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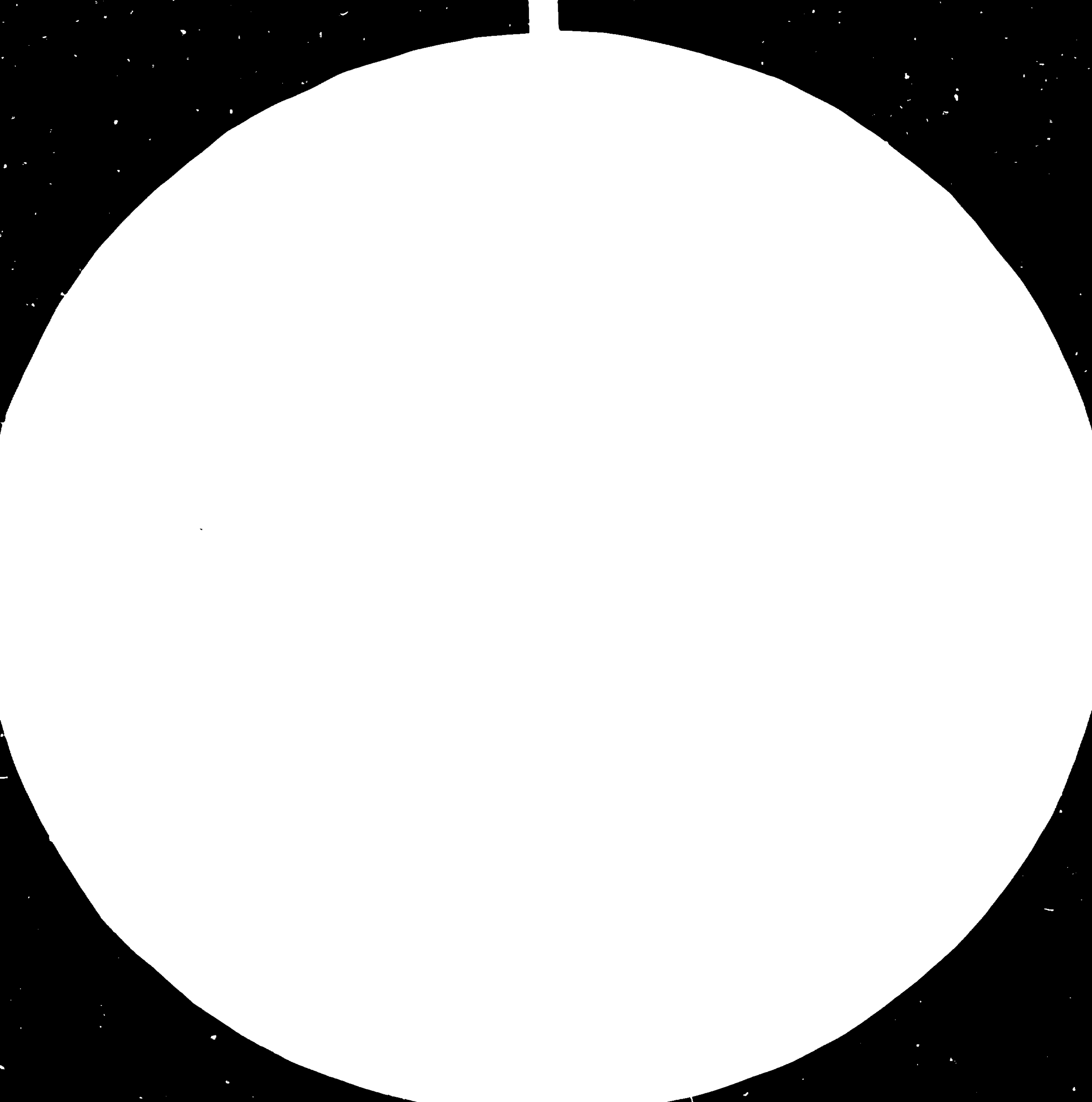

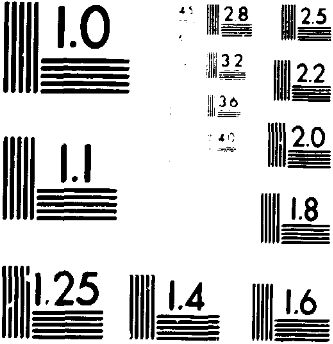

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

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14125
(1 of 2)

US/INT/84/100

7. UNIDO WORKSHOP

ON

FERTILIZER PLANT MAINTENANCE,

Documentation Part I:

Plant Maintenance Departments

of

CHEMIE LINZ AG

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HISTRORICAL DEVELOPMENT OF CHEMIE LINZ AG

Start of erection work in 1940, heaping up the area near the Danube for 2 - 4 meters with gravel from the port.
Question of location: the new plant was situated next door to VOEST because there was a surplus of coke oven gas.

The original name of our company was "Oesterreichische Stickstoffwerke AG" (translated: Austrian Nitrogen Plants Ltd.). Initially only nitrogen fertilizers were produced. This old name was too complicated and too long for international use. So we changed it to "CHEMIE LINZ AG" some years ago.

Original layout of our facilities:

1st extension step: 50 000 t N
2nd extension step: 100 000 t N
Start of production - Primary N: October 1942
CAN : March 1943

In the year 1944 we had reached a production of 55 000 t primary N.

During the second world war our plant was hit by 800 bombs. From May 1945 to July 1946 production partly stood still due to damage and shortage of power.
In 1948 the former production level was reached again.

It was boosted strongly in the following years.

	1957	1967	1977
Production of primary N:	164 000 t/a	275 000 t/a	466 000 t/a

The number of different products increased during the same time from 200 to 1300.

The most important results of our chemical-technical investigations you will find in the CHEMIE LINZ Know-How brochure.

The most significant erections:

1939	Foundation of the enterprise "Österreichische Stickstoffwerke AG" with a target of 50 000 t N per annum.
1943	Start-up as an enterprise producing only nitrogenous fertilizers.
1944/45	800 bomb hits, closing of the plant
1945/46	Reconstruction, installation of the departments investigation, development, sales and training.
1948	Foundation of pharmaceutical division and continuous extension of all plants.
1953	Foundation of the production line for plant protective agents.
1954	Start of the plants "Gypsum Sulphuric Acid" and SSP.
1960	Start of organic production facilities (preplastics and plastics).
1975	Erection of the plant at Enns (acrylonitrile).

ORGANIZATION OF CHEMIE LINZ

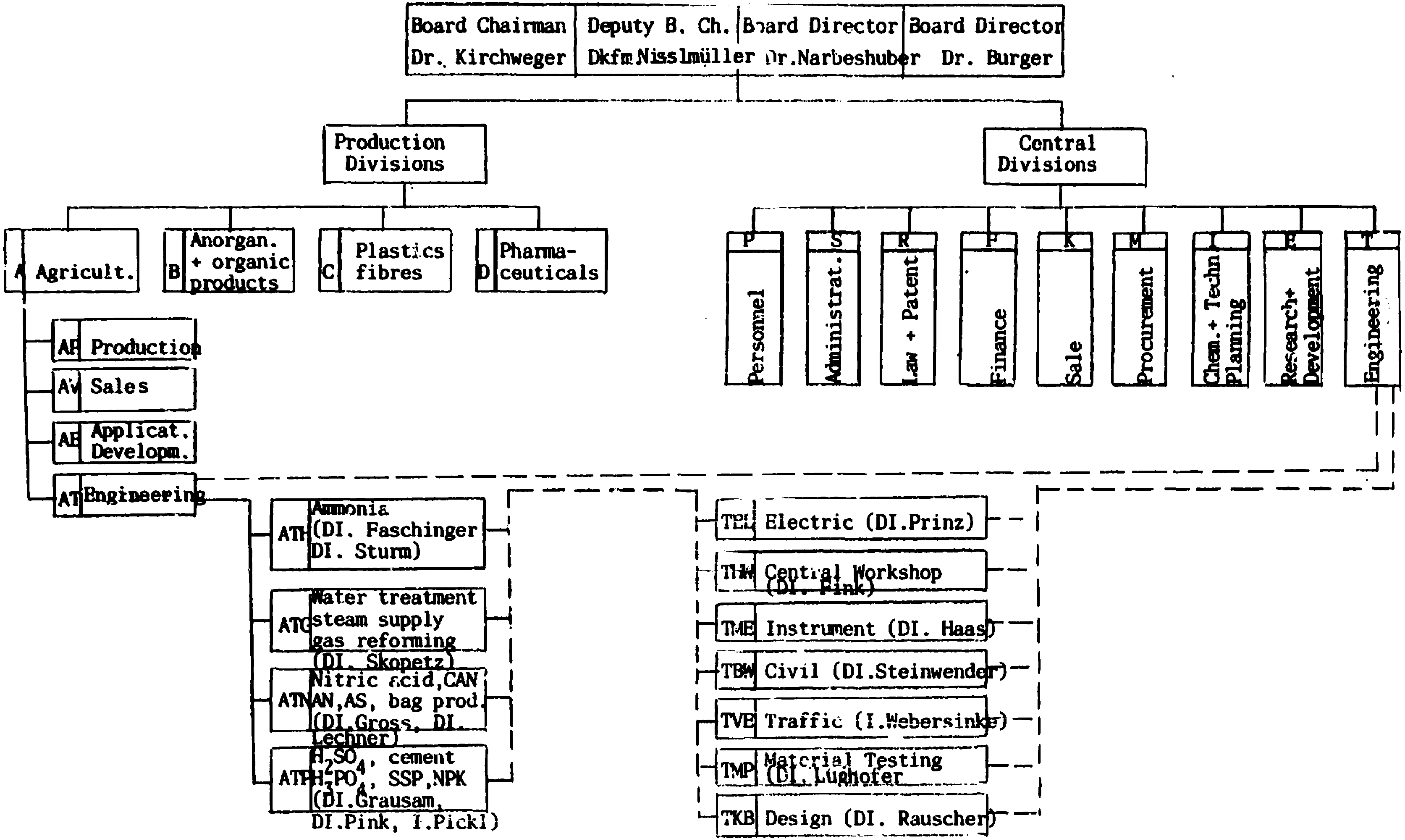


TABLE OF DEPARTMENTS YOU CAN VISIT DURING THE COURSE

ATH	Division A, engineering, high pressure Single train plant for NH_3 production, old ammonia synthesis plant, ammonia storage
ATG	Division A, engineering, gas preparation Synthesis gas preparation from coke oven gas and natural gas, gas reforming plant, water supply for the whole company, boiler feed water treatment, oxygen plant
ATN	Division A, engineering, nitrogen fertilizers Nitric acid, CAN, ammonium nitrate, ammonium sulphate, storage, bagging an shipping, plastic bag
ATP	Division A, engineering, phosphate fertilizers Sulphuric acid and cement from gypsum, sulphur burning plant, single superphosphate, NPK phosphoric acid, storage for fertilizers and raw materials bagging and shipping.
BTH	Division B, engineering, urea Urea and melamine plant, storage, bagging
THW	Central engineering, main workshop Manufacture and repair of vessels, heat exchangers, pipes,... Machining shop, repair of pumps, gears,...

TEL Central engineering, electrical department
Planning of electrical equipment of new Chemie Linz plants,
electrical maintenance, balancing of rotors

TME Central engineering, instrument department
Planning of instrumentation systems,
weighing systems, maintenance and repair

TMP Central engineering, material testing department
Recommendations concerning material selection for new and existing plants, checking of welding seams, corrosion test,...

You will have also the opportunity to visit the following departments for a short time:

TBW Central engineering, civil department
Planning of new buildings and maintenance of buildings, streets, rails, sewerage. Insulation and painting group.

US Safety department
Safety instructions, registration of accidents, fire brigade, safety kit (masks, filters, respirators,...)

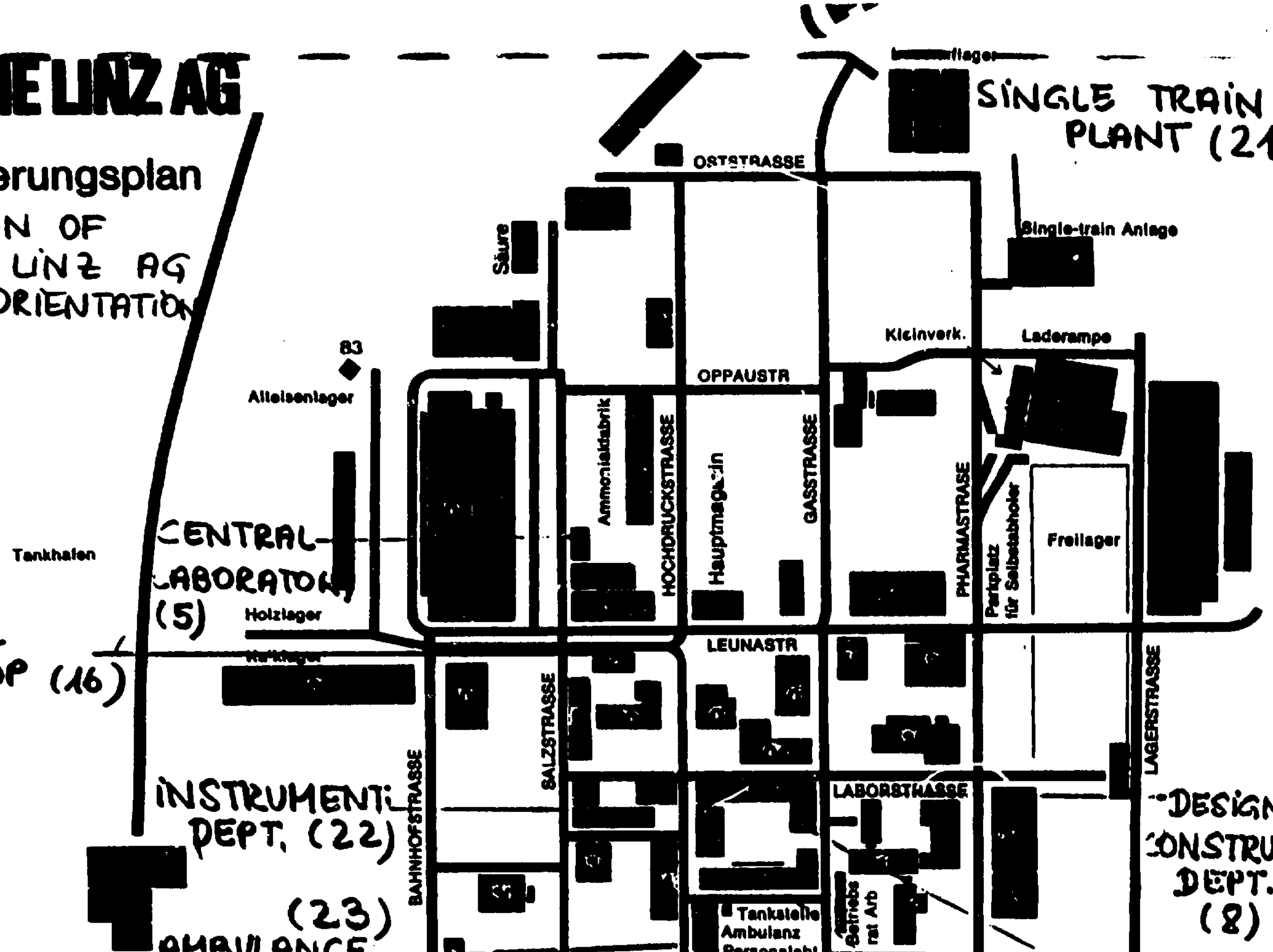
TKB Central engineering, design
Coordination of all investments (new plants), improvements in existing plants together with production- and maintenance departments, working out of drawings and investment programs.

LCS	(CHEMSERV CONSULTING)-a 100% subsidiary of Chemie Linz AG Central planning licenses Licenses and know-how from Chemie Linz AG
GBR	Discussion with members of the works council
MMV	Central division M (procurement) Stores, computer system
PAW	Central division P (personnel), training school Training of apprentices, workers and employees in lectures and courses.

CHEMIE LINZ AG

Orientierungsplan

SITE PLAN OF
CHEMIE LINZ AG
TO YOUR ORIENTATION



ATTENTION!

Zur Beachtung!

Ein- und Ausfahrt an den Werkstoren nur nach Einweisung

Bei längerem Halten ist der Motor abzustellen

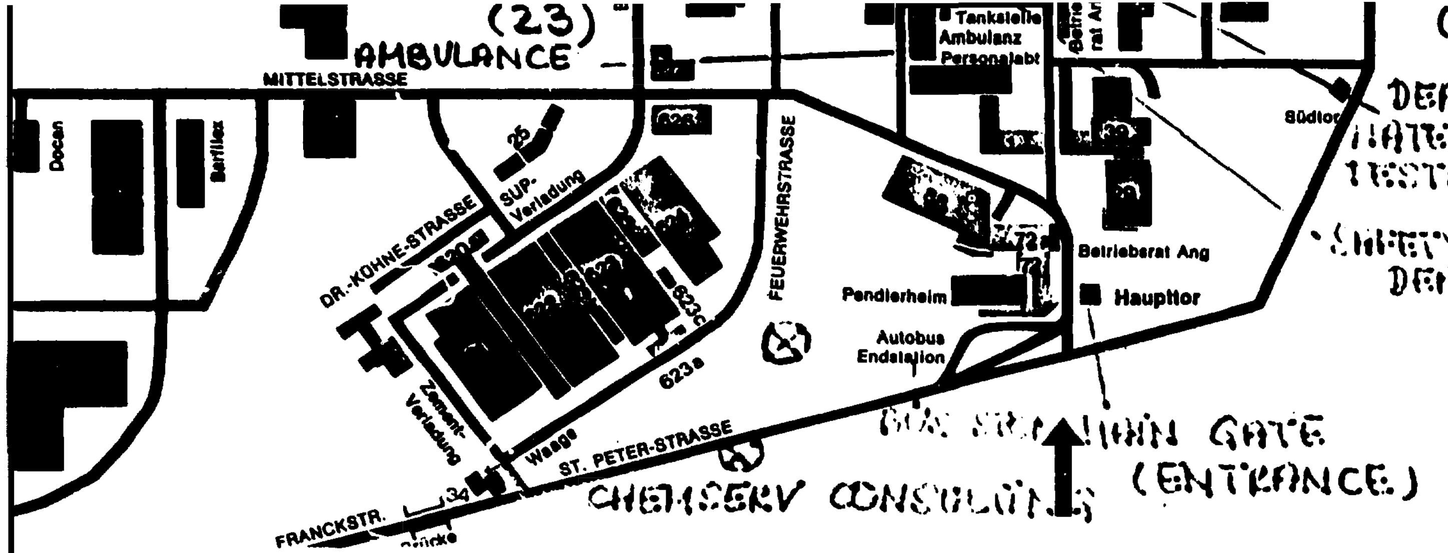
PASS THE GATE
ONLY AFTER INSTRUC

Die zulässige Höchstgeschwindigkeit beträgt 15 km/h.

MAXIMUM SPEED
IS 15 Km/hour.

Rauchen ist im gesamten Werksgelände, mit Ausnahme besonders bezeichneter Bereiche verboten.

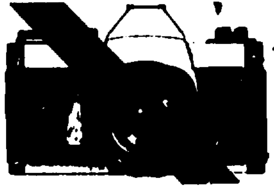
DON'T SMOKE IN THE
AREA OF CHEMIE LIN
EXCEPT IN THE



AREA OF CHEMIE LINZ EXCEPT IN THE SPECIALLY MARKED ROOMS

Das Hantieren mit offenam Feuer ist verboten (Explosionsgefahr)

DON'T HANDLE WITH FIRE (EXPLOSIONS)



DON'T PHOTOGRAPH

Fotografieren im Werk ist verboten.

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MECHANICAL JOBS FOR OPERATORS

During start-up of a new plant we normally have some maintenance personnel in shift (1 or 2 shift fitters). If the plant is in continuous operation there is no maintenance personnel in shift. For the complete plant of Chemie Linz only in two departments (ATN and ATP) each one shift fitter is working. For example the single train ammonia plant, water treatment and also urea plant don' t have a shift fitter.If there is a fault the operating people (production) can call the stand-by service (on call service).

For every production department

1 chemical engineer or production foreman.

For every maintenance department

1 mechanical engineer or maintenance foreman and
2 fitters with good knowledge of the plant are on call for the time of one week after the normal working time and during weekend.

A few years ago an apprenticeship scheme for chemical plant operators was launched in Austria. After the normal education at school (normal age is 15 years) a young person can join e. g. Chemie Linz and can learn this profession for 3 years. During this apprenticeship at school, workshops and different plants the person becomes familiar with small maintenance jobs. Therefore in Chemie Linz the operators are allowed to carry out certain maintenance jobs under supervision of the production foreman and on the production department's responsibility.

Maintenance jobs allowed for operators are listed below:

Mechanical jobs allowed for operators in department ...

After order and instruction by the shift foreman the following jobs are performed by production side after relevant guidance by the maintenance side in the units later mentioned.
Beside general precautions, the following particular safety instructions have to be considered:

Pipes and pumps are to be depressurized and drained, hand wheels of valves - if required - are to be locked, blinds have to be installed, switches for motors are to be locked or fuses are to be removed by the electrical department. For jobs with aggressive media the common safety means (e. g.: goggles, protective suits, rubber boots, gloves, etc.) have to be used. Flight devices or masks are to be kept ready, also water in form of a flexible water tube. If NO, SO_2, CO/CO_2 or other dangerous gases excape, the working area has to be left immediately.
In principle all jobs are to be carried out in such a way that neither the worker nor his surrounding will be endangered.

For all jobs for which a work permit was required up till now a work permit is also necessary in future (see safety instruction no. 6 - maintenance jobs in the plant).

General instructions for all jobs

1. Do not use wrench extensions to tighten screws.
2. Tighten nuts or flanges and lids crosswise and uniformly.
3. Clean sealing surfaces before installation of new gaskets. Treatment of gaskets before use:
   for steam, cold water, hot water, air, sulphuric acid, lye: mixture graphite+ oil;
   for nitric acid, NPK slurry, ammonia: silicon grease
4. Only use undamaged bolts of sufficient length in the required quality and use undamaged nuts. Grease before use.
5. In the case of changing armatures pay attention to material pressure range and flow (arrow).
6. The general allowance to fulfill maintenance jobs is limited by normal pressure 10.
7. Welding jobs are not allowed.
8. To erect scaffolds higher than 1.5 m is not allowed (call scaffolders).

Gasket materials to be used

Steam, water, condensate, cold gases, compressed air, lyes	Klingerit 400 UNIVERSAL (blue) or Klingerit red
Phosphoric acid	Rubber reinforced by fabric
Nitric acid	Klingerit 400 or Klingerit Acidit
Sulphuric acid 99%	Klingerit red or Teflon

Sulphuric acid below 76%, H_2SiF_6	Klingerit Acidit or Klingerit red
Oils, coating agents	Klingerit oilit or Klingerit red

Beside the already mentioned general jobs for every unit of the department particular jobs are listed up which are also allowed to be performed by production personnel:

Some examples:

Bagging and shipping (unit 629)

Greasing of vehicles (dumpers, fork lifts, wheel loaders)	WOWP
Bag welding machines: Turn or change of razor blades	
Clean the filters of the vacuum pump	
Equalize felt disk	
Clean preheater and pre-pressing device (grease with silicon oil)	WOWP
Replace tubes	
Check and clean cooling water filters	
Adjust ammeter for heater	
Loading of accus	WOWP

Central raw material storage (unit 631)

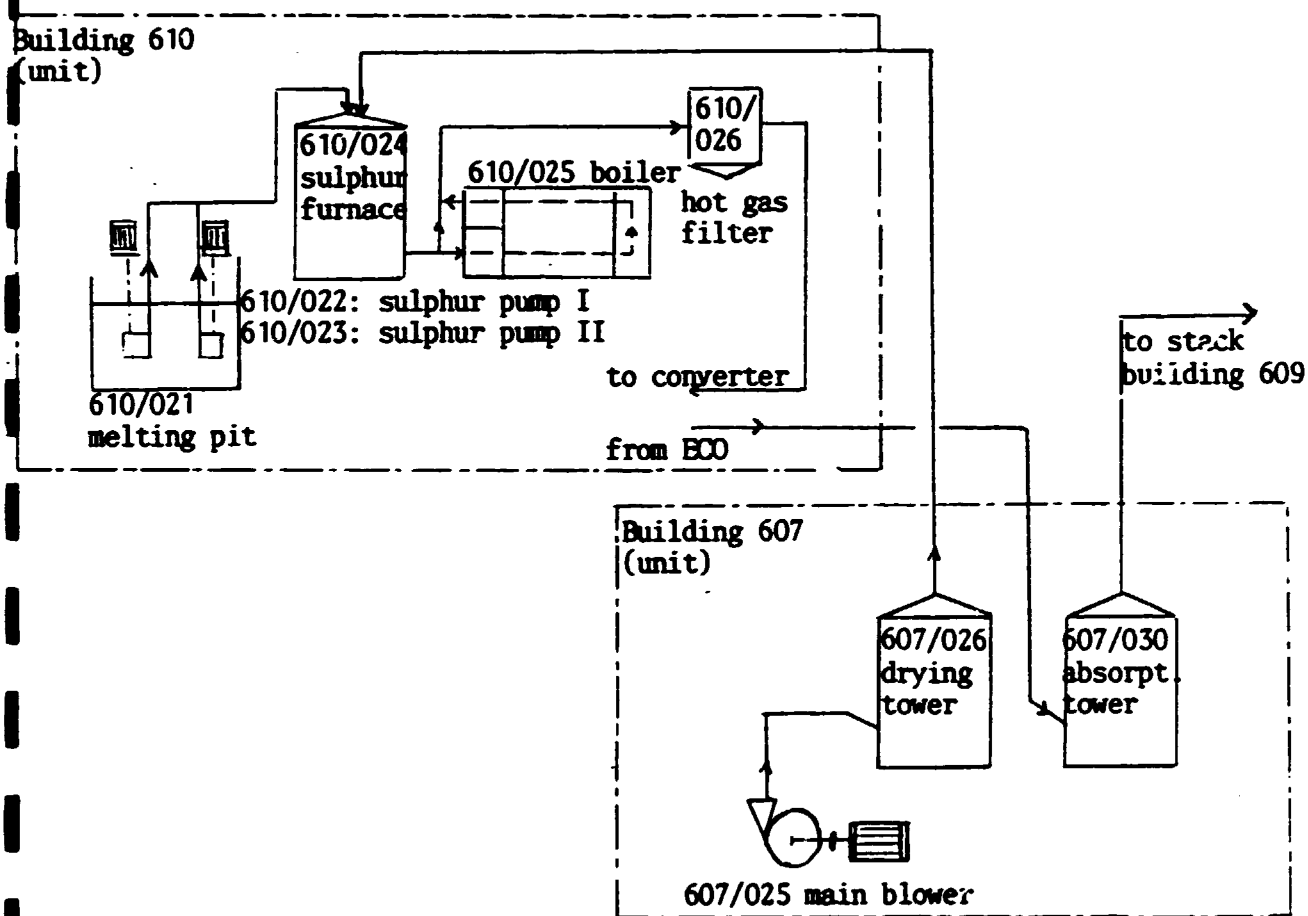
Change armour plates on conveyor chutes	WWP
Repair small defects on belts	WWP
Change shear bolts on reclaimers	WOWP
Replace grease nipples and grease tubes	WWP
Clean oil pneumatic hammers	WOWP
Replace rubber aprons and belt cleaners	WWP

TYPE OF JOB	REMARK
Sealing glands on valves and pumps up to PN 10, small jobs on steam, condensate and warm water lines up to 7 bar.	Tighten screws equally. Lantern rings should not touch the shaft. Be sure that all screws are in good condition. "Klinger" valves are allowed to seal only in closed position. (with work permit)
Remedy leakages on armatures (e.g.glands,flanges of pipes) immediately after depressurizing and drainage.	Pay attention to general precautions; be sure that pipes are empty, wear protective clothes (with work permit).
Changing small valves and armatures(e.g.condensate traps) up to ND 100 and up to an operating pressure of 10 bar.	
Connection and disconnection of flexible tubes for compressedair, oil, water, acid as well as mounting of clamps	Use tubes only if clamps are mounted. Pay attention that the right tube couplings and reliable clamps are used (without work permit).

Setting and removal of small blinds (without groove) as well as connection and disconnection of corresponding pipes.	Pay attention to general precautions, depressurize and drain the pipes, use protective clothes. If electrical connections of earthings are to be disconnected inform electrical department before starting the job (with work permit)
Opening of lids for cleaning of vessels, hoppers, pipes and chutes. Provisional sealing of steam, condensate, acid and water pipes by means of clamps.	Use required protective clothes (with work permit).
Connect and disconnect oil, acid and other wagons or tankers without using threaded clamps.	Pay attention to safety instruction no. 23 - loading of wagons - and no. 28 - safety in the field of shunting (without work permit).
Refill and adjust drop-oilers as well as checking existing central-lubrication devices for functioning. Refilling grease pots.	Use only non-contaminated grease of prescribed type. Exception: central lubrication of filter in NPK plant will be maintained by the maintenance personnel (with work permit).

Take care for all points to be lubricated e. g. nipples, grease boxes, oil droppers (on compressors). Exception: all closed lubrication sy-stems (gear boxes,...)	Consulting lubrication chart. Exception: grease nipples and grease boxes in NPK plant (without work per-mit).
Help for lubrication of run-ning pan-conveyors by means of a motor-grease-press.	One man stands in visual contact with the greaser on the emergency switch of the conveyor (with work permit).

INVENTORY SYSTEM OF CHEMIE LINZ AG



Each building in the company has a separate number. For administration buildings the numbers 1 - 99 are reserved. For the different buildings in the plants the numbers 100 - 999 are in use. Each machine and apparatus has an apparatus number (e. g. 610/024 - sulphur furnace of Monsanto plant). The first three figures mark the unit in which the machine is in action.
The second three figures determine different machines in a certain unit (building). Electrical motors are separately numbered and inventoried by the electrical department. All machines and motors in the field and the replacements in stock are marked with the apparatus number.

Example of inventory record

610/021 Sulphur melting pit, 21 000 x 4 300 x 1 500 mm, with coils and agitator.
Three phase current motor, 5.5 kW, 1 400 RPM, gear transmission to 84 RPM, motor number 693970

610/022 Sulphur pump, vertical type, size 1¼, VSO - 861 - 1/4, temperature of molten sulphur 135oC Fa., Lewis & Co TPC motor, 4.8 kW, 2 870 RPM, motor number 694200

610/023 Sulphur pump, equal with 610/022
TPC motor, 4.8 kW, 2 870 RPM, motor number 694201

610/024 Sulphur furnace, vertical construction, 3130 ø x 7750 high, steel shell, brick lined, manufacturer: Reisner & Wolff

610/025 Waste heat boiler, 1 800 Ø x 7 600 long, 225 m2 surface, 16 kp/cm2 steam pressure, insulated, regi-number 2236, boilerfeedwater-drum 1500 Ø x 5000 long, 10 m3 volume

610/026 Hot gas filter ......

SALARY SYSTEM - LEAVE

In Austria there is a collective agreement between the Federation of Trade Unions (labor unions) and industry. At intervals of 1 to 2 years the two parties fix the wage increases for a certain period.

In Chemie Linz AG there is a special system called "Salary regulation". Our salary is calculated as a sum of four groups:

1. Basic salary (BS)

   It depends on the position of the employee. The scale of basic salary is divided into 23 steps.

2. Seniority value in percent of the basic salary (SV)

   $$SV = \frac{67 \times \text{years of service with Chemie Linz}}{90 - \text{entry years (age)}}$$

3. Experience value (EV) in percent of the basic salary.

   This value is 1% per CL service year up to a maximum of 18%.

4. Personality value (PV)

   It depends on the opinion of the employee's supervisor and increases from 0 to 33.6%.

<u>Monthly salary: BS + SV + EV + PV</u>

Holiday (leave credit)

Up to 20 service years:	24 week days (4 weeks) Mo - Sa
More than 20 service years:	30 week days (5 weeks) Mo - Sa

Years of study are credited as service years to the following extend:

Charge for Technical High Schoold:	3 years (duration of school: 5 years)
Charge for Technical University:	5 years (duration: 5-8 years)

More than 25 Chemie Linz service years:	30 actual working days (6 weeks)

Additional freetime

for marriage, birth of a child, moving house, death of relations in the amount of 1 to 3 days.

Recreation leave in company-owned hostels

Every 21 months:	Production and maintenance personnel in very dusty and dirty areas.
27 months:	Foremen and workers, laboratories
37 months:	Employees in production offices
96 months:	Employees in administration offices

WORKING WEEK

In Austria the 40 hour week is generally worked.

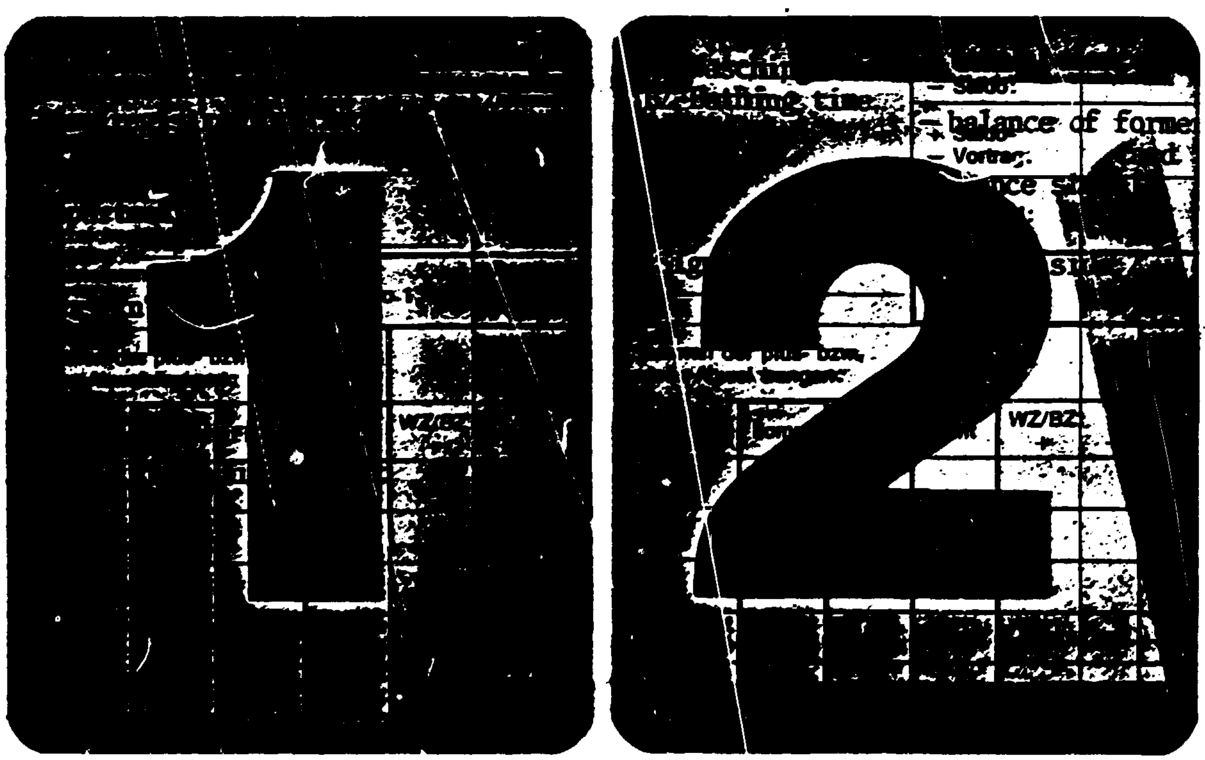
<u>General shift</u>

Flexible working time:

start in morning:		6.30 till 8.30 h
		3/4 hour lunch break
close in afternoon:	Mo - Th:	15.30 till 17.30 h
	Fr:	12.30 till 14.00 h

Recording of actual working time on "time registration cards".

front side back side



The maximum plus or minus balance allowed for one complete registration card is 10 hours. Employees of Chemie Linz AG can take two free mornings or afternoons or one free day per month if they do not infringe the 10 hour limit and if their superior gives his consent.

Shift system

Most of our plants are on stream 24 hours per day. For these production lines in the different departments there are 4 shift groups working 8 hours per day according to a shift table. These groups also meet the 40 hour week with temporally fixed free shifts.

Examples of different shift systems:

		A	B	C	D	
2 shift groups A, B	Monday-Friday	6-14	14-22			bagging and loading
3 shift groups A,B,C	Monday-Friday	6-14	14-22	22-6		superphosphate
4 shift groups A,B,C,D	the whole week	6-14	14-22	22-6	free	most production plants

SUGGESTION SYSTEM

In 1953 Chemie Linz AG introduced a suggestion system.

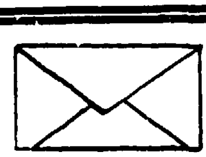
How to make a suggestion:

1. The idea

Everybody can make suggestions. The office "Suggestion System" and the members of the works council will help composing a suggestion.

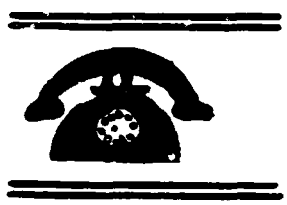
2. Presentation

Possible via the superior, the office of suggestion system or the works council. One can also put the proposal into the "suggestion letter box".



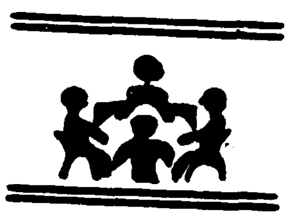
3. Registration and examination

The office checks the suggestion formally and asks for the opinion of one or more experts.



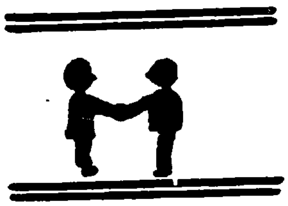
4. The decision

Acceptance or rejection of suggestions is the duty of a "suggestion commission".



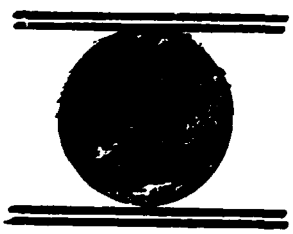
5. Reward

The experts calculate the annual savings and suggestion commission has to fix the reward.



6.Payment

If the suggestion is worth while the employee will get the reward together with his/her monthly salary.



We distinguish estimable and computable suggestions. An estimable suggestion can be rewarded with AS 200,-- up to AS 3.000,--, depending on the result of the evaluation system.

Criteria in the evaluation system:

Importance	important	negligible
Kind of solution	original	already used
Effect of the proposal	complete change	insignificant change
Frequency of application	often	single
Site of suggestion	own business	foreign business
Elaboration	practically tested .	not tested
Realization cost	up to AS 3000,-.....	more than AS 5 000,--

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ORGANIZATION OF MAINTENANCE DEPARTMENT FOR AMMONIA PLANTS

A ... division A (agricult. chemicals)
T ... Engineering
H ... high pressure plant

OFFICE:

- **A T H - M A N A G E R** — Mr. L E C H N E R
  - Draughtsman — Mr. Hochholdinger
  - Secretary — Mrs. Weigl

WORKSHOP:

- **Chief Foreman** — Mr. Affenzeller
  - **Mr. Windl** — foreman for steam and water turbines centrif. compr. special water pumps in the single-train unit old HP plant dept. in Enns
    - 1 deputy foreman, 3 group leaders, 4 fitters
  - **Mr. Philipp** — foreman for reciprocating compr. in the single-train old HP plant and other depts. in our company
    - 1 deputy foreman, 2 group leaders, 4 fitters
  - **Mr. Wenninger** — foreman for HP vessels in the NH_3 loop of the s.t. unit and old HP plant
    - 1 deputy foreman, 3 group leaders, 7 fitters
  - **Mr. Affenzeller** — foreman for HP steam system vessels with brickwork vessels up to 40 bar in the s.t.unit and old HP plant
    - 1 deputy foreman, 2 group leaders, 6 fitters

The foremen are allocated to defined jobs.
The workers can be shifted between the 4 foreman groups if necessary.

RESPONSIBILITY of Maintenance Department for Ammonia Plants

Maintenance of the existing ammonia single-train unit and old HP plant in the best way (good performance, low cost, short time).

Improvement and rationalization of the different facilities and processes.
Preventing of accidents.
Control of maintenance costs.
Working out of shutdown programs.
Co-operation with different departments concerning expansion of existing plants and installation of new plants.
Good contact with production personnel and some central departments (central workshop, electrical dept., instrument dept., civil dept., design, safety, ..)

Stand-by service from Friday to Monday

1 engineer or foreman
2 fitters

HISTORY OF AMMONIA PRODUCTION PLANT (ATH)

1942: start of ammonia production at 75 000 t N per year
with 4 units, each with 80 t N per day

1966: expansion to 300 000 t N per year

1975: start up of ammonia single-train unit
design target: 200 000 t N/year
1978: 242 000tN/year (we had a general overhaul lasting 6 weeks)

Due to good operation and good maintenance the percentage running time of all our facilities is very high.

(100% = 365 days per year)

e. g.: reciprocating compressors 99,5%
general revision every 45 000 hours = 5 years

SINGLE-TRAIN UNIT MAINTENANCE

Design target for the unit: 240 000 t/year NH_3, i.e. 850 t/day NH_3.

February 1975: start up of ammonia production

<u>Production figures</u>

1975	200 000 t/year NH_3
1976	263 000 t/year NH_3
1977	292 000 t/year NH_3
1978	294 000 t/year NH_3
1979	340 000 t/year NH_3
1980	308 000 t/year NH_3
1981	306 000 t/year NH_3
1982	321 000 t/year NH_3
1983	309 000 t/year NH_3

daily production now: 1 000 t NH_3

For maintenance we needed:

	hours	material (Mio. AS)
1975	117 000	11.2
1976	84 000	5.9
1977	60 000	7.1
1978	108 000*	10.0*
1979	40 000	1.6
1980	90 500**	4.8**
1981	101 500***	12.0***
1982	37 000	2.8
1983	106 000****	14.0****

*) 1978: first general overhaul (LTS-cat. changed)

**) 1980: shutdown to replace catalyst in primary reformer. (2^{nd} overhaul)

***) 1981: was the 3^{rd} general revision (LTS-changed HTS-changed)

****)1983: 4^{th} general overhaul (1^{st} bed HTS, Mehtanator, NH_3-syntesis cat. changed)

For the technical maintenance there weie needed:

	hours	material (Mio. S)
*)	67 000	7.0
**)	50 000	3.0
***)	58 000	8.3
****)	70 000	12.0

The investment cost for the single-train unit was about AS 500 Mio. in 1974.

On stream days:

	Syngas production	NH3 production
1975	280 days	217 days
1976	317 days	294 days
1977	335 days	321 days
1978	326 days	313 days
1979	362 days	355 days
1980	328 days	314 days
1981	332 days	308 days
1982	365 days	361 days
1983	313 days	327 days

DEVELOPMENT OF SYNGAS COMPRESSORS OF SINGLE-TRAIN PLANTS

The first Single-Train plant (designed by Kellog) incorporated syngas centrifugal compressors which were developed by Clark. The pressure in the ammonia reactor was fixed at about 160 bar. To reach such a pressure Clark designed compressors with two cases. The speed was approximately 10 000 rpm.

To improve the efficiency of ammonia synthesis it was necessary to increase the pressure in the ammonia reactor. Nuovo Pignone, BBC, Cooper-Bessemer and Clark designed compressors which reached a pressure of 320 bar.

One of the problems of high-speed centrifugal compressors is their low weight, compared for example with reciprocating compressors.

The pipelines to and from the compressor have large diameters, and pressures are high.

Therefore it is very important to prevent forces of reaction affecting the compressor. This is also a very important point for steam turbines. The reaction force of steam pipelines is - owing to the high temperature of steam (500oC) - very large. In our plant we did not have satisfactory experience with "pipeline carriers with springs" because the reaction force of the spring depends on the spring constant.

So we envisaged carriers held by weights. This kind of carrying pipelines needs more space, the advantage is to have constant forces applied to the pipelines.

EXPERIENCE IN SEALING THE 4TH STAGE OF THE SYNGAS-COMPRESSOR

After having operated our syngas compressor for half a year we had to take the compressor out of operation due to increased oil consumption. Removing the seals we noticed that the seals on the recycle side were still intact but on the syngas suction side the high-pressure sealing was damaged. The white metal was melted and the O-ring was embrittled.

Enclosure 1 shows how the seal consumption increases.
In enclosure 2 the operating conditions of the seals are shown.
A drawing of the seals with dimensions is shown in enclosure 3.

In enclosure 2 it is obvious that on 7.9, 9.9 and 12.9 the seal oil temperature TI 6025 had increased.

Except for this temperature no other disturbance was noticed. The result of analysis of the residuals found on the sealring in the case of the compressor and in the automatic oil separator was that the residuals were not breakdown products of the oil.

The residuals (zinc dithiophosphate) are produced in a reaction between oil and ammonia at the existing high pressure.

After having repaired the compressor we had a seal oil consumption between 1 and 5 litres per day.

The embrittled O-ring material was iron. But viton is not resistant against ammonia and we changed it to Silikon with success.

To avoid the formation of zinc dithiophosphate Nuovo Pignone made the following arrangement:

1. To install a connection between syngas discharge and balance gas.

2. The pressure in the balance gas should be kept about 0.5-1 bar higher than the syngas suction pressure. Through this improvement the pressure of ammonia in the reference pipe is reduced .

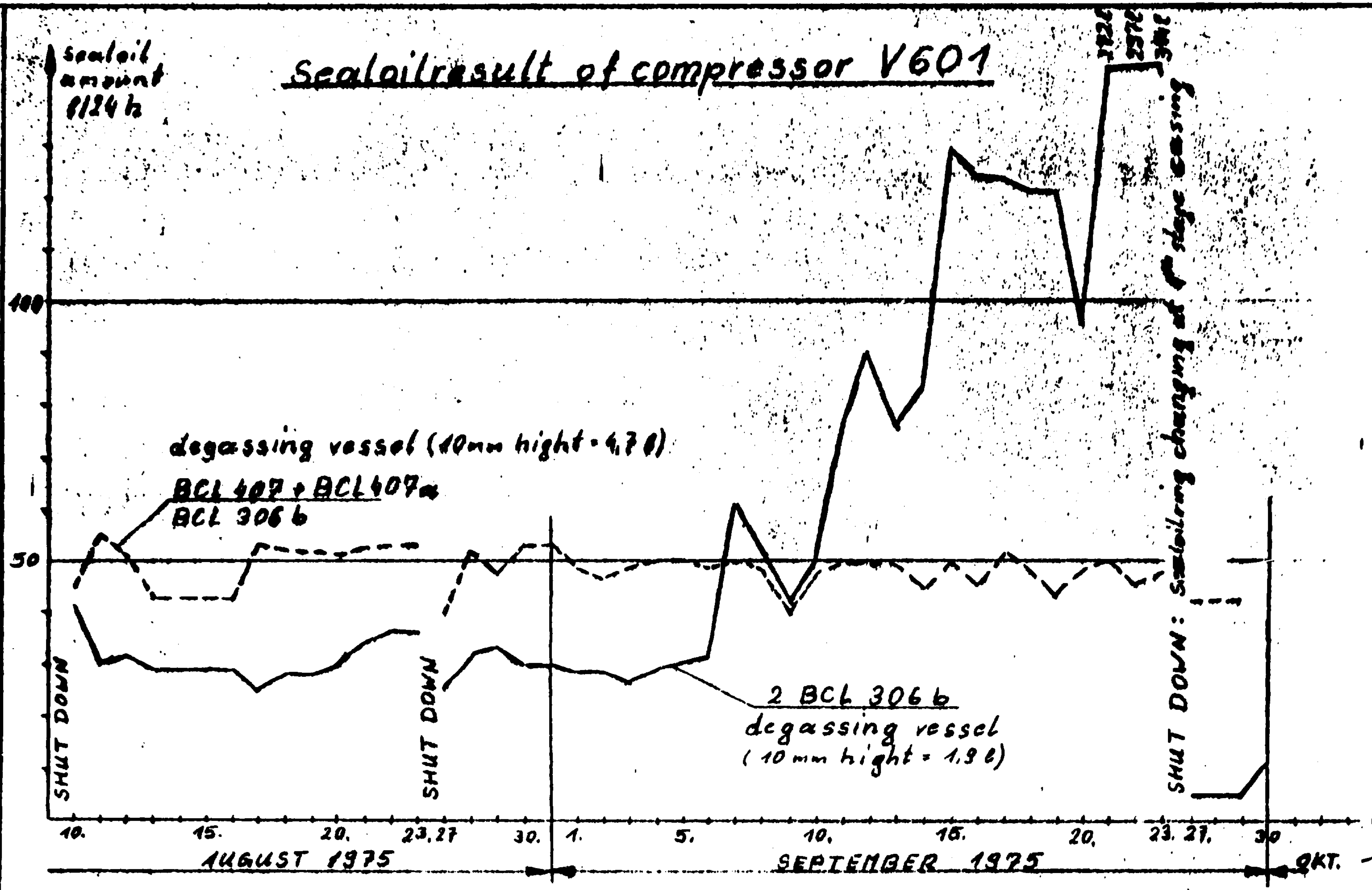
After having installed this connection pipe we did not have any difficulties with the seals in the 4th stage. Care must be taken that the quench gas in the connection pipe has a temperature lying higher than the dew point of the gas.

If the temperature is below the dew point the labyrinths could be damaged by erosion.

The arrangement of the quench gas pipe can be seen in enclosure 4.

CHEMIE LINZ AG

Enclosure 1 : V601



encl.2

OPERATING CONDITIONS COMPRESSOR V 601 (4^{th} stage)

Day-averadge-value

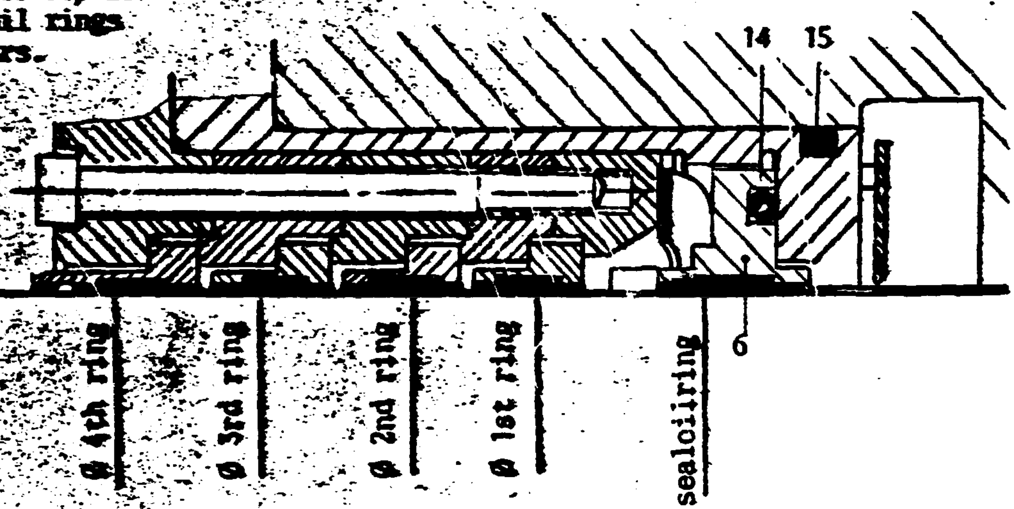
Pressure given in bar ,Temperature given in C

AUGUST		03	04	05	06	07	08	08	10	11	12	13	14	15	16	17	18	19	20	21	22	23
TEMP.INLET 4 st.	T607	26	26	27	26	26	27	27	26	26	26	27	27	27	27	27	27	27	28	28	27	27
PRES.OUTLET 4.st	P607	267	255	260	260	255	258	258	250	250	254	252	255	251	250	248	250	250	255	252	248	250
TEMP. OUTLET 4.st	T608/T646	31/83	31/82	31/83	31/83	31/82	32/84	31/82	30/82	30/82	31/84	32/84	32/84	32/84	32/84	32/83	33/83	32/83	34/84	34/84	33/82	33/83
PRES.INLET RECYCLE	P626	260	253	255	260	255	260	258	250	258	256	250	255	251	250	245	250	246	265	250	248	250
TEMP.INLET RECYCLE	T609	20	21	21	21	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
PRES.OUTLET RECYCLE	P609	271	268	265	270	265	270	265	255	258	262	260	265	262	260	255	250	255	266	260	265	258
TEMP.OUTLET RECYCLE	T610	28	28	28	28	27	28	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
TEMP.JOURNAL BEARING 4.st	T626/T627	66/52	65/52	66/52	65/52	65/51	66/52	65/51	66/51	66/51	65/52	65/52	65/52	65/52	65/52	65/51	65/51	65/52	66/52	66/52	66/52	66/52
TEMP.THRUST BEARING 4.st	T631	67	66	67	67	67	67	66	66	66	66	66	66	66	66	66	66	66	68	68	67	67
TEMP.JOURNAL BEARING 4.st		72	72	73	74	72	73	73	72	72	73	72	72	73	72	73	72	72	73	73	73	73
TEMP.AXIAL BEARING 4.st		72	72	72	72	72	73	72	71	71	72	72	72	72	72	72	72	76	73	73	73	72
TEMP.SEALOIL PRES.SIDE	T16024	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	84	85	85	85	84
TEMP.SEALOIL SUCT.SIDE	T16025	89	89	89	89	84÷89	90	89÷92	90	90	87÷93	92	92	93	92	93	93	92	93	93	93	92
OIL-PRES.JOURNAL BEARING A	P6023	1,85	1,84	1,84	1,84	1,85	1,84	1,84	1,85	1,85	1,85	1,86	1,85	1,86	1,86	1,86	1,84	1,84	1,83	1,83	1,83	1,82
OIL-PRES.JOURNAL BEARING B	P6059	1,52	1,50	1,50	1,50	1,50	1,50	1,50	1,51	1,51	1,50	1,52	1,52	1,51	1,51	1,51	1,51	1,50	1,50	1,49	1,50	1,49
OIL-PRES.AXIAL BEARING	P6024	1.62	1,65	1,64	1,64	1,64	1,64	1,64	1,65	1,65	1,64	1,65	1,65	1,65	1,64	1,65	1,65	1,65	1,65	1,65	1,63	1,64
SEALOIL-PRESSURE	P6038	190	190	190	190	190	191	191	185	186	189	188	189	190	190	185	189	185	191	191	189	184

ENCLOSURE 5

STUFFING BOX - COMPRESSOR V 601 - 2 BCL 306/b

Measurement after repair change of sealoil rings after 3 318 hours.



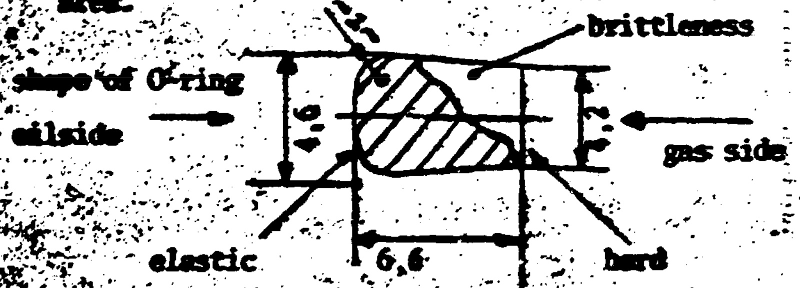
Suction side (axial thrust bear.)	94,00	94,15	94,15	94,14	94,06	diameter
Recycle side (coupling)	94,09	94,15	94,15	94,15	94,05	in mm

Failures

1) Molten white metal of seal oil ring (part 6).

2) Residuals of oil on seal oil ring, discharge pipes and separator.

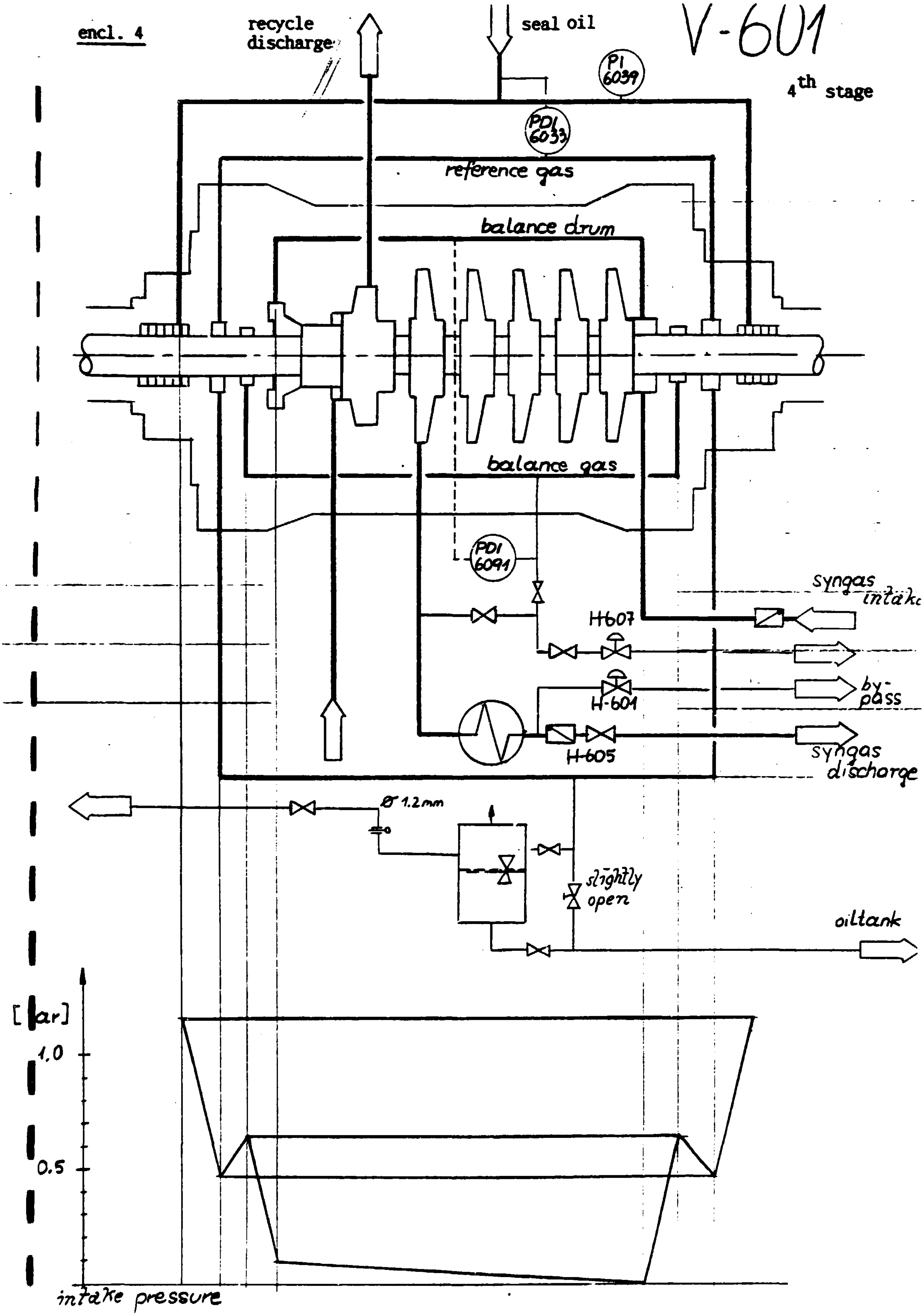
3) O-ring (part 15) broken at several steps and brittleness at gas-side area.



encl. 4

V-601

4th stage



TECHNICAL EXPERIENCE WITH THE BENFIELD SYSTEM

1. Low-pressure pumps P 401/402 for Benfield solution

When starting our plant we noticed that the low-pressure pumps developed a noise. We suspected the reason for this noise to be cavitation.
Although we checked the pump in the presence of Worthington experts we could not find any indication of cavitation.

We insisted on the warranty being prolonged for a further year by Worthington.
Worthington' s expert agreed to this, and explained the noticed noise with circulation.

Before the extended warranty had elapsed we checked the impeller once again very exactly, but no sign of cavitation was found.

When we had to change the seal rings three months later we noticed the first indications of cavitation - the back of the blades were galled.

Steps for solving this problems

a) welding the galled surface with electrodes consisting of hardfacing alloy,

b) introduction of 3 - 4 m3/h nitrogen into the suction pipe of the pumps.

We have two low-pressure pumps for Benfield solution. In the suction pipe of one of these pumps there are two elbow pipes. At this pump we found cavitation only on one side of the double fluted impeller.
The suction side of the second pump is connected to a tee in the main suction pipeline.
At this pump we found cavitation on both sides of the impeller after only 4 200 working hours.

Our engineering firm, Uhde, found out that the noise of the pump disappeared when the pump was operated at 115% of the normal flow rate.
When the flow rate was reduced the noise increased. This symptom was also an indication that the noise was caused by circulation.

2.High-pressure pumps P 403/404

Washing and cleaning our plant during start up revealed that the seals were contaminated with dirt. So we had to replace them from time to time.

After plant start up it was not necessary to change the packings for about one year. But after this time we had a lot of problems with the Pacific seals. Sometimes we had to change the rings after as little as one week.
We found out that the spare rings supllied by Pacific were not flat and full of cracks.

Up till then the seal rings had been greased with Benfield solution. Having such a lot of problems with seals we changed the medium for greasing the seal rings and used condensate with a temperature of 65 - 70oC.

Condensate of such a temperature is more qualified for greasing seals than Benfield solution.

The pressure of the condensate has to be a little bit higher than the intake pressure of the pump.
To make this improvement it was necessary to install a condensate cooler and a controlling system.
Since we started operating with this modification the seals have to be changed approximately once a year.

3. Efficiency of the CO_2 removal system

After having started our plant we did not obtain the efficiency of gas purification guaranteed by Uhde. After a lot of difficulties investigations we found out that the bad distribution of potassium carbonate solution was the reason for our problems. By installing baffles we improved the distibution of Benfield solution to the ceramic intalox.
The efficiency of purification increased after this modification. Finally we installed two redistributers in our absorber and reached the design efficiency.

OPERATING INSTRUCTIONS - V 103

for a vertical, double-acting reciprocating compressor, with two cranks, compressing gas in two single stages.

The operator must be well instructed about the function of the compressor.

A) Design dates

Medium:	natural gas
Flow rate:	37 000 Nm3/h
Suction pressure:	20.9 bar, adjustable
Discharge pressure:	46 bar
Speed:	495 rpm
Controlling system:	automatic reverse flow regulation to 50 % of design gas flow

B) Starting up of the compressor

1. Inform the central command station of our company about the start up of the compressor. Between two starts it is necessary to wait 20 minutes after the first start because during start of the motor coils are heated.

2. Open the cooling water main valve and also valves for the cooling system of the different parts of the compressor, (steel packings, cylinders, oil cooler).

3. Check the level of oil tank. If oil temperature is below 10oC it is necessary to heat up with steam.

4. Start auxiliary oil pump and check oil pressure, (minimum 2 bar).

5. Open valves in suction pipeline and in bypass pipeline. Check the suction pressure. With regard to the rate of suction pressure see point C 1.

6. Drain the condensate separators F 103 and F 104 (separator in front of the compressor and after bypass cooler).

7. Open valves in discharge pipeline.

8. Start the motor and observe the oil pressure.

9. Switch off the auxiliary oil pump and check the oil pressure once again.

10. If everything is prepared the compressor is charged by slowly closing the bypass valve and by means of the reverse flow controlling system.

C) Operation of the machine

1. It is very important to take care that the difference in pressure between discharge and intake is not higher than 27.4 bar.

Therefore it is necessary to adjust the discharge pressure in dependance of the suction pressure. For example: if the discharge pressure is 44 bar the intake pressure may be 16.6 bar as minimum.

The intake pressure should not be less than 8.8 bar, in this case the maximum discharge pressure is 36.2 bar. The intake pressure should not be higher than 27 bar, it is important that this maximum pressure is not reached.

2. Following points have to be checked periodically and must be written in an operating book for instance every hour:

a) intake pressure (safety valve is set a 30 bar), discharge pressure (safety valve is set at 46 bar)
b) oil pressure after cleaner
c) oil temperature after oil cooler
d) temperature of discharge
e) temperature of compressor bearings
f) temperature of motor
g) temperature of motor oil
h) temperature of cooling air to the motor
i) temperature of cooling air from the motor
k) current consumption of the motor

3. During the inspection round every two hours following points are to be checked:

a) seal packings for tightness
b) draining of separator F 103 and F 104
c) compressor for knocking, grumbling and unusual noise of the valves
d) level of the oil tank

4. Cooling water flow rate is to be adjusted not to exceed a maximum temperature of 45oC outlet.

5. The compressor is to be switched off immediately if

a)a bearing or a seal packing is overheating or if a seal packing leaks

b) lube pressureoil is less than 1.5 bar

c) if a knocking noise is suddenly heard or if the valves do not operate properly

d) a safety valve does not close after blowing down

D) Switching off the compressor

1. Switch off the motor
2. Close valves in discharge pipeline
3. Close valves in intake pipeline
4. Close cooling water main valve
5. If necessary purge compressor with nitrogen

E) General maintenance

Crankcase is filled with oil, type Mobil oil extra heavy, with a viscosity of 60 - 83 c St at 50oC temperature. Oil leakages have to be made good with the same oil type. If the compressor does not operate for a longer period the compressor must be turned by hand once a day. Before doing that the auxiliary oilpump has to be switched on.

DATA V 103

Important: The difference in pressure between intake and discharge may not be higher than 27.4 bar.

	item	Operating range	Alarm/shut down
Intake pressure	PIALLHSL	see point C 1	High: 18/10 bar low: 28/- bar
Discharge pressure	PIAHHSH	max. 44 bar	45/52 bar
Temperature of discharge	TIAH 110 TIAH 116	max. 110°C	130/-°C
Oil pressure after cleaner	PIALISL 113	2 - 3 - 4,2 bar	2/1,5 bar
Instrument air pressure	PIALSL 221	7 - 7,5 bar	4/4 bar
Oil temperature after cooler	TIALH 113	25 - 40°C	Low: 18/-°C high: 50/-°C
Temperature of compressor bearing east	TIAHHSH 107	45 - 65°C	70/80°C
Temperature of compressor bearing west	TIAH 111	60 - 70°C	75/80°C
Temperature of cooling air to the motor	TIAH 101	5 - 35°C	40/-°C
Temperature of cooling air from the motor	TIAH 102	25 - 60°C	65/-°C
Temperature of motor bearing	TIAH 106	40 - 65°C	70/-°C
Temperature of motor coils	trah 104	60 - 90°C	105/-°C

DRAWING UP A PROGRAM FOR A GENERAL OVERHAUL OF A SINGLE-TRAIN PLANT

1. During operation of our plant all technical defects and leaks are registered in a booklet. These defects do not make it necessary to turn off our plant but the next shut down of the unit all these defects must be repaired.

2. The technical department evaluates the program for the maintenance work to be done on tanks, boilers, coolers, etc. In a discussion with TÜV (technical inspection department) and the material testing department the class of inspection is determined.

The technical department is also responsible for the inspection of the machines. As a general rule, a machine which operates normally should not be opened.

Before deciding to open a machine or not, two consideration should be taken into account:

a) By measuring the efficiency it is possible to recognize a defect or wear for example on the labyrinths or on the balance drum.

b) By comparing the operation data with the data recorded at the first start up of the machine, a conclusion can be drawn about the condition of the machine.

Therefore it is very important to register all data recorded after the first start up of the machine very exactly.

The particular jobs which have to be done are ordered in groups (from 100 to 700, see enclosures).

Every work must be evaluated in regard to length of time and to the number of required workers by a foreman. Afterwards a bar chart showing the number of the necessary and disposable workers must be produced.

GROUP 100

O - 101 — Heater for heating naphtha or natural gas.
Open and close manhole cover.
Inspection of the projecting bars of the burners.

W - 101 — Nitrogen preheater
Open lid for official inspection.

GROUP 200

W - 202 II, W - 208 III, W - 210 Superheater for high pressure steam.
Pressure check.

W - 207 Superheater for medium pressure steam.
Pressure check.

W - 209,
W - 211 Heater for process air.
Pressure check.

V - 202,
V - 203 Combustion air blower, flue gas blower. Cut out the shaft cover for oil level inspection glass and for grease nipples. Inspection of the guide blade bearings.

O - 201 Primary reformer.
Open two of the collector pipe covers, check and close.
Open manholes, inspect fireclay cover.
Clean flue gas duct.

O - 204 Additional heating for waste gas.
Open manholes, inspect fireclay cover.

O - 202 Additional vessel
Inspectin and cleaning of inside.
Repair combustion air heat-exchanger (no. 4 is blocking)
Inspect wall at inspection hole.
Clear lubrication pipes.

Combustion air and waste gas duct

Inspection and cleaning

B - 210 Mixing station for steam and natural gas.
Inside inspection and check natural gas baffle.

W - 215 Water preheater
Remove heat-exchanger tubes for inside inspection.

B - 208 Relief tank
Open manholes, block off, official inspection.

B - 203 Degasifier tank
Widen passage for L-206 (level controller).
Check shower (system Stork) and change T-parts.

B - 209 Instrument air tank
Inspection and cleaning of tank and level controller.

P - 207
P - 208 BFW pumps
Clean filter, P-208: change flange of valve for minimum load pipeline.

T - 203 Turbine for P-207
Repair oil leak at coupling cover.
Change insulation.

B - 212 Natural gas mixing station
Remove and inside inspection.

K - 201 Secondary reformer
Open for changing air nozzle.

W - 201 Process gas heat exchanger
Open both manhole covers.(Gasket of the hot manhole is not tight)
Cleaning and inside inspection.

W - 203 BFW preheater
Change pipe bundle, inside inspection.
Change drain valve. Install test blades.

B - 201 Steam boiler
Open and inside inspection. Pressure check (pressure check also for no. 4083 and 4162 - support system).

T - 201 Turbine for process air compressor.
Inspect rotor. Repair oil leak at the compressorside coupling cover.
Repair seal packing of control valve and the leak at the pipeline for the pressure-indicator of the injector; the idling-device does not function properly.

W - 204 — Condenser for T-201
Open flange and inside inspection.
Repair cooling-water pipe to the condenser.

V - 201 — Process air compressor
Check low-pressure and high-pressure rotor.
Gearbox-side high-pressure rotor bearing is leaking.
Clear air-cooling of low-pressure compressor.
Change cooling-water valve for 4th stage. Check non-return valve.

W - 214 — Process air cooler
Inside inspection, also for condensed water tank and level controller.

T - 202 — Turbine for generator
Repair seal box of steam entrance valve.

T - 204 — Back-pressure turbine for generaor
Repair seal box of steam valve.

GROUP 300

W - 301 Gas heat-exchanger

Pressure check. Repair leaky hand-gasket.

K - 301 NT- CO- converter
Official inspection, manholes to be opened in service. Change nozzle for condensate.

W - 302,
W - 303 BFW preheater
Official inspection
Repair baffle T-310

K - 302 Low temperature converter
Open manholes to change catalyst.
Official inspection.

GROUP 400

K - 401	**Absorber** Open manholes, remove ceramic intalox and inspect inside. Install redistributors. Revision of the level controller.
F - 403	**Lye separator** Open for official inspection. Revision of the level controller.
W - 401	**Steam generator** Open for official inspection (inside revision and pressure check)
W - 402	**BFW preheater** Remove heat-exchanger. Pressure check (2 times).
W - 403	**Reboiler** Open forofficial inspection (inside and pressure check)
W - 404	**Solution air cooler** Remove distribution pipe, pressure test.
W - 408	**BFW cooler** Remove bundle (inside inspection)
B - 404	**Relief tank** Open manholes for cleaning and inspection

F - 401 Condensate separator

Open manholes for cleaning and inside inspection

F - 402 Condensate separator

Open manholes for cleaning and inside inspection. Change draining valve. Official inspection of level controller.

F - 406 Lye double filter

Inside inspection. Grind 4-way valves. Change valve in the pipeline to the filter (valve case is corroded).

K - 402 Desorber

Gpen manholes for inside inspection and cleaning.

Repair corroded pipeline to P-405.

Install PV/H-411 and PV/H-412 in CO2 pipeline system

F - 407 Injector

Control injector nozzles and valves.

W - 406 BFW preheater

Change pipelines of BFW-system

T - 401 Benfield Solution turbine

Seal bearings of guide-baldes. Change pipelines for greasing seals with condensate of T-401 and highpressure lye pump P-403.

GROUP 500

K - 501 Methane generator
Open manholes for inside inspection

F - 501 Condensate separator
Open manholes for inspection inside and inspection of level controller.

W - 501 Gas/gas heat exchanger
Remove heat-exchanger for official inspection and pressure check.

W - 502 Boiler
Open for cleaning and inspect inside.

W - 503,
W - 504 Final gas cooler
Open for cleaning and official inspection.
Weld in a valve in cooling-water pipeline.

GROUP 600

T - 601 Syngas turbine
Inspection of condensation turbine rotor and of the condenser. Repair of cooling water pipe. Check start up equipment and adjust it. Change prepared oil pipelines.

V - 601 Syngas compressor
Inspection of bearings, seal-system and rotors of cases 1 - 4. Install capacity flow measuring nozzles in balance drum pipes of stage 2 and 3 (F-6006 and F-6007). Change gas cooler. Official inspection of separator F-606 (also level controller), F-601, F-602, F-603, F-605, seal oil tanks no. 4054 - 4057, level controllers 4156 and 4157, and separators 4208, 4058 and 4059.
Install valves in seal-oil pressure pipes of seal-oil pumps.
Change oil-filters and clean oil-heaters.
Change one of the oil-cooler bundles and clean the other one.

O - 701 Start-up heater
Inspect supports, pressure check.

W - 701 Waste heat boiler
Open "Brettschneider" gasket.
Official inspection, pressure check.

W - 708	BFW preheater Open "Brettschneider" gasket(seal ring is leaky) Official inspection, pressure check.
B - 701	NH3 expansion tank Open tank for cleaning and official inspection
B - 706	Mixing station Remove for inside inspection
F - 701	NH3 separator Open lids and remove pipelines to the separator Clean and inside inspection.
F - 702	NH3 separator Open lids and remove pipelines. Clean and inside inspection.
W - 703	Gas cooler Remove elbows of two of the five coolers. Pressure check these coolers.
W - 704	Gas heat-exchanger Open flanges and remove bundle. Cleaning and inside inspection.
W - 705	Freezer Remove flanges for inside inspection.

GENERAL DESCRIPTION MATERIALS FOR: — — — — — — — — — — — —

APPLICATION	CODE Mat. Nº.	Internat. Code		COMPOSITION (%) C	Si	Ma	Cr	Mo	Ni	V	Ti	
(0-40 bar up to 100°C)	1,0305	St 35,8		0,10 0,18	0,15 0,35	0,40 0,70	0,70 1,00	0,40 0,50				
ligh pressure steam lines 40÷128 bar (from 400-525°C)	1,7335	13CrMo 44										
igh pressure syngas 0-325 bar (up to 300°C)	1,0305	St 358		≤0,17	≤0,35	>0,40						P,S max. 0,0:
0 - 35 bar (from 300-450°C)	1,5415	15 Mo 3										
0 - 35 bar (from 450-515°C)	1,7335	13 CrMo 44										
rimary reformer tubes	-	Gx 40NiCrNb 3324	36x Type	0,35	max.	max.	23					
pigtails	1,5415	15 Mo 3	Pompey France	0,45	1,5	1,5	27					
collector system	1,5415											
lines for brickwork	-	X 10NiCrAlTi 3320	Incoloy 800	0,12÷ 0,20	0,15÷ 0,35	0,50÷ 0,70		0,25÷ 0,35				P,S max. 0,03
esulphur-reactor shell	1,7335	13 Cr Mo 44										
econdary reformer shell	1,5415	15 Mo 3										0,75 Cu
lines for brickwork		X10 NiCrAlTi 3320	Incoloy 800	0,03	0,50	0,70	21,5		34		0,6	0,30 Al
team waste recovering boiler tubes		15Mo/Inconel 600										
tube plate	1,7335	13CrMo 44	BHW 35	≤16	0,10÷ 0,50	1,0÷ 1,60	0,20÷ 0,40	0,60÷ 1,20				P.S max. 0,02:
shell	1,8807	13MnNiMo 54	Type Boveiy									
shield, ferrules, lines for brickwork		X 10NiCrAlTi 3320	Incoloy 800									
ethane reactor shell	1,7335	13 CrMo 44										
mmonia converter shell		ATMNiMoV	Type VOEST	0,15	0,33	1,40		0,47	0,66	0,12		
basket	1,4550	X10CrNiMoNb 1812	(hydrogen resist.)	≤0,10	≤1,0	≤2,0	17,0÷ 19,0		9÷ 11		>5x C	Nb > 8xC
ligh temperature converter	1,7335	13 CrMo 44										
ow temperature converter												
igh pressure syngas 325 bar 380÷400°C	1,7779	Altherm 50 20 CrMoV 135	Type VOEST	max. 0,21 0,17÷	0,30÷ 0,50 0,15	~1,2 0,30÷	3,0÷	0,5÷		0,45÷		P.S max 0,0.

MAIN MATERIALS USED IN SINGLE-TRAIN UNIT

		CODE			COMPOSITION %									APPLICATION
		Mat. n°.	internat. code		C	Si	Mn	Cr	Mo	Ni	V	Ti		examples
NORMAL STEEL	HEAT RESISTANT	1,0305	St. 35.8		≤0,17	≤0,35	≥0,40						P.S max. 0,05	water , gas and steam pipelines up to 300°C
		1,0425	H II		≤0,20	≤0,35	≥0,50						-"-	shell for desorber, absorber
		1,5415	15 Mo 3		0,12 0,20	0,15 0,35	0,50 0,70		0,25 0,35				P.S max. 0,04	shell for secondary reformer
		1,7335	13Cr Mo44		0,10 0,18	0,15 0,35	0,40 0,70	0,70 1,00	0,40 0,50				-"-	pipes in waste-heat system up to 550°C
		1,7380	10Cr Mo910		≤0,15	0,15 0,50	0,40 0,60	2,00 2,5	0,90 1,10					desulphur-reactor shell for waste-heat-boiler
		1,7709	21Cr MoV57		0,17 0,25	0,15 0,35	0,35 0,85	1,20 1,50	0,65 0,80		0,25 0,35			bolts up to 550°C
STEEL	HYDROGEN RESISTANT	1,7779	20Cr MoV135	N9	0,17 0,23	0,15 0,35	0,30 0,50	3,00 3,30	0,50 0,60		0,45 0,55			pipelines in ammonia synthesizer
				ATMNiMoV (T.VOEST)	0,15	0,33	1,40		0,47	0,66	0,12			shell for ammonia converter
HIGH ALLOY	STAINLESS STEEL	1,4541	X10CrNiTi189	SAS 2	≤0,10	<4,0	<2,0	17 19		9 19,5		5X %C		pipes and vessels for corrosive media lines for brickwork
			X10NiCrAlTi	Incoloy 800	0,03	0,5	0,7	21,5		34		0,6	0,75 Cu 0,30 Al	
STEEL	CASTING	1,0619	GS-C25		0,80	0,40	0,65	≤0,03						cases of naphtha pumps
		1,4027	G-X25Cr14		0,14	0,24	0,49	13,2		0,97				cases of boiling water pumps
		1,4552	G-X7CrNiNb 189		0,065	1,30	1,35	18,9		9,44			N6 0,68	cases of Benfield pumps

Time schedule for inspecting and replacing of the converter insert and catalyst change in NH_3 converter K-701, ammonia single train plant

shift working time: 2 x 8 hours for technical department

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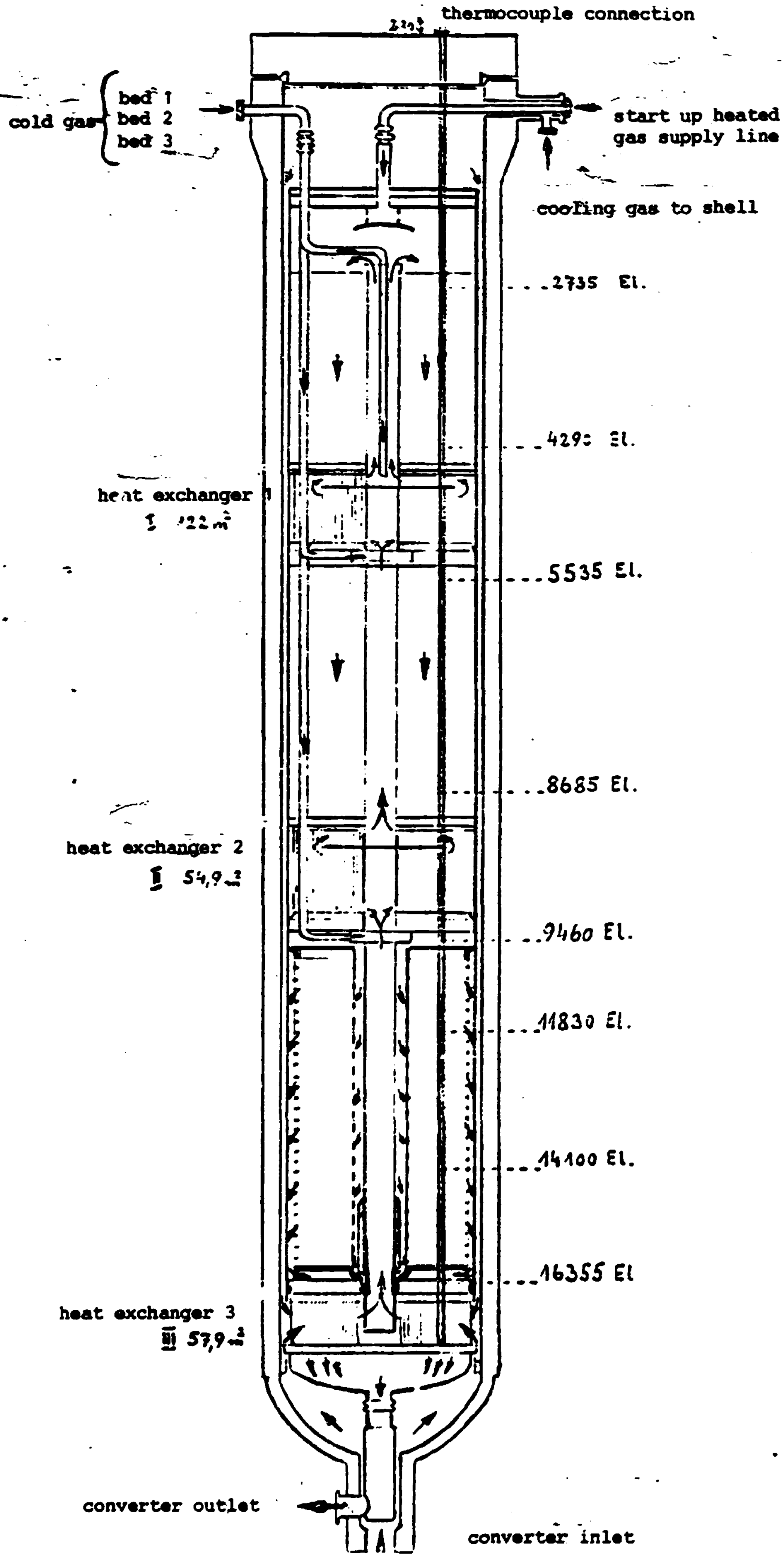
work to be carried out:

1 - depressurizing and purging
2 - off converter blinding
3 - mounting pipes for deactivating
4 - deactivating converter (APA) catalyst material
5 - dismounting of converter cover and preheating pipe
6 - removing expansion joints and covering plate
7 - removing covering plate over material and cooled gas tube catalyst
8 - fitting exhauster and template for the cold-gas tube
9 - exhausting first catalyst layer (APA)
10 - removing exhauster and template for the cold-gas tube
11 - removing upper heat exchanger
12 - fitting exhauster and template for the central well
13 - exhausting second catalyst layer (APA)
14 - removing exhauster and template for the central well
15 - removing middle heat exchanger
16 - fitting exhauster and template for the central well (lower portion)
17 - exhausting third catalyst layer
18 - removing exhauster and template for the central well (lower portion)
19 - removing lower catalyst suuport ring
20 - refitting covering plate over material; mounting the catalyst coupling facility; removing and laying flat the converter insert
21 - removing insert support ring
22 - cleaning the furnace shell inside; testing welds (TNP); inspecting the interior (TÜV)

./2

23 - blinding-off converter shell; mounting of converter cover (for pressure testing)
24 - fitting converter shell with water; pressure testing by TMP
25 - draining converter shell, removing converter cover and all blind covers
26 - installing insert support ring
27 - installing converter insert plus lower heat exchanger and radial section
28 - mounting hoisting facility for cat. material
29 - mounting template for central well (lower portion)
30 - filling third catalyst layer (APA)
31 - removing template and mounting middle heat exchanger
32 - mounting the second catalyst material support ring and the template for the middle central well
33 - filling second catalyst layer (APA)
34 - removing template and mounting the upper heat exchanger
35 - mounting the upper catalyst material support plate and template for the upper central well
36 - filling the first catalyst layer (APA)
37 - dismounting template and hoisting facility for catalyst material
38 - mounting covering plate for catalyst material
39 - fitting expansion joints, packing all glands, prepairing for mounting the converter cover
40 - mounting the converter cover
41 - welding on the leakproof lenses of the preheating pipe and converter exit pipe; remove dummy flanges
42 - purging and pressure build-up (APA)
43 - activating catalyst material (APA)


thermocouple connection
cold gas
bed 1
bed 2
bed 3
start up heated gas supply line
cooling gas to shell
2735 El.
4290 El.
heat exchanger 1
5535 El.
8685 El.
heat exchanger 2
54,9
9460 El.
11830 El.
14100 El.
16355 El
heat exchanger 3
57,9
converter outlet
converter inlet

chemserv
CONSULTING GES.M.B.H.

A M M O N I A   P L A N T

Low Pressure Section

and Water Treatment

ITEM	INSTRUCTOR
1. Organization of dept. ATG	Skopetz
2. Responsibilities of dept. ATG	Skopetz
3. Daily routine work	Skopetz
4. Flowsheet cooling water supply	Luger
5. Flowsheet boiler feedwater plant	Luger
6. Flowsheet waste water neutralization	Luger
7. Cooling water return to Danube by elevation pumps	Skopetz
8. Flowsheet natural gas steam reforming	Luger
9. Maintenance to point 4, 5 and 6	Skopetz
10. Maintenance to point 10	Skopetz
11. Special materials for the primary reformer	Luger
12. Demonstration pigtail-nipping	Workshop
13. Demonstration pressure filter flushing	Luger
14. Maintenance process air compressor	Skopetz
15. Inspection process air compressor	Skopetz
16. Pneumatically regulated suction valves	Luger
17. Piston rod sealing	Skopetz
18. Guide ring controlling	Skopetz
19. Used materials in boiler feedwater plant	Luger
20. Used materials in steam reforming plant	Skopetz
21. ATG - museum	Skopetz

2. Responsibilities of dept. ATG

Dept. ATG is responsible for maintenance in the following plants:

107, 146	Old and new water station (river water and cooling water supply)
140	Chlorination station for well water (0.7 - 0.8 mg Cl/h H2O)
144	Horizontal pumps for well water
204	Air separation plant (2 units, each 1 700 Nm3/h O2), compressed air supply
204 a, b	Bottling of oxygen and compressed air
206, 209	N2 gasometers (2 000 m3, 500 m3)
207	O2 gasometer (10 000 m3)
208	Cracked ammonia (N2 + H2) holder (25 000 m3)
R. Br.	Pipe bridges
RN	Network of pipes, piping of: KOG, natural gas, heating gas, cracked gas, steam 25, 20, 7, 2 bar, compressed air, river well, hot (90oC), warm (40oC), drinking water, boiler feedwater, condensate, oxygen.

Machines, compressors and pumps in dept. urea (except standard pumps).

212	Battery (block) of bottles for high-pressure N2
202	Old gas reforming plant
220	Naphtha and Orthoxylol tanks and pump stations (tank farm)

Pipelines for naphtha and orthoxylol

101, 211	Natural gas pressure reducing stations
110	Old boiler house (2 units, each 12 t/h steam 25 bar)
110 a, b	Contact sludge circulation reactors (flocculators)
203	Boiler feed water treatment
213	Naphtha intermediate storage facilities
214	Naphtha steam reforming plant (ICI plant)
148	Waste water neutralization

Dept. ATG has to organize all planned shut downs for these plants and also for the several machines (routine overhaul). ATG is in this way responsible for the maintenance cost in all plants also for the cost of foreign departments working in a. m. plants.

Resp. for programs, spare parts.

3. Daily routine work

Maintenance philosophy

DANUBE WATER

pH	8
conductivity	263 x 10 S/cm (S=Siemens
	1 S = 1A:1V = 1:Ω)
CO_2 (free)	2.0 mg/l
O_2	6.7 mg/l
alkalinity	2.55 mval/l
hardness	8.6o dH = 153.9 ppm
	= 3.1 mval/l
non-carbonate hardness	1.5o dH = 26.8 ppm
	= 0.6 mval/l
MgO	19.4 mg/l
CaO	58.8 mg/l
solid residue from evaporation (105oC)	214 mg/l
solid residue on ignition (650o)	122 mg/l
$KMnO_4$	19 mg/l (max. 30 mg/l)
Fe	0.31 mg/l
SiO_2	3.9 mg/l
HCO_3	156 mg/l
NO_2	0.08 mg/l
NO_3	14 mg/l
Cl	9 mg/l
SO_4	29 mg/l
P_2O_5	0.19 mg/l
NH_4	0.12 mg/l
Na	6.6 mg/l
K	4.0 mg/l

suspended sticks max.	12 mg/l (for short time max. 200 mg/l)
average	3 - 40 mg/l
fouling factor of waterside by tube temp. of cooling water side	≤50oC = 2 x 10
	>50oC = 4 x 10
temperature: winter 1oC summer: 20oC	temperature rise of return water: 10oC

K S U - R e a c t o r (Flocculator)

The "Contact-Sludge-Circulation Reactor" is especially used for conditioning of surface water which must be cleared of suspended matter, colouring substances, organic contaminants and carbon. Furthermore good results are attained in other fields of water treatment, especially deironing, demanganation, deacidifying, deoiling, sterilizing (degerminating), removing substances with disagreeable odour or flavour, but also algae and float lime. In the water treating process many of these effects are to be attained simultaneously.

General technical data

Capacity:	5 - 3 000 m3/h (per unit)
turn-around time: (dwell time)	about 60 - 90 minutes
internal circulation:	3 - 5 x quantity of flow (capacity)
saving of chemicals:	30 - 40% compared to conventional plants
speed of climb-up:	approx. 3 - 5 m/h
transparence in cleaned water:	often 1.5 - 2.0 m
turbidity content in discharged water:	10 mg/l, often 3 - 5 m/h
rate of blow down:	0.5 - 1.0% of capacity
sludge content:	15 - 25 g solid matter/l (97.5 - 98.5% water)

Function

First the untreated water flows into the cylindric middle part and there it is mixed with recycled deposite products and chemicals. The rising stream is produced by a speed regulated mixer which works like a circulation pump. This mixer makes a good mixture of all components: raw water, chemicals and activated sludge. With the aid of the contact effect of the sludge the formation of flakes begins immediately and increases quickly. After having passed the mixing zone water comes into the reaction zone and changes its direction of flow. In this zone all chemical reactions happen, whereby the flakes grow and grow.

Then a part of the water comes into the ascending pipe, while the other part flows to the outer parts of the reactor. On the bottom edge of the lower cylindric part of the big cone a sharp separating zone is formed between sludge and clear water. Sludge particles sink to the bottom, clear water rises to the surface. In the outer area of the big cone the climbing speed drops and therefore even small sludge particles cannot rise. The clear, conditioned water flows into a top collecting channel (groove). By a slowly turning desludger the sunken sludge is transported into the slime pit and is then further thickened. An automatic valve removes the sludge from the reactor intervals.

Operation

The characteristic feature of the KSU reactor is the internal circulation; a quantity of 3 - 5 times of the capacity flow is circulated in the mixing and flocculent zone. In this cycle a lot of activated sludge is carried along, so that each particle of raw water is often in contact with sludge and chemicals. The particles of slime work as crystal centers on which products of precipitation settle down directly. This principle of so called "contact sludge circulation" is the real reason for the surprisingly good conditioning effect. Good working of the reactor is revealed by the sharp separating zone between muddy water and rising clear water, further on the quick sinking process of old dereacted sludge.

Total demineralization / fundamental principles

It has long been known that salts dissolved in water dissociate more or less into their components that means into ions, common salt (kitchen salt), for example, dissociates into the positive sodium ion and the negative chlorine ion. This dissociation makes water electrically conductive and so it is possible to separate cations and anions by direct current. Nearly all salts dissolved in water dissociate into cations in this way; and anions the most important of them can be put in order as in the following scheme:

cations:	anions:		
Ca	$(HCO_3)_2$	K	H
Mg	$(HCO_3)_2$	K	H
Ca	SO_4	N	H
Mg	SO_4	N	H
Ca	Cl_2	N	H
Mg	Cl_2	N	H
Na	Cl	neutral salts	
Na_2	SO_4	neutral salts	
Na_2	SiO_3	neutral salts	
K	= carbonate hardness		
N	= non-carbonate hardness		
K + N = H	= total hardness		

Not all ions are equally well absorbed or delivered by ion exchangers. A very good exchange is given between cations and hydrogen ions and between anions and hydroxyl ions. Polyvalent ions of heavy metals like iron and manganese are taken up by cations first, followed by alkaline earths like calcium and magnesium, with potassium and sodium of all. A cation exchanger loaded with these ions is regenerated by acid. In this process the cations are dislodged by the hydrogen ion of the acid. According to the law of mass action (Guldberg and Waage' s law) a surplus of acid is necessary (over and above the theoretical quantity) for finishing the regeneration. The same applies the regeneration of anion exchangers by a sodium hydroxide solution. If the ion exchanger substance is exhausted the ion most difficult to be exchanged will break through first: sodium at the cation exchanger and silicic acid at the anion exchanger.

The ions capable of being exchanged are not only on the surface of the grains of the exchange resin but also inside (interior). That means that exchanging reactions need a certain minimum time to obtain relations between quantity of water, speed of filter process and quantity of exchange resin.

Variations are possible, such as strongly acidic and slightly acidic cation exchanger or strongly basic and slightly basic anion exchanger. Slightly acidic cations exchangers can be regenerated without a surplus of acid and slightly basic anion exchangers without a surplus of sodium hydroxide (caustic soda). In a combined employment of "slight" and "strong" exchangers it is possible to further use the surplus of chemicals which is absolutely necessary for the "strong" exchangers for the regeneration of the "slight" exchangers. By this a lot of chemicals can be saved. So it is more economical.

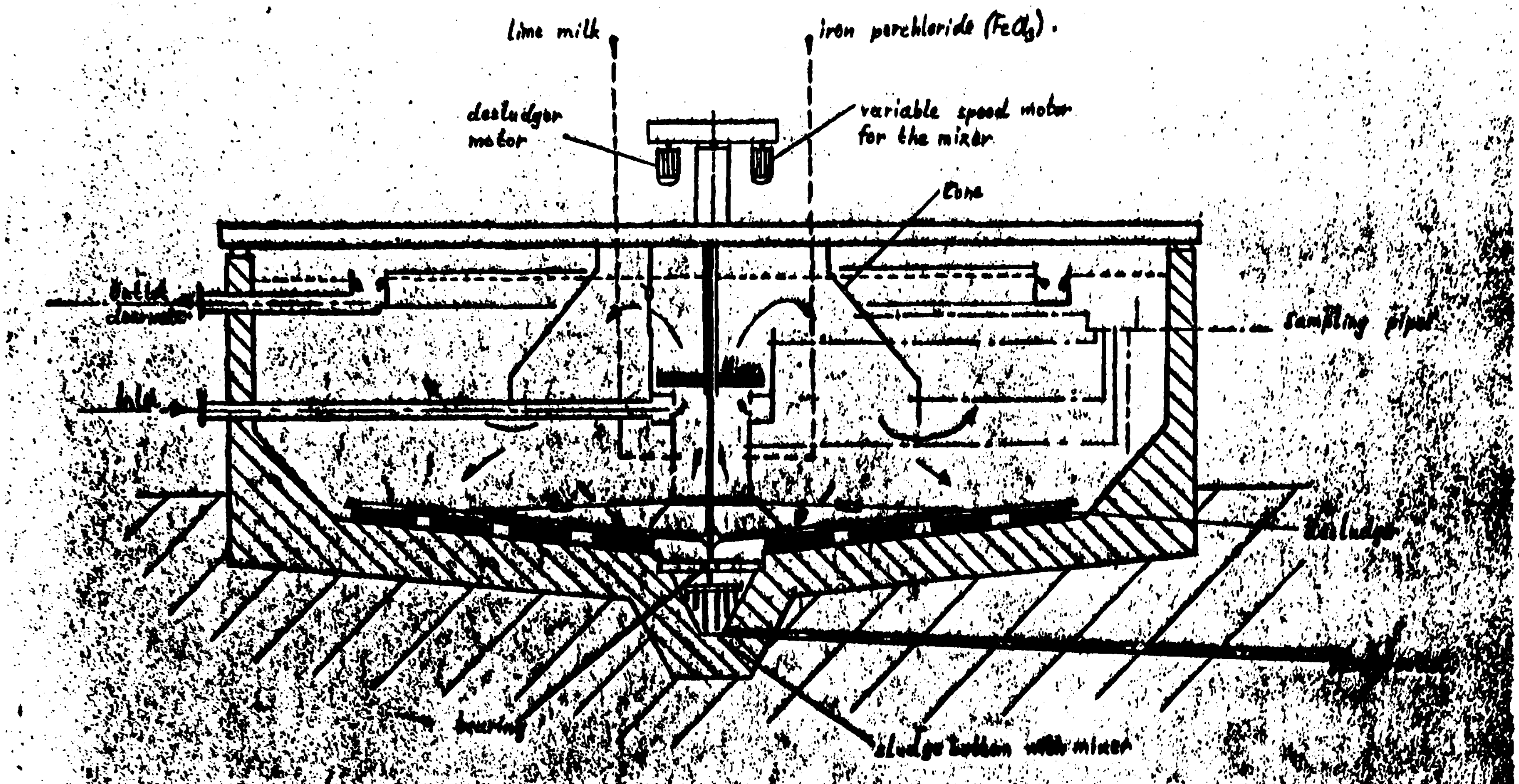
The combination of a contract sludge circulation reactor with sand filters and a total ionization (demineralization) enlarges the economical possibilities of application of total demineralization plants, especially of plants with large hourly capacities.

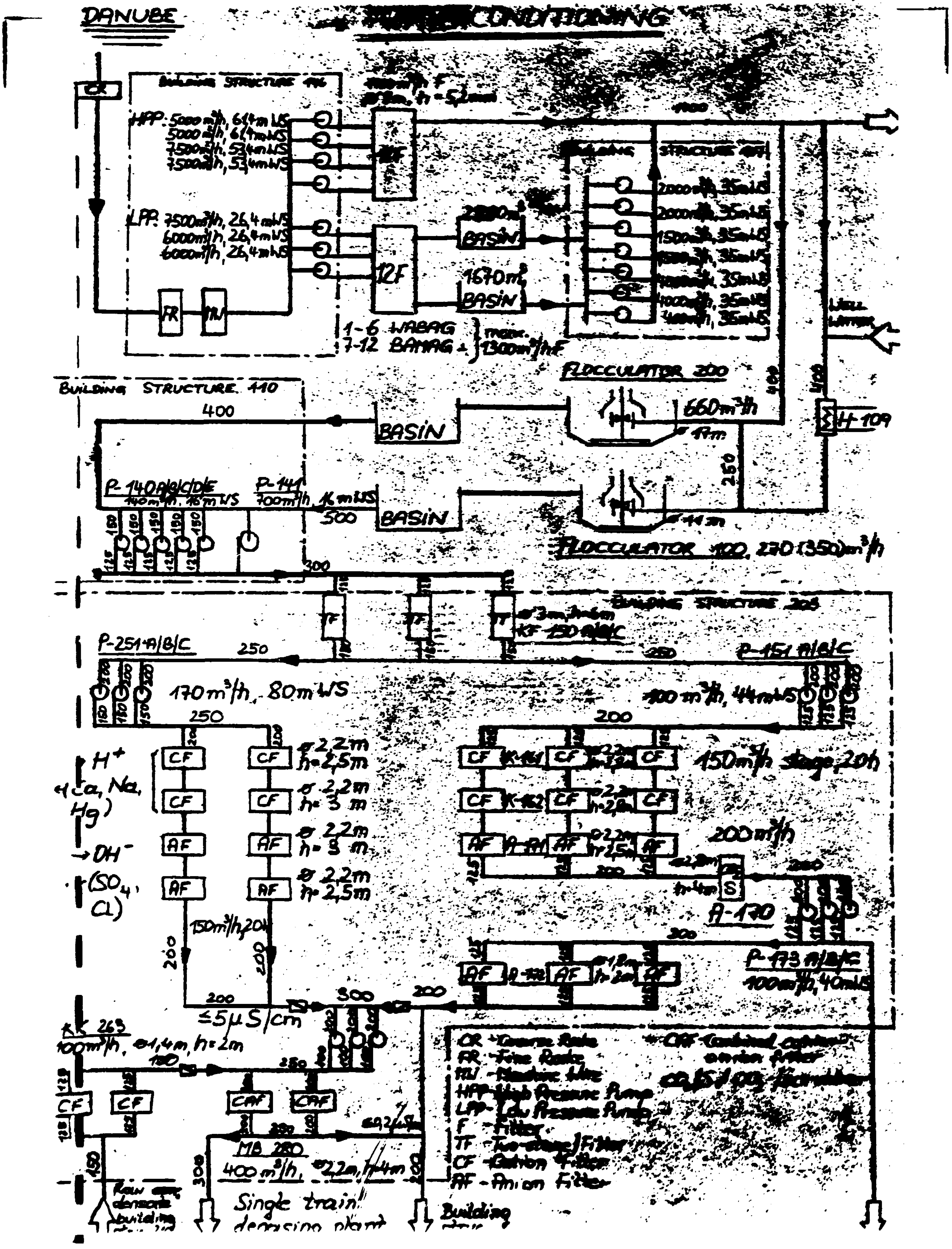
Total demineralization/Process

Such a plant consists of cation and anion exchangers which must be regenerated when the substance (resin) is exhausted. The regeneration process lasts for 4 - 6 hurs. During this time the plant is working with another row. So it is necessary to have at least two rows of apparatus. Further it is a great advantage to have clear water reservoirs (vessels) at the end of the plant for short time requirements of 3 - 4 hours, e. g. for small repairs or short trubles.

Mixed bed filters are situated only in the last stage; they are considered to be safety devices. The water treatment should be finished before mixed bed filters. They have only the function to catch or to kill irregularities or natural "slippage". By this working safety (reliability) of the plant is increased, and for pre-inserted filter groups cost in deminsioning of all apparatus (filters) and operating expenses can be saved because this apparatus can be fully loaded without risk.

FLOCCULATOR



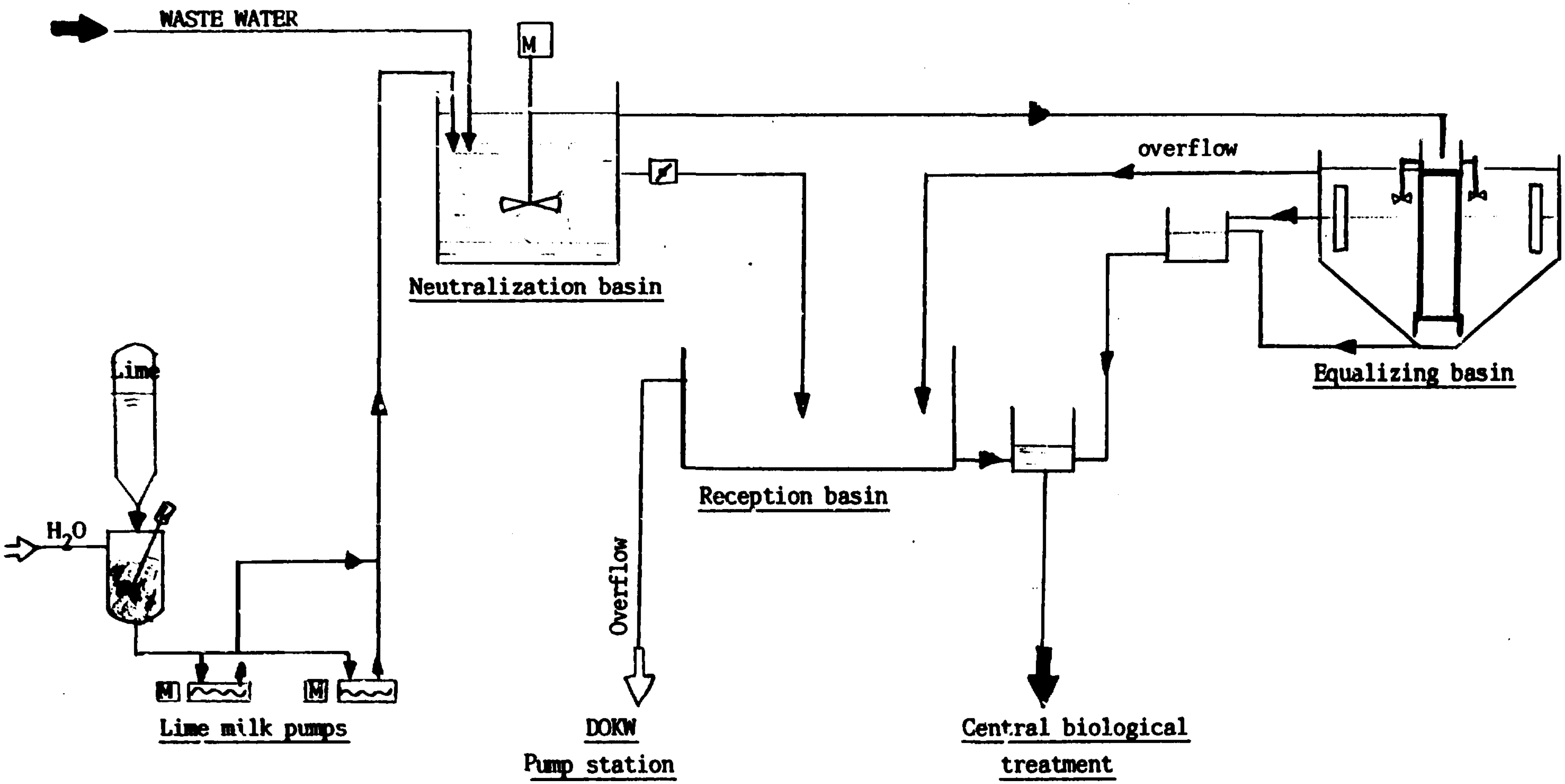

DANUBE
CONDITIONING
BUILDING STRUCTURE 410
HPP: 5000 m³/h, 61,4 m WS
5000 m³/h, 61,4 m WS
7500 m³/h, 53,4 m WS
7500 m³/h, 53,4 m WS
LPP: 7500 m³/h, 26,4 m WS
6000 m³/h, 26,4 m WS
6000 m³/h, 26,4 m WS
FR
MW
12F
BASIN
1670 m³
1-6 WABAG
7-12 BAMAG
max. 1300 m³/h F
FLOCCULATOR 200
660 m³/h
H-109
BUILDING STRUCTURE 410
400
BASIN
P-140 A/B/C/D/E
140 m³/h, 16 m WS
P-141
700 m³/h, 16 m WS
500
BASIN
FLOCCULATOR 100, 270 (350) m³/h
300
TF
P-251 A/B/C
250
P-151 A/B/C
170 m³/h, 80 m WS
100 m³/h, 44 m WS
250
200
H⁺
(Ca, Na, Mg)
→ OH⁻
(SO₄, Cl)
CF
AF
ø 2,2 m h=2,5 m
ø 2,2 m h=3 m
ø 2,2 m h=3 m
ø 2,2 m h=2,5 m
150 m³/h stage, 20 h
200 m³/h
A-170
S
150 m³/h, 20 h
P-173 A/B/C
100 m³/h, 40 m WS
≤5 µS/cm
KK 263
100 m³/h, ø 1,4 m, h=2 m
CAF
MB 280
400 m³/h, ø 2,2 m, h=4 m
Single train demising plant
Building
CR - Coarse Rake
FR - Fine Rake
MW - Mechanic Wire
HPP - High Pressure Pump
LPP - Low Pressure Pump
F - Filter
TF - Two-stage Filter
CF - Cation Filter
AF - Anion Filter
CAF - Combined cation anion filter

Organic waste water system

In our factory there are two different waste water systems. One is the normal cooling water return system and the other one is water contaminated with organics. This contaminated water we have to collect in a special channel system with several pump stations and fan stations for the air supply in the tube systems. This system falls into a neutralization basin. There we have to neutralize the waste water to a pH in the range from 6 - 8 (the average should be about pH 7).
The pH of the waste water coming from the different departments should be minimum pH 4. After neutralization with lime milk and mixing the neutralized water runs into an equalizing basin. After equalizing the water goes to central biological treatment in Asten (near the power station Abwinden-Asten).

If the pH limits in the neutralization basin are exceeded a butterfly valve opens automatically and the waste water runs to a reception basin.

WASTE WATER NEUTRALISATION



NAPHTHA STEAM REFORMING PLANT (ICI PROCESS)

General

Engineered by Humphreys & Glasgow, London, 1964 - 1966; erected by ourselves. Laying out: 3)0 t Np/d (365 t NH3/d) at a pressure of 28 bar (max. 31 bar). Beyond the ICI licence (our risk) we increased the working pressure (inlet prim. reformer) to 38 bar and the daily output to 420 t Np (510 t/d NH3). We had bought machines, apparatus and pipes qualified for higher pressure.

Feedstock

1966 (start up) - 1976 naphtha (strait run benzines); since 1976 - natural gs.

Maintenance

	hours	material cost (mill. AS)
1974	21 000	1.3
1975 general overhaul	56 000	7.4
1976	24 000	1.6
1977 general overhaul	46 000	4.2
1978	16 000	1.6
1979	21 000	0.8
1980	49 000	0.9
1981	16 000	0.1

On stream days:

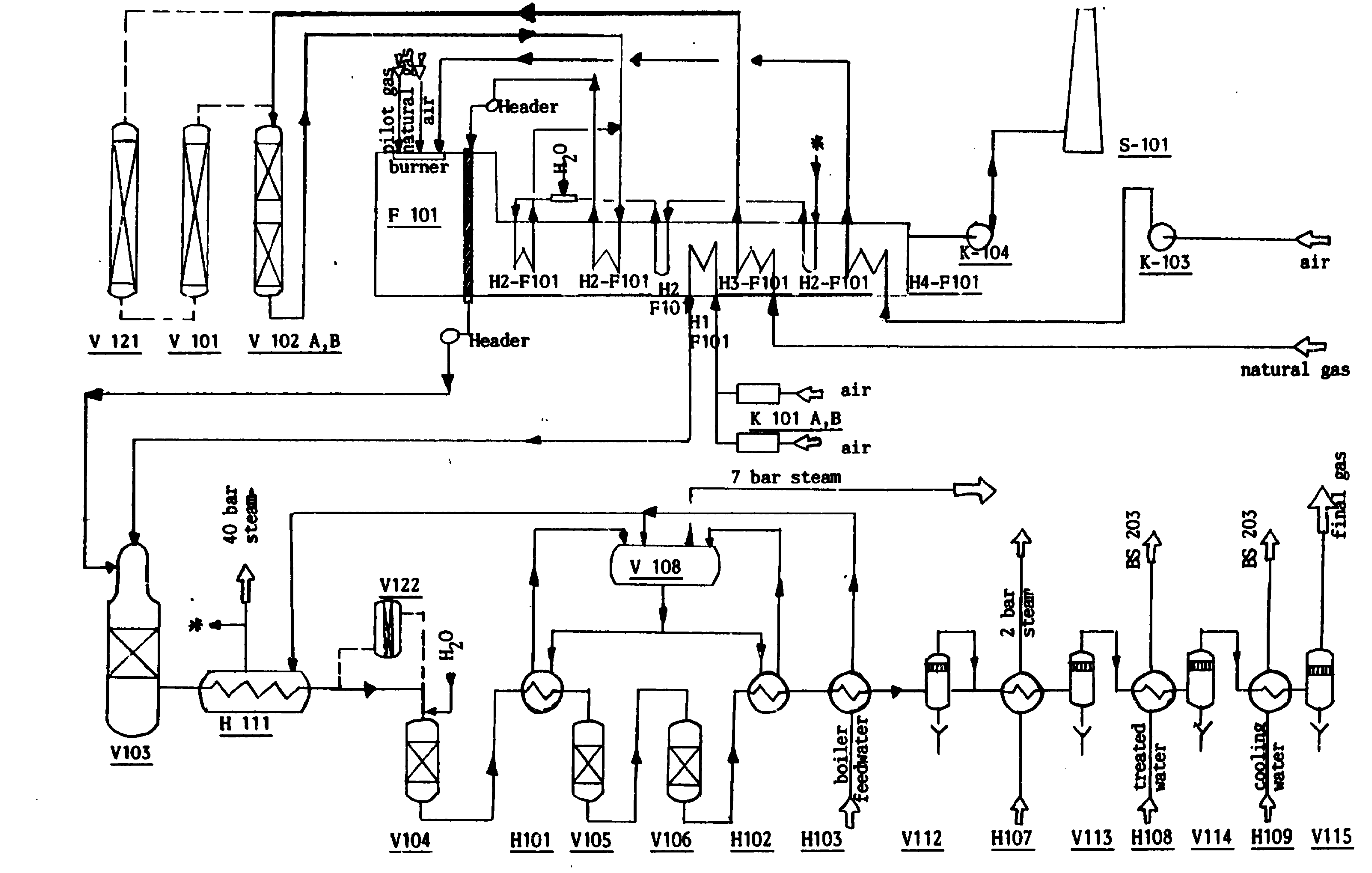
1974		363
1975	gen. overhaul	324
1976		366
1977	gen. overhaul	325
1978	intended 3shut down during Single-Train shut down for welding-piping connections between both plants.	
		362
1979		365

HISTORY OF Np PRODUCTION (ATG)

Np ..... parts of N in NH3 (14 Mol N + 3 Mol H = 17 Mol NH3)

Spring 1940:	start on raising the ground level about 2 - 4 m.
Autumn 1942:	Start of production on basic KOG. (1 unit for desulphuration, 3 units for gas dividing and 3 - for CO conversion).
1944:	Output 55 000 t Np/a
1944/1945:	about 800 bombs from allied airforces exploded in Chemie Linz area and plants
May 1945:	-
July 1946:	No production as neither KOG nor energy were available.
1948:	1944 output level reached again
↓	production increase
1965:	to 237 000 t Np/a or 718 t/d max. (3 units for desulphation, 6 for gas dividing and 7 for CO conversion)
1966:	start up of naphtha steam reforming plant
↓	increase
1974:	to about 320 000 t Np/a
1979:	to about 520 000 t Np/a
1980:	to about 480 000 t Np/a

NATURAL GAS STEAM REFORMING



F - 101	Primary reformer
H 1 - F 101	Process air heater
H 2 - F 101	Heater for steam
H 3 - F 101	Natural gas heater
H 4 - F 101	Combustion air heater
K - 101 A/B	Air compressor
K - 103	Combustion air fan
K - 104	Flue gas fan
S - 101	Stack
V - 101*	Primary desulphurizer
V - 102 A/B	Secondary desulphurizer
V - 103	Secondary reformer
V - 104	Primary CO converter
V - 105	Sulphur catch vessel
V - 106	Secondary CO converter
V - 108	Steam drum
V - 112, 113, 114, 115	Gas separator
V - 121*	Carbon catch vessel
V - 122*	Potassium catch vessel
H - 101	Waste heat boiler
H - 102	Waste heat boiler
H - 103	Boiler feedwater
H - 107	2 bar steamboiler
H - 108	Treated water cooler
H - 109	Raw water cooler
H - 111	Waste heat boiler

*) Only with naphtha steam reforming in progress.

1. Furnace tube

a. G - X 40 CrNiSi 2520 = W.Nr. 1.4848 = ASTM A - 297 - HK

Approximate analysis:	C~0.4%, Cr~25%, Ni~25%, Si~2.5%
Melting point:	1 400oC
Working temperature:	800 - 950oC
Weldability:	good
Thermal expansion between 20oC and 1000oC:	10.0 10^{-6} m/moC
Heat conductivity (20oC):	0,147 J/cm soC
Tensile strength (20oC):	440 N/mm2
Yield point (20oC):	245 N/mm2

b. G - X 35 NiNb 2424 = W.Nr. 1.4855

Approximate analysis:	C~O, 35%, Ni~24%, Cr~24%
Melting point:	1 350oC
Working temperature:	850 - 1 000oC
Weldability:	good
Thermal expansion between 20oC and 1000oC:	19.6 . 10^{-6} m/moC
Heat conductivity (20oC):	(0.148 J/cm soC)
Tensile strength (20oC):	440 N/mm2
Yield point:	245 N/mm2

c. X 10 CrNiAlTi 3220 = W.Nr. 1.4876 = Incoloy 800

Approximate analysis:	C~0, 1%, Cr~32%, Ni~20%, Al≤0.6 %, Ti≤0.6%
Melting point:	1 350oC
Resistant in air up to:	1 150oC
Weldability:	good
Thermal expansion between 20oC and 1000oC:	18.7 . 10^{-6} m/moC
Heat conductivity (20oC):	0.097 J/cm s oC
Tensile strength (20oC):	540 N/mm2
Yield point (20oC):	245 N/mm2

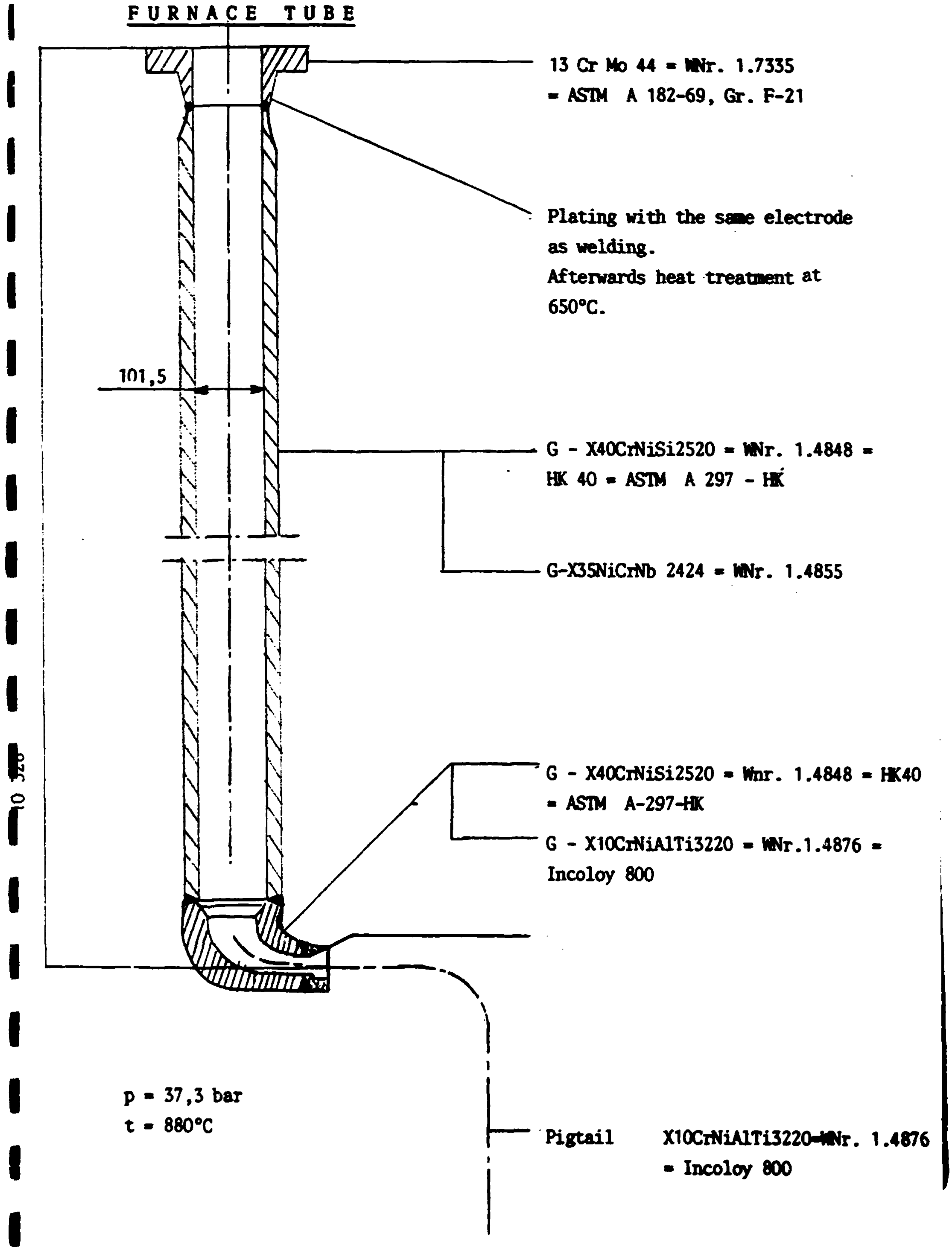
d. 13 CrMo 44 = W.Nr. 1.7335 = ASTM A 182-69, Gr. F-12

Approximate analysis:	C~0, 13%, Cr~1%, Mo~o.4%
Working temperature:	max. 530oC
Tensile strength (20oC):	440 N/mm2
Yield point (20oC):	275 N/mm2

2. Convection zone

a. 10 CrMo 9 10 = W.Nr. 1.7380 = ASTM A 199-Gr. T22

Approximate analysis:	C~0, 1%, Cr~2%, Mo~1%
Working temperature:	max. 530oC
Tensile strength (20oC):	440 N/mm2
Yield point (20oC):	265 N/mm2


FURNACE TUBE
13 Cr Mo 44 = WNr. 1.7335
= ASTM A 182-69, Gr. F-21
Plating with the same electrode
as welding.
Afterwards heat treatment at
650°C.
101,5
G - X40CrNiSi2520 = WNr. 1.4848 =
HK 40 = ASTM A 297 - HK
G-X35NiCrNb 2424 = WNr. 1.4855
10 328
G - X40CrNiSi2520 = Wnr. 1.4848 = HK40
= ASTM A-297-HK
G - X10CrNiAlTi3220 = WNr.1.4876 =
Incoloy 800
p = 37,3 bar
t = 880°C
Pigtail X10CrNiAlTi3220=WNr. 1.4876
= Incoloy 800

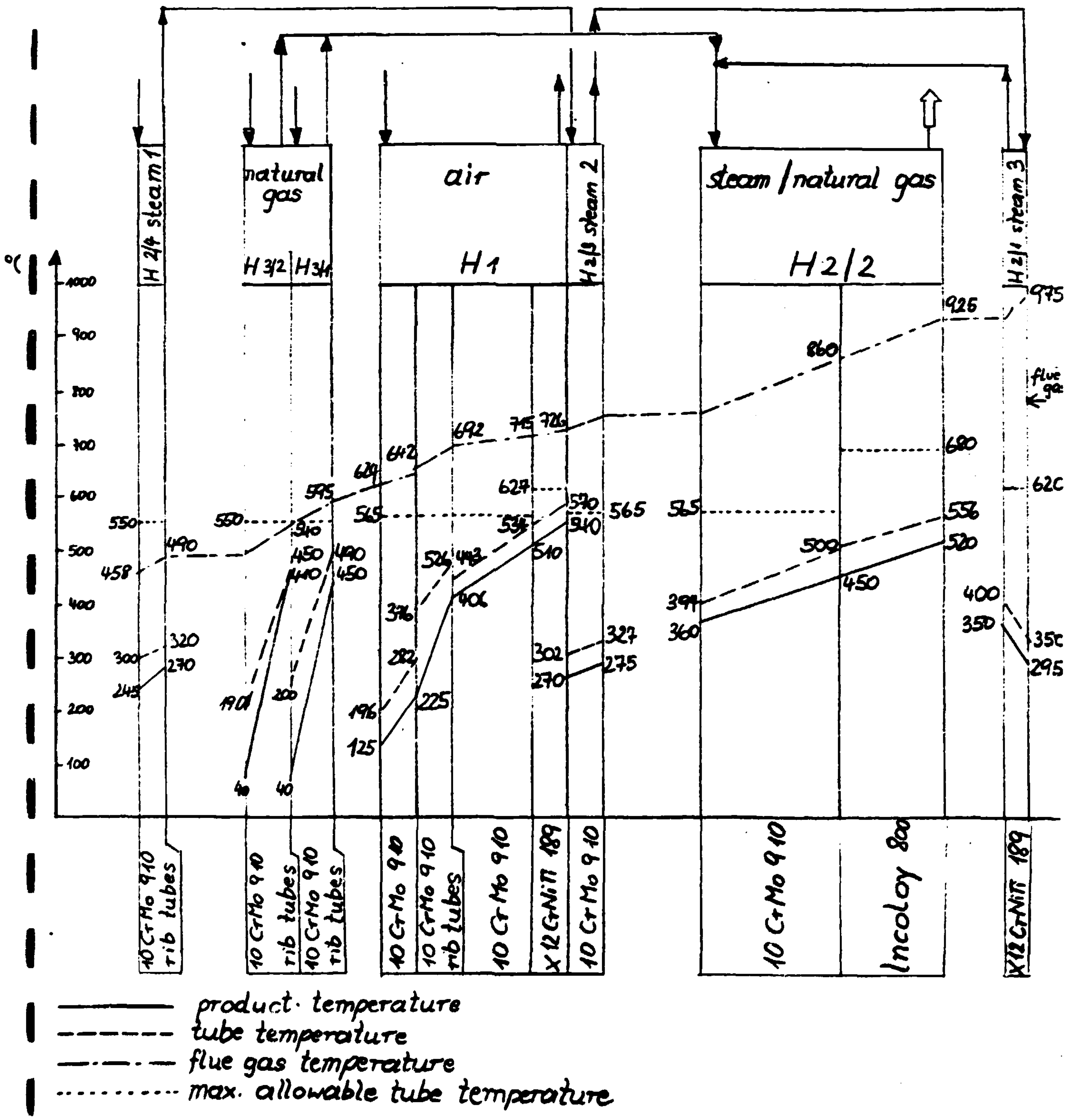
b. X 12 CrNiTi 18 9 = W.Nr. 1.48878 = Austenitic steel CrNi 150 : 17/4 N 634 (H32)

Approximate analysis:	C~0.12%, Cr~18%, Ni~9%, Ti~4 x C
Resistant in air up to:	800oC
Weldability:	good
Thermal expansion between 20oC and 1000oC:	19.0 . 10^{-6} m/moC
Heat conductivity (20oC):	0,147 J/cm soC
Tensile strength (20oC):	490 N/mm2
Yield point (20oC):	245 N/mm2

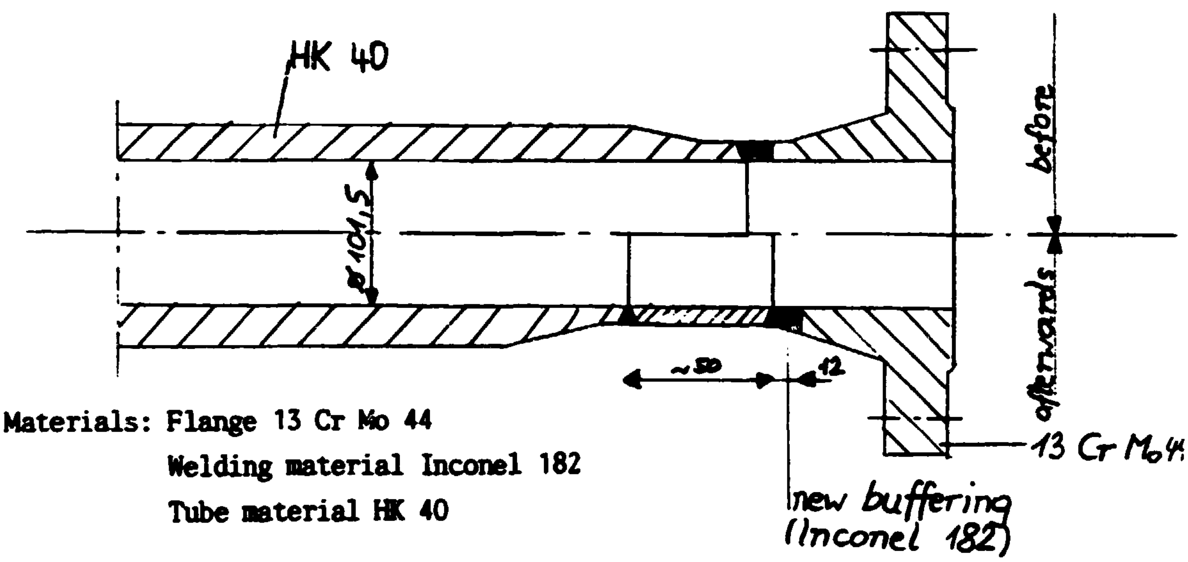
c. X 10CrNiAlTi 3220 = W.Nr. 1.48876 = Incoloy 800

see 1. c.

CONVECTION ZONE



Welding procedure for furnace tubes after stress corrision:

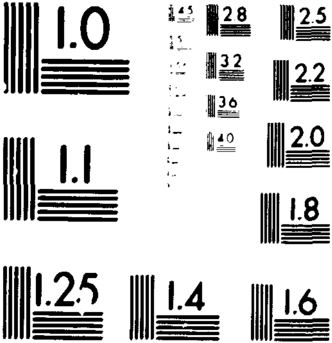


Materials: Flange 13 Cr Mo 44
Welding material Inconel 182
Tube material HK 40

1. Cut the flange
2. Turn the flange for buffering
3. New buffering (material: Inconel 182), minimum 12 mm
4. Buffering turn to wall thickness.
   The front is to cut under 90oC.
5. x-ray test - quality is IIW-black
6. Heat the flange for half an hour at 700oC - cooling to 300oC
   in the oven, rest in air.
7. Turn the weld phase
8. Dye penetrant test of the buffering
9. Dye penetrant test of the tube end
10. Cut the failers and turn the weld phase

11. Dye penetrant test this weld phase
12. Weld the flange; pay attention to the length tolerance.
    Welding: ground Inconel 182, rest with Boehler Fox NiCr70Nb.
    By heating to 70oC avoid condensate rise.
13. Dye penetrant test the ground of welding.
14. Dye penetrant test the top layer.
15. x-ray test quality IIW-black
16. Be careful during transport - tubes are brittle!

85.01.16
AD.86.07



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

BLANKING-OFF REFORMER TUBES DURING PLANT OPERATION

B. Estruch

1. Introduction

When a reformer tube bursts during service the loss of gas through the leak is not necessarily intolerable but the leaking gas ingnites inside the furnace and causes overheating of the surroundings. To prevent damage to the refractory and to the neighbouring tubes, it is necessary to isolate the failed tube.

To achieve this either the design must make provision for shutting off any individual tube or, if simply welded up connections are used, the whole unit must be shut down and cooled so that the failed tube can be cut out and replaced, or the connections plugged by welding.

Because the outlet pigtails usually operate in the region 700 - 800oC, and no valves are known that could be fitted in each pig-tail, and because at any rate the expense and complication of fitting them in the design would be considerable, an all welded design is normally adopted. Initially, when an overheated tube leaked the furnace had to be taken off line losing some 36 hours' production. This represented a serious loss of output. Apart from that, in reformer plants built for the production of town gas the manufacturing authority is under legal compulsion to maintain a minimum gas pressure, and it could hardly afford to shut down a furnace even for only 30 hours should a tube fail during a period of peak demand. Consideration was therefore given to methods of blanking-off leaking tubes which would not necessitate shutting the plant down.

2. Background

It has been standard practice for many years to squeeze mild steel pipes on gas and water service when it had become necessary to isolate a line and a number of devices are commercially available for this purpose. However the application of gross plastic deformation to pressure equipment containing hot inflammable gases had not been considered. The commercially available apparatus for low temperature service is hydraulically operated, which is an advantage, but the frame has to be dismantled and then reassembled on to the pipe to be squeezed. This would have been perhaps acceptable for inlet pigtails where the temperature is around 400oC, but the manipulation involved would not be acceptable in the proximity of the hot outlet pigtails (700 - 800oC). For that reason a G-clamp squeezer was designed so that the unit could be placed onto the pigtail where it runs horizontally adjacent to the reformer tube (Clark and Elmes Paper 2, Fig. 2) and all that was required in the way of preparation was to remove the lagging on this selection.

3. G-Clamp Squeezer

Details of the squeezer are given in the drawing in Fig. 1 and the photograph of Fig. 2. It is driven by a short 6 ton hydraulic ram, manufactured by Epco Flexi-Force.

The main advantages of this design are:

(1) The G shape of the frame reduces manipulation near the pipes before squeezing to hanging the device onto a horizontal part of the pigtail.

(2) It is connected to the pump by means of a pressure hose of convenient length so that the operator is at a safe distance while the tube is being squeezed. It is relevant to mention here that, in the event of a pigtail cracking while being squeezed, Billingham experience has shown that the fire that results from a pigtail failure does not cause significant damage.

(3) Should any accident happen to the hydraulic ram, to the hose or to the pump the quantity of oil involved is very small (1 - 2 pints).

(4) After squeezing the jaws can be fastened together by means of screws to form a permanent clamp to prevent the internal pressure opening up the squeezed pipe. The G clamp and hydraulic ram can then be removed by simply letting the jaws slide off along the guides shown in the drawing.

(5) The jaws are kept in position by means of ball catches while the clamp is being hund and while pressure is being applied.

(6) Two lateral sheet metal pieces locate the clamp jaws on the pipe and are crushed away as the squeezing operation is in progress.

4. Laboratory Tests

Although from the above considerations it appeared that blanking-off reformer tubes by flattening the inlet and outlet pigtails could be achieved with reasonable safety it was decided to carry out some preliminary tests on a laboratory scale.

In order to simulate plant conditions a test rig was arranged in which a length of pipe could be electrically heated by making it an integral part of a circuit connected to a low voltage high current source. One of the ends of the tube was blanked-off and the other connected to a 275 p.s.i.g. steam line. Provision for measuring the steam pressure and for measuring and controlling the temperature during the tests were made. Samples of both Incoloy and Cr-Mo pipe were tested. The clamp itself was tested under a 7 ton load without it showing any permanent set.

4.1 Incoloy Pigtails

Two samples of extruded Incoloy DS tubing, 1 11/32 in. o. d. x 8 s. w. g. (as used for the fabrication of the outlet pigtails) were used for the trials. One sample was ex-stored but was aged for 72 hours at 800oC in order to bring it into a condition nearer to that of the pipes after service. The second sample was cut from an actual pigtail which had failed due to the presence of manufacturing defects after a few months in service.

These samples were heated to 800oC before squeezing. During the first test the temperature dropped quite considerably as the jaws touched the tube, but by insulating the ends of the pipe the temperature drop was eventually reduced to about only 20oC.

In all, eight trials were performed. The results were completely satisfactory except in one case, when a number of small cracks developed on the outside of the pipe but no leak occurred. This cracking was not thought to be significant because the trial was done on a part of the pipe which had been overheated to nearly melting point during the initial attempts to adjust the temperature. Figure 3 shows the general appearance of the tube and Figure 4 a cross-section through one of the flattered parts.

4.2 Cr-Mo Pigtails

The tests were done at 400oC on a length of 1% Cr-Mo steel pipe 13/16 in o. d. x 5/32 in. wall as used for the inlet pigtails. At this temperature the tube was too strong for the squeezer and a perfect flattening could not be achieved. In order to increase the stress on the pipe the width of the jaw faces of the clamp was reduced from 1/2 in. to 1/8 in. but then the ductility of the material war insufficient and the tube wall sheared. It was found possible to avoid this by carrying out the operation in two stages. In the first a set of jaws with slightly curved faces (1/2 in. width) was used. This spread the deformation over a large area but still left a gap between the two wall faces. A second pair of jaws with faces 1/8 in. wide and semi-circular cross section was used to close the gap. To achieve this the load had to be increased to 8.5 tons. The clamp withstood this overload well. Figures 5 and 6 show the results of the tests.

During the tests it was found that the original jaws in 18/8/Ti were too soft and yielded appreciably during operation. This was prevented by protecting the jaw faces with welded inserts of heat treated FV520(B) steel whose yield strength is about three times higher than that of 18/8/Ti steel.

5. Plant Experience

The pigtail squeezer has been used successfully on several occasions to isolate leaking reformer tubes. Squeezing the inlet pigtails has proved to be as easy in the plant as it was in the preliminary trials.

On the other hand with pigtails trouble has experienced on the three or four occasions owing to cracks forming during the operation. It appears that the difficulties are due to a combination of the following factors:

(1) Embrittlement during service. It is known that the ductility of Incoloy DS decreases with time due to an age hardening process. The use of Incoloy 800 which is now readily available and reputed to be less prone to embrittlement during service will probably improve matters.

(2) Decrease in temperature. As soon as the flow or hot gas through the pigtail is restricted the metal temperature begins to fall and so does its ductility. The more quickly the operation is completed the less likely is trouble to occure. The possibility of locally increasing the temperature of the outlet pigtail prior to squeezing is also being considered.

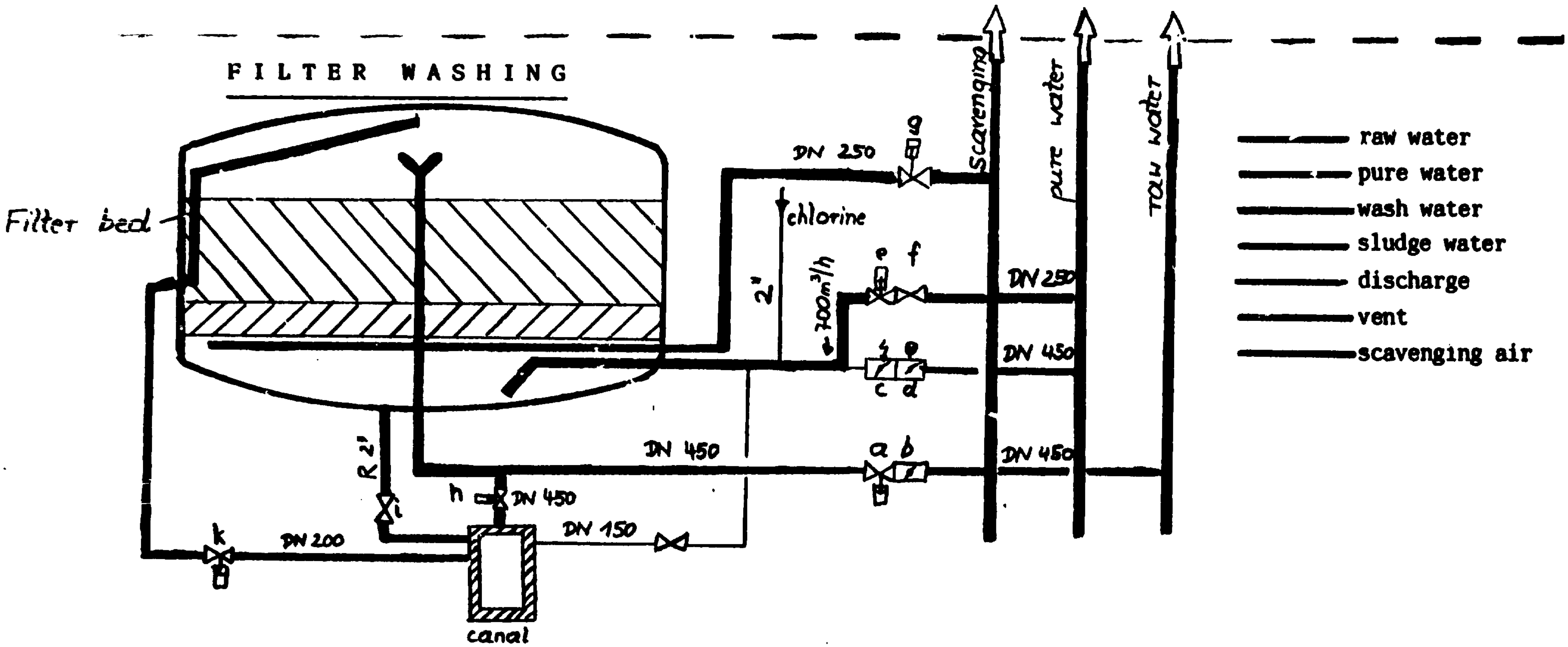
(3) The occasional presence of score marks on the surface and stringers of inclusions inside the pipe wall which facilities the initiation and propagation of cracks.

In spite of these occasional difficulties it always has been possible to blank-off the failed reformer tube. Even after cracks have appeared in the pigtail its flattening has been achieved at a second attempt.

The use of screwed jaws to maintain the pitail gas tight has proved to be necessary. Whenever the jaws have been removed the leakage of gas from the reformer tube has been seen to increase gradually becoming excessive after some time. A second application of the squeezer and permanent clamping of the pigtail has been sufficient to reduce the leakage to a negligible amount.

Conclusion

Blanking-off failed reformer tubes without having to shut the plant down, by squeezing the inlet and outlet pigtails at a temperature and under pressure, has been a complete success. So far no untoward incidents have occurred; provided adequate care is taken, the isolation of the failed tube can be achieved without danger to the operating personnel or to the plant.



Filter:

Ø = 8 000 mm
h = 5 200 mm
v = 240 m³
q = 1 000 m³/h H_2O
p = 6 bar gauge

		open	closed
1. discharge	1 minute	i, k	a, b, c, d, e, f, g, h,
2. air	2 minutes	g, k	a, b, c, d, e, f, h, i,
3. air + water	11 minutes	e, f, g, h, k,	a, b, c, d, i
4. air + water + chlorine	4 minutes	e, f, g, h, k, +chlor.	a, b, c, d, i.
5. water	3 minutes	e, f, h, k,	a, b, c, d, g, i,
6. fill up with water	4 minutes	e, f, k,	a, b, c, d, g, h, i,
	25 minutes		
to filter		a, b, c, d	e, f, h, h, i, k

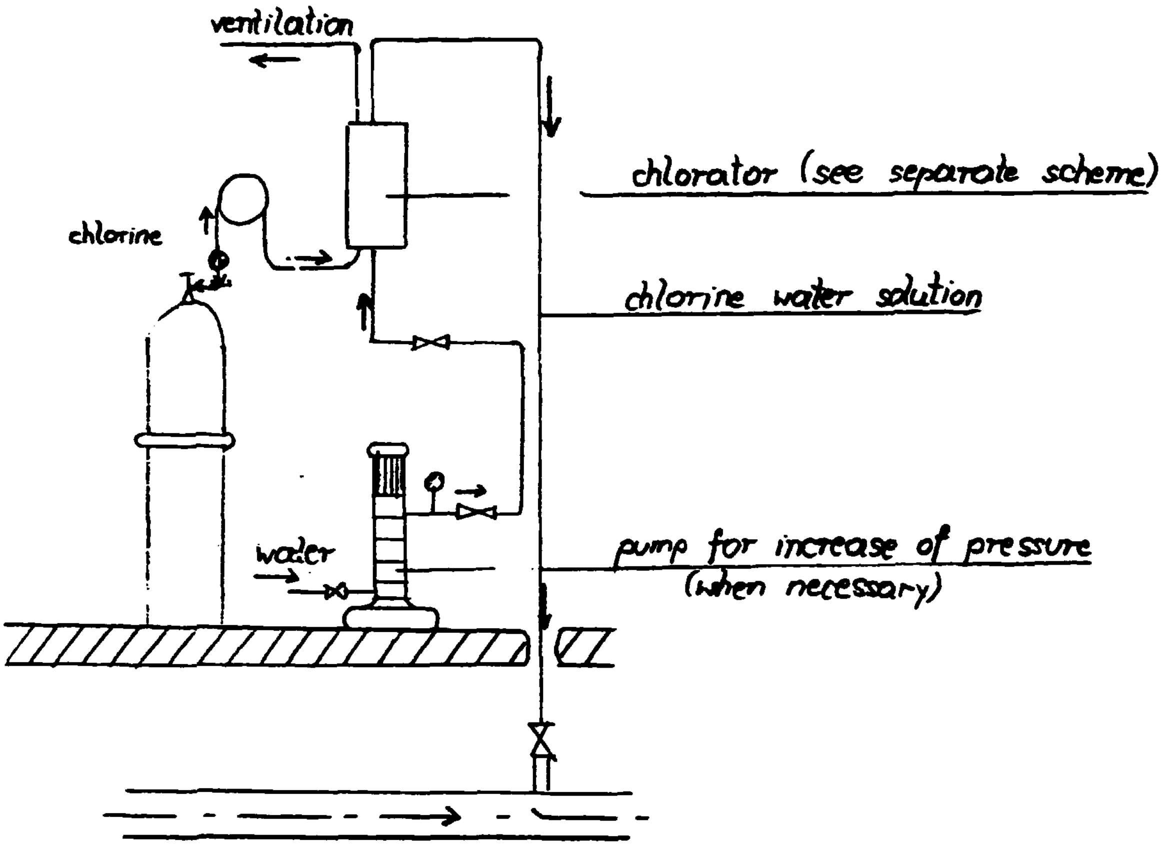
C H L O R I N A T I O N

The injector forms a vacuum for intaking chlorine gas and mixing with water. The ball and the membrane prevent a flow back of the water into the chlorine installation when the solution outlet is closed or stopped up. For the injector to function well, it is necessary that the pressure ahead of the chlorine inlet is very high against the back pressure.

The chlorine gas comes at pressure to the chlorine pressure reducing valve. There the pressure will be reduced below the atmospheric pressure because this valve opens ~~only~~ when the injector forms a vacuum. If gas comes into the valve without vacuum conditions, the membrane will lift and the gas escapes through the vent pipe.
The chlorine flows from the pressure reducing valve through a volumenometer to an adjustable V-nozzle which regulates the chlorine gas capacity. After that is situated a vacuum regulating valve for building a suitable vacuum is set.

When the chlorine supply is empty or shut off the vacuum regulateing valve closes. If the throttles effect is not enough, the diaphragm will take off by the vacuum and air will enter, satiating the vacuum.

CHLORINATION



1	Compensation hole
2	Vacuum regulating valve
3	Chlorine / water solution
4	Injector
5	Water
6, 7	Adjustable V-nozzle
8	Volumenometer
9	Chlorine inlet
10	Chlorine gas reducing valve
11	Ventilation

Inspection of machinery in stage 2 and 3 - compressor east

Steps

1. Measurement of guide rings at all of the 4 cylinders.

2. Cleaning of cooling chambers of all cylinders.

3. T.inspect the position of piston rod with frame level (a upper and bottom dead center). The crosshead must be presse on the running surface.

4. Remove piston and piston rod. To inspect or to flush (t level) the surface in the mainstop.

5. Remove bush, inspecting by TMP and refit. Measurement over cross at upper and bottom dead center, inspection with frame level. Inspection must be done with valves fitted.

6. Measurement of crosshead clearance.

7. Remove bolt of crosshead. Inspection of state of fit.

8. Remove crosshead and inspect in mainshop. (T flush the furnace).

9. Remove balancing weight.

10. Remove side rod.

11. Measurement of breathing (swelling) of crankshaft.

12. Measurement of clearance of connecting rod bearing (big-end bearing). Measurement of 2 ∅ (crank pin stud crank eye).

13. If modification of clearance is necessary, bolts must be fitted according to settled (defined) extension.

14. Both bearing bushes (pillows) must be fixed in the casing!

15. Points 3 - 13 apply equally to both stages.

16. After measuring swelling in both stages, remove main bearings 2, 3, 4 and 5.

17. Removing main bearing
    a. Measurement of clearane
    b. Notice length of bolts in fixed state
    c. Notice length of bolts in loosened (unscrewed) state
    d. Remove pillows. The crankshaft must be lifted by hydraulic tool half the clearance
    e. Inspection of pillows by TMP
    f. Inspection of bearing necks (journals) by TMP

18. Replace main bearings.

19. At both stages: as for point 11.

20. Measurement of guideway of crosshead (Ø and II) of both stages.

21. Measurement of cylinder.

22. Replace side rods.

23. Replace crosshead.

24. Replace air packing, oil packing and piston (without rings!). Measurement of state of piston (clearance between piston and bush). Distance on the side on which the crosshead slides.
1.7 - 1.8 mm on the second stage and
1.4 - 1.5 mm at the third stage from the piston.

25. Testing the state of piston rod with frame level.

26. Finish assembling; measurement of dead space.

27. Cleaning: air filter, oil filter, oil tub (tank), steam traps, nerve, oil fitting. Tightness test of air coolers.

28. Test run

29. Inspection by TMP
   a. Screws and threads
   b. Crosshead
   c. Pillows
   d. Bearing necks (journals)
   e. All antifatigue shafts of screws
   f. Shoulder of bushes
   g. Ribs of cylinder covers (tops)
   h. Shoulder of cylinders
      (connection between cylinder and casing)

Absorption Safety Loop in LINDE's air separation plant

From main condenser liquid oxygen comes to a pump which delivers it alternatively to one of two absorption vessels filled with gel. Then liquid oxygen flows back to the main condenser. By this liquid O2 is permanently in circulation through an absorption apparatus. It holds back (absorbs) 98% of acetylene (propene). All hydrocarbons not absorbed, like ethene, propane and so on enrich somewhat in the fluid.

By the absorption safety loop 1% of O2 production andby evaporation of this rate the remaining hydrocarbons are removed from the separation column (main condenser) for the most part.

The absorption vessel has a service life of 8 days. After this time the filling must be regenerated and the circulation passes through the other vessel. The content of acetylene in the main condenser is limited to 0.1 ppm. Analysis is carried out daily. For safety reasons hot nitrogen (at a pressure of 5 bar) is used as the regeneration medium.

BOILER FEED WATER TREATMENT	LIST OF MATERIALS
Parts of plant	Materials
Sand filters with fittings and piping	Carbon steel ASTM A 283-C, with internal painting tubes: A 53-A valves: grey iron A126-class B
Ion exchangers with fittings and piping	C-steel: RST.37.2., internal rubbercoated or stainless steel vessels: C-steel A264,grade 6 367 clad. tube: A 43-A, austenitic CrNi steel valves: A126 - class B austenitic CrNi castings
Pumps in the area of ion exchangers	A126, class B, internal rubber coated or stainless steel, AISI 316 B

H2SO4 (76%) dosing pumps with f. and pipes	PVC Teflon
Na(OH) (50%) dosing pumps with fittings and pipes	PVC
FeCl3 dosing pum	PVC
Flocculator	Carbon steel, normal steel with painting.

STEAM REFORMING PLANT	LIST OF MATERIALS
Parts of plant	Materials
Furnace tube	G-X 35NiCrNb 2424, no. 4855 G-X 40CrNiSi 2520, nc. 4848 HK 40, ASTM A-297, 25 Cr/20Ni
Outlet header	Centrifugal and static castings 27 Ni/18 Cr Wrought fittings: Incoloy Alloy 800
Outlet pigtails	Incoloy 800, no. 4876 Incoloy Alloy 800
V 103 - secondary reformer	shell: ASTM A 105 GII (P1), A 212 Gr. B flange: ASTM A 515-60 bolts: ASTM A 320 grade L7, A 193, Gr. B 16
H 111 - waste heat boiler	shell: A 105 Gr. I (P1) tubes: A 335 Gr. P11 flange: A 387 Gr. B P 4
V 104 - primary converter	shell: A 204 Gr. B, ASTM A 335 Gr. P1 flange: A 204 Gr. A
HH 101 - waste heat boiler	shell: ASTM A 515 - 60 tubes: ASTM A 106 Gr. B

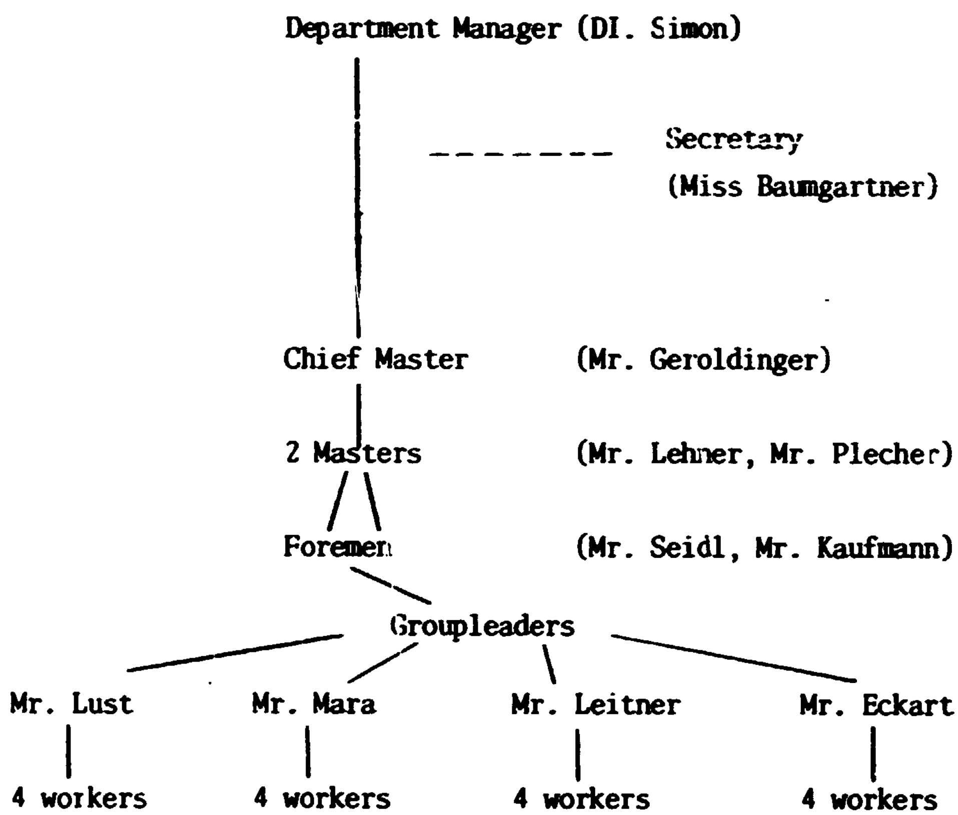
STEAM REFORMING PLANT	LIST OF MATERIALS
Apparatus in convection zone	Materials
Heater for steam H2/1 F101	austenitic steel CrNi ISO: 17/4 N634 (H 32) ASTM A 199 Gr. T 22 (P5), A 335-P22
Heater for steam H2/4F101 Heater for steam H2/2F101 and natural gas	ASTM A 199 Gr. T22 (P5) A 335 - P22 ASTM A 199 Gr. T22 (P5) A 335 - P22 austenitic steel CrNi, ISO 17/4 N634, Incoloy 800
Process air heater H1F 101 natural gas heater H3/2F 101	ASTM A 199 Gr. T22 (P5), A 335 -P22, austenitic CrNi steel, ISO: 17/4 N634 (H 32) ASTM A 199, Gr. T 22 (P5) A 335-P22

STEAM REFORMING PLANT	LIST OF MATERIALS
Apparatus	**Materials**
V 105 sulphur catch vessel	shell: ASTM A 212, Gr. B A 105 Gr. II Pl flange: ASTM A 105, Gr. I bolts: ASTM A 194, Gr. 4
V 106 secondary CO converter	shell: ASTM A 515, Gr. B, A 105 Gr. II Pl flange: ASTM A 105 - I bolts: ASTM A 194, Gr. 4
H 102 waste heat boiler III	shell: ASTM A 515, Gr. 60 tubes: ASTM A 210, Gr. A-1
H 103 boiler feedwater	shell: ASTM A 515, Gr. 60 tubes: ISO: R683 T 13/23 a ASTM A 240, Gr. TP 316 (P8)
V 112, V 113, V 114, V 115 gas separator	shell: ASTM A 105, Gr. I Pl demister: ASTM A 240, Gr. TP 316 (P8)

chemserv
CONSULTING GES.M.B.H.

O R G A N I Z A T I O N   BTF

Maintenance group for Melamine and Urea Plant



U R E A P L A N T

Our new urea plant was built in 1975/1976 and substitutes an old 300 m ton/day plant.

The start up was early 1977. The design capacity is 1 000 m ton/day. It is a SNAM PROGETTI PROCESS. After overcoming various start up problems. We can say that the performance of the plant is good. Since 1978 we reached an on-stream factor of 330 days per year.

Major equipment and its vendors:

equipment	vendor
CO_2-compressor (5 stage reciprocating compressor)	GHH (BRD)
NH_3-pumps 7 plunger pump	Worthington (BRD)
carbonate pumps 5 plunger pump	Worthington (BRD)
ejector, vacuum system	Koerting (BRD)
reactor	VÖEST Alpine - Austria
carbamate separator	VÖEST Alpine - Austria
stripper	FBM Milan - Italy
centrifugal pumps	Ochsner Linz - Austria
belt conveyor system	M.U.T. Stockerau - Austria
scrapper	Schade (BRD)
weighing system sack welding machine	Libra (BRD)

MAINTENANCE PROBLEMS OF THE UREA PLANT

The major problem in an urea plant is the sealing of the high pressure section. It is of vital importance that the surfaces and the lens are very clean. The lens hardness must be less than the hardness of the piping.
The gasket of the reactor manhole is an aluminium-teflon tape gasket.

A second point is the high pressure pumps. We use pumps designed and fabricated by Worthington (Hamburg). After 1,5 year of service we can say that they work satisfactory. The piston packing lasts about one year. The valves have to be changed about every six months.

The packing (details give the attached drawings) has to be prepressed. Valves fail mainly because of spring breaks.
This can be influenced by the spring material and the spring geometry.
The CO_2-compressor which is maintained by ATH had problems mainly because of vibrations.

Material problems mainly existed during the start up-phase. The welds of the reactor lining had to be repaired (lining material is 316L).

Until now the large width belts in the prilling-tower are not satisfactory. We have to change them after about 1,5 year which is a too short time of service. We plan to substitute these synthetic belts by rubber belts.
In the urea storage the main problem was the sack-welding-machine. This mainly was a problem of adjusting the welding temperature and the lenght of the cooling zone on the sack-welding-machine.

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Ejector. Vacuum System	Koerting (BRD)
Reactor Carbamate separator	Vöest Alpine (A) " " "
Stripper	FBM Milano (I)
Centrifugal pumps	Ochsner Linz (A)
Belt Conveyor System	Mut Stockerau (A)
Scrapper	Schade (BRD)
Weighing System Sack Welding Machine	Libra (BRD)

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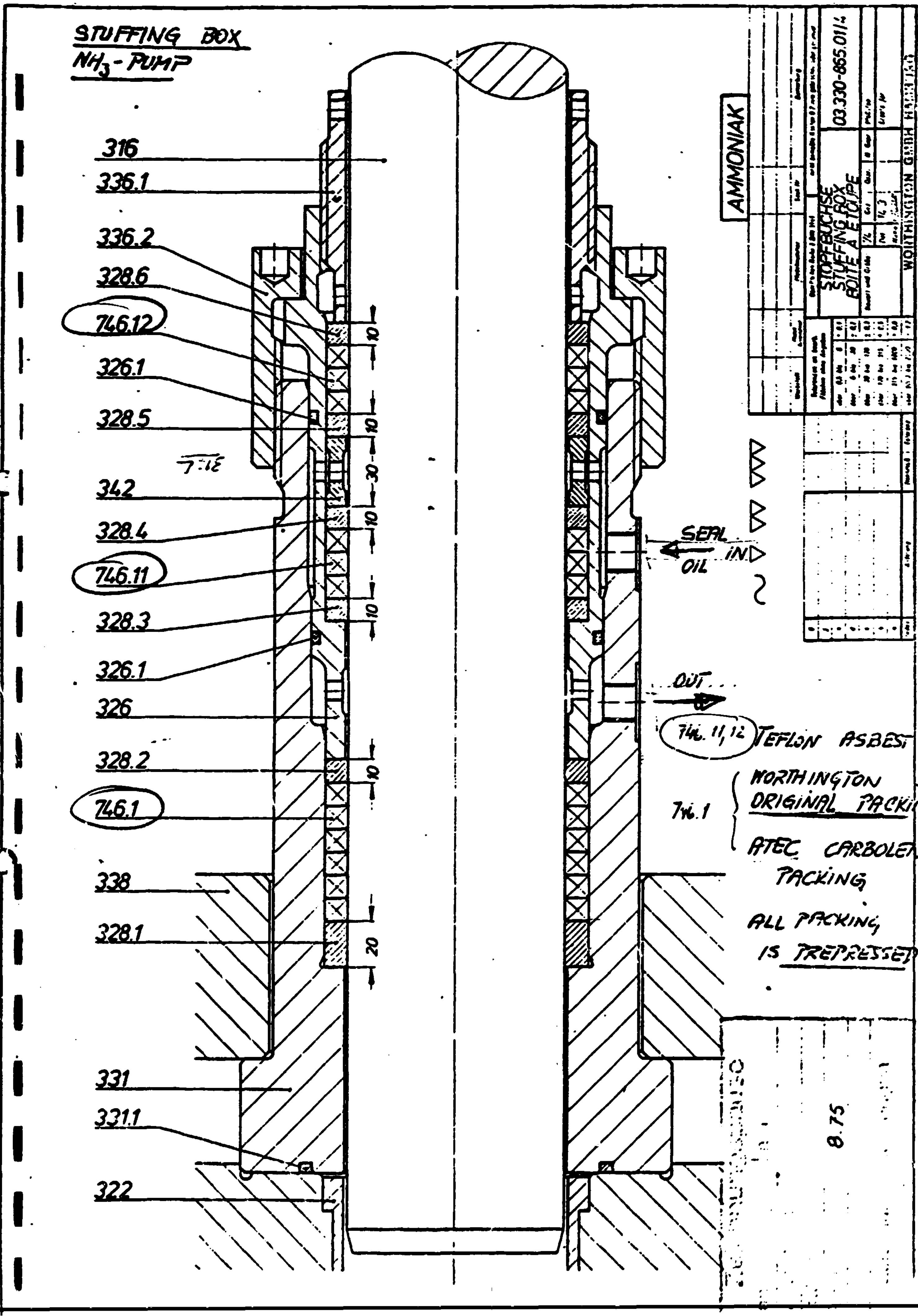
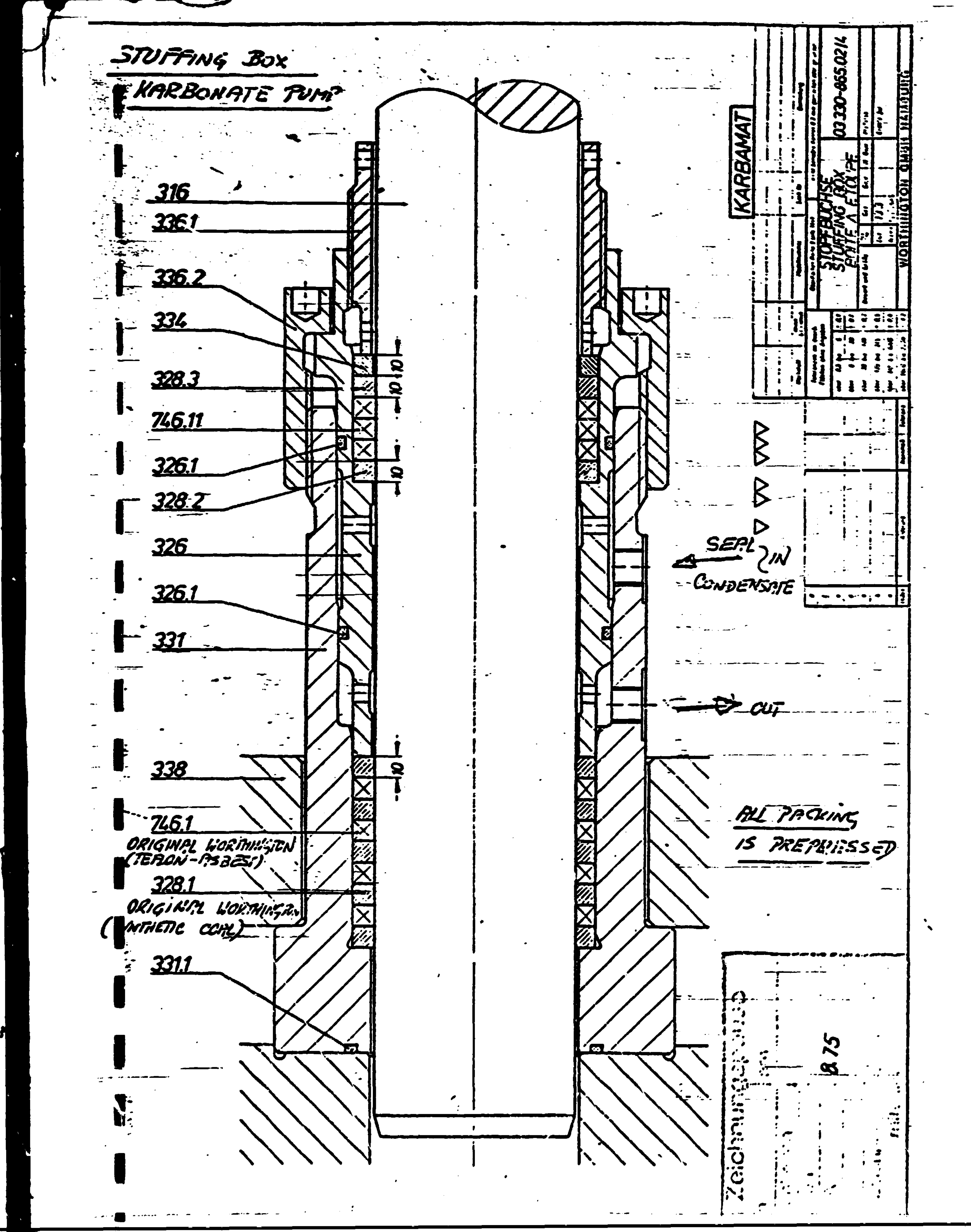


STUFFING BOX
NH_3-PUMP
316
336.1
336.2
328.6
746.12
326.1
328.5
342
328.4
746.11
328.3
326.1
326
328.2
746.1
338
328.1
331
331.1
322
10
10
30
10
10
10
20
SEAL
OIL
IN
OUT
AMMONIAK
STOPFBUCHSE
STUFFING BOX
BOITE A ETOUPE
03.330-865.0114
WORTHINGTON GMBH
746.11,12 TEFLON ASBEST
746.1 WORTHINGTON ORIGINAL PACKI
ATEC CARBOLEN PACKING
ALL PACKING IS PREPRESSED
8.75


STUFFING BOX
KARBONATE PUMP
316
336.1
336.2
334
328.3
746.11
326.1
328.2
326
326.1
331
338
746.1
ORIGINAL WORTHINGTON (TEFLON-ASBEST)
328.1
ORIGINAL WORTHINGTON (SYNTHETIC COAL)
331.1
10
10
10
10
10
SEAL IN
CONDENSATE
OUT
ALL PACKING IS PREPRESSED
KARBAMAT
STOPFBUCHSE
STUFFING BOX
PUMPE
03 330-865.0214
WORTHINGTON GMBH HAMBURG
Ø75

CRANKSHAFTSEALING

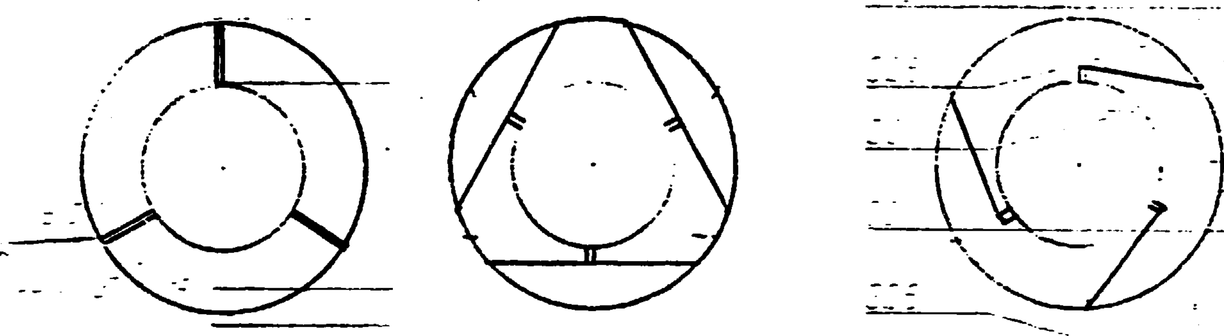
CO_2-compressor - urea-plant

Kranz packing typ G.

Packings with hosespring-sealing elements type G are mainly designed for steam-machines.

Advantage: for high and low-pressure the same elements can be used (same unit assembly systems).

The packing consist at least of two sealing elements in one casing, which are fixed together with a gland.
On the high pressure side mostly is a throttle ring for keeping off contaminations installed.

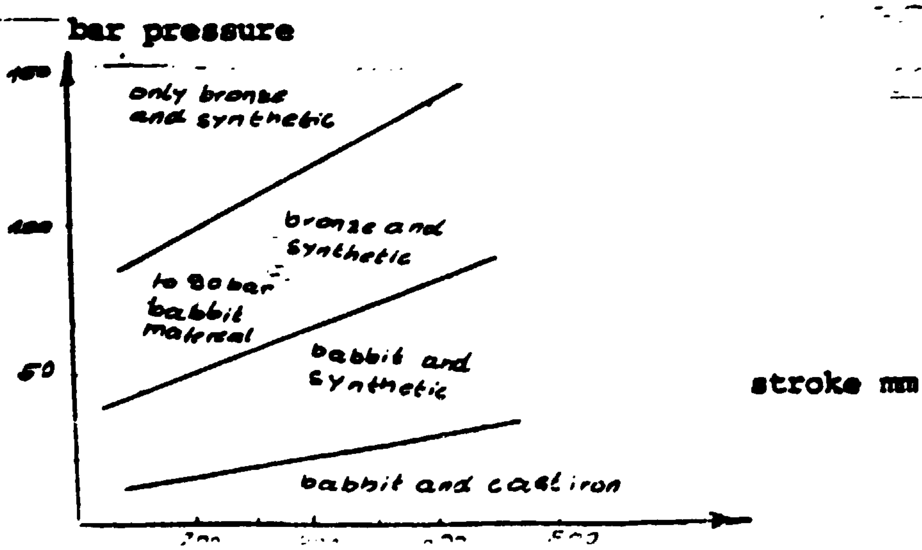


A three parts-radial cut — B six parts-tangential — C three parts together

Always two rings are fixed together to one sealing element.
Normally type A + B or type A + C.
On the pressure side the first element is "A".

Radial clearance few mm (2 ÷ 5 mm)
Axial clearance 0,28 ÷ 0,35 mm (thermal elongatron)

Materials of seal rings



Survace-roughness of the crankshaft

Synthetic-materials p > and high temperatures
0,3 - 0,5 um

Teflon: max. 0,5 ÷ 0,8 um

picture 1) oil lubricated packing

SPECIAL STAINLESS STEELS

FOR UREA SERVICE

INTRODUCTION

Urea was the first organic substance made altogether synthetically. Urea, $CO(NH_2)_2$ is mainly used as a high-nitrogen fertilizer but also as cattle feed and as intermediates for technical resins, etc.

The production of urea has grown very rapidly during the last 20 years, but still a high continuous expansion is expected. It has been estimated, that the growth rate will be about 10% per year in the beginning of the 1980's.

Today urea is generally produced in large plants integrated with ammonia-production based on reforming of natural gas or naphtha. It can therefore be foreseen that the greatest expansion will take place in countries where natural gas is available or in places where naphtha is refined and where the energy prices also are favourable.

The process development during the last decades has made it possible to build plants with higher capacity and efficiency. This has also required a development of new materials to be used in these processes.

Sandvik as a major supplier of tubes for the fertilizer industry has closely followed these new requirements and this has led to the development of a range of special stainless steels for urea service.

PROCESS DESCRIPTION

Urea is made by compression of ammonia and carbon dioxide to a pressure of 150-220 atm in a high-pressure reactor. The temperature is in the range of 180-200°C (355-390°F). The following reactions occur:

1. $NH_3 + CO_2 \longrightarrow NH_4\ CO_2\ NH_2$ (ammonium-carbamate)
2. $NH_4\ CO_2\ NH_2 \longrightarrow H_2O + CO(NH_2)_2$ (urea)

The urea solution from the second reaction will also contain unreacted carbamate, ammonia and carbon dioxide which are removed in several purification stages and recycled to the reactor.

The pure urea solution can be treated in several ways depending on the final use, but it is most common that the urea is delivered as prills. In the production of such prills the solution is evaporated to high concentration. The melt thus obtained is sent to a prilling tower where droplets of molten urea will fall in a counter-current flow of air to form prills. Other finishing processes for urea is granulation or crystallization.

PROCESS DEVELOPMENT

There has been a stepwise development of the urea process to achieve higher efficiency and yield as well as less energy consumption. Also the requirements regarding pollution control are being considered. At the same time the requirements on construction materials have increased where the temperatures and pressures have been increased.

The first of these process development steps was the so-called total recycle process, where the separation of urea and excess gases (NH_3 and CO_2) is performed by a stepwise reduction of pressure combined with heating. A drawback of this procedure is its high energy consumption.

The next step was to develop a way to reduce the energy consumption of the total recycle process. This was done by introducing high pressure (HP) decomposition (~80 atm) immediately after the reactor. A flow-sheet of such a process of Montedison design can be seen in Fig. 1. The introduction of high pressure involved some material problems, especially as regards heat exchanger tubing.

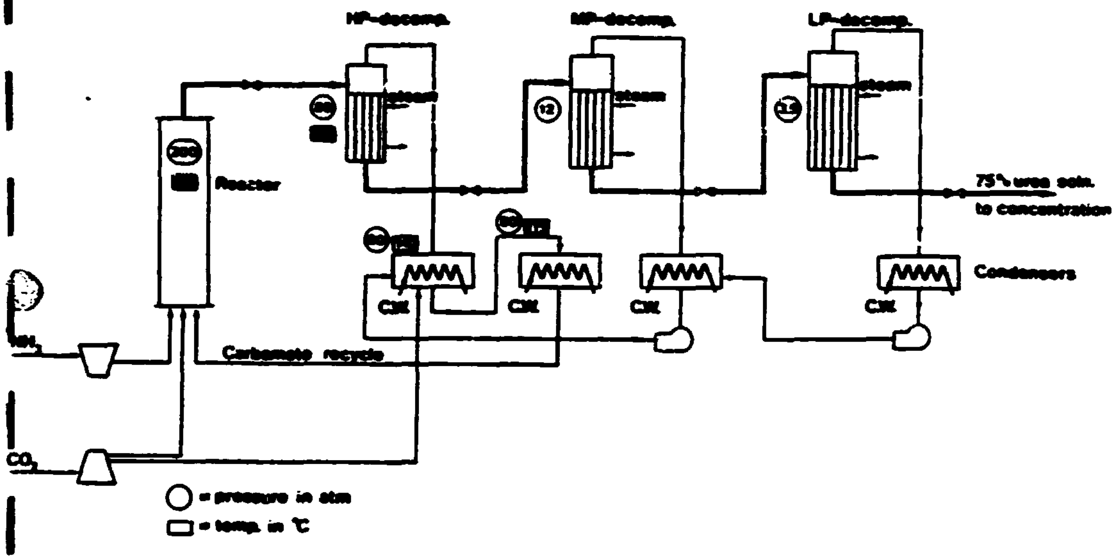


Fig. 1 Flow-sheet. Montedison urea total recycle process with HP-decomposition.

As a third development step the stripping process was introduced, which also has led to drastic energy savings. This process has also met with great success on the market.

In this process the decomposition of carbamate and recycling of gases is carried out without substantially lowering the pressure. Carbamate coming from the reactor is decomposed in the steam heated tubular stripper by contact with the ammonia or carbon dioxide gas. The liberated gases go overhead to the HP condenser (carbamate condenser) where carbamate once again is formed under the same high pressure as in the reactor. This reaction is exo-thermic and the heat is recovered by generation of LP steam which is used elsewhere in the plant. Two stripper processes are commercially available today and together they have the major part of the urea market. In the Stamicarbon stripping process, Fig. 2, developed by DSM, Holland, carbon dioxide is used as stripping medium.

In the Snamprogetti stripping process ammonia is used as stripping medium. As to the plant-layout and process principles there are great similarities with the Stamicarbon process. Fig. 3 shows a flow-sheet of the HP-part of the Snamprogetti process.

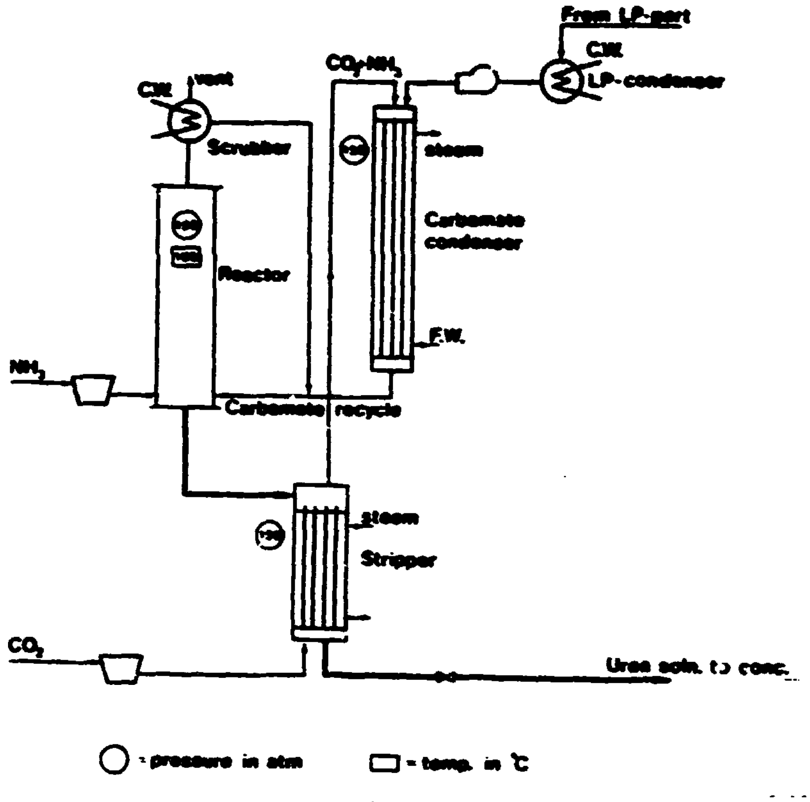


Fig. 2 Flow-sheet of the Stamicarbon urea stripping process.

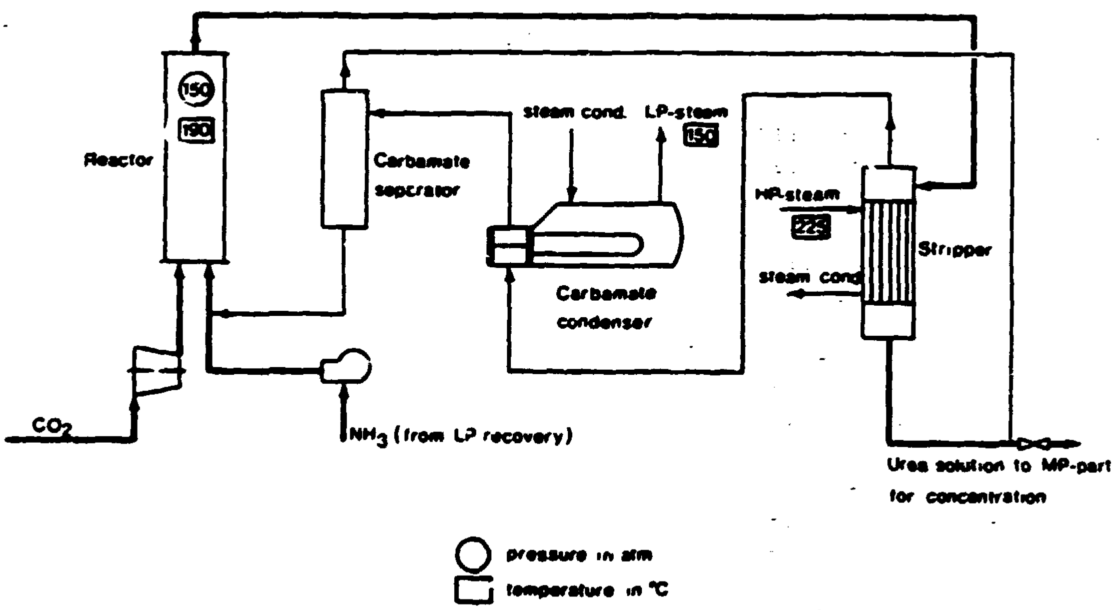
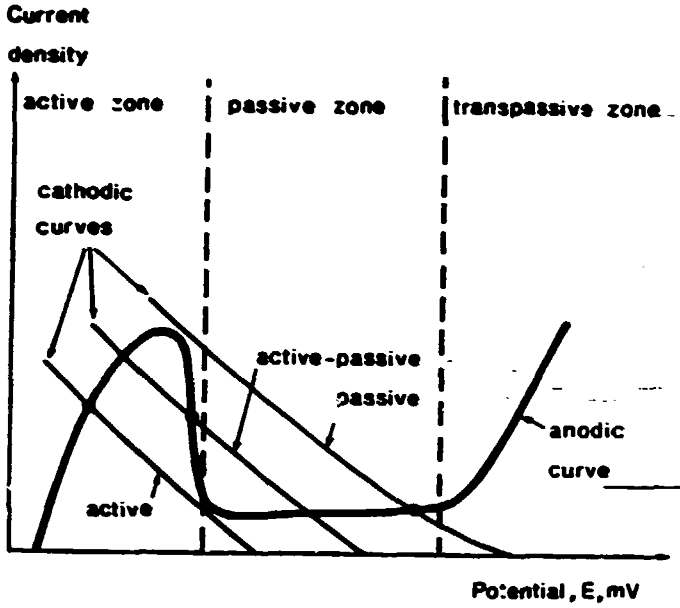


Fig. 3 Flow-sheet of the Snamprogetti urea stripping process. High pressure part.

CORROSION ENVIRONMENT

Ammonium carbamate is present in the reactions taking place both in the reactor and in the decomposition stage. It is known to be a very aggressive agent on stainless steel and its behaviour can well be compared with an acid. In fact, a distinct passive range can also be seen as in the case of sulphuric acid, see Fig. 4 (2).

Fig. 4 Anodic polarisation curve for a stainless steel in an ammonium carbamate solution.



The most important factors that govern the corrosion of stainless steels in carbamate solutions are

- the composition of the process liquid
- the oxygen content
- the temperature
- the metal composition

Regarding the composition of the process liquid, of course the amount of the corrosive carbamate plays an important role on the corrosion rate but also the ammonia/carbon dioxide ratio and the water content seem to be important. Of utmost importance is no doubt the oxygen content in the carbamate solution, and if it is sufficient, the steel will remain in the passive state. Otherwise active corrosion will take place (see Fig. 4). The level of sufficiency is determined by the type of steel being used. For safety, therefore, oxygen is added continuously to the feed. The partial pressure of oxygen in the gas phase has a direct influence on the oxygen content in the urea synthesis solution (see Fig. 5). (3)

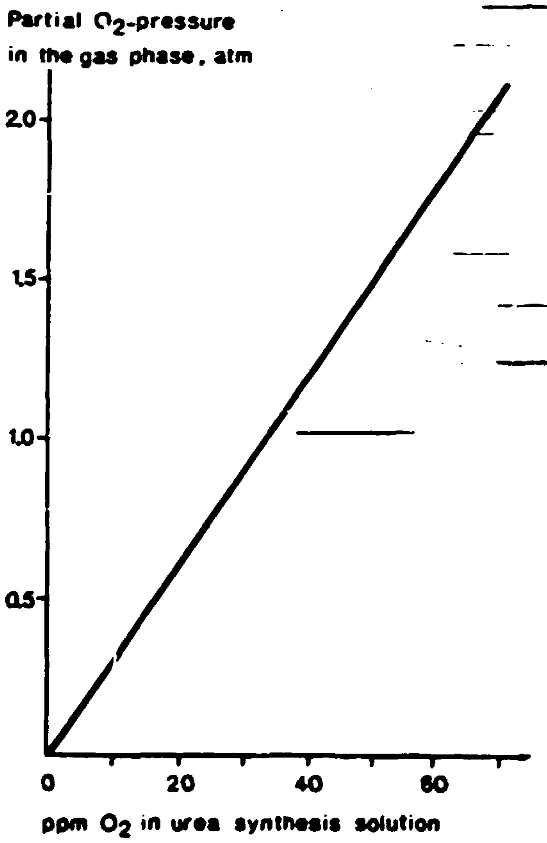


Fig. 5 Solubility of oxygen in urea synthesis solution as a function of the partial pressure in the gas phase. (3)

The urea synthesis reaction and the decomposition of the carbamate are favoured by an increasing temperature. On the other hand the corrosion of metallic materials increases very much with increasing temperature, see Fig. 6. (3)

As discussed above, it is essential that the steel is in the passive state in the urea synthesis solution in order to avoid heavy corrosion. The alloying elements playing an important role on the passivation behaviour of steel are above all Cr and Mo. It has also been found that carbamate solutions can attack the ferrite phase obtained in austenitic steel, for instance after welding or after improper heat treatment. Also intermetallic phases like sigma phase are heavily attacked in carbamate solutions. Thus it is essential that the material has a very stable austenitic structure. Strong austenite forming elements are Ni and N. To avoid problems after welding a low impurity level is also required.

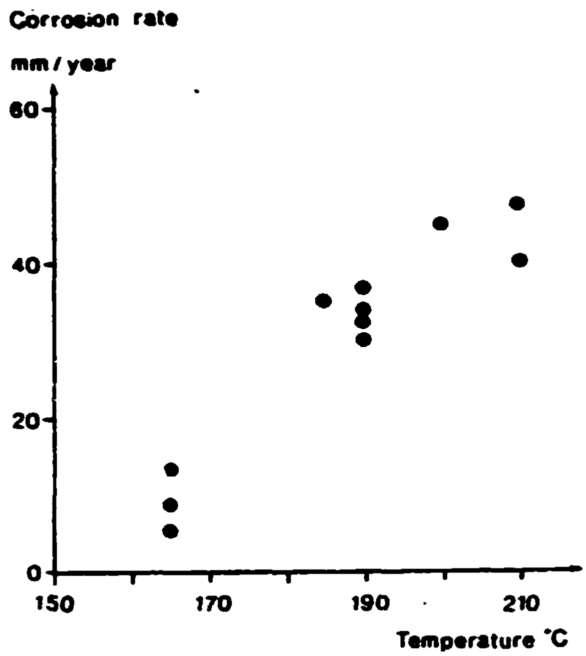


Fig. 6 Corrosion rate of active AISI 316L in urea synthesis solution as a function of temperature. (3)

STAINLESS SPECIAL STEELS FOR UREA SERVICE

For many years the standard construction material for severe urea plant service has been AISI 316L with additional requirements on corrosion properties, while 316 and 304L have been adopted for low-pressure service (< 25 atm). In some critical parts like reactors, strippers and HP-decomposers, 316L has been used to the limit of its corrosion resistance. The acceptance of 316L in this service has been a compromise based both on technical and economical considerations but also on the fact that previously there was no other austenitic stainless steel available being resistant enough to fulfill the requirements. Titanium and zirconium have good resistance in carbamate solutions, but imply great problems in fabrication and still more so for the maintenance. Furthermore, these materials are very expensive. However, titanium tubes have up to now been specified for the stripper in the Snamprogetti process.

As a result of close cooperation between urea licensors and steel manufacturers there are today austenitic stainless steels on the market specially designed to combat corrosion in the various plant equipments. Furthermore, much experience from plant service is available which shows both technical and economical advantages. At the same time also the availability of these materials is such that almost every type of delivery form can be offered.

DESCRIPTION OF SANDVIK 2RE69

As discussed under the heading corrosion environment, steels used in urea synthesis solutions must have a very thoroughly balanced composition of the elements Cr, Mo, Ni and N as well as a low impurity level. A steel which fulfills these requirements is SANDVIK 2RE69 which is the result of extensive research carried out by Sandvik in close cooperation with DSM/Stamicarbon. 2RE69 has the following nominal composition (%):

C	Cr	Ni	Mo	N
≤0.020	25	22	2.1	0.12

General properties

The structure is fully austenitic and the steel has almost the same physical properties as normal 18/8-steel as regards density, specific heat, thermal conductivity, thermal expansion, etc. (for specific data please see Sandvik data sheet 1,870 E). The well designed composition of the steel accounts for its extremely good structure stability. Therefore, very low values of the ferrite content in the parent metal and in the fusion zone of a weld can be achieved.

Mechanical properties

The mechanical strength is higher than that of normal austenitic stainless steels. This is due to the nitrogen addition. As the temperature in the urea process is about 200°C (390°F), a tensile test performed at about this temperature is generally required by the customer. Test results can be seen in the following table 1.

Table 1 Mechanical properties, minimum values

Grade	Yield strength 0.2% offset At 20°C (68°F)		At 200°C (390°F)		Tensile strength At 20°C		Elongation A5 At 20°C
	N/mm²	ksi	N/mm²	ksi	N/mm²	ksi	%
316L	195	28	145	21	500	73	45
2RE69	270	39	200	29	580	84	30

Corrosion properties

One of the most important features of 2RE69 is its ability to repassivate even during severe reducing conditions. Because of this, the oxygen content in the synthesis solution needed to keep the passive layer of the steel is much lower than for 316L-material. For instance, at about 200°C (390°F) an extremely low oxygen content (3 ppm - see ref. 3) is sufficient for 2RE69, while at a corresponding O_2 content 316L material is active and corrodes at a rate of up to 40 mm/year (1575 mpy), compare Fig. 6. Small disturbances in the oxygen supply owing to improper plant operation can therefore be tolerated without causing any drastic changes in the corrosion rate of 2RE69.

General corrosion

2RE69 has very good resistance to general corrosion. This is illustrated in Fig. 7 showing the isocorrosion curve in sulphuric acid.

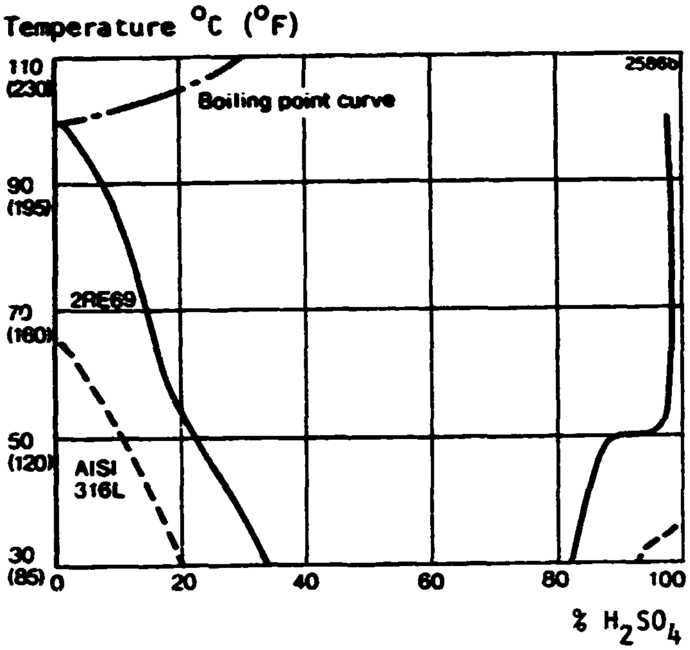


Fig. 7 Diagram showing isocorrosion of 2RE69 and AISI 316L in sulphuric acid. The curves represent a corrosion rate of 0.1 mm/year (4 mpy).

Intergranular corrosion

Owing to its low carbon content and the low level of impurities, 2RE69 possesses very good resistance to intergranular corrosion. The grade passes all known tests on intergranular corrosion. As an example it can be mentioned that even after 10 hours' sensitisation at 650°C (1200°F) no attack was found after Strauss testing (boiling in a H_2SO_4-$CuSO_4$ solution containing Cu-chips).

Corrosion in a urea synthesis solution has a predominantly intergranular/general-corrosion appearance. For that reason Huey-testing has been specified by licensors as a general acceptance test for materials to be used in urea service. Although it has not been proved that the corrosion potential in urea plant streams does in any way correspond to that of the Huey-test, it has been found that correlation exists between the service life and the Huey-test result. The following case story can give some further evidence to this statement:

"In a high-pressure decomposer working at about 80 atm. tubes according to SA-249 Tp 316L installed in a new plant lasted for 5 years. A new set of tubes also according to SA-249 Tp 316L was ordered for replacement. These tubes failed already after 6 months despite substantial increase of the oxygen which was added to reduce the corrosion. Huey-testing of the two different Tp 316L-materials later revealed that the average corrosion rate was 14.07 mils/year for the tubes which lasted 5 years and 268 mils/year for those which lasted only 6 months. A Huey-test before the installation of the second delivery of tubes would have served as a warning. Instead of Tp 316L SANDVIK 2RE69-tubes were installed in this plant. No attack whatsoever has been found on these tubes so far, even though they have been carefully inspected during several shut-downs."

Mainly owing to its high chromium content and low impurity level, 2RE69 exhibits an excellent resistance in the Huey-test.

One interesting and important feature of 2RE69 is that it never shows an accelerating corrosion rate in the Huey-test. A tough requirement on the corrosion rate can also be met. The maximum attack is 1.0 µm/48 hrs (= 0.18 mm/year) for both as-delivered and welded tube material. For comparison it can be mentioned that for SANDVIK 3R12/AISI 304L the maximum attack is 0.4 mm/year for tubes in the quench-annealed condition. Welded specimens may be expected to yield higher values than quench-annealed specimens.

Selective attack

In connection with the Huey-test the selective attack is also controlled in microscopa. It has namely been found that when butt ends of tube and bar material are exposed to carbamate solutions, excessive corrosion can occur if the sensitivity to selective attacks of the material is not carefully controlled. Specifications require the selective attack not to exceed a certain value.

Pitting corrosion

The pitting corrosion resistance is excellent owing to the high Cr-content and the addition of Mo. When tested in 5% $FeCl_3$ + 10% NaCl at 25°C (77°F) during 24 + 72 + 72 hours, no attack occurred. The pitting resistance can also be expressed as E_{br} = break-through potential for different solutions. Fig. 8 illustrates E_{br} in a 3% NaCl-solution for different stainless steels.

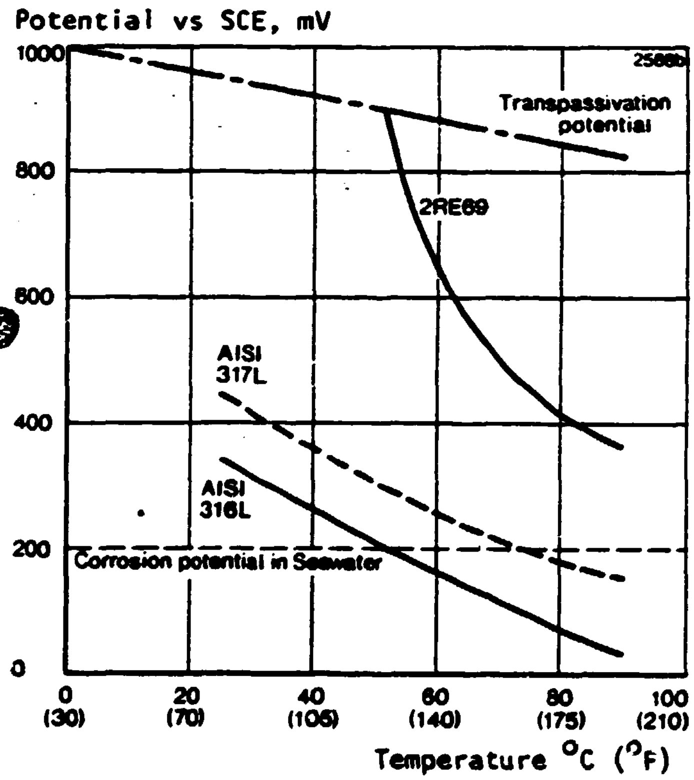


Fig. 8 Pitting potentials of 2RE69, AISI 316L and 317L in a 3% NaCl solution, scanning rate 20 mV/min.

These results indicate that 2RE69 can be used for example in seawater at rather high temperatures without being attacked.

Stress corrosion cracking (SCC)

The high Ni-content of 2RE69 gives the material a good resistance to stress corrosion cracking but does not guarantee immunity. SCC-tests in 40% $CaCl_2$ at 100°C (210°F) have indicated higher threshold stresses than for both 304L and 316L, see Fig. 9.

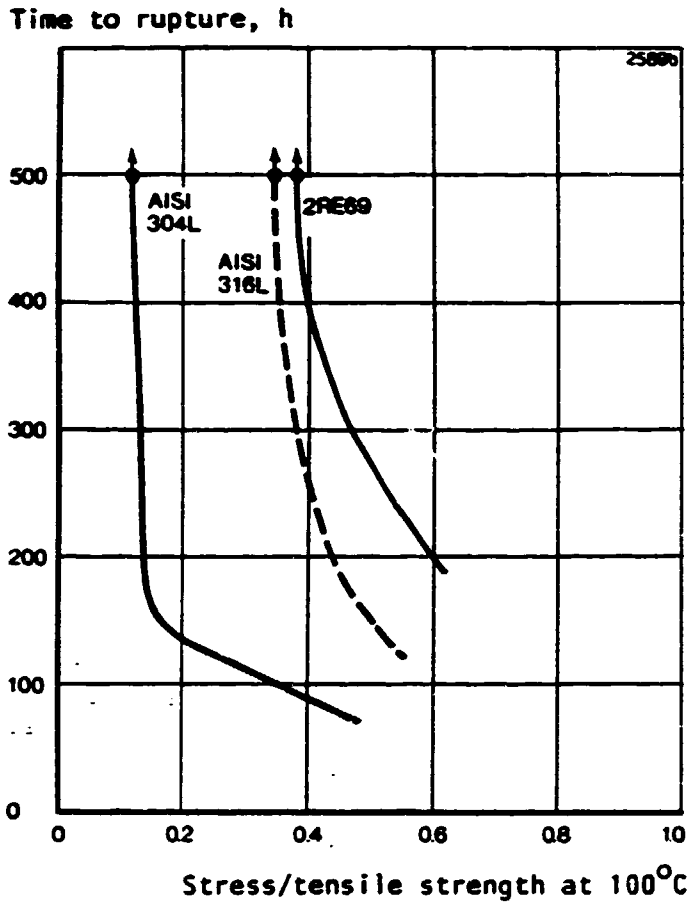


Fig. 9 Results of SCC-tests in 40% $CaCl_2$ at 100°C (210°F). pH = 6.5. Aeration. Time to rupture as a function of applied stress divided by the tensile strength.

Conclusion

It is apparent from the above that 2RE69 is not only a very good material for urea synthesis solutions. It can be used to advantage also in combined service, i.e. carbamate solutions on one side and chloride containing waters on the other side.

Welding

As mentioned earlier, the ferrite content in the parent metal and in the fusion zone of a weld should be restricted to very low values in order to avoid selective corrosion attacks. On the other hand, it is a well-known fact that a certain ferrite content is required to avoid hot-cracking problems when welding austenitic stainless steels. In order to meet the requirements for urea plant service, another solution had to be found. Research was concentrated on the hot cracking mechanism and the role of different alloying elements in this respect. For instance, the influence of different manganese-additions was investigated and 4.5% was found to be an optimum manganese level. This manganese content is high enough to reduce the hot cracking to a minimum but low enough not to form sigma-phase in the weld metal. Accordingly a new filler metal - SANDVIK 2RM69 - with the following composition was developed: C max 0.020% Mn 4.5%, Cr 25%, Ni 22%, Mo 2.1% and N 0.13%. This filler has been extensively tested both mechanically and from a corrosion point of view, see table 2 and table 3.

Table 2 Mechanical properties of welds at 20°C (68°F)

Type of filler	Welding method	Tested part	Tensile strength N/mm²	ksi	Red. of area %	Elongation[3] %
2RM69	TIG[1]	Welded joint	650	94	56	
	TIG	Weld metal	760	110		73
2RM69 (= Smit Jungo 3465)	MMA[2]	Welded joint	618	90	49	
		Weld metal	669	97		50

[1]TIG = Tungsten Inert Gas
[2]MMA = Manual Metal Arc
[3]Elongation of a hole drilled in the specimen, original hole diam. 3.5 mm (0.138 inch)

Table 3 Results from Huey-testing, ASTM 262, Practice C, 5 x 48 h

Material tested	Average corrosion rate mm/year	mpy
Base metal 2RE69	0.10	4.0
2RM69 TIG-wire, weld metal	0.07	2.8
2RM69 TIG-wire, welded joint	0.10	4.0
2RM69 MMA-electrode, weld metal	0.09	3.5
2RM69 MMA-electrode, welded joint	0.08	3.2

These results show that the properties of SANDVIK 2RM69 conform very well to the requirements on 2RE69.

SANDVIK 2RM69 is available not only as bare wire for TIG-welding and covered electrodes for MMA-welding but also as strip for submerged-arc surfacing. The latter product is especially suitable for cladding of tube sheets, vessels, reactors, etc.

SANDVIK 3R60 UREA GRADE AND SANDVIK 3R69

For parts of the urea plant where the conditions are not so severe, a specially designed 316L material is being used. Adjustment of the composition and special measures in the manufacture give this steel, SANDVIK 3R60 Urea Grade, better intergranular corrosion resistance, lower corrosion rate in carbamate solutions and better results in the Huey-test than ordinary 316L. For 3R60

Urea Grade the requirement on a maximum corrosion rate of 0.6 mm/year (24 mpy) in the Huey-test can be met. This steel is being used mainly as tubes in HP-condensers, HP-piping, HP-scrubbers and decomposers. A further development of this alloy is SANDVIK 3R69, developed according to the same principles as for 3R60 Urea Grade and meeting all the necessary requirements but with the advantage of having higher mechanical strength owing to a nitrogen addition. 3R69 is especially being used for HP-piping. Composition, mechanical properties and corrosion resistance for these alloys are compiled in tables 4, 5 and 6 below.

Table 4 Chemical composition (nominal), %

	C max	Cr	Ni	Mo	N
3R60 Urea Grade	0.030	17.5	14	2.5	-
3R69	0.030	17.5	13.5	2.8	0.18

Table 5 Mechanical properties at 20°C (68°F), minimum values

	Yield strength 0.2% offset N/mm^2	ksi	1.0% offset N/mm^2	ksi	Tensile strength N/mm^2	ksi	Elongation A5 %
3R60 Urea Grade	195	28	235	34	500-650	72-94	45
3R69	300	43.5	340	49	600-800	87-116	40

Table 6 Huey-test values (quench-annealed tubes)

Grade	Corrosion rate, max mm/year	mpy
3R60 Urea Grade	0.6	24
3R69	0.6	24
316L	>0.6	>24

THE APPLICATION OF SANDVIK SPECIAL STAINLESS STEELS FOR UREA SERVICE

Reactor

Under deviating process conditions very aggressive corrosion may occur in the reactor where carbon dioxide, ammonia, ammonium carbamate, water and urea are handled under high temperature and pressure. The size of the reactor may vary depending on plant capacity, but a height of 20 m (66 ft) and a diameter of around 1-2 m (3.3-6.6 ft) are not unusual.

This pressure vessel is made from high-strength carbon steel, but to resist the corrosive environment lining with an austenitic stainless steel is necessary. Up to now this lining has been made almost solely of 316L type of plate which in many instances has shown limited service life.

Under the above circumstances there are two possibilities to satisfy these new requirements on corrosion resistance in the reactor lining: either by using plate of 2RE69 (AVESTA 254 SFER) or by surfacing with SANDVIK 2RM69 as strip or wire welding electrode. Even though strip surfacing has not yet come to practical use for this application, the process development has now reached such a level that the method must be regarded as an interesting alternative.

Both methods are applicable for the production of new vessels as well as maintenance of old ones, but for practical reasons surfacing must be regarded as more interesting for new vessels.

Stripper

The stripper unit is a steam heated tubular heat exchanger with steam on the outside of the tubes and the reaction products inside the tubes. The urea solution and carbamate are flowing downwards while the gases boil off overhead.

It has appeared that strippers made of AISI 316L give adequate performance provided the gas-liquid flows are evenly distributed and sufficient oxygen is added. However, it has been proved that the process condition cannot always be kept within specified limits and Stamicarbon therefore recommends the use of steel of type 25Cr/22Ni/2Mo, SANDVIK 2RE69, for their strippers. Today full-scale tests are also running in strippers working with ammonia as stripping medium.

Since the first delivery in 1971 SANDVIK 2RE69 has been delivered as stripper tubes for more than 70 plants. Of course, the performance is subject to a very careful follow-up. The outcome hitherto has shown that the corrosion rate is extremely low.

Injection tubes (ferrules)

The reaction products are fed into the stripper by a special injection system. The exact design varies a little between the different processes but in principle it consists of thickwalled tubes with channels, which distribute the feed evenly to achieve the best process conditions. Because titanium tubes showed erosion corrosion in this type of service, tests were carried out with SANDVIK 2RE69. Positive test results further led to complete installations and 2RE69 is today to a large extent used for this application.

Carbamate condenser

In this heat exchanger, also called high-pressure (HP) condenser, the gases are condensed and carbamate is also formed. This reaction is exothermic and the heat is used for the generation of LP steam. Since the temperature here is lower on the process side than in the stripper, the corrosion conditions are less severe. Therefore, modified AISI 316L, i.e. 3R60 Urea Grade, will do in most cases. For demanding service 2RE69 is a very good alternative and several plants have changed to this grade also in order to minimize maintenance.

High-pressure decomposer

In processes working without strippers the decomposition of the carbamate takes place in so-called decomposers working with a stepwise lowering of the pressure. The first of these heat exchangers, the HP-decomposer (8 MPa), is exposed to severe corrosion conditions. 2RE69 has therefore replaced the modified AISI 316L which was earlier the standard material here.

Other units

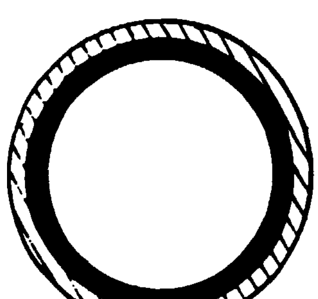
Normally the corrosion conditions are not so severe in other parts of the plant which operate at lower pressures and temperatures. 3R60 Urea Grade can therefore be recommended as a suitable construction material for units like scrubbers, condenser, HP-piping, etc.

An interesting alternative to 3R60 Urea Grade for use in HP-piping is the nitrogen alloyed stainless steel 3R69 which has 50% higher yield strength at room temperature. This makes it possible to design with thinner walls and accordingly to reduce costs.

Where chloride-containing cooling water is used 2RE69 offers very good corrosion properties as already shown.

ECONOMY

Assuming the life-time of stripper tubes in 316L with 5 mm (0.197 inch) wall thickness is the same as for 2RE69 with 3 mm (0.118 inch) wall thickness the following calculation can be done.



2RE69 saves money

Stripper tubes in 316L 34% more expensive

Dimensions: 3R60 Urea Grade 35 x 5 mm; 2RE69 31 x 3 mm

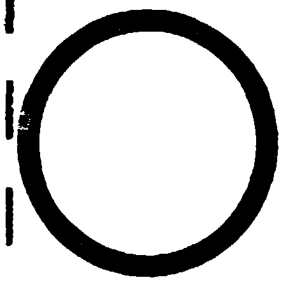
Weight ratio: $\frac{(35 \times 5)}{(31 \times 3)} \Rightarrow \frac{3.67\ (kg/m)}{2.10\ (kg/m)}$

Price ratio: $\frac{1}{1.3}$

Cost ratio: $\frac{3R60\ U.G.}{2RE69} = \frac{3.67}{2.10} \cdot \frac{1}{1.3} = 1.34$

Fig. 10 Cost comparison for stripper tubes in 3R60 Urea Grade and 2RE69.

Also when comparing the cost of titanium tubing with that of 2RE69 it is obvious that much money can be saved in ammonia stripping plants by replacing titanium. Because of the higher strength of 2RE69 a wall reduction is possible also here. (The calculation in Fig. 11 is based on the fact that $R_{p0.2}$ at 230°C (445°F) is 142 N/mm^2 (20.5 ksi) for titanium and 195 N/mm^2 (28 ksi) for 2RE69.)



Titanium tubes 2.5 times more expensive

Dimension 27 x 3.5 mm

Weight ratio $\frac{\text{Ti}}{\text{2RE69}} \sim \frac{1}{1.75}$

Price ratio $\frac{\text{Ti}}{\text{2RE69}} \sim \frac{4.5}{1}$ (kg-prices)

Cost ratio $\frac{\text{Ti}}{\text{2RE69}} = \frac{4.5}{1} \cdot \frac{1}{1.75} \sim 2.5$

Fig. 11 Cost comparison for stripper tubes in titanium and 2RE69.

CONCLUSION

The development of new stainless steels has been an important contribution to the urea technology by giving economical advantages and improved safety in service. These steels are "tailor made" in the sense that they solve specific corrosion problems in urea plants. On the other hand, long and favourable experience with them has made them so well established that today the urea industry could call them standard steels.

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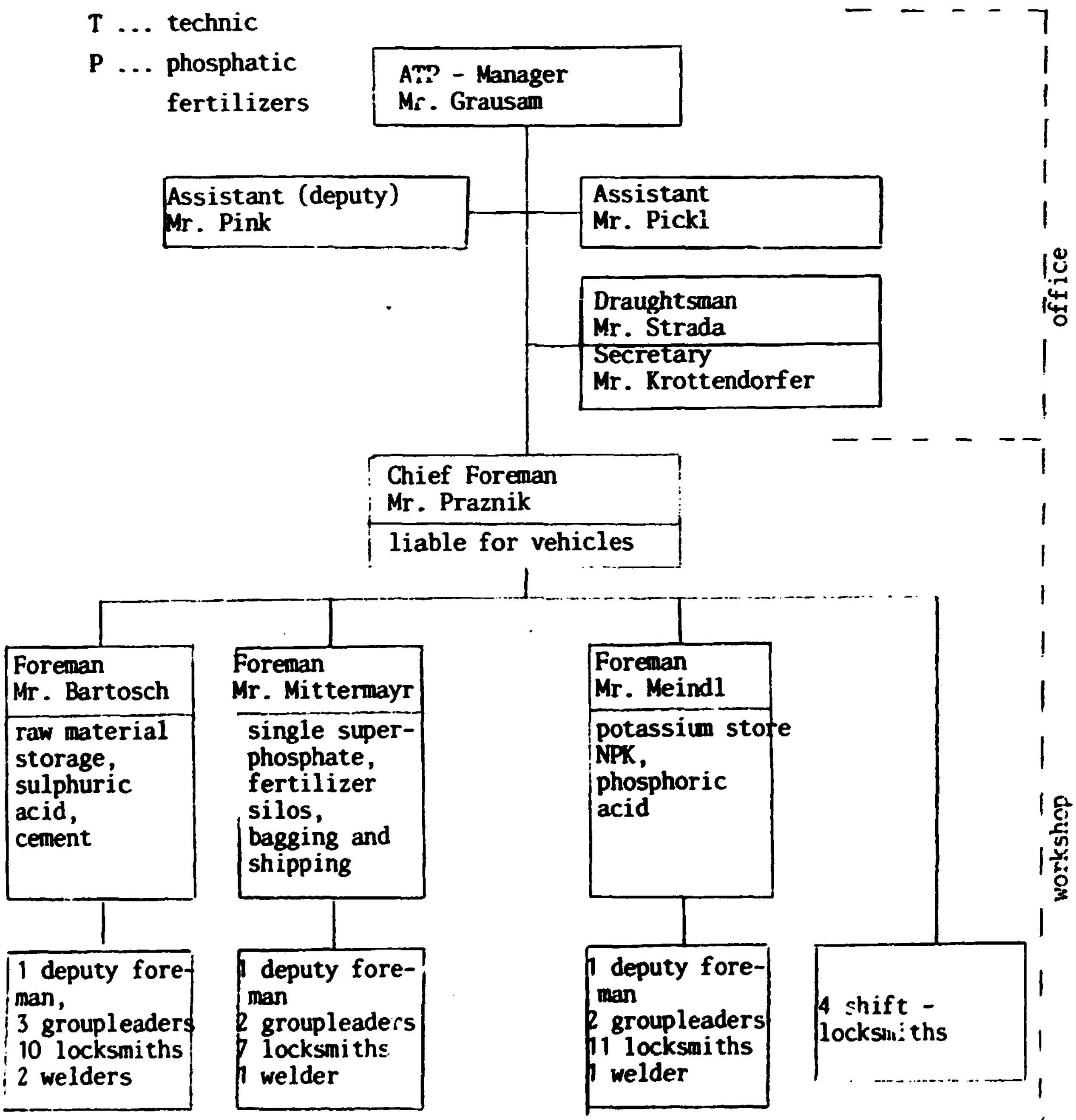
3) R. De Jonge, F.X.C.M. Barake and J.D. Logeman, DSM: "Corrosion and corrosion prevention in stainless steel urea plants", Chemical Age of India, vol. 26, No. 4, april 1975, pages 249-260.

ORGANISATION DEPT. ATP

A ... division A (agricult. chemicals)

T ... technic

P ... phosphatic fertilizers



The foremen are allocated to certain plants. The workers if necessary one can shift between the 3 foremen - groups.

RESPONSIBILITY OF DEPT. ATP

Surveillance, check, maintenance, repair of different production units, stores raw material and final products, bagging and shipping, laboratory.

Spare parts particulary used only for a special purpose in one, two or three departments - order, record, store, use.
Common spares like screws, bolts,... are in the central store.

Drawings: Draughtsman for sparepart-drawings, modifications in the plant, sketches. Small projects are made by the department, larger projects are made be the design-department. Drawings of design-department must be signed by the concerned maintenance and production departments. Record of drawings.

Contacts with outdoor companies, agents and representatives, suppliers of spares, machines, ...
Visit to suppliers. Correspondence with different companies, filing of correspondence.
Prospects, leaflets about special machines, parts, technics, materials used in the department.

Contacts with other departments of Chemie Linz concerning repair, investment, production, design, finance, ...

Supervision of delivery dates concerning spares, outdoor repairs, ..

Elaboration of shut-down-programs in cooperation with production and central-departments.

Safety in the workshop and for all field repairs. The whole equipment has to operate in a safe condition.

Safety instructions according to the Austrian law (one time per year), accident-notice.

Information of foremen and staff, other departments, superiors, ... daily, weekly, monthly, quarterly, ...

Investment programs of small volume, repair programs, estimation of cost.

Cost control for maintenance, monthly computer prints, quarterly reports to division (comparison precast - actual).

Collecting of literature and papers concerning used operations, machinery and processes.

Training of foremen and workers in the field of technical knowledge, safety, efficient performance of repairs, ...

Experiments and tests of new parts and products.

Coordination and cooperation with production department (daily morning discussion).

Showing of plants to our customers and other interested groups (schools, ...)

Collection and filing of experience, repair cards, ...

Stand-by or on-call service

from Friday to Monday
1 engineer or foreman
2 locksmiths

Calculations concerning machines, parts and the process.

Energy conservation (e.g. screw compressor - new or repair?)

Engineering, process variables, physical chemistry.

Accomplishment of authority-orders like pressure tests, yearly check of conveyors, earthing measurement of tanks for burnable liquids.

Obligations concerning pollution control (oil, waste gas treatment, ...)

Mutual control of maintenance and production deparments resp. central departments.

Participation on seminars, courses, study of literature, visit of industrial fairs (e.g. ACHEMA, ...) to improve technical knowledge.

Expert for suggestion system.

Personnel problems - salary, transfer to other departments, overtime, ...

Job as adviser of start-up personnel in Austria or a foreign country.

Training of people from other companies.

HISTORY OF PHOSPHATE - FERTILIZER - PLANTS (APP - ATP)

1954: Start of gypsum-sulphuric acid plant (production of sulphuric acid and cement from anhydrite).
Single superphosphate (now low demand).
Storages, bagging and shipping stations.

1958: Mixed fertilizers (closed after start of NPK-plant)

1958: Sulphur burning plant (Monsanto). Continuous improvements and expansions to increase capacity.

1964: NPK-plant (1 granulator, 12 reactors, 1 cooler) - PEC process

1966: Phosphoric acid plant, Prayon process

1967: First expansion of NPK-plant (plus 1 granulator and 6 reactors)

1969: New NPK-storage with conveyor bridges, bagging and shipping in the south area of the company.

1970: Second expansion of NPK-plant (plus 1 cooler and some improvements)

1972: Third expansion of NPK-plant (1 granulator, 14 reactors, 1 cooler)

1978: Second belt conveyor from NPK-plant to storage. Equipment to use valve-bags.

1979: Second economizer for Monsanto plant.

From start-up of the plants up to now the capactiy of the different facilities have increased by removing bottlenecks, for example:

Monsanto plant	Layout	75 t/day H_2SO_4
	Actual	180 t/day H_2SO_4
Phosphoric acid	Layout	60 t/day P_2O_5
	Actual	130 t/day P_2O_5

Due to good operation and good maintenance the percentual operating time of all our facilities is very high (100% = 364 days per year):

Examples:

	1977	1978	1979	1980	1981
Gypsum sulphuric acid plant	96%	95%	96,1%	97,6%	97,6%
Monsanto plant		98%	97,3%	94,8%	94,8%
Phosphoric acid plant	94%	93%	93,9%	93,9%	93,8%
NPK-plant I	96%	94%	96,1%	95,1%	95,1%
NPK-plant II	93%	95%	96,7%	95,1%	95,0%

ACTUAL PROGRAMS, PROJECTS AND PROBLEMS FOR DEPARMENT ATP

Wheel loader wiht 1 m^3 shovel
Loading conveyors for very long wagons
Palletizer for open air storage, unit 634
Replacement of fork lift truck
Replacement of dumpers by a wheel loader - 3 m^3 shovel
Replacement of heat exchanger VI - sulphuric acid plant
Replacement hot gas filter - Monsanto plant
Replacement of phosphate scale - phosphoric acid plant
Improvements on bulk loading systems - units 620 a and 633 a
Speed-controllers for belt conveyors
Belt conveyors for coke
Unloading and loading of ships
Asphalt for open sulphur storage
Dose of trace elements
Improvement conversion in Monsanto plant
New sulphuric acid plant - double absorption
Sound protection - unit 601
Dose of coating agents (siliceous earth)
Lacerating machine for paper bags
Dedusting units for phosphate and potassium
Second palletizer for unit 634 (open air storage)
Scales for bulk product
Replacement cement bagging machine
Tank for AS - lye
Utilization of sulphur concentrated iron oxide
Preparation of hot water for division C
Bulk loading into vessels

Replacement KSB - compressors
Extension silo, bagging and shipping - unit 633
Coal dust combustion for cement kiln
Utilization of acid-oil in the kiln
Dedusting of waste gases of spherodizer I and II
Sale of caterpillar (tracked vehicle)
Removal of fertilizer-rests from boxes - nearly empty - unit 633
Utilization of excess steam
Pipeline for sulphuric acid between the units 608 - 626 - 627
Covers of eternit on conveyor bridges
Cleaning of cement silos
Investigations about use of palettizers in unit 620 a
Investigations about corrosions on spherodizers
Reduction of P_2O_5- and F-content in by-product gypsum

Repair painting of conveyor bridges
Roof repair of clinker storage
Repair of chimney sulphuric acid plant
Repair painting - unit 631
Repair or replacement of electrostatic wet gas precipitator

DIFFERENT TYPES OF PUMPS USED BY

ATP

Medium: sulphuric acid

CENTRIFUGAL PUMPS (horizontal)

producer:	Ochsner, Austria
type:	U-MOR
capacity:	100 m³/h - 20 m (50°C) 98%
material:	Cr-casting (Ni-alloyed)
speciality:	hydraulic shaft sealing; useable for high inlet pressure
use:	circulation pump - acid store
function:	hydraulic sealing by auxiliary impeller; in operation no contact of shaft and stuffing box because of axial shaft movement
working period:	about 12 months (temporary working)

producer:	Rheinhütte, West Germany
type:	RE 150/265
capacity:	240 m³/h - 20 m (up to 120°C - 98%).
material:	n° 4136
speciality:	hydraulic sealing - impeller with back-side vanes
use:	circulation pump for absorbing tower

function:	stillstand - double stuffing box and special ring valve working - hydraulic sealing
working period:	about 12 months (continuous working)

producer:	Rheinhütte, West Germany
type:	RE 80/250
capacity:	50 m^3/h - 20 m; 60°C; 66 - 78%
material:	18% Si-casting
speciality:	divided, removable casing in steel casting-wear resistent Si-parts for acid contact. Hydraulic sealing - impeller with backside vanes. Double stuffing box and special ring valve.

SUBMERSIBLE PUMPS (vertical)

producer:	Rheinhütte, West Germany
type:	GVS 150/265
capacity:	113 m^3/h - 15 m, 100°C, 98 %
material:	n° 4136, carbon shaft box
use:	circulation pump-drying and absorbing tower
working period:	about 12 months (continuous working)

M e d i u m: Liquid sulphur

SUBMERSIBLE PUMPS

producer:	Rheinhütte, West Germany
type:	GVS 25/220
capacity:	2,5 m^3/h - 45 m liquid sulphur, 135°C
material:	cast iron, steel shaft, shaft protection box n° 4034
speciality:	steam heated casing (3,5 bar)
use:	sulphur to furnace
working period:	about 12 months (continuous working)

CENTRIFUGAL PUMPS (sludge pumps with packing fluid)

producer:	Klein (Jeumont Schneider), France
type:	wd 100g
capacity:	40 m^3/h - 40 m, 1 450 rpm
material:	n° 4460 or G-X CrNiMo 27,5 shaft n° 4580 plate welding with Celsit 50Nb
speciality:	special designed impeller stuffing box with TFE-packing and sealing liquid. Exchangeable wear disks and rings.
use:	NPK-slurry to spherodizer and circulation
working period:	about 4 months (continuous working)

producer:	Worthington
type:	2 CNG 104
capacity:	30 m^3/h - 6 bar, 1 800 rpm

material:	"Worthite" - 20Cr/25Ni + 2,5Mo -Nb stabilized and thermal treated shaft n° 4586
speciality:	variable split of impeller by movement of the casing cap.
use:	NPK-slurry circulation
working period:	about 4 months (continuous working)

M e d i u m: Phosphoric acid

H_3PO_4-slurry - 30% P_2O_5, 3% H_2SO_4,
60% liquid - 40% solid, 80°C,
y=1,7

SUBMERSIBLE PUMPS (centrifugal, vertical)

producer:	Ochsner
type:	30 BAV B 80
capacity:	41 m^3/h - 18 m, 1 450 rpm
material:	n° 4500, n° 4577
speciality:	impeller with backside vanes exchangeable wear disks and rings
use:	slurry to filter
working period:	about 5 months (continuous working)

M e d i u m: washing water (5% H_2SiF_6; 2-3% SiO)
- waste gas cleaning = 1,05 t= 30 - 50°C

CENTRIFUGAL PUMP (horizontal)

producer:	Ochsner, Austria
type:	E-Mor 2213/50 H
capacity:	25 m^3/h - 45 m - 2800 rpm
material:	all parts with fluid contact - rubber lined, shaft protection ring n° 4550
speciality:	hydraulic sealing (patent Mackensen)
use:	circulation pump for waste gas cleaner

F I T T I N G S used by ATP

M e d i u m: sulphuric acid

producer:	Rheinhütte, West Germany
type:	gate valve - AZ 1915
size:	DN 150, Pn 6
material:	n°4136, stuffing box n° 4410, TFE-asbestos packing
speciality:	two piece casing, seating parts easily to regrind exchangeable wear parts, no pressure on stuffing box if valve is closed, low pressure drop because of low turbulence.
use:	for circulation pump to absorber - 98%/120°C
working period:	several years

producer:	Tuflin
type:	process valve with TFE-sleeves
size:	DN 70
material:	ductil iron - fully TFE-lined
speciality:	rotating plug in a TFE-sleeve which is locked in the body. Without stuffing box and lubrication, seals are not exposed in either open or closed position.

use:	outlet of acid dilution - 72-76% H_2SO_4
working period:	

<u>M e d i u m: phosphoric acid</u> up to 80°C

up to 35%

producer:	Erhard
type:	diaphragm calce FD (rubb.. squeeze valve)
size:	DN 125, Pn 10
material:	cast iron - rubber lined diaphragm - soft rubber
speciality:	without stuffing box, exchangeable rubber lining and diaphragm, lifting limitation
use:	throttle valve in acid pipes.
wo: ing period:	

producer:	Dürholdt
type:	tyre valve
size:	DN 50, Pn 10
material:	cast iron for casing with anticorrosive protection layer; resistant rubber tyre. (TFE - silvered rubber parts for sulphuric acid)
speciality:	without stuffing box, exchangeable rubber parts
use:	stop valve for phosphoric acid
working period:	

Medium: NPK-slurry, Y = 1,3 to 1,7 / 110 to 140°C
bicalciumphosphate
ammoniumnitrate
calciumnitrate-, chloride and 20% water

producer:	Worcester
type:	4466 T ball valve
size:	DN 100 (25)
material:	n°. 4401 for body, ball and shaft. TFE for sealings
speciality:	no maintenance, no greasing, exchangeable wear parts
use:	stop-valve for NPK-circulation
working period:	about 2 months
producer:	Chemie Linz
type:	--
size:	DN 80
material:	n°. 4580 tube in Si-casting, TFE-sealing
speciality:	exchangeable tube and disk, simple construction
use:	throttle valve for NPK-slurry to spherodizer
working period:	3 months
producer:	Tuflin
type:	D 127 throughway valve
size:	DN 50
material:	stainless steel for body (18-10 Mo) TFE for ring, sleeve and diaphragm.

speciality:	no maintenance and lubrication
use:	slurry circulation
working period:	several weeks

producer:	Gecos West Germany
type:	PR-plug valve
size:	DN 100
material:	TFE-sealing
speciality:	no stuffing box
	lubrication box for all time greasing
use:	slurry pipe to spherodizer

HOW TO DRAW UP A SHUT DOWN PROGRAM
(gypsum sulphuric acid plant)

Factors for planned shutdowns in Chemie Linz

a) weather conditions (labour, plant)
b) availability of personnel (principal leave time in winter and summer)
c) energy situation (surplus or shortage of steam)

Planned shutdowns of large plants in Chemie Linz mostly are timed
April - June
September - October

Chemie Linz practice in timing of large shutdowns

1. Determination of shutdown date by production and maintenance department.
2. Coordination of mentioned shutdowns by central division T (technic) according manpower availability.
3. Coordination of fixed shutdowns with all concerned departments (production-, maintenance-, procurement-, sales-, energy department,...)
4. Draft of shutdown program by maintenance department (shutdown book). Discussion and completion of the draft together with production dept.
5. Estimation of shutdown time and manpower demand.
6. Typewriting of program, copying, distribution of program one to three weeks before shutdown.
7. Arrangements with personnel department and works council concerning working time, overtime, shift work, additional allowance. Information of staff by notice.
8. Shutdown discussion with all concerned workshops (engineers, foremen) one week before shutdown.

9. Integration of personnel from other maintenance departments, allocation of jobs to skilled working groups of department workshop and central workshop.
10. Preparation of job permits according to shutdown program by production- and maintenance-foremen.
11. Shutdown of plant, cooling down to working conditions, start of jobs. Some jobs can be started before shutdown.

SHUTDOWN - PROGRAM

GYPSUM SULPHURIC ACID PLANT

The shutdown time is appointed by the renewal of the high voltage installations for electrostatic hot-gas- and wet-gas-precipitators:

Sept. 14th - 15th, 1982:	Shutdown and cooling down of the plant after removal of kiln-crusts by means of high pressure water spraying system. Removal of existing high voltage device by TEL.	
Sept. 16th - 19th, 1982:	Cleaning of high voltage room. Take care to remaining elelctrical installations, e. g. insulators	
	whitewashing of the room	TBW
	cleaning after whitewashing	TBW/APZ
Sept. 20th - 22nd, 1982·	Erection and assembly of the new high voltage machines, TEL	
Sept. 23rd, 1982:	Testrun, start of the plant.	

Unit 601 (raw meal preparation)

1. Clean suction air duct between filters and compressors (arrange supply from CL-network) APZ/ATP
2. Check batch weighers in raw meal mixing station TME
3. Check of journal bearings of mixer and screw conveyors ATP
4. Change water valves below mixing station ATP

5. Repair elbows in pipe for pneumatic transport of phosphate from unit 601 to phosphoric acid plant. THW
6. Check rotary valves and screw conveyors in mixing station. ATP
7. Repair filter for homogenization plant start job on 1982 09 13. ATP
8. Drawing for impeller of coke-filter fan ATP
9. Convert phosphate mill for grinding of cement (1982 09 13) and back to phosphate (1982 09 20) ATP
10.
11.
12.

Unit 602 (kiln plant)

1. Check brick-lining of the kiln and the heat exchanger TBW/APZ/ATP
2. Alignment of kiln ATP
3. Check apron conveyors and clinker crusher ATP
4. Repair clinker cooler ATP
5. Repair chute from clinker cooler to apron conveyor ATP
6. Repair chute from belt weigher to kiln ATP
7. Check main drive of kiln ATP
8. Check redler conveyor for cracks ATP
9. Change bearings on SO_2-hot gas fan THW
10. Renew ceramic plates in raw meal hopper for belt weigher TBW
11. Check granulation filter ATP
12.
13.
14.

Unit 605 (gas preparation)

1. Investment program 1707 - "High voltage device, GS-plant, unit 605 (replacement)." appointed time see page 1 — TEL
2. Change frames for spraying electrodes (enforced type), measure guide-slots of precipitation electrodes in electrostatic hot gas precipitator — ATP
3. Repair leakage on lead duct upstream wet-gas-precipitator — THW
4. Redler conveyor C-repair tension station on deflection pulley — ATP
5. Renew chute from redler conveyor C — ATP
6. Lead jobs on gas duct outlet cooling tower — THW
7. Repair gas coolers (start job on 1982 09 06) — THW
8. Assemble new frame to return water pump — THW
9. Repair leakage on ceiling of high voltage room — TBW
10. Renew drain of collecting tank for washing acid — THW
11.
12.
13.

Unit 607 (contact plant)

1. Screening of catalyst (mounting of electric host) — APZ/ATP
2. SO_3 duct, renewal of tee - inlet heat exchanger I and I a — THW
3. Check and clean pipe, outlet drying tower — APZ/ATP
4. Check plastic lined pipes (experiments) for sulphuric acid — ATP/TMP
5. Check acid resistant brickwork in drying and absorption tower — TBW/ATP
6. Remove distance piece with compensator, prepare saddle and support of duct — THW

7.	Welding job inlet of distribution through 3, absorption tower	ATP
8.	Assemble distance ring in pipes above acid pumps	ATP
9.	Check moisturizer (flange leaks)	ATP
10.	Renew flanges bypass heat exchanger VI, DN 400	THW
11.	Check submerged suction pipes for acid pipes for acid pumps inside tanks	ATP
12.	Check heat exchanger VI and associated ducts (timder)	ATP
13.	Set blinds into gas duct downstream SO_2 blower (cleaning)	ATP/APZ
14.	Replace gaskets eventually flanges in gas duct outlet catalyst-bed "F"	THW
15.	Change armatures and acid pipelines	ATP
16.		
17.		
18.		

Unit 609 (waste gas cleaning)

1.	Repair gas inlets into waste gas scrubbers	THW
2.	Adjust condensate pipe coming from electrostatic precipitator	THW
3.	Change gaskets at siphon inlet electrostatic precipitator	ATP
4.	Repair AS-lye tank (steel, lead, sandblasting, painting)	THW
5.	Lead jobs (leaks) on electrostatic precipitator	THW
6.	Repair neutralization pit	TBW
7.		

General jobs

1.	Change of safety valves	ATP
2.	Scaffolding jobs according request	TBW
3.	Electrotechnical and instrumentation jobs	TEL/TME
4.	Insulation jobs after instruction	TBW

S H U T D O W N - P R O G R A M

PHOSPHORIC ACID PLANT

. Removing and control of all agitators and gears of the reactors.
2. Change of gear box for agitator n°. 3.
3. Repair of brickwork - reactor n°. 1.
4. Control of brickwork - reactor n°. 2 - 10 and acid circulation tanks by the civil department.
5. Control of metal plates inside of reactors.
6. Removing and cleaning of discharge pipe of evaporation cooler.
7. Control of rubber lining - evaporation cooler.
8. Control of rubber lining and water nozzles - vacuum condensers.
9. Mounting of new rock phosphate scale.
10. Removal and control of agitators and vertical pumps ~~of acid~~ circulation tanks.
11. Control of rock phosphate bunker and pneumatic extraction.
12. Control of vertical pumps for filter and evaporation cooler.
13. Repair of belt conveyor for gypsum.
14. Repair of gypsum chute.
15. Control of pan filter and distributor.
Control of variable speed gear.
16. Change of filter cloth and filter plates if necessary.
17. Removing and cleaning of dipping pipes of reactors.
18. Control and cleaning of waste gas scrubbers.
19. Control of extraction gans of gypsum throw-off chute ~~and pan~~ filter.
20. Remove of sulphuric acid metering unit.
21. Remove and cleaning of flow meters for sulphuric acid dilution coolers 1 - 4.
22. Remove and cleaning of control valves for 5% and 12% acid and washing water.

23. Removing and cleaning of flow-meter of wash-water and 5% acid.
24. Control of metering unit of SiO_2.
25. Calibration of transmitter for vacuum gauge.
26. Control of all shafts of agitators in the reactors including the plastic liners.
27. Control of lead-lining at the bottom of pan filter.
28. Repair of dust filter of rock phosphate bunkers.
29. Remove and cleaning of wash-water pip-filter.
30. Control of gypsum-slurry tank and agitator.
31. Change of pipes in the area of sulphuric acid metering unit.
32. Control of discharge vessels on pan filter - change of rubber plates.
33. Control of reactors 1 - 10.
34. Control and repair of stower pipeline - rock phosphate.
35. Change of sulphuric acid dilution cooler n°. 2.
36. Remove control valve for vacuum of evaporation cooler.

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37. Control of sulphuric acid pipelines being on test (teflon lined).
38. Check of dimensions of conical bottom - evaporation cooler.
39. Repair of frames - pan filter.
40. Get going of slide plate between reactor 1 and reactor 10.

ATP

TEST RECORD

plant: phosphoric acid plant

place: transport of gypsum (by-product)

object: gypsum, pump App. n°. 423 084

actual status: impeller material n°. 1.4580
test n°. II

modification: impeller material n°. 1.4460 (increased Cr content, lower Ni content)

purpose: material test (resistance)

method: comparison of erosion rate (two pumps at the same time)

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start of the test: 1981 06 26

	weight start	weight end	G kp	h	erosion rate
impeller I	8,8	6,7	2,1	4349	0,48 g/h
impeller II	9,2	5,9	3,3	5571	0,59 g/h

controll: 1982 03 19

end of test: 1982 06 02

result: 20% less erosion with mat. n°. 1.4460

conclusion:

cost: 12% higher price of material

average cost of one repair:

efficiency: -20% erosion / + 12% price --- o.k.

performance: in future order only 1.4460

CHECK - BOOK FOR BELT CONVEYORS

According authority regulation § 95 ADSV all belt conveyors have to be checked yearly. The results must be recorded. The inspection is ordered resp. carried out by the responsible maintenance foreman.

A) Check of a stationary belt conveyor comprises the following items:

1.	Test pre-alarm before starting the conveyor	APP/ATP
2.	Test all safety switches	APP/ATP
3.	Check safety devices on drive pulley	ATP
4.	Test all pull-line switches	APP/ATP
5.	Check safety devices on tail pulley	ATP
6.	Check safety devices on tension-station	ATP
7.	Check belt-cleaners	ATP
8.	Check idlers and return idlers	ATP
9.	Check function of non-return brake and condition of protective cover	ATP
10.	Check protective caps over coupling and shaft	ATP
11.	Pay attention to squeeze-points on feed- and discharge-chutes.	
12.	Are all earthing wires in good condition?	ATP/TEL
13.	Particularities: e. g.: has the conveyor to be equipped with an electric-conductive belt and is such a belt actually used?	ATP

B) The inspection of a transversable or moveable belt conveyor covers all the items of a stationary conveyor according A) plus the following additional points:

1. Test limit switches for turning or movement	APP/ATP
2. Protective cover on moving-motor	ATP
3. Rail-cleaners	ATP
4. Test alarms if anyone exists	APP/ATP
5. Drag-cable with suspension or cable drum including protective equipment	ATP/TEL
6. Electric collectors and electrical lines and protective shield	ATP/TEL
7. Tranction winches with ropes	ATP/T-RV

In the following tables the checks are to be confirmed with date and signature. Troubles recognized during inspection are to be described under a footnote at the end of the booklet. The trouble must be solved immediately. After a repeated check the regular condition must be stated with date and signature.

After the checks carried out in a distance of one year the checkbook is to be shown to the department manager who has to sign the checkbook.

Our safety department and all authorities are allowed to ask for the checkbook.

The sketched economizer is a construction of Rheinstahl Eco GmbH

Seamless carbon steel, steelpipes
fin-tubes of cast iron
two-piece elbows (cast iron) with asbestos sealing, filling the hollow between interior and exterior elbow with iron-file-chips.
housing gastight welded
water in- and outlet protected with cast iron and stuffing box.

The first ECO-Design in the Monsanto-plant of Chemie Linz AG was similar to the system at Chittagong. Since 1965 we have three steam generators between the passes of the converter (cooling the SO_2/SO_3-gas) and one economizer after the 4th pass in a construction as shown above. All tubes and elbows are inside the housing protected with cast iron against corrosion. We can recommend this system and we warn against a construction with flanges. In Europe there are only a few experienced manufacturers of these tubes, i.g.:

Foster Wheeler, Great Britain
Rheinstahl ECO GmbH, West Germany

The steel pipes either will be shrinked into the cast iron fin-tubes or the diameter of the steel pipes will be increased in consequence of overpressure after fitting with the cast iron fin-tubes. The cast iron shield has to be very tight avoiding condensation and corrosion.

Acid distribution

In our acid plants we have different acid distributors:

Monsanto plant: distribution cup with overflow weirs. The material of the cup is Meehanite CB3 with $<$ 3,3 % C, $>$ 2,7 % Si, 0,6 % Mn, 0,3 % Cr, $>$ 0,5 % Cu.

Anhydrite plant: through distribution system in cast iron with downcomers in ceramic. Experiments with downcomers in stainless steel 1,4580 and cast iron have not been satisfactory.

INSTRUCTION FOR PLASTIC - LINED PIPING SYSTEMS

Plastic-lined piping systems consist of a corrosion resistant inlinger and a compression-proof steel-tube: steel-plastic-compound-tube.
These compound pipes are produced by different methods of manufacture and vaious plastic qualities: polyproylene, kynar, FEP, PTFE, ...
The maximum length is about 6 000 mm.

General design

The inliner is seamless and it is bordered over the flanged pipe. The lapped flange is a separate part of the pipe. The plastic borders fulfill the function of a dasket between the different lined tubes and they avoid any fluid contact with the metallic tube. The inliner must be chemically resistant. PTFE can be used for nearly all liquids like acids, solvents, oils up to temperatures of 260°C.

Plastic lined pipes have to be ordered in the proper length for installation because it is not very easy to shorten the delivered pipes or to change them in any other way additionally.

Assembling of TEFLON-lined H_2SO_4 pipes

1. Jobs at the H_2SO_4 pipelines are not allowed before released by the production department. All safety measures prescribed on the job-permit (safety goggles, face shield, acidproof overall, acidproof gloves,

rubber boots, ...) have to be observed absolutely.

2. Assembling of piping system

2.1 All delivered piping parts are equipped with protecting covers on their open ends. To remove the covers it is only allowed a short time before assembling. If they are removed only for inspection they have to be fixed again to avoid damage of inliner-flanges.

2.2 The pipes and fittings should not be put down to the ground without cover. Always use a carton or the disassembled protecting cover as a sole plate to avoid damage of the plastic border.

2.3 All delivered piping parts have to be checked by the material testing lab before assembling. On the inliner a high voltage breakdown test should be carried out by means of a "Poroscope". Testing voltage is 15 KV. Also measurement of inliner-thickness and a visual control of the complete supply must be executed.

2.4 Tubes and fittings lined with Teflon or plastic have vent-holes or other desing measures that gases enclosed between steel pipe and inliner can escape and leakages can be recognized immediately. For the last reason during installation one has to oberv that vent-holes look to the ground. If the piping system will be painted keep all the vent-holes open.

2.5 Before installation one has to inspect all piping parts visually (inside and outside). Contaminations are to remove. The flanges of the inliner must be cleaned carefully with a cloth to get clean sealing joint.

2.6 It is not allowed to install additional gaskets between the Teflon flanges. Only for connections of lined tubes with metal, glass, ceramic, etc. one has to use an additional Teflon-gasket.

2.7 Torques for screwing down:
If you overwind the screws it is possible that the Teflon-flanges will be deformed which results in leakages. To avoid this failure the following initial torques have to be observed:

DN 80, screws according DIN 601 a) 6 x M 16 initial
torque = Nm
b) 8 x M 16 initial
torque = 45 Nm

Threads of bolts must be oiled to define exactly the stress due to torsional moment. If there does not exist a torque-wrench you have to use a normal wrench with a maximum length of 150 - 200 mm for tightening of screws and supporting the heads of the bolts. After starting and operation on normal temperature all flanges have to be inspected and tightened again the the case of leakage. Teflon-lined pipelines must not be used as earthing connection for electrical devices or as contact pole for welding machines.

3. Mounting of compensators

3.1 For mounting of compensators consisting of Polyfluoron-PTFE-bellows and two steel flanges the instructions according item 2. are valid. Furthermore you have to consider that bolts for flanges show with their head to the expansion-bellows and the nuts are situated on the flanks of the pipeline-flanges. This is necessary to get no reduction of compensator-expansion by use of bolts too long.

3.2 Torques for screwing down

According to § 2.7 the following initial torques have to be observed:

DN 80, screws according DIN 601 a) 6 x M 16 initial
torque = 90 Nm
b) 8 x M 16 initial
torque = 67 Nm

3.3 Adjustment of compensators

Before mounting of compensators you have to calculate the installation length.

Required data:

a) Compensator length: 95 ∓ 25 mm deflection
   minimum: 70 mm, maximum: 120 mm

b) Operating temperatures
   maximum 40°C (maximum acid temperature)
   minimum minus 20°C (shutdown in winter time)

c) Surrounding temperature at the time of mounting

Adjust the nuts which limit the compensator length to the maximum. Control of expansion and contraction of piping system is possible by observation of the compensators.

4. Operation

During start-up of the piping system pressure and temperature should be increased continuously.

5. Precautionary measures for disassembling

5.1 For disassembling of inlined tubes and fittings it is not allowed to introduce parts of metal like pliers, levers or screw-drivers between the flanges because the sealing joint will be damaged.

5.2 It is forbidden to use torch-cutting for disassembling. The maximum allowed temperature is 260°C for the Teflon-inliner. Blocked nuts must be removed by means of a chisel or a metal saw.

5.3 The precautionary measures valid for assembling have to be observed generally.

SAFETY DESCRIPTION OF NPK - PLANT
unit 626

The situation of the plant is to see on the site-plan. Approach roads, formation-places for fire-brigade and fire plugs situated around the NPK-plant are to keep accessible.

The building was erected without use of burnable construction materials. Emergency ways (flight-ways) inside the building are marked by "flight arrows" and plates "Emergency Exit". Three flight stairs in each of the two plants lead from the different floors to ground level outside the building. Orientation lights installed above the emergency exits burn about one hour after electricity failure. The normal staircases are equipped with an empty fire-fighting-system. Fire extinguishers and flight masks placed in sealed boxes are checked continuously by our fire brigade. Normal contact with the fire brigade is made by telephone, in emergency cases also by fire-alarms installed in the two staircases (tested in a distance of one week together with siren-alarm after contact with the fire brigade).

Alarming of persons inside the plant can be carried out by the central intercom-system or the two sirens in the old and the new plant. In arrangement with our department "Safety" near dangerous areas safety devices are placed (jumping-bubs with warm water, emergency showers, eye-flushing bottles).

The following parts of the plant are checked in ordered and constant distances by Chemie Linz departments:

- earthing resistance in the whole plant, in particular on the storage tanks for coating agents
- check of lighting rods
- tightness test on natural gas manifold
- lifts, hoists, winches, cranes
- pressure vessels
- belt conveyors
- gas burners and interlock system

The natural gas fired burners for preparation of hot air can be switched off by emergency push buttons from the spherodizer switchboard or from a place outside of the production plant. The burners will shutdown automatically in the following cases:

- failure of spherodizer fan
- failure of spherodizer main drive
- failure of primary- or secondary-air fan
- pressure of combustion air too low
- flame failure (UV-cell)
- gas pressure too high or too low
- reaching of maximum temperature gas inlet or gas outlet of spherodizer
- electrical failure on thermocouple connected with shutdown system

Closed to the natural gas control-valves inside the building CH_4-probes are installed to alarm a potential untightness. Temperature of hot air is measured at spherodizer inlet and -outlet in each plant by 3 different thermocouples for registration, alarm and turn off. Adjustment of alarm- and shut-down-temperatures necessary by changing of production only can be carried out by instrument personnel.

POSSIBILITIES TO REDUCE SHUT - DOWN - TIMES

AVOIDANCE OF BREAKDOWNS AND TROUBLES - EXAMPLES

LONG STOPPAGE TIMES DUE TO:	DECREASING RESP. AVOIDANCE OF STOPPAGES	EXAMPLE	PLANT
1. Cleaning of the plant	modification of operation	H_3PO_4-tank, filter head	PA
	cleaning during operation	hammers on spherodizer	NPK
	modification of construciton	constr. below roller crusher	NPK
	use of more personnel (organisation)	cleaning of kiln (burning/ CO_2/gun/H_2O)	G-SA
	cleaning procedures		
	cleaning device	pneumatic tools for cyclons	NPK
	improvement of working conditions	podestals, additional working floors	G-SA
	protective devices		
	avoiding of cleaning points	grid in duct spherodizer	NPK
		cyclons	
		drums of belt conveyors (rubber cover, bar-drums)	
		insulation of scavenging-air-ducts to filters (condensation)	
2. Changing of parts due to:	Use of suitable material	delbag filter (stainless steel)	NPK
- wear		teflon-lined mixer	SA
- corrosion		armour plates (bofors, Cr) for mills	CEMENN
- fatigue	increasing wall thickness		
	improved construction	inlet-armour plates	CEMENT
	changing process	vibration-cracks on reactors	NPK
		wetting of waste gas:steel -- PP	SA

3. Overload: mechanical thermic electric	changing operating conditions exact lay-out control - switch off well timed shutdown generous lay-out strengthening of parts proper operation	roller brusher - - impact crusher shear pin bucket elevator speed controller (crusher - - elevator) hot spots on kiln shell dust filters screw conveyors for powdering agent	NPK STORAGE NPK G-SA NPK NPK
4. Unproper operation due to ignorance convenience of operator fear, fright lack of time	more attention better knowledge (teaching, training) more experience proper planning comprehension of superior for production losses	trouble with caterpillars switch gear for kiln reciprocating sulphur pump KCl (potassium) in reactors 1+2	SILO G-SA SA NPK
5. No improvements in process on machines in repair technology	don't fight against troubles, try to avoid them observation on the spot - subsequent conclusion good contact with other dept. (exchange, of experience and knowledge) courage to experiments	cleaning of spherodizers screw conveyors with rubber trough lab - plant	NPK NPK

6. False repair	good knowledge of machines		
	good knowledge of process		
	comparison of different repair methods	bottoms of drying- and absorption-tower	SA
	thinking about economy		
	preparation of a repair	timetable, shut down programme	
	care for spare parts		
	estimate of repair volume and time		
	repair for supervision of maintenance		
	identify fault before shut down		
	discussion of repair with locksmith before start		
7. General items	filing of experience	repair cards	
	knowledge of life-expectancy - overhaul cycles	measurement thickness of wear-parts	
	knowledge of trouble-symptoms (noice, temperature, length, ammeter,..)		
	preventive maintenance during operation		
	working climate in the group		
	financial stimulus (personnel motivation)	additional allowance (dust, noice,..)	

GUIDELINES FOR SUCCESSFUL FIGHT AGAINST THERMAL DECOMPOSITION OF NPK-FERTILIZER

The necessity of the use of labour-saving products in the field of agriculture leads to fast increase of the demand for mineral fertilizers in general and NPK-products in particular.

These fertilizers are not explosive or self-flammable under normal transport- and storage conditions. Complications are not to be expected.

NPK-fertilizers containing ammonium-nitrate can decompose slowly at temperatures above 130°C particularly due to influence of fire. At some fertilizers decomposition will stop if heat transfer from outside is stopped. Other formulars can decompose completely over the whole mass of stored fertilizer and can develope a large volume of hot nitrouse gases (350°C) and water vapour.

These gases are poisonous, the fight against hot spots can only be performed by use of breathing devices (in the open with B/ST- or F/ST-filters, in closed silos as well as in areas of high concentrations with heavy breathing devices).

NPK-fertilizers mostly are stored in paper- or plastic bags. An interruption of the reaction by water irrigation of the bag-piles will not be expected. The most secure method to avoid extension of the hot spot is to divide concerned mass of fertilizer from the rest; to transport it to the open air and to make full use of water spraying to stop reaction.

In case of decomposition of bulk fertilizer it can be brought to open air at an early stage of reaction (e. g.: by shovels). Another way is it to spoil out the endangered amount of fertilizer by means of a strong water jet.

A T T E N T I O N !

The fight against decomposition by other measures (e. g. foam, carbon dioxide, steam, covering with sand or fertilizer) is useless. Decomposition even can be accelerated by such measures. In case of decomposition of palletized material fork lifts can be used to remove the concerned piles to the open air. Under certain circumstances wetting of the storehouse can be avoided. There is no danger for explosion for the fork-lift-driver. But he has to wear breathing devices.
After some time of reaction the bags will fall to pieces. The decomposing fertilizer then can be spoiled by a strong water jet.

Poisened persons are to lay to the ground with face, body in half-side-position, keep the person calm and provide a doctor immediately. Wash eyes and mouth with neutralizing products (e. g. bicarbonate of 3 % concentration, but no boron-water), eventually start breathing with oxygen.

Guidelines about useful storage of mineralfertilizers are distributed to all warehouses, the final users (farmers) will be informed in a proper manner.

This information is distributed to all fire bigades of Austria!

GENERAL GUIDELINES FOR FERTILIZER STORAGES

Under normal transport- and storage conditions mineral fertilizers are neither explosive nor self-flammable.

In general it is sufficient to the fertilizer dry and clean to avoid contact of different products and in consequence chemical reaction of the mixtures.

Fertilizer with ammonium-nitrate (e. g. CAN, NPK) can decompose under influence of extern fire or heat at temperatures above 130°C. Decomposition will proceed slowly without extern heat supply through the total fertilizer mass. A yellow-brown, pungent smelling, poisonous smoke will be developed (nitrouse-gases-dangerous breathing-poison).

PREVENTIVE SAFETY MEASURES

In the following recommendations it is observed that it is possible to exclude certaily danger of thermal decomposition. Fire in a storage decomposition can be avoided with high propability.

Please observe:

1. Clean storage rooms before storing of fertilizer containing ammonium-nitrate. In particular follow this instruction for bulk-stores.

2. Burnable products, e. g. coal, sulphur, corn, oil and fuels also acids, unslaked lime, CAN and thomas-phosphate are not allowed to be mixed with fertilizers and are to be be stored separately.

3. In the storage room smoking, using of fire or open light, also welding and soldering is prohibited.

4. Take provisions that it is not possible to heat ammonium-nitrate-containing fertilizers from outside. Steam lines (even if insulated), electrical cables, electrical motors and heat producing lighting fixatures also hot exhaust gases of vehicles may not contact fertilizer.
   Also there must be a guarantee that conveyors for fertilizer transport can not run hot.

5. If fire is occuring in the area of the warehouse the fire brigade must be informed immediately.

FIRE AGAINST DECOMPOSITION

If recommendations mentioned above are not considered or in case of fire close to the stored product a slow decomposition has started the following measure must be taken immediately:

1. To fight against the hot spot fire brigade with heavy breathing devices must be called for. Information of spontaneous helpers about peculiarity of the stored product and all necessary precautions.
   Keep away curious persons from the endangered zone!

2. Wait for arrival of fire brigade, do not fight alone and in your own responsibility against the decomposing fertilizer. The hot spot increases only very slowly. There is no danger that product starts buring or explosing.

3. Open all windows and doors of the storehouse to enable free smoke exhausting. Do not breath the smoke and leave the endangered zone immediately! Open windows and doors only from outside if necessary by force! Keep away persons and animals from the area of smoke.

4. We want to mention explicitly that a fight against decomposing fertilizer by means of foam- or CO_2-extinguishers, steam, by covering with sand or other fertilizers is useless. Such measures even can accelerate decomposition.

5. All fire brigades are informed about fight measures. Instructions of the fire brigades are to be obeyed strictly.

This information is distributed to all costumers (warehouses and farmers)!

F A C T S   A B O U T   S I L O   S T O R A G E   F O R   N P K

unit 633

length:	186 m	
width:	53 m	volume of the building: 125 000 m³
height:	22 m	

12 boxes, each 5 000 tons = 60 000 tons storage capacity
repair box for reclaimer
possible extension: 4 boxes each 5 000 tons = 20 000 tons

max. storage height:	14 m	wall thickness between the boxes:
max. storage width:	43 m	1 m number of gates to the storage: 24
max. storage length:	14 m	

Mechanical equipment

2 reclaimers delivered by SCHADE (West Germany), each for a capacity of 180 t/h weight of one reclaimer: 40 t

capacity of feed conveyors:	2 x 60 t/h
capacity of reclaimers:	2 x 180 t/h

Head building with control room, screens and crushers

length:	46 m
width:	15 m
height:	27 m

Bagging and shipping

length:	106 m	
width:	19,5 m	width of the loading ramp: 9,6 m
height of towers:	24 m	

Mechanical equipment: 2 bagging and shipping stations, each for 60 t/h bagged product and 60 t/h bulk product.

Belt conveyors

feed conveyors to storage silo	2 336 m
conveyors between silo and bagging station	700 m
conveyors for wagon loading	56 m
conveyors for ship loading	777 m
conveyors to open air storage	35 m
total	3 904 m

Energy supply

electrical energy	800 kW installed power
drinking water	
separate station for compressed air	
steam supply	
fire water supply over 14 hydrants	
supervision and control from 2 control rooms	
the whole plant is equipped with dedusting filters of high efficiency	
additional streets	650 m
additional railway lines	4 500 m

2 dayrooms for operating personnel, rooms for supervisors, modern sanitary facilities

SAFETY MEASURES FOR THE COMPLEX FERTILIZER STORAGE AT CHEMIE LINZ PLANT SITE

A. PRODUCT

- complex fertilizer (NPK) or occasionally CAN (28%) with max. 0,4% C.
- storage feed temperature max. 50°C. Continuous measurement by means of two independent thermocouples. Temperature is indicated and recorded with max. alarm in the control room of complex fertilizer plant.

B. DESIGN MEASUREMENT

1. Belt conveyors

- belt with in the silo in flame-adverse material
- speed controller (shut off)
  strainght running control (alarm)
  emergency switch with pull lines (shut off)
- lower belt temperature-control by pyrometers for the storage feed conveyors
  (alarm in the control room of the silo)
- division of the belt bridge into fire fighting sections by means of waterspray-curtains
- emergency exits (ladders) marked by arrows (always two exits for each belt bridge in addition to the stairs in the corner stations)

- metal detector before the entrance of the silo (shut off of conveyors) and additional magnetic metal-pick-up at the way out of the complex fertilizer plant
- swivel chute located in the last delivery station before the silo for discharge of the belt conveyor to the open air.
- arrangement of the belt conveyors so that they cannot be an initial heat source for the fertilizer
- fire extinguishers (CO_2) within a distance of 35 m along the belt system
- telephone system with connections in a distance of 100 - 150 m
- interlocking of all belt conveyors to ensure shut down of preceding conveyors in case of failure

2. Silo

- partition to 12 boxes, each with a max. capacity of 5 000 t
- thickness of partition walls designed that in case of a decomposition in one box ignition in a neighbour box due to heat transfer is not possible
- all civil engineering material used is flame resistant
- feed product is screened by gratings to remove lumps
- heat sources like steam supply lines and electrical cables are not in contact with the fertilizer
- electrical equipments are mounted sidewards and designed in wet-room-standard

Man switches are outside of the silo.

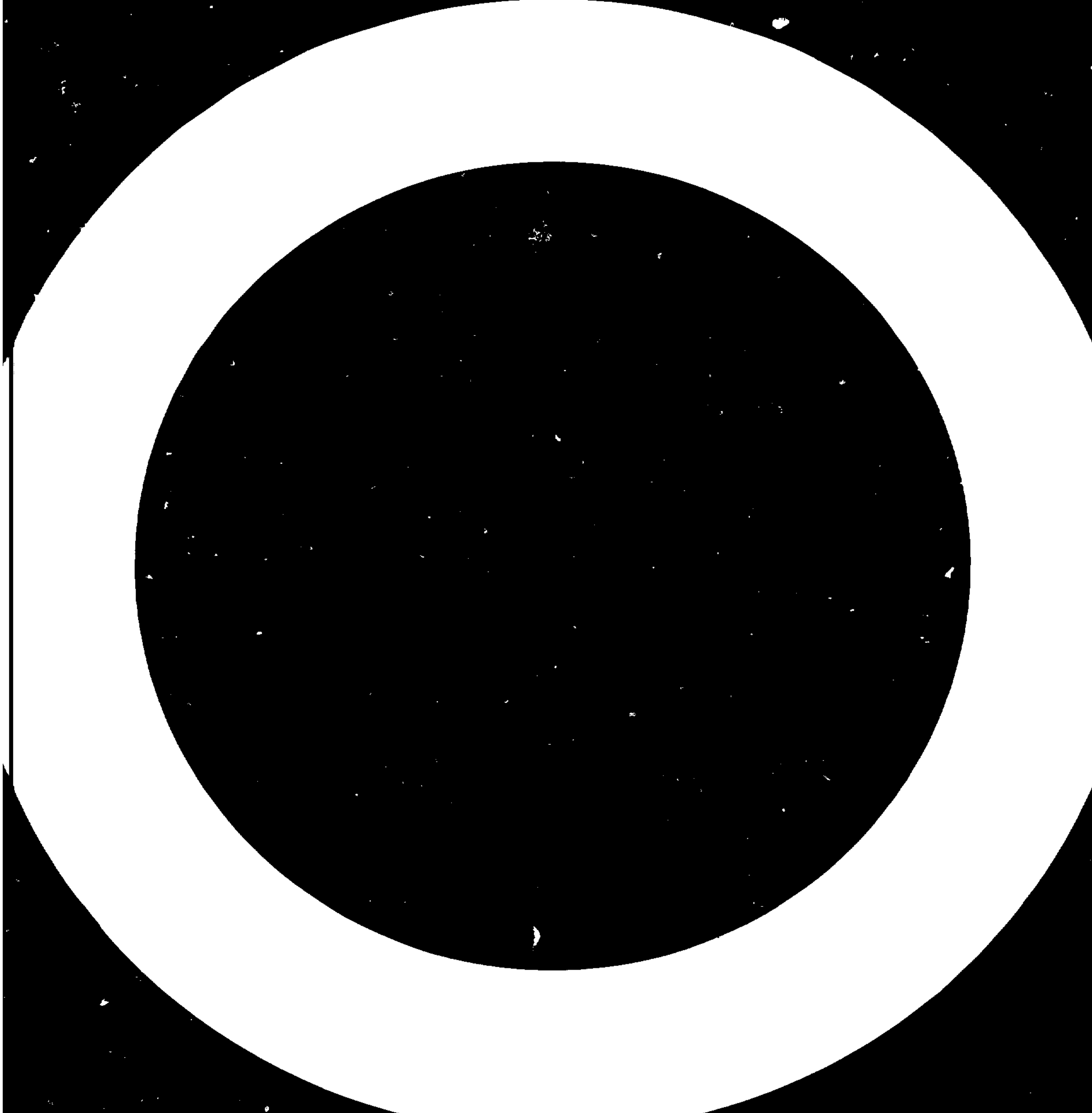
- lighting rods protect the silo
- emergency orientation lights in the roof top of the silo, along the reclaimer path and in the lateral belt-channels (automatically switched on in case of power failure). No bulbs but only fluorescent tubes are used.
  Hamdlamps are not permitted.

- windows for opening and closing along the roof top (5% of the ground floor area)
  All windows are remote-controlled from outside the silo by a separate supply of compressed air and daily operating tests.
- emergency exits from the roof top, the reclaimer pathes and the conveyor bridges marked by arrows
- extinguishing line (dry) for fire water in the head building of the silo
- flooding line for each belt channel with a capacity of 2,5 m^3/min.
- hydrants outside the silo connected with a ring system of 400 - 600 mm diameter
- 12 mobile wter canons each for 1,5 m^3/min adjustable for spray or jet application
- free outlet of product slurry after opening of the doors on the end of the belt channels
- emergency exits from the lift
- separate repair box for repairs on the reclaimer and jobs with fire

C. MEASURES BY ORGANIZATION

- general strict prohibition of smoking
  exception: dayrooms, office of supervisors, workshop and control-room in the head building of the silo
- repair jobs are only allowed in accordance to the written "job permit"
- welding within the storage silo only under special supervision and not near the product. Control of the spot for 6 hours after finishing of the job by means of an infra-red-instrument

- operating mauals for all working places, safety instructions every half a year
- control of the storage silo every half an hour recorded by means of a printing-watch and control book
  wireless contact of the control person to fire-brigade
- sufficient respirators for compressed air and gas masks, most of the operating personnel is trained in heavy gas protection
- free access for the trucks of the fire brigade
- warning plan (sequence) in the case of danger
- shovels and buckets are available



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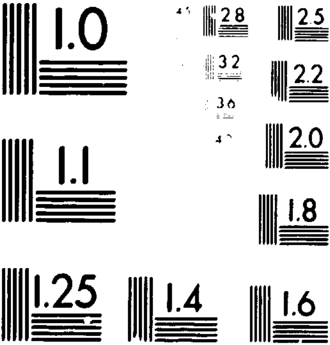
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(2 of 2)

7. UNIDO WORKSHOP

ON

FERTILIZER PLANT MAINTENANCE

Documentation Part II:

Technical Departments

of

CHEMIE LINZ AG

CHEMSERV CONSULTING GES.M.B.H.

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UNIDO

1984 04 03

PRINCIPLES OF PREVENTIVE & PREDICTIVE PLANNED MAINTENANCE SYSTEMS

SUMMARY: The author gives a short survey of maintenance in a Chemical Plant in Austria, CHEMIE LINZ. In most European plants predictive maintenance is only just starting, mainly because the facilities for collecting the necessary information about plant items during operation have not been installed in plants now in operation. For future plants predictive maintenance must be considered from the initial planning phase, and the author believes this will decrease maintenance costs by ten to 15 percent.

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1. INTRODUCTION

When I started my industrial career in a European Chemical Plant twenty years ago nobody talked about Preventive Predictive Planned or any other maintenance systems I can hardly pronounce. There was a rigid distinction between production and maintenance, production people were not even allowed to handle any maintenance tools, and usually production people complained that the maintenance was performed in an inadequate way and maintenance people complained that production people ruined all the equipment. Everybody tried to do his best, and to blame the other side for any malfunctioning of the equipment.

What is it to do one's best, i.e. to repair everything, that has broken down to the highest possible standard, to waste as many spares as the purchasing department is able to procure, and not to care about any costs. This led to marvellous operating hours of equipment, such as 99.6 percent (for example a reciprocating compressor), and also to admirable cost bills. Maintenance people did not understand these long, difficult to read sheets of paper with endless columns of figures and/or believed them to be a useless game of the accounting fellows'. As long as every ton of ammonia, every pellet of plastic was needed and sold on an ever growing market, as long as companies could notch up double-figure growth rates in turnover, everybody wanted to get goods to sell and not shut down plants for maintenance.

But when the tide turned, we got a first oil shock, people started to watch costs. The first oil shock passed and everybody believed the good times would prevail; we forgot the costs again. Only the second oil shock and a long lasting recession led Europeans to change their attitude to unnecessary costs - and maintenance costs are the largest portion of overhead costs.

In parallel another shift occured: the size of the maintenance items, i.e. the plants, grew. The old ammonia converters in our plant had a daily capacity of about 100 metric tons of ammonia. Today 1000 tons are usual. Transformers had a power of six megawatts, today 20 MW is a small one. We had nine 100 ton converters, and five small transformers. One reciprocating compressor had a capacity of 1600 cubic meters per hour, a single train turbo has ten times the output. The moment one of these parallel items fails, we won't run into trouble, if we have plenty of spares and manpower, manpower just waiting for the moment they can prove their ability to mend anything, to prove their ability to work round the clock. We could perform this BREAKDOWN MAINTENANCE in a quick and very expensive way. The fitters were happy with all the overtime and special allowances.

If you have a single train plant with only one transformer, one blower and one motor the whole unit will be shut down for the time you need to maintain one item, and if you get the breakdowns in the right pattern you may assume that the plant will be shut down every month for repairs.

So there are two reasons to review our maintenance strategy. One reason is the direct costs of maintenance, and the other reason is the indirect costs of lost production.

That's exactly the point where maintenance people fall asleep. They know all that much better than me, they changed their philosophy long ago, they are all performing preventive maintenance. And what is preventive maintenance? Now well that's obvious, shut down the plant annually, replace everything that is expected to fail during the next running period, replace everything that has failed once in the past and tell the production manager that he's got an awful good plant and he can run it until the next shutdown. Now gentlemen this is not preventive maintenance. This is nothing else but our old philosophy, waste anything but production.

I suppose now I should stop gossiping and come to the topic of my essay. The first question is, what is maintenance?

2. DEFINITION OF MAINTENANCE

In the company I am employed with, and in all other companies I know, there is a confusion between maintenance and erection. Usually it is not possible to distinguish between very small investment jobs and maintenance. E.g. the installation of a new wall socket in my office. Naturally this is erection, but do you believe it's worth at starting the usually very time consuming, paper wasting procedure of an investment order? I don't. For all those small jobs we have blanket work orders, and we believe any job consuming less than 15 craftsman manhours to be maintenance, as long as we need no special materials or spares. Wall sockets are plenty in our central store, our electrician will perform this job in half an hour so installing one wall socket is maintenance. If we start to replace the electric installation in our workshop, with all the safety switches, all the cables for the motors etc, this is investment, even if there was a very old rotten electric grid, 40 years old.

Special difficulties arise in plants shortly after comissioning, when we find out all the misjudgements we made in the planning phase, when we find out certain malfunctionings of our equipment. It is usually easier to raise the maintenance costs to 6 or 8 % of the investment costs, during the first year of operation, than to go to the board to confess that we built rubbish.

The boundary between maintenance and erection will vary from plant to plant and from time to time. Also the regulations about taxes and depreciation will influence this border. If we try to be honest people, naturally we are, we must confess that in our plant actually 12 % of maintenance are investment jobs, i.e. these 12 % construction are accounted on maintenance.

This has all been about what maintenance is not- but we are still waiting for what maintenance is. So please this is my very unorthodox definition of maintenance

Maintenance covers all efforts to keep or restore the availability of any facility to the worst possible condition, so that this facility is just able to fulfil its duty at the lowest overall cost.

Any facility is quite obvious, it might be a tanker or a grinding machine. Worst possible condition and lowest overall costs need some more explanation. This really is the topic of my presentation, and I am going to explain that in some detail in the following paragraphs.

Worst possible condition means the facility, the equipment, must just be able to fulfil its duty. The worst possible condition for the desk of our managing director is polished and brightly shining, for a tanker it might be that she stands gales of heaviest force, and for pollution control equipment it might be absolute safety -as far as something like absolute exists. The mandatory rules or governmental regulations for vehicles or chemical plants may imply very high maintenance standards, but please don't maintain, mend or repair anything above any standard or regulation.

Lowest overall costs are all wages, prices, duties, taxes, margins, fines, warranties or whatever else one can imagine, that will influence the turnover of an enterprise.

3. TYPES OF MAINTENANCE

According to the definition in our plant we have two ways of maintenance

- corrective maintenance
  - breakdown maintenance

- planned maintenance
  - scheduled maintenance
  - preventive maintenance
  - predictive maintenance

4. BREAKDOWN MAINTENANCE

Terrible word. One of the great old General Managers of our company used to insult us as break down engineers, he also used to tell us, that he could hire engineers like us from the labour exchange. So breakdown maintenance is something we should forget, we only perform planned maintenance. I don't agree. Remember worst possible condition, lowest costs.

Take a grinder. There are several hundreds of them in use in our company, you can get a new one in the nearest super-market. The value of this item lies in the range of five working hours of our craftsmen. I refuse to do any maintenance on that. If it breaks down I'll replace it. If any safety regulations are offended, assume the insulation of the cable is defective, I'll discard it. Definitely in the jungle, seventy miles from the capital in a country where you have to spend foreign exchange to get a grinder, I will do everything to keep or restore the usability of this item.

So where and when should we discuss about breakdown maintenance? In my company, in central Europe, we do breakdown maintenance on all small items, that do not influence safety or operability of a plant, especially

- standby equipment
- motors up to 5 kW
- standard pumps
- electronic equipment
- electric hand tools

Standby equipment is a very simple expression, and I admit that we have a lot of standby items where we do predictive maintenance. But generally standby items will be very small and cheap, I don't believe you have standby compressors, and we will have time to start the standby pump or blower when the operating item fails.

Standard electric motors are quite cheap, they got a lifetime-greasing in their ball bearings, and up to 5 kW we keep spare motors in our store. They can be replaced within a few hours, even during holiday time. Squirrel-cage motors are very reliable, and we have good experience with this practice for almost 6 years.

Standard pumps we keep in stock as well. In this case troubles might arise with the mechanical seals. They are resistant usually only to very defined media. So we keep the spare pumps partly dismantled, different types of seals ready on shaft sleeves, just assemble it (can be done by any operator) and replace. The service pump will be repaired during regular working time and kept as a spare again.

For electronic equipment we do have very few possibilities of maintenance. European companies just like to replace electronic cards. We get spare cards from the manufacturer changed against the damaged cards at half regular price. Electronic equipment for plant control is normally redundant with the standby system fully operative. With that we can shut down our plants safely. Until now we do not dare to operate a plant designed for redundant process control systems with only one UCM. We do not stock cards, we can get them any time of the year with the next plane from the airport of a European capital for our special process control systems. E.g. a failure occured at 2 p.m. Call to Schiphol NL, at 10 p.m. the replacement card was on the plane. If you cannot use these airport stores, it is necessary to keep stocks of all essential cards.

If you want to repair electronic cards in your company by yourself, you need special testing devices to locate the fault. Replacing the defective transistor, processor or other assemblies is very easy. The handling of the testing devices with very sophisticated test routines needs qualified engineers with long training in the manufacturer's workshop. In our company we have electronic equipment worth about $ 1.7 Mill, our engineers spent 10 manmonths for training at the manufacturers' just to get familiar with the handling of the functioning systems. They believe they could do all the maintenance on the cards themselves, if they only had the tools for that, but until now I refused to procure electronic test systems for a price of about $ 100000, and waste the time of my instrument engineers. I believe it "lowest overall costs" to phone to Schiphol, or send a car Sunday afternoon to a scales-manufacturer to fetch a spare card, as also happened.

The greatest difficulty with breakdown maintenance is the flair of unability with it. It is simply more fashionable to maintain regularly, never to have a cut out, than to be called a bungler for the failure of the equipment. Our production managers are starting to accept our attitude towards non-critical items, but their superintendants and shift engineers still do not understand the point of our philosophy.

Also it has been impossible to give clear, easy-to-follow advice on what equipment should be treated as non-critical; we got several complaints, and the maintenance manager himself frequently has to interfere and assign items for breakdown maintenance. From my report you will guess that in case of doubt I prefer planning.

5. SCHEDULED MAINTENANCE

What people usually call preventive maintenance is simple scheduled maintenance. Take a plant with lots of distillation columns and associated coolers and evaporators. Such a plant needs regular cleaning; in cold countries maybe once a year before summer starts, in a hot region even more frequently. So the maintenance people have a wonderful time once a year, or at any other regular interval, with the opportunity to dismantle, repair, change, maintain and mend whatever they are in a mood to. Most production managers will support maintenance against top management in claiming funds for these jobs, because nobody sleeps better than a production manager with a brand new restored plant.

This I believe is the worst method of maintenance, and we don't want to wast our time with this topic. Just let's try to find a definition for scheduled maintenance.

> Repair of a plant, replacement of parts periodically, without knowledge of performance in the near future, without headaches about the "overall costs" is not preventive maintenance but scheduled maintenance.

6. PREVENTIVE MAINTENANCE

Now I should try to define the term preventive maintenance. People much more clever than me have done this and from the various definitions I have mixed up this one.

> Preventive maintenance comprises all efforts to define or to estimate the possible failure causes of equipment, to calculate the reasonable operating time and to correlate this with necessary plant shutdowns from the point of view of minimizing overall costs, and the performance or nonperformance of checks, inspection, overhaul and repair based on these efforts.

For example: our plant has to be shut down every spring for cleaning the heat exchangers, to improve heat transfer during the hot season. We have a reformer furnace with high alloy heat-resistant tubes, these tubes have an expected lifetime of 70000 hours, and they must be replaced by some rules after these 70000 hours. They will reach the end of their life 6 months after shutdown. Price of one tube is $ 4000, we have got 100 of them. One day of shutdown means a production loss of $ 50000, changing tubes will take us 10 days (startup included). Labour costs are approx $ 14000.

Total replacement cost of tubes

$ 4000 x 100 + $ 14000 = $ 414000

These tubes should last for 70000 operating hours. We have left half a year life span, makes 4000 hours. The value of these 4000 hours is

414000 : 70000 x 4000 = $ 23600

One day of operation costs $ 50000; multiply this by ten, and I would be crazy if I wasted a single thought on delaying the replacement of tubes to any other time, but the annual cleaning shut down.

This calculation is correct, as far as the mathematical functions are concerned. But it is wrong if we consider "overall costs". Always we accept the assumption that we have to replace the tubes. This assumption we will drop later on with predictive maintenance. So what is wrong with our calculation? The mistake is, in Europe you never can calculate with production loss per day. Maybe your stores are bursting, maybe the marketing manager is going to sell the top 5 % of production at a price 20 % below production costs. Let's assume the latter, and let's check what we've got to do then.

We need information about the plant, or the item: how does it behave with different load, what are the fixed costs, what are the variables? With a single machine the reply to these questions might be quite easy, but we also need it for our whole reformer plant. So let's try to find some characteristics of all items.

If we consider costs versus capacity, we will get a curve which applies to all kind of equipment. The fixed costs will be incurred even during standstill. Fixed costs are salaries, wages, depreciation, taxes, rental, interest etc. The variable costs are zero at standstill. They will rise very fast if we just start the restricted by the increase in efficiency of the equipment. Somewhere we will reach the maximum efficiency; in our experience it lies somewhere near 80 % of nominal load with chemical plants. At last variable will start rising exponentially, when we pass the nominal variables will start rising exponentially, when we pass the nominal capacity. Variable costs are mainly energy sources and raw materials, spares, maintenance. If we try to plot this we'll get the cost/load curve.

```
  1                                       *
c 1                                     *      variable costs
o 1                               *
s 1                    *
t 1         *
s 1     *
  1   *
  1  *                    estimated max one third of total
  1*
  1--------------------------------------------- fixed costs
  1
  1                       estimated two thirds of total
  1
  1----------------------------------------------------
                                1
                              100 %                     load
```

```
  1                       *
e 1               *                      *
f 1            *                               *
f 1         *
i 1     *
c 1
  1----------------------------------------------------
                                1
                              100 %                     load
```

Just below we have plotted the efficiency/load curve, as I mentioned we assume maximum at about 80 %.

With these tools we start another calculation.

Not being able to sell 5 percent of the production at a sufficient price would induce us to operate the plant at

95 % capacity. This leads to a decrease in costs, less trouble in production, more easy operation, better and quieter holidays for all of us. Actually we calculate

range of production nominal= 100 %	decrease in capacity	decrease in variable costs
110 %	1 %	2 %
100 %	1 %	1 %
90 %	5 %	2 %
80 %	5 %	1 %

Until now we have been in the lucky position of being able to operate our plants with at least about 80 % load. But I am afraid that in a few years I will be able to give you details even for the lower percentage ranges of production.

We are still looking for the average plant load if we shut down the plant for another 10 days

operating time	350 days per year	95 % load
operating time	340 d/a	97 - 98 load

$$0.95 \times 350:340 = 0.978$$

For this 2 to 3 % increase in load, we have to find out the decrease in efficiency. Calculation from this estimated assumption is not practicable ... just assume that the decrease in efficiency will be in the range of 1.5 %.

loss in efficiency		1.5 %
total plant costs per day (average)		50000 $
daily loss	50000 x 0.015 =	750 $
loss for ten days		7500 $

So we found out now, if we are going to shut down the plant at a time reasonable for changing the tubes, we will lose for the whole year of operation $ 7500 and we will gain $ 23600, and these 16000 dollars are a lot of money for us. Definitely we have to consider not only the money, we have to care for the risk of shutting down and restarting, and also we have to think of the possibility that we will have to do some breakdown maintenance sometimes in the course of this year. In a case like this we would delay the replacemant of the tubes and go for another shut down.

I agree with you that this is a very simple stupid example, but in our company we calculate like this. Now with the furnace tubes of course, they are a special example for predictive maintenance, but I believe the principles of what we call preventive maintenance have been explained.

When and where do we use preventive maintenance? The first question is, what do we need for preventive maintenance, how do we get the information about the equipment we need? How can we find out the maximum efficiency, the lowest maintenance cost etc?

We need a production manager who cooperates witn the maintenance people. A production manager who is willing to admit that nobody needs the full capacity of a plant, a production manager wno gives access to all records and findings from the process side. We need operators who have a feel for the equipment and confidence in the maintenance people. The feelings of the operators must be taken seriously by the maintenance people. Operators usually are right. In my company we involve production people in maintenance. Let them damage some bolts or some gaskets. We all did when we started to learn our job.

We need experience on the equipment, experience about the probable causes of failures, about usual wear, about the procurement time of spares, about the tools we need for a unforeseen breakdown (if our calculation and experience failed). Experience you gain only after a certain period of operation.

For the startup and the initial running time one has to rely on the advice and the manuals of the equipment manufacturers. Usually you will get reference lists from manufacturers, and if you are lucky, and the reference company is not a competitor for your own product, you can profit from the experience of fellow companies. Also we believe that we all have a certain technical knowledge, and certain common experience. So most of us can guess what will be the main problems with equipment in advance. In spite of all that- we like to maintain newly erected plants, that went on stream recently in the orthodox way, i.e. keep plenty of spares, check and replace brandnew things, and blame ourselves for wasting money and manpower.

The right time to start real preventive maintenance we believe is after one year of operation, when we reach the bottom of the bathtub life curve, i.e. when all the initial failures of the equipment are erased, and usually the startup spares have been consumed. The preparations for preventive maintenance of course are started during erection of the plant. They are exactly the same that we need for scheduled planned maintenance.

The decision to start preventive maintenance is taken by the divisional head of production and by the technical-maintenance manager. Those people will check the failures of the equipment which occured till then, they review the data and manuals received from the equipment manufacturers during procurement and erection phase, they discuss with the sectional heads of similar plants, and they even discuss with the operators. I always admire myself what details about machines I can get from operators, if I only take the time to discuss with these people, and if I can give them the feeling that I am really interested in their opinion.

Well, now we have all the information about the plant, we have all the calculations about efficiency and marketing, and now we have to take the decision, we have to take the risk. It is a risk not to replace and repair when there is time, to keep the machines running, to go on eroding the contacts, to watch the temperature rising in the transformer, to run out of spares. In this place I must admit that the risk of missing spares is the smallest one. From FRG I can get spares usually within a few hours, i.e. with the next plane. As I mentioned, last time we did send a car on Sunday to fetch a card for a scales, and I myself once went to the UK, to Sheffield, to procure piston rings; I was back after 16 hours. So as regards spares we are in a very easy position in Europe. In a country with restrictions on foreign exchange, (in one country it took us several weeks to get spares from Singapore) the spares situation has to be looked at in a quite different way, and I personally always refused to waive any spare requisitions even when we did set up a very effective predictive maintenance there. I assume in your countries there won't be any difficulty with foreign exchange, so the situation is the same as in my country.

Now we have the decision to start preventive maintenance, but how do we perform it? During erection, and specially during commissioning with all the vendors' reps at site we set up a very detail cardex about the equipment installed in the plant. This is normal and necessary for all types of maintenance and not worth mentioning here. Modern people have stopped using a cardex, they feed the data to a computer. Actually we have several computers for maintenance, but we started only last year to assess a comprehensive EDP-aided maintenance management system. Let's assume we got a cardex, maintenance is equal whether you record it on a computer or in a cardex. Only life is easier with EDP. So we have the cardex, we have recorded all instructions about greasing, about inspection, about regular replacement of wear-parts, we have long lists about spares, one copy with the cardex, spares that are recommended by the vendor, spares on stock in our store. We have the information where we get the spares from, how long the regular procurement should last. And we have a lot of typical jobcards, but unfortunately (or better say fortunately) blank, because we have not yet performed the job for the first time. The job cards may be kept with the equipment cardex or separately, that's a question of practice; you only have to ensure that the jobs on the cards are performed at the time or intervals indicated - for the initial phase, as long as you have no experience, as long as you have not started preventive maintenance. This all is necessary for our old system, scheduled planned maintenance as well as for any system. It has got nothing to do with preventive maintenance. But the effort put into setting the information system up must be considerably higher for our preventive maintenance system, for the accuracy of information has a decisive influence on the decisions to be taken.

It is the job of our assistant engineers, with the aid of the foremen and the vendors` reps, to collect the data and to write the cardex cards (of course not the typing). We have cardex cards for all items with item numbers, for major valves (every day we get discussions about major), for special tubing (e.g. the outlet tube of the ammonia converter), for tank gauges, for all instrument equipment necessary for cost accounting and cost clearing (e.g. orifices for NG) that makes a total of 500 cards for a reformer plant, and maybe 250 for one maintenance engineer. The instruments and electrical items are kept at the instrument and electrical people`s offices, respectively, but they observe several plants each.

I personally prefer two sets of all documents, even if we only record the maintenance events in one copy and the second one will lose its value very soon. With EDP and terminals in several offices everybody has unlimited access to the records about equipment of course. The master copy is kept with the AMEs in the plant workshops, and everyone has all the cards for the equipment he is responsible for. The job cards are kept with the foreman, and it is his duty to sign them, and store them in such a way that he is able to follow up the timing of the necessary jobs. The performance of the jobs, all additional work performed at the equipment in question, all findings of our inspection department, results of oil analysis, analysis of deposits on the blades or the casings, operating hours, time consumption for the job performance, down time of equipment due to maintenance and inspection, anything of any interest about the equipment, must be recorded in the cardex, hand written by the AMEs, somtimes with unidentificable characters. In parallel the job cards are completed with estimated time, number of crafts, tools, safety equipment, consumables and spares. Still normal planned maintenance.

It should be the duty of the foreman to inform the assistant engineer or the plant engineer about any unforeseen events. Naturely the plant engineers have to follow up all the jobs performed in their plants, but they cannot -nobody can- keep all the events involving one item in their mind.

Information about very large breakdowns you also can get from your cost bills. We get them monthly from our accounting dept. But the many small time and cost consuming repairs submerge in a balance sheet about a cost center - usually one plant.

Getting the information from the cardex is the most difficult job for the managers. It is simply not really possible without EDP-aided systems, and real preventive maintenance only will start with all the information we can get from the computer.

Today it is the duty of the AMEs, AEEs and AMC to initiate procedures if there is trouble with the equipment. Everybody gets to know, and everybody will remember if we lose a blade of our syngas driver. But nobody registers, that every two years -this is a real example, it happened three times - the bearings of a blower crashed, damaging the housing and the shaft. They belong to an FD fan of a small boiler. In our plant, we have sufficient capacity for steam production, at least in summertime, so nobody was excited about the cut out of this boiler, everybody forgot and the AME with his cardex did not care.

What we want from our cardex or data file is all information about the equipment to estimate the life span and to define necessary overhauls. We want information about running time at 99 % load, at 95 %, if possible we want a curve maintenance costs versus load, we want a connection between maintenance costs and idle time (ball bearings will be damaged during standstill), we want the consumption of power at all plant conditions. It is a terrible job to correlate 500 items, we have large sheets of paper where we indicate all the questions and try to mark them with the information we have. But still with all these aids preventive maintenance stays guess-stimation without EDP. We have started to feed data about 120000 items to a computer, thus setting up the plant data base. We are going to select an EDP equipment evaluation system by the end of this year. It seems that we can procure the software from a sister company, and use this with very little adaptation. One thing must be considered before one starts to set up the plant data file. The information must be fed in in such a way, that all variables for EDP processing are defined in advance. With this I admit that I personally have already chosen the type of EDP-system, i.e. there are only a few systems with which we can handle our data files.

Now we have info-estimation, we declare our "large sheets of paper" the basis for preventive maintenance (this is rubbish of course, but the best we have at present) and we extend or reduce the inspection intervals, we run our bearings 6 years instead of three (as recommended by the vendor), and we refuse to do stroke if we believe from our info-estimation that it is unnecessary. We do or we try to do the maintenance in the worst possible way, we query any time the necessity of any job, we delay shutdowns to the most suitable times, we extend or reduce the running time of our machinery to what we believe gives us the lowest overall costs. Safety of course and governmental regulation and rules border activities. Still the safety of people is our paramount target.

We have many failures, we have still a lot of breakdowns on equipment which we believed would last for a calculated time. Usually when we try to analyse the reasons for unforeseen troubles, we find the reason in ourselves, we find that we forgot to think about very simple physics, we find that we underestimated certain facts, and we believe that we will have less than 10 % breakdowns (on working time basis) once we have our EDP-system operative. If we can get the system by the end of the year it should be possible to do the adaptation of the programs within one year. By this time we assume that we will have recorded on data files about 100000 items, and we believe this will be the basis for a very effective equipment evaluation for a very effective preventive maintenance.

And the benefits for our sleepless nights: We have decreased maintenance costs, based on the actual plant status by 20 % in five years, and I promised our board the same reduction once more within three years after preventive and of course predictive maintenance becomes active, i.e. after installation of a comprehensive computerised system. In the initial phase we have more plant breakdowns than we had during the period of time based maintenance. But always remember lowest overall costs. Additionally I believe if we only learn to handle our new tool in a more effective way, i.e. get fewer simple mistakes in our assumptions and calculations, we will get even less downtime with our plants.

7. PREDICTIVE MAINTENANCE

The principle of preventive maintenance is to collect information from the past, from similar equipment or from overall technical knowledge, rules and standards. Generally we do not know the real reason for the behavior of any item in the past. For all interpretations of failures and findings we make a lot of assumptions. It would be nice if we could ask the patient "how do you feel", "did you sleep well last night", "would you like another cup of oil". Can we, we can. We all have been using predictive maintenance from the start. Remember the oil reservoir of a large turbine, maybe ten tons of very expensive oil. Are you going to change it after a certain time, or in time with some recommendation? We will check the status of the significant variables regularly and we wont think about changing unless we find wrong numbers. But what are we doing in checking these particular values? We are asking the oil how it feels. Many of us have large rotating machinery with very tricky gaps and clearances in the balancing pistons and thrust bearings, and many of us have probes there to check the clearance in operation. The patient tells you any minute it feels. This is predictive maintenance.

> All findings and all information we collect during the operation of an item from the item itself about status and condition, and all steps we take in response to these findings, we call predictive or condition based maintenance.

Fine, maintenance based on condition; our old manager used to put his fingertips on the casing of a turbine, and he could tell exactly what was wrong (he still believes he could). Naturally this is predictive maintenance, but with a plant costing half a billion dollars we should spend some money on monitoring equipment.

Before we start arguing about monitoring equipment we should find out what could be and what should be monitored. The possibilities for monitoring are ample and dear. For almost every task one can get very effective instruments today. These instruments are horribly expensive and we in our company are horribly incompetent in using of this equipment. First you need qualified engineers to start with predictive maintenance and then one should survey the market for possible instruments. Probably you expect now a statement about economy. Unfortunately in this special case I am absolutely convinced that every dollar spent on predictive maintenance has such a high rate of return that I don't calculate economy. We started with simple instruments and only when we got to the limit of these devices went for better appurtenances, and again had to start to learn the handling of these. The possibilities for predictive maintenance at present are as follows

- during operation
  - vibration monitoring
  - sonic tests
  - temperature monitoring
  - elastic deformation

- during standstill
  - nondestructive testing
  - visual inspection
  - plastic deformation

7.1 VIBRATION MONITORING

Every moving part vibrates. Even if we get totally perfect balanced rotors they will bend in some way in installation, thus giving a displacement of the centre of gravity resulting in a rotating force. Practically we have residual unbalances in our rotors and shafts, we have -some- misalignment, we have -very slightly- bent shafts, so definitely we have vibration. We all know the different vibration severity charts, which we can estimate the pemissible vibration from, dependent on speed, on the kind of equipment, weight of rotating masses etc. During comissioning the manufacturer probably will prove that the machine is running well within the limits. We get the manual where usually all details about vibration are put down. Sometimes with very large machines we are lucky enough to have permanent built-in vibration monitoring, with instruments indicating directly the amplitude of the vibration, with set values for alert and cutout, additionally giving readings about the displacement of the shaft in different directions. This of course is perfect predictive maintenance, if one can "read" the readings, and if the readings are recorded. Sets with automatic recording are available.

For the major part of our machinery this is wishful thinking and we will only check vibration when our fingertips give the alert, or when vibration is so terrible that our operators start complaining. Wonderful we have this nice monitoring equipment, we get a nice vibration curve, maybe we first have to consult the manual of the vibratometer how to use it, and definitely we will get peaks in the curve. But we won't know how to interpret and how to deal with our findings.

The problem is that we first have to get familiar with using the equipment, we have to train engineers for handling it, and we need the vibration pattern of the equipment in sound condition to get any results from our funny curves. All manufacturers of monitoring equipment I know, and I know some of them, will give you excellent manuals, not only about the instrument, but also about general questions of vibration, vibration monitoring and interpreting the readings. They all also have training engineers and for quite reasonable expenses one can get those gentlemen at site to explain the vibration monitoring equipment and have initial tests performed. Naturally they have the experts to identify the causes of difficulties with the equipment, but the most experienced expert can help you very little if he just gets one reading of one status of the equipment in an already unsound condition.

The main mystery about vibration is that we must know the behaviour of our process equipment in as many conditions as possible. In the ideal case we should record vibration from the very first startup and have regular recording at scheduled intervals. Usually we start with every week recording, and extend the intervals of sampling to those of the overspeed tests (of our turbines). The readings are recorded on charts or (the most way) in computers, and one can get an idea about the change in the properties of the equipment by comparing the different charts. The computer of course does this automatically. I must confess we are very oldfashioned, we have no computers.

Before we start to spend 10000 dollars we should try to get an idea about what we want and what is available on the market. First we have to know what is vibration and how do these instruments work, or what is the difference between an instrument costing $ 500 and one for $ 5000.

Important variables for vibration are the frequency (the number of events per time unit, or the rotating speed in radians per time unit, usually called omega) and the amplitude (the motion of the material). Our fingertips simply tell us that something is moving to and from and that it is moving very fast. But we do not have the sense to define the distance travelled and we cannot count the number of movements per second if they lie in a range of 50 cps. Electronic instruments can, they can at least count the number of events. Further we need a reference to the equipment, we want to know when or where in relation to the position e.g. of the rotor we get the maximum amplitude. Very easy we get a mark on the shaft, the keyphasor, and this is the coordinate from where we count each cycle from 0 to 2pi. The very first instruments, some 20 years ago, did nothing else than count the revolutions of the shaft by means of such a keyphasor (that might be any unsmoothness of the shaft, such as wedges, scratches or even a simple of chalk) and register the movement of the shell or casing in relation to our keyphasor. This gives a connection between shaft speed and shaft angle to displacement i.e. double max amplitude. Really the most modern instrument pickups work in a very similar way.

I apologise but I suppose we should try to remember a few things about our long forgotten physics. If we take a solid particle and get it moving in a regular i.e. cyclic way, it's going to vary its position in a coordinate system. If we plot this position versus time we get these nice goniometric curves such as sinus, cosinus etc. Usually one solid particle does not exist by itself, at least not in mechanical engineering, so we have adherent particles in all three dimensions of space. If all these particles move in the same way there will be no "event" between them. Actually the vibration theory of solid material shows that they tend not to vibrate in a uniform way; they like to form knots and maxima resulting in strain in the atomic structure of the molecules and these create the stresses that we want do avoid. By limiting the amplitude we can limit the stresses.

To move the particle from one side of the maximum amplitude to the other I need speed, and this velocity is achieved by acceleration. This acceleration is what we really are afraid of, for it gives us forces. For an effective vibration analysis we need the values of displacement (two times amplitude only for sin or cos curves) the velocity and the acceleration. To my understanding it is very easy to measure these values on stationary parts such as shells and casings. But definitely it is more difficult to measure the acceleration of a shaft with a speed of 200 revs per sec. Now let's remember our math lessons: by differentiating we can get velocity and acceleration from displacement, and by integrating speed and position from acceleration. Here the very differences between the sets of the different manufacturing companies start. It seems to be extremely difficult to get accurate acceleration from two times differentiated amplitude because high frequency noises become more amplified (they have higher factors) than the signal itself. The usual recommendation of the standardizing organisations is to measure velocity for vibration monitoring instead of displacement today. I would follow this advice for all equipment with higher speeds than the electric grid frequency, and of course for all accurate measurements such as for balancing etc. But even this vibration-speed is not accurate enough for very sophisticated high rpm machinery such as steam turbines, and companies recommend using acceleration monitoring for frequencies higher than 1 kHz. As I told you I like to procure the most expensive sets for vibration monitoring; I personally would head (not from the start) for a complete set that can measure displacement, velocity and acceleration.

A common objection against comprehensive instruments (apart from the price of course) is the difficult handling of terribly expensive sets, weighing several kilograms, with 15 to 20 cables hanging around in our compressor house. One can fabricate portable racks, maybe on rollers, that can be lifted by the cranes usually available with important machines. On these racks also the recorders - modern people use computers for recording- and the filters can be placed and with suitable equipment we can get printed charts right beside the machine. So what recorders and what filters?

The vibration pickups send electric signals to a register inside of the monitor. As we have no senses to receive such signals we need a display on an oscilloscope or we have to get the variables printed or plotted against time i.e. phase layer against our earlier mentioned reference keyphasor. This plot for me is nothing like a funny curve.

There are usually maxima in this curve and at the price of a mere sleepless night one might find that generally these maxima are related to the shaft speed. A very expensive way of measuring revolutions per second.

Every curve can be resolved into many cyclic functions (sin,cos) according to Fourier's analysis; this is what we call a spectrum. The only thing I remember about Fourier analysis is that I always tried to crib the terrible integrals from my neighbour during tests. So it is not very likely to perform these analysis by hand. Fortunately the sellers of monitoring equipment also don't like these integrals, and electrical engineers have developed very easy-to-handle instruments that do this job for us. These are the spectrum analysers, filters for our funny curve that split it into its components. These filters can be tuned in such a way that only one narrow band of the (unlimited) number of cyclic functions can pass at the set tuning, and this can be recorded. Then adjust next tune you'll get the next curve; usually only four or five curves will be important. Searching for the important frequencies may be a tedious job. Sets with automatic sweep are available; the instrument performs the tuning itself. Vector filters also can eliminate the influence of the runout, geometrical deficiencies of the shaft, by subtracting the vector of the moving shaft surface (only the part due to geometric ovality).

Also I have mentioned recorders and computers. Expensive pickup sets may have 15 to 20 connections for probe cables, so one can record 15 to 20 sample points at once. The direct processing of all readings of a very big machine with 20 probes may not be possible, and it might be advisable to store the probe readings on a recorder or in a computer and do the analysis of the readings later on. The computers can be used additionally to file the output of the filters. They can calculate and indicate the variations from one recording to the next. They can be set to prefixed maximum values, giving an alert when these setpoints are exceeded.

According to my opinion these very expensive, very effective instruments cannot and should not replace the very cheap and simple battery powered ones. The latter can be handled very easily, maybe by specially trained millwrights and technicians, maybe even by our maintenance manager. They can be carried around very easily they give simple readings and are well suited to finding out that something has changed. One should start to get experience with these simple instruments.

In the initial phase you should go for assistance by specialized companies who have the instruments and the experienced engineers to perform the most trickly jobs. This is the point where economy starts and we are very well calculating the cost for hiring a monitoring group for very special purposes against the expenses incurred if we ourselves purchase a special set, have our people trained, and use them for monitoring.

We have now a lot of curves, we have special frequencies with their amplitudes, and now we have to start to find out which part may produce this special vibration. Usually by some sleuthing sense one starts to check the frequency of the spectrum curves and try to correlate it to revolutions of components of the machine. I have never been lucky enough to find the most simple example that usually is presented in this connection.

You have an antifriction ball bearing for instance with 26 balls. Running speed is fifty cycles per second, internal diameter of the bearing race is 84.3 mm, ball diameter is 14.25 mm.

Speed of the race

omega = 2pi * n

v = r * omega   v = 0.0843/2 * 2 pi * 50

v = 13.2 meters/second

Velocity of the ball around its centre is half of this speed, because the outer race is fixed.

v = 6.6 m/s

Speed of the ball

omega = v / r   omega = 6.6/(0.01425/2)

omega = 929 radians per second

revolutions n = omega/2pi   n = 929/2pi

n = 148 rps i.e. cycles ps

If you find that these 150 cps are related to the frequency of one of your spectrum curves, it is one ball of your bearing that is causing trouble. Usually not the balls but the races get damaged. How often per second does a ball pass one special spot of our race?

velocity of our ball   v = 6.6 m/s

circumference of one revolution

s = pi * (d race + d ball)

s = pi * (0.0843+0.01425)

s = 0.31 meter

frequency n = v / s   n = 6.6/0.31

n = 21 rps i.e. cps

We got 26 balls, so we get 26 times 21 makes 554 events per second. Again if we find a frequency of about 550 cps in our spectrum we got the fault.

Unfortunately the problem never has been solved in such an easy way in my case up to now. Usually one has to go very thoroughly through the equipment, one has to calculate endless columns of speeds, and indeed it would be a good idea to calculate important cycles in advance and record them in our maintenance file. The greatest difficulties arise with gears when we get response from the teeth, modified by some geometrical deficiencies, by the back-lash, by some movement of gearwheels on the shafts where the pressure of the edge contact varies. In this case we will get unidentified sidebands and we will definitely need advice from the manufacturer.

Normally the big manufacturing companies can give you help very quickly and in a very effective way, if only they can get the necessary data. First they have the experts and also they have machines in service with many clients, and it is a fact that difficulties arise in the same way with several items of the same type. Sometimes they can give you advice even on the phone if it is possible to transmit a full picture of vibration to them.

Up to now we got no advice and very little help with vibration of the tubing and pipes. They are manufactured by ourselves and we can't go back to any supplier. In severe cases we had to add brackets and supports and even change the construction of lines themselves. But this is erection, not maintenance.

One problem left is the comparision of readings taken at different times. It is of paramount importance to take the sampling absolutely on the same spot every time. Therefore it is recommended to install in site probes in the equipment. There are special plugs available and you just have to link them up with extension cables. This is the main reason why predictive vibration monitoring is not used more widely. Our old motors, turbines etc. have not these probes installed. Without them the whole thing remains a little bit uncertain. For very large equipment it may be economical to install sensors during shutdowns.

The major part of the analysis gives uniform results for similar rpm, steam temperature, pressure, load etc. Sometimes the only explanation for changes in vibration is the ambient temperature. When we get increasing unbalance in an air compressor this is an indication for coating of impellers by dust. With a steam turbine it may announce silica deposits on the blades. One should check the quality of demin water very carefully. Once we simply found a loose anchor bolt causing an increase of amplitude. Changes in vibration pattern are mostly due to the process variables and not to the equipment itself.

Generally the assumption is accepted that fluctuations in vibration at a ratio of less than 2.5 are normal. If we get near a ratio of 4 we start investigations. A factor of 10 should be most alarming. These statements of course only can be a rough guideline. We have to follow the advice of the suppliers of the plant equipment.

7.2 SONIC TESTS

Gases and liquids passing through a nozzle may achieve sonic flow if the ratio of pressure inside to outside as above a certain minimum. These sonic waves might be in a frequency band to be received by the human ear. Then we don't need predictive maintenance. There is a leak somewhere. But very slight untightness will result in ultrasonic sound. This sound can be detected by ultrasonic detectors at a time one cannot hear that. Unfortunately these very small leaks tend to increase; specially if the temperature changes, as happens during a shut-down. It is most frustrating if with a brand new restored plant just starting production after four weeks' shutdown just one steam flange starts blowing. Naturally it will be on an holiday.

Before shutdown two technicians check every flange with the ultrasonic detector, we got one with earphones, but they are available also with soundmeters. All flanges with the slightest leakage are tightened up during the following overhaul.

The detection of one untight valve out of a series of valves also can be performed by this ultrasonic detector.

Another sonic test is said to be performed with nuclear power plants: the recording of crack-scraming. Crack propagation in metallic walls due to strain produces acoustic emissions. These can be recorded by special soundmeters and hopefully the vessel can be shut down in time. I am in the lucky position of never having heard this crack-screaming.

7.3 TEMPERATURE MONITORING

Temperature monitoring is important with all parts that operate at a limit temperature or are protected fr[illegible] overheating by refractory. Reforming tubes operate at limit temperature, and a few degrees overheating may decrease their lifetime considerably. Naturally there are people who can estimate the tube wall temperature just by watching (the people with the sensitive fingertips). I prefer pyrometers. These are optical instruments with a built-in reference light source. All dark bodies will give the same light spectrum at the same temperature. The light source inside of the instrument is a glowing wire that is projected onto the focusscreen as well as the surface of the tube. When the colour of both bodies is identical both have the same temperature. The adjustment of the colour of the glowing wire can be done either by varying the current (thus really changing temperature) or by a grey wedge (whereas the real temperature remains constant). The calibration is done in such a way that one can read degrees directly from a scale. I suppose everybody operating reformer tubes got such an instrument.

Refractory lined metallic walls operate at low temperatures. They may rupt long before they start glowing. A heat-sensitive varnish is a very reliable indicator of temperature. For different limit temperatures different pigments, i.e. different colours, are available. It simply changes its colour at a known temperature. Immediate steps to cool down the tubes or walls have to be taken.

The varnish is damaged once onverheated and the equipment has to be repainted after repair.

This varnish is terribly expensive and additionally will change its colour if we operate near the changing point for a long time. Infrared cameras and/or photometer can be used instead of the varnish. They won't give continuous information about temperature, but they give values of the exact temperature and the prints may be kept for records. This method is used specially with rotary kilns for cement production.

Naturally these infrared cameras or infrared radiometers may be used for all temperature reading of moving components.

Many other deficiencies with equipment will produce changing temperatures. Damaged insulations of cryogenic plants may be detected by portable resistance type thermometers, long before ice formation starts. Damaged suction valves on reciprocating compressors can be identified not only by spitting but better by measuring the increase, blocked steam traps by the decrease in temperature.

7.4 NONDESTRUCTIVE TESTING

With the availability of temperature resistant probes for ultrasonic test equipment we started to check wall thickness cracks etc. in our equipment even during operation. Again it is most important to take the readings at the very same spot every time. This method was proved with several sample pieces even against our boiler inspectors and we were able to extend inspection time of boilers for two years with regular ultrasonic tests performed. The limit temperature for the probe is 380 deg.C.

Nondestructive testing during standstill also can be placed with predictive maintenance if it avoids unnecessary dismantling of the item. It is performed to give us an idea about the status of the equipment without wasting working hours and spares for unnecessary handling.

7.5 VISUAL INSPECTION

All visual inspection is predictive maintenance. With our eyes we doe not dismantle the equipment and also we do not watch a pump for recreation but to find out something about it. In this place with this regard indeed I was thinking of fibre optics for inspection. These fibre optics really are the dreams of every maintenance man. If something is wrong with something I always desire to creep inside, I would like to become a tiny dwarf to enter the equipment through a nozzle or a gap. Fibre optics enable us to enter the vessel with our eyes. With proper cables one will get excellent observations. The cables have to be replaced frequently. If one third of the fibres are ruptured the glass fibre cable must be discarded. Internal surfaces of heat exchangers, boilers and vessels can be watched through instrument flanges with no need of cutting welds or unbolting high pressure manways. Naturally inspection only can be performed during standstill.

7.6 PLASTIC DEFORMATION

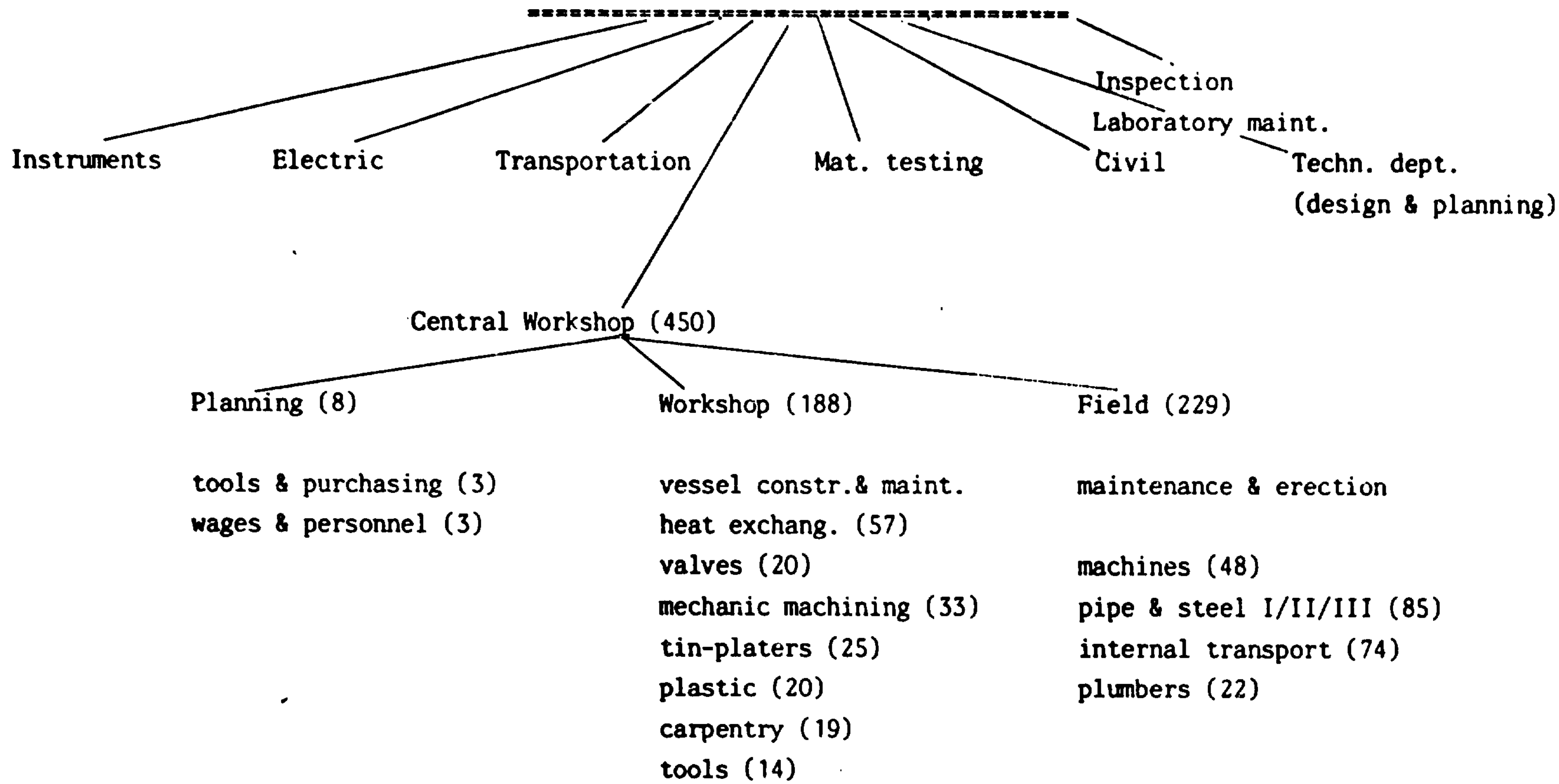
I want to come back to our furnace tubes. They have a scheduled lifetime of 70000 hours at a certain temperature and a certain pressure. After 70000 hours they should have expanded by two percent and this is the permissible limit for pressurised tubes. Did they really expand by that value? Is two percent really the limit for plastic deformation? So first we check the expansion during every stop and we have known for a long time that the rate of deformation is much lower than assumed at the time of design (we never operate at design temperature and at design pressure). So let's operate until a time when we will reach this two percent increase in diameter. We could operate for a further 12000 hours before the first tubes reached their lethal condition. The remaining question was whether it is really necessary to replace the tubes after reaching the preset value. Well we did replace one. And this one was checked by all means of material testing known to us. First we found out that the elasticity of the cast material (it is very poor) was still acceptable. Tensile strength and yield point were excellent. Micro finishing reveiled no sign of changes in the structure. So there was no objection to extending the lifetime of the tubing for another 12000 hours. The maximum expansion we reached until now was 16 percent increase in diameter. In this tube we found already circumferential cracks and it would have ruptured very soon. At present we are sure that we can go for 10 percent expansion without any risk in this very special case (no carbonisation) at the very special temperature (960 deg.C). At a lower temperature the tubes will behave differently, but the experience about influence of all limiting factors is what we call predictive maintenance. The manufacturers of tubes must not become nervous. We also damaged one set of tubes after 56000 hours by overheating with wrong temperature readings. The damage to the tubes was found out by regular checking of the expansion in diameter.

The benefits from predictive maintenance: we get fewer inspection jobs at scheduled shutdowns, better advance planning of shutdown work so well. Also I believe that we will get fewer breakdown jobs once our system really becomes effective. Even if I get only a few days margin to prepare an unscheduled shutdown we can perform a certain job less costly than during a cutout Friday afternoon. Additionally it is generally assumed that replacement of wornout components in time is less troublesome than repair of whole machine damaged by this single part.

So after several years, we won't need any engineers, all the jobs will be performed by monitoring equipment. Fine we all can go for holidays. Unfortunately this is not our future. The more sophisticated the equipment becomes, the better and more qualified engineers we will need. There will be a selection, a selection caused by the computers, and a selection by plant supervising facilities. A selection of better engineers, a selection that started a long time ago, the selection of the fit, of those who are ready to accept new methods, of those who are ready to learn new ways of maintenance.

The author, Karl Fink, is maintenance manager at CHEMIE LINZ, a European chemical industry; he is responsible for technical affairs, erection and maintenance. For further information contact LINZ CHEM-SERV, POB 296, A-4020 Linz/Austria/Europe.

AUXILIARY DIVISION T



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AUXILIARY DIVISION T

Civil department

Responsible for all civil work, planning, erection, maintenance, workforce 163 people
Head: Mr. Steinwender, Mr. Kincel

Electrical department

Responsible for all electrical affairs, bound to obey special mandatory rules, planning, erection maintenance, workforce 233 people
Head: Mr. Prinz, Mr. Salzmann

Central workshop

Responsible for all mechanical erection, certain part of maintenance limited to the tasks of the production related shops, mashine shop, internal transportation, workforce 410 people
Head: Mr. Riener, Mr. Deischinger

Technical department

Responsible for planning of investment projects and special maintenance jobs. Coordinates the planning sections of civil electrical and instrument department, workforce 65 people
Head: Mr. Rauscher, Mr. Weber

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LABORATORY MAINTENANCE

Instrument department

Responsible for procurement, installation and maintenance of instruments,
workforce 173 people
Head: Mr. Haas, Mr. Forsthuber

Inspection department

Performs all inspection jobs, responsible for cooperation with authorities, follows up all standards, regulation' and other restrictions implied by governmental rules (only for technical affaires),
workforce 18 people
Head: Mr. Lughofer, Mr. Mittermeier

Transportation department

Responsible for all external transports, road and rail, maintenance of mobile equipment,
workforce 176 people
Head: Mr. Webersinke, Mr. Roob

Two ways of maintenance

Corrective maintenance
Brak down maintenance: for electronic equipment
electric motors up to 5 KW
standard pumps
electric hand tools

Planned maintenance

Scheduled maintenance for newly erected plants with little experience about the equipment

Preventive maintenance for the large portion of our plants

Predictive maintenance has only just started in Chemie Linz AG

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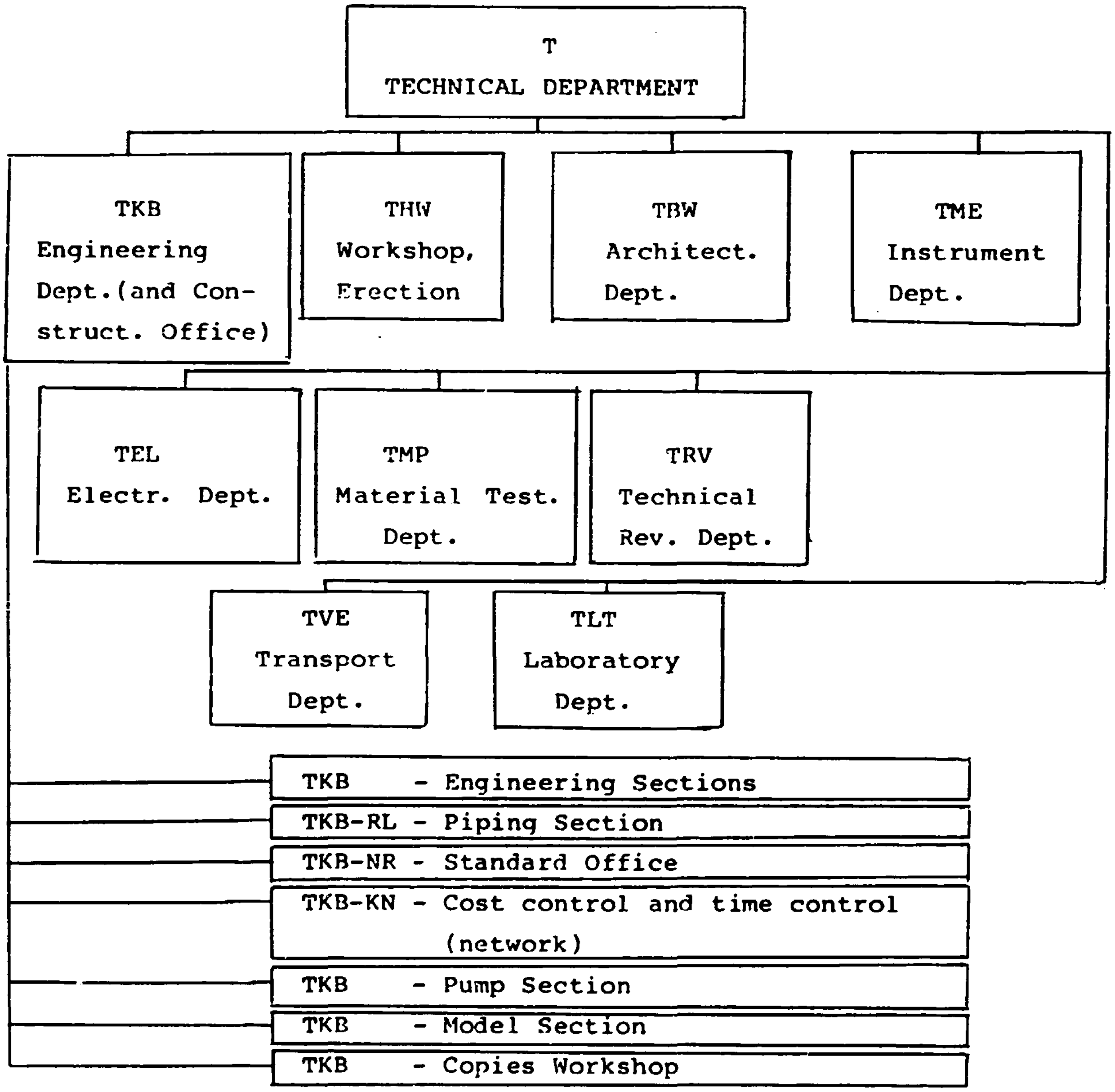
THE ENGINEERING DEPARTMENT OF CHEMIE LINZ AG is a section of the TECHNICAL DEPARTMENT (T)



ORGANIZATION SCHEDULE -- T E C H N I C A L D E P A R T M E N T

Managing Committee

↓

Planning Department

↓

Engineering Department

↓

Activities of the Engineering Department:

Basic Engineering

design basis (see CO2 liquefaction)
basis data of the process (e.g. melamine of urea guide)
process flow diagram (see CO2 liquefaction)
material balance
plot plan
process P and I diagram
time schedule (CO2 liquefaction and urea plant)
project medium key
description of the plant
list of motors and
specifications for the machines and apparatus (e.g. V - 340)
specifications for the instruments
data sheets (A/B 6)
costing for the project

Detail Engineering

P and I flow diagram (see CO2 liquefaction and instrument symbols)
quotation for machines, apparatus, pipes, etc.
orders for machines, apparatus, pipes, etc.
plant model
pipework isometrics
measuring and regulation (control) diagram
checking of the orders
checking of the workshop drawings
orders for erection
manual handbook
commissioning and test run
control of the project costs and control of the time schedule
(e.g. melamine plant, urea plant)

INSTRUMENT SYMBOLS

the letters mean:

	in first place	in second place	in third or subsequent place
A	analysis	alarm	alarm
B	conduction	controller	controller
D	specific gravity	-	-
E	-	element	-
F	flow rate	-	-
G	-	glass	-
H	remote control by hand	-	-
I	-	indicator	indicator
L	level	-	-
M	moisture	-	-
P	pressure	-	-
R	-	recorder	-
S	number of revolutions	circuit	circuit
T	temperature	-	-
V	viscosity	-	valve
W	weight	shell	-

plus:

d ... difference

h ... mech. thermometer

r ... proportion

pH ... pH value

Q ... counter

AH ... alarm high

AL ... alarm low

SCOPE OF SUPPLY FOR EXTENDED BASIC ENGINEERING

The following documents will be supplied according to a time schedule to be agreed upon for the procurement, construction and acceptance of the plant and its elements. All documents will be kept up to date and will be elaborated in German language (possibly English) according to the metric system (international system of units acording to DIN 1301). Symbols or designations shall correspond to Chemie Linz AG standards, to Austrian standards or DIN standards with respect to the Chemie Linz AG short designations. Documents will be submitted in the form of prints and one reproducible each.

P) Process Flow Diagram with quantities of the materials and their composition within the different phases of the process, operating data, thermal balance, consumption of raw materials and energy yields. Above data will be indicated for minimum, normal and maximum throughput description of the process.

b) Draft layout indicating platform loads (forces, weights and moments) and ceiling break throughs, according to which construction drawings can be prepared. Final installation drawings, foundation drawings, indicating weights, forces and moments.

c) Piping and Instrument Flow Diagram with all process and energy pipe networks comprising all machines, apparatus, fittings as well as measuring and regulating equipment. The diagram will be established in such a way that the relation between process flow diagram, installation drawings, model, isometrics and measuring and regulating diagram will be clearly shown. As far as possible the dimensions and levels of apparatus and machinery will be shown according to scale. Material data lists, media codes, classifications for pipework, fittings and seals.

d) Specifications (descriptions and dimensional sketches, data for the pipe connecting sockets, i.e. quantity, nominal widths and nominal pressure, material, static and dynamic loads, permissible loss, amounts of heat, temperature, pressure and the like) for all machines and apparatus including required steel structures herefore, if any, to permit relevant design drawings to be prepared and/or the equipment to be built. Workshop drawings with parts lists of equivalent documents with apparatus data or apparatus details for equipment which require special design.

e) Plant model on a scale of 1:25 (details possibly 1:10) consisting of structural framework with stairs, platforms and ladders, all apparatus and machines, pipe bridges, process and energy pipework, main routing of measuring and regulating lines as well as of electric cables.

f) Pipework isometrics with parts lists for all pipelines with fitting lengths in all three levels. Indication of sliding and fixed points and/or determination of pipe supports indicating static and dynamic values as far as they have to be specified by the engineering company. Determination of pipe connecting sockets on the apparatus in plan form with level indication. Provisional list of materials at the beginning of planning for the complete pipework including fittings and accessories. Specifications for special pipe material not yet included in the documents of Chemie Linz AG.

g) Specifications for insulation and painting of machines, apparatus, pipework and steel structures.

h) Measuring and regulating (control) diagram with specification list for the measuring and control devices with indication of nominal values, measuring and regulating (control) range and relevant permissible deviations, information on material coming in contact with the media as well as indication of physical values (pressure, temperature, density, viscosity, etc.) safety settings for the regulating and/or control fittings, interlock diagram and alarms for the instrumentation of process engineering. This documentation must be detailed enough to permit ordering of the corresponding equipment items.

i) Specification of electro-technical equipment.
Draft of distribution system (one-line diagram), provisional motor list, power mains and lighting facilities. Summary of critical points in regard to explosion proofing (drawing of explosion hazard zones) control and interlock and alarms.

k) Checking of our drawings and of technical order specifications for all plant equipment from the process engineering point of view.

l) Description of the plant, start-up and operating instruction, control and analysis procedures.

m) Commissioning and test run by competent persons of the engineering company.

TIME-TABLE FOR THE DELIVERY OF THE PARTICULARS FOR AN ENLARGED BASIC ENGINEERING

	months
Process Flow Diagram and process description -	......
Draft layout with waste gas and waste water particulars -	......
Final installation drawing one month after receiving the last particulars -	......
Simple Piping and Instrument Flow Diagram (Process P and I Diagram) -	......
Piping and Instrument Flow Diagram (P and I Diagram) -	......
Media codes, classifications for pipework, fittings and seals -	......
Provisional list of materials for the complete pipe material -	......
Specifications for equipments with longer terms of delivery (reactors, compressors, etc.) -	......
Specifications for equipment with the shortest terms of delivery -	......
Plant model -	......
Pipework isometrics with parts lists -	......
Specifications of the measuring and regulating devices -	......
Provisional motor list -	......
Draft of the electric distribution systems -	......
Plan for explosion and hazard zones -	......
Control and interlock diagram and alarms -	......
Start-up and operating instructions (operating instruction manual) -	......

ad. 1. PICKLING OF PIPELINES

a) Thrust through system

This method was used for the long pipes on the pipe bridges. There the pickling solution (e.g. hydrofluoric acid) was injected into a temporally limited water-flow.

b) Closed circuit system

This system was used for pipes temporarily connected to closed circuits. See fig. 1.
All valves were left installed.
Hoses, pumps, mixing tank with steam heating and some valves were contractor's account.

During the design of the pipes there should be a communication with the pickling contractor to set the right nozzles and flanges in the pipes for filling pipes with pickling solution. So you can pickle the pipes every time again after repairing the pipes.
Before asking a pickling contractor you should know the diameter nominal, length, volume and the inside surface of the pipes (area) you want to have pickled.

Before pickling all pipes ready have to be welded and water pressurized. If you had not done this before there would be new surface oxidation.

ad 2. PICKLING A NATURAL CIRCULATION BOILER

acts:

steam volume: 40 t/h
pressure: 42 bar
temperature: 450 oC
volume of the water tubes: 22,5 m3
(without economizer and superheater)

Pickling by the auto-circulation system

The performance procedures were the same as described for pickling the pipes with the closed circuit system.
To have the required pickling speed, air was blown through lances into the downcomers.
The auto-circulation is caused by inserting air-lances into the tubes. The lances were taken through the upper water drum into the tubes.

Pickling storage tanks (see fig. 2)

These tanks were pickled with a 4 - 5 % solution of cold hydrochloric acid.

Blowout of high-pressure steam pipes from the boiler to the turbine (see fig. 3)

After chemical cleaning, the pipes were blown out with steam which was generated in the boiler.
There we tried to achieve a high steam speed in the long pipe (400 m/s). So we had good mechanical cleaning.

Performance procedures at Chemie Linz AG

a) flushing with water

b) degreasing in addition with ion-neutralized solution.
t = 60 - 80 oC

c) pickling with a solution of 1 % inhibited hy(ofluoric arid.
t = 40 - 50 oC

d) stabilization with a 0,1 % solution of citric acid

e) passivation in addition with ammonia and H2O2 until the pH of effluent was 10,2

f) after drainage of the system the surface was dried and prssurized with nitrogen

The effluent solution was neutralized with lime (Ca(OH)2) to the required pH.

Time required

This procedure needed the following times (without preparation time):

flushing	- a)	some hours
degreasing	- b)	12 hours
pickling	- c)	5 hours
stabilization	- d)	14 hours
passivation	- e)	24 hours

STRESS ANALYSIS OF PIPING SYSTEM

Basic steps of calculation:

1. Procedure of design starts with making a freehand isometric piping sketch.

2. Spot preliminary locations of hanger or supports, locate hangers at or near any concentrated loads (heavy valves, risers,...). Pick up all horizontal bends, to prevent any excessive overhang. Hanger spacing must be close enough to prevent excessive sagging.

3. Study building steel.

4. Check for interference (pipes, constructions)

5. Calculate distribution of weight - important to obtain zero load at equipment flange.

6. Summarize hanger loadings.

7. Calculate distribution of expansion to hanger.

8. Calculate distribution of equipment movement.

9. Summarize movements.

10. Choose hangers or supports for loadings and movements.

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Pressure-vessels-according with the official Austrian Code in the view of the designer

1. Introduction

In chemical plants there are a lot of pressure-vessels necessary for carrying-out chemical processes with high pressures and temperatures. For protection of persons and surroundings the Austrian legislator has issued an official code which rules the construction, installation and service of pressure vessels. Therefore Chemie Linz must be in the position to check the vessels built by suppliers whether they are in accordance with the Austrian Code as well as to use the Austrian Code in case of repairing or building vessels by Chemie Linz in our own workshop.

The following explanations shall give a short summary of the general rules of the Austrian Code for pressure-vessels, as far as they are of especial interest for the designer.

2. Short Summary of the official Austrian Code

The Austrian Code is issued by the ministry of buildings and technics. This Code regulates as mentioned, the construction, installation and service of pressure-vessels.

For the designer are of especial interest:

Nr. (1) validity of the official Austrian Code
Nr. (2) materials
Nr. (3) Calculation and design
Nr. (4) Equipment
Nr. (5) manufacturing and inspection
Nr. (6) supervision and approval

And now the above mentioned points shall be couridered some what particularly.

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2.1 Validity of the official code

The aim of the Code is the protection of persons and surroundings. This means for pressure vessels especially with regard to design fabrication acid equipment that they have to withstand safely the allowable pressure and allowable temperature and to withstand stesses as to dangerous reactions of the substances. They have to be built of appropriate materials and have to get proper equipment.

Design, construction, testing and service of pressure vessels need the working together of the manufacturer the independent expert and the plant management.

In accordance with the code the pressure vessels are classified in 3 main groups: (see table 2)

1. steam boilers
2. steam vessels
3. pressure vessels

3.1 Group I: not moveable vessels

3.2 Group II: moveable vessels for transport

For each of these groups there are official determinations depending mainly on the mechanical dangerous patential, which is expressed through the capacity and pressure, that is the pressure-capacity-result in bar liter, further depending on the handled substances determined limits on the pressure vessels have to be built fully in accordance to the official code and underlie the duty of official approval and supervision.

The main limits therefor-official approval or not are shown in table 1:

For example there is no official approval necessary for steam-boilers (see table 1, Nr.1)

if (1) the pressure is less or equal 0,5 bar

or (2) if the pressure lies between 0,5 bar and 1 bar and the capacity is less or equal 50 000 l

or (3) if the pressure exceeds 1 bar the pressure-capacity result must not exceed 20 bar l.

Below the above mentioned limits there is no official approval necessary, beyond the limits official approval is necessary.

For steam-vessels (see table 1,Nr.2) the limits are similar as for boilers, but the result pressure times capacity is higher (300 bar l instead of 20 bar l).

For pressure-vessels with compressed or under pressure liquefied gases there are the main limit noted under Nr. 3 of table 1.

2.2 Materials

It must only be used approved and tested materials with guaranteed properties in accordance with the conditions of the code.

The producer of the material needs the first time recognition and approval of the authority befor beginning with production. The producer of the material must prove, that he has the technical equipment and personell that enables him to produce the materials in accordance with the Code and further, that he has the equipment for the testing of the material.

Welding materials must also meet the demands of the code.

Materials, which have proved on basis of the code during a long time are listed in Austrian standards or material sheets of the TÜV.
(TÜV = Austrian Inspection Authority "TÜV")

Other materials or materials beyond the limits of the standards or new developed materials need an individual approval by the authority.

Materials must only be used with certificates of recognized organisations, the material must be stamped or marked for control purposes.

The selection of materials for pressure vessels or of parts of pressure vessels results with regard to the expected mechanical or thermal loads, with regard to possible chemical influences and with regard to the consideration of fabricaiton, especially welding and heat-treatment.

2.3 Calculation and design

The pressure vessels have to be calculated and designed according with the formulas and rules of the Code. The calculation is accomplished with global formulas.

If for special cases no rules are available in the Austrian-Code-then rules of other codes-mainly german-are accepted by the authority.

In the calculation of the well-shickness here must be taken into account the pressure, temperature, allowable strasses, joint officiency, allowances, especially the corrosion-allowance for chemical service and of course the geometric dimensions of the part.

Some rules for calculation:

Design-pressure must be higher than the operating pressure under consideration of static pressures and the possible lower pressure at the beginning of flowing-off of the safety-valve. Therefor the design pressure should be minimum 10 to 15 % higher than the operating pressure.

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Test-pressure is usual 1,5 times the design-pressure, in some cases 1,3 times the design-pressure, but minimum design-pressure plus 1 bar. For special substances the test-pressures are higher as the mentiones values (e.g. for ammonia minimum 25 bar)

Design-temperature for fired vessels it is a minimum of 250 centigrade (degree Celsius), but minimum the temperature of th fluid and additional 25 to 65 contigrade depending on the kind of heat-transfer.

For unfired vessels the design-temperature is at a minimum the temperature of the handled substances.

Allowable stresses:

The safety-coefficients are ruled by the code depending on different limits for the strength with regard to the temperature.

For example: There must be taken in account 5 safety-coefficients for steels at higher temperatures and of course, the lowest allowable stress determins the calculation.

Normally the engineer thinks of the safety-factor in the ratio of the characteristic strength limit of the material and the actual stress in the part. It shall be mentioned that realy the safety-factor has more to cover, e.g. deriations in the behaviour of the material, especially as to fabrication (e.g. in the heat-influenced zone), simplified calculation methods and global calculation models, deriations in the conditions of service, tolerances and deriations of the actual part from the designed part (e.g. deriations of shape) and other uncertainties.

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Joint-efficiency

for welded seams is usual 0,8, but also efficiencies up to 1 are possible with the permission of the authority and under special fiebrication conditions (e.g. then the seams have to be checked totaly 100 % by x-rays or super sonics).

Corrosion allowance

is a minimum of 0,75 mm, but must be more for corrosive service. It can be unconsidered, if the material is resistant against corrosive service or if the basic material (mostly carbon steel) is lined or claded with corrosion resistant material e.g. stainless steel, nickel, copper and so on or if it is protected with special coats e.g. plastics-coats (but simular paint is not accepted as such resistant coat).

The selection of the material as to corrosion is done in close connection with our department for testing of materials, (T-MP) which has a longtime experiance with our plants.

The calculation must be done for the pressure stressed parts. Those are mainly cylindrical and conical shells, dished heads - which are mostly elliptical or spherical shaped - plain covers, tubesheets, flanges, bolts, openings in shells and dished heads, tubes, safety-valves and so on.

For some parts of pressure vessels Chemie Linz has available calculation programs for calculation by the electronic computer of Chemie Linz.

Before beginning with fabrication at supplier's or Chemie Linz workshop the drawings and computations must be checked and approved by the recognized authority (TÜV at Chemie Linz).

2.4 Equipment

The minimum equipment is ruled by the code and checked by the official authorities.

For example: Minimum equipment for pressure-vessels, group I (not moveable) There is necessary at a minimum.

(1) 1 safety-valve

(2) 1 pressure-gange with red mark for allowable highest pressure

(3) 1 drawing-device at the lowest point

(4) 1 fabrication-plate

(5) 1 Inspection-opening (manhalc), below 800 mm, vesseldiameter: handhole or simular openings)

2.5 Manufacture and Inspection

Only manufacturers are permitted, whose workshops and personnel is examined. The workmanship is pamanent checked by the official recognized authority.

For example: Welders have to repeat their examination within at least one year. They loose their qualification if they interrupt their work for a longer time than 3 months.

The welding seams on the pressure-vessels have to be checked total or partly by X-rays or supersonics.

The manufacturer of pressure vessels must have at least a welding qualification class 2 according with Austrian standard ÖNORM M7812, part 2. Therefor the manufacturer needs a foreman for the welders. But for vessels with higher demands e.g. vessels with poisonous or etching substances or vessels for liquified and inflammable gases beyond 1 000 l capacity or pressure-capacity-result more than 50 000 bar l the fabricator needs the qualification class 1 and a welding-engineer.

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After fabrication of the vessels, there is required a hydrostatic test with water at soon temperature, in extraordinary cases, testing can be done with other liquids or gases, too.

These tests are to be repeated after installation and by the code determined periods of servece.

2.6 Supervision

Supervision is done by the official permitted authorities, usually TÜV at Chemie Linz or recognized foreign authorities for delivery from a foreign country.

The contact-department at Chemie Linz is therefor our technical-revision (T-RV).

Supervision begins with the first drawings and calculations of the vessel and ends with the taken-out of action.

3. Final there is to notice that - belonging to the higher demands of pressure vessels under the rules of the Code - there are also higher requirements for the manufacturer and the plant management with regard to equipment for fabrication and inspection, qualified personnel and organization.

Table 1. General view: Validity (classification, acceptance)

Classification of the pressure-apparatus and short-characterization		No official acceptance is necessary if (p = pressure in bar) (V = capacity in litres l)
1. <u>Steam-boilers (mostly fired)</u> In these vessels steam is generated and used <u>outside</u> of them.		(1) $p \leq 0,5$ bar (2) $0,5$ bar $< p \leq 1$ bar and $V \leq 50\,000$ l (3) $p > 1$ bar and $p\ V \leq 20$ bar l
2. <u>Steam-vessels</u> Steam comes from outside into the vessel or the steam generated in the vessel <u>must not</u> flow out.		(1) $p \leq 0,5$ bar (2) $0,5$ bar $< p \leq 1$ bar and $V \leq 50\,000$ l (3) $p > 1$ bar and $p.V \leq 300$ bar l
3. <u>pressure-vessels</u> Vessels with compressed or under pressure liquefied gases	3.1. <u>Group I:</u> not moveable vessels	(1) $p \leq 1$ bar (2) 1 bar $< p \leq 3$ bar and $p.V \leq 300$ bar l (3) for air and some other gases 1 bar $< p \leq 10$ bar and $p.V \leq 3000$ bar l
	3.2. <u>Group II:</u> moveable vessels for transport	special conditions

1. The table gives only a general view. Beyond that there are still some exceptions depending on the kind of construction and substances.

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CHEMIE LINZ MELAMINE PROCESS

PROCESS DESCRIPTION

Melamine, a raw material for the plastic industry, need to be produced from calcium cyanamide via dicyandiamide, but is now mainly produced from urea.

Chemie Linz AG succeeded in developing a continuous process at atmospheric pressure for the production of melamine from urea, thus achieving technical progress and solving all problems satisfactorily.

The Chemie Linz AG Melamine Process operates at atmospheric pressure. The formation of melamine proceeds - in the same way as with all other processes starting from urea - according to the overall equation

$$6\ CO(NH_2)_2 \longrightarrow C_3N_3(NH_2)_3 + 6\ NH_3 + CO_2$$

The reaction is endothermic.

The melamine is produced in two steps. First, urea is thermally decomposed into an equimolar mixture of isocyanic acid and ammonia:

$$CO(NH_2)_2 \longrightarrow HNCO + NH_3$$

H = + 780 kcal/kg urea (solid), endothermic reaction.

This gas mixture is diluted with additional ammonia and fed to a catalytic reaction. During this second step the isocyanic acid is converted into melamine and carbon dioxide.

$$6\ HNCO \longrightarrow C_3N_3(NH_2)_3 + 3\ CO_2$$

H = - 714 kcal/kg melamine, exothermic reaction.

These separate process steps permit carrying out each reaction within the optimum temperature range. Consequently the formation of unwanted by-products is reduced to a minimum; and a recrystallization is not necessary.

The first reaction takes place in a heated fluidized sand bed. There is practically no abrasion and therefore the reaction gases need not be filtered. The second reaction is effected in a fixed catalyst bed. There is no contamination of the product gases due to catalyst dust. Such contamination would necessitate filtration and crystallization. The reaction heat is used for preheating ammonia. The melamine formed in the catalyst bed is gaseous at reaction temperature. It is condensed in a subsequent cooler, where melamine crystals are formed in an aqueous suspension. The remaining components of the reaction gas mixture can thus be separated from the suspension very easily.

The melamine can be easily separated from the mother liquor by a centrifuge or a filter. Due to this wet separation and the subsequent drying melamine with high bulk density is obtained. High bulk density is an advantage for storage, transport and further processing.

According to the overall equation 2.86 tons of urea are theoretically needed for the production of one ton of melamine with 0.81 tons of ammonia and 1.05 tons of carbon dioxide as by-products.

As the formation of melamine from isocyanic acid has a yield of 91 - 95 %, 3.1 tons of urea are required to produce one ton of melamine in practice.

The unreacted isocyanic acid is hydrolized into ammonia and carbon dioxide or formed into urea.

PROCESS DESCRIPTION OF A MELAMINE PLANT

If the urea to be treated is available in solid form this is first melted with steam (1,2). If urea is available in liquid form there is of course no need to melt it. The melt is delivered to the decomposer (3) by pumps. The heat required to decompose the urea is obtained from a circulation salt bath which is maintained at the right temperature. The reaction takes place in a sand bed reactor, fluidized with hot ammonia. In the decomposer (3) a gas mixture, consisting of isocyanic acid and ammonia, is formed. This is delivered to the catalyst reactor (5), where the isocyanic acid is converted to gaseous melamine, and carbon dioxide is set free. The reaction heat is used to preheat ammonia.

The mixture of gaseous melamine, ammonia and carbon dioxide goes to the separator (6) where fine crystalline melamine suspended in water is obtained by direct cooling.

Due to extraction of heat by water evaporation the separation gases entrain water vaporous. A great part of this water vapour is condensed in the following off gas cooler (7) and returns to the separator (6). The off-gas is sent to the off-gas treatment unit.

The suspension from the separator (6) is pumped into a collecting tank (8) and cooled via cooler (9), whereby part of the dissolved melamine crystallizes out.

The suspension is pumped to the centrifuge or filter (10) where melamine crystals and liquid are separated. The mother liquor is recirculated to the melamine separator where it serves as a cooling agent.

To obtain the desired moisture in the final product the melamine from the centrifuge or filter is dried in drier (11). The cooling zone in the drier cools the melamine so as to be suitable for storage.
The sieve (12) and mill (13) beyond enable removal of agglomerates formed in the drier.

The product from the drier is ready for sale. It is weighed (14), bagged and stored.

Off-gas utilization

The off-gas consists of carbon dioxide, water vapour, inert gases and a lot of ammonia. The major part of this ammonia was fed to the catalytic reactor in the synthesis for the fluidization. The minor part was set free during reaction.
There are different alternatives available for utilizing the off-gas and mother liquor economically.

The following possibilities may be mentioned:

a) Separation and return of the ammonia from the synthesis and absorption of the residual off-gas to produce an ammonium carbonate solution. This carbonate solution can be delivered to fertilizer plants for conversion into ammonium nitrate, ammonium sulphate or ammonium phosphate.

When passing this ammonium carbonate solution to an urea plant consideration should be paid to the fact that the hight percentage of water reduces the efficiency of conversion into urea.
An improvement is obtained through conversion of the ammonium carbonate into an ammonium carbonate solution, thus reducing the water rate.
A better alternative would use a process, developed by Chemie Linz and used in serveral plants.

b) Obtain an ammonium carbonate solution as in a) above and separate this into ammonia, carbon dioxide and water, with only marginal increase in investment and utility requirements. Thus the melamine plant is independent of any other plant because the pure ammonia can be exported in liquid form or used anywhere.

PROCESS DESCRIPTION OF AN OFF-GAS TREATMENT UNIT

The off-gas goes to the ammonium carbonate column (=NH3-separation, 21) where CO2 is washed out forming an ammonium carbonate liquor supersaturated with ammonia. The surplus of ammonia is cooled and dried with liquor ammonia on the top of the column. The bulk of this ammonia is compressed (16), preheated (4) and returned directly to the melamine plant for re-use. A small part of this ammonia stream is further compressed (17), liquified (18), separated from residual inert gases and fed to the top of the ammonium carbonate column (21).
The balance of the ammonia gas obtained at the top of the column (21) leaves the plant and is available for further use in other units. This quantity corresponds to the ammonia produced during the melamine synthesis.

The ammonium carbonate solution is stripped off from the free ammonia in the NH_3 stripper (15) and delivered to the lower stage of the CO_2 stripper (19), which operates under elevated pressure. In the lower steam-heated stage the ammonium carbonate solution is decomposed. In the upper stage the NH_3 is scrubbed with water and the pure CO_2 leaves the plant for further use. The ammonia water obtained in the sump, which still contains slight amounts of carbon dioxide, transfers its heat in the NH_3 CO_2 stripper (20). A high proportion goes to the ammonium carbonate column (21). The remainder is decomposed in the NH_3 CO_2 stripper (20). Gases expelled in this column are recycled to the ammonium carbonate column. The separated water can be used as washing water or purged.

CONSUMPTION FIGURES PER TON (METRIC) OF MELAMINE

Consumption		Expected	
Urea (100 %)		3.10	t
NH3 liquid		0.3	t
Process water (condensate)		1.2	t
Catalyst			
(2 years' life)		2.5	kg
Electric power	6 kV	500	kWh
	500 V	280	kWh
Fuel		14.4	Gj
Steam	15 bar	3.0	t
	6 bar	4.0	t
Cooling water	15 oC	800	m3
Nitrogen	5 bar	40	Nm3
Instrument air		40	Nm3
Compressed air		400	Nm3

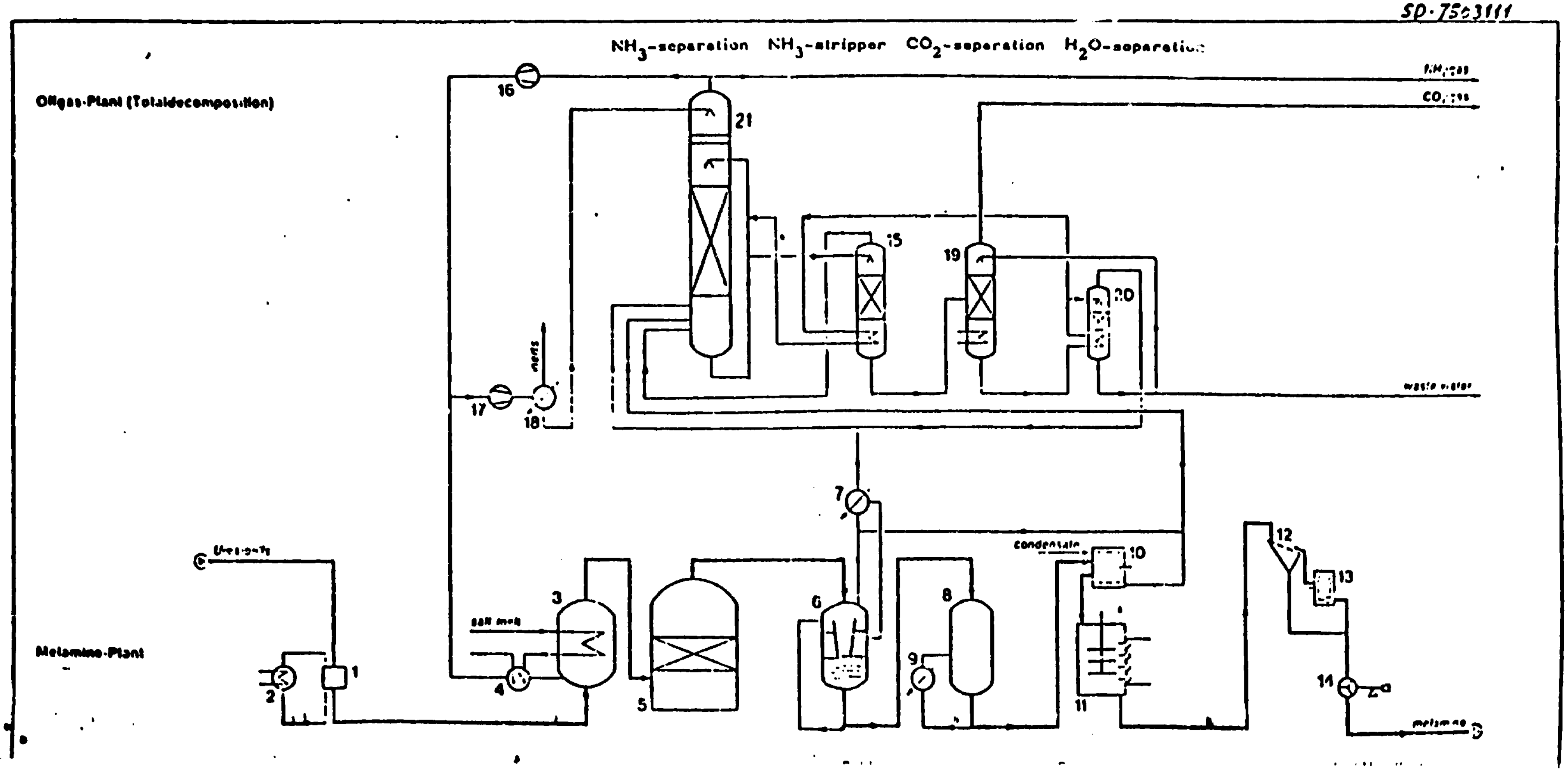
Credit			
NH3 gas	1 bar	1.2	t
CO2 gas	20 bar	1.1	t
Condensate		5.0	t

Effluent		
Mother liquor from recrystal	0.03	m3
with 1 kg melamine		
20 g NaOH		
90 g Na-ammelide		
	0.03	m3
Cooling water	800	m3

CHEMIE LINZ-MELAMINE PROCESS

1. Melt vessel
2. Circ. heater
3. Decomposer
4. NH_3-preheater
5. Contact furnace
6. Separator
7. Recooler
8. Collecting vessel
9. Circ. cooler
10. Centrifuge
11. Drier
12. Sieve
13. Mill
14. Scales
15. NH_3-Stripper
16. NH_3-compressor
17. NH_3-compressor
18. Condenser
19. CO_2-separation
20. H_2O-separation
21. NH_3-separation

SD-75c3111



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Design basis for Urea plant 1000t/day

1. Location of the plant

1.1. Location: Linz

1.2. Basline altitude over see:

253,80 m above Adrive = works hight +0,00 = street

2. Climate

2.1 Rain and snow fall:

max. 180 l/ha, sec. during 15 min. (1 ha = 10 000 m^2)

		max.
Raindensity	(mm/h)	26,5 (mm/h) during 20 min.
Snowhight	(m)	17 cm/day
Snowload	(kg/m^2)	75 kg/m^2

2.2 Air temperature:

middle temp. during a year: 10 °C
warmest month (July): 35 °C
coldest month (Jannuary): - 20 °C

middle temp. during a day: summer max + 27 °C
winter min - 14 °C

moisture of the air: max. 100 %
min. 18 %
middl. 72 %

2.3 Wind and air pressure:

2.3.1. <u>main direction of the wind (in %):</u>

NW	33,1 %	E	8,2 %
W	18,4 %	N	6,9 %
SE	17,8 %	S	4,4 %
NE	8,7 %	SW	2,5 %

2.3.2. <u>kind of air in this area:</u>

Industry air

2.3.3. <u>Wind velocity and pressure (max):</u>

0 - 6 m:	v = 28,2 m/s	9 = 50 kg/m^2
6 - 8 m:	v = 32,2 m/s	9 = 65 kg/m^2
8 - 20 m:	v = 35,8 m/s	9 = 80 kg/m^2
20 - 100 m:	v = 42,0 m/s	9 = 110 kg/m^2

middle wind velocity: 2,5 m/s

2.3.4. <u>Air pressure:</u>

normal:..... 738 mm Hg
min.: ..... 711 mm Hg
max.: ..... 760 mm Hg

2.4. <u>Underground water level:</u>

highest level about + 247,5 m over see

2.5. <u>Frost point:</u>

0,90 m under ground

3. **Architecture basis:**

3.1. **Limited building hight:** no

3.2. **Freebord under piperacks:** 4,8 m

3.3 **Earthquake force:** 0,005 g

4. **Energies:** (utilities)

4.1. **Steam:**

4.1.1. **Kind of steam:**

pressure (bar)			temperature (°C)		
normal	max.	min.	normal	max.	min.
6	7,2	5	200	250	160
22	25	21	230-260	300	(216-230)

4.2. **compressed- and instrument air, nitrogen:**

	pressure (bar) max.	min.	temp. (°C)	Moisture
Instrument air:	7,4	6,6	20	-
compressed air:	4,5	2	20	until 100 %
nitrogen:	4,5	2,5	20	30 g/Nm^3

4.3. Electrical energy:

	tension	numbered of phases	Frequent
Engine 160 KW	6 kV	3	AC 50 Hz
Engine 160 KW	500 V	3	AC 50 Hz
Lights	380/220 V	3/Mp	AC 50 Hz
Control tension	220 V	2	AC 50 Hz
Instruments	24 V	2	AC 50 Hz
Signal devices	24 V	2	DC
Magnet valves	24 V	2	DC
hand tools and hand lights	42 V	3,2	AC 50 Hz

electric protection standards:

6kV - net :

500 V net :

380/220 V net :

42 V net :

220 V - control tension:

lightning protection :

4.3.1.

4.3.2. Electrical instalations are under ground, under floor or on piperacks (it depends of kind of using).

4.4. Wast water:

4.4.1. Wast waters (Rain, cooling water and plant water) are drained:
canal: concret, not resistent against acid canal sole + 249,5 m

4.5. Water: river water (cooling water)

./5

4.5.1. Physical data:

Net-pressure :	normal	2,2	bar
	max.	3,3	bar
	min.	1,6	bar
Temperature :	max.	21 °C	
	min.	2 °C	

water temperature after heat exchanger: max. 40 °C

allowed cool water heat-up: $\Delta t < 15$ °C

$\Delta t \geq 15$ °C inspecial cases after discussion.

Fouling-factor:

for wall temperature (water side): ≤ 50 °C : $2 \times 10^{-4} \frac{m^2 h\ °C}{kcal}$

> 50 °C : $4 \times 10^{-4} \frac{m^2 h\ °C}{kcal}$

4.5.2. The cooling water lines installation (under or over ground) depends on the using case.

4.5.3. Water analysis (industrial water)

pH	8,0
conductivity	263.10^{-6} skm
free CO_2	2 mg/l
O_2	6,7 mg/l
alkality	2,5 mval/l
hardness	8,6° d.H.
carbonat hardness	7,1° d.H.
rest hardness	1,5° d.H.
MgO	19,4 mg/l
CaO	58,8 mg/l

evaporating wast at 150 °C	214 mg/l
glowing wast at 650 °C	122 mg/l
$KMnO_4$	19 mg/l
Fe	0,31 mg/l
SiO_2	3,9 mg/l
HCO_3	156 mg/l
NO_2	0,08 mg/l
NO_3	14 mg/l
Cl	9 mg/l
SO_4	29 mg/l
P_2O_5	0,19 mg/l
NH_4	0,12 mg/l
Na	6,6 mg/l
K	4,0 mg/l
suspended metter max.	12 mg/l (can be higher for short time)
normal	3 - 4 mg/l

4.6. Boiler feed water:

pressure: min 3 bar
max 6 bar
Temp. max 90 °C

5. Raw materials:

5.1. liquid ammonia:

5.1.1. pressure: max. 13 bar
normal 10 bar
min. 8 bar

5.1.2. Temperature: max. 25 °C
normal 0 to + 10 °C
min. - 15 °C

5.1.3. Analysis:

NH_3	99,8 + 99,9	weight - %
H_2O	0,02 + 0,10	weight - %
S	1 ppm	normal case
	2 ppm	brache down case

Oil and Fe little amount
rest gases 200 to 400 Nml/100 g NH_3 (liquid)

analyses of rest gases

CO_2	10 + 20	volume %
H_2	20 + 30	volume %
CH_4	25 + 35	volume %
N_2-Av	25 + 35	volume %

5.2. CO_2 - gas:

5.2.1. pressure : 0,1 bar

5.2.2. temperature: max. 40 °C

5.2.3. analyses:

CO_2	max. 99	min. 90 volume %
Inert gases:	max. 10	min. 1 volume %

a) at max. 10 volum % inerst gases:

H_2	60 - 70	vol. %
N_2	25 - 33	vol. %
Ar + CO	3 - 7	vol. %
CH_4	2 - 3	vol. %

b) at min. 1 vol. % inert gases:

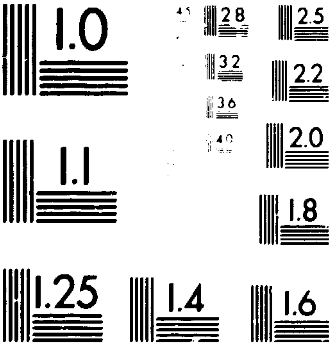
H_2 90 vol. %
N_2 10 vol. %

H_2S max. 1 mg/Nm^3 CO_2 (normal case)
2 mg/Nm^3 CO_2 (trouble case)

H_2O - saturated (0,1 bar, 40 °C)

6. diverse:

6.1. max. noise: 85 dB (nearer than 1 m to the engine)



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

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Inspections adviced by Austrian law, which are done by T/RV

1. Steam boiler (generator):

These are vessels closed on all sides, which are producing vapors with a pressure higher than the atmospharic pressure, the vapors are used outside the vessel.

p x v > 20 (1 bar) at p> 1 bar

2. Steam vessel:

These are vessels in which vapors are produced by chemical processes or in which vapors are dilivered to start chemical processes.

p x v > 300 (1 bar) at p> 1 bar

add. 1. and 2.

Before starting manufacturing the calculations and drawings are checked by the TÜV.

After manufacturing the TÜV control if the vessel is exactly made like the drawing and if the right, checked materials are used.

After this a water-pressure test is made, sometimes nondestructive testing are done by the TÜV.

If all the test are positive, the TÜV will give his stamp on the vessel-sign and the TÜV also write a Steamboiler or steamvessel certificat.

Before start up it is necessary to check if all the adviced equipments are installated and if they are functionable.

./2

Equipments for steam boiler:

2 Water level indicators (one must be a water level indicating glass)

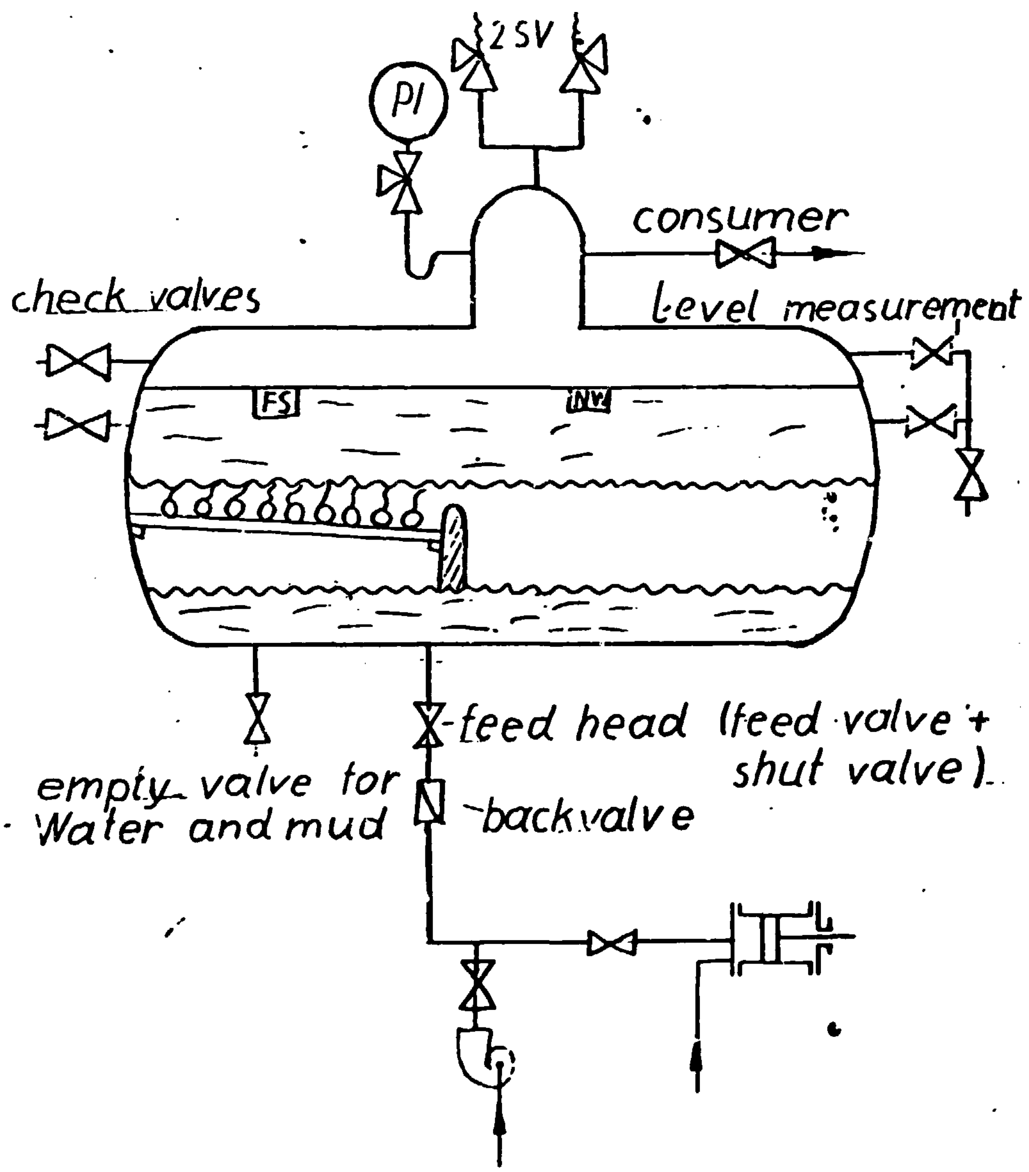
2 Safety valve (they must blow down at the highest allowed working pressure (release pressure) and they must be able (together) to blow down whole the vapor which is produced in the vessel, without increasing the working pressure more than 10 %.

1 steam pressure indicator

1 water level mark (which shows the lowest allowed water level)

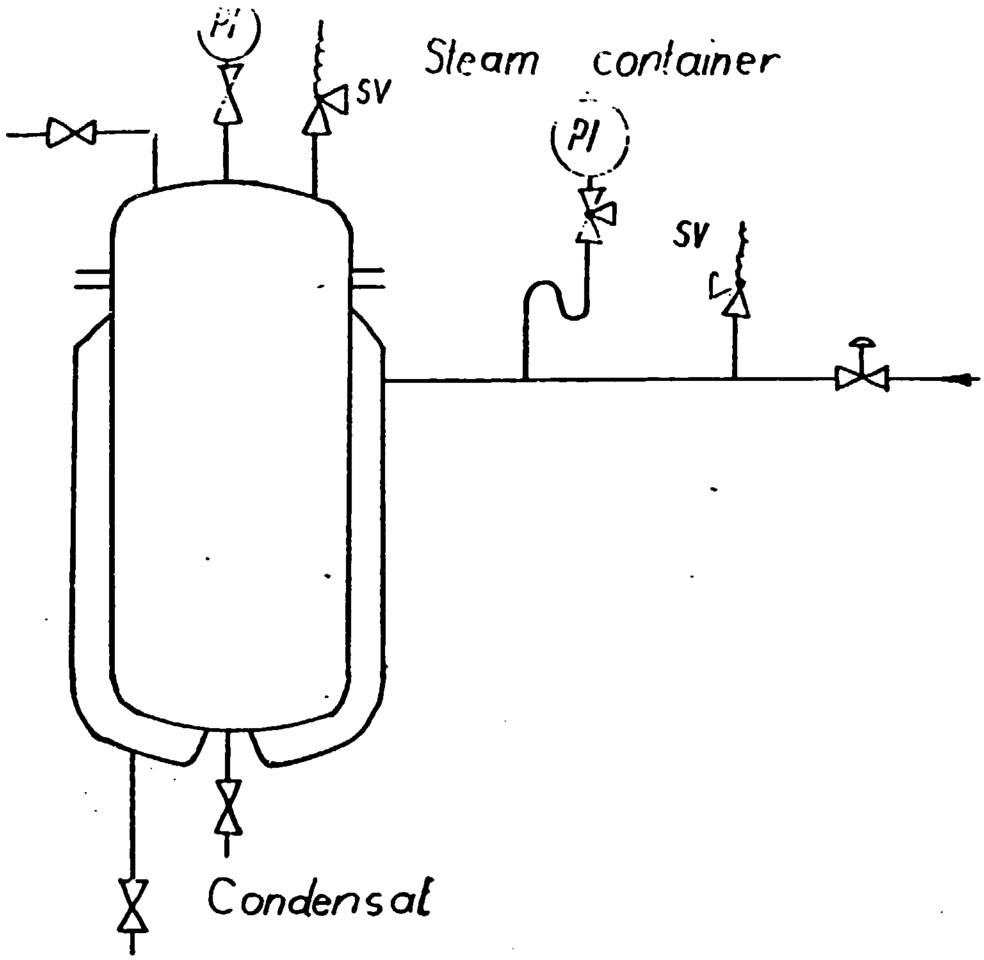
1 manufacturer sign with name , place, number, year of manufacturing and highest allowed steam pressure.

Other devices you will see at the sketch.



Equipments for steam vessels

Each room need a pressure indicator and a safety valve.
Ather devices you will see at the sketch.



Inspection intervalls of steamboiler and steam vessels

inside inspection:	all 3 years
main inspection:	all 6 years
outside inspection:	every year between main and inside inspection.
main inspection:	inside inspection + outside inspection + water pressure test.
outside inspection:	main points are the equipment and their function.

3. Pressure vessel (tank)

a) stationary pressure vessels:

Vessels in which compressed gases or liquified gases are stored (in pressure higher than 1 bar).

p x v 300 (1 bar), with p max = 3 bar by pressure vessels in general.

p x v 3000 (1 bar), with p max = 10 bar by pressure vessels for compressed air, nitrogen or inert gases.

Equipment: pressure indicator and safety valve

Inspection intervalls:

Inner inspection: all 3 years (pressure vessels in general)

main insepction: all 3 years (pressure vessels in general and vessels for; compressed air, nitrogen and inert gases)

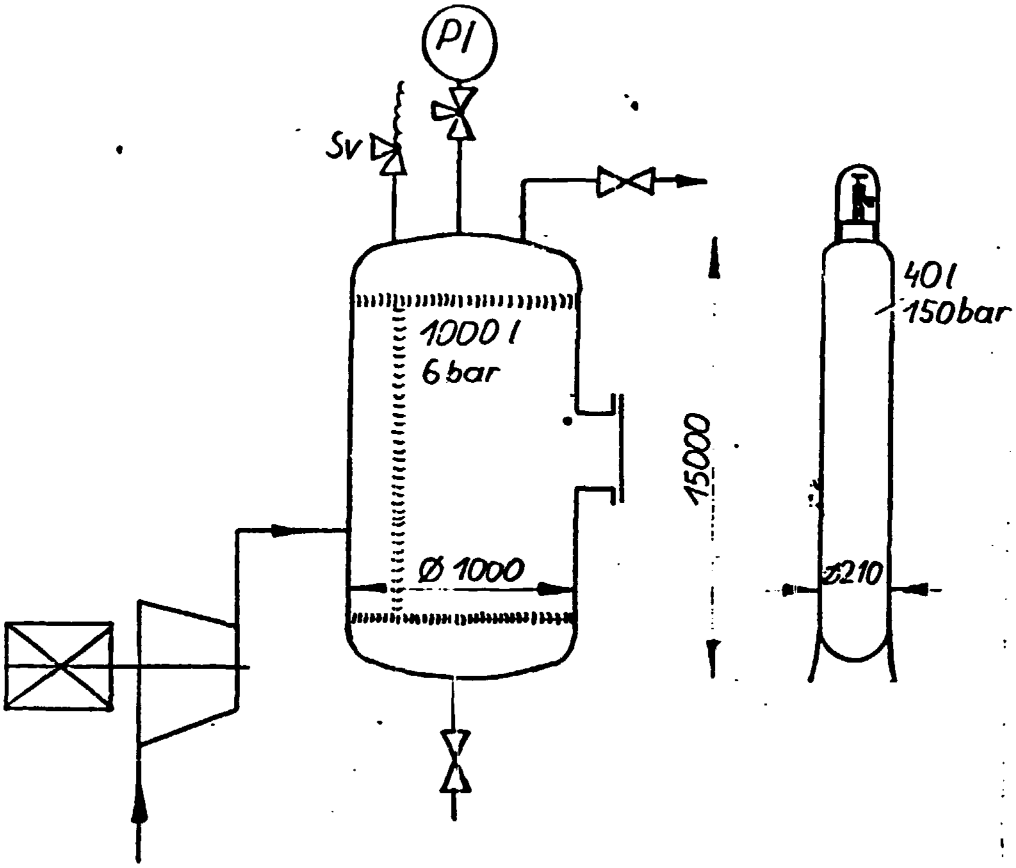
b) moveable pressure vessels (dispatch tanks)

devided in:

- bottles (e.g. compressed air bottle): diamiter until 420 mm, 2 m length, 150 l volume
- tank container: volume more than 450 l with load suspension divice.
- barrel
- vehicle vessel (volume more than 1 000 l)
- Put on tanks
- Battery of bottle cells
- Battery of barrels or tanks
- fuel tanks
- dispatch tanks for liquid, granular or powdery materials

Inspection methods and inspection intervalls are given in the international regulation RID (for railways) and ADR (on roads).

Sketch of pressure vessel and bottle:



Delivery tank
i.e. Ammonia

liquid ϱ = 0,7
gaseous ϱ = 0,77

1 kg liquid to 1,86 l filling
40 l liquid 21,5 kg ≈ 28 m³ gas

SV = Safety valve
PI = Measure instrument (pressure)
ϱ = density

add. 1.,2.,3.: There is no inspection regulation for pressure vessels which are under the given pressure-volume-mark (p x v). The inspection should be done if the conditions of the vessel demand it (order for inspection come from plant side).

4. Centrifuge (separators)

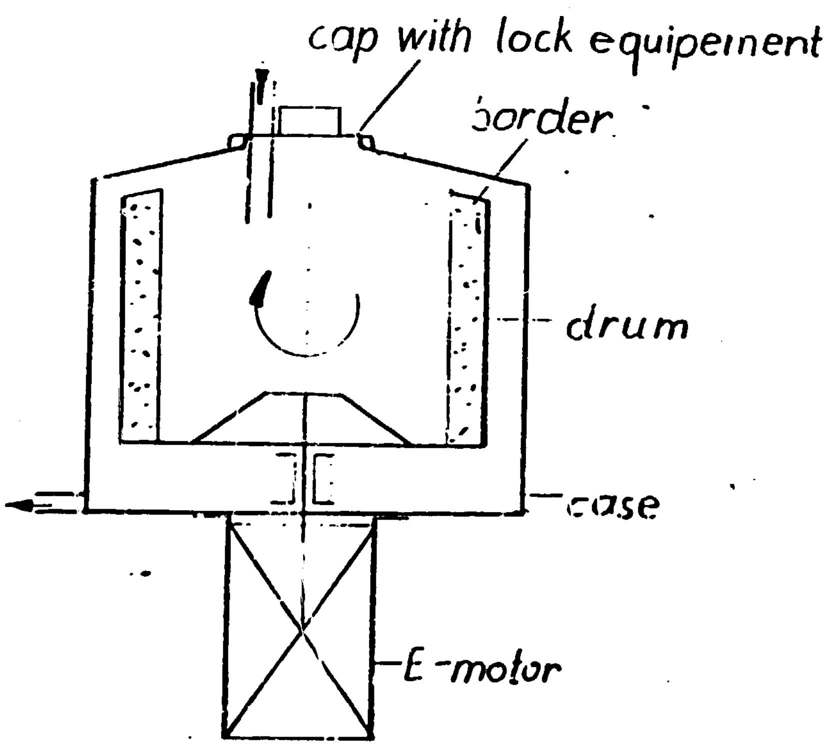
Before start up the TÜV had to do a design test (only centrifuge drum) and an acceptance test.

By the calculation of the drum you had to use the safety factor 4 for the breaking strength of the used material.

By the acceptance test you had to check if the function of the cover locker is so, that it can only be opened by standing drum.

Inspection intervall: every year.

centrifuge

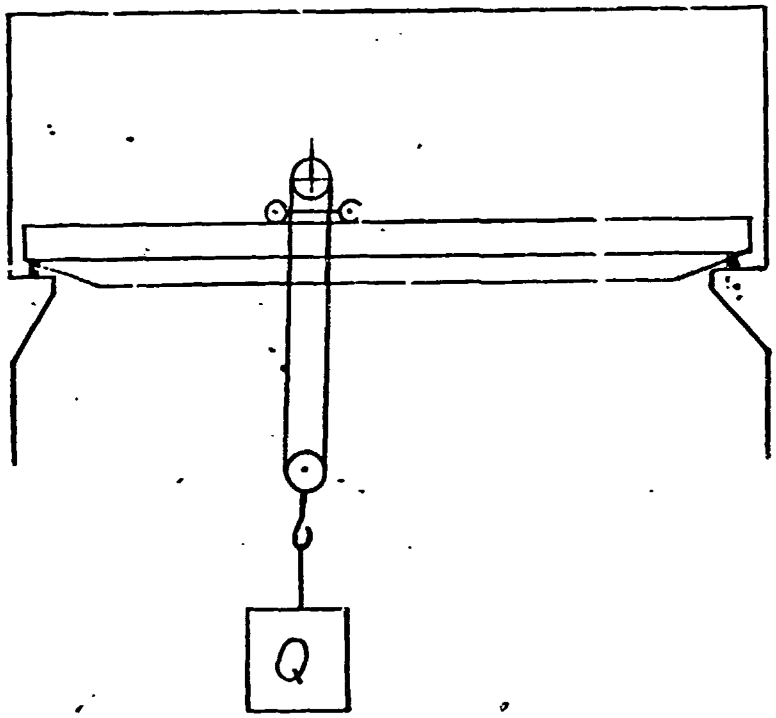


5. Lifting gears (hoists)

It includes Cranes, winches, electric cain hoists and pulley blocks. The first inspection is done by the TÜV.

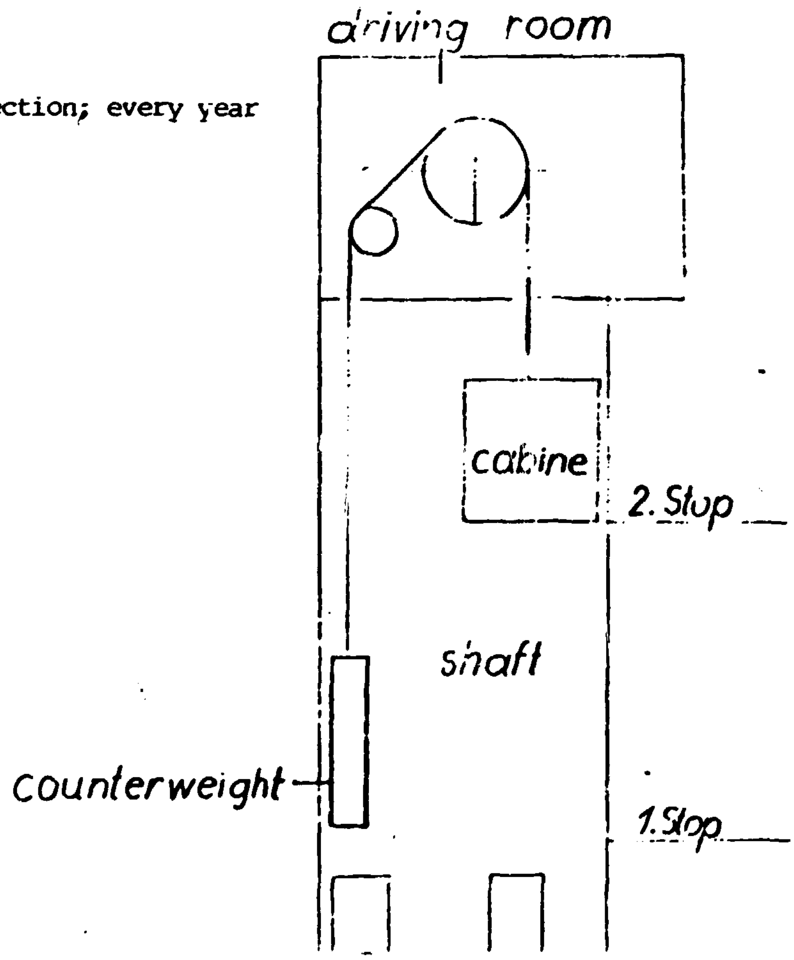
Building crane and building lifts must be checked by the TÜV after every new errection on a new place.

Inspection intervall: every year



6. Lifts

Inspection: after errection; every year



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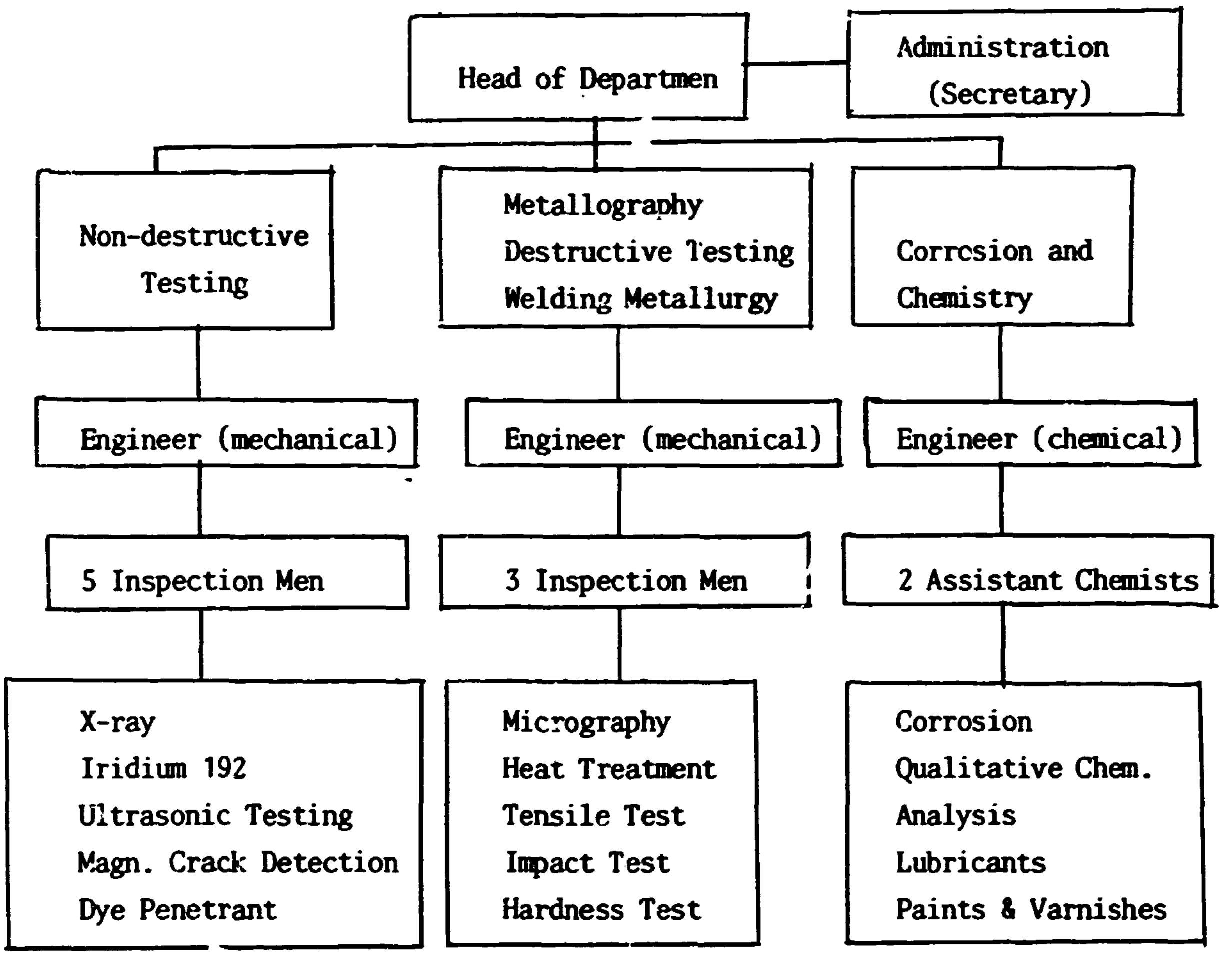
ORGANIZATION OF THE MATERIALS TESTING DEPARTMENT



MATERIAL TESTING DEPARTMENT IN THE CHEMICAL INDUSTRY

SCOPE OF WORK

The work of a material testing department can be described as follows:

1. The department is responsible for all materials which are used in the plant on vessels, pipelines, engines and structures.

2. It has to ensure that the right material is supplied for a given process or service conditions.

3. It has to check the vessels and installations in service for damages, and suggest measures to avoid such damages.

4. It has to ensure that construction and maintenance work is done properly from the point of view of the applied material and the service conditions.

Materials used in the chemical industry

1. Most widely used are the metallic materials

a) Within this group iron an steel and its alloys have the broadest application, for instance: carbon steel, cast iron, steels for boilers and heat exchangers, where little or no corrosion is to be feared; steels for lowtemperature service, stainless steels, ferritic and austenitic, for corrosive environments, steels for high-temperature service, steels resistant against attack by hydrogen, etc.

b) Nickel and its alloys, for instance: nickel-molybdenum alloys of the Hastelloy type and nickel-chromium alloys of the Incoloy and Inconel group, for corrosive environments or high-termperature service; nickel-copper alloys in plants for water treatment.

c) Copper and copper alloys
These materials are not as widely used as the above mentioned. For instance: heat exchangers in the oil systems of turbines and compressors are made of these materials.

d) Aluminium and its alloys, mainly for storage tanks and pipelines for relatively non-corrosive media.

e) Lead is no longer used on a wide scale; it is found in some parts of sulphuric acid plants.

2. Non-metallic materials

a) Enamelled vessels, valves and pipes for high corrosive service or where high purity of the product is demanded, i.e. in the pharmaceutical industry.

b) Rubber lined vessels
Natural and synthetic rubber is a very good corrosion-resistant material which can be used in a rather wide range at ambient or slightly elevated temperatures, i.e. up to 80 degrees centigr. at the utmost.

c) Thermoplastics, (for instance: polypropylene, polyethylene or others) have like nearly all organic materials a temperature limit of application.

d) Fluorinated plastics like Teflon and Viton, which have high corrosion resistance and a high temperature limit.

e) Resins - phenolic, epoxides, etc. - which can be used as corrosion or weather resistant overlays on the inside and outside of tanks, vessels, even heat exchangers.

To deal with materials successfuly the expert has to know:

- the chemcial composition,
- the metallographical structure,
- the mechanical values,
- the influences - mechanical, thermal, chemical - upon the material under service conditions.

Therefore in our department we have three main kinds of tasks:

1. mechanical and metallurgical,
2. non-destructive testing,
3. chemical, that is in the field of corrosion.

For the above mentioned problems it is necessary to use a certain range of investigations.

1. Identification of materials

At repair and maintenance of engines it can become necessary to replace damaged pieces, for instance bolts, small axles etc., the material of which is unknown. Therefore one has to make some identification tests; hardness, metallographic structure, tensile and yield strength.
This kind of test must also be done when there is no connection between the delivered material and the certificate of the manufacturer.

2. Investigation of damage

Here the visual investigation of the damaged parts under a binocular microscope is one of the most important methods. For instance: in case of rupture the operator can find out whether fatigue of the material, corrosion or mechanical force initiated the cracking of a piece under investigation.

3. Non-destructive testing

Non-destructive testing is mainly applied to check construction and repair work, i.e. check the welding. It is also used for detecting failures in material such as sheets, pipes, castings, etc.

Such defects may be cracks, slags, piping in castings, etc. In the case of welding checks the investigations have to ensure that the welding has been done properly, that any pores are not unduly big or numerous, and that no slag and no cracks are present.

The methods in this field are:

- radiography, x-rays or radio-isotopes,
- ultrasonic measurements,
- crack detection by the magnetic method or dye penetrant,
- control of temperature in case of heat treatment - preheating and post-weld heat treatment.

4. Corrosion

Control of vessels running under severe conditoins by means of visual investigation, ultrasonic measurements, control coupons which are installed inside the vessels. Selection of the right material for given process conditions by tests in the laboratory or with samples in the vessels.

It must be pointed out however, that none of the above-mentioned methods can be used in isolation; it is necessary to apply two or more methods to clear up a case. Therefore the expert in material investigation has to keep all these possibilities in mind. Further the material testing department has to make proposals upon the application of materials in new installations or plants, upon issuing standards for material quality, welding procedures, control and investigation work.

As manifold as the work to be done is the equipment.

1. Mechanical and metallurgical testing

Here our department can do the following investigations and tests:

a) Measuring yield and tensile strength by a testing machine with a load of 20 tons.

b) Measuring hardness by two hardness-testers, one for Vickers (H_V) and one for Brinell (H_B).
The Vickers tester works with a diamond shaped like a pyramid, with a quadratic base, which is impressed into the surface of the material. The Brinell tester works by means of a sphere made of hardened steel; one gets an impression in the form of a circle.

c) Measuring impact strength.

d) For metallographical work we have grinding and polishing devices, to manufacture test pieces, which are to be investigated under a metal microscope.

e) A binocular microscope for visual investigation of damaged pieces of equipment.

2. Non-destructive testing

a) Radiography

For this kind of work we have 2 sets of apparatus for x-ray with 160 and 240 kilovolts respectively, as well as 3 sets of apparatus with radio-isotopes. We use iridium 192.

3. In the field of corrosion there is the usual laboratory equipment. But as already mentioned we do a lot of investigation work with samples in the vessels, which gives better results, as the samples are tested directly under service conditions.

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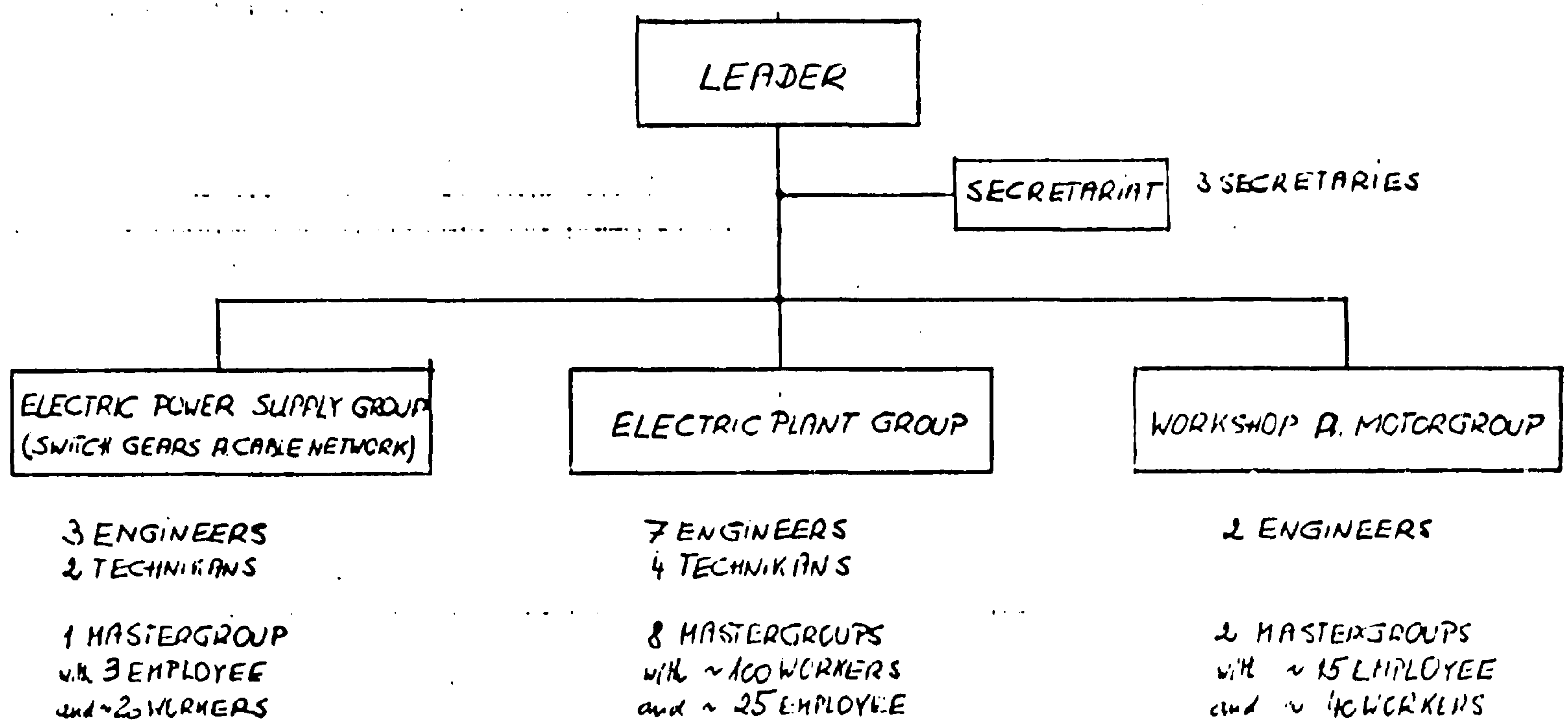
1. ORGANISATION OF ELECTRICAL DEPARTMENT



Σ ~ 65 EMPLOYEE

and ~170 WORKERS

TEL/Sa/Le
1983 10 06

2. ACTIVITIES

Erection of new electrical plants

- detail engineering
- work out orders
- check manufacture of electr. equipments
- start all the new electr. equipments

management of elec. equipments

- periodical tests
- maintenance
- repair of breakdowns, mistakes a. troubles

The electrical department is responsible for the right technical planing and for the working of all electrical equipments without troubles.

3.DATA

Electric power supply (CL I and CL II):

Consumtion of electric energy per year ~ 700 Mill. kWh incl. 5 % self generating

power top ~ 94 MW

efficiency hours ~ 8000 hours

Transformers: 8 x 20 MVA, 2 x 31,5 MVA } 223 MVA from 110 kV to 6 (10) kV

78 transformers from 6 or 10 kV to 500 or 660 or 380 V ≙ ~ 90 MVA

Switch fields: 12 piece ...... 110 kV

185 .... 6 or 10 kV

225 .... for transformers, motors and distribution

Cable network: high and low tension cable ..... 280 Km (in the earth)

Electrical equipments in production plants:

12 000 high and low tension motors (incl. reserv) with a deficiency rate of 3 ÷ 4 % (incl. 1 % electrical failure)

40 000 lamps

3 000 magnetic valves

20 000 alarmes

3 000 telephonapparatus

Lz.No. building: place: plant: accounting dpt.:

driving motor:

reference No.:
date:
firm:

MOTOR:
firm:
fabric. No.:
type:
shape:
explos. protect.:
construction:

kW	% ED		Rpm	
kW	% ED		Rpm	
V	50 Hz	e2 =	V	
A		i2 =	A	
cos φ =		Ja/Jn =		
η =		% Ma/Mn =		

price:
dimension sketch:
dispatch:

GEAR:
firm:
fabric. No.:
type:
shape:
gear ratio:
Rpm:

squirrel-cage / slip-ring runner
expl. protect.: te = s
insulation class:
shaft end kp

expl. protect. rescript:
goods received:
date:
No:
account No.:

spare part: Lz.No.
same dimension
installed spare part:

drum - Ø mm mm lg
V = m/s mm rubber coated

coupling:

belt disc:

footmotor / gear:

B =	mm	D =	mm
A =	mm	E =	mm
H =	mm	F =	mm
C + E =	mm	GA =	mm

flangemotor / gear:

P =	mm	K =	mm
N =	mm	D =	mm
M =	mm	E =	mm
T =	mm		

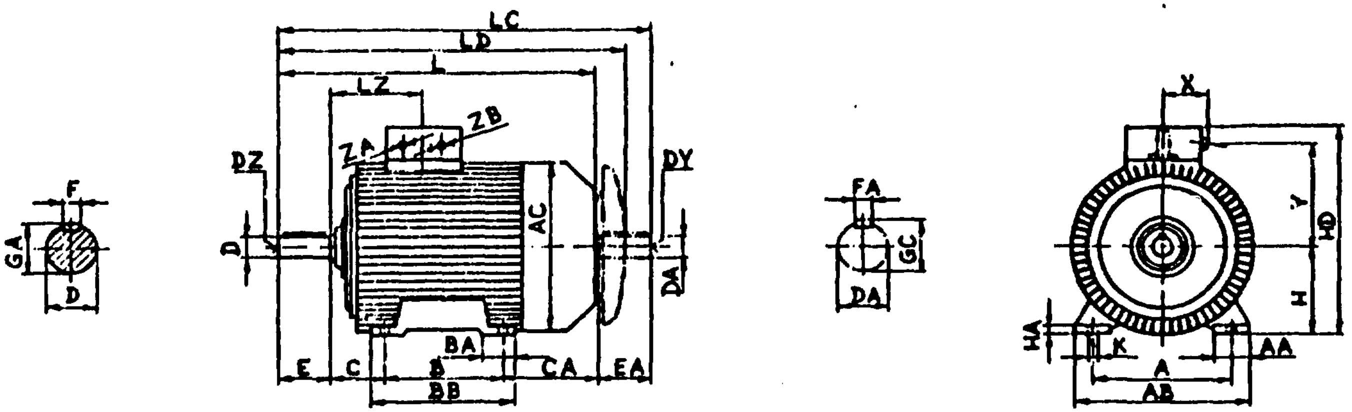
remarks:

Kind of repairing work	account No.	going out comming in	firm workshop el.dpt.	return ready at workshop el.dpt.

L O C A T I O N :

date	building	plant	driving motor	back (date)	remark	ordered by

R E M A R K S :



shape	type: MCD	Pol-No	dimension A	AA	AB	B	BA	BB	C	CA	H	HA	K	AC	HD	L	LC	LD			connection point LZ	X	Y	ZA	ZB	shaft end D	DA	E	EA	F	FA	GA	GC	DZ	DY
90L	309K	2.4	140	40	180	125	40	155	56	160	90	13	10	185	284	376	441	410			110	145	130	21	—	24	24	50	50	8	8	27	27	M8	M8
	309L	2...6	140	40	180	125	40	155	56	160	90	13	10	185	284	376	441	410			110	145	130	21	—	24	24	50	50	8	8	27	27	M8	M8
100L	310[illegible]	4	160	45	205	140	45	180	63	180	100	14	12	202	317	428	503	465			110	145	155	21	—	28	28	60	60	8	8	31	31	M8	M8
	310L	2...8	160	45	205	140	45	180	63	180	100	14	12	202	317	428	503	465			110	145	155	21	—	28	28	60	60	8	8	31	31	M8	M8
[redacted]										200	[redacted]						530	496			[redacted]		155	30	30	[redacted]	28	[redacted]	60	[redacted]	8	[redacted]	31	[redacted]	M8
132S	313T	2	216	60	276	140	60	185	89	200	132	18	12	264	390	491	589	541			140	180	185	30	30	38	38	80	80	10	10	41	41	M12	M12
	313S	2...8	216	60	276	140	60	185	89	200	132	18	12	264	390	491	589	541			140	180	185	30	30	38	38	80	80	10	10	41	41	M12	[illegible]
132M	313N	6	216	60	276	178	60	225	89	200	132	18	12	264	390	529	627	580			140	180	185	30	30	38	38	80	80	10	10	41	41	M12	M12
	313M	4...8	216	60	216	178	60	225	89	200	132	18	12	264	390	529	627	580			140	180	185	30	30	38	38	80	80	10	10	41	41	M12	M12
160M	316N	2.8	254	70	320	210	70	260	108	177	160	20	15	313	438	583	715	638			150	180	200	30	30	42	42	110	110	12	12	45	45	M16	M16
	316M	2...8	254	70	320	210	70	260	108	177	160	20	15	313	438	583	715	638			150	180	200	30	30	42	42	110	110	12	12	45	45	M16	M16
160L	316L	2...8	254	70	320	254	70	300	108	177	160	20	15	313	438	621	759	676			150	180	200	30	30	42	42	110	110	12	12	45	45	M16	M16

all dimensions in mm

GEISTIGES EIGENTUM der FLIN-UNION AS

1979	Dat.	Name	Werkstoff	Bed. pro Stk.
Bearb.	10-16		Oberfläche	
Gepr.	10.16			
Norm.				
Maßst. 1:1	DIMENSION-SKETCH		MTK-A	
			6128660MC	
			Ersatz für Orig gl Nr v. 1975-12-04	

BALANCING AND MEASURING VIBRATION

1.Balancing

1.1 Introduction

Unbalanced centrifugal forces and momenta are undesirable because because of:

- high dynamic bearing forces -- reduction of useful life
- vibration -- fatigue fracture
- reduction of friction
- reduction of porduct value (employment)
- noisy machines
- influence on personnel

Balancing is the process of attempting to improve the mass distribution of a body so that it rotates in its bearings wihtout unbalanced centrifugal forces.

1.2 Measuring unbalance

Unbalance is a vector, therefore the amount and the angle of unbalance must be measured.

1.2.1 Centrifugal balancing machines

(balancing machines that provide for the support and rotation of a rotor and for measuring vibratory forces of motion due to unbalance in the rotor once per revolution)

a) Soft bearing (above resonance) balancing machine

(operating at a speed above the natural frequency of the suspension-and-rotor system)

Resonance balancing machine: a balancing machine operating at a speed equal to the natural frequency of the suspension-and-rotor system.

Compensating (zero force) balancing machine: a balancing machine with a built-in calibrated force system which counteracts the unbalanced forces in the rotor.

Direct reading balancing machine: a balancing machine which indicates the unbalance directly.

b) Hard bearing (below resonance) balancing machine

a balancing machine operating at a speed below the natural frequency of the suspension-and-rotor system. A dynamometer and an extremely rigid foundation and machine construction must be employed.

c) Field balancing

The process of balancing a rotor in its own bearings and supporting structure at full speed. Measurements are made with field balancing equipment.
Under such conditions the information required to perform balancing is derived from measurements of vibratory forces or motions of the supporting structure and/or measurements of other responses to rotor unbalance.

1.2.2 Indicating systems

- wattmetric indicating system
- voltmetric indicating system with phase-sensitive rectifier
- voltmetric system with stroboscope and filter
- voltmetric indicating system with marking of ungular position on the rotor itself
- compensator with mechanical or electric indication

1.2.3 Motion transducer

- piezo-electric motion transdueer: the voltage signal is proportional to the acceleration
- electrodynamic motion transducer: the voltage signal is proportional to the velocity
- inductive motion transducer: the voltage signal is proportional to the displacement

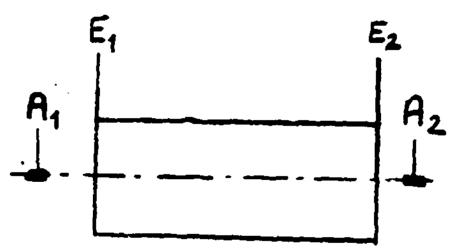
1.3 Balancing procedures

1.3.1 Static balancing

(is a condition of unbalance for which the central principal axis is displaced only parallel to the shaft axis)
For disk-shaped rotors the use of only one correction plane may be sufficient, provided the bearing distance is sufficiently large and the disk rotates with sufficiently small axial run-out. Single plane balancing can be done on a pair of knife edges without rotation of the rotor (gravitational - non rotating - balancing machine) but is now more usually done on centrifugal balancing machines.

1.3.2 Dynamic balancing

(is a condition in which the central principal axis is not coincident with the shaft axis)



E 1,2 ... Correction plane
A 1,2 ... Measuring plane

a) A run with the original unbalance.

The vectors,

$\overrightarrow{V_{1,0}}$

$\overrightarrow{V_{2,0}}$ are measured

b) A known trial mass (m1) is mounted in plane E1. The vectors V 1,1 and V 2,1 are measured. Remove the trial mass and note the position at 0oC.

c) A known trial mass (m2) is mounted in plane E2. The vectors V 1,2 and V 2,2 are measured. Remove the trial mass and note the position at 0oC too.

<u>Evaluation</u>

Graphic evaluation: rarely used because it is protracted and fallible.

Numercial evaluation: for equation see "Static and Dynamic Balancing". It is best calculated with a programmable calculating machine.

1.4 Balance Quality of Rotating Rigid Bodies

Even after balancing the rotor will possess residual unbalance. By means of the measuring equipment available today unbalance may now be reduced to rather low limits. However, it would be uneconomical to exaggerate the quality requirements. To which extent the unbalance must be reduced, and where the optimal economic and technical comprise on balance quality has to be struck, can be correctly determined in individual bases only by extensive measurement in the laboratory or in the field.

In general we can say:

The residual unbalance force:	$F = m.r.w2$	m = unbalance mass
Acceptability limit:	$F = G/10$	G = rotor weight

It follows: $m\ 10 \times \frac{G}{r.n^2}$ m (kg); G (N); r (m); N (min^{-1})

For example: G = 100 kg
r = 100 mm $\quad m\ 10 \times \frac{1\,000}{0,1 \times 6000^2}\ 3 \times 10^{-3}$ kg = 3 g
n = 6000 min^{-1}

Terms of reference are given by VDI 2060:

On the basis of section 1.4 balance quality grades have been established which permit classification of the quality requirements. Each quality grade Q comprises a range of permissible residual unbalances (e.w.).
See figure 1.

The quality grade Q equivalent to the centre of gravity-velocity. The centre of gravity-displacement is given by:

$e = \frac{Q}{W}$ Q (mm/s); w (s^{-1}); e (mm);

The permissible residual unbalance:

$m = \frac{e.G}{r}$ m(g); e (mm); G (kg); r (m)

For example:

G = 100 kg

r = 100 mm

n = 6000 min^{-1}

Q = 2.5

e = 0.004 mm

m = 4 g

In general, for rigid rotors with two correction planes, one-half of the recommended residual unbalance is to be taken for each plane. For disk-shaped rotors the full recommended value holds for one plane.

2. Measuring Vibration

2.1 Introduction

High vibration is undesirable, for the reasons given in section 1.1.

2.2 Hints for measuring

It is possible to measure displacement, velocity or acceleration. For evaluating

$$(s;\ v = \frac{ds}{dt},\ a = \frac{d^2s}{dt^2})$$

the vibration it is best to measure the rms-value of vibration velocity V rms.

$$V_{rms} = \sqrt{{}^{2} \qquad \frac{1}{T} \qquad T \qquad V^2\,(t)\,dt}$$

The vibration severity of a machine is to be measured at operational speed. For variable-speed machines the measurements should be made at many speeds in order to locate the resonance frequencies which may possibly occur.

The machine support may significantly affect the vibration levels measured on the machine. During testing the machine should be either mounted on its operational foundation or - in case it is a small assembly - soft mounted/suspended on springs.

Test sould be made preferably in x, y, z directions (choose the bearings of the machine).

2.3 Evaluation Standards

Comparing the measured values with the limit values specified in the recommendations, will permit an estimation of the severity of vibration to be carried out readily.
A machine may be qualified according to the examples of Quality Judgement (see "Vibration Signature Analysis Techniques and Systems"). At first the tested machine has to be classified according to one of the six specified machine classes. Subsequent-ly the limit values for the quality groups "good", "allowable", "just tolerable" and "not permissible", can be taken from the appropriate table. By comparing the measured vibration severity with these limit values an easy evaluation of the vibratory state can be made. Up to now, examples of quality judgement have been established by the International Standard Organization VDI 2056 for the machine classes K to T. The machines in classes D and S vary considerably in their vibration characteristics and for this reason a classification in the same manner as with the first four classes has not yet been possible. For further explanations refer to the detailed description of proposed VDI 2056, ISO 2372, BS 4675.

Definition of machine classes

Class K:

Individual parts of engines and machines, integrally connected with the complete machine in its normal operating condition (production electrical motors of up to 15 kW are typical of machines in this category)

Class M:

Medium-sized machines (typically electrical motors with 17 to 75 kW output) without special foundations; rigidly mounted engines or machines (up to 300 kW) on special foundations.

Class G:

Large prime movers and other larger machines with rotating mass mounted in rigid and heavy foundations which are relatively stiff in the direction of vibration measurement.

Class T:

Large prime movers and other large machines with rotating mass mounted on foundations which are relatively soft in the direction of vibration measurement (for example turbongenerator sets, especially those with lightweight substructures).

Class D:

Machines and mechanical drive systems with unbalanceable inertia effects (say, due to reciprocating parts), mounted on foundations which are relatively stiff in the direction of vibration measurement.

Class S:

Machines and mechanical drive systems with unbalanceable inertia effects (say, due to reciprocating parts), mounted on foundations which are relatively soft in the direction of vibration measurement; machines with rotating slackcoupled masses such as beater shafts in grinding mills; machines like centrifugal machines, with varying unbalances, capable of operating as self contained units without connecting components; vibrating screen, dynamic fatigue-testing machines and vibration exciters used in processing plants.

F A U L T S

This survey of faults in operation is not focussed on a particular turbine - in other words it is of purely general interest.

1) lubrication and bearings
2) safety and monitor devices
3) control system
4) steam quality
5) blades
6) labyrinths (shaft seals)
7) noise and vibration
8) general points

1) **Lubrication**

1.1 Bearing temperatures rise

If bearing temperatures rise, this represents a serious danger to the turbine, which must therefore be shut down immediately if no success is achieved in dealing with the cause listed below and lowering the temperature to the values given in the data sheets. Various factors may be responsible for bearing temperatures rising:

1.11 Shortage of coolant water:
This means that cooling is inadequate, which can be recognized by a rise in outlet temperature of both oil and water from the oil cooler.

1.111 Coolant water inlet temperature too high

1.112 Oil cooler clogged:
This may affect either the water or the oil side; it is revealed by the oil outlet temperatur rising while the coolant water outlet temperature stays the same or goes down (see section 1.34).
If 2 oil coolers are installed, switch over.

1.113 Insufficient bleeding on the coolant water side of the oil cooler: interferes with heat transfer as in 1.112 (see section 1.12 for bleeding on the oil side).

1.12 Shortage of oil:

1.121 Shortage of oil is revealed by a drop in oil pressure; it is due either to the oil reservoir sinking too far, or to insufficient bleeding of the oil cooler, oil filter - particularly in twin systems - or other leads to unsatisfactory cooling and inadequate lubrication.

1.122 Oil filter clogged:
If spring-loaded bypass valves are fitted, non-purified oil enters the bearings (see section 1.3).
Keep an eye on the pressure drop or the pressure drop indicator. If a twin oil filter exists, switch over.

1.123 The auxiliary oil pump gets switched off too soon after the turbine has been shut down - keep an eye on bearing temperatures and switch auxiliary oil pump back on. The process of final cooling down is concluded only when the heat stored in the impeller and and housing has been conducted away (see secion "shut down" in the user manual). Keep to the guidelines provided by the AEG-Kanis staff on site during commissioning.

1.124 Replacing oil cooler:
If the oil cooler is not replaced properly, damage will result. To reduce the risk of this happening as far as possible, it is a good idea to affix a flowsheet next to the oil coolers.

1.13 The causes listed above apply in the case of insufficient heat dissipation in relation to constant heat input. However, it can happen that heat is dissipated satisfactorily in line with the design data, but excessive heat is input and leads to a bearing temperature rising. Examples of such causes:

1.131 Rough running due to serious mineral despits on blades (increased frictional heat)

1.132 Increased axial thrust on the thrust bearing in the case of serious heavy mineral deposits due to increased impeller chamber pressure (increased frictional heat)

1.133Vibration in the machine driven transmitted to the turbine

1.134 Incorrect alignment (increased frictional heat)

1.135 Extended turbine operation with steam conditions for which it was not designed (e.g. running without a load for too long: the bearing on the exhaust steam side gets too hot)

1.136 Damage to bearing metal, due to mixed friction

1.137 Damage to bearing metal and bearing surfaces as a result of storage and/or transport

1.138Interference with free thermal expansion (serrated coupling jams)

1.139 Shims yield

1.14 Unexpected causes which can neither be identified quickly nor dealt with at once.

If suitable measures (e.g. for sections 1.131 to 1.135 providing spare capacity in the design of the heat dissipation system) fail to lower the bearing temperatures to the levels specified, the turbine must be shut down.

1.2 Lubricant oil pressure too low

This will cause damage to the turbine; so the auxiliary oil pump must be switched on at once, possibly by a monitor device in the automatic switching-on mechanism. Possible causes:

1.21 Main lubricant oil pump no longer pumps

1.22 Main oil filter clogs:
In the case of filters with a relief safety bypass,these by-passes open, so the supply of oil to the turbine continues. Open and clean the oil filters.

1.23 Shortage of oil due to leaks:
Can easily be detected from the oil level (cf. section 1.12). At this point the turbine manufacturer recommends fitting a mechanical lock on the shut-off valves on the oil pumps and oil reservoir, so that they cannot be closed by accident or by unauthorized persons.

1.24 Rise in oil supply temperature

1.25 Insufficient final cooling time for the bearings after shutting down. If in doubt, cool down for too long rather than too short a period. (Cool down either with the auxiliary oil pump or with a special final cooling pump.)

1.26 Unforeseeable causes which can neither be rapidly identified not dealt with at once.

Note

In some oil system circuits the bearing oil pressure drops from a higher value to that specified in the data sheet as the turbine speed increases to operating speed. This is due to the increasing suction of the bearing with increasing speed, and should not be regarded as a fault.

1.3 Lubricant oil contaminated

The function of the oil aggregate is of crucial significance for the turbine set to operate reliably. Contaminated oil must therefore be avoided as a cause of faults during operation.

As a matter of principle, the oil aggregate gets flushed out before starting up for the first time (flushing oil removed; lines, oil reservoir, filters, etc. cleaned with care); see supplement 4a.

1.31 After start up keep a careful eye on the oil filter (pressure drop or pressure drop indicator) and clean it regularly. Once the turbine has been commissioned, clean the oil filter at regular intervals: once a week at first, later once a month.
Keep records of this!
In the case of twin filters:
switch over and clean the off-stream filter

1.32 Aggregates with separate oil reservoir:

A partition divides the oil reservoir into the return half and the supply half. An oil strainer its built into this partition in such a way that it can be removed together with its mounting frame. As a basic rule, the strainer should be cleaned at regular intervals after commissioning, say once a week. Whether the strainer in the partition has accumulated much material can be seen from the oil levels ahead of and beyond it; levels will be significantly different only if the strainer needs cleaning.

A draining valve is located at the deepest point of the sloping reservoir floor on each of the partition. The sludge draining valve is located ahead of the strainer. To drain the oil reservoir completely, both valves must be opened (because of the partition).

1.33 If condensate has got into the oil circuit, it should be drained off with the 2 drain valves only after the system has been shut down for around 12 hours, to give it time to settle out.

Draining condensate out of the oil reservoir:

Take an oil sample once a week and test it for condensate.If condensate is present, it may be necessary to drain it off with the machine running, until clear oil comes out. However, it is naturally preferable to drain condensate off only after the system has been shut down for 12 hours.

1.34 Cleaning the oil cooler:

Depending on the extent of contamination (see section 1.112), the oil cooler(s) must be cleaned at least once a year - both the water and the oil side. When removing the tube stack, take great care that the gland packing is not damaged; it must seal the sliding head efficiently. If necessary, replace the packing.

1.35 Do not hose the outside of the oil resrvoir down to clean it - there would be a risk of water preheating into the reservoir (cf. supplement 4a, section 4).

1.4 Damage to bearings caused by running backwards

Experience has shown that, when turbo compressors and turbo pumps are switched off, there is a risk of the non-return valve in the pump/compressor delivery pipe jamming and failing to close (or leaking), so that after slowing down machine and turbine rotate in the reverse direction. This is not good for lubrication, and the bearings get damaged as a result, possibly in conjunction with damage to the labyrinth seals and blades. (The thrust bearing is designed only for rotation in one direction).

Before switching off, ensure that the non-return valves move as freely as possible; if the pump/compressor still runs backwards, apply countersteam immediately until the non-return valve is closed. The turbine must turn in the intended direction. The tachometer does not indicate turning in the wrong direction.

The delivery pipe on the main oil pump driven by the turbine shaft is usually equipped with a non-return valve, so that the oil pumped by the auxiliary oil pump cannot be drawn in the wrong direction.

<u>Important</u>
Every time that damage occurs to a bearing, check the turbine for correct alignment; realign with care if necessary!

2) Safety and monitor devices

2.1 Emergency shutdown triggered by excessive speed

Possible causes:

2.11 As excessive speed may be due to a control valve spindle jamming, check this by reading the valve scales before starting up again (see section 3.11)

2.12 Pressure in delivery pipe suddenly dropping, in the case of compressor/pump drives

2.13 If an emergency shutdown is caused by excessive speed, the following points should be noted:

2.131 Allow the turbine to slow down to half speed

2.132 Reset the emergency shutdown valve by turning to the right all the way to the stop, and latch it in place

2.133 Latch the emergency shutdown device in place only when the turbine speed has gone down to roughly half of rated speed

2.134 Set the speed setpoint to the lowest possible value

2.135 Before speeding up turbines with oil pumps driven by the turbine shaft or transmission again, check the lubrication oil pressure. If necessary, switch the auxiliary oil pump on (if it does not start up automatically).

2.136 The turbine is ready to start running again, once the emergency shutdown device is back to normal and the cause of its being triggered has been identified and dealt with.

2.2 Emergency shutdown due to excessive wear on the thrust bearing

Applies to turbines with axial position monitor. Excessive wear occurs in the case of mineral deposits as a result of the increased impeller chamber pressure, which leads to increased axial thrust. In addition, axial vibration of the machines driven cause increased wear via the pressure of the coupling serrations on the turbine impeller.
The axial pressure gauge reveals the degree of wear. Before the limit values specified in the data sheet are reached, appropriate steps must be taken; if necessary, ask for a fitter to be dispatched. The turbine is at risk, and if possible it should not run until the damage has been repaired. Do not change settings.

2.3 Other forms of emergency shutdown

As regards any other emergency shutdown devices possibly included in the supply schedule, which are connected to the 3-way solenoid valve by means of temperature or pressure-dependent contact devices or act on the emergency shutdown system hydraulically, the user manual should be consulted if a fault develops; if necessary, it is advisable to get in touch with the manufacturers.

2.4 Damage to/faults in emergency shutdown valves

2.41 Sealing surfaces:

due to foreign matter

due to excessive loading

due to the guide sleeves being detached

due to erosion of the sealing surfaces

due to the cone wobbling as a result of pressure equalization

2.42 Glands:

due to being one up too tight (valve does not close)

due to mineral deposits (valve does not close)

due to unsuitable packing material

due to roughness on spindle

due to packing being inserted incorrectly

2.43 Dealing with faults discovered:

by means of regular checks for smooth running (see supplement 16 or 16a)

by partly closing the valves to dislodge mineral deposits, without turning the turbine down

Important

If the emergency shutdown valve glands emit steam and get tightened up to seal them again, it is essential to check that the valve in question moves freely afterwards. To do this, trigger an emergency shutdown, or close valve by hand. The closing movement must not be impeded in any way.

2.5 Safety features

2.51 The automatic starter for the electric auxiliary oil pump may fail because it is connected up incorrectly or set wrong.

2.52 The automatic starter for the auxiliary oil turbo pump may fail because it is connected up incorrectly or set wrong. The manufacturers recommend fitting a bypass with the appropriate shut-off valves in the live steam line to the turbo pump, so that, if the automatic device does not work, it is possible to intervene manually to ensure the supply of oil.

2.53 Spring-loaded safety and relief valves frequently cause critical fluctuations in the flow both of steam and of oil. This can be cured by:

2.531 A slight change in the setting

2.532 Fixing/supporting the valve, i.e. securing it against vibration mechanically

2.533 Refitting the safety valve at a different point on the line

2.534 If none of the methods just listed cures the fault, the only possibility is to replace the valve with the next size up or a different type.

Note

Unless the safety devices work satisfactorily, the turbine operation is at risk.

2.6 Monitor devices

All indicators, recorders and alarm devices are of great importance for trouble-free turbine operation; if they develop faults, they must therefore be repaired or replaced.

3) Faults in speed control

3.1 Nozzle group control valves

3.11 Mineral or other deposits may lead to a control valve jamming, so that the force of the closing spring is insufficient to close the valve. In this case the turbine must be shut down and the valve dismantled and cleaned. If the turbine stays in operation for any reason, it is possible - as an emergency measure - to modify the opening sequence of the valves shown in a setting schematic (normally diagram 33). One can try to close the control valve in question by tapping it gently, using a soft (copper) drift.

As a preventive measure, we recommend modifying the load from time to time, in order to prevent deposits forming on the control valve spindles. It is possible to simulate changes in load by throttling the emergency shutdown valve somewhat; the control valves then open fully and desposits are dislodged.

3.12 As a result of fluctations in the steam mains (which may be caused by the boiler, by a safety valve or by a pressure reducing unit) a valve spindle can sometimes shear due to alternating stresses. In such cases the turbine must be switched off and the valve in question dismantled. As an emergency measure, it may be necessary to replace it with a dummy.

3.13 Valve getting altered or unsiutable:
use the setting schematic (normally diagram 33) to check this and cortect it.

3.2 Speed controllers

If speed controllers jam, this is almost always due to contaminants.

Faults in:
speed controller supplied by KALB: see supplements 71/71a/71b/71c
speed controller supplied by Jahnss: see faults section in user manual (list of contents, V2)
speed controller supplied by Woodward: see Woodward documentation (documentation index in user manual)
other speed controllers: see faults section in user manual (list of contents, V2)

3.3 External causes

The live steam pressure (and possibility the blending or reaction pressure fluctuates, and thus affects the functioning of the speed controller. This is usually due to a pressure reducing unit not working properly, or to a safety valve on the boiler causing changes in pressure.

4) **Condition of steam**

4.1 Contamination with minerals

For types of contamination, and procedures for getting rid of them, see the full explanation given in supplement 43.

The mineral content of live steam can form deposits on runner and guide blades, thus gradually restricting the cross-sections of the turbine. The extent to which the turbine has been fouled can be judged from impeller chamber pressure and exhaust steam temperature; it is therefore important to keep a careful check on these.

If the live steam does not meet the purity specification given in supplement 68, mineral deposits may develop after a time in some circumstances. There is no way of knowing in advance, though, which parts of the turbine mineral will be deposited in - this depends on many different factors.

Mineral deposits in the initial stages cause an immediate increase in impeller chamber pressure; on the other hand deposits in the later stages have very little effect on impeller chamber pressure, but are associated with increased exhaust steam pressure. However, this last point applies only above the saturation line of the i/s diagram.

It is advisable to take advantage of any possibilities in existence for connecting up pressure gauges, and to pay attention to their readings. As a general rule, the turbine will be at risk if the pressure rises above the impeller characteristic curve. In all doubtful cases the manufacturers should be called in.

Results of minerals being deposited:

4.11 Drop in performance due to simultaneous reduction in adsorption capacity and in the thermal head made use of

4.12 Excessive load on thrust bearing

4.13 Excessive load on labyrinth glands

4.14 Excessive load on blades

4.2 Foreign bodies in steam

To protect the turbine from foreign bodies, a steam strainer is located upstream of it; this retains any objects above a certain grain size. Before the turbine is commissioned, it is essential to ensure that the steam lines are clean. If work has been carried out on a steam line, it will certainly be necessary to clean it again. Small foreign bodies have the same effect on the blades as sand blasting, i.e. the turbine will certainly be damaged as a result.

The wire mesh (wire gauge 0.4 mm, mesh size 0.6 mm) provisionally fitted over the steam strainer should be removed within 4 to 6 weeks of commissioning, partly because of the pressure drop and partly because it has only a short service life.

4.3 Water in steam

It is essential to prevent any entrained water in the steam reaching the turbine. In the circumstances indicated in supplement 1, it will therefore be necessary to install water traps in the live steam line or in secondary steam feeders.

5) Blades

Damage to the blades may be the result of corrosion and pitting: the load-bearing blade cross-section is weakened and the sympathetic vibration frequency changed. This usually leads to fatigue failure. Turbines must not be damp (exposed to moisture) when stationary. In line with supplement 1, shut-off paths should therefore be used to prevent corrosion of the stationary turbine. In addition, the instructions for conservation given in supplement 37 must be complied with.

Most forms of damage to the blades are due to mineral deposits, water shock, water in steam of foreign bodies. Close attention should therefore be paid to section 4 of these instructions.

Fouling can occur if the rotating device is not switched on as and when the turbine gets preheated. Preheating the turbine when stationary is not permissible, regardless of whether live steam or countersteam is used for this. Fouling can also occur if the rotating device is not switched on for uniform final cooling, in which case the non-uniform cooling which may then occur leads to the impeller warping. The situation is the same if the rotating device breaks down during final cooling, and is to be started up again after the fault has been cured. In such cases it is absolutely essential to rotate the turbine runner at least 2 full turns, using the hand wheel on the rotating device motor or a suitable auxiliary device, before applying power. If possible the turbine should be rotated for approx. 1 hour before starting up. After starting up, check that the turbine runs smoothly at low speed. Only if the turbine gets heated through uniformly is the runner straight, and smooth running ensured. Only then can the turbine be run up to full speed without risk.

6) **Labyrinths (shaft seals)**

If a labyrinth seal is damaged (by radial or axial fouling) it will usually leak too much steam and therefore need replacing.

Possible causes of damage

6.1 Fouling at excessive relative expansion - pay attention to running-in times

6.2 Incorrect handling when openingthe turbineor when fitting/ removing the labyrinths

6.3 Excessive impeller chamber pressure due to mineral deposits

6.4 Impeller warping due to asymmetrical heating up or cooling down when stationary, followed by incorrect starting up

Damage to labyrinths as a result of

6.5 damage to a bearing:
6.51 running bearing damage (leads to radial fouling)

6.52 thrust bearing damage (leads to axial fouling)

7) **Noise and vibration**

If unusual noise is heard shut the turbine down immediately, get in touch with the manufacturers.

7.1 Drive to turbine incorrectly aligned. Check alignment, and realign using the values defined in the aligning instructions.

7.2 Causes of noise

7.21 Noise from the machine: investigate the cause

7.22 Noise in serrated couplings:
due to inadequate lubrication, due to incorrect aligning, due to the swelling of turbine, transmission or machine (deviating from the alignment instructions), due to acid vapors, due to employing used lock plates, due to deposits

7.23 Noises from turbine:
shut the turbine down, turn by hand as mechanical check, check the bearings, check the labyrinths, check the running tolerances, inspect the blades, check for: foreign bodies, unsatisfactory rebalancing, rebalancing without half coupling

7.3 Swelling due to heating up:

Any possible swelling (in particular affecting the exhaust steam pipe) during heating up must be taken into account in aligning the turbine. If noise develops, realign.

7.4 Rough running:

This is due to blade damage, a warped impeller or incorrect aligning. Asymetrical deposits on or erosion of the blade, or shifts in the position of the windings in the generator, can cause imbalance and thus rough running. Pay attention to critical speeds as applicable!

8) General points

If the instruction given in the user manual are complied with consistently, faults will be kept to a minimum and the extent of damage can be limited effectively if a fault does occur.

8.1 Operate the turbine only with the technical data given. This covers: live steam pressure, steam temperature, exhaust steam pressure, rate of temperature change, speed, bearing temperatures, oil pressures

8.2 Comply with the inspection/testing instructions provided.

TROUBLESHOOTING

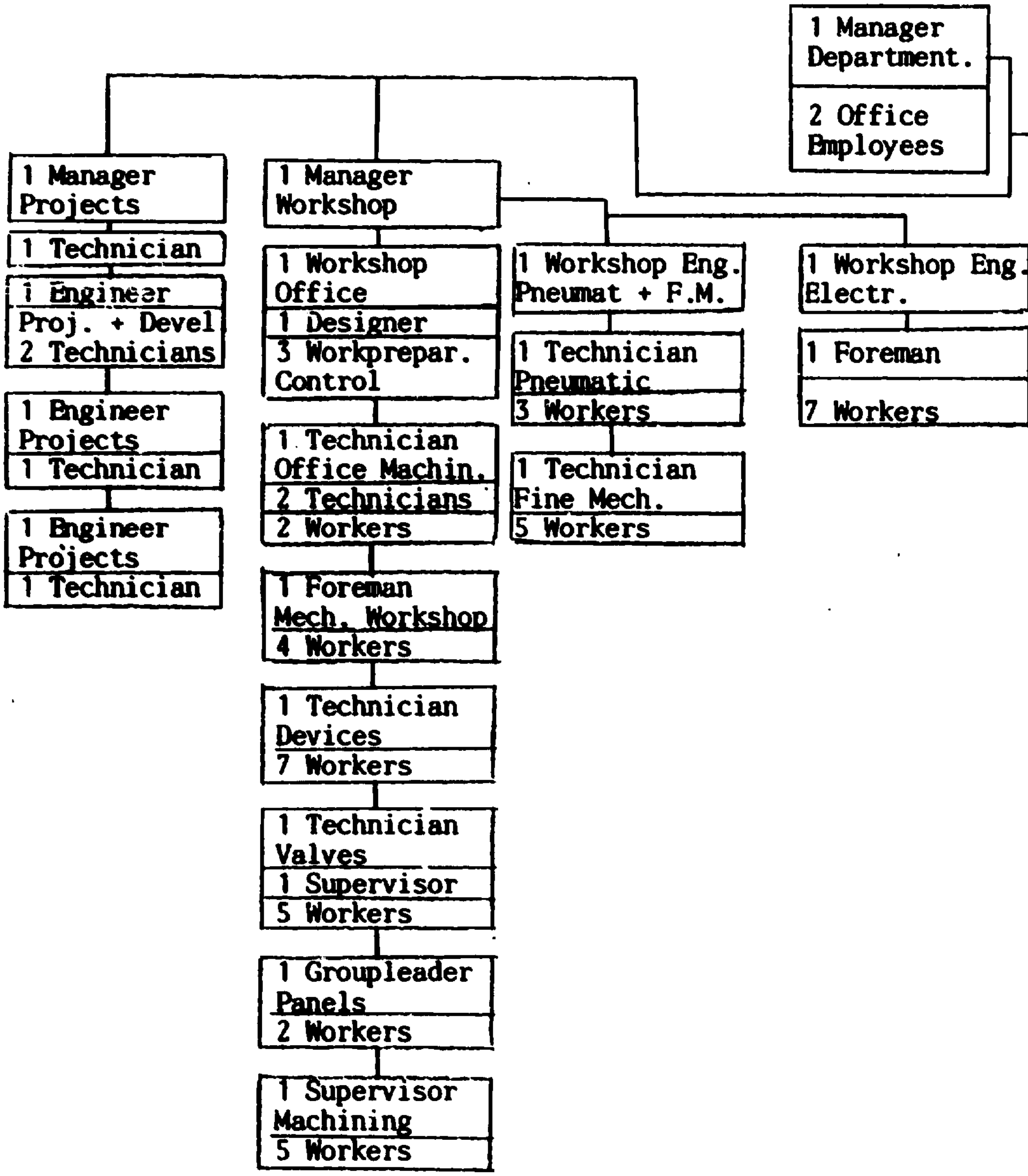
The table below lists the main sources of trouble, possible causes and the remedies advised. If none of the remedies mentioned cures the fault, you should get in touch with Nuovo Pignone, Florence.

FAULT	POSSIBLE CAUSES	REMEDY
vibration in and unusual asounds from compressor	incorrect alignment	dismantle coupling. Run drive unit alone. If the drive unit runs vibration-free, the fault may be due to wrong alignment. To check alignment, please refer to the corresponding section of the user manuals.
	damage to coupling	check state of coupling
	compressor rotor unbalanced	inspect the rotor to find out whether the fault is due to dirt accumulating; if necessary, re-balance
	wear in bearing due to contaminated oil	check the bearings and replace if necessary
	forces transmitted to the housing via the gas lines, leading to incorrect alignment	the pipelines must be properly anchored to avoid excessive forces acting on the compressor housing. The lines must be sufficiently elastic to accomodate thermal expansion.

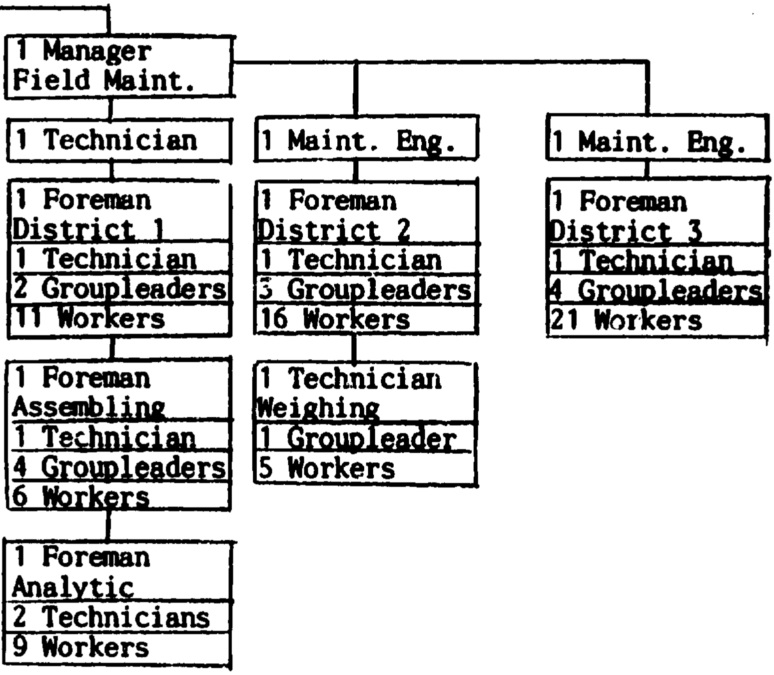
	imbalance in coupling	dismantle coupling and check for correct balance
	pumping	separate the operating conditions of the compressor from those of the pumping
	machines running close to the compressor	isolate the foundation pads in question and from each other, and increase the elasticity of any connecting pipelines
damage to support bearings	incorrect lubrication	check whether the oil used corresponds to that recommended. Check at regular intervals whether the oil is free of water and contaminants.
	incorrect alignment	check the alignment and correct if necessary
	bearing clearance does not comply with drawing	check the clearance and correct if necessary
	imbalance in compressor or coupling	refer to the corresponding sections under the heading "vibration"

damage to thrust bearing	excessive axial pressure	check whether the coupling is clean and installed so that excessive axial pressure is not transmitted from the machine coupled up to the compressor
	incorrect lubrication	refer to the corresponding section under the heading "damage to support bearings"
damage to oil seal rings	incorrect alignment and/or vibration	refer to the corresponding section under the heading "vibration"
	dirt in oil	check the state of the filters, and replace clogged filter inserts. Check that the pipes ar clean.
	ring clearance does not comply with drawing	check the clearance and correct if necessary
	insufficient oil pressure	check that the pressure of the reference gas does not drop below the prescribed minimum value

ORGANIZATION OF TME (INSTRUMENT



D E P A R T M E N T)


1 Manager Field Maint.
1 Technician
1 Maint. Eng.
1 Maint. Eng.
1 Foreman District 1
1 Technician
2 Groupleaders
11 Workers
1 Foreman District 2
1 Technician
3 Groupleaders
16 Workers
1 Foreman District 3
1 Technician
4 Groupleaders
21 Workers
1 Foreman Assembling
1 Technician
4 Groupleaders
6 Workers
1 Technician Weighing
1 Groupleader
5 Workers
1 Foreman Analytic
2 Technicians
9 Workers

TME - SHIFT AND STAND-BY SERVICE

Permanently present (call with "fault number")	7 days stand-by service (call via "guide office")	additional analytical service Sat., Sun + Holiday, 3h in the plant	Weekend and holiday stand-by service of eng. (call via "guide office")	QUALIFICATION
1 Shift-worker				WAGE RECEIVER WITH GOOD KNOWLEDGE OF LOCATION - FUNCTION
←		1 engineer stand-by service		ENGINEERS
←	1 plant group for district 1			foremen, group leaders and manual workers with in-depth knowledge of their plant areas and/or their specialized group
←	1 plant group for district 2			
←	1 plant group for district 3			
←	1 weighing machine experts			
Sat. Su. Holid. 3h in plant ←	1 analytical experts			
" ←		1 additional analytical service		manual workers in analytical service group

SHIFTERS ARE CHANGED YEARLY AND SPECIALLY INFORMED BEFORE SERVICE IN SHIFT
CHANGE OF STAND BY SERVICE AT TUESDAY 6h, SCHEDULE FOR 6 WEEKS IN ADVANCE
INFORMATION FROM "GUIDE OFFICE": VIA TELEPHONE, WIRELESS, TAXI

THE CIVIL ENGINEERING DEPARTMENT IS A SECTION OF THE TECHNICAL DEPARTMENT T

TBW
civil engineering departm.
DI. Steinwender

ARCHITECTURE
- overground workings in general
- pharmaceutical buildings
- storage construction
- housing construction

DI. Pechmann

MANAGEMENT
- cost estimate
- advertisment
- supervisory
- cost account

Ing. Putz

CONSTRUCTION WORKING
- bricklayer
- bricklayer for furnace
- sewer worker
- carpenter
- painter
- track worker
- insulation worker

BUILDING TECHNIQUE
- heating
- air condition
- sanitary facilities
- Insulation

Ing. Pichler

INDUSTRIAL CONSTRUCTION
- industrial builing
- storage construction
- special buildings
- statics

DI. Kincel

STEEL CONSTRUCTION
- industrial building
- pipe racks
- halls
- statics

DI. Gruber

PUBLIC AND FOUNDATION ENGINEERING
- streets
- railway trackag[e]
- sewerage
- survey

DI. Almesberger

CIVIL DEPARTMENT - ACTIVITIES AND ORGANIZATION

The main tasks of the civil department are:

- Planning of structures, streets, sewers, tracks and other civil constructions (pipe racks, bridges, wells etc.), including all technical house equipment (except electrical equipment)
- Surveying of the construction
- Supervising of the erection of all constructions
- Maintenance of all constructions
- Administration of all documents, static calculations and plans concerning civil activities
- Contact with authorities concerning problems of public interests or Chemie Linz interests.

Planning, surveying, administration of documents and the contact with the authorities are done by the planning group which is devided in 5 subdivisions.

- industrial plants construction and statics
- building-, storage- and pharmaceutical plants construction
- steel constructions
- sewers, streets, railway and surveying
- water installations, heating and ventilation, air conditionning, insulating.

The planning group includes about 30 employees. Up to the sum of 200 million Schillings (about 15 million Dollars) of erection costs a year, this group can fulfill its tasks itself. If there are several extensive projects at the same time, outside contractors support the planning group.

Supervision and repairing are done by the supervisions group. The 15 members of the supervision group have to supervise the erection and repairing done by outside contractors, and they have to direct the 7 repairing groups:

- bricklayers, floor tilers and roofers (20 men)
- special bricklayers (refractory brickwork, acid- and lye resistant brickwork), coating (20 men)
- sewermen (20 men)
- carpenters and scaffold carpenters (20 men)
- painters (houses and steel constructions) (20 men)
- insulaters (pipes, boilers, furnaces etc.) (20 men)
- railway track repairing group (10 men)

Every group is led by a forman and an assistant forman. Some five workers, bricklayers scaffold carpenters and insulating workers are within reach day and night for emergency in production plants. During the winter track workers are also within reach, because the switches can be blocked by snow and ice.

To give a picture of the work that has to be done by these 150 men it is necessary to know some datas about the Chemie Linz plant in Linz.

The plant area is about 1,5 km^2.

Some 350 buildings and other constructions of civil character stand there. Approximately 120 000 m^2 of roofs are to be kept in good condition. A special problem is the coating of the countless steel constructions, pipes and boilers in an aggressive atmosphere. About 15 km of streets, 15 km main sewers and 35 km railway tracks with some 120 switches are to be repaired continuously.

About 100 million Schillings (7 million Dollars) are spent for maintenance every year. One half of the work is done by the Chemie Linz repairing team, the other one is done by outside contractors.

The repairing group is kept as small as possible. The number of the workers is just as high as it must be, allowing the group to do:

- all emergency jobs in a quick way, even during night and weekend
- all jobs that are too little extensive or too difficult to survey to give it to outside contractors
- all jobs that need special workers or special knowledge of the plants.

The main jobs given to outside contractors are:

- roofing of large roofs
- coating of steel constructions
- housepainting
- repairing of streets and railway tracks.

Steel painting: (CL-standard)

Swedish standard SIS 055 900
for normal cases Sa 2 1/2 (metalical clean)
for special cases Sa 3 (metalical blank)

Painting systems:

	binder	priming coat pigment	top coat pigment	No. of coats priming/top		thicknes of coats		Temperature resistance
				inside	outside	inside	outside	
linseed oil painting	linseed oil	minium	white lead, zinc white	2/2	2/3	140 μ	175 μ	+ 70 °C
synthetic painting	alkyd resin with oil	minium, zinc chromat	white lead, zinc white	2/2	2/3	140 μ	175 μ	+ 70 °C
chlorine rubber painting	chlorine rubber with 8 % oil	minium	diffrent e.g. TiO_2	2/2	2/3	140 μ	175 μ	+ 70 °C
2-component painting	resin + accelerator system	minium, zinc chromat	white lead, zinc white	2/2	2/3	140 μ	175 μ	- 50 °C to + 120 °C
silicon painting	silicon	zinc dust	aluminium powder	2/Ø	2/2÷3	70 μ	140 - 175 μ	+ 400 °C

APPLICATION:

Linseed oil painting or linseed oil painting mixed with synthetic painting:

Mainly for outside painting, it is weathering resistent, but dry slowly--> therefor mixed with synthetic painting.

Synthetic Painting:

For painting inside, if there are no troubles in sight.

Chlorine Rubber Painting:

Painting if there will be chemical influences, for inside and outside.

2-Component Painting:

Painting for temperature variations between - 50 °C and + 120 °C, also as high-quality painting for outside tanks.

Silicon Painting:

Painting for hot pipelines and vessels up to + 400 °C.

FIRE RESISTANT MATERIALS

General view

The different qualities of fire resistant material depend on the different working conditions.

There is no material that is resistant against everything. Especially bricks are either resistant to acids (e.g. SO_2 in the flue gas) or to quick changing temperature. Other bricks are especially used for heat insulating (light bricks). Of course it is always important to use the special plaster for the special brick.

The different possibilities of heat-resistant linin are:

- lining with bricks
- lining with stamped material
- lining with squirted material.

The operating instructions for these materials given by the manufacturer of the material have to be observed very exactly. The thickness of the plaster between the bricks is about 2 - 3 mm regarding fire plaster and less regarding fire-resistant cements.

It is absolutely necessary to use only materials which are free of SiO_2 (99 % Al_2O_3) for waste heat boilers. SiO_2 causes corrosion on pipes and piepe-bottoms.

Generally:

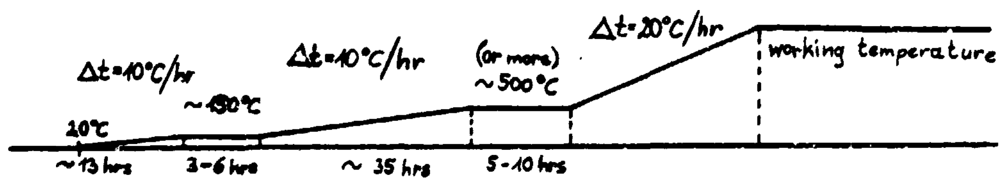
Materials with a high content of SiO_2 are more acid resistant. With increasing content of Al_2O_3 (35 % and more) acidresistance decreases whereas and resistance to quick changing temperature and high temperature increases.

Drying and heating up of new plants

a) Drying is necessary for getting out the water of the plaster.

b) Heating up the first time has to be done very carefully in order not to destroy the lining.
   Up to 150°C - the humidity of the plaster evaporates,
   up to 500°C - the chemical boundet water evaporates.
   Due to these facts it is necessary to stop the increasing of the temperature for a while at the above mentioned temperatures.
   The duration of these stops depends on different things (material, insulation, thickness, largeness of the boiler)

c) The time-temperature-diagram shows an increase of about 10°C per hour up to 150°C, then a stop (see item b)), once again 10°C per hour up to 500°C, a stop again, and then 20°C per hour up to the working temperature.



Attention:

Please use the time-temperature-diagram of the flue-gas and not the diagram of the crack-gas.

Heating up of an already used lining

The diagram depends on the time during which the plant stood still. If it was only for a few days: 10°C up to 150°C about 5 hours, stop, 20°C up to 500°C, stop for 5 hours, 20°C up to working temperature. If the stillstanding time is longer of there is a wet climate the diagram is similar to that to heating up a new plant.

Storing the materials

It is necessary to store different qualities at different places (the different materials often are looking similar). Please protect materials from water and temperatures under 0°C and liquids for cements from sun.
Do not use materials which are older than 1/2 - 1 year (except bricks). Good bricks should not differ more than 1 % in length, they must not have cracks and broken edges.

FIRE RESISTANT MINERAL WOOLS

They are used for filling tension joints and joints between steel pipes and fire material and for heat insulation. They are resistant to temperatures up to 1 250°C.

Trade marks: CERAFELT, KAOWOOL

LINING OF CL-SINGLE TRAIN PLANT

PRIMARY REFORMER:

Wall fireside:

bricks: Schamottestein "A III"
product of MAGINDAG, Krems
Austria
Temp: - 1 250 °C
Al_2O_3 ~ 30 - 33 %

Firelight brick: 'Styrozell 8"
product of MAGINDAG
Temp: - 1 400 °C
Al_2O_3 ~ 35 %

Thermal conductivity 0.33 W/m °C
γ = 0.8 kg/dm³ = 8 000 N/m³

Wall insulation outside:

Skamol bricks: Fa. Skamol

Gas tunnels:

bricks: Schamottestein "A III"
MAGINDAG

Floor:

Insulating fire concrete:
"PLICAST LW Mix 106"
by "PLIBRICO - Austria"

FLUE GAS TUNNEL:

Fire side:	Casting: Super FAB by PLIBRICO Temp: 400 °C - 1 600 °C Comp: Al_2O_3 45 % SiO_2 49 % Fe_2O_3 1,1 %
2 layers fire light: bricks:	FS 11 + FS 8 product of MAGINDAG, Austria, Krems
Insulation near the steel plates:	Insulating fire concrete "PLICAST LW Mix 106" by "PLIBRICO - Austria"

C O N V E C T I O N   S E C T I O N :

Walls:	Casting:
+ Ceiling:	"Plicast LW Mix 124"
	PLIBRICO - Austria
	Temp. up to 1 100 °C
	Al_2O_3 25 %
	SiO_2 45 %
	Fe_2O_3 8.5 %
Floor:	Casting:
	"Plicast 28"
	PLIBRICO AUSTRIA
	Temp: up to 1 450 °C
	Al_2O_3 47 %
	SiO_2 44 %
	Fe_2O_3 1,1 %
Floor insulating:	Fire light bricks

SECONDARY REFORMER:

Wall:

bricks:
"K 99"
by Dr. Otto Germany
99 % Al_2O_3

fire light concrete:
"Plicast Petrolite S9"
max T = 1 800 °C
comp: ?
by PLIBRICO Austria

insulating casting:
"Plicast Petrolite 11"
by PLIBRICO Austria
max t = 1 100 °C

comp:	Al_2O_3	25 %
	SiO_2	59 %
	Fe_2O_3	0,5 %

INFORMATION ABOUT CORROCEM

Corrocem is an additive for concrete.

This additive gives concrete more resistance

against NAC and ASU.

Corrocem is a powder

at least 60 kg/m^3 concrete should be added
at least 300 kg/m^3 sulphat resisting cement
is necessary

$\frac{\text{water}}{\text{cement}} = \frac{0.45}{1}$ or less

corrocem makes uncured concrete more liquid

corrocem has to be mixed with cement and sand before water is added

corrocem has to be mixed up itself, because its different components can seperate during transport.

Producer: NORSK HYDRO
NORWAY

Supplier: Producer of Joli & Co
Vienna
Austria

INFORMATION ABOUT LIQUIDS THAT ARE USED FOR CONNECTION OF OLD AND NEW CONCRETE

1. BETONFIX

consistence:	milky fluid mixable with water
application:	1 part BETONFIX is mixed with 4 parts water This fluid is brushed onto the surface of the old concrete. Before it gets dry the new concrete has to be set in place.
supplier:	AGRO A-4600 Wels Postfach 109 Austria

2. SIKA-LATEX

consistence:	fluid mixable with water
application:	see BETONFIX
supplier:	SIKA-PLASTIMENT GesmbH. 6700 Bludenz Bings Austria

chemserv
CONSULTING GES.M.B.H.

COMPUTERIZED MATERIAL MANAGEMENT DEPARTMENT OF CHEMIE LINZ AG

The business of dept. MMV of CL is to manage utility and process materials that means making available materials at the right time, on the right place and in the right amount.

At the moment about 24 000 items are managed and stored in 6 different storage - areas.

These parts we call utility and process materials, which are required in different sections of Chemie Linz AG to maintain the plants, for repairing services and for preventive maintenance jobs.

The average stock has a value of about 45 mill AS. The annual turn over of 6 storages amounts about 130 mill AS.

MMV manages the following utility- and process-materials:

- iron and steel
- non ferrous materials
- piping materials
- mounting parts
- process materials
- tools, outfit materials
- high pressure materials
- requirements for machines
- electrotechnical requirements
- civil material
- process demand
- miscellaneous
- armatures
- drive machinery parts
- traffic demand
- requirement for machines and apparatus
- packing materials

In dept. MMV also the central material acceptance is included. In total 40 000 material arrivals per year are to manage. From this number about 14 000 arrivals are for utility- and process materials which are stored in dept. MMV.

The management of the utility and process materials was done on conventional ways until 1980, it means the registration card handling (booking, ascertainment of the demand, issue of demand orders for the purchasing dept., issue of material arrival records and diverse statistics) was written by hand.

The personnel demand until 1980 for administration and distribution resp. take over of the utility and process materials was

32 employees and
28 workers

In 1979 the board of CL has ordered to start investigations about computer aided material management for utility and process materials. Lateron all articles (spare parts and raw materials of stores) should be managed by a computer aided system.

We are following this system in practice still now.

An investigation about the actual situation was started, a weak point analysis and a feasibility study were prepared.

./3

The feasibility study should show the way of rationalization with the aim

- to get more information
- in shorter time
- to economize employees

This means first of all to reduce inventory of utility and process materials in the future and therefore to spare costs and personnel.

To reach this aim, we need the application of a computer.

A comparison of the actual situation and the target conseption gives the result that the application of an electronic data processing system is possible.

The system, which we consipated, should cover the following functions

- an online stock management
- a computer aided automatic stock control and disposition
- an automatically print out of demand orders
- an automatically print out of material arrival records
- an inquiry processing and maintenance system

According to the installation of a low end computer system in the material management dept. and an adequate re-organisation we planned a saving of 8 employees and a reduction of the inventory stock (about 10 %).

The analysis resulted - due to the use of computer and screens - that 8 working places could be economized in the future.

Before installation of the computer aided system in all stores control of inventory was carried out by 2 persons. After introduction of the new system only one man is necessary per store. In addition swing-man is required to substitute the store- or inventory manager in case of sickness or leave.

As mentioned before the central material arrival is also a section of dept. MMV and due to the fact that appr. 40 000 material arrival records had been written by hand yearly, it was also possible to reduce the personnel in this section by using the computer aided system.

We made the experience to reduce the inventory stock due to the fact, that we feed the computer with datas (e.g. replacement time and costs, storage capacity), which make an automatical print out of demand orders possible.

Some of these factors are processed by means of the formular of "ANDLER" concerning the economic lot size (extrapolution). If recorder print is reached the store manager automatically is requested for disposition of concerned article.

./5

The prepared demand order records are automatically transfered to the computer system of the purchasing dept.

The development of computer aided system for material management dept. took 2 years.

Time requirement

- investigation	......	2 men-month
- actual situation recording, detail analysis, target conseption	......	7 men-month
- master file recording, system development, programming and test	......	64 men-month
- system delivery	......	11 men-month
	total	84 men-month

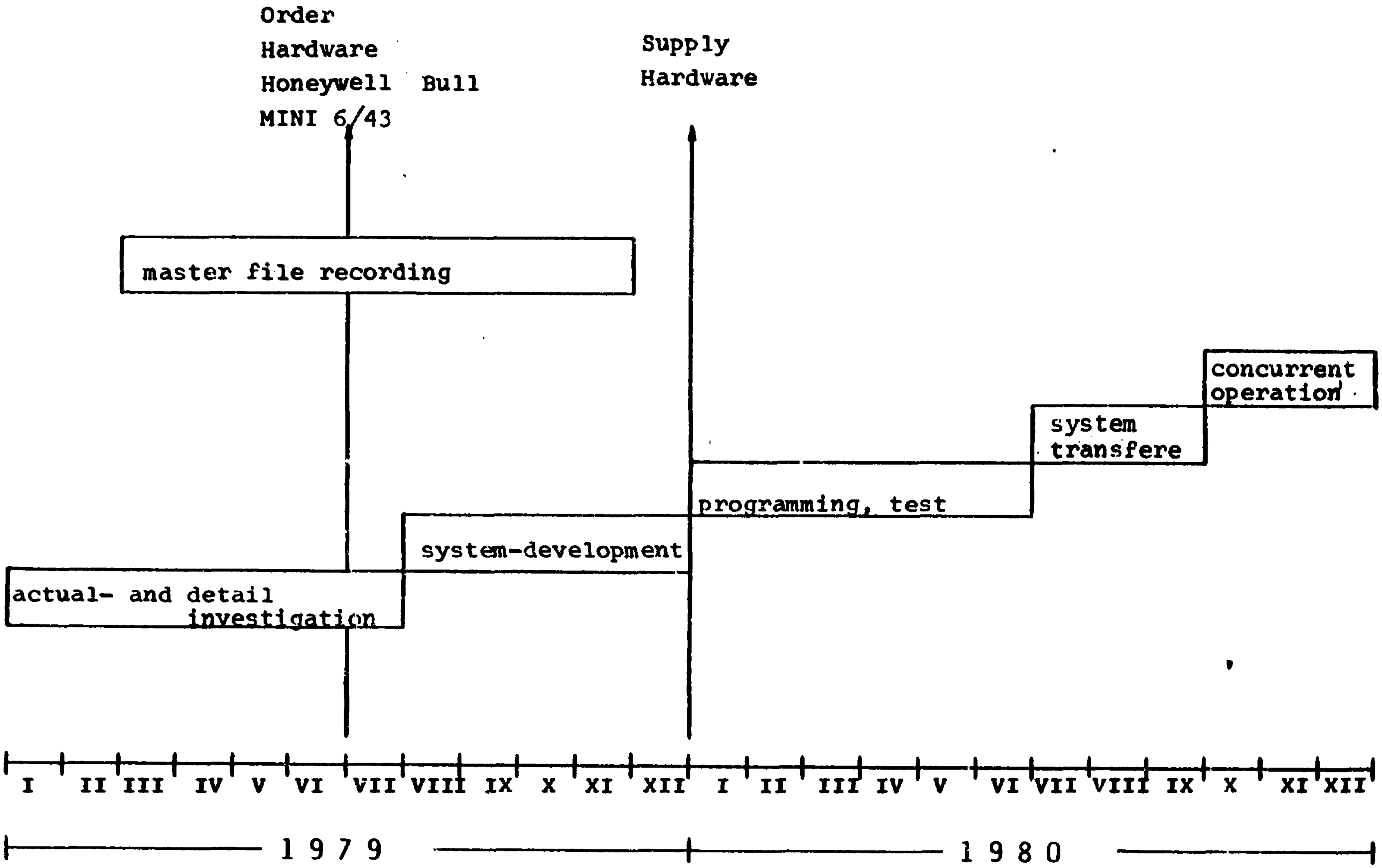
The different jobs were done by computer dept. of Chemie Linz and material management dept. (enclosure 1).

Regarding to already realized successes and savings we calculate the following rentability result by a running time until the end of 1985.

personnel saving	6.8 Mill AS
storage tribute saving	1.4 Mill AS
minus additional investments	
low end computer and maintenance	- 1.7 Mill AS
Project installation, programming, system analysis, controlling and insurance	- 2.1 Mill AS
investment success	4.4 Mill AS

TIME SCHEDULE

Enclosure 1



Due to the computer aided system in material management dept. we reduced the storage stock-without changing the service efficiency - at about

1981 minus 2,76 Mill AS = 7.38 %
1982 minus 1.21 Mill AS = 3.26 %
1983 minus 2.61 Mill AS = 7.94 %

of the whole storage stock.

OPERATION OF THE SYSTEM

In our system there are two functions.

The first includes all jobs carried out by inventory manager on computer terminal (MMV LA).

The second function concerns the activities of central material management dept. (MMV ZW).

The first function, carried out by the inventory manager for the administration of utility and process materials as well as for the punctual demand order printing are divided in fife main groups: (enclosure 2)

- INQUIRY OF FILES
- MAINTENANCE OF FILES
- INVENTORY AND DISPOSITION
- CORRECTION OF ACCOUNTING
- ORDERING PRACTICES

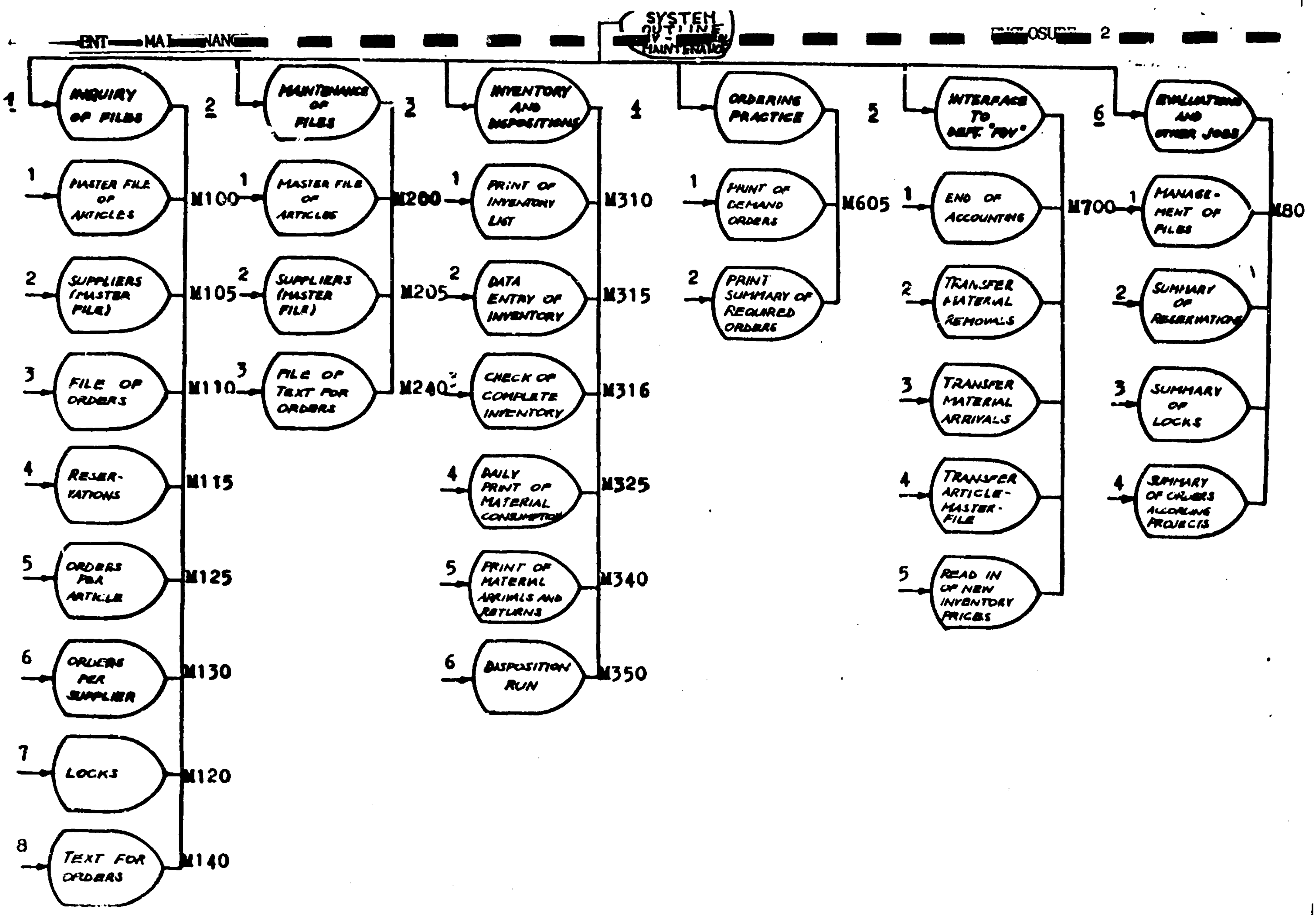
./7

The second function - so-called central maintenance - includes the following points: (enclosure 3)

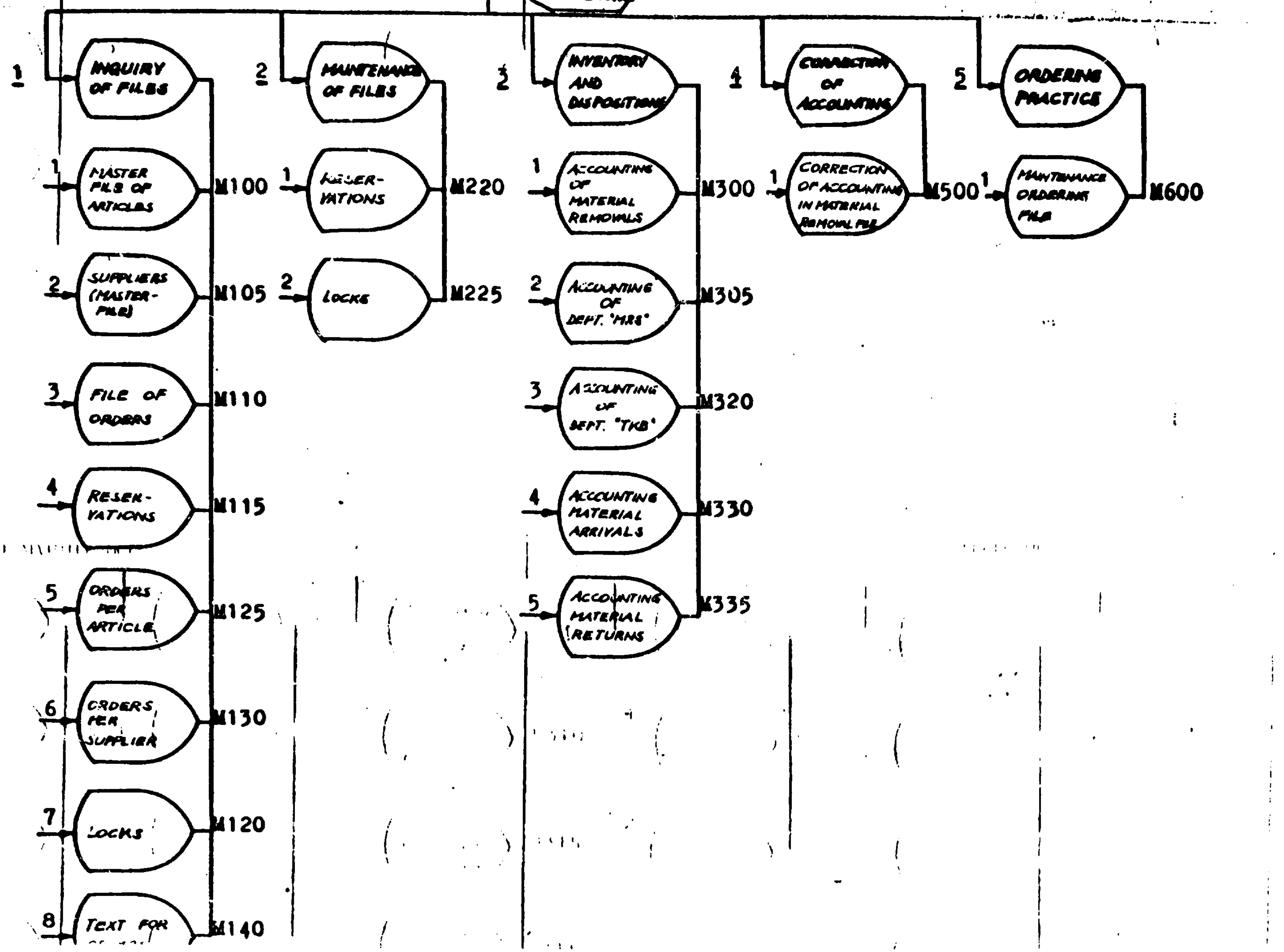
- INQUIRY OF FILES
- MAINTENANCE OF FILES
- INVENTORY AND DISPOSITION
- ORDERING PRACTICES
- INTERFACE TO DEPT. "EDV"
- EVALUATION AND OTHER JOBS

The online system installed in dept. MMV was the first module of an integrated electronic data procurement system of Chemie Linz. Later other departments - audit dept., material accounting and procurement - should be included, which is done particularly until now.

All astimation of the computer programs were done by EDV dept. of Chemie Linz, to consider all interfaces of different departments in Chemie Linz AG.


SYSTEM OUTLINE
ENCLOSURE 2
INQUIRY OF FILES
MASTER FILE OF ARTICLES
SUPPLIERS (MASTER FILE)
FILE OF ORDERS
RESER-VATIONS
ORDERS PER ARTICLE
ORDERS PER SUPPLIER
LOCKS
TEXT FOR ORDERS
M100
M105
M110
M115
M125
M130
M120
M140
MAINTENANCE OF FILES
MASTER FILE OF ARTICLES
SUPPLIERS (MASTER FILE)
FILE OF TEXT FOR ORDERS
M200
M205
M240
INVENTORY AND DISPOSITIONS
PRINT OF INVENTORY LIST
DATA ENTRY OF INVENTORY
CHECK OF COMPLETE INVENTORY
DAILY PRINT OF MATERIAL CONSUMPTION
PRINT OF MATERIAL ARRIVALS AND RETURNS
DISPOSITION RUN
M310
M315
M316
M325
M340
M350
ORDERING PRACTICE
PRINT OF DEMAND ORDERS
PRINT SUMMARY OF REQUIRED ORDERS
M605
INTERFACE TO DEPT. "FDV"
END OF ACCOUNTING
TRANSFER MATERIAL REMOVALS
TRANSFER MATERIAL ARRIVALS
TRANSFER ARTICLE-MASTER-FILE
READ IN OF NEW INVENTORY PRICES
M700
EVALUATIONS AND OTHER JOBS
MANAGE-MENT OF FILES
SUMMARY OF RESERVATIONS
SUMMARY OF LOCKS
SUMMARY OF ORDERS ACCORDING PROJECTS
M80

SURVEY OF E..-SYSTEM (STORAGE)



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