mixed with acid in ordr to wash the metals formed in the column . After each column ,a tank of stripping is implemented .



8 Zinc recycling

8.1 Fly Ash Handling

1. Pre-Washing:

   - Take a 10 grams sample of dried fly ash

   - Mix the sample with distilled water for 5-10mins under the following conditions (solid/liquid ratio 10:1 (ml/g), number of washing twice) - Under these conditions, the prewash can remove 86% Na, 70% K, 12% Ca, 1.2% Al, and 0.5% Pb from the fly ash.

   - Perform vacuum filtration.

   - Analyze the metallic elements in the leachate using ICP/AES spectrometer.

2. Leaching Tests:

   - Vacuum dry the pre-washed sample at 75ºC overnight
   - Mix 1 gram of the prewashed sample with 40mL (0.1M) citric acid, for a contact time of 20mins, at pH=3 (adjust the pH using concentrated HNO_3 and NaOH) and at room temperature.
   - Filter the suspension and send the clear solution for heavy metal content analysis by means of ICP/AES spectrometer.

     Optimum metal removal was achieved under the following conditions: liquid/solid ratio 40 (ml:g), citric acid concentration 0.1 M, contact time 20 min, and pH 3.0 at room temperature.

- Required tests: XRD for fly ash powder sample as received and the fly ash residues after water washing and acid leaching

8.2 Bottom Ash Handling (200-250 kg/t)

1) Collect fresh bottom ash samples from the burning incinerators and dry them at 25°C.
2) Manually separate the un-burnt parts such as the screw, wire, plastics.
3) Prior to leaching, reduce the size of the samples to 500microns with a roll crusher in order to remove the magnetic content (Iron Removal).

4) Subject the bottom ash samples (Tailings and concentrates) to leaching tests **(24hours)** in order to notice the amenability of the samples for metal recovery along with optimization of parameters.

   - To calculate the mass of nitric acid to use in leaching the ashes, we should determine the flow rate of ashes.

   - In example, liquid to solid (L/S) ratio = 5:1 ➔ for every 1kg of ashes, add 5L of Nitric acid.

   - It is important to be concentrated (15.8 mol/L-1.42 g/cm³) to avoid the leaching of Fe that will be extracted mechanically.

   - Considering that each hour 800 kg of waste will be incinerated, which forms 338 kg of ashes (bottom ash and fly ash), this quantity needs:

     - Each hour, 1690 L of acid
     - During 10 hours of incineration, the quantity of ash becomes 338*10=3380 kg
     - In 10 hour, the amount of acid that we need is 16900 L

5) Liquid-Liquid Extraction Column:

   – Add the nitric acid solution (including heavy metals) to the column from the upper left vessel, and keep adding until the nitric acid reaches the level of this vessel.

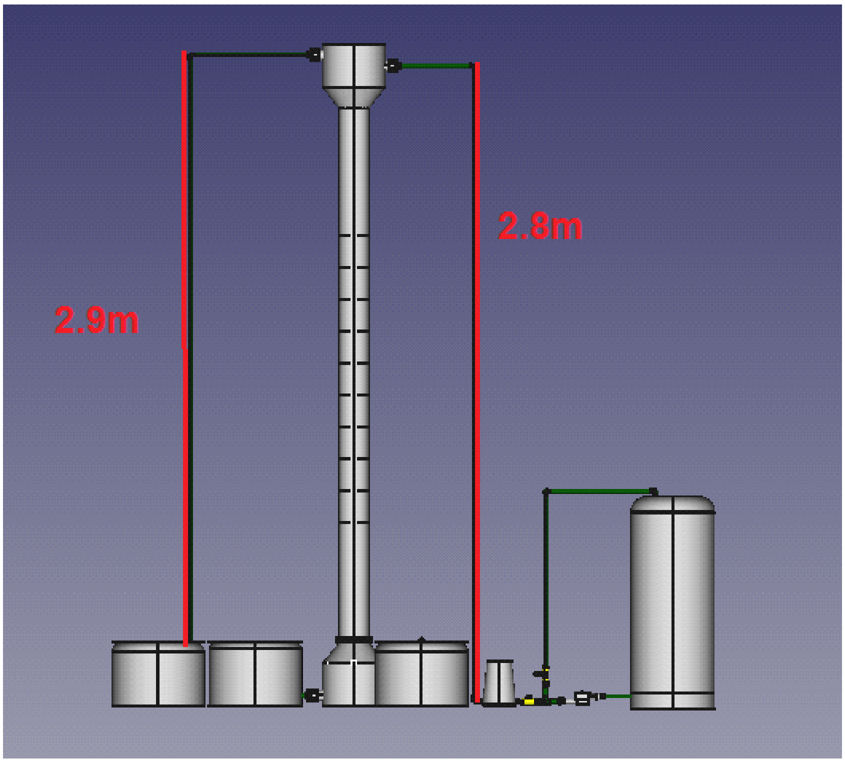
   – Add phosphonic acid from the lower left vessel (3mL phosphonic acid/1L of nitric acid solution)

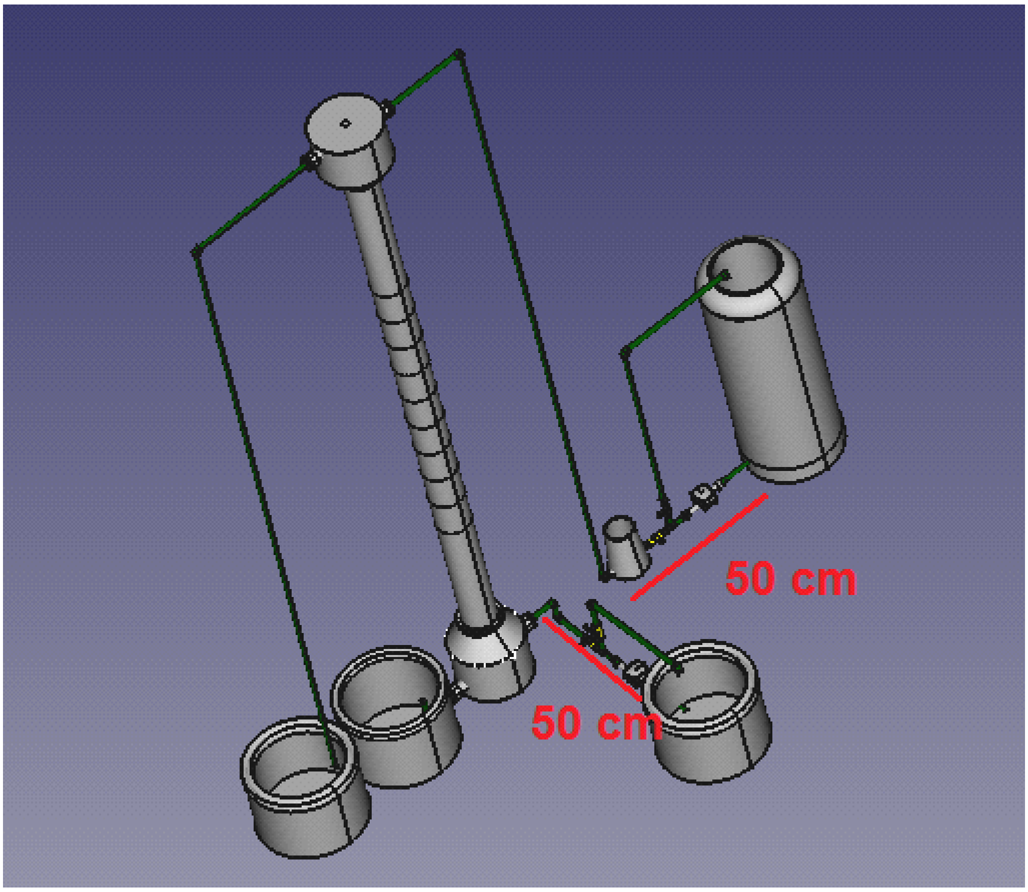
   – Turn on the mixer for a certain time (ex: 1hr), stop a while to see if two separate phases appear.

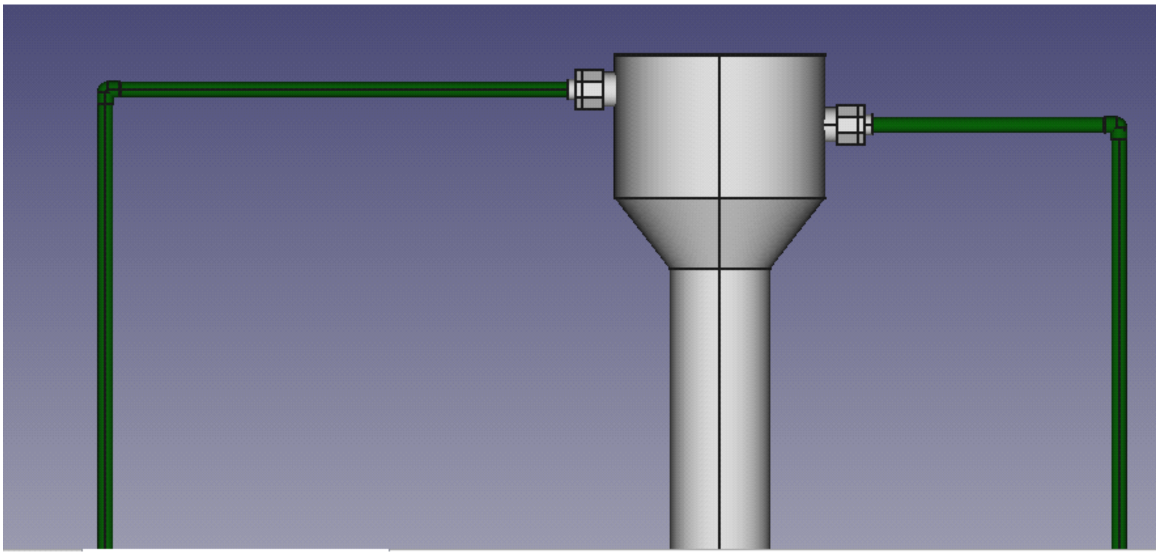
   – If yes, remove the upper layer through the upper right vessel and then remove the lower layer through the lower right vessel.

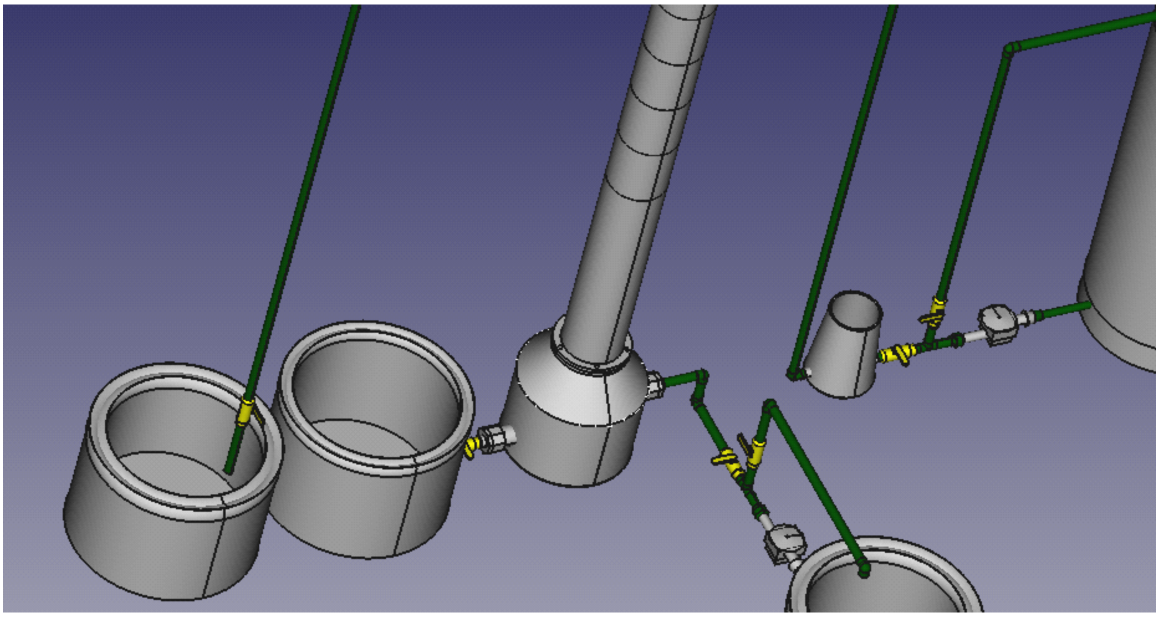
9 Heavy Metals Test Rig

	heavymetalrecoverypipes150619.FCStd









parts needed :

- 4 valve
- 4 pipes (4m each)
- 3 medium sized tanks
- 2 electrical pumps (> 1hp)
- 4 moukhalef + wasel zira3e
- 9 turnes 90 ppr
- 2 tees ppr

initial cost : ~ 200 $

10 Methane Liquification Unit

بسم الله الرحمن الرحيم

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

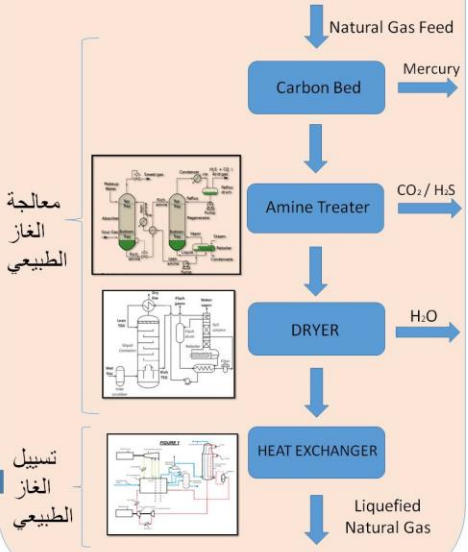
طاقة الشمال
North Lebanon Alternative Power
www.nlap-lb.com

Methane liquefaction تسييل الغاز الطبيعي

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)

LNG Production diagram


Natural Gas Feed

Carbon Bed → Mercury

Amine Treater → CO_2 / H_2S

DRYER → H_2O

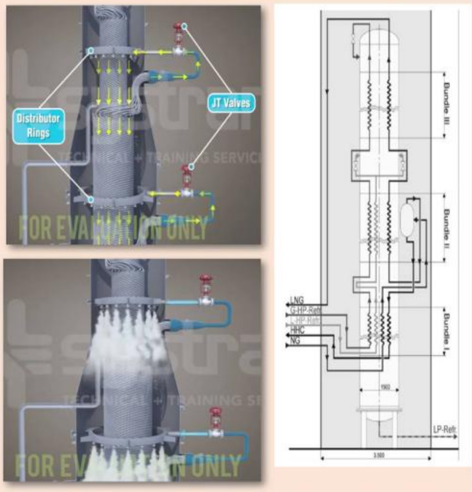
HEAT EXCHANGER

Liquefied Natural Gas

معالجة الغاز الطبيعي

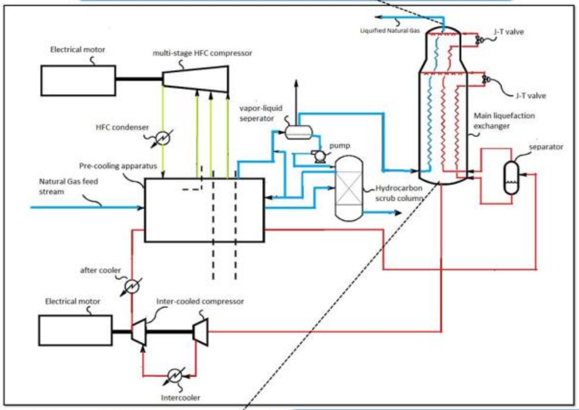
تسييل الغاز الطبيعي

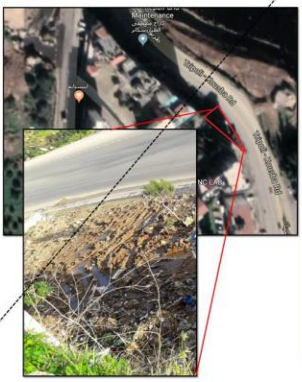
Microchannel heat exchanger (MCHE- main heat exchanger in LNG plant)



- 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 (mixed refrigerant) 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.

Liquefaction process of natural gas





1. Pre-cooling of pre-treated natural gas feed (heavy hydrocarbon oils, particulates, CO_2, H_2S and water removed) stream is performed in 1-5 cooling stages in series, for example, represented by the pre-cooling apparatus (As shown in the figure above).
2. Pre-cooled stream may then be sent to a hydrocarbon scrub column which scrubs away heavier (C3+) components of the feed using a cold liquid reflux stream in order to adjust the heating value of the final LNG.
3. Vapor stream from the scrub column reflux condenser may be sent to the cryogenic section of the plant that fully condenses and sub-cools vapor stream to form LNG product stream.
4. The cryogenic section comprises the main liquefaction exchanger. In the cryogenic section, either a refrigerant consisting of mixed hydrocarbons with 0-30 mole% N2 or pure N2 may be used, for example.
5. 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-coolant.
6. The main liquefaction exchanger may be a wound coil exchanger, a plate-fin exchanger, or any other exchanger typical for cryogenic service.
7. The LNG plant is destined to be placed beside the incinerator as shown in the figure at the left.

Maryam Abdel-Karim

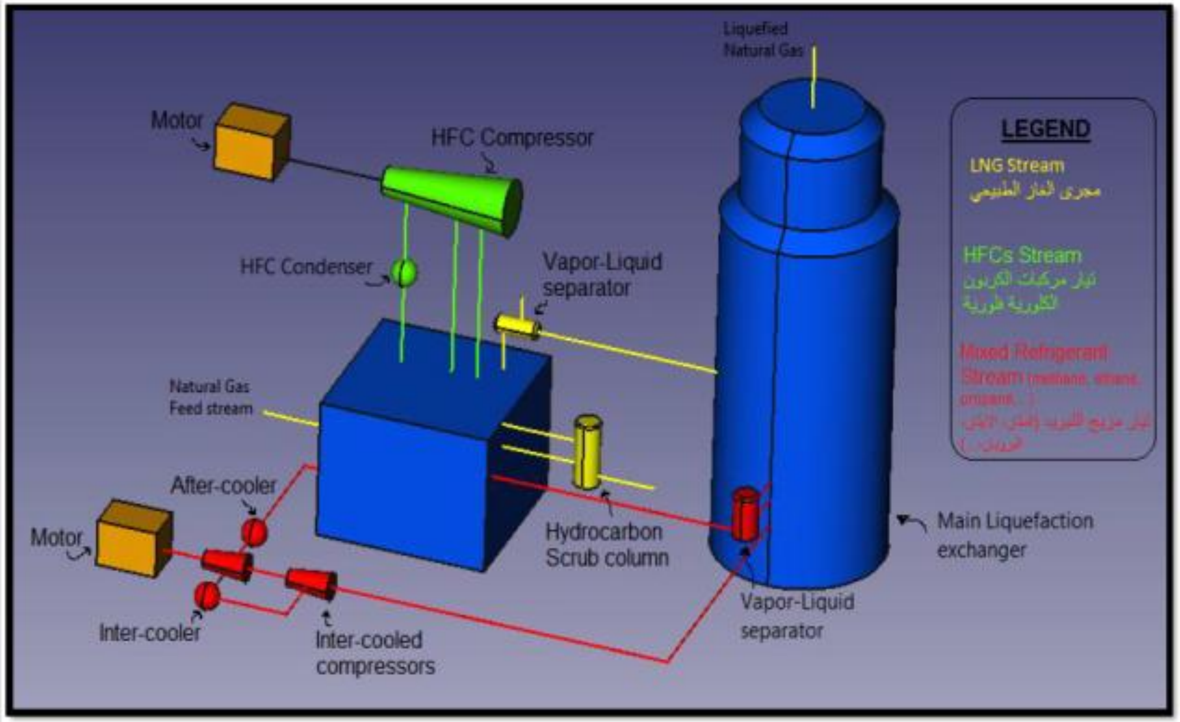
@AECENAR/NLAP Dec 2018

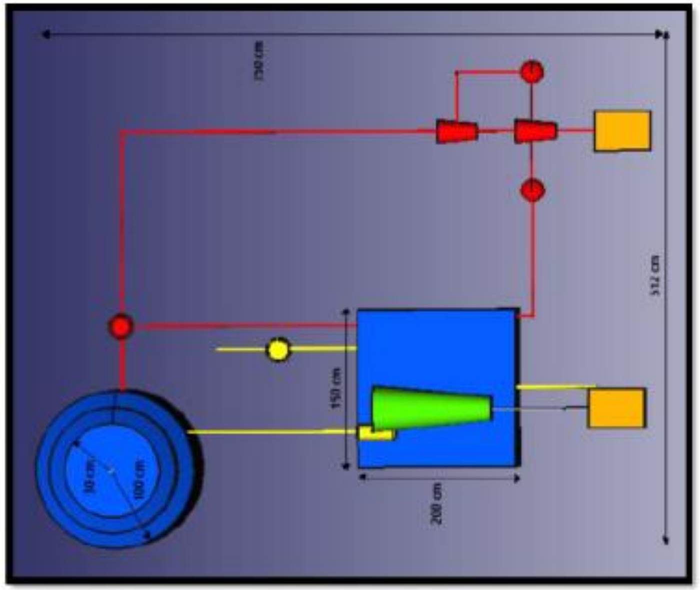
For Details see NLAP-WEDC_Report 2(2018)

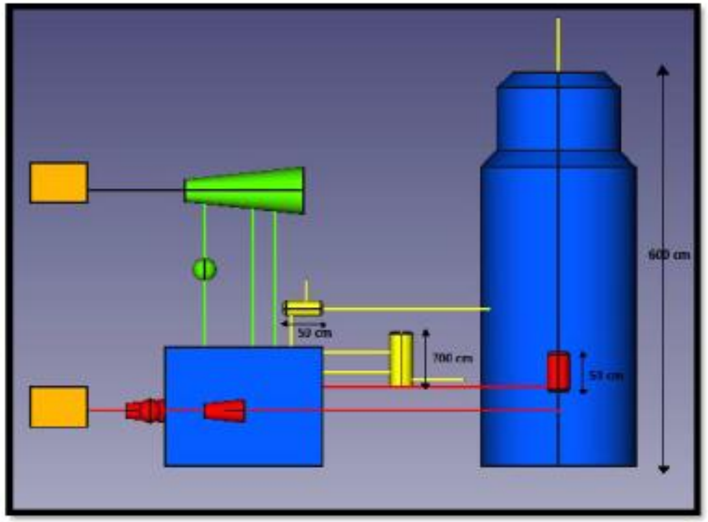
MethanLiquificationUnit.FCStd (not final version, below: final version)

Methane Liquefaction

تسييل الغاز الطبيعي







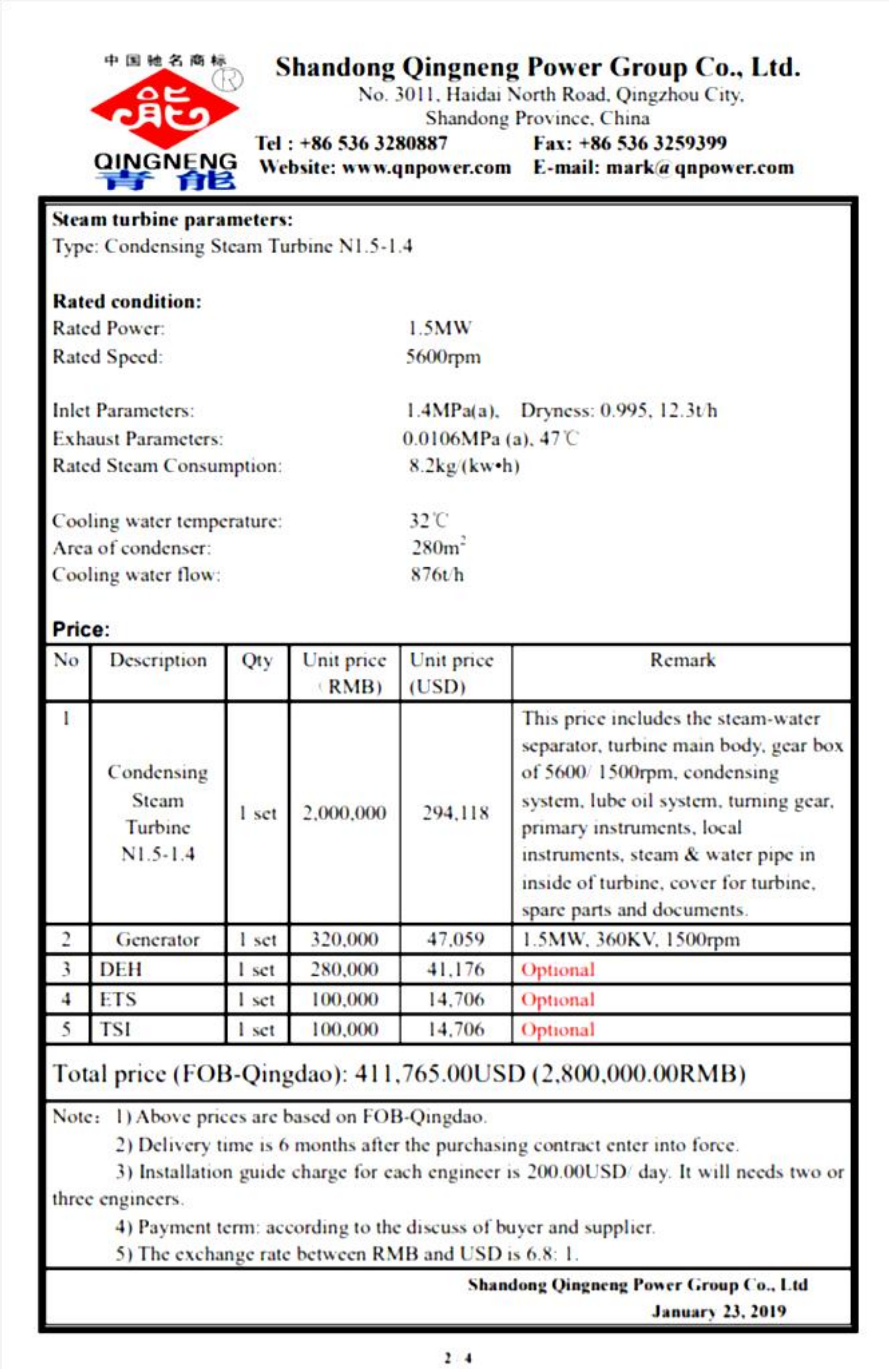
Maryam Abdel-Karim

*الأرقام الموجودة ارقام تقريبية

11 Electrical Power Distribution for a 2 MW power plant in Mashha

11.1 Requirements

11.1.1 Capacity of the turbine (4 offers)



Shandong Qingneng Power Group Co., Ltd.
No. 3011, Haidai North Road, Qingzhou City,
Shandong Province, China
Tel : +86 536 3280887 **Fax: +86 536 3259399**
Website: www.qnpower.com **E-mail: mark@ qnpower.com**

Steam turbine parameters:
Type: Condensing Steam Turbine N1.5-1.4

Rated condition:

Rated Power:	1.5MW
Rated Speed:	5600rpm
Inlet Parameters:	1.4MPa(a), Dryness: 0.995, 12.3t/h
Exhaust Parameters:	0.0106MPa (a), 47℃
Rated Steam Consumption:	8.2kg/(kw•h)
Cooling water temperature:	32℃
Area of condenser:	280m^2
Cooling water flow:	876t/h

Price:

No	Description	Qty	Unit price (RMB)	Unit price (USD)	Remark
1	Condensing Steam Turbine N1.5-1.4	1 set	2,000,000	294,118	This price includes the steam-water separator, turbine main body, gear box of 5600/ 1500rpm, condensing system, lube oil system, turning gear, primary instruments, local instruments, steam & water pipe in inside of turbine, cover for turbine, spare parts and documents.
2	Generator	1 set	320,000	47,059	1.5MW, 360KV, 1500rpm
3	DEH	1 set	280,000	41,176	Optional
4	ETS	1 set	100,000	14,706	Optional
5	TSI	1 set	100,000	14,706	Optional

Total price (FOB-Qingdao): 411,765.00USD (2,800,000.00RMB)

Note: 1) Above prices are based on FOB-Qingdao.
2) Delivery time is 6 months after the purchasing contract enter into force.
3) Installation guide charge for each engineer is 200.00USD/ day. It will needs two or three engineers.
4) Payment term: according to the discuss of buyer and supplier.
5) The exchange rate between RMB and USD is 6.8: 1.

Shandong Qingneng Power Group Co., Ltd
January 23, 2019

POWER PLANTS
OIL REFINERIES
SALE & RELOCATION

LOHRMANN
INTERNATIONAL

Taunusstr. 5a
65183 Wiesbaden/Germany

Tel. +49 (0) 611-50402-0
Fax +49 (0) 611-50402-50

www.lohrmann.com
info@lohrmann.com

For Sale:	Pre-owned 3 MW Steam Turbine Condensing-Type
Ref.-No:	STG-29.16

Brief plant description:

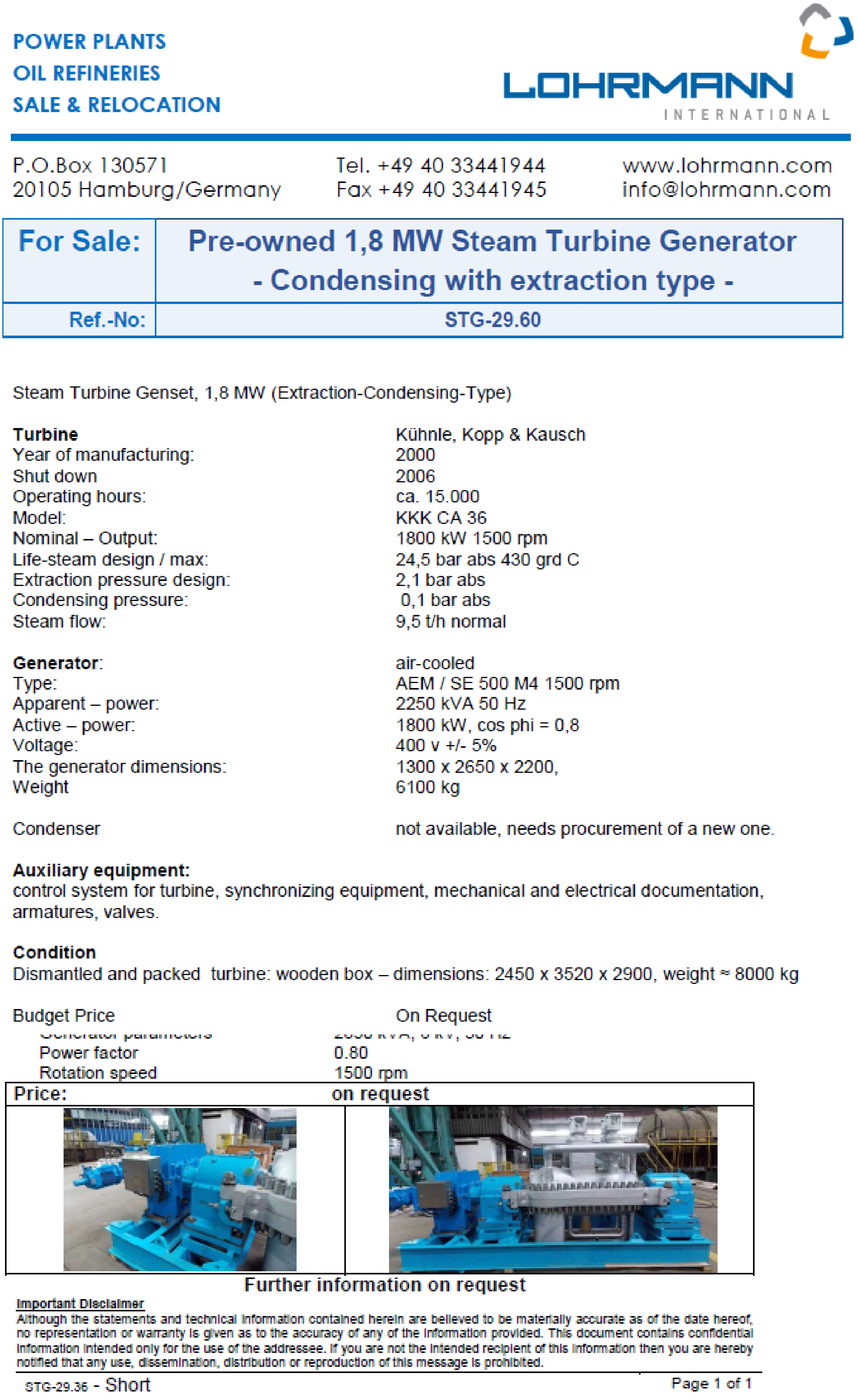
The power plant had a general revision in 2005. There have been around 19,000 operating hours since last then. All equipment is in excellent condition and ready for relocation.

Description of major plant components:

Turbine	
Manufacturer	KKK Siemens, AFA 6 Da
Year of commissioning	1997
Power output	3000 kW
Steam parameters	21.5 bar abs. / 275°C
Rotation speed	11543 / 1500 rpm
Exhaust pressure	0.23 bar abs
Steam consumption	23.1 t/h @ 3 MW

Generator	
Manufacturer	Leroy Somer LSA 56 BL7-4P
Parameters	10 kV, 5200 kVA, 50 Hz

Condenser	
Manufacturer	Serck Como, CD 36/48 HSK 180- 1 fl. Axial
Rating	approx. 19.5 kW_{th}
Steam flow max.	32 t/h
Condensing pressure	0.23 bar abs
Cooling water flow	1200 m^3/h
Surface	274 m^2



POWER PLANTS
OIL REFINERIES
SALE & RELOCATION

LOHRMANN
INTERNATIONAL

P.O.Box 130571
20105 Hamburg/Germany
Tel. +49 40 33441944
Fax +49 40 33441945
www.lohrmann.com
info@lohrmann.com

For Sale:	Pre-owned 1,8 MW Steam Turbine Generator - Condensing with extraction type -
Ref.-No:	STG-29.60

Steam Turbine Genset, 1,8 MW (Extraction-Condensing-Type)

Turbine	Kühnle, Kopp & Kausch
Year of manufacturing:	2000
Shut down	2006
Operating hours:	ca. 15.000
Model:	KKK CA 36
Nominal – Output:	1800 kW 1500 rpm
Life-steam design / max:	24,5 bar abs 430 grd C
Extraction pressure design:	2,1 bar abs
Condensing pressure:	0,1 bar abs
Steam flow:	9,5 t/h normal
Generator:	air-cooled
Type:	AEM / SE 500 M4 1500 rpm
Apparent – power:	2250 kVA 50 Hz
Active – power:	1800 kW, cos phi = 0,8
Voltage:	400 v +/- 5%
The generator dimensions:	1300 x 2650 x 2200,
Weight	6100 kg
Condenser	not available, needs procurement of a new one.

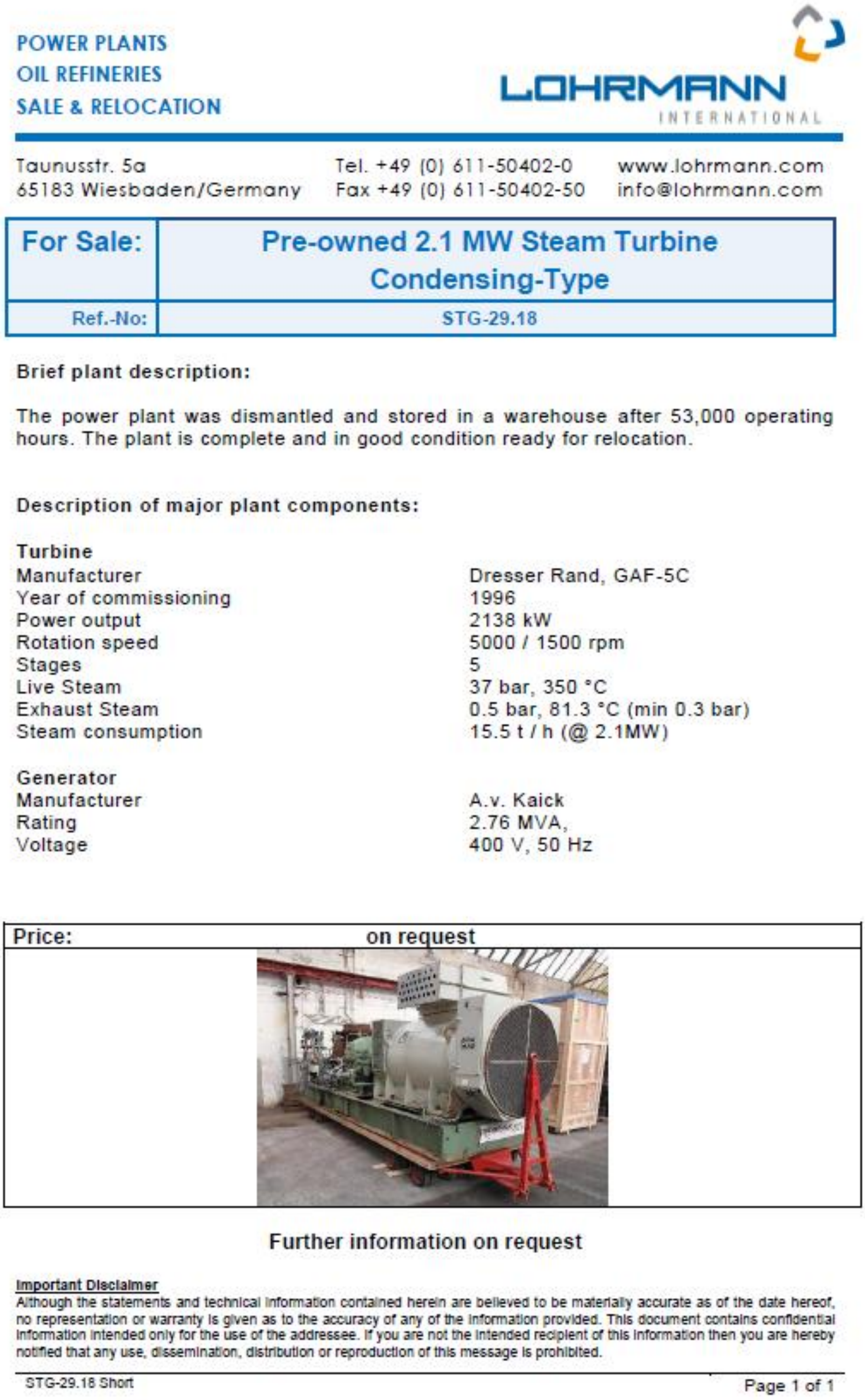
Auxiliary equipment:
control system for turbine, synchronizing equipment, mechanical and electrical documentation, armatures, valves.

Condition
Dismantled and packed turbine: wooden box – dimensions: 2450 x 3520 x 2900, weight ≈ 8000 kg

Budget Price	On Request
Power factor	0.80
Rotation speed	1500 rpm
Price:	**on request**

Further information on request

STG-29.36 - Short
Page 1 of 1



POWER PLANTS
OIL REFINERIES
SALE & RELOCATION

LOHRMANN
INTERNATIONAL

Taunusstr. 5a
65183 Wiesbaden/Germany

Tel. +49 (0) 611-50402-0
Fax +49 (0) 611-50402-50

www.lohrmann.com
info@lohrmann.com

For Sale:	**Pre-owned 2.1 MW Steam Turbine Condensing-Type**
Ref.-No:	**STG-29.18**

Brief plant description:

The power plant was dismantled and stored in a warehouse after 53,000 operating hours. The plant is complete and in good condition ready for relocation.

Description of major plant components:

Turbine	
Manufacturer	Dresser Rand, GAF-5C
Year of commissioning	1996
Power output	2138 kW
Rotation speed	5000 / 1500 rpm
Stages	5
Live Steam	37 bar, 350 °C
Exhaust Steam	0.5 bar, 81.3 °C (min 0.3 bar)
Steam consumption	15.5 t / h (@ 2.1MW)

Generator	
Manufacturer	A.v. Kaick
Rating	2.76 MVA,
Voltage	400 V, 50 Hz

Price: **on request**

Further information on request

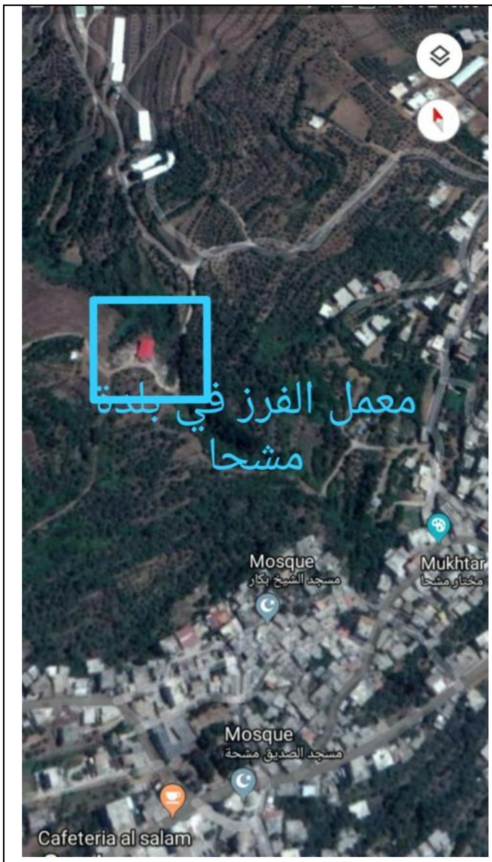
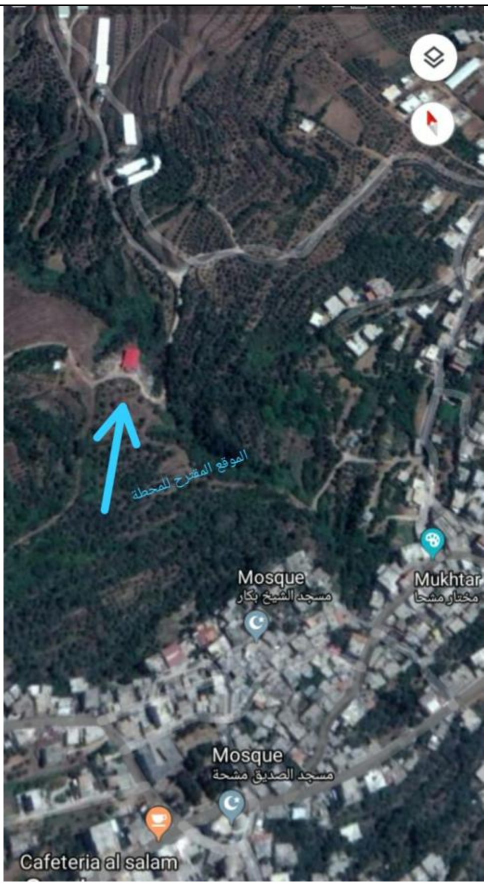
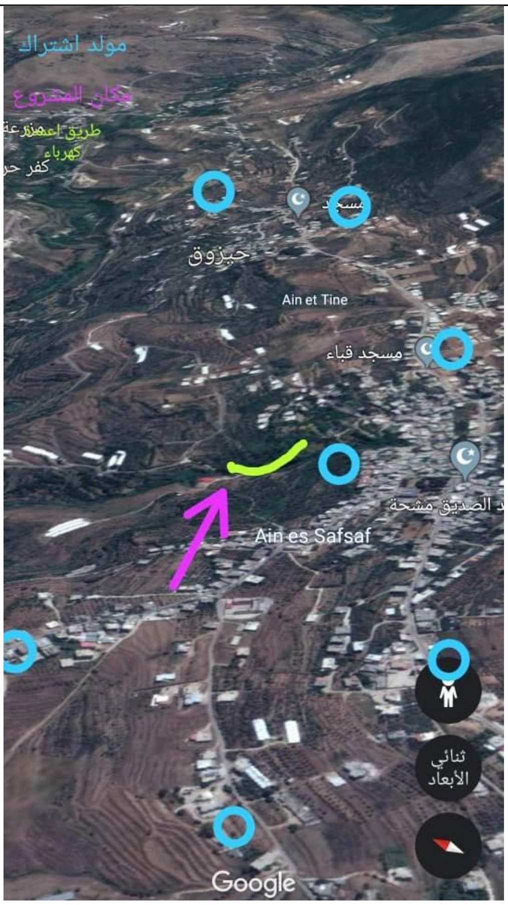
Important Disclaimer
Although the statements and technical information contained herein are believed to be materially accurate as of the date hereof, no representation or warranty is given as to the accuracy of any of the information provided. This document contains confidential information intended only for the use of the addressee. If you are not the intended recipient of this information then you are hereby notified that any use, dissemination, distribution or reproduction of this message is prohibited.

STG-29.18 Short

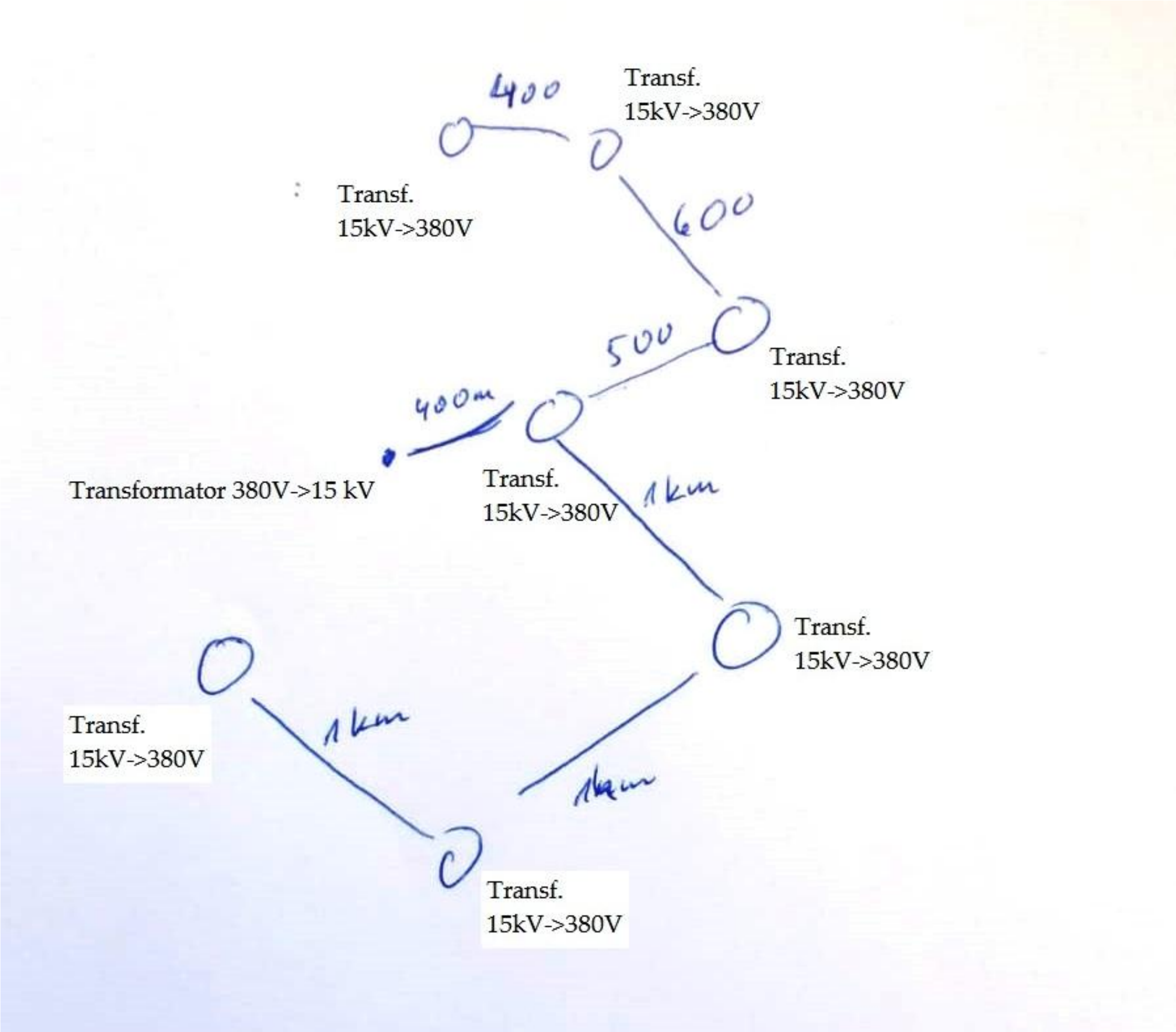
Page 1 of 1

Figure 50:turbines of 2 MW

11.1.2 Distribution network at Mashha

		
		نقط لمتورات الاشتراك الحالية (200-300 كيلو وات)

First design of network



11.2 Working plan

Before the implementation of the system of distribution, it is necessary to know some details about the consumption of electricity in the area of the project . In addition to, the map of the area.

11.2.1 GIS map

We need a GIS map to know the ground where we implement the towers, the transformers and the cables. In addition to, the distance between the main plant and the points of distribution on hand and between point of distribution and houses on other hand; in order to know **the loss of electricity** before arrive to each house in **cables (section) and the transformers**. This is important to reduce the need of transformers and cables. A s**uitable software** can choose the best method to connect the points of distribution to the main source of electricity.

11.2.2 Loads

The consumption of electricity differs according to the time of consumption (morning, afternoon, night) and to the season. then, a map of the consumption must be taken in account in purpose to know the transformers that we are in need and the suitable turbine. the **loads must be between 50 and 80 % of the capacity of the turbine**.

Bus company can provide us the data sheet of loads in Mashha.The voltage of the turbine must be 20 to 30 % greater than the loads.

The period of working of the turbine differs in according to the time of consumption.

11.2.3 Transformers

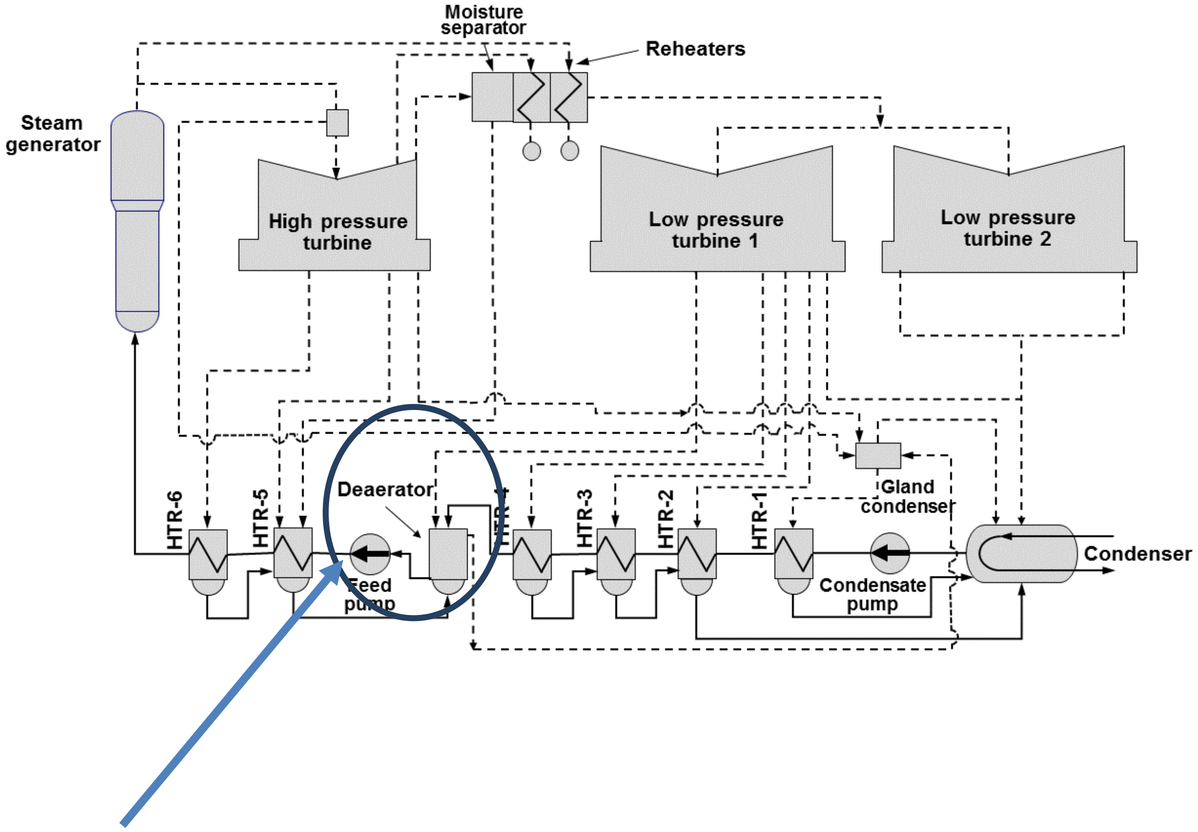
The cooling system (water or air or oil) of the transformer plus the loss in cables leads to a loss between 2.5 to 6% of the main voltage.

The real consumption affects the choice of the turbine (cos ϕ).

12 PURIFICATION OF WATER AND DE-OXIDATION (Deaerator)

Maysaa Kamareddine, Last update: 3.12.18

12.1 Deaerator Basics



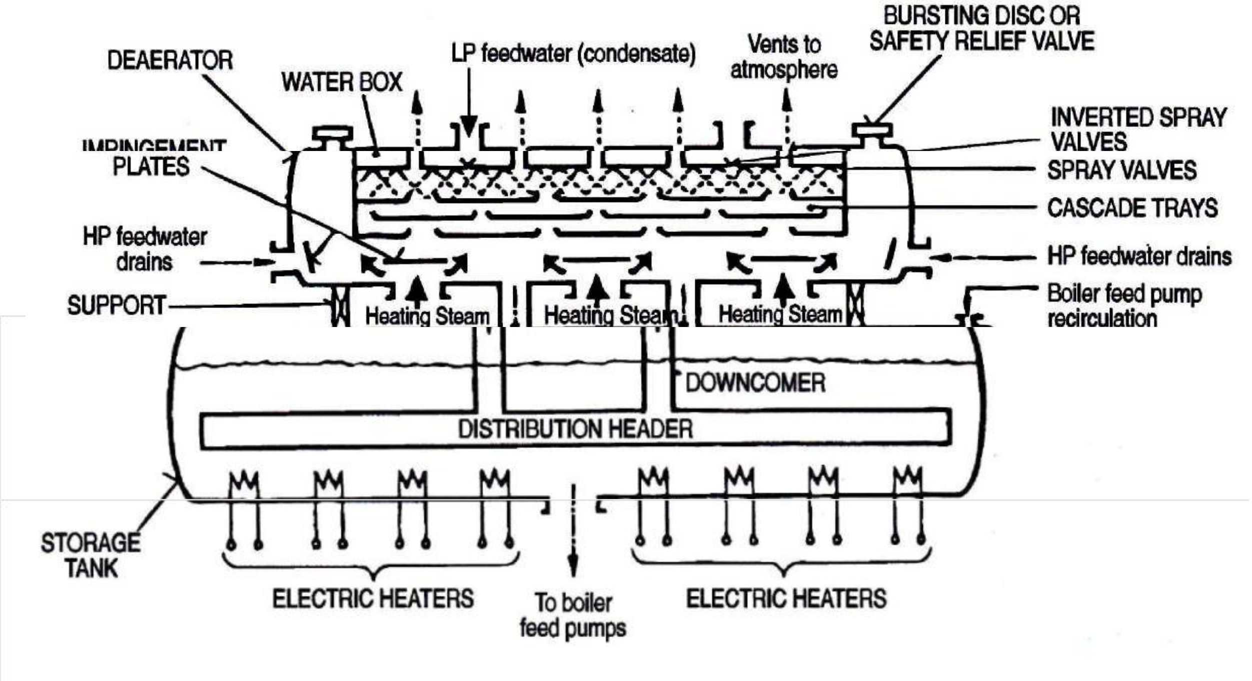
This is the first process to purify water after sorting from the condenser "Deaerator".

The *deaerator* is part of the feedwater heating system and receives extraction steam from the turbine. The condensate to be heated and the extraction steam are intimately mixed in the deaerator by a system of spray nozzles and cascading trays between which the steam percolates as shown in next Figure. The condensate is heated to saturated conditions and the steam condensed in the process. Any dissolved gases in the condensate are released in this process and removed from the deaerator by venting to the atmosphere or to the main condenser. This ensures removal of oxygen from the system particularly during turbine start-up and minimizes the risk of corrosion within the system. Venting to the atmosphere reduces the load on the condenser vacuum pumps, but results in some steam loss unless provision is made to condense it and return it to the condensate system. Venting to atmosphere is only possible if the deaerator pressure is above atmospheric as it is at higher loads.

جهاز التنشيط هو جزء من نظام تسخين الماء المغذي ويستقبل بخار الاستخراج من التوربينات. يتم خلط المكثف المراد تسخينه و بخار الاستخلاص بشكل وثيق في تنفيس بواسطة نظام من فوهات الرش والصواني المتتالية التي يتسلل منها البخار كما هو مبين في الشكل التالي يتم تسخين المكثفات إلى ظروف مشبعة والبخار مكثف في العمليه. يتم تحرير أي غازات مذابة في المكثف في هذه العملية و إزالة من deaerator عن طريق تنفيس في الغلاف الجوي أو إلى المكثف الرئيسي. هذه يضمن إزالة الأوكسجين من النظام خاصة أثناء بدء التوربين ويقلل خطر التآكل داخل النظام. التنفيس في الغلاف الجوي يقلل من الحمل على المضخات الفراغية للمكثف ، ولكن ينتج عنها بعض ضياع البخار ما لم يتم التضمين ذلك وإعادته إلى نظام المكثفات. التنفيس إلى الغلاف الجوي ممكن فقط إذا كان الماسك الضغط فوق الغلاف الجوي كما هو الحال في الأحمال العالية. في نظام محطة الطاقة ، مساعدة يتم توفير (البخار) بأحمال منخفضة للحفاظ على درجات حرارة مرتفعة في خزان جهاز التنشيط.

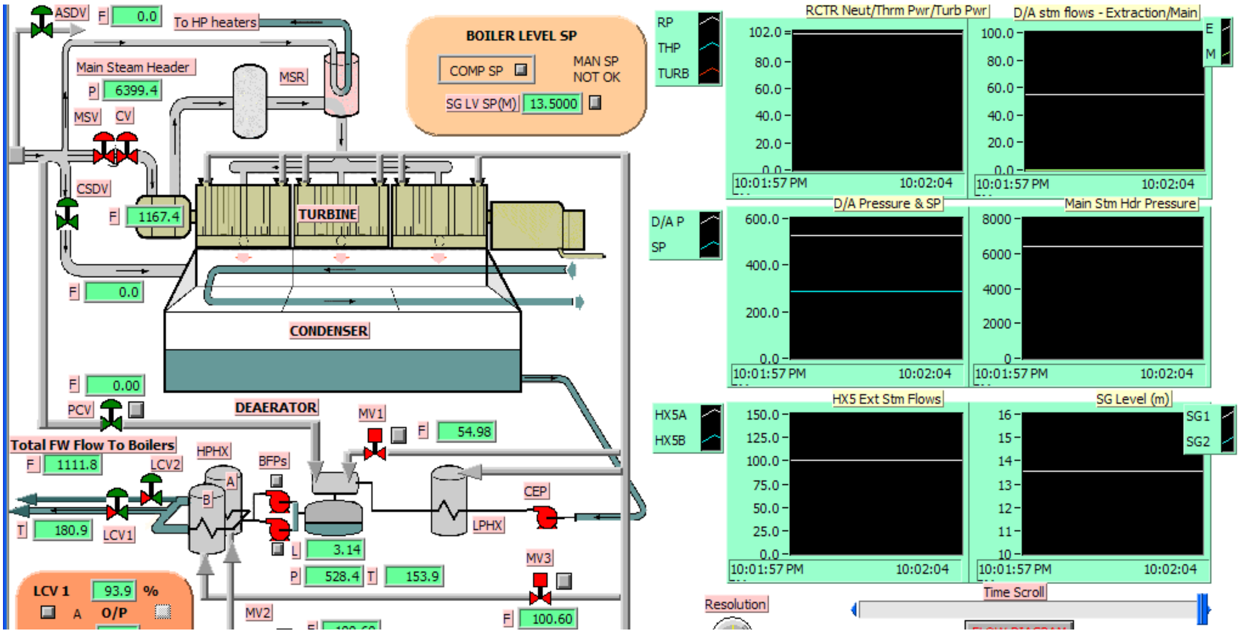
12.2 The deaerating principle

Deaeration is based on two scientific principles. The first principle can be described by Henry's Law. Henry's Law asserts that gas solubility in a solution decreases as the gas partial pressure above the solution decreases. The second scientific principle that governs deaeration is the relationship between gas solubility and temperature. Easily explained, gas solubility in a solution decreases as the temperature of the solution rises and approaches saturation temperature. A deaerator utilizes both of these natural processes to remove dissolved oxygen, carbon dioxide and other non-condensible gases from boiler feedwater. The feedwater is sprayed in thin films into a steam atmosphere allowing it to become quickly heated to saturation. Spraying feedwater in thin films increases the surface area of the liquid in contact with the steam, which results in more rapid oxygen removal and lower gas concentrations. This process reduces the solubility of all dissolved gases and removes them from the feedwater. The liberated gases are then vented from the deaerator.



Immediately below the deaerator is the *deaerator storage tank*, where a large quantity of feed water is stored at near saturation conditions. In the event of a turbine trip, the steam generator will require an assured supply of feed water to maintain the required water inventory during subsequent stabilizing conditions, during which residual heat must be removed. During such conditions, the loss of extraction steam to the high pressure feedwater heaters renders them ineffective, and water from the deaerator storage tank is pumped into the boiler or steam generator without further heating. If deaerator pressure is maintained between 0.5 MPa and 1.0 MPa, then the corresponding temperature of this stored feed water will be between 150°C and 180°C. With an adequate supply of water at this temperature in the deaerator storage tank, damaging thermal shock to the steam generator can be avoided.

The deaerator storage tank is usually located at a high elevation between the reactor containment and the turbine hall to ensure an adequate net positive suction head at the inlet to the feedwater pumps, thus minimizing the risk of pump cavitation.



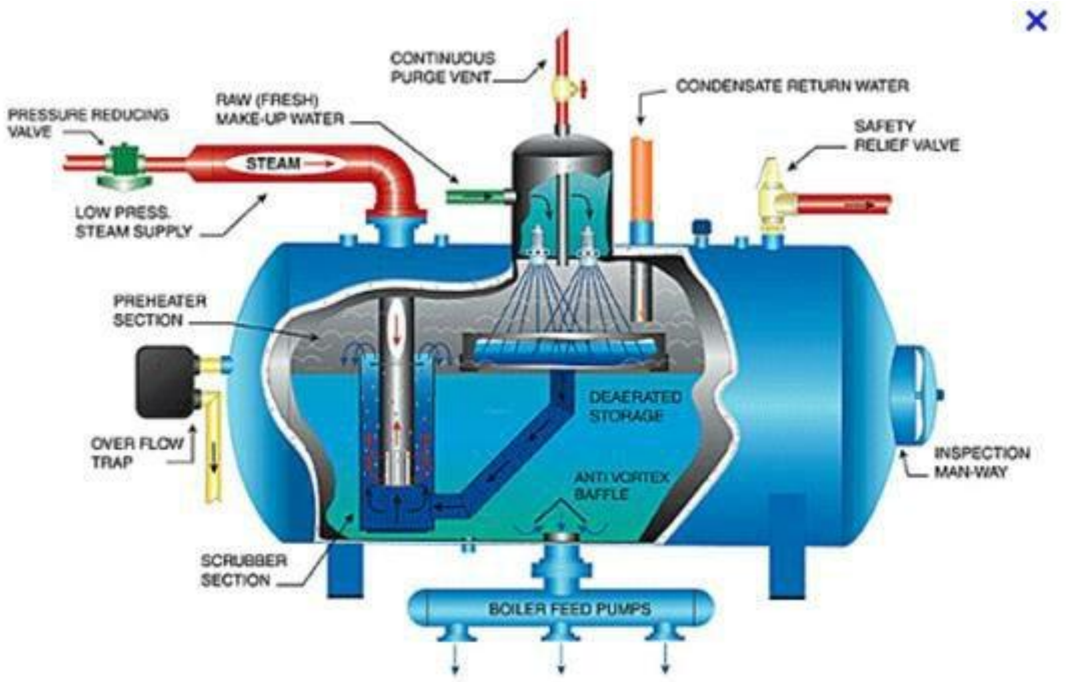
This screen shows the portion of the feedwater system that includes the condenser, low pressure heater, deaerator, the boiler feed pumps, the high pressure heaters and associated valves, with the feedwater going to the steam generator level control valves, after leaving the

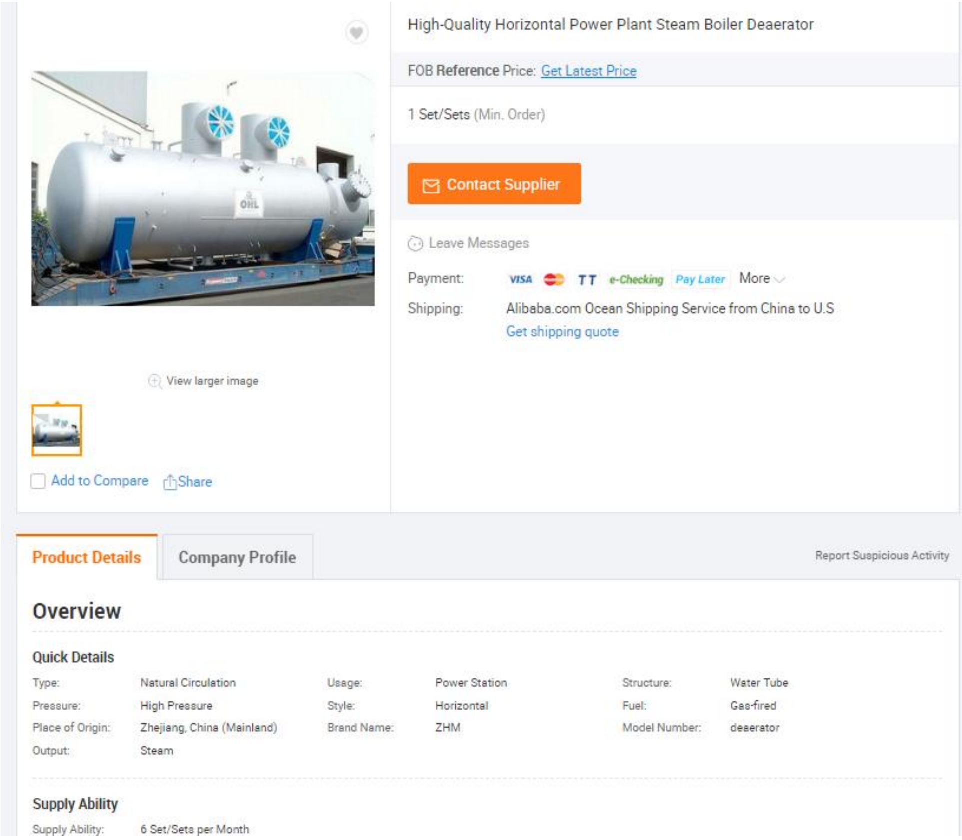
HP heaters.

The following display parameters and pop-up controls are provided:

- Main steam header pressure (KPa), steam flow through the turbine governor valve and the bypass valve (Kg/s).
- Deaerator level (m) and deaerator pressure (KPa); extraction steam motorized valve status and controls from turbine extraction, as well pressure controller controls for main steam extraction to deaerator. The extraction steam flows (Kg/s) are shown respectively for turbine extraction as well as for main steam extraction to the deaerator.
- Main feedwater pump and auxiliary feedwater pump status with associated pop-up menus for 'ON/OFF' controls.
- HP heater motorized valves MV2 and MV3 and pop-up menus for open and close controls for controlling extraction steam flow to the HP heaters.
- Feedwater flow rate (Kg/s) at boiler level control valve (LCV1 & LCV2) outlet and feedwater temperature (°C).
- Pop-up controls for "auto/manual" for boiler level control valves LCV1 & LCV2.

12.3 DEAERATOR FROM alibaba





High-Quality Horizontal Power Plant Steam Boiler Deaerator

FOB Reference Price: Get Latest Price

1 Set/Sets (Min. Order)

Payment:

Shipping: Alibaba.com Ocean Shipping Service from China to U.S

Get shipping quote

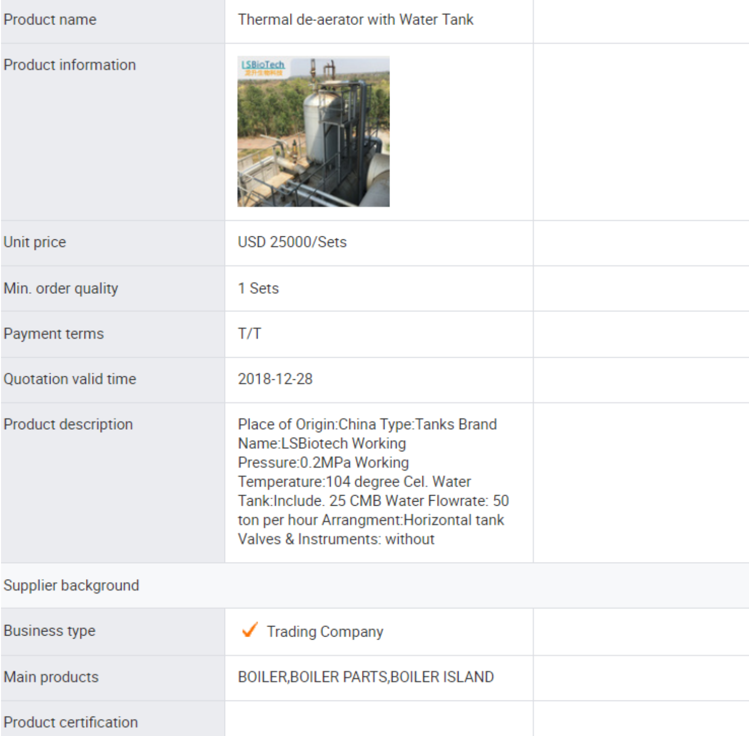
Overview

Quick Details

Type:	Natural Circulation	Usage:	Power Station	Structure:	Water Tube
Pressure:	High Pressure	Style:	Horizontal	Fuel:	Gas-fired
Place of Origin:	Zhejiang, China (Mainland)	Brand Name:	ZHM	Model Number:	deaerator
Output:	Steam				

Supply Ability

Supply Ability: 6 Set/Sets per Month

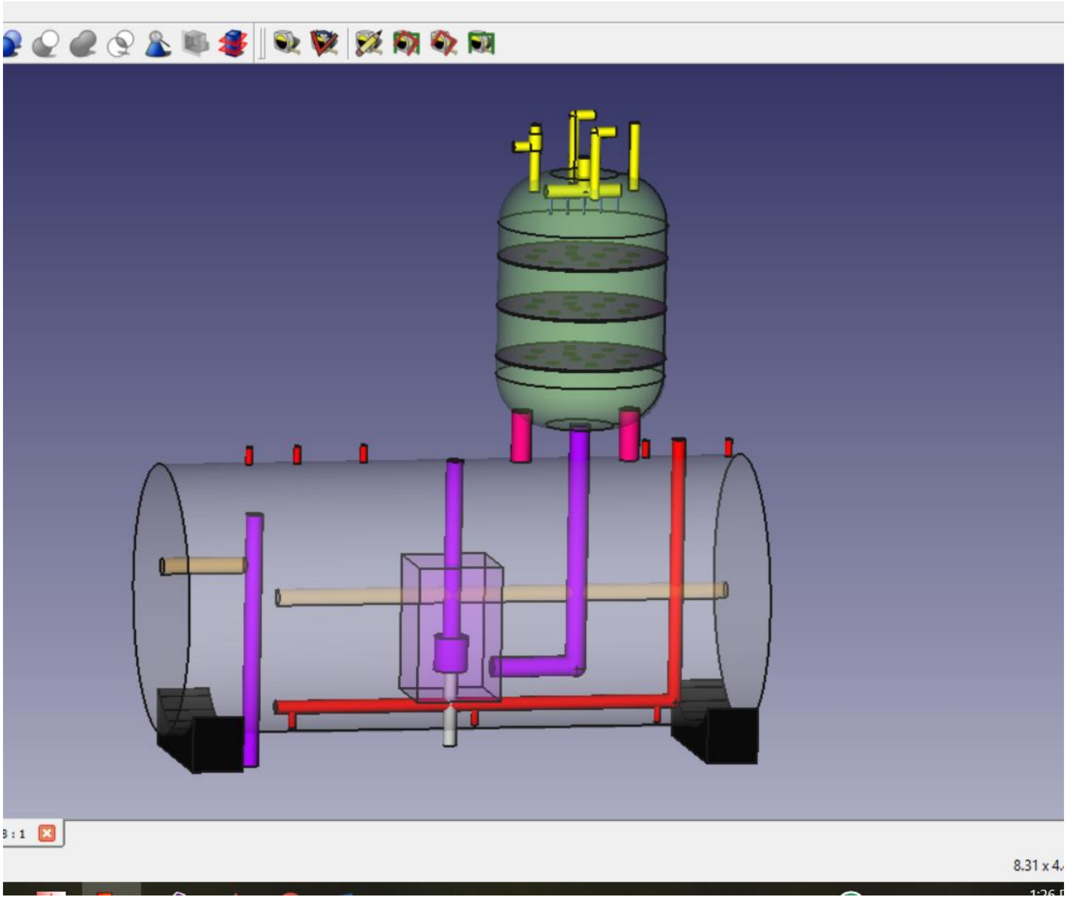


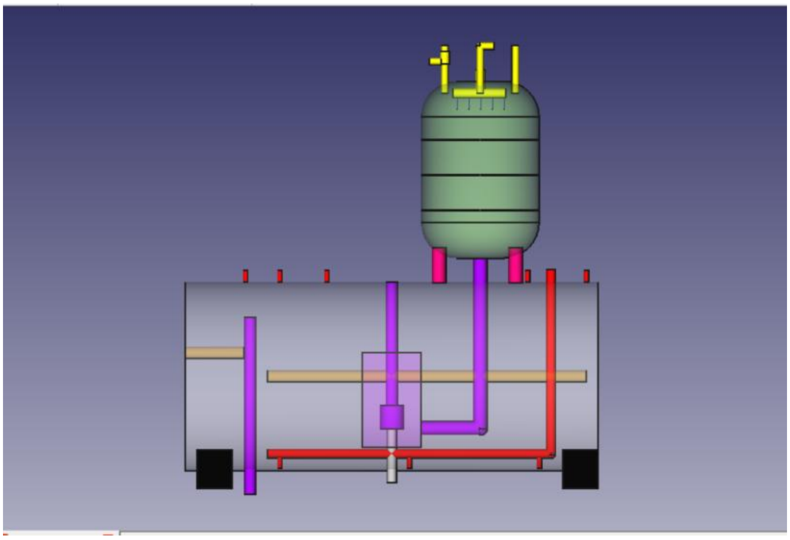
Product name	Thermal de-aerator with Water Tank
Product information	
Unit price	USD 25000/Sets
Min. order quality	1 Sets
Payment terms	T/T
Quotation valid time	2018-12-28
Product description	Place of Origin:China Type:Tanks Brand Name:LSBiotech Working Pressure:0.2MPa Working Temperature:104 degree Cel. Water Tank:Include. 25 CMB Water Flowrate: 50 ton per hour Arrangment:Horizontal tank Valves & Instruments: without
Supplier background	
Business type	✓ Trading Company
Main products	BOILER,BOILER PARTS,BOILER ISLAND
Product certification	

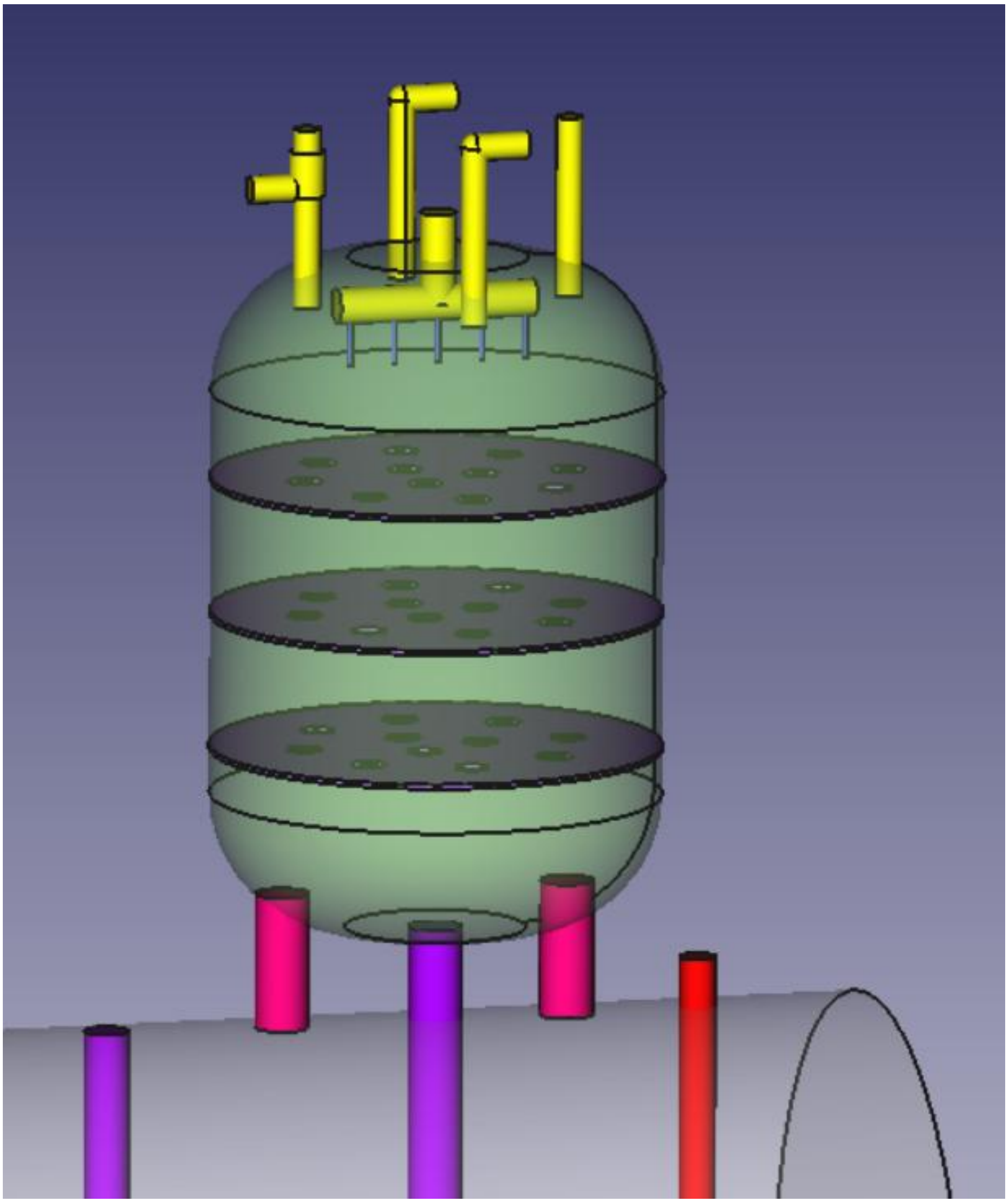
the flowrate is 50 t/hour. It should be 2500 t/h approximately

12.4 freecad design

dearator031218.FCStd







12.5 Deaerator Systems from Zmerly, Tripoli

13 Cooperation with Greentrack (فرز من المصدر)

13.1 Meeting 25.9.2019

خضر عيد من جبل محسن

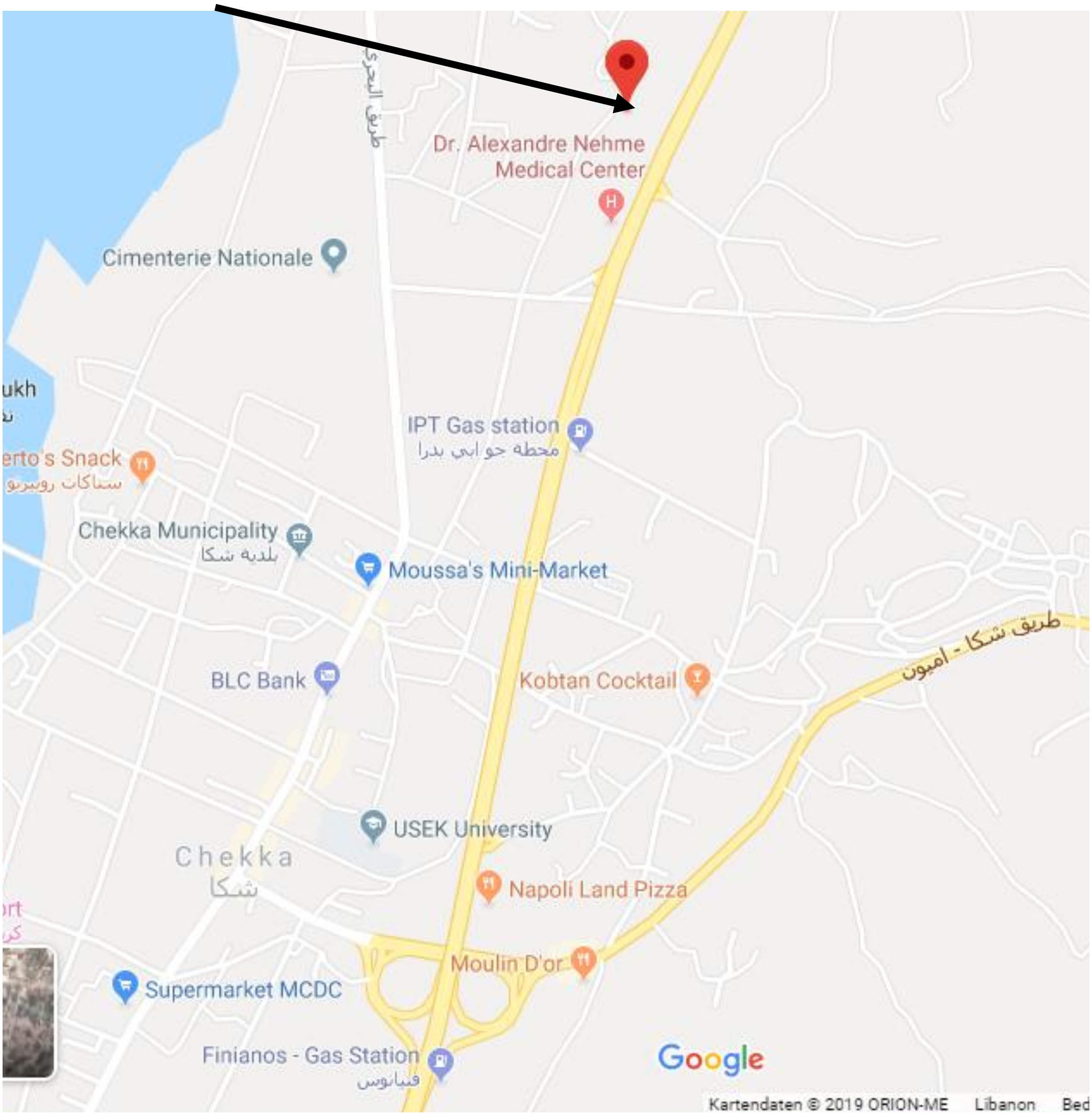
13.2 Suitable for Recycling

Sorting facility (at Tripoli - Jabal Muhsin)

13.3 Refused Waste Jabal Muhsin (for incineration)

13.4 Planned Waste Incineration at Chekka

13.4.1 Hangar of refused waste



14 TEMO-IPP Operational Test at Ras Maska

14.1 Preparations 26.8.-28.9.2019

14.1.1 Official Permission from Ras Masqa Municipality

Request

[00:07, 28.8.2019] Samir Mourad: صباح الخير سيدة ليال. ارسل لكم الطلب والمستندات تحضيرا لموعدنا قبل ظهر اليوم.

[00:10, 28.8.2019] Samir Mourad:

1. Request for long enduring test (about 3 days)

2. Documentation of former tests in Ras Nhache:

http://aecenar.com/index.php/downloads/send/3-meae-institute/359-281016masterthesismayssakamareddine-temo-ipp (see pages 94-101). All emmission were according to the limits of emissions in Lebanon:

<pictures from test in Ras Nhache 2016>

[00:10, 28.8.2019] Samir Mourad: 🌀our filter system

[00:10, 28.8.2019] Samir Mourad: monitoring system for emmisions (actually we got an offer from a German company):

<document from Gasmet emissions measurement>

next morning: answer by whatsApp, that Major Simon Nakhoul has subscribed the request (see below the substcribed request)

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.

بلـدية راسمسقا
تاريخ الورود ٢٧/٨/٢٠١٩
رقم ٦٩٤

وتفضلوا بقبول فائق الاحترام.

د. سمير مراد
AECENAR , LSA ومدير مؤسسة طاقة الشمال

مع الموافقة دون أي مسؤولية
مترتبة على البلدية

رئيس بلدية راسمسقا
سيمون نخول

14.1.2 Mechanical Issues

14.1.2.1 Installing Fuel Burner and Tank for Fuel Burner, Fuel Spray

- Tank on terasse at Ras Maska
- location: tbd.
- connections/valves
- Spray System for Fuel (Solenoid Valve)

14.1.2.2 Primary Water Tank

- Checking connecting with Condensor, pump, outlet

14.1.2.3 Cooling Cycle

- Water Tank (from Ras Nhache)
- connecting pipes
- pump (Ras Nhache)

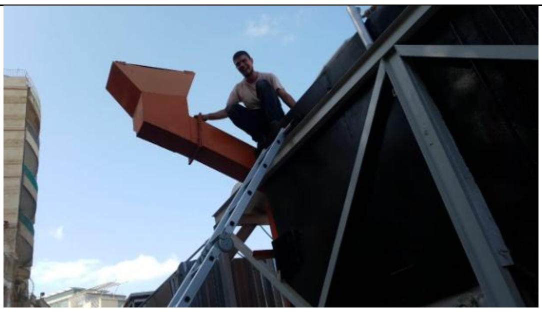
14.1.2.4 Filter System

- Transformator 30kV (optional) (W ?)
- Spray System for Sodium Carbonate (Solenoid Valve, Kompressor)
- Heat Exchanger (optional)
- Installing 2. Exhaust Fan

14.1.2.5 Steam inlet to turbine and condensor

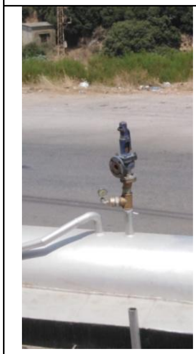
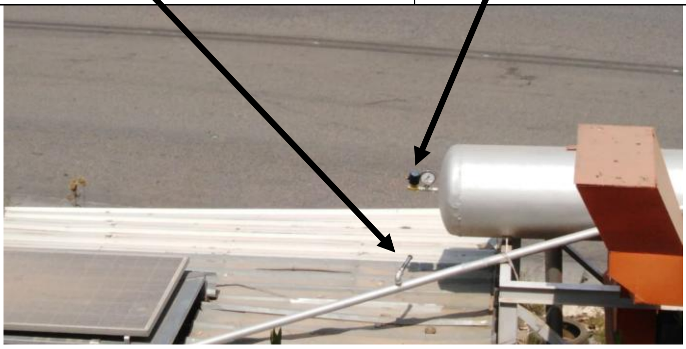
Before	During Work 30.08.19	After
	 	

14.1.2.6 Waste Inlet

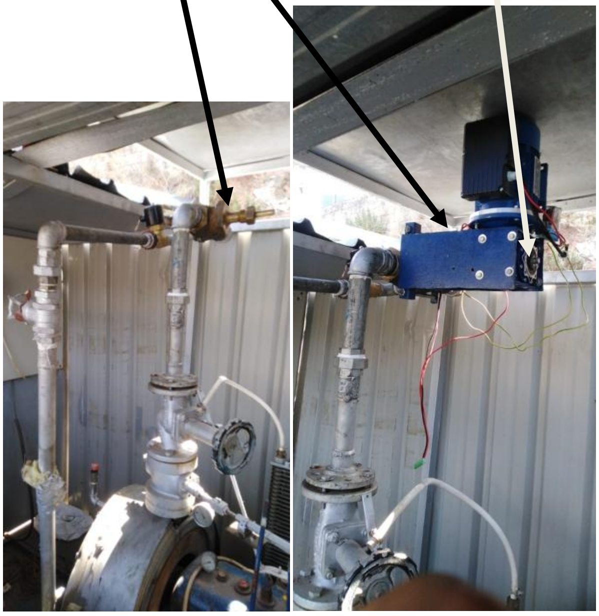
Putting Waste from Container into Waste Inlet 	

14.1.3 Automation System

14.1.3.1 Periphery Instruments for Boiler Pressure Control (BPC)

Mechanical Safety Valve	pressure sensor	Atmospheric discharge valve	Condenser Discharge Valve
			

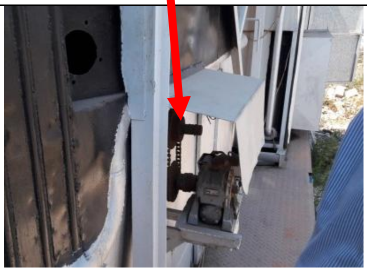
14.1.3.2 Periphery Instruments for Turbine Govering System (TGS)

Turbine Govering Valve	RPM Sensor
تثبيت للgear 	

14.1.3.3 Periphery Instruments for Boiler Level Control (BLC)

Level Sensor	Primary Pump (3 phase power supply) (ON/OFF Interactive Control)
	 

14.1.3.4 Periphery Instruments for Incinerator Control System (INC)

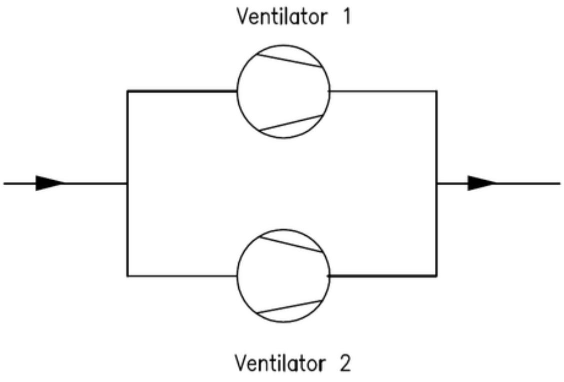
Primary Air Supply Fan to Incineration Chamber (Interactive ON/OFF Control)	Secondary Air Supply Fan to Incineration Chamber (Interactive ON/OFF Control) Tbd	Fuel Burner To be purchased? سامر يسأل (Interactive ON/OFF Control)	Incinerator Camera (Glass Window) القطر 12.3 سنتم (Human Operator supervises)	تشغيل محرك لتحريك النفايات Waste Band Motor (ON/OFF Control)
		Manual ON, after max. 1 minute automatic OFF مكان Tbd.	  	

14.1.3.5 Filter Control System

Control Valve (ON/OFF) for sodium hydrogen carbonate spray valve تشغيل رش للفلتر (Pressurized tank with sodium hydrogen carbonate, compressor)	Electric Filter 30 kV Power Supply (Interactive ON/OFF Control)	Control Valve (ON/OFF) Exhaust Fan 2 (شفاط بعد غرفة الحرق مباشرة و الى cyclotrone) Operator sets to ON	Control Valve (ON/OFF) Exhaust Fan 1 (بعد baghouse فلترات) Operator sets to ON
			

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**.



Beim **Reihenbetrieb** wird eine Druckerhöhung erreicht.

14.1.3.6 Cooling Cycle

pump, Control Valve (ON/OFF)	Condensor Cooling Cycle Connections	Water tank for cooling cycle
 		 

14.1.3.7 Cabinet for PLC

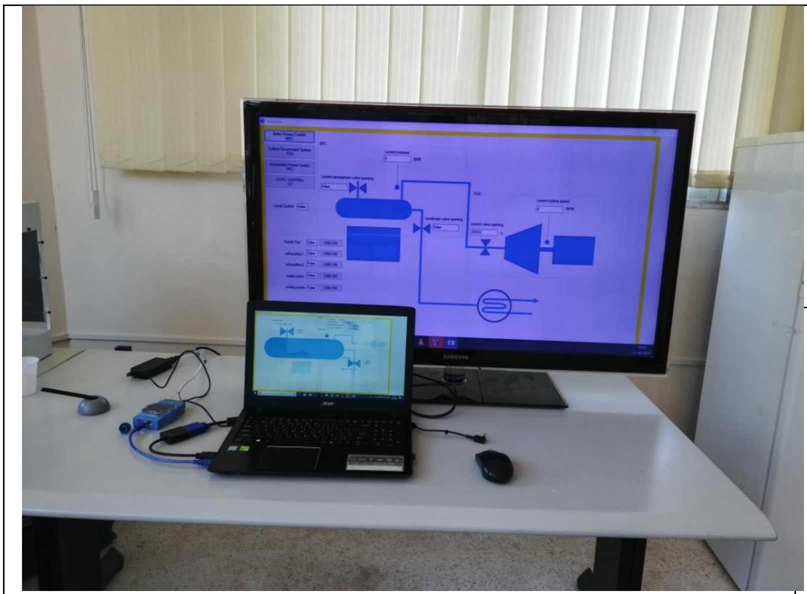
PLC

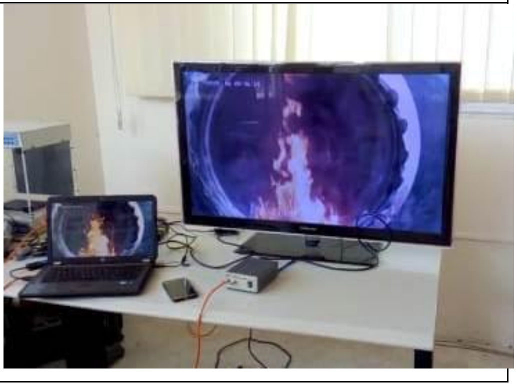
Modbus Cable

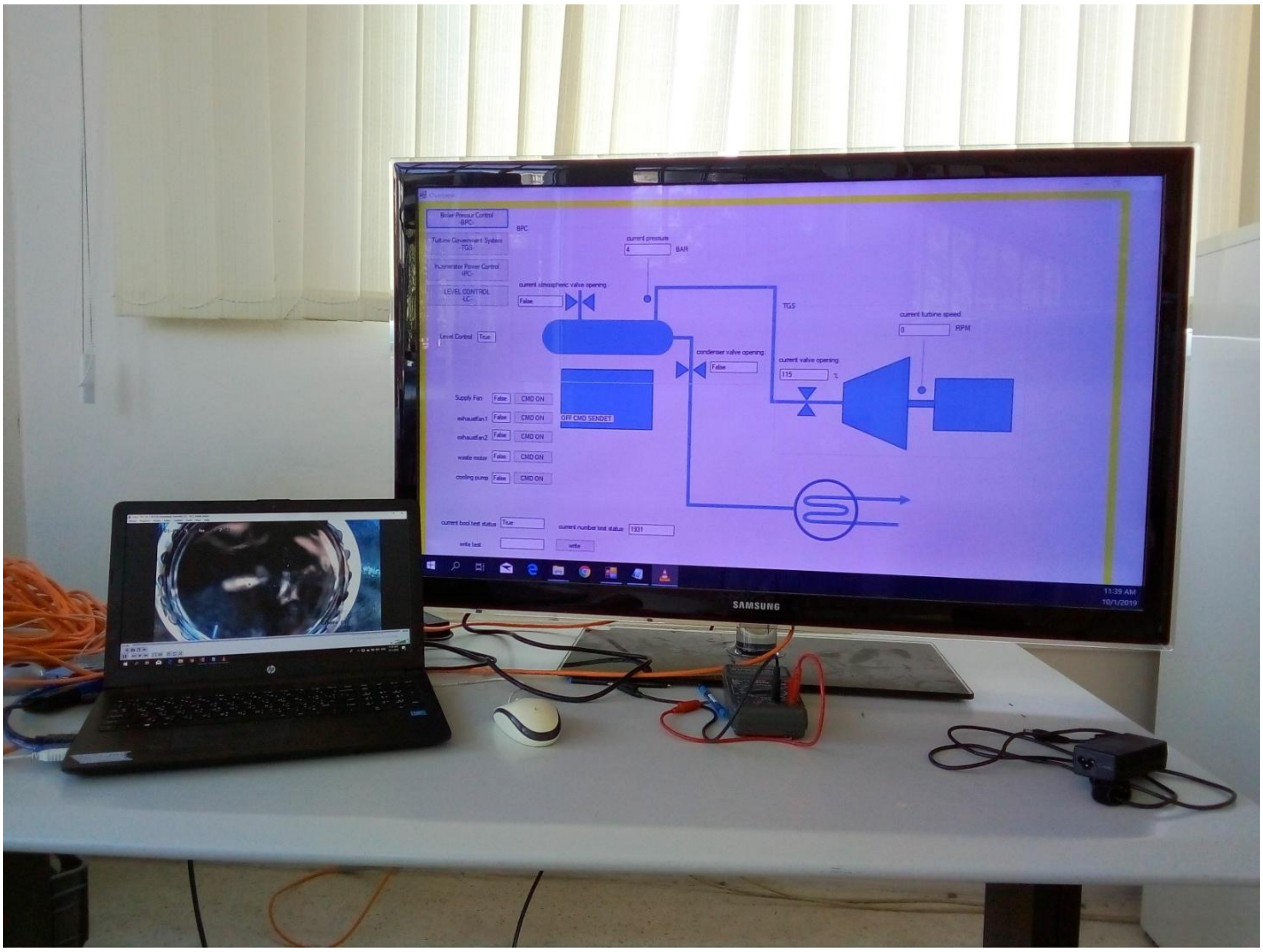
IP Cable for Camera

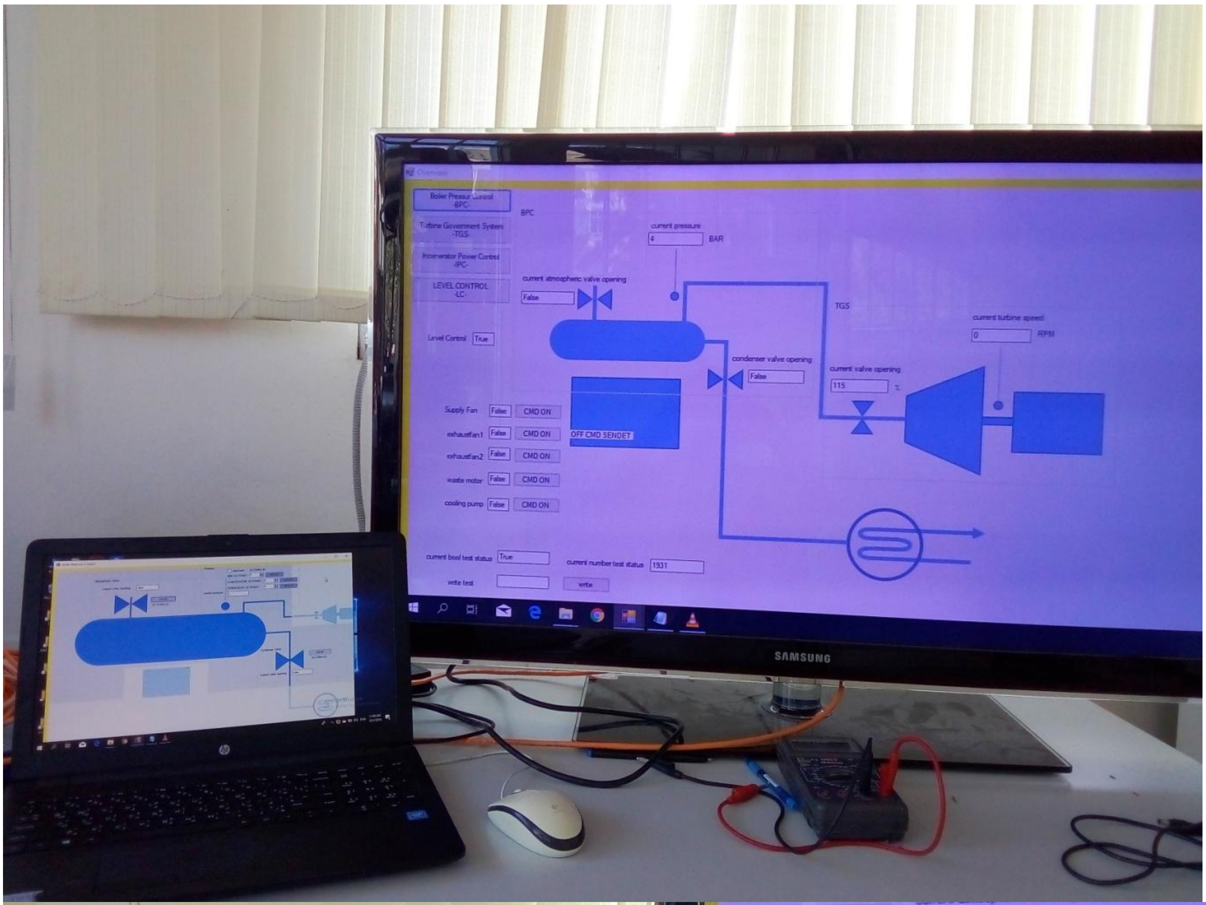
14.1.3.8 Graphical User Interface (GUI)

MEAE Laptop, Large Monitor, modbus cable (see PLC Cabinet)









Level Control True

Supply Fan False CMD ON

exhaustfan1 False CMD ON

exhaustfan2 False CMD ON

waste motor False CMD ON

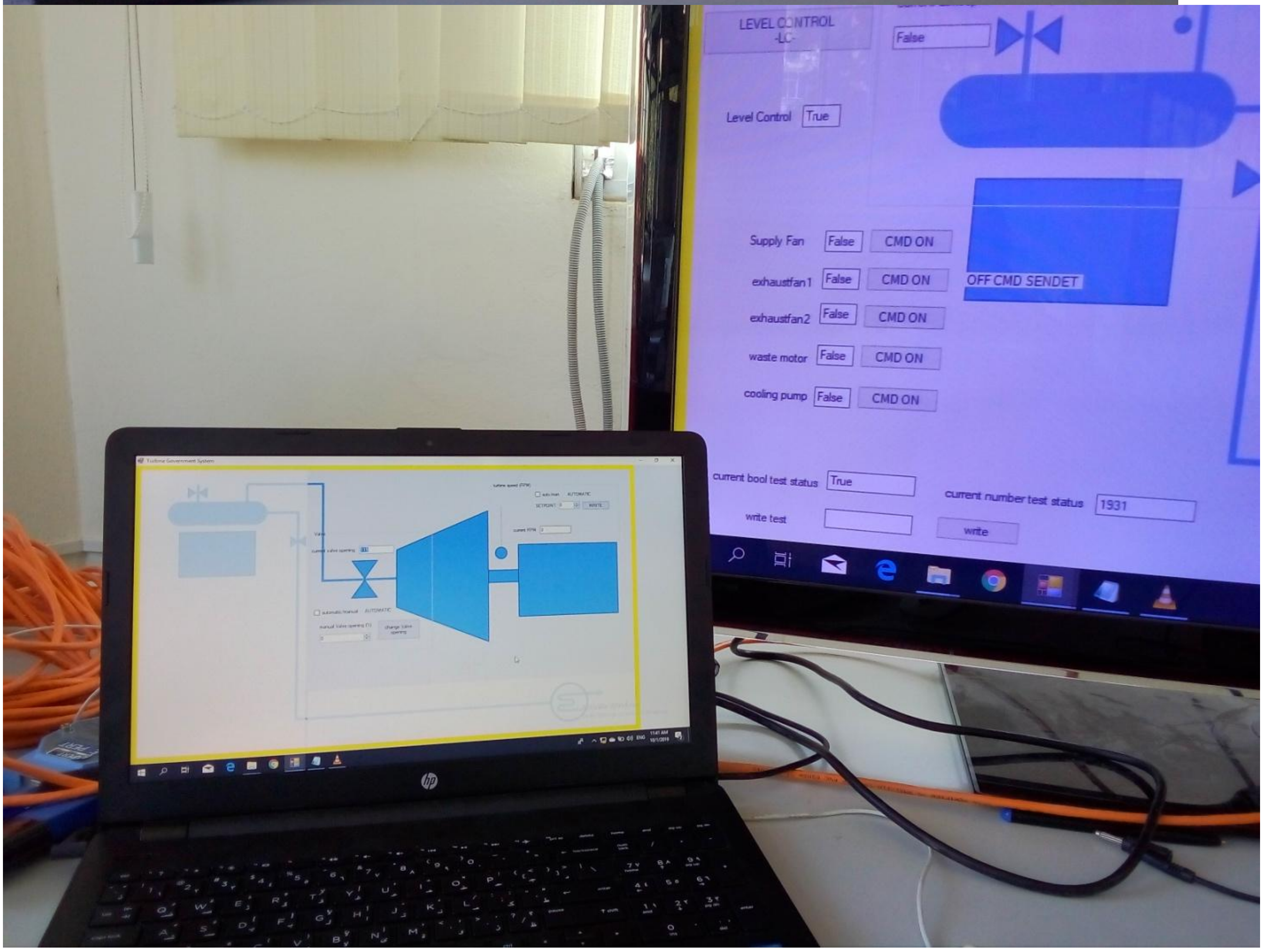
cooling pump False CMD ON

OFF CMD SENDET

current bool test status True

current number test status 1931

write test



False

Level Control True

Supply Fan False CMD ON

exhaustfan1 False CMD ON

exhaustfan2 False CMD ON

waste motor False CMD ON

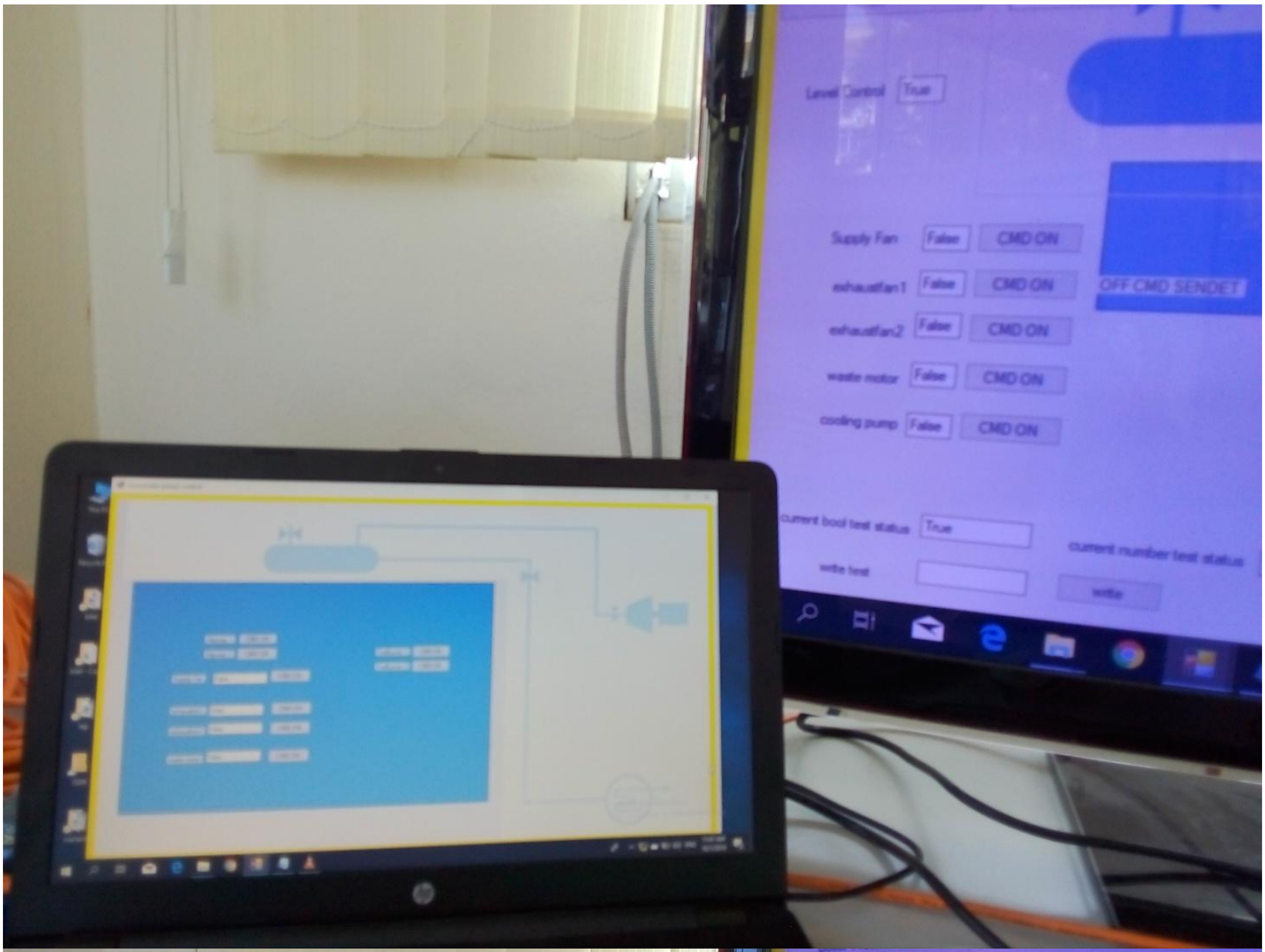
cooling pump False CMD ON

OFF CMD SENDET

current bool test status True

current number test status 1931

write test



Level Control True

Supply Fan False

exhaustfan1 False

exhaustfan2 False

waste motor False

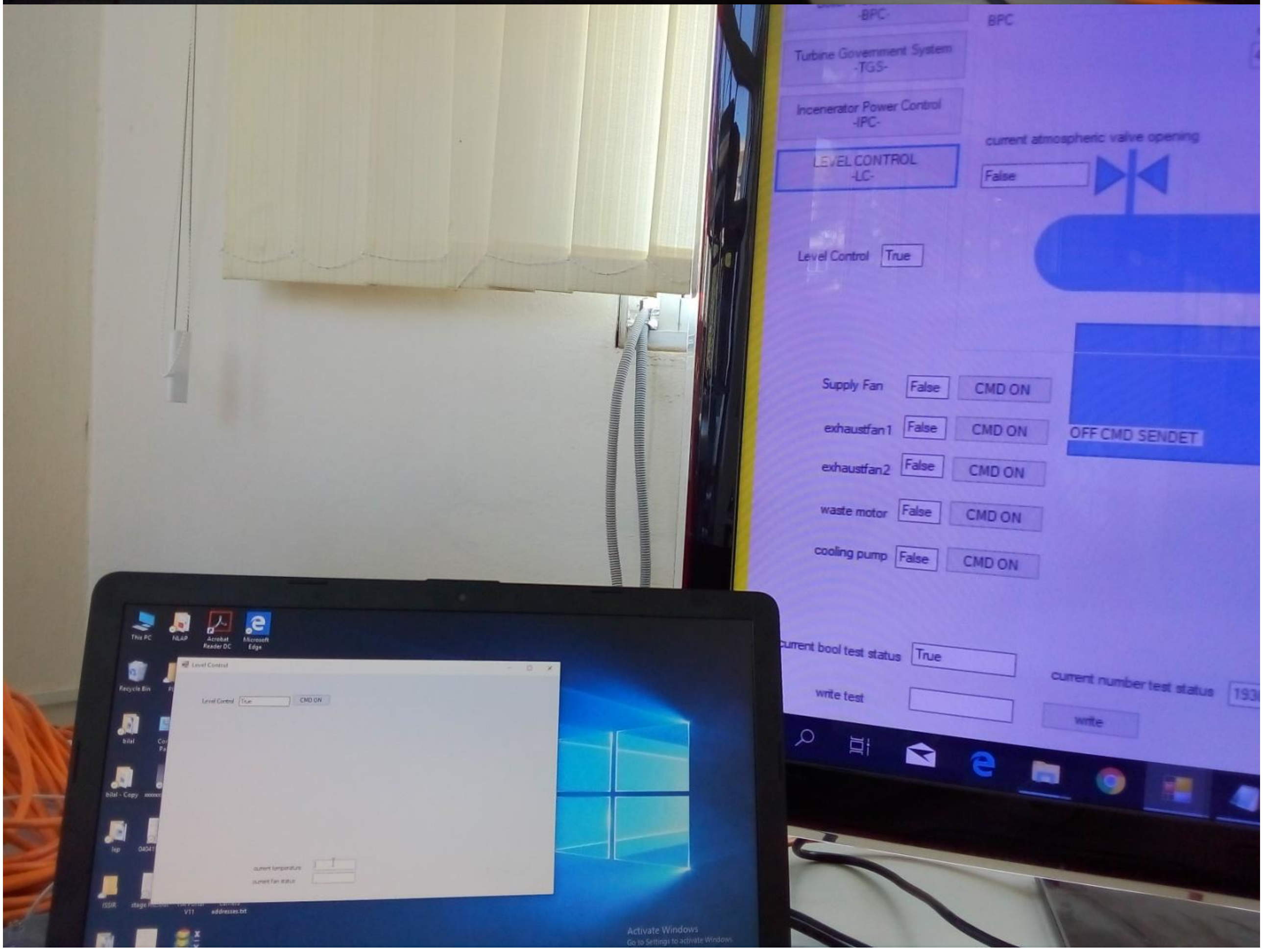
cooling pump False

OFF CMD SENDET

current bool test status True

write test

current number test status



current atmospheric valve opening False

Level Control True

Supply Fan False

exhaustfan1 False

exhaustfan2 False

waste motor False

cooling pump False

OFF CMD SENDET

current bool test status True

write test

current number test status 193

Level Control True

current temperature

current fan status

14.1.4 Preparing/Cleaning Ground

- لَمّ النفايات
- وضع سياج او اواني حمر توضع فيها الماء (من البلدية) من ناحية الشارع

14.1.5 Waste Management

نفايات مفروزة. من دار عمار (زياد ملك يسأل ر. خالد زعبي)

14.1.6 Costs

Mechanical Issues		
Automation System	2.9.2019 100$ given to A. Kassem to buy cables and extra PLC Extension Module (8 IN, 8 OUT) 3.9.2019 25.000 LL given to A. Kassem for cables	

14.1.7 Summary Parts for Incinerator (Check List)

اللوازم لتشغيل المحرقة دون توليد الطاقة الكهربائية

		الوضع الحالي	المسؤول
~~Fuel Burner~~	~~Fuel Burner~~	~~--------~~	
-	~~Installing Fuel Burner~~	~~--------~~	
-	~~Tank for Fuel Burner~~	~~--------~~	
-	~~Spray System for Fuel (Solenoid Valve)~~	~~--------~~	
-	~~Installing Tank, pipes for Fuel Burner~~	~~--------~~	
		~~--------~~	
Filter	~~Transformator 30kV (optional) (W ?)~~	~~--------~~	
	~~Spray System for Sodium Carbonate (Solenoid Valve, Kompressor)~~	~~--------~~	
	~~Heat Exchanger (optional)~~	~~--------~~	
	~~Second Exhaust Fan (قبل الداخون)~~	~~------~~	~~عبد الله و ايهاب~~
	~~Check Baghouse Filter~~	At place	
	~~3 Trays (Cyclotrone, E-Filter, 3.Filter)~~ ~~تسكير وقتي لفتحات الفلترات حتى يسحب الشفاط فقط من غرفة الاحتراق~~		
Waste Inlet	Putting Waste from Container into Waste Inlet (سكة لإدخال النفايات)	TOT, aluminium	سمير

Incineration Chamber	~~Primary Air Supply Fan to Incineration Chamber (Interactive ON/OFF Control)~~	~~في محلها. يجب ان تربط بالPLC~~	
	~~Secondary Air Supply Fan to Incineration Chamber (Interactive ON/OFF Control)~~	~~---------~~	
	Incinerator Camera + Cable Network	To be installed	عبد الرحمن و ابو عمر
	Waste Band Motor (ON/OFF Control)	To be tested	

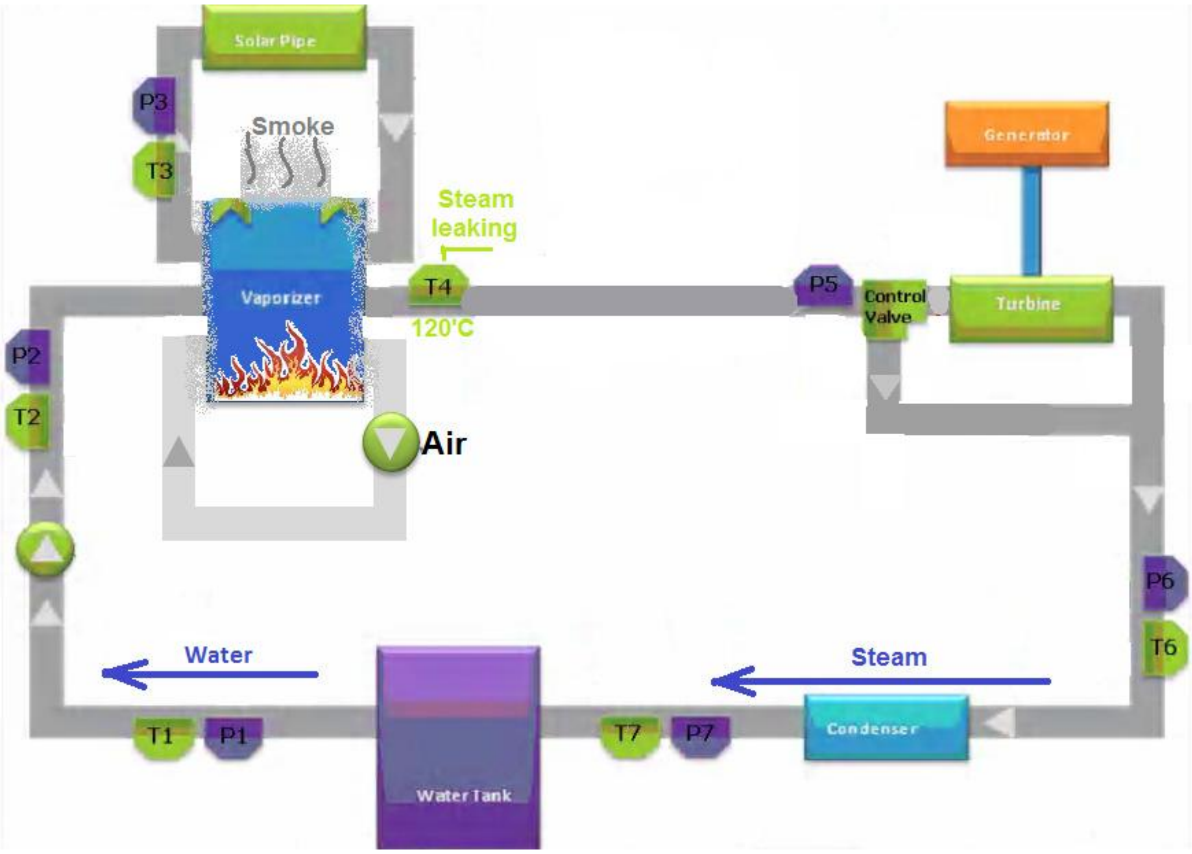
14.1.7.1 Still Open Issues at 24.9.2019

المسؤول	الوضع الحالي		
~~عبد الله و ايهاب~~		~~تجهيز نقطة تشغيل النفايات (الفتحة من قبل الشارع لغرفة الحرق)~~	Mechanical
		تلحيم الفتحات-	
		~~تفقد الفلترات-~~	
		~~سكة تدخيل النفايات مع طبقة يلي بتسكر~~	
سمير		تنظيف حول الماكينا	Facility
سمير		وضع حد للامان من قبل الشارع	
سمير	ممكن بالاجار 3 phases	اشتراك كهربا 3 phase	تشغيل محطة توليد الكهرباء
سمير	ممكن بالاجار 3 phases	اشتراك كهربا 20 A	
سمير	ممكن بالاجار 3 phases	كابلات phase3	
ابو عمر		توفير مياه للتبريد	
ابو عمر و عبد الرحمن		فحص ال valve الكبيرة مع حساس السرعة	

14.2 System Test Specification / Plan (for electricity generation)

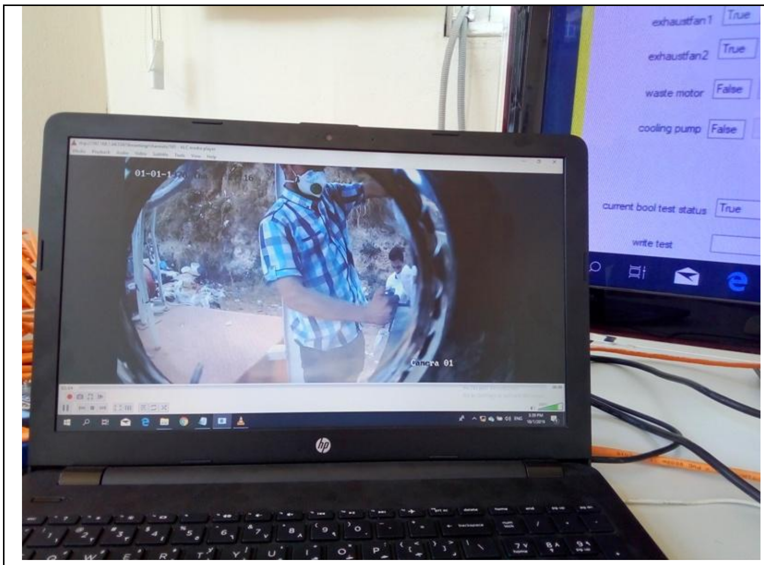
Unit	Test Activity	Expected Post condition	Post condition	Result
Control system	Read Temperature values from Temperature sensors: T1, T2, T3, T4	T1: Linear Value		
		T2: Linear Value		
		T3: Linear value		
		T4: Linear Value		
	Read Pressure values from the pressure sensors: P1, P2, P3, P4	P1: Linear Value		
		P2: Linear Value		
		P3: Linear Value		
		P4: Linear Value		
	RPM Sensor	Linear Value		
	IR Sensor	Clear Reading		
	Open & Close Valves	Full Open		
		Full Close		
		Step Open\Close		
Vaporizer	Ignite fire on the vaporizer for a half of hours without water	No leaking smoke		
		Stable Temperature value		
		Emergency Fire extinguishing		
	Ignite fire on the vaporizer for a half of hours with water	Valve controlled via PLC OPEN\CLOSE		
		No leaking water		
		No leaking steam		
Condenser	Full by water	No leaking water		
	Enter steam	No leaking steam		
		Steam should be transfer to water		
Pipes	Pipes between vaporizer and turbine	No leaking steam		
	Pipes between turbine and condenser	No leaking steam		
	Pipes between condenser and water tank	No leaking water		
	Pipes between water tank and vaporizer	No leaking water		

Turbine	Turbine mechanical	Flexible turn		
	Turbine oil	On the Right levels		
Generator	Connection to turbine	Well connected		
	Power output	Well connected		



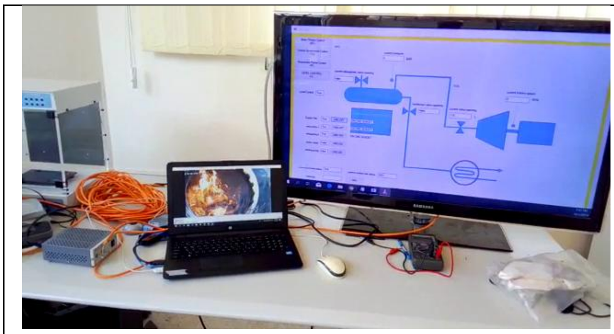
14.3 Test 01.10.2019, 15.30-16 (30min) incineration

14.3.1 Testteam



14.3.2 Before Incineration (Ignition)

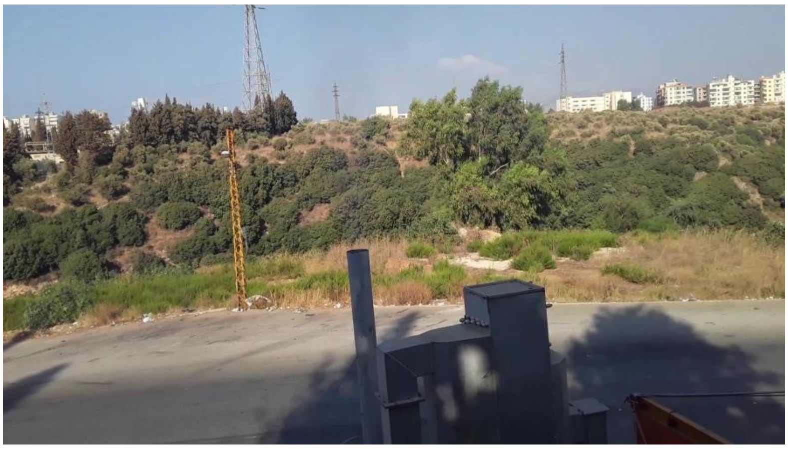
14.3.3 At Begin of Incineration



No smoke

14.3.4 About 20 min. after ignition

Grey smoke



14.3.5 After incineration

about 80% of original volume (after 30 min.)

14.3.6 Results

14.3.6.1 capacity of incinerator

material: 25 packs x 50kg = 1 ton 125 kg;

Test 01.10.2019, 15.30-16 (30min) incineration

in incineration chamber could be put 2-4 packs (=100-200 kg). To be incinerated in 1 hour => about 1ton in 8 hours.

14.3.6.2 To be improved:

- additional baghouse filter -> less smell/less color of smoke
- additional fan/mounting green fan more effectively
- closing gaps: at incineration chamber
- better closing for door of incineration chamber

14.3.7 Ashes Analysis

Leaching with citric acid, Liquid-Liquid

Test 01.10.2019, 15.30-16 (30min) incineration

Test 01.10.2019, 15.30-16 (30min) incineration

Test 01.10.2019, 15.30-16 (30min) incineration


G 20
SCHOTT
MAINZ
JENA GLAS
1l
VWR
Household


AL JOUDA
الجودة
حامض الليمون
CITRIC ACID
100% SATISFACTION GUARANTEE
Best Quality
تجارة وصناعة مواد غذائية
Commerce & Industrie Alimentaire

Test 01.10.2019, 15.30-16 (30min) incineration


VWR
VICON
ON/OFF
ZERO
PRINT
ENTER
F
CAL
ACCULAB
Sartorius group

Test 01.10.2019, 15.30-16 (30min) incineration

14.4 Reparations after Test on 1.10.19

- Closing of leaks in incineration chamber
- putting second exhaust fan parallel to first exhaust fan immediately before chimney
- direct exhaust way between last filter (baghouse filter) and fans.

14.5 Test 4 (27.12.2019): Leaks, Suction and Filtering

Unit	Test Activity	Expected Post condition	Post condition	Result
Control System	Open & Close Fans	Open\Close main fan (Big fan)	Opened and closed normally	Success
		Open\Close secondary fan (small fan)	Opened and closed normally	Success
		Open the two fan together	Opened and closed normally	Success
	Connect to burning room camera	Clean and clear live video	Image not too much clear	Done with remarks
Burning room	Ignite fire on the Burning room for 10 minutes	No leaking smoke in the room	There are leaking smoke, check below for details	Leaks should be fixed
		Stable Temperature value	normal	Normal
Suction System	Keep fire burning and turn on Main Fan for 10 minutes	Smoke coming out from the funnel	Yes it is, funnel smoke density: about 4/10	Nothing to do till the next test
	Keep fire burning and turn off main fan wait a minute then turn on the secondary fan for 10 minutes	Smoke coming out from the funnel	Yes it is, funnel smoke density: about 2/10	Nothing to do till the next test
	Keep fire burning and turn on the two fans together for 5 minutes	Smoke coming out from the funnel strongly	Yes it is, funnel smoke density: about 5/10	Nothing to do till the next test
Filtering System	Keep fire burning with two fans and check the smoke color and smell	Smoke with no or transparent color	Transparent from the funnel and white from the leaks	Good result
		Smoke with no smell	There is smell but it may be caused by leaks	Nothing to do till the next test

Test date and time:

The test take place in Tripoli, Haikaliyeh on Friday 27-12-2019 at 2:00 PM and it takes about 42 minutes.

Test participators:

Supervise this test Eng. Mahmoud Zohby,

And Mr. Abdul Rahman Mourad on the control system

With Mr. Bilal and Ibrahim Mourad on the burning and test tasks.

Test record:

All the test procedure was video recorded using a 4K camera

Videos are available on company server on:

Detailed info:

In the beginning of the test after burning the garbage, the smoke start to leaks from the burning room and the smoke path.

Below are the most important leaks places with images:

Place 1: burning room

Place 2: garbage entrance

Image 3: the beginning of the smoke path

Place 4: electro-filter circles

Place 5: burning room main door

Next Tasks:

1. Fix leaking places, with checking of fixes result by immediate test
2. Reinstall the compressor and the powder valve instead of the stolen one
3. Install fuel burner
4. Find a way to get rid of the mesh
5. Install a fire extinguisher to safely extinguish the fire in emergency cases
6. Enhance the garbage entrance way or install a garbage shredder
7. Install pollution sensors or make a contract for regular checks during works
8. Install temperature sensors all around the steam path
9. Complete working on the Electro-Filter
10. Revise the control system with its control interface

This report is prepared by Eng. Mahmoud Zohby
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+961 3 671621

14.6 NLAP-IPP_DemoPlant_Operation Start-Up

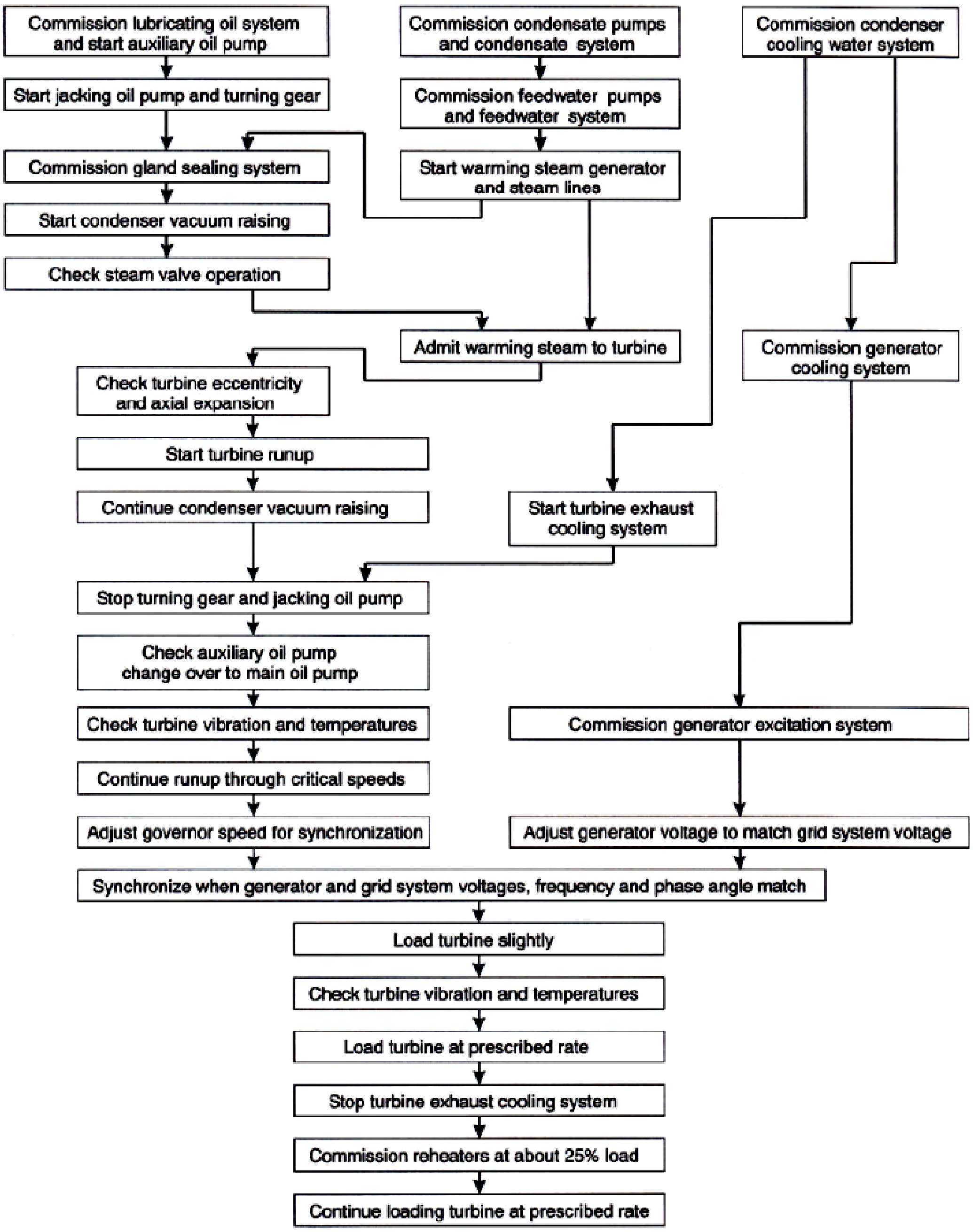

Figure 26 Major activities during start-up and loading

References

[1] Tom Smolinka,1 Emile Tabu Ojong1 and Ju¨ rgen Garche2, "Hydrogen Production from Renewable EnergiesdElectrolyzer Technologies," vol. chapter 8, pp. 103-128.

[2] Pier-Olivier Nault et Nicolas Tremblay, "Générateur d’hydrogène," 2013.

[3] Y. Sano, "PRODUCTION OF ELECTROLYTC WATER," Feb. 27, 2004 .

https://abgs-gmbh.de/2014/04/16/fachartikel-lueftungsanlagen/

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