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UNITED NATIONS

INDUSTRIAL DEVELOPMENT ORGANISATION

VIENNA - AUSTRIA

07533

FINAL REPORT

MAINTENANCE AND REPAIR IN THE FERTILIZER INDUSTRY IN INDIA

IS - IND - 74 - 017

POLYTECHNA PRAGUE - SLOVCHEMIA

DUSLO ŠAĽA

1976

1. INTRODUCTION

One of the methods to secure adequate nutrition for the present rise of the world population is the way to increase yields of the existing agricultural area by using chemicals.

For this purpose plants for the production of industrial fertilizers are being built in various countries. As it is generally known, for the present sophisticated production technologies in fertilizer plants and particulary in large - scale production units are set high requirements regarding operational and maintenance activities. Only by a proper control of these activities it is possible to approach or achieve designed production rates at the required efficiency.

In this sense and for the achievment of this aim should also the realisation of the project " IS/IND/74/017 Industrial Maintenance and Repair in Fertilizer Industry in India " be regarded as an assisting factor.

Within the scope of this project we tried to transmit maximum of our experiencies gained at longterm operations of similar production capacities in our country. In our maintenance activities we have directed our effort to the realisation of the motto: " Values should be produced by machines and equipment and not consumed for repairs ".

According to the Contract between the United Nations Industrial Development Organisation and Polytechna - Technical Cooperation Agency for provision of services relating to Maintenance and Repair in the Fertilizer Industry in India - Contract No. 75/14, Project No. IS - IND 74 - 017 and briefing notes from Vienna on 27 May 1975 given by Mr. Verghese the team of the Contractor should perform the following:

- to identify deficiencies in the field of maintenance and repairs in the plants and to recomend remedial measures,
- to prepare a concrete plan for each visited plant to promote and increase capacity with the inclusion of a scheme for preventive maintenance covering an intensive layout of Mechanical, Managerial, Organisational and Economic aspects of the maintenance and repair area,
- to estimate additional investment requirements and other necessary inputs in order to increase the production of each plant as well as an economical and financial evaluation including foreign currency savings,
- a study of the spare-parts stock position including recommendations of improvements proposals if warranted in procurement, fabrication and use of spare parts,
- to estimate the number of the skilled workers for maintenance and submit recomendations for the improvement of their utilization.

In compliance with on-the-spot assistence on maintenance problems the suggestions and the recommendations for further improvements should be given as far as possible and included in the reports.

The overall objective is also to solve actual problems existing in the plants.

In this report regarding the operation of each plant an analysis about the loss of production should be made which can be atributed especially to maintenance or non-availability of spare parts.

We have started our work on the Contract on the 3 rd of June after our departure from Prague. We have landed in India at the Bombay airport on the 4 th June 1975 and reached New Delhi the same day afternoon.
On the 5 th and 6 th June 1975 we have solved all organisational problems connected with our stay in India. Discussions have taken place at the UNDP, Ministry of Petroleum and Chemicals.and Centeral Office of Fertilizer Corporation of India Ltd.
It was decided that the work will start at the FCI'S Trombay Unit. Therefore we left for Trombay on June 6 th 1975. After a short discussion, the next.day we started to investigate the problems in the factory.
Mr. S.N. Jain - Addl, Chief Engineer / Mech./ and Mr. T.M. Das - Dy, Chief Engineer / Chem./ were our counterparts at the FCI - Trombay Unit.
We have completed our work at FCI - Trombay Unit on July 1 st 1975 and left for Sindri via Calcutta and Dhandab.
On July 2 nd we have met our counterparts for our work at Sindri Unit - Mr. G.K. Kuriyan - Dy, Chief Engineer / Process/ and Mr. M.N. Das - Dy, Chief Engineer / Mech. Mce/.
Our work at FCI - Sindri Unit was finished on July 23 rd and an July 24 th we left Sindri and reached Durgapur the same day afternoon. After a short meeting with the General Manager Mr. K.H. Chaurey an other representatives of the factory we have started our investigation in maintenance and production problems of the factory. The counterparts for our work at FCI - Durgapur Division were Mr. M.T. Bhandari - Addl. Chief Engineer / Chem./ and Mr. S.K. Mukherjee - Addl. Chief Engineer / Mech. /.

By request of the Central Office FCI as well as The Ministry of Petroleum and Chemicals, Government of India, our stay in FCI - Durgapur Division was prolonged up to September 26 th 1975. The Neyveli Lignite Corporation also agreed to a reduction of our visit to their plant which was scheduled for September.

We have finished our stay at the FCI -.Durgapur Division on September 26 th and left for New Delhi.

During our short stay in New Delhi we have clarified all problems connected with our further work in India. We have discussed the related matters with representatives of the following organisations: UNDP, Central Office of FCI, The Ministry of Petroleum and Chemicals, and Regional Office of Fertilizers and Chemicals Travancore Ltd.

The journey to Cochin was organized on October 1st 1975.

We have gradually started to study the problems at the FACT Udyogamandal Division on October 2 nd 1975. Our counterparts at our work were Mr. V. Cecil Dorairaj - Senior Engineer / Chem./ and Mr. M.B. Bose - Senior Engineer / Mechanical Mce/.

After completion of our study at the FACT Udyogamandal Division on October 31 st 1975 we have continued in our work at the FACT - Cochin Division.

Our counterparts at theFACT Cochin Division were Mr. R.K. Menon - Senior.Engineer / Planning of Mechanical Maintenance / and Mr. A.R. Ramachandran - Electrical Engineer / Technical Service /.

On November 28 th 1975 we have concluded our work at the Fact Cochin Division and left for New Delhi.

During the stay at Delhi we were provided with more information about the plants in FCI - Trombay and Sindri Units.

On December 8 th and 9 th we have attended the FAI-ISMA Conference held by The Fertilizer Association of India. On December 10 th we left New Delhi and on December 11 th 1975 early in the morning we left India by plane from the Bombay airport.

3. CONCLUSIONS

3.1. Prevention and technical preparation of repairs.

To secure the continuity of any production process and to increase the capacity of production lines from the viewpoint of economy, raises day by day higher demands for operational stabilisation of the production equipment. The transition from interrupted production with small capacities to continuous large capacity units is realisable only under precondition of high functional reliability of production equipment. This should be secured not only by a renewal of its technical or mechanical condition, but also by a complex care both during its exploition as well as in the course of repair works or overhaul. Longterm experiences undoubtedly confirm that the only way for securing a trouble-free operation of production devices at minimal costs and minimal man power expenditures leads to prevention, and through technical preparation of activities based on specialisation and centralisation.
On the other hand, there are prevention claims of technical capacities in respect both to quality and quantity. Nevertheless it should be stated that an orientation of technical capacities in this area is substantially more advantageous , as an orientation to the removal of consequences after a inconsistently performed prevention.
In the factories visited FCI ana FACT we have stated, that each factory has different condition for carying out the maintenance activities / different possibilities to get services from other companies in the field of carying out repairs or in the field of technical solution for the maintenance problems, different technology used in the factories, different capacity of the plants etc./

For that reason it is not possible to organise the maintenance in all factories according to one organisational structure. It is possible to use the same or very similar organisational structure for such as factories as FCI Durgapur Division and FACT Cochin Division.

To increase the level for maintenance activities in the factories visited it is necessary to solve some of the typical common problems / the specific problems are detailed in the analysis for the respective factories/.

Our recommendations for implementation are as follows:

1. To achieve an balance in the relation of maintenance and production. For this purpose responsibilities of capital items should be divided in the following way:

   - Production department to be responsible for upkeep of the plant and equipment for their economical utilisation, for every day attendance and for running the plant according to operation manual.
   - Maintenance department to be responsible for basic mechanical condition of the plant and all activities connected with this requirement.
   - Technical service department to be responsible for the highest technical level and consequently for such optimum operating parameters which will optimize production at the lowest unit costs.

   <u>Evaluation rules:</u>

   - Production department - plant output per hour.
   - Maintenance department - working hours of plant.
   - Technical service department - cost per unit of product from the point of view of technical requirement.

Such a share of responsibilities enables the maintenance department to establish the necessary running time as well as requirements for shut-downs for the plants in compliance with the overall plan of available running hours. This should be the first step in maintenance planning.

2. To enable the maintenance to intervene in the whole attendance cycle of capital items. To pay attention to the principles of attendance for capital items, starting from all prerealisation phases, i.e. processing of the investment project.

Practise shows that if a supplier does not receive correctly and carefully detailed basic data this can gives him the chance to supply equipment of inferior quality.

Therefore we consider as necessary to detail a technical project for future capital items with the viewpoint to all criteria of complex care for capital items including provisions of the investor with the services from a selected suppliers having skilled teams in maintenance practice, further unification, typification, requirements on the extent of quality checks etc.
The quality control of the equipments or of the whole supply can mostly be performed only by maintenance staff, as the other divisions usually have neither the specialists required nor the necessary equipment for these checks. The advantage of this system is that equipment of high quality can be ensured and at the same time the maintenance personnel becomes familiar with such equipment. Of course the maintenance action during an erection period has also other duties, e.g. the preparation / training / of its personeel, preparation of the maintenance instructions, review of operation instructions, verification of the operating personnel qualification, classification of the equipment according to its importance in the production process, determination of methods for repairs etc.

3. In order to increase the effectivity and mainly the technical standard of performed maintenance activities we recommend to centralize the maintenance up to a maximum extent. For this purpose we recommend to build up adequate technical support for the maintenance regarding regulations and designs which achieves its aim also by elaboration of statutes, instructions and standards as well by provision of service in the area of design, control and checks.

4. Establishment of technical inspections for mechanical technological equipment during operation and repairs. These inspections we recommend to perform on compressor, pumps, and selected chemical equipment and further in the scope of anticorrosion and lubricant services.

Within these activities competent maintenance experts carry out such inspections in the aim for a complex appreciation of the mechanical technological equipment.
For instance the specialist for compressors checks the observance of the operating instructions during operation of the equipment as well as service records for the past time / 2 - 3 months/ where he checks the adherence to operational parameters and checks also parameters directly indicated on the machine. Moreover he verified the knowledge of operation instructions and analyses also the recorded troubles at the engine in operation.

Similarly are carried out inspections during repairs, where he thematically is directed to check the adherence of maintenance instructions, to verify the knowledge of maintenance personnel and to carry out checks of some functional dimensions etc.
The findings are analysed and effective remedial measures are taken.

5. To utilize and develop the possibilities of the nondestructive diagnosis for machines and equipment / sensing and analysis of vibration, ultrasonic, radiography, thermovision etc./.

6. To rise the technical standard of the designing departments to a level where it should be able to produce equivalent spare parts on the basis of drawing documentation and in this connection to perform supervisor activity and to rise the level of repairs.

   In order to rise the efficiency we recomended to perform a classification of the spare parts at least according to these characteristics:

   - spare parts which can be made by own factory facilities,
   - spare parts which can be made in INDIA,
   - imported spare parts which are necessary only up to the time of mastering their manufacture in INDIA,
   - spare parts from import.

   According to this design capacity should be regulated to handle spare parts.

7. To rise the technical level for renovations of spare parts and to perform the analysis regarding spare parts service.

3.2 Observation in the field

During our visits in the respective factories we have studied organisation standards of each factory and their production programme. Further we have studied:

- the organisation of maintenance department in detail,
- the outfit of central workshop and plant workshops and all activities carried out by them,

- preparation and execution of maintenance and repair jobs in the plants,
- the technical level of repair jobs,
- utilisation of man-power,
- the procurement and storage of spare parts.

Quite a lot of our time was spent in the plants to discuss the problems of the plants with the respective plant managers and plant engineers. Results from these discussions are given in our report, i.e. suggestions and recommendations for solution of the problems.
The operating instructions are mainly very rough. In many plants we have seen only operating manuals from the supplier, which were issued to the operators. The best situation in this field is in the FACT Udyogamandal Division, where for each plant are prepared very detailed operating instructions with simple drawings for each vessel and machine. In the FACT Udyogamandal factory is also prepared a list of duties for each operator and each worker in maintenance. A similar list of duties is prepared also for the technical staff.

Recommendations were made for each plant for improoving the maintenance organisation as outlined in this report. In some plant we have observed that the machines should be kept in better and cleaner condition. According to our experiences cleaning of machines is not only a matter of outer appearance, but it is a basic reqisite of preventive maintenance. Clean and well painted pipelines, vessels and structures not only prolong the life of the plants but also enable a better and more safe operation of the plants. In some plants we have seen that high pressure lines are badly corroded from outside. The extensive corrosion in some factories is due to high humidity and is mainly due to very high corrosive environment of the factories. It is very necessary to work out a method of protection against corrosion for each area of the factory separately. It is recommended to elaborate the so called " corrosion map " for the factory with the technology of painting of respective lines and vessels. Pipelines with different colour paint should be used for different medium. The painting must be done properly. All the rust or scale must be removed up to the metallic surface and then the lines can be painted with the prime coat and few layers of finishing coat. Painting the equipment without previous cleaning as it is done in some plants has no sense. Suitable painting specifications for condition similar to that in India is given in annex No. 23.

The Sindri Unit uses in some plants out of date technology. The plants are for a long time in operation and this causes also many problems in production and mainly in maintenance. The level of preventive maintenance in Sindri Unit is very poor. The repairs on the plants are mainly concentrated on the removing of the break downs problems. There are many deficiencies in the basic maintenance of machines and equipment like cleaning, greasing, removing small leakages, protection against corrosion etc.
There are also problems caused by imperfection in the field on inspection in maintenance like unsatisfactory checking and repair of the functional surfaces, unbalanced rotor of rotating machines, not keeping the prescribed clearences etc.

The Durgapur factory is a modern unit with 600 TPD single stream ammonia plant and 1000 TPD urea plant in two lines with common prilling tower. This first single stream ammonia plant in India designed by P and D Division of FCI and FEDO in cooperation with Power Gas Corporation from England and Tecnimont from Italy has some design deficiency.

The principal problems causing the limitation have been collected and an end to end survey was carried out. These main problems were also discussed on a meeting in the Durgapur factory on August 14 th 1975. To some of them we have also given our opinion in this report.
According to our estimation the ammonia plant is able to achieve an 75 to 80 % capacity without any modification. It is necessary to stabilize the whole process. For that purpose the amount of produced steam must be increased. It will be necessary also to change the mode of operation of the syngas compressor according to the new instruction from Nuovo Pignone. The effort to keep the ammonia plant in a 100 % good condition is leading to very frequent shut downs and quite big production losses. Similar plants like that in Durgapur are running usually with some small deficiency, e.g. leaks, nonavailability of spare machines or equipment etc. To our opinion the production and maintenance staff should bear some reasonable risk. A certain extent of risk, in reasonable range is that, which in accordance with the knowledge about processing and maintaning leads to a safe operation of the plant.

During our stay at the Durgapur Division the plant was stopped 8 times. From which the reasons for a 3 time stoppage were unsatisfactory solutions in previous repairs. According to our observations the duration of repairs is to long due to unsatisfactory technical solutions and organisation of the same. According to our opinion the duration of repairs is possible to reduce to about 50 %.
During our study of maintenance and process problems in FACT Udyogamandal Division we have seen many common problem for all plants. Some of the plants are quite old and the machines and equipment are becoming obsolete. The prolonged services of the plants need not only more attention from the

maintenance side but also renewal of some machines or equipments. When replacing machines then new and up to date types should be selected.

There is in the Udyogamandal factory quite a big production loss due to inter-dependence of the plants. Since there is not enough refrigeration capacity, the production of ammonia is reduced whenever some ammonia consuming plant is stopped for maintenance. There is also lack of storage space for ammonia and up to now the possibility of selling ammonia for other ammonia consuming factories remain unsolved. Likewise, when ammonia production is low there is a necessity to reduce the production of acids and fertilizers. The CO_2 released from CO_2 removal is not fully utilized for the production of liquid CO_2 or dry ice, even though the dry ice plant is already installed. CO_2 is vented to the atmosphere because of excise problems connected with the sale of dry ice. There was also a lot of production loss due to power supply failure. For example, the Composite Ammonia plant was stopped in the years 1974 - 75 22-times and in the first two quarters of the current year, 13 times due to power supply failure. The power supply failures are causing not onlyloss in production, but also it has a very negative influence upon the condition of the plants mainly upon Primary/ / Secondary reformers and heat recovery system. In the primary reformer, the sudden interruption of flow mostly affected the reformer tubes and catalyst. The same refers also to generators in the Texaco Gasification plants.

During our stay at the FACT - Cochin Division the factory had a steady production. On November 8 th the Urea Plant Achieved a production of 1 004 tonnes. The plant has so at first time achieved the rated capacity . The ammonia plant

was in operation with two interruptions with an average output of about 52 % of the rated capacity.
All limitations of production are included in the Plant operations Improvement Programme. After completion of this programme the plant will be able to produce full capacity. The production and maintenance departments at FACT - Cochin Division are staffed with experienced engineers. They are able to bear the reasonable risk in the plants. This can be seen from solutions in maintenance problems of the ammonia plant.

In all factories we have seen the obvious effort to substitute the foreign machines and spare parts with indigenous ones to save foreign currency. But we have seen that such substitution was in many cases not succesful. This is because the substitution of spare parts and machines is organized by the respective plant engineers. On this level it is not possible to take into account the full complex of problems like corrosion problems, hydraulic conditions, design problems etc. There must be also taken into account the viewpoint of typi fication and standardization of new machines and spare parts. It is also very important to keep good contacts with the suppliers so as to enlarge the possibilities for the choise of the best one. This can be performed only by a high qualified group of engineers.

The fertilizer factory, first of all the new modern units producing ammonia need very steady power supply. The consequence of frequent power failures is not only loss of production, but also the reduced service life for equipment.

The unreliable power supply is the common problem for the majority of the visited factories.

Gradualy with building the modern big units arise the problem of quality of cooling water. The closed cooling water system needs more attention to avoid the high fouling of the coolers due to high rate of corrosion and growth algae. The cooling water needs chemical treatment. Such as services can be offered by specialised companies like NALCO, DREW CHEMICAL, NALFLOC BETZ and others. The best method is to start with the chemical treatment of the cooling water at the time of commissioning of a new plant.

4. RECOMMENDATION

4.1. F C I - TROMBAY UNIT

4.1.1. Plant Installation

No.	Plant	Capacity TPD	Year of commissioning
1	Ammonia Plant	350	1965
2	Urea Plant	300	1965
3	Metanol Plant	100	1966
4	Nitric Acid Plant	320	1965
5	Suphala / NPK/ Plant	800	1965
6	Sulphuric Acid Plant	200	1965
7	Phosphoric Acid Plant	100	

Moreover there are also some small chemical plants which produce chemicals like Concentrated Nitric Acid, Ammonium Bicarbonate, Sodium Nitrate, Sodium Nitrite, Methylamine and Argon.

4.1.2. SHORT DESCRIPTION OF THE PLANTS

4.1.21. Ammonia plant

The Ammonia plant is designed to produce liquid anhydrous ammonia. Rafinery gas and/or petroleum naphta is used for the process. The plant is based on Shell Partial Oxidation Process. There are four trains of gas generation. The rest of the plant is laid out in two independent streams. The raw synthesis gas from the Shell Partial Oxidation Process units passes through CO convertors to produce carbon dioxide and hydrogen by shift reaction. After purification and removal of impurities the proportion of hydrogen to nitrogen is adjusted to 3 : 1 and this gas is synthesized under a pressure of 365 kg/cm^2 over the catalyst to produce ammonia.

4.1.22. Urea Plant

Urea is produced by reaction between ammonia and carbon dioxide at 220 kg/cm^2 pressure and 185 . 190°C temperature. Ammonium carbamate is formed by this reaction instantaneously and in the further process step is de hydrolyzed to urea. The urea reactor effluents contain about 30% urea and 30% carbamate. It is decomposed into ammonia and carbon dioxide by heating-up in stages. Decomposed components are recycled back into the autoclave as a carbamate solution. The urea solution is concentrated in evaporators and prilled. The plant is laid out in three independent streams up to evaporation and two streams thereafter.

4.1.23. Metanol Plant

The metanol plant is designed to produce metanol of standard commercial grade using petroleum naphta as feedstock. The naphta is purified first and reformed with steam in reformers. The exit gas is further processed, compressed and converted to crude methanol which after rectification yields methanol of standard technical grade.

4.1.24. Nitric Acid Plant

The Nitric Acid Plant was designed to produce 320 TPD of equivalent 100% nitric acid produced as 57-59 % aqueous solution. The process adopted in this plant is a high pressure process / 7.7 kg/cm^2/ in which ammonia is catalyticaly oxidized to nitric oxide over a platinum - rhodium catalyst. The nitric oxide produced is further oxidized to nitrogen dioxide and absorbed in water to form 57-59 % acid.

4.1.25.SUPHALA / NPK / Plant

The Suphala plant produces 600 tonnes per day of 15:15:15 ammonium phosphate nitrate product. The plant is divided into two reaction streams. Each reaction stream is connected with two spherodizers, where the slurry prepared in the reactors is granulated and dried. The product from the spherodizer is screened and cooled in the cooler, then coated with the red colour in a coater and finally sent into the silo.

4.1.26.Sulphuric Acid Plant

The plant is designed to produce 200 tonnes per day of 100 % H_2SO_4. The acid is produced as 98 % acid of commercial purity. The plant can be operated on either straight sulphur feed or as a combination of sulphur and H_2S gas stream separated from refinery gas in the Ammonia plant. Sulphuric acid is produced by burning sulphur and/or H_2S to form SO_2 which in turn is oxidized to SO_3 in the presence of vanadium pentoxide catalyst and absorbed in water. The entire plant has been laid out in one single stream only.

4.1.27.Phosphoric Acid Plant

This plant is designed for 100 tonnes P_2O_5 per day on a 100 % basis. The grinded phosphate rock, 75 % sulphuric acid and diluted phosphoric acid are mixed together. The reaction temperature is maintaned between 90 and 100°C.

The slurry is cooled down by means of air in crystalizers to 53°C and flows to a horizontal tilting pan filter. 30 % P_2O_5 acis obtained from this process is concentrated to 50 % P_2O_5 acid.

4.1.3. PROBLEMS IN TROMBAY UNIT

4.1.3.1. Short service life of feedstock preheater coils.

The failures on feedstock preheater coils are very high. We have investigated details of failures, replacement cost etc.

a/ Estimated cost of ammonia per ton-Rs. 1 000.-
Loss of ammonia production due to failures of feedstock preheater coils per year - 3 476 000.
This is 7% of total loss and 18% of losses due to mechanical break downd.

b/ Repair cost coil ....Rs 4 400
Taking 20 repairs within a year,
total repair cost per year ....Rs 88 000

c/ Cost of new coil / carbon steel/..Rs 101 000
Taking new coils used within a year as 8, total cost of new coils per year ....Rs 808 000

d/ So total cost/year together with production loss ....Rs 4 372 000

e/ Estimated cost of a new coil/stainless steel / ....Rs 550 000

From our viewpoint, coils made out of stainless steel should give better service life. The above cost analysis justifies the use of stainless steel coils.and we recommend therefore the same on a trial basis. Another advantageous material which can be tried is Cr-Mo steel. Depending upon the quick delivery, we feel, that Cr-Mo and/or stainless steel should be tried out based on field results a final choice of the substitute material can be made.

4.1.3.2. Short service life of gland packing at the carbonate solution pumps for CO_2 removal.

We recommend to introduce pressure water to the gland packing so that small amount of water flows continuously through the packing to the pumps.

4.1.3.3. Short service life of piston rings and piston at the high pressure nitrogen/air compressor.

The cause of the problem is a frequent carryover of rust from the suction pipeline to the compressor and the air being moist as it comes from the air chiller. We suggest to install dual filters into the line and to change the suction line for stainless steel one.

4.1.3.4. Frequent damage of mechanical seals at the heater saturator pumps.

To install small pumps for pumping clean condensate to the mechanical seal. It is possible to use Flexibox equipment made in England, which has been successfully used in our ammonia plant.

4.1.3.5. Short service life of piston, piston ringe and liner at the IV stage CO_2 compressor.

We suggest to use graphited teflon piston rings. Attempts should be also made to run the gas temperature a few degrees higher in the 4 th stage cylinder. The supplier of the machine, however, must be consultated before making these changes.

4.1.3.6. Vibration and inadequate refrigeration of expansion engines.

Apparently the problem on these expansion engines exists right from the time of the plants start up. Based on technical discussions, we feel that these machines possess inherent design deficiencies. It might be worthwhile to consider replacement of these machines by another type of machine with proven performance.

4.1.3.7. Leakage in aluminium plate and fin type reversing exchanger in the air separation unit.

Regarding failures on the reversing exchangers, it might be better to get in touch with the equipment supplier for establishing the probable cause of failure and mode of repair.

4.1.3.8. Improper function of scrubbing column in the nitrogen scrubbing unit.

These reason for malfunction of the liquit nitrogen scrubbing unit may be due to incorrect fixing of the trays /not in correct horizontal position/. It is also possible that some trays were damaged during start up of the cold box when the unit is not satisfactorialy dried out.

4.1.3.9. Fouling of intercoolers at the air turbocompressor and low throughput.

Fouling of intercoolers at the turbocompressors reduces the capacity of the ammonia plant. The losses in production during the last year due to above failure amounts up to 1483 tonnes of ammonia. This is 3% from the total losses of ammonia. Therefore it is suggested to install an oil filter into the suction line of the turbocompressor. It was brought to our notice that it is being considered to install an additional compressor to meet the shortfall in air supply, which to our opinion is a step in to the right direction. The shortfall due to low frequency of power supply will also be made up with the additional compressor. This is an item which we consider as a limiting factor of the ammonia plant. We have also two air intake headers used in dependance from the wind direction. Each header is about 1 km long. We suggest that the installation of similar headers should be reconsidered at the installation time of an additional air compressor.

4.1.3.10. Corrosion and errosion on superheaters in the CO conversion.

Corrosion and errosion on superheaters in the CO conversion section appears to be due to presence of CO_2 in the system. The portion of piping which is subject to repeated failures should be replaced by stainless steel and sharp bends should be avoided at the elbows. It is necessary to keep on stock adequate spare material available for replacement from time to time.

4.1.3.11. Opening of the top enclosure at the ammonia synthesis converter.

For opening the cover of the ammonia reactor in our factory a piece of iron of about 1000 kg weight is used. Its function is as a ram for dropping on the plug from a height of about 2 meters. The impact loosens the gasket and then it is easy to open.

4.1.3.12. Steam leakage through glands of steam valves.

We recommend to repack the gland packing during shut down each year.

4.1.3.13. Leakages in coils of waste heat boilers at the Shell gasification section.

The leakages on the coils of waste heat boilers occure due to erosion caused by the presence of fine particles of carbon as well as particles of brick lining from the reactor entrained with the gas which flows through the waste heat boiler coils. We suggest to keep an adequate number of spare coils ready for replacement whenever failure occurs. Also the diameter of the coils should be increased as much as possible depending on space avilable.

4.1.3.14. High pressure carbamate pumps.

The problems of the packing of carbamate and ammonia pumps is a complex one involving lubrication, cooling, corrosion and liquid sealing. It was solved in our Urea plant in cooperation with the MERKEL company of West Germany. Thiscompany has a lot of experiencis in this field. The service life of packing in a carbamate pump is about 3 months and in an ammonia pump about eight months.

4.1.3.15. Wear out of crank shaft.

The crank shaft is worn out due to packing leakage and cabamate contamination of the oil.

4.1.3.16. Failure of variadrive.

We recommend to change the variadrive for a hydraulic one which is very easy to operate from the control room by means of a pneumatic controller. We recommend also to change these pumps with slow speed ones. According to our experiences, Worthington pumps are the best for carbamate service.

4.1.3.17. Corrosion of manifolds due to breakthrough of CO_2. Unsatisfactory service life of packing im ammonia pumps.

It is very necessary to install in the suction line of ammmonia booster pumps a couple of strainers with very fine mesh. We have seen that the installed pumps are working with very high speed of the plunger. For a better performance and longer life of packing we suggest also to replace the ammonia pumps for better types, for instance from the above mentioned Worthington company.

4.1.3.18. Problems on recovered ammonia compressor.

The possibility to alter the process in such a way that itwould not be necessary for the compressor to operate was discussed. This needs to install a new high pressure decomposer, high pressure / 17 kg/cm^2/ condenser and absorber.

4.1.3.19. Check valves on autoclaves not holding.

The installed check valves are in horizontal position. We also have similar valves and face the same problems as at Trombay. We have installed high pressure condensate injection points for flushing the lines whenever operating conditions are disturbed. . We suggest to install the valves in a vertical line.. Insufficient intercooling of the air turbocompressor. We suggest to check the design of the coolers and if necessary, bigger size intercoolers should be installed.

4.1.3.21. Frequent pickling requirement of catalyst due to entrainment of rust particles from ductings and intercoolers.

According to our experience the air-ammonia mixture has to be filtered. We have observed that filtration candles from ceramics are not satisfactory. We recommend the use of porous stainless steel candle filters.

4.1.3.22. Leakages on exchanger train due to corrosion. Corrosion of bubble caps in absorption tower.

Because of corrosion checks must be carried out if material of proper guality is used, which should be 304 L stainless steel. The steel must have austenitic structure without any chromium carbide and with a delta ferrite content maximum 2 %. We suggest to carry out the metallographic analysis of used material.

4.1.3.23. Erosion on grinding mills, ductings, cyclones, rollers, bull rings, exhausters and impellers.

We suggest to protect the equipment against erosion by hand metal spraying. In this field we have very good experiences. A Swiss company UTP which has also an agency in India can be contacted.

4.1.3.24. Erosion on reactors, failures of couplings, Base plate cracking. Cracking of supports.

From the viewpoint of corrosion, the used material is suitable but it has a low erosion resistance property. It would be better to use a material which is suitable both in regard to corrosion and erosion. Corrosion on the welding seams results from stress corrosion in nitrate medium.

4.1.3.25. Very frequent failures of sleeves, casings, impellers, shafts and bearings of slurry pumps.

The reason for a short service life is due to high erosion rates. Therefore we suggest:

1. To keep the slurry at lowest viscosity by means of heating and insulating the suction and delivery lines.
2. Avoid contamination by mechanical impurities.
3. To simplify the suction and delivery lines up to a maximum to obtain the lowest pressure drop.
4. The pumps should installed on a maximum possible high point to reduce the delivery pressure.

There are three pump makers that have proven to stand up to this service with reduced maintenance costs.

These are:

A. Bungartz / FRG /

B. Ensival / Belgium/

C. Wilfley / USA /

Because of the erosive properties of the slurry, stainless impellers and casing have a limited service life. The hardness of the stainless steel casting will improve the service life of the pumps. Rebuilding the pump by building up worn parts of the pump casing with carborundum is being practised successfully in FRG at least on one plant. Recommended metallurgical composition for pumps is given in Annex 21.

4.1.3.26. Failing lifter plates of spherodizer.

We recommend to use carbon steel manufactured by an electric furnace or open hearth process including silicon killed process. The silicon content must be in the range of 0,10 - 0,30 % max. to reduce nitrate cracking.

4.1.3.27. Scale formation and material deposition in spherodizer.

The spherodizer must be regulary cleaned to avoid scaling.

4.1.3.28. Carbon deposition leads to a frequent shut down of the furnace.

Carbon deposits are formed due to incomplete burning of oil. By using proper nozzles and by maintaining constant pressure of both atomising air and oil this problem can be overcome.

4.1.3.29. Crushing capacity of the pulverizer is poor due to scale formation etc.

According to our experience it is a normal occurence. It needs cleaning at reguler internals.

4.1.3.30. Shearing of input shaft assembly and failure of tie rod bearing of screens.

The screens used in the Suphala plant are out of date. Their operation is unreliable and they are a source of dust. We suggest to use vibration screens divided into two stages. Screens of testified design used in our factory are oversize screens supplied by UHDE / vibrations obtained by an excentric motor/. The fine screen is an electromagnetic vibration type from the RHEWUM Company. This was necessary to design in case for possible switch-over of the power input, for hygroscopic material and for a very high powder content.

The vibration screen used in the nex unit is not the best design because of folowing reasons:

- inconvenient access for sieve cleaning,
- difficult tensioning of sieve,
- difficult to change the sieve,
- cracking of sieve in places, where the vibrating heads are fixed,
- the sieve must be made out of stainless steel.

The proper function of dedusting equiment is very important during the operation.

4.3.3.31. Other problems in the NPK plant.

We suggest to use another design of the bucket elevator. The elevator should have two plain linked chains. The buckets must be fastened to the chains with very strong hooks. The buckets must not be a part of the chains and should be the weak point of the mooving system. The bulk quantity of the material should fall into the buckets so as to reduce the scooping of material as far as possible.

The bearing exposed to possible pollution should be replaced by nongreasable bearings made out of graphite teflon material with air pressure inside. A pressurized bearing helps to avoid the ingress of polluted air from surrounding. The same could be adopted for the bearings submerged in agressive medium. For very corrosive medium it is possible to use polyethylene tubes with glass reinforced plastic. The chutes must be very steep. They should be made out of steel structure. The functional surfaces should be made out of rubber sheet. The material has a negative adhesion to the rubber. This enables an easy cleaning in case of sticking material because of an elastic chute surface.

On pipes with larger diameter, separators and storage vessels, vibrators and/or loose hanging chains should be installed.

According to our experience the NPK plant has to be stopped once in 7 days for about 8 - 12 hours. Such periods should be used for cleaning some equipment as well as for other cleaning jobs. According to our knowledges the new unit was installed by an out of date technology.

4.1.3.32. <u>KCl and DRF weigh feeders.</u>

We feel that SCHENK type weigh feeders should give troublefree service as we have found it from our experience.

4.1.3.33. <u>Dust collectors.</u>

We have Prat Daniel type wet scrubers, which according to our experience are giving good service.

4.1.3.34. <u>Problems of Sulphuric Acid Plant and Concentrated Nitric Acid Plants.</u>

It is known that acid plants are of highly corrosive nature. We recommend therefore the use of a better corrosion resistant material as plastics. Untill this is done we suggest that adequate spares for piping, valves, pump parts etc. should be on stock.

4.1.3.35. <u>Inadequate capacity of water treatment plant and higher oxygen content in boiler feed water. Frequent failure of pressure tubes at the boilers in the Steam Generation Plant.</u>

The non-availability of boiler feed water and steam caused a loss of 2888 tonnes of ammonia and 14465 tonnes of urea. In the urea plant it represents 27 % from the total amount of loss in last year. It is very necessary to have a good quality of boiler feed water. According to rough calculation, the water treatment plant at the Trombay unit is overloaded. For a preparation of about 200 m^3/h boiler feed water for the whole factory it will be necessary to install another unit of ion exchangers with installed conductivity meters. According to our experience the maximum conductivity of boiler feed water for steam generation at a pressure of 40 kg/cm^2 must be below 2 micro S.

The iron content should be less than 0,2 ppm. The steam condensate from the whole factory can be used as rough water. The oxygen content in boiler feed water must be very low. For that reason it is recommended to dose hydrazine to the deaerator. The excess of hydrazine in water should be 0,15 ppm. An analysis can be easily carried out by the Lovibond comparator. method For alkalinization it isrecomended to use chemicals like SLCC 35 from DREW Chemical Company or NALCO. Even a small amount of salts, mainly iron content, can cause severe corrosion on boiler tubes. The inferior quality of boiler feed water can be also on of the reasons of feedstock preheater coil failures in the plant.

4.1.4. VI. MECHANICAL MAINTENANCE AND REPAIR

4.1.4.1. The position of Maintenance Department in the factory.

Keeping in view the compexity and magnitude of maintenance activities the maintenance is bifurcated into two sections, namely the mechanical maintenance as one independent section and electrical, instrumentation and civil maintenance comprised in the other section. Both of these two maintenance sections are, from the organisational viewpoint, on the same level with the production, technical services, material management services and training department. An advantage for all maintenance activities is the fact that the Deputy General Manager has a maintenance backround.

The organisation chart Annex No.1 regarding the maintenance department shows that responsibility at the base is divided between plant engineers and service section of maintenance.

The responsibility area of the maintenance department includes some typical process activities like water treatment and steam generation.
The central workshop is supervised by the deputy chief engineer of the ammonia and steam.generation plant, but it serves the needs of all plants.
If in the organisation chart the strength of helpers is ignored, the ratio between workers and other technical. staff works out to 4,5:1, which is a reasonable figure.

4.1.4.2. Responsibility, duties and authority of different maintenance sections.

The responsibilities, duties and authority of the whole maintenance department and its various sections have not been formally step by step outlined. No concrete. description of duties for each function is available. However, according to the Management Services Department, steps have been taken to spell out the duties and responsibilities of managers and supervisors. The job description for persons in the workmen category has already been laid down.

4.1.4.3. The level of planning in maintenance and their self-sufficiency.

No long - term plan was caried out and the actual plan for preventive maintenance in an extent of one year is in its nature to general and without determination of repair cycles and scope of individual repairs. This is not based on the actual running time in hours of each machine and thereby does not reflect the hours for which a machine can be safely kept in line.

Therefore, this plan of preventive maintenance is formal, and it is necessary to recate it on the basis of safe running hours of a machine. It was explained that during 1974 an exhaustive survey of the plants has been carried out by a team of engineers of Trombay Unit and P and D Division to establish the condition of equipment and based on the same, an implementation plan has been drawn up with a view to remove the weak points in the plants. This survey has been done because the plants are in operation already 10 years up to now.

It has been observed by us that the Boiler Inspection in compliance with statutory requirements is quite strict, which is as given below:

External cleaning	-	Once within 3 months
Internal Inspection	-	Once within a year

Once within 10 years, the boiler should be disposed in bare condition by exposing the pressure tubes and removing of bric work etc. Communication with the Government Boiler Inspectorate is kept by the service section of the maintenance department.

The high pressure piping is checked for corrosion by ultrasonic testing every year.

For turbocompressors in the Nitric Acid Plant, Ammonia Plant and for the air blower in the Sulphuric Acid Plant records are maintained in respect to periodic overhauls carried out by specialized agencies.

The level of vibration is measured with the vibration meters available in the factory. These readings are indicating vibration values and do not detail analysis of the vibration.

The selfsufficiency of maintenance in execution of repair works is considerably high and in respect to total costs, it is 84 % made by its own capacity and 16 % by external agencies.

The maintenance costs as a percentage value of plant costs rised up to 3,1 for the year 1972-73 and for the last three years to an average figure of 4,4.

4.1.4.4. Precautions and solutions for the technical problems of maintenance i.e. Technical Services.

The maintenance department has not a separate section for carrying out inspections at the plant and for solving the technical problems concerned with maintenance, repairs of machines and equipment, and also to analyse and determine the factors which contribute to an excessive maintenance, say excessive vibrations, pulsations and temperature of liquids etc. causing failures, excesive corosion and so on. Maintenance problems are studied by Technical Services for solutions and major problems are referred to the Planning Development Division at Sindri which cares to the needs of the whole F.C.I.

For the obtained solutions from Sindri, detailed engineering, specifications etc. are prepared at Trombay. This cycle between suggestions, solution and execution of problems takes considerable time. Therefore, we suppose that such problems like corrosion of feedstock preheater coil, which to our opinion should be possible to control within a reasonable time extent, have not yet been satisfactorily solved, although some modifications have been carried out from time to time during the last 2 to 3 years. Because of this problem, the Trombay unit had suffered considerable losses in respect to repairs, installation of new coils and production loss.

The services rendered for the maintenance department by the Technical Services Dept. consist:

- Chemical analysis
- Ultrasonic tests in pipes and vessels
- Vibration measurements on rotating machines, but without analysis
- Hardness tests of materials according to Brinell scale
- Suggestions reagrding the use of painting materials and thickness measurements in corrosive fields
- Coordination with P and D at Sindri for problems reffered to them
- Coordination with foreign plant and machinery suppliers whenever services of their experts are required.

In respect to the needs of Technical Services for the maintenance department, the Technical Services Department is not adequatly equipped and staffed. For such a wide range of services, there are only two engineers, one for N.D.T. and one for corrosion problems.

In the field of balancing rotating machines, services of external companies are used. For special welding problems, assistance of external companies is available, at times.
Inspections of incoming spare parts and materials performed by the materials menagement section are including dimension checkings only, carried out with minimum of measuring facilities.

The design section of the Maintenance Department which prepares fabrication drawings and specifications for simpler spares along with the system of documentation is on a good technical level. The section for standard dokumentation, AZO PRINT machine as well as its outfit with space and materials is on a reasonable level.

The maintenance department does not have the capability for X-ray, stress-relieving and metallographical analysis, which are performed by external agencies. The dye-penetrant examination is carried out departmentally. There is no organised system for:

- inspections at the workshop where spare parts are produced and reconditioned as well as other jobs are made,
- inspections regarding repair and reconditioning.

The central workshop and also the plant workshops are provided with just a minimum of facilities and they are not on a proper level consistent with maintenance requirements and repairs of machines and equipment in a chemical factory of this magnitude.
There is also a central tool and jig store from where it is possible to borrow special tools and ljigs by the staff of the Central Workshop as well as plants. It is suggested that suitable action should be taken to establish a control set-up where periodicaly the special tools, jigs and fixturgs could be checked for their accuracy compared with Standard fixtures.

4.1.4.5. Technical preparation for repairs. Method and level for executing repairs.

For maintenance and repair of machines and equipment detailed instructions are not available. Only manuals from the suppliers are available which according to our experience are not sufficient. These are mostly used by Supervisors and Experienced workers for repeated re repairs.

The management service provides computer reports periodically which results in good ideas regarding the level and use of spare parts, repair analysis showing the frequency of individual repairs and pointing out the major bottleneck areas in the plants. For the maintenance department are given 5 types of reports:

- Maintenance report: This shows equipmentwise, datewise, various jobs done during the month/year, man hours spent on various jobs, time taken for each of this job etc.
- Maintenance summary report: This shows equipmentwise frequency of some jobs performed during the month/year. This also shows man hours spent on planned and breakdown jobs separately for a month/year period.
- General analysis: Analysis showing jobs which took too much time for maintenance or which occured too frequently.
- Manpower utilisation: The available manpower hours with used man hours calculated per month/year and utilisation reported.

  Repair on special equipment and jobs to be carried out during longer shut-downs/annual turnrounds.

The Management Service Group prepares CPM/PERT charts for a systematic and methodical follow-up of various activities within time-bound schedules to repair speciali equipment and jobs too be carried out during longer shut - - downs annual turnrounds.

Overhauls and repairs of the most complicated machines like turbocompressors at the ammonia plant, nitric acid plant and airblower at the sulphuric acid plant are executed by using services from outside companies.

These overhauls are carried out by the departmental force, under an overall supervision of specialists from the suppliers. Such overhauls and repairs are executed by close coordination and on a very good technical level.

Repairs of machines are based on inspections carried out by the process and maintenance staffs in the plants on a day-to-day basis and periods where the machines are scheduled for maintenance as per preventive maintenance plan and also in accordance with the operating parameters indicated on the machines. The repair cycle of each machine is not fully followed, analysed and progressed, which should be actually made on a positive running hours basis as detailed elsewhere in the report. The repairs are carried out just on the place and/or nearby of their installation in the unit. During a repair procedure, dimensional inspection, checking of alignment ovality etc. are carried out. The damaged parts are also repaired in the central workshop. The good quality of repair is achieved also due to availability of spare parts.
Production losses as a cosequence of break downs due to nonavailability of spare parts are showh below:

	Total loss of production in tonnes	Loss of production due to mechanical maintenance break downs in tonnes	Loss of production due to nonavailability of material/ steels tubes and spare parts/% from total loss	Loss of production due to nonavailability of spare parts % from total loss
Ammonia Plant	49,442	19,443	3,3 %	2,5 %

Urea Plant	53,609	7,197	2,5 %	2,1 %
Nitric Acid Plant	36,996	6,633	-	-
Suphala /NPK/ Plant	81, 499	31,327	14 %	9 %

\+ Loss due to non-availability of spare parts for carbamate pumps. Repairs on heat exchangers which must be completely re-tubed is get to be done by ex ternal agencies. Similarly, in case of welding work, wherever X-ray and stress relieving operations are involved, the latter must be carried out by external agencies who exclusively specialise in these field.

Whenever high pressure vessels and other specialise vessels, equipment etc. are to be procured, an exhaustive specification sheet it prepared giving the overall size of equipment, operating and design parameters, corrosion allowances, international standards under which fabrication is to be done etc. and accordingly the manufacturer carries out detailed engineering and equipment supply. External companies are also executing balancing procedures of impellers for turbocompressors and pumps as well as X-ray of welding seams.

The effectiveness of plant maintenance is enhanced due to the fact that there are small workshops near the production units. The availability of maintenance in case of breakdowns is quite high.

Whenever a breakdown occures beyond normal working hours, approximately within two hours from the time, of the breakdown occurence, the maintenance group is at the job site which involves several hands coming from their residences. In such cases, always one engineer is in charge. The engineers coming for evening and night inspections are altered every week. The shift maintenance is decentralised so as each plant is under the supervision of the shift foreman / in charge/. The maintenance staff on shift includes technicians. For the whole factory there are 22 technicians per shift.

4.1.4.6. The outfit of plant workshops.

The plant workshops are usually equiped with three or four welding machines, one or two bench drilling machines, one or two electric hand drilling machines, vises, double wheel grinding machine and with several work tables.

The technicians are equiped with sufficient amount of tools of satisfactory quality.
The special tools/big spanners, torque, spanner, wheel puller, measuring instruments / are stored in a tool store nearby the workshop.
The working space of the plant workshop is proportional to the outfit of the workshop.
The maintenance people down to supervisors and foremen are capable to work according to drawings and technical documentation.

4.1.4.7. The outfit of the central workshop.

The central workshop is satisfactorily equiped for services to meet the demands like repairs, machining, inspection of spare parts for the plants who carry out repairs within the plants. The central workshop is not geared up for major assemblies of equipment etc. as per existing set up this workshop is not expected to handte such jobs in a routine manner.

Tool storage for the central workshop:

- Special heavy duty tools for dismantling operations.
- Measuring instruments / vernier callipers, micrometer callipers, inside micrometer callipers, dial micrometer / are not available in sufficient amount and assortment.
- Tools for machining: lathe tools, screw-cutting tools. screw dye, borers etc. are in a satisfactory amount, but in most cases in bad technical condition / damaged cutting edges, wrong grinded respectively/.
- People working on the machines are able to work according to drawings and sketches at desired profesional level. We are happy to note that a group of competent welders are available in the central workshop. They are well equiped with welding and cutting machines, with space for welding operations and welding materials. Their professional skill for welding carbon steel, and aluminium give the guarantee to fulfil the requirements of the very important part of maintenance.

The central workshop is equiped with an overhead travelling crane with a lifting capacity of 10 tonnes. This crane can be used along the entire length of the workshop.

Besided the above mentioned services, it is on the work schedule to recondition the spare parts by means of bushing and welding. The central workshop operates in two shifts.

4.1.4.8. Organisation of small shut downs and general shut downs.

The plant managers and plant engineers prepare the shut down schedules for individual plans in advance. The coordination of the plans for shut downs are made by the maintenance engineering section of the maintenance department. For the finalised scope of shut down jobs a detailed programme in the form of a diagram with critical path / CPM/PERT/ is prepared. This diagram is prepared in cooperation with the maintenance, process and management service group.

This diagram is during the shut down constantly watched, monitored and updated in case of changes and after the shut down it is evaluated and analysed by the above mentioned group.
The shut downs usually take place in April or May in respect to the beginning of the planning year period and suitability of the weather.
The general shut down from the viewpoint of common power and steam conditions is also dovetailed with the total shut down in the months April - May and the duration of the same, in average is as below:

For water and steam	48 hours
For power	24 hours

4.1.4.9. Storage of spare parts and other materials.

In the area of spare parts purchase, material management works by using the computer IBM 1401. This computer follows 40 000 items of individual spare parts. To each spare part is given a value of minimum, maximum and optimal amount which has to be kept in store. The figures are corrected according to the actual consumption of spare parts by the maintenance department. While purchasing the spare parts, it is taken into account the delivery time and the time which is necessary for completing the purchase formalities.

A report from the computer showing the spare parts stocks is given each month.

The department responsible for the purchase of spare parts also takes into account its economical consequences and in collaboration with the maintenance department also factors like quality, design changes and other technical requirements. Spare parts for new plants are worked out by sections hendling the respective project and after consultations with the maintenance department they organize procurements.

Purchased spare parts are stocked in the materials management stores.

Required spare parts in case of break downs are purchased on the base of a requisition signed by the chief of the Maintenance Dept.

The incoming spare parts are received at the inspection section of the stores, and are subject of a quantity control. Spare parts of good quality are given to the warehouse and the spare parts of wrong quality and/or wrong dimensioned are claimed and/or sent back to the supplier.

The percentage of spare parts, which are rejected amounts in average about 10 %.
For materials/steels, pipes, flanged, bars and rods etc./ instructions are prepared, concerning kind , amount and quality of materials which have to be kept in stock. These instructions are followed:

The spare parts are stored separately for each plant. Standardized spare parts like bearings, packings, fittings, holts, nuts etc. are stored at a common place for the wholefactory.
During our visit at the stores we have ascertained the folowing:

- With the parts for individual plants are stored also standardized materials like tubes, flanges, valves and gaskets etc.
- The stored spare parts are not sufficiently protected against corrosion. Some spare parts are corroded oven on functional points.
- The storage and handling of low carbon steel is not satisfactory.
- The inspection section is insufficiently equipped with measuring devices.

4.1.4.10. Summary and recommendations.

The organisation of the factory services as well as the organisation of the maintenance department has still not achieved such a level where it should be possible to build up a system which can form conditions for full implementation of a preventive maintenance.
The principal defect in the present system is the fact that when building new plants, the maintenance aspects are not fully taken into consideration. To our opinion the organisation of maintenance can be worked out and efficiently established by the time

when plant comes into operation. That means the following steps should be taken:

- selection of technology, machines and equipment from the viewpoint of the most progressive design, taking into account standardization and unification etc,
- checking the erection of machines and equipment,
- technical preparation for maintenance including the outfit with workshops, spaces, tools, spare parts and materials in advance before start up of the plant,
- utilization of the plant including maintenance and repair,
- modernization of the equipment,
- until the physical liquidation of assets.

According to obtained information, the full strength of the maintenance force is posted in the new plants for the start-up and precommissioning stage. At the present set-up of maintenance, no specific section is established for the following functions:

- technical progress in design of machines and equipment and their use for maintenance and repair,
- technical progress in maintenance techniques / using,
- special tools and jiggs, technology of repair etc./
- technical progress in maintenance management.
- a system for rewarding the initiative of engineers for improvement, suggestions and inventions whis is very important for the technical progress which should be considered and established.

The factory and/or the maintenance department respectively have enough sections and engineers which are able to use the aid of preventive maintenance.

An excellent means for planning and preventive maintenance are the reports and information, which provide a very good basis for the determination of repair cycles, duration of repair, amount of man hours for repair and also maintenance and repair costs. These reports together with reports which show the state of spare parts on stock enable to work out a perfect annual plan of preventive maintenance and its layout to month-plans.

Based on computer data available for the maintenance, it is advisable to spread these to work out a long-range plan of preventive maintenance.
To prepare the basis for the elaboration of a plan of preventive maintenance, i.e. its progress and mainly its execution in respect to the growth of the technical level including activities, flexibility and economy, we suggest to carry out the following steps:

- The maintenance department should be associated and made responsible for its activities with the inception of the project. This means already from the initial preparation stages which include project details, investment planning.lay.out of technical specifications, checking eguipments quality as well as maximum utilization of facilities during the period of its effective service life-

- To separate from the maintenance department the typical process activities like water treatment and steam generation.

- To reshuffle the organization of sections and/or functions respectively, which are concerned with technical problems but without direct connection to mechanical maintenance, i.e. to incorporate the inspection for incoming materials and spare parts into the mechanical maintenance by transferring personeel, and checking devices. Further, the present staff for ultrasonic, vibration, hardness and corrosion control including its testing equipment should be separated from the technical service and incorporated into the mechanical maintenance.

- For the achievment of the above aims, proposed changes concerning the maintenance department are shown in annexure No. 2-6. The aim of this changes is a formation of " brain centres " for maintenance and moreover to create conditions for a smooth and gradual centralization of maintenance activities as well as for future planning and improvement in economy.
- To elaborate regulations, which will point out the scope of activity, responsibility, duties and authority for the whole department and for each section including the function down to the level of supervisor. This will clearly define any responsibility of each individual thus eliminating the duplicity of responsibilities.
- Categorization of equipment and machineries according to their importance in the production process.
- Determination of optimal working hours concerning equipment on the basis of detailed analysis in planned shut downs of the plants.
- To elaborate instructions for machine maintenance and equipment maintenance.
- To elaborate a plan for preventive maintenance:

  / long term plan for general repairs and overhauls,
  five year plan for repairs,
  annual plan for repairs,
  monthly plan for repairs/.
- Additional equipment suggested for the maintenance department. Checking instruments for the mechanical maintenance department:

Instrument for measuring contents of delta ferrite.
Portable metallgraphic microscope.

Photographic apparatus.

Instrument for diagnostics of anti-friction bearings without dismantling them.

Instruments for measuring length, diameters, evenness, threads and roughness of surfaces.

<u>Plant workshops.</u>

Centre lathe.

Powered hacksaw.

Instruments for measuring diameters and length.

Circular shears for cutting gaskets with different diameters, driven by hand.

Bench shears.

<u>Central workshop.</u>

Portable jig work for machining flange joints and flanges of equipment.

Circular shears for cutting gaskets with different diameter, driven by hand.

Shearing machine for cutting shields up to a thickness of 12 mm.

Tool grinding machine.

Surface grinding machine.

Cylindrical grinding machine.

Honing machine.

Mobile shop for central shift maintenance.

Tractor and two trucks.

Shaping machine.

4.2. FCI - SINDRI UNIT

4.2.1. Plant Installation

No	Plant	Capacity TPD	Year of commissioning
1.	Cokeoven Plant	600	1954
2.	Semi Water Gas Plant	1,18 mil. Nm3 of converted gas/day	1951
3.	Gas Reforming Plant	Equivalent to 189 tonnes ammonia/day	1959
4.	Naphtha Gasification Unit	Raw gas equivalent to 60 tonnes of Amm/day	1969
5.	Ammonia C.C.C.Plant	276	1951
6.	Ammonia Monteoatini Plant	189	1951
7.	Ammonium Sulphate Plant	974	1951
8.	Ammonium Sulphate Nitrate Plant	406	1959
9.	Urea Plant	71	1959
10.	Nitric Acid Plant	225	1959
11.	Sulphuric Acid Plant	400	1969

In addition to the above there is a small plant for the production of Ammonium Nitrate with explosive grade. Moreover the following plants of the Sindri Rationalization Programme will be also completed:

Sulphuric Acid plant 880 TPD

Phosphoric Acid Plant 360 TPD
Triple Superphosphate Plant 1 145 TPD

In addition to the Rationalization programme, the Modernisation Project which consist a 900 TPD Ammonia plant based on partial oxidation of heavy oil as well as a 1 000 TPD total Urea Plant will be started.

4.2.2. SHORT DESCRIPTION OF THE PLANTS

4.2.2.1. THE COKEOVEN PLANT.

The cokeoven Plant has one batery with two bloks each including 30 ovens. The capacity of the plant is desigued for 600 TPD of Coke.

The plant-serves for two purposes i.e. by supplying coke to. the Semiwater Gas Plant and Cokeoven Gas to the Gas Reforming Plant. Crushed coal is heated in brick lined ovens, out of contact with air to drive off the volatile matter which contains mainly tar, gases and vapours. The gases after removal of Tar, Ammonia and Benzol are transfered to the Gas Reforming Plant. Coke obtained from ovens is crushed and screened to supply the Semi-water Gas Plant.

4.2.2.2. THE SEMI - WATER GAS PLANT.

The Coke is fed to generatore where it is suitably heated with air and steam to obtain hydrogen and nitrogen for ammonia production. The gases are after dust and H_2S removal transfered to the CO conversion unit at atmospheric pressure, where CO is converted to CO_2 while a required gas for the ammonia synthesis /H_2 and N_2/ is obtained. The converted gas is then transfered to the Ammonia Plant. There are 9 generators and four unit of CO-conversion.

4.2.2.3. THE GAS REFORMING PLANT.

The Cokeoven gases are purified with the hydrocarbons a part of which is cracked and followed by a pressure CO--conversion process to provide the necessary hydrogen for ammonia production. Nitrogen is separately obtained by liquifaction of air. The proper $H_2 + N_2$ mixture is transfered to the Ammonia Plant. There are two units including air fractionation, gas fractionation, cracking and CO conversion. The two units of air fractionation are Linde clasical and Linde Frankle types Achieving production capacities of N_2 3500 Nm^3/h, 2800 Nm^3/h, O_2 500 Nm^3/h and 1600 Nm^3/h. Besides there is a Naphtha Reforming Plant which gives gas equivalent to 60 TPD Of Ammonia.

4.2.2.4. THE AMMONIA PLANT.

Gas from a Semi-water gas plant is compressed and purified. After removal of CO_2 and CO the gas is synthesised in a four stream synthesis ammonia plant with a total capacity of 276 TPD. There are 9 reciprocating compressors to compress the synthesis gas to a ammonia synthesis pressure up to 360 kg/cm^2.

Synthesis Gas $/H_2 + N_2/$ from the Gas Reforming Plant is directly transfered to a two stream synthesis plant. There are two reciprocating compressors to compres the synthesis mixture up to 300 kg/cm^2. The rated capacity of this plant is 189 TPD of Ammonia.

4.2.2.5. THE AMMONIUM SULPHATE PLANT.

Ammonia and Carbon dioxide from the Ammonia plant are undergoing reaction a to give ammonium carbonate. This ammonium carbonate reacts with gypsum followed by filtration, evaporation and crystalisation to provide crystals of ammonium sulphate containing 21 % nitrogen. Another product of reaction i.e. calcium carbonate is being utilized to produce cement.

4.2.2.6. THE AMMONIUM SULPHATE NITRATE PLANT.

Ammonia is reacted with 53 % nitric acid to obtain ammonium nitrate which is then granulated with ammonium sulphate to yield ammonium sulphate nitrate / double salt/, which contains 26 % nitrogen. Each unit except the absorption tower has two streams.

4.2.2.7. THE UREA PLANT.

In urea plant was adopted the one-through process. High pressure / about 180 kg/cm^2/ ammoniaand carbon dioxide are reacting in the reactor to produce urea with a 46 % nitrogen content. The tail gas is used for the ammonium sulphate production by direct acid neutralisation.

4.2.2.8. THE NITRIC ACID PLANT.

Ammonia is oxidized at low pressure by air on a platinum-rhodium catalyst to nitric oxide. The gases after further oxidation and absorption give 53 % acid. This acid is used for the production of double salt.

4.2.2.9. THE SULPHURIC ACID PLANT

A mixture of pyrites and elemental sulphur /10:1/ is roasted to give sulphur dioxide which is converted to 98 % sulphuric acid by conventional oxidation and absorption process.

4.2.3. PROBLEMS AT THE SINDRI UNIT.

4.2.3.1. Deformation of Battery still.

Deformations are caused by pushing coke from the bathery still and due to exposure to high temperature. The damaged parts will be replaced.

4.2.3.2. Corrosion at 3-Way reversing cocks installed in rich gas line.

The corrosion at 3-way cocks is possible to minim ze by proper greasing of functional surfaces. It is necessary to use grease with high meltint point mixed with graphite and/or molykote /MoS_2/.

4.2.3.3. Excessive corrosion and abrasion of the Exhaust gas rotor.

We feel that corrosion concentrates particulary at the rotor. We recommend to solve the problem by collaboration with P and D Division of FCI and the supplier GHH.

4.2.3.4. Corrosion at the rich gas ring main header and pipes.

The service life Of the lines is 10 years. It is possible to increase the service life by using epoxide painting from inside and or by applying linings from glas reinforeed plastic for tubes with large diameters.

4.2.3.5. Failure of refractory components.

The poor quality of bricks should be discused with the supplier. It was suggested to replace the damaged bricks by new ones to achieve the required uniform heating. The damaged mechanical parts should also be gradualy changed.

4.2.3.6. High abrasion of hammers at the coal crusher. The low service life of hammers of the coal crusher is possible to solve by hard facing of the functional surfaces. The procedure is described in 4.2.3.56.

4.2.3.7. Bush bearing at the screw conveyor.

Failure of the bearing at the serew conveyor is caused due to imperfect greasing. We recommend to modify the bearing by machining distribution groves inside the bush. The bearing should be closed by suitable packings to avoid dust penetration.

4.2.3.8. Grate - frequent failure.

We assume that the service life of the grate up to 2-2,5 years is satisfactory because of a very high abrasive effect of the ash with a high silica content.

4.2.3.9. Hot gas line - frequent brick line falling.

The gas line has a diameter of 950 mm. The working temperature is 600-650°C and pressure about 450 mm w.g. We recommend to replace the brick lining by a cast lining of proper quality. This will require to weld on at the inside wall of the tube some brackets. As to our knowe-ledge good experience in this field has the Plibrico company from England.

4.2.3.10. Grate table side gaps.

The worn out places should be repaired by hard facing using electrodes eith following composition:

a/ 1.2 % C, 13 % Mn, 1.9 % Si. By cold welding it is possible to achieve a hardness of 200-280 Hv.

b/ 1.2 % C, 2.2 % Mn, 4.4 % Si, 2.2 % Cr. By the use of cold welding the achieved hardness will by 550 Hv.

4.2.3.11. Distributor chute-frequent damage and replacement.

We suggest to use cast steel with the following composition:

a/ 0,4 % C, 25 % Cr, 13 % Ni suitable for temperatures of 1.100 - 1.250°C

b/ 0,3 % C, 0,5 % Mn, 21 % Cr, 39 % Ni suitable for temperature of 1.200°C.

4.2.3.12. Convertor - cracks and frequent leakage as a consequence of ageing.

The equipments are 24 years in operation. Thus the service life in respect to this is very good, but in any case it requires to pay more attention for to maintenance jobs.

4.2.3.13. Gas leaks through glands working at higher temperatures.

Lenkages ar coused by the use of unsuitable packing material. We use succesfully is in Our factory for very hot gases.packing material " Italpac tipo 8 " delivered from Italy.

4.2.3.14. Failure of bearings in compressors for coke-oven gas and nitrogen.

This failure of bearing is caused by damaged friction surface on of the crank shaft pin. The friction surface is very rough. We recommend to repair the crank shaft pins by means of grinding and polishing. The friction surface of the cross head should also be smooth and proper clarances are to be maintained.

4.2.3.15. Failure of connecting rods at cracked gas compressors.

Three in succession repeated break downs indicate that the connecting rods are of improper design. We recommend to solve the problem in colaboration with the P and D Division of FCI and with the supplier.

4.2.3.16. Corrosion of NH_3 liquor pumps of the Ammonia Washing Section.

The corrosion of dividing ring can be solved by using ring from material AISI 321.

4.2.3.17. Corrosion in Cokeoven gas holder.

We recommend to replace the corroded parts by new sheets. It is essential to clean throughout the inside part of the gas holder after repair jobs. The best method is sand blasting. After cleaning it is recommended to paint the inner surface with a paint based on epoxide. The prime coat should be red lead. The epoxy paint should consist three coats. It is also possible to repair the gas holder by means of glass reinforced plastic material.

4.2.3.18. Frequent failures of boiler superheater at thecracking unit.

There is no corrosion from inside, but only errosion from outside due to carry over of the catalyst. We suggest to protect the tubes from Outside. For each row of tubes should be used a quard plate made from material which is resistant to temperatures up to 800°C. Such material should hove the following composition: 0,15 - 0,25 % C, 0,9 - 1,5% Mn, 0,6 - 2 % Si, 6 - 26 % Cr, L - 6 % Al. It is also possible to use stainless steel 18/8 with hard facing against erosion, for instance with electrode composition of 4% C, 7 % Mn, 2 % Si, 20 % Cr.

4.2.3.19. Leakage of NH_3 pre-cooler at the gas and air fractionation unit.

We feel that the corrosion of the tubes occur due to condensation of water during the cold period. In presence of some impurities electrochemical corrosion appears comming from outside of the tubes. The weak points are mainly on tube welds. We suggest to carry out metalografic analysis on the corroded tubes.

4.2.3.20. High NO content in gas after water scrubber.

For reducing the NO content it is possible to use catalyst type RPK-1 with 0.1 % Ru and 0,1 % Pd on alumina. The NO content after gas passes through the catalyst shows 0,01 ppm.
The catalyst is produced by:
Retkinskij zavod
Gaskomitet po chimii
Retkinc
U S S R

4.2.3.21. Gland packing leakage at stage 5 of the synthesis gas compressor.

We suggest to purchase the gland packing for the above stage from the original supplier. The Indigenous gland packing should be improved and tested by a stand-by compressor.

4.2.3.22. Gasket leakage at stag 4 of cooler floating head.

Replacement of jointing materials by plant maintenance is not successful. The used stainless steel bolts are having different thermal expansion / $16.3.10^{6}$ deg^{-1}/ in comparison to carbon steel / $11.3.-11.7.10^6.deg^{-1}$/. We recommend to use again bolts from carbon steel. The flange can be also welded to the shell.

4.2.3.23. Frequent failures of inter stage cylinder valves especially at stage 5.

We suggest to use again copper coated asbetos gaskets which gives the best results.

4.2.3.24. Water carryover from water scrubbers.

The Raschig rings are covered with organic matter. We suggest to open the towers during a shut down for a period of one week. The dry deposit is likely to be washed out with water. It is also suggested to fasten the packing in the tower from the top with a grate. The best solution is to replace the packing in the tower by kittle plates used in CO_2 removal at the Texaco Gasification Plant at the FACT - Udyogamandal Division or by whirling plates used in CO_2 removal at our factory.

4.2.3.25. Poor performance of the turbine control system.

Poor performance is caused by:

a/ insufficient flowrate of oil from receiver to the hydraulic column. We suggest to check the diameter of the connecting line.

b/ the control mechanism of the turbine is worn out and has very high clearances.

4.2.3.26. Poor capacity of water pump.

The poor output of the pump is caused by weared seals, thus the water is bypassed. The problem can be solved by using material AISI 321 for the seal ring and by replacing the rotor one.

4.2.3.27. Failure of turbine pedestal bearing and pump bearing.

The rotor should be balanced during each repair of the pump and turbine because of their high speed and high weight. The gland packing must be tight. / The oil in the bearings is spoiled with the out coming water/. More attention must be paid to the storage and filling up of the oil.

4.2.3.28. Extremly poor performance of turbine.

The performance of the turbine is poor because the casing and the rotor are worn out. It is also necessary to repair properly the control system. The casing should be replaced. The turbine should be assenbled with the original clearances.

4.2.3.29. Sluggish performance of servomotor and its pilot valve and sluice valve.

We recommend to check the coordination between the inlet of the pressure oil into the hydraulic column and the outlet of the oil from the column at the second side of the piston. The coordination is possible to achieve by proper throthling of the outlet valve.

4.2.3.30. General corrosion of water scrubber turbine and its various parts.

The corrosion is due to high CO_2 content in water. In our factory carbon steel is used and the service life goes up to 3 - 4 years. We suggest to solve the corrosion problem in colaboration with the P and D Division of FCI.

4.2.3.31. Gland leakages of primary circuit valves at the Montecatini convertors.

According to our experience it is a normal practice to tighten these joints before restarting i.e. after a longer shut down. This leakage is due to different thermal expansion of the materials.

Carbon steel : L = 11.3 - 11.7. 10^6 deg^{-1}
Silver : L = 20.10^6 deg^{-1}

4.2.3.32. Frequent failure of grinding mill at the Ammonium Sulphate Plant.

We suggest to recondition the rollers of the mills by using hard facing reinforcement described in point 4.2.3.56. For the welding procedure of the gear box casing we recommend to use a technology developed by the U.T.P. Company from Seitzerland, which has also its agency in India. For welding roots, electrodes UTP 88 H should be used. The electrodes have the following composition: 3 % Cu, 5 % Fe, 3 % Mn, 1 % Si and the rest Ni.
Further layers should be carried out by electrodes UTP 8 " Weichflus " with a composition of 99,2 % Ni and the rest Mn and Fe. It should be carried out as cold welding.

4.2.3.33. Vessels at the Ammonium Sulphate Plant are not in sound condition.

Corrosion is proportional to the operating time. We suggest to replace these vessels.

4.2.3.34. Reduced operating capacity of the filters due to leakage of valve head.

According to obtained information the leakage starts after one year in operation.
Because the construction is simple, we suggest to replace the sealing plates every 10 month.
The worn out valve plate has to be renowed and reused.
We also suggest to replace the bearings of the worm by roller bearings. The bearings must be closed on both sides with seals.

4.2.3.35. Leaks in the drier and cooler shells.

The drier and cooler will be replaced in scope of the Rationalization scheme for the Sindri Unit.

4.2.3.36. Vacuum engine.

a/ defective feather valves
b/ frequent knocking sound.

a/ We suggest to fix the pressed joint on the crank shaft with the sunk key, which must be so calculated as to be able to bear whole load.

b/ The repaired and checked cylinder valves must be kept in a dry and clean condition. We recommend to use for that purpose plastic bags. Further we also reco-mmend to replace the absolete construction of the valves. The problem should be discussed with the supplier of the valves. We have in this field very good experiences with the HERBIGER. Company from Austria.

4.2.3.37. Gland leakage of the pumps.

It is very important to recondition during the repair of pumps the bushing and the stuffing box chamber. For reconditioning the shafts or bushes on the packing surfaces we recommend hard facing finished by machining. The used packing should be based on teflon. Pumps, which are pumping clear liquids can be equiped with mechanical seals. For pumping mother liquor we recommend to use soft packings. It is necessary to ensure proper washing of the gland seals by using water with higher pressure.
To improve repair works of pumps we suggest to carry out a balance of each impeller of the respective pump.

4.2.3.38. Poor performance of the cooling tower pumps.

Poor performance of the cooling tower pumps, which are pumping water to the barometric condenser results from casing and rotor wear off. We recommend to replace the worn off pumps. The old pumps should be repaired and renewed by means of welding.

4.2.3.39. Corrosion of pumps and gland leakage.

For the slurry pumps it is possible to use soft packing only. The packing should be based on teflon and asbestos and washad with water. For high corrosive and abrosive substances are usualy used pumps made out from material with a following composition: 0.017% C, 29% Ni, 20% Cr, min. 2% Mn. min. 3% Cu, 1% Si.
For the above purpose it is also possible to use pumps according to specification given in Annex No. 21

4.2.3.40. Cracks at the vaporiser and crystaliser bodies.

For Ammonium Sulphate soulution is used the same material as for Urea, The low carbon steel material AISI 316 L with 2,7% Mo and a delta ferite content of max. 2% is a very sensitive material in respect to contamination. Therefore it is very important to keep up during work with the above mantionod material the so called conditions. of hygiene. This means to avoid carbonisation of the steel. For grinding it is necessary to use grinding disc made out from fused alumina.

During grinding the material temperature must not exceed 300°C. Welding must be carried out by the lowest possible current. The welded up layer must have a diameter as low as possible. Highest attention should be paid to cleanliness of welding edges. For arc striking it is necessary to use a piece of 316 L steel. Before putting into operation, the whole vessel must be pasivated with some agent based on HNO_3.

4.2.3.41. Vaccum problem in Lurgi section of the Double Salt Plant.

According to obtained informations, the vacuum pump will be replaced by a steam injector.

4.2.3.42. Frequent cleaning of driers and interconnected units.

The plant has to be stopped at regular reasonable intervals. Such intervals should be utilized for maintenance jobs and for all cleaning jobs at the plant.

4.2.3.43. Failure of reactor liners due to corrosion -bulging of liners.

To avoid corrosion of the liners, which are made out of AISI 316 L with 2,7% of Mo and a delta ferite content of max. 2%, it is very important to keep a proper oxygen content in CO_2. According to our experience it is better to operate with a higher oxygen content. We are operating in our factory with 0.6 - 0.8% of oxygen in CO_2.

It is also very important to drain the convertor during each shut down lasting more than four hours. During repairs it is necessary to keep the same conditions as described above in point 4.2.3.40.

4.2.3.44. Frequent damage of conveyor structures due to lumps falling from prilling tower.

This problem can be solved by a proper operation of the prilling nozzles. The operators must watch the pressure of the urea solution and distribution of prills in the tower. The prilling nozzels must be regularly cleaned by means of steam.

4.2.3.45. Brittle prills.

The prills are brittle because they are hollow. This is caused by high water content in the dissolved urea after the vacuum concentrator. We suggest to replace the second vacuum concentrator by another type.
We feel that the evaporator from the Switzerland's LUWA Company should give trouble free service as we have found it from our experience.

4.2.3.46. Low capacity of turbo compressor in the Nitric Acid Plant.

We recommend to use for steam production in the Nitric acid plant demineralized water only. Demineralized water should be also used for injection into the steam. By using demineralized water for steam production salt deposit on the turbine blades will be reduced to a minimum.

High Vibrations of the compressor can occur due to non balanced rotor, and incorrect clearance of the bearings and/or due to spliting of oil film in the bearings. The allowed vibrations according to Czechoslovakian standards are given in Annex No. 22.

4.2.3.47. Premature failure of heat exchangers /pollution of cooling water/.

The high corrosion due to pollution of cooling water can be to solved by installing a new separate cooling tower for the barometric condenser of the Double salt plant or to use stainless steel for coolers of the plants, as for instance at the steam condenser of the air compressor turbine.

4.2.3.48. Unsatisfactory performance of the ammonia screw compressor.

For a good service of the screw compressor it is necessary to ensure perfect filtration of ammonia. We suggest to replace the worn rotors by new ones. The worn rotors should be repaired by the supplier.

4.2.3.49. Corrosion of M.S. structures.

We recommend to paint the structures regulary with a suitable paint. It is possible to use the paint according to the specification given in annexture No. 23

4.2.3.50. High NO content in tail gas due to poor performance of cooling tower pumps.

This can be solved as described in point 4.2.3.38.

4.2.3.51. Frequent failure of boiler elements at the Sulphuric acid paint.

During an examination of the boiler we have observed that the corrosion occurs on the tubing bends. The corrosion penetrates mainly from outside, less from inside. We have found that the used material of tubes BS 30.59/7 is suitable for this purpose in respect to temperature.

For welding of tubes we recommend to use electrodes with the following composition: 0.5 - 0.12% C, 0.45 - 0.9% Mn, max. 0.4% Si, 0.4 - 0.65% Cr, 0.5 - 0.75% Mo, max. 0.3% Ni, max. 0.05% P, max. 0.04% S.

Further we recommend to examine the kind of material used for guard plates. The guard plates must be welded on with the lowest possible welding current while avoiding to strike the arc on the tubes. It is also necessary to find out if the material of the tube bends was subject to heat treatment / normalization heat treatment/.

On the basis of these findings we arrived to the conclusion that due to frequent shut downd of the plant electro corrosion occurs on the outside surface of the tubes.

New tubes, wich will be installed in the boiler should have a larger wall thickness. For the bends we reccommend to use tubes with a 4 mm wall thickness. We recommend also to avoid any welding on tube bends.

4.2.3.52. Failure of the acid piping system.

The tubes should be replaced after some reasonable time. We suggest to use better corrosion resistant material like Ferosilit. It should have the following composition: 0.5-0.8% Cu, 0.3-0.8% Mn, 14-16% Si.
We recommend to keep adequate spare pipes on stock.

4.2.3.53. Seepage of water from basin of cooling tower.

We suggest to use a protective lining on the basin of the cooling tower with glass reinforced plastic from inside.

4.2.3.54. Failure of preheater.

Because the temperature at the heater tube bundle can rise up to 600°C we recommend to use stainless steel tubes from AISI 321/17-20% Cr, 8-11% Ni, max. 2% Mn, max. 0,12% C /.

4.2.3.55. Elongation of chain at the pyrite elevator and cinder elevator.

The existing elevator is about 38 m high. The elevator has an obsolote construction. We suggest to divide the elevator into two shorter elevators with linked chains and to fix the buckets to the chains by very strong hooks. The bucket must not be a part of the chains.
For the chains better material from steel with very high strenght should be used.
The service life of the chains represents 3.5 to 4 years. Thus we suggest a preventive change of the chains after 3 years.

4.2.3.56. Excessive wear of Gyratory crusher mantle and grinding rings.

The cone and the ring of the gyratora crusher are made out of manganese steel with 14 % Mn. The hardness is about 400 HB. For reconditioning of these parts we suggest to apply hard facing by using eloctrodes with the following composition:

a/ 0.2% C, 0.6% Mn, 0.4% Si, 13% Cr. The hardness of welding material is about 450 to 500 HV.

b/ 3% C, 2.2% Mn, 2.5% Si, 3% Cr, 3.5% W, 1% V. Welding must be carried out with preheating up to 400--450°C and after welding the material should be slowly cooled down. The achieved hardness is 700-900 HV.

c/ 0.8% C, 1.2% Mn, 1.1% Si, 1.8% Cr. Preheating 350°C. Achieved hardness 625-725 HV.

It is also possible to use electrodes from the UTP Company, which has an agency in India.
Electrode UTP 711 - 35% Cr, 4% C - achieved hardness 613 HB.
Electrode UTP 75 - 10% CrC, 72% WC - achieved hardness 800 HV.
Before using the electrodes for hard facing we suggest to. consult the proper method with the supplier of electrodes.

4.2.3.57. Excessive wear of jaws at the jaw crasher.

Here it is possible to use the same method as above. There is also possible to screw on the base material to another plate which is provided with a hard facing layer.

4.2.3.58. Frequent leakage of gas headers up to packed cooling tower.

Replacement of corroded headers. It is necessary to pay more attention to protection against corrosion by means of painting.

4.2.3.59. Belt weigher.

The Schenk type - West Germany or Transporta type-Czechoslovakia weigh feeders should give trouble free service as we have learned from our experience.

4.2.3.60. Cyclones.

The low efficiency of cyclones is due to leakage of the double flap valves. We suggest to install an elastic flap. As a flap material it is possible to use for this purpose, sillicon rubber, which can resist up to 315°C. The bottom parts of the cyclones should be left without insulation.

4.2.3.61. Dust precipitators and packed cooling tower.

By increasing the efficiency of cyclones, the amount of dust which is coming to the dust precipitators and packed cooling tower will be reduced.

4.2.3.62. Drag link conveyor for cinder.

We recommend to divide the drag link conveyor into two shorter parts each with a separate drive. About 70% of faults ar caused by imperfect welds between chain links, which are made out of cast steel and cross girders which are made out of rolled steel. We suggest to use for the critical parts forged steel or welded carbon steel with hard facing on functional surfaces.

4.2.3.63. Mist precipitators.

We recommend to install before the mist precipitator a louver separator with a demister. Such a separator will remove about 95 - 98 % of mist.

4.2.3.64. Converter.

When fitting the cast iron supporting rods and charging the catalyst it is necessary to check if the supporting rods are fitted in an absolute vertical position. The supporting rods must not be bend stressed.

4.2.3.65. Submerged acid pumps.

We recommend to carry out following precautions:

a/ to use a bearing with higher dynamic power by installing a double row self-aligning ball bearing and/or a roller bearing of the same type in place of present ball bearing.

b/ to use conical shaft by which a higher flexural rigidity will be achieved.

c/ instead of a combination of cast iron and stainless steel for the second bearing a combination of stainless steel and teflon should be applied.

4.2.3.66. Cinder cooler.

The new reconstructed cooling system is good, but we suggest to cool down the cinder by air. The heat can be reduced by welded cooling ribs at the outside part of the cooler.

4.2.4. MECHANICAL MAINTENANCE AND REPAIRS :

4.2.4.1. The position of Maintenance Deptt. in the factory.

The maintenance deptt. from the view-point of organisation is on the same level as the Production Department. On the same level is also the Technical Service and the Power House. The maintenance is classified into the three aqualy levelled proups :

1. Mechanical and Civil Maintenance.
2. Electrical Maintenance.
3. Instrumentation Maintenance.

The Power House Maintenance is a separate section under the supervision of the Power House Management. The aim of our study is mechanical maintenance / Annex.7./ and Power House Maintenance.
The Mechanical Maintenance is clasified into four basic proups. Some of these proups are handling plants with very different activities as for instance the Central Workshop and Gas Plant Maintenance. Into the responsibility scope of the maintenance department are included some not typical maintenance activities like Transport and Lubrication / recovery of oil etc./.
The position of the Power Plant at the Sindri Unit is not reasonable. The unit has its own maintenance group for steam and power generation, but it has no maintenance for pump stations, water and steam lines etc. This maintenance jobs are made by the mechanical engineering section. For some heavy works the Power House maintenance colaborates with the Central Worskshop and the M.E.S. Section.

The Civil maintenance is incorporated into the Machanical Maintenance Department, but some Civil Engineering works like refractory, acid proof brick lining, insulation and lagging are carried aut by the M.E.S. Section.

4.2.4.2. Plant maintenance groups are organised as independent sactions with full responsibility for the technical state of machins and eguipments in the plants. The Plant Engineer is responsible for all activities of the plant maintenance. These activities are as follows :

- Maintenance planning.
- Planning and execution of annual shut-down.
- Prepare instructions for machines and equipment maintenance.
- Coordination of jobs during repairs between the Central Workshop and / or an external agency /.
- Procurement of spare parts and inspection of in-coming port into stores.
- Carry out the repairs with the possibility to utilise services of the Central Workshop concerning inspetion of impellers, machining and repair of spare parts and assemblies, as well as specialised jobs like welding etc.
- To examine and solve all technical problems which arise during operation and repair of machines and equipment . For this purpose the Plant Engineer utilises the services of the P a D Divn. at FCI.
- To evaluate suggestions and recommendations submited by P a D Division of FCI and by external agencies and to carry out the improvements.
- Preparation and planning of maintenance budget.
- Preparation and completion of technical data reports with respect to equipment of the plant.

- Technical inspection during operation of machines by means of checking and measuring the vibrations. Vibration control is carried out by the Technical Services, but evaluation is made by the Plant Engineer.
- To test pressure vessels and lifting tackles / excluding boilers as per statutory stipulations / and to maintain records of the same.
- Planning inspection of boilers in connection with Government inspection etc.

4.2.4.3. Level of maintenance planning :

For each plant is prepared a yearly plan of maintenance where individual repairs are planned, based on cycles achieved from experiences. Such yearly plan is checked and actuated in particular for each month. The deficiency of the plan is that the cycles of repair are not propressive but in many occasions they have narrowed. The cycles of repair are not basedon the actual running time in hours of each machine and thereby they do not reflect the hours for which a machine can be safely kepr on line. The premature repairs are not satisfactory analysed. High number of break - downs on machines which are "prevetive" mainteined shows that the plan of preventive maintenance is formal. In the prevetive maintenance it is not taken into consideration the view-point of differential care for individual capital items according to their importance for the production.
The maintenance costs as percentage of the cost of capital items have been worked out to be 6% for the last yr, The self - sufficiency of maintenance in execution of repair works represents about 99%. This is very high because of very large repair facilities.
In regard to balance procedures of larger rotating machines services of external companies are used only.

For repairs of turbocompressors and steam turbines are in some occasion utilised services of the suppliers. The loss of production due to break - downs and maintenance works within the period 1974 - 1975 is shown below.

Plant	Target	Actual	Shortfall /total loss /	Loss of prod.due to Mechl. Mce.	% from Target
Cokeoven	21900	21 516	384	20	0,8 %
Gas Plant	91 670	78 056	13 614	1 478	1,6 %
Gas Reforming	32 760	22 723	10 037	3 332	11,1 %
Ammonia Plant	124 430	76 779	23 651	2 311	1,8 %
Double Salt	48 086	26 721	21 364	10 222	21,5 %
Urea Plant	14 820	9 173	5 647	3 750	26,5 %
Sulphate Plant	236 500	197 777	38 723	5 590	2,4 %
Sulpuric Acid Plant	55 800	32 664	23 136	17 482	31,5 %
Nitric.Acid	50 099	37 091	13 008	9 881	19,6 %

For the critical items there are in the plants installed stand-by machines / with exception of the Nitric Acid Plant /. We could not find, due the percentage of losses duo to non - availability of spare parts, because such informations are not available. In our opinion the losses due to non - availability of spare parts are very small, because there is very high stock of spare parts at the central store and also at the handy stores of individual plants.

4.2.4. Technical preparation and technical level of repair work execution :

For maintenance and repair of machines and eguipments detailed instructions are not avalable, except for several importand machines.
Asimilar situation is in the field of drawing documentation, which we consider as very important for inspection of parts, assemblies and whole machines. Repairs are carried out only according to practical experiences of workers and supervisors obtained by repeated repairs during a long period.
To work in accordance to drawings or to read drawings are able people down to the level of supervisor, foreman and some high skilled workers. Tehhnical inspections of jobs are carried out by supervisors.
There is no rule to keep records of all operating and mechanical parameters from machines before there repair e.g. pressures, temperatures, vibration, output, run out etc.
No optimal technical conditions are prepared for the execution of repairs. So it happens that the technical parameters of a repaired machine does not achieve designed figures and / or for technology necessary parameters respectively. This refers mainly to repairs of pumps and reciprocating - compressors. We see the reasons as follows :

- Imperfect inspection of important parts before assemblage of a machine i.e. dimensions of impeller and casing of the pump. This is the reason for not keeping up clearances between the wheel and casing, tightness of seals between individual wheels etc.
- Characteristic of springs for compressor valves not adeguatly checked.
- Characteristic of piston ring thrust not adequatly checked.

- Impellers of pumps, compressors and turbines are not balanced / for instance the impeller of condensing turbine at the power house after replacing a complete row of blades is not balanced /.

For balancing procedures at the Sindri Unit a balancing machine with the possibility to balance implellers in the range of 5 - 300 kg. by fluent changing the speed in the range of 500 - 1,500 r.p.m. is available.

- Due to unsatisfactory storage of spare parte like shafts, piston rods, piston rings, impellers etc. in the Central store and also in Plant handy stores damages on functional surfaces are appearing.
- During preventive maintenance of pumps and recipocating compressors, the damaged main functional surfaces are not repaired. We have seen that a compressor was after repairs reassembled without repairing the damaged Crank shaft pins. The fricition surface of the cross head was also damaged. Grindings of crank shaft pins are not carried out in spite of the fact that such facilities, are available in the Central Workshop.
- Repairs of the machines are carried out mainly just on the spot and / or adjacent to their installation in the unit. The workshops are utilies only in very few cases.

Repaires of important machines like turbocompressor and reciprocating compressors are noted in the log book of the Plant Enginner, but it is also not a rule.
For repair works of some pressure vessels as for Urea conversion / are prepared instructions, which are on a good technical level, including also documentation for the repair. On high pressure lines, pressure vessels, boilers and materials exposed to high corrosive and / or erosive substances respectively are carried out ultrasonic tests.

For maintenance of larger assemblies and parts of the plant like the CO_2 removal section, the air separation unit. and the ammonia convertor instructions of repair works are elaborated and in some occasions net Works are prepared. The level of basic maintenance works is very low. Most of the joints on steam lines are leaking. Also the gland packings of valves for water and steam are leaking. Leakages of gland packings im pumps and leakages in the lubrication system / also on compressors / are reducing the service life of machines and foundations / destruction of foundations leads to higher vibrations of machines /. Unsatisfactory is the quality of lubrication. Improper storage of oil, filling funnels are open and are provided with very rough sievs. It is not paid enough attention for cleaning of machines and their surroundings and in this respect we would like to point out that here is the begining of preventive maintenance, and not only in perfect planning and carrying out statistics.

4.2.4.5. The outfit of plant Workshop.

Working and store spaces of the plant Workshops are proportional or higher than it is necessary for the execution of jobs.
The plant workshops are usually equipped with following facilities :
- Welding machines
- Pedestal drilling machine
- Electric portable hand drilling machines
- Double wheel grinding machine
- Sawing machine
- Lathe / in some cases /
- Enough tools

Special tools like large spaners, jigs, jacks, screw dyes, electrodes and also sensitive measuring devices are stored at the handy plant maintenance store, In some cases tools and measuring devices from the tool store are utilized in Central Workshop.

As a serious deficiency of the plant workshops are large quantities of materials placed in the Workshops, handy storages and also on their surrounding. This material has a different quality. It is a mixture of new, wear out and damaged spare parts as shafts, wheels, bushes, complete assemblies, complete rotors for pumps, piston with piston rod and piston rings, double wheels, whole machines, pumps, gears, valves, tubes and jointing material.

The common defect is insufficient protection against corrosion, against damage and mixing good materials and parts with scrap material.

4.2.4.6. Solution of technical problems in maintenance and Technical Services :

According to the organisation chart of the maintenance department, there is no special authority for solving technical problems related to maintenance. Solutions regarding technical problems are made in the scope of plant maintenance nad/or Central Workshop respectively. In view of the fact that the plant maintenance is very busy with the day-to-day maintenance, there is no space for proper technical solutions on a competent level. According to our experience, the plant maintenance staff should first of all identify the problems and then obtain and execute an ananbigous solution only.

Otherwise situations are arising where solutions of technical problems in maintenance take considerable time and/or some problems are left without technical solution.

This method resulted in :

- destruction of the connection rod in the das compressor, which occured there times.
- repeated failures of boiler at the Sulphuric Acis Plant.
- low performance of the machines and equipments like pumps, compressors, separators etc.
- a considerable number of break downs on individual plant etc.

Another deficiency in the present set-up of the maintenance department is, that there is no group or authority which is prepared not only to provide solutions in technical problems but also to utilise technical progress in maintenance. The desing office from the view-point of organisation belongs to the Central Workshop.
The outfit of the design with space, materials, equipments is on a good level. There is also enough technical personal / designers /. The scope of the work is wide sparead. The design office prepares small projects for reconstructions in collaboration with the P a D Division of FCI. Further it designs pressure vessels, prepares fabrication drawings for spare parts, archives and updates the drawing documetation from the whole Sindri Unit

During our visit we have found the following shortages :

- There are used two measuring systems / inch,mm /.
- Fabrication drawings have to many general notes. / for instance the drawing for fabrication of the evaporator for the Sulphate Plant, from material AISI 316 L /.
- The number of drawings for spare parts and assemblies of machines, which are necessary during the excution of repairs is very small.
- Low technical level of the sketches prepared for the machine workshop.

The inspection of quality in maintenance is carried out on the level of plant maintenance / supervisior or Foreman / where also the respective activities like fabrication and reconditioning of spare parts, repair of machines etc. are performed. This system of technical inspection is unsatisfactory.

An advantage for clearing technical problems by maintenance is the neighbourhood of the P a D Devision at FCI and the good ralations between them and the Sindri Unit.

Services of the P a D Division at F.C.I. :

- Solutions in corrosion and material problems including chemical analyses, mechanical examinations and metalografic analysis.
- Calculations of pressure vessels and parts of machines.
- X-ray and ultrasonic control.
- Control of delta ferit content etc.

According to information obtained from the maintenance department the services of the P a D Division of FCI are timely and on a good level.

As a significat deficency from the maintenance side is that the connections and utilisation of the results are left on the level of plant maintenance. This makes unable to arrive to an effective utilisation of the solution of problems from the view-point of the whole factory.

The services of the Technical Service section in the field of vibration control are for maintenance requirements not sufficient. This is because the obtained figures from the measuring devises are not evaluated and therefore it isnot posible to make proper analyses of vibrations.

4.2.4.7. Central Workshop and Cantral Fabrication Shop.

The Central Workshop is very good outfitted with space and machines.

The services of the Central Workshop are very wide spread and include :

- Checking of spare parts and assemblies during repair works.
- Repair and / or adaptation of patrs / shafts, bushes, etc.
- Machining new spare parts.
- Fabrication of spare parts by means of casting from cast iron, brass and some alloys.
- Repair of valves.
- Repair of heat exchangers by means of tubes changing.
- Repair of whole machines for plant maintenance.

The machine Shop works in there shifts.
During our visit at the Central Workshop we have learned that the activities of the Central Workshop are not planned and have no connection with the plan of preventive maintenance of individual plants.
Moreover a low quanity of repairs are carried out concering all machines. The Central Workshop repaired during June only 7 pumps and 3 gears. Also instruction for the repair of machines are not available. Repairs are mostly carried out under the supervision of experienced workers only. They do not use drawing decumentation.
There are also missing instructions for fabrication, repair or recondition of spare parts.
The condition of metal-cutting tools and measuring devices in the workshop and store is on a low standard. In the Workshop are available quite a lot of spare parts, which should to be reconditioned.
Many machines are not utilised.
For the fabrication of spare parts are not used suitable measuring devices. For rough measuring works they use very accurate measurind deviced as for instance a micrometer calliper instead of a vernier calliper. Some parts are made new by using only a calliper.

The fabrication inspection is carried out by a Foreman or by a Chief Foreman.

4.2.4.8. Maintenance section for Welding, Fabrication and Structural works :

For executing their activities the section has more than sufficiently spaces and it is also very good equipped with machines.

The range of services is very wide.

There are adopted even the technicaly most difficult technologies like Welding of cast iron, brasses, Aluminium, Alloy steel, Welding on hard facing etc.

We have found the following defiencies :

- No satisfactory hygiene by handling and working with low carbon stainless steel like AISI 316 L.
- No detailed instructions are provided for welding works. Such instruction should included all welding procedures starting edges from preparation up to the final operation / for instance pasivation, X-ray, ultrasonic checking, hardness test etc./.
- The professional skill and rich exerience of the chief of welding section should be supplemented by a specialist with welding theory knoweledge.

4.2.4.9. Inspection of boilers and pressure vessels :

All the Waste Heat recovery Boilers are inspected and tested once in two years, whareas Directly Fired Boilers are inspected and tested once per yaar. Such inspection and testing are to be carried out by the Chief Inspector for Boilers of the Bihar State and certificates in this respect allowing operation of the same should to be obtained from this authority.

All high pressure vessels are normally to be tested once per year. The test of a high pressure vessel is carried out by the respective Plant Engineer.

4.2.4.10. Shift Maintenance :

The shift maintenance is decentralised to each plant. The maintenance staff on shift is under the supervision of the shift maintenance forman. The shift maintenance for the whole factory comprises 30 supervissors and 108 workers as it is shown below.

Plant	Supervisors :	Technicians: + Helpers
1. Material Handling	4	12
2. U.N.D. H N	4	15
3. Ammonia	4	14
4. Sulphuric Acid	4	4
5. Cokeoven	3	14
6. Gas Plant	3	16
7. Sulphate	4	15
8. Gas Reforming Plant	4	14
9. Power House	-	4
Total :	30	108

According to our experience such shift maintenance can not be considered as economical nd this reason, we suggest to change it to a centralised shift maintenance.

4.2.4.11. Organisation of Annual Shut Down :

The Plant Engineers and the Plant Managers prepare the annual shut down schedules for each individual plant in advance. The coordination of plants for the shutdowns is made by the Industrial Engineering Departmant, which carries out its analysis and prepares a diagram with a critical path by the use of a computer. During the shutdown this diagram is constantly watched, monitored and updated and after the shut down it is evaluated. The shut downs usually take place at the beginning of the planning year period and also in respect to the suitability of the weather. From the view-point of common power and steam supply there is no interruption, because the whole factory is divided into few groups. Thus general shut-downs are not necessary.

4.2.4.12. Storage of Spare Parts and Other Materials :

The store follows about 48,000 items of individual spare parts, with a total value of Rs. 65 millions.
This sum represents more than 20% from the total value of capital items at the Sindri Unit. The above mentioned proportion is very high.
The spare parts are stored separately for each plant and are well arranged on the shelfs with proper indications.
In collaboration with the respective Plant Engineers each spare part item is limited with a minimum and maximum quantity which has to be kept in the store.
For other materials / valves, shels, pipes and jointing material etc./. Written instructions are prepared for the kind and quanity, which have to be kept on stock.

Procurement of spare parts :

a./ When a certain number of spare parts in store is reduced to a minimum, the respective Plant Engineer is informed about it.

b./ The respective Plant Engineer sends his requirement for spare parts with the necessary drawings etc. to the store deptt. where the purchase requisition is filled up.

c./ Requirements for some spare parts are collected at the Purchase Department.

d./ Evaluation of obtained offers and selection of the best.

e./ The incoming spare parts are inspected by the respective Plant Engineers.

f./ Spare parts of good quality are given to the spare parts store.

g./ Spare parts of inferior quality are claimed. The amount of spare parts which is rejected represents about 5% from the whole.

During our visit in the Store, we have ascertained the following state :

a./ Very high amount of spare parts on stock.
b./ Low turn over of spare parts.
c./ The spare parts are not sufficiently protected against corrosion. Some parts like shafts, pistons, piston rings, compressor valves etc. are corroded on the functional surfaces.
d./ The handling and storage of low carbon stainless steel like AISI 316 L and AISI 304 L is not satisfactorily.

4.2.5. SUMMARY AND RECOMMENDATIONS :

For the achievement of higher effec[illegible]ivity in maintenance [illegible]ctivities, i.e. hi[illegible] technical standard inclusive planning, we [illegible]end the following precautions :

4.2.5.1. To eliminate fr[illegible] [illegible]aintenance department, the typical non mai[illegible] activities like Transport and Lubrication. [illegible] section should be part of the Material [illegible]ment Department.

4.2.5.[illegible]. The Power House s[illegible] included into the Production Department. T[illegible]intenance section of the Power House shoul[illegible] subject of the Maintenance Department.

4.2.5.3. Technical Service[illegible] the view-point of their activities should [illegible] incorporated into the Production Department, [illegible] the measuring and evaluation section including [illegible]onnel should joine the Maintenance Deptt. The [illegible]intenance and Fabrication Department we recom[illegible] to organise according to the chart shown in A[illegible] 8,9. The aim of this organisation is [illegible]ble the following activities.

4.2.5.3.1. To elaborate a p[illegible] of preventive maintenance for the whole factory [illegible] well as central planning of maintenance activiti[illegible] plan should be centraly watched and evalu[illegible] [illegible]lanning and control of maintenance budget. To [illegible]er repairs from external agencies.

4.2.5.3.2. Quality inspections of :

- Materials and spare parts, which are coming to the factory.
- Spare parts machined or recondition at the Central Workshop.

4.2.5.3.3. Checkings and inspections of machine repairs.

4.2.5.3.4. Inspections of boilers, pressure vessels and cranes.

4.2.5.3.5. To check and to inspect the operation of machines. To establish a special group for carrying out balancing procedures of impelers to make measurements and analysis of vibrations on machines in the course of operation and to provide diagnoses of anti-fricition bearings without dismantling them. The balancing machine from the electrical maintenance shop should be transferred to the balancing group.

4.2.5.3.6. Solutions in technical problems of maintenance concerning of :

- Application of new methods in maintenance management.
- Progress in design of machines and equipment.
- Solution of technical problems arising during operation and repair of machines and equipment.
- Corrosion, welding and heat treating.
- Lubrication.

For these activities also services of the P a D Division of FCI should be utilised / their specialists and measuring devices /.

4.2.5.3.7. To increase the technical level of the desing office, as well as its capacity and responsibility for the proper function of spare parts designed by them.

4.2.5.4. To elaborate regulations, which will for the whole department, each section and function point out their activity, responsibility , duties and authority.

4.2.5.5. To carry out a proper categorisation of the equipment and machines according to their importance for the production.

4.2.5.6. Centralisation of maintenance in case of the most imporant machines and equipment for production.

To establisch groups for :

- Technical preparations for the repairs of pumps, compressors, steam turbines, gears, blowers, valves etc. which will be carried out at the Central Repair Shop / C.R.S. / and by the plant maintenance.
- Technical prepration for the fabrication and recondition of spare parts, fabrication and overhauls of vessels and heat exchangers, fabrication of structures, which will be carried out at the Central Fabrication Shop / C.F.S. /.

Note : For the above Centralisation should be utilised also Workshop spaces, machines and equipment, and staff of the existing plant maintenance groupe. The centralisation should be carried out in a smooth and gradual manner. We suggest to begin with repairs, which are already successfuly carried out by the plant maintenance and/or by the Central Workshop respectively, By the centralisation of repairs, build up on this basis connection will be continionsly maintained to the plan of preventive maintenance.

4.2.5.7. The individual plant maintenance groups should be organised in such a way where a single separat group will be responsible for closed production cycles. FOr instance Ammonia Production, Production of Acids and fetilizers, steam production, water treatment and ist distribution.

4.2.5.8. Centralised Shift Maintenance. This promotes elasticity, higher technical level and economy.

4.2.5.9. To separate from the Mechanical Engineerig Service Section, The refractory jobs and the insulation and lagging jobs. This activities belong to the Civil maintenance.

4.2.5.10 To bear responsibility for the procurement and storage of spare parts in prescribed quanity and quality by the Material Management Department. For this activity we recommend to utilise the computer of the P a D Division of F C I . We also recommend to use the computer programme which is already used at the Trombay Unit.

4.2.5.11. To establish a proper storage of spare parts and materials in the Central Store, but also in the plant Workshops and thier handy stores. The stored parts should be protected against corrosion and mechanical damage. The present umnsatisfactory condition especially at the plant Workshops and handy stores should be put into order by a classification of materials and spare parts into groups :

- Good for use
- Suitable for recondition
- Scrap

To keep in the handy stores only an optimal stock while the other spare parts should be returned to the Central Store.

4.2.5.12. To maintain the proper condition of tools in all workshop and Central tool store.

4.2.5.13. To maintain in proper condition the measuring devices. The accuraty of measuring devices must be regularly checked according to the standards.

4.2.5.14. To introduce a very strict system for proper lubrication of machines in the plants. Clean thoroughly the machines and equipments as well as their surrounding.

4.2.5.15. By systematic activity of the maintenance management to achieve a higher level in basic maintenance / training, issuing instructions, competition etc. /.

4.2.5.16. To establish a bonus system for rewarding any exceptional initiative of engineers in case of improvements, suggestions and inventions.

4.2.5.17. To elaborate unanbigous rules for an evaluation of workers in respect to their technical level and ability.

4.2.5.18. The maintenance department should bear responsibility for its activities right from the inception of a new project. This means already from the initial stages when project details are worked out, investment planning done and when technical specifications are laid down. It should then continue in quality control of equipments up to the utilisation of production facilities during the period of their effective service life.

4.2.5.19. Suggested additional equipments for the Maintenance Department.

- Balancing machine for impelers.
- Instrument for vibration analysis.
- Instrument for carrying out diagnosis of anti-friction bearings without dismantling them.
- Ultrasonic D-meter for wall thickness control.
- Portable instrument for hardness tests.
- Tube expander with automatic force control.
- Torgue wrenches for repair group of machines.
- Instruments for measuring length, diameters, evennes and roughness of surfaces.
- Tools for cutting metals.
- Mobile workshop for the Central shift maintenance.
- Ciruclar shears for cutting gaskets wtih different diameters, driven by hand.

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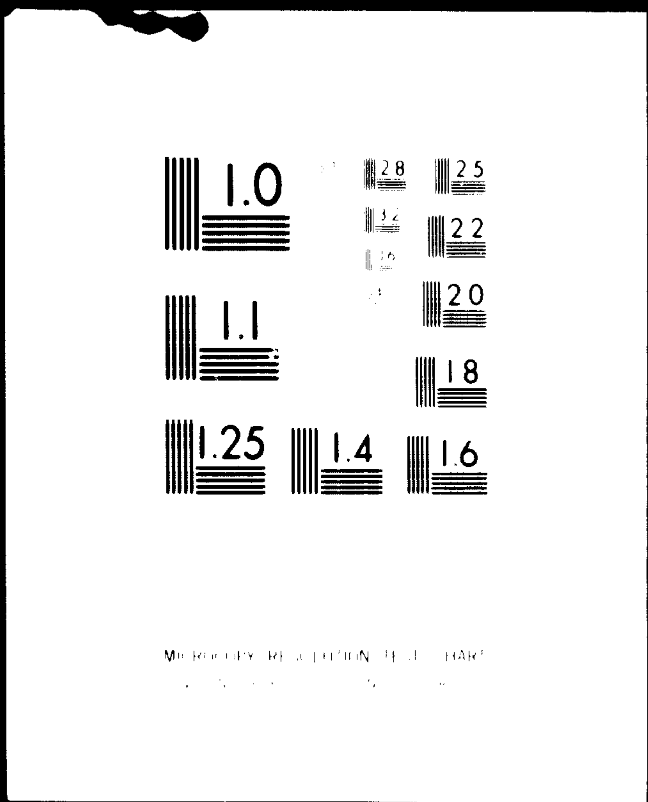

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4.3. F C I DURGAPUR DIVISION .

4.3.1. Plant Installation.

No	Plant	Capacity TPD	Year of Commissioning
1.	Ammonia Plant	600	1 973
2.	Urea Plant	1 000	1 973

In addition to the above main plants there are auxiliary plants like a Steam Generation Plant, Raw Water Treatment plant, Boiler Feed Water Plant.

4.3.2. Short description of the Plants.

4.3.2.1. Ammonia Plant.

After bringing down the sulphur content of naphtha to the permissible limit, naphtha is reformed in a reforming furnance in presence of a nickel catalyst at a temperature of 800^0 and pressure of 23 kg/cm^2. As a result of the above process a reformed gas consisting hydrogen, carbon - monoxide and carbon - dioxide is produced. The gas contains also unconverted methane.

Then air is added to the reformed gas to supply the necessary nitrogen required for the formation of synthesis gas. The unconverted methane undergoes partial oxidation for the production of hydrogen. The raw synthesis gas thus formed contains carbon - dioxide and carbon - monoxide in addition to hydrogen and nitrogen. Further conversion of carbon - monoxide into carbon - dioxide and hydrogen is achiveved by reacting the gases with steam in presence of an ironoxide catalyst. This enables to obtain some more hydrogen, which is utilized for the production of ammonia while the by product carbon dioxide removed from the gas by Vetrocoke CO_2 - removal is used for the production of urea in the urea plant.

The synthesis gas is further purifi [illegible] ation. The purified synthesis gas is compress [illegible] kg/cm^2 pressure in a single centrifugal com [illegible] he recompression of the recycle gas is also achieved [illegible] compressor. The compressed gas is converted into [illegible] the synthesis reactor in presence of an iron catal [illegible] ous ammonia is cooled down and converted into liq [illegible] , which is sent to the urea plant.

4.4.2.2. The Urea Plant.

In the urea plant, liquid ammonia and [illegible] dioxide are reacted at about 200°C and put un [illegible] ure up to 220 kg/cm^2 in a specially lined reactor wher urea is formed. At first, it is obtained as a 30% sol [illegible] ch is concetrated furter to 99,5% melt and allowed [illegible] through a prilling tower. As the melt falls thr [illegible] tower, uniform prills are produced. These are convey [illegible] conveyor belt to the bagging plant or silos as requir [illegible]

4.3.3. Problems at the Durgapur Division.

4.3.3.1. Carry over of water fro [illegible] drum.

The vertical steam drum has no suffi [illegible] ation surface. There is also a very high veloc [illegible] generated steam which leads to poor separation [illegible] over of water drops. This results in higher con [illegible] on of salts in steam and can cause fouling of the ste [illegible] heater or low performance of the steam turbines. We recom end to replace the vertical erangement for horizontal as [illegible] achieve better control and operation. The horizontal dr [illegible] hould be so dimenzioned that the amount of water [illegible] r will hold upfor 10 minutes of full capacity of gen [illegible] ion in case of a boiler feed water pump failure.

4.3.3.2. The design of the Fluc Gas Waste Heat Recovery System is inadequate and the high pressure steam superheater capacity is limited to approximately 95 tonnes against re - quirement of 115 tonnes/hour.
We recommend to carry out modifications proposed by the supplier of the superheater or according to suggestions given by the P a D Division of F C I i.e. to install an externaly fired superheater for steam, produced by ammonia reactor boiler

4.3.3.3. There have appeared difficulties with the shell of the Reformed Gas Boiler, particulare hot spots at the spool piece connection. This problem had not appeared during the last nine months.
The situation will be improved by the installation of a new waste heat boiler shell and a new arrangement of the refractory lining. We suggest to provide the new shell with a manhole for an easy inspection of the boiler tubes.

4.3.3.4. Failure in the first boiler feed water heater. According to informations from the maintenance department and on the basis of an examination carried out at the first boiler feed water heater after a repair of some leakages, we have arrieved to the conclusion that the reason of very frequent failures results from the unsatisfactory solution concerning joints between the tube and tube plate.
The problem of tube ruptures due to vibrations and unsatisfactory anchoring of the tubes was solved during the repair of the tube bundle by the Larsen Turbo Ltd. at Bombay. The tubes were better fixed at the baffle plates and the clearance between the baffes and shell was minimized. During this re - parature have been also modified joints of the tubes and the tube sheet according to drawing No. 7-H-3115.

This solution enabled to achieved satisfactory tightness of the first boiler feed water heater in cold condition, which was proved by pressure tests.

There were not taken into account conditions under which the first boiler feed water heater operates. Inlet gas temperature is 450°C and outlet temperature of boiler feed water is 220°C. This means that the different heat expansion of different materials was not taken into consideration. The tubes made from AISI 347 with dimensions 20x2 have expanded to the tube sheet with a thickness of 275 mm. The expansion had taken place in the lower part in a length of 75 mm. The material of the tube sheet is 16CS3. The tube is then welded to the layer of AISI 347 material which is deposit welded to the tube sheet from the water side./in the original solution the weld was the only connection betwen the tubes and the tube sheet and no expansion occured/.

The weak point in the new solution is the seal weld. Different heat expansion of the used materials leads to destruction /cracking/ of the welds. Also the failure of the expanded joint between tubes and tube sheet is a result of different heat expansion.

Because the repair of the tube bundle which is now in operation requires a lot of time we recommend to purchase a new tube bundle. When purchasing a new tube bundle it must be taken into account beside the strengtht, corrosion resistance and regidity, also heat expansion. The new tube bundle must be designed for the working pressure of 175 kg/cm^2.

4.3.3.5. There have been failures on the high pressure boiler feed water lines at the flanges and also on the higt pressure steam lines causing complete shut down of the plant. These failures are caused mainly due to very frequent shut downs and start ups. Therefore it is necessary, during a start up of the plant all joints very carefully to observe and tighten. It is also very important to use for high pressure and high temperature joints the proper and desiged jointing material / bolts /. It should be recommendet to use in the maximum possible range weld joints. It is possible to weld also valves. For that reason it is necessary to have facilities for carrying out repairs of valves at the place of their installation.

4.3.3.6. The control valve on the high pressure boiler feed water pump discharge which should maintain a constant flow of water in the line /FRC 505/ has not given reliable service. This by-pass line had also failed due to heavy corosion. The valve is no more important because there are already installed new B.F.W. pumps which need not a constant flow controller. The installed hand valve is sufficient for the start up period. During normal operation the valve should be completely closed.

4.3.3.7. The lean solution pump for the vetrocoke causes frequent failures on the gland sealing which consequently requires stoppage and repacking. The seal ring inside, also becomes worn due to usage of improper construction materials. Proper washing of the gland seals should be performed by using water at higher pressure. The water should constantly flow through the gland to the pump.

The erosion results mainly from small pieces of packing material in the Vetrocoke solution. This is possible to minimise by fixing the packing in the towers by means of grading. The larger broken pieces of the packing should be removed and a strainer with a large surface should be installed inside the regenerator at the outlet tube. It is also important to install strainers with fire mesh in the suction line of the pumps. The eroded casing of the pumps is possible to repair by means of welding.

For the lean solution pumps is also possible to use Mechanical seals which are washed with water. But we consider this modification as unecessary.

4.3.3.8. The performance of the intercoolers at the synthesis gas compressor is inadequate.

The desing of the intercoolers must be properly checked by some design office as for instance the P a D Division of F C I. In case that it will be ascertained that the cooling surfaces are not large enough then it would be necessary to replace these intercoolers by new and bigger. According to our opinion the lower cooling effect is due to a high fouling factor from the water side. It can be improved by chemical tratment of the cooling water described hereinafter. During our visit at the Ammonia Plant we have seen that unproper sealing material had been applied for coolers in the machinery house and we think that same mistake is made with other coolers. The seal is not tight when using seals from unproper materials and most of the water is by-passed between inlet and outlet of the coolers. So, the cooling effect is low.

4.3.3.9. The performance of the water cooled condenser remained as a cause of limitation as the cooling is not adequate. During the shut down in the time from 27.7.75 to 15.8.75, the condenser was opened. The tube bundle is in poor condition. It can be clearly seen, that the tubes are corroded and dirty. Mechanical cleaning is impossible while proper cleaning is possible only by using a proper cleaning method for instance according to proposal from Drew Chemical Corporation. There was also changed the flow of cooling water so that the velocity of the water was reduced to 50%. In half of the cooler was also changed the counter current flow to cocurrent flow.

The gap between the deviding plant and tube bundle was minimised by inserted wooden plates. So, also minimised the amount of by-passing water.

When starting up the operation, the temperature after the condenser indicated 45 - 50°C and there was also some condensation of ammonia. We recommend to operate the plant only after a throughout cleaning of the water system by higher, pressure and higher load. Onxly when this is done, then it is possible to find out if the water cooled condenser is underdesigned. We recommend to check the tightness of the gas inlet chamber to the water cooled condenser during some next shut down.

4.3.3.10. Leakage through the diaghragm of the 4 th bareel between the make up gas and the circulating gas. According to the Ammonia Plant project it is possible use for hydrofining of naphtha the H.P, purge gas or recycle gas from the first stage discharge of the synthesis gas compressor.

The H.P. purge gas contains 100 ppm of NH_3. Acoording to given information the NH_3 content in the recycle gas during operation with a 60,% output represents only 200 ppm. Even with a higher NH_3 content, the recycle gas can be used for hydrofining naphtha. The NH_3 content in the gas entering into the comox catalyst is very low. In case the NH_3 content in the recycle gas represents 1%, then the NH_3 content in raphtha at the inlet to the catalyst comox will be noly about 300 ppm. This is a very low concentration and can not effceted the reaction at the catalyst. The nitrification of the the naphtha vaporriser is also not higher due to a very low NH_3 content at the naphtha inlet.

When the synthesis loop load is risen upto 55% with a 19% set point on the antisurge valve, then the antisurge valve MC 1.4 will be closed. The by-pass valve MC 1.3 is open 33%. Up from that time there is no containation in the make up gas as well as in the gas from barrels 1,11 and 111. So the synthesis gas from the discharge of 1 barrel can be used for hydrofining naphtha.

4.3.3.11. The seal oil system becomes disturbed during a power failure, particulary when the instrument air also fails. This results in losses of large quantity of oil. The seal oil system need to be improved. The control valve for its proper function should be checked in case of a shut down. The control valves to the leaking vessels must be therefore closed. For this reason it is necessary to install a by-pass valve of the oil pump which will be in case of trip fully open.

4.3.3.12. The coupling between the driving machine and the compressor has always oil leaks through the covers. We recommend to install a separate oil line from the coupling cover to the oil receiver by using a pipeline with a larger diameter.

The cover should be vented to the atmosphere. To ensure the inert atmosphere of the oil space a small flow of nitrogen should be constantly passed through.

It is necessary to check the jointing and sealing surfaces for their proper shape.

4.3.3.13. Frequent leakages of intercoolers and condenser. This will be improved by chemical treatment of the cooling water. Proper treated cooling water is much less corrosive.

For mechanical cleaning of the heat exchangers and coolers, is in our factory successfully used the high pressure pump "ATUMAT". The pressure is adjustable in a wide range. Further informations can be provided by the supplier :

VOMA GmbH
A 1210 Wien 21
Wenheitgasse 26
A u s t r i a

4.3.3.14. The capacity of the compressor is not adequate to go up on load as the efficiency of the ammonia cooling condenser 1.4 E_1 is insufficient.

By improving the quality of the cooling water will be also improved the condensation of ammonia in the water cooled condenser.

We recommend to operate the am[illegible] highest possible pressure. This [illegible] by a reduction of the cooling with [illegible]ry NH_3 evaporator 1-4 E4 or by increasin[illegible]ent in the synthesis loop.

According to our opinion the ca[illegible]tion compressor is sufficient. Thi[illegible] by running the plant on full capaci[illegible]

4.3.3.15. The machine become[illegible] due to antisurge devices not working [illegible] vibration of the control valve is possible [illegible] better anchorage of the valve. During our [illegible] Durgapur Division, the matter was clear[illegible]

4.3.3.16. Fouling of cooler[illegible] tubes. There are many reasons of tube failu[illegible] coolers. The leakage of the joint between the [illegible] due to:

- Stress caused by different the[illegible] tubes and the shell.
- Very high differences between [illegible] of the tubes and the shell.
- Vibration of the tube bundle du[illegible] in the heat exchanger.
- Unsuitable joint between the tube[illegible]
- Improper welding technology or [illegible] between tubes and tube plates
- Thermal or pressure shocks due [illegible]

Each leakage of the heat exchanger[illegible]rent reasons. It is here impossib[illegible]al method of repair per each case[illegible] solution must be for each case mad[illegible] technical analysis.

4.3.3.17. Too many start ups and shut downs of the primary reforming.
The reforming tubes, mainly at the bottom area, i.e. weldolets, outlet pigtails, headers, outlet header on secondary reformer and the whole boiler system in the flue duct, must be checked for changes of geometric shape /diameter, straightness, roumdness etc / and cracks. In case that some defects will be found then it in necessary to carry out also the other tests e.g. hardness test, metalografic analysis, ultrasonic and X-Ray respectively.

4.3.3.18. Air leakage of the primary reformer furnace through tube glands and burners.

This furnace was designed for a steady operation. Very frequent shut downs and start cause that the gland packing is damaged. This can be repaired during a shut down, but also during the operation of the plant. When the plant operates at 60-70% all burners have to be lit. This enables to control the proper oxygen content at the stack inlet. It is necessary also to optimalize the combustion of the burners. The heat in the furnace must be uniform. Also leaks in the flue duct must be sealed.

4.3.3.19. Gasket in transfer line and reformer tube inlet. There is in use a suitable gasket for reformer tube inlet and for the transfer line. The tightness of flanges during the start up of the plant should be checked and if necessary they should be retightened.

4.3.3.20. Tube failures at the flue gas waste heat boiler and process gas waste heat boiler.
The tube failures can occur because of overheating or as a consequence of manufacture fault. After inspection of the superheater and waste heat boiler at the flue gas duct we have found that the tubes are in good condition. We recommend to cary out minimum once per year the inspection of the flue gas duct and measure the diameter and other geometric shapes of the tubes. Moreover from such inspection have to be kept records, and they should be carry out by the same personnel.

4.3.3.21. High temperature at the flue gas outlet.
The combustion air heater should be inspected. According to our experience, the heat exchanger is getting to be dirty. This was also found by the inspection of combustion air at the Durgapur Ammonia Plant.

It is recommended to clean the heat exchanger regulary by means of brushing at least once per year during the annual shut down. It is also recommended to keep up maximum cleanliness in the surrounding of the combustion air fan.

4.3.3.22. Castable refractory.
We are using in our enterprise the services of the Plibrico Company from Austria. In many cases we hawe replaced the castable refractory with incoloy shirt by another stronger type which is resistant against erosion.

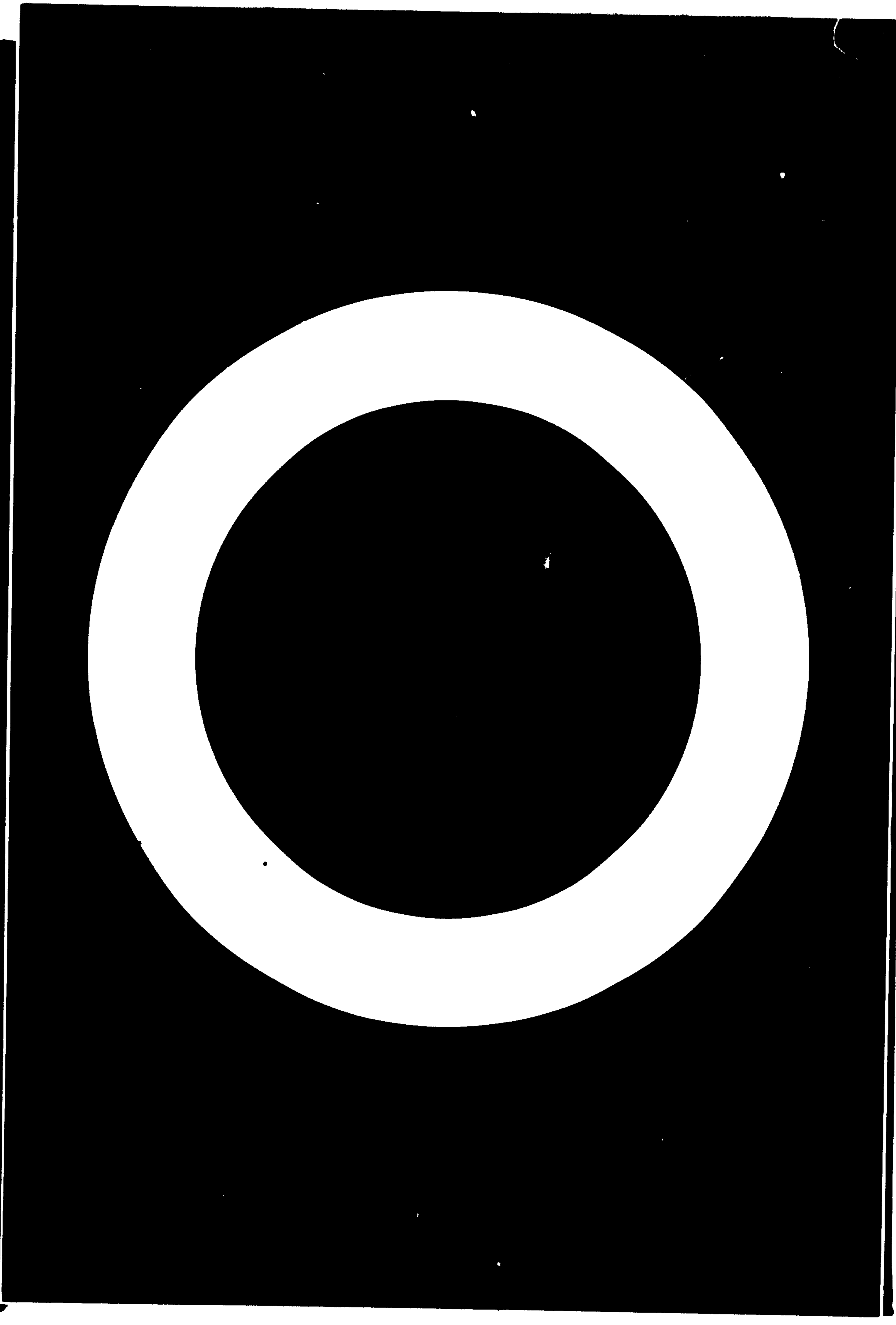
The tubes and vessels with refractory linings are painted with termocolour paint. We are using green colour, because the change of the colour to white can better recognised. In some high effected places we recommend to install instruments for measuring of the surface temperature with record and alarm in the control room. The tubes should be min. once per shift completely checked for hot spots.

4.3.3.23. Pressure vessels.
According to our [illegible] standards the following inspection are carried out.

a./ Outside inspection are carried out minimum once per year. Within this time is to be checked:
- The overall condition of the vessel.
- The condition of safety devices / relief valves / , control valves , block valves, alarms etc. /.
- The function of measuring devices and vessel safety accessories.
- Method of operation and adherance to the operating instructions.
- The cleanliness and condition of the vessel and its surrounding.
- Knowledge of the operating instruction by the operators.

b./ Inside inspection should be carried out once per three years. The inside inspection should be made after the walls have been properly cleaned and all deposits removed. The vessel must be good isolated from all connection lines by means of blanking. The inside inspection should include surface checking for cracks, deformation, corrosion and condition of, protective painting. Higher attention must paid to stress areas like branches, manholes, welding joints etc. For the inspection are used ultrasonic, X-ray, dye penetration, magnetic and metalogerafic tests etc.

c./ Pressure test - Such test concering pressure vessels is carried out once per 10 years and after each repair. Inspections are carried out by the inspectors who are usually employees of the factory, but are examined by the Govt. inspection and are authorised for this purpose.
Each inspection report is recorded into the inspection book of the vessel.



The lens gaskets for all ID, which are used in the ammonia plant upto 200^{O}C must be tin plated against corrosion. The thickness of the slecrolytic tinning should be 5 to 20 micronss.

4.3.3.25. Synthesis gas compressor.

a./ For an evaluation of the running conditions of the synthesis gas compressor continuous measurements of vibration are established. In spite of this we recommend to examine once per week the vibration of the compressor by means of a portable measuring device, which is available in the factory.
In case of higher vibration we suggest to cary out further measurements in collaboration with the P and D Division of FCI or other outside agendy. The analysis of vibrations show the frequency and reason for additional or increased vibration.
We recommend to adhere to the control cycles provided by the manifacturer for checking the coupling and other parts of the machine.

b./ For balancing procedures of a rotor in position are suitable balancing machines type WPI manufactured by the Shenk Company from West Germany in a range of 180 to 100.00 r.p.m. According to received information such a balancing machinr is available at the Central Mechanical Institute in Durgapur. We suggest to make arrangements for using this device for FCI Durgapur Division.

c./ Because the compressor is of an unique construction it is necessary to clarify with the supplier of the machine the problem of hot alignment. It is very important to follow the instruction of the maker.

For instance for our compressor at the Nitric Acid Plant, which has two turbine and two compressor barrels it is prescribed that the clearance for anchoring bolts between the nut and washer in cold condition should be 0.03 - 0.05 mm.

d./ There is in the store the spare steam turbine for the lubrication pump. We suggested to install this spare turbine for the auxiliary pump so the oil circulation will not be effected in case of power failures.

e./ The cycles of verhauling are provided by the supplier. The time between two overhauls represent usually about 24,000 running hours.

Rough check list for general overhaul :

- To dismantle and open all vessels, coolers, oil filters, oil receiver and carry out a proper cleaning.
- Inspection and repair of all pumps.
- Inspection and repair of all vessels.
- To check the geometric shape of pins.
- To measure all bearings to carr out their repairs if necessary.
- To check all bushes and to carr out their repair if necessary.
- To check the geometric shape of pins.
- To check repair and/or change of the labyrinths respectively.
- Cleaning, checking run out and balancing of the rotors.
- Repair of parting planes of stators, bearing pedestals and carrying out their sealing.
- Checking of the foundation bodding.
- Whole alignment of the machine.
- To check all pressure gauges, thormocouples, control valves and alarms.
- To change the oil and check the oil system for its proper function.

- Renew all paints.

f./ The seals and the bearing should be inspected according to schedule provided by the supplier or as a consequence of seal leaking or higher vibrations of the bearing.

g./ When checking the shaft supports, then all pins for their geometric shape should be checked, / degree of taper, alliptical or oval shape/. The allowed ovality for a pin is 0.00 - 0.01 mm, max. 0.015 mm. During the measuring procedure checking is also made for cracks scratches etc. Reduction in diameter of the due to machining hsould be not more than 3% from the original diameter.

On the bearings are carried out the following checks : condition of white metal and clearances, measuring the tthrust force of the bearing housing to the bearing shell, checking the supports of bearing by blue colour. The measurements of clearances are carried out by using a lead wire with a diameter of 1-1,5 mm and length of 20 to 25 mm. This wire is put between the pin and upper part of bearing at least on two places. The thisknass of the wires is measured by means of a micrometer. The thrust force of the bearing housing to the bearing shell is measured also with a lead wire, which is put between the bearing housing, bearing shell and betwwen the lower and upper part of the bearing housing. The different thickness of lead gives the overlap betwwen the bearing housing and the bearing shell. This overlap should be 0.05 to 0.06 mm, according to the diameter of the bearing. In regard to linings for the tilting and journal as well as thrust bearing we recommend to apply at some specialised company. We recommend also to carry out the first overhaul of the compressor under the supervision of the supplier.

4.3.3.26. Failure of the burner in secondary reformer.
On the 27.7.75 was the ammonia plant stopped due to a hot spot on the top part of the secondary reformer. The reformer was opened on the 31.7.75 after it was cooled down sa we could obseved the damaged burner.

Reason for failure of burner :

According to our cousideration the reasons of the burner failure are resulting from :

1. Embrittlement of material, chiefly in the effected zone of welds due to long lasting heat effect in the range of 750-850°C. This temperature causes an intensive precipitation of the sigma phase / composition of Cr. and Fe with the 45-48%. Cr and the rest is iron content / and chromium carbides in the grains limit.
2. Due to unnecessary long projection of the burner and becouse of insufficient fixing of the same it is coming to vibration and destruction of the tube in its critical point at the weld joint near the place where the burner is fixed.
3. Carbonisation to materials of the burner from the gas side.
4. Overheating the burner due to low velocity of the outgoing air, insufficient blow out of the hot flame from the burner.
5. Repeated heat expansion due to very frequent shut downs and start ups.

SUGGESTIONS :

1. It should be used a material with a lower inclination to sigma phase formation, which means to substitute the iron by nickel. / The nickel forms no carbides, prevents migration of chrome and forms austenit /.

Suitable nickel chrome based materials are :

Ni	90	Cr	10		
Ni	80	Cr	20		
Ni	80	Cr	14	[illegible]	6
Ni	74	Cr	16		
Ni	65	Cr	20		

2. At the critical point to remove the weld and if possible to use a tube with a higher wall thickness. As a critival part of the burner can be taken the length of 2 m from the upper flange.
3. Because the material becomes during the operation brittle a good fixing of the buner should be ensured. We suggest to use the spacing pipes, which should be mechanically fixed on the burner a pipe by a sleeve and bolts in three levels i.e. each level on three points. The spacing tubes must be provided with a piece of sheet which enables sliding by heat expanding / see photograph of secondary reformer from DUSLO SALA /.
4. The burner must be regularly checked each year.
5. The main header from the primary reformer, the part of the secondary reformer and the waste heat boiler should be painted with thermocolour paint. We recommend to use the green colour paint because in this case the colour change can be better indentified.

OTHER RECOMMENDATIONS :

In respect to the extend of damage of the burner at the secondary reformer / total degradation of material / we recommend to carry out a chemical and metalogrephical analysis. According to our experience the condition of the burner / as we have been informed by the maintenance department at the Durgapur Division it should be Incoloy 800 / is inadequate for its service like in production.

We consider that an often interrupted operation of the plant as well as very frequent break downs mainly becouse of power failures and subsequently the start ups have effected also other parts of the primary and secondary reformer. These are the reasons why we suggest to check the condition of the following parts :

1. The reforming tubes, mainly on the bottom piece, weldolets, outlet pigtails, headers and the outlet header of the secondary reformer.
2. The whole boiler system and flue duct.

The above mentioned equipment is necessary to checked for: Change of geometric shape / diameter, straightness, roundess etc./ and cracks. In case that some defects will be found, then also other tests like hardness test, metalographic analysis, ultrasonic and X-Ray tests should be carried out. In case that the material of the new burner will be incoloy 800 then the following procedure can be applied :

a/ Adapt the welding edges in accordance with the sketch.
b/ The welding edges must be degreassed by saponate.
c/ The root must be welded in an atmosphere of argon from inside.
d/ Fow welding is possible to use electrodes Inconel 182 with the composition 74% Ni, 16% Cr, 0.13% C.
e/ The thickness of the welding layer should be max. 2.5 mm.
f/ The tack welds and the finishing craters should be grinded out.
g/ Before welding the next layer carry out a dye check,
h/ Electrodes before use should be dryed out in 1 to 1.5 hours at a temperature of 200 - 260°C.

For welding the joint between incoloy and carbon steel material electrodes with the following composition should be used :

0.07% C, 6% Mn, 1% Si, 3% Fe, 18% Cr, 2% Mo, 1% Ti, 0.5 Nb, rest Ni.
During preparation of the welding edges it is neccesary to remove by means of grinding the old weld and the by welding effected zone.

4.3.3.27 Failure of H.P.B.F. water line.
For the achievement of a better performace of the Boiler Feed Water Pumps, the original pumps supplied by TERMOMECCANICA have been replaced by a better type TORISHIMA HDB-100/9.
The new pumps are provided with a minimum flow arrangement.
The discharge pressure of the previons TERMIMECCANICA PUMP was 150 kg/cm^2 and therefore the whole boiler feed water system / pipes, valves, boiler feed water heaters / was designed for a working pressure of 135 kg/cm^2 and design pressure of 150 kg/cm^2.
The discherge pressure of the Torishima HDB-100/P pumps is 150 kg/cm^2. By fully closed discharge valve is the pressure 175 kg/cm^2.
Because of this fact it is necessary to control the discharge pressure by means of a control valve on the by pass line.
The control valve has a diameter of 50 mm a-nd is designed for a pressure drop from 150 kg/cm^2 to 4.5 kg/cm^2. The diameter of the pipe from the discharge of the pump to the control valve FRC 505 was originally 40 mm. During the start up when nearly the full amount of water was by passed the velocity of the water in that line was very high - about 30 m/sec.
On 1st of July there was a leak on the bend of the by-pass line and some pieces of the eroded line were replaced by new ones.

On 20 th of august there were installed new block valves with small diameters which bring up the speed of water by by-passing the full amount upto 43 m/sec. This caused vibration during the operation time. As a result of this it came to rupture of the by pass line on the weld joint which was bad eroded.

Reasons of failures :

1. Badly eroded pipe due to high velocity of the water.
2. Water shocks duo to high throttling of the water caused by different diameters of the by pass line, control valve and block valves.
3. Lower thickness of the pipe due to corrosion from outside.
4. Insufficient anchorage of the line. By a proper anchorage leakage of the pipe can occure only due to erosion in the longitudial direction.

Recommendations :

1. Carry out inspections on the most important equipments of the steam system like the start up boiler, R.G. Boiler, Steam superheater. There appeared danger of damage during a shortage of boiler feed water.
2. To replace the T Piece by a new one with diameters 80/80/65.
3. To check wall thickness of the boiler water line with diameter 80 mm by the use of ulrasonic.
4. To instal a new line with diameter 65 mm and design pressure 200 kg/cm^2. The control valve should have diameter 65 mm for a pressure of 200/4,5 kg/cm^2. The line after the control valve should have a diameter of 80 mm and design pressure of 16 kg/cm^2.
5. Before the control valve should be installed a block valve with a diameter of 65 and pressure of 200 kg/cm^2.

6. When the by pass control valve will be closed, the pressure of the boiler feed water will be higher. Before rising the working pressure up to 175 kg/cm^2 all pipes and Vessels must be checked.
7. When the new tube bundle will be installed in the first boiler feed water heater, then it is not necessary to use this by pass, except at the very biginning of the start up.
8. During the start up of the plant it is reasonable to use a steam driven boiler feed water pump. This enables to operate with a lower pressure and the by pass valve can be closed. The motor driven pump may be started by a 60% load. In case of erosion of the by pass control valve PRC 505 we recommend to switch over to the turbine driven pump. The block valve before the control valve FRC 505 can be closed and the control valve repaired.
9. Problems similar to the above must be cleared in their whole complexity. We suggest to use the following system :
   a/ Find out the reason of failure.
   b/ Establish the scope of possible damage.
   c/ Suggestion for taking measures to prevent a reappearance of the failure.
   d/ To elaborate technologic instructions for the repair where inspection should be included. These technologic instructions must be submited in a written form.
   e/ Repair or modification of the damaged equipment.
   f/ To carry out a detailed technical analysis in reference to the reasons of the failure and make corrections according to the accepted measures if necessary.
   g/ To prepare the documentation of repair which includes certificates of used materials, results of inspection, X-ray and ultrasonic checkings etc.

h/ To use these results for avoidings the some failure on similar places in the factory or at the whole FCI respectively.

4.3.3.28. Additional valve on the by-pass methanator.
The problem of leakage at the by pass of the mathanator is possible to solve in two ways :

a/ by installing a second valve with a vent valve between the two.

b/ by bringing a small amount of syn. gas from the 1st stage of the syn. gas compressor to the by pass valve so that the pure syn. gas will prevent the leakage of the not methanated gas.

4.3.3.29. Replacement of semi-lean air cooler.
The water cooler has such a disadvantage, that it is not possible immediately to recognise leakages of tubes. In case of a tube failure, the whole cooling water will be contaminated with arsenic. Another disadvantage of the water cooler is the high fouling factor of the cooling water. From this point of view is the air cooler much better.

4.3.3.30. CO_2 compressor.
Corrosion of the compressor valves, pistons and liners is mainly due to : Carry over of water drops from separators into the compressor. Condensation of water from compressed gaseous CO_2 due to low temperature. The condensate is saturated with CO_2 and forms a weak acid, which cause severe corrosion in the compressor. We recommend to check the proper separation of water and keep the prescribed in let temperatures to the individual stages of the compressor.

4.3.3.31. Carbamate pumps .

The pumps are of a very robust construction. The crank mechanism is overdiamensioned. The driving gear is suitable and includes the possibility of speed changing /combination steam turbine and gear box/.
Very unsatisfactory is solved the basic part of the pump-the stuffing box.
We suggest to modify the pump so that the stuffing box should be detached from the crank mechanism. This ensures that in case of leakage of carbomate, the carbomate cannot enter the crank case.
The stuffing box should be modefied in such a way that water will be used for cooling and flushing the packing. This water will also carry out the leaking carbamate through the packing. The number of packing rings should be increased. The used packing should be teflon based with asbestos. The problem of the packing for carbamate pumps represents a complex of factors involving liquid sealing, friction, corrosion and lubrication. We recommend to consult this problem with the supplier of the packing material. The MERKEL company of WEST GERMANY has a lot of experiences in this field. Until the problem of carbamate pumps will be completely cleared we suggest.
To enlarge the diameter of the drain for carbamate passing through the packing.
To pressurise the crank case with inert gas and thus to avoid peneration of carbamate to the oil.

4.3.3.32. Corrosion of the ammonia recovery lines.

We suggest to replace the Ammonia recovery lines and the ammonia sub coller E13 by stainless steel. It is also recommended to install a couple of fine strainers in the suction of the H.P. ammonia pumps.

This will avoid corrosion of the pumps and ensure their proper function.

4.3.3.33. High temperature of prills from prilling tower. We suggest to install under the prilling tower a fluidized bed cooler. The cooler can be also installed to another place i.e. at the route from the prilling tower to the storage house.

4.3.3.34. Atmosphere on top of the prilling tower. The problem of non suitable atmosphere for a continous work on the top of the prilling tower is possible to solve by providing the workers an air conditioned room, where they can spend the time between checking and cleaning of the sprays. A proper solution of the working atmosphere on the top of the prilling tower requires to seal all sprays against the cooling space of the prilling tower.

4.3.3.35. Recovery of uera and ammonia from seal pots. Ammonia from the weak solution is possible to recover by distilation in a separate column heated by steam up to the boiling point. For a better utilization of heat we recommend to install in the system plate heat exchangers.
The ammonia gas with some CO_2 can be absorbed in the second condenser E4 and so return it to the process.
During the distilation process in the column also some urea will be decomposed. Recovery of Urea from weak solution is very expensive.

4.3.3.36. Screening of urea and melting of urea lumps and dust.
We suggest to install a second screan with 1 mm mesh.

The oversize from the old screen and dust from the new installed screen will be colected and transfered to the disolving tank. The disolving tank must be outfitted with an agitator and steam heating coil which enables to keep the liquid at about 80°C. When the concentration of urea achieves 70 to 75% it is pumped to the vaccum separator G4 though the Vaccum Distiler E6. After concentration is the urea prilled again. It is very important to install strainers with fine mech in the suction of the solution pumps.
The line from the disolving tank to the plant must be steam traced and good insulated. It is to suggested to wash the line with condensate after the solution is pumped out from the disolving tank to the plant.

4.3.3.37. Unreliable power supply.

The ammonia plant ran during the period of October 1973 to December 1974 with interruptions as a consequence of 32 shut downs due to power failure. The plants were tripped mainly due to vol tage dips or complete power failure. In some cases also the power supply restricted.
According to our experience power failures have a very negative influence on operational conditions of the plant mainly on the condition of Primary and Secondary reformers and also on the heat recovery system.
As a consequence of power failures the ID and FD fans are stopped immediately. At the same time the whole plant is also tripped, but the heat absorbed in the refractory of the primary reformer affects the reformer tubes. The reformer tubes due to the above mentioned heat are over heated mailny at the bottom part. This results in a decrease of the service life of the tubes. The overheating and subsequently quite quick cooling down of the catalyst in the reforming tubes leads to destruction of the same and causes a high pressure drops across the primary reformer.

The heat of the reformer refractory effects negatively also the radiant shield boiler and steam superheater. Moreover also overheating of the burner in the secondary reformer occures. The consequences of power falures is possible to recognise mainly after a certain time of operation.
Therefore, it is very important to have a good and steady power supply for the Ammonia Plant. The situation at the FCI Durgapur Division, is possible to solve by improving the power supply from outside or by installing an additional boiler for steam generation where steam will be generated in such a quanity which will be necessary for producing about 10-15 MW with respect to the future possible expansion of the factory. For that purpose should be installed a turbogenerator with the above mentioned output, which enables self-sufficiency in power supply for the whole factory. The new installed boiler may also cover the deficiency in steam consumption for the Urea Plant.

4.3.3.38. Cooling tower problem.

The cooling water system needs more attention to avoid the high fauling of the coolers. According to our experience it is very necessary to use some progressive methods in chemical treatment of the cooling water system at a modern chemical factory as it is also the factory of Durgapur. Some action to improve the quality of cooling water was already taken. The same problem in our factory was successfully solved by using chemicals from the DREW CHEMICAL CORPORATION Company from U.S.A.
The whole cooling system was cleaned as followes :
During the cleaning procedure it was kept in the cooling water 25 ppm of P_2O_5 by using hexametaphosphat.

By means of sulphuric acid PH was lowered to 6 and later to PH=3 to 3.5. For cleaning purposes was used Biocide 230 and Drewsperss 738. The whole procedure lasted about 6 days.

After the cleaning period we use to keep the following concentration of chemicals in our cooling water system :

P_2O_5	- 7 to 10 ppm.
Zn	- 2 to 4 ppm.
Drewsperse 738	- 25 ppm.

Once per month and or according to the amount of algae about 300 kg of BIOCIDE 230 are added to the suction of the cooling tower pumps. The PH of cooling water is kept at the value between 6.5 to 7 by using sulphuric acid. Some very dirty coolers have been cleaned separatly, by means of circulation of some special chemicals from the above mentioned company. Details in this matter can be consulted with their experts.

There are also some other companies, for instance Nalco from USA, which can offer similar services.

4.3.3.39. Boiler Feed water.

For the ammonia Plant, where high pressure steam is produced at 135 kg/cm^2 is very important to have available enough boiler feed water with high purity. According to our experience the water conductivily should be normally 0.2 micro S and maximum 1 micro S for a very short period. The silica content must be kept below 0.02 ml/l and the iron content below 0.03 mg/l. The iron content is very important because higher iron content leads to severe corrosion in the boiler tubes.

The existing D.M. Plant is designed for 170 m3/hr but the requirement for the plant is about 230 m3/hr.

It is also reasonable to reconsider in this respect the expansion of the factory / Granulation Plant / and the installation of the 4 th boiler and turbogenerator. Thus it is necessary to build a new unit, with a higher capacity. According to obtained information a new D.M. unit with a capacity of 110 m^3/hr. D.M. water is under implementation where it will be apparently possible to produce very high quality water for the generation of high pressure steam. It is also reasonable to install a new storage tank for polished water with a capacity about 300 m^3 as to ansure enough B.F. Water for the ammonia plant at a minimum, 3 hours full production time.

The capacity of the existing D.M. Plant is possible to increase by using ion exchanger resins of higher quality. The oxygen content in the boiler feed water must be very low. The excess of hydrazine after the deareator should be 0.15 ppm. For alkalization we recommend to use a combination of ammonia water and other organic alkalizators like S-L-C-C from DREW CHEMICAL CORPORATION or some ofter chemicals from NALCO. Alkalization by using Na OH and sodium phosphate for the generation of very high pressure steam is not good. The PH value in the steam drum must be kept between 8 and 10.

4.3.3.40. Second deareator from the steam Generation Plant.

The Steam Generation Plant was designed with two operating boilers and the third one as a stand-by. When operating all the three boilers the capacity of the dearcator will be to low.

It is necessary to operate all three boilers, because the amount of steam consumption in the plants is higher as the designed amount.

4.3.3.41. Second steam driven Boiler Feed Pump.
The pump should be installed for the same reason as above.

4.3.3.42. Taproge system for cleaning condensers.
For cleaning the steam condenser of the process air compressor turbine during operation is possible to use the TAPROGGE system delivered by Ludwig Taprogge.

Reinigungsalagen fur Rohren-Warmetaucher
4034 Angermund.Bez.Dusseldorf,Postfach 140
West Germany.

4.3.4. MEINTENANCE AND REPAIR.

4.3.4.1. The position of maintenance department at the factory.

The mechanical maintenance department is on the same level as the production departemnt. On the same level is also Electrical maintenance. The other parts of maintenance like Civil and Instrumentation are included into the Technical Service Deptt. The subject of the analysis is the Mechanical maintenance. The organisation chart of this department is includ[illegible] in Annexure 10. The execution of maintenance activities is carried out by the plant maintenance ! organised according to the technological lay-out of the factory / and Central Workshop.

Technical requirements for the mechanical maintenanc are covered by the " Technical Wing " divided into the modification section, drawing office and record section, technical cell. There are also some non maintenance activities like Transport Pool and Services.

The organisation chart shows the following compositi[illegible] of the maintenance staff :

Technicians, Reggers, Welders	-	107
Helpers.	-	51
Total:	-	158

The technical personnel represents 63.

Thus there is a ratio of 1 : 2.5 between the technical personnel and workers and between technica personnel and skilled workers only 1 : 1.6.

We see in this organisation the fellowing deficiences :

- Duplicity of sections.
- The jobs and duties of the respective section are not exactly specified.
- No specified jobs and duties for each function.
- A very high number of technical personnel and rather a low number of workers, which are divided in very small groups where is the number of technical personnel higher than the number of workers.
- There are some non typical maintenance activities like Transport Pool and Services.

4.3.4.2. The level of Maintenance planning.

For the plan of prevctive maintenance are claborated methodical instructions.
These are not followed due to many other difficultes for instance to many design deficiencies, carrying-out modefications, low load of plants, etc. Presently this plan is substituted by a programme for repairs and modifications.

DEFICIENCY :

- There is not available Any long term plan for repairs.
- There is no coordination between plans of mechanical maintenance electrical and Instrument maintenance.
- The machines are not categorized according to their importance in the production process.
- The maintenance plan is not upto-dated as regards the plan for a shorter period like a month.
- Not for all machines are specified the cycles of repairs.
- The repairs are not based on the actual running time in hours.
- The time, necessary for repairs is also not fixed.
- The maintenance department is upto now self sufficient to cover all repairs in the plants. The loos of production due to mechanical maintenance during the year 1974-75 and within the quarter of 1975-76 is shown below :

PRODUCTION, SHORTFALL AND BREAKDOWN
STATEMENT OF THE PLANTS,
POSITION UPTO THE 30.6.75

Plant		Target	Rated Capacity Yearly	Rated Capacity For 3 months April to June 1975	Actual Production	Short Fall from Rated Capacity	Loss due to Mech. Break downs	Loss due to all Break downs	Loss due to non-availability of spare parts
AMMONIA PLANT.	1974 - 1975	16,937	1,98,000	-	25,638	1,72,362	-	-	nil
	1975 1 Q. 1975	46,600	1,98,000	49,500	14,429	35,071	1,377	4,112	nil
UREA Plant.	1974 - 1975	22,000	3,05,090	-	32,559	2,72,441	-	1,34,496	nil
	1975 1 Q 1975	72,000	3,05,000	76,325	20,325	55,925	2,118	6,326	nil

NOTES: - ALL FIGURES IN METRIC TONNES.

- LOSS IN PRODUCTION DUE TO PREVENTIVE MAINTENANCE WAS NIL AS THIS ACTIVITY WAS ACTUALY PERFORMED DURING THE PERIOD OF SHUT DOWN DUE TO EQUIPMENT FAILURE ETC.
- SOME DATA NOT AVAILABLE.

At the ammonia plant there are the following single machines :

1. I.D. Fan.
2. F.D. Fan.
3. Syn. gas compressor.
4. Refrigeration compressor at the ammonia synthesis.
5. Process air compressor.
6. Refrigeration compressor at ammonia storage.

4.3.4.3. Plant maintenance, Mechanical praparation of repairs / technical level of repairs.

The plant maintenance groups are organised as independent sections with full responsibility for the condition of machines and equipment in the plants. The responsible person for all activities of the plant maintenance as the Plant Engineer.

The plant maintenance carries out all activities connected with the care of the capital items like planning of repairs, checking of incoming spare parts, clearing technical problems, co-ordination of activities in relation to the central workshop, technical inspection of machines during their operation and carrying out repairs.

There are no elaborated instructions for repairs of machines. The repairs are carried out only according to the informations given by the supplier in the manuals and according to the experience of the high skilled people. The maintenance department has a very small amount of drawings for spare parts, assemblies and mechines, which may enable to carry out proper mechanical inspections of them or correct assembles of machines.

The whole available data, witch shows condition of the machines as for instance achieved working parameters, vibrations, run out of the machine, input of motors are not collected before repairs are carried out. For the execution and carry out of special repairs there are not enough skilled people, and therefore complicated repairs must be made under the supervision of Plant Engineers.

The documentation of repairs as in presentation is not uniform in the whole factory and also of a different level / rather of low standard /. It was arrange that some machines are provided with log-books or equipment history cards. These are now at the begining of their use. Equipment history cards are in comparison to other plants on the best level ot the Urea plants.

In case of overhaul repairs or breakdowns there is not given any time schedule or duration for such repairs. There are prepared schedules based on days and not on a hour work basis and moreover without any details.
As a coordination group for purpose acts the Productions Department.

According to our opinion it is necessary to introduce regulations which will clearly determine that the Production deptt. is first of all responsible for-keeping the plant and equipment for their economical utilisation and for a daily attendance and running of the plant according to operating instructions. The maintenance deptt. is to be responsible for the mechanical condition of the plant. Planning, coordination and execution of maintenance and repairs are the scope of duties for the maintenance deptt. The leading position in maintenance should be given to mechanical maintenance.

The duty of the " Technical Wing " is, to specify the reasons of breakdowns and failures of machines and equipment and to eleborate suggestions which will ensure that these failure will not be repeated. They must also carry out technological instructions for repairs including technical inspection during the execution of repairs.

The technical level of maintenance in not satisfactory. We arrived to this conclusion as we have observed the following shortages :

- Unsatisfactory organisation during the repair of the burner in the secondary reformer.
- High amount of leakages on flange joints and glands of the valves.
- Leakage of gland packing on pumps.
- Leakage of the oil system at turbo compressors, pumps and steam turbines.
- Incorrect sealing the seals between chambers of the coolers at the process air compressor. There are used sheaths from electric cables instead of rubber strips.
- During repairs of rotating machines, the rotors are not balance .

Working spaces of the plant workshops are rather small, but sufficient in the case of centralisation maintenance activities. Special tools like spanners, jacks, hand grinders, portable drilling machines, measuring devices, spare parts and gaskets are stored in the plant handy stores in a sufficient amount. The condition of these materials is unsatifactory.
The high number of technical personnel in the plant maintenance results from decentralization of the maintenance activities, non-availability of clear instuctions for repairs, poor system of technical inspection for repairs etc.

4.3.4.4. Inspections and solutions of technical problems in maintenance. Technical Services.
For carrying out the above mentioned activities there are included in the organisation chart the following sections :
- Modification section.
- Drawing office.
- Technical Cell.
- The modification section is responsible for :
- X - Ray inspection of welds according to the request of the plant Engineer.
- Measuring vibrations and evaluation of the obtained figures. The measuring is done not regularly, but only on request.
- Co-ordination of services from external agencies, like the P D Division of FCI, Research Institutions and other design offices.
- Technical specifications of new machines and equipment, which should be purchased according to recommendations received from Tecnimont and after an aprobation from the PQD Division of FCI.

In respect to the mechanical maintenance needs, the Drawing office is not adequately equipped and staffed. There are only two people, who can carry out some design jobs.

There exists also a registration section which keeps on file all drawings, standards and manuals. The drawings are up to dated. There are prepared fabrication drawings for spare parts according to requirements from the plant maintenance groups. The number of prepared drawings is very low. The duplication of drawings is on a reasonable level.
The technical cell from the organisation point of view belongs to the plant maintenance group. The duty of the technical cell includes planning and inspections of pressure vessels, cranes and boilers in connection with the Government inspection.

Documentation of repairs and inspection. In collaboration with the P D Division of FCI this section carries out ultrasonic tests on high pressure lines and lines with very aggressive medium. At the present time this section only starts its job.
The above mentioned sections have the following deficiency :
- Duties and responsibilities are not clearly specified .
- There is no planning in their activities.
- Some activities are performed only partly.
Due to this deficiency, the main portion of technical problems is solved by Plant Engineers.

Inspection for the quality of material and repairs in regard to maintenance activities / incoming spare parts, reconditioned and fabricated spare parts in Central Workshop and quality of repairs machineries and equipment / are not organised systematically. These inspections are carried out on the level of a General Foreman, Foreman or Assistant Foreman for a respective plant.

4.3.4.5. Central Workshop :

The Central Workshop is situated in a spacious hall, which is split into two aisles.
Each such aisle is provided with a crane. To the workshop is possible to carry material for repair on railway wagons of locomotive. This workshop with big storages, offices with distribution of pressure air and electric connections fulfills the criteria of a modern Workshop.

The activities of the Central Workshop are including :

- Reconditioning and or fabrication of spare parts according to requirements of the plants.
- Fabrication of pressure vessels with a design pressure, upto 16 kg/cm^2.
- Fabrication of structures.

- Recondition of spare by means of welding, metalizing.
- Heat treatment of smaller parts.
- Smith jobs.
- Inspections and repairs of vehicles and Cranes.
- Services in the field of welding for the whole factory.

The Central workshope is working on a general shift only. The activities of the central workshop are not planned and there is no connection to the maintenance plan. Jobs are carried out according to obtained orders.

To an order is usually abtached the drawing, sketch or sample. On the above basis are also spare parts fabricated, reconditioned or repaired. The final inspection of quality is carried out by the Plant Engineers, general forman and assistant foreman respectively. In the Central Workshop are employes twelve welders. The jobs carried out by this group are on good professional level.

SHORTAGES :

- The activities of the central werskhop are not planned.
- The technical level of sketches and drawings is low.
- For machining are used only rulers and calipers, which enable only rough checking.
- The cutting tools are grinded by the user / for instance turner /.

In the central cutting tool stores are stored mostly damaged tools inspite of the fact that there is installed the tool grinding machine.

- There are not available elaborated technological instructions for the fabrication of spare parts, vessels etc.
- Material specifications for fabrication are made only in the workshop by the chargeman or forman.

- The drawings are not showing the unfolded surfaces, for instance the surface of a cone, scheme for cutting sheets.
- There are not prepared technological instructions for welding, deposit welding and heat treatment.
- The available spaces of the workshop and also the machine are not satisfactorily utilized.

4.3.4.6. Shift maintenance : The shift maintenance is centralized and organised by the plant maintenance staff. The people in the shitf maintenance group are changed every six months.

The shift maintenance group on shift includes the following staff :

Chargeman - 1
Technician - 2
Rigger - 1
Helper - 1

The shift maintenance has a separte workshop and the current programme of this group is to replace and clean the burners on the primary reforming.

The idea to cancell the shift maintenance is according to our experience a wrong step. The shift maintenance is neccessary to keep complete and to equippe it properly with skilled people, tools and machines. The group should obtain clear job specifications and an adequate reserve programme. The cleaning jobs should be made by operators.

We recommend the following composition of the shift maintenance group on shift.

- Supervisor
- Turner
- Specialist for compressors
- Welder
- Specialist for pumps

- The rest of the group are technicians

The advantage of such organised shift maintenance will be evident during the operation fo the plants on full capacity.

4.3.4.7. Storage of spare parts and other materials :

The plant engineer in collaboration with the material management works out a plan for the purchase of spare parts. For each kind of spare part is given the minimum and maximum amount which must be kept in the store.

The offers for individual spare parts are technically evaluated by the plant engineer. He is responsible for the right choice of spare parts.

The incoming spare parts are received in the incoming section of the store, where the parts are checked for their quality and quantity. The inspection for quality is carried out by the plant engineer. The spare parts are stored in the primary store and are for each plant separately itemise. The parts are good protected against corrosion. The total value of the stored spare parts represents 36,065.000. This atherwise represents 5.3% from the total value of capital itmems of the Durgapur factory.

For materials like bars, rods, sheeds, tubes, jointing material etc, are elaborated instruction which iclude kind, amount and quality of those, materials which should be kept on stock.

There are also stored impollers for all compressors and turbines as spare parts. Stored are also some impellors for pumps, complete pumps, complete steam turbines for oil pumps and for the synthesis gas compressor as well as a whole catridge for the ammonia converter and some complete heat exchangers.

It is planned to use the spare parts according to the following suitable time schedule :

12 months for insurance spare parts from India.
6 months for consumable spare parts from India.
24 months for foreign spare parts.

The amount of insurance spare parts represents 3% of the value from the respective item.

We have ascertained the following deficiency :

- The standardised spare parts like bearings, oil seals, mechanical seals and gaskets etc. are also stored item wise.
- Extremly poor storage of steels with a very low carbon content as for instance 316 L.
- Very poor storage of ceramic insulation materials /bricks / in free area.
- No satisfactory cleanliness and order in the storages.
- Some machines for the Granulation plant are not sufficiently protected against corrosion and are stored in a free area in spite of the fact that the Central workshop is half empty and provides also the possibility to use the crane for unloading the machines from wagons.

4.3.4.8. Summary and recommendations :

4.3.4.8.1. To separate from the maintenance department the non typical maintenance activities like Transport Pool and Services. These sections should be incorporated into the material Management Deptt.

4.3.4.8.2. Because the Durgapur Division is a modern fertilizer factory with sophisticated laynut and with large scaled spaces of workshops and also by taking in account, the fact that the maintenance deptt.is at the begining of its formation, we suggest the centralisation of all maintenance activities / see annexure No.11/ .

... leading position in such a centralized maintenance should be give to mechanical maintenance. This creates conditions for the best care of the capital items, uniform planning and achievement of higher effectivity in maintenance activities. The final aim by establishing the Technical wing / ... annexure ... / is the formation of a " brain centre " of maintenance. This group should prepare conditions for :

- Inspection in respect to quality of all maintenance activities.
- Elaboration of rules and regulations for carrying out all maintenance activities.
- Clearing technical problems arising during operation and repair of machines and equipment.
- Utilization of technical progress in maintenance, techniques for maintenance and repairs.
- Application of technical progress in maintenance management.
- Concentration of design capacities etc.

For these activities the service of the P D Division at FCI, the Central Mechanical Research Institute and the local manufactures are beling utilized, but their participation should be increased.

4.3.4.8.3. To achieve economy in the system of preventive maintenance we recommend to cary out the categorisation of the equipment and machineries according to their importance for production.

4.3.4.8.4. To elaborate regulations and rules, which will point out activity, responsibility duties and authority for the whole department and for each section as well as for each function up to the level of supervisir.

This will enable to define a clear cut responsibility of each individual, thus eliminating the duplicity of responsibilities.

4.3.4.8.5. The most important section i.e. The mechanical maintenance we suggest to organise according to the chart given in annexure No.12a. The aim of the organisation is to centralise the maintenance activities, which will promote them to a higher technical level and also to a higher economy.

4.3.4.8.6. To colaborate instructions for maintenance and repair works of machines and equipment with respect to theit caterorisation.

4.3.4.8.7. The first overhauls or repairs of turbo compressors and steam turbines should be carried out by external agencies or suppliers together with the local maintenance personnel.

4.3.4.8.8. Each contemporary plan of maintenance should be supplemented by following data : cycles of repairs, time needed for repairs, date of the last overhaul and the cost of individual repairs.

4.3.4.8.9. To prepare the system of uniform dokumentation for repairs, overhauls, checkin during operation etc.

4.3.4.9. Proposals for providing additional equipment to the maintenance deppt.

-- Portable instrument for hardness test.
- Portable metalographic microscope.
- Ultrasonic D-meter for measuring thickness.
- Instruments for measuring diameters, length, evenness and roughness.
- Tools for cutting metals.
- Honing machine.
- Tube expander with automatic force control.
- Surface grinding machine.
- Testing device for testing valves and safety valves.
- Portable Grit/sand blasting machine.
- SFAME - SPRAY - metalizing device.
- Portable jig for machining the flange joints and flanges of equipment.
- Balancing machine for balancing impellers of compressors and pumps upto 1000 kg.
- Tensometer.
- ATUMAT - High pressure water pump for cleaning coolers.

4.4. FACT - UDYOGAMANDAL

4.4.1. Plant Installation

S.No.	Plant	Capacity TPD	Year of commissioning
1.	Monsanto No.II.Sulphuric Acid Plant	68	1947
2.	Ammonia Sulphate	150	1947
3.	Superphosphate	150	1947
4.	Monsanto No.I	68	1950
5.	Ammonium Chloride	35	1955
	FIRST STAGE OF EXPANSION 1958/1961		
6.	Air liquefaction Plant	1180 Nm^3/hr.	1958
7.	Chemiebau Sulphuric Acid Plant	160	1959
8.	Ammonia/Expansion 1. Electrolytic Hydrogen Route	40	1960
9.	Prayon Phosphoric Acid Plant	25	1960
10.	Ammonium Phosphate Plant No.1	100	1960
11.	Third Ammonium Sulphate Plant	75	1961
	SECOND STAGE OF EXPANSION 1962		
12.	Oil Gasification Plant No.1 /Texaco Partial Oxidation Process/	80 +	1962
13.	Air Liquefaction Plant No.II	2400 Nm^3/hr.	1962

\+ In stage with commissioning of this plant Wood Gasification was scrapped and net addition to ammonia capacity was only 40 tonnes making the total to 120 TPD.

III. STAGE OF EXPANSION 1965/1966

14.	Tonnage Oxygen Plant	5000 Nm^3 Oxygen/hr.	1966
15.	Ammonia Plant / Texaco Gasification route II/	140	1965
16.	Sulphuric Acid No.IV Plant	450	1965
17.	Phosphoric Acid No.2 Plant	100	1966
18.	Ammonium Phosphate No.2 Plant	300	1966
19.	Addition to Ammonium Chloride Plant	40	1966

IV. STAGE OF EXPANSION 1971/1972

20.	Composite Ammonia Plant	120	1971
21.	Ammonium Phosphate Plant 20:20 grade	150	1973

There are also other non-fertiliser plants for the production of chemicals such as the Sulphur Dioxide Recovery Plant, Sodium Silico Fluoride Plant, Sodium Fluoride Plant., Hydrated Calcium Silicate Plant, Cryolite Plant and the Dry Ice Plant.

4.4.2. SHORT DESCRIPITION OF THE PLANTS.

4.4.2.1. The electrolytic hydrogen plant.

Hydrogen is in a high state of purity obtained by this process. The cell used for the production of hydrogen is of a filter press type. This is made up from plates and frames arranged alternately. Each plate has two sets of electrodes, one attached to either side of plate. One side acts as the cathode and the other as the anode. On the face of each electrode there is an asbestos diaphragm.

The cells are filled with electrolyte which is 15 to 20 % solution of caustic soda.
By the function of electric current, hydrogen is liberated at the catothes and oxygen at the anodes. The hydrogen produced is available in a gas holder at a pressure of 250 mm water gauge. The Oxygen is used in the Texaco Partial Oxidation process.

4.4.2.2. The Air separation plants.

There are two air separation plants capable of giving sufficient nitrogen for the manufacture of 130 tonnes of ammonia per day. Air is filtered and scrubbed in order to remove impurities and is furtner compressed in a compressor up to 15 kg/cm^2. The present carbon dioxide is removed by scrubbing with caustic soda solution. This is cooled in an ammonia precooler to about 5°C. The air is then dried in a drier using alumina.

The dry air is further liquefied by cooling it down to-164°C and further to-170°C. The liquid air is separated in the lower and upper column by rectification. The obtained nitrogen contains 50 ppm of oxygen. The oxygen is 99,5%.

4.4.2.3. The tonnage oxygen plant.

There are two identical unit each having 50 percent of the total capacity. The air is drawn through a filter, scrubbed with water, further precooled by means of liquid ammonia and compressed to 5.5 kg/cm^2 in a turbo-compressor.
The compressed air is then brought into direct contact with cooling water in the direct cooler. This removes any residual dust and also cools the air down to 35°C. The air after leaving the direct cooler is then divided into two streams. The larger one passes through the regenerator, where it is cooled down to - 1[illegible]°C. The air leaving the regenerator is admitted at the rectification system. The smaller stream is compressed up to 207 kg/cm^2. The compressed air is them cooled down by liquid ammonia to -12°C and dried. The compressed and dried air is cooled down to-175°C and expanded partly in an expansion engine or through an expansion valve. After rectification of the liquid air, pure nitrogen and oxygen is obtained. In this unit is also liquefied nitrogen for the nitrogen wash unit.

4.4.2.4. THE TEXACO GASIFICATION PLANT.

Hydrogen, sulficient for daily production of 220 tonnes of ammonia is produced by this process. The capacity of hydrogen production of the first plant is equivalent to 80 tonnes ammonia per day. and the capacity of the second plant 140 tonnes per day.

Demineralized water is sent through a condensate preheater and the steam raised by this is mixed with naphtha whereupon this mexture of naphtha and steam is further prehated upto 400°C. This preheated mixture at 390°C goes to the burner of a generator along with oxygen.

The partial oxidation of [illegible] carried out in the generator at 30 kg/cm^2 [illegible] The product of com-bustion is cooled down to [illegible] C by direct contact with water in the lower part of the generator. The recovered carbon is sent to the [illegible] cycle system.

The conversion of carbon [illegible] and steam to hydrogen is carried out in the [illegible] temperature of 400-500°C. Carbon dioxide which represents 2 [illegible] of the total gases leaving the conversion [illegible] absorbed in the absor-bing towers with kittle pl[illegible] water under a pressure of 25.5 kg/cm^2.

The gas leaving the carbon dioxide absorbers passes into a M.E.A. absorber, where the CO$_2$ content is reduced down to 1-2 ppm. This is further removed by scrubbing the gas with a 8 % caustic soda solution.

4.4.2.5. The NITROGEN WASH PLANT.

The object of the nitrogen wash plant is to remove the carbon monoxide and methane contained in hydrogen pro-duced by the oil gasification plant and thus to render it [illegible]suitable to the ammonia synthesis section.
The gas coming from the oil gasification plant is cooled down by liquid ammonia and the moisture is removed by passing htrough an activated [illegible].
Furtner is the gas [illegible] - 185°C wherefore it enters the nitrogen wash column. In the nitrogen wash co-lumn impurities such as methane, carbon monoxide and ar-gon are almost complutly separated from the feed gas.
The hydrogen - nitrogen gas mixture leaving the top of the nitrogen wash column gives back its cold to the inco-ming feed gas as well as to incoming nitrogen before leaving the nitrogen wash unit.

4.4.2.6. THE AMMONIA PLANT.

There are three synthesis loops, with capacities to produce 40 tonnes, 80 tonnes and 140 tonnes of ammonia per day. Suitable interconnections are provided in such a way that gases from one loop can be diverted to other loops if required.
All the loops are working at a pressure of 350 kg/cm^2. The ammonia produced in the synthesis converter is condensed by water cooling in a cooler down to 40°C and by liquid ammonia in a chiller down to – 5°C. The liquid ammonia is drained of to the storage system after dropping down the pressure to about 20 kg/cm^2.

4.4.2.7. THE COMPOSITE AMMONIA PLANT.

The naptha is at first desulphurised in two stages. The desulphurised naphtha is then mixed with superheated steam and sent to the reformer tubes in the primary reformer. The gas from the primary reformer at a temperature of 800°C is transferred to the secondary reformer where hot process air is injected in such a quantity that the final gas contains H2 and N2 at a 3 : 1 ratio. The gas is then cooled down to 3[illegible]0°C and transferred to the high temperature converter which contains iron Oxide promoted with chromium Oxide catalyst. The product gas from the high temperature converter is then again cooled down to 200°C and sent to the low temperature converter.

The gas after CO conversion containing 0.3% CO while .21% CO2 is washed by the MEA solution in the CO2 absorber.

The gas after the CO2 removal containing 0.77% CO2 and 0,38% CO is sent to the methanator. The exit gas from the methanator contains H2 and N2 at a ratio 3 : 1 with an inert content of 1.03 %.

This gas is compressed to 345 kg/cm^2 and sent to the synthesis loop, where liquid ammonia is obtained. The liquid ammoniais released in two stages and transfered to the storage tanks.

4.4.2.8. The SULPHURIC ACID PLANT.

There are four contact sulphuric acid plants in operation with a total installed capacity of 7.0 tonnes/day. The contact process using elemental sulphur is adopted in all these four plants.

Sulphur is melted by using indirect steam. The filtered sulphur is pumped to the sulphur burner attahed to a combustion chamber. Air is dried by scrubbing it with sulphuric. acid.
Burning of sulphur produces heat and the gases leaving the combustion chamber have about 1 000°C. These gases are cooled down in a waste heat boiler to 500°C.

After the gases have entered the converter, the SO2 is oxidized to SO3. The sulphur trioxide cooled down to 200°C in an economiser is absorbed in 98,5 % acid. Owing to absorption the temperature of acid rises and is ± cooled down by circulation through water cooled cast iron pipes.

4.4.2.9. THE AMMONIUM SULPHATE PLANT.

Ammonium sulphate is produced by two different processes, one by direct neutralisation of ammonia and sulphuric acid and the other by the Merseberg process. The total capacity of the plant is 600 tonnes per day.

A. DIRECT NEUTRALISATION.

Ammonia and sulphuric acid react to form ammonium sulphate. The neutralisation is carried out in a crystalliser. As a result of the ammonium sulphate formation couplet with evaporation, crystalisation inside the crystaliser body takes place. The crystals so formed are pumped to centrifuges where they are separated from the mother liquor. The moist crystals are dried in a vertical dried and bagged after weighing.

B. THE MERSEBERG PROCESS.

Measured quantities of ammonium carbonate and weighed guantities of gypsum are transfered to a premixing tank and further to five tanks fitted with agitators. The slurry leaving the final reaction tank is sent to chalk filtration.
The filtrate is a strong solution of ammonium sulphate, which is further clarified. The clear sulphate solution is heated and sent to a neutralisation tank where sulphuric acid is added. It is then pumped to the evaporator cum-crystalizer. Vacuum is maintained in the evaporator by implementing ejectors. The crystals are separated from the mother liquor by centrifuges. The moist crystals are dried and bagged.

4.4.2.10. PHOSPHORIC ACID.

Phosphoric acid is manufactured by the wet process where a reaction of rock phosphate with sulphoric acid takes place. Basically there are two kinds of reaction systems for the phosphoric acid produution i.e. the multiple tank reaction system and the Dorr - Oliver single tank reaction system.

The Prayon multiple tank reaction system has got an installed capacity of 25 TPD of P_2O_5 while the Dorr - Oliver single tank reaction system will have 100 TPD of P_2O_5. The rock is treated in the process by dilute sulphuric acid, which can be different for any individual process. Both processes are giving slurries which are pumped to a filter. For that purpose is used the tilting pan filter with a counter -current washing of the cake, first with a 12% acid, then with a 5% acid and finally with fresh water. The filtrate is usually 30 to 33% acid, which is the product acid.

4.4.2.11. THE AMMONIUM PHOSPHATE PLANT.

The capacity of the plant is 300 tonnes per day of a 16:20 grade phosphate.
Phosphoric acid, sulphuric acid and ammonia enter through flow controllers into a reaction tank where the substances are kept agitated. In onder to supply the inert material, gypsum as well as unfiltered phosphoric acid slurry from the phosphoric acid plant are added. The thick slurry flows into the blunger where it meets recirculated undersize granules, crushed oversize granules and recovered dust. The granulation takes place in the blunger. The granulated wet product from the blunger flows to a rotary drier. The material leaving the drier is screened and sent for bagging.

4.4.2.12. THE AMMONIUM PHOSPHATE PLANT 20:20 GRADE.

In this plant is to the slurry obtained as above, added in the blunger along with the recycle also some urea. In to the blunger is also injected some liquid ammonia.

4.4.2.13. THE SUPERPHOSPHATE PLANT.

The fine rock powder is mixed with dilute sulphuric acid in a mixer. The mixture is dumped into the " Den " from where the product is sent to the curing place. It takes about a fortnight to get a batch of cured supherphosphate. The produced superphosphate contains approximately 16-17%. of P_2O_5.

4.4.2.14. THE AMMONIUM CHLORIDE PLANT.

Ammonium chloride is produced by direct neutralization of ammonia and hydrogen chloride. The reaction is carried out in a cylindrical tank with a conical bottom known as the saturator. The formed ammonium chloride is crystalized out. When a sufficient quantity of crystals is formed the slurry is whitdrawn from the saturator and the crystels are separated from the mother.liquor by centrifuges. The crystals are dried and bagged.

4.4.3. PROBLEMS AT THE FACT UDYOGAMANDAL DIVISION

4.4.3.1. Failures of the thrust bearing of the Pump Turbine Unit.

The pump consists two stages. The first stage of the pump is provided with a double wheeled impeller, so the axial forces are eliminated. The second stage of the pump is provided with a single wheeled impeller. The axial force is received by the thrust bearing which often causes problems. Some modification was effect to improve continuous lubrication by means of an oil pump which to a certain extent has reduced the frequency of failures of the thrust bearing.

We recommend to clear the problem in an elimination of the axial force by means of drilling holes into the impeller which will result in equal pressure on both sides of the same. The axial force is also possible to eliminate by the installation of an balancing drum.

4.4.3.2. Six stage nitrogen compressors.

The 1000 HP Clark Compressors were originally designed to compress synthesis gas. After the second stage expansion, these compressors are used to compress nitrogen. When taking in account that the specific gravity of synthesis gas is 0.38 kg/m^3 and the specific gravity of nitrogen is 1.25 kg/m^3, then it is clear that these compressors are working in much worse condition. Discharge temperatures at different stages of compression exceed specification values and it is necessary to limit the final pressure to 300 mg/m^2 instead of the original design pressure for the ammonia plant i.e. 350 kg/m^2. This reduces the total capacity of the ammonia plant, especially at the service life and of the synthesis catalyst. The sixth stage cylinder block of this machines develops cracks and hence these cylinder blocks must be more frequently replaced.

These compressors are in service for the last 28 years. Not only the spare cylinder block is very costly, but its procurement has also become very difficult.

The stator cooils of the motors of these compressors have been replaced several times. Still flashing of the stator coils has become a common phenomenon.

Because the production of ammonia is considerably reduced and there is need of ammonia for the NPK plant at the Cochin Division Phase II, we suggest therefore to install instead of two compressors a new one which will have a proper design for such conditions.

4.4.3.3. Refrigeration difficulties.

Together with the 40 TPD synthesis loop were installed also 3 Vilter refrigeration compressors. After the second stage expansion, resp. when the Demag refrigeration compressor was installed and the production of ammonia was stepped up from 40 to 120 TPD, it was ascertained that the refrigeration compressors are not fully utilised for a steady draw of gaseous ammonia from the refrigeration system to the consuming plants.

In spite of the fact that after the construction of the 3-rd stage expansion plants refrigeration requirements have been increased no refrigeration system was included. It was assumed that the consuming plants will draw sufficient ammonia vapor for relieving the refrigeration load. In the 4 th stage expansion was at the Composite Ammonia plant installed, an ammonia compresor which could not be until now put into regular service due to certain inherent troubles.

The Vilter refrigeration compressors are showing also problems. One of the machines is out of service because of a cracked cylinder. These machines have become absolete in relation to their upto date advanced manufacture and therefore such major spares as cylinders, pistons etc. cannont be readily obtained.

The situation had become very aggravate and the production of ammonia is controlled by the ammonia consuming plants. During our stay at the factory, one stream, the Texaco Gasification plant was stopped and the lead of the Composite Ammonia plant was reduced to 90 %. The daily loss of production was roughly 150 TPD of ammonia.

We recommend to install a new compressor with a capacity which will cover the total refrigeration needs of the whole factory. This compressor should be installed in the Composite Ammonia plant. The Installation of a new compressor will enable to utilise the full capacity of the ammonia plants. The surplus of ammonia can be used for the production of NPK in the Cochin Division - II.

4.4.3.4. C.P. Air Compressor in A.L. Plant.

During the repair of valves at the compressor, it is necessary to check the evenness of the valve plates and body. The valve plates must be correctly lapped. The properties of the springs should be as prescribed. The fatigue stressed springs must not be used. After assembling the valves, we recommend to check them by the use of kerosene as a testing liquid. Upto now is at the Udyogamandal factory, for valve testing used oil which is due to its high viscosity less suitable. The repaired and checked valves must be kept in dry and clean condition. We recommend to use for that purpose plastic bags.

4.4.3.5. Leaks in air separation and gas separation units.

In our factory, till recently all nitrogen wash units were made out of copper. Because the used copper was of insufficient purity, we had very often leakages in the cold boxes. After the substitution of copper for stainless steel the problem of leakage was solved. The used material is AISI-321. In case of repeated leakage in the units of the udyogamandal factory, we recommend the critical pieces to replace gradually by material AISI-321. During such modification, it is recommended to change the position of the valve so that it will be possible to repair it without removing the insulation from the cooling box.

In case that it will be necessary to weld the copper tubes, then we recommend to use the argon arc welding only.

It is also recommended to remove as far as possible the flange joints inside the cold box to and substitute them by welded joints.

During the annual shut down of the air separation unit, it is necessary to carry out inspections of all valves and relief valves.

4.4.3.6. Dezurick valves at regenerators.

The plant is in operation for about 10 years. There are four Dezurick valves. During this period only four times there was leakage of these valves. According to pur opinion, the service of the valves is satisfactory. Since the leakages of these valves appeared only after a longer period, it can be considered as a consequence of the rubber property / ageing/. Repair of the valves is easy and already mastered. We recommend to keep permanently one spare valve ready for replacing the leaking one.

4.4.3.7. R.G. Boiler failures.

TheR.G. Boiler is a horizontally installed heat exchanger, exchanging heat between the Outlet gases from the secondary reformer at a pressure of 28 kg/cm^2 and a temperature of 940°C and passing through the tube side and water at 35 kg/cm^2 into the shell side. The gas temperature is reduced to 360°C, which is a suitable temperature for introduction into the HT shift converter.

In November 1972, the plant had to be stopped due to leakage of water from the shell side to the gas side. The fron end tube plate is protected from the high temperature gas by castable refractory, Gas is introduced into the tubes through incoloy 800 ferrules. All held together on the outside of the castable lining by an incoloy protection plate.

We have observed that the protective shield had been buckled and broken up and the castable lining broke up into shreds. Moreover the tube tips were burned off and the tube plate was extensively cracked.

The boiler was retubed after welding up the cracks on the tube plate with the inclusion of proper annealing.

The repaired boiler worked till October 1974 without much trouble. In October 1974, it failed again in the same manner as above. Meanwhile the new boiler, which was ordered arrived on site and was installed. From that time onwards, the new boiler is in operation.

We have the same problem in our 300 TPD Ammonia plant. The boiler was replaced for the same reason after 7 years, in operation.

The principal reason for failures of the castable lining are the to frequent shutdowns mainly due to power failures, when the temperature drops all of a sudden from 940°C down to the water temperature which is about 240°C.

In place of the castable lining we have used for the new boiler a better material, which is more resistant against erosion and which was used as the incoloy protection shield made from several pieces.
The incoloy shirt of the inlet chamber was not used. In case that the incoloy shirt in the chamber is used, then it is necessary to solve the problem of its heat expansion. The heat expansion of the incoloy material is quite high. By neglecting this fact, it can cause damage to the castable lining and subsequently it can result in failure of the vessel.

For an immediate indication of failure at the castable lining in the inlet chamber of the waste heat boiler, we have installed devices for measuring the temperature of the shell on criteria points in the upper part. The temperature is recorded in the Control Room. As soon as the temperature is raised an indication of alarm light and sound is actuated.

We recommend to paint the shell of the R.G.Boiler with thermocolour paint which indicates the incidental hot spots.

Very frequent shut downs, mainly as a consequence of power failure have according to our experience a very negative influence on the condition of the primary reformer, secondary reformer and heat recovery section. These are the reasons why we suggest to check once per year the condition of: reforming tubes, outlet pigtails, buttom headers, burner in secondary reformer, outlet from secondary reformer, lining of the inlet chamber of the reformer gas waste heat boiler and the tubes of the steam superheater in the flue duct.

It is also very important to care always for a good quality of the boiler feed water. The tubes are exposed in the inlet part to very high heat stress. In case of interior boiler feed water/high content of iron or silica/, very severe corrosion, occurres which as we have learnt from our experience leads in a few days to failure of the tubes.

4.4.3.8. Frequent failure of gland packings at the synthesis gas compressor.

At the present, Indian made packings are used, because it is difficult to obtain imported spares within a required time. This packing is not of an adequate quality. According to our experience, it is very difficult for the high pressure stages to substitute the original gland packing by another one. Thus we recommend to use for the 3 rd stage cylinder and for the circulator gland packings from the original supplier. It is necessary to have enough spare packing to avoid losses in production.

4.4.3.9. Failure of the transfer line.

We suggest to paint the transfer line with a thermocolour paint. This enables to recognise the hot spots. The line should be checked minimum twice per shift.

4.4.3.10. Refrigeration compressor.

The refrigeration compressor is of a very complicated construction. We recommend to solve the refrigeration problem in its whole complexity described in point 4.4.3.3.

4.4.3.11. Frequent failures of the river water pumps.

The river water pumps are pumping the water straight from the river through a suction line without any filtration. The total waste from the FACT plants, Udyogamandal factory and other factories is discharged to the river. The water contains gypsum, limestone, soot and many other chemicals. Such a polluted water is used for cooling in the direct barometric condensators. Apparently for this purpose, the impurities in water have no importance. During our examination of the pumps we have ascertained that minimum attention is given to the condition of the pumps. The pumps have had leakages on the glands, they are running with excessive vibration, the anchoring bolts are loose and the pumped water is very dirty.

The attempt to filtrate the water was unsuccessful. We recommend to carry out a chemical analysis of the river water within a period at least one month. The analysis should serve as a basis for a proposal to procur new pumps made from corrosion and erosion resistent material.

4.4.3.12. Failure of sulphate elevators at the 3 rd Stage Ammonium Sulphate plant.

The elevator chains are of a very complicated construction. The buckets are carried with two chains. We suggest to replace the chains by plain linked chains and to fix the buckets on the chains with forged hooks. The buckets must not be a part of the chains and should be the weak point of the mooving system.

4.4.3.13. Corrosion and erosion of the pusher centrifuge.

During our inspection at the plant, we have found that there is no corrosion on the centrifuge. The damage of the grid is due to excessive friction. It is essential to check the geometric shape of the rotating parts of the centrifuge and adjustments should be made for correct and prescribed clearances, More Attention should be paid to the stored spare parts and also when fitting them on the machine. We have seen that the new spare parts are already damaged in some places.

4.4.3.14. Low output of blower at the Monsanto Acid Plants.

Air is sucked through a tower, where it is scrubbed with sulphuric acid to remove moisture and then the dried air enters the air blower. Because the demister used in the drier column removes not 100 % mist from sulphuric acid, the impellers and casing of the blower are therefore attacked by severe corrosion. The lower output of the blower causes quite high production losses. Theloss due to a low output of the blower in both Monsanto plants represents 19.200 tonnes of acid per year. The estimated cost for one

tonne acid 1. 460/-.
Therefore, we recommend to solve the problem by making such an arrangement as it is made in the No.4, Simon Carves Acid plant. From the maintenance point of view, it is also better to use fans instead of blowers.

4.4.3.15. Frequent failures of agitators in single tank reactor at the phosphoric acid plant due to corrosion, erosion etc. Originally, these agitators were made out of stainless steel 316 L whith a rubber/lining. Already several months after the plant was commissioned the rubber lining of the agitators failed due to corrosion and subsequently the metal also corroded. Since then, the agitators have been repaired and serviced. The blades were replaced by mild steel with rubber lining to get a better binding of the lining. Even now the cost and rate of repair or replacement of these agitators are very high. During the last five months, the plant was stopped for replacement and examination of these agitators 213 hours. The total production loss within that time represents about 1000 tonnes of P205.

There are six agitators of three different types. The corrosion observed at the feed side of agitators is higher as on other parts. It is absolutely essential to keep all these six agitators in trim condition for a continuous acting of the slurry to complete the reaction before overflowing to the filter feed tank. Whenever an agitator is to be lifted up, there is chance for the settling of gypsum and silicates around the neighbouring area. In addition to this , if the corrosion of the blades is detected late, then the gypsum accumulation will reduce the off-bottom fistance of the agitators. This also will have harmful consequences.

Agitators made ou of better meterial and construction will definitely reduce the failures and downtime arising from previous agitators, and this certainly whill enable the plant to maintain the capacity production of P205. It was recommended to use AISI 317 L which is a suitable material for this purpose.

Equipment made out of HV-9 material with the composition of 19-22 Cr, 24-26 Ni, 4-5 Mo and 0.08 max. C are working very satisfactorily in the 25 TPD Prayon phosphoric acid plant which was commisioned in 1961. Both materials AISI 317 L and HV-9 are not available in India. The HV-9 material is more expensive, but it has been already testified as good for the desired working condition.

The approximate cost of this /6 Nos.for immediate use and 3 nos. spare / will come to about 1,300,000/-. But the production saving estimated after replacing the existing agitators with the one made out of HV-9 will be about 2400 tonnes of P205 a year. This works out to 12,700,000/-. if converted in terms of total cost of products. Also the profitability will go up substantially as more P205 will be made in comparison to the present, because the availability of P205 is a limiting factor to further ammonium phosphate production.

Considering all the above details, it is recommended to procure from abroad 9 agitators made out of HV-9.

4.4.3.16. Frequent failures of phosphoric acid and slurry pumps.

The original construction material of slurry pumps was 20:25, an alloy of stainless steel with a composition of 20% Cr, 25% Ni and 3% Mo. This material has a fairly satisfactory resistance when high grade rock phosphate is used as per specification, particulary with less chloride. The situation worsened in 1968 when a consignment of Jordan rock of about 0.8% chloride as NaCl had to be processed in contrary to the specified 0.07%. During this period, corrosion of the stainless steel equipments including these pumps increased very fast. Now it was decided to import.the pumps in accordance whith the original specification.

We recommend to use pumps which have proven to stand upto this service with reduced maintenance costs. Such pumps can be purchased from the following companies:

1/ Bungartr - West Germany
2/ Ensival - Belgium
3/ Wilfley - U.S.A.

The General specification for slurry pumps is given in annexure No. 21.

4.4.3.17. Corrosion of the Drier Shell.

The shell of the drier is badly corroded in a length of 3 m. i.e. on the feed side, where the ammonium phosphate has a high moisture content. The drier is in operation for about 10 years. The shell thickness is 16 mm. The problem will be solved by replacing the corroded piece by a new one. We have in our N.P.K. plant carried out a similat repair which was made on the spot. The turning rolls were used as a positioner. To ensure good welding of the material, we recommend to carry out a welding test right on the place where the new piece will be connected with the old one. The test should be done by means of a small plate of material welded on the shell or by welding on grinded place. Furthermore it is important to carry out inspection for cracks. We recommend to line out the corrosion exposed part of the drier with stainless steel plating. It is suggested to adopt the method of stainless lining from the FCI Sindri Unit where such method is used for the drier in the sulphate plant.

4.4.3.18. Build-up of carry over dust particles from the system to the blades of the fume fan and subsequent failure of the fan. We recommend to clean the blades by water washing from the already installed water jets. The washed out dust should be collected in a separator below the fan. Connection between the fan and dust separator should be made through a tube with a larger diameter. The water will be drained through hydraulic seal. The washed out dust will be drawn out from the bottom of the separator.

4.4.3.19. Failure of electric motors limiting switch-off devices in cases when elevators are overloaded and subsequent failures of reduction gears, elewators shafts etc. occure. We suggest to install an electrical protection or mechanical shearing pin coupling respectively.

4.4.3.20. Damage of brick lining in combustion chamber of drier at the Ammonium Phosphate plant.
We suggest to use for the lining in the combustion chamber of drier at the Ammonium Phosphate plant the castable lining with a proper anchorage. The anchorage can be made in the same manner as for the R.G. Boiler at the Composite Ammonia plant.

4.4.4. MAINTENANCE AND REPAIR.

4.4.4.1. The position of the maintenance department in the factory.

The Maintenance Department is on the same level with the production department and along with the Technical Services Department they report to Dy. General Manager / Technical/.

The maintenance is decentralised into two independent parts:

1/ Mechanical and Civil Maintenance.
2/ Electrical and Instrument Maintenance.

The scope of our study is confined to the Mechanical maintenance Department only. The organisation chart of this group is shown in Annexure 13.

The factory which started up production in 1947 has undergone four major steps of expansion. The last of these expansion steps was completed in 1971.

In spite of the fact that the plants are laid out on a large area, the maintenance is organised in groups, which are individualy responsible for closed production cycles as the:

1. Ammonia Maintenance
2. Sulphate Maintenance
3. Phosphate Maintenance

There are also some centralised groups as the:

4. Central Workshop
5. Fabrication Shop, Welding Shop, Material Conservation and Prventive Maintenance Section.

The Organisation Chart in Annexure 13 shows the following composition of the maintenance staff:

	Workers	Helpers	Techn.Personnel
Plant Maintenance	254	8	40
Central Workshop	175	33	20
Fabrication,Welding. Conservation,Preventive Maintenance	106	4	16
	535	45	76

The ratio between the technical personnel and workers is 1:7.6 and the ratio between technical personnel and skilled workers is /without helpers/ 1:7.

The technical backing for mechanical maintenance is provided by the Technical Services Department and preventive Maintenance Section.

We see in the present organisation the following deficiency: In spite of the fact that the production dep. and mechanical maintehance dep. are equated in the organisation chart, in practice the production department seems to be in a dominant role.

There are some non typical maintenance activities like filling of NH_3 and SO_2 into the cylinders. This activity including cylinder testing is executed by 2 engineers and 48 workers. The daily output of this group is about 10 tested cylinders and about 300 filled cylinders.

4.4.4.2. The level of planning in maintenance.

The planning of activities in Mechanical Maintenance is carried out by the Preventive Maintenance Section.

The principal plan is the anual " Maintenance Programme ". In this plan are included shutdown periods for each plant to enable execution of repairs, modifications, cleaning and ispections according to statutory regulations. In the maintenance programme are also included other needs of plants as for instance replacement of catalysts, removal of NO from the nitrogen wash plant etc. The annual plan is prepared in coordination with the electrical and instrument departments. The cycle of repairs, which were detrmined from the statistic data obtained during the operation of individual plants serve as a basis for the preparation of a maintenance programme.

For major maintenance works / duration of more than 10 days/ the programme is prepared by the Preventive Maintenance Section. This section prepares for each plant a preventive maintenance master schedule for each anual quarter. Such a plan is handed over to the respective plant engineer for its execution. At the end of each anual quarter the respective plant engineer makes a review of the schedule by pointing out devations and then it is sent to the preventive maintenance section for recording.

It is reported that only 50 - 70 % of the schedule is normally. completed.

The maintenance costs for the financial year 1974-75 have achieved 11,267 million rupees. This represents 3,5% of the total value of capital items of the FACT, Udyogamandal Division for the above period.

Most of the maintenance work is done by the companies own labour facilities and only a small percentage / 4-5% / of the work is carried out by outside agencies.

Shortages:

- No importance was given in the organisation chart for the preventive maintenance group.
- There is no available a long term plan of repairs.
- The maintenance plan is not uptodated in plans for shorter periods as a month. The one quarter plan divided into weeks due to changes in the production programme losses its validity.
- Any categorisation of the machines and equipments according to their importance for the production has not been carried out.
- The cycles of repairs are not progressing in comparison to cycles achieved in similar plants.
- The time between two repairs of a machine is not based on the actual running time in hours.
- There is not enough coordination between the activities of the Central Workshop, Fabrication Shop and Welding Shop within the plan of preventive maintenance.
- The rate of breakdowns is quite high. No analysis is carried out to find out the reasons for breakdownd premature repairs.
- The costs for repairs are watched as a total. Costs for individual items of repairs are not available.

PRODUCTION SHORTFALL AND BREAKDOWNS

Statement of Plants for the period 1974-1975

P l a n t	Rated capacity	Target	Actual production	Shortfall from rated capacity	Loss due to all break-downs	Loss due to mechanical breakdowns	Loss due to non-availability of spare parts
Ammonia/Gasification/	72600	81600	37954	34646	32714	8096	
Ammonia /Composite/	39600		24463	15137	10247	3996.7	
Sulphuric acid	246180	195000	157664.5	88515.5	70660	7432.9	DATA NOT AVAILABLE
Ammonium sulphate	198000	150000	93313.3	125686.7	90340	13691.0	
Phosphoric acid	41250	27600	20279.7	20970.3	18933.7	4034.85	
Amofos 16:20	132000	90000	68230.7	63769.3	54331.8	9463.11	
" 20:20	49500	35000	23803.35	25696.65	23412.46	9107.38	
Superphosphate	49500	38000	33431.3	26608.7	25951.0	83.3	
Ammonium chloride	24750	10000	9661.0	15089.0	14481.7	314.1	

PRODUCTION, SHORTFALL AND BREAKDOWNS
STATEMENT OF PLANTS FOR THE PERIOD 1975-76
/ Upto 30.9.1975 /

in tonnes

P l a n t	Rated capacity	Target	Actual production	Shortfall from rated capacity	Loss due to all brekdowns	Loss due to Mechanical brekdowns	Loss due to non-availability of spare parts
Ammonia /Gasi-fication/	40260	32900	15483.9	2[illegible]776.1	13865.9	3576.5	
Ammonia /Com-posite/	21960		13427.8	8532.2	5647.5	2218.5	
Sulphuric acid	136518	64500	84785.0	5[illegible]733.[illegible]	36093.0	1[illegible]391.0	
Ammonium sulphate	109800	55000	54604.3	5[illegible]195.2	482[illegible]9.1	66[illegible].9	DATA NOT AVAILABLE
Phosphoric acid	22875	11520	9981.97	12893.03	11030.53	2728.97	
Amofos 16:20	73200	38500	32237.6	4[illegible]962.4	31290.03	8373.68	
" 20:20	27450	13700	12443.15	15006.85	11163.5	2895.80	
Superphosphate	27450	16400	10395.7	17054.3	16679.3	756.51	
Ammonium chloride	13725	5000	3112.05	10612.95	10290.97	53.12	

4.4.3. Plant maintenance, Technical organisation of repairs.

Head of the plant maintenance is the plant engineer. He is responsible for the execution of all mechanical maintenance works, and for an efficient running of the plants in the division which should be performed in such a way as to maintain maximum production. To achieve the above mentioned aim, he follows the plan of preventive maintenance and utilises the staff of the plant maintenance as woll as the services of the Central Workshop, Fabrication and Weding Shops.

More than 50 % of the technical staff and workers from the Plant Maintenance Department are carrying out their activities within the plant maintenance groups.

The Plant Engineer and Plant Manager are responsible for planning of spare parts, but for the procurement procedure. bears resposibility only the Plant Manager. In our opinion, by the very nature of the job, the Plant Engineer is supposed to have better knowledge of the spares. So it is better to have the responsibility for procuring spares in the maintenance section.

Detailed instructions for repairs are available only for a small number of machines. Repairs are mostly carried out according to information given by the suppliers in their manuals and according to experience.

The maintenance department is in possession of a very small number of drawings for spare parts, assemblies and machines. This is not sufficient if proper inspections should be carried out at various stages right from the receipt of spare parts to their final assembly on machines / equipment . The quality of jobs carried out by maintenance groups is inspected by the respective Chargeman.

The whole available data are not collected before starting a repair. This is important as it, shows the condition of machines, like achieved working parameters, vibration, run out of the machines, input of motors etc.

The documentation of repairs made in some Log Books in the plant maintenance and also in the preventive maintenance section, does not contain enough useful information.

The liasion engineer between the Government Boiler Inspectorate and the repair of boilers is for the whole factory the Chief Mechanical Engineer.

Ultrasonic tests on high pressure lines are carried out once in a year. Records concerning results from boiler inspection, hydraulic tests of pressure vessels and ultrasonic tests are kept by the Plant Manager. Repairs are carried out mainly on the spot at the place of installation in the plant.

For the execution of maintenance works there is available the Central Workshop, the Fabrication and the Welding Shop. In spite of the fact that the plant maintenance performs about 60 to 70 % of all maintenance works, there are no separate plant workshops. The working places for tha plant maintenance are located just within the spaces of the plants. Such places are provided with small electric hench grinders and vices. The other tools are kept in the central tool stores / Tool Crib/ with a 24 hr. service for the whole factory. The above mentioned deficiency as well as the partly absolete plants and nonavailability of spare parts have a negative influence on the quality of repairs. For the condition of the plants from the viewpoint of anti corrosion protection bears responsibility the Plant Engineer, Plant Manager and also the Civil Maintenance. The quality of painting seems to be rather poor since the appearance of some equipments give an impression that they have not been painted for a long time. It is quite strange that some equipments are more corroded from outside as from inside where they are effected by the medium. This is extremely dangerous for the high pressure lines and gas lines. In the phosphate plant maintenance group is included a group for rubber lining / 3 workers / and welding of plasties/ 4 workers/.

The mechanical maintenance carries out replacements of catalysts and packings, which to our opinion, belongs to the activity of the production departments.

4.4.4.4. Inspection and solution of the technical problems in maintenance.

For the accomplishment of the above mentioned activities bears responsibility the Technical Services Department. The mechanical section of this department carries out the following activities:

- Inspection of the incoming spare parts.
- Preparation of sketches and drawings of spare parts on request.
- Calculations and drawings for repairs and fabrication of pressure vessels and heat exchangers.
- Archivation and uptodating documentation of the machineries and equipmen. for the whole factory.

- Standardisation of spare parts and materials.
- Archivation and uptodating of standards.
- Duplication of drawings.

The Technical Service Department prepares complete projects for small modifications including cost estimations. They also carry out standardisation of machines, while replacing imported machines by indigenous ones. The shortages of that department are its maintenance services which are insufficient and thus the main portion of the technical problems connected with processing and maintenance of the machines and equipment are left to be solved solety by the plant staff.

Inspections for the quality of recondition or fabrication of spare parts, further repairs of fabrications of pressure vessels are not based on standards or codes laid down by professional bodies.

No inspections on running machines and equipment by using the methoda of vibration control, ultrasonic tests, x-ray and by measuring the creep of materials etc. are being carried out.

4.4.4.5. Centralised activities of mechanical maintenance.

4.4.4.5.1. Central Workshop.

Scope of activities at the Central Workshop:

- Recondition of spare parts according to requirements of the plant maintenance. The value of reconditioned spare parts is about Rs. 100,000/-per year.

- Fabrication of spare parts. The value is about Rs. 300,000/-per year.
- Complete overhaul of pumps and fans.
- Checking spare parts and assemblies during repairs of machine which are carried out by the plant maintenance.
- Repair and testing of valves and relief valves.

In collaboration with the fabrication shop, production of tubesheets, bolts, flanges etc.

- Smithy jobs.
- Manufacture of small ferrous and non-ferrous castings such as pump casings, impellers etc. according to requirements of different plants.
- Procurement, storing and issue of lifting and handling tools, cutting tools, precisiom tools like micrometers, verniers etc. for the work in various plants.
- Testing of gas cylinders as per regulations.
- Filling of SO2 and ammonis cylinders.

The central Workshop is situated in a common biilding with the FACT ENGINEERING WORKS, an independent manufacturing organisation which produce equipment for chemical paints.

The Central Workshop works on general and evening shifts. The jobs are carried out according to obtained orders. Together with an order is usually given the drawing, sketch or sample.

Shortages:

- There are no technological instructions for the fabrication and reconditioning of spare parts.
- There is no plan for the Central workshop activities.

These activities have also no connect... preventive maintenance.

- Such machines like pumps and fans are ... repaired without relevant drawings or technical manual, in other words they are repaired according to the judgement and experience of workers and chargemen
- The condition of tools in the central ... unsatisfactory. The cutting tools are ... ground-ded properly.
- The inspection of quality is carried out by the respective Chargeman which we consider as a practice not adopted elsewhere.
- The rotating parts of machines ...
- The workers are not rewarded according to ... quality of accomplished work.

4.4.4.5.2. Fabrication and Welding Shop

The fabrication and welding shops are two ... tions. They are situated in separate workshop

Activities of the Fabrication Shop:

- Fabrication and erection of structures
- Prefabrication and erection of pipelines
- Fabrication of pressure vessels and heat ...
- Repair of the above mentioned equipment .

In the Fabrication shop, 47 workers and 3 ... supervisors are employed. The jobs are carried out according to the orders from the plant maintenance. Technical preparation, inspection of the jobs and collaboration with the Central Workshop and FMW are carried out by the supervising staff of this section itself.

The Fabrication Shop works on general shift only.

There is no plan of acitivities for the Fabricating Shop. The technical preparation of jobs is unsatisfactory. There is no proper documentation for pressure vessels, which should contain certificates for used materials, results of x.ray, x. ray, records from dye penetration check, results of hydraulic test etc.

Activities of the Welding Shop:

The Welding Shop covers for the whole factory all needs of maintenance in the field of welding. There are employed 51 welders.

The shop is equipped so far as it is able to handle weldings of all sorts of steels, cast iron, copper and aluminium. They carry out argon arc welding and metallizing also. The deficiency is that there are no available technological instructions for welding, which should incorporate all necessary steps:

- Specification of electodes..
- Preparation of welding edge.
- Parameters of welding -/ current and diameter of electrodes, preheating etc./.
- Necessary heat treatment.
- Required tests like x-ray, ultrasonic test, hardness test etc.

The welding shop is not sufficiently equipped for the accomplishment of all required tests.

4.4.4.5.3. Material Conservation.

The section includes 2 supervisors and 14 workers. The main activity of this section is to collect salvagable steel material from various plants, sort it out and arrange the disposal of non salvagable materials.

4.4.4.5.4. Preventive Maintenance.

Beside activities described in Chapter 4.4.4.2. the Preventive Maintenance Section carries out the following works:

- Preparation of a lubrication schedule for each plant and each piece of equipment. Application periods, types of lubricant to be used etc. are fixed after consultations with the M/s. Indian Oil Company and M/s. Hindustan Petroleum Corporation.
- Procurement of lubricant and control of its distribution to plants from the Material Department.
- Procurement of general spares like bearings, oil seals, veebelts etc. required for various plants which is made in coordination with the material mangement / purchase section/.
- Arangements for the purchase of critical spare parts from the local market in case of emergancy.

4.4.4.6. Shift Maintenance.

The area maintenance crew and the welding section are functioning during all the three shifts. 12 Workers from each area will report for duty at the evening and at the night shift. One chargeman will report for duty in each area during the evening and night shift and he will allocate works to the workers reporting for duty in the respective area. As regards the welding section 4 welders will report for duty during the evening and 2 welders during the night schift. These shift welders will carry out works in all maintenance areas as per instructions from each concerned area respective from the maintenance shift chargeman. The shift maintenance carries out 25 - 30 % of the whole amount of maintenance jobs in the plants.

4.4.4.7. STORAGE OF SPARE PARTS AND MATERIALS.

The Materials Manager is responsible for storing the spare parts. The stores contain about 34.000 items of individual spare parts which represents total value of Rs. 36.2 millions. This makes 11,2 % from the total cost of capital items at the FACT, Udl. Dvn. For. about 2,400 stored items which have to be kept on stock is given the minimum amount.

The resent procurement procedure of spares is subject of the plant management. Lists of spare parts are prepared by individual plant managers. These requests from the whole factory are collected by the Materials Manager after which they are evaluated by a committee which consists representatives from the Materials, Finance, Production and Maintenance Departments. They decide about the purchase of spare parts according to their importance for the production.

Offers from suppliers are evaluated by the respective plant manager and plant engineer.

The incoming spare parts are received by the receiving inspectors. This section belongs to the Technical Service Department and includes four inspectors.

Spare parts which do not conform to specification are rejected. The percentage of spare parts which are rejected is about 8 %. The spare parts are stored on well arranged shelfs. At the end of each financial year an elaborate of details about the amount of spare parts in store and their storing time is prepared by means of the computer.

In the stores the spare parts are categorised by a brief specification and store code No. which enables to identify them as easily, respective to which plant/equipment they belong.

The general spares like bearings, oil seals, V-belts etc. can be taken out from the stores directly by requisitions signed by the respective plant engineer. Requisitions for other spare parts must be signed by the respective Plant Manager.

The spare parts, which were not used in the plant are returned to the store with their full value. The reconditioned parts are also stocked in the stores.

Shortages:

- The present procedure for the procurement of spare parts is very complicated.
- Responsibility for the procurement of spare parts is given to the operation [illegible] and not to the plant engineer who has better [illegible] of the spare parts.
- The inspection for quality of the incoming spare parts is unsatisfactory.
- The protection of spare parts against corrosion should be improved.
- Unsatisfactory stor[illegible] [illegible] materials, / bricks/
- There is no specified [illegible] for the maximum and minimum amount of spare parts which have to be kept in the stores / on stock/.

4.4.4.8. RECOMMENDATIONS

The production and the maintenance departments should have the following responsibilities:

- The production department should be responsible for the upkeeping of machines and equipments, for their economical utilisation, as well as for an every day attendance and for running the plants according to the operating instructions.

The operation staff should be made responsible for:

- keeping the machines and equipments and their surroundings in clean condition,
- oiling and greasing the machines according to lubrication instruction.
- Replacement of the [illegible]
- Cleaning vessels, heat [illegible] [illegible] condensors etc.

The Maintenance Department should bear responsibility for the mechanical condition of the plant as well as for activities connected with this objective. Protection of Plants and equipment from corrosion should also be the responsibility of the maintenance department. The following aims should be the principal rule for evaluating the performance of the rpoduction and maintenance departments.

- production department - Plant output per hr.
- maintenance department - Working hrs.of the plants within an year.

Such a division of responsibilities would enable for the maintenance department to establish the available running time of the plants as well as requirements for shutdown consistent with the plan of available running hours. This should be the first step for planning in maintenance.

The share of responsibility is also a basis for mutual inspections in their activities.

- From the activities of the maintenance department is necessary to eliminate such a non-maintenance activity like cylinder fillings. This work should be transfered to the production department. The maintenance should carry out only hydraulic tests and repairs of cylinders.
- To achieve conditions for an uniform planning and full application of preventive maintenance, we suggest to organise the maintenance department according to the chart shown in Annexure 14. The leading position in this organisation should be given to the mechanical maintenance.

- Such regulations should be elaborated, which will point out the activity, responsibility, duties and authority for the whole department as well as, for each section and function down to the level of chargeman. This will enable to define the clear-out responsibility of each individual thus eliminating the duplicity of responsibilitities.
- To establisch a separation of repairs between the Central Workshop and the Plant Maintenance.
- For the achievement of economy in the system of preventive maintenance, we recommend to categorise the equipments and machines according to their importance for the production.
- For the procurement of spare parts and other materials the Material Management should by fully responsible.

The materials management in collaboration with maintenance department should for all items of spare parts specify the minimum, maximum and optimal amount which should be kept on stock.

The maintenance department should be responsible for:

- The mechanical evaluation of offers for spare parts by taking into account the minimal cost and the optimal function of spare parts.
- Taking over materials in a required quantity from the store in time.
- Keeping the turn round of the spare parts.
- Reducing types of spare parts and materials by means of standardisation.
- Inspection of incoming spare parts and materials including archivation of technical documentation like certificates, results of tests etc.

We recommend to incorporate the Technical Services Dept. into the maintenance department and to organise this part of maintenance according to the Chart given in annexure 15.

This creates good conditions for:

- Clearing problems arising during operation and repairs of the plants in their whole complexity.
- Inspections of quality in maintenence activities like inspection of incoming spare parts and materials, spare parts which are fabricated in the company's workshop etc.
- Inspection of running machines which should confirm if they are processed according to the operating instructions.
- Inspection of the proper lubrication carried out by the operators.
- Carrying out the measurements and evaluations of vibration.
- Analyses of all breakdowns and premature repairsto find out the reassons of the failures and submiting suggestions for taking measures to prevent a repeat of similar failures.
- Utilisation of the technical progress in maintenance techniques.
- Application of technical progress in management of maintenance.

Further we recommend to increase the capacity of the drawing office as to achieve a higher number of drawings for spare parts and assemblies, which are very necessary for the fabriction of new spare parts as well as for recondition works and for the fabrication of spare parts by indigenous companies to substitute the imported parts for repairs of machines and equipments.

The mechanical and Civil Maintenance we recommend to organise according to the Chart shown in Annexure 16.

We recommend to centralise up to the maximum extent repairs of the most important machines and equipments determined for production.

The fabrication and reconditioning of spare parts as well as the fabrication and repairs of heat exchargers and the fabrication of structures should be technicaly prepared by a specialy established group. All these activities will be car carried out by the central repair and fabrication shop.

A workshop building with all essential equipments should be provided for the plant maintenance group as the faciltties available now are not adequate for the jobs carried out by them.

The problem of protection against corrosion of the plants and structures should be cleared immediately.

Proper storage of parts in the central workshop and plant maintenance workshops must be ensured.

All precautions must be made for the good condition of tools in central tool store.

Measuring devices must be keept in proper condition. The accuracy of the measuring devices must be regularly checked according to standards.

The workshop and working places of the plant maintenance should be keept in clean condition and good order.

It is necessary to increase the [illegible] tenance.

We recommend to introduce the [illegible] tation for machines and equipments [illegible] irs, hydraulic tests, ultra[illegible]

We suggest the followin[illegible] additio[illegible] maintenance department:

- Sheet rolling machine. Max. pl te [illegible]
- Horizontal boring machine.
- Lathe - admit between centr[illegible]
  seing over bed [illegible]
- Balancing machine for dynamic b[illegible]
- Portable metalografic micro[illegible].
- Stress relieving machin[illegible] for [illegible]
- Tube expander with autom[illegible]
- Instruments for measurin[illegible] dim[illegible], [illegible] hness.
- Metal cutting tools.
- Portable jig for machinin[illegible] the fl[illegible] ges of equipments.
- Testing device for testing valv[illegible]

4.5. THE FACT - COCHIN DIVISION

4.5.1. PLANT INSTALLATION

No	Plant	Capacity TPD	YEAR OF commissioning
1	Ammonia Plant	600	1973
2	Urea Plant	1000	1973

As an oxiliary plant is considered the Thermal Plant, which includes the raw water supply, boiler feed water treatment, steam generation and power generation.

4.5.2. SHORT DESCRIPTION OF THE PLANTS

4.5.2.1. The Ammonia Plant.

Sulphur content from the raw naphtha is removed in two steps. The naphtha coming out of the desulphurisation section will contain only less than 0,5 ppm of sulphur. Desluplhurised naphtha is heated and mixed with super-heated steam before it enters the primary reformer tubes which contain a nickel based catalyst.

Gas mixture from the primary reformer enters the secondary reformer, where suficient quantity of air is admitted to give a final gas of H_2 and N_2 at a ratio of 3 : 1. In the HT converter CO content is reduced to approximately 2.2 % and in the LT converter to 0.23 %. Removal of CO2 from the gas is done by washing the gas counter currently with Vetrocoke solution. Here is the CO2 content reduced to 0.1 %.

The methanation unit is designed to reduce the total CO and CO2 content to less than 10 ppm.
Synthesis gas from the reforming section is compressed in a four stage centrifugal compressor to a synthesis pressure of 250 kg/cm^2. The compressed gas together with the circulating gas circulates through the synthesis loop where liquid ammonia is produced.

The NH3 condensed at the separators, condensers and evaporators is sent to a let down tank operating at a pressure of 2[illegible] kg/cm^2. The produced ammonia is stored in spheric storage tanks.

4.5.2.2. The Urea Plant.

Urea is manufactured by reaction NH3 and CO2 at a pressure 220 kg/cm^2 and a temperature of 190°C. 97 % pure CO2 is compressed to 220 kg/cm^2 and delivered to the reactor at 140°C. Liquid ammonia from storage is boosted to about 3[illegible] kg/cm^2 and admitted to the reactor by means of high pressure pumps after preheating. Recycle carbonate is also delivered to the reactor and after compression to the reaction pressure.
The unconverted NH3 and CO2 are separated from the urea solution by reducing pressure and heating with steam in 3 stages. Dilute urea solution is filtered and fed to a vacuum distiller at the top of the prilling tower. A melt of 9[illegible].5% concentration at 140°C is fed to the sprayers. By a free fall through the convective uprising column of air, the prills becomes solid. They are collected in a belt at the base of the tower and conveyed over a belt weigher to the silo.

4.5.3. PROBLEMS ARISING IN PLANTS AT THE FACT COCHIN DIVISION

The Fact-Cochin Division started trial production of ammonia and urea in May 1973.

Till now the ammonia plant has not achieved the rated capacity of production. Various factors have contributed to failures which have prevented to achieve the optimum level of production.

The Management has taken several steps to identify the areas iof failures in all functional activities. An end-to- end survey of the plants was carried out to identify all technical problems encountered in the plants.

The problems were studied by the FACT Engineering Design Organisation which subsequently recommended possible remedies.
As a result of the above survey, following precautions are made. It was organised an Improvement Programme for Plant Operations. Completion of this programme is expected to take about 30 months mainly because of the lead time required for critical equipment . Some items in this programme have been already completed and yet some others are in progress.

We have studied this programme and our comments on the same with other recommendations are given below:

4.5.3.1. Cooling water.

The cooling water at the FACT-Cochin Division causes many problems because of high fouling and corrosion. The analysis of raw water from the lake gives the folliwing results:

pH	- 0.95
Conductivity	- 26.8
Alkalinity as $CaCO_3$	- 9 [illegible]m
Free chorine	- nil

Chloride as chlorine	- 5 ppm
Nitrate	- 0.[illegible] ppm
Silicate as SiO_2	- 4 ppm
Sulphate as SO_4	- 1.1 ppm
$KMnO_4$	- 7.9 ppm
Dissolved O2 as O2	[illegible].4 ppm
Total hardness as $CaCO_3$	- 7.1 ppm
Calcium hardness as $CaCO_3$	- 4.1 ppm
Mg hardness as $CaCO_3$	- [illegible] ppm
NH_3 /free and saline/ as NH_3	- [illegible].31 ppm
Copper	- 0.01 ppm
Iron	- 0.16 ppm
Chromium / CrO_4/	- nil
Arsenic	- nil
TDS	- 25 ppm
Suspended solids	- 10 ppm
Total solids	- 35 ppm

The present corrosion and fouling nature of the cooling water is expected to overcome by chemical control of the water quality. At present in the cooling water is dosed chromate at an amount of 100 mg/l in circulation and chlorine in the form of a bleaching powder. According to our experience the above mentioned cooling water treatment is not sufficient. It is necessary to use some modern progressive method of chemical treatment.

In our factory we had similar problems which we were able to solve successfully by using chemicals from the DREW CHEMICAL CORPORATION Company USA.

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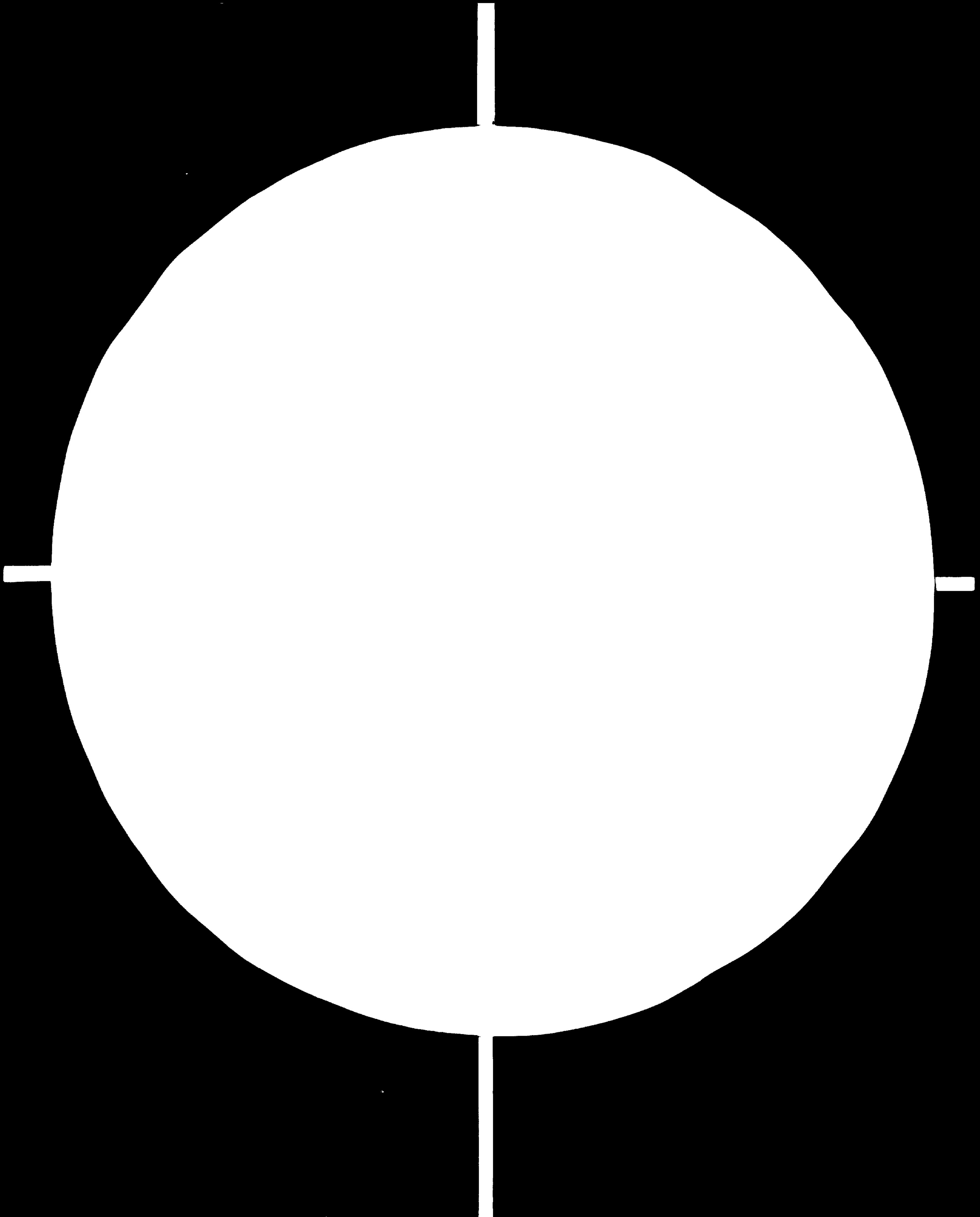

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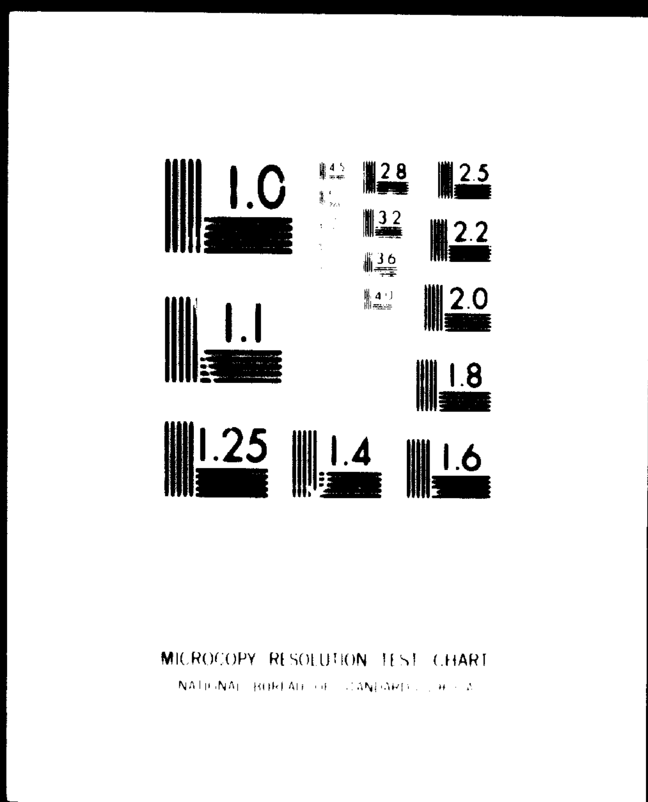

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The whole cooling system was cleaned as follows:

The water was kept in circulation. The P_2O_5 content in the water was kept during whole cleaning on 25 ppm by dosing hexa-metaphosphate. The pH was slowly lowered by dosing H_2SO_4 to 6 and later to pH 3. For the cleaning of coolers was used biocide 230 and drewsperse 738. The whole cleaning procedure required about 6 days. During the cleaning the analysis of iron content in cooling water was observed.

In normal condition the following concentration of chemicals are kept in the cooling water:

P_2O_5	-	7 - 10 ppm
Zn	-	2 - 4 ppm
Drewsperse 738	-	25 ppm

Once per month or according to the amount of algae about 2300 kg. of biocide 230 is added to the suction of the cooling water pumps. The pH of the cooling water is kept on by using sulphuric acid at a value between 6.5 to 7.0.

Recommended limits for the cooling water are:

Calcium hardness as $CaCO_3$	- max. 300 ppm
M-alkalinity as $CaCO_3$	- max. 200 ppm
Conductivity	- 1 500 uS
Chloride as chlorine	- max. 60 ppm

By reaching one of this concentrations some water from the circulation is necessary to blow down.

Some very dirty coolers as for instance the water cooled condenser in the ammonia synthesis and ammonia condensers in the refrigeration loop were cleaned separately by means of circulation and some special chemicals from the above mentioned manufactures. For details it is necessary to contact their experts. There are also some other Companies like Nalco from USA, Betz from West Germany and others, which are offering similar services.

For cleaning the condenser of the process air compressor turbine during operation we recommend to install the TAPROGE system. For further information ask

Ludwig Taprogge
Reinigungsanlagen für Rohren-Warmatsuchar
4034 AUGERMUND
Bez. DUSELDORF, Postfach 140
West Germany.

4.5.3.2. Water cooled ammonia condenser.

The condenser will give better performance after proper cleaning for which it is needed a good cleaning method, for instante a method offered by the Drew Chemical Corporation.

Further it is necessary to check the gap between the dividing plate and tube bundle and also between the dividing plate and the shell. This can be avoided by the use of wooden plates or other suitable material.

During a longer shutdown we recommend [illegible] tightness of thegas inlet chamber to th[illegible] condenser.

For better performance of the ammonia synth[illegible] tial to find out if it is anywhere availabl[illegible] for a water cooler of high pressure which [illegible] table to install in a byp[illegible] of the existin[illegible]. Such a cooler is probabl[illegible] v[illegible]il[illegible]ble at the [illegible] mandal Division in the 40 [illegible]D [illegible]onia loop, [illegible] out of use.

We recommend to clear the problem by inst[illegible] i- tional air cooler. According to our experi[illegible], [illegible] pro- vides good cooling performance if the environ[illegible] factory is not very bad. Such a cooler with [illegible] for cooling the air can cool down the [illegible] to [illegible] the air temperature is 30°C. The performance c[illegible] ved by installing an air cooler before the [illegible] water condenser.

Air coolers for ammonia syntheses are manufactured in many countries including Czechoslovakia.

Careful calculations should be carried out to find out the investment and operating costs for both cases i,e, for air cooling and for the system suggested in POIP. In case of an air cooler installation is not necessary to build a new separate cooling tower.

4.5.3.3. High consumption of fuel.

The high consumption of fuel occures also due to high inlet temperature to the stack. Instead of 150°C the temperature is now 190-200°C.

The combustion air preheater should be inspected during longer shut-downs. According to our experience the heat exchanger is getting dirty. [illegible] to clean the tubes of the preheater by means of brushing minimum once per year during the normal shutdown. The surrounding of the combustion air fan should be kept in clean condition.

4.5.3.4. Silica carry-over from the steam drum.

We suggest to check the design of the boiler system and the demister. This should be done by the supplier or by FEDO. In modern high pressure steam generating units a combination of ammonia water is used for the alkalization of boiler water with the inclusion of some organic alkalizators like S.L.C.C. from the Drew Chemical Corporation. Similar chemicals can be used from Nalco or other companies.

4.5.3.5. Silica deposit on the turbine blades.

The existing method for removing silica deposit from the blades of the turbine which is used in our factory is described in annex No 24.

4.5.3.6. Start-up programme of the ammonia plant.

It is possible to reduce the start-up time by increasing the flow of nitrogen through the plant during the heat up of the plant. This will enable to spare about 8 hours from the total start - up time. For the start-up of the ammonia plant it is possible to use also CO_2. In that case. it is necessary to elaborate special start-up instructions.

4.5.3.7. Erosion of the lean solution pumps.

The erosion of the pumps is mainly due to small pieces of packing materials in the Vetrocoke solution. It is possible to minimise it by fixing the packing in the towers from the top of the layers by means of grids. The larger broken pieces of packing should be removed by installing a strainer with a large surface inside the regenerator on the solution outlet. It is also important to instal strainers with fine mesh in the suction line of the pumps.

4.5.3.8. Substitution of Vetrocoke for Benfield CO2 removal.

This question can be answered only after calculations are carried out by some design organisation like PDIO.

4.5.3.9. Treating the plant effluent from the Vetrocoke system. The only possible method is to dilute the effluent with large quantities of water before entering the sewer. If the concentration is high then the water should be evaporated and the solid with high concentration of arsenic should be put in a concrete drum and burried deep into the earth or thrown into the sea.

4.5.3.10. Vapourised naphtha as a fuel.

By using vapourised naphtha as a fuel the operation of the plant will be quite complicated. The naphtha must be kept minimum at 200°C . The burners must be replaced by another type and also the whole piping must be replaced by a larger diameter with new control valves etc. The modification should be very expensive. We suggest to replace only the burners by another type where it is possible to use steam instead of atomising air.

4.5.3.11. Temperature control in primary reformer.

For better a control of the uniform heating in the furnace of the primary reformer, we recommend to install devices for measuring the temperature in each flue duct canal in the reformer furnace.

4.5.3.12. Recommended inspections at the primary and secondary reformer.

We recommend to carry out each year during the annual shut-down inspections on the following equipment :

Reforming tubes, mainly on the bottom part, weldolets, outlet pigtails, bottom headers of the primary reformer, outlet header in the secondary reformer, burner in secondary reformer, whole boiler in the flue duct.

The equipment is necessary to check for an eventual change of their geometric shape like diameter, straightness, roundness etc. It is also important to check and look for cracks.

In case that some defects are found then it is necessary to carry out also other tests like hardness test, metallographic analysis, ultrasonic and X-ray respectively.

4.5.3.13. Thermocolour painting.

We recommend to paint all vessels and tubes lined with refractory inside, with a thermocolour paint. The green colour paint by its exposure to the heat, changes its colour to white. This enables immediately to recognize the hot-spots.

4.5.3.14. Ammonia level in the store.

A similar problem in our four sphere stores was solved by installing a new measuring instrument, which works satisfactorily. The type of this instrument is BM 22 from KROHNE

41 Duisburg
Postfach 493
West Germany

4.5.3.15. Removal of leaks during the operation of the plant.

To remove leaks on the gas lines and also steam lines is possible by using a special procedure from

FURMANITE INTERNATIONAL Ltd.
Dockray Hall Road
Kendal LA 9 4RY
CUMBRIA
England

4.5.3.16. Cleaning of the coolers and condensers.

For mechanical cleaning of coolers and heat exchangers the high pressure pump " ATUMA " is successfully used. There is possible to adjust the pressure in a very wide range. For further information is necessary to contact.

VOMA GMBH
A 1210 Wien 21
Wenhoitgasse 26
A u s t r i a

4.5.3.17. CO_2 compressor.

1. Vibration of the CO_2 compressor is due to its unsatisfactory and wrong anchoring. The present system of anchoring gives no chance to compensate vibration, but even to transfet the vibrations from one side to another. As a resutl of this vibration are cracks noticed on the weakest places of the system.

2. Corrosion of the CO_2 compressor occures mainly due to carry over of drops from separators into the cylinders and subsequently by condensation of water from compressed gaseous CO_2 due to low temperature.

The condensate is saturated with CO_2 and forms weak acid, which causes bad corrosion in the compressor.

We recommend to check the proper separation of water and keep the prescribed inlet temperatures to the individual stages of compressor by a few degrees higher.

4.5.3.18. Carbamate pumps.

1. In our Urea plant we have at the suction of the carbamate pump installed two valves with a bleed valve between them. We recommend to use a similar solution at the FACT COCHIN Plants.

2. The cracks in R.V. blocks are due, to wrong construction of the blocks from the view-point of alternating stress and homogenity of material. Welding of the blocks is only a temporary solution.

We recommend to solve the problem by the use of a stronger forged block. This block should be non-sensitive to alternating stress. It means to avoid every notch from the construction side and all technological notches / ensure that all functional surfaces will be smooth/.

3. The service time of plungers and service time of packing are closely related to each other. The service time of plunger depends on:
   - corrosion resistance of the used material
   - working temperature in packing area, hardness of packing and specific pressure of packing.

The material of plunger is usually W. No. 1.4460. which has a hardness of about 350 HB / 37 HRC /. The best results are achieved by a hard chromium plating of plungers. The achieved hardness is up to 70 HRC.

The double gland arrangement with the possibility of cooling between the two glands gives the best results.

This problem is mastered by the Worthington Company. The pumps from the above mentioned Company are working satisfactorily in many Urea plants, including two Urea plants at our factory. The already proven packing material is the P.T.F.E. material from the MERKEL company of Hamburg, West Germany.

4.5.3.19. Cylinder valves.

The valves should be properly reconditioned before they are fitted in the cylinder. It is necessary to check the valve guard, seal plates, springs and other components.

The plates should be checked for evennes and cracks, whereupon they can be lapped. The springs should be checked for fatigue streds. After assembly of the valves they should be checked by means of kerosene to ensure tightness. When the valves are tight, it is recommended to wrap each valve separately to plastic bag and store them in the compressor house ready for use.

4.5.3.20. Control of vibrations.

The inspection section keeps measuring devices for controlling vibrations and carrying out analyses of vibrations. For an evaluations of obtained figures they have not enough criteria.

As to enhance improvement of this activity we have handed-over basic data for such evaluations used in our factory.

4.5.4. MAINTENANCE AND REPAIR.

4.5.4.1. Position of the maintenance Department.

The maintenance department is on the same level as the Production Department and along with the Technical Services Department, they report to the Deputy General Manager / Technical/.

The Maintenance Department is divided as follows:

1. Centralised plant maintenance
2. Civil maintenance
3. Electrical maintenance
4. Instrument maintenance
5. Central workshop

The technical background for whole maintenance and production is provided by the Technical Services Department.

The scope of our study is confined to the centralised plant maintenance and to the Central Workshop. The actual organization chart of these groups is shown in annexure No. 17.

The chart shows the following numbert of maintenance staff:

	Workers	Helpers	Techn. personnel
Centralised plant maintenance	79	-	24
Central Workshop	59	4	8
Total	138	4	32

The ratio between technical persOnnel and workers is 1:4.4. The are some following deficiencies in the present organization:

- Organizatucnal detachment of the centralised plant maintenanse and Central workshop
- There are no conditions for an uniform planning in maintenance
- Operation of the heavy equipments like cranes, portable compressors, road rollers etc. are not typical maintenance activities.

4.5.4.2. Planning in maintenance.

The planing of the activities in the centralised plant maintenance is carried out at present by the Planning and Inspection section. This programme consists a yearly. plan of preventive maintenance for the respective plants. The plan is based on cycles of repairs obtained from statistics and cycles provided by suppliers. For each week is prepared a list of jobs which should be carried out according to the plan of preventive maintenance for each plant. After the inspection or repair Work is executed the area engineer elaborates a " check chart-cum-history card ". This document is returned to the Planning and Inspection section where the results of repair or inspection are recorded.

In the course of all maintenance activities, entries should be made into the following forms:

- Clearance for maintenance work
- Electrical permit for working on driven equipment
- Labour allocation report

Preventive maintenance, which is not carried out according to the maintenance programe respective problems arising during operation which cannot be removed without a shut-down of the plant are recorded by the Planning and Inspection section. These jobs are carried out durin the next shut-down or break-down of the plant. For these jobs is prepared a detailed programme.

The area engineer in this system is responsible for organizing and excuting repaire and also for the availability of necessary materials and spare parts.
The cost for maintenance in the year 1974-75 amounts to 5 milions. This represents abput 1% from the value of capital items. The planned maintenance budget for the year 1974-75 was 19 millions, which represents about 3.5% from the value of capital items.

We have observed the following deficiences:

- In the used system and present condition the activities of preventive maintenance are confined to repairs of standby machines or inspection of running machines respectively. Repairs of single machines are carried out only during a break - down of other related equipments of the plant or at the breakdown of such a single machine. This system enables to fulfill the plan of preventive maintenance upto about 70-80%. In case of a stable operation of the plants / which is coming now/ it is very important to carry out the programme of preventive maintenance for single machines. Preventive repairs must be carried out within the desired time i.e. acording to the cycles of repair which are based on hours for which a machine can be safely kept on line and according to the vibrations and working parameters like temperature, pressure, etc.

It is not possible in such conditions to wait for some breakdown in the plant, because this makes also the most perfectly built system of planning as a formal matter.

- There is not elaborated any long term plan of repairs.
- No scope of work is given for individual repairs.
- The plan of preventive maintenance is fulfilled without taking into account the actual running hours of the machine.
- The used cycles of repair are not compared with cycles achieved in other similar plants.
- The maintenance budget is watched only as a whole and only by the Finance department.
- From the economy poin of view it is necessary to pay dieferential care to the machines i.e. according to their importance for production.
- Into the plan of preventive maintenance are not included activities of the central worshop, which is best equipped with machines and materials within the whole maintenance departments.

An analysis in regard to loss of production attributed to maintenance or non-availability of spare-parts is not possible to.carry out because there are no suitable data available.

PRODUCTION [illegible] AND BREAKDOWNS

Statement of the Plant 1974 - 197[illegible]

Plant	Rated capacity	Target	Actual production	Short-fall	Loss due to mechanical break down	Loss due to non-availability of parts
UREA PLANT	330 000 330 000	115 000	87 128	27 872	Data not available	

Statement of the plant 1975 - 1976
up to 31-10-1975.

UREA PLANT	yearly 330 000	89 000	75 709	13 291	Data not available	

It is reported that up-till-now there was no loss of production due to non-availability of spare parts.

Also no data are available which show the share of works by outside agencies. It is assumed that also in the future such figures will not be included into the plan

4.5.4.3. Technical preparation, execution and documentation for repairs.

The centralised plant maintenance is fully responsible for the technical condition of machinery and equipments of the plants, which is based on planning, technical preparation of repairs and availability of spare parts and materials up to the execution of all maintenance activities in the plants. The plants are divided into five different areas, each managed by an area engineer.

This engineer is responsible for.

- day-to day manpower planning
- scheduled maintenance of equipments and mechinery in his area
- supervision of works carried out with respect to quality and economy
- immediate attention to break-down jobs
- coordination with the production department and other service departments for day-today work
- submitinf indents for procurement of spares and accesories.

No instructions äre available for repairs of machines and. eguipments. Repairs are carried out according to rough instructions given in the manuals by the manufactures and mainly according to the experience obtained from repeated repairs.

The centralised plant maintenance has only some drawings, which were left be-hind in the plant after completion of. the erection. Complete documentation is kept in the Technical Services Department.

There it is possible to study the documentations, but it cannot be taken to the plant.

The whole available data, which shows the technical condition of machines as for instance achieved working parameters, vibrations, run out of the machines, input of motors, etc. are not collected prior to repair. During more extensive repairs of rotating machines expecially high speed machines, there is no rule for dynamic balancing of rotors. The inspection for quality of repairs on emachines and equipments is carried out by the respective area engineer or technician / supervisor/ respectively. The documentation of repairs is unsatisfactory. This is introduced only into Log Books where it is good for statistics and planning.

For maintenance purposes there is a factory built central workshop. The centralised plant maintenance carries out 90-95% of all repairs. Repairs of machines are executed mainly on the.spot i.e. at the place of thier installation in the plant. The services of the central workshop are used only partly.

There rea only small workshops in individual plants, but the existing working spaces are sufficient in case of total centralisation of repairs. It is desirable to furnish the plant maintenance workshop with some more machines as for instance lathe pedestal boring machines, power hacksaw and circular shears for cutting gaskets. The handy store of the central plant maintenance is used for already used spare parts. Essential toools are also distributed to each craftsman and technicien. The special tools and measuring devices are stored in the tool store of the Central workshop.

4.5.4.4. Inspections and solutions of technic l problems in maintenance.

According to the organisation chart the personnel for carrying out inspections and solutions of the technical problems in maintenance is split into the following sections:

4.5.4.4.1. Inspection section at the centralised plant maintenance.

4.5.4.4.2. Incoming inspection at the material management.

4.5.4.4.3. Technical service department.

4.5.4.4.1. This inspection section is according to the organization chart combined with the Planning section and carries out the following activities:

- regular control fo vibration on machines and evaluation of obtained figures
- ultrasonic thickness test of selected pipelines
- x-ray inspection /upto now this is not executed since there is no qualified person available/.
- measuring of skin temperature by means of pyrometer
- identification of defects in metals by means of ultrasonic and magnaflux detector.

The following inspection prograramme was prepared:

- Outside inspection of pressure vessels once within 6 months.
- Inside inspection of pressure vessels once within 4 years. The inside inspection of pressure vessels is possible to substitute by hydraulic pressure test or ultrasonic test.
- Boiler inspection. Communication with the Government Boiler Inspectorate is organised through the Technical Service Department, but the actual execution of Inspection including related activities are carried out by the inspection Section. The principal deficiency of these activities is the fact that the programme prepared is not followed because the Inspection section is inadequately staffed.

4.5.4.4.2. The incoming inspectors carry out the inspection of quality and quantity at the incoming spare parts. There are two inspectors. They belong, according to the organization chart, to the Materials Management.
The jobs are carried out with an insufficient amount of drawings. The inspection is limited only to dimension control of the spare parts.

4.5.4.3. The technical Services Department provides for maintenance the following services:

- solutions in maintenance problems by own or by means of
. FEDO
- Communication with the Government Boiler Inspectorate.
. They keep records from inspections and repairs of boilers
- archivation and upto-dating of drawings and other technical documentation
- preparation of drawings.for spare parts
. duplication of drawings.

The deficiency of the department is that the services are not. at an appropriate level in the field of materials, corrosions, welding and calculations. Morveover the.technical level of the produced drawings is unsatisfactory.
The services obtained from FEDO are on a nigh technical level,.but they are confined only to process engineering problems.

4.5.4.5. The Central Workshop.

The central workshop is situated in a spacious hall equipped with a crane which can operate throughout the hall. At the surroinding spaces of the main hall is located the central tool store, the.store of reconditioned parts and valves ahd the smithy shop.

Activities carried out by the Central Workshop:

- fabrication of spare parts
- reconditioning od spare parts
- modification
- repair and testing of valves and cylinder valves of compressors
- retubing of heat exchangers
- smithy jobs.

These jobs are carried out according to received orders. Usualy to such orders are attached drawings sketches, samples , or descriptions of the respective jobs. At present there are about 100 orders. The priority for each order is given by the respective Plant engineer. The priority of jobs for the whole factory is given from the engineer-in-charge. Planning in the Central workshop is confined to requests of materials which are necessary for carrying out the required jobs. The weekly plan for Central workshop is worked out on the basis of priority of jobs and their scope. There are enough measuring devices and cutting tools. The tool store, renders its services for the whole maintenance department. The central workshop works round the clock. Inspection about the quality of jobs is carried out by the respective engineer or technical / supervisor/ respectively.

Deficiencies:

- The quality of repar depends in many ways on the specialization of the maintenance staff. Best conditions for such specialization are given by centralization of the maintenance activities. For this purpose is provided a central workshop. At present the extent of repairs carried out in the Central Workshop [illegible] is very low. According to our opinion it is necessary to achieve the following share of repairs.

Cental plant maintenance - 30 to 40 %
Central workshop - 60 to 70 %

From that point of view we can see that the Central workshop which is in its position according to the organisation chart . an independent section contributes not adequatly for this aim. The idea to include the Central Workshop into the Technical Services Department is according to out opinion a wrong desision.

- Repaire of machines are carried out without suitable documenatation.
- The workers are not revarded according to the quality and quantity of the jobs carried out by them.
- There is no atempt to enhance working iniciative through more money.
- The damaged tools are also stored in the Central tool store.
- Fabrication and reconditioning of spare parts is carried out according to documentation, which is on a very low technical level.

4.5.4.6. Shift maintenance.

The mechanical maintenance staff is working in the plant round the clock. These trained staffs at various levels are a must for immediate attention to any emergency in the plant.

The staff is headed by a shift engineers in the rank of either a junior or a senior engineer. There are easy communication facilities in the project and availability of any additional help in case of emergencies is no problem at all.

Besided the shift engineer attends also to all coordinating problems in the plants a special " Call Officer " in the time from 10 p.m. to 6 a.m. The staff in its spare time is obliged to do routine works, inspection, preventive maintenance, house - keeping etc.

4.5.4.7. Store of spare parts and other materials.

The stores of spare parts and materials belong to the Material Management. They stock about 16000 items, out of which about 9000 items arespare parts.
The value of the spare parts in the store represents 20 millions. This is 3.65% from the total cost of capital items. The total cost of capital items at the FACT-Cochin Division is 550 millions. For all items of spare parts which have to be kept in the Store is given a minimum and maximum requirement.

In case that the number of indigenous spare parts comes down to a minimum then they should be replenished by the Purchase Department without assistance from the maintenance department. In case of foreigh made spare parts the respective area engineer should raise the indent.

In a case of a Breakdown the needed spare parts are purchased promptly by the Purchase Department.

The incoming spare parts are received by the incoming inspectors. Spare parts which do not conform to the specification are rejected. The amount of rejected spare parts is about 1%. Spare parts are stored mainly on shelves and are kept separately for each plant. There exists a catalogue of spare parts, which gives brief specification and store code number to enable an easy identification, respective to which plant it belongs. Each month are summarised values from the computer report, which show details about stored spare parts. The spare parts which were not used in the plant are returned to the store. These are also stocked along whith reconditioned spare parts. The spare parts can be taken from the store by a requisition signed by an appointed representative of maintenance.

It is necessary to improve the protection against corrosion for the future. It is also necessary to improve the inspection of incoming spare parts.

4.5.5. RECOMMENDATIONS.

4.5.5.1. Sucha non-maintenance activity as to organise the utilisation of heavy equipments should be separated from maintenance activities. This activity should be attached to the Materials Management, which has the possibilities for an economical utilisation of these equipments.

4.5.5.2. Shear of responsibility between the maintenance and the production department for the care of capital items.

4.5.5.3. To create conditions for:

- complete care of capital items
- uniform planning
- prompt solution of technical problems arising during operation and repairs of machines and equipments
- economy of maintenance activities.

We recommend to organise the maintenance department according to the organisation chart given in annexure No 18. The leading position in this organisation should be given to the mechanical maintenance.

4.5.5.4. The most important part of maintenance, which is the mechanical maintenance, should be organised according to the chart shown in annexure no.19.

4.5.5.5. To establish in the Technical department a common technical background for maintenance according to the annexure no.20. For this purpose should be used specialists from the following sections:

- incoming inspectors from the Materials Management
- part of the Technical service department whith a drawing office
- inspection section from the central plant maintenance.

This department will use also services from FEDO in the field of process inginoering.

4.5.5.6. Elaboration of rules which will point out the activity, duties and authority for the whole department and for each section and function.

4.5.5.7. Repairs of machines and equipments should be divided between the central plant maintenance and the central workshop with the common aim to a maximum centralisation of re. pairs in the central workshop. There is essential to establish a group which should carry out technical preparations for the fabrication and recondition of spare parts and for repaire of machines and equipments.

4.5.5.8. The workshop of the central plant maintenance should be equipped with the basic machines, like lathes, pedestal drilling machines, power hacksaws and circular shears for cutting gaskets.

4.5.5.9. To achieve economy in the system of preventive maintenance it is necessary to pay special care to individual machines and equipments. From that point of view it is essential to carry out categorisation of machines and equipments according to their importance for the production.

4.5.5.10. Conditions should be created for uniform planning, coordination in the plant between the individual sections of maintenance, watching the activities of maintenance by means of a maintenance budget and for elaborating the long term plan of maintenance.

4.5.5.11. Rewards and bonuses should be introduced for the maintenance staff according to the production of the whole factory and according to the amount and quality of the job carried out.

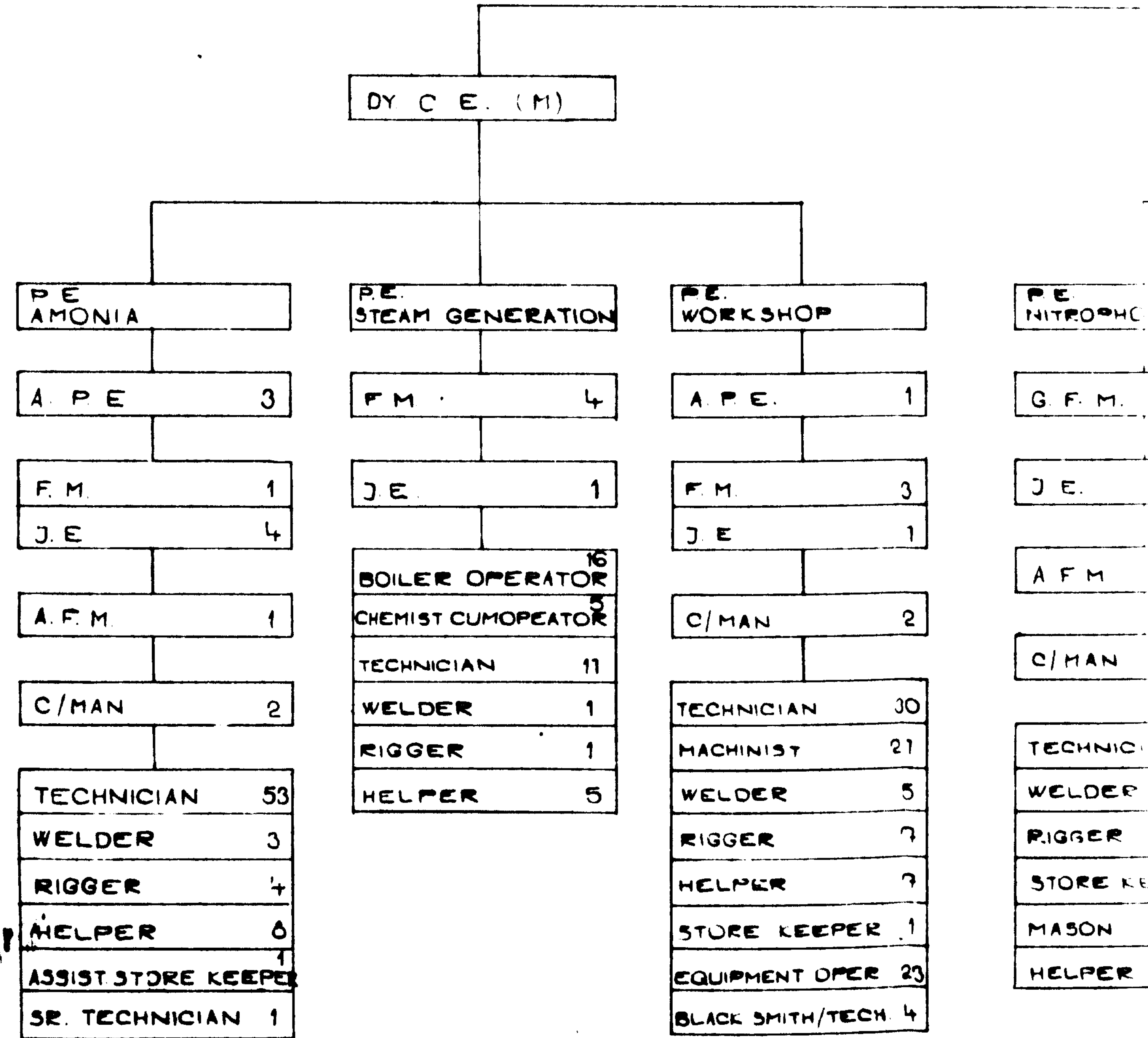
4.5.5.12. Proper storage of parts in the central spare part store and also in the handy stores of the central plant maintenance must be ensured.

4.5.5.13. To ensure proper conditions of the cutting tools in the central tool store. We recommend to grind the tools by specialists employed in the central tool store.

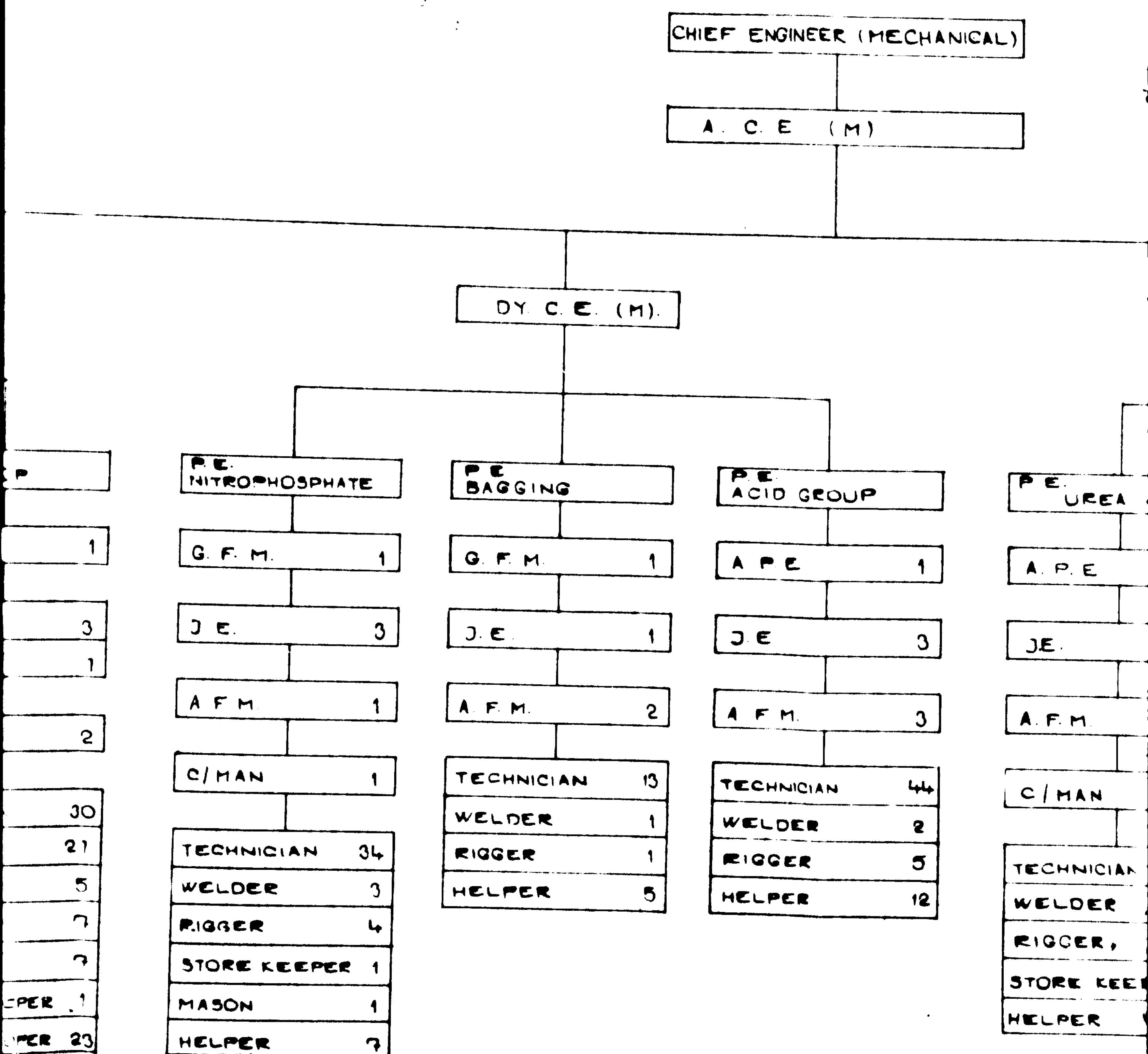
4.5.5.14. Suggested additional equipments for the maintenance department:

- Balancing machine for dynamic balancing impellers
- Instrument for analysis of vibrations IRD 350
- Vibrations meter cum sound level monitor IRD 308
- Hydraulic press
- Horisontal boring machine
- Pedestal drilling machine
- Portable metalographic microscope
- Portable instrument for hardness test

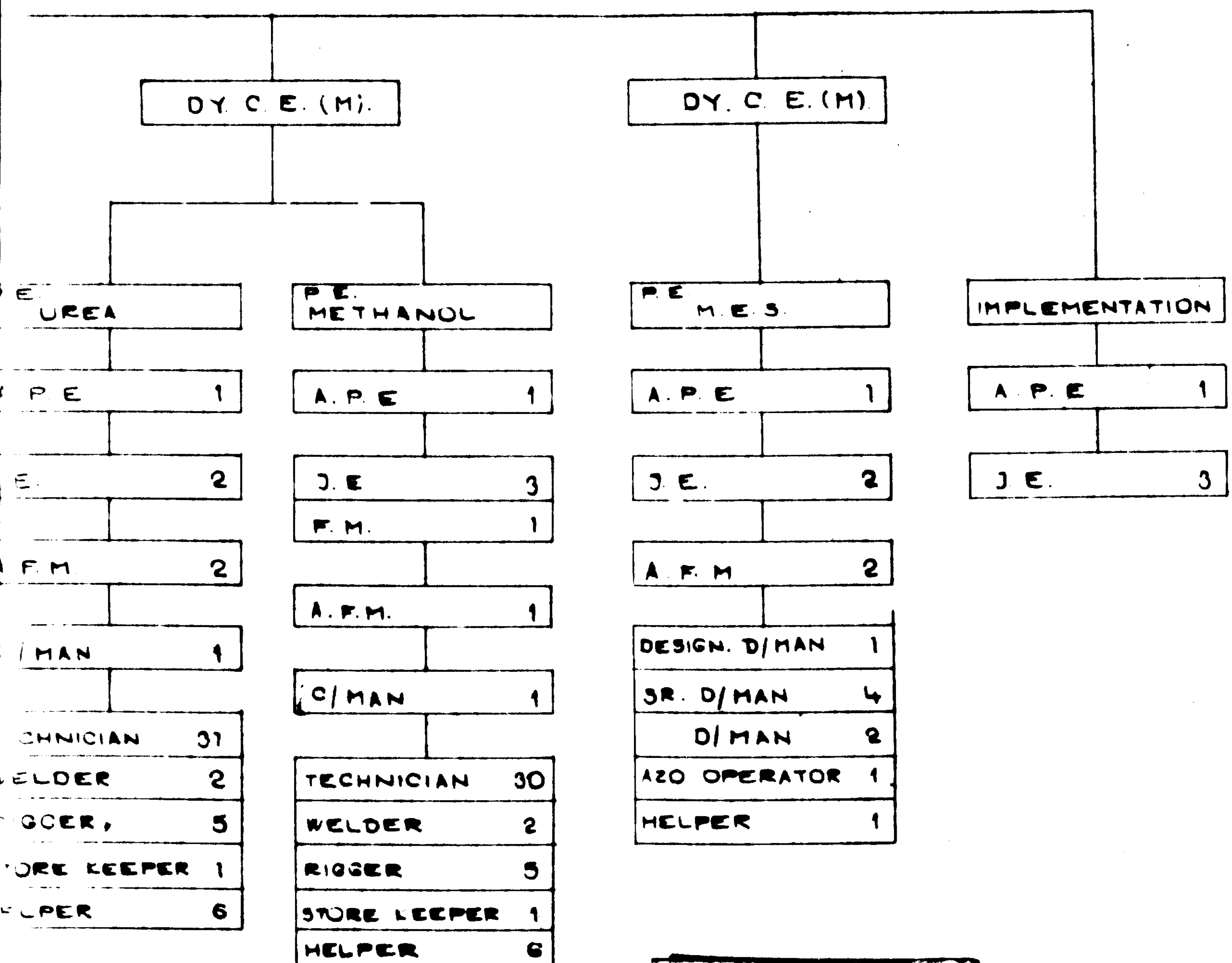
- Lathe - swing over bed 600 [illegible] between centres 5 m.
- Lathe - swing over bed 450 [illegible] admit between centres 1.5 m.
- 3 nos - lathe- swing over bed 250 [illegible] admit between centres 1 m.
- Horisontal boring and milling machine
- Tool grinding machine.


DY. C. E. (M)
P.E. AMONIA
A. P. E 3
F. M. 1
J. E 4
A. F. M. 1
C/MAN 2
TECHNICIAN 53
WELDER 3
RIGGER 4
HELPER 8
ASSIST STORE KEEPER 1
SR. TECHNICIAN 1
P.E. STEAM GENERATION
F M 4
J. E 1
BOILER OPERATOR 16
CHEMIST CUMOPEATOR 5
TECHNICIAN 11
WELDER 1
RIGGER 1
HELPER 5
P.E. WORKSHOP
A. P. E. 1
F. M. 3
J. E 1
C/MAN 2
TECHNICIAN 30
MACHINIST 21
WELDER 5
RIGGER 7
HELPER 7
STORE KEEPER 1
EQUIPMENT OPER 23
BLACK SMITH/TECH. 4
P.E.
G. F. M.
J. E.
A F M
C/MAN
WELDER
RIGGER
MASON
HELPER

ORGANIZATION CHART MECHANICAL MAINTE



1AINTENANCE

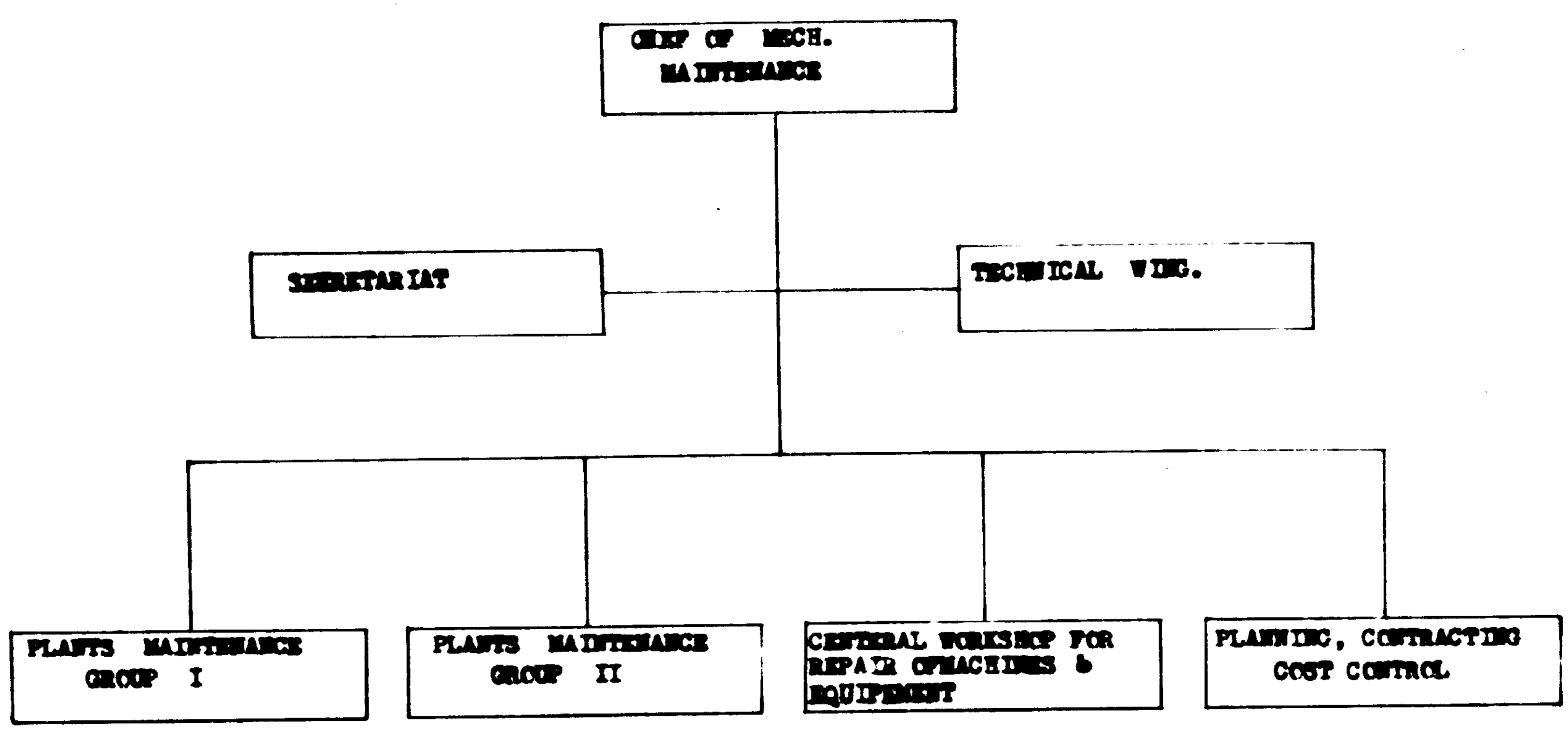


SECTION 3

ANNEX 2

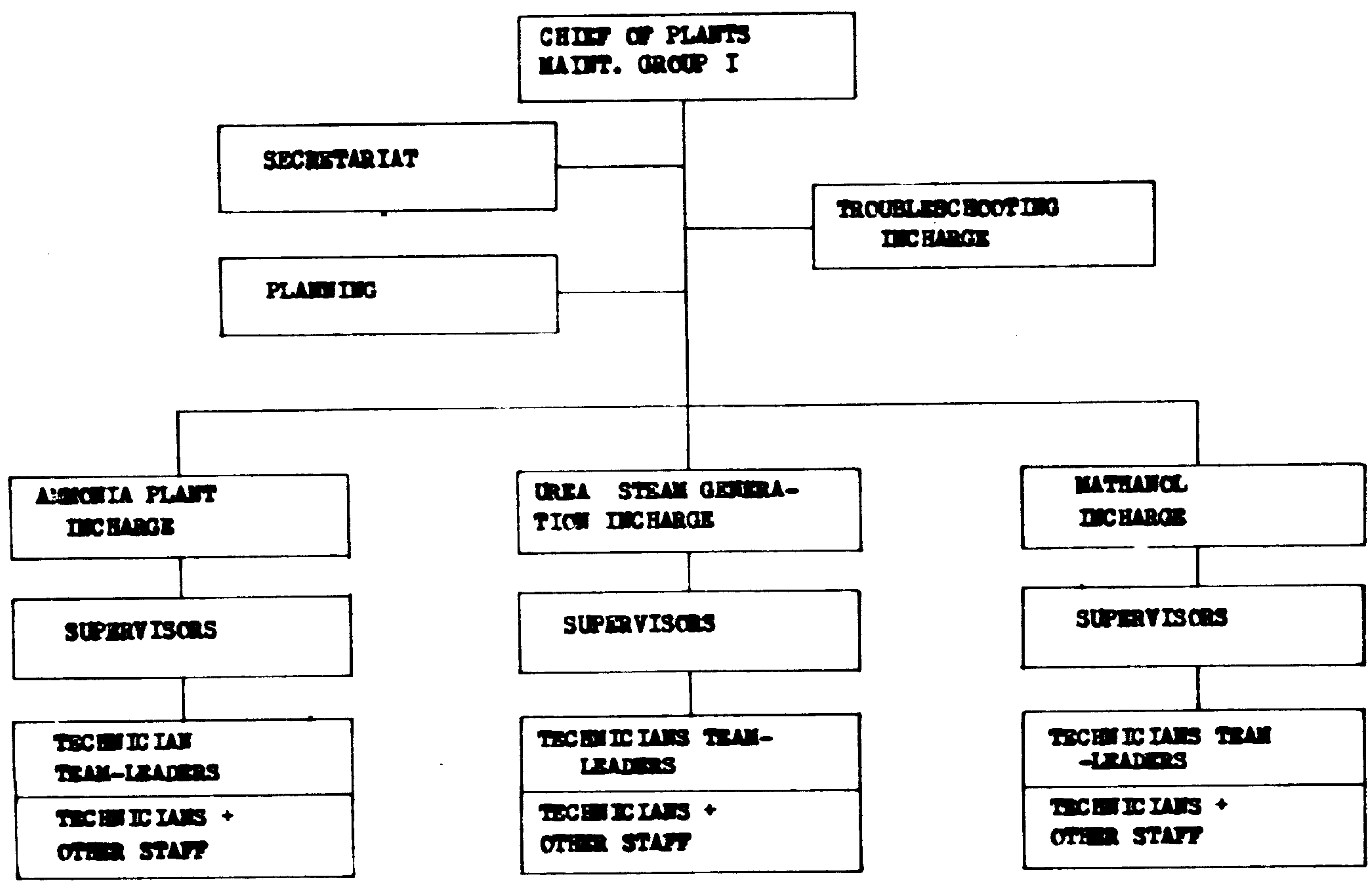
PROPOSED ORGANISATION STRUCTURE

MECHANICAL MAINTENANCE DEPARTMENT



TROMBAY UNIT

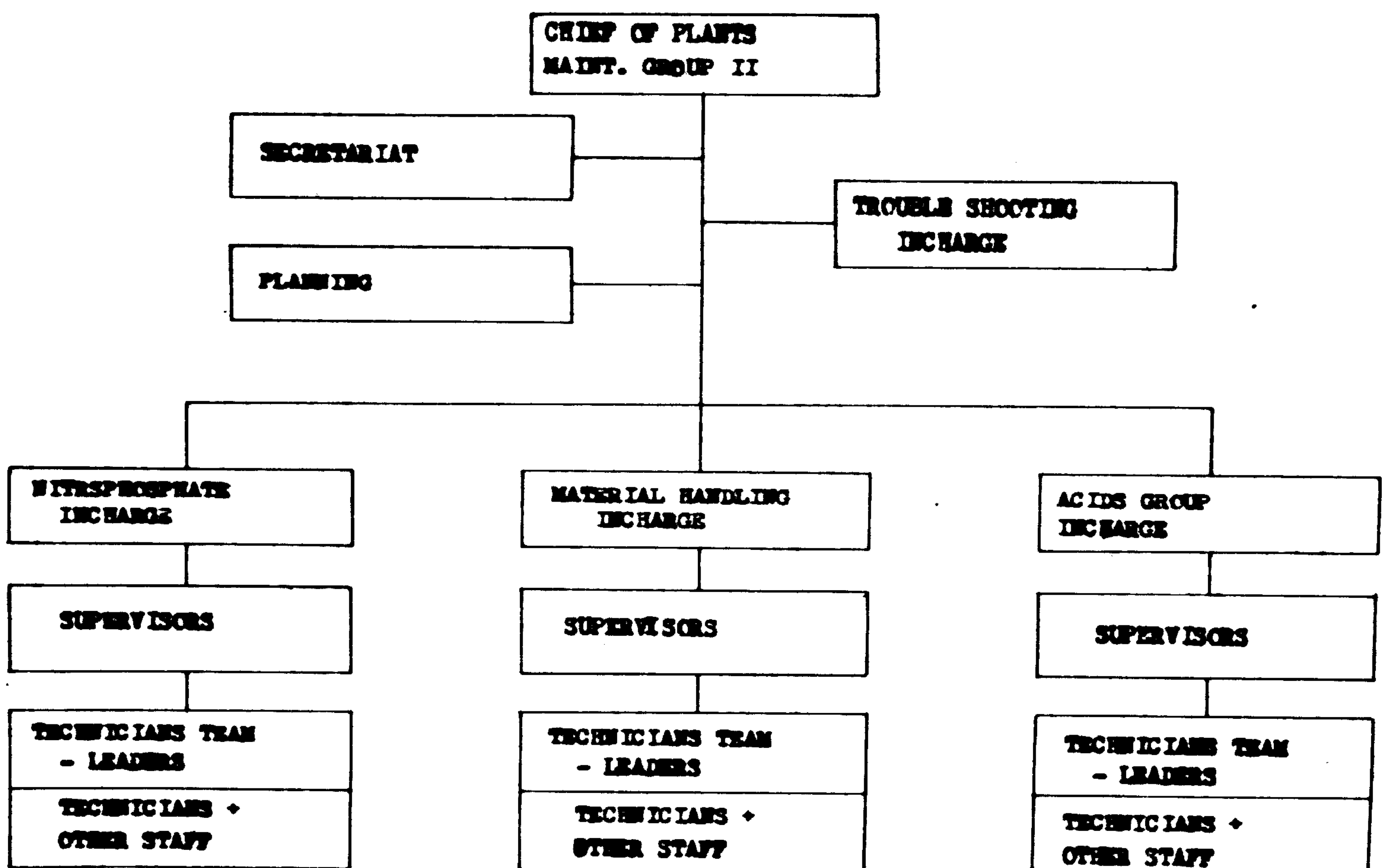
SUGGESTED SET - UP FOR PLANTS MAINTENANCE, GROUP I



TROMBAY UNIT
SINDRI UNIT

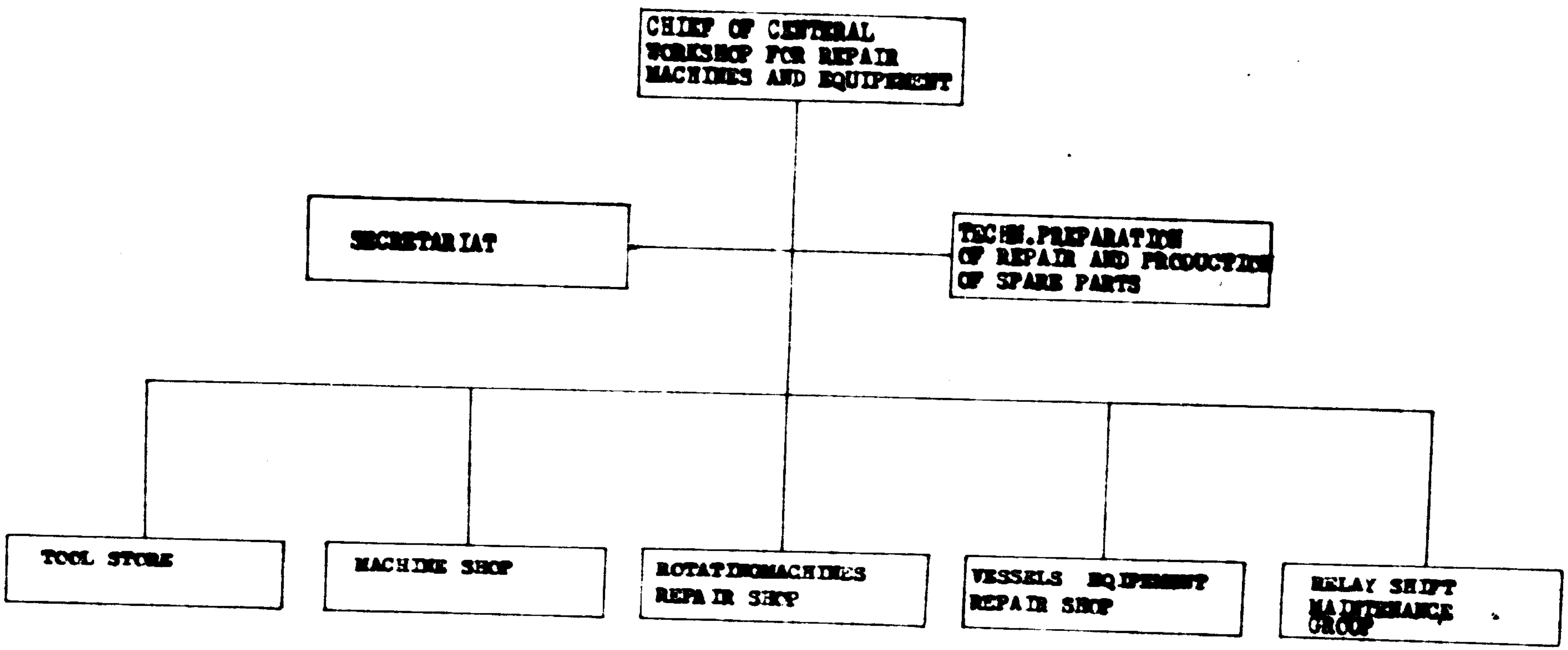
ANNEX 4

SUGGESTED SET-UP FOR PLANT MAINTENANCE, GROUP II



TROMBAY UNIT
SINDRI UNIT

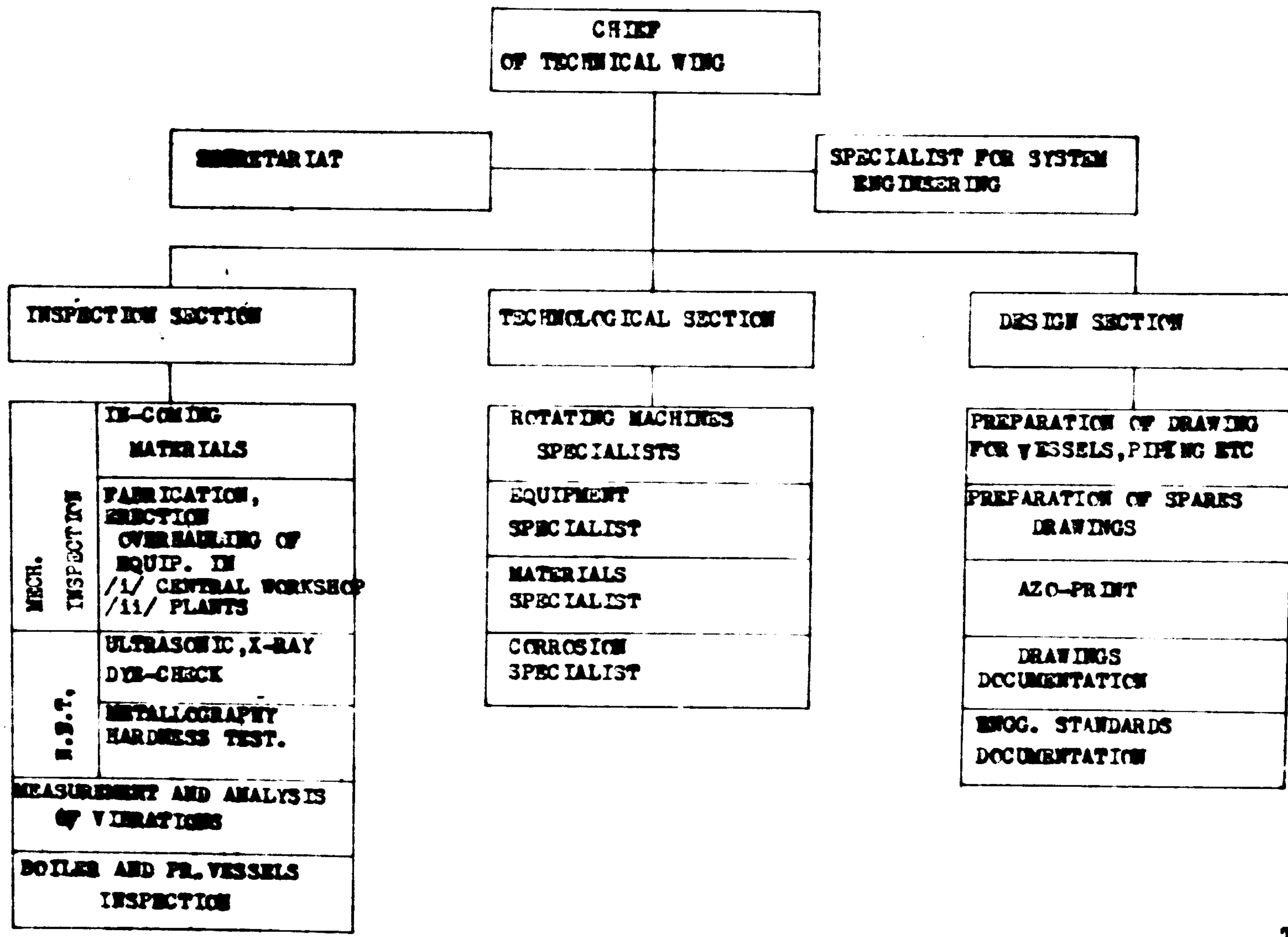
SUGGESTED SET - UP FOR CENTRAL WORKSHOP



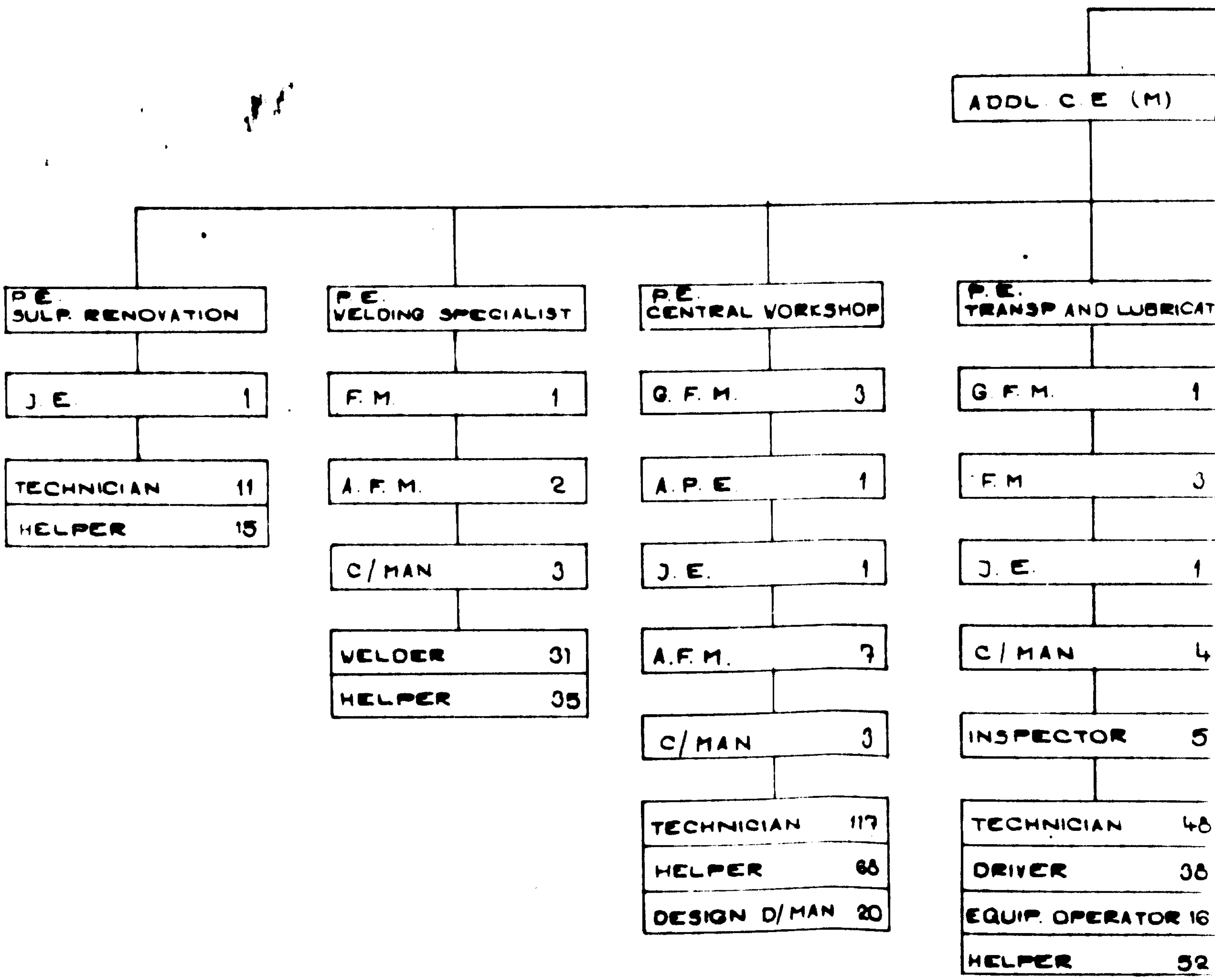
TROMBAY UNIT
SINDRI UNIT

ANNEX 6.

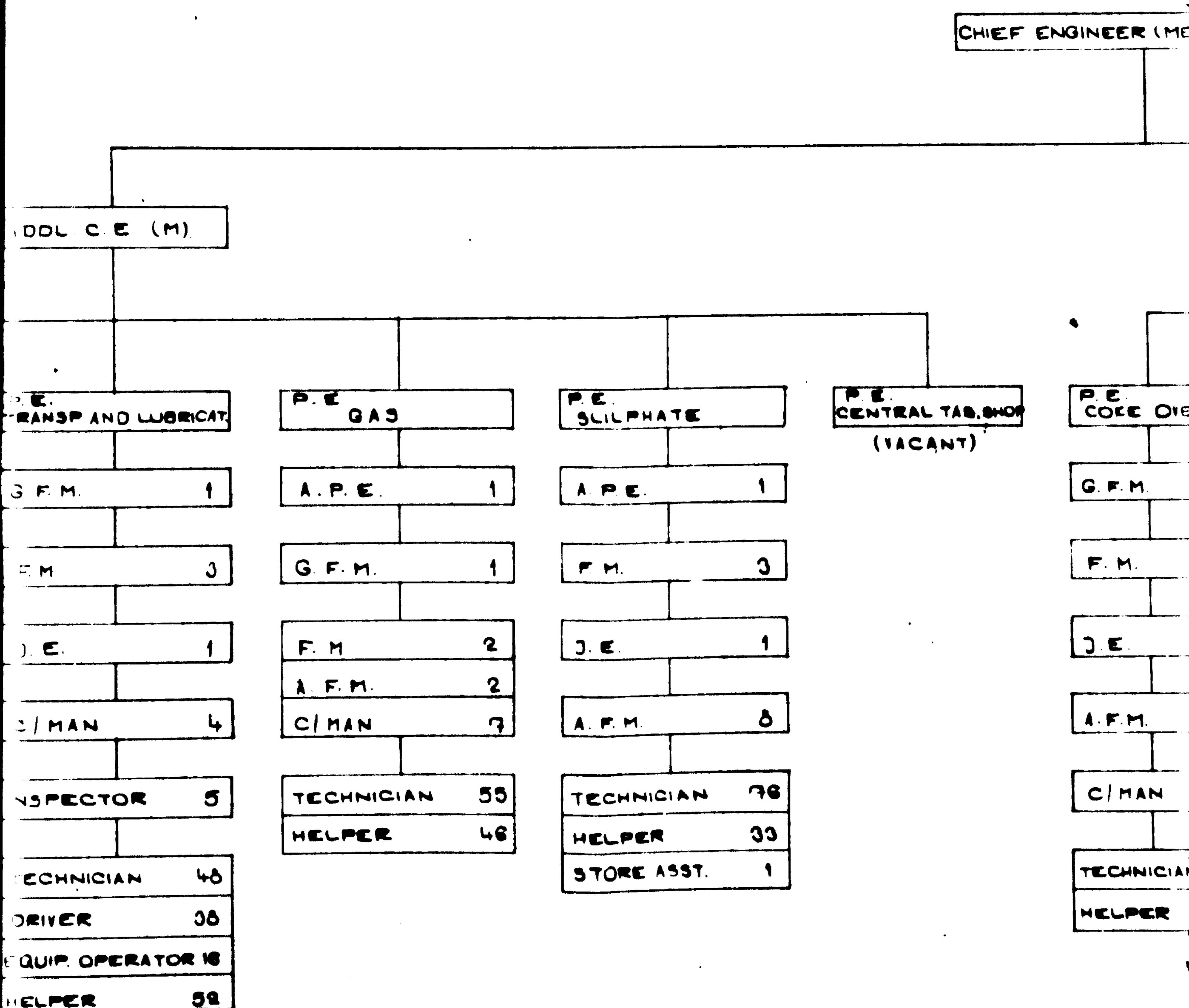
PROPOSED SET - UP OF TECHNICAL WING OF MECH.
MAINT. DEPTT.



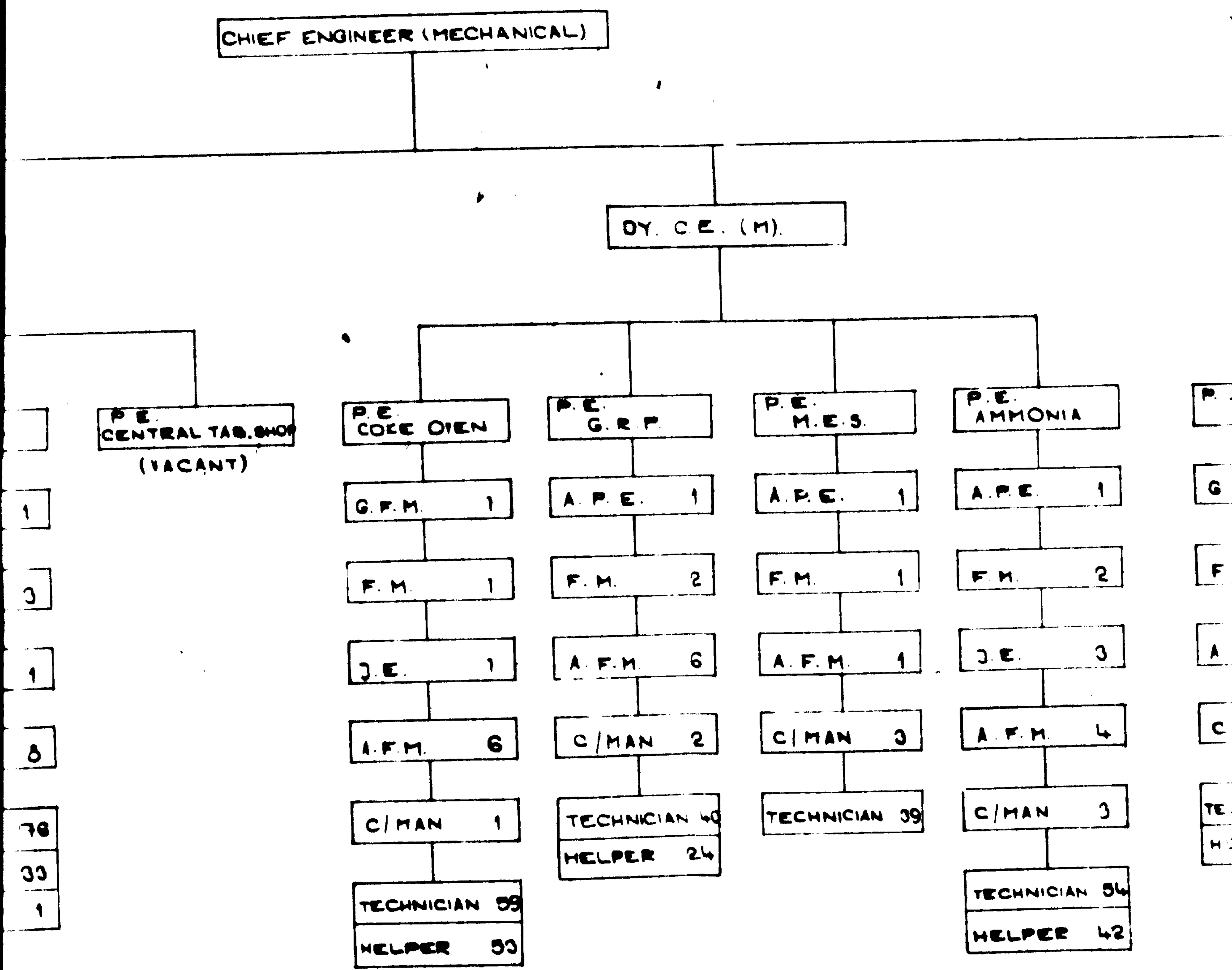
TROMBAY UNIT
SINDRI UNIT.


ADDL. C. E. (M)
P.E. SULP. RENOVATION
J. E. 1
TECHNICIAN 11
HELPER 15
P.E. VELDING SPECIALIST
F. M. 1
A. F. M. 2
C/MAN 3
VELDER 31
HELPER 35
P.E. CENTRAL VORKSHOP
G. F. M. 3
A. P. E. 1
J. E. 1
A.F. M. 7
C/MAN 3
TECHNICIAN 117
HELPER 66
DESIGN D/MAN 20
P.E. TRANSP AND LUBRICAT
G. F. M. 1
F. M 3
J. E. 1
C/MAN 4
INSPECTOR 5
TECHNICIAN 48
DRIVER 38
EQUIP. OPERATOR 16
HELPER 52

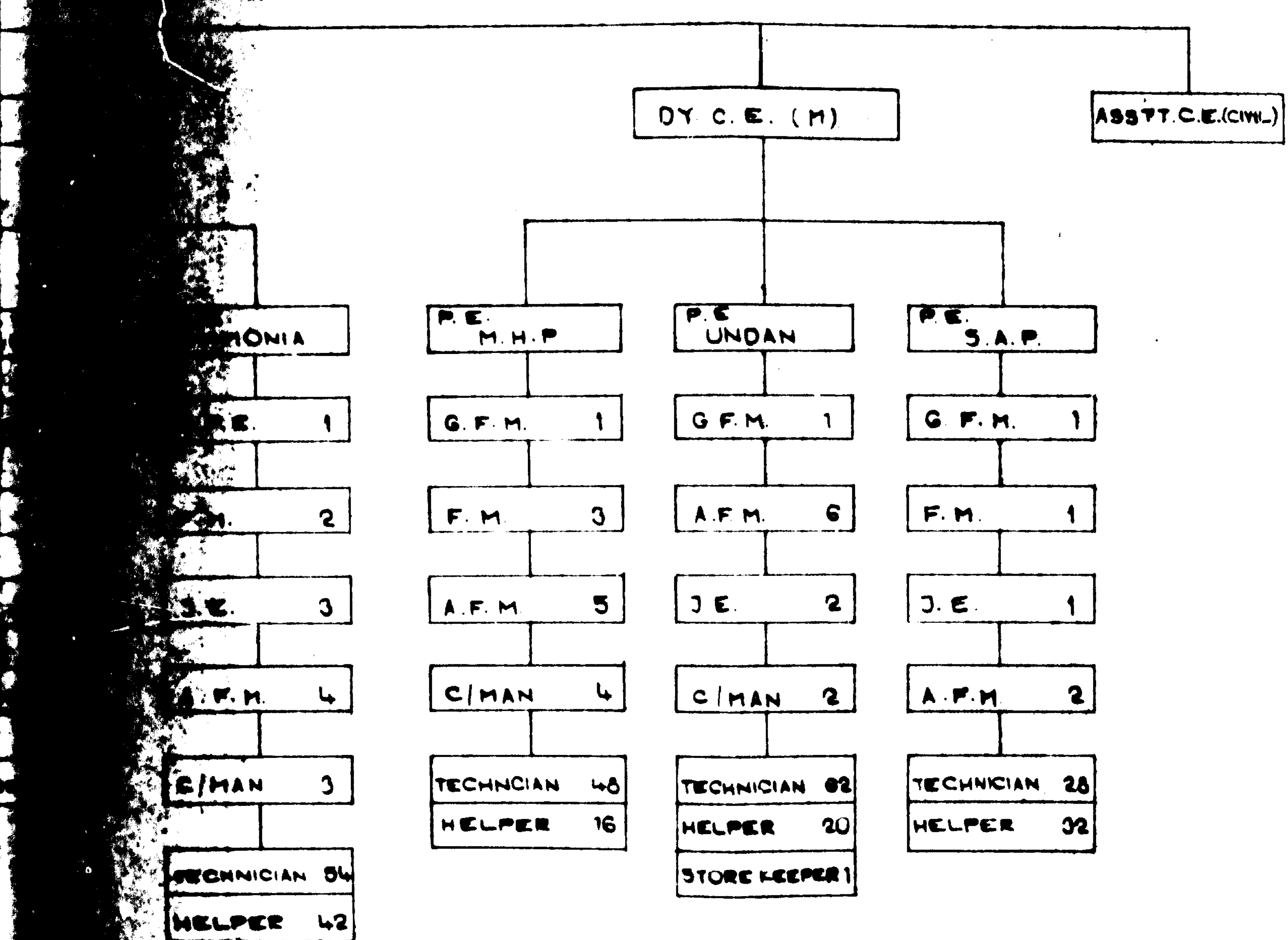
ORGANIZATION CHART ME



ORGANIZATION CHART MECHANICAL MAINTENANCE



SECTION 3

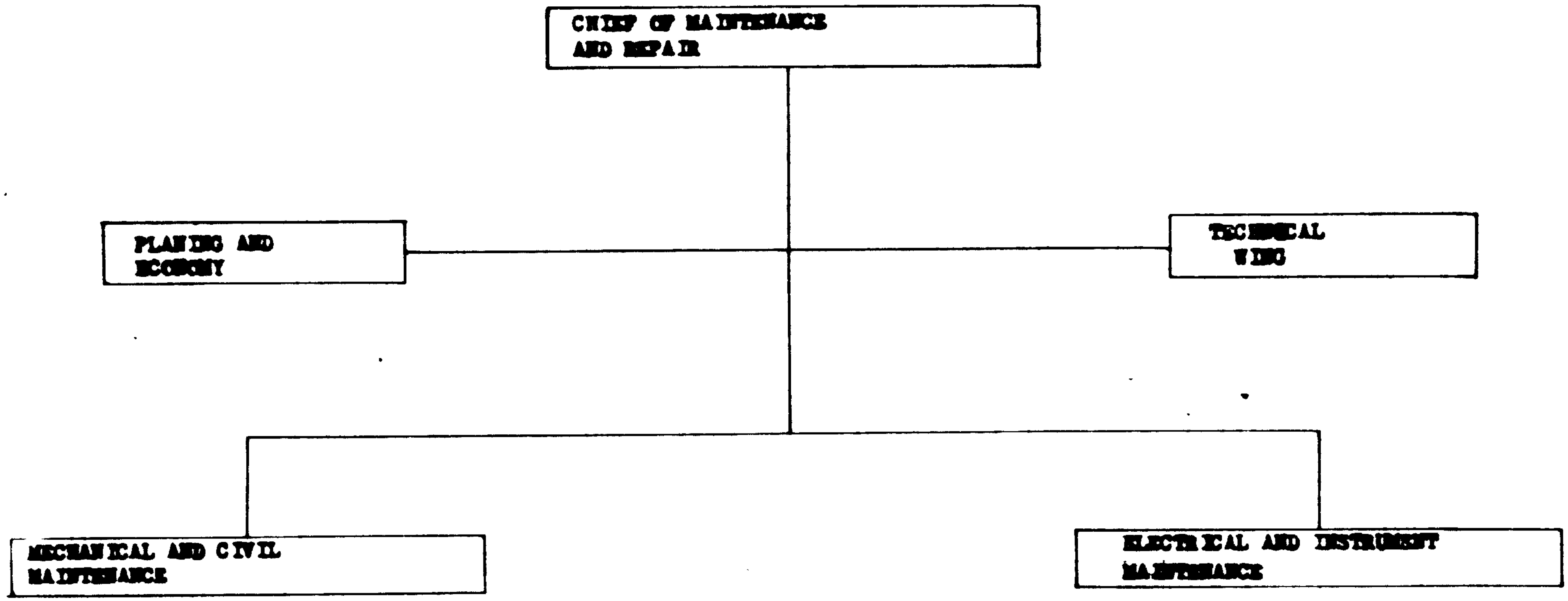


SECTION 4

SINDRI UNIT

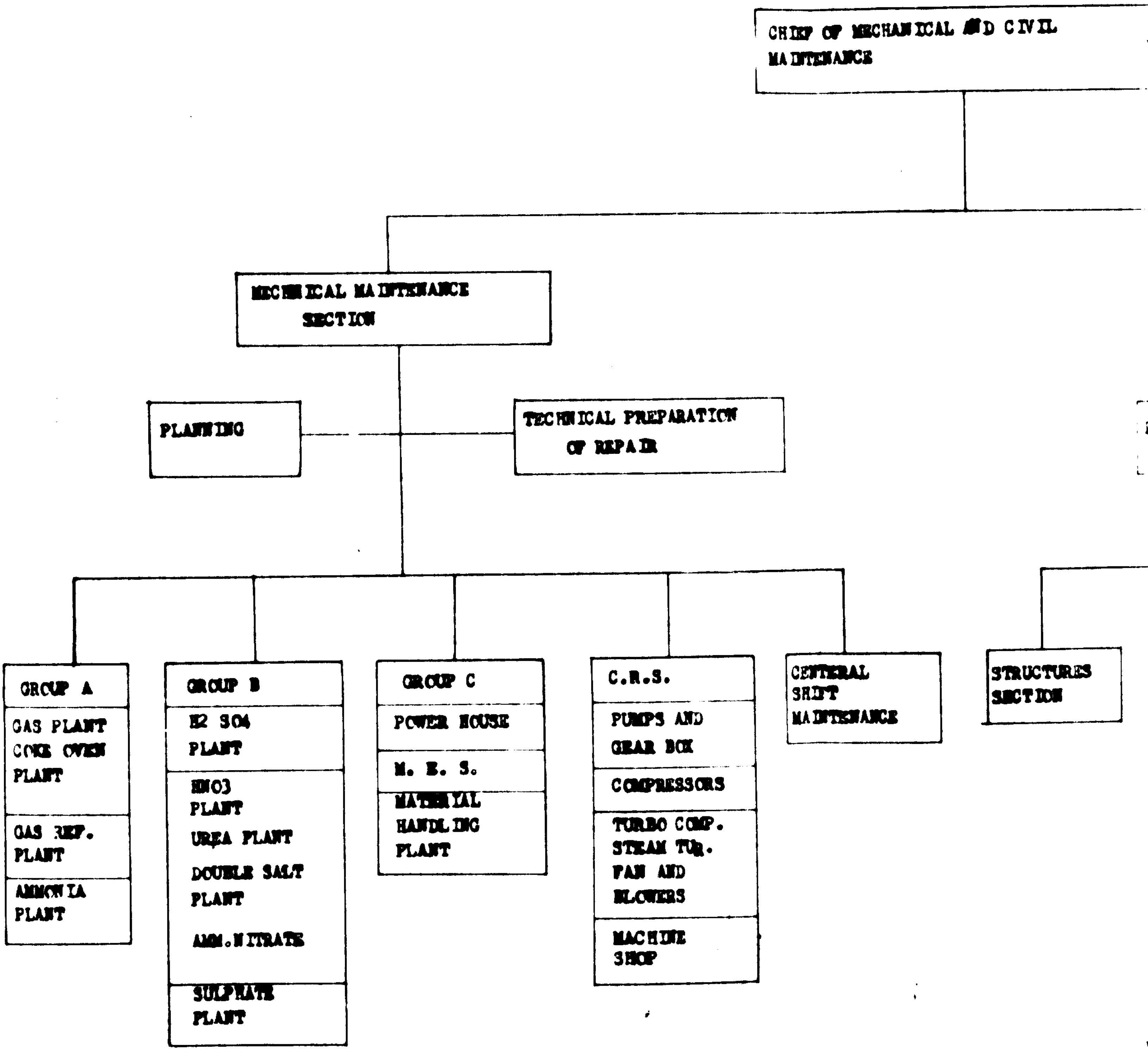
PROPOSED ORGANIZATION STRUCTURE

MAINTENANCE



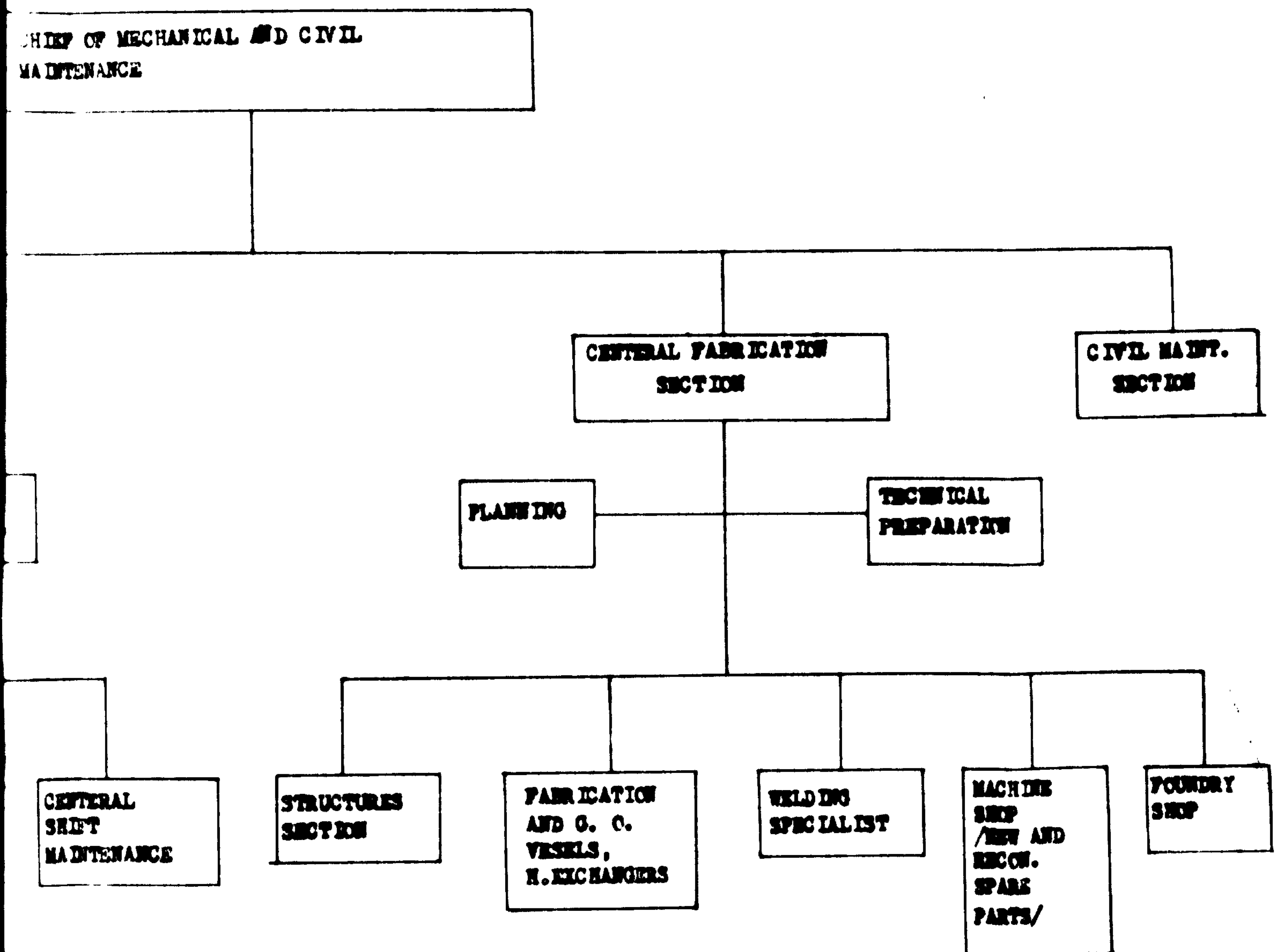
SINDRI UNIT

PROPOSED ORGANISATION STRUCTURE MECHANICAL MAINTENA[NCE]
AND FABRICATION DEPARTMENT



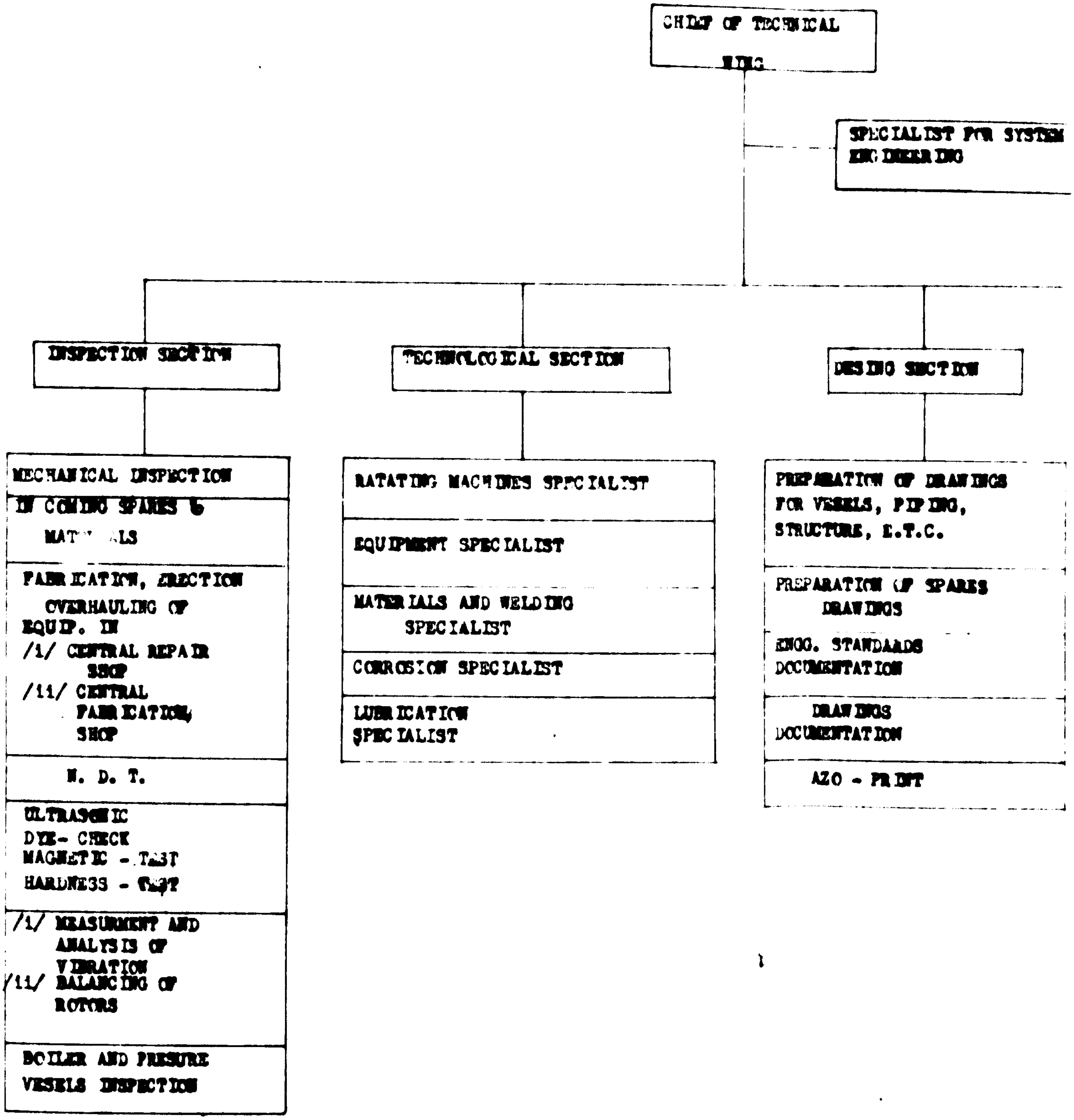
ATION STRUCTURE MECHANICAL MAINTENANCE

ABRICATION DEPARTMENT

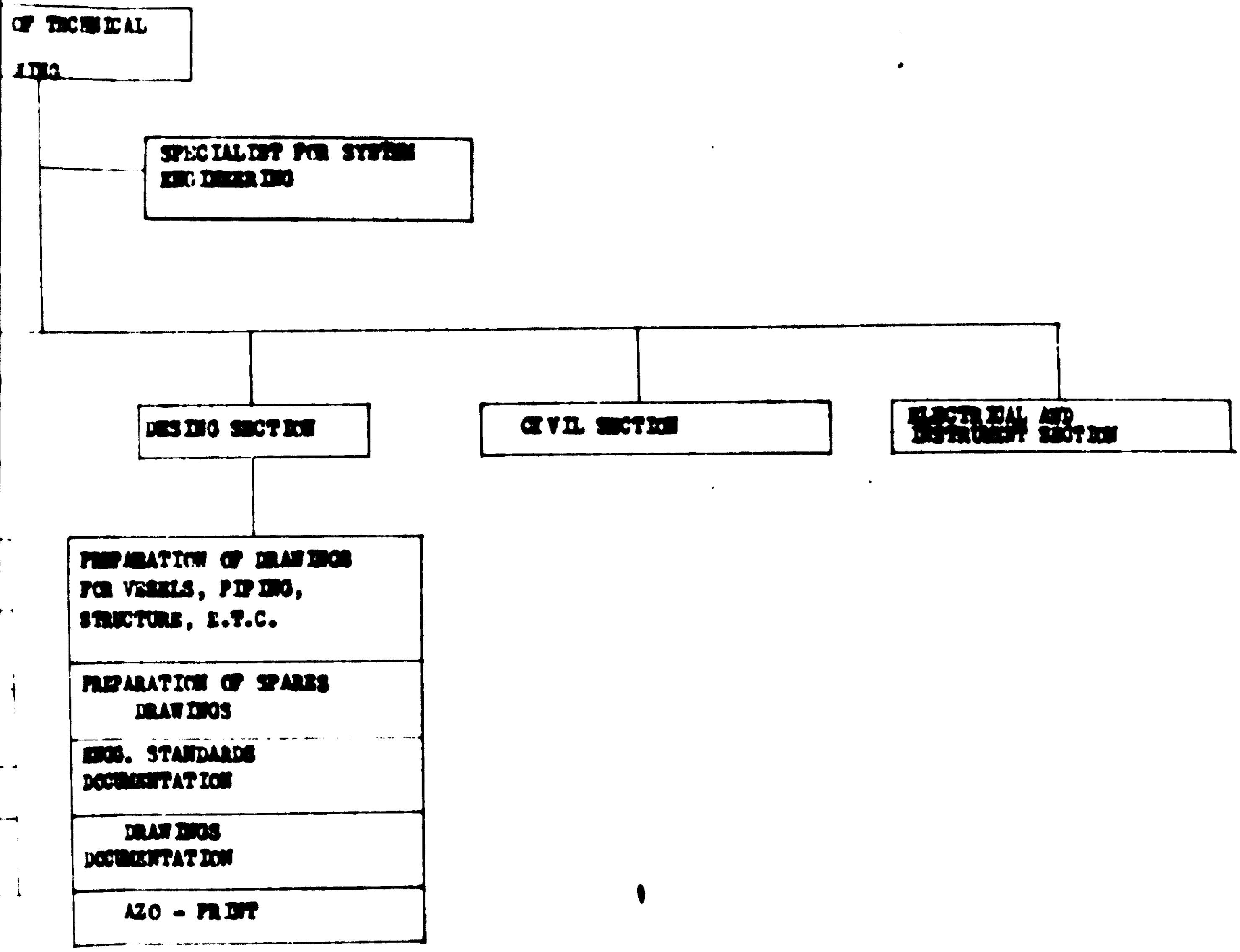


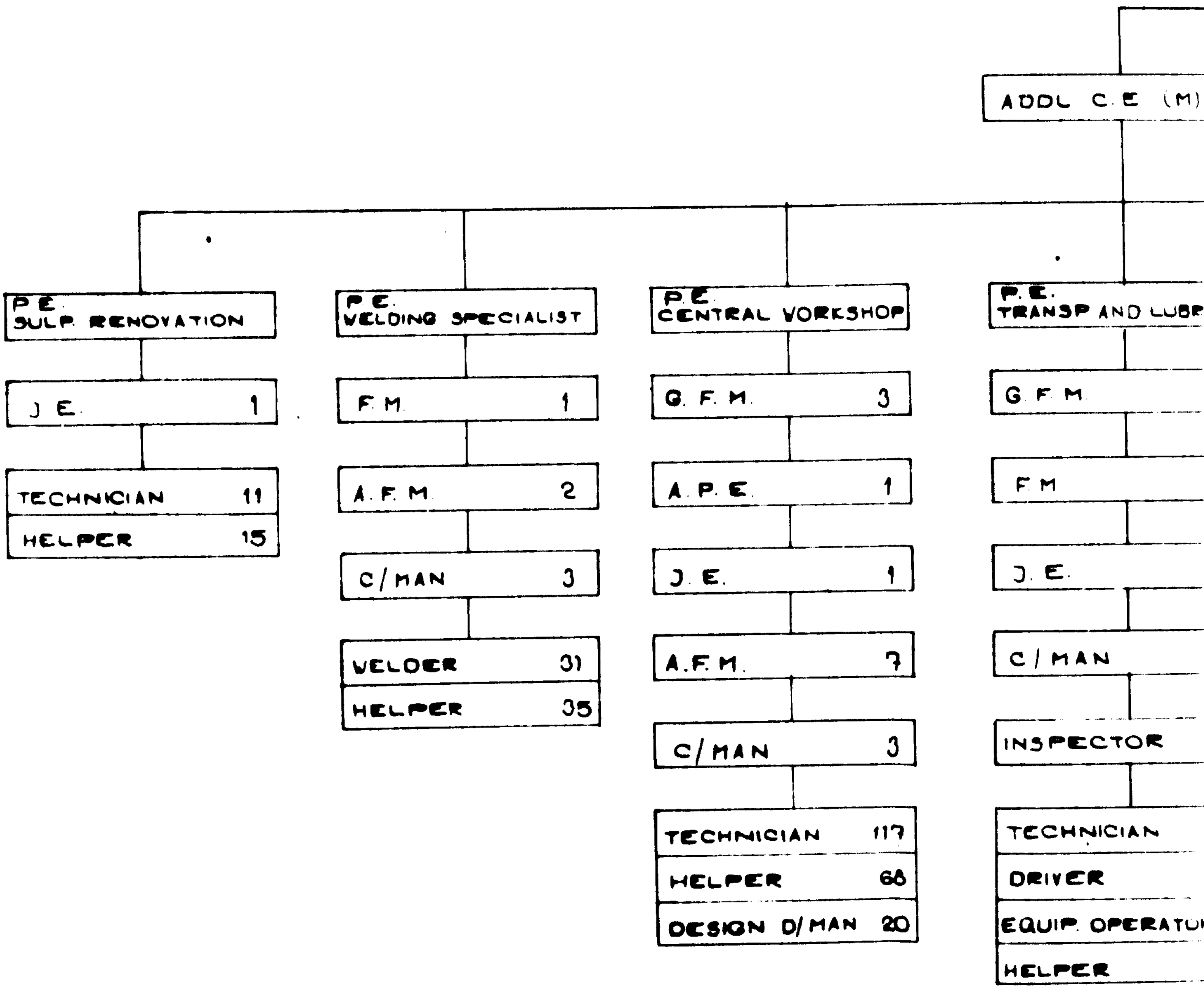
SINDRI UNIT

PROPOSED SET - UP OF TECHNICAL WING



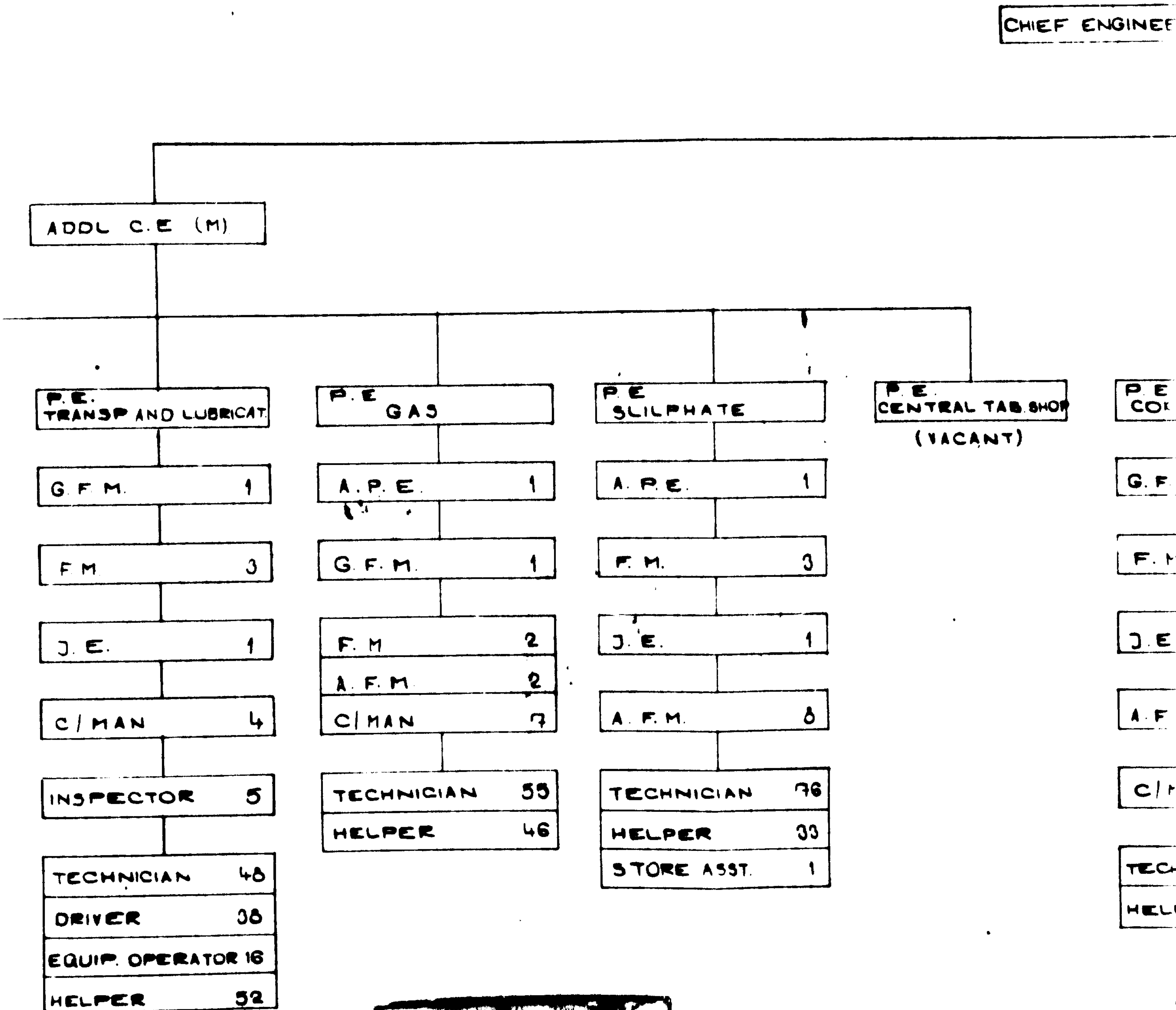
SET - UP OF TECHNICAL WING



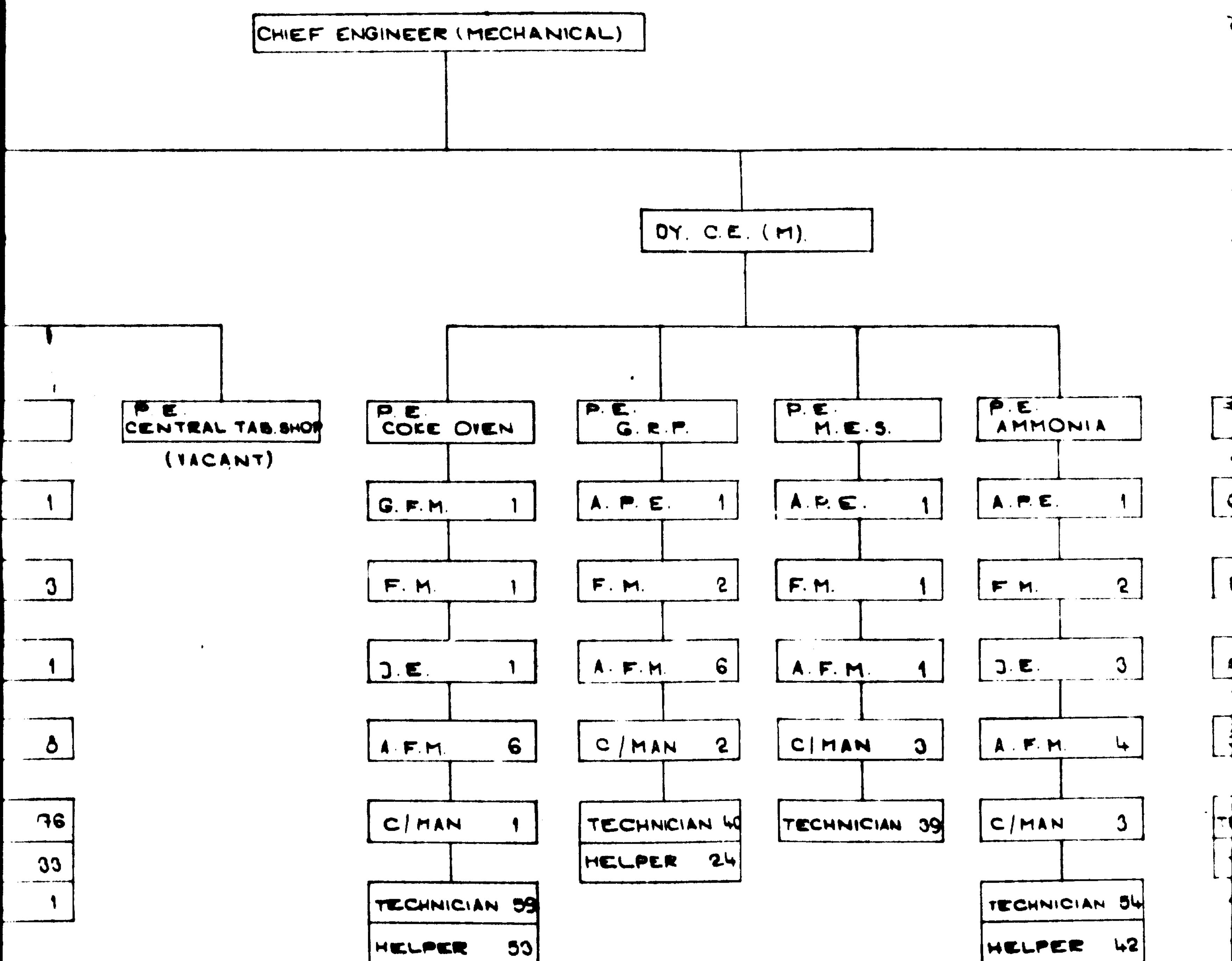


ADDL. C.E. (M)
P.E. SULP. RENOVATION
J.E. 1
TECHNICIAN 11
HELPER 15
P.E. VELDING SPECIALIST
F.M. 1
A.F.M. 2
C/MAN 3
VELDER 31
HELPER 35
P.E. CENTRAL VORKSHOP
G.F.M. 3
A.P.E. 1
J.E. 1
A.F.M. 7
C/MAN 3
TECHNICIAN 117
HELPER 68
DESIGN D/MAN 20
P.E. TRANSP AND LUBR
G.F.M.
F.M.
J.E.
C/MAN
INSPECTOR
TECHNICIAN
DRIVER
EQUIP. OPERATO
HELPER

ORGANIZATION CHART



ORGANIZATION CHART MECHANICAL MAINTENANCE



SECTION 3

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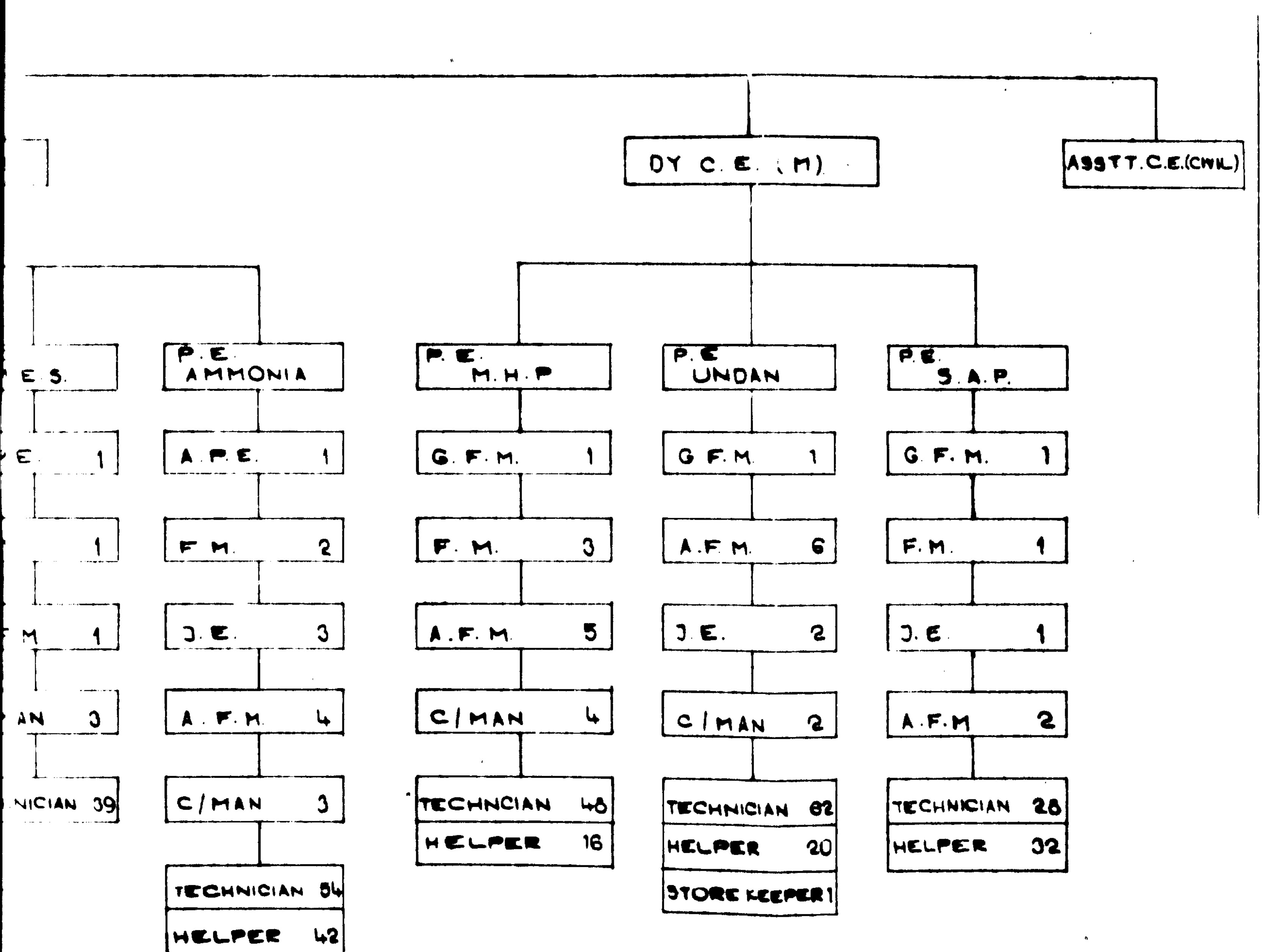


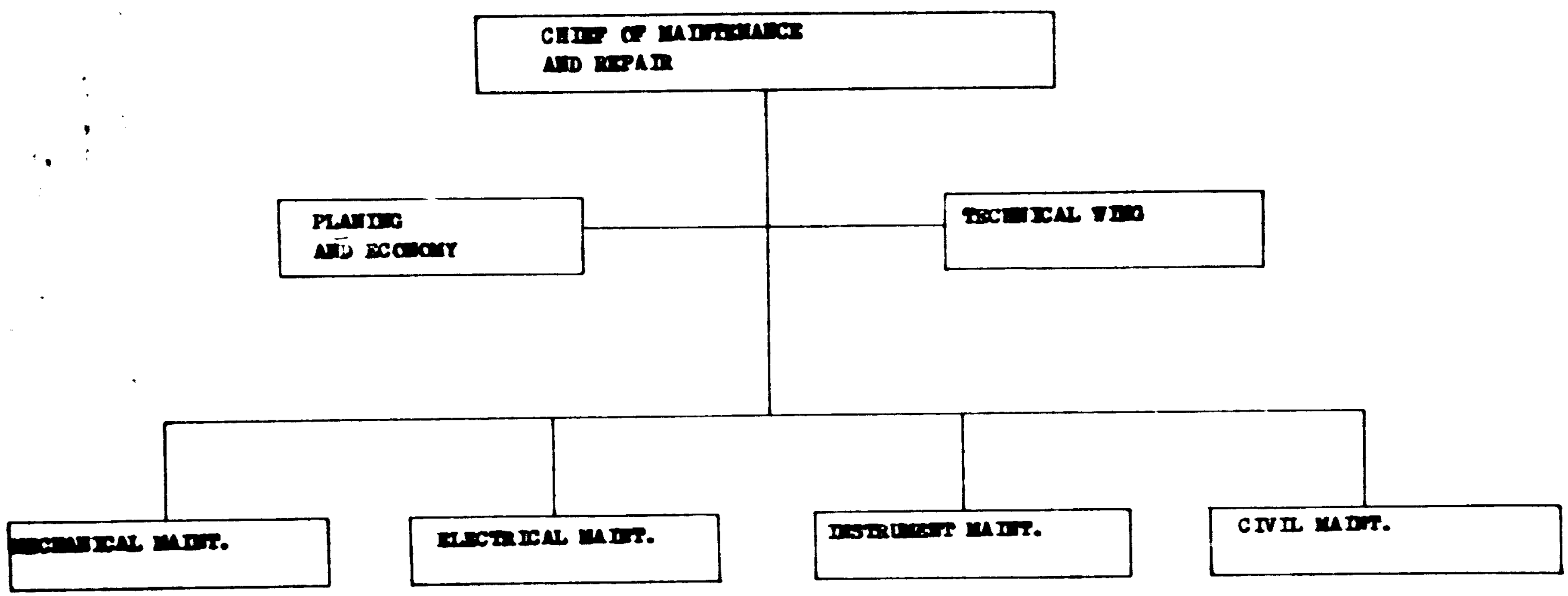
SECTION 4

SINDRI UNIT

ANNEX 11.

PROPOSED ORGANISATION STRUCTURE

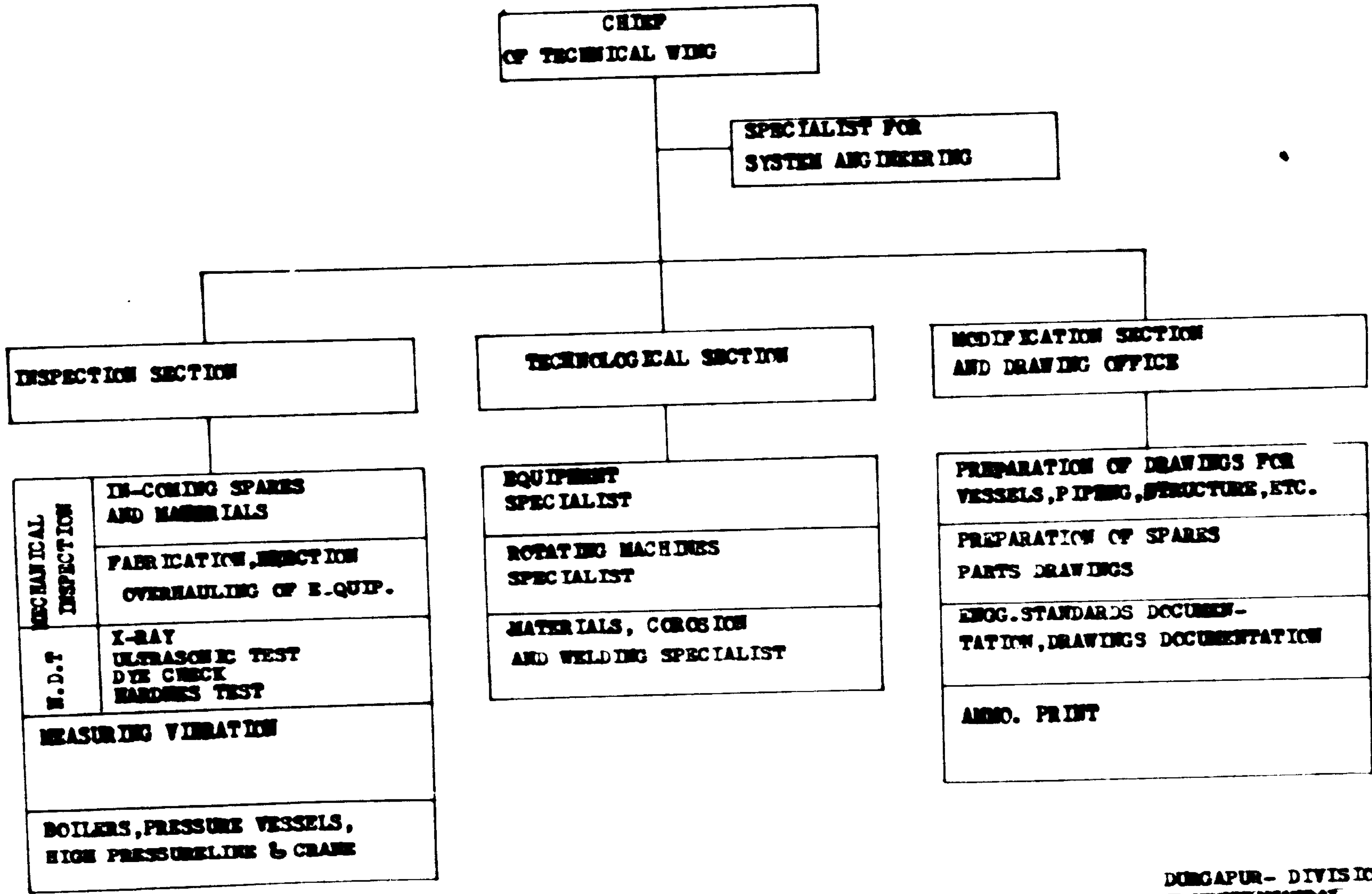
MAINTENANCE AND REPAIR



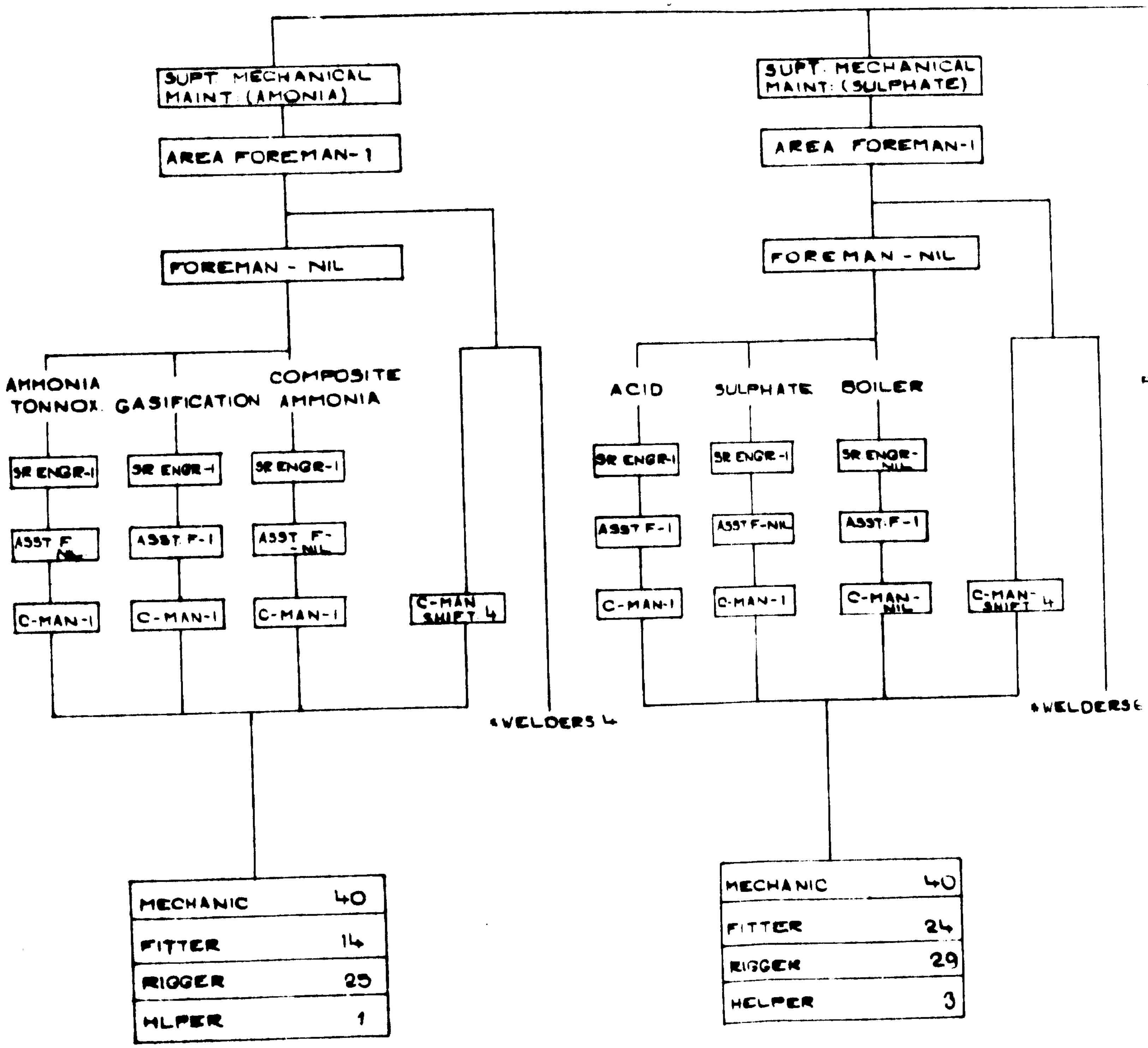
DURGAPUR - DIVISION

ANNEX 12

PROPOSED SET - UP OF TECHNICAL WING

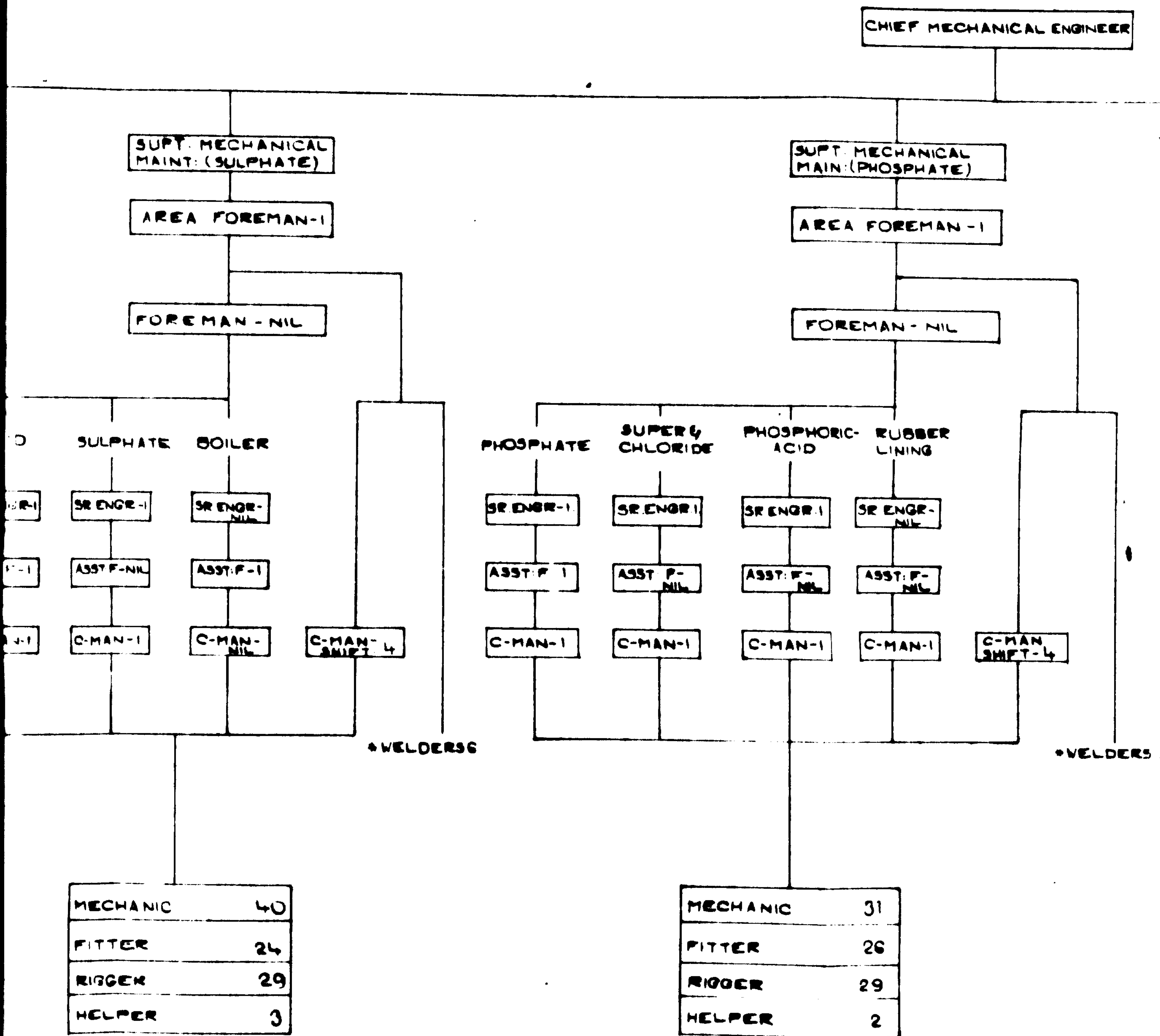


DURGAPUR- DIVISION
FACT UDYOGAMANDAL

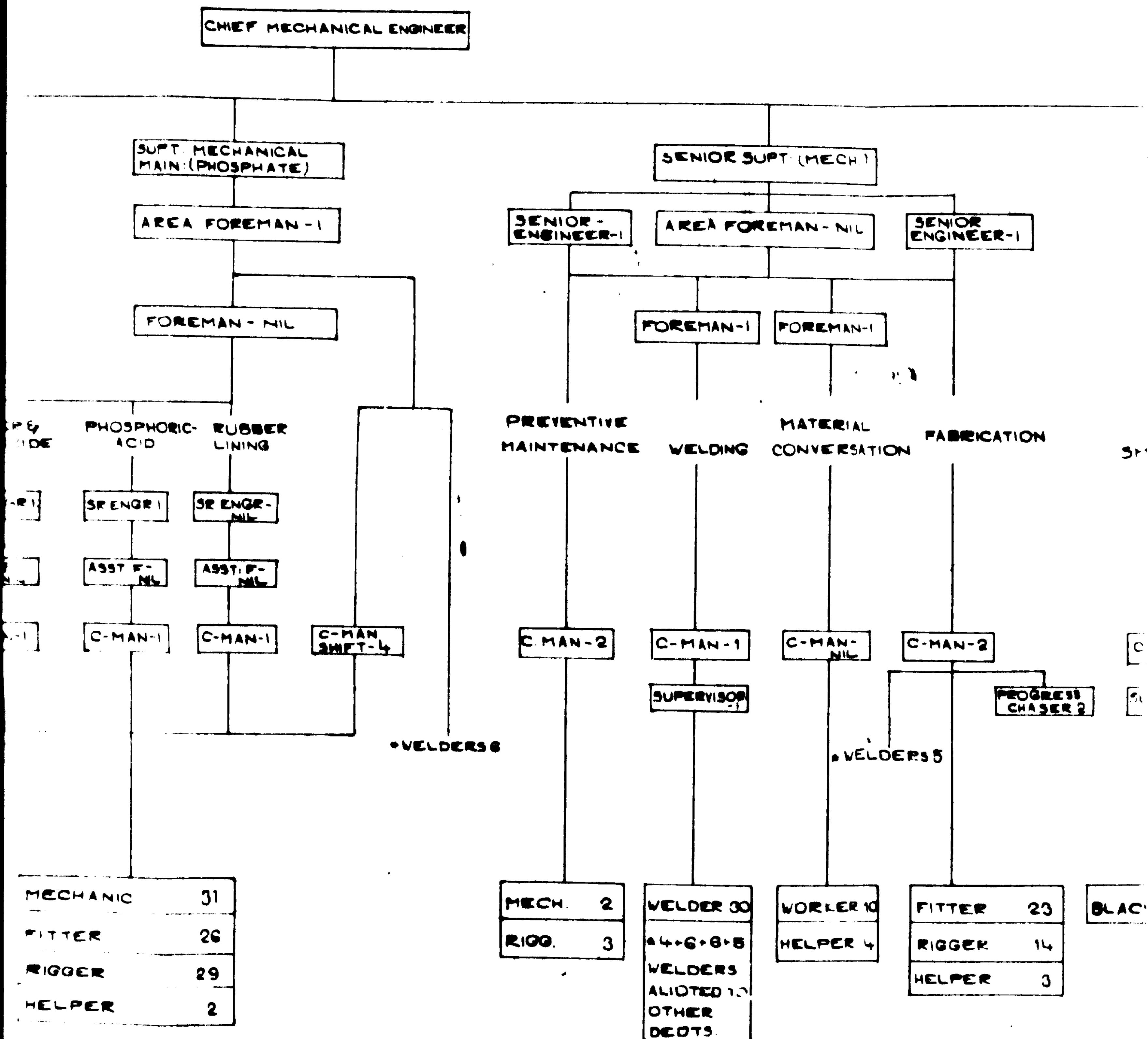


SUPT MECHANICAL MAINT (AMONIA)
AREA FOREMAN-1
FOREMAN - NIL
AMMONIA TONNOX
GASIFICATION
COMPOSITE AMMONIA
SR ENGR-1
SR ENGR-1
SR ENGR-1
ASST F NIL
ASST F-1
ASST F-NIL
C-MAN-1
C-MAN-1
C-MAN-1
C-MAN SHIFT 4
*WELDERS 4
MECHANIC 40
FITTER 14
RIGGER 25
HLPER 1
SUPT MECHANICAL MAINT (SULPHATE)
AREA FOREMAN-1
FOREMAN - NIL
ACID
SULPHATE
BOILER
SR ENGR-1
SR ENGR-1
SR ENGR-NIL
ASST F-1
ASST F-NIL
ASST F-1
C-MAN-1
C-MAN-1
C-MAN-NIL
C-MAN-SHIFT 4
*WELDERS
MECHANIC 40
FITTER 24
RIGGER 29
HELPER 3

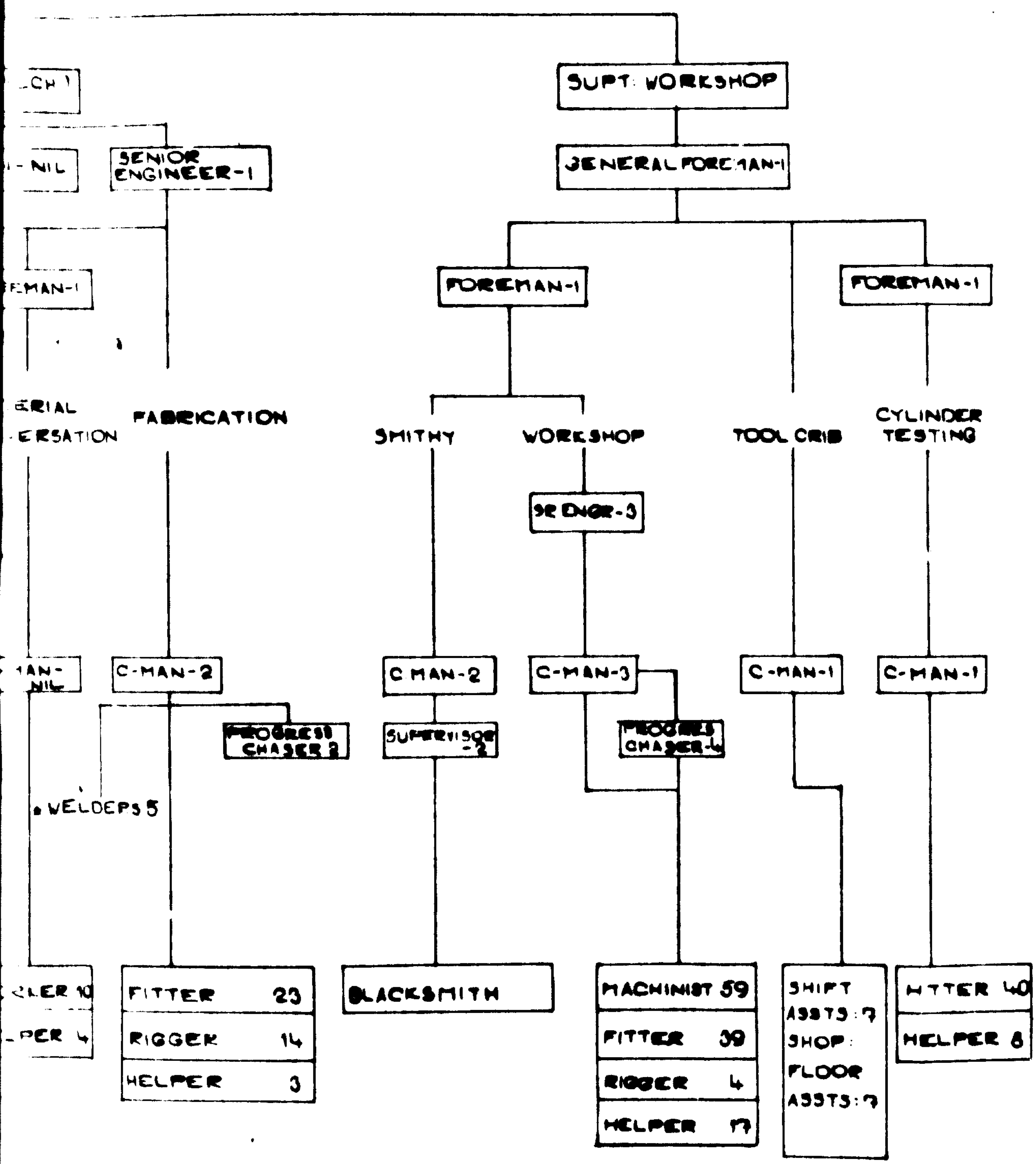
ORGANISATION CHART MECHNICAL



NISATION CHART MECHNICAL MANTENANCE



SECTION 3

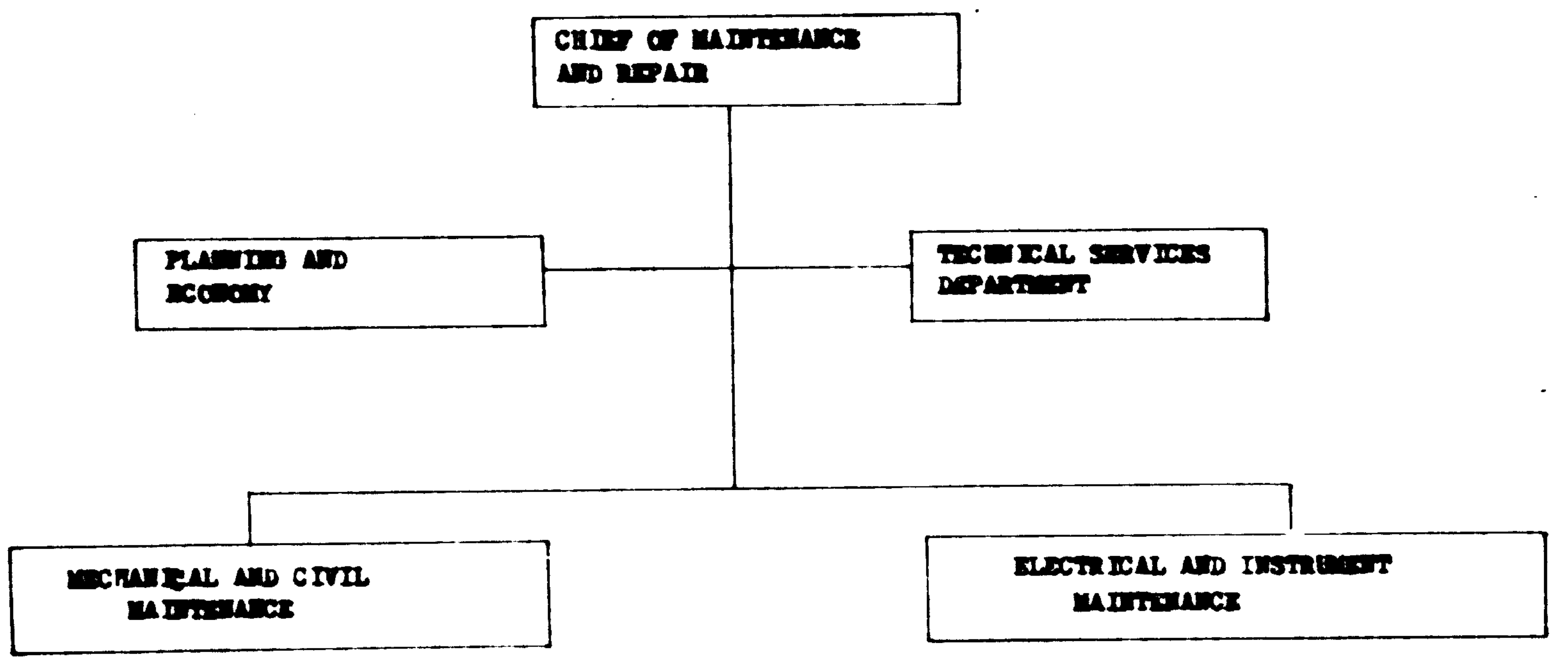


SECTION 4

FACT UDYOGAMANDAL

PROPOSED ORGANISATION STRUCTURE

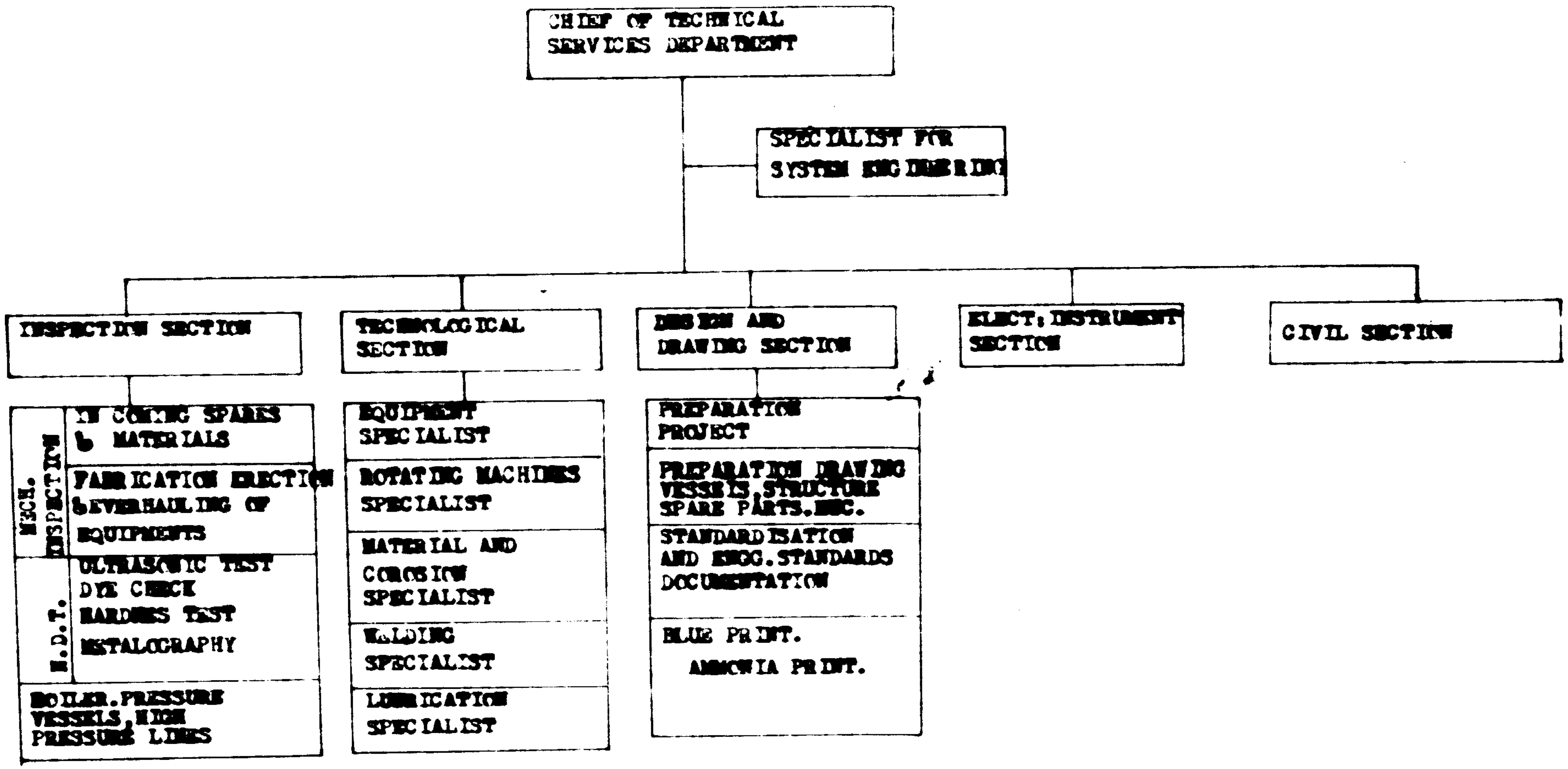
MAINTENANCE AND REPAIR



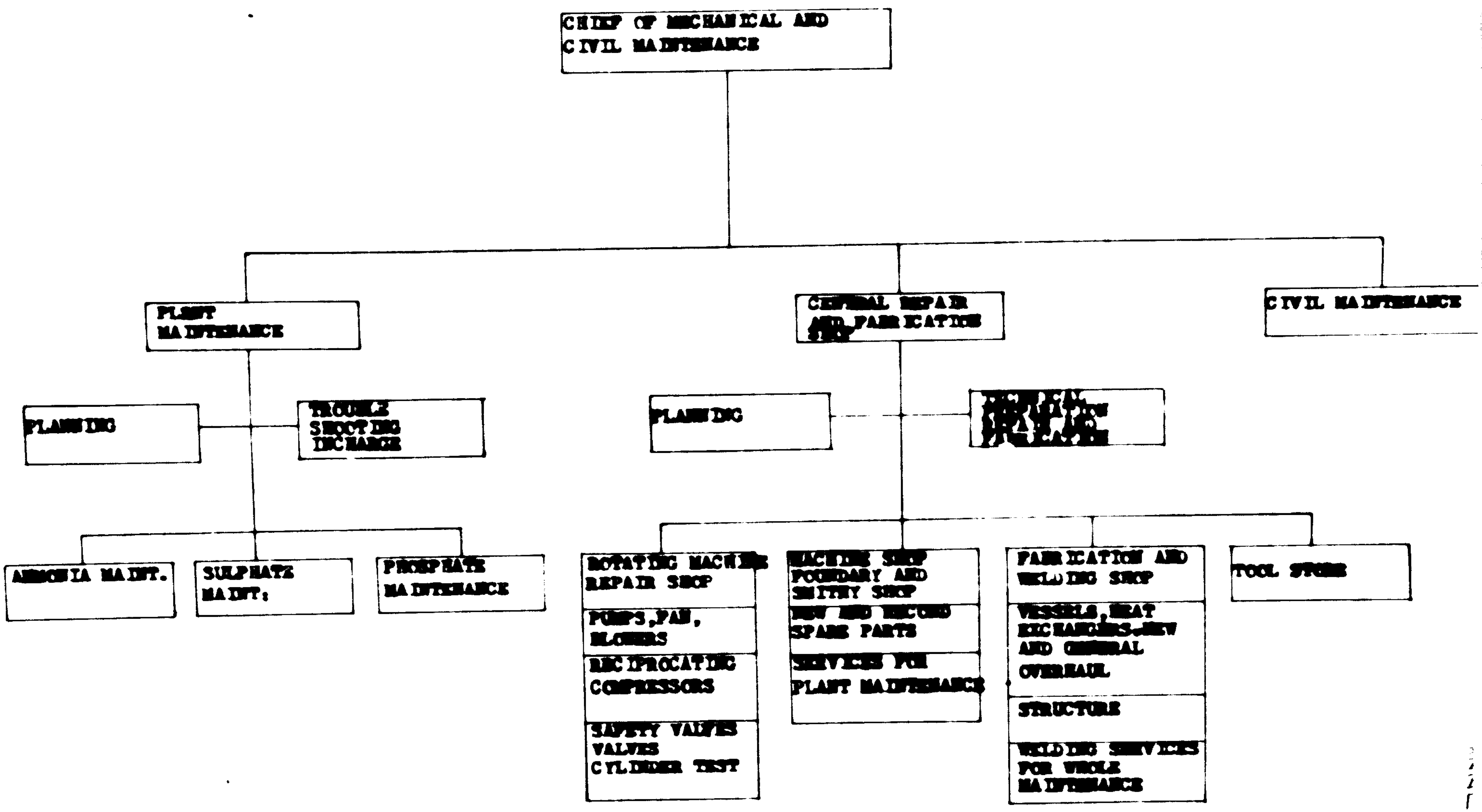
FACT UDYOGAMANDAL

ANNEX 15

PROPOSED SET - UP OF TECHNICAL SERVICES DEPARTMENT

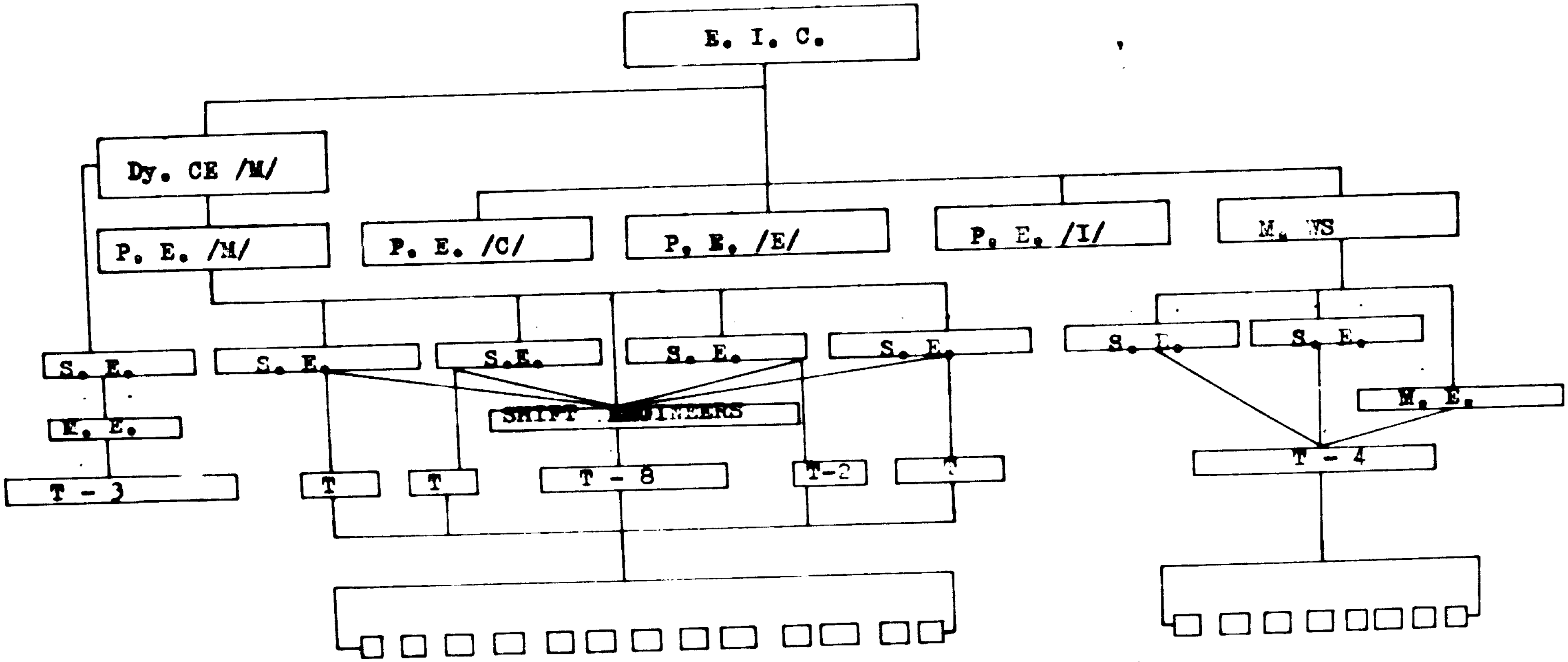


PROPOSED ORGANISATION STRUCTURE MECHANICAL AND CIVIL MAINTENANCE



ANNEX

ORGANISATION CHART /MECHANICAL MAINTENANCE



Fitters	47
Welder	11
Rigger	20
Blacksmith	1

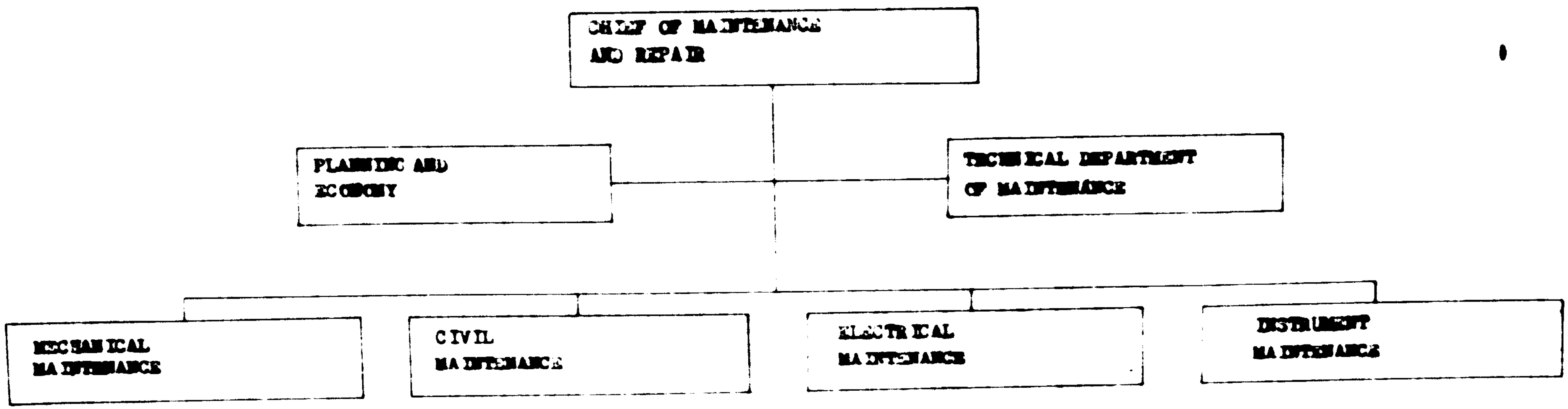
Machinist	24
Fitter	11
Welder	4
Blacksmith	4
Toolroom Asst.	4
Riggers	6
Helpers	4

COCHIN

ANNEX 18

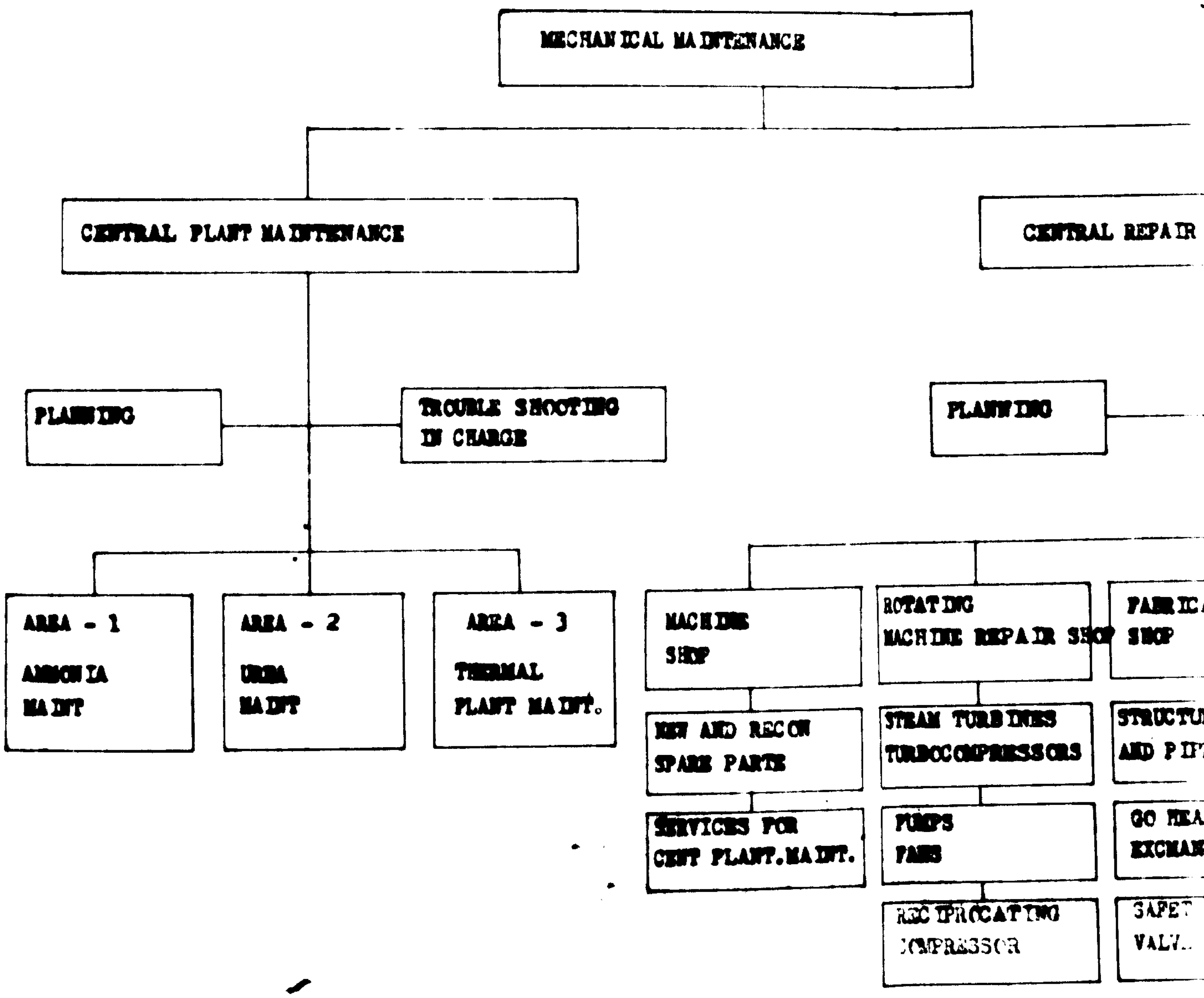
PROPOSED ORGANISATION STRUCTURE

MAINTENANCE AND REPAIR

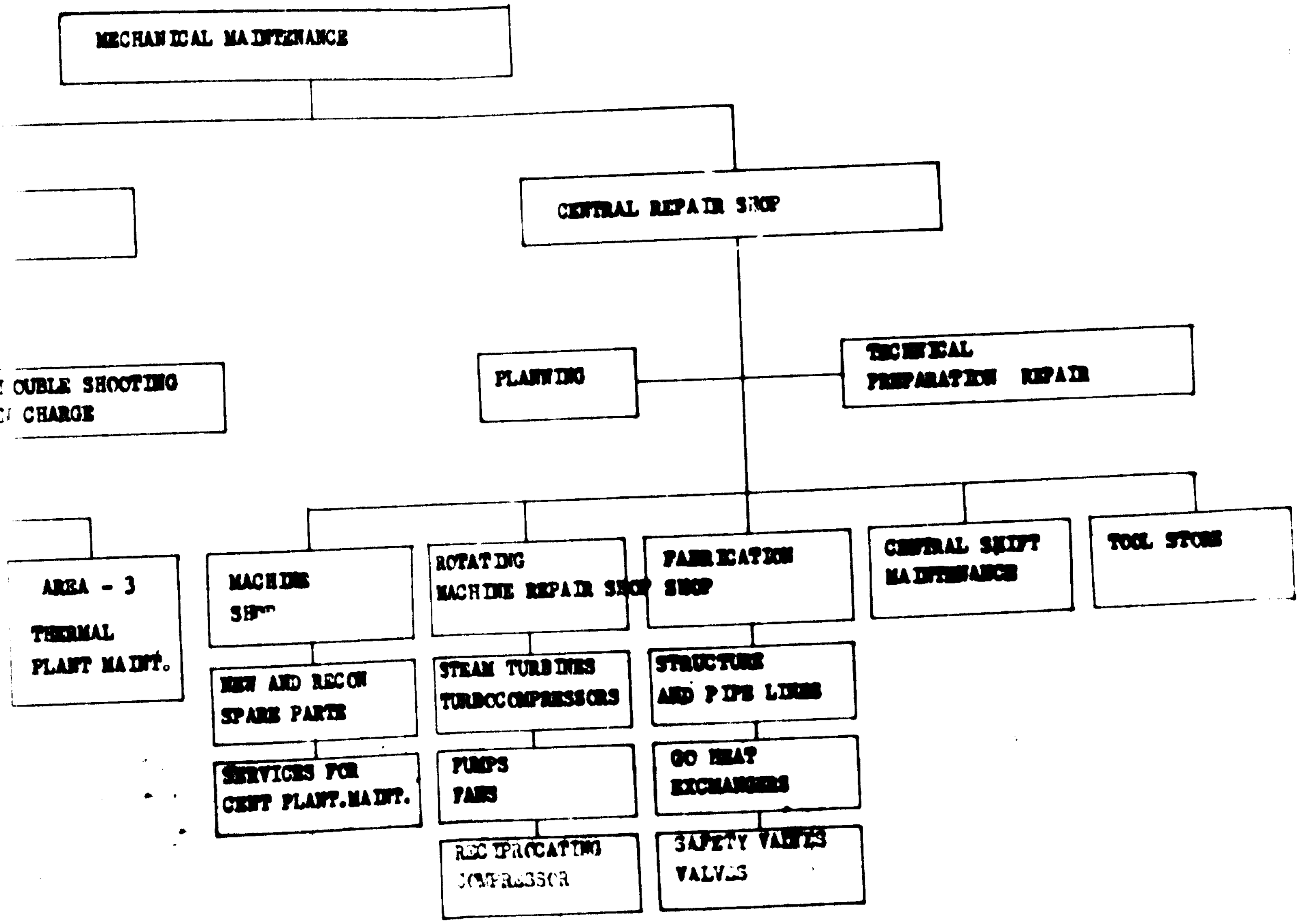


COCHIN

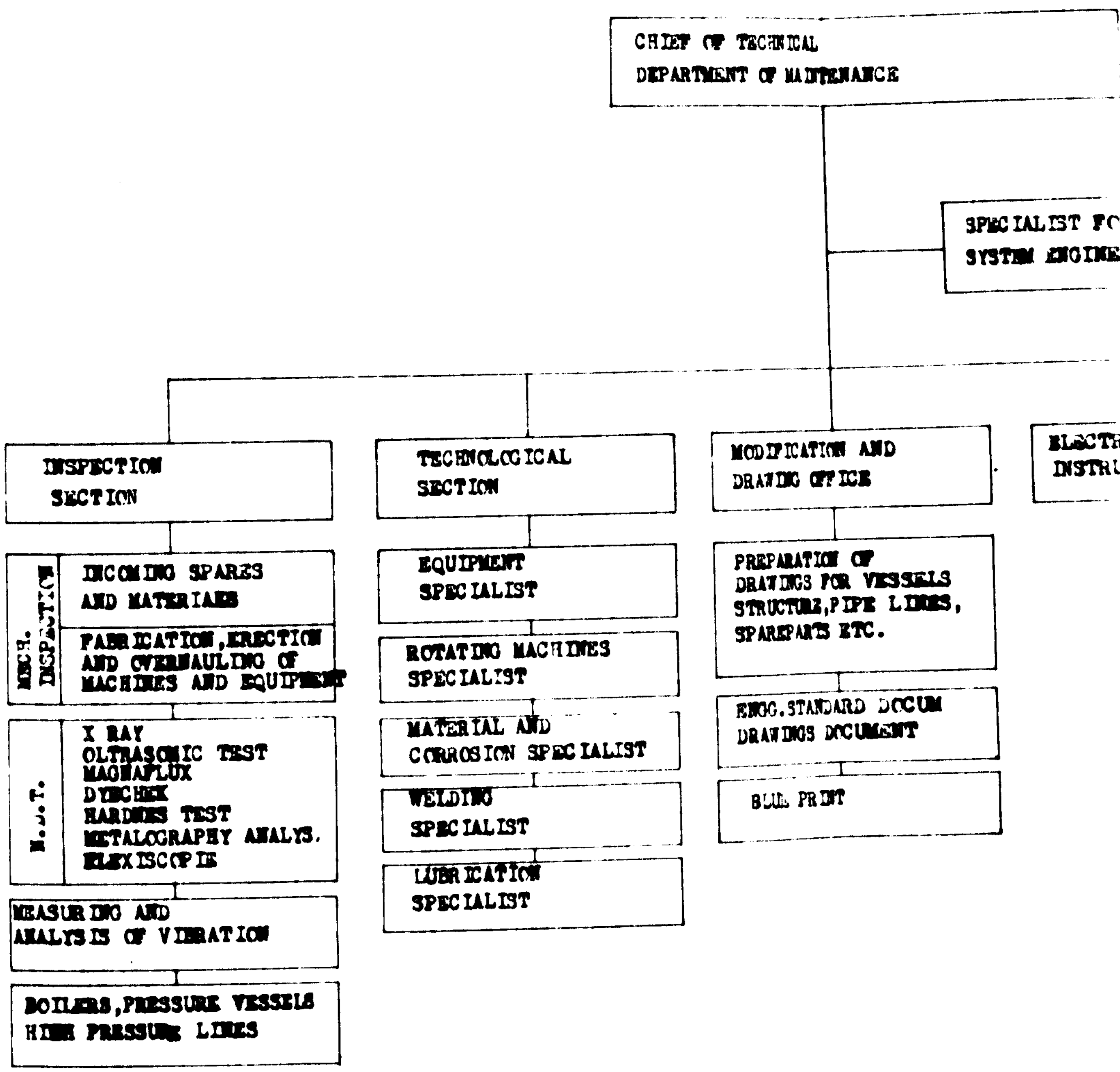
PROPOSED ORGANISATION STRUCTURE MECHANICAL MAINTENANCE



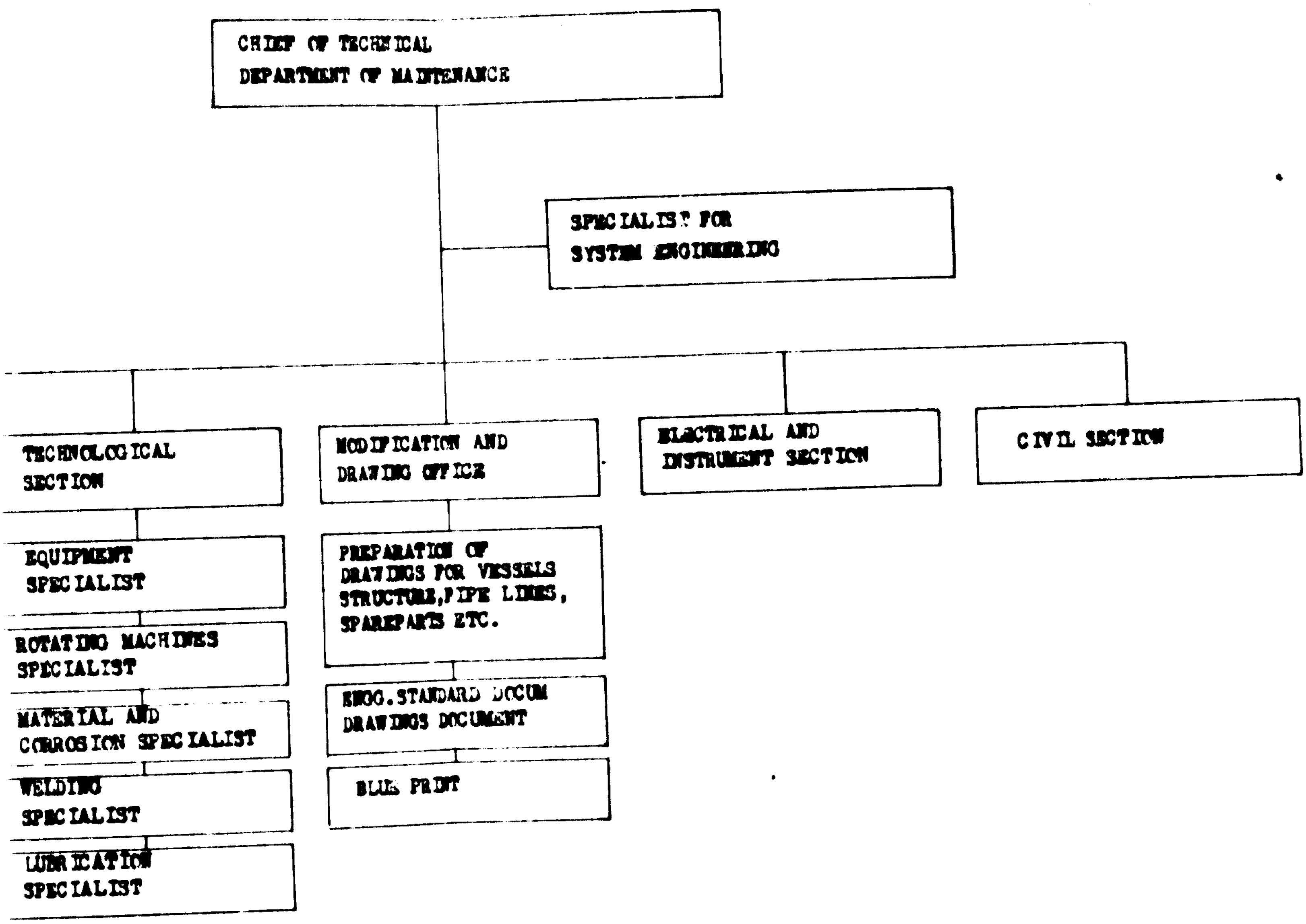
SED ORGANIZATION STRUCTURE MECHANICAL MAINTENANCE



PROPOSED SET - UP OF TECHNICAL DEPARTMENT OF MAINTENANCE



PROPOSED SET - UP OF TECHNICAL DEPARTMENT OF MAINTENANCE



GENERAL SPECIFICATION
- for Slurry Pumps

Description : Centrifugal slurry pump operating as single stage unit.

Materials handled : The pump will handle fertilizer which is made from the following materials and may be exposed to these materials, their sales, or compounds formed from mixtures of these materials.

Phosphate rock	Ammonium Nitrate	Limestone
Nitric Acid	Potassium Sulphate	
Phosphoric Acid	Ammonium Sulphate	
Triple Super Phosphate	Kieserite	
Water	Ammonia	
Potassium Chloride		

Construction material : The following materials of construction werw successful in different countries. In each case protection against abrasion by slurry offers greater protection than high-grade alloy composition. Alloy compositions recommended should have Brinel hardness of no less then 230. For all wet surfaces in contact with slurry contains up to 1/2% abrasive silicondioxide /sand/.

	USA	British	German
Alloy Code	Cd_4MCu	R-53	28/4 Mo
Carbon /C/	0.4	0.15	
Manganese /Mn/	1.00	0.75	-

Silicon /Si/	1.00	1.00	-
Phosphorous /P/	0.04	-	-
Sulphur /S/	0,04	-	-
Chromin /Cr/	25-27	15.00	26-28
Nickel /Ni/	4.75-6.00	Balance	4-6
Molybdenum /Mo/	1.75-2.25	18	2.0
Tungsten /W/	-	3.0	-
Copper /Cu/	2.75-3.25	-	-
Iron /Fe/	Balance	8.0	Balance
Ultimate tensile strength	7.750 kg/cm^2	-	-
Yield point	6.700 kg/cm^2	2.400 kg/c.	-
Elongation	10 %	10 %	-
Brinel Hardness	-	250	260-270

Continued/...

General Specification - Slurry Pumps

Packing / Recommended /: Lantern ring with braided teflon packing and water flushed gland. Vendor must detail recommended packing and gland flushing.

Base Support : Common cast iron base plate is to be provided by supplier.
For pulley drive motors, mounted above pump, vertical motor supports are to be provided. Motor will be 50 cycles, TEFC or P-33, totally enclosed, fan-cooled. squirrel cage induction type. Vendor shall detail shaft size and supply both motor and pump sheaves or coupling.
Coupling guards have to be provided by vendor. A service factory of min.1.15 is to be respected.

PAINTING SPECIFICATIONS

1. General Conditions :

1.1. The materials to be used in connection with the work of this section shall be applied and used in strict accordence with the specifications or printed directions of the manufacturer and these specifications or printed directions shall from a part of these specifications.

1.2. Should there be any conflict between information show on the drawings, that given in the specifications and that on any other contract document. the Resident Engineer shall be notified of same, and the final decision shall be determined by the Resident Engineer.

2. Scope of Work :

2.1. The surfaces to be painted are classed as follows :

a/ Equipment

b/ Structural steel, steel piping, steel handrails, and steel conduit.

c/ Insulated equipment, ducting and piping.

d/ Matal doors, trim and other metal work.

e/ Wood doors, trim and other woodwork.

f/ Galvanized metal.

g/ Interior masonry.

h/ Exterior masonry.

2.2. The surfacec not to be painted are as follows :

a/ Metal office, toilet, shower, and laboratory partitions, unless specifically authorized.

b/ Office firnuture and equipment.

c/ Platic, rubber, transite, aluminum, copper and stainless steel surfaces, roofing, and siding.

d/ Laboratory equipment, lockers and shelves.

e/ Grating and floot plate unless specifically authorized.

f/ Instrument and electrical panel boards.

2.3. The following items shall not be painted and must be protectod :

a/ Sprinkler heads.

b/ Firedoor fusion links.

c/ Fire extinguishers.

d/ Safety shower valves.

e/ Safety valves.

f/ Valve stems.

g/ Fuse boxes.

h/ Push buttons or switches.

i/ Tool number or equipment identification plates.

j/ Pipe line identification marks /except to renew/.

2. Scope of Work

k/ Acoustical walls and ceilings and tiles.
l/ Sight glasses and cases.
m/ Industrunents and their cases.
n/ Signs.

2.4. Any excess paint on items listed in paragraph 2.3 must be removed before completion of work.

3. General :

3.1. The works " Paint " ,"painted" and "painting" when used in connection with conditions , workmanship and the like, shall be understood to include other materials to which the instructions may be applicable.

3.2. Each coat MUST differ slightly from the preceding one in color. When primers are used as an intermediate coat, tinting shall be with lamp black or carbon black, When the intermediate coat is identical to the top coat, the intermediate coat be either a different color of the same manufacture or the topcoat tinted with white paint of the same manufacture.

3.3. The color of the final coat shall in all cases be approved before application. In addition to such small samples as may be necessary a final sample of each main color, if directed, shall be applied on one of the surfaces where it is to be u-sed. The finishing colors will be selected at the job site to match existing color shemes and will be approved by the Resident Engineer or his representative.

4. Conditions :

4.1. No paonting shall be done on damp surfaces, in freezing temperatures, when the temperature is below 40° F, when condensation is likely to occur, or when the surface temperature is less than 5°F above the dow point of the surroundign air.

4.2. No interior or exterior painting shall be done in a specific area until approval is given by the Resident Engineer or his representative.

4.3. No painting shall be done until other work likely to cause dust and dirt has been completed.

5. Workmanship :

5.1. All work shall be done by skilled workmen in a thorough and workmanlike manner. Materials shall be evenly spread and free from runs, sags, visible laps and bruch marks.

5.2. All adjoining surfaces and materials hall be protected and any point spots removed without damage ot other work.

5.3. All work shall be done in a safe manner. Normal safety and fire precautionss shall be observed at all times. Special plant safcty and fire requirements must be observed.

6. Cleanliness :

6.1. The premises shall be maintained free from accumulations od waste material and rubbish. At the completion of the work, all rubbish - /including sand and grit from blasting /, tools, scaffolding and surplus materials shall be removed.

The area shall be left in a clean, orderly and acceptable condition .

6.2. All materials shall be properly and completly piled at points designated by the Resident Engineer or his representative. They shall be housed, and protected from the wather in accordance with manufactures recommendations. All other work shall be protected from damage during the execution of this work by covering with drop cloths or other means.

7. **Inspection :**

7.1. The resident Engineer or his representative may inspect all details of surface preparation, and paint application including weather conditions outlined in paragragh 4.1.

7.2. The Resident Engineer or his representative may check to see that there are no hot spots, bleeding hollows or blemishes in any finished paint job.

7.3. The Resident Engineer or his representative may take any thickness measurements of the applied paint films to assure compliance with paragraph 9.7. These thickness measurements are in addition to these normaly taken during the progress of the work.

7.4. Material and workmansip not in accordance with the drawings and specifications shall be rejected and all defective material and workmanship shall be promptly replaced.

8. Surface Preparation :

8.1. Equipment.

Surfaces of tanks. blowers, heat exchangers and the like shall be prepared by hand cleaning and/or power tiol cleaning as outlined in Structures Painting Council Specifications SSPC - SP-2 and SP-3. Sand brush off as outlined in SSPC SP-7 is allowable provided it can be done in an isolated area or it will not interfare with any other construction work being performed in nearby areas. Power tools shall not burnish the steel surfaces, dull impact tools shall not force scale into the base metal. All dust, moinsture, oil and grease shall be removed prior to paint application. The edges of old paint films stall be feathereed and only tight paint films shall be aalowed to remain on the surface. When more than 3/4 of the painted surface area is intact and on shop primed items, only spot cleaning and apot priming is required, elsewhere, full cleaning and full priming is required. No surface shall be prepared that will not be primed the same day.

8.2. Structural Steel, Steel Piping, Steel Handrails ond Steel Conduit :

Surfaces of structural steel, valves, pumps, piping and the like shall be prepared by hand cleaning and/or power tool cleaning as outlined in Structures Painting Council Specifications SSPC SP-2 and SP-3. Power tools shall not burnish the steel surfaces, dull impact tools shall not force scale into the base metal.

All dust, minsture oil and grease shall be removed prior to paint application. The edges of od' paint films shall be feathered and only tight paint films shall be allowed to reamin on the surface. When more than 3/4 or the painted surface area is intact and on shop primed itmes, only spot cleaning and spot priming is required, elsewhere, full cleaning and full priming is required. No surface shall be prepared that will not be primed the same day.

8.3. Insulated Equipment. Ducting and Piping :

Exterior pipe and equipment insulation shall have been weatherproofed by the insulator. Where aluminum jacketing is used, it shall not be painted. Where mastic watherproofing is used, it shall not be painted unless othewise specified. All exposed interior covering and insulation, except aluminum jacketing shall be painted. All insulation shall present a surface free of gaps and breaks and all joints shall be caulked or sealed with suitable tape.

8.4. Metal Doors, Trim and Other Metal Work :

All surfaces shall be scraped and wire brushed to remove rust and loose scale.

8.5. Wood Doors, Trim and Other Wood Work :

All new and old surfaces shall be finish sanded. All nail holes, screw holes, cracks etc, shall be filled with putty or platic wood prior to sanding and priming. All knots shall be scrubbed with turpentine and sealed with shellac.

9. **Application :**

9.1. All surfaces shall be dry and free from dust, greane or oil at the time any coating i. applied. Base or prime coats shall be in good condition and the surface well covered by touching up any bare or abraded spots. If less than 1/4 of the sufrace ared is sopt cleaned, spot priming and spot second coating shall be sufficient. Ina all other cases, full priming and full second coating shall be required. But, in any case, the finisch oeat shall be a complete coat.

9.2. All painting shall be done in a neant, thorough and workmanlike manner. All coats shall be applied by either brush, spary, hot spary, roller or airless spary in such a manner as to produce an even coating of uniform thickness and without wrinkling of lifting previous coats. Care shall be exercised during spraying to avoid excessive evaporation of the volatile constituents, loss of material into the air, and the brindging over of crevices and corners, When paint is being applied by brushing, the surfaces should be cross brushed to secure uniformity of surface and the specified thickness of paint film. All undercoats shall dry without excessive gloss and be suitable for the proper application and adhesion on subsequent coats. If gloss develops on any prime or intermediate coat, the are must be sanded to remove excess glass.

9.3. All corners, crevices and accessible surfaces must be coated. All bolt heads, nuts, bolt ends, rivets and the like shall be given an extra coat of primer before general priming. All field coats shall be applied after erection except for these surfaces which will become inaccessible after erection.

9.4. Paint shall be applied only to surfaces that are thoroughly dry. Paint shall be applied only under atmospheric condtitions that will cause evaporation rather than condensation of moisture. Prime coats hall be applied immediately after surface has been cleaned. At time of application of each successive coat, the undercoats shall be freed of dust, grease or any foreign matter which night affect intercoat adhesion.

9.5. Paint shall be thinned only shen absolutely necessary and only immediately prior to application. Painters shall not add thirer to paint after it has been thinned to the correct consistency as specified. All thinning shall be done in accordance with the manufacturers instructions.

9.6. Equipment or structures which have been painted shall not be handled, worked on, or otherwise disturbed until the paint coat is completely set. Sufficient time shall elapse between coats to permit them to dry hard. All coats of painted sudfaces shall be unsarred and completely intergal at the time of application of al succeding coats.

9.7. On steel, the primer shall be applied at a covarge rate not graater than 250 square fest per gallon and the dry film thickness shall not be less than 1.8 mils. The intermediate and finisch coats shall be applied at a coverage rate not greater than 250 square feet per fallon and the dry film thickness of each individual coat shall not be less than 1.4.mils. The total film build of the 3 coat system should average 5.0 mils, but shall not be less than 4.6 mils. On shop primed or shop primed and shop painted steel, only the film thickness for the field applied coat or coats shall be applicable.

9.8. The silcene waterproofing compound shall be, applied liberally as a heavy running coat with a rundown of is inches. The work shall start at top of the wall and proceed downward.

9.9. Application shall be in accordance with the attached paint schedule which defines the required number of coats. Final color selection will be made on the job site.

9.10. Any application not meeting these specifications shall be removed and replaced in accordance with these specifications.

10. **Materials :**

10.1. All materials shall be the trade.marked products of the manufacturs named. All materials shall be delivered in the original packages with labels intact and seals unbroken.

10.2. No materials shall be changed in any way except as specified. Thinners must be pure. All paints and thinners shall be used in strict accordance with the manufacturers directions.

11. Product Names and Suppliers :

11.1. Equipment - Interior and Exterior

1. Spor or full prime : Prufcoat P-50 Primer-Prufcoat Laboratories, Inc.
2. Intermediate coat : Valchem Epoxy Enamel-American Marietta Co.
3. Finish coat : Valchem Epoxy Enamel-American Marietta Co.

11.2. Structural steel, steel piping, steel handrails and steel conduit

1. Same as Equipment.

11.3.a /Insulated equipment and ducting

1. Sealer : Polyvinylacetate Sealer-Gliden Co.
2. Finisch Coat : Valchem Epoxy Ename-American/Marietta Co.

11.3.b / Insulated piping-valves and fittings

1. Sealer : Polyvinylacetate Sealer-Glidden Co.
2. Finisch Coat :90 Asphalt Aluminum Paint/American Marietta Co.

11.4. Metal doors, trim and other metalwork

1. Spot or full prime : Prufcoat P-50 Primer-Prufcoat Laboratories, Inc.
2. Finisch coat : Valchem Epoxy-Enamel-American-Marietta Co.

11.5. Wodd doors, trim and other woodwork.

1. Prime Coat : Valchen Epoxy Enamel-American/ Marietta Co.
2. Finisch Coat : Valchem Epoxy Enamel-American / Marietta Co.

11.6. Galvanized metal

1. Wasch primer : Wash Primer P-10 Prufcoat Laboratories, Inc.
2. Primer : Prufcoat P - 50 Primer-Prufcoat Laboratories Inc.
3. Intermediate coat : Valchem Epoxy Ename-American-Marietta Co.
4. Finisch Coat : Valchem Epoxy Anamel-American - Marietta Co.

11.7. Masonry - Interior

1. First coat : Polyvinylacetate Sealer. Glidden Co.
2. Finisch coat : Polyvinylacetate Sealer - Gludden Co.

11.8. Masonry - Exterior

1. First coat : Clear Wall-Glidden Co.
2. Finisch coat : Clear Dri-Wall-Glidden Co.

COLOR SCHEDULE

I. Manufacturing Buildind - Interior.

1. Block walls	- 4 feet dado	- medium green
	- above dado	- light green
2. Ceilings		- white

3. Piping - bare - medium gray
   - insulated-valves and fittings - aluminum
4. Production equipment - lower parts - medium gray
   - upper parts - pastel green
5. Handrails - toeplates - ladders - alert orange
6. Fire piping and equipment - fire red
7. Miscellaneous steelworkdoors, stairways, platforms - dark green

II. Manufacturing Building - Exterior

1. Block walls - clear silicone
2. Piping - bare - medium green
   - insulated-valves and fittings - aluminum
3. Handrails - toeplates - ladders - alert orange
4. Miscellaneous steelwork-racks - dark green
5. Building trim - gray / same as inside /

III. Utility Area

1. Equipment - pastel colors
2. Piping - medium green
3. Hadeails-toaplates-aldders - alert orange
4. Fire piping and equipment - fire red
5. Structural steel - other steelwork - dark green

N O T E : All areas and surfaces marred and damaged during construction must be touched-up in accordance with paragraph 9.1. the colors are to match these presently on the surface.

The required Valchem Epoxy Enamel colors for steel and equipment are listed below and are available from Ferriss Distributing Co., Pensacola, Fla.

Medium Gray	6307
White	6301
Pastel Green	163_G-38
Medium Green	163-G-42
Dark Green	163-G-39
Alert Orange	163-Y-11
Fire Red	6313

Adesses :

American - Marietta Co.
Valdura Div.
101 E. Ontario St.
Chicago 11, 111.

Prufcoast Laboratories, Inc.
50 E. 42 nd St.
New York 17, N.Y.

Glidden Co.
900 Unixon Commerce Guilding
Cleveland 14, Ohio

VIBRATION OF MACHINES

At the FACT, Udyogamandal factory a measuring device is available for controlling vibration and carrying out analyses of vibration. This device was not upto now used, because no criteria is available for an evaluation of obtained figeres.

As to enable the utilisation of this device for the improvement of your preventive maintenance, we geve you the basic criteria used in our factory. Rules for evaluations of vibration at the FCI Sindri Unit werw already given.

General

1/ The basic values achieved by measuring are double amplitudes of maximum displacement /2Sm/ in micrometers and velocity /Vef/ in mm. S^{-1}.

2/ Cycles for measuring machines are carried out according to the following categories :

- machines of category 1 - each 7 days.
- machines of category 2 - once in 60 days.
- machines of category 3 - according to the requirements from maintenence or production dept.

3/ The measured values are reccorded and achieved for 5 years.

4/ The basic masurement must be carried out

- before repair of machine
- after repair of machine
- in prescribed cycles

5/ The maintenance department is responsible for maintaining the machines in such condition, that the vibrations are kept below limits given hereinofter.

6/ The users / operating people like shift foreman, plant manager etc. / are responsible for processing the machines within the limits of vibrations. When there is a sudden change of sound or increase of vibration at the gear box, bearings, crank case of machine etc., the operating people are obliged to ask immediately for the execution of vibration control. In case of emergency they must immediately stopp the machine.

The duty of the operators is to make continuous control of the sound from the machines, also hand-touching.

7/ It is the duty of the user of the machines, whenever the vibration measuring devices are installed, to ensure that they are watched and the values are recorded in a log sheet.

Instructions for permitted values of vibration according to the CSN Standards.

1. Steam turbines

The maximum permitted double amplitude /2 S/ of vibration for bearing pedestals of steam turbines at 99-101 % of rated speed with nominal output or 50 % of nominal output is given below.

For rated speed 1500 RPM - $2\ S_M$ = 60 micro m
For retad speed 3000 RPM - 2 Sm + 40 micro m
For retad speed
more than 5000 RPM - 2 Sm + 20 micro m

For generator turbines it is allowed during idling to run without exiting the 50% higher vibration. For speeds between above given values the value of vibration is calculated using the linear interpolation method.

2. Turbo Compressors

The maximum permitted double amplitude /2 Sm/ of vibration for bearings of turbocompressors in all directions and in the whole working range of the turbo compressor for frequencies given by speed :

1500 RPM	2 Sm = 80 micro m	
3000 RPM	= 40	"
6000 RPM	= 20	"
12000 RPM	= 10	"
24000 RPM	== 5	"

For vibration which includes more components whith different frequency, is taken the following value of speed V = 6.3 mm/s.

Theallowable value of vibration between the given speed is to be calculated by means of the linear interpolation method. The same permitted values are given for gear boxes of turbo compressors.

3. Centrifugal pumps

The maximum permitted double amplitude /2 Sm/ of vibrations for pumps connected to motors or steam turbines with rated capacity are given below :

375	RPM	2 SM	=	120 micro m
1500	RPM		=	100 micro m
3000	RPM		=	60 - do -
6000	RPM		=	30 - do -

4. **Fans**

Evaluations in vibration of fans are carried out according to given diagrams No. 1 and No. 2.

5. **Motors**

The effective values / Vef / or equivalent value /Veku/ of vibration speed must not exceed the value N given in the table below.

The figures are not valid for commutator motors and single phase motors.

Class of accuracy	Speed n RPM	Spedd of vibration Vef or Veku for motors with shaft high H in mm Speed in mm/s.					
		H=132		H=132 to 255		H-255 to 315	
		Vef	Veku	Vef	Veku	Vef	Veku
N-Normal	600-3600	1.8	2.5	2.8	4.0	4.5	6.3
R	600-1800	0.71	1.0	1.12	1.6	1.8	2.5
Higher	1800-3600	1.12	1.6	1.8	2.5	2.8	4.0
S	600-1800	0.45	0.63	0.71	1.0	1.12	1.6
High	1800-3600	0.71	1.0	1.12	1.6	1.8	2.5
P	600-1800	0.28	0.4	0.45	0.63	0.71	1.0
Very High	1800-3600	0.45	0.63	0.71	1.0	1.12	1.6

Values received from installed motors may differ from that in the table upto about 10%. For motors with the shaft higher than 315 mm and for 3 phase commutator motors the double amplitude of vibration at nominal output and steady condition must not achieve the following values :

Upto 187	RPM	2 Sm	= 180 micro m.
187 to 375	RPM		= 120 - do -
375 to 1500	RPM		= 100 - do -
1500 to 3000	RPM		= 50 - do -

Washing of back - pressure and condensing turbines with caustic solution.

Washing with caustic solution enabl to cl n th the blading without dismantling the housing. Th opin that a good washing performance can be achi d only s saturated solution compound is generally strongly t . The best washing effect can be achieved by using solution-contained steam which h a t mperature t l t value of 220-240°C is often stated s th t f v ing washing steam temperature. Thus the caustic solution Contacting the silica layer form a water-sol b und which is water soluble

$$SiO_2 + 4\ NaOH = Na_4\ SiO_4 + 2\ H_2O$$

According to experience it is not in vit n c t sol. down the solution contained steam to the t mperatu of the saturated steam. In many cases such oper ti n n s b f llowed at all. Which means th t according t thi it would never be possible to wash condensing turbin s a great part of the back-pressure turbines. For instance if the corresponding pressure of the saturated st n 1 .5 t t wash steam temperature of 250°C.

A sufficient conversion process / reaction between NaOH and SiO_2/ can be achieved also with superheated st .

But the silica deposit converted into th water soluble water - glass bound must be washed out by subsequent st steam washing procedure. Even with steam washing t per pproximatly at 180°C, satisfactory results have been .

Therefore the steam washing temperature at backpr ure turbines should vary between 180 and 240°C, and t n turbines with regard to the waste steam/ exhaust st / temperature is should vary between 180 and 200°C on th turbine inlet.

This enables to achieve a change in temperature range of the silicions zone.

In case that it is clearly determined, that only the L.P. part of a multi-cylindrical condensing turbine is silicious, then it is posible by means of condensate injection into the overflow.to maintain substantionaly lower the waste steam temperature.

The temperature at the waste steam connection branch should not exceed 140°C by which are given good conditions for a smooth mechanical run. The washin procedure with caustic solution is divided in two parts.

In the first part a reaction starts.through the effect of caustic solution on the silicious layer. Therefore at the bigining of the washing procedure, the condensate arising from the effluent usualy of lowamount only, will have in comparision to the injection proportion a low content of NaOH. If a decrease of NaOH in the condensate is clearly determined, then it can be considered as an indication that reaction bad already started. Simultaneously with the expanding time of washing the NaOH content is increased up to the outlet value and it can through a local concentration of the caustic solution far exceed this value.

The silicious layer was.in the water-glass bound converted into a gelatine similar mass.

Because the necessaty water content is missing as a result of the overheated steam effect during the softening process, therefore the viscous mass remains sticking at the blading. Only through a wet steam wash designed as the second.part procedure can be achieved a clean removal of the deposit.

As soon as the wet ~~steam becomme within the silicious zone~~ effective a black-brown output of the deposit occurs. At certain circumstances can within this time arise from the effluent a high concentrated NaOH mixture so the handling should be carried out with special care.

At all circumstances should be available protection facilities for persons which are supposed to come into contact with concentrated solution. It must be always available a bucket of fresh water as to enable to rinse instantly down any caustic solution which eventualy contacted the skin. Particulary protected should be the eyes.

For the steam-solution mixture was purposefully determinated a 2-3 percentage part of NaOH. A substantialy lower part of solution as it appears by the use of a 10 percentage caustic solution leads to longer softening time. A higher concentration in the wash steam is not recommended and it is generaly stated within the above magnitude order. There is usualy as a wash agent used caustic solution which is mostly commercialy available in a 45 percentage concentration or natriumhydroxyd which should be used in weight parts.

The turbine should be run during the washing procedure with about a 15 - 30 % speed. This will require a hourly steam quantity approximately 2 % of the maximum steam throughput. The wash steam feeded into the turbine should have a NaOH concentration of 2.3 %. The most available wash agent is caustic solution with a 45 % NaOH wt. Therefore the steam rate of the available imported steam must be known for this calculations. Other required data are more or less based on experiences. The resulted value will vary through this only unsubstantialy. The required wash-steam quantity remains at such calculation unconsidered.

As to achieve applicable conditions for the injection of the caustic solution it should be necessary to prepare in the container a solution-condensate mixture with a 15-25% $NaOH$ wt. For the achievement of a steam-solution mixture at approx. 200°C and with a 2-3 % $NaOH$, imported steam fr over 500°C will be required.

1. A steam cooler corresponding to the size of the turbine should be manufactured. Flange connection for wash steam pipings on turbines should be carried out for an output up to 4 MW with ID 40, further for an ouput up to 10 MW with ID 50, for an output up to 25 MW with ID 65 and at an output over 25 MW with ID 80 to 100. The flange connection for the piping of imported steam should be detrmined according to the steam pressure.

2. In front of the solution pump up to the solution cooler should be installed a pipe au ID 15 and close before the steam cooler should be fitted a fine dosing valve.

3. To the other flange connection of ID 15 should be fixed a condensate piping. The available condensate pressure must be at least 3 at over maximum expected [redacted] wash steam pressure in the cooler. It may be preferable to install in this case a pipe connection from the boiler feed water pump. Such pipe should then have a five dosing valve.

4. At the draining pipe of the steam cooler should be installed a valve. The end of the drainage pipe must be visible.

5. The steam cooler should include a connection for imported steam with a fitted valve.

6. The steam cooler should be connected to the imported steam line through a wash-steam line.

7. The steam cooler should include proper instruments for measuring pressure and temperature.

8. Close at the turbine inlet the wash-steam pressure should be controlled. The instrument which is mostly connected close before the quick action stop valve has a to large range. Therefore it should be changed for other one with a proper control range.

9. The turbine draining and the draining of the bleeding pipes before the bleeding valve should be as far as they are connected to a collecting pipe split behind the valve.

10. It should be provided a solution container with a volume at about 0.5 m^3. The connection to the solution pump should have ID 25 mm. The condensate-solution mixture over such quantity can be refilled during the washing procedure.

11. The solution pump should be designed for delivery head of 8-10 at and for flow rate of 0.5 m^3/hr.

12. For washing a condensing turbine are also necessary the following additional equipment:

   a/ As far as at the condenser no emergency exhaust manifold over the condenser piping is available, then a pipe at ID 100-250 mm leading into the atmosphere must be installed.

   b/ At least 50 mm over the condensate piping at the steam side, but below the exhaust pipe should be installed an overflow pipe with ID 20-40 mm. The water outlet must be observed.

   c/ At the bottom area of the condenser on the steam side a feed line with ID 15-20 mm should be installed. As cooling water can be used raw water or condensate. Through a continuous flow of cooling water a part of the steam temperature and the formed solution mixture will be carried off. Requirements will be for approx 3-8 m3/hr. water.

In case that the turbine is by sufficient after cooling or after a long shut -down period brought down to a housing temperature at about 200°C, then the wet steam washing can be started. The auxiliary oil pump as far as it is not already in operation should be switched on.
The imported steam valve and eventually the existing bleeding valves are closed. The quick action stop valve and the control valves as well as the relief value on back.- pressure turbines should be opened. The draining valves should be opened about to one turn. These valves should be during the washing procedure readjusted in such a way as to enable for the condensate formed in the turbine to descent but a superfluous outlet of steam should be avoided.
By means of the valve a continuous cooling water flow in the condenser should be ensured.
The housing will apparently before starting the washing procedure not achieve the required temperature of 200°C. Therefore a cooled down turbine should be operated before the washing procedure so far with wash steam and without any solution injection until the required temperature of the housing is achieved.

After the enclosure of the valve flap for fresh steam, the turbine will run through the steam cooler with opened quick action stop valves and control valves at a speed of about 500-800 r.p.m. At the same time the steam temperature will drop with a gradient of 2°C/min which can be performed by condensate injection at the steam cooler valve. After achieving a steam temperature of 240°C it is recommended to continiu the operation with this value for a period of about 15 minutes. Only after this should be the condensation stopped. The required steam quantity for a turn operation of 500-800 r.p.m. should be set up by means of the inlet value to the cooler.

According to the estimates, the pressure in the st[illegible] cooler will indicate to 6 - 8 atm. The draining valve must be so far opened as to enable to discharge od eventualy formed condensate, but on the other hand no large steam formation should occure.

After this the solution pump is put into operation and in the case of back pressure turbines a steam temperature at 240°C is set up. The wash- steam temperature shoul be purposefully dropped within a period of one hour to 180°C and ag in raised up to 240°C.
The operation of condensing turbines should be proceeded according to their characteristic, but in any case with a wash - steam temperature of 180-200°C.
According to experience the washing time should take 3 to 4 hours. This operation is indicated as a softening procedure and it must not be reckonned that a remarkable amount of condensate will be discharged, but in any cicumstances the formed condensate on the NaOH content should be strongly observed shortly before the washing starts. As far as an intensive reaction between the NaOH and the SiO_2 appears, then it means that the NaOH content is very low.

With a simultaneous increase of the washing time can the NaOH content of the formed condensate achieved nearly the designed value of the steam mixture or it can be even higher. The SiO_2 Content is only very low or it is not present at all.
During the softening procedure forms the caustic solution with the silicalayer a water soluble water-glass bound. As to achieve a good removal of this water-glass bound from the turbine it is necessary to carry out an additional washing with wet steam. The steam temperature with remperature gradient of 5°C/min will drop with the same r.p.m. down to the saturated

steam temperature of the respective pressure in the steam cooler. It can happen at certain circumstances that the wet steam behind the steam cooler will expand and here with again arrive into the superheated area. Therefore at the injection of condensate should beeared, that certain surplus of condensate will be discharged at the drain valve. The steam condition before the turbine must also be checked!
As soon as in the turbine the saturated steam value is achieved, suddenly appears at the drainages a great amount of condensate which has a blackgrey colour.
During this first condensate discharge can at certain circumstances also be discharged a high percentage NaOH mixture, which means that particular attention should be payd during this period.
The wet steam washing should be carried out at such a length of time until all impurities are removed from the discharged condensate. This can hold on 2-3 hours. The turbine unit should be brought after the washing procedure to normal operational conditions and immediately after this put into normal carvise.

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