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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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DP/SYR/86/009

SYRIAN ARAB REPUBLIC

Technical report: Maintenance and operation of mechanical components in fertilizer plants*

Prepared for the Government of the Syrian Arab Republic
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Zoltan SZABO, expert in maintenance and operation of mechanical components

Backstopping officer: G. Anestis,
Section for Integrated Industrial Projects

United Nations Industrial Development Organization
Vienna

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* This document has not been edited.

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I. PURPOSE OF PROJECT

The project is aiming at assisting the Goverment of the Syrian Arab Republic in assessing the effectiviness of various mechanical components in industrial plants producing fertilizers and sugar and to develop and supervise R+M programmes in order to ensure a stable operation of the respective plants and related equipment.

The assignment was splitted for:

General Establishment for Chemical Industries, and
General Organisation for Sugar.

A. General Establishment for Chemical Industries

In general, all the thirteen companies (specialized in ten subsectors) managed by this Establishment suffer from low capacity utilization, high losses, high energy consumption and low quality products.
The request of the management of the Establishment was to concentrate on key problems with regard to turbines, compressors and boilers in fertilizer plants at Homs.

II. GENERAL FERTILIZERS COMPANY

The General Fertilizers Company is one of the most important, biggest complexes in the chemical industry of Syria. It was founded in 1967, and the production of the fertilizer industry is very important (direct effect on the agricultural sector).

The Company has three basic Plants.

A. Nitrate Fertilizer Plant. (Calnitro) (1967)

The Nitrate fertilizer plant includes the following units:

- Ammonia Production Unit with 50.000 Mt.p.a. design capacity
- Nitrate Acid Production Unit with 87.500 Mt.p.a. design capacity
- Fertiliser Production Unit with 140.000 Mt.p.a. (26% concentration) ammonium nitrate design capacity.

The Ammonia Production Unit was stopped in 1982 because a new Ammonia--Urea Unit was established, and the ammonia has been provided by the new Plant for fertilizer production.
In 1987 the Unit was restarted for about 7-8 months.
At present the Unit is out of operation due to the reason mentioned above.
According to the information given by the management of the Plant, the Unit is conserved and internaly pressurised by nitrogen.
The compressors of the Unit are reciprocating types (Novo Pignone) driven by electric motors.
Due to the fact that the Unit is out of operation there is no significant maintenance work but the external corrosion is high. It is important to note that theoretically the maintenance cost of a non--operating unit is close to that of an operating one. It would be profitable to find some basis for utilization (exportation or local use of products).

The Nitrate Acid Production Unit is operating with full capacity without significant difficulties.

The two turbocompressor driven by steam turbines are running smoothly. Adjusting the bearings of this machines is difficult but during turn--arounds it is solved locally.

The Fertiliser Production Unit is running with 100 % capacity, having a 12 hours stopover for regulat maintenance each week. There is no important maintenance problem except for the high concrete corrosion//erosion of the concrete structures.

General Notes for the Calnitro Plant:

- The Plant is more then 20 years old but running in good condition.
- The maintenance of the units is adequate.
- The number of operators, maintenance staff and management (including their own administration) is about 600.
- The Plant is equipped with its independent utility systems.

B. TSP Production Plant

The TSP Plant (implemented by the Romanian Industrial Export Company) includes the following units:

- Sulphuric Acid Unit with 560.000 Mt.p.a. design capacity
- Phosphoric Acid Unit with 165.000 Mt.p.a. design capacity
- Super Phosphate Unit with 450.000 Mt.p.a. design capacity
- Aluminium Fluoride Unit with 3000 Mt.p.a. design capacity

The Sulphuric Acid Unit is running with full capacity. Due to the faulty design and bad material specification and supply, the SO_2, SO_3 and sulphuric acid leakages have exceeded acceptable limits.

With continuous maintenance and great difficulties the Unit is capable to run. Water, air and earth pollution is not controlled.

The Phosphoric Acid and Super Phosphate Units are operating approximately at 30-40 % of their design capacity. For producing fertilizers the raw phosphate material is locally supplied by the General Phosphate Company.
One of the main problems is the high calcium, chloride and silica content of the raw phosphate rock. For this reason, fouling and erosion are extremly high in the pipes and equipment. There are no adequate flushing systems to remove such deposits.
Process design is obsolete, and the adaptation has been outdated too.

The rubber lined piping has not been standardised during the engineering design. Due to this fact the piping elements and fittings are not replaceable, and any leakages in this system are followed by shutdowns or partial shutdowns.
Rubber lining for spool-pieces is provided locally.

The material specifications for pump and acid-agitator impellers have not been proper. As a consequence of extremely high erosion and corrosion effects the service life of the HISTALLOY impellers is too short. The plant management has been advised to use teflon or teflon coated impellers instead of the expensive HISTALLOY material.

The instrumentation of the Units is totally out of order. All process parameters are controlled manually on the basis of experience.

The underground systems are extremely corroded. This corrosion has overpassed the dangerous limits. The corrosion of the concrete and steel structures is uncontrollable.

During the visit of the Phosphoric Acid Unit it was out of operation due to an uncontrollable acid leakage into the main power cable trench.

The water and earth pollution is not controllable.

The management is unable to do the necessary maintenance due to the following reasons:
- The units are dangerous to health.
- The necessary skilled workers are not available.
- There is no special interest for the workers to do any work under the highly poor conditions existing in these units.

The only solution is a total revamp or building a completely new Plant.

The Aluminium Fluoride Unit is completly out of order and operation.

General notes for the TSP Plant:

- The process and the engineering design of the Plant is outdated (more than 40-50 years old).
- Due to the faulty engineering design and material supply the final acceptance has not been executed.
- The maintenance of the Plant is difficult and at some Units is impossible.
- The Plant is equipped with its independent utility systems (the boiler feed water quality is the best one at this Plant within the Company).
- The technical management of the Plant is working with a maximum willpower and is well qualified, the difficulties are not attributable to them.
- The number of operators, maintenance staff and management (including their own administration) is about 1200.

C. Ammonia-Urea Plant *

The Ammonia-Urea Plant was built by Creusot-Loire Enterprises (France), and includes the following units:

- Ammonia Unit with 1000 Mt liquid ammonia per day design capacity
- Urea Unit with 1050 Mt.p.d. design capacity
- Utility Unit (because of its impcrtance, this will be handled separately)

The Urea Unit consumes 600 Mt ammonia per day for producing fertilizers. The surplus is used as the feedstock of the ammonia nitrate production of the Calnitro Plant or prepared for exportation. Originaly the Plant was designed on naphtha basis with 300.000 Mt.p.a. theoretical consumption. In 1987 a partial revamp was executed by Creusot-Loire Enterprises for using natural gas as the feedstock of the ammonia synthesis.
(The processes of the Ammonia and Urea Units are practically given, therefore the further part of this section is touching the process itself only as much as necessary.)

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Note: According to the requirement of the General Establishment for Chemical Industries, this Plant is one of the focal points of the mission.

The Ammonia Unit is running with 70-95 % capacity, depending on the actual status of the main rotating machinery and equipment. The process is Kellogg design. According to the usual design philosophy, all rotating machines are supplied with the necessarry stand-by units, except for the following expensive main compressors:

- 103 JT Synthesis Gas Compressor
  The Manufacturer of the compressor is Dresser (France)
  The compressor is driven by a Siemens turbine

- 102 JT Natural Gas Compressor
- 101 JT Air Comporessor
- 105 JT Ammonia Compressor
  All these compressors and their steam turbines are manufactured by Creusot-Loire (France)

The simplified steam system of the unit is shown in Fig. 1.
The driver of the syntgas machine 103 JT is practically a two-stage turbine. The total quantity of high-pressure steam (105 barg, generated in the waste-heat boiler) passes through the back-pressure turbine, driving the syntgas compressor. Since the back-pressure must be high enough to provide steam for the reforming section (about 40 barg) the power of this turbine is not enough and a second one (condensation type) is fitted on to the same shaft with an admission pressure of 40 barg, and this turbine handles load variations.
The turbine has not been opened since its erection (1978).
The Company do not have the neceserry documentation, spare-parts and experience to open the turbine and do the maintenance.
The manufacturer offers his expert to be present during the turbine maintenance. Without documentation the Company is advised to accept the offer and after getting the mandatory spares perform Unit turn--around. For the compressor the same procedure is to be followed.

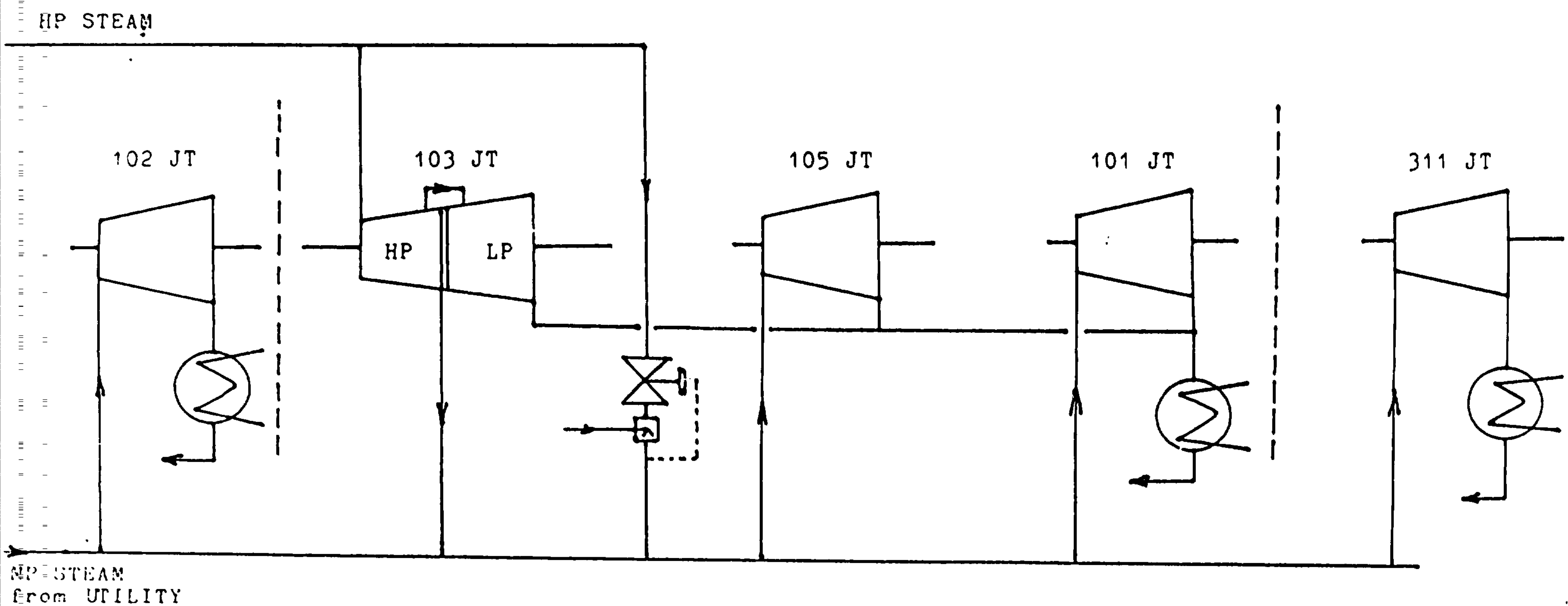

HP STEAM
102 JT
103 JT
HP
LP
105 JT
101 JT
311 JT
MP STEAM
from UTILITY

FIG. 1

Advance remark: The quality of the boiler feed water is not adequate. Due to that fact salt deposits are found in the other turbines. If the turbine of the syntgas compressor is fouled, this would stop the Unit for months. Urgent action is needed!!

Axial displacement is very close to the alarm setting (0.27-0.3).

It is to be mentioned hereinafter that such turbines need very careful control of the lubricating and governor oil.
It is also important to note that all start-ups and shutdowns mean extra loads and possibility of failure. (During the last monthly period there were two shutdowns of the Unit.)

According to the manufacturer's offer the delivery time is 9 months from the opening of the letter of credit and official order.

As far as the compressor part is concerned the necessary documentation and instruction manuals are available but neither the mandatory spare parts nor the special tools mentioned in the instruction manual are available. The management is advised to check again this information and at the same time ask an offer from the manufacturer for them.

According to Manufacturer's Service Manual it is advised to open the compressor and inspect the bearings, the sealing labirinths and the blading every year.
Some parts of the compressor have not been opened and checked for more than ten years!! Taking into consideration this fact the Company is advised to order an extended spare parts list!

The other three big steam turbines (namely: 102 JT, 101 JT, 4105 JT) and the smaller ones in the Unit are receiving steam from the medium pressure (40 barg) system supplied with steam from the exhaust of turbine 103 or from the HP steam system through a pressure reducer. The rate of this reduced pressure steam is approximately 200 Mt.p.hr. In addition steam produced by the utility boilers is also utilized for this purpose at a rate of 2 x 60 tons/hour.

The 102 JT Natural Gas Compressor is relatively new.
The guarantee period expires in the near future. The turbine is a condensation type. The condenser is separated from the others because it was built during the revamp of the unit.
The machine is running smoothly. The only problem during the guarantee period was that the steam control valve-disk has broken. It has been changed and the manufacturer was notified.

It is important to mention that at some places the expansion joints are fixed or not released properly after the erection.
This failing of release would cause the displacement or unnecesary loading of the machine or the nozzles, and later the increase of the vibration and bearing failure. One example is the steam outlet of the 102 JT turbine. (It is not sufficient to grind off the weld of fixing for erection. It is important this fixing is to be removed!)

The 101 JT Air Compressor is one of the critical machines of the Unit. It is important to mention that the 101 JT and 105 JT are driven by the same type of turbines. At the very beginning the Company had the two machines and two spare rotors. During the approximately 10 years of operation various kinds of failures have occured (shaft broken two times, axial bearing disc failure two times). The failed rotors were changed or repaired but at the present there is no complete spare rotor available in the Company.

The simplified adaptation flow sheet of compressor 101 JT is shown in Fig. 2.

The actual status of the compressor at the beginning of April, 1989. Neither the low pressure stage nor the high pressure stage have been opened from the start-up of the Unit. The outlet pressure was dropping day by day, putting in danger further operation. Considering that a complete overhaul is foreseen in about 3 weeks in order to change all refractories at the burners of the primary reformer, the management was advised to act as follows:

- reduce the instrument air system pressure from 7.9 to 5 barg
- start the instrument air compressor and separate the instrument air system from the process air compressor. (It is a faulty view that the so-called "stand-by" compressor is needed only for the start-up of the Unit.)
- reduce the anti-surge blow-down rate with maximum 5 %. (In the future it would be convenient to reduce the anti-surge blow-down consulting the way with the manufacturer because the present blow-down is too much and this is a complete energy loss.

  One of the possibilities is shown in Fig. 3:

  Use the anti-surge blow-down as a basis of instrument and service air supply for the whole Company with a common air receiver and eliminate the interstage bleeding.)

The construction of the compressor is given, therefore the following factors are reducing the capacity:

a) Neither of the knock-out drums (or very few) are operating properly. The level controller instrument loops are out of order and the mechanical traps are also in bad condition. As a result of the above, the operators can choose only between the following two possibilities:

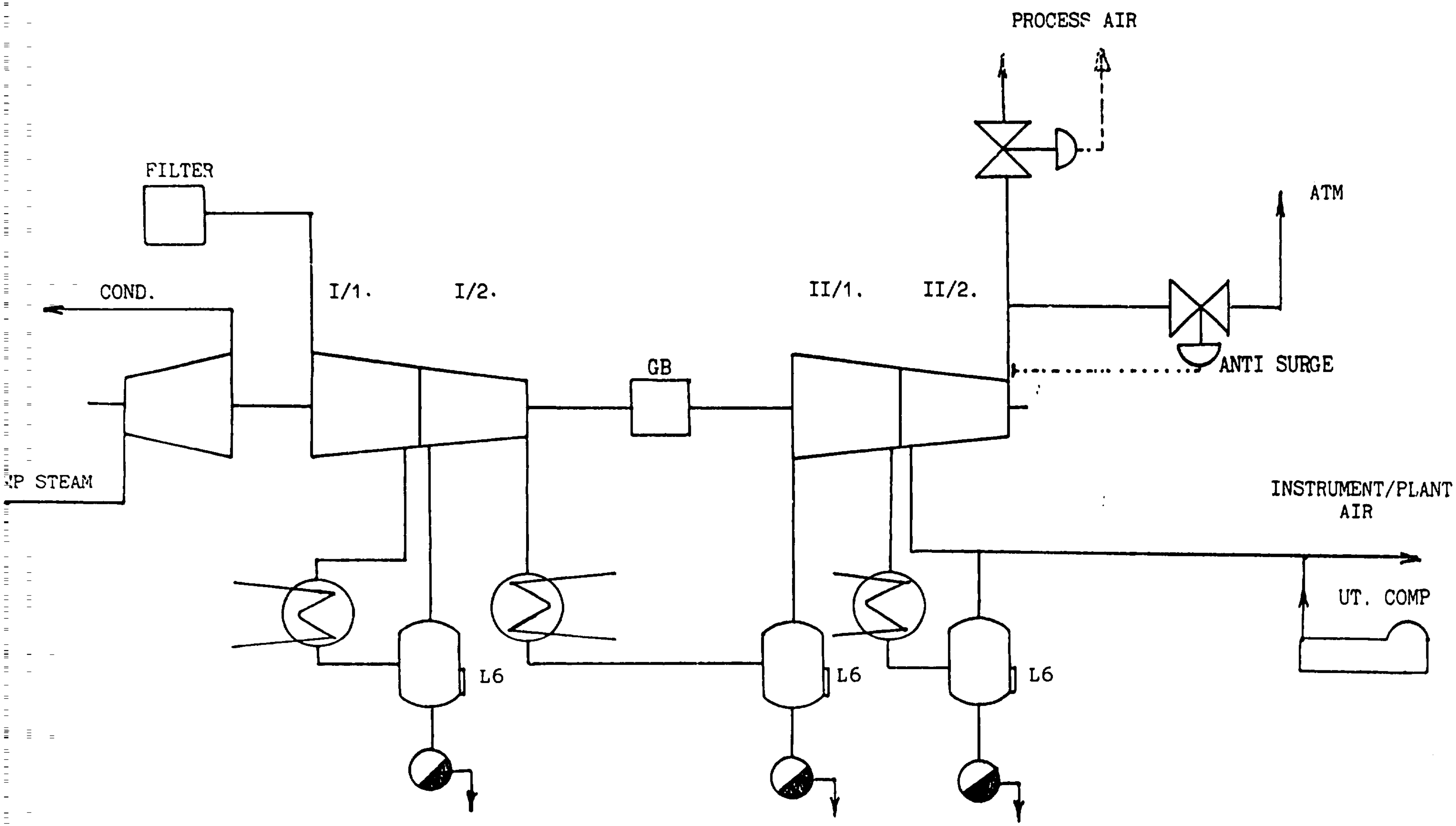

PROCESS AIR
ATM
FILTER
COND.
I/1.
I/2.
GB
II/1.
II/2.
ANTI SURGE
P STEAM
INSTRUMENT/PLANT
AIR
UT. COMP
L6
L6
L6

FIG. 2

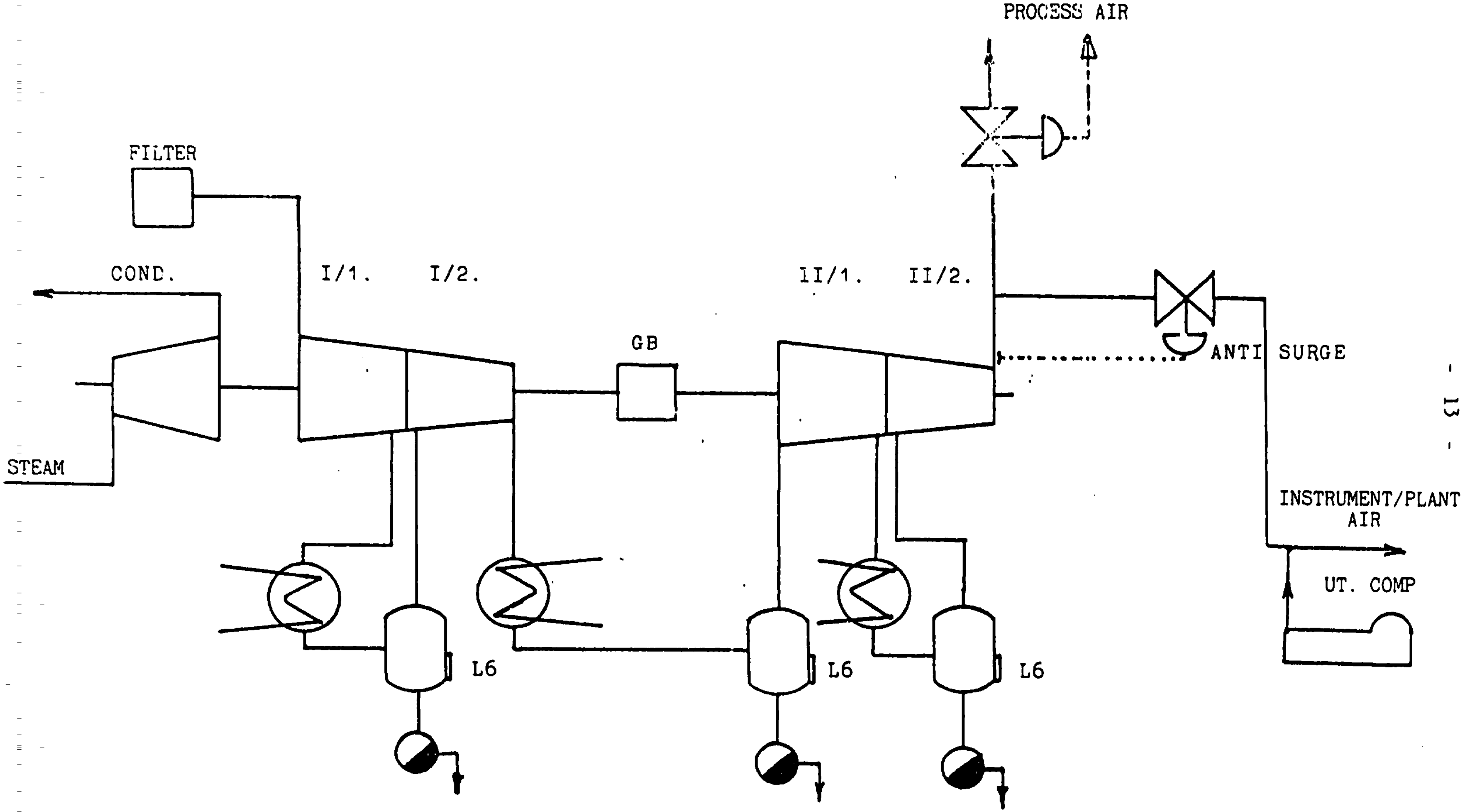

PROCESS AIR
FILTER
COND.
I/1.
I/2.
II/1.
II/2.
GB
ANTI SURGE
STEAM
INSTRUMENT/PLANT AIR
UT. COMP
L6
L6
L6

FIG. 3

- open the bottom by-pass blow-down valve of the knock-out drum in order to drain the knocked-out liquid drops. The blow-down is not controlled and a huge quantity of gas is lost.

- close the bottom by-pass blow-down valve of the knock-out drum, which means that the gas loss is avoided but the knock-out drum is not operating and all liquid drops are carried over to the next stage of the compressor and damage the labyrinth seals betwen the stages. Also the corrosion is extremely high not only in the compressor internals but also in the interstage equiment and piping. (All the corrosion products /rust/ are going through the compressor, with an effect similar to or more dangerous than that of the liquid drops themselves.)

b) The interstage labyrinth seals betwen the impeller and the stator, furthermore the shaft-mounted guide-vane seals are totally destroyed.

Considering that the Company intends to produce the spare labyrinth seals locally and the damaged labyrinth seals would be one of the main reasons for the reduction in discharge pressure, some theoretical and practical information are given herebelow: The principle of the arrangement of labyrinth seals is shown in Fig. 4.

The labyrinth seal may be of stepped (a) or plain (b) construction. The sealing action of the labyrinth seal is ensured by the adiabatic expansion of the gas in each chamber.

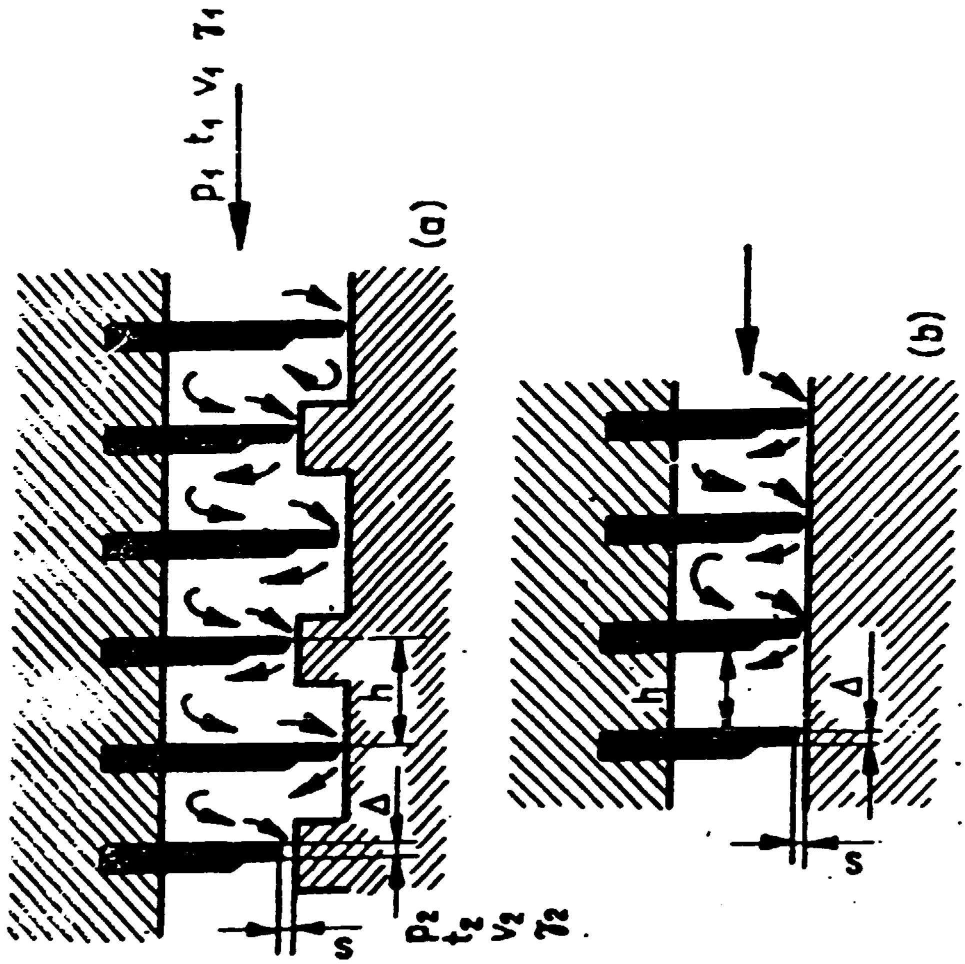


FIG. 4

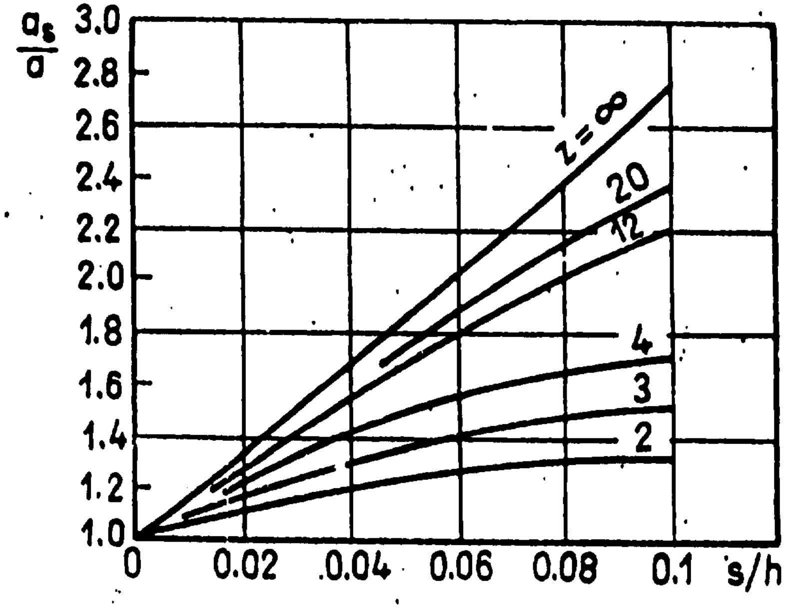
If the number of labyrinth strips is i (at least 4) and the pressures on the two sides of the labyrinth are p_1, p_2, the volume of gas flowing through the cross-section is:

$$G = a.f\sqrt{g\frac{p_1^2 - p_2^2}{i.p_1.V_1}}$$

where: $f = D_s. .s$, the flow cross-section, and, according to the designations in Fig.4., s = clearance (mm); D_s = mean diameter of clearance (mm), p_1 and p_2 = pressures in atm, γ_1 = specific weight of the gas, $kg.m^{-3}$. Further, substituting $0.1\pi\sqrt{g} = 1$,

$$G = a.D_s.s\sqrt{\frac{1 + \frac{p_2}{p_1}}{i}} \cdot \sqrt{\gamma_1(p_1 - p_2)} \quad \text{(kg)}$$

The value of factor a depends partly on the construction of the labyrinth and partly on the coefficient of expansion.
With a stepped labyrinth, a may be substituted by 0.7.
When the labyrinth is plain the value of a_s is greater.
With the distance between the strips denoted by b, a_s/a can be plotted against s/h and the number of strips, i. See Fig. 5.
The number of the interstage labyrinth strips is usually 4 to 5.
The edge of the strips should be rectangular, as otherwise factor a may increase by 20-25 %.



a_s/a
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0
0.02
0.04
0.06
0.08
0.1
s/h
z=∞
20
12
4
3
2

FIG. 5

The thickness of the labyrinth strip should be as small as possible. It is clear that the attrition of the labyrint segments has two effects:

- the size of the clearance increases.
- factor a increases too.

The eccentricity of the clearance deteriorates the sealing action. This is the reason why the regular cleaning of the labyrinth spring casings is very important.

The recommended minimum dimensions of clearances are:

$$s = 0,2 + 0,6 \cdot \frac{D_s}{1000} \quad (mm)$$

The usual application of the interstage labyrints is shown in Fig. 6. The cylindrical surfaces of the ring on the shaft and the impeller against the labyrint strips are also attrited.

It is recommended to check and re-finish these surfaces, if necessary and/or possible.

c) The unnecessary anti-surge blow-down (it is recommended to modify the system as mentioned above.)

d) The interstage bleeding for instrument air supply (this bleeding reduces the discharge pressure approximately with 1 barg).

e) Extremely high rate of fouling in the suction filter.

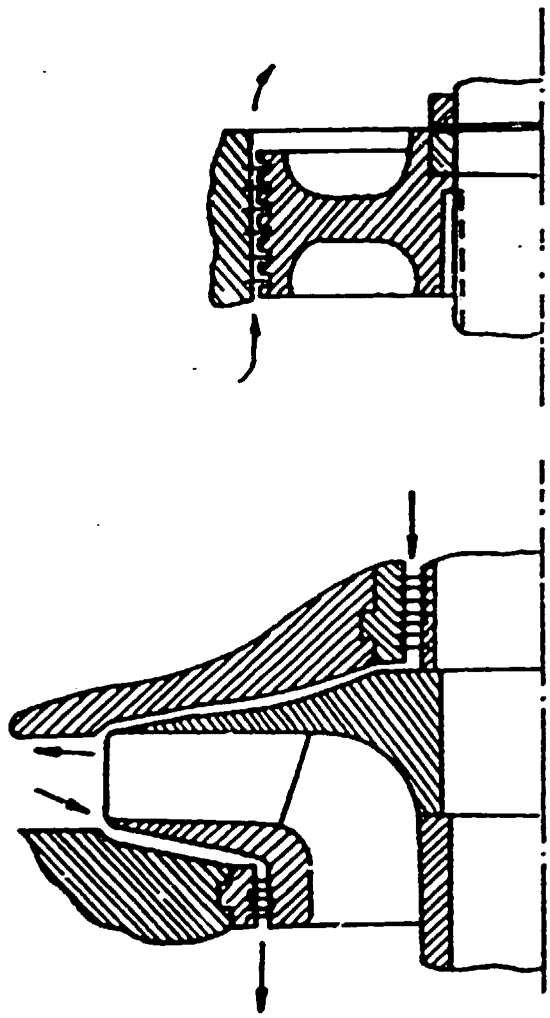


FIG. 6

During the last period of the mission the Unit was stopped for turn-around. The responsible section of the company has opened the follow-following parts of the machine:

- The turbine where both the rotor and the stator were fouled with salt deposits (not only the profiles but the labyrinths too*).
  The salt deposits were removed partly by washing with chemicals and partly by mechanical cleaning. (I have to confirm that no mechanical cleaning procedures using abrasives are recomended!!)
  It is strongly recommended to check the labyrinths and protect them from any mechanical damage or abrasive action.

- The high pressure stage (because of the spare-parts availability may be considered better.)
  Due to the fact that the machine has not been opened since the start--up of the Unit, it was impossible to take out the rotor using the normal traditional procedures. The clearances were extremely high and also the corrosion and the rust and the rust-powder deposits on the surfaces were unacceptable.

There were not taken the necessary steps to do the maintenance of the other part of the machine and the systems belonging to the machine, namely: the low power stage, the knock-out drums, the suction system and filter and the interstage piping.

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* Note: The 102 JT, 101 JT and 105 JT are driven by Creusot-Loire action-type turbines where turbine stages are separated by diaphragms and the seals are labyrinth seals.

It is strongly recommended to do the maintenance completely at each machine. Upon restarting the compressor all rust and dust deposited in the equipment and piping will be carried over to the next stage and damage the seals in it.
Considering that maintenance and cleaning have not been executed since 10 years, it is recommended to blind the machine from the connected pipelines, to form a complete washing loop and to do a chemical cleaning, washing and drying as it is usual at the start-up period.

The 105 JT Ammonia Compressor is working in similar condition as 101 JT. The capacity ot the responsible organisation for the maintenance of the rotating machines does not allow to open two big machines at the same time. (Organisational problems will be discussed later.) It would be supposed that during the maintenance the Company has to foresee similar difficulties.

The Urea Unit is operating with 70-95 % of its capacity.
Utilization of maximum capacity is depending first of all on the status of the CO_2 turbocompressor 311 JT. (Fig. 7.)

The troubles could be grouped in the following categories:

- knock-out drums are not operating properly because of the level controllers' failure,
- the labyrinths are attrited,
- the O-rings between the stages and also between the rotor block and the casing are loosing their elasticity and with this the capability for sealing.

  This is because moisture drops enter the compressor absorbing CO_2 and carbonic acid is formed. The carbonic acid at this pressure is very corrosive. To increase the life-time of these O-rings the following steps are to be taken:

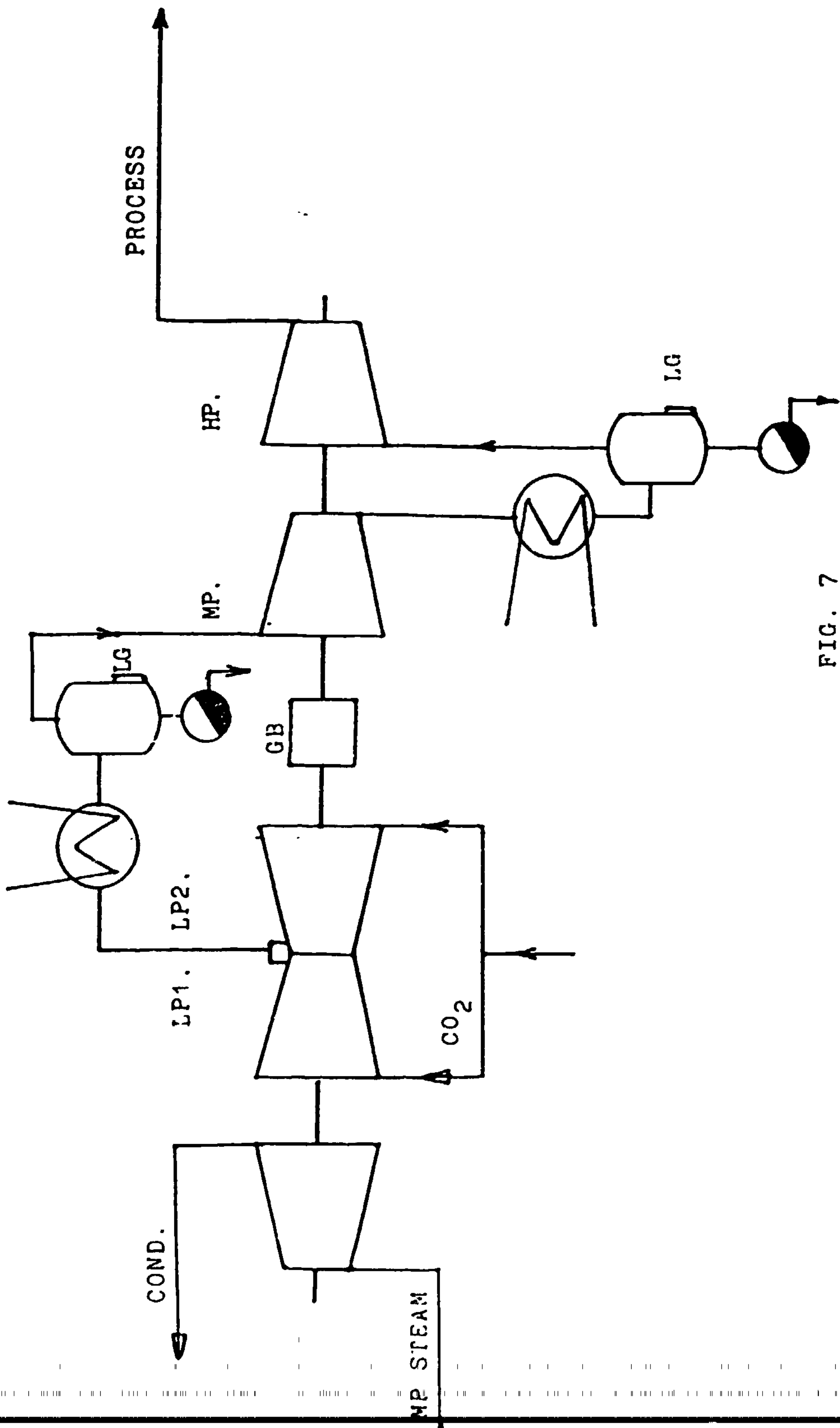


FIG. 7

= do the proper maintenance of the level controller of the knock-out drums, and inspect/service them regularly,

= contact directly the manufacturer of such sealing materials to find the most suitable material for this service.

As a result of the troubles with the CO_2 compressor, the Unit has a lot of leakage problem. The ammonia concentration in some areas is so high that it is impossible to approach the machines or work there without gas masks. It is strongly recommended to eliminate these leakages during the turnaround period!

The Utility Section is the most critical part of the Plant.

The main troubles are:

- There are a lot of leaks in the steam system (not only in the Utility Section but also in the Units).
- Because of the leakages and unnecessary blow-downs all the boiler feed pumps are operating (the stand-by ones also).
- The boiler feed water tempering plant is not working properly and the capacity is not enough.
  Collected water streams are used without any treatment and control.
  The quality of the water is not controlled adequately.
  This is the reason of the deposits in the utility and waste heat boilers and also of the fouling of the turbines with salts.
  IT IS THE MOST DANGEROUS TROUBLE IN THE COMPANY! Urgent action is needed!!
  It is recommended to increase the capacity of the water treatment plant, or build a parallel new one, or use the other possibilities of the Company, such as form a unified boyler feed water system.
- The utility boilers are operating under very poor conditions.
  The burners are not controlled properly. There are unnecessary (at some places permanent) blow-downs.

THERE IS NO REGULAR BOILER AND PRESSURE VESSEL INSPECTION!!!
(Refer to the General Recommendations.)
The external and probably the internal corrosion is high (because of improper boiler feed water deaeration).

- The cooling water supply is good as far as the capacity and the water temperature are concerned, but water treatment is not continuous because of the shortage of chemicals.

General Notes for the Ammonia-Urea Plant:

- The Plant is a very compact group of units.
- The maintenance is partly acceptable (as far as the capacity of the rotating machines maintenance section is concerned) but the efficiency of the Plant's own maintenance is not too good, and the spare parts supply is also problematic.
- The Plant is equipped with its independent utility system.
- The number of operators, maintenance staff and management (including their own administration) is 580.

D. MAINTENANCE ORGANIZATION

The general organisation of the Company is shown is Fig. 8.

This figure shows only the main functions of the maintenance group. As it can be seen, the Company has three "semi-independent" Plants with their own maintenance organisations. With this divided maintenance staff neither the Plant Maintenance Section nor the Technical Directors suborganisation can do a properly coordinated full turnaround maintenance.

The separate Plants can not interchange their maintenance staffs and thus their activity is totaly isolated. Obviously the efficiency of the maintenance work is very low, as a consequence.

The Company is recommended to reorganise its maintenance system, and establish a concentrated maintenance direction.

It is recommended to reinforce the Maintenance Section for Rotating machines and also to form a Technical Assistance Department with the following main functions:

- collect data on technical troubles in operating units
- provide technical documentation for maintenance and local spare-parts manufacture
- prepare plans for turnaround activities
- provide for necessary cooperation with other local companies and manufacturers, if applicable.

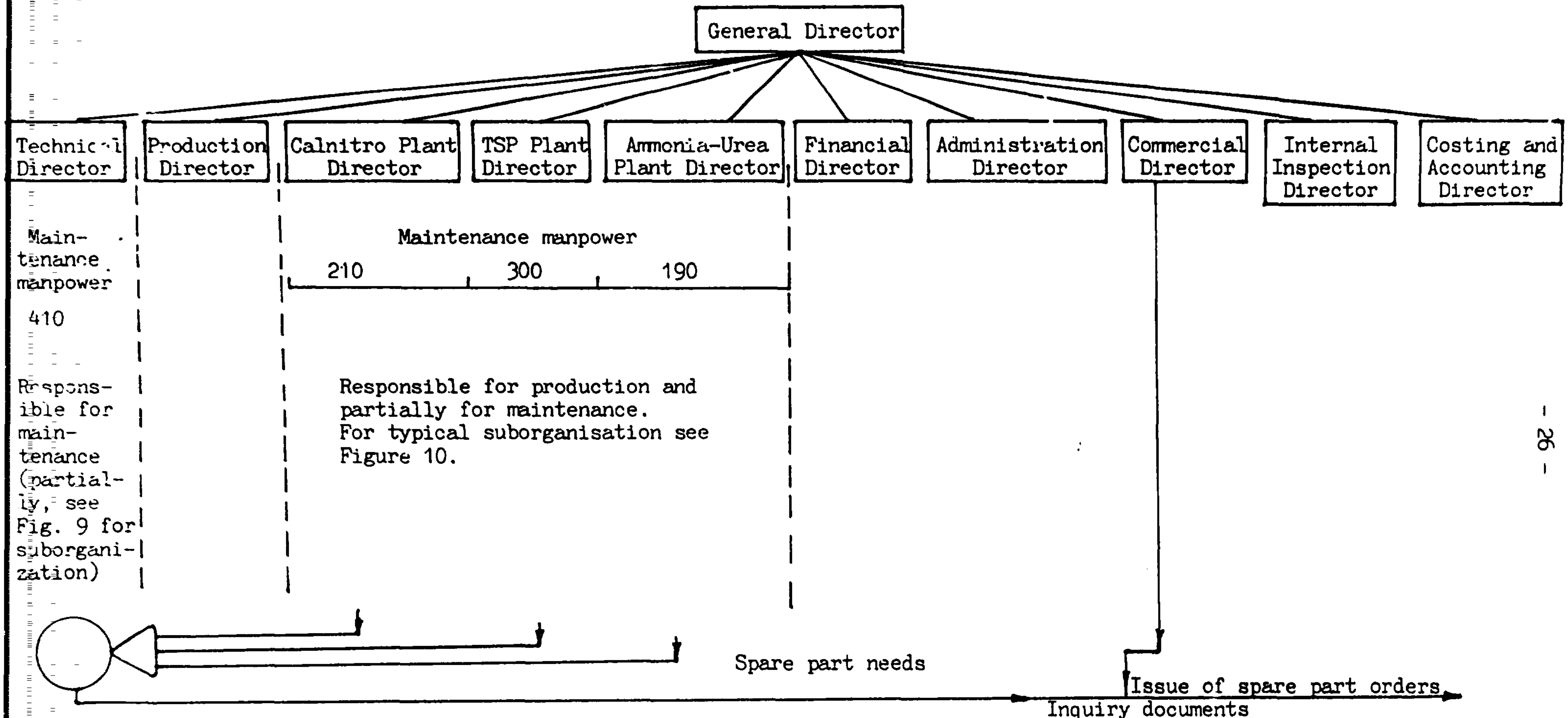
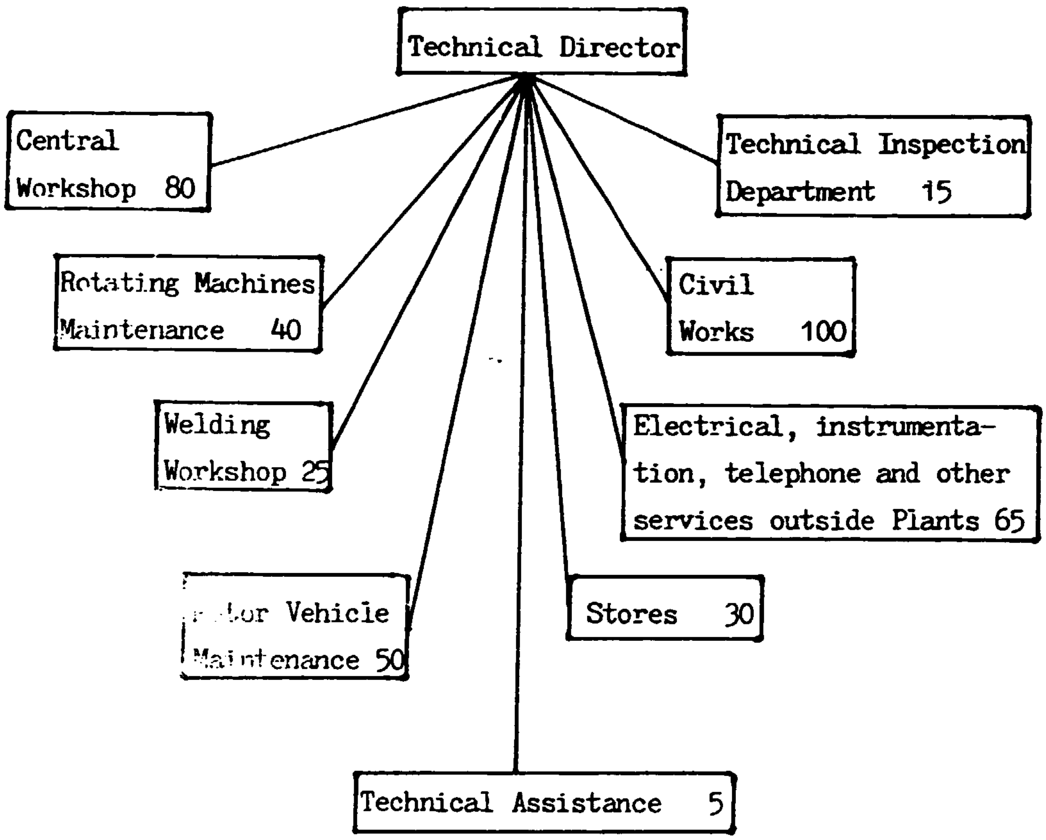


Figure 8 - General Company Organization



Total number of personnel 410

Figure 9 - Suborganisation of the Technical Director and staff numbers

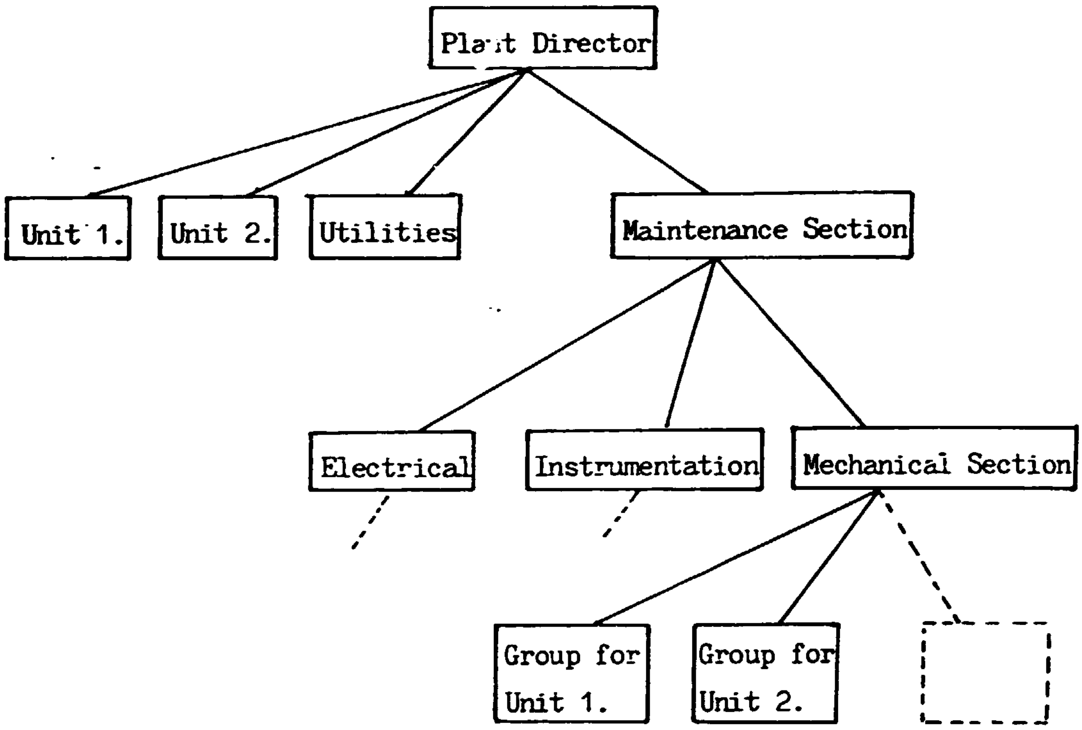


Figure 10 - Typical suborganisation of a Plant Director

III. GENERAL RECOMMENDATIONS

1. There is no preventive maintenance at the Company.
   The present method, when all problems which occur cause a full or partial shutdown of production units, is too expensive.
   With preventive maintenance and well planned turnarounds the number of shut-downs and short stop-overs can be reduced and the costs of preparation and spare parts are much less than the cost of lost production.

2. There is neither boiler inspection nor central boiler inspection insitute or authority in the country! The situation is similar with pressure vessels. It is strongly recommended to issue a national boiler and pressure vessel code or standard and also to regulate the inspection system. Till the edition of such a code the Company is advised to issue its own internal procedures, if necessary (on the basis of any similar European code).

3. Reorganise the maintenance at the Company and establish a Central maintenance system.

4. Reconsider the incentive system and also the system of control for strengthening labour discipline.

5. It is recommended to send to high level consultation/training courses held at manufacturers of the main compressors/turbines in the Ammonia-Urea Plant the following personnel:

   - Mr. Ali Al-Yossef, Technical Director
   - Mr. Issa Gerges, Department Head

6. There is no regular education/training for skilled workers and foremen. It is recommended to establish training centers in each larger city for this purpose and particularly in the bigger industrial centers.

Acknowledgements

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