elf aquitaine norge a/s

FRIGG FIELD
TCP2 COMPRESSION
FINAL REPORT

volume 2/1

PROJECT DEVELOPMENT

STAVANGER

NOVEMBER 1981

1. HISTORICAL RECORD:

1.1 Engineering

- 1974 — Preliminary studies
- Jan./Feb. 1975 — Engineering call for bid issued
- June 1975 — Telex of intent to Kvaerner - Technip
- January 1976 — Engineering contract S139 signed awarded to KVAERNER ENGINEERING/TECHNIP GEOPRODUCTION
- December 1979 — Main work completed (except follow-up)
- Jan. 78/Sept. 81 — Integration studies performed by EAN-Engineering Department
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1.2 Purchasing

- May 1976 — First purchase order issued for sleeves sea-water outfall holes - column 5
- April 1977: — Purchase order for 3 turbo-compressors awarded to KONGSBERG VÅPENFABRIKK.
- January 1978: — Purchase order for 2 turbo-generators awarded to NYLANDS VERKSTED/STAL LAVAL CONSORTIUM.
- April 1979: — Delivery of the turbo-compressors on the yard. 1 month later than contractual delivery date).
- June 1979: — Delivery of the turbo-generators at the contractual delivery date.

1.3 Onshore construction

- December 1977: — Onshore construction call for bid issued.
- June 1978: — Onshore construction contracts awarded to:

  a) SPIE-BATIGNOLLES/VIGOR - Yard 1 - ORKANGER (N) contract E76 for compressor modules 30 - 31 - 33 and control room module 32.

b) OIL INDUSTRY SERVICES (O.I.S.) - Yard 2 - EINAR ØGREY MEK. VERKSTED, KRISTIANSAND (N) contract E77 for pancakes 40 - 41 - 44 containing: Power plant for Emergency diesel generator.

c) O.I.S. NYMO MEK. VERKSTED, GRIMSTAD - contract E78 for pancakes 42 - 43 - 45 - 46 containing fresh and sea water utilities.

- September 1979: Onshore construction contract S922 awarded to HJELMELAND INDUSTRY - HJELMELAND (N) for warehouse and offices modules - auxiliary decks.

1.4 Transport and lifting

- June 1979: Transport and lifting call for bid issued.
- November 1979: Order sent to Heerema for lifting engineering.
- January 1980: Final contract S940 with Heerema signed.
- February 15 1980: Load out onto barges completed Yard 3 - Grimstad.
- March 13 1980: Load out onto barges completed Yard 4 - Hjelmeland.
- March 31 1980: Load out onto barges completed Yard 2 - Kristiansand.
- April 29 1980: Load out ont barges completed Yard 1 - Orkanger.
- May 18 1980: Loading onto semi-submersible crane vessel "Balder" in the BYFJORDEN, Stavanger completed.
- May 20 1980 13h00: Departure of "Balder" from Stavanger.
- May 21 1980 14h00: Arrival of "Balder" on FRIGG FIELD.
- May 22 1980 to May 26 1980: Offshore lifting, total duration 104 hrs.

1.5 Hook-up and commissioning

- October 1979: Hook-up call for bid issued.
- March 1980: Telex of intent to UIE NORGE for hook-up works
- April 1980: Hook-up contract S984 signed.
- May 26 1980: BERGE WORKER derrick barge at FRIGG for temporary accomodation.
- May 30 1980: Bridge connection BERGE WORKER/TCP2 and start-up of the hook-up works.
- June 9 1980: TREASURE SUPPORTER flotel rig replaces BERGE WORKER.

  July 4 to July 17 1980: Work completely stopped due to strike of safety personnel.

- July 31 to August 2 1980: Piping subcontractor on strike.
- August 28 - 29 1980: Part of hook-up personnel on strike.
- Oct. 2 1980: Gas in TCP2 treatment - end of "cold period".
- Oct. 10 1980: Production start-up on TCP2 treatment as scheduled.
- December 1980: End of "hook-up lump sum period".
- February 1981: End of "hourly rate period" - end of hook-up contract.
- March 16 1981: Departure of TREASURE SUPPORTER.

1.6 Start-up

- February 25 1981: Gas in fuel gas network.
- March 23 1981: Start-up turbo-generators-
- April 10 1981: First test: Compressor line B: running hours 10.
- August 17 1981: Second test: compresson line C: running hours 50.
- September 24 1981: Compressor C operational in line.
- October 14 1981: Compressor A operational in line
- November 20 1981: Compressor B operational in line

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ENGINEERING - SUMMARY

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B. Structure detailed report.
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A. ENGINEERING - GENERAL.

As already stated in the historical record in June 1975 the joint venture KVAERNER ENGINEERING/TECHNIP GEOPRODUCTION (KE/TP) was granted a contract for the erection on TCP2 platform of a compression plant.

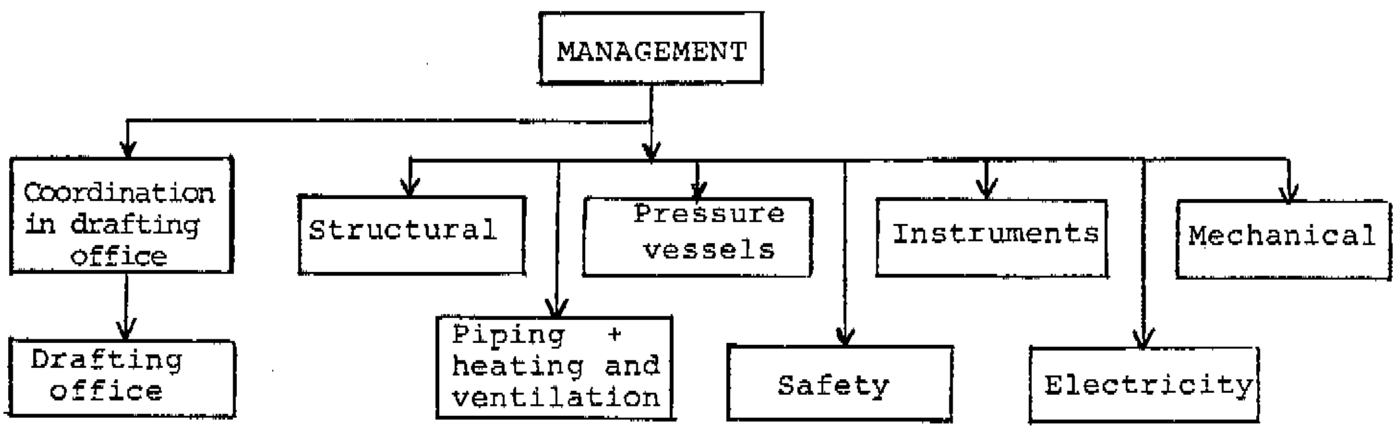
1. TYPE OF CONTRACT.

This contract was of "at cost"-type with reduction in rates above a certain ceiling for engineering and management for all phases of the project engineering itself, procurement, expediting, inspection, hook-up, commissioning, start-up. It has been modified several times between 1975 and 1981. These modifications and their causes will be detailed later on.

The aim of the present paragraph is to review the two phases engineering and follow-up.

2. PROJECT ORGANIZATION.

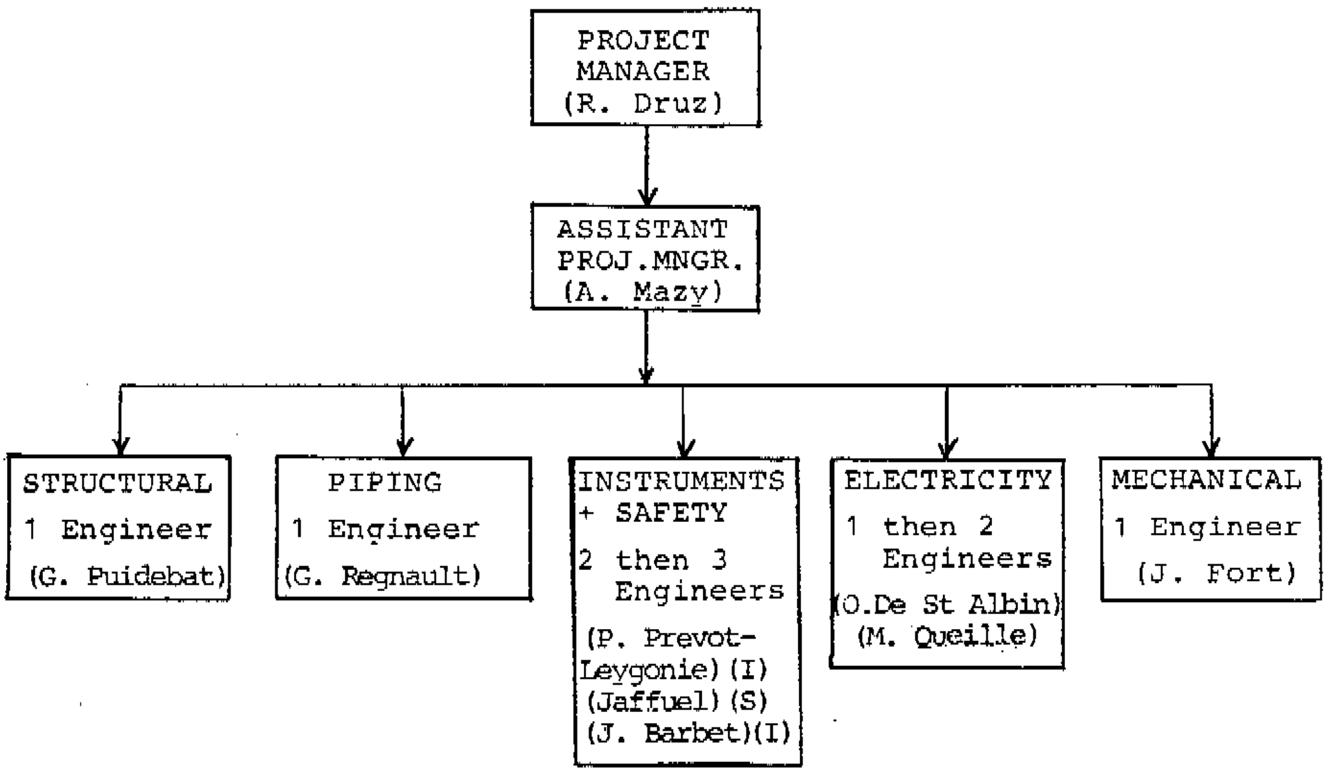
2.1 In KE/TP. The project was split in following sections during the engineering phase:



After the engineering phase the follow-up team was made up of some specialists coming from the hereabove section and selected by EAN.

2.2 In EAN.

At the beginning of the project the EAN team was consisting of one project manager and one project manager assistant acting as mechanical specialist. This very small team was supposed to follow the overall and detailed progress. To approve the main technical choices proposed by KE/TP and to check all invoices. But very soon the need for various specialists appeared and the team was gradually reinforced with one then two instrument engineers, one then two electrical engineerings, one structural engineer, one piping engineer, one mechanical engineer, the project manager assistant becoming technical coordinator.



3. LOCATIONS OF TEAMS.

In the contract with KE/TP it was foreseen that the main engineering studies (all plot plans, main drawings, main purchase orders) should be issued from Technip Geoproduction offices (Rueil Malmaison) by a team including only some KE people and the detailed engineering should be performed in Kvaerner Engineering Offices (Oslo) by a team including only some TP specialists. This was achieved with a small change in 1979, as fas as locations are concerned.

The KE/TP follow-up team has always been located in Stavanger in EAN offices (See fig. 1).

For EAN team the two first locations were Paris then Oslo in order to keep a close contact with KE/TP, and then Stavanger to make easier the coordination with integration team, O.C.D. yards, hook-up and commissioning teams (see fig. 1).

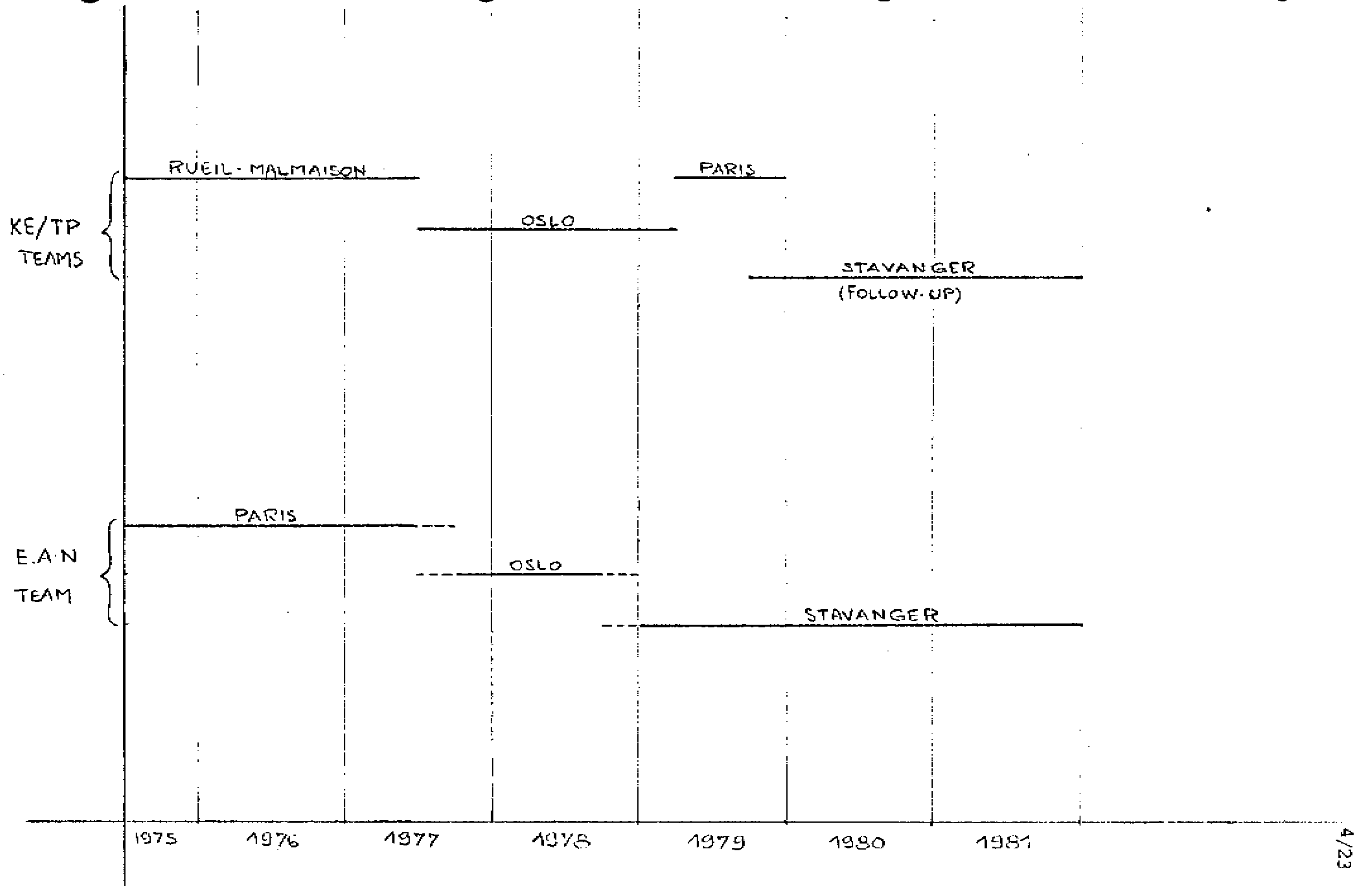


FIG. 1. LOCATION OF ENGINEERING TEAMS ALL ALONG THE PROJECT.

4. HOURS SPENT IN ENGINEERING

4.1 By KE/TP

4.1.1 Between June 1975 and 25th February 1979.

("At cost" period 319 600 hrs.

4.1.2 Between 26th February and end December 1979

(Lump sum period) 120 000 hrs (est

Total of engineering hours: 439 600 hrs.

Notes:
1. This total amount included all hours spent in management, coordination, specialists, drafting, clerical, filing, etc.
2. It has not been possible to get from KE/TP a splitting up of these hours into various sections.
3. An estimate of hours spent by KE/TP in structural, piping, instruments, electricity and mechanical has been done by EAN specialists and is included in detailed reports attached.
4. This total amount excludes hours for procurement and construction supervision.

4.1.3 Between July 1979 and December 1981.

(Follow up team) 66 ooo hrs.

Notes:
1. This amount includes all hours spent in management, specialists, drafting, clerical, filing, etc...
2. No splitting up made by KE/TP into various sections.

4.2 By EAN.

4.2.1 Between June 1975 and December 1979
(Supervision of engineering) 39 500 hrs.

4.2.2 Between January 1980 and December 1981
(Supervision of follow-up team and start up assistance) 25 500 hrs.

Total hours spent by EAN 65 000 hrs

Note: As secretaries and filing clerk were used by all sections within the project group (cost control, hook-up, commissioning etc..) this total amount does not include any clerical and filing hours.

4.2.3 Splitting up of these amounts.

	Supervision of Engineering	Supervision of follow-up and start-up assistance
Structural	3100 hrs.	4200 hrs.
Piping	3300 "	3700 "
Instruments+Safety	15600 "	8600 "
Electricity	10200 "	4800 "
Mechanical	7300 "	4200 "
TOTAL	39500 hrs.	25500 hrs.

5. INFORMATION ABOUT SOME DOCUMENT NUMBERS ISSUED BY KE/TP ENGINEERING AND FOLLOW-UP.

5.1 KE/TP engineering.

5.1.1 Purchase Orders

209 purchase orders have been issued during engineering phase. Most of them have been amended at least once and sometimes 14 times.

5.1.2 Requisitions.

191 requisitions have been issued.

5.1.3 Technical specifications.

410 technical specifications have been issued (70 R.P., 328 S.P., 12 S.M.)

5.1.4 Technical notes.

20 technical notes have been issued.

5.1.5 Special subcontracted studies.

Some special studies have been subcontracted:

- "HISPANO-SUIZA THM 1304 GAS TURBINE EVALUATION" subcontracted to M.T.I.
- "NUOVO PIGNONE COMPRESSOR DESIGN EXPERTISE" subcontracted to Fern Engineering.
- "Sea-water level fluctations in platform columns"(several reports) subcontracted to Laboratoire Central d'Hydraulique de France
- "Sea water rejection shaft design and behaviour" subconcontracted toLaboratoire Central d'Hydraulique de France
- "Water hammer in sea-water network" subcontracted to Neyrtec
- "Support frame vibration behaviour" subcontracted to Metravib.
- "Short-circuit calculations" subcontracted to SNEA(P) Socetec and EFI.
- "Low pressure vent height calculations" subcontracted to Trondheim Institute.

5.1.6 Drawings

5.1.6.1 KE/TP drawings.

6418 KE/TP drawings have been issued.

5.1.6.2 Vendor drawings.

2711 Vendors drawing have been collected, checked and used.

5.2 Follow-up

5.2.1 Engineering modifications

For the yard, hook-up, commissioning, start-up assistance 230 engineering modifications have been issued with following splitting up:

* 19 strucutral modifications
* 17 piping "
* 102 instrument "
* 40 electricity "
* 6 mechanical "

5.2.2 Troubleshooting diagrams.

The follow-up team has been in charge of issuing both instrument and electrical troubleshooting diagrams.

* 722 T.S.D. have been issued in instrument and safety
* 2035 T.S.D. have been issued in electricity (drafting subcontracted)

6. MAIN TECHNICAL CONSTRAINTS FACED DURING THE PROJECT:

When the first reliable and detailed informations have been known on the compression plant the design of TCP2 platform, support frame and treatment facilities was frozen and the construction in progress. As a consequence the possible modifications and reinforcements were very limited and two main constraints came due to this fact:

- Limited available surface on the main deck without compartmentalization (compression module location) and with compartmentalization on the cellar deck (utility modules and pancakes). Nevertheless this limitation has not induced a lot of troubles in the project.
- Limited possible total weight and pinpoint repartition of weights to be installed on the support frame. This constraint has been the most important one all along the project and has been considered as a major criterion in the selection of some main equipments (gas turbine of jet-derivative type, plate heat exchangers, high characteristic steel for gas piping and flanges, cupro-nickel material for sea-water piping, separators of cyclonic type both at suction and discharge of compressors etc...).

Some other constraints of less importance occured due to the fact that the compression plant had to be integrated in an existing treatment plan: Existing tie-ins (main gas piping, fire fighting sea-water, glycol, ethanol, diesel oil, instrument and service air etc...).

7. MAIN TECHNICAL CHOICES AND GUIDE LINES.

7.1 General scheme.

As there was on Frigg Field two completely separate trains of gas production, treatment and expedition the basic idea has been to get 2 turbo-compressors each of them being devoted to only one line. But, in addition to the normal maintenance work, turbo-compressors need in marine environment frequent stops for water-wash. This implied to add at least one turbo compressor spare. Accordingly the scheme shown on Fig. 2 has been selected as the best for following reasons:

* it minimizes the piping length
* it minimizes the valve number
* it minimizes the outlet separator number
* it allows the use of flat swing check valves in place of ball valves.

} ⟶ WEIGHT SAVING

The only inconvenience of this scheme is that it is not possible to run simultaneously compressors A and C on TP1 line or compressors B and C on TCP2 line for safety reasons. That compels the operators to stop the running machine prior to start the substitute one (but the capacity of lines is large enough to make this a false problem) and imposed the need of an interlock system between inlet HV valves (N.P.D. request).

7.2 Machine Environment.

7.2.1 Turbo-compressors: In order to make maintenance operations possible whatever the weather is the in-door solution has been choosen.

7.2.2 Turbo-generators: The in-door solution has been chosen for the same reason:

7.2.3 Control room: A centralized control-room for all equipments, permanently manned has been chosen after discussions and agreement with production people.

7.2.4 Emergency diesel generator, diesel fire pumps, electrical sub-station, control room heating and ventilation system, main 5500/380V transformers: All those equipments are located in-door in order to keep the same philosophy than on existing installations and to improve their reliability.

7.2.5 Other equipments: All other equipments are in out-door configuration.

7.3 Selection of main equipments.

The main criteria for the selection of equipment have been all along the project:

- reliability: All bidders have been requested to document their offers with references in same or very close operation conditions. Those references have been checked

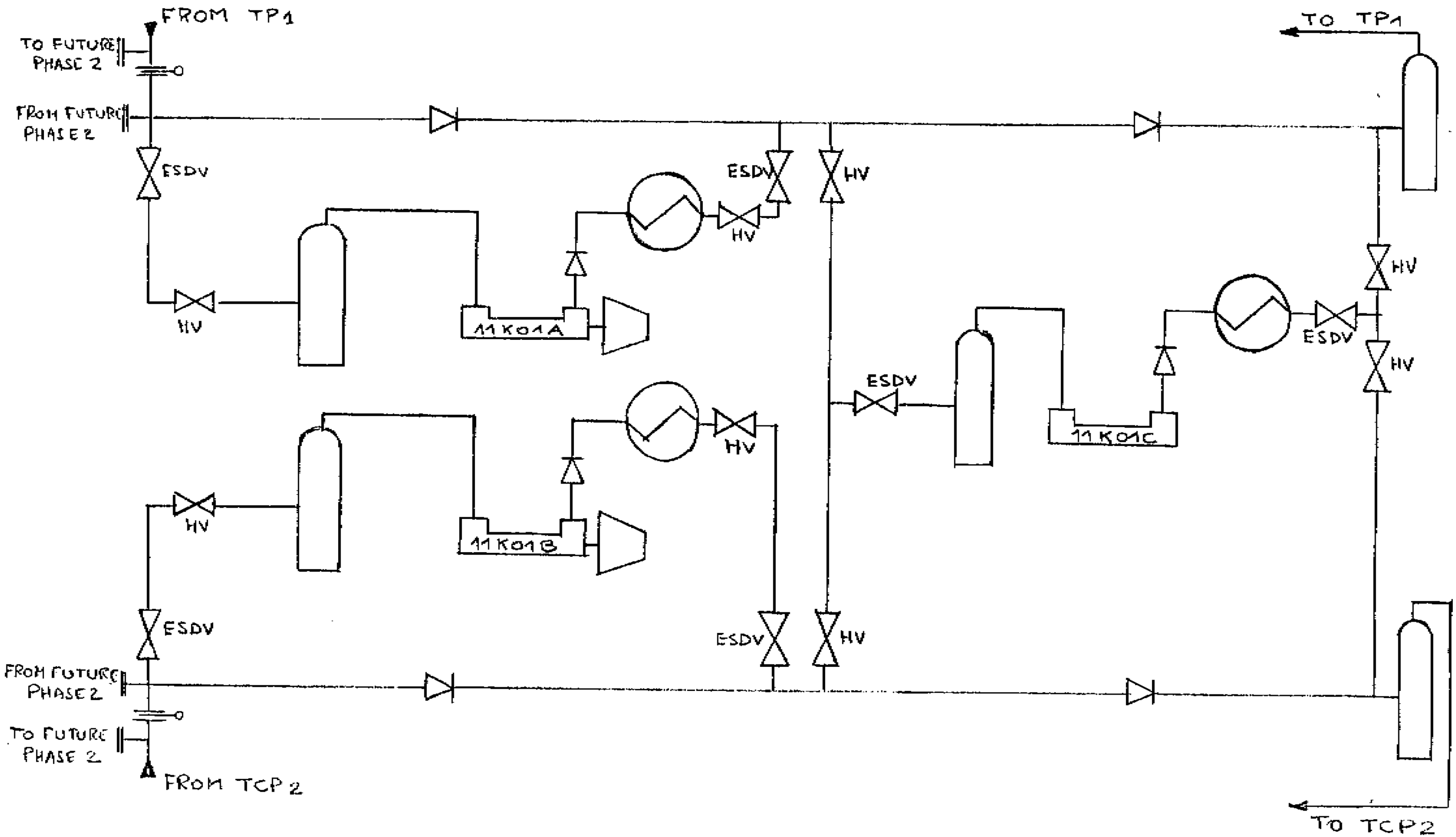


FIG 2. SIMPLIFIED SCHEME

very carefully mostly by visits in users facilities. In the same way the selection of materials has often been led by reliability considerations (i.e. cable trays in stainless steel).

- weight as low as possible
- overall dimensions compatible with the available areas
- price
- norwegian content.

7.3.1 Turbo-compressors.

In addition of hereabove criteria the aim of the project was to install the highest power amount so that the compression phase 1 be used as long as possible. The way chosen by EAN to select the turbo-compressor vendor has been to launch two separate calls for bids, one for the gas turbines and one for the centrifugal compressors. Then to request the two selected bidders United Technologies Int. and Alsthom Atlantique, to make an arrangement, the turbine's vendor being the responsible for the complete machine. It happened that these two vendors had a common norwegian sub-contractor Kongsberg Våpenfabrikk and this one was granted the leadership for the complete package. This rather complicated arrangement did not work very well as it will be explained in comments chapter.

7.3.1.1 Gas turbines.

After the bid tabulation and the pre-selection the last choice was between U.T.I. (FT4C-3F) and Kvaerner Brug (General Electric Frame 5). Finally U.T.I. was chosen for following reasons:

* higher power available: 38000 HP for FT4C-3F 33000 HP for frame 5
* lower weigh: FT4C-3F is of jet derivative type, frame 5 is of heavy duty type
* easiest maintenance: FT4C-3F is of modular type, frame 5 is of classic type.

However at the time of order the 3F free turbine (3 wheels) had no industrial experience but several dozens were sold and were supposed to be started up before our delivery time. Therefore EAN reserved his right to revert to the former type (2 wheels) in case where U.T.I. would have experienced too much troubles with these new 3F, and a complete information from U.T.I. was requested during meetings every two month. This was achieved at EAN satisfaction and allowed to stick with the 3F free turbine.

7.3.2.1 Centrifugal compressors.

After bid tabulation and pre-selection the final choice was between Alsthom Atlantique (under Nuovo Pignone license), Elliott-England and Kvaerner Brug (under Dresser license). In a first step Kvaerner Brug was rejected because EAN had no confidence in the rotor design (shaft too flexible wheels in back to back arrangement). In a second step the two offers from Alsthom Atlantique and Elliott-England were considered as technically similar. Only two reasons led EAN to choose Alsthom Atlantique:

* Both the project manager and the project manager assistant had had good experiences with Nuovo-Pignone in their former assignments.
* At the time of order Elliott was experiencing technical problems on several locations all over the world (Ekofisk, Lybia...).

7.3.2 <u>Electrical Power Plant</u>.

Since the very first electrical power balance estimates it was obvious that the existing power plants on TP1 and TCP2(T) would not be able to supply all consumers on Frigg Field including the possible future extensions. The need for a power plant in compression facilities was then clear. Two possibilities were possible:

* To build a power plant able to feed only the compression plant plus the possible future extensions
* To build a power plant able to feed all the Frigg Field the existing ones becoming spares.

The second solution was adopted and the power balance was settled at 21 MW (16MW for all installations known, including compression, plus 5MW reservations for future extensions).

After bid tabulations and preselection the choice to be done was between:

* G.E.C. UK: 2 sets E.A.S.1/33 of 10,17 MW each
* Stal laval: 2 sets GT.35 of 13,5 MW each
* Hispano-Suiza: 3 sets THM 1304 of 7 MW each

In a first step G.E.C. was eliminated (price slightly higher than the two other competitors, overall dimensions too close to available space).

In a second step EAN selected Hispano-Suiza for the following reasons: More flexibility and reliability with 3 sets in stead of 2, easiest maintenance, same price and same norwegian content as Stal Laval.

A recommendation was introduced to norwegian authorities in that way, but for political reasons the Stal Laval solution was imposed to EAN.

7.3.3 High pressure gas piping material.

Due to the fact that in Frigg gas composition there is no H_2S it was possible to make the HP piping and flanges from an high yield strength steel. That solution allowed the project to save approximately 130 tonnes of dead weight.

7.3.4 Cooling system.

There was two kinds of needs for cooling: compressed gas and lube oil of turbo-compressors and turbo-generators. Three possible ways to achieve this cooling were examined:

* Directly by air through air coolers
* Directly by sea-water through gas/sea-water and oil/sea-water exchangers.
* By fresh-water running in closed loop through gas/fresh-water and oil/fresh water exchangers. In this solution the fresh-water had to be cooled and the only possibility was to use the sea-water.

The first solution (air) has been rejected because the total available area for compression was not large enough to withstand the needed air coolers.

The second solution has been abandonned because at the time of inquiry KE/TP did not find any manufacturer ready to build exchangers handling on one side 32 MMSCM/d gas at 105^{O}C and on the other side sea-water.

Therefore the only remaining solution has been worked out

7.3.5 Sea-water cooling network.

Three main ideas have led the studies:

* select the materials used very carefully so that the corrosion attacks should be reduced to a minimum. This work has been done in close cooperation with D.D.T. specialists in Paris.
* Make the arrangements as simple as possible so that the number of valves, check-valves, etc... should be minimum (in fact with the modular configuration adopted it has been possible to avoid the use of valves and check-valves on the main 28" pipes).
* Keep the weigh as low as possible.

7.3.5.1 Arrangement.

As aforesaid a modular arrangement has been chosen with 2 modules for phase 1 including each:

* 2 submerged pumps
* 1 sea-water filter
* 2 plate heat exchangers
* 1 sea-water rejection shaft
* associated 28" pipe

At end of phase 1 the cooling needs will require only one module in operation. Therefore the back-up installed is 100%.

For phase 2 all the necessary space has been reserved to add 1 module with the exeption of sea-water rejection shafts (each of them is able to handle 10000 M^3/H and the necessary taps are already in place). At this time the cooling needs will require two modules in operation therefore the back-up installed will be 50%.

Note: At request of production people a study has been done by KE/TP in order to examine what would be the cooling needs in case of the gas temperature downstream the fresh-water/gas exchangers should be lowered to 30°C. As a result of this study it would be necessary to change two sea-water pumps (4000m^3/H each in place of 2000 m^3/H presently), and to add two plate heat exchangers with associated piping. A space reservation has been done in area located south of pancake 43 for these two additional exchangers and in area located south of top of column 5 for the piping. The necessary taps on the sea-water rejection shafts are already in place.

7.3.5.2 Sea water pumps.

Due to the large dimensions of these pumps and the lack of available reservations outside the platform columns the

the only possible locations were inside the columns. So 4 locations have been taken in column 3 and 2 in column 5. The top of column 3 being rather emcumbered the submerged electrical motor driven pump type took the lead.

After bid tabulation and pre-selection the choice was between K.S.B. (Germany) and Thune-Eureka (Norway). From a material quality, performances, price the two offers were equivalent. The difference was in experience. KSB was able to prove that he had some pumps of the same range in operation without any major trouble while Thune-Eureka had no experience at all for this type of equipment. As a consequence EAN introduced a recommendation to norwegian authorities for the purchase of 4 KSB pumps. For political reasons this recommendation was rejected and after discussions EAN was allowed to buy 2 KSB pumps and 2 Thune-Eureka pumps.

7.3.5.3 Sea-water filters.

Nothing to report.

7.3.5.4 Plate heat exchangers.

This type of exchangers has been selected for the following reasons:

- good resistance against corrosion (plates in titanium)
- weight lower than tubular type
- easy maintenace
- experience in marine environment.

After bid tabulation the choice was between Alfa-Laval and A.P.V. the two offers were technically equivalent and A.P.V. has been selected because of their lower price.

7.3.5.5 Sea-water piping material.

The problem was to select a material able to:

* handle a flow of sea-water running at a speed as high as possible so that the diameter of the pipe be the minimum (saving in weight)
* avoid all corrosion problems in stagnant sea-water (at stand still)

After an extensive review of all available materials (Rilsan coated steel, Resin armed with fiber glass, various copper alloys, titanium,stainless steel) only two were found possible Cupro nickel 90/10 and titanium. In spite of the very high water speed allowed by the titanium (more thant 8 m/s) this solution was rejected for two reasons:

* wall thickness of pipe very small (fragility)
* no possibility to weld on site (addition of a lot of flanges, no repair offshore).

so the cupro-nickel 90/10 has been chosen.

7.3.5.6 Sea water rejection shafts:

The free discharge from the support frame level to the sea of so large quantities of water (minimum 8000 m^3/H in phase2) was declared unrealistic since the beginning of the project. As there were no provision in external platform column walls for anchoring of large pipes it was decided to discharge the cooling sea-water inside column 5. Nevertheless the need for large pipes avoiding the free discharge remainded obvious (protection of other equipments inside the column).

A study has been done by "Laboratoire Central D'Hydraulique De France" in order to define the rather sophisticated design of this discharge pipes called "sea-water rejection shafts". Taking benefit of the material selection done for the piping and knowing that the maximum water speed in the shaft is 18 M/S with no risk of stagnant water it has been possible to choose the special Avesta 254 SMO (High content of manganese) stainless steel.

8. GENERAL COMMENTS

8.1 Contract with KE/TP

As aforesaid in paragraph A-1 was of at cost type with a light reduction in rates above a certain ceiling. It is undoubted that at time of signature of this contract the lack of experience, both on engineering and on EAN sides, for the erection offshore of large compression plant have not allowed to chose another type of contract (impossibility to define a detailed scope of work). Nevertheless it is sure that this type of contract does not motivate the contractor concerning the delivery times and the quality of issued documents. That is what we have experienced all along the engineering phase of the project as explained in the historical review hereunder.

8.2 Historical review.

8.2.1 Target dates

At the very beginning of the project the main objective was to have the compression operational on 1st October 1980. In order to achieve this the engineering phase (basic and detailed) was scheduled to be completed end of June 1978.

In fact due to continuous planning slippages the engineering has been declared completed end of December 1979 and the compression plant was operational on 1st October 1981 (first turbo-compressor operational end of September 1981, second turbo-compressor operational mid October 1981, third turbo-compressor operational mid November 1981). This delay of one year had no effect on Frigg Field gas deliveries the decrease in pressure of the reservoir being lower than estimated in 1975.

8.2.2 June 1975 till February 1979. "At cost" phase

8.2.2.1 June 1975 - September 1977. Basic Engineering in Paris.

Between June 1975 and spring 1976 the engineering was to determine the best turbo-compressor arrangement, to issue the preliminary lay-outs taking into consideration the existing machines on the market, to issue the corresponding electricity load balances and weight estimates. During this phase all ran smoothly and EAN has nothing to report about.

Between spring 1976 and September 1977 when the first specifications in view of purchasing the main equipment and the drafts of purchase orders were issued for EAN approval the quality of these documents was so bad and therefore the comments from EAN so numerous that an urgent need for an increase in EAN team appeared. It has been done by the recruitement of one instrument engineering and one electrical engineering in 1976, one structural engineer and one piping engineer in 1977.

Nevertheless the basic engineering has been completed in September 1977 without any delay when the purchase orders for the main equipments have been placed (turbo-compressors, water separators, main fresh-water pumps, tubular and plate heat exchangers)

Then the transfer of engineering studies from Paris to Oslo Took place during June-September 1977 as foreseen.

8.2.2.2 October 1977 till February 1979. Detailed engineering in Oslo

- Since the beginning of the detailed studies in KE offices (KE manpower plus some specialists from TP) several problems appeared:

    - Difficulties from KE to supply the project team with skilled personnel mainly in Instrumentation, Electricity, Safety, Procurement and Inspection.
    - Excessive personnel turn-over in TP team due to income tax problems.

- Excessive absences of the TP project manager who were apparently still involved in other business in Paris.
- Poor coordination in the project mainly between instruments and electricity in spite of EAN engineer efforts.
- Poor qulity of issued documents (specifications and drawings)mainly in Instrument, Safety, Electricity and Heating ventilation.
- Deficiency in checking of vendor drawings (KE/TP regarding the vendor supply as a package and checking only the battery limit).

The consequences of these problems are obvious:

- Contiuous slippages in delays for the delivery of Engineering documents.
- Reinforcement of KE/TP team mainly with personnel coming from TP Paris further to EAN recriminations
- Low progress of the project although the percentage of progress presented in KE/TP report has always been overestimated.
- Large increase of hours spent in engineering: at 25th February 1979 the total amount of hours spent was 319 000 (Excluding Procurement & Inspection and construction assistance) associated with a progress of 81% estimated by KE/TP. This total amount has to be compared with the estimation of the contract: 146 900 hours in contract S139 including amendments 1.2.3.

Facing this situation several decisions were taken both by EAN and KE/TP:

By EAN:

- Change in the type of contract for the end of engineering. KE/TP was requested to submit a lump sum proposal and an agreement was reached for a sum of 24 000 000 NOK. This amount has been increased by 2 400 000 NOK after a claim at end of study. This total amount of 26 400 000 NOK corresponds to approximately 195 000 hours all spent in Instruments, Safety and Electricity.

- Withdrawal from KE/TP responsibility of Procurement Inspection management, yard construction management, Hook-up, Commissioning and start-up management.
- Reinforcement of EAN specialist team with first a mechanical engineer then an instrument engineer and an electrical engineer used as EAN representatives in KE/TP offices and acting as quality controllers, and a Procurement-Inspection Leader.
- Postponing of the target date for the operation of the compression plant by one year (From 1st October 1980 to 1st October 1981).

By KE/TP:

- Transfer from Oslo to Paris of the instrument, safety and Electricity section.
- Large increase in the manpower in these sections
- Creation of quality control team.

8.2.3 February 1979 till December 1979. "Lump sum" phase.

After all these modifications the efficiency of KE/TP engineering has been improved but the accumulated delays were so important that the engineering completion took place only at end of December 1979. (Although the planning issued together with the lump sum amendment foresaw an engineering completion at end of June 1979).

8.2.4 January 1980 till December 1981. Follow up phase.

The follow up (yard, hook-up, commissioning and start up assistance) was performed in Stavanger in EAN offices by a small KE/TP team consisting of specialists selected by EAN working under the technical responsibility of EAN engineers, KE/TP keeping the administrative responsibility. This arrangement has worked satisfactory and allowed the project to cope with the necessary corrections, the important modifications demanded by the start up team (not always well justified) and even to issue the troubleshooting diagrams for Electricity, Instruments and safety.

8.3 Comments

The main comment is an obvious conclusion of the historical review: When an "at cost" contract is passed with an Engineering a team of specialists must be constituted in client side from the very beginning. The mission of this team is to perform an accurate quality control so that the progress announced by the engineering becomes credible.

The second comment concerns the locations: It is obvious that the too numerous locations of various teams has created a lot of problems due to communication difficulties and time lost in movings. The worst period was at end of 1978 (Beginning of yard construction) when KE/TP was in Oslo, EAN team partly in Oslo partly in Stavanger the three years being in Orkanger, Kristiansand and Grimstad. As an evidence of fact this dispersal of people should be avoided as far as possible.

B - STRUCTURE

1. PRELIMINARIES

The purpose of the whole project was to design, build and install 4 big modules on the platform maindeck and 7 pancakes on the cellar-deck or lower deck, and also to equip columns 3 and 5. Although this report is normally limiteu to the Engineering company and its management by the customer it will aslo be related to the costs and consequences on the planning created by construction and installation problems, so that the reader may be granted with consideration and estimation elements for future projects.

2. CONSTRUCTION TECHNICS

Information concerning the main characteristics of the modules and pancakes structures (lay-out, general view, over-all dimensions, weights, function etc.) are given in Annex 1.

2.1 Type of structure

2.1.1 Modules: metallic caisson with a 9 m cantilever on the east side and directly resting by way of 4 plates, on the TCP2 support frame. The 3 turbo-compressor modules (No. 30, 31 and 33) are of the very standard type, that is with vertical North and South lattice girders, transversal frames on a 6 m spacing made of standard commercial, or fabricated on the site sectional irons, upper and lower floor made with reinforced steel plates - their conception is similar to that of the treatment modules set on the western part of the same platform however the "utilities" module no. 32 does include an additional floor (total height above 20 m) and also a crane on a pedestal with a 10 tons capacity at 36,6 m.

The 4 lifting padeyes have been set on the upper level (main deck) for modules 30, 31 and 33 and on the lower deck for module 32, which is much higher and heavier. We shall later on come back on the padeyes design and realization problem. The outside vertical walls of the modules have not been taken into account for the resistance of the vertical lattice beams. In reality, because of the important number of penetrations (piping, electricity) and of the necessity to minimize the structures dead weight due to the maximum capacity of the support frame, it did not appear interesting to use an "integrated wall" structure, more especially as the "gas tight", or in class II zone types,. could be made with stainless 2 mm thick steel-plates (gain in weight).

In zone I, the walls were of the A60 type (60 minutes resistance to fire) that is a 4 mm steel plate with 75 mm thick glasswool insulation.

Finally, the floor steel plates reinforcement was realized after a comparison study for weight reduction with non symetrical angle bars rather than with bucket shaperd bended plate.

2.1.2 Pancakes: standard flat structures, realized with a fabricated plate girder, commercial sectional iron and reinforced steel plates. The pancakes are resting at the cellar deck level of the support frame, on 4, 6 or 8 bearing plates. In fact pancakes 41 (turbo-generator) and 45 (diesel generator and battery room) are closed metallic caissons, with standard vertical lattice girders, all the other elements being similar or identical to the modules.

Padeyes have been set on the lower or upper level.

2.2 Engineering specifications

Engineering specifications are based on the following official rules:

- DnV 1974 rules: rules for the desing, construction and inspection of fixed offshore structures.
- DnV's technical notes for: lifting study, fatigue calculation of crane pedestal etc..

- Norwegian code of practice for steel structures computation and design 1973.
- NS.3052. Loadings (especially used for calculations of shapefactors for wind loads).
- Environment design conditions have been summarized in Annex 2.
- KE/TP has established an "Archtecture" specification but, on the other hand, Elf specifications for materials (steels) painting, construction and controls have been directly used with some modifications.
- The METRAVIB COMPANY checked the vibration behaviour of the modules and the TCP2 support frame (theoretical study with limited elements computation for the modules and pancakes, and experimentation for the support frame).

2.3 Structures design

As already mentioned in paragraph 2.1, the structures belong to the standard lattice type (commercial sectional steels on fabricated beam). Maximum thicknesses, of the beam steel plates did not exceed 40 mm except for the modules padeyes made with 70 mm thickness plates.

Floor plates varied from 8 to 12 mm and were re-inforced with non symetrical angle bars, on a 600 mm spacing. Walls were made of black steel plates 4 mm thick, reinforced by 80 x 60 x 4 mm angle bars.

Claddings and some "gastight" walls were made of stainless ribbed 2 mm thick steel plates leak-proof welded on the structure.

Totally, welded design, except for some bolted joints in order to facilitate offshore functions during hook-up.

All the roofs (upper decks) or opened pancakes, floors have not been designed with construction deflection or general slope for water drainage.

At the modules bearing plates level some areas have been reinforced, so as to be used as a base for jacking up, weighing and installing the skidding pads for the load-out from the yard (only localzed reinforcements have been added on request on the framework of the much lighter pancakes).

Modules computations have been checked on a computer assuming that lifting would be conducted with 4 inclined slings (for padeyes located on the upper part) for no 30, 31 and 33, and with 4 vertical slings (for padeyes on the lower part) for no. 32.

Pancakes calculations were made manually.

2.4 Lifting and padeyes

The 3 modules no. 30, 31 and 33 have been designed, since the beginning (most unfavourable case for upper - deck girders, taking compression stresses generated by the inclined loads in the slings into account) with welded 70 mm thick steel plate padeyes set at the upper deck level and 4 inclined slings hanging directly from the barge crane - hook - this set-up, rather simple to prepare, allowed to avoid the use of a spreader bar or beam, but also limited the gauge for the installation of equipment on the upper deck (pipe, supports, valves, small piping, turbines exhaust pipes..).

The end to end welded joint, perpendicular to the stress direction in the padeye, is the only part of the system which can induce into prefering another desing, without joint, but in our case this would have raised the problem of bending a 70 mm thick steel plate, since the inclination angle of the padeye is only known at the last moment, after weighing on the yard, which does not allow a logical and much simpler fabrication in the workshop.

Another critisism is the external position of the padeyes which because of the large dimensions of the shackles and axles, made the installation of two adjacent modules more complicated by interference and possible shocks (this happened to be the the case for modules 33 and 32, the last one complicating the problem because of its larger height.

In that case the spacing between two modules should have been increased but it was too late to envisage such a modification in this project already settled since the beginning of the structures design in Oslo (this should be taken into account for future projects).

Module 32 padeyes were set on the lower part and lifting was realized with vertical slings and spreader frame. This arrangement allowed to have a lighter structure for the module and an important gauge on the roof (onshore installation of the crane and its boom) As an inconvenience, there is a certain instability of the module, although the lifting went on extremely well, the necessity of cutting out the padeyes before installing adjacent, modules, and the very important difficulty for the withdrawal of the slings (damage by shock of the slings on the equipments due to the movement of the barge crane and the spreader frame).

This unusual set-up should be avoided and a design with padeyes on the upper part is preferable for modules and pancakes.

Some criticism for desing with padeyes on the lower part on pancakes no 44 and 45 since, there too, interferences, shocks and difficulty to take off shackles and slings have been found.

To summarize and taking into account the fact that lifting does represent the most unfavourable case for calculation and dimensioning of the main frameworks, the engineering company should carry serious assumptions and design studies since the very beginning in order to avoid surprises, modifications and difficult discussions when selecting the liftor.

2.5 <u>Weighing, load-out, transportation and seafastening.</u>

At end of construction, on the yard, modules and pancakes have to be weighed (confirmation of the positon of the gravity center and total weight for final setting of the tilted padeyes and final dimensioning of the lifting equipment), transfered to the barge, fastened on it then transported to the Frigg Field for final installation.

These constraints should also be taken into account along with the design studies and not when it is time to realize these operations.

As an example, weighing and load-out required 4 reinforced areas on the structures at the bearing plates positions in order to position jacks and skidding pads. There - when designed and calculated since the beginning of the studies these strengthenings do not distrub the yards because of difficult and costly modifications at the last minute.

This is why internal seafastening of equipments and namely all the electrical compartments should be taken into account when designing the fixation on the structures of the said equipments all along with the preparation of the design drawings and the checking of the skid plans of the equipments.

Barge seafastening for transportation is, on the other hand, only studied at the end of the project and just before renting the barge (this study was made by the liftor, for the compression case, and did not require but a small local reinforcing of the damping joints).

All this of course assumes that the engineering compay has been granted with the responsibility for all these problems and that it does have the corresponding competencies. We shall at least mention that weighing was conducted by the "load cells" method (weighing with 4 load-cells, fed in parallel by the same pump, the 4 bearings being simultaneously weighed).

This simple and fast method gives a 1% precision, but it showed surprising distributions of the reactions on the 4 bearings due to a distorted and hyperstatic system that was not at a neutral state on the 4 construction bearing just before weighing.

The final position of the center of gravity deducted from the weighing and slightly different from the theoretcal calculated position (maxi. 0,50 m) was taken into account by the liftor to determine the slings length. The package position during lifting was practically horizontal which confirmed that weighing results were right.

2.6 Shimming.

The maximum acceptable horizontal slope for the modules equipments and for the drainage system required a shimming to be provided under the modules and pancakes bearing plates, taking into account the geometrical shape of the support frame in 1980, before installation of the compression and the self deformation of it due to the loads of the compression phase I.

A survey on the platform combined with a theoretical deformation calculated with a computer proved that the no. 30 extreme North module had to be shimmed 90 mm - which was done before lifting.

A check on the level after setting showed a maximum bearing unevenness of 12 mm, which was quite acceptable and confirmed theory results.

Consequently , no vertical jacking had to be conducted on the platform, although the structures had been designed for this.

2.7 Installation tolerance on platform.

In order to avoid a skidding on support frame in the North-South and chiefly East-West direction, which implied a complicated equipment and operation, it had been decided that modules and pancakes would be installed with a horizontal tolerance of ± 25 mm,thanks to the installation of guides on the yard (and bumpers on theplatform),after a survey of the modules/pancakes and of the support frame itself.

The installation of these guides had to be rigorous to insure a successfull operation. Although considered by certain people as "a too constraining and out of common tolerance", this tolerance has been obtained for most packages and was not obtained when positioning of the guides had not been properly realized and controlled (East-West direction) - the "out of tolerance" has however been accepted thanks to the displacement or modification of a H.P. piping line (secondary piping lines could be displaced).

Consequently, no skidding in the East/West direction had to be conducted (this would have been a difficult and costly operation, the success of which was only obvious in the theoretical study.

2.8 Criticism and control of the design.

Since the structures were quite standard, general design and details do not require special criticism but for the following forgotten, or considered too late, joints (excluding padeyes already described hereabove).

a) Since no construction counter deflection or slope for rain water drainage had been designed on the roof and open floors, the last ones showed a concave deformation due to welding which kept the water and made it necessary to add up draining boxes, difficult to position in the middle of very numerous pieces of equipment and very costly to install at the end of the workings.

For future projects, an efficient water drainage should be designed on the upper decks of the modules and on the pancakes exposed to rain.

b) Reinforced areas for jacking operations on the yard (weighing) and skidding pads installation (load-out) had not been provided since the beginning of the studies (pancakes) or were insufficiently important under the modules, which required reinforcing plates to be installed at the last moment (extension of delay, painting destruction etc.).

c) The way the equipments skids have been fixed onto the floors did not properly solve the corrosion problem. In fact, the skid must be welded water-tight on the floor steel plate and the skid should be designed in such a way that not water infiltration is possible, so that the inside is isolated "for life" or else the skid should be raised (at least 0.250, on beams, themselves tightly welded on the floor plate, and, in that case, painting maintenance can be done by access to this free space.

Any intermediate solution will create unattainable non-tight zones, impossible to reach for re-painting.

d) Internal seafastening of equipments, piping and particularly electrical and control compartments (electrical substation, battery room, control room) must be thought of since the beginning and not before leaving.

e) Although these studies were not clearly a part of the scope of work of the engineering company at the beginning, modules and pancakes shimming and mainly packages installation setting within and on the support frame must be a permanently present concern of the designer since guiding, tolerance for installation (for hook-up connection and shimming problems for a good horizontality on the platform when too lately taken into account induce last moment difficulties and modifications.

f) Mention must also be made of the importance (easiness and amount of work) of offshore connection: connection between modules, connections between modules/pancakes and support frame, walkways, staircase installation etc.. Studies must also since the beginning include a design facilitating and minimizing installation connections offshore.

g) Calculation and design have been officially controlled by DnV Oslo, which also gave its agreement on all specifications.

The excellent relationship with this certification organization provided very easy solutions for all the calculation desing and welding problems raised by this project.

All shop drawings of the constructors have been controlled by the engineering company.

2.9 Steel specification and construction.

Elf specifications for steels and construction were not discussed with DnV.

The steel qualities used were as follows:

a) Padeyes (special structure) HS-20 or ST 42-3N for thickness below 50 mm, H4-40 for thicknesses above 50 mm (charpy V at - 40°C).

b) Primary structure (Main beams and trusses Charpy V at - 20°C, HS-20, SHS-20 and ST 52-3N.

c) Secondary structures (floor, pipe support) charpy V at 0°C - ST 37-3/U or M.L.O.

d) Non structural steel (walkways, stairs)no resilience_ ST37-2.

For T shaped welded joints, steel plates were ordered in SHS quality (Quality 2).

As it was already said in the report concerning TCP2 support frame, the fabrication specification is not well adapted for standard modules construction and it should be redesigned as it had been suggested. We have thus added in appendix additions concerning NDT. Controls on welding and construction tolerance eventually accepted by DnV.

Since thickness were below 50 mm (excepted for the modules padeyes) no PWHT was conducted on the weldings.

Although they had end to end 70 mm thick welded joints, the padeyes have not been annealed in agreement witn DnV, since they were considered as a provisional structure. As a set-off, a ratio and U.S. 100% control has been systematically realized on the padeyes.

Finally, yards constructions have been controlled on site by DnV and the ultrasonic control did not raise any discussion.

2.10 Painting

Paint application on these structures because of the long construction and storage times added to the numerous modifications and additions during construction, always creates a badly solved problem.

Elf specification was applied and the system adapted was the HEMPEL, as on the treatment modules (products standardization for maintenance purposes). It must be noted that steel plates ordered from USINOR FRANCE were delivered shot-blasted and pre-painted (SA2,5 sanding and 15/20 μ first layer) - this solution, cheap in our case, should facilitate and minimize sanding on site, but it does not seem that the results obtained were as good as it had been expected.

2.11 Operating loads of compression phase I.

The total load added by the compression equipment remained slightly below the maximum decided in 1977 and compatible with the TCP2 support frame. This last equipment has been checked in August 1980 and all stresses remained under or equal to those checked in 1978.

3. INDUSTRIAL ORGANIZATION OF THE PROJECT.

The industrial organization of the project has been characterized by 5 points deserving to be pointed out, to explain the heavy work load always facing the EAN team responsible of the project:

a) management of the KE/TP engineering was directly realized by EAN

b) the various entities concerned were not geographically dispersed (at least during the intital design phase in Oslo) but, as a set-off, construction was realized in 3 Norwegian yards geographically far from each other.

c) the EAN management has been transferred to Stavanger when the KE/TP engineering remained in Oslo (5 months period with a new lum sum contract) the follow-up team on other hand, did follow EAN management in Stavanger, which allowed to remain efficient in this area.

d) yards and hook-up preparation management was conducted by EAN instead of being entrusted to the engineering, as initially planned.

e) the purchasing and inspection follow-up KE/TP team has also been transferred to Stavanger in 1979 and directly supervised by an EAN representative because of the problems raised by that part of the job.

The localization of the management and construction yards centers provides an explanation for the coordination and communication difficulties met by all parties.

The spreading out of constructions in 3 yards allowed to better remain within the planned delays and not to be dependant upon a single contractor, but it considerably complicated the studies and management work, since although not multiplied by three, the system had to be adapted for the 3 yards.

Qualities and defects of such an organization will be analyzed along with the following sub-chapters:

- EAN management at the engineering and construction level
- Criticism of KE/TP engineering
- DnV action (certification authority)
- Steel procurement and manufacturing quality
- Contractual follow-up

This analysis takes into account the general Frigg job context and the fact that the project has been totally realized in Norway:

- The engineering preparation, call for bids and, in a less important manner structures ordering phase has may be been slightly to short, although it took the already realized projects into account.

Elf policy was to remain as much as possible within the initial planning while maintaining a certain quality of execution.

In order to properly understand the selections made and the difficulties encountered, it must be remembered that KE/TP engineering was a franco norwegian company with the human and language problems to be faced in such an association, that the yards were also in Norway with their own climate competence and productivity problems and finally that the 3 yards dispersion was a complication as far as coordination and standardization are concerned.

3.1 <u>EAN management for engineering structures</u>.

It has been directed by one person only amongst the EAN management team, which, because of the quality of the services provided by the engineering too often had to get into details and apply an exhausting control at all times.

It would be necessary for similar circumstances to strenghten the team with a structure designer in charge of the checking of the details (drawings, specifications, take-off etc.) So that the man in charge would have more time to devote to important problems related to general design, orders,budget planning and relations with other specialities and yards, not forgetting DnV.

Indeed, the EAN management job was not to systematically check all the obtained work of KE/TP and namely whether errors are made on the drawings, but anyway if this proves to be required to face a situation not improved by the engineering such a check-out by an addition of man power would pay out since any drawing error found on the yard is very expensive and disturbs the planning.

Finally, since the engineering was not competent enough for the lifting problem the preliminary studies under EAN Stavanger responsibility (OCD Department) did not begin early enough, which ended up in late design and calculation modifications.

3.2 Criticism of KE/TP engineering.

It must be mentioned that the structure/architecture team was totally KVAERNER and that one TECHNIP person only was in charge of coordination together with follow-up of loads, weight, gravity center specification and take-off problems.

This team began its studies in Oslo with 4/5 persons and reached a maximum of 12 persons, including yards shop drawings controllers.

Follow-up in Stavanger was conducted with a maximum of three people including a calculation engineer.

We shall not make any remarks on the design and calculations quality since the structures have been checked by DnV and accepted without any special difficulties.

Criticism will, as a set-off, concerns the evolution of the project inside the engineering and the specific problems of the structure studies:

a) the self weights of the structures have been under estimated since the beginning, so that not very clear revisions of the weight follow-up did appear.

b) Take-off for steel orders have not been revised in time in despite of our request and this is how about 170 tons of non secondary supplementary steel were only known of at opening of the job sites, hence the starting difficulties encountered in September-October 1978.

c) Internal relationship and coordination with other specialities has not always been efficient and practically did not exist in the monorails for hoist case. In fact, monorail beams have been designed by the structure people when the hoist specialist himself was ordering an equipment for a completely different beam configuration. Besides, some heights under the hook proved to be insufficient, which also jointed out a lack of seriousness or of coordination in the disassembling study plans for maintenance equipments.

d) During the engineering line phase, the problems (at design level) related to lifting, weighing, load-out, transportation, installation on the support-frame and hook-up have been slightly forgotten and set aside which made necessary for us to solve them with the follow up team much later. (the contracts scope of work should be more precise and clear in this area.)

e) too many details errors in the drawings were made because of a lack of control inside the team itself.

It seems that within KE; all draftsmen remain responsible of their work and are not controlled, as this is currently done in other engineering companies willing to provide their clients with a correct work.

f) Not very much flexibility proved to be available from KE to increase the number of people at work when necessary (shop drawings controllers were provided by TP) and a very long time has been required to straighten out the situation again when it was difficult.

g) Consequences of paragraphs c) and f) hereabove were a delay for the plannings and an important difficulty for EAN to understand why some delays were occuring and when some of the operations could be brought to an end.

This is mainly due to the fact that the engineering itself did not understand its own inability to carry a planning to a good end with no delay, and its lack of adaptation capacity when faced with the difficulties inherent to such a project.

A precise example is, taking into account the progress of the piping speciality that of the definition and design of all the piping supports. It proved impossible to know what volume these supports had and when the last drawings would be ready.

This is a great disturbance for the yards not mentioning all the piping and electricity penetrations through the walls which changed many many times in respect to position .

The total number of construction drawings went up to 293 (architecture not included) and, for information, the average key letter indication A,B,Cetc.. before construction was 3, the figure one, 0, 1, 2, 3 etc... during construction was also 3 with a maximum of 6 in each case (some plans were revised up to 12 times..)

This last criticism must however be tempered by the fact that the structure team cannot work efficiently when it does not receive in time informations from other specialists and that any modification made by EAN also disturbed the good operating of the engineering.

3.3 <u>DnV action</u>.

Specifications were approved by DnV Oslo which controlled

KE/TP calculations and design with no special problem. Construction controls on the yards themselves were also conducted by DnV.

3.4 Steel procurment and manufacturing quality.

Structural steels, that is about 1900 tons (with a surplus of 10%) were ordered by EAN from take-offs prepared by KE/TP and this, before selecting the yards.

Taking into account a delivery time of 2,5 months for steel plates (USINOR FRANCE), which was very short and 2,5 to 5 months for sectionnal irons (THYSSEN, Germany) which was more painful, it was possible to deliver steels on the yards at their effective opening date to begin construction.

This method certainly allows to gain a lot of time since the yard cannot order its steels before signing the contract, but it cancels the yard responsibility if errors are found, hence the necessity of an official DnV acceptance at the mill, in addition ot the control made by EAN/KE-TP themselves.

Since quality steels cannot be found on the shelves and since a mill rolling requires a minimum of about 3 months this method is the best one to shorten the general planning and allows a fast start-up for the yards.

In one case, this start-up was difficult since, although 85% of the steels had been delivered at yards opening, some important sectionnal irons were lacking, which stopped fabrications.

3.5 Contractual follow-up

Engineering follow-up was easy in Oslo since the respective offices were close together, but it became more difficult during the lump sum phase after transfer of the management to Stavanger, when KE/TP remained in Oslo and the KE/TP follow-up team was also transferred to Stavanger. The follow-up part and end of project with all concerned gathered in

Stavanger did not raise any coordination problem.

As far as the request for bids issued at the end of 1977, the structure file (number of drawings ready and sufficiently detailed weights estimation and how the one distributed etc.) was not sufficiently ready and precise to prevent the constructor from complaining later, or when modification and inevitable additions in such a project were made. Unit prices list for additional work in order to face change orders was not precise and detailed enough which, no doubt, complicated the EAN yard management job in order to better evaluate additional prices systematically presented by the contractor at each new plan revision, and they were numerous until load-out.

4. RATIOS AND PLANNING.

4.1 Ratios

The reader might refer to Annex 3 where various interesting ratios concerning the cost of the structures are provided. As far as the KE/TP engineering part is concerned, we must mention that it has neither been possible to obtain the overall time spent for the structures nor the final cost of this discipline. It is consequently a global estimation distributed and discussed with one of the structure team representatives that is given in Annex 3.1 and 3.2, and not an official set of results transmitted by KE/TP to EAN. Moreover, costs have been estimated by us from actual costs per hour invoiced by KE/TP. All these figures are consequently minimum results which should be increased by change orders or details that we do not know or which are difficult to extract from the budgets.

Annex 3.3 to 3.10. average ratios can be considered valuable, together with an average price of 55,00 NOK per kilogram for modules/pancakes structure installed and connected on a compression platform.

We can comment as follows on these ratios:

a) Engineering:
Although computation hours have not been substracted from the hours spent on design ratios hour/plan and hour/ton are high.

The total time spent to check shop drawings is also high.

b) Construction:
The date at which steels were purchasing was favourable.

Hour/ton ratios are high for main structures and rather average for small frameworks (walkways, stairs, handrails, pipe supports).

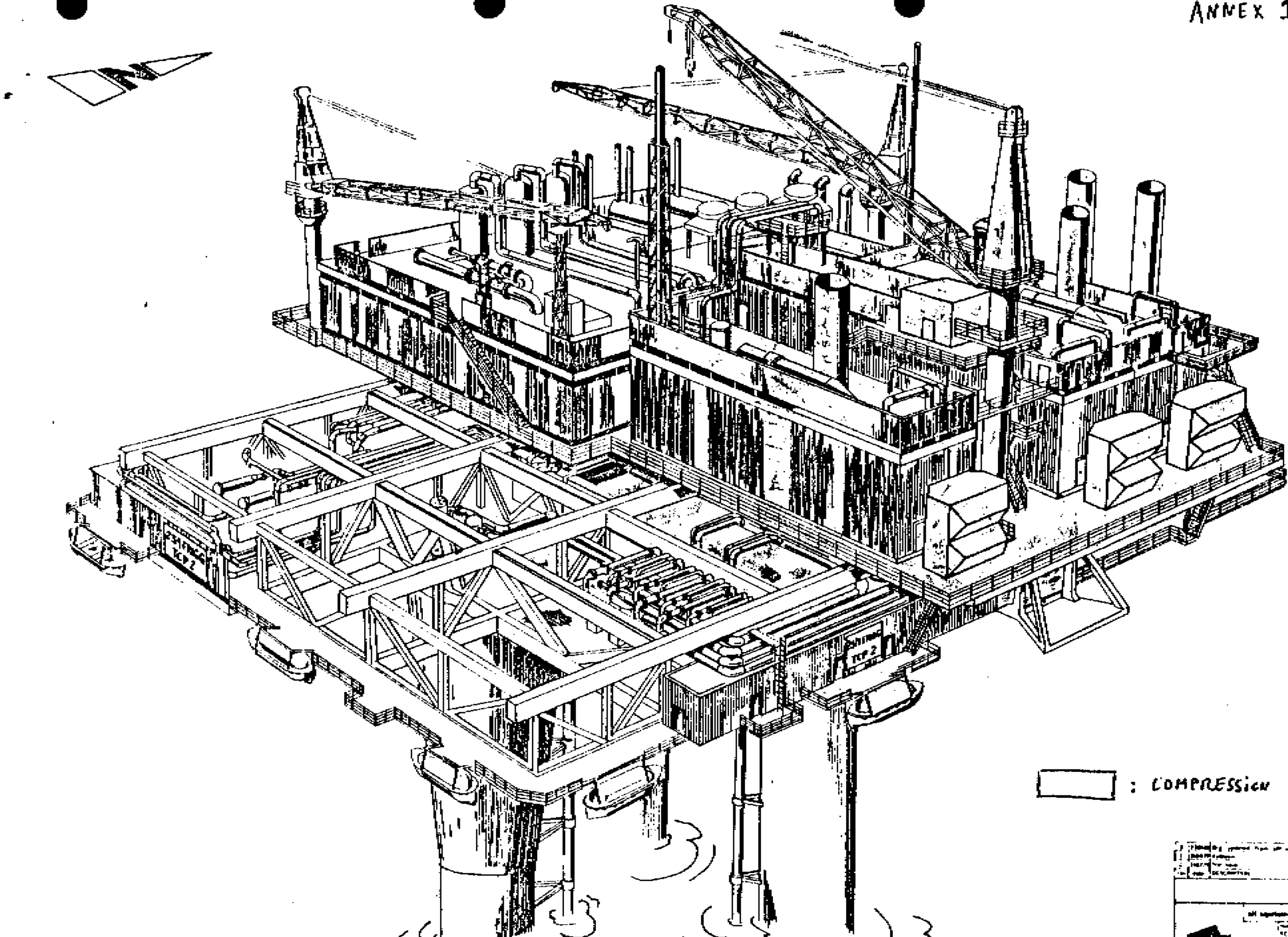
c) EAN management and DnV control costs have not been estimated and taken into account.

D.2 PLANNING

The overall project planning has been summarized in Annex 4 for the various main chapters without entering into the detail of each operation.

Lifting, initially planned for June/July 1979 was realized one year later, but his did not bring any trouble to exploitation.

ANNEX 1



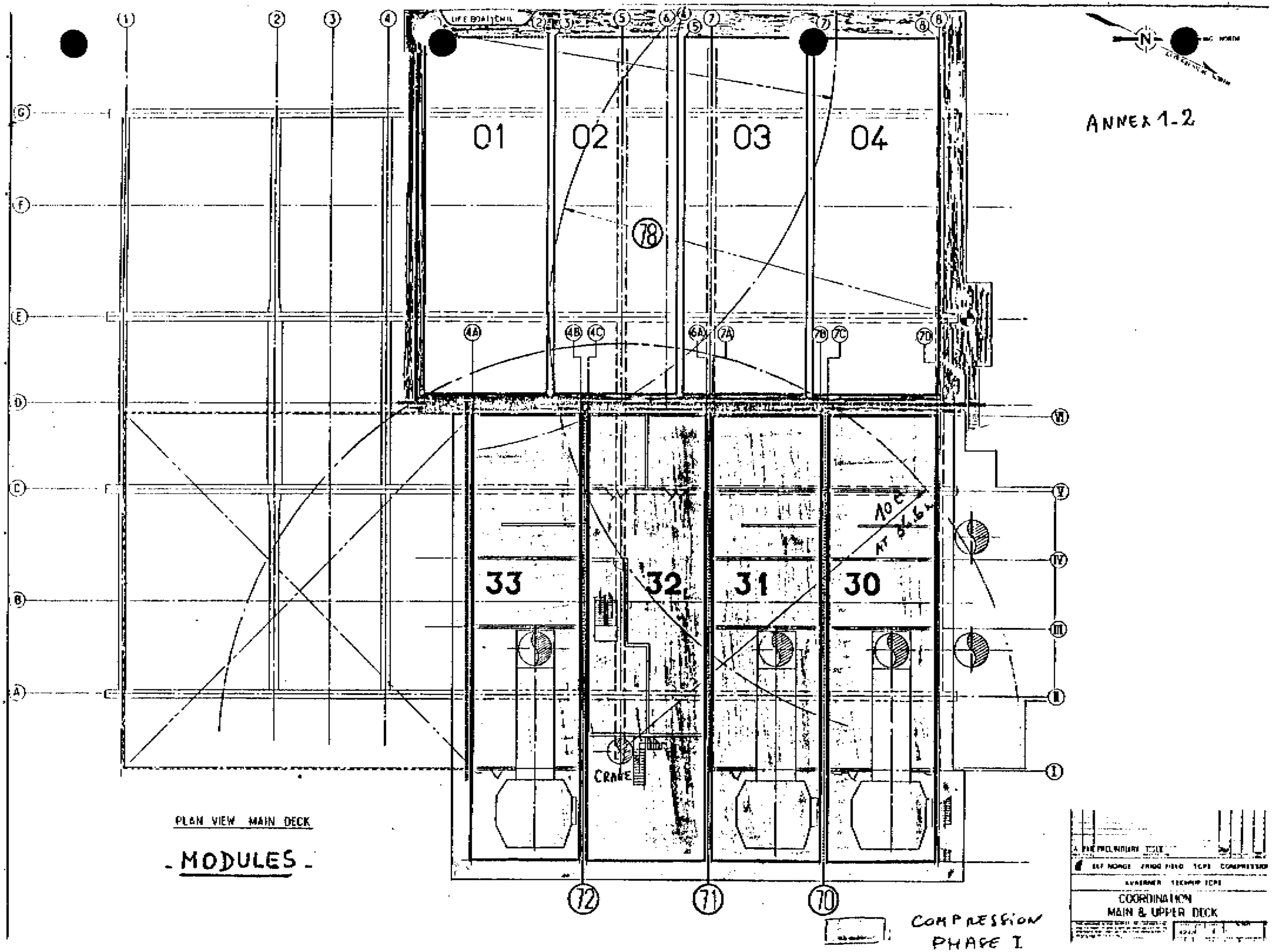
☐ : COMPRESSION PHASE I

PERSPECTIVE OF
TCP 2 PLATFORM

FRIGG FIELD

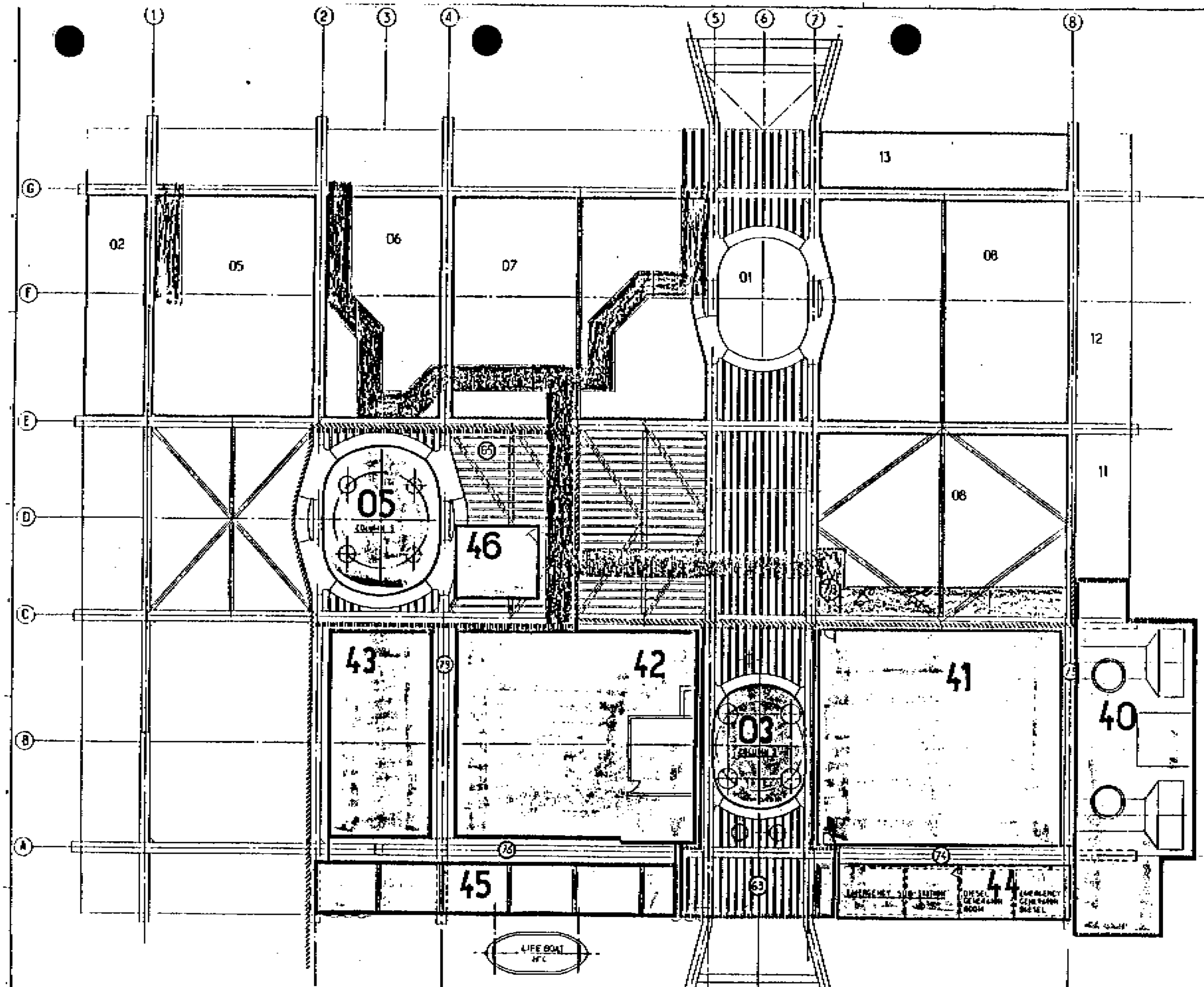
2

ANNEX 1-2



LIFE BOAT/CHIL
01
02
03
04
78
33
32
31
30
CRANE
72
71
70
PLAN VIEW MAIN DECK
- MODULES -
COORDINATION
MAIN & UPPER DECK
COMPRESSION
PHASE I

ANNEX 1.3

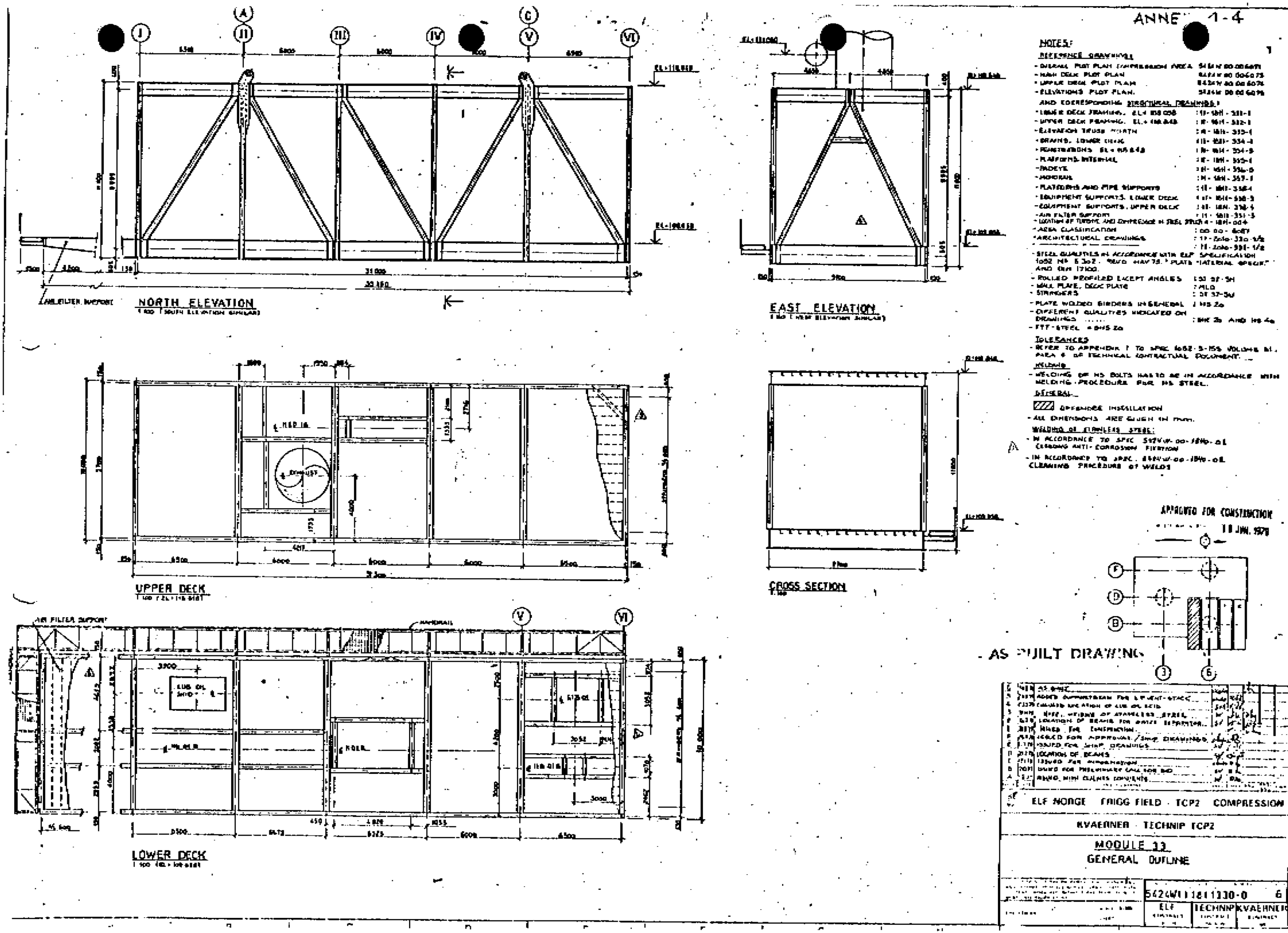


PLAN VIEW CELLAR DECK

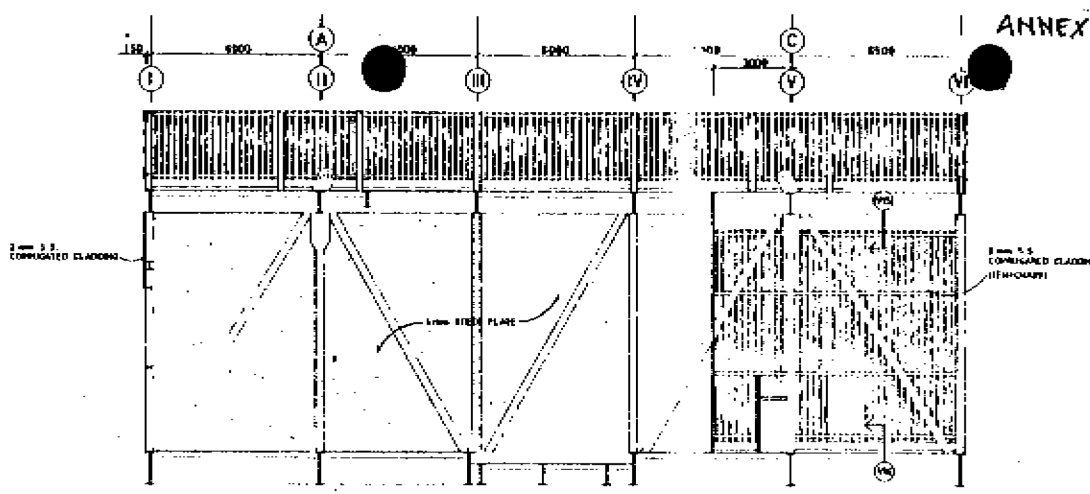
-PANCAKES-

: COMPRESSION PHASE I

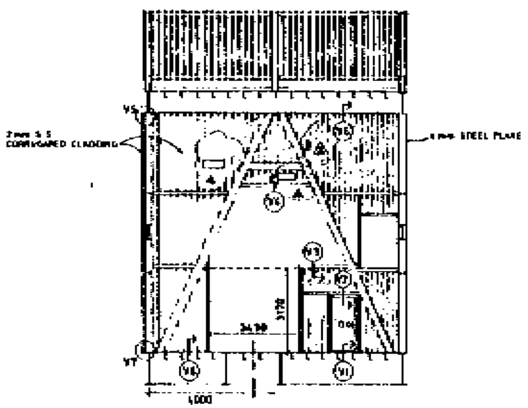
COORDINATION
CELLAR DECK



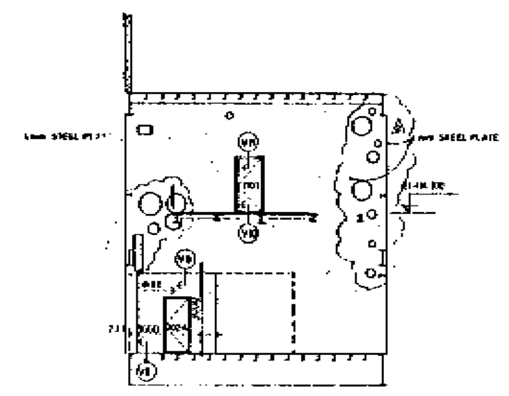
ANNE 1-4
NOTES:
NORTH ELEVATION
EAST ELEVATION
UPPER DECK
CROSS SECTION
LOWER DECK
AIR FILTER SUPPORT
HANDRAIL
LUB OIL
EXHAUST
APPROVED FOR CONSTRUCTION
AS BUILT DRAWING
ELF NORGE FRIGG FIELD · TCP2 COMPRESSION
KVAERNER · TECHNIP TCP2
MODULE 13
GENERAL OUTLINE
5424W11181 1330-0 6
ELF
TECHNIP
KVAERNER



SECTION A-A

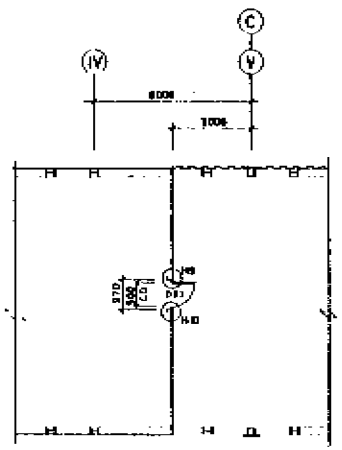


SECTION B-B

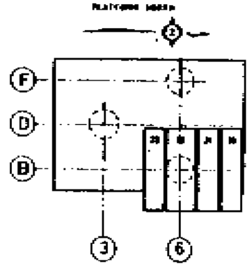


SECTION C-C

REFERENCE DRAWINGS:
ARCHITECTURAL:
PLANS & EXTERIOR ELEVATIONS
WALL DETAILS PLAN
WALL DETAILS SECTION
ARCHITECTURAL SPECIFICATION



GRATING DECK PLAN



NOTE: ONLY MAJOR PENETRATIONS SHOWN

2		ILLUSTRATIONS ADDED	DC
1		ISSUED FOR CONSTRUCTION	FA
D		ISSUED FOR YARD INFORMATION	FA
C		ISSUED FOR APPROVAL	FA
B		ISSUED FOR INFORMATION	FA
IA		INTERIM ISSUED FOR COMMENTS	FA
		MODIFICATIONS	

ELF NORGE · FRIGG FIELD · TCP2 · COMPRESSION

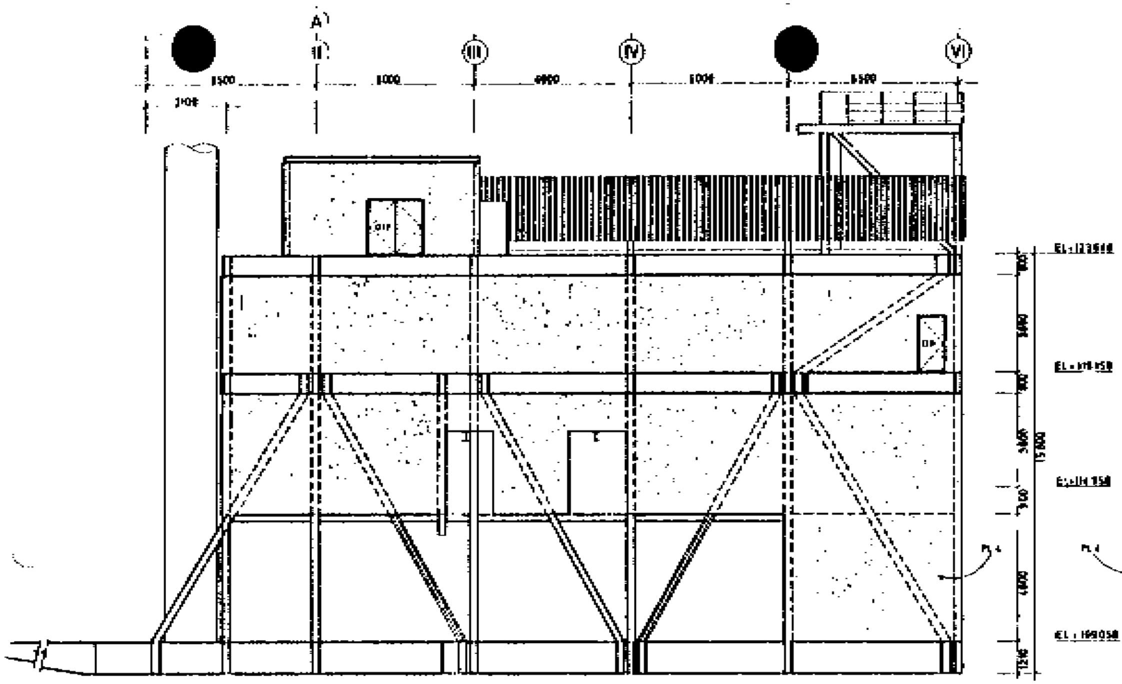
KVAERNER · TECHNIP TCP2

MODULE 33
ARCHITECTURAL
INTERIOR ELEVATIONS & SECTIONS

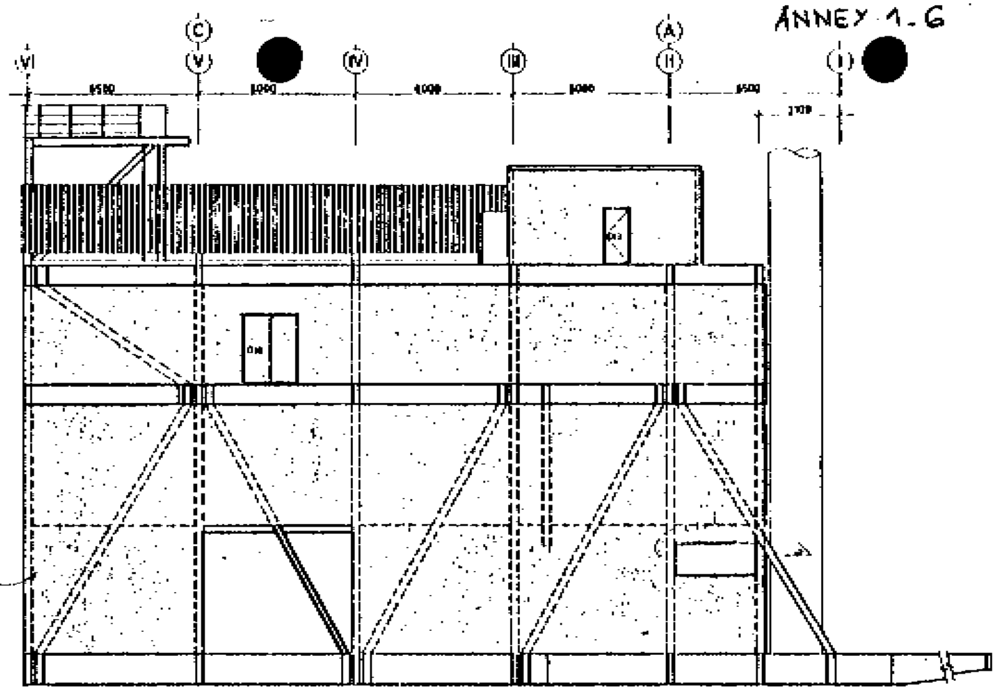
5424W 11 20 1 0330 - 2 | 2

ELF CONTRACT | TECHNIP CONTRACT | KVAERNER CONTRACT

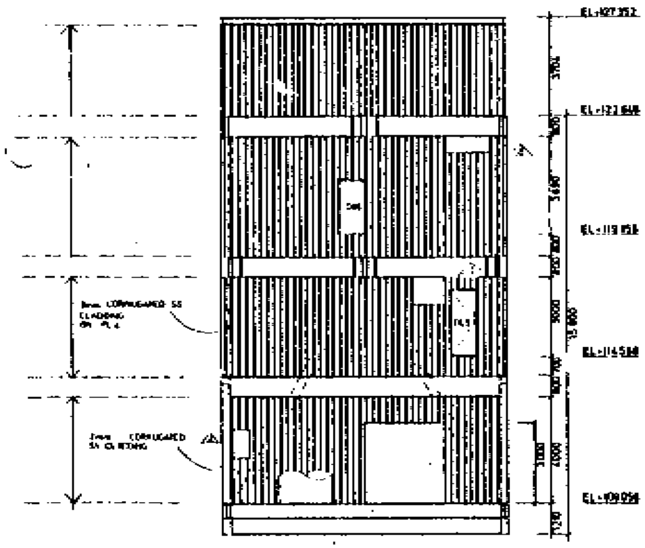
ANNEX 1.6



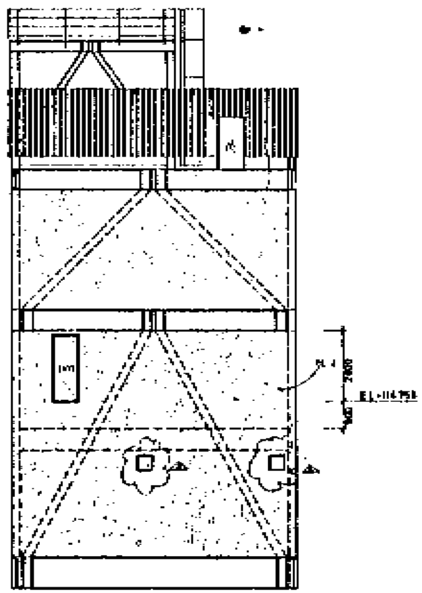
NORTH ELEVATION



SOUTH ELEVATION



EAST ELEVATION



WEST ELEVATION

REFERENCE DRAWINGS:

GENERAL

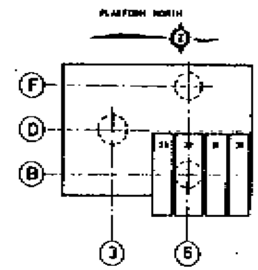
STRUCTURAL

ARCHITECTURAL

ARCHITECTURAL SPECIFICATION

PLANS

INTERIOR ELEVATIONS & SECTIONS



MAJOR PENETRATIONS

ISSUED FOR CONSTRUCTION

ISSUED FOR APPROVAL

ISSUED FOR INFORMATION

INTERNAL ISSUE FOR COMMENTS

ELF NORGE - FRIGG FIELD - TCP2 - COMPRESSION

KVAERNER - TECHNIP TCP2

MODULE 32

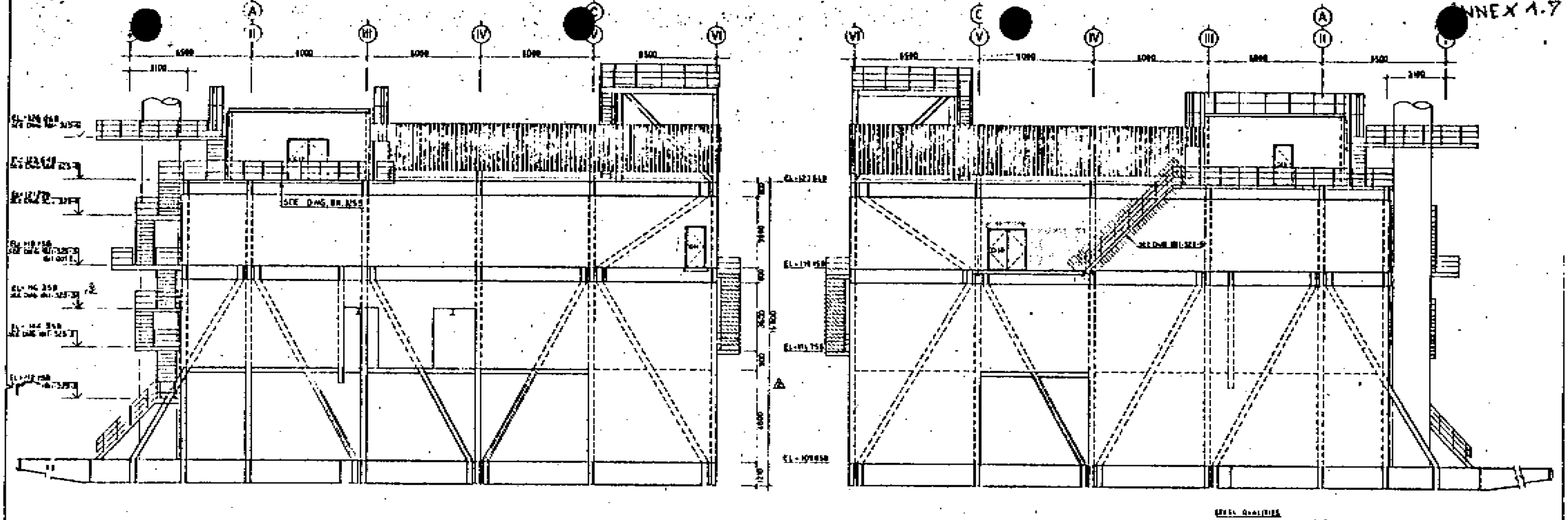
ARCHITECTURAL

EXTERIOR ELEVATIONS

5424W 11 2010320-2 3

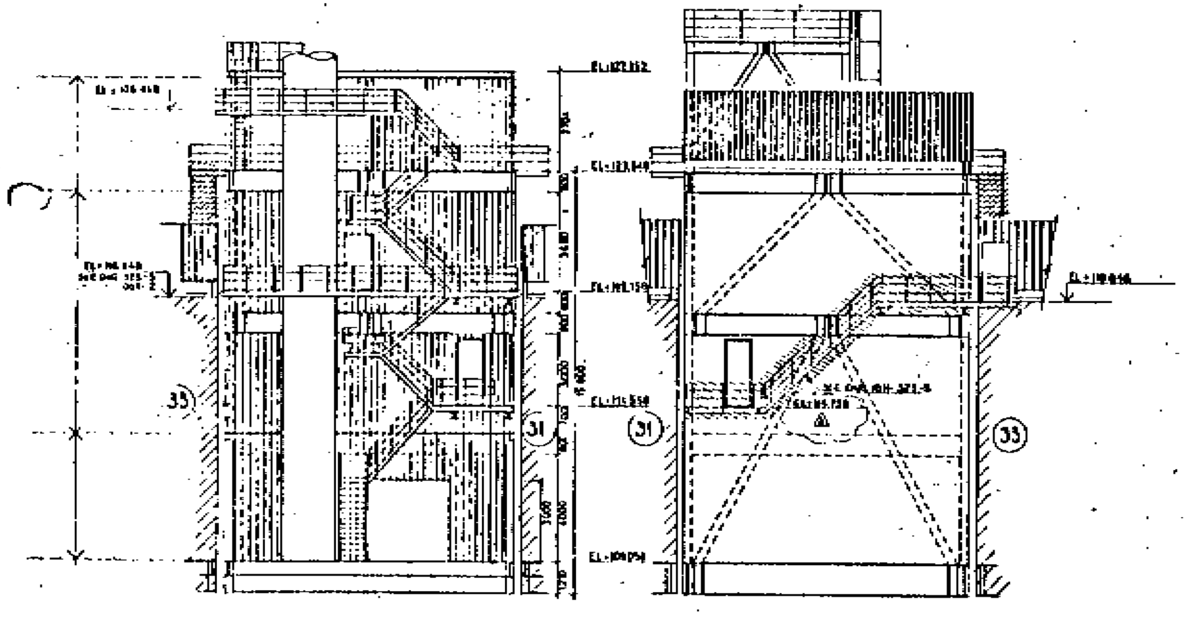
ELF CONTRACT	TECHNIP CONTRACT	KVAERNER CONTRACT

ANNEX 1.7



NORTH ELEVATION

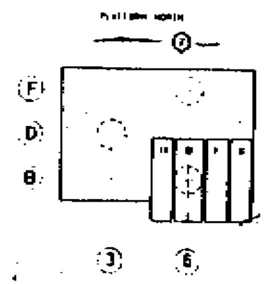
SOUTH ELEVATION



EAST ELEVATION

WEST ELEVATION

APPROVED FOR CONSTRUCTION
25 JUNI 1979



STEEL QUALITIES

TOLERANCES

WELDING

REFERENCE DRAWINGS:

GENERAL

AS BUILT DRAWING

ELF NORGE · FRIGG FIELD · TCP2 · COMPRESSION

KVAERNER · TECHNIP TCP2

MODULE 32
OUTLINE
OUTSIDE STAIRCASE & WALKWAYS

5424W11	811320-2	4
ELF	TECHNIP	KVAERNER

OVERALL SIZES AND TOTAL WEIGHTS OF MODULES/PANCAKES.

	L m.	l m.	H m.	Dead weight of structures (tons)	Total weight in lifting condition (tons)	Total weight in operating condition (tons)
30	40,85	10,0	14,0	350	837	960
31	40,85	10,0	14,0	318	850	980
32	40,85	10,90	20,20	560	1123	1286
33	40,85	10,0	14,0	335	770	900
40	24,28	9,0	8,57	66	132	174
41	18,80	16,30	8,36	220	509	557
42	19,30	16,30	7,55	150	276	504
43	16,30	8,30	8,06	54	152	288
44	20,80	5,50	7,50	68	146	160
45	28,43	4.00	5.36	65	118	193
46	6,95	5,85	5,70	33	60	70

- ALL WEIGHTS IN METRIC TONS

For modules dead weight of structures represents from 37% to 49% of lifting weight and from 32% to 43% of operating weight.

For pancakes dead weight of structure represents from 35% to 55% of lifting weight and from 18% to 42% of operating weight.

ANNEX 2

TCP2 COMPRESSION PHASE I.

MODULES AND PANCAKES

ENVIRONMENT FIGURES FOR CALCULATIONS.

Operational conditions

* Storm condition

$$V_{10} = 55\ {}^{m}/sec$$

$$V_{Z} = V_{10} \quad 0 < Z < 10\ m$$

$$V_{Z} = V_{10}\sqrt{0,93 + 0.007 \times Z} \quad Z > 10\ m$$

Gust wind veolocity (3 sec. gust)

$$V_{t}\ (gust) = V_{10}\sqrt{1,53 + 0,003 \times Z} \quad (V_{10} = 55{}^{m}/sec \quad Z > 10\ m)$$

* Operating condition $V_{10} = 35{}^{m}/sec$

* Deflections of TCP2 support frame have been taken into account according to KE structural analysis made in 1979.

* Crane pedestal has been calculated under fatigue loading (DnV design procedure no. 10D 50 - 3 - 1078. Date: Nov. Dec. 1!

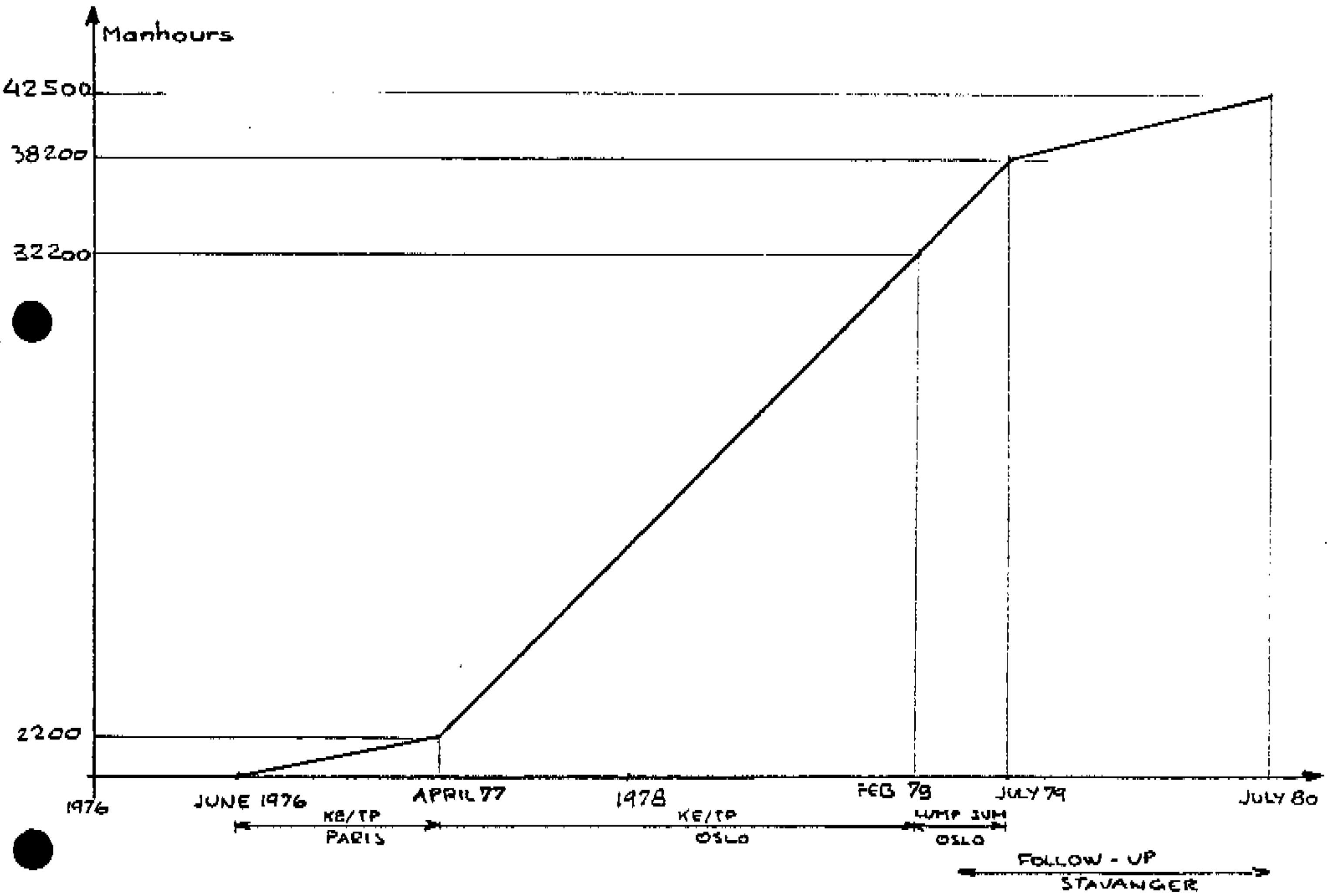
* Air temperature: - 9°C to + 22°C.

ANNEX 3-1.

ENGINEERING OF COMPRESSION MODULES/PANCAKES

PROGRESS OF KE/TP MANHOURS.

Calculation + Design + Shop drawings checking.



1) Engineering study in PARIS (2 people): 2200 h June 76/April 77

2) Engineering study in OSLO (max. 13 people from whom 3 for shop drawing checking. Average 6 people).: 33000 h from which 3000 for shopdrawing checking. April 77/February 1979.

3) Engineering lump sum in Oslo (Average 5 people) 6000 h March 79/July 79.

4) Follow up in Stavanger (2 people): 4300 h May 79/June 80

5) End of Project in Stavanger (max. 1 people): ≃ 200 h July 80/ December 1980.

ANNEX 3-2.

TOTAL KE/TP ENGINEERING MANHOURS SEPTEMBER 1st 1980

439600 h

(Excluding yard services, hook-up engineering, hook-up offshore)

Total structure engineering manhours = 42700 h (9,7% of total)

Split up as follows:

A)	Engineering studies (Calculating + design)	35200
B)	Shop drawing checking	3000
C)	Follow-up	4500

Middle ratios:

Ratio $\dfrac{\text{Total manhours (A+C)}}{\text{Total number of drawings(1)}} = \dfrac{39700}{329} =$ 121 h/dwg

Ratio $\dfrac{\text{Total manhours (A+C)}}{\text{Total weight of structures(2)}} = \dfrac{39700}{2219} =$ 17,9 h/ton

Ratio $\dfrac{\text{Total number of drawings}}{\text{Total weight of structures}} = \dfrac{329}{2219} =$ 0,15 dwg/ton

1) KE/TP design drawings included architectural drawings (No. 36)
2) Total weight of structures fabricated by yards included secondary and nonstructural structures.

ANNEX 3-3

MISCELLANEOUS RATIOS.

1) Estimation of total cost of engineering.

- We have estimated an average price per manhour for the structural team of 6 people during 1978 and 1979 (1 engineer + 1 adjoint + 4 draftment)

1978	:	171 kr/h
1979	:	187 Kr/h
1980	:	215 kr/h (only 2 people)

- For the period in Paris (June 1976/April 1977) KE took a rate of 118 kr/h i.e. 1978 value without escalation (+ 45%)

- We have added too extra costs for reproduction, mail travels, computer and miscellaneous expenses:

$$\frac{120\ 000 \times 42.700\ h}{7\ 200\ h} = 711\ 700\ kr$$

2 200 h x 118	=	259 000 kr
30 000 h x 171	=	5 130 000 "
6 000 h x 187 *	=	1 122 000 "
2 660 h x 187	=	497 420 "
1 840 h x 215	=	395 600
TOTAL:		7 404 620 kr

Estimation of TOTAL ENGINEERING COST but without KE/TP management

7 404 620 + 711 700 = 8 117 000 kr

* HAVING NO LUMP SUM SPLIT COST FOR THIS PHASE WE TAKE A RATE PER MANHOUR OF 187 KR (1979 PERIOD).

ANNEX 3-4

MIDDLE RATIOS

Ratio : $\frac{\text{TOTAL ENGINEERING COST}}{\text{TOTAL WEIGHT OF STRUCTURES}} = \frac{8\ 117\ 000}{2219 \times 10^3} = 3{,}66$ kr/kg

Ratio : $\frac{\text{TOTAL ENGINEERING COST}}{\text{TOTAL MANHOURS (A+B+C)}} = \frac{8\ 117\ 000}{42\ 700} = 190$ kr/h

YARD CONSTRUCTION MANHOURS PER TON AND PRICE PER KILO (3)

	TOTAL WEIGHT tons	TOTAL MANHOURS	MANHOUR PER TON (h)	LUMP SUM OF CONTRACT	UNIT PRICE PER KILO	FINAL COST	FINAL UNIT PRICE (3) PER KILO
Yard 1	1548	264 223 (1)	171	$15\ 098 \times 10^3$ (1439 tons)	10,50	$54\ 164 \times 10^3$	34.99
Yard 2	355	60 000	169	$3\ 548 \times 10^3$ (292 tons)	12,15	$5\ 250 \times 10^3$	14 79
Yard 3	316	44 700	142	$1\ 811 \times 10^3$ (272 tons)	6,66	$3\ 900 \times 10^3$	12.34
TOTAL OR AVERAGE	2219	368 923	166 (average)	$20\ 457 \times 10^3$ (2003 tons)	10,21	$63\ 314 \times 10^3$	28,53 (average)

1) Not included about 3000 manhours to end yard 1 construction (they have been transferred offshore)

2) Including load-out (we have not been able to remove corresponding manhours)

3) These prices are calculated without supplying of structural steels (ST52-3N, HS-20, HS-40, M.L.O.), painting and load out.

NOTA: In total weight are includedladders, stairs, handrails, walkways, cladding....

PAINTING RATIOS (WITH SANDBLASTING)

YARD 1

$$\frac{14598 \times 10^3}{1548 \times 10^3} = 9,43 \text{ kr /kg}$$

$$\frac{14598 \times 10^3}{34\ 000} = 429 \text{ kr/m}^2$$

$$\frac{34\ 000}{1548} = 22 \text{ m}^2\text{/ton}$$

YARD 3

$$\frac{2517 \times 10^3}{316 \times 10^3} = 7,97 \text{ kr/kg}$$

$$\frac{2517 \times 10^3}{8000} = 315 \text{ kr/m}^2$$

$$\frac{8000}{316} = 25,3 \text{ m}^2\text{/ton}$$

INFORMATION ABOUT STRUCTURAL STEELS AND STAINLESS CLADDING ORDERED BY EAN.

++++++++

- Cladding Z2CND 17/13 th = 2 mm   S = 2000 m^2
  Price C & F 1978   406,20 FF/m^2

- Supplying of plates (From 6 to 100 mm)
  - main order

Quality SHS - 20	125 tons	P_1 =	2,307 FF/KG
" HS - 20	560 tons	P_2 =	1,678 FF/KG
" HS - 40	80 tons	P_3 =	1,822 FF/KG
" M.L.O.	400 tons	P_4 =	1,534 FF/KG

NOTA: Price per kilo: H.T. ex-works 1978.

$$\text{TRANSPORTATION PRICE} = \frac{467\ 239 \text{ kr}}{1312,47} = 356 \text{ kr/ton}$$

ANNEX 3-6

TOTAL PRICE FOR PLATES WITH SHOTBLASTING + PRIMER COATING 15 p:

2 129 915 FF

Average price per kilo : $\frac{2\ 129\ 915}{1165}$ = 1 828 FF/KG
(H.T. ex works with primer coating)

Total weight of plates 1165 tons *)

- Supplying of profiles (until heb 600)

  - Main order

Quality ST37 - 3U	183 tons		
ST52 - 3U	215,5 tons	P ≃	267 kr/kg
ST52 - 3N + ST37 - 3U	196,6 tons		

NOTA: Price per kilo: H.T. C & F 1978 with shotblasting + primer coating

Total price for profiles	:	1 591 227 kr
Average price per kilo	:	267.4 kr/kg
Total weight of profiles	:	595 tons

TOTAL TONNAGE ORDERED BY EAN (Main p.orders)	1760 tons
AVERAGE PRICE PER KG.	2,59 kr

1 FF = 1,2 kr

*) In fact we have ordered a total of 1 312,47 tons of plates.

NOTA: In plates price we have added transportation cost of 356 kr/ton (France - Norway).

MISCELLANEOUS RATIOS:

- Vibration study (incl. platform tests) $\frac{710\ 844 \times 1,2}{2219 \times 10^3} =$ 0,38 kr/kg

- Checking of C.O.G.

  \+ Internal seafastening study : $\frac{439\ 680 \times 1,2}{2219 \times 10^3} = 0,24$ kr/kg

- Weighing of modules/pancakes on yards $\frac{364\ 000}{2219 \times 10^3} = 0,16$ kr/kg

AVERAGE RATIO

	PRICE H.T. - NOK/KG	PERCENTAGE
Engineering Study (Calculation-design-shop drawing checking)	3,66	8,0%
Vibration study	0,38	0,8%
C.O.G. checking + Internal seafastening study	0,24	0,5%
SUBTOTAL STUDIES	4,28	(9,6%)
Structural steel	2,59	5,8%
Yard fabrication	28,53	63,8%
Weighing on yard	0,16	0,4%
Painting	9,18	20,6%
SUBTOTAL FABRICATION	40,46	(90,4%)
TOTAL PRICE PER KG BEFORE LOAD OUT	44,74 *)	100 %

* In this ratio it is not included:

1) D.n.V. Control (Engineering + Fabrication)

2) EAN Management for engineering and construction.

MISCELLANEOUS RATIO:

Load out ratio for yard 1 (Information got from yard 1 Report)

$$\frac{1330 \times 10^3}{1548 \times 10^3} = \underline{0,86 \text{ kr/kg}}$$

ANNEX 3-9

LIFTING AND HOOK-UP INFORMATION ABOUT STRUCTURES.

1) LIFTING RATIO

Lump sum contract:

-	Engineering :	200 000 kr
-	Onshore work - transportation	10 900 000 kr
-	Support frame cleaning + lifting	5 875 000 kr
	TOTAL	16 974 000 kr

$$\text{RATIO} \quad \frac{\text{LIFTING PRICE}}{\text{TOTAL LIFTING WEIGHT *)}} = \frac{16\ 975\ 000}{5818 \times 10^3} = \underline{2{,}92 \text{ kr/kg}}$$

*) In this total weight is included temporary pancakes, manitowac crane .... etc. and not only compression modules/pancakes which weighed 5026 tons.

2) Hook-up ratios (Rough information)

Total price (manhours + contractor management)

: 13 000 000 kr (Without EAN Management)

Total productive labout = 60.000 hours

$$\text{Ratio:} \quad \frac{\text{Total price}}{\text{Total structure weight}} = \frac{13\ 000\ 000}{2219 \times 10^3} = \underline{5{,}86 \text{kr/kg}}$$

$$\text{Ratio:} \quad \frac{\text{Productive labour}}{\text{Total structure weight}} = \frac{60\ 000}{2219} = \underline{27 \text{ h/ton}}$$

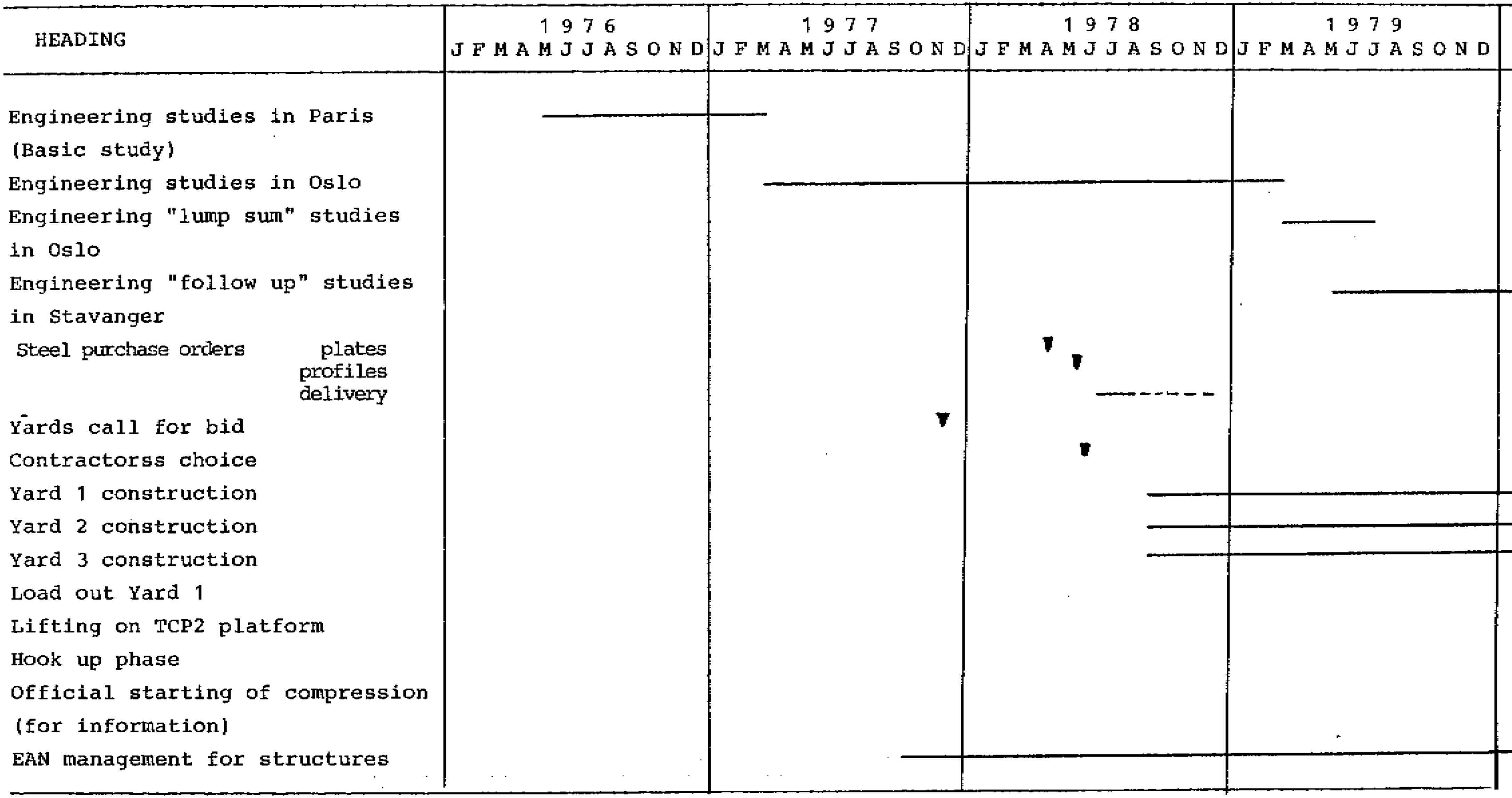
ANNEX 3-10

AVERAGE PRICE PER KILO FOR STRUCTURES
INCLUDED LOAD OUT, LIFTING AND HOOK-UP:

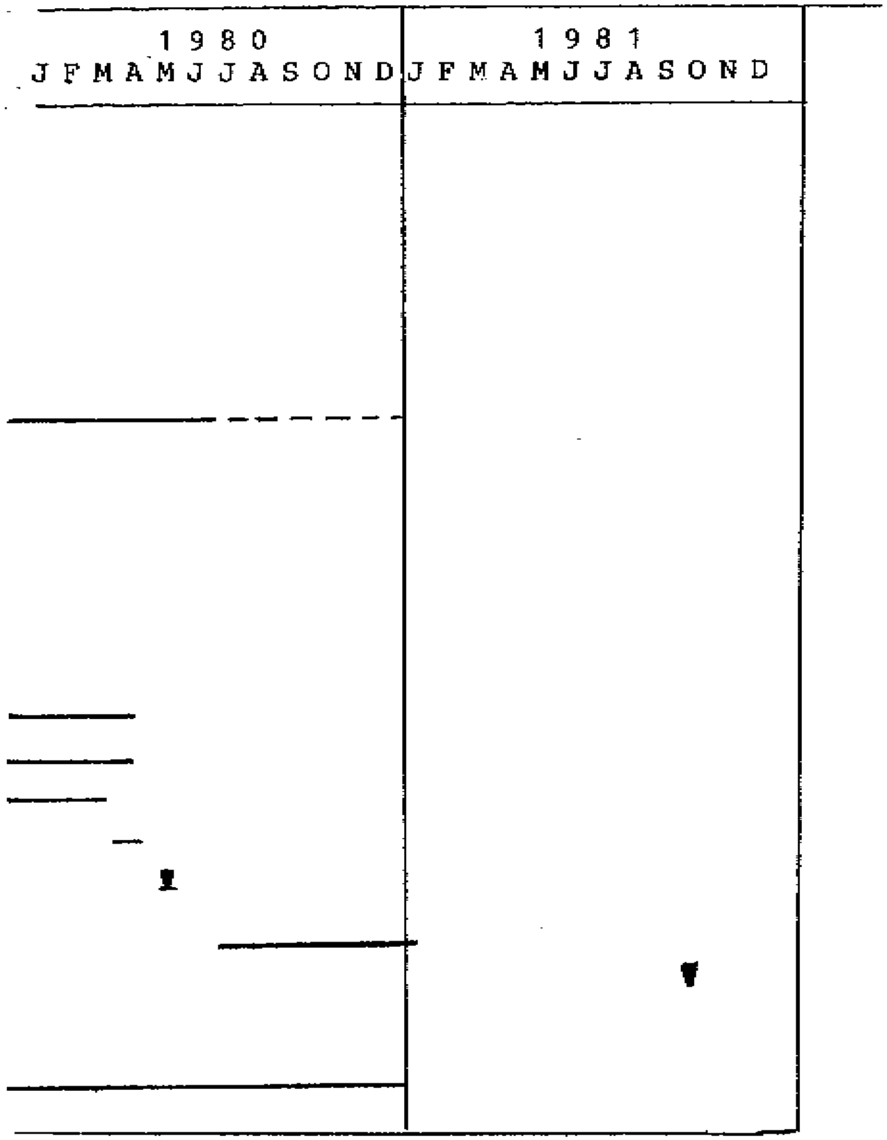
Price per kg before load out	:	44,74
Load out (yard 1 ratio)	:	0,86
Lifting	:	2,92
Hook-up	:	5,86
Total	:	54,38 kr/kg

ANNEX 4

MODULES AND PANCAKES OF COMPRESSION PHASE I



GENERAL PLANNING (STRUCTURES)



C-PIPING DETAILED REPORT

G. Regnault

1. THE LINES.

1.1 HP Gas.

20", 22", 24" 26" Ø (API 5LX 70) Use of a 50 kg/mm^2 yield strength steel has permitted to save 130 t on pipe and fittings dead weight (this compared to treatment materials).

No welding problem was met and post weld heat treatment has been avoided.

Only SUMITOMO was able to supply us at the time of order but USINOR is now able to deliver such a steel.

This steel is to be recommended for future projects.

1.2 Flare.

18", 16" (A 333 Gr 6) the -56°C special requirements created a lot of delivery problems. This steel was used for homogeneity with existing installation.

This solution should be avoided for future projects and use of stainless steel would be better (the price increase of base materials would only be small compared to losses of time on site due to supply problems).

1.3 Sea-water.

28" CuNi. this material was chosen to allow 2,5 to 3 m/s speed thus the pipe sizing was "small".

It has been chosen among:

* titanium (too thin wall thickness and impossible to perform welding on site).
* rilsan coated - epoxy resin armed with glassfiber (not available in such a size)
* copper alloys (too low water speed)

This CuNi was also already used in north sea for sea-water lines.

1.4 Hydraulic.

Use of piping sizing on headers is correct but all branches would have been better with tubing sizing and swagelock type fittings.

1.5 Drainage.

This simple system has still the following problems:

* hydraulic guards are not defined by any code it shall be clear before design, we took 80 mm for compression (150 on treatment side).
* they shall be sized large enough to be able to drain possible additional fire water.
* "swimming pools" on deck are existing. Solution to avoid it would be to locate the gullets when the deck erection and when all equipments are installed.

1.6 Other lines of small size.

Galvanized lines have been prohibited and replaced by stainless steel.

This is a good solution providing good care is taken on connections to carbon steel and on the supporting points.

2. STUDIES

In June 1978 equipments were located and HP lines, cooling water and sea water lines (cooling) were the only ones to be clearly defined but almost no isometric was issued (see curve).

In September 1978 when construction yards started the only approved for construction isometrics (AFC) was those for

HP lines on lot 1 (Orkanger). This HP lines prefabrication (≃ 450 t) was subcontracted to Ponticelli in Ambes (France).

The work was performed on 3 different construction yards which was making more problems for the engineering.

2.1 Lot 1 - Orkanger (subcontractor Ponticelli).

Total piping weight: 712 t
isometrics issued: 409 (plus revisions)

Big modifications occured after the construction started on following systems:

* FLARE defined only end of 1978.
* fuel gas metering modified middle 1979.
* drains modified middle 1980 (hydraulic guards and pipe sizing due to additional fire water lines)
* hydraulic system modified middle 1979 (installation of break flanges for hook up)
* fire water system increased on top of modules beginning of 1979
* HP lines bypass modified beginning of 1979
* reversible blinds added beginning of 1979

2.2 Lot 2 - Kristiansand

Total piping weight = 20 t
isometrics issued = 58 (plus revisions)

Lot 2 isometrics where only issued end of 1979, beginning of 1980.

2.3 Lot 3 - Grimstad

Total piping weigh = 177 t
isometrics issued = 168 (plus revisions)

Fabrication of the sea water lines (CuNi) has been performed by Yorkshire Imperial Metals. Progress of drwg. issues was constant from September 1978 to beginning 1979.

As an evidence we can see that the engineering should have been in the December 1978 progress at the date of starting the construction (or the construction should have been started in January 1980) to avoid almost all the engineering problems specially those due to vendor drawings.

3. MATERIALS PROCUREMENT

Due to engineering progress to low at construction starting date an inacurate estimation of required materials was done. The clear lines where the HP gas and sea-water.

Meanwhile a lot of material was ordered but we had big delivery problems due to unreliable vendors and sometimes a poor material workmanship from the contractors (SBV mainly).

In an other hand very large quantities of materials shall be ordered when the design progress is too low (specially for small size material). The price of non-used materials will be very small compared to the stand by on yards and further modifications.

When being in a hurry, the materials should be ordered ex. works, which leaves us the choice of transporation (to avoid the cheapest carrier i.e. the longer transportation time).

4. FOLLOW UP

A peak of 4 people have been dealing with the end of engineering and with the modifications done after engineering.

The work was to make sketches when required according to site requirements, modifications, end of studies. They had to visit yards when required and the purpose was to have sketches done in very short time.

The main tasks were:

- report of comments on the general arrangements (from structural, electricity, instrumentation, isometric as built)
- as built drawings
- vendor assistance (halon system) sea water rejection shafts
- sea fastening of piping
- supporting
- list of spare materials required after fabrication
- updating P.I.D.
- modifications of drainage, fuel gas, flare, tie-ins
- sketches to answer all the hook up requests.

During hook up phase, many details have been tested and 17 piping modification requirements issued.

This part of the work was more a subject of details on general lay outs than engineering.

5. DOCUMENTS

5.1 General arrangements.

23 drawings have been issued and revised 5 times. These drawings show pipe routings as well as cable trays, equipments, structures.

5.2 Isometrics.

635 isometrics have been issued and revised twice as an average.

5.3 Tie ins.

25 tie-in drawings issued.

5.4 Support drwgs.

5.5 Specifications.

* Piping and valves (revised 11 times!)
* Fabrication specification was issued and completely rewritten by ELF
* Hydrotest and flushing
* Painting (ELF spec.)

5.6 Materil take off.

Computerized MTO has been done but as isometrics were done following TP routines, as take off was done according to KE routines and subcontracted to and external company for programming and printing the time between new information and dispatch of the prints was very long.

The computerized MTO is recommended for future projects because of:

* computer possibilities (item number, description, required quantities, spare, purchased quantities, P/O references weights, etc... can be indicated)
* possibilities of different prints according to the needs.

As in piping the materials are so numerous, this document is essential.

5.7 Requisitions

Were printed from MTO by type of material (flanges, pipes, fittings, carbon steel, stainless etc.) this was a good solution except that we were obliged to wait for the computer print out a too long time.

5.8 Numbering.

Was very heavy and should be more simple. Often are met two drawings with same drawing number (the code, area, unit number, preceding the drwg. number are different) this leading to misunderstandings.

We suggest that we give the numbering system to the engineering prior to start the project in order to be homogeneous with the existing installations if any and to standardize the numbering whatever the engineering is.

5.9 Datas.

See Annex 1 for weight and isometrics issued.
See Annex 2 for isometrics issued and manhours
See Annex 3 for manhours splitting-up.
Isometrics are taken as reference drawings as they are the final documents used for prefabrication, and installation on the yards.

6. CONCLUSION

* the joint venture between KE (Kvaerner Engineering) and TP (Technip) has obviously created many problems by using once KE routines once TP routines. We shall also say that KE did not put qualified people on the piping part of the project the only qualified people was coming from TP but it has been such a flow of personnel that, once one was in the picture, he was leaving. However the leaders have always been the same.
* the purchasing and inspection did not have enough men to make a proper work in the limited time we had.
* the project coordination was much too heavy to be efficient between all the specialists and to schedule properly the works (piping section has been increased twice on ELF request in August 1978).
  The "delivery in time" was not present in the minds.
* the vendor drawings have created many modifications during the project progress (outlet changes, lay out modifications, efforts on nozzles changed).

In conclusion, we can say that, if the engineering would have had 4 months advance or if the yards had started in January 1979, the engineering works would have been satisfactory.

ANNEX 1.

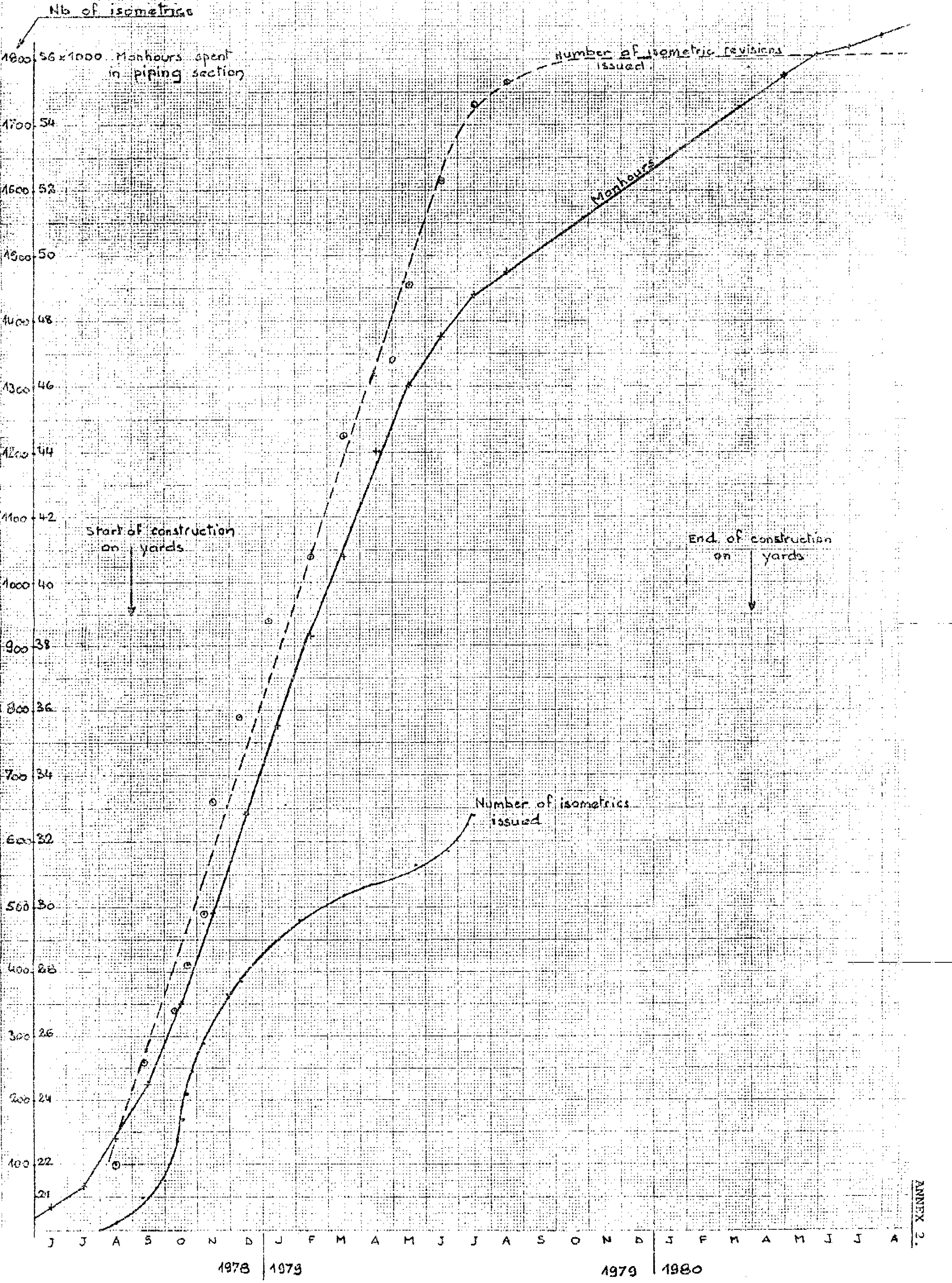
WEIGHTS AND ISOMETRIC QUANTITIES.

LOT	AREA	TOTAL WEIGHT (T)	PIPING WEIGHT (T)	o/o PIPING	ISOMETRIC QUANTITY	ISOMETRIC *) REVISIONS
1	30	910	215	23,6	100	273
	31	910	230	25,3	112	283
	32	1220	72	5,9	90	210
	33	840	195	23,2	107	258
SUBTOTAL LOT 1		3880	712	18,35	409	1024
2	40	175	7	4	20	46
	41	545	10	1,8	24	72
	44	155	2,5	1,6	14	38
SUBTOTAL LOT 2		875	20	2,3	58	156
3	42	340	57	16,8	71	152
	43	170	48	28,2	29	68
	45	130	37	28,5	29	64
	46	60	8	13,3	16	16
	63	150	22	14,7	21	48
	65	55	5	9,1	2	4
SUBTOTAL LOT 3		905	177	19,6	168	352
GRAND TOTAL		5660	909	16,1	635	1532 *)

*) not included: 300 isometrics issued for information.

2,4 revisions done by isometrics
0,5 revisions for information done by isometrics

Average 3,0 revisions per isometric


Nb of isometrics
56 x 1000 Manhours spent in piping section
Number of isometric revisions issued
Manhours
Start of construction on yards
End of construction on yards
Number of isometrics issued
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
21
J J A S O N D J F M A M J J A S O N D J F M A M J J A
1978
1979
1979
1980

ANNEX 3.

MANHOURS SPLITTING UP:

	HOURS	o/o
Leader & coordination	2500	7,5
General drwgs.	7540	22,5
- General arrangements, tie-ins, specifications		
Isometrics	9160	27,5
Supports	3970	11,8
Checking	6505	19,4
Material take off & requisitions	3830	11,4
Follow-up	4600	*)

Engineering	33505
Follow up	4600
	38105

*) On engineering time only.

D. ELECTRICITY DETAILED REPORT

O. De Saint-Albin

PART 1. PRELIMINARY.

1. PRELIMINARY

The electrical part of TCP2 COMPRESSION PROJECT was consisting of two functions

1- to supply electrical power to compression plant facilities
2- to supply electrical power to the whole Frigg Field interconnecting the existing platforms.

The former Frigg Field network was consisting of five platforms supplied from their own autonomous electrical production units and a 5,5 KV distribution system interconnecting these platforms. Subsequently numerous possibilities in operating methods were available, considering the whole electrical power supply and individual supplies to each platform.

The purpose of Compression project was to install on TCP2 the main power plant supplying in Normal Operation the whole field by means of two generating sets. The other main generating sets would be used as stand-by units.

The basic data was the load balance on each platform resulting of meter readings for TCP2(T), TP1, Q.P., CDP1 and DP2. For TCP2 COMPRESSION it was an estimate:

PLATFORM	INSTALLED LOAD (kW)	LOAD IN NORMAL RUN	POWER FACTOR	DEMAND REQUIRED (kVA)
TCP2-C	9 580	6 800	0,8	8 500
TCP2-T	1 700	900	0,85	1 060
T P 1	1 700	900	0,85	1 060
Q P	1 270	600	0,85	710
CDP 1	1 700	350	0,85	410
D P 2	850	300	0,85	350
TOTAL	16 800	9 850	-	12 090

Load balance on each platform.

This report will consist of four main parts:

2. Project organization

3. Technical part

4. Project development

5. Conclusion

Part 2. Technical choices.

2.1 Generating sets
2.2 5,5 KV. network
2.3 380 V network
2.4 Emergency supply
2.5 Transformers
2.6 Cables
2.7 Bulk material
2.8 Neutral system - earthing
2.9 Short circuit
2.10 Protection
2.11 Electrical ESD
2.12 Operation

2.1 Generating sets.

The former 5,5 KV network was supplied by means of 6 generating sets:

3 x 3,5 MVA sets TA1-TA2-TA3 for TP1
3 x 1,75MVA sets TA4-TA5-TA6 for TCP2(T)

Q.P. was supplied from either TP1 or TCP2(T).
CDP1 from Q.P. and DP2 from TCP2(T)

The 5,5 KV was only used as distribution voltage (no consumer on this voltage) the installed load was 7 000 KW and load in normal run 3 000 KW.

For the compression project the installed load was estimated at 9 500 KW and the load in normal run at 6 500 KW.

INSTALLATION	INSTALLED LOAD LOAD (KW)	LOAD IN NORMAL RUN (KW)	REQUIRED POWER (MVA)
Former network	7 000	3 000	3,5
TCP2 Compression	9 500(est)	6 800	8,5
TOTAL	16 500	9 800	12,0

In its final shape the 5,5 KV network is supplied from TCP2 Compression. So two STAL LAVAL generating sets GO1A and GO1B are located on TCP2(C) each generator having 17,15 MVA capacity.

Comment:
Following technical and Commercial bid comparison three possibilities were presented by Engineering for EAN approval. Solution 1, 2 and 3 (3 being the recommended solution) Norwegian Authorities suggested to keep solution 2, this explain the reason why we have two big sets instead of three smaller units (see paragraph A.7.3.2 hereabove).

2.2 5,5 KV network (see annex 1).

The 5,5 KV network is in a radial structure, in which each one of Q.P. TP1 and TCP2 treatment 5,5 KV switchgears are connected to TCP2 compression switchgear by means of two feeders.

The whole network can be powered by means of 8 gas turbine driven generators:

- TA1, TA2, TA3 on TP1
- TA4, TA5, TA6 on TCP2(T)
- GO1A, GO1B on TCP2(C)

Each one of TCP2(C), TCP2(T) and TP1 switchgear is composed of three bus sections separated by two bus-tie circuit breakers.

Except for TCP2 compression, the 5,5 KV switchgears are equipped with circuit breakers.

TCP2 compression switchgear is equipped with circuit breakers for the feeders to platforms and with vacuum contactors to supply 5,5 KV/380 V transformers and 5,5 KV motors.

Platforms CDP1 and DP2 are supplied in a radial way by means of one feeder only.

Comment:

a) It is not usual to mix circuit breakers and vacuum contactors. After 6 months operation we have no special comment concerning the vacuum contactors and we recommend this solution for high voltage motors.
b) We can consider as an anomaly to have 3 bus sections and 2 generators. The design was to have 3 generators and we kept this design in order to make possible an eventual change.
c) The quality of the TCP2 Compression 5,5 KV switchgear is good. Both MERLIN GERIN circuit breakers and GEC vacuum

contactors are reliable and experienced equipment.

d) Authorities made reference to "Norwegian High Voltage operation regulations" specially for earthing equipment during maintenance on the switchgear.

2.3 380 V. network (see annex 2)

The low voltage distribution system is a standard radial type with a main 380 V. switchboard split in 2 bus sections with symetrical supplies to subdistribution panels. It can be fed:

* in normal conditions from two 2500 KVA transformers
* in shut down conditions from a 1200 KVA diesel-generator.

An interlock system avoids paralleling of the 2500 KVA transformers.

In normal condition the main 380 V switchboard supplies the emergency 380 V panel. In case of electrical shut down the emergency panel can supply the normal switchboard - these operations are manually done.

Comments:

c1) In case of failure of one transformer the change over is manually done. An automatic change over source should be considered as a better solution.

c2) As a general the design of all low voltage panels is not suitable for good access and maintenance. For installation the following points must be carefully checked:

a. back access of the panels
b. front access with place large enough for connections
c. a strong follow up in factory in order to check the quality and operating/functions with tests.
d. to order to the panel manufacturer bolts and cable glands for buss bars and cable entries.
e. to make sure that current transformers are sized according to the cables installed on the Yard.

c3) It is not possible to supply both fuel gas switchboard from one 1MVA transformer. This is an exception and not in line with the philosophy in the main 380 V switchboard in which both buss section A and B can be supplied by one 2,5 MVA transformer. For process reason it is not necessary to have both fuel gas packages supplied simultaneously at full power.

c4) Concerning turbogenerator the MCC switchboard Manufacturer recommends to supply it directly from 5,5 KV generator through a specific transformer. In such a way turbogenerator is not dependant of the network. We recommend this solution for all generators.

2.4 Emergency supply (see annex 3)

The emergency network is consisting of three main equipments:

* the diesel generator
* the no break system
* the distribution panels.

2.4.1 Diesel generator

The main comment is concerning the dual function of the TCP2 Compression diesel generator. It is first an emergency supply in case of ESD situation.

In such a case, electrical trips occur according to ESD logic diagram. The diesel starts automatically and only supplies emergency consumers (less than 200 KVA).

The second function is the auxilliary supply of essential consumers in case of loss of normal voltage but with no emergency situation. In that case, the capacity is 1200 KVA and it is possible to resupply the main 380 V normal switchboard by manual closing of circuit breakers, from the emergency switchboard.

Comment:

No comment except that an automatic closing of the circuit breakers in order to resupply the normal 380 V switchboard has been requested by production at end of start-up. This is possible but we do not recommend it.

2.4.2 No break system.

This system is consisting of three subsystems:

- 110 V DC for electrical
- 110 V DC for instruments
- 220 V AC for instruments

The 110 V DC systems are equipped with 2 lines working in parallel each one having a 100% capacity.

Comment:

This system is working properly but it is not possible to use line no. 1 battery bank with line no. 2 battery charger. A manual switch could be provided in order to get this possibility.

The 220 V AC no break system was previously designed with 2 identical lines (rectifier + battery - inverter) one in operation, one in stand-by and a static switch for automatic no break change over of inverter outputs. We have got a lot of troubles with this system and the new design is consisting of 2 independant systems with inverter and a line back up transformer connected to a static switch. We have so doubled the capacity and the system is now working properly in spite of high inrush current due to transformers in the load.

Comment:

Concerning the AC no break system the main comment is to recommend not to use transformer in the load. The output voltage of the inverters must be prescribed to the vendors.

2.4.3 Emergency distribution switchboards

Comments:
There are two comments concerning these panels:

a) it would have been a more flexible solution to get the possibility of supplying this panel from both buss sections of normal 380 V switchboard. As it is now, only buss bar B is connected to the emergency switchboard.

b) A 400 KW load bank have been designed in order to load the diesel when it is used during test/maintenance period. From our point of view this solutions is not the best way and we recommend to use the network for this purpose as far as it is possible.

2.5 Transformers

Comment:
The main comment for the transformers concerns the necessary interlock in order to avoid parallel running. It should be better to have the possibility to run the transformers in parallel (mainly to transfer the load). This must be done with right adaptation between size of transformer and short circuit capacity of buss bars in 380 V switchboard (override possibility is not accepted by norwegian authorities).

Offshore we have got a problem with wrong size of low voltage plugs on the transformer and section of cables to be connected

2.6 Cables

Comments:
Yards claimed on bad quality of cables:

* variation of overall diameter
* innersheath dissolved with armour in connection with cables. We draw the attention on cable glands. In spite of clear specification, a lot of cable glands were not suitable for these cables. This

is mainly a problem of Vendors and inspection.

2.7 Bulk material

They are:

* local control station
* Junction boxes
* sockets outlets
* lighting fittings
* cable ladders

Comment:
We recommend to consider existing material offshore and to get approval of Maintenance people. Following these recommandations we did not have any problem.

- We have used stainless steel cable ladders instead of galvanized and we recommend this solution.
- A clear definition must be done in order to have segregation where EXe and/or EXd classified equipment must be used.

2.8 Neutral system - Earthing.

For each one of the main gas turbine driven generator, the neutral is connected to earth by means of a 17Ω impedance. Consequently the 5,5 KV network neutral must be considered as earthed through impedance, which value is depending on the number of generators in operation.

The distribution system is three phased with solidly earthed neutral. In addition there is a separate protective earthing wire. Inside each module there is an earthing loop. All modules and pancakes are interconnected by a main earth ring which is connected to structure each x meters.

Comment:

Because in our installation neutral is not used the circuit breakers are three poles and neutral bars are equipped with links. However our feeling is that this arrangement is not the best and circuit breakers should be four poles in order to switch the neutral.

2.9 Short circuit (see annex 4 and 5)

The main problem we have met concerning this matter is due to the extension of the former network with addition of two big generators, 5,5 KV motors and short distance between generation and consumers.

In order to get a minimum short circuit level we have specified generators with high subtrancient reactance value (20%).

The main data, design criteria and results are given in annex 4 for 5,5 KV network and annex 5 for 380 V network.

Comments:

Concerning the 5,5 KV short circuit calculations we point out that Norwegian Authorities rules are more stringent than standards (IEC and BS) three different calculations have been performed:

1. in SNEA(P) FRANCE
2. in SOCETEC FRANCE
3. in EFI NORWAY

The results with all the 8 existing turbo-generators running are the following:

I peak (KA) / Switch gear	SNEA (P)	SOCETEC	EFI	AUTHORIZED LIMIT
TCP2 (C)	79	82	86,5	95
TCP2 (T)	77,8	79,4	84,8	78
TP1	74,4	73,7	80,4	78
Q.P.	65,8	61	71	78
CDP1		20,7	19,3	25
DP2		16	16,3	25

A lot of discussions concerning coefficients to be used, rules, took place but no compromise was accepted by Norwegian Authorities. So, interlocks have been installed in order to avoid parallel running of the 8 generators.

Concerning low voltage network the calculation was made in SNEA PAU and all switchboards and cables are correct except TCP2 Compression main 380 V switchboard for which short circuit capacity was to short in case of parallel running of both 2,5 MVA transformers. As far as override is not accepted by Norwegian Authorities an interlock avoids the parallel running.

2.10 Protection

Comment:

1) Norwegian regulation is not so stringent than IEC concerning earth fault protection except for lighting and trace heating circuits for which earth fault relay with high sensitive settings must be installed.

2) Concerning selectivity, this matter must be carefully studied by Engineering as far as Panel manufacturer does not take care of it.

2.11 Electrical ESD (see annex 6)

From NPD regulations, an emergency shut down system is a system which, when initiated,operates the emergency shut down valves, stops and isolates the process equipment and eliminates any potential sources of ignition.

The electrical equipment are potential sources of ignition and some of them are source of hazard (gas turbine, battery).

But some electrical equipments are needed to feed essential and emergency equipment which must be kept alive for people safeguard.

Comment:
The main comment is that ESD philosphy must be defined at the beginning of the project as far as it has consequences on all studies. The following main points must be carefully designed and discussed with every specialist in the project (Process - Structure - Electrical - Instrument and Safety) they are:

- Regulations
- Area classification
- Electrical equipment classification (Ex)
- Electrical room
- List of
  * emergency auxilliaries
  * essential
  * non essential
- location of electrical ESD system
- procedure to restart

As a conclusion a clear philosophy, for what is regarded non essential, essential and emergency, must be set up, as well as area classification requirements for equipment remaining alive after gas detection.

For TCP2 Compression a PLC is used for process, ESD but electrical logic and actions are done in a relay panel. We do not recommend to split these functions. For future project, the PLC should integrate the complete ESD system from detectors up to trips and any action.

2.12 Operation of Frigg Field network.

In spite of no special comment concerning operation of the network we will give the principles of operation.

In normal operation the electrical power of the whole 5,5 KV network is ensured by means of GO1A or GO1B. The other generating sets are used as stand-by. The diesel motor driver generating sets are emergency generators and they cannot be connected with 5,5 KV net. In order to get the best selectivity of protections, the loops made by TCP2(C) switchgear and the TCP2(T) TP1 and Q.P. switchgears are open in normal coperation.

The stand-by operation is when the two STAL LAVAL generators are out of service simultanoussly.

Q.P., CDP1 and DP2 are islanded and their diesel generators automatically started.

TCP2(T) is islanded and supplyied by its own generators (1 Kongsberg is sufficient).

TCP2(C) and TP1 are supplied by TP1 generators. Depending of number of available sets a load can be done on TCP2 Compression.

Part 3. Project Organization.

1. Generalities
2. Basic and detailed Engineering
3. Procurement
4. Vendors Follow-up
5. Yards Follow-up
6. Hook-up, Commissioning, Follow-up
7. As built - troubleshooting diagram.

1. GENERALITIES.

The Engineering was performed by Franco-Norwegian Joint Venture KVAERNER/TECHNIP. Norwegain part was mainly KVAERNER ENGINEERING company which is a recent daughter company of the large group KVAERNER BRUG. French part was TECHNIP but with a few experience in OFFSHORE activity. (PETROLAND).

2. BASIC AND DETAILED ENGINEERING.

No basic engineering was defined by ELF in the Engineering contract with KE/TP. In addition to that the limit of Engineering work between basic and detailed Engineering was not clear and the consequences have been a permanent misunderstanding between KE/TP and EAN management because a general engineering defined as sufficient for Construction in France is not sufficient in Norway.

Comment:
For future project a clear limit of engineering work must be given in the contract. We do not recommend a middle distance limit between basic and detailed engineering. For each item:

* switchboards
* cables
* consumers.

Kind and limit of document must be clearly stated. We recommend the maximum of details in engineering work and minimum studies on yards.

3. PROCUREMENT

No special comment concerning this activity for which the procedure was rather good. We only met problems with norwegian bidders who offered material not manufactured in Norway. Very often a lot of subcontractors or middlemen were introduced and we suffered a lot from this fact:

- * No respect of specification
- * difficulties to get documentation.

4. VENDOR FOLLOW-UP

KE/TP considered vendors as fully responsible of their package and limited the follow up to check the limits of supply and quantity. In fact in order to answer EAN comments they discovered after a few months necessity of a detailed ckecking of drawings in regard to KE/TP specifications and EAN requirements. This explain a large additional work and increasing of manpower = 1 Specialist Engineer and 2 draftmen in KE/TP. On our side, an Engineer specialised in Engineering follow-up was requested (M. Queille) and necessary up to the end of Engineering work.

In connection to this vendors follow-up activity were the inspection problems. Due to lack of manpower inspections were limited to visual and quantity ckeckings and this is certainly not sufficient. We strongly recommend to include in inspection job ticket:

- Cenformity and respect of Engineering drawings
- Checking in detail that eventual Engineering modifications are performed
- Operating tests.

We point out that in addition to the inspector, an Engineering representative is often necessary in manufacturer for part of these inspections.

5. YARDS FOLLOW-UP

It appeared that this activity revealed oneself to be the most important of the project. In the yard contract KE/TP was supposed to supply Engineering guide drawings and Yard to perform detailed drawings.

- Engineering detailed drawing according to EAN/KE-TP interpreting

- Construction details according to yard interpreting.

In order to solve this misunderstanding a strong Follow-up team took place and problem was solved. We consider that no detailed study have been performed by yards. They only performed shop drawings and as built. We recommend this limit as far as Yards generally have no Engineering manpower.

The main critisism can do is that Follow-up team started to late and the only solution was to issue sketches attached to Engineering drawings. It involved a lot of claims from Yards.

6. HOOK-UP. COMMISSIONING FOLLOW-UP.

As far as the yards follow-up team have been used for Hook-up and commissioning follow-up, a good continuity was ensured.

7. AS BUILT. TROUBLESHOOTING DIAGRAMS.

It is clear that troubleshooting diagrams ready for commissioninf is the best solution. But these TSD are never included in Engineering contract.

We succeeded for 5,5 KV equipment to perform the TSD in due time in order to be used by commissioning team. So, we received back from commissioning commented TSD which can be considered as "as built drawings".

In addition, these TSD are made according to standard used by maintenance and production people.

For the rest of the equipment the TSD have been performed after commissioning. As an evidence they cannot be as built. The best way would be to include in Engineering contract the TSD. In such condition, Engineering will perform and design documents ready to be completed in TSD.

Part 4. Project Development.

1. Phases. Schedule
2. Reasons of delay
3. Staff - Quantity - Ratio

1. **Phases - Schedule (see annex 7.8)**

Engineering started in Paris in 1976.

In summer 1977 KE/TP moved to Oslo to start basic engineering and procurement activity.

The engineering work was supposed to be finished mid of 1979 In fact in March 1979 it appeared that Engineering was minimum 6 montths late and decision was to move in TECHNIP Paris in order to increase manpower for Electrical and Instrument sections.

At the same time, part of people came to Stavanger in order to start yards follow-up.

End of 1979 people who where in Paris joined Stavanger and Engineering was officially final and all forces assigned to Follow up activity.

2. **Reasons of delay.**

- Misunderstanding concerning the limit of engineering
- Only head of electrical section belonged to KE/TP. All other people being contracted. This was not good conditions to use KE/TP procedures and standards.
- All along the project, the electrical leader changed three times, and finally, a contracted Engineer took the responsibility.
- No sufficient manpower according to detailed studies requested by EAN.
- lack of coordination, particualarly when manpower increased to eighty people.
- unclear limit of supply between instrument and electrical sections.
- Yards, for which call for bid have been placed too early, were calling for detailed drawings which were not ready.
- Changes of philosophy in EAN included a lot of modifi-

cations in engineering drawings as far as in Vendors (delay in delivery on yards).

- Many amendments induced a lot of additional work

    * new take offs
    * modification of specifications.

- Wrong organization in KE/TP between Specialists - Project and draftoffice. In addition the supervision from head office in Paris.
- The construction in three different yards, have had a lot of consequences, particularly in Instrument and Electrical.

    * split of cables and equipments
    * Hook up junction boxes.

- Late philosophy from EAN concerning emergency and Safety functions (ESD) involved many modifications.
- In order to answer to yards requests a lot of additional works have been performed. Ex.: Split and marking of cables in Cable trays.
- We draw the attention on a decision from project coordinator in KE/TP which induced hard consequences:

  the fact that piping arrangement be considered as synthesis drawings for piping, electrical Instrument and Safety.
- Finally, the main reason for delay is too many changes and modifications involving many new issues for drawings. For most of the drawings issue 10 have been reached.

3. Staff - Quantity - Ratios

3.1 Staff (See annex 7 and 8)

- Total engineering manhours 439 600 hrs.
- Electrical engineering manhours 66 300 hrs.

= 15,1%

Comment:
66 300 hrs includes KE/TP follow-up up to September 1981. It does not include 5,5 KV interconnection study. The split per year of Electrical engineering is:

1976	1800 H
1977	11400 H
1978	19800 H
1979	21600 H
1980	7200 H
1981	4500 H
Total	66300 H

3.2 Quantity

EQUIPMENT	PRICE K NOK	WEIGHT TONS
Turbogenerators	30 000	300
Switchboards	10 300	67
Cables	3 800	56,5
Diesel-generator	1 800	9
Transformers	700	15
Bulk	3 100	18

Switchboard's length 125 m
Total cable's length 106 km

Number of drawings	AO	43
	A3	1 035
	A4	1 410
	TOTAL	2 488

Number of troubleshooting diagrams 2 035 (A3)

Comment:
TSD include Engineering + Vendors documents.

3.3 Ratios

$$\frac{\text{Turbogenerators cost}}{\text{Weight}} = \frac{30\ 000\ 000}{300\ 000} = 100 \text{ NOK/KG}$$

$$\frac{\text{Electrical equip. Cost}}{\text{Weight}} = \frac{19\ 000\ 000}{165\ 000} = 120 \text{ NOK/KG}$$

$$\frac{\text{Total equip. cost}}{\text{Weight}} = \frac{49\ 000\ 000}{465\ 000} = 106 \text{ NOK/KG}$$

$$\frac{\text{Electrical equip. weight}}{\text{Installed power}} = \frac{165\ 000}{6\ 800} = 25 \text{ KG/KW}$$

$$\frac{\text{Total cable length}}{\text{Installed power}} = \frac{105\ 800}{6\ 800} = 15 \text{ M/KW}$$

$\frac{\text{Equipment Cost}}{\text{Installed load}}$
- → With turbogen. 7 300 NOK/KW
- → Without turbogen. 3 000 NOK/KW

$$\frac{\text{Total manhours}}{\text{Number of drawings}} = \frac{66\ 300}{2\ 500} = 26{,}5 \text{ H/Drawing}$$

Part 5. Conclusion.

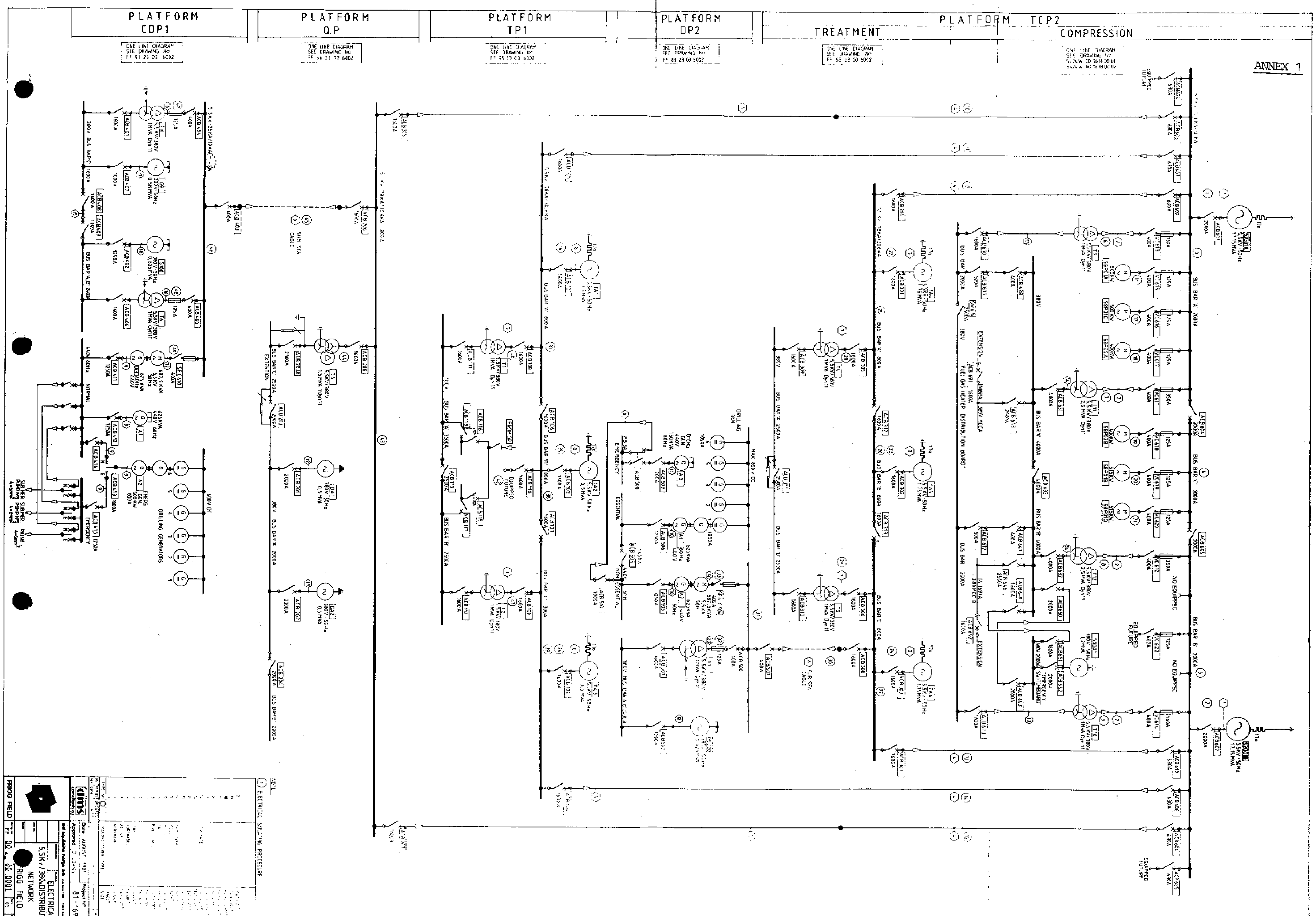
All along chapters and paragraphs we gave comments and they can be considered as conclusion.

We just list hereunder the most important points:

1. Basic is necessary
2. Clear limit for engineering work
3. Coordination must be considered as an important job
4. To get approval from authorities on

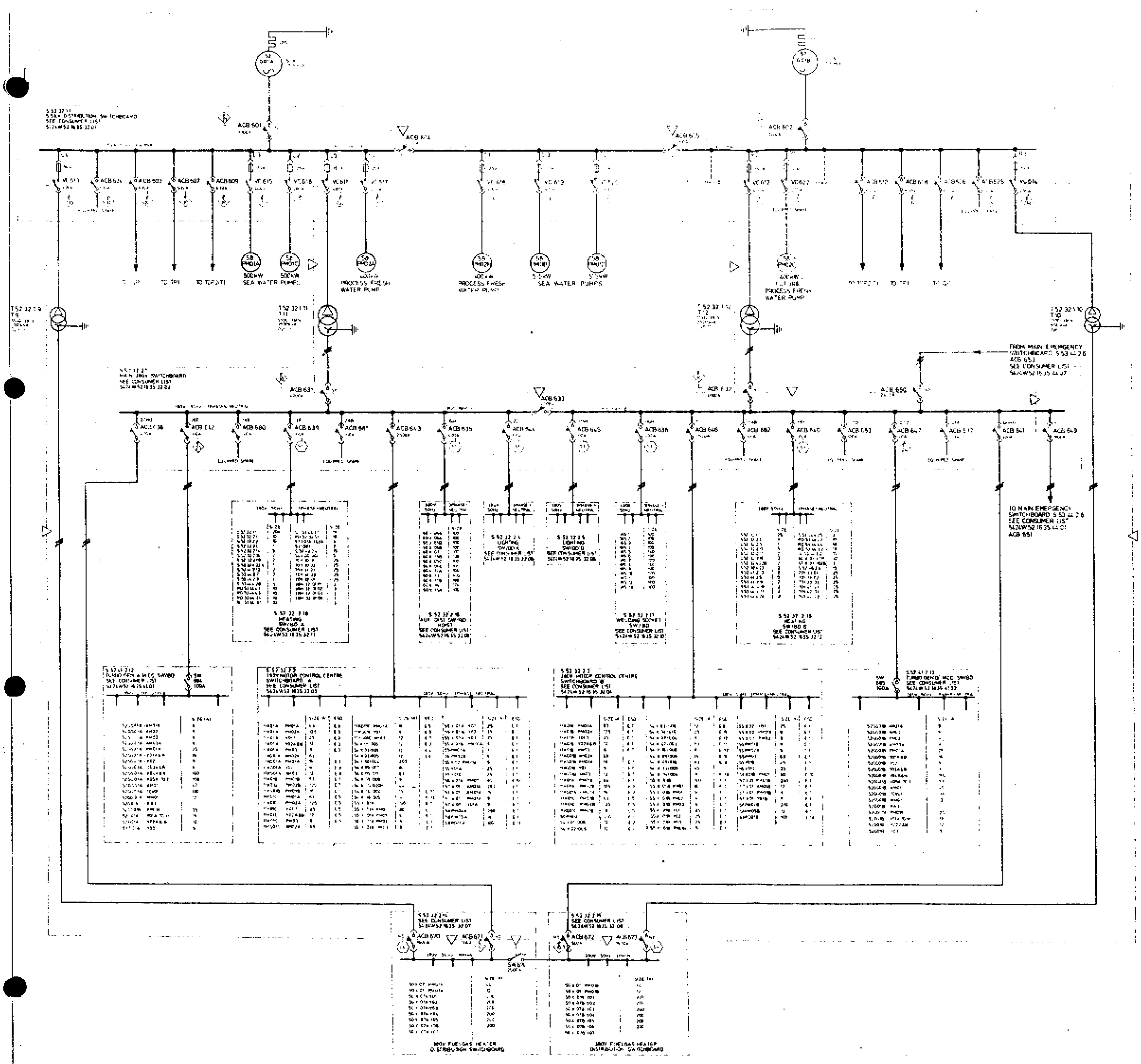
   - basic
   - single lines

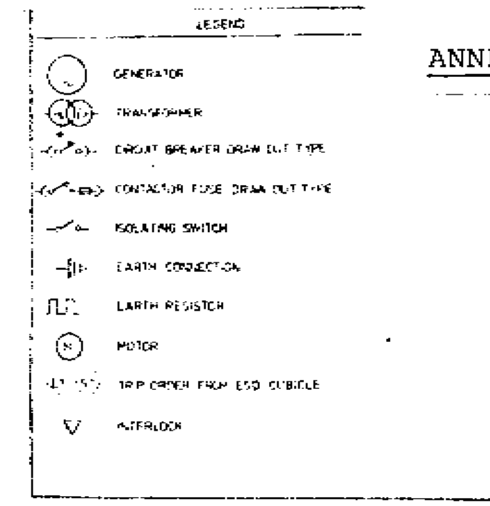
5. Inspection not limited to quantity
   Tests must be included.
6. Engineering drawings in line with troubleshooting standards
7. To avoid so many revisions.



PLATFORM CDP1
PLATFORM Q.P
PLATFORM TP1
PLATFORM DP2
PLATFORM TCP2
TREATMENT
COMPRESSION
ONE LINE DIAGRAM SEE DRAWING No FF 51 23 02 6002
ONE LINE DIAGRAM SEE DRAWING No FF 56 23 17 6002
ONE LINE DIAGRAM SEE DRAWING No FF 55 23 03 6002
ONE LINE DIAGRAM SEE DRAWING No FF 83 23 03 6002
ONE LINE DIAGRAM SEE DRAWING No FF 55 23 50 6002
ANNEX 1
ELECTRICAL ISOLATING PROCEDURE
ELECTRICAL 5,5KV/380V DISTRIBUTION NETWORK
FRIGG FIELD

ANNEX 2.





NOTE: NEUTRAL DISTRIBUTED ONLY S 52 32 . 16 / S 52 32 . 18 / S 52 32 24 / S 52 32 25

REFERENCE DRAWINGS:

5424 W 00 16 33 00 03 EMERGENCY SYSTEM SINGLE LINE DIAGRAM

5424 W 00 16 32 00 04 ELECTRICAL SHUTDOWN SCHEMATIC DIAGRAM

ELF NORGE · FRIGG FIELD · TCP2 · COMPRESSION

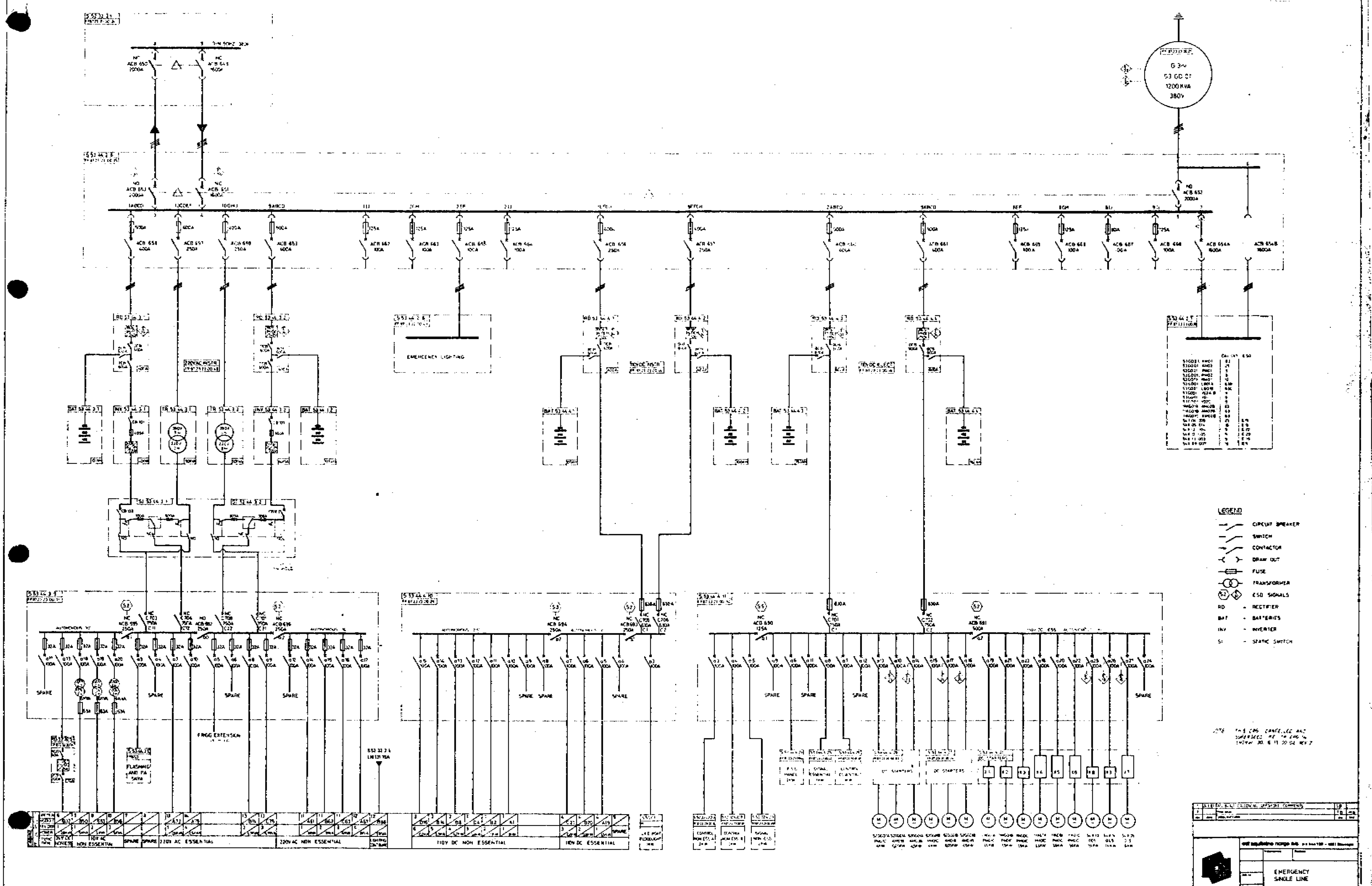
KVAERNER - TECHNIP TCP2

SINGLE LINE DIAGRAM

5424W00 16330001

ELF TECHNIP KVAERNER

ANNEX 3.



G 3~
53 GD 01
1200 KVA
380V
EMERGENCY LIGHTING
220VAC NON ESSENTIAL
220V AC ESSENTIAL
110V DC NON ESSENTIAL
110V DC ESSENTIAL
FLASHING AND PA
SPARE
LEGEND
CIRCUIT BREAKER
SWITCH
CONTACTOR
DRAW OUT
FUSE
TRANSFORMER
ESD SIGNALS
RD - RECTIFIER
BAT - BATTERIES
INV - INVERTER
SI - STATIC SWITCH
EMERGENCY
SINGLE LINE

A N N E X _ _ 4.

5,5 KV SHORT CIRCUIT CALCULATION.

1 - SCOPE

The purpose of this note is to estimate the maximum values of short-circuit currents for faults occurring on one point of the 5.5 kV network of Frigg Field in its final layout.

From these short-circuit current evaluations it will be checked whether th characteristics of electrical equipments (breaking and making capacities, section of feeders) are acceptable and whether any provision should be made (interlocking devices) in order to limit the number of generators running in parallel.

Nota : This technical note replaces the calculation note issued in July 1979.

2 - DESIGN CRITERIA

2.1 - General

These evaluations have been performed in accordance with the electrical data in our possession.

- Power balance.
- Characteristics of equipments (switchgears, transformers, feeders, motors).

The method of evaluation defined hereafter is based on the calculations of resistances and reactances of each equipment and on the arrangements of the IEC publication n° 363 (short-circuit current evaluation with special regard to rated short-circuit capacity of C.B. in installations in ships).

2.2 - Short-circuit duration

When a short-circuit appears, for a fault occurring on a point of a network, the current will be asymetrical, including both A.C. and D.C. components, which decreases in time. The maximum peak currents are obtained after the first half-period (10 msec). The short-circuit duration can be divided in three periods of time :

- from 0.01 sec to 0.08 sec, approximately.
  This period corresponds to the subtransient characteristics of rotating synchronous and asynchronous machines. The asymetric component of the current becomes equal to zero at the end of this period.

.../...

- from 0.08 to 0.5 sec : Period corresponding to the transient characteristics of the rotating machine. During this period the generator exciters get up to their ceiling voltage.

  The opening of circuit breakers is generally operated during this period.

- over 0.5 sec period corresponding to the steady state conditions of synchronous generators (no more contribution of motors).

2.3 - Network layout

These short-circuit current evaluations have been performed according to the following assumptions :

- all main generators (TA1 to TA6, GO1A and GO1B) running in parallel.
- all feeders between different switchgears energized (all incoming, outgoing and bus-tie breakers closed).
- the fault occurring on the network is a "Bolted three-phase short-circuit" (without resistance).

This represents the most unfavourable conditions of operation for the Frigg Field network.

The different load balances taken into account in this study have been defined in the basic philosophy of operation previously issued by SOCETEC.

3 - SHORT-CIRCUIT CURRENT CALCULATIONS

3.1 - Subtransient period

3.1.1 - Generators and transformers

All impedances are defined on the R + jX form.

a) When the value of R is not known (this is the case of transformers), it can be deducted from the asymetrical coefficient by the formula $K - 1 = e^{-\frac{Rt}{L}}$ where K is the asymetrical coefficient ($\geqslant 1$) and from the following table :

$L\omega/R$	1	1.5	2	3	4	5	6	8	10	14	∞
K	1.06	1.15	1.24	1.38	1.46	1.56	1.62	1.68	1.74	1.80	2

.../...

As the asymetrical coefficient is 1.8 for transformers, their resistance is equal to the fourteenth of their reactance.

b) For generators, I.E.C. publication n° 363 recommends to take into account the subtransient impedance $Z'' = R_s + j X''_d$

where R_s = stator resistance

X''_d = direct axis sub-transient reactance.

3.1.2 - Motors

The problem is more complicated for the motors because :

- the aperiodic component damps with the stator time-constant.

- the sinusoïdal component damps with the rotor time-constant.

As these time-constants are generally equal, the amplitudes of their components are always equal and give 2 for the asymetrical coefficient.

This leads us to consider that the resistance of motors is R = 0.

For this impedance in the subtransient period, we must use the value corresponding to 10 msec. by the formula :

$$I_{cc} = I_D \sqrt{2} \quad e^{-t/\tau_1} \cos \psi - (1 - \sigma)\, e^{-t/\tau_1} (\cos \omega t + \psi)$$

where :

- $\sigma = 0{,}05$

- $\tau_1 = \tau_2$ = 15 msec for LV motors and 40 msec for HV motors

- $\psi = 0$ for the most unfavourable conditions.

If we take I_D = 6 In as an average value, we obtain the following results.

- HV motors = Icc = 13 In (peak value)
  Icc = 4 5 In (eff. value)

- LV motors = Icc = 8 7 In (peak value)
  Icc = 3 In (eff. value)

Nota : For LV motors it is necessary to take into account the cables with regard to the damping that they involve. The following calculations have been performed according to an average value of 1.65 as asymetrical coefficient for LV motors and of 2.8 In as Icc value.

3.2 - Transient period

3.2.1 - Generators

For the calculations corresponding to the transient period it is unneccessary to take into account R and X values for the generators. Their impedance Z can be directly drawn from the value of the transient reactance X'd.

3.2.2 - Motors

As a general rule, it can be considered that the contribution of motors at the beginning of the transient period is equal to their rated output.

3.2.3 - Generator cables

Their impedance is the same as during the subtransient period.

3 - IMPEDANCES CALCULATIONS

3.1 - Subtransient period

3.1.1 - Generators

Generator	Rated output MVA	X"d %	R Ω	X Ω
G01 A	17.15	20	0.004674	0.35276
G01 B	17.15	20	0.004674	0.35276
TA 1	3.5	16.7	0.0353	1.443
TA 2	3.5	16.7	0.0353	1.443
TA 3	3.5	16.7	0.0353	1.443
TA 4	1.75	16.3	0.1231	2.8175
TA 5	1.75	16.3	0.1231	2.8175
TA 6	1.75	16.3	0.1231	2.8175

3.1.2 - Transformers

Transformer	Rated output kVA	Ucc %	Z Ω	R Ω	X Ω
T1 - T2	1000	5.1	1.543	0.110	1.539
T3	1500	5.1	1.029	0.073	1.026
T4 - T5	1000	4.84	1.464	0.104	1.460
T6-T7-T8	1000	4.34	1.313	0.093	1.310
T9 - T10	2500	7	0.847	0.060	0.845
T11 - T12	1000	5	1.513	0.108	1.504

3.1.3 - Motors

Reference	Rated output kVA	Icc/I_N	R Ω	X Ω
58 PM 01A	602.4	4.5	0	11.159
58 PM 01B	620.5	4.5	0	10.833
58 PM 01C	602.4	4.5	0	11.154
58 PM 01D	620.5	4.5	0	10.833
58 PM 02A	470.6	4.5	0	14.284
58 PM 02B	470.6	4.5	0	14.284
58 PM 02C	470.6	4.5	0	14.284
TCP2 C (T9)	1250	2.8	4.479	7.391
TCP2 C (T10)	1250	2.8	4.479	7.391
TCP2 C (T11)	1000	2.8	11.199	18.478
TCP2 C (T12)	1000	2.8	11.199	18.478
TCP2 T (T5)	550	2.8	10.181	16.798
TCP2 T (T6)	550	2.8	10.181	16.798
TCP2 T (T7)	500	2.8	11.199	18.478
TP 1 (T1)	750	2.8	7.466	12.319
TP 1 (T2)	750	2.8	7.466	12.319
QP (T3)	800	2.8	6.999	11.549
CDP1 (T6)	250	2.8	22.398	36.957
CDP1 (T8)	250	2.8	22.398	36.957

3.1.4 - <u>Feeders</u>

Feeder	R Ω/km	X Ω/km	length	R Ω	X Ω	Z Ω
G 0 1 A - TCP2-C	0.0465	0.0942	10	0.0005	0.0009	0.0010
G 0 1 B - TCP2-C	0.0465	0.0942	10	0.0005	0.0009	0.0010
PM 01 A - TCP2-C	0.529	0.085	37	0.0196	0.0031	0.0198
PM 01 B - TCP2-C	0.529	0.085	37	0.0196	0.0031	0.0198
PM 01 C - TCP2-C	0.529	0.085	32	0.0169	0.0027	0.0171
PM 01 D - TCP2-C	0.529	0.085	32	0.0169	0.0027	0.0171
PM 02 A - TCP2-C	0.529	0.085	53	0.0280	0.0045	0.0284
PM 02 B - TCP2-C	0.529	0.085	56	0.0296	0.0048	0.030
PM 02 C - TCP2-C	0.529	0.085	59	0.0312	0.0050	0.0316
T 9 - TCP2-C	0.154	0.0785	43	0.0066	0.0034	0.0074
T 10 - TCP2-C	0.154	0.0785	37	0.0057	0.0029	0.0064
T 11 - TCP2-C	0.154	0.0785	46	0.0071	0.0036	0.0080
T 12 - TCP2-C	0.154	0.0785	40	0.0062	0.0031	0.0064
TA 4 - TCP2-T	0.154	0.0785	32	0.0044	0.0025	0.0055
TA 5 - TCP2-T	0.154	0.0785	34	0.0052	0.0027	0.0059
TA 6 - TCP2-T	0.154	0.0785	42	0.0065	0.0033	0.0073
T 4 - TCP2-T	0.151	0.1005	48	0.0072	0.0048	0.0087
T 5 - TCP2-T	0.151	0.1005	52	0.0078	0.0052	0.0094
T 7 - TCP2-T	0.195	0.0785	1100	0.2145	0.0863	0.2312
TA 1 - TP 1	0.154	0.0785	6	0.0009	0.0005	0.0010
TA 2 - TP 1	0.154	0.0785	6	0.0009	0.0005	0.0010
TA 3 - TP 1	0.154	0.0785	9	0.0014	0.0007	0.0016
T 1 - TP 1	0.154	0.0785	19	0.0029	0.0015	0.0033
T 2 - TP 1	0.154	0.0785	19	0.0029	0.0015	0.0033
T 3 - Q P	0.154	0.0785	26	0.0051	0.0020	0.0055
T 6 - CDP 1	-	-	-	-	-	-
T 8 - CDP 1	-	-	-	-	-	-
TCP2-C - TCP2-T	0.0465	0.0942	80	0.0037	0.0075	0.0084
TCP2-C - TCP2-T	0.0465	0.0942	40	0.0019	0.0038	0.0042
TCP2-C - TP 1	0.0465	0.0942	280	0.0130	0.0264	0.0294
TCP2-C - TP 1	0.0465	0.0942	250	0.0116	0.0235	0.0262
TCP2-C - Q P	0.0465	0.0942	470	0.0218	0.0443	0.0494
TCP2-C - QP	0.0465	0.0942	430	0.0200	0.0405	0.0452
Q P -- CDP 1	0.195	0.0785	700	0.1365	0.0549	0.1471

3.2 - Transient period

3.2.1 - Generators

Generator	Rated output (kVA)	Z'd %	Zd Ω
G01 A	17 150	25	0.441
G01 B	17 150	25	0.441
TA 1	3 500	20	1.729
TA 2	3 500	20	1.729
TA 3	3 500	20	1.729
TA 4	1 750	22	3.803
TA 5	1 750	22	3.803
TA 6	1 750	22	3.803

3.2.2 - Motors

Motor	Rated output (kVA)	Z Ω
58 PM 01 A	602.4	50.216
58 PM 01 B	620.5	48.75
58 PM 01 C	602.4	50.216
58 PM 01 D	620.5	48.75
58 PM 02 A	470.6	64.28
58 PM 02 B	470.6	64.28
58 PM 02 C	470.6	64.28
TCP2 C (T9)	1 250	24.20
TCP2 C (T10)	1 250	24.20
TCP2 C (T11)	500	60.50
TCP2 C (T12)	500	60.50
TCP2 T (T4)	550	55.00
TCP2 T (T5)	550	55.00
TCP2 T (T7)	500	60.50
TP 1 (T1)	750	40.33
TP 1 (T2)	750	40.33
QP (T3)	800	37.81
CDP1 (T6)	250	121.00
CDP1 (T8)	250	121.00

3.2.3 - Transformers and cables

See values given in chapters 3.1.2 and 3.1.4.

4 - CALCULATION RESULTS

4.1 - Subtransient period

The impedance diagram corresponding to the subtransient period is given in Appendix 1.

The results of calculations and characteristics of equipments are given in the following table of results (value given under 5.5 kV).

Switchgear	Rated I s/c (peak)	I s/c (peak) guaranteed by Manufacturer	Equivalent impedance	Lw/R	P s/c (MVA)	Asym. coeff.	Icc peak (kA)
TCP2 C	95 kA	-	0.005490606 + j 0.100775173	18.35	299.73	1.84	81.99
TCP2 T	78 kA	96.4 kA	0.006467542 + j 0.102675735	15.88	294.03	1.82	79.46
TP 1	78 kA	96.4 kA	0.008786383 + j 0.107622332	12.25	280.14	1.77	73.77
Q P	78 kA	96.4 kA	0.015901662 + j 0.121333046	7.63	247.20	1.66	61.01
CDP 1	25 kA	-	0.150333120 + j 0.175349519	1.17	130.97	1.07	20.76
D P 2	25 kA	-	0.217363741 + j 0.188269655	0.87	105.19	1.03	16.03

.../...

The calculated values of Is/c (peak) are given by the formula

$$Isc\ (peak) = \frac{Ps/c}{5500 \times \sqrt{3}} \times k\sqrt{2}$$

, k being the asymetrical coefficient (Lw/R).

As it has been supposed that the 8 main generators were running simultaneously the total output power available is 50.05 MVA for a maximal consumption of 12.1 MVA. So it can be considered that each generator is 1/4 loaded.

The IEC 363 recommandation defines a load factor for the contribution of generators.

k = 1.1 when full loaded

k = 1.0 when unloaded.

So the results should have been multiplied by a coefficient equals to 1.03 in order to take into account the load of generators at the instant the fault occured. This has been neglected in order to take into account the impedances of busbars and connections between equipments.

The results given hereabove are maximum values corresponding to the most unfavourable conditions of operation (see chapter 2.3).

Whipp & Bourne (Manufacturer of TCP2T, TP 1, QP switchgears) guarantees by his letter dated 12th March, 1980 that his switchgear up to now considered as 78 kA peak rating, may in fact withstand a peak current of 96.4 kA under a p.f. of 0.02 or more. So the calculated subtransient short-circuit currents remain lower than the equipment ratings.

4.2 - Transient period

See the corresponding impedance diagram (Appendix 2 here attached).

Switchgear	Equipments rating (1)	Ps/c	Is/c
TCP2 C	38.0 kA (350 MVA)	223.4 MVA	23.5 kA
TCP2 T	30.6 kA (290 MVA)	219.9 MVA	23.1 kA
TP 1	30.6 kA (290 MVA)	212.3 MVA	22.3 kA
QP	30.6 kA (290 MVA)	190.6 MVA	20.0 kA
CDP1	10.0 kA (95 MVA)	99.3 MVA	10.4 kA
DP 2	10.0 kA (95 MVA)	82.5 MVA	8.7 kA

.../...

These rated values are given under 5.5 kV from the manufacturers data sheets.

5 - CONCLUSIONS

From the calculation results given here above it appears unnecessary to provide interlock devices to limit the number of generators running in parallel. All calculated values are lower than design values and the simultaneously running of all the generators is an exceptional operation method only scheduled for tests or transfers on load (short time duration operations).

ANNEX 5

380 V SHORT CIRCUIT CALCULATION.

I - INTRODUCTION

The purpose of this study is to estimate the maximum values of short-circuit current for faults occuring on one point of the 380 V network of TCP 2 (C)

From these short circuit current evaluations it will be checked whether the characteristics of electrical equipments (breaking and making capacities, section of feeders) are acceptable.

II - SHORT-CIRCUIT CALCULATIONS

2.1 - Scope

Being a succession of dipole in series the programme gives the val e of the short circuit power, its argument in comparison with the voltage origin vector, and the short-circuit current value downstream of each dipole.

2.2 - Formulae

The folowing formula shall be used

$$(S'' \text{ or } S')dwn = \frac{1}{\dfrac{1}{(S'' \text{ or } S')ups} + \dfrac{1}{S'' \text{ or } S'}}$$

Z

(S" or S')up

S''_n or S'_n

(S" or S')dw

Where :

(S" or S') ups is the short-circuit power (subtransient or transient) upstrea

(S" or S') dwn " " " downstre

S''_n or S'_n " " " of the di

- Calculation of S''_n or S'_n (Symmetrical rms values)

a) Generators

$$S''_n = \frac{S_n}{X''_d} \quad \text{and} \quad S'_n = \frac{S_n}{X'_d}$$

Where :

S_n is the rated power

X''_d is the direct axis subtransient reactance

X'_d is the direct axis transient reactance.

.../...

b) Induction motors

$$S''_n = 3,14\ S_n \qquad \text{and } S'_n = S_n$$

Where :

S_n is the rated power

3,14 is the ratio : $\dfrac{\text{Im peak max}}{\text{In}} \times \dfrac{1}{1,8\sqrt{2}}$

and $\dfrac{\text{Im peak max}}{\text{In}} = 8$ (to IEC 363 - 1972)

Im peak max is the maximum current peak value at the first half cycle.
In is the rated current.

c) Transformers

$$S''_n \text{ or } S'_n = \frac{S_n}{Ucc}$$

Where :

S_n is the rated power

Ucc is the impedance voltage (%)

d) Cables

$$S''_n \text{ or } S'_n = \frac{U^2}{R}$$

Where :

U is the operating voltage
R is the resitance of one phase

e) Reactors

$$S''_n \text{ or } S'_n = \frac{U^2}{Lw}$$

Where :

U is the operating voltage
Lw is the reactance of one phase

f) Maximum possible peak value of the short-circuit current

The maximum pssible peak value of the current (I peak), is calculated from the subtransient current rms value (I")

$$I\ peak = K \sqrt{2}\ \ I''$$

Where :

K is the asymetrical coefficient :

$$K = 1 + e^{-\frac{R}{L} t} \qquad (1 < K < 2)$$

The maximum peak value is assumed to occur at time t = T/2. T being the time of one cycle.

$$I\ peak = (1 + e^{-\frac{R}{L} \cdot \frac{T}{2}}) \cdot \sqrt{2} \cdot I''$$

2.3 - Method of use

The method consists in calculating S" or S', θ, I" or I' downstream of each dipole, in the following order : upstream towards downstream.

Single line diagrams components and results are marked during calculations in the calculation sheets given in appendix I.

III. Component data

3.1. Short circuit values on 5.5 KV network.
(TCP 2 Compression buss bar)

Subtranscient period

S"	=	296.64	MVA
θ	=	89,36	deg.
I"(rms)	=	31,14	KA

Transcient period

S"	=	222,8	MVA
θ"	=	89,27	deg.
I"(rms)	=	23,39	KA

3.2. Characteristics of transformers

$T_9 - T_{10}$	P	=	1	MVA
	U_p	=	5.5	KV
	U_s	=	0.38	KV
	U_{cc}	=	5	%
$T_{11} - T_{12}$	P	=	2.5	MVA
	U_p	=	5.5	KV
	U_s	=	0.38	KV
	U_{cc}	=	7	%

3.3 - Impedances of cables

S (mm^2)	R (Ω/km)	L (mH/km)
380 V		
3 x 10	2,2	0,464
4 x 16	1,38	0,430
4 x 25	0,87	0,412
4 x 35	0,63	0,389
4 x 50	0,46	0,345
4 x 70	0,32	0,326
4 x 95	0,23	0,310
4 x 120	0,18	0,308
3 x 150	0,15	0,290
3 x 240	0,092	0,280
3 x 400	0,059	0,270

5,5 kV		
1 x 3 x 120	0,154	0,2 498
3 x 1 x 120	0,151	0,3 199
1 x 3 x 95	0,195	0,2 498

3.4 - Short circuit capacity of apparatus

As the rated breaking capacity for fuses, having rated voltage up to and including 500 V ac, are not less than 50 kA (IEC 269-2) all apparatus in series with fuses are protected if they have making capacity up to and including the cut-off current.

For circuit breakers and swithboard (bus-bars) we must verify if short-circuit currents (peaks and rms) does not exeed the rating currents.

TCP2 (C)

1) MCC (S52 32 21) and S 53 44 26

EGA	Motor control centre	145 kA peak	70 kA rms
Merlin Gerin	Codis N100	—	100 kA rms
Merlin Gerin	DSA1 1 600	140 kA peak	63 kA rms

2) S 52 41 2 12 - S 52 41 2 13 - S 52 32 2 14 - S 52 32 2 15

Hazemayer	Duco 32 (Fuses)	—	100 kA rms
Merlin Gerin	Codis N100	—	100 kA rms

3) S 52 32 2 16 - S 52 32 2 17

Merlin Gerin	Codis N100	—	100 kA rms

IV - CALCULATION RESULTS

4.1 - Asymetrical coefficient calculation

For this calculation, we must take into account the resistance of transformer. As the asymetrical coefficient for transformers is 1,8, their resitance is equal to the fourteenth of their reactance. The argument of short circuit power above transformer composed with the argument of transformer give the assymetrical coefficient below transformer.

TCP2 (C)	CALCULATION RESULTS		CHARACTERISTICS OF APPARATUS	
Site of fault	Subtransient I peak (kA)	Transient I rms (kA)	Making Capacity (kA)	Breaking Capacity (kA)
Bus bar A and B S 52 32 2 1	123	47	140	63
Switch board A S 52 32 2 2	116	44	–	50
Switch board B S 52 32 2 3	117	45	–	50
S 52 41 2 12	(13,5)→ 10*	(9,5)*	–	50
S 52 41 2 13	13,5	9,5	–	50
S 52 32 2 14	80	28	–	50
S 52 32 2 15	80	28	–	50
S 52 32 2 16	61	34,5	–	100
S 52 32 2 17	67,5	35,5	–	100
53 44 2 6	44,5	23	140	63
S 52 32 2 4	23	16		
S 52 32 2 5	23	16		
S 52 32 2 18	28	19		
S 52 32 2 19	28	19		

* (Prospective current) [illegible]

4.2. - CABLES PROTECTION

During short-circuit, a feeder is protected if its time/current characteristic is above the time/current charateristic of protection equipment.

4.2.1. - Time/current characteristics

- Feeders

Curves are given by the formula (for time up to 5 s)

$$r = K \frac{S}{I} \qquad \text{where K (cooper - PVC) = 115}$$

- Protection equipment

Time/current characteristics are given by constructors.
For Merlin Gerin circuit-breakers, feeders'protection is given by the constructor by I^2t characteristics.

4.2.2. - Method of use

The superposition of feeder characteristic and fuse or circuit-breaker characteristic show directly for how long short-circuit protection is realised (It will be necessary to check that thermal relay breaks overcurrents before this time)

* All curves are given in appendix II

* For each platform, all cables section and associated protection are given in appendix III.

4.2.3. - Time protection of cables during short circuit

Cable section/phase	Short circuit protection	Time of pro[illegible] t[illegible]
TCP2 (C)		
* MCC S 52 32 2 1		
50	Codis N100 80/100 125 A	> 5 s
2 x 90	Codis N400 D400 500 A	> 5 s
2 x 120	Codis N400 D400 500 A	> 5 s
400	DSA 1 1 600 DIRS 10 000 A	> 5 s
3 x 400	DSA 1 2 500 DIRS 16 000 A	> 5 s
incomer 6 x 400	: 46,6 kA rms for more than 5 s	
* SWBA S 52 32 22		
2,5	Fuses aM 25 (6-10-16)	2,5 s (>[illegible]
	Codis N100 10/15 A (aM 40)	> 5 s
4	Fuses aM 20	> 5 s
6	Fuses aM 63 (40)	1,2 s
10	Fuses aM 63	> 5 s
25	" aM 80	> 5 s
35	" aM 160	> 5 s
95	" aM 160	> 5 s
150	" aM 355	> 5 s
* SWB S 52 32 2 3		
2,5	Fuses 36 A (25-20-16-10-6)	1 s
	Codis N100 10/15 (40 A)	> 5 s
4	Fuses aM 50 (36-20)	> 1 s
6	" aM 63	> 1 s
10	" aM 80 (63-36)	> 4 s
16	" aM 50	> 5 s
35	" aM 160 (125)	> 5 s
70	" aM 250	> 5 s
150	" aM 355	> 5 s

* Turbo gen A(B) S 52 41 2 12 (13)

2,5	Fuses aM 20 (16-10-6-4)	> 5 s
	Codis N100 10/15 (aM 40)	> 5 s
4	Fuses aM 36	> 5 s
6	" aM 50	> 4 s

* S 52 32 2 14 (15) (Distribution switchboard)

2,5	Fuses aM 16	> 5 s
6	" aM 50	> 4 s
50	" aM 250	> 5 s

incomers : 3 x 400 : 27,8 kA rms for more than 5 s

* S 52 32 2 17

25	Codis N100 55/80 (125 A)	> 5 s

* S 52 32 2 16

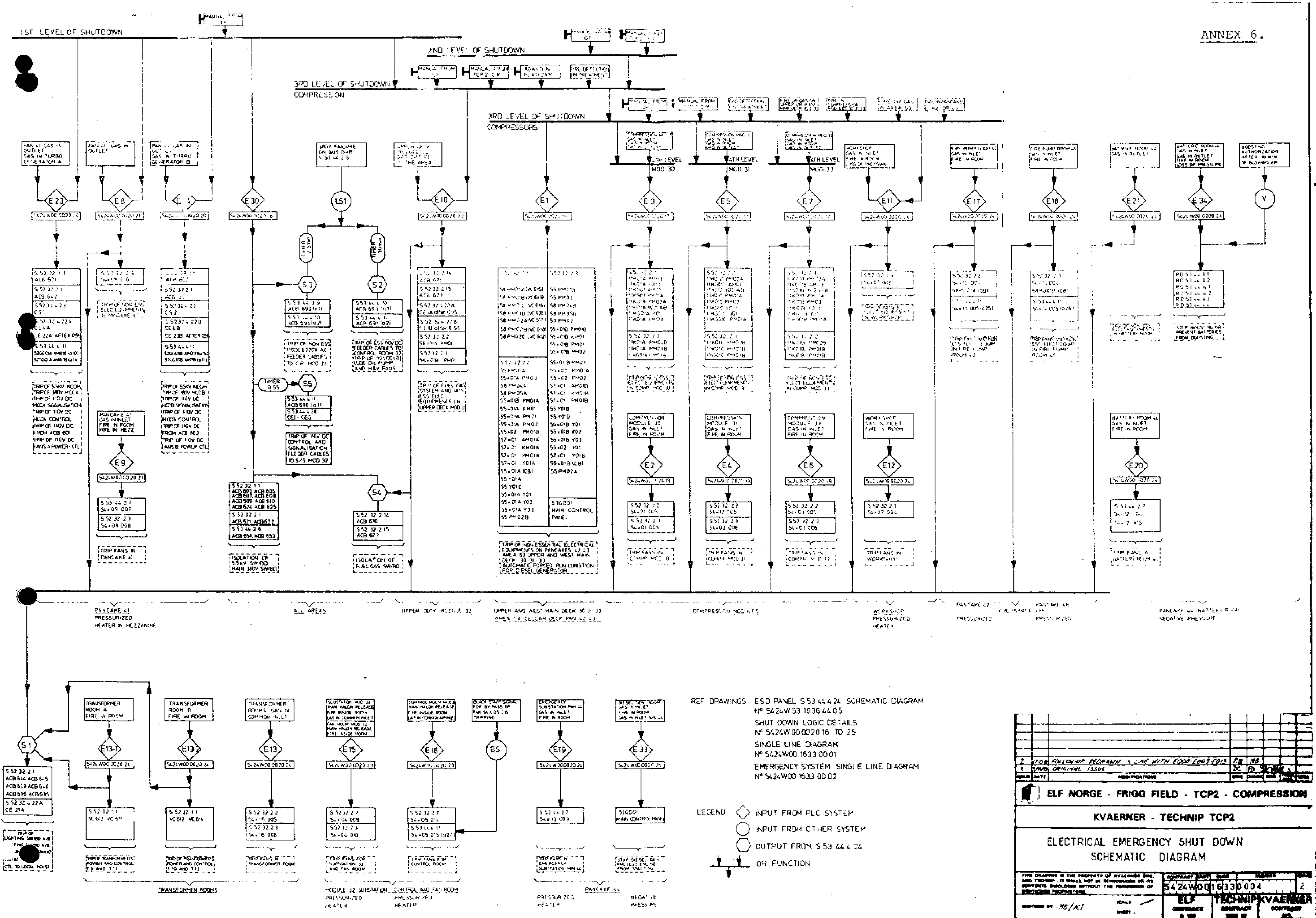
6	Codis N100 25/40 (80 A)	> 5 s

* Main emergency SWB

95	Codis N100 80/100 (125 A)	> 5 s
2 x 95	" N400 D320 (500 A)	> 5 s
2 x 150	" N400 D400 (500 A)	> 5 s

.../...

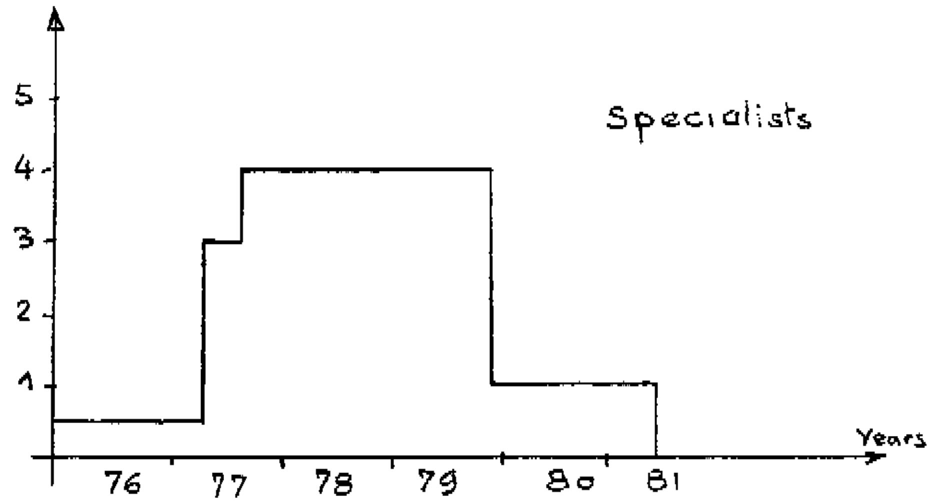
ANNEX 6.

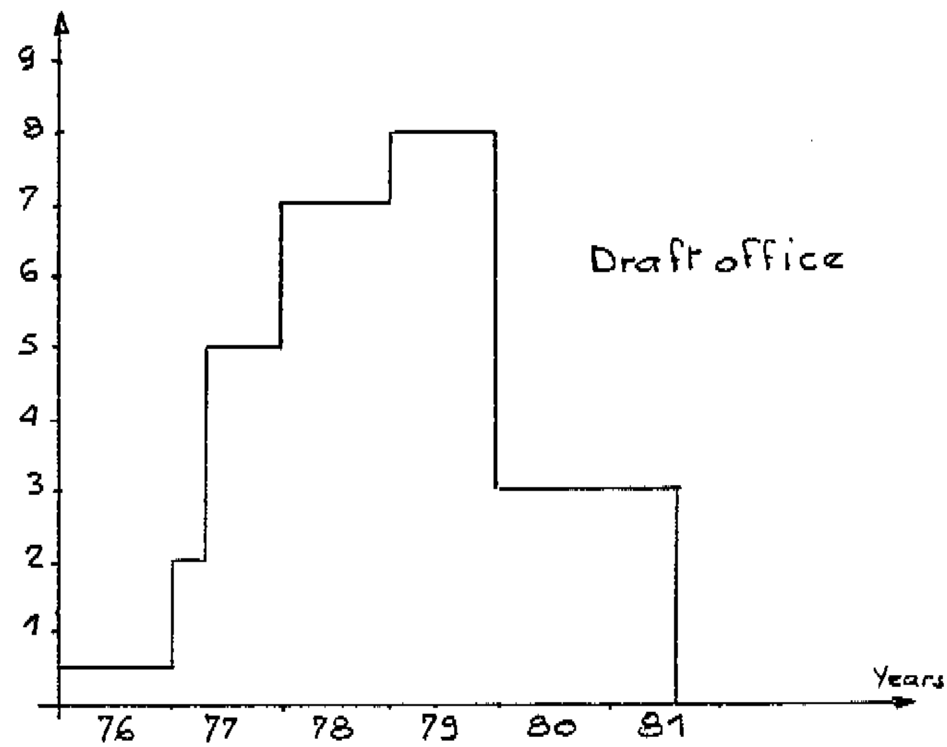


1ST LEVEL OF SHUTDOWN
2ND LEVEL OF SHUTDOWN
3RD LEVEL OF SHUTDOWN
COMPRESSION
3RD LEVEL OF SHUTDOWN
COMPRESSORS
PANCAKE 41
PRESSURIZED
HEATER IN MEZZANINE
UPPER DECK MODULE 32
COMPRESSION MODULES
WORKSHOP
PRESSURIZED
HEATER
NEGATIVE PRESSURE
TRANSFORMER ROOMS
MODULE 32 SUBSTATION, CONTROL AND FAN ROOM
PRESSURIZED
HEATER
PANCAKE 44
PRESSURIZED
HEATER
NEGATIVE
PRESSURE
REF DRAWINGS
ESD PANEL S 53 44 4 24 SCHEMATIC DIAGRAM
Nº 5424W 53 1636 44 05
SHUT DOWN LOGIC DETAILS
Nº 5424W00 0020 16 TO 25
SINGLE LINE DIAGRAM
Nº 5424W00 1633 00 01
EMERGENCY SYSTEM SINGLE LINE DIAGRAM
Nº 5424W00 1633 00 02
LEGEND
INPUT FROM PLC SYSTEM
INPUT FROM OTHER SYSTEM
OUTPUT FROM S 53 44 4 24
OR FUNCTION
ELF NORGE - FRIGG FIELD - TCP2 - COMPRESSION
KVAERNER - TECHNIP TCP2
ELECTRICAL EMERGENCY SHUT DOWN
SCHEMATIC DIAGRAM
5424W0016330004
ELF
TECHNIP
KVAERNER

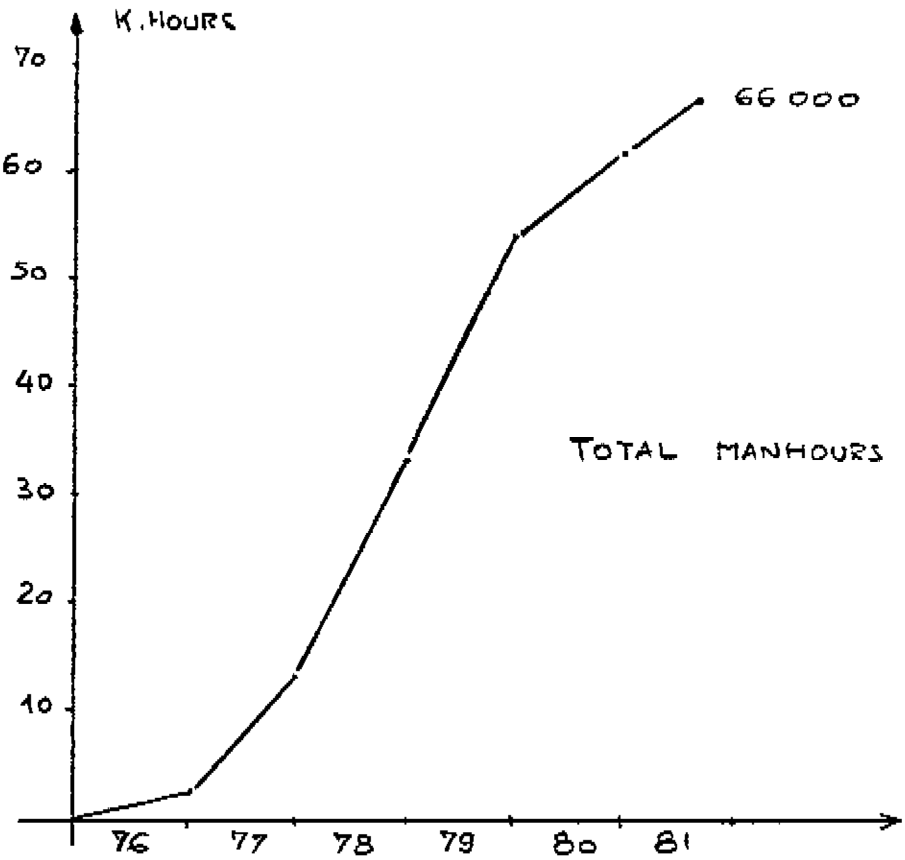
ANNEX 7

ENGINEERING MANPOWER





ANNEX 8


K.HOURS
70
60
50
40
30
20
10
66 000
TOTAL MANHOURS
76
77
78
79
80
81

E-INSTRUMENTS AND SAFETY

DETAILED REPORT

P. Prevot-Leygonie

PART NO. 1

Technical Part.

.1. Technical choices

.2. General Standard.

.3. Equipment.

.4. Routing of cables.

.5. ESD - Blow down control circuit

.6. Instrument power distribution

.7. Foxboro Spec. 200

.8. Automatism of main consumers.

.9. Hydraulic Units.

.10. Control Room.

1. TECHNICAL CHOICES.

Due to a lack of general specification from EAN, the technical choices were submitted to EAN by KE/TP.

Final decision were taken after approval from the Authorities (DnV-NPD).

People working within EAN Engineering team had at the beginning of the project no back-up from Frigg Field; this led to some modifications in the course and at the end of the project.

2. GENERAL STANDARD.

2.1 Regulations - Voltage - Frequency.

Voltage foreseen by Electrical section was 110 V DC - 110 V AC In fact due to the vendors standard, 24 V AC/DC were added during the project.

The choice of 110V is to be avoided in Instrumentation - at least in Norway were equipment fed by this voltage must be maintained by qualified, authorized electricians.

We consider that 48 V would have been the best voltage but this necessitates to impose it to all vendors.

Frequency on Frigg Field is 50 hz.

2.2 Pneumatic - Electronic circuits.

Production Department requested to use pneumatic circuits wherever possible. As far as this information came late pneumatic circuits have been used for all local controls but electronic circuits were maintained when response time must be short.

2.3 Safety equipment logic.

In order to keep safe the fire and gas detection it was decided to double the detectors in all areas. For a production reason - in order to avoid frequent shut down - logic 2/2 was used. Alarm is given by the first detector; shut down is initiated when coincidence between both detectors.

2.4 Conductors size.

1,5 mm^2 was chosen on compression and agreed by Authorities. In fact it appears that in a lot of cases 0,75 mm^2 would have been sufficient.

3. EQUIPMENT.

3.1 Use of electronic relay - Programmable logic controller.

The use of a programable logic controller for safety - gas, fire detection - halon release, deluge valves control - ESD logic and control, has been decided after long discussions with Production/Maintenance Departments. An agreement came for two P.L.C. in parallel for the following reasons:

- Better reliability compared with relays
- Not limited flexibility (modification of program very easy)
- Gain of room.

The choice of two P.L.C. in parallel is in line with the safety logic philosophy. The outputs are combined in such a way that ESD actions will be initiated only in case of coincidence. If one of the P.L.C. is out of order, all its outputs become in ESD state.

All outputs of the P.L.C. are normally (no detection) energized so that ESD action are initiated in case of loss of both P.L.C. Exception are the outputs corresponding to the Halon release on which is foreseen a manual activation.

Allen Bradley P.L.C. was chosen due to the size of the memory (up to 12 K) offshore reference and price. Electromagnetic relays have been used on the remaining part of the project:

- Miniature GA MTI relays for process automatisms
- EP3-EP5 MTI relays were required by EAN Production/ Maintenance for duplication of informations within Safety.

Comments.

We consider that the use of P.L.C. should have been extended to the complete project. The use of mini - P.L.C. could be done for each part of a big project. The saved time for modifications of the logic compared with relay technology can be very high for an important project. Reliability being better. This being said the use of a P.L.C. does not eliminate the necessity of electromagnetic relays. Galvanic isoloation between outputs and consumers is necessary.

Allen Bradley outputs cards used in TCP2 Compression were normally tested by the internal program. In fact we discovere that the control transistor of the output transistor (Darlington mounting) was not tested so that the fault does not appear in case of fault.

Allen Bradley supplies other types of cards which do not present this inconvenient. Our output cards were chosen because this type is used on all ELF P.L.C. This should be avoided.

3.2 Gas detectors.

Choice of Gas detection system has been made by Maintenance after a series of tests carried out on Frigg Field.

The decision have been taken very late. After Sieger type detectors Engineering was requested to use Icare (French Company) detection system. These gas detectors which are now installed are working without trouble.

To be mentioned, however, that the calibration potentiometer should be installed outside the rack in order to avoid removing of the cards at each calibration.

Size connection cables to the "Test" key is too big (1,5 mm^2 instead of 0,75 mm^2).

3.3 Fire detection.

Same equipment (Minerva) have been provided in Compression than in Treatment part. The system have been supplied by Telesystemer.

In order to carry out tests on the equipment, each output terminal is equipped with a knife terminal.

As the output is not energized in normal Condition (Standard from Telesystemer) it is not possible to get a visualisation of the test position (by-pass cabinet). This is not accepted by Safety department because of the possibility to forget open terminals after tests.

In fact Engineering should have foreseen a two positions keys (normal - test) instead of these terminals. This would have allowed to install a test camp when key on test position.

3.4 Earthing system.

3.4.1 General

Earthing was not enough studied by Engineering before yard construction. This led us to various earthing systems on yards and within vendors packages. A complete standardization has been necessary during hook-up period.

Inside each cabinet in control room we have:

- one earth bar for intrinsically safe circuits
- one earth bar for screens
- one earth bar for metallic parts and armor of cables.

All them being connected to the general earthing network of the control room.

3.4.2 Armor.

Due to DnV request the armor was earthed at each junction box. It would have been much easier to make a continuity of the armor inside junction box (see 3.4.3.).

3.4.3 Junction boxes - cable blands.

Plastic Ex(e) junction boxes have been used everywhere for instrumentation and safety.

The requirement to have earthing of the armor has necessitated a special earthing terminal inside the box and a cable gland used especially for the connection with a metallic part outside.

Special care must be taken for the entry of the cables inside the plastic junction boxes. No bend can be accepted and the cable must be well clamped in order to avoid stress on the box.

Advantage of these box-type is obviously the low weight. Delivery of such boxes equipped with terminals is very short in Norway.

Ex(d) Hawke 501 cable glands for armoured cables were installed. In fact industrial cable glands should have been sufficient.

3.4.4 Cables, cable trays

Further to NPD - DnV requirements for hazardous areas following types of cables have been installed:

- Fire resistant armoured, screened cables for safety circuits
- Flame retardant armoured, screened cables for other circuits.
- Standard screen cables for connection between panels inside control room (safe area).

Due to corrosion problems encountered on cable trays in others installation of the Frigg Field it was decided to use stainless steel cable trays.

3.4.5 Conclusion

Due to the fact that many regulations were involved in the project, we never got a clear statement from Authorities regarding earthing system.

The earthing of the armor when plastic junction boxes are used is not easy. Armor should be considered as a screen i.e. isolated at one end, earthed at the other. Continuity of the armor should be made inside junction box.

4. ROUTING OF CABLES

Both instrument and safety cables were routed in the same cable trays. However, depending of the types of signals three different cables trays were foreseen:

- 110V circuits
- Low voltage circuits including analog signals
- Intrinsically safe circuits.

5. ESD BLOW DOWN VALVES CONTROL CIRCUITS.

Control of ESD and blow down valves have been designed in line with the Frigg Field standard: Electrical ESD informations are sent to Solenoid valves fitted on pneumatic circuits Pneumatic actuators operate hydraulic actuators:

The control

- Automatic in case of ESD signal for ESD valves
- Manual from control room for blow down valves
- Manual from local stations after authorization.

from control room for both ESD and blow down valves.

In a first stage Engineering had foreseen automatic step by step decompression of the compression circuit due to flare capacity.

Production decided to consider this decompression as first priority and to follow the Frigg philosophy for the control of the blow down: only manual opening.

Modifications of blow down valve cabinets have been necessary

Only one derogation has been accepted: automatic blow down as been kept for Compressors due to their particular technology.

6. INSTRUMENT POWER DISTRIBUTION.

In order not to stop the production when maintenance is carried out on an equipment, possibility to isolate each circuit have been foreseen.

Instrument power distribution located in control room consists of five cabinets (220 V AC - 110 V AC - 110 V DC - 24 V AC - 24 DC). Each cabinet consists of cells of Merlin-Gerin F32 circuit breakers (10 by cells) and one disconnecting switch for each cell.

For intensity less than 1A only fuses have been used.

After completion of the cabinet it was discovered that Merlin Gerin did not garantee any more the F32 circuit breakers for use on 110 V DC for a breaking capacity of 10 KA.

Merlin-Gerin after a complete study of the distribution network have now provided us with test certificates for each of the feeders except for 10 amp. and over normal rating. These breakers will be replaced by F32 H type suitable for 110 V DC.

7. FOXBORO SPEC 200.

Foxboro analog instruments spec 200 have been used due to the flexibility and the easy calibration.

The voltage input of these instrument necessitated I/U converters for resistance thermometer circuits.

8. AUTOMATISMS OF MAIN CONSUMERS (PUMPS).

Instrument section has been in charge of all automatisms As a general rule, Engineering had foreseen only one type of control of the various compression pumps:

- Automatic mode with automatic start of the stand by pump in case of failure of the main pump - all process securities being included in the logic.
- normal mode
  - from control room including process safety devices
  - from local station without process safety devices (forced run)

In fact production department requested to modify it as follows:

- Same automatic mode.
- No manual start/stop from control room
- Manual start/stop from local station including all process safety devices.

This philosphy has been known very late (end of commissioning phase).

To our knowledge automatic mode have never been tested and therefore used during start up phase.

9. HYDRAULIC LIMITS.

The hydraulic power pack consists of two Rexroth variable displacement piston pumps.

Following running mode was foreseen:

- one pump continuously running - pressure being controlled at 210 bars by a discharge safety valve.
- The second pump was in stand by and started at 190 bars in the hydraulic circuit.

For standardization of the hydraulic power packs of the Frigg Field, following modification was requested by Production:

- Intermittent running of one pump between two pressure set points.
- High pressure set point lowered at 140 bars. (This reduction of pressure was possible taking into account the torque of the valves and the speed of manoeuvering).

Actuators used on valves are WANDFLU make. No tests were carried out on them in the factory (lack of time). During offshore tests it was discovered that due to the leaks on the actuator control cabinets the hydraulic pump on duty starts each 30 minutes. Decision is now taken to replace them by PARKER actuators already used on the treatment side.

10. CONTROL ROOM.

10.1 General.

At the first stage of the project, TCP2 Compression control room was foreseen as an unmanned room. All controls were carried out from Q.P. platform.

After six months EAN decided to transfer the control on TCP2 and to keep all informations on Q.P.

It is only in 1979 that EAN took the decision to limit the amounts of informations to Q.P. due to lack of channels in Telemetry.

Around 65 m length of cabinet have been installed in the control room. Remaining room is foreseen for phase 2 of the compression and possible future extensions.

10.2 Suppliers of panel/cabinets.

Process cabinets and mimics have been built by EGA. The contracts was placed with Norsk Hydro Rjukan.

Fire - gas detection, programmable unit cabinets were delivered as package by Telesystemer, Icare and Allen Bradley respectively.

Foxboro converters panels were delivered by Hartmann (Oslo).

Turbo-compressor cabinets were supplied by U.T.I. but built in Norway by NORCONTROL.

10.3 False floor.

A false floor has been designed in the control room in order to have an easy routing of the cables between panels and from the field to the panels.

10.4 Interface cabinets.

For easier maintenance, interface cabinets (terminal boards) were foreseen for all informations coming to or outgoing from the control room.

Due to lack of room, only instrument/Electrical informations transit through such a cabinet (cabinet no. 20).

10.5 Comments on some of panels located in control room.

10.5.1 Control desk.

Control desk was designed for a very few information such as blow-down authorization from Q.P. - Telephone - Interphone etc..

During tests of the compressors, people in charge discovered that more informations were necessary from other part of the Frigg Field moreover, Frigg Extension Project have formulated the wish to send informations on TCP2 control room.

For this reason it has been decided to re-design the control desk in order to incorporate these new data (Work will be done after compression start up completion).

10.5.2 Pressure Switches Cabinets.

Due to the request from Production to use pneumatic circuit wherever possible it has been necessary to install a cabinet of pressure converters. These converters are hooked up to a rail on inside the cabinet. Their disconnection is quite uneasy. New plugged converters have been designed by the manufacturer and the change of the existing ones in now foreseen.

10.5.3 Mimics.

Mimics are of sticked pieces design in order to allow easy modification. In order to have them as clear as possible Panalarm annunciators have been combined with them.

P A R T   N O . 2.

Project Development.

.1. Instrument section workload

.2. Organisation of the project

.3. Phases of the project.

.4. Manhours spent in instrument and safety.

.5. Schedule

.6. Comments on the project development.

1. INSTRUMENT SECTION WORKLOAD.

Instrument section was in charge of the following items within the project:

- Instrumentation
- Safety
- All automatisms (which are under electrical responsibilitu on other projects)
- Public address, telephon, interphone
- Ventilation detailed drawings

On all these items instrument section provided the documents hereabove:

- Basic engineering documents
- Detailed engineering documents (detailed plot plans, mounting standard etc.)
- As built and trouble shooting documents

Only shop drawings have been issued by yards. They were consisting mainly of instrument support schemes.

As examples:

- the compression index sheet list shows around 20.000 different items (relays excluded)
- Around 2.200 local instruments were installed (see annex no. 1)
- Around 2.000 cable book A3 sheets were issued.

2. ORGANIZATION OF THE PROJECT.

Engineering has been performed by Joint Venture Kvaerner Engineering - Technip Geoproduction (KE/TP). Under the project Manager each section was managed by a section leader. Coordination was supposed to be made by Project Engineer.

Franco-Norwegian Joint Venture has been of bad effect on the project development: language and responsibility problems occured.

Coordination in KE/TP was insufficient especially between electrical and instrument section.

Vendor follow up was performed by mechanical specialists who were not always able to understand the questions from or to the vendors. On EAN side there was only one specialist by section during the main part of the project. This partly compensated the lack of coordination within KE/TP but due to the amount of work no detailed check of Engineering documents was performed.

3. PHASES OF PROJECT.

3.1 Phases.

On engineering side, we can consider the following phases of the project:

- Basic engineering
- Purchasing - Inspection
- Yard construction
- Hook-up documents
- Commissioning start-up documents
- Troubleshooting diagram. As built drawings.

3.2 Basic engineering.

Due to different interpretation of "Basic engineering" betweer EAN and KE/TP, this phase which was considered to be complete middle 1979 by KE/TP ended only middle 1980.

Basic engineering on KE/TP point of view consisted in purchasing documents and guide drawings for yard construction It appeared that this was not sufficient.

Integration, follow-up of vendors documents were not foreseen by engineering. This obliged engineering to have a new team

(6 men) especially for this job from middle 1979 up to middle 1980.

3.3 Purchasing - Inspection.

Regarding purchasing following comments must be noted:

- Necessity to find vendors in Norway (Control Room, fire detection, cables)
- Very late delivery of the control room. Very expensive claims from Norsk Hydro for each modification.

Inspection has been of very poor quality all along the project due to lack of manpower regarding electrical and instrumentation. No tests have been carried out in vendors' workshops and a lot of modifications have been done later.

3.4 Yard construction.

As mentioned in paragraph 1.1 above, only guide documents were foreseen for yard construction. Although the contracts with the yards mentioned that detail Engineering was yards supply it appeared that they were not able to carry out this work. To be underlined that yards began to work only when they have got a cable book on which the tagging of each terminal was given. This has been the most critical phase for instrumentation section on Engineering side.

To be noted that the construction was done on three different yards. This has entailed Engineering to define their limit of supply and split all documents yard by yard.

3.5 Hook-up.

Hook-up preparation has been done by an independant team. Many modifications of Engineering documents have been done during this phase. New split of the project appeared at that time. Engineering documents were split by units, Hook-up documents being split by systems.

Offshore work consisted in tasks often made in a hurry based only on cabling. All Engineering documents as cable books or loops were not dispatched to the offshore hook-up team. A lot of questions raised at that time from TCP2 and necessity appeared to send people from Engineering.

In fact the problem was mainly that the yard had not finished its works. Onshore Hook-up team did not know were they stopped so that either lacks or double wiring appeared.

3.6 Commissioning - Start-up.

As far as Cable books were fully detailed, Engineering did not mention terminal numbers on the control loops. It rapidly appeared that every informations were needed on these loops by Commissioning. This entailed Engineering to give all details on them:

numbering of cables, tagging of terminales,

No particular comments on start-up except numerous modifications were necessary within packages.

3.7 Troubleshooting diagrams. As built drawings.

As built drawings and troubleshooting diagrams have been drawn by Engineering section. This allowed to keep during start-up phase, people from Engineering available for eventual modifications. Commented drawings came late from offshore and troubleshooting diagrams were delayed by 3 months.

4. MANHOURS SPENT IN INSTRUMENTS AND SAFETY

Instrument and Safety Engineering manhours roughly represent 110.000 hours i.e. around 25 % of the total KE/TP Engineering manhours. Off this can be subtracted the 8.000 hours spent on troubleshooting diagrams and as built drawings. Comments regarding this high ratio will be given in paragraph no. 6.

5. SCHEDULE

Engineering schedule was delayed by approximately one year.

6. COMMENTS ON THE PROJECT DEVELOPMENT.

We will try hereunder to give the main reasons of

- The high ratio of instrument manhours in the Engineering
- The slipping of the schedule.

6.1 Organization.

As mentioned in the corresponding paragraph coordination problem remained during the project due to:

- location of the different teams. Remember that during a part of 1979 EAN was in Stavanger, KE/TP was in Oslo then in Paris and construction was done on three different yards.
- Joint-Venture KE/TP
- Poor transit of informations between Engineering sections
- Lack of EAN checking of Engineering documents (Only two men on EAN side).

6.2 Work amount.

The remaining work amount was not evaluated by Engineering. This can be explained by the misunderstanding regarding the basic Engineering definition, by the complexity which appeared during the project and the transfer to Instrument section of studies which were not foreseen at the beginning (see paragraph 1 and 3.2). Documents issued by Instrument section are as follow:

- Specifications: around 80 . total about 2.500 sheets.
- drawings: A0 format: 75
  A3 format: 2520 (troubleshooting diagrams excluded)

6.3 Capability of the yards.

We explained in paragraph 3.4 that it was discovered at the beginning of the construction that the yards were not able to carry out detailed studies. If this had been known before perhaps the yards would have started six months later.

6.4 Late decisions from EAN.

Decisions from EAN were very late all along the project for example:

- Programmable unit controler.
- Gas detector
- Instrument hook-up mounting standard which have been changed 3 times further to Production change in philosophy.

6.5 Modifications requirements.

Laté modification requirements from EAN and authorities have been a cause of delay in Engineeing. We can give some of them:

- A second fuel gas metering required by Authorities.
- Change of pumps control philosophy
- Change of blow down valves control philosophy.

6.6 Vendors documents follow-up/Integration.

As mentioned in paragraph 3.2 an extra team of 6 men has been necessary during 6 months due to the fact that Engineering KE/TP did not consider the checking and integration of vendor data as mandatory from the beginning in such a project.

A N N E X 1

INSTRUMENT AMOUNT.

	UNIT												
	11	50	53	54	55	56	57	58	63	64	67	68	TOT
FLOW													
Flowmeters					4								4
Indicators								12			3	2	17
Controllers					2			1					3
Recorders		2											2
Switches	10				6								16
Straigntening vane								8					8
Valves		3											3
LEVEL													
Indicators	4							3					7
Controllers	9	11											20
Gauges	14	7	1	1	5	1	7	2			2		40
Switches	50	17	3		5	1	5	11			4		96
PRESSURE													
Indicators	48	18		15	5	22	15			1	45		169
Controllers		5		10		2	1				2		20
Switches	83	36		3	10	3	14	12			40		201
Safety valves	52	19		9	3	16					8		107
TEMPERATURE													
Elements	97	5						8					110
Indicators	35	13			10	2	19	23					102
Controllers	5			17	4								26
Switches	38	5		13	2	1	18						77
Thermowells	6	6				2		12					26
Safety valves		6											6
Recorders		2											2
TRANSMITTERS	27	23		35	3		2	5					95
CONTROL VALVES	52	19		2	7		2	3			1	4	90
HAND VALVES	7	5						18					30
EMERGENCY SHUTDOWN VALVES	18	26											44

	UNIT												
	11	50	53	54	55	56	57	58	63	64	67	68	TOT
MISCELLANEOUS													
Converters	7												7
Boosters	3	1			2		1	1					8
Burners	6												6
Pilot and solenoid valves	59	30	1	5	29		1				1	12	138
Opening quick valve	13	15											28
Push Button		37	2	51	16	5		28				19	168
Moisture controller				2									2
Damper actuator				52									52
Quick Bleed off Relay				36									36
Analysis Element					2								2
" controller					2								2
Square root actuator					2								2
Dew point switches							2						2
Flame		2										4	6
Quick acting valve												6	6
Restriction orifice			1									10	11
Rupture disc	3	2											5
SAFETY													
Gas detectors	24								105				129
U.V. detectors										30			30
Fire alarm box	6									45			51
Smoke detectors										64			64
Temp detectors										22			22
Fire detector	9												9
Halon control unit											12		12
Box halon sphere											40		40
Alarm Ball											13		13
Chemical panel											7		7
TOTAL LOCAL INSTRUMENTS													2180

F - MECHANICAL DETAILED REPORT

J. Fort

S U M M A R Y

F1.	The scope of the Mechanical Section
F2	Mechanical engineering coverage
F3	The basics of selection
F4	The problems faced during the project

D O C U M E N T

F1	Mechanical equipment list and description
F2	Turbocompressor contract arrangement.

F1 THE SCOPE OF THE MECHANICAL SECTION.

F1.1 General

The TCP2-C project being aimed at installing compression facilities of large scale onboard the TCP2 platform, it seems reasonable to think that the mechanical section was of great importance all over the project. In fact, this statement is only true as far as the basic selection of components is concerned and as far as the start up phase is concerned.

Basically, the scope of the mechanical section during such a project is:

- to make the selection of the various equipment needed to achieve the duty.
- to be an interface between the vendors and the various other sections within the Engineering team.
- to provide assistance to the start up team when time comes to put the machines on stream.

These points are of course of vital importance because a wrong selection of a major component can jeopardize the whole project, but they do not involve a great number of people, of money or of documents.

The attached document F1 is giving the list of the mechanical equipment which has been taken care of by the KE/TP mechanical section.

This list is not always in coincidence with the splitting up which had been done within the EAN team.

The discrepancies are the following ones:

- items 13 (crane) and 14 (hoists) have been followed within EAN by the Structural section.
- a few packages have not been followed within KE/TP by the mechanical section but are comprising some mechanical equipment:

- HVAC (treated by Instrumentation)
- Fresh Water Makers
- DOSAPRO dosing set
- F.G. packages (pumps)

However the list as per document F-1 represents a good picture of the mechanical equipment.

F-1.2 Ratios

- The total amount of the P.O. placed by the mechanical section is 126 217 178 NOK, representing 10,18% of the total project but 76,22% of the overall main equipment budget line (AFE 236 111 : 165 600 000 NOK).
- The number of vendor drawings is 693 (844 with the additional mechanical items treated by other sections) representing 25,60% of the overall vendor drawings (2 711)

No engineering drawing was directly issued by the mechanical section which is in fact more an interface between each other individual section and the vendors than a section in charge of designing really anything.

F-2. MECHANICAL ENGINEERING COVERAGE.

The mechanical engineering coverage has been done by two different instances:

- the KE/TP engineering mechanical section
- the EAN mechanical project engineer.

F-2.1 The KE/TP engineering mechanical section.

The number of hours spent by this section is approximately 11 000, spread over a period of 3 years, from september 1976 until summer 1979.

The scope of this section can be split into two different phases:

F - MECHANICAL DETAILED REPORT

J. Fort

S U M M A R Y

F1. The scope of the Mechanical Section
F2 Mechanical engineering coverage
F3 The basics of selection
F4 The problems faced during the project

D O C U M E N T

F1 Mechanical equipment list and description
F2 Turbocompressor contract arrangement.

F1 THE SCOPE OF THE MECHANICAL SECTION.

F1.1 General

The TCP2-C project being aimed at installing compression facilities of large scale onboard the TCP2 platform, it seems reasonable to think that the mechanical section was of great importance all over the project. In fact, this statement is only true as far as the basic selection of components is concerned and as far as the start up phase is concerned.

Basically, the scope of the mechanical section during such a project is:

- to make the selection of the various equipment needed to achieve the duty.
- to be an interface between the vendors and the various other sections within the Engineering team.
- to provide assistance to the start up team when time comes to put the machines on stream.

These points are of course of vital importance because a wrong selection of a major component can jeopardize the whole project, but they do not involve a great number of people, of money or of documents.

The attached document F1 is giving the list of the mechanical equipment which has been taken care of by the KE/TP mechanical section.

This list is not always in coincidence with the splitting up which had been done within the EAN team.

The discrepancies are the following ones:

- items 13 (crane) and 14 (hoists) have been followed within EAN by the Structural section.
- a few packages have not been followed within KE/TP by the mechanical section but are comprising some mechanical equipment:

- HVAC (treated by Instrumentation)
- Fresh Water Makers
- DOSAPRO dosing set
- F.G. packages (pumps)

However the list as per document F-1 represents a good picture of the mechanical equipment..

F-1.2 Ratios

- The total amount of the P.O. placed by the mechanical section is 126 217 178 NOK, representing 10,18% of the total project but 76,22% of the overall main equipment budget line (AFE 236 111 : 165 600 000 NOK).
- The number of vendor drawings is 693 (844 with the additional mechanical items treated by other sections) representing 25,60% of the overall vendor drawings (2 711)

No engineering drawing was directly issued by the mechanical section which is in fact more an interface between each other individual section and the vendors than a section in charge of designing really anything.

F-2. MECHANICAL ENGINEERING COVERAGE.

The mechanical engineering coverage has been done by two different instances:

- the KE/TP engineering mechanical section
- the EAN mechanical project engineer.

F-2.1 The KE/TP engineering mechanical section.

The number of hours spent by this section is approximately 11 000, spread over a period of 3 years, from september 1976 until summer 1979.

The scope of this section can be split into two different phases:

- the basic engineering for the selection of the type of machine for the main duty, gas compression and electrical generation.

This phase took place from September 1976 to March 1977 and involved different specialists from both TECHNIP and KVAERNER (about 3000 h)

- The detailed engineering phase, comprising the finalization of the specifications for the main duty, the preparation of the specifications and P.O. for all the other equipments and the management and coordination of the relations between vendors and KE/TP other engineering sections, from beginning 1977 until summer 1979 (about 8000 h).

F-2.2 The EAN coverage.

The EAN scope in that discipline can be split into three phases:

- basic engineering phase: one engineer was permanently assigned to work on the selection of the main duty machines.
- detailed engineering phase: the different mechanical P.O. placed by KE/TP engineering mechanical section were followed by different project engineers within the EAN group: engineering section head, electrical specialist, instrumentation specialist...
- follow up and start up phase: there has been no KE/TP follow up on the mechanical side.

The follow up was done from February 1979 until end 1980 by a mechanical project engineer (J. Fort) newly assigned on the project and to whom the responsibility for all the mechanical items was transferred from then on. The start up of the turbocompressors and turbogenerators was also supervised on the mechanical side by the EAN engineering mechanical project engineer.

F-3 THE BASICS ABOUT THE EQUIPMENT AND ITS SELECTION.

The list and basic description can be found in document F-1 attached to that section.

The detailed description will be found in the general synopsis enclosed in the report.

However the following ratios can be given in addition to these various descriptions:

	Weight / kW available	Cost / kW available
Turbogenerators	11.5 kg/kW	1 150 NOK $_{77}$/kW
Turbocompressors	5,3 kg/kW	790 NOK $_{77}$/kW

These ratios take the driven equipment into account but the major contribution to the reduction of weight and cost per kW with the unit power must be found in the turbine, the UTI machine being with comparison to the STAL LAVAL one:

- lighter because jet derivative
- cheaper because mass produced.

The reason for selection of the suppliers is given hereabove in paragraph A-7.3 for the main components:

- turbine for compressor drive A-7.3.1.1
- compressors A-7.3.1.2
- turbogenerators A-7.3.2
- S.W. cooling pumps A-7.3.5.2

Concerning the other items, the selection was made according to the criteria as listed in A-7.3 page 12/18.

A special remark should be made about the two fire pumps supplied by FRANK MOHN and of a very special design: submerged 1st stage pump driven by a submerged hydraulic motor receiving its H.P. oil from an oil pump driven by the Diesel which is also driving by direct coupling the 2nd stage pump.

At the time of the selection, the safety and mainenance people within EAN were really shocked by the difficulties got with the SPP pumps installed on the treatment side and this favoured the selection of the FRAMO solution which was not really a prototype because it had already been selected by PHILLIPS for EKOFISK.

F-4. THE PROBLEMS FACED DURING THE PROJECT.

F-4.1 Turbocompressors

The relationship between the vendors and EAN and KE/TP has been all over the contract excellent with UTI but rather difficult with the other partners, KONGSBERG, ALSTHOM and ACB.

The detail of all the problems which have been faced and the way they have been solved can be found in a specific document: "FRIGG Field turbocompressors start up report" ref. 311 E Com./81/391/JF/BC on 23.11.81 which is not attached to this final TCP2-C project report.

However the resume of these problems is given hereafter:

F-4.1.1 During the engineering phase.

The management by KE/TP and EAN of the contract was extremely difficult due to the very complicated arrangement of this contract.

The sketch herewith supplied as per document F-2 is self explanatory, but on top of the obvious problems of responsibility and coordination implied by the numerous partners, it must be mentioned that the compressor vendor ALSTHOM lost the license from NUOVO PIGNONE in the course of the contract and this did not simplify the scheme.

F-4.1.2 During the construction phase.

Due to delay in the workshop schedüle for compressor fabrication the compressors and their skids were delivered incomplete on the construction yard, in ORKANGER.

The compressor vendor was therefore requested to complete the work on the yard and this was extremely ackward to manage because there is an obvious incompatibility between the small piping work, mechanical adjustments and the instrumentation hook up and calibration which remained to be done on the compressor skids and the heavy piping and structural work which was performed at the same period on the yard, together with sandblasting and painting.

The L.O./S.O. tests which had also to be done were permanently thwarted by poor working conditions and other priorities on the yard.

F-4.1.3 During the start up.

The following problems occured and were solved as mentioned hereafter:

- collapse of temporary suction filters: happenened three times, one with the original design filter, one with the same filter from which the fine external meshes had been removed, once with a new design filter specially prepared by N.P./ACB (compressor vendors) to avoid such a problem.

  It was solved by getting rid of the filters!

- destruction of antisurge valves: the original valves as specified by the compressor vendor were of the whisper type for noise reduction. They were completely destroyed during the first start up attempt in April 1981 on compressor B. The reason was found in the sensitivity of these whisper trims to liquid carry over and solid particles bombarding at a time when we were trying to start the compressor B on a particularly dirty closed loop.

This problem was solved by changing the whisper trims into conventional ones less sensitive to liquids, and cleaning thoroughly the piping before the next strt up attempt.

- The sensitive turbine control cables were rejected by UTI because subject to eddy currents (screens pair by pair were not insulated one from any other). They were replaced by special cables from "MULLER et LANDAIS", France (P.O. 8120 359 in March 1981)
- S.O. low pressure rings consumption. The problem was already located during the check out period on the yard, however it was suspected that the high consumption was the result of some by pass due to the possible presence of sand in the system. However a tentative new design was made by EAN to prove the compressor vendor that something had to be done in this area. The EAN desing consisted in reduced clearance new L.P. rings.

  Later on, during the commissioning, N.P. supplied new rings with reduced clearance and the results were improved. It was not sufficient anyway and EAN was obliged to call for a new desing again from N.P. which reverted during start up with a set of still reduced clearance L.P. rings. The reduction this time was drastic but the results good.

  The problem can be considered to be solved now with this last type of rings.

The following table is summarizing the history on this problem

- SHAFT Ø 190 MM - PUMP 130 l/MN

DATE	DESIGN	CLEARANCE	FLOW L/MN	COMMENT
1977	Original design by N.P.	18-22/100 on Ø	Expected 80 Actual 200 in static cond.	Not acceptable
Spring 1980	Tentative design by ELF	13-14/100	Actual 70 in static condition	O.K. but static test only
January 1981	New design no. 1 by N.P.	15-17/100	Expected 50 Actual 130 in running and static cond.	Not satisfactory
October 1981	New design no. 2 by N.P.	10-12/100	Actual 40 in running and static cond.	O.K.

F-4.2 Turbogenerators

There were no major problems during the start up phase and the relationship during the engineering phase had been quite excellent.

The only two serious problems met during the start up were not connected to the engine itself but to external systems:

- STAL LAVAL complained about the quality of the F.G. (condensate problem)
- a high frequency resonance (upper mode) of the pancake was detected at 50 hZ. Although acceptable as far as the mechanical stress is concerned, this resonance should be moved to avoid people discomfort and control panel devices vibration and calibration outage.

F-4.3 Diesel Emergency Generator.

Very good quality of the product and extreme reliability of automatic start.

The only corrections consisted in:

- installing the air compressors on silent blocks.

- increasing the capacity of the preheating system to keep a sufficiently high oil and water temperature even in very cold and windy conditions.

F-4.4 Fire pumps.

The relations with the vendor during the engineering phase was not always very easy due to the lack of experience from the vendor as a packager and also to a slow response on the KE/TP requests.

During the commissioning, start up, the various serious following problems occured:

- leakages on hydraulic piping between hydraulic pump and submerged 1st stage pump motor, and between submerged hydraulic motor and sea. This necessitated 7 dismantling of the complete column and submerged pump before the problem was acceptably cured.
- Compressed air column build up in the piping between 1st stage and 2nd stage without priming of the 2nd stage. A piping modification on the 2nd stage pump air trap arrangement had to be done.
- Improper engineering of the electrical junction boxes, making it necessary to remove the supplied boxes and to replace them by new bigger ones.
- Various problems on the pneumatic panels
- Failures to start on automatic. In spite of several modifications carried out by STEWART and STEPHENSON on that matter, this major problem cannot be considered to have been really solved.
- Improper water pressure control on the engine. Solved by changing the pressure regulators.
- Problems of hydraulic interface with the ventilation dampers. Solved by piping changes.

F-4.5 Air compressors

Two main problems:

- poor quality of the skid and of the packaging when the package arrived on yard.
- many problems during start up:

    * no piping connection between cylinders and cylinder end cover for cooling water (oversight from construction)
    * very poor reliability and very difficult calibration of the pneumatic control cabinet.
    * wrong torque wrenching of the nut tightening the cylinders on the rods, with two unbolting, one detected before any major failure, the other one with piston, rod, cross head destruction after a few months operation.

F-4.6 S.W. pumps.

No problems were met with the 2 KSB pumps which passed successfully the durability test demanded by EAN.

But a lot of problems with the 2 T.U. pumps, discovered mainly during the durability tests:

- wrong design of the motor bearings presenting a typical half frequency whirl. PLEUGER was obliged to redesign the bearings.
- high level of vibration on the coupling side bearing of the pump: new stiffer design for the connecting piece between pump and motor was incorporated by T.U.
- very poor reliability of the vibration probes in marine environment.
- casting problems on the Ni-Cu alloy pump body. Grinding of the whole body had to be done.
- PLEUGER motor burn out during the tests.

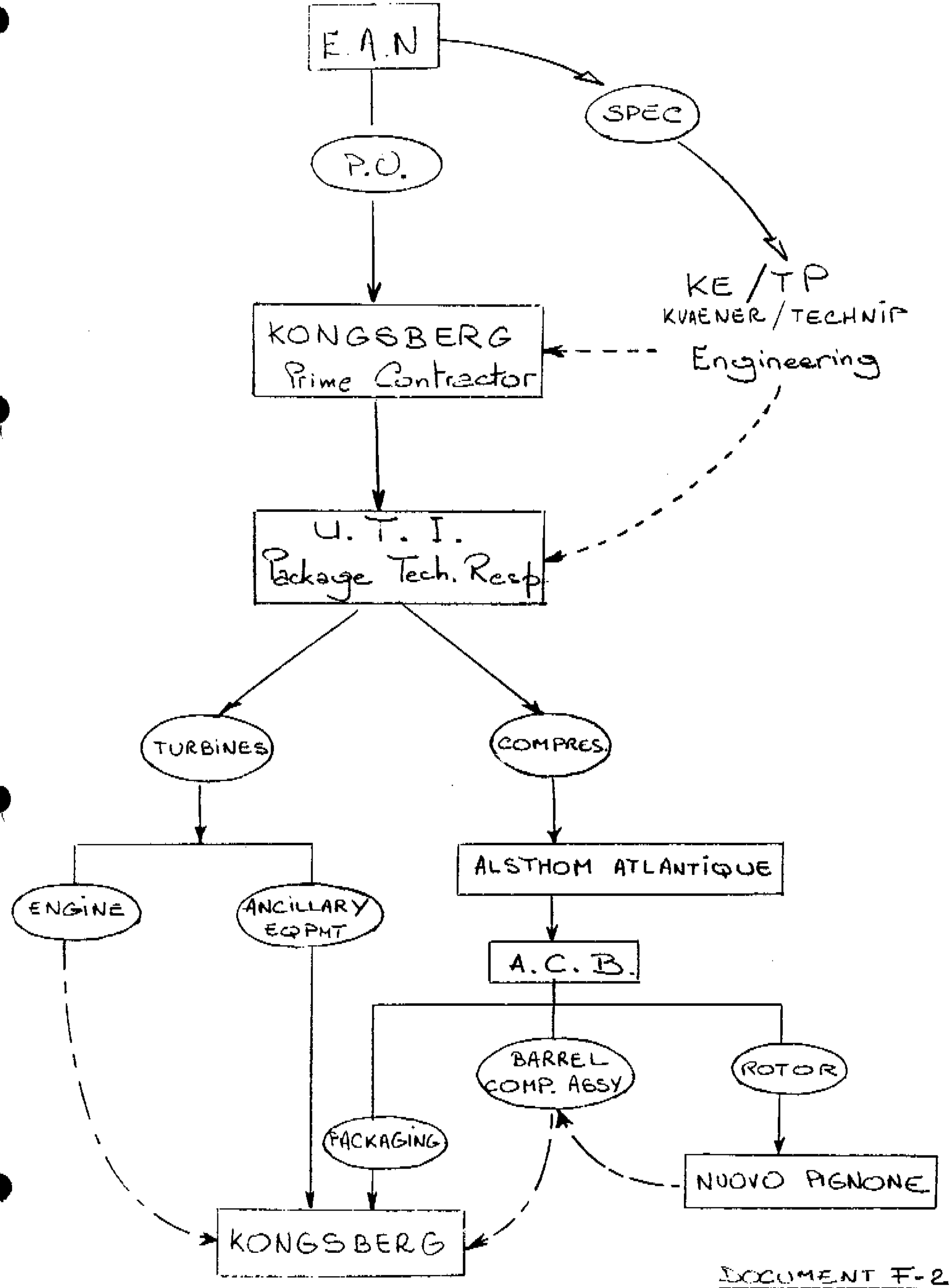
All these problems accumulated a delay amounting to one solid year by comparison with the contractual schedule.

F.4.7 Crane

No quality problem with the exception of a wrong positioning of the connecting pads of the boom to the crane itself.
But a major delay problem with a total delay in the range of 6 months hampering seriously the progress on the construction yard.

F-4.8 Other components

No comment.


E.A.N
SPEC
P.O.
KE / TP
KVAENER / TECHNIP
Engineering
KONGSBERG
Prime Contractor
U. T. I.
Package Tech. Resp
TURBINES
COMPRES.
ENGINE
ANCILLARY EQPMT
ALSTHOM ATLANTIQUE
A.C.B.
BARREL COMP. ASSY
ROTOR
PACKAGING
NUOVO PIGNONE
KONGSBERG

DOCUMENT F-2

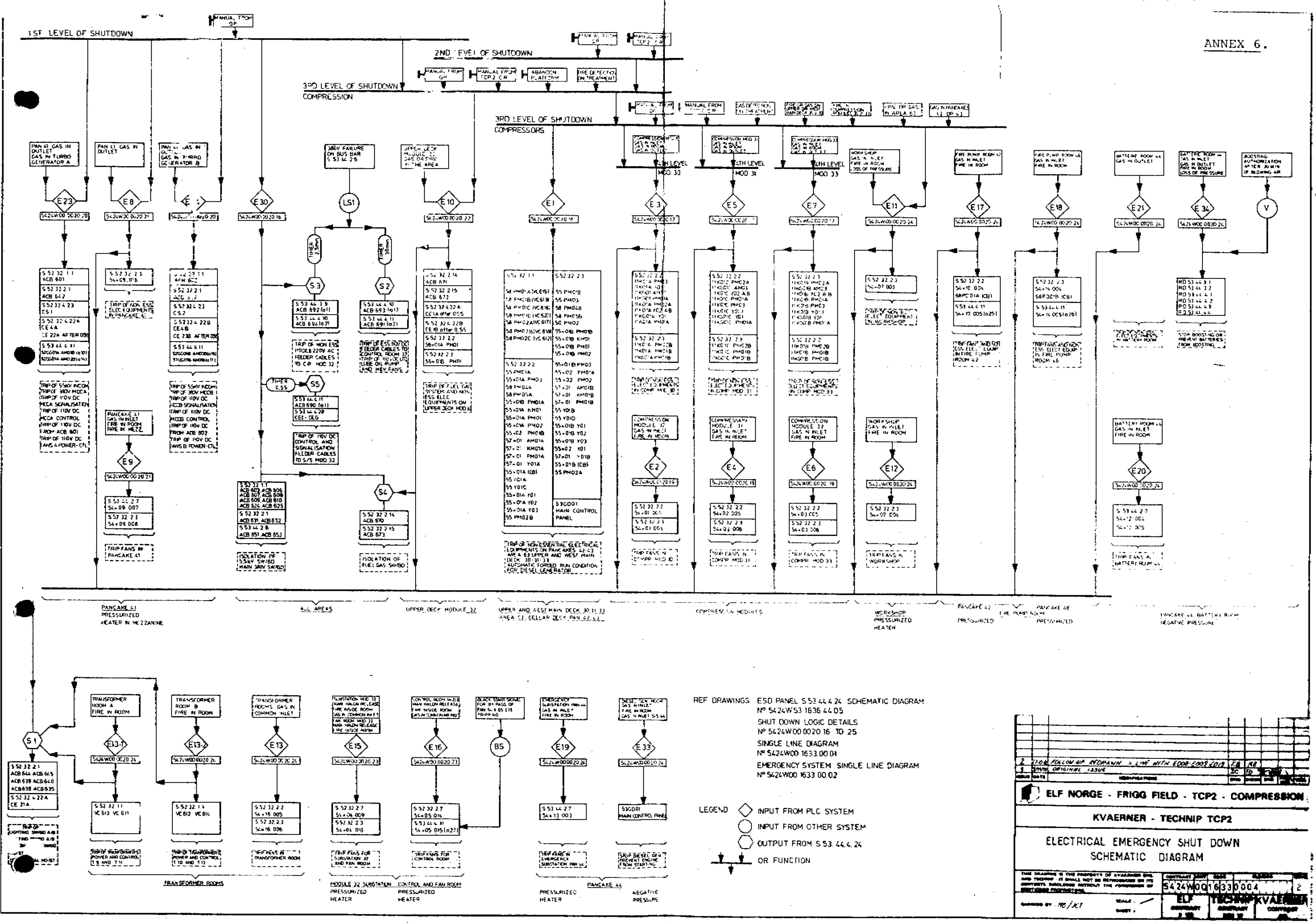
	DUTY	LOAD FACTOR	KE/TP TAG NUMBER	SUPPLIER TYPE	MAIN DATA	PRICE NOK	P.O. AND DATE	DELIVERY DATE	NUMBER OF VENDOR DRAWINGS
1	Gas Compression	3 lines - 2 duty - 1 spare	Prime mover Gas turbines 11 KG 01 A 11 KG 01 B 11 KG 01 C	UTI - TPMS FT4C - 3F	- Aeroderivative - GG: twin spool - FT: 3 stages 2000/4200 RPM - Max output: 32 MW - Weight: 80 T	10 340 290 US $ = 54 634 589 NOK	172151 to Kongsberg Våpen-fabrikk prime con-tractor - 23.07.77	March 1979	215
			Compressors: 11 K 01 A 11 K 01 B 11 K 01 C	- ACB under NUOVO PIGNONE licence - BCL 607 A	- Barrel type - 7 stages - 2000/4200 RPM - compression ratio up to 1,8 - flow up to 17 000 ACM/H - Ps about 100 B - Pd about 155 B - Weight 90 T	18 996 395 FF = 21 296 407 NOK	172151 to Kongsberg Våpenfabr. prime con-tractor	April 1979	64
2	Electrical generators	2 lines - 1 duty - 1 spare	52 GO 1 A 52 GO 1 B	STAL LAVAL turbine GT 35 gen. ASEA GTA 1125 CD	- Turbine semi heavy duty - GG twin spool - 3000 RPM - Turbine output max 13,5 MW - Alternator 17,15 MVA - Weight 150 T	30 000 000 NOK	172157 - 21.12.77	June 1979	148
3	Diesel Emergency Generator	- 1 line Emergency	53 GD 01	SACM	- Diesel V 16 double turbo - 1500 CV - 1500 RPM - Alternator NEBB	1 171 810 FF = 1 425 796 NOK	172161 08.03.78	February 1979	37
4	Fire pumps	- 2 lines Emergency	68 PO 1 A 68 PO 1 B	FRANK MOHN	- Diesel DDA pack-aged by S.S. driving directly 2nd stage FRAMO pump - Diesel driving also hydr. pump - Oil from hydr. pump driving downhole hydr. motor/1st stage FRAMO pump	2 196 805 NOK	172226 24.09.78	July 1979	46
5	Air compression/ treatment	- 2 lines - 1 duty - 1 spare	57 X 0 1 A 57 X 0 1 B	WORTHINGTON BDCB 16"1/4x8"1/4x5"	- delivery press. 10 bars - 500 m^3/h - air receiver, dryer, all auxil. equipm. incl.	1 427 000 FF = 1 599 776 NOK	172162 22.02.77	April 1979	41
6	S.W. pumps	- 4 by groups of 2 - 2 on duty - 2 spares	58 P O 1 A 58 P O 1 B 58 P O 1 C 58 P O 1 D	58 P O 1 A/C KSB SUZ 400-500/2	- submerged set - both pump and motor KSB - 2000 m^3/h, 60 m - 5,5 kV - motor PLEUGER	4 651 000 NOK	172163 08.03.78	February 1980	21
				58 P O 1 B/D THUNE EUREKA CLD 300 2x1 KDE	- submerged set - pump T.U. - 2000 m^3/h, 60m - 5,5 kV	4 948 735 NOK	172164 08.03.79	contract-ual 01.02.80 act.Jan 81	17
7	F.W. pumps	- 2 lines - one duty - one spare	58 P O 2 A 58 P O 2 B	DRESSER HVC 16 x 18	- 5,5 kV - 2000 m^3/h - 1 stage - 45 m - 1500 RPM	900 000 FF = 1 008 969 NOK	172152 28.02.78	March 1979	4
8	F.W. uti-lities pump	2 lines - one duty - one spare	58 P O 4 A 58 P O 4 B	THUNE EUREKA 48 x 19 TC	- 1500 RPM - 460 m^3/h - 54 m	279 200 NOK	172170 24.02.78	November 1978	9
9	F.W. make up pumps	2 lines - one duty - one spare	55 P O 1 A 55 P O 1 B	GUINARD VM 8 x 12	- centrifugal - 4 stages - 3000 RPM - 12 m^3/h, 38 m	22 630 FF = 25 370 NOK	172171 23.02.78	August 1978	6
10	T.E.G. make up pumps	2 lines - one duty - one spare	55 P O 2 A 55 P O 2 B	GUINARD	- screw pump - 1400 RPM - 5 m^3/h, 6 bar	52 705 FF = 59 086 NOK	172161 23.02.78	August 1978	2

	DUTY	LOAD FACTOR	KE/TP TAG NUMBER	SUPPLIER TYPE	MAIN DATA	PRICE NOK	P.O. AND DATE	DELIVERY DATE	NUMBER OF VENDOR DRAWINGS
11	F.W./teg pumps	2 lines - 1 duty intermittent - 1 spare	58 P O 5 A 58 P O 5 B	KSB B6 B3	- 3000 RPM - $20m^3/h$ - 35 m - centrifugal 3 stages	15 885 DM = 44 521 NOK	172169 20.02.78	September 1978	7
12	Wash down	1 duty intermittent	50 P02	KSB BPN 374/6	- submerged pump/ motor set - 6 stages - 3000 RPM - 114 m^3/h, 132 m	76 685 DM = 214 924 NOK	172168 20.02.78	November 1978	24
13	Crane	1 duty intermittent	60 x 01	NYLANDS VERKSTED	- 30 tons at 12,5m - 2 DIESEL DDA - 1 duty - 1 spare - 2 hydraulic pumps - hydraulic powered winches	3473 000 NOK	172267 02.11.78	contractual Sept. 1979 - actual February 1980	20
14	Hoists	all intermittent duty	VARIOUS	MUNCK	- all electrical explosion proof - up to 12 tons - 13 electrical - 6 manual	459 000 NOK	172266 = 16.11.78	October 1979	32
	TOTAL					12 217 278			693

DOCUMENT F-1.

(Part 2 of 2)

ANNEX 6.


1ST LEVEL OF SHUTDOWN
2ND LEVEL OF SHUTDOWN
3RD LEVEL OF SHUTDOWN
COMPRESSION
3RD LEVEL OF SHUTDOWN
COMPRESSORS
4TH LEVEL MOD 30
4TH LEVEL MOD 31
4TH LEVEL MOD 33
380V FAILURE ON BUS BAR
PANCAKE 41 PRESSURIZED HEATER IN MEZZANINE
ALL AREAS
UPPER DECK MODULE 32
COMPRESSION MODULES
WORKSHOP PRESSURIZED HEATER
PANCAKE 42 PRESSURIZED
FIRE PUMP ROOM
PANCAKE 46 PRESSURIZED
TRANSFORMER ROOMS
MODULE 32 SUBSTATION PRESSURIZED HEATER
CONTROL AND FAN ROOM PRESSURIZED HEATER
PANCAKE 44
PRESSURIZED HEATER
NEGATIVE PRESSURE
REF DRAWINGS
ESD PANEL S 53 44 4 24 SCHEMATIC DIAGRAM
Nº 5424W53 1636 44 05
SHUT DOWN LOGIC DETAILS
Nº 5424W00 0020 16 TO 25
SINGLE LINE DIAGRAM
Nº 5424W00 1633 00 01
EMERGENCY SYSTEM SINGLE LINE DIAGRAM
Nº 5424W00 1633 00 02
LEGEND
INPUT FROM PLC SYSTEM
INPUT FROM OTHER SYSTEM
OUTPUT FROM S 53 44 4 24
OR FUNCTION
ELF NORGE - FRIGG FIELD - TCP2 - COMPRESSION
KVAERNER - TECHNIP TCP2
ELECTRICAL EMERGENCY SHUT DOWN
SCHEMATIC DIAGRAM
5424W00 1633 0004

3. PROCUREMENT OF EQUIPMENTS AND MATERIAL.

1. Generalities

* The contract signed between EAN and KE/TP stated that the purchasing, inspection, expediting and follow-up of the purchase orders and shipping would be performed by the KE/TP teams in Oslo and Paris.
* From the first delays in delivery, the project management had some serious suspicions about the efficiency of the above operations.
* As a matter of fact, the inspections at mill by the TP inspectors were not always scheduled in accordance with the emergency requested by our project but in accordance with the TP most economical program of travel.
* On the other hand, the TP inspectors in charge of technical inspections did not worry about the manufacturing progress and target date of delivery, contrary to their actions performed in that way for their own "turn key" contracts for which they were responsible of the delivery date.
* Many dates of delivery were spreaded within a small period of time and did not allow a serious technical checking without increasing the inspection team.
* The relevant informations were not fully reported nor in due time to the project management.
* We will also point that, except for some very important equipments (turbo-compressors; turbo generators; steels..) most of the purchase orders placed by KE/TP were not seriously negociated to make sure of the date of delivery.
* Many purchase orders were subject to technical modifications during manufacturing or, as for the electrical cables, subject to modifications of quantity requested too lately.
* Many other purchase orders were delayed due to a lack of balancing between the number of KE/TP purchasers and their load of work.
* For all the above reasons the project management decided to transfer to Stavanger the KE/TP team in charge of the procurement except for the purchasing of material theoretically needed for construction onshore, and to place it under the EAN control.

* Following this transfer the very critical situation was partially improved by a scheduling of inspections in accordance with the yards requirements, by a close contact with the yards to give them the most accurate informations about dates of delivery in order to modify their program accordingly, if possible, and by placing some purchase orders, through EAN purchasing department, to deliver the critical missing piping in emergency.
* Nevertheless, the situation was too much critical to be fastly recovered and, in addition, some people among the team transfered did not appreciate their new assignment under EAN control.

* The transfer of the team was performed in January 1979. The was as follows:

  - a manager and his assistant
  - a technical chief inspector
  - a mechanical inspector
  - an electrical inspector
  - an instruments inspector
  - a welding inspector
  - an inspector for piping, valves, fittings
  - a shipping clerk
  - a clerk in charge of expediting and local purchasing
  - a clerk in charge of follow-up and dash-boards:

    material coordination report
    composite expediting report

  - a filing clerk, also in charge to check the mill certificates and to prepare the vendors data books.

2. Onshore construction phase

* Number of purchase orders placed by KE/TP for the main equipments 225
* In addition, about 400 complementary purchase orders have been placed by EAN
* Number of month-inspection (except vacations) from January 1979 50
* Number of inspection reports 410

- * As a result of the actions performed by the new inspection - expediting team settled in Stavanger, the delivery of many purchase orders were improved and particularly for the piping material (pipe, flanges, bolts, gaskets) as well as for a lot of purchase orders concerning standard instruments or electrical equipments for which the Orkanger Yard was in a very critical situation.
- * But, for some equipments it was not possible to make up for lost time in manufacturing due a too much important delay gathered before the assignment of the team in Stavanger.
- * Many of these equipments were also delayed due to technical manufacturing problems or technical modifications ordered by the engineering department during manufacture.

- * These equipments are listed hereafter:

  - Prefabricated piping at PONTICELLI Bordeaux which were partially delivered (327 tons delivered instead of 519 tons ordered). The balance was manufactured by the contractor at Orkanger.
  - The 3 turbo-compressors KONGSBERG have been delivered at Orkanger not completed in order to go on with the module fabrication.
  - The fuel gas exchangers A.C.B. were not delivered on shore in time due to technical problems with welding of turbulars.
  - Concerning the electrical switchboards and instruments panels cabinets the delay in manufacturing was mainly due to the numerous engineering modifications.

  - As for some other manufacturers, they were late only because their bad organization (the AKER crane was delivered 6 months later than the contractual date of delivery in spite of the written promises sent by the AKER's general manager).
  - Some others, NORSK KABELFABRIKK for instance, were never able to give us an accurate date of delivery in spite of our numerous claims. Each new delivery date given were postponed a lot of times before shipment.
  - Fortunately, some of them like FRANK MOHN (safety fire pumps) did their best to reduce their delay,

- The only big equipment delivered on time was the two turbo-generators manufactured by STAL LAVAL.

3. Results of the inspection - expediting team.

Due to the important quantity of equipments and material manufactured at the same time for which the dates of delivery were concentrated within a short period, and due to the very important time spent by travelling and reporting, our inspectors could not stay more than one or two days at the workshops for each visit.

This is not enough, for big equipments, to have a good knowledge of the workshop efficiency in order to make the right analysis of the progress and to discuss seriously the problems with the people responsible in the factory.

So, two and sometimes three inspectors by discipline would have been necessary for mechanical and electrical equipments during at least the three first months of 1979, in order to perform a very complete control including precommissioning of the equipment checking of relevant documents, packaging and protection for a long time storage.

4. Storage of material and equipments at yards.

The storagae and administration of material was perfromed by and under the contractor's responsibility. An EAN supervisor was in charge of checking the operations and to report to Stavanger the status of the material received and missing in order to make actions of expediting against late suppliers.

At Kristiansand and Grimstad the above operations were generally carefully performed and the informations transferred at Stavanger in due time whilst a lot of misunderstandings and disputes arise with Orkanger due to the higgledy-biggledy contractor organisation (wrong and late informations, references missing, unjustified claims, unfairness).

5. Shipping

A contract was signed between EAN and SUNDBYE OSLO to perform all shipments of material and equipments from the supplier's workshops to our 3 yards.

The main difficulty in shipment operations was to know, in case of delay of delivery on site, where the material was stopped to make action. SUNDBYE was never very interested in making strong investigation in that case and our shipping employer made it himself.

Another difficulty was the wrong splitting made by the suppliers and sometimes by SUNDBYE to deliver the material on the 3 separate yards. Finally, we have stopped the contract and our shipping employer placed himself the purchase orders for shipments. In case of urgency we rented special trucks to pick up and deliver the material in time.

6. Hook up

The material required for the hook up were delivered and stored on the yards until the lifting with all the construction surplus All those material were shipped by trucks to a Stavanger warehouse specially open for this purpose. But the sudden delivery at Stavanger of about 10 trucks of material (and 2 boats for spools), for which the packing lists were not carefully issued (and often missing) obliged to assign five storekeepers to unpack, to identify to store, to mark, to verify, to issue documents of receipt, to open a particular Kardex within a very short period in order to be ready to deliver the material required for the first hook up tasks.

In addition to the above operations of storage and shipments for hook up tasks, our team kept a close contact with offshore people to supply their requests for material.

For fear of falling in lack of material at the beginning of the hook up,offshore hook up team requested too much material which was delivered in time within a very short period.

In addition to the material received from the yards we have placed 1400 purchase orders for the hook up team to perform his job. The main difficulty was not to secure the material from the suppliers but in some cases to obtain precise specifications and references of the requested material from the offshore requesters.

7. Surplus

The surplus material either coming from yards or sent back from offshore have been identified and stored at Stavanger warehouse to be used if possible for the future projects, specially a large quantity of electrical cables (60 kilometers of various sizes).

8. Documentation

All technical documents regarding material and equipments have been consolidated to make the "vendors data books" filing.
For each purchase order the following documents were filed:

- Mill inspection reports
- Material certificates issued by manufacturers
- Technical documents (data sheets, spare parts lists, maintenance manuals)

10 sets of 50 volumes have been made and dispatch to the various departments concerned:

Maintenance offshore and onshore, warehouse, purchasing, engineering, central filing, for future needs after the project completion.

4. ONSHORE CONSTRUCTION YARDS.

4.1 General Description of the work.

4.1.1 Extend of the work.

The works comprise the fabrication of modules, pancakes, connection spools, support structures destined to be installed on TCP2.

The services to be provided by Contractors include:

4.1.1.1 The preparation of detailed technical and administrative documents like:

* final and detailed fabrication documents and shop drawings
* welding procedures
* final and detailed engineering design related to onshore installation operations: transportation, erection, connections, heavy handling
* recording of all fabrication works
* programme of the work including: planning network, histograms, monitoring of the work.

4.1.1.2 The receipt, storage and control of Company supplied material and equipments.

4.1.1.3 The supply by contractor of all materials and consumables not furnished by company.

4.1.1.4 The fabrication, installation,onto testing of all steel, mechanical, electrical and instrument systems.

4.1.1.5 The protective coating of all structures, pipework with supply of paint and application.

4.1.1.6 The load-out and sea-fastening onto the cargo barge.

The modules, pancakes and appurtances are classified in three lots. Each lot is defined as a functional and geographical entity:

- the lot 1: Gas compression: Main deck of TCP2
- the lot 2: Electrical Generation: Cellar deck (N.E.) of TCP2
- the lot 3: Cooling systems: Cellardeck of TCP2

The contract specified that within each lot, the modules and pancakes had to be assembled according to their final configuration on TCP2 in order to:

- perform commissioning services and full load test
- pressure-test all pipework prior to offshore installatio
- avoid further clashes or interferences while installed on TCP2.

4.1.2 Split of the work between the 3 construction yards.

The work was split in three construction yards as a result of technical and economical and political considerations.

The lots being defined as described above, the Call for Tender was submitted to 16 contractors or association of contractors. Out of this call for tender, 13 bids were received. In order to compare the offers, and to take into account previous experience of constructions for the Frigg Field, a theoretical cost representing 50% of extra-work computed with the price lists given was added to each bid price.

The analysis gave the following results:

LOT 1:
- lower price for PONTICELLI
- same medium prices (+30% to 50%) for other French and foreign yards
- same high prices (+75% to 100%) for the other yards.

LOT 2 AND 3:
- lower price for PONTICELLI, OIS and FRANCE ENTREPRISE
- high prices (+30% to 80%) for the other yards.

Without political constraints, the choice would have been PONTICELLI who has in addition serious references.

But the choice of a foreign yard being slightly hypothetic, it was decided, in agreement with partners and Norwegian authorities:

- for the lot 1, to call for a second run the three mani Norwegian contractors:

  VIGOR
  KVAERNER ENGINEERING
  AKER

  with the aim to lower the price, if necessary by subcontracting the prefabrication of the pipework to foreign yards.

- for the lots 2 and 3, to choice OIS who offer a price of 12% above PONTICELLI.

The final result of discussions were:

LOT 1.	AKER/CMP.	SBV/ PONTICELLI	KVAERNER/FRANCE ENTREPRISE
Lump sum	56 180	45 000	45 148
extra work (evaluated)	36 233	30 840	32 481
TOTAL	92 413	75 840	77 629
Norwegian Content	52%	86%	90%

AKER, associated to CMP made the price lower by transferring to Foreign content.

VIGOR and KVAERNER lowered their prices of respectively 26% and 34% below the first offer by subcontracting the pre-fabrications and by decreasing the cost of their works.

AKER/CMP was rejected due to the high price, a low Norwegian content, and a geographical split of modules which was non attractive.

KVAERNER and VIGOR were very close; KVAERNER offered a covered construction site but no facilities to perform the full load test of compressors. VIGOR offered the best unit prices and good facilities to perform the full load test. Consequently it was decided to commit the work to VIGOR associated to SPIE-BATIGNOLLE.

4.1.3 General contract condition

4.1.3.1 Type of contracts

The contracts were presented under the form of eleven volumes of documents to form the integral contracts, numbered as follows:

E 76	with SBV (Orkanger yard, lot 1)
E 77	with OIS (Einar Øgrey yard, lot 2)
E 78	with OIS (Nymo yard, lot 3)

They comprised:

- Commercial parts
  - Volume 1
    - A. Particular Conditions
    - B. Price Schedule
    - C. Contractor's Means

- Volume 2

  General Conditions

- TECHNICAL PARTS

  * Volume A: General Documents
  * Volume B: Structural and Architectural
  * Volume C: Equipment and Tests
  * Volume D: Piping
  * Volume E: Electricity
  * Volume F: Instrumentation
  * Volume G: Insulation and Ventilation
  * Volume H: Painting
  * Volume I: Load-out

4.1.3.2 Contractual conditions

The contract price is a lump sum deemed to cover all detail studies, the fabrication and the installation of everything shown on the drawings and/or the PID, and/or the various equipment schedules, and shall include the installation, together with all required fabrication and installation of material indicated as company-furnished, and the supplying by contractor of all material not listed as company-furnished.

In case of discrepancy between the quantities of material given in the lists of company-furnished material and quantities shown on the other contract documents, the lists of company-furnished material are considered to be the basic of the contract price.

Each contract price was broken down into a schedule of partial lump sums.

For both additional work and deleted work, the unit rates given in the particular conditions apply either positively or negatively as the case may be.

4.2 Report on Orkanger yard (SBV lot 1)

4.2.1 Organization

4.2.1.1 Contractor and subcontractor

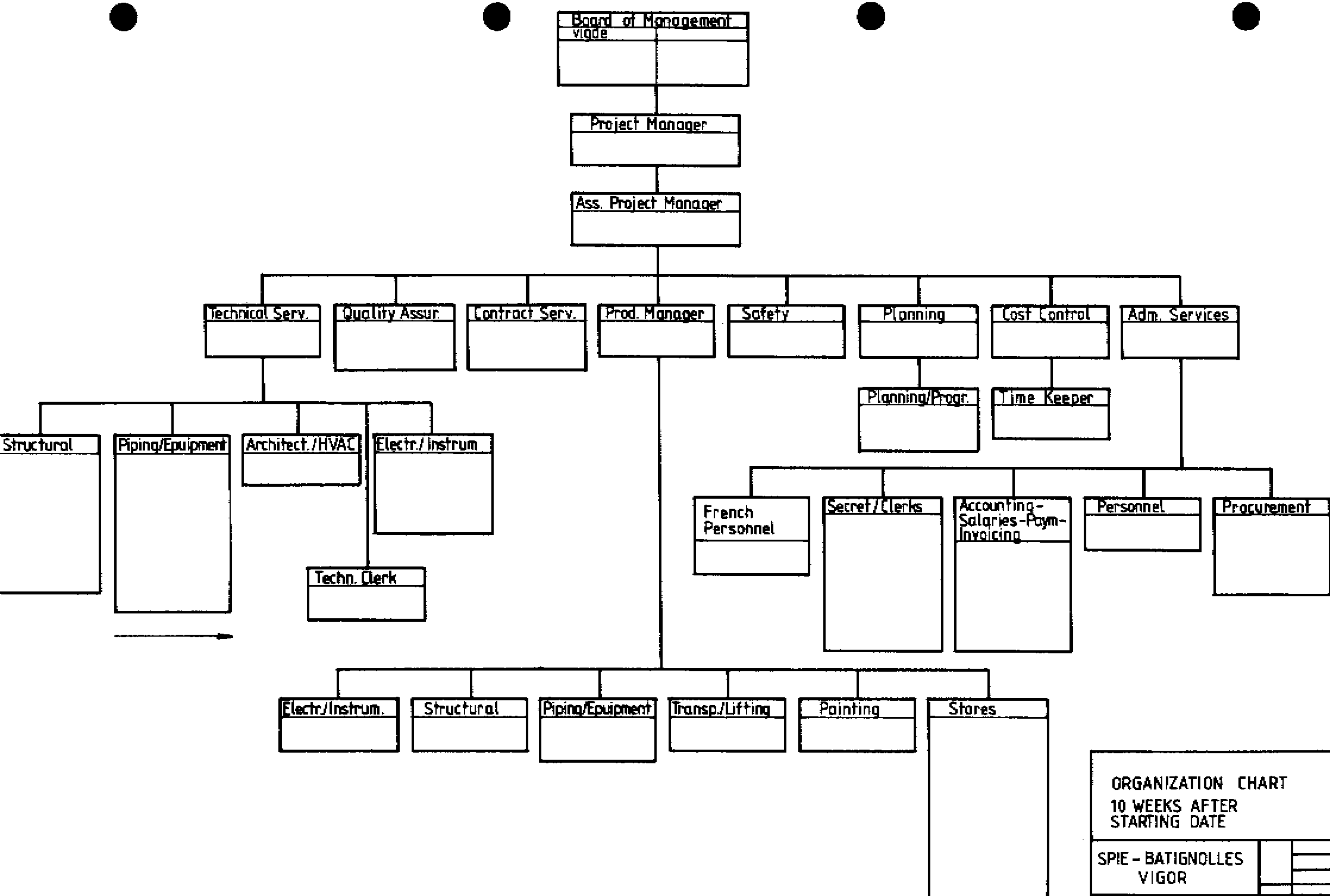
The contractor SPIE-BATIGNOLLES - VIGOR is a Franco-Norwegian Joint Venture. SBV rents its facilities and personnel from VIGOR A/S (85%) and personnel from SPIE-BATIGNOLLES.

Main subcontractors are:

- PONTICELLI (Ambès) Pipework prefabrication from September 1978 to April 1979 (2% in work value)
- KVAERNER BRUG (Egersund). Modules deck prefabrication from September 1978 to January 1979
- VCON - Electrical and instrument installation
- INDMA - Painting
- MONTALEV - Load-out consultant and equipment
- FINDICATOR - Welders
- STÅLKONSTRUKSJONER - Steelwork
- OMEK - Steelwork and hoists installation
- TEKNISK ISOLERING - Pipe insulation
- IKAS - Wall insulation
- S.E. TRADING - False floors

The contractor's management was organized as shown on charts given overleaf.

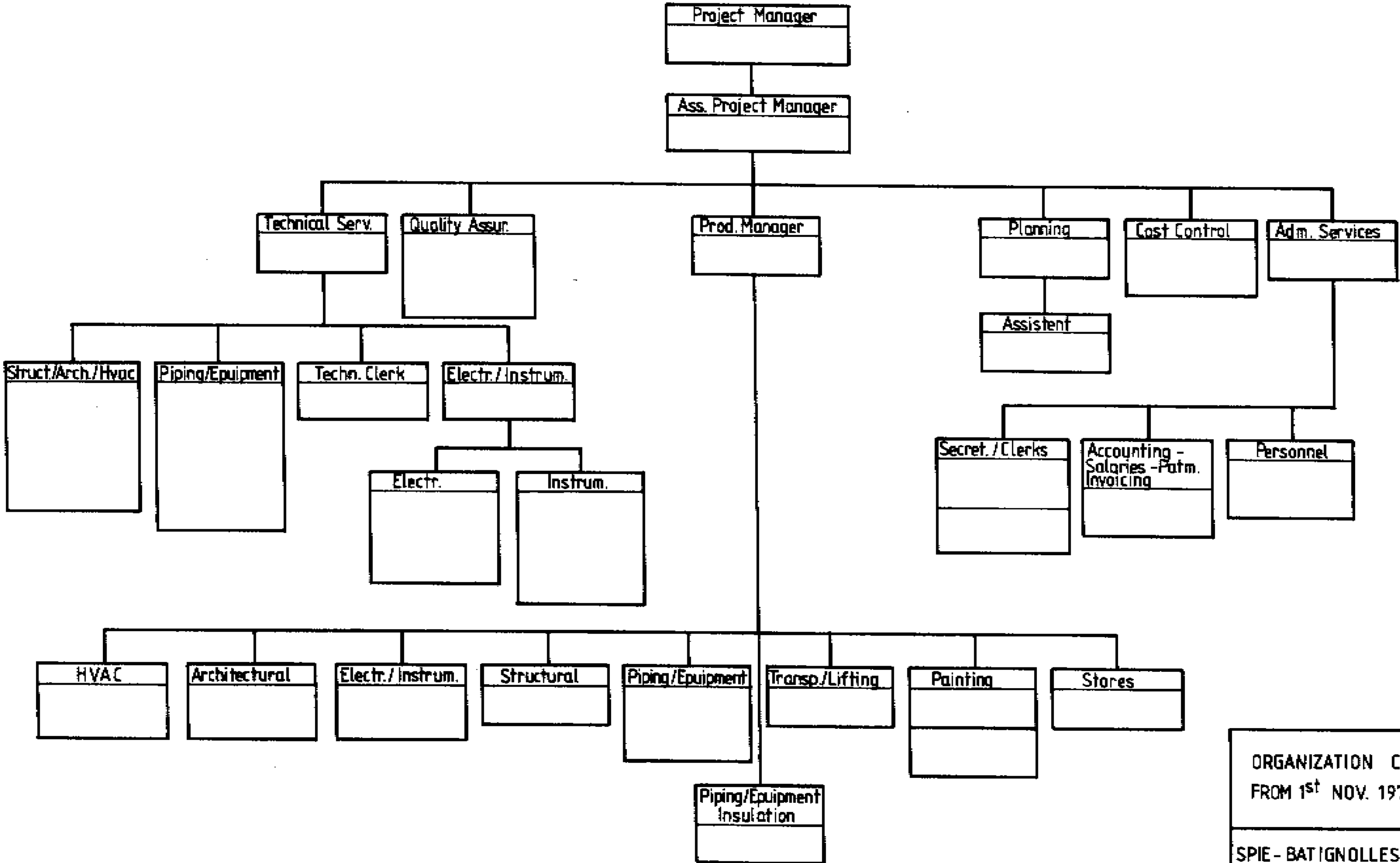
- first is typical organization 10 weeks after award of contract
- second is typical organization on 1st November 1979 when the work was proceeding on unit rates basis.



ORGANIZATION CHART
10 WEEKS AFTER STARTING DATE

SPIE - BATIGNOLLES
VIGOR

TCP2 COMPRESSION
CONTRACT E76



ORGANIZATION CHART
FROM 1st NOV. 1979

SPIE - BATIGNOLLES
VIGOR

TCP2 COMPRESSION
CONTRACT E76.

4.2.1.2 EAN supervision.

The organization was a pyramidal chart established at the contract award date, but was revised in December 1979 into a functional centered organization.

All supervision personnel was contracted to KVAERNER/TECHNIP, NORSK HYDRO, DnV, COMSIP, SOFRESID, with the exception of the supervision manager, piping engineer and compressor engineer.

Some changes occured to allow the organization to cope with the ever changing situations during the construction and the various and different capacities of the persons.

4.2.2 Scope of work

4.2.2.1 Initial scope

Contract E 76 EAN - SBV included the following quantities

4.2.2.1.1 Structure based on typical bid drawings

- main structure 1239 T
- secondary structure 20 T
- shop drawings material supply for secondary structure

4.2.1.1.2 Equipment

No weight specified initially only listing

- 3 suction drums
- 2 water separators
- 3 coolers
- 3 compressors
- 3 turbines
- 1 expansion tank
- 1 purge tank
- 2 fuel gas packages
- 1 fuel gas heater

- 4 ventilation packages
- 1 crane

4.2.2.1.3 Piping

Itemised material take off and drawings included in contract gave following weights:

-	total	521 T
-	prefabrication	421 T

In addition contract included 100 T supports not specified either as pipe standard supports or supporting structure.

Detail studies spool drawings and isos below 2" to be performed by contractor.

4.2.2.1.4 Electricity.

Itemised material take off included in contract, conducted SBV to estimate the work load in electricity at about

19 300 hours.

4.2.2.1.5 Instrumentations

Itemised material take off and process and instrument diagram and layout drawings, conducted SBV to estimate the work load in instrumentaion at about 31 600 hours.

4.2.2.1.6 Heating and ventilation.

Itemised take off and layout drawings.

4.2.2.1.7 Insulation.

Itemised take off.

4.2.2.1.8 Architecture - Doors take off.

4.2.2.1.9 Painting.

Take off based on ratio of square meters per ton of steel.

4.2.2.1.10 Load out.

Typical barge drawing with skids.

4.2.2.2. Final scope.

4.2.2.2.1 Structures

Weight before load out

	Mod. 30, 31, 33	Mod. 32
Main structure	918 T	500 T
Secondary structure	27 T	69 T
Wall structure	18 T	20 T

Differences with contractual take off:

Main structure	200 T
Secondary structure	27 T
Wall structure	83 T

Quantities differences due to items not known or underestimated at contract award, like structural pipe supports, cladding desing improvement, reinforcement for lifting.

Modifications subsequent to construction start September 1978

- Evolution of padeye from bent plate to integrated welded design 30, 31, 33 (January 1980)
- Padeye 32 defined (Mid 1979)
- Deck drain position definition (January 1979)
- Pipe load carriers defined and necessary deck reinforcement "holds" removed (january 1979)
- Electrical/Instrument rack supports and defined penetrations (September 1979)

- Panel supports (March 1979)
- Plate girder stiffener design error (December 1978)
- Stainless cladding anticorrosion trap modification (early 1979)

The in shop prefabrication of the deck section at KVAERNER BRUG, Egersund finished in January 1980 excluded all of the modifications above which were done outside on erected primed structure in the winter 1980.

4.2.2.2.2 Piping.

- Weight at end 644 T, not including pipe supports, increase over contract 120 T as follows:

pipe above 2"	427 T
below 2"	1,5 T
valves etc. above 2"	123,4 T
hook up spools	92,1 T

In addition, standard pipe supports (excl. rack) 20,9 T
pipe racks, weights included in structural

- Weight differences due to
  - high pressure vent, low pressure vent, fire water excluded in contract take off.
  - several modifications like:

  - HP gas valve bypass flow sheet error (valves inverted) and break flanges added.
  - HP full load test branches, instrument branches altered and spectacle blind added.
  - Spring supports recalibrated and support details reinforced.
  - entire HP and LP relief system defined.
  - HP relief 2nd circuit (March 1980)
  - FG (fuel gas)
    * change to stainless for turbine gas Dec. 1979
    * 2nd metering circuit February 1980
    * routing errors, flowsheet changes.

- Entire FW firewater system defined.
- Drain modifications to increase flow capacity and ensure gas seal (January 1980 - April 1980)
- Hydraulic fluid circuit definition (May 1979 - January 1980) and addition of break flanges.
- Halon system definition (January 1980) and revision (March 1980)
- Compressor vent alteration, seal oil pipework change.

Of the prefabrication possible of 431 T only 327 T was possible at Ambes by Ponticelli due late and inadequte flow of materials. The remainder of the prefabrication was done at the same time as the erection at Orkanger and the major modifications were done on primed erected pipework for the same reasons.

80% of the late modifications required a second hydrotest.

4.2.2.2.3 Equipment

The equipment list did not change significantly. Certain items increased the scope without any consequences (vent stack, hydraulic panels, etc.)

The crane installation access necessitated the cutting off of module 32 cantilever as the separation of the modules at that time prevent hydrotest and painting completion.

The compressor installation was not a single straight lift of a complete assembled, piped and wired package as had been foreseen in the contract. The compressor pipework had to be modified and partially remade and the electrical and instrument installation done entirely after installation.

The lift of the skid (minus pipework) and afterwards the barrel into place was done through a hole made in the module upper deck module 33, 31. Module 30 had no roof and no hole was needed.

The sandblasting continuosly taking place and the repair of compressor pipework required several flushing operations. The influence of sand metal filings or slag on the shaft seals affected the test of the seal oil system.

Examples of misfit between equipment and structure occured on the following items:

- compressor skid - holes in wrong place, drawing errors. Initially no drain in compressor sump.
- fuel gas skid/module deck water corrosion trap.
- hoists interference with pipework and structure, power supply incorrect. Monorail size adjustment needed.
- suction drum branch connection tailored to suit in timely manner.
- control room ducting interface with cable routing, light: false ceiling needed detail study.
- crane adaptor platform supports different from designed platform.
- crane boom needed inversion of ends to fit crane.
- instrument or electrical connections discrepancies were encountered on turbo compressor, fuel gas skid, hoists, ventilation.

The equipment erection is estimated as the initial forecast. The interfaces between the equipment shown on vendor drawings and the modules was insufficiently defined and unchecked at inspection up to the equipment was delivered on site.

4.2.2.2.4 Electricity

Quantity changes

- Cables quantities multiplied by 3.

Modifications since start of construction.

- Single line diagram changed
- Segregation of cables introduced
- Interconnection and shutdown requirements.

- Intermodule junction boxes introduced
- Specifications and requirements evolved, i.e.: glands, earthing of calbes, continuous.
- Interface with equipment specified after equipment arrival.

Consequently, the routing and penetrations of cables were not possible to define until August 1979, and in the case of the substation the already installed routing was removed and replaced.

4.2.2.2.5 Instrumentation

It had been intended in February 1978 that the construction should include the supply of the control room panels and interconnections, this option was dropped during the negotiations of the contract.

Quantitiy changes

- cable
- polytube
- penetrations

Modifications after construction start:

- Definition of instrument mounting standard
- Control room field connections
- Control room interconnections
- Public address layout and circuit
- Fire and gas detector positioning
- Tray sizing revision
- ESDV definition

The changes delayed and compressed the work which had to be done parallel with pipe hydrotesting, painting etc.

4.2.2.2.6 Ventilation

No important changes in quantity.

4.2.2.2.7 Painting

No significant change.

4.2.2.2.8 Insulation

Scope defined (December 1979) from isometrics and lines.

4.2.2.2.9 Architecture

Quantity changes:

- All A60 and thermal insulation
- Some doors
- Soundproof panels and false floor substation.
- False walls, ceiling, floor control room.

4.2.2.3 <u>Changes in the work</u>

The original contract signed between EAN and SBV was for a lump sum of 43 560 KNOK for the construction and load-out of the modules. The contract included up to 50% extra work to be done within the original period because it was known from the beginning that the contract did not include the whole scope due to the status of the engineering design.

The contract was based on take off in most disciplines, and additional work was to be done in accordance with the unit rates, agreed lump sums or hourly rates.

The contract fixed a procedure of transmitting work to contractor or a job order, with a time limit of 14 days for the contractor to dispute the compensation or consequences of the increase of the job order. This last issue, which was deemed to protect company against further claims, was in fact the cause of a systematic claim procedure initiated by contractor. It was natual that the contractor aimed at maximising his gain from the deviation from the contract.

The technical description of the scope was also found to be imprecise due to the evolution in the desing and the differences in interpretation of what was extra or was not.

The scope of management and detail studies included in lump sum was underestimated by SBV and due to the construction proceeding on incomplete information, the management had to be strenthened and this addition was another item for diagreement.

The delay in details affected the day to day sequence of work and the productivity suffered with overheads and yard costs accordingly.

Many efforts by EAN to guide the discussions onto the technical basis for agreements and realistic pricing were thwarte by a quantity surveyor of SBV who had a vested interest in maintaining the conflict.

It was also clear very early that SBV could not afford to pay for any of their mistakes and were aiming at covering their costs plus. In effect, SBV had little influence on their production, productivitywise and costwise, and had no knowledge or ability to know their costs or predict them until a long time after. Therefore, SBV were unable to accept a settlement unless the lump sums offered were comfortable.

The solution chosen was to reimburse the first part of the contract (until November 1st 1979) at what was presumably cost plus, and to set up a reimbursable contract for the period after.

The reimbursable con-ract enabled EAN to establish a more constructive relationship with WBV and jointly take decisions influence works to the interest of the construction.

4.2.3 Statistics.

All values given in this chapter may differ from the final cost report, because the present statistics might not include some escalations or settlements issued at the time of this report.

4.2.3.1 Overall cost

The overall cost may be split in 3 parts (NOK x 1000)

-	Works costs	NOK 158.085
-	Materials/services	" 8.790
-	Currency cost	" 1.741
	TOTAL:	NOK 168.616

1. The works costs includes all costs related to the module construction, and compares direcly to the contract lump sum of NOK 43,56 mill.

2. Materials/services normally supplied by EAN, procured through SBV

3. Currency cost. The contract defined a fixed split between NOK/FF at a fixed exchange rate of 1 FF = 1.1 NOK.

   With an actual currecny rate of 1 FF = 1.2 NOK, the real cost of the lump sum portion was not 43,56 mill. NOK, but

NOK portion:	34.848 mill. NOK
FF portion:	8.712 mill. NOK
	43.560 mill. NOK
(1.2-1.1) x FF portion	871 "
Real lump sum value:	44.431 mill. NOK

The final split between the disciplines has been calculated using the contractual price per hour for the different crafts, adjusting for the different working hours and conditions, and the prefabrication at lower price.

4.2.3.2 S-curves

The progress is based on calculation by points, defined as 1 point equal 435,6 KR.

The points herebelow describe the physical works performed on the yard or subcontractors shops.

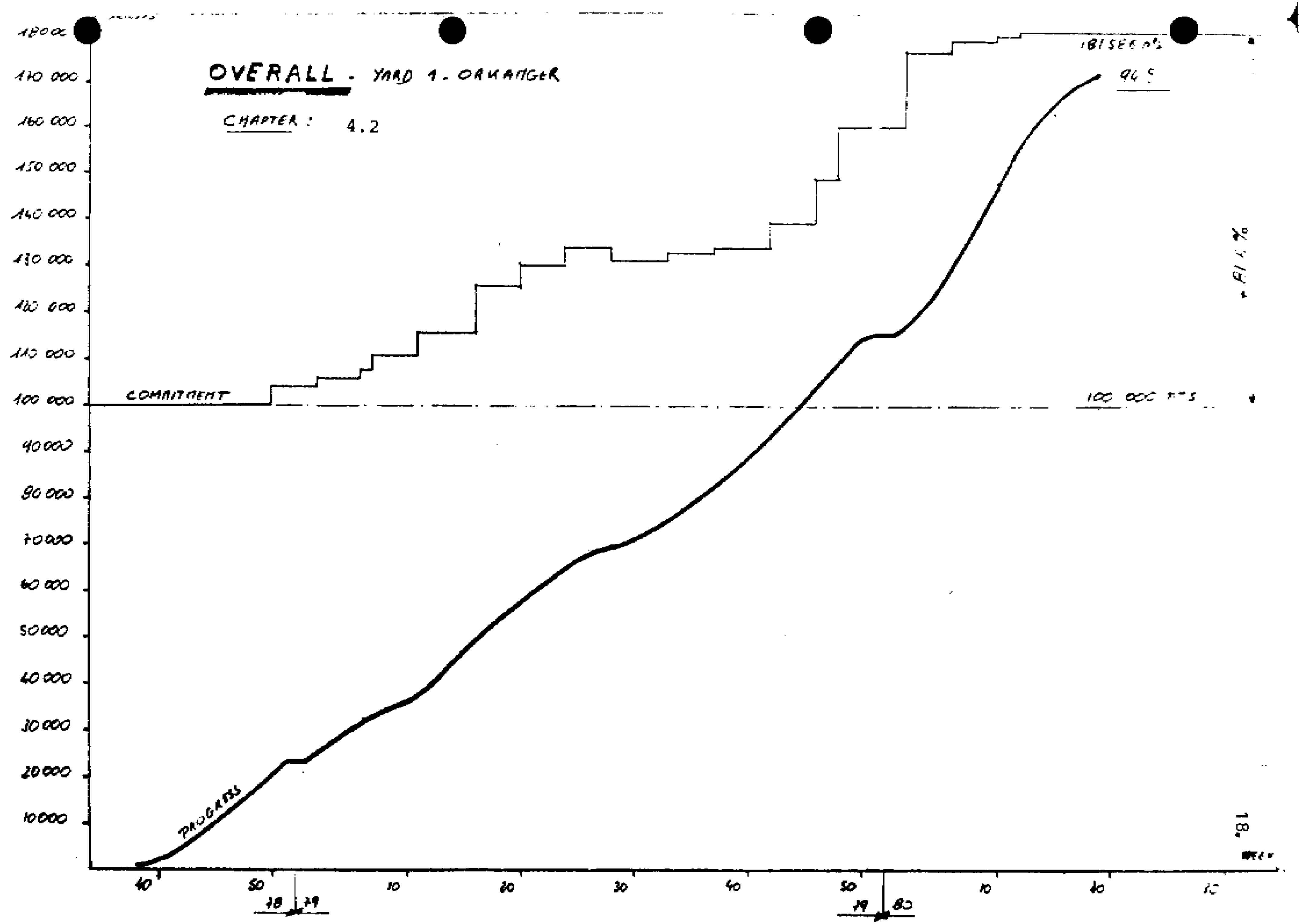
Disciplines	Original lump sum (pts)	Committed on wk 12 1980 (pts)	Increase
Structure	34660	61182	+ 75,5%
Piping	25938	49362	+ 90 %
Equipment	5059	7236	+ 43 %
Electricity	8101	16749	+107 %
Instrumentation	9118	20390	+124 %
Insulation	1111	861	- 23 %
Painting	7038	14336	+104 %
Architecture	1754	5987	+241 %
HVAC	3046	3018	- 1 %
Load out (1)	4175	2465	- 41 %
TOTAL (2)	100000	181586	+ 81,6%

(1) Without barge seafastening
(2) Without yard facilities (storemen, crane, scaffolders, NDT, carpenters).

We can note that the increase (additional quantities and modifications) is far above the limit indicated in the original contract:

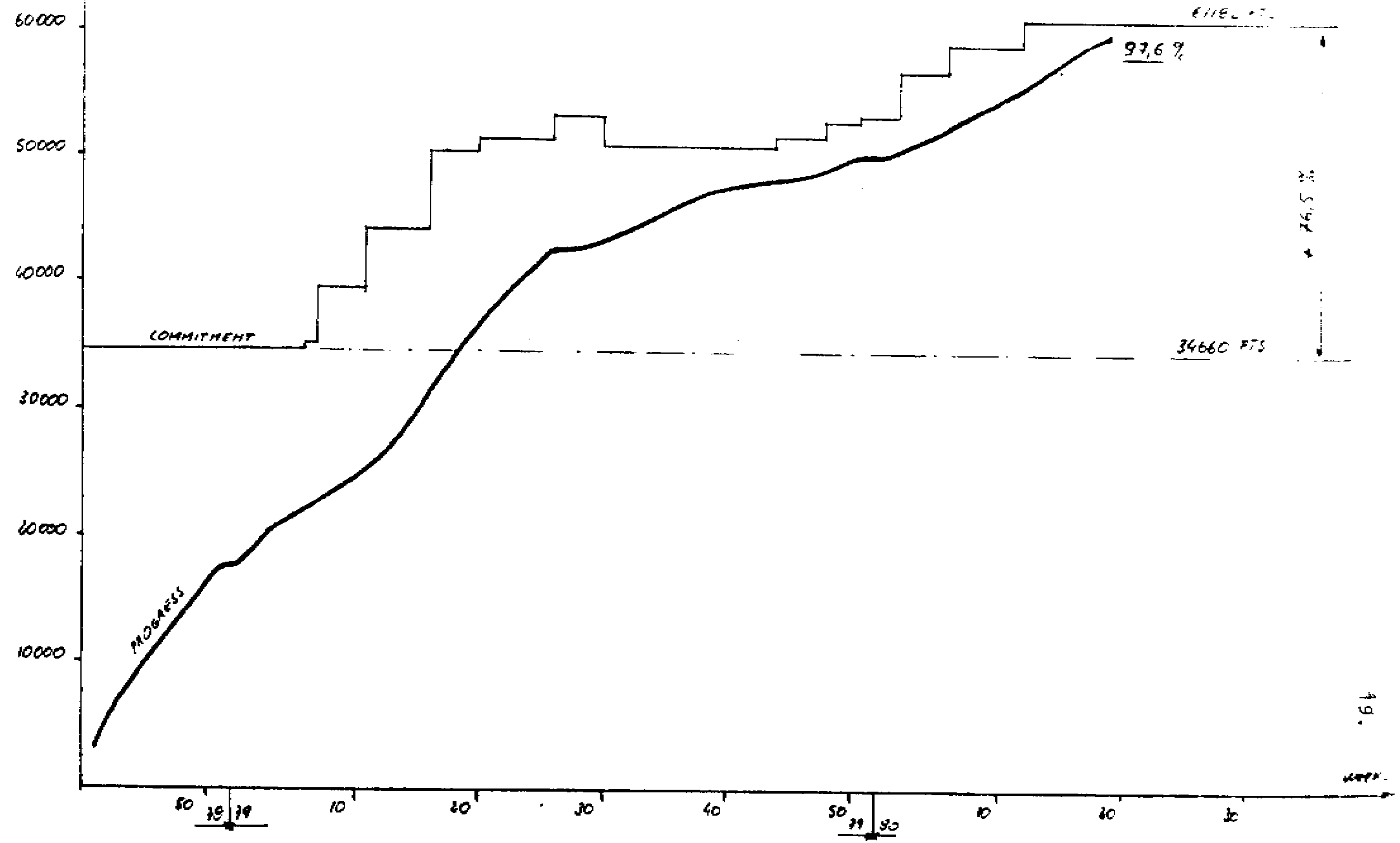
+ 81,6 % against + 50 %

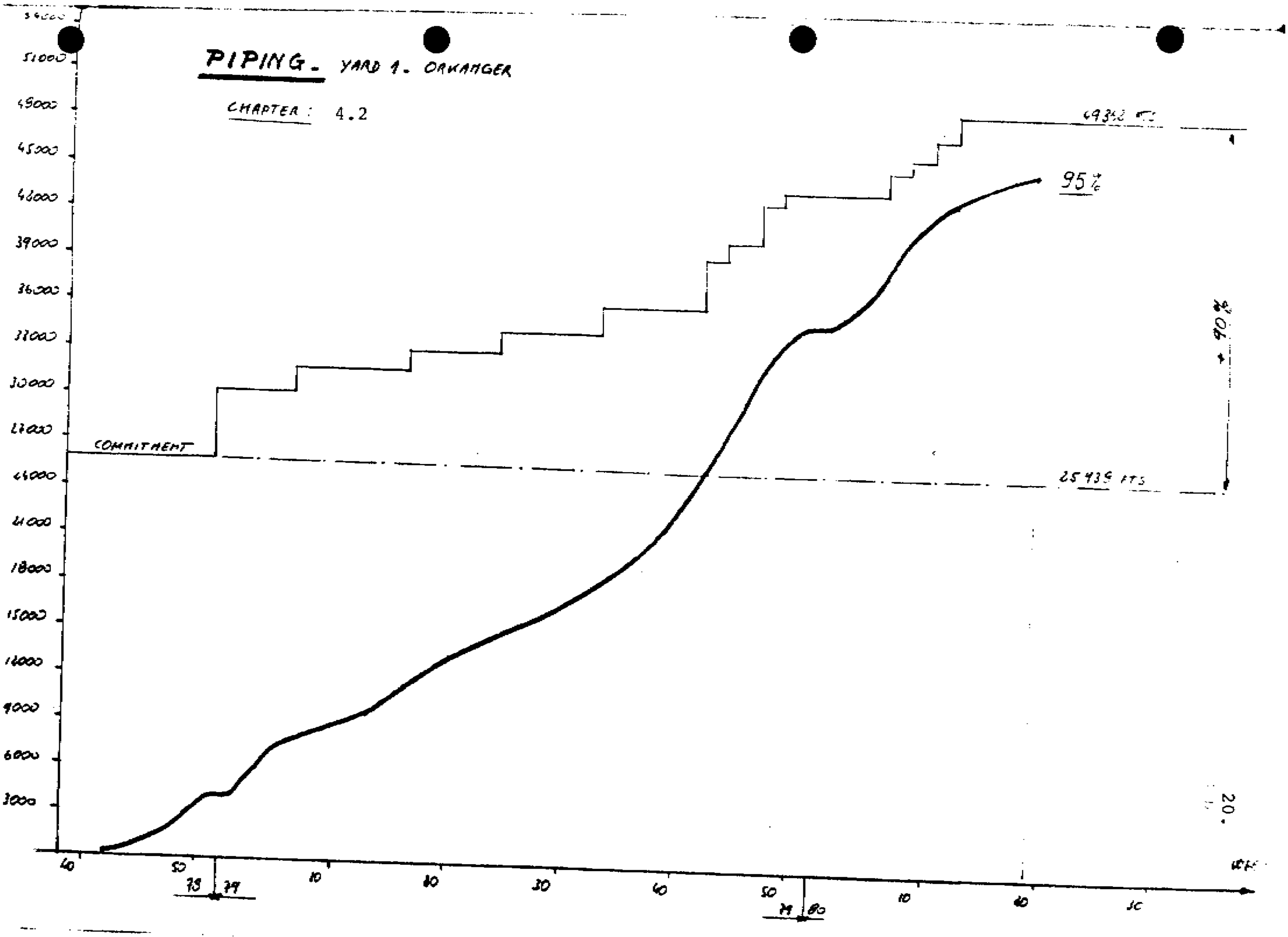
S-curves for overall, and disciplines activities are given overleaf.


OVERALL - YARD 1. ORKANGER
CHAPTER: 4.2
COMMITMENT
PROGRESS
100 000
180 000
170 000
160 000
150 000
140 000
130 000
120 000
110 000
100 000
90 000
80 000
70 000
60 000
50 000
40 000
30 000
20 000
10 000
40
50
10
20
30
40
50
10
40
78
79
79
80
WEEK

STRUCTURE. YARD 1. OAKANGER

CHAPTER 4.2




PIPING - YARD 1 - ORKANGER
CHAPTER : 4.2
49348 FTS
95 %
90 %
COMMITMENT
25 439 FTS
54000
51000
48000
45000
42000
39000
36000
33000
30000
27000
24000
21000
18000
15000
12000
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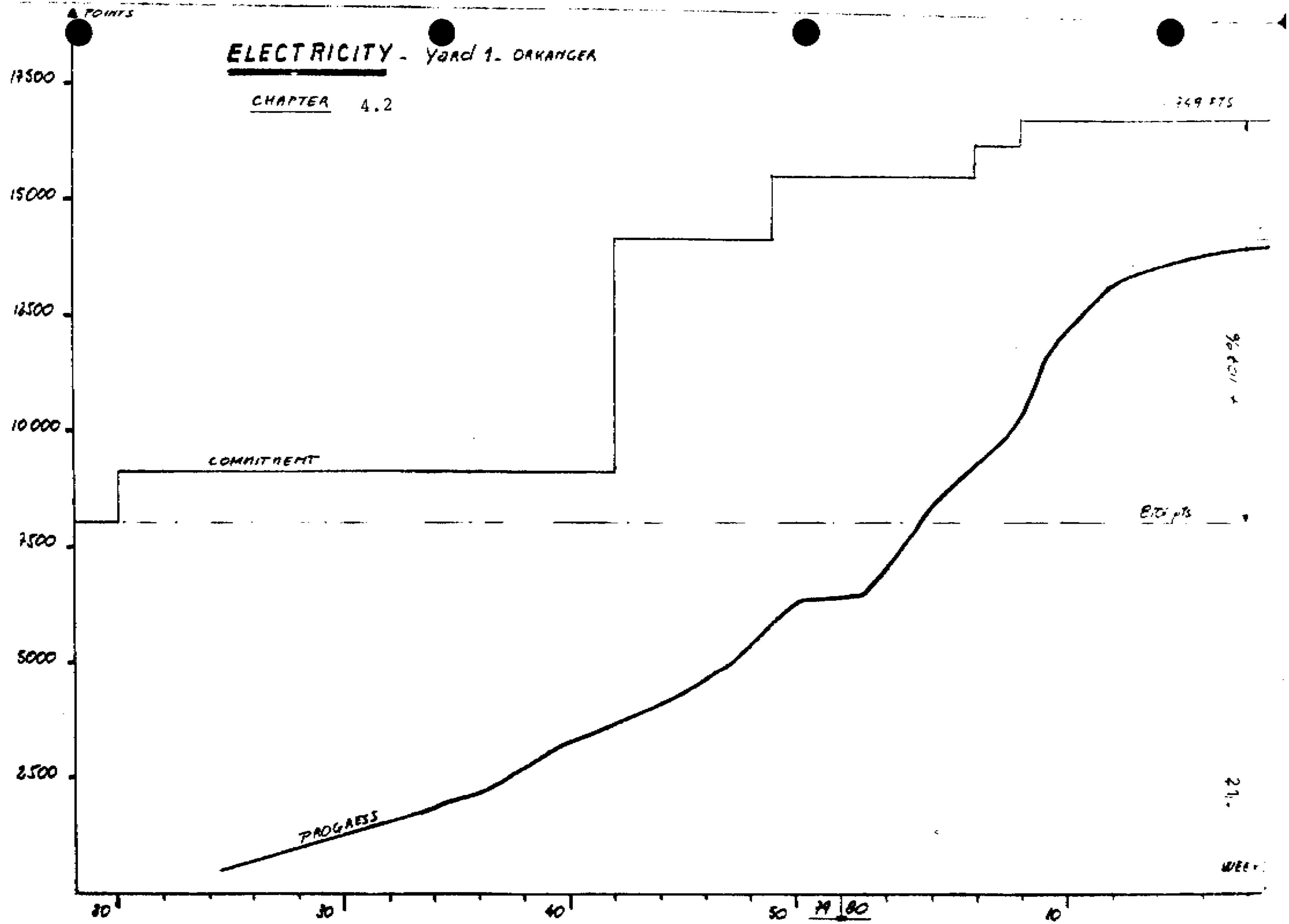
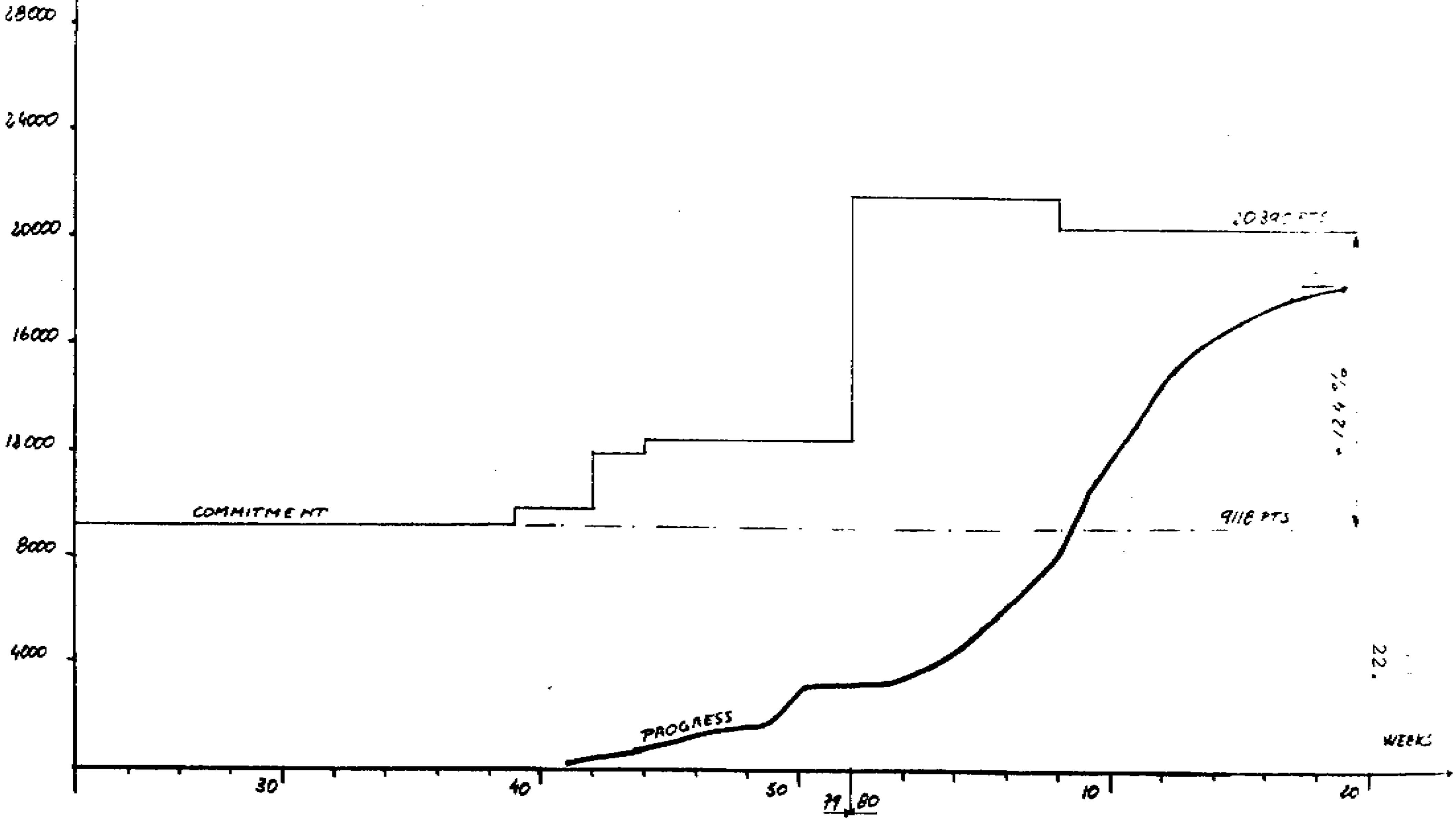
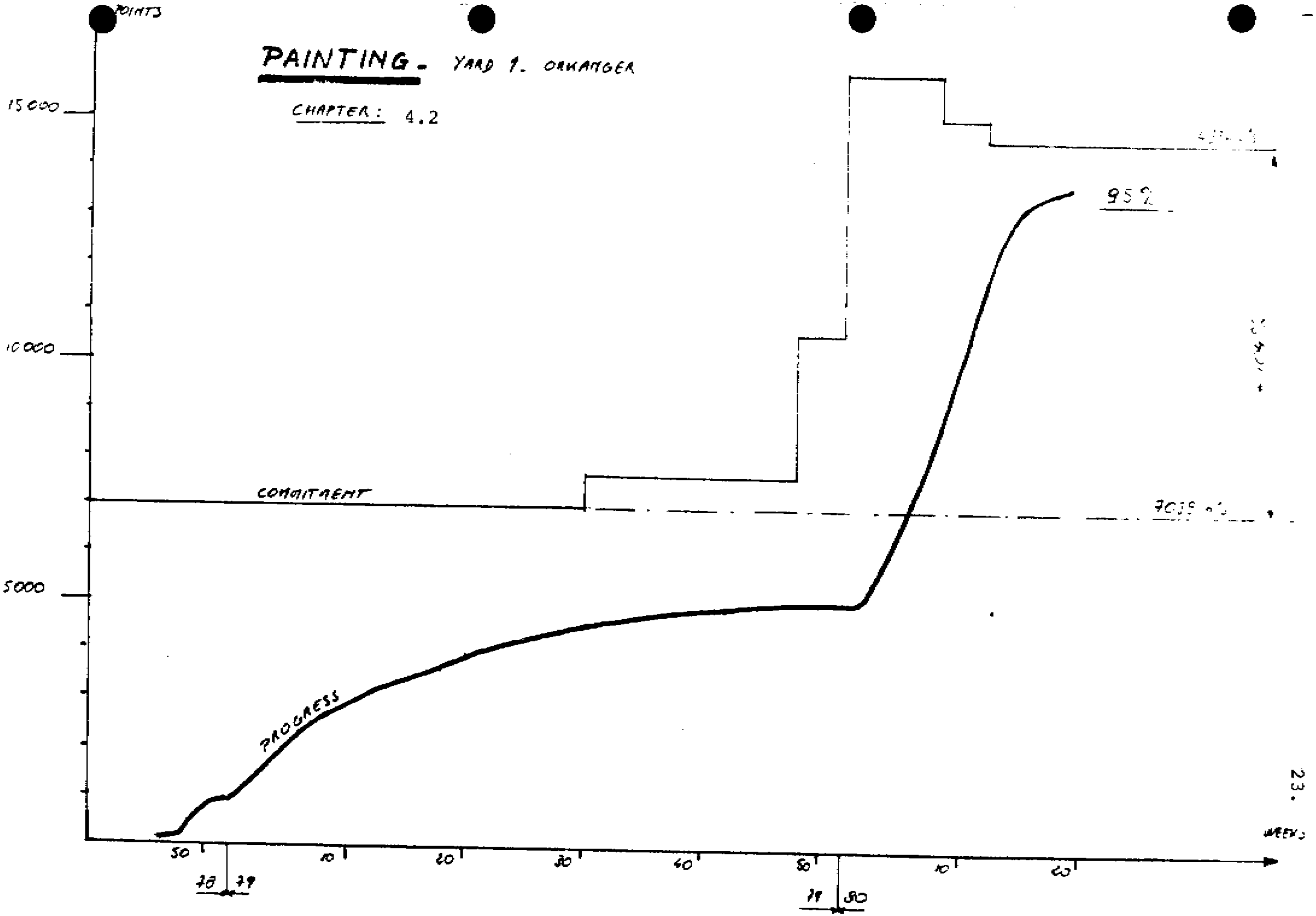
80
10
20
30
YRS


POINTS
ELECTRICITY - Yard 1. ORKANGER
CHAPTER 4.2
17500
15000
12500
10 000
7500
5000
2500
COMMITMENT
PROGRESS
WEEK
20
30
40
50
79
80
10

INSTAUMENTATION - YARD 1. ORKANGER

CHAPTER : 4.2




POINTS
PAINTING - YARD 1. ORKANGER
CHAPTER: 4.2
15 000
10 000
5000
COMMITMENT
PROGRESS
95%
WEEKS
50
10
20
30
40
50
10
20
78
79
79
80

4.2.3.3 Cost per discipline

	(NOK x 1000)	
Structure	36.952	(144 kr/hr)
Equipment	2.473	(206 kr/hr)
Piping	42.842	(210 kr/hr)
Electricity	7.286	(168 kr/hr)
Instrumentation	9.704	(168 kr/hr)
Insulation	388	(155 kr/hr)
HVAC	966	(155 kr/hr)
Painting	9.985	(141 kr/hr)
Architecture	1.723	(144 kr/hr)
Load out	916	(144 kr/hr)
Sub-total productive	113.235	
Yard services	15.747	(123 kr/hr)
Staff	29.103	(210 kr/hr)
Works total	158.085	

Comparison contract lump sum/final price: (including services and management)

Discipline	Contract lump sum	Final value	Deviation %
Structure	15.098	54.164	+ 259 %
Equipment	2.204	3.255	+ 48 %
Piping	11.878	56.472	+ 375 %
Electrical	3.526	10.332	+ 193 %
Instrumentation	3.293	13.467	+ 297 %
Insulation	484	551	+ 14 %
HVAC	1.327	1.372	+ 3 %
Painting	3.066	14.598	+ 376 %
Architecture	764	2.503	+ 228 %
Load out/Onshore assist.	1.820	1.330	- 27 %
TOTAL:	43.560	158.044	+ 263 %

4.2.3.4 Manhours

This study is based on the hours estimate done on 21.03.80 (6 weeks before load out). These hours represent the scope of works which should have been done on the yard, some of these hours were transferred offshore due to camp facilities limitation from February 1980 til the load out. These hours are:

Structure	3000	hours	transferred	offshore
Piping	3000	"	"	"
Equipments	1000	"	"	"
Electricity	3000	"	"	"
Instrumentation	8000	"	"	"
Insulation	500	"	"	"
HVAC	0			
Painting	5000	"	"	"
Architecture	1000	"	"	"
TOTAL	24500	hours		

Manhours: initial offer and real performed hours per discipline: (productive hours)

	Initial offer (hours)	Hours spent	Increase or Decrease o/o
Structure	100653	264223	+ 162 %
Equipments	14691	12006	- 18 %
Piping	75324	209237	+ 178 %
Electricity	23525	47371	+ 101 %
Instrumentation	26479	57759	+ 118 %
Insulation	3226	2500	- 23 %
HVAC	8846	6232	- 30 %
Painting	20438	70816	+ 246 %
Architecture	5094	11967	+ 135 %
Load out	12124	6359	- 47 %
TOTAL	290400	688470	+ 137 %

Overall hours spent

Productive hours	688470
SBV management	138584
SBV yard facilities	128022
TOTAL	955076
EAN supervision on yard:	65500

4.2.3.5 Production ratio.

4.2.3.5.1 Introduction.General ratio kr/ton or kr/kg

First interesting ratio is the number of hours per ton. Based on weight of modules end of March and total forecasted hours.

	Weight (T)	Productive hours SBV + yard facilities	Management hours SBV	EAN supervision yard hours
Mod 30	847			
Mod 31	861	B = 816492	C = 138584	D = 65500
Mod 32	1126			
Mod 33	774			
TOTAL	A = 3608			

* Productive ratio B/A = 226,3 hr/ton
* Contractor management ratio C/A = 38,4 "
* Overall contractor ratio (B+C)/A = 264,7 "
* EAN supervision ratio C/A = 18,1 "

- And the same ratio in kr/kg

* Productive ratio (average 1 hr = 161 kr) 36,43kr/k
* Contractor managment ratio (average 1 hr = 210 kr) 8,06 "
* Overall contractor ratio (aver. 1 hr=166kr) 43,94 "
* EAN supervision ratio (average 1 hr = 352 kr) 6,37 "

4.2.3.5.2 Disciplines Weight

This ratio gives the value of the discipline regarding the total cost of productive hours.

Discipline	Weight	Initial weight (contract)
Structure	38,4 %	34,7 %
Equipment	1,7 %	5,1 %
Piping	30,4 %	25,9 %
Electricity	6,9 %	8,1 %
Instrumentation	8,4 %	9,1 %
Insulation	0,4 %	1 %
Painting	10,3 %	7 %
Architecture	1,7 %	1,7 %
HVAC	0,9 %	3 %
Load out	0,9 %	4 %
TOTAL	100	100

Rem.: Load out does not include barge seafastening.

4.2.3.5.3 Ratio productive/non productive hours

SBV management	14,6 %	
SBV productive manpower (1)	72,5 %	(1) Up to forement
SBV yard facilities (2)	12,6 %	(2) Storement, carpente[illegible] Scaffolders, NDT, Crane drivers.
TOTAL SBV hours	100 %	

4.2.3.5.4 Ratio EAN supervision/Total SBV hours

$$\frac{\text{EAN supervision}}{\text{TOTAL SBV hours}} = \frac{65500}{955076} = 6,9\ \%$$

4.2.3.5.5 Efficiency

Discipline	Efficiency
Structure	0,7
Piping	0,7
Equipment	1
Electricity	0,9
Instrumentation	0,9
Insulation	1
Painting	0,6
Architecture	0,9
HVAC	1
Load out	1
TOTAL	0,76

4.2.3.5.6 Structure

- Prefabrication + installation 176 hours/ton
- 1490 tons

4.2.3.5.7 Equipments

- Total weight of equipments installed: 930 tons
- Hours spent included : unloading
  transport
  lifting
  fixation
- Ratio: 14 hours/ton

4.2.3.5.8 Piping

Total weight	piping and valves	719 tons
	supports	22 tons
		741 tons

Ratio: 282 hours/ton

But: Total hours spent: 209200 consist of quantities increase and modification (about 60.000 hours)

A better ratio is calculated with hours less modifications (209200 - 60.000)

Ratio: 201 hours/ton

4.2.3.5.9 Ventilation

Duck + equipment 25 tons
Ratio: 251 hours/ton

4.2.3.5.10 Architecture

-	Insulation on wall (2000 m^2)	4 hours/m^2
-	False floor installation	2 "
-	False ceiling installation	2 "

4.2.3.5.11 Painting

- Sandblasting and primer were performed just after prefabrication in the paint shop.

34000 m^2	33000 hours	1 hour/m^2

- After erection sweepblasting - primer - final coats

34000 m^2	37000 hours	1,1 hour/m^2

- Overall ratio: 2,2 hour/m^2

4.2.3.5.12 Electricity

a) Overall 174 tons 270 hours/ton
b) Steelworks 4000 m cable trays, ladders + 1830 supports
168 junction boxes
99 multicable transit
22 substation panels
437 lighting fitting supports
72 socket outlet supports
33 local contral station supports

22000 hours (46 % of electricity)

c) Cable pulling 52.400 m / 12.300 hours
Average cable length: 16,4 m
Ratio: 4,3m/h.

d) Cable connection 4 hours/cable connected

e) Earthing cable 3240 m
calweld 1667 m 2300 hours

f) Small power installation 1800 hours

g) Public address 13200 m cable
602 connections
74 loadspeakers 3800 hr
36 flushing lights
91 junction boxes

4.2.3.5.13 Instrumentation

a) Overall weight 86 tons 5800 hours
674 hours/ton

b) " loops 119 hour loop (485 loops)

c) Steelworks: 9 km tray + telex
260 instrument supports
16 bulkhead supports
44 MCT
83 junction boxes
169 hours (29 % of instrumentation.

d) Cable pulling 46,6 km
3,5 m/hour
Average length in control room 21 m
" " in modules 50 m
" " from 32 til pancake 80/100 m

e) Multitube/single pulling 11300 m(5100 m single
1,4 m/hour

f) Connection in control room 3/4 hour per connection

4.2.3.5.14 Load out

- Seafastening internal module: 25 tons
  ratio 0,015 ton seafastening per ton of piping and equipment
- 200 hour/ton of internal seafastening
- Seafastening on barge 110 tons
  ratio 0,03 ton of seafastning per ton of module
  67 hour/ton of seafastening.

4.2.4 Planning, progress and general comments.

4.2.4.1 Method and Organisation: Planning.

- SBV have organized themselves in September 1978 accordin to the information they knew from the contract and assuming that all the material and drawings should be delivered two weeks before the starting date they have shown in the planning attached to the contract. This has failed due to:

  - Late delivery of nearly all the material and drawings
  - Additional work (82%) far above the highest figure forecasted in the contract (50%)
  - Lack of management and skilled manpower to deal with an extraordinary situation.

- From September 1978 til November 1979 manual bar chart planning issued by SBV have mainly been used as a tool for claim discussion and nearly no measures have been taken to recover delays which were obvious on almost all the activities, except one time on structure (march - May 1979) when EAN decided to pay on timesheets addition- al structural manpower. This was due to the fact that a that time SBV found no insurance to recover the cost of the measures which should have been taken. More they have preferred to demobilize piping crew (June 1979) arguing it was not possible to transfer them to structure works regarding internal Spie Batignolles-Vigor contract (which was shown not true later).

- Internally within SBV one planning engineer with one assistant were supposed to collect discipline plannings prepared by discipline leaders and to organize overall planning and yard construction together with the general foreman. This was theoretical and coordination between disciplines has not been good.

- From November 1979 til May 1980 contract has been changed (from lump sum to time sheets), and it has been possible for EAN to have SBV working according to EAN choices (priorities on the works - mobilization of man-power). This was a real improvement; on the other hand this has had great effect on the cost. (But regarding the result of the first period and additional millions of kroners we have been obliged to pay, we can say that the cost result is almost the same). On some weeks SBV have invoiced more than 15000 hours (without manage-ment!). During that period most of the plannings have been prepared by EAN and moreless taken in account by SBV. This period has given EAN the opportunity to mea-sure some of the reasons of the highest SBV cost:

  - impossibility from SBV to complete a task within the forecasted time (except for piping - but can we say it was a success when all the estimates were made taking in account the low efficiency on the yard).

  - very bad preparation of the works: It happened very often that tasks were delayed before they started just because preparation on site had not been studie enough.

  - impossibility from SBV to complete a task when started which means more hours to come back on it, to have quality department involved and to complete it.

We have to note that, if we got more flexibility from SBV during this second period, on the other hand SBV have autho-ritatively reduced the EAN beds in the camp which had great effects on structure, elelctricity and intstrumentation.

4.2.4.2 Progress: Method and Organization

- Due to the evolution of the contract progress measurement methods have changed from time to time.

  At the beginning we used as a reference the contractual splitting of the lump sum (43.650.000 kr = 100 000 pts) with possibilities to increase these points when additional job orders are issued. But it appeared very quickly that this splitting was far from the reality, and in addition additional quantities and a lot of modifications have deeply modified the original scope of work. But each time we have modified the progress procedures, we have tried to keep the possibility to compare the new progress to the previous one.

4.2.4.2.1 Structure

<u>1st step:</u>
Progress per area on main items and construction activities
Example: Main deck 33 prefab: cut. tackweld. weld. control
erection: weld. control.

Theoretically it is a good idea, but it is difficult to connect to a defined scope of work.

<u>2nd step:</u>
Progress per drawing number and construction activities.
Example: dwg 30.1.1. prefab. erection. walkway install. grating fixation. punch list

We kept 10 % of the value of the drawing for punch list works and quality control. The use of a computer to handle this method has saved a lot of time.

3rd step:
Punch list (at the time of change of contract)
Each work was estimated in term of manhours and actual progress was calculated every week and compared with the initial estimate.

This was a good tool to measure the efficiency and to allocate manpower. But SBV have been reluctant to use it at the beginning.

4.2.4.2.2 Piping

1st step:
Progress per spools and isometrics with construction activities.

- Prefabrication 33 LV 67001.1 - spool A cutting - assembly - weld - control.

  Each spool was given a value (unit of effort): combination of weight and size.

- Erection: Same method as prefabrication. Value of valves included in downstream spool. Little material below 2" considered as one theoretical spool.

- Prefabrication and erection were followed by computer which saved a lot of calculation and permitted to get progress per area.

- Pipe supports: prefabrication weight follow up
  erection " " "

- Distance pieces: as pipe supports

- Flushing, test, rebuilt: progress per system. Each system was given the UOE value of the spools it was made of.

- Cumulative was made with following estimate:

prefabrication	35%
erection	32%
pipe supports	18%
flushing, test rebuilt	15%

2nd step:
As per structure 3rd step.

4.2.4.2.3 Painting

1st step:
Square meter of the week compared to contractual total surface.

2nd step:
New estimate of hours per areas taking in account repairs before final coat and real surface to paint.
Hours splitted per area according to:

Sandblasting + zinc	65%
Repairs	25%
Final coat	10%

4.2.4.2.4 Electricity, instrumentation, heat tracing.

Take off per items and progress measured per items installed Cumulative made by estimate of hours/kroners to install one unit of one specific item.

Example:

	to install	installed	%	unit	total value	% value
Pulling cable 12 x 1,50	1200 m	240	20%	0,3 hrs	360	72
	A	B	C	D	A.D.	B.C.

Plus one separate follow up for modification.

4.2.4.2.5 Architecture

Take off per item and progress per items installed. Cumulative through hours/kroners estimate to install one specific item.

4.2.4.2.6 Insulation

Take off and hours estimate per area. Cumulative through hours/kroners.

4.2.4.2.7 HVAC

Hours estimate and progress per area and cumulative through hours/kroners.

4.2.4.2.8 Equipment

Listing of equipments to install and physical status per equipments. Cumulative through hours/kroners.

- One of the biggest difficulties of the progress status has been the constant re   of the total estimate of the scope of work because:

  * the original contract did not give a right status of the works to perform.
  * some systems were not included in the original lump sum.
  * the modifications we have had to include in the progress follow up have been at the end about 55% of the original lump sum!
    (82-55 = 27% for quantities increase)

- SBV have not been able (or not interested) to handle the progress measurement and nearly all the procedures have been given by EAN. Even with that their tendency has been a constant overestimation which was destroying all the uses one could find in such a tool for management purpose. EAN have been obliged to reestimate and recalculate nearly all the weekly progress

- From March 1979 till December 1979 we got a terminal on the yard (General Electric - Mark III). Because of lack of time we only developped some programs: Structure and Prefabrication - Erection in Piping: This was quite useful because lack of SBV results and enabled EAN/SBV to control the progress.
- It was forecasted to develop instrument and electrical programs, but the troubles got in those disciplines did not give any chance to use an informatic procedure.
- We can regret not to have got this tool at the beginning with programs already developped. If material had been followed with computer help, we would have saved a lot of effort and concentrate our energies on a better contr of SBV.

4.2.4.3 Planning: Initial and Historical.

See planning attached.

4.2.4.2.1 Structure.

- Decks were prefabricated in Egersund (Kvaerner Brug) They were delivered not entirely completed in Orkanger with about 2 months delay due to late delivery of steel plates, "hold" on drawings and loss of efficiency from Kvaerner Brug. Some decks have even been subcontracted to Maritime Service by Kvaerner Brug. Erection on yard (started on 1.12.79 with 2 months delay) has been underevaluated by SBV and the manpower has never been sufficent to keep any of the SBV planning (together with a very low efficiency).
  EAN have paid additional structural people (15500 hours) in March-April - May 1979 to allow start of piping erection. In addition numerous job orders were issued for modifications (stiffening substation deck, sliding doors jacking points, staircases, cladding fixation), or to allow equipment installtion (fixation on decks, cutting of upper decks for compressor entrance, cutting of 32 cantilever for crane lifting).

Thousands of hours were also spent for repairs of welding or sealing of area before painting. The result is that the modules were loaded out with about 3000 structural hours not performed.

4.2.4.3.2 Equipment

If compressors were finally only one month delayed regarding the contractual delivery date (March 1979), on the other hand we can note that this date was unrealistic regarding the other trades: no entrace in modules when compressors arrived (cutting of upper deck). No piping erection could start before compressor installation. In addition compressor skids arrived not completed and with one year work on the yard, were not yet completed!

Other equipments:

- 5 airroil drums: 3,5 montsh delay (received March/April
- 3 natural coolers: no delay (received end February 1979)
- fuel gas packages: 6 months delay (received 21.9.79)
- crane: received February 1980 (contractual load out 1.11.
- excnangers fuel gas: never received on yard
- hydraulic package: 13 months delayed (received Sept. 197
- transformers delayed from Sept. 1979 til Jan. 1980
- Electrical switchboards. delayed fom Nov.-Dec. 1979 till mid 1979
- Instrument panel/cabinets: last received in April 1980.

4.2.4.3.3 Piping.

Prefabrication and erection have been done out of any logic due to the absence of drawing: last isometric drawings received end of June 1979 instead of December 1978 (at that time we had 66% of isometrics) and material up to end 1979.

Prefabrication which should have been completed in Ambes on January 1979 has been transferred to Orkanger with 65% progress on 20.06.79.

In addition wrong material/elbows flare/LV, modifications (FG metering system 2 times, flare, open drain, production

requirements... clashes with structure have deeply affected the progress. As an average each isometric has been revised 3 times after we got the approval for construction drawing. Last test was performed end of March 1980.
Efficiency has been almost satisfactorily in such an environment.

4.2.4.3.5 Electricity.

Start of electricity was late due to the structure and piping But perhaps this has been a chance regarding the status of the studies and the delivery of cable trays and cables. Modules leave Orkanger with about 5 km cables and 5 panels not installed.

It has been very difficult to get SBV working on EAN priorities. On the other hand status of studies was too bad for direct use of drawings for construction (cable trays of substation dismantled and rerouted in December 1979). First cable has been pulled end of December 1979 between substation and control room (15 months after the beginning of the construction).

4.2.4.3.5 Instrumentation.

Due to status of drawings and material EAN have asked SBV on 07.09.79 to stop everything (few cable trays installed) up to furhter notice (december 1979).

Even with that construction has been hampered (mounting standards change to autoclave, control room connections not well studied, bad desing of cable trays on upper deck compression modules, cable and multitubes pulling during winter).

On April 1980, 30% of cables were connected in control room and nearly nothing done in module 33 and upper deck 32. About 8000 hours were transferred offshore.

4.2.4.3.6 Insulation.

Piping insulation and equipment insulation have to be done after painting completed. Start was mid February 1980 and everything should be completed when load out.

4.2.4.3.7 Painting.

As a rule steel has been sandblasted and primed just after prefabrication and before erection. This, plus the numerous modifications on structure, piping, electrical and instrument steelworks have obliged to sweepblast again all the areas before final coating.

We started this second phase on January 1980 up to the end. It has been quite long due to welding repairs discovered at the time of sweepblasting, access to areas (other trades have to be out) and weather. (during some weeks it has been nearly impossible to get the right curing temperature even with additonal protection and heaters).

Staircases, walkways and ladders were galvanized when prefabricated. They should have been painted but this will be done offshore. All the areas were painted once but a lot of repairs have to be done offshore.

4.2.4.3.8 Architecture

Wall insulation was subcontracted to Teknisk Isolering. The design of the insulation plus the efficiency of this company gave a bad result (in time and quality).
False floor and false ceiling were not completed due to seafastening (only supports installed).
Frame doors have been installed but a lot of hours have been spent due to wrong opening.

4.2.4.3.9 HVAC.

No major problem for the installation of the equipments. For the instrumentation itself, drawings will be done after installation.

4.2.4.3.10 Trace heating.

This was a direct contract EAN/VCON and progress was hampered by piping completion, painting schedule but also bad dossier from VCON.

4.2.4.3.11 The load out.

The main surprise during preparation was the discovery that SBV rollers and jacks did not fit with the forecasted jacking points. About 5000 hours were lost in March/April 1980 and this is the main reason for the non-completion of the stru- ture (s-e 6.3.1.).

The planning was done using the load out procedure as a basis The load out procedure included the ballasting of the barge and the movement of the modules up to the quay and onto the barge.

Planning and job function were defined by the procedure. The time scale and job sequence was fixed by the convenience of tides and the sequence of the critical activities - jack module on bogies, move moduel, load out, jack down module seafasten module enough to prevent risk when moving barge.

4.2.4.3.12 Run tests.

They were forecasted in July/August 1979 and then cancelled.

NOTES

FORECAST SBV 4.4.78 - - - -
REAL SCHEDULE ——— R

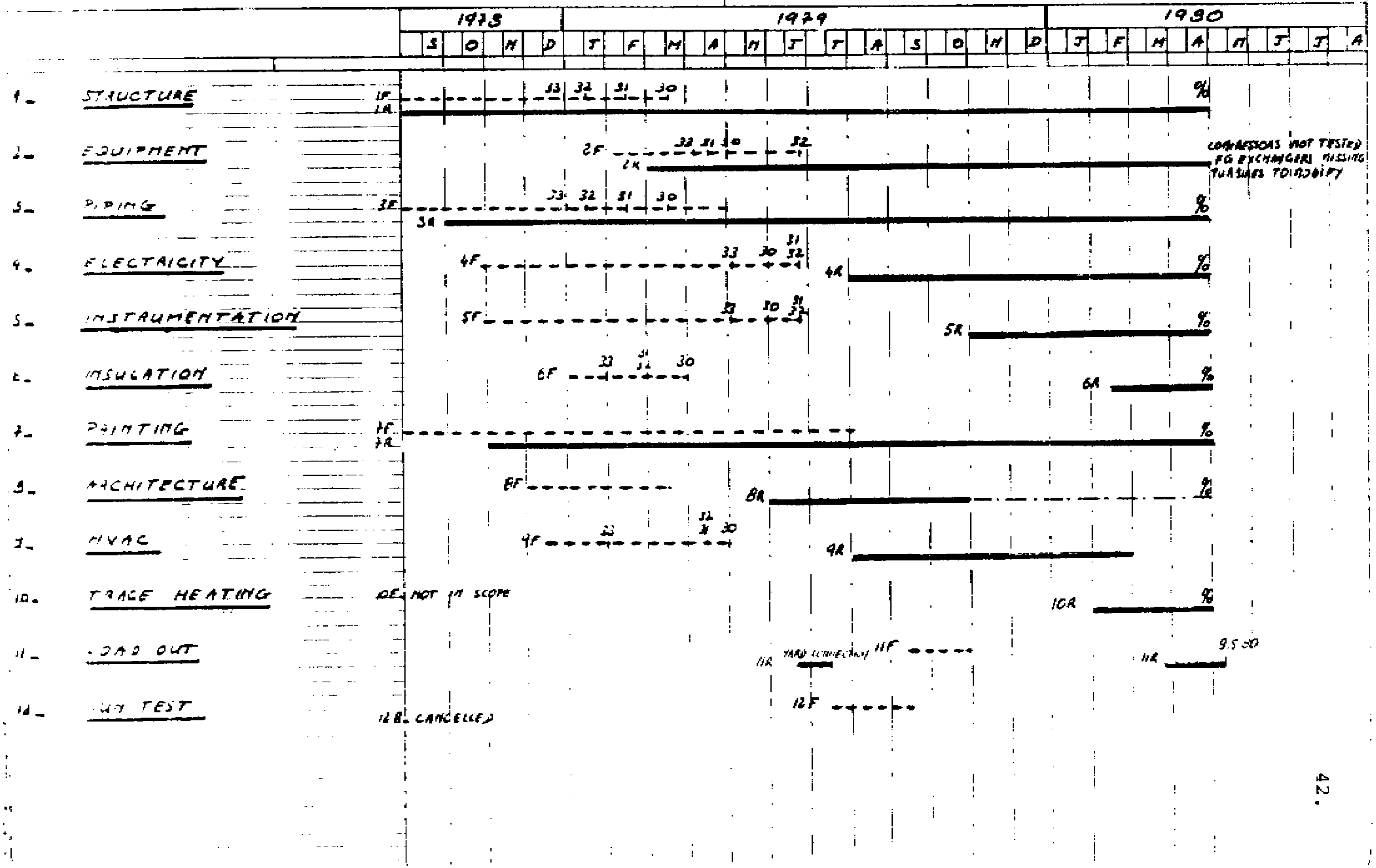
elf aquitaine norge a/s

by: YAI

PROGRAMME

4.2.4

OVERALL PLANNING



42.

4.3 Report on Yard 2 - Kristiansand (Einar Øgrey A/S)

4.3.1 Organization

4.3.1.1 Contractor and Subcontractor.

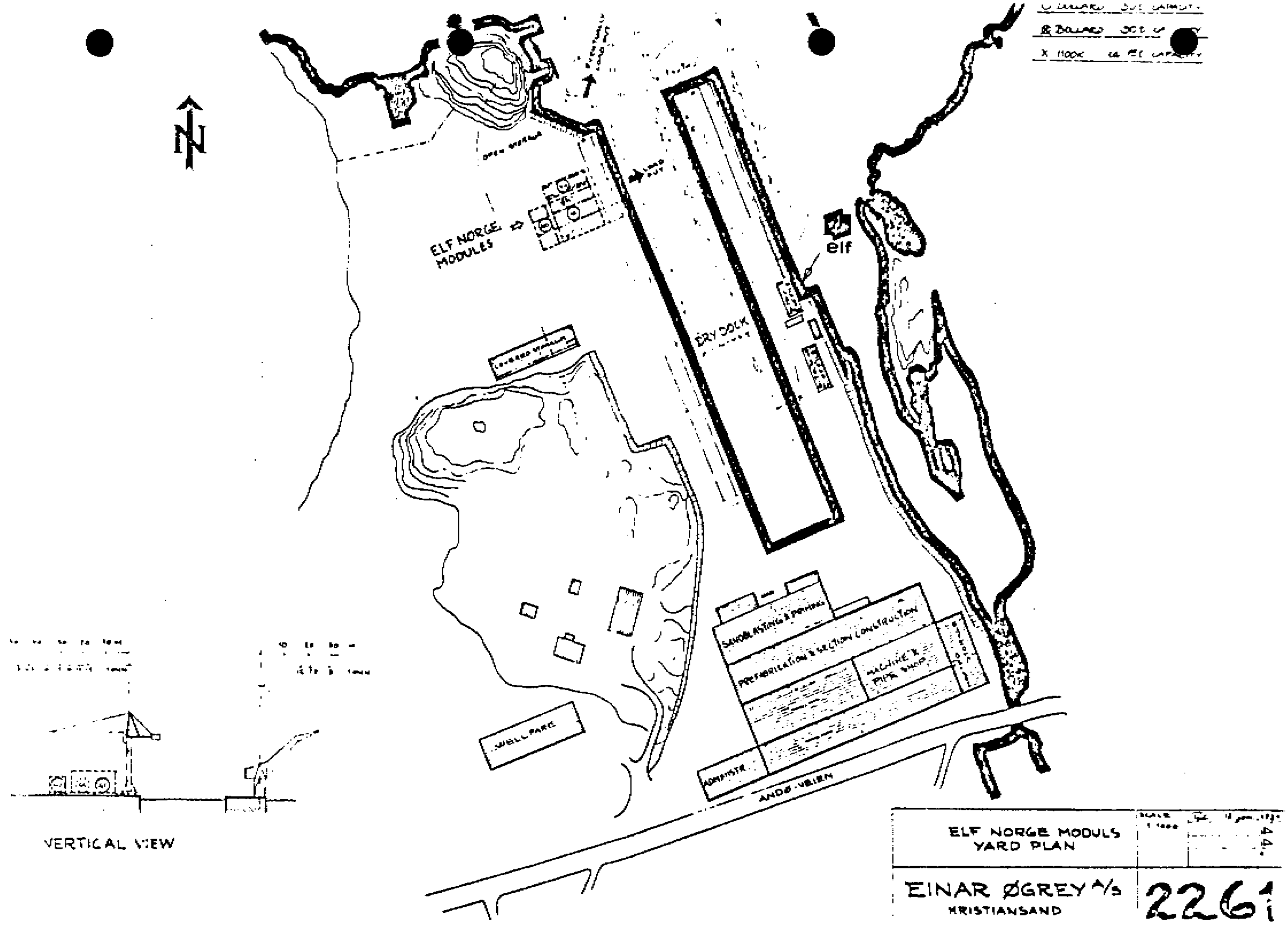
Oil Industry Services A/S, (OIS), holder of the two contracts covering all the TCP2 Compression pancakes, distributed the construction over two Norwegian yards - Einar Øgrey A/S (EØ) at Vågsbygd/Kristiansand S. handling the pancakes P. 40, P. 41. P. 44 (and the L.P. vent stack by the end), and Nymo A/S handling the utilities in Grimstad.

EØ carried out the structural, piping and mechanical works and subcontracted the rest as follows:

- Vestfold Elektriske Diesel (V.E.D.) becoming Vestfold Contracting A/S (V.con) for electrical and instrument.
- Viftefabrikk A/S for ventilation
- Teknisk Isolering A/S for insulation
- Det norske Veritas (DnV) for welding quality control with the assistance of SØTS Grimstad school laboratory
- Normaritim A/S in Horten for load-out preliminary studies which were finalized by Montalev.

To be also noted that:

- the main EØ's suppliers were Leif Hübert in connection with Aspelin Stormbull for structural and piping missing items, and Tolartois all stainless steel -cable ladders, trays and telex.
- Mammoet Stoff (EAN) did the pancakes weighting
- Bloms Oppmåling A/S carried out the overall dimensional surveys.
- Heerema transported the pancakes.


ELF NORGE MODULES
DRY DOCK
elf
SANDBLASTING & PAINTING
PREFABRICATION & SECTION CONSTRUCTION
MACHINE & PIPE SHOP
WELLFARE
ADMINISTR.
ANDØ-VEIEN
VERTICAL VIEW
ELF NORGE MODULS
YARD PLAN
EINAR ØGREY A/S
KRISTIANSAND
2261

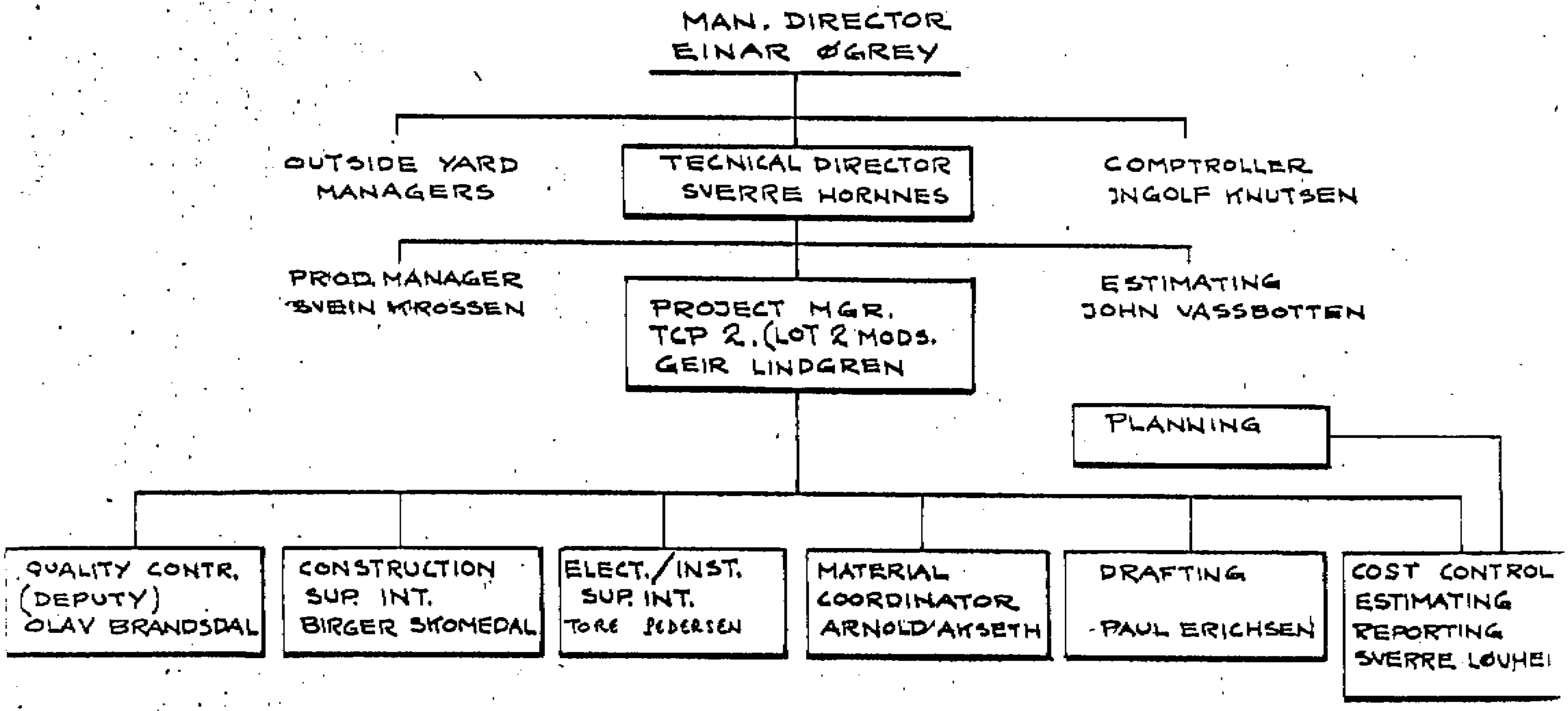
4.3.1.2 Contractor organization chart see two sheets overleaf showing

- Einar Øgrey Organization

- V.con Organization

4.3.1.3 EAN Organization see organization charg overleaf.

YARD ORGANIZATION / PROJECT MANAGEMENT LOT 2 MODULES

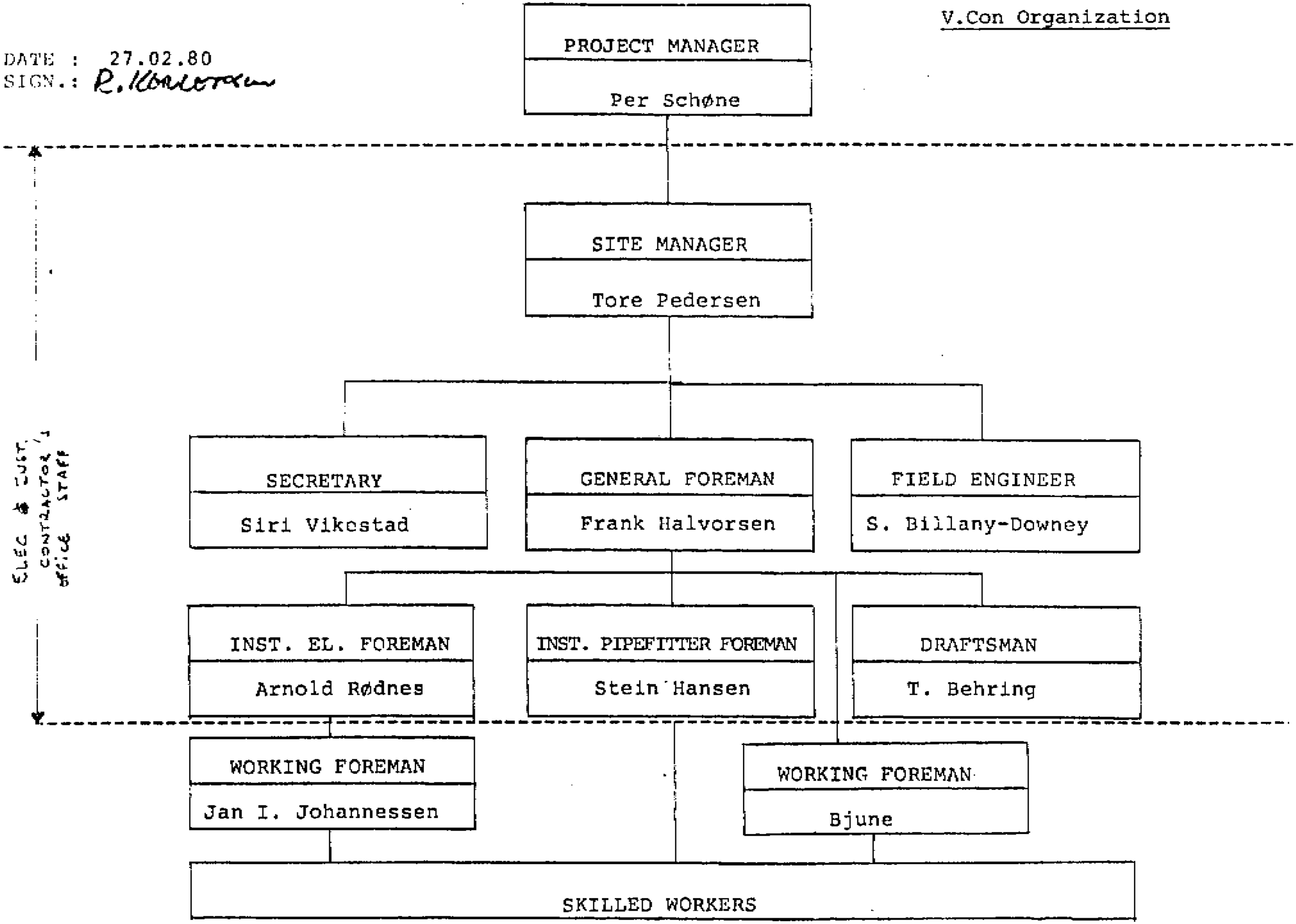


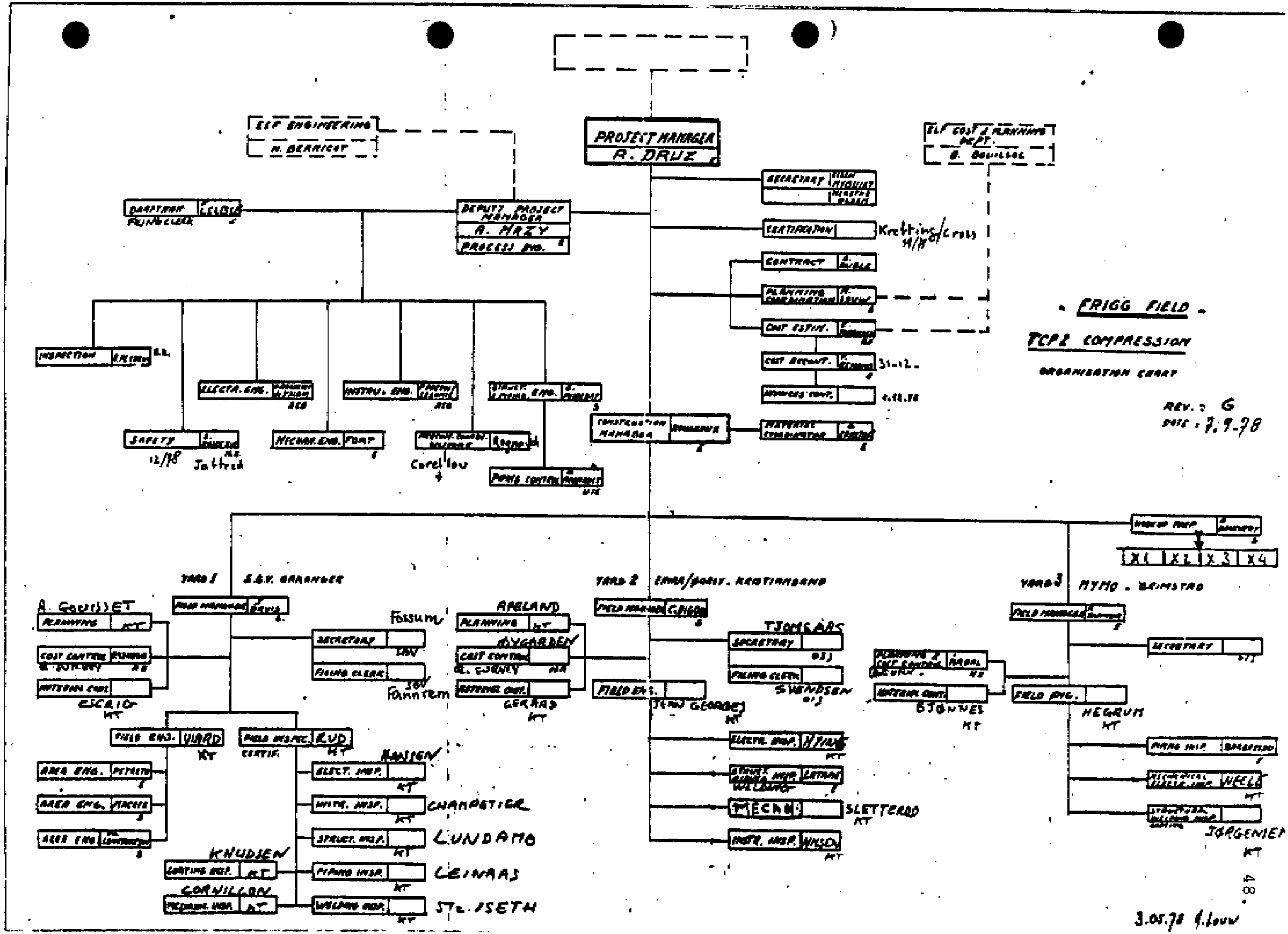
4001

PRO T: FRIGG COMPRESSION TCP2 LC KI

V.Con Organization

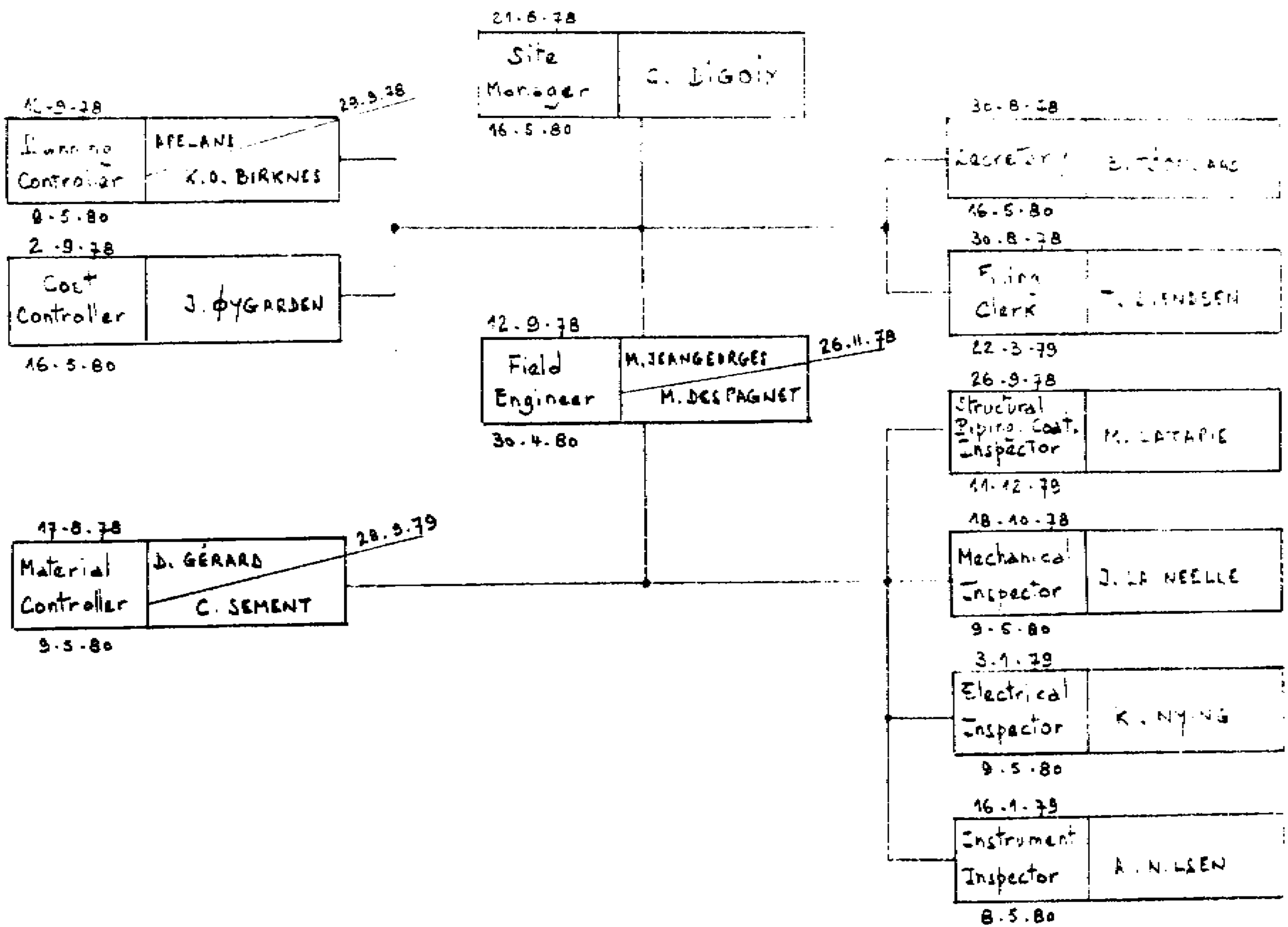
DATE : 27.02.80
SIGN.: [illegible]





ELF ENGINEERING
PROJECT MANAGER
R. DRUZ
DEPUTY PROJECT MANAGER
A. MAZY
PROCESS ENG.
SECRETARY
CERTIFICATION
CONTRACT
PLANNING COORDINATION
COST ESTIM.
COST ACCOUNT.
MATERIAL COORDINATOR
CONSTRUCTION MANAGER
INSPECTION
SAFETY
ELECTR. ENG.
MECHAN. ENG.
INSTRU. ENG.
PAPERS CONTROL
- FRIGG FIELD -
TCP2 COMPRESSION
ORGANIZATION CHART
REV.: G
DATE: 7.9.78
YARD 1
YARD 2
YARD 3
FIELD MANAGER
PLANNING
COST CONTROL
MATERIAL CONT.
FIELD ENG.
FIELD INSPEC.
AREA ENG.
COATING INSP.
ELECT. INSP.
INSTR. INSP.
STRUCT. INSP.
PIPING INSP.
WELDING INSP.
FILING CLERK
HOOKUP PREP.
X1
X2
X3
X4
A. GOUISSET
APELAND
TJOMSAAS
SWENDSEN
BJONNES
HEGRUM
KNUDSEN
CORNILLON
HANSEN
CHAMPETIER
LUNDAMO
LEINAAS
SLETTERØD
JØRGENSEN
3.05.78
48

~ E.A.N KRISTIANSAND ORGANIZATION ~



4.3.2 Scope of work

4.3.2.1 Structural

COMPANY SUPPLY	CONTRACTOR SUPPLY
. Design drawings which indicate all main dimensions, welding and connection details, penetration drawings, standard drawings of stairs, ladders, railings, walkways, etc.	. Preparation of all shop drawings including drawings of auxiliary lifting structures of stairs, ladders, railings, walkways.
. Fabrication Specifications. Painting Specifications. Steel Specifications.	. Drawings of required Temporary Works (e.g. drawings for temporary bracing to ensure the rigidity of the structure in the fabrication phase).
. Architectural Specification.	. All detail drawings and calculations necessary for the fabrication of auxiliary structures for lifting and/or skidding operations during load out.
. Architectural outline and detail drawings.	
. Detailed drawings of deck supports on barge, sea fastening bracing, and deck reinforcement (if any) Rigging Platform, Spreader Beam Bar.	

		PAGE	REV	DATE
[illegible]	[illegible]W.11.R.[illegible] rev.1			
[illegible] - C[illegible]	Structural Take-Off		1	12/3-78

Pancake 40, 41 & 44

Item		Pancake 40	Pancake 41	Pancake 44	
1	Main Structure	45t	160t	43t	
2	Wall Structure	-	25t	9t	
3	Special Structure	-	-	-	
	Summary (10% cont. incl)	50t	204t	57t	

4	Surface of Cladding	$111 m^2$	-	$159 m^2$	
5	Surface of Grating	$122 m^2$			
6	Stairs	22m			
7	Ladders	20m			
8	Handrails	136m			
9	Structures for fixation of item 5 - 8:	5t			

Notes:

Wall Structure include stringers for Cladding.
No contingency taken into account for item 4 - 8.

4.3.2.2 Piping

The piping take-offs attached to the contract under itemized forms were summing up as follows:

P. 41	1800 kg
P. 41	5900 kg
P. 44	850 kg
TOTAL	8550 kg

PIPING

COMPANY SUPPLY	CONTRACTOR SUPPLY
1. EQUIPMENT	
Plot plans showing the itemized equipment location.	
Hazardous classification area drawing.	
Vendor's drawings final issue.	
Piping standard specification.	
2. PIPES	
Piping arrangement drawing showing: - The pipes routing all sizes indicating location and elevation. AS GENERAL INFORMATION: - Electrical and instrument main cable tray, - Junction boxes, - Ventilation equipment, - Fire fighting equipment, - Main structural beams, - Walkways, ladders, access platform.	If needed detailed shop drawings in accordance with Company installation drawings and the piping standards.

P I P I N G

COMPANY SUPPLY	CONTRACTOR SUPPLY
2. PIPES (con't)	
Sections and details will be produced when pipe routing can not be clearly shown on the drawings.	
Piping standards.	
3. ISOMETRICS	Details drawings or isometrics for line below 2" and complementary pipe support.
Isometric drawings of lines equal and above 2" (Sufficient information for routing of lines below 2" will be shown on arrangement drawings).	If needed spool drawings for line equal and above 2".
Each isometric will have its own bill of material.	
Total bill of material per module.	
4. SUPPORTS	
Pipe support standards.	All support details drawings specified by Company standards.
Special pipe support drawings for line equal and above 2"	
Spring support design and calculation note of considered lines.	Pipe supports drawings for lines below 2".

P I P I N G

COMPANY SUPPLY	CONTRACTOR SUPPLY
5.	SEA FASTENING AND LIFTING Shop drawings of support on barge and sea fastening. Temporary pipe support design take-off and purchasing.
6. FABRICATION General design installation and fabrication requirements.	

4.3.2.3 Electrical - Scope of work

For details see statistics (Chapter 3.3)

4.3.2.4 Instrument - Scope of work.

CONTRACTS: [illegible] EVANGER 5424W [illegible]	[illegible]	PAGE	REV	DATE
[illegible]P.1500.08 - ANNEX 1	PRELIMINARY [illegible] TAKE OFF LIST	14	1	[illegible]

CELLAR DECK

PANCAKES 40, 41 44

3	Pressure Safety Valves
19	Solenoid Valves
20	Diaphragm Operated Control Valves
19	Pressure Gauges
19	Pneumatic Pressure Switches
2	Electric Pressure Switches
8	Pneumatic Pressure Transmitters
4	Pneumatic Pre-sure Controllers
8	Flow Indicators
3	Pneumatic Flow Transmitter
16	Temperature Indicators with Well
3	Thermowells
6	Resistance Elements with Well
3	Level Gauges
2	Level Indicators
4	Pneumatic Level Switches
3	Electric Level Switches
18	On/off Switches
3	Selector Switches
25	Gas Detectors
14	Smoke Detectors
28	Heat Detectors
8	Fire Alarm Boxes
3	Pneumatic Control Boxes

CONTRACT: 480 KVAERNER 5434W TECHNIP	FRIGG COMPRESSION TCP 2	PAGE	REV	DATE
[illegible].1500.08 - ANNEX 1	PRELIMINARY INSTRUMENT TAKE-OFF LIST	15	1	[illegible]

CELLAR DECK

PANCAKES 40, 41 & 44

2	Junction Boxes (Pneumatic) . 7 terminals	
6	" " " . 12 "	
8	" " Electrical . 12 terminals	
4	" " " for fire and gas detection	
	2 x 24 terminals	
1000 m	Pneumatic tubing single tubing 1/4" OD SS.	
400 m	" " " " . 3/8" OD SS.	
200 m	" multicore tubing 7 x 5/6 SS to the control room (2 multi length 100m)	
600 m	" multictore tubing 12 x 5/6 SS to the control room (6 multi length 100 m)	
800 m	Electric cable 12 x 1,5 to the control room (8 cables length 100 m)	
500 m	Electric cable 2 x 1,5	
800 m	Electric cable for gas detection system 12p x 1,5 to the control room (8 cables length 100 m)	
900 m	Electric cable for gas detection system 1p x 1,5	
60 m	Cable Tray	400 mm.
300 m	" "	600 mm.
500 m	" "	50 mm.

I N S T R U M E N T

This part should be read in conjunction with the R.P. 5424W.[illegible], Rev.3.

COMPANY SUPPLY	CONTRACTOR SUPPLY
1. CABLE TRAYS	
- Routing of cable trays wider than 250 mm routing, which includes only size and elevations (by module and general).	- Detailed drawings for cable trays in accordance with Company outline drawings. (The drawings are to be sent to Company before commencement of installation). Routing of cable tray between 100 mm and 250 mm.
- Company to specify the make, type and size: - of main trays wider than 250 mm between Control Room and Junction Boxes.	- Take-off and purchasing of all cable trays.
- of secondary trays wider than 250 mm between Junction Box and Instrument.	- Design and Drawings of All supports.
- Company to specify size and location of openings for multi-cable transit.	- Detailed fixing drawings.

I N S T R U M E N T

COMPANY SUPPLY	CONTRACTOR SUPPLY
2. CABLES	
. Cable specification, Vendor sketch.	- Purchasing of some cables.
. Cable list (temperature, alarms, etc.).	
. Main junction box: outline and connection drawings.	- Drawings of instrinsically junction boxes.
. Control Room terminals drawings as given by Vendor.	- Drawings of some small explosion-proof Junction boxes.
. Safety cable list, (ESD, fire, etc.)	
3. TUBES AND MULTI-TUBES	
. Specification of tubes and multi-tubes, Vendor sketch,	. Purchasing of some tubes and multitubes.
. Multi-tubes list, terminal single Control Room drawing.	. Drawings of local pneumatical junction boxes.

I N S T R U M E N T

COMPANY SUPPLY	CONTRACTOR SUPPLY
4. AIR SUPPLY	
. Main header Air Supply routing.	- All studies about piping and tubing for Air Supply lines from instrument to the first valve on main header.
. Air Supply standard mounting.	
5. LOCAL INSTRUMENT MOUNTING	
. Company specify: - type of mounting for each instrument - type of material required - type of instrument by item - location shown on Isometric and plot plan.	- Materials take-off for pipes, connections, supports etc. - Standard support drawings.

I N S T R U M E N T

COMPANY SUPPLY	CONTRACTOR SUPPLY
6. CONTROL ROOM	
. PANEL	
- Front view principle drawings. - Frame principle drawings. - Rear panel equipment principle drawing. - Mimic general diagram. - Control loop diagram. - Electrical supply. distribution diagram. - Instruments, specifications and Vendor drawings.	- All mechanical drawing for manufacturing (the drawings are to be sent to Company before beginning of manufacturing). - Mimic drawing scale 1/1. - Front view sheet metal. - Control Room terminals cubicles drawings. - Installation Specification.
. CUBICLES	
- Standard cubicles arrangement and equipment principle drawings. - Control loop diagram. - Schematic relay diagram. - Instruments, specifications and Vendor drawings.	- Mechanical drawings for manufacturing. - Equipment drawings. - Connections drawings. - Installation Specification.
. MISCELLANEOUS	
- Control Room arrangement. - Packages drawings. - Limit of studies for cubicles and panels are shown on Control Room - Arrangement Drawings. - False floor skid principle drawing.	- Drawing for fabrication and installation of false floor.

I N S T R U M E N T

COMPANY SUPPLY

. MISCELLANEOUS (con't)

- Alarms list.
- Electrical supply distribution diagram.
- Company to specify size and location of openings for multicable transit in classified walls and floors.

. DRAWINGS AND DOCUMENTS FOR ADJUSTMENT AND TESTING

- Control loop diagrams.
- Terminals drawings.
- Vendor drawings.
- Piping Instrumentation Diagrams.
- Telecontrol System.
- Instruction Manuals.

CONTRACTOR SUPPLY

- Take-offs of miscellaneous materials.
- Detailed drawing for installation of all MCT [x].
- Specification of size and location for all MCT not covered by note hereagainst.

- Control loop adjustment and synchronism sheets.

[x]MCT: Trade Mark (Multi-Cable-Transit)

4.3.3 Statistics and changes in the work

4.3.3.1 Structural

1) Basic quantities.
Ref. KE-TP take-off summary.

Structural Categories	P.40	P.41	P. 44	Weight No of hours
1) Main structures Items 1, 2 & 3B	64 tons 6070 hrs	205 25125	57 6821	326 38016
2) Secondary structure Items 4,5,6, 7,8 & 9	5 2132	5 2072	8 3280	18 7484
3) Architectural	1	11	7	19 5000
TOTALS	70	221	72	363 50500

Architectural contents:

	P.40	P.41	P.44	Total
1) Insulated surface	0	534 m^2	293	827 m^2
2) Part of 1) mechanically protected with Plannja panels	0	340	176	516 m^2 i.e. ca. 62% of 1)
3) Personnel doors ca 1m x 2,15m	2m	3m	5m	21,5m^2
4) Maintenance doors 2 leafs ca 2,5m x 2,5m	0	1m	1m	12,5m^2

We can consider that the "architectural surface" may be estimated as the sum of the following surfaces.

a) Surface of the pancakes which could be for the same cost entirely A60 - insulated with mechanical protection

   * Fully treated surface cost (supply & fitting)

     500 NOK/m^2

   * Basic insulation only (supply & fitting) 270 NOK/m^2

$$X = \frac{827 \times 270 + 516\ (500-270)}{500} = 634\ m^2$$

b) Surface of the doors : 34 m^2

   Architectural surface ca. 634 + 34 668 m^2

2) Drafting.

	P.40	P.41	P.44	TOTAL
Shop drawings no.	40 Ʉ	78	49	167
Miscellaneous	6	6	6	18
TOTAL	46	84	55	185

"Miscellaneous" includes:

- Outside erection area preparation
- Contractor preliminary take-offs
- Contractual quantities follow-up.

3) Ratios

Activities	P.40	P.41	P.44	Overall ratios
1) Main structure	95 hrs/ton	123	120	117
2) Secondary Structure	426	414	410	416
3) Architectural		- 75 hrs/m² - 263 hrs/ton		
4) shop drawings	1 Units 0,66 ton	1/0,38	1/0,76	1/0,51
	13,3 drafting manhours/drawing including: - 8,65 hrs first issue - 4,65 hrs various up-dating (ca. 35%)			

LP vent stack:

- Built under a separate lump sum contract of 220000 NOK
- Tubular lattice girder - triangular section
- Weight 12 tons
- Secondary structure - 5 platforms with ladders
- Manhours 5140 ⟶ 428 hrs/ton

4.3.3.2 Painting

1) Basic quantities

Surfaces	P.40	P.41	P.44	
1) Structural	973 m²	4578	1814	7365 m²
2) Fuel tank/P.44 & ventilation plants within the 3 pancakes				100 m²
3) Piping	35	125	22	182 m²
				7647m² 10000hr

2) <u>Ratios</u>

	P.40	P.41	P.44	OVERALL
1) Structural design - contract estimate	$20m^2$/ton			
- actual valves	$14,1 m^2$/ton	21,8	27,9	$21,4 m^2$/ton
2) Overall efficiency	1,3 hrs/m^2			

.4 Piping

PIPING CATEGORIES	WEIGHT TON	DESCRIPTION LENGTH OF AVERAGE DIAMETER	ACTUAL MANHOURS	ERECTION RATIOS HRS/TON
1) Overall piping but Stal Laval's				
a) $\varnothing_{nom} \geqslant 2"$	17,1	* 14,8 tons of cumulated length (without fittings) all diameters. * fittings weight 2,3 tons flanges, valves, bolts, tees, etc.. i.e. 15% of overall weight * Equivalent to - 750 Ø - 720 Ø	6200	360 * Supports & hydrotests included for all lines even for offshore erector - installed closure spools.
b) $\varnothing_{nom} < 2"$	1,2	Equivalent to 270 1"	1675	1400
2) Stal Laval piping	3,1	Equivalent to 150 3"½	2000	650
OVERALL:	21,4		9875	460

Remark: Concerning the Stal Laval piping with thickness being not to different welding is concerning 667 inches of diameter i.e. $\frac{2000 \text{ hours}}{667} = 3$ hours/inch

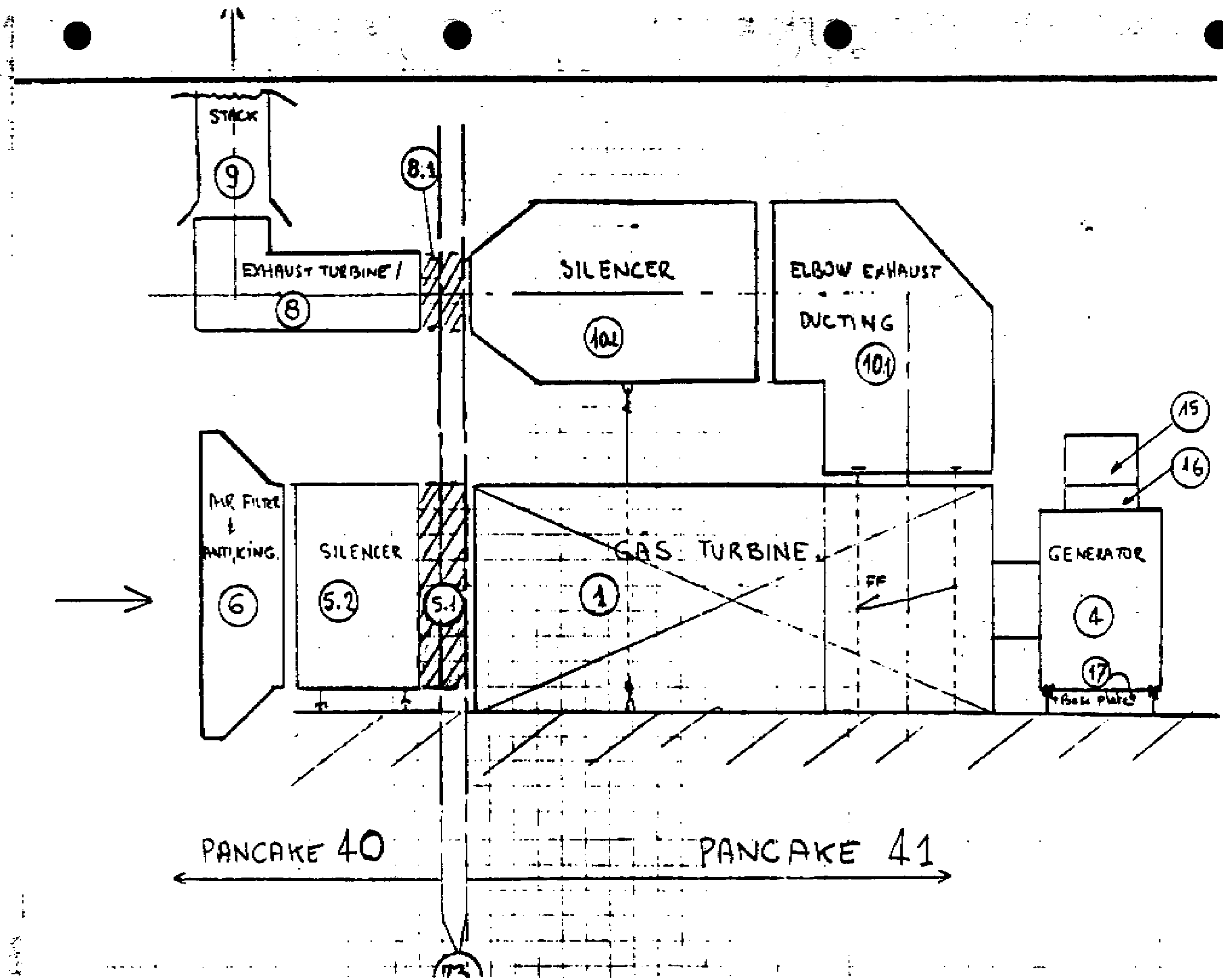
4.3.3.4 Mechanical

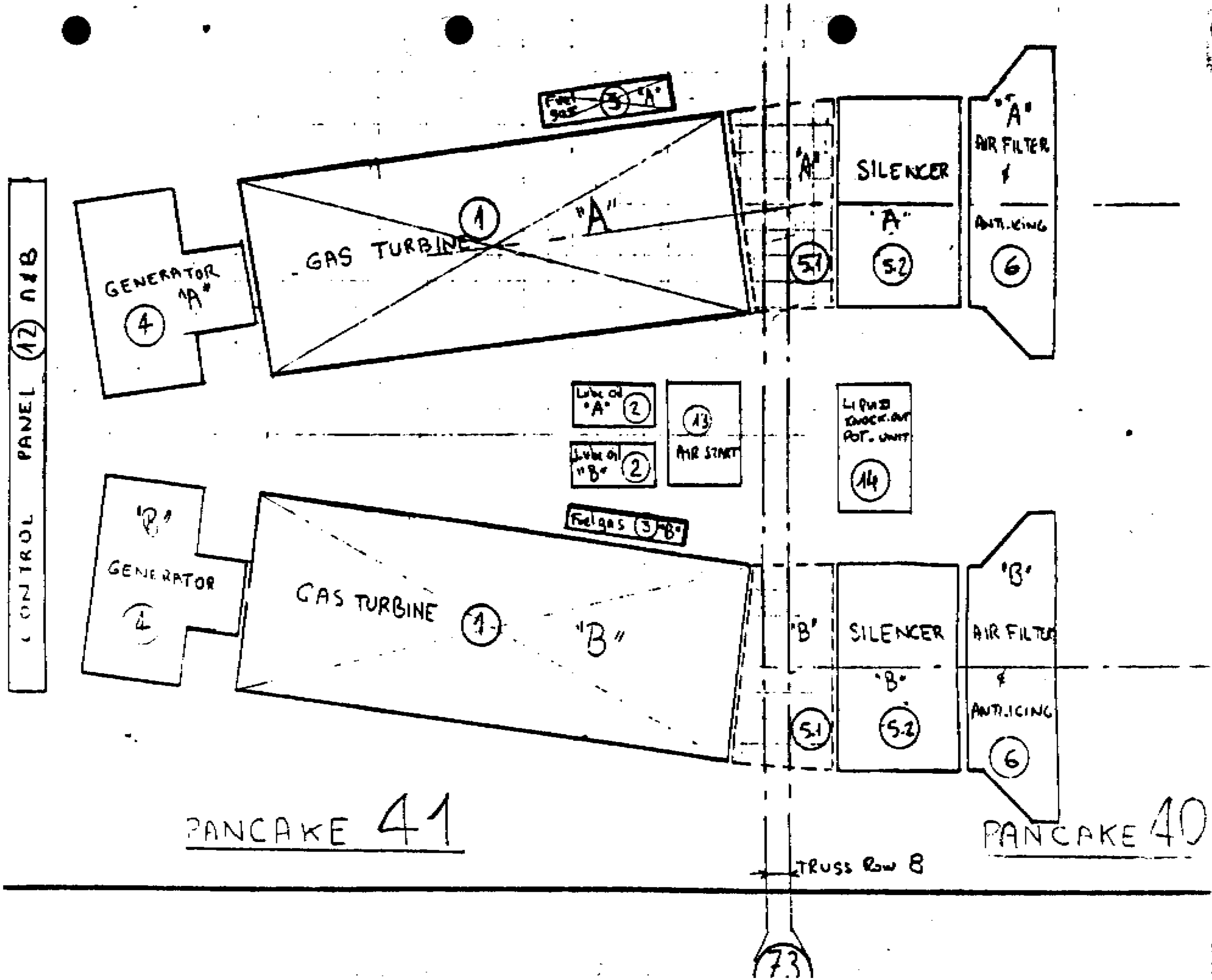
ACTUAL ERECTION

	Number of main items	Weight installed tons	Man-hours	Erection ratio hrs/ton	Contract Indications
1) SACM Emergency diesel plant installation	7 + 2 in 4)	25	750	30	2 mech. items + 1 panel in 4) s/s
2) VIFTEFABRIKK ventilation units install.	5	6,3	1000	159	4 units
3) STAL LAVAL equipment - mechanical - elec & inst. panels	 34 9	 305 9,5			 3 turbo-generators 9 panels
4) Additional Elec 6 Inst panels or packages - sub-station - battery-room	 25 6	 20 13	10250	29,5	 13 panels 1 set of batteries 110V/instr.
5) Halon racks	7	3			2 units
6) Hoists	2	1			
	95	382,8	12000	31,5	

Remark: to be noted that the contract list of equipment was based on the installation of 3 turbo-generators.

STAL LAVAL EQUIPMENT


STACK
9
8.1
EXHAUST TURBINE /
8
SILENCER
10.2
ELBOW EXHAUST
DUCTING
10.1
15
16
AIR FILTER
&
ANTI-ICING
6
SILENCER
5.2
5.1
GAS TURBINE
1
GENERATOR
4
17
Base plate
PANCAKE 40
PANCAKE 41


CONTROL PANEL (12) A&B
Fuel gas (3) "A"
GENERATOR "A" (4)
GAS TURBINE (1) "A"
"A" (5.1)
SILENCER "A" (5.2)
"A" AIR FILTER & ANTI.ICING (6)
Lube oil "A" (2)
Lube oil "B" (2)
(13) AIR START
LIQUID KNOCK.OUT POT. UNIT (14)
Fuel gas (3) "B"
"B" GENERATOR (4)
GAS TURBINE (1) "B"
"B" (5.1)
SILENCER "B" (5.2)
"B" AIR FILTER & ANTI.ICING (6)
PANCAKE 41
PANCAKE 40
TRUSS Row 8
73

4.3.3.5 Electrical.

DESIGNATION	CABLE LENGTH Est.contract quantity	Actual quantity	NO. OF CONNECTIONS Est.contract quantity	Actual quantity
CABLE LAYING & CONNECTIONS	meters	meters	U	U
5500 V Elastomeric cable armoured copper conductors				
1 x 400 mm^2	0	683		
600-1000 V —— idem ——				
			EARTHING NUMBERS	
EARTHING - MAIN CABLES & LINKS	meters	meters	U	U
Laying & Fastening of insulated cable 70 mm^2 copper for the main loops	290	789		
—— idem —— 35 mm^2	130	727		
TOTALS	420	1516		
	CABLE SUPPORT LENGTH		UNITS NUMBERS	
CABLE TRAYS - LADDERS	meters	meters	U	U
	525	1902		
Bend - tee				987
MULTI - CABLE TRANSIT	FOR ELECTRICITY & INSTRUMENTS			
Frame 141 mm x 233 mm			36	119
PUSH BUTTON CONTROL STATIONS			10	12
LIGHTING INSTALLATION				
Fluorescent tubes fittings 2x40w			88	89
Junction box 2,5 mm^2			94	14
Junction box 6 mm^2			0	22
220 V socket outlet 2 x 25 A			9	12
24 V socket outlet with transfo			9	12
Welding socket outlet			4	3

4.3.3.6 Instrument.

DESIGNATION	Est. length contract qty	Actual length	Actual connections no.	
CABLE LAYING & CONNECTIONS	meters	meters	U	
	3000	12143	667	
TRAYS & TELEX	meters	meters		
	860	2236		
PNEUMATIC TUBES	2200	1560		

ELECTRICAL AND INSTRUMENT RATIOS

a) Shop drawing for both trades

- 6 cable trays lay-outs
- 15 cable trays sections
- 99 MCT lay-outs
- 11 lighting lay-out and supports details
- 1 safety instrument plot plan
- 9 junction boxed details
- 1 cable pulling list

b) Split of work for both trades (acc. to used manhours)

S - Steel work: cable ladders, trays, telex and miscellaneous supports.

F - Equipment: installation of miscellaneous items except main equipment like panels which were installed within mechanical.

N - Cable pulling

P - Connections and tests

E - Earthing for both trades

		ELECTRICAL	INSTRUMENT
S		44,7 %	65,3 %
F		2,7 %	2,7 %
N		16,7 %	18,2 %
P		20,2 %	13,8 %
		ELECTRICAL	INSTRUMENTS
Cables length		12104 meters	12143
Earthing "		758	758
Tube and polyt		-	1600
TOTAL		12862	14501
Weight both trades		Ca. 61,3 tons	
Manhours	Including: 1) - precommissioning 2) - and commission. (carried out under FAN, Stvgr. responsibility)	22500	27250
1) Without overheads		22500	27500
2) with overheads (14%)		26246	31787
manhours per meter (everything included		1,75h/m(1) 2,04h/m(2)	1,88 (1) 2,19 (2)
Manhours per ton		812 h/ton (1) 947 h/ton (2)	
Average overall weight per average meter of cable or tube		$\frac{61300}{12862 + 14501} = 2{,}24$ kg/m	
Steel work hours per average of link		0,91 h/m	1,43 h/m
Pulling hours per average meter of link		0,34 h/m	0,4 h/m
Earthing manhours per average meter of earthing link		2,72 h/m or 67,5 h/ton of equipm.	

4.3.3.7 Manhours statistics

Overall hours spent

- Productive hours 138125 hours
- Contractor's overheads 23000 "

TOTAL 161125 hours

- EAN 2 yard supervision 29975 hours
  (of which 4291 hrs spent by the contractor's filing clerk and secretary working for ELF)

- Vendors assistance 5520 hours

Management ratios

- Contractor's $\frac{23000}{161125}$ = 0,143
- EAN 2's $\frac{29971}{161125}$ = 0,186

- Overall management (Contractor's + EAN 2's) = 0,329

REMARK: To be also noted the estimated hours spent on the yard by:

- various engineering representatives ca. 1000 h:
- the commissioning team ca. 2000 h:

Number of hours per ton based on weight of pancakes by the yard departure.

Item	Weight tons (A)	Productive hrs. spent (B)	Contractors overheads (hrs) (C)	EAN 2 management (hrs) (D)
P. 40	140	138125	23000	29971
P. 41	515			
P. 44	152			
L.P. vent stack (separate lump sum).	12	5140		

Overall contractor's ratio $= \frac{B + C}{A} =$ 203 hours/ton

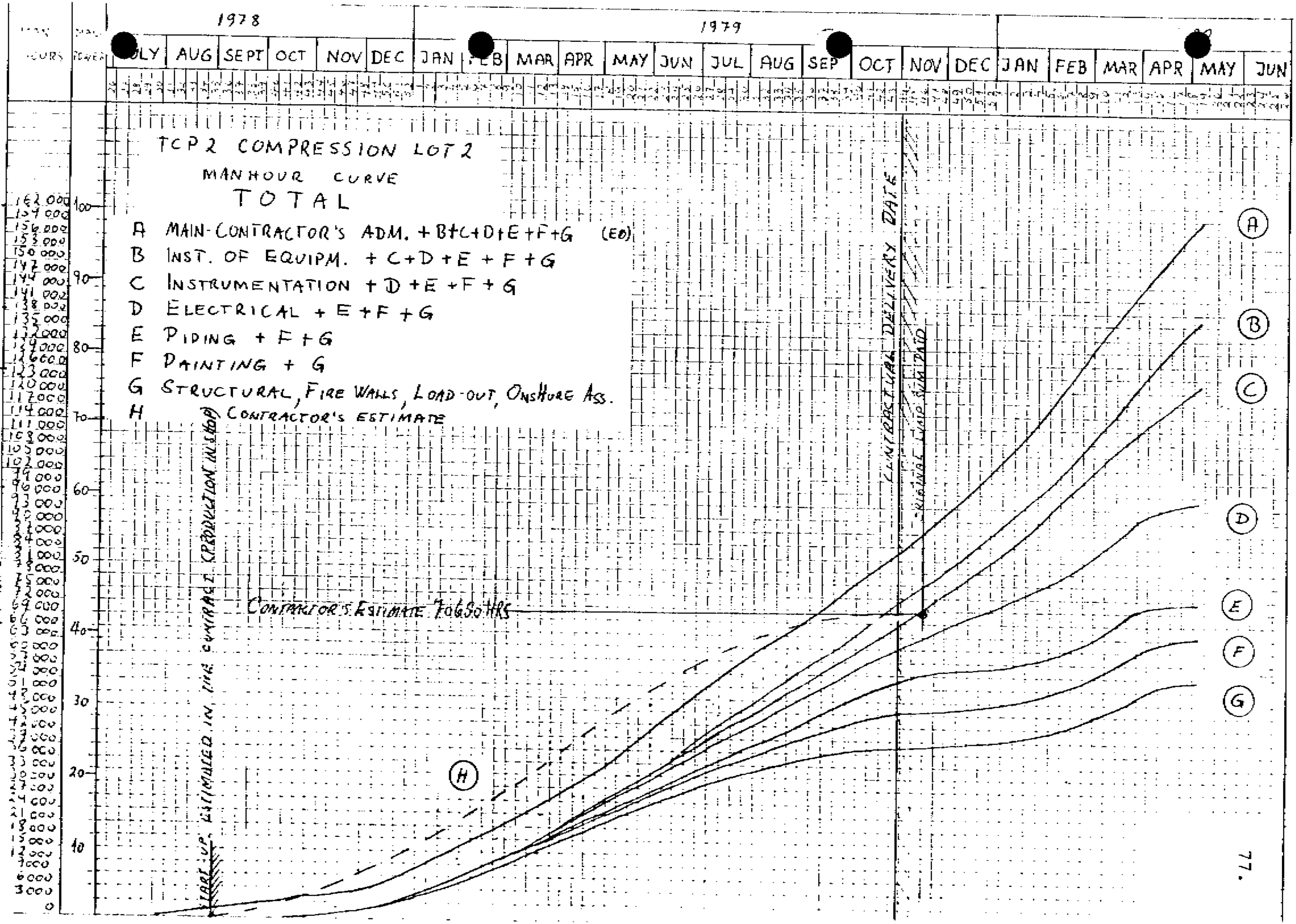
Productive ratios

- Pancakes $= \frac{B}{A} =$ 171,2 hours/ton
- L.P. vent stack $= \frac{B}{A} =$ 428 " "

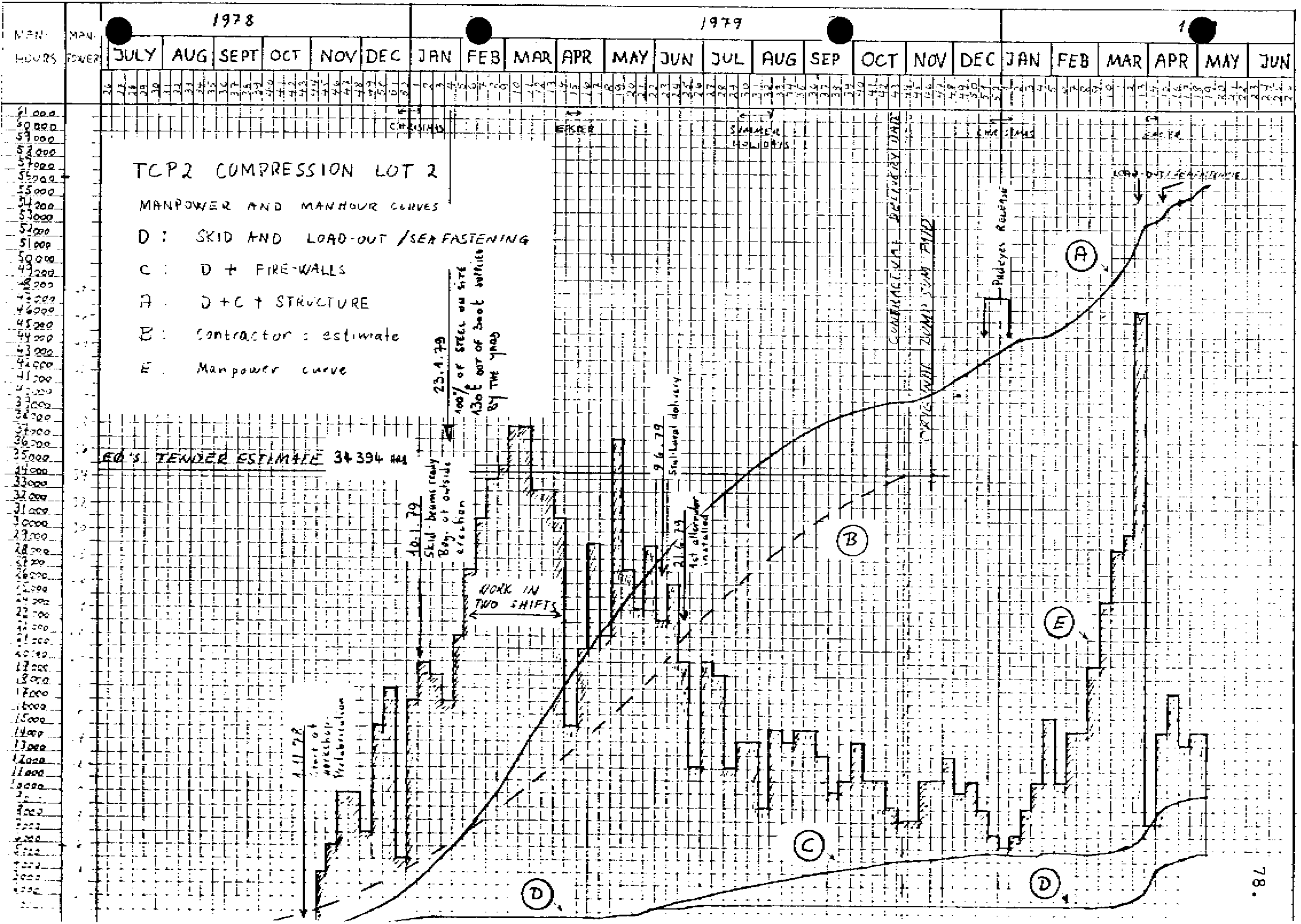
Management ratios

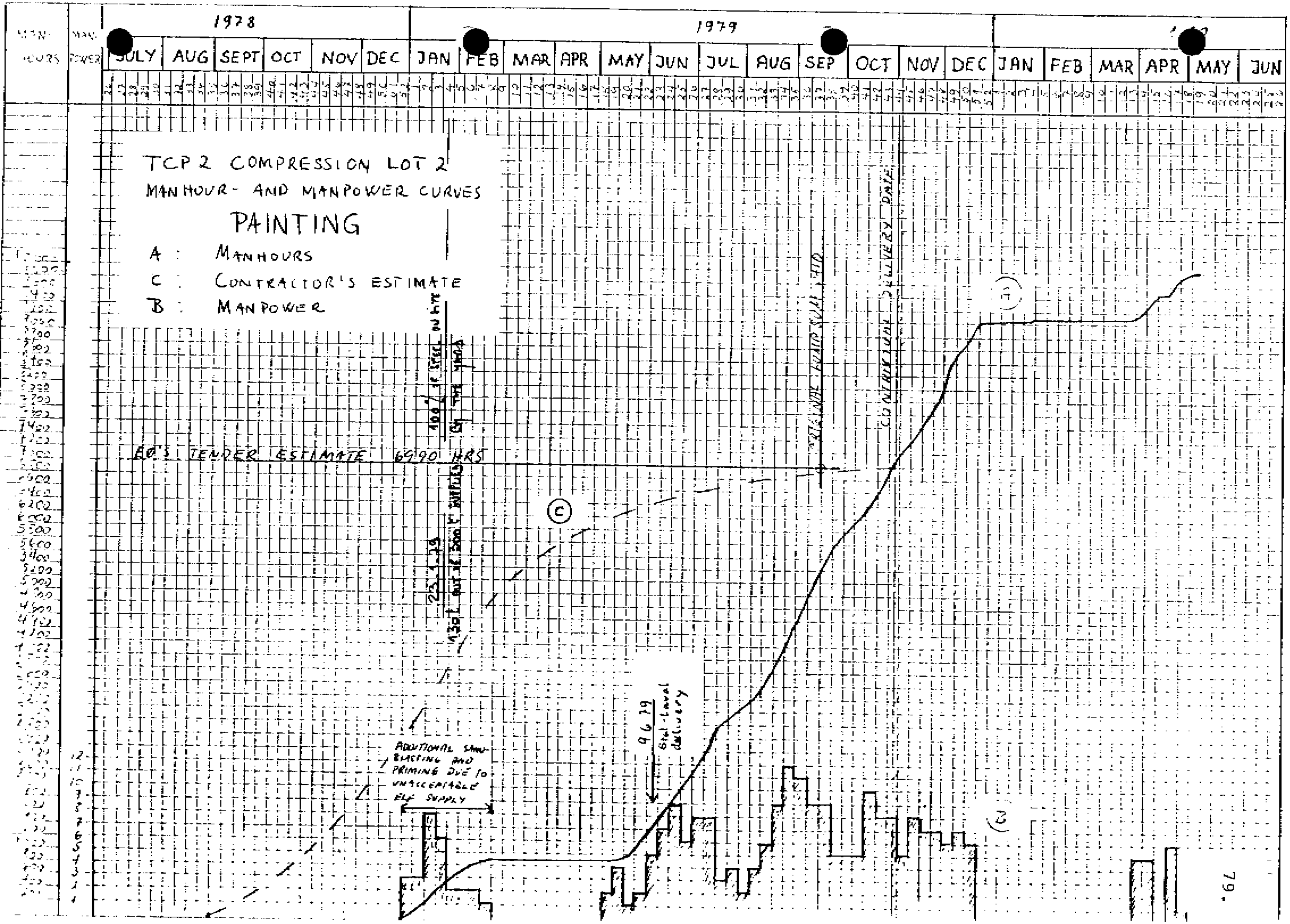
- Contractor's $= \frac{C}{A} =$ 28,1 hours/ton
- EAN 2's $= \frac{D}{A} =$ 36,6 " "
- Overall management $= \frac{C + D}{A} =$ 64,7 " "

4.3.3.8 S.curves.

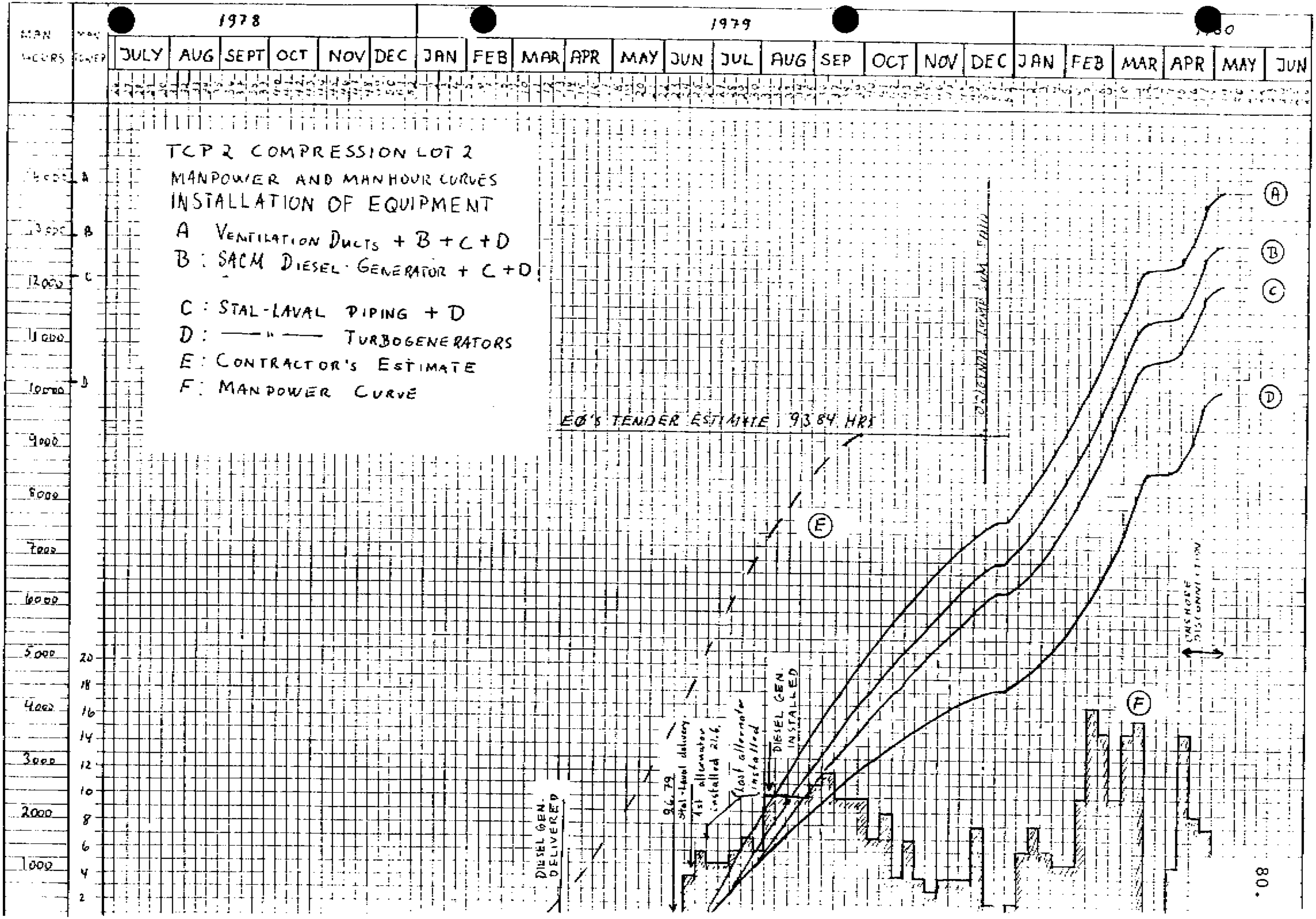


1978
1979
JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
TCP 2 COMPRESSION LOT 2
MANHOUR CURVE
TOTAL
A MAIN-CONTRACTOR'S ADM. + B+C+D+E+F+G (EB)
B INST. OF EQUIPM. + C+D+E+F+G
C INSTRUMENTATION + D+E+F+G
D ELECTRICAL + E+F+G
E PIPING + F+G
F PAINTING + G
G STRUCTURAL, FIRE WALLS, LOAD-OUT, ONSHORE ASS.
H CONTRACTOR'S ESTIMATE
CONTRACTOR'S ESTIMATE 70650 HRS
CONTRACTUAL DELIVERY DATE
A
B
C
D
E
F
G
H
100
90
80
70
60
50
40
30
20
10
0
3000
6000

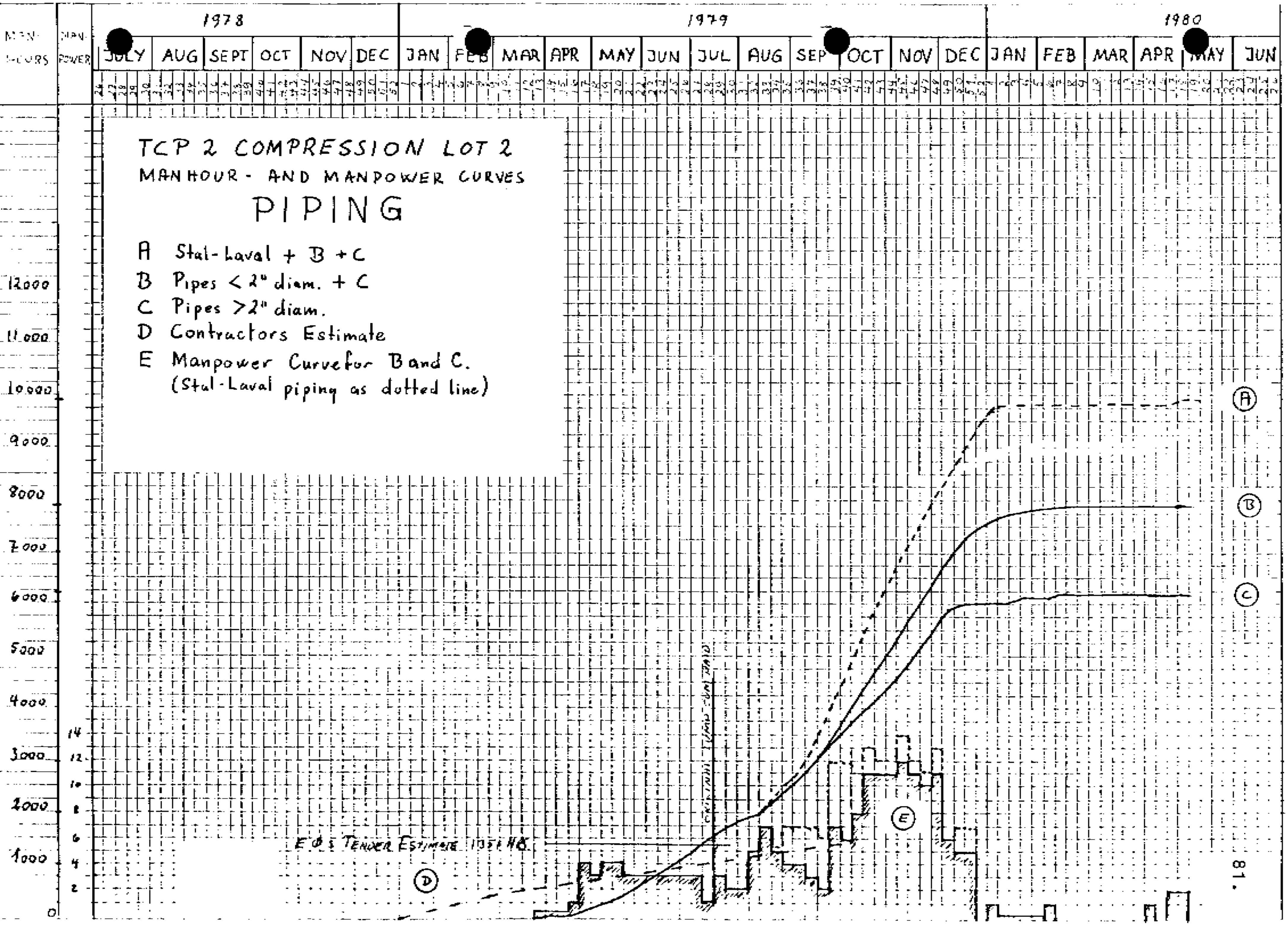

TCP2 COMPRESSION LOT 2
MANPOWER AND MANHOUR CURVES
D : SKID AND LOAD-OUT / SEA FASTENING
C : D + FIRE-WALLS
A : D + C + STRUCTURE
B : Contractor : estimate
E : Manpower curve
MAN-HOURS
MAN-POWER
1978
1979
JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
CHRISTMAS
EASTER
SUMMER HOLIDAYS
CONTRACTUAL DELIVERY DATE
ORIGINAL LUMP SUM PAID
Padeyes Release
LOAD-OUT / SEA FASTENING
EQ'S TENDER ESTIMATE 34 394 mh
23.4.79
100% of steel on site
130 t out of 300 t supplied by the yard
10.1.79
Skid beams ready
Bay of outside erection
WORK IN TWO SHIFTS
9.6.79
Structural delivery
21.6.79
1st alternator installed
1.11.78
Start of workshop prefabrication
A
B
C
D
E

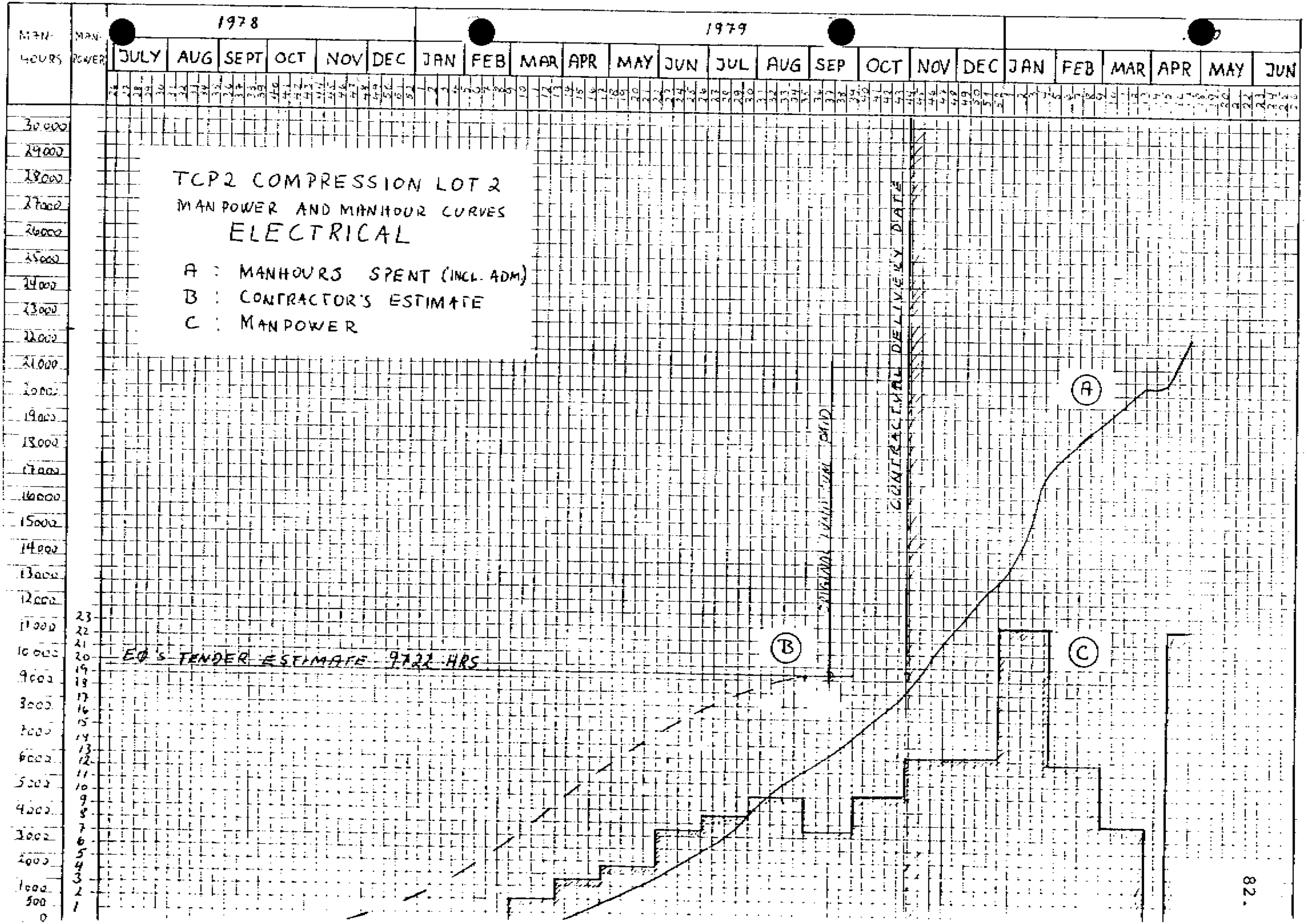


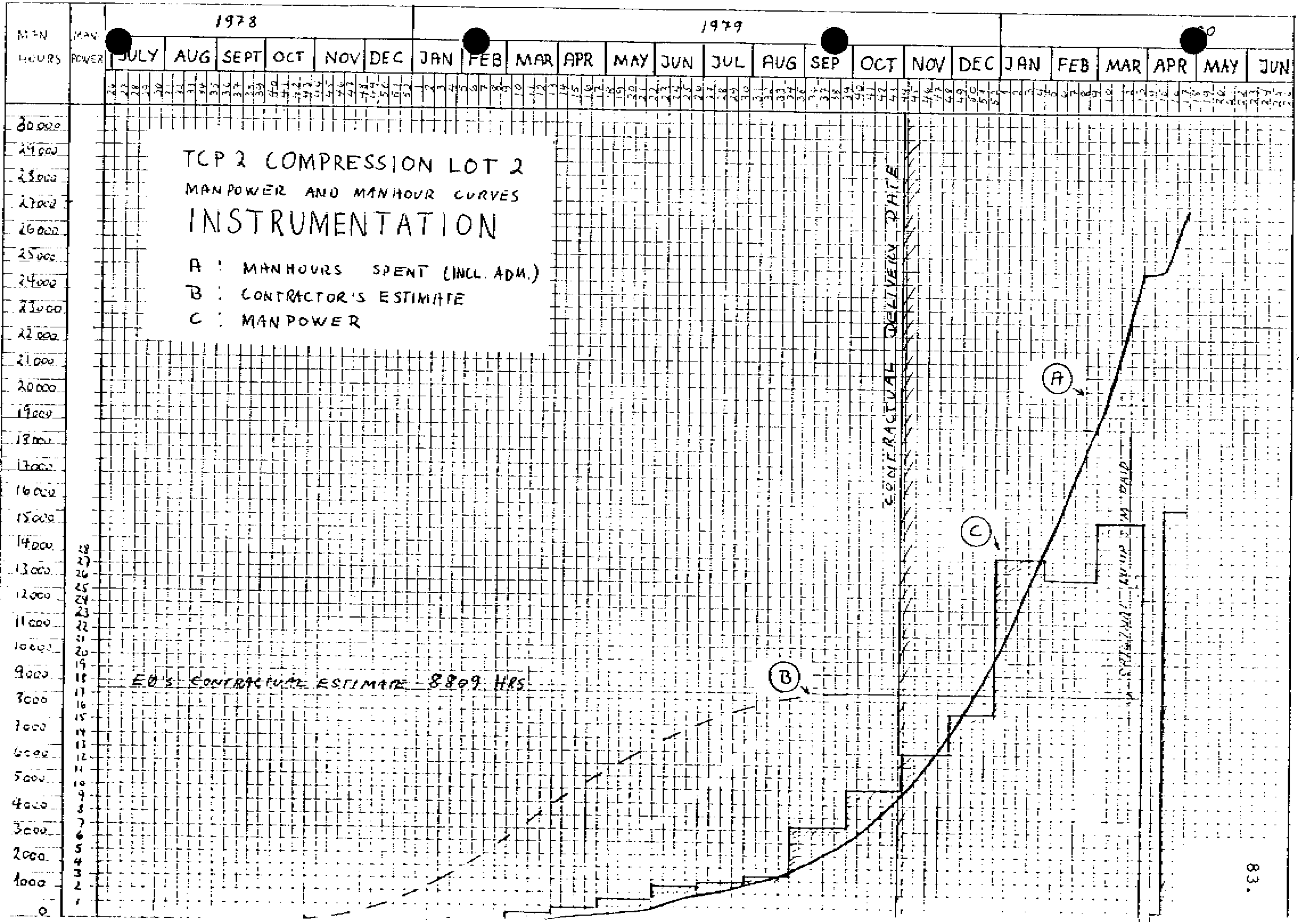
1978
1979
JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
TCP 2 COMPRESSION LOT 2
MANHOUR- AND MANPOWER CURVES
PAINTING
A : MANHOURS
C : CONTRACTOR'S ESTIMATE
B : MANPOWER
EO'S TENDER ESTIMATE 6990 HRS
ADDITIONAL SAND-BLASTING AND PRIMING DUE TO UNACCEPTABLE ELF SUPPLY
9.6.79
CONTRACTUAL DELIVERY DATE



TCP 2 COMPRESSION LOT 2
MANPOWER AND MANHOUR CURVES
INSTALLATION OF EQUIPMENT
A Ventilation Ducts + B + C + D
B : SACM Diesel-Generator + C + D
C : Stal-Laval Piping + D
D : —— " —— Turbogenerators
E : Contractor's Estimate
F : Manpower Curve
MAN HOURS
MAN POWER
1978
1979
JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
EØ'S TENDER ESTIMATE 9384 HRS
DIESEL GEN. DELIVERED
Stal-Laval delivery
1st alternator installed 21.6.
last alternator installed
DIESEL GEN. INSTALLED
ONSHORE DISCONNECTION
9000
8000
7000
6000
5000
4000
3000
2000
1000
20
18
16
14
12
10
8
6
4
2


TCP 2 COMPRESSION LOT 2
MANHOUR - AND MANPOWER CURVES
PIPING
A Stal-Laval + B + C
B Pipes < 2" diam. + C
C Pipes > 2" diam.
D Contractors Estimate
E Manpower Curve for B and C.
(Stal-Laval piping as dotted line)
MAN-HOURS
MAN-POWER
1978
1979
1980
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
12000
11.000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
14
12
10
8
6
4
2
E Ø's TENDER ESTIMATE 10398 H.
A
B
C
D
E


TCP2 COMPRESSION LOT 2
MANPOWER AND MANHOUR CURVES
ELECTRICAL
A : MANHOURS SPENT (INCL. ADM)
B : CONTRACTOR'S ESTIMATE
C : MANPOWER
1978
1979
JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
MAN-HOURS
MAN-POWER
EØ's TENDER ESTIMATE 9722 HRS
CONTRACTUAL DELIVERY DATE
A
B
C


TCP 2 COMPRESSION LOT 2
MANPOWER AND MANHOUR CURVES
INSTRUMENTATION
A : MANHOURS SPENT (INCL. ADM.)
B : CONTRACTOR'S ESTIMATE
C : MANPOWER
MAN HOURS
MAN POWER
1978
1979
JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN
CONTRACTUAL DELIVERY DATE
EB's CONTRACTUAL ESTIMATE 8809 HRS.
A
B
C
30000
29000
28000
27000
26000
25000
24000
23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0

AT : 30.03.80
IGN: R. Abildgaard [signature]

MANPOWER HISTOGRAM

FRIGG COMPRESSION LOT II

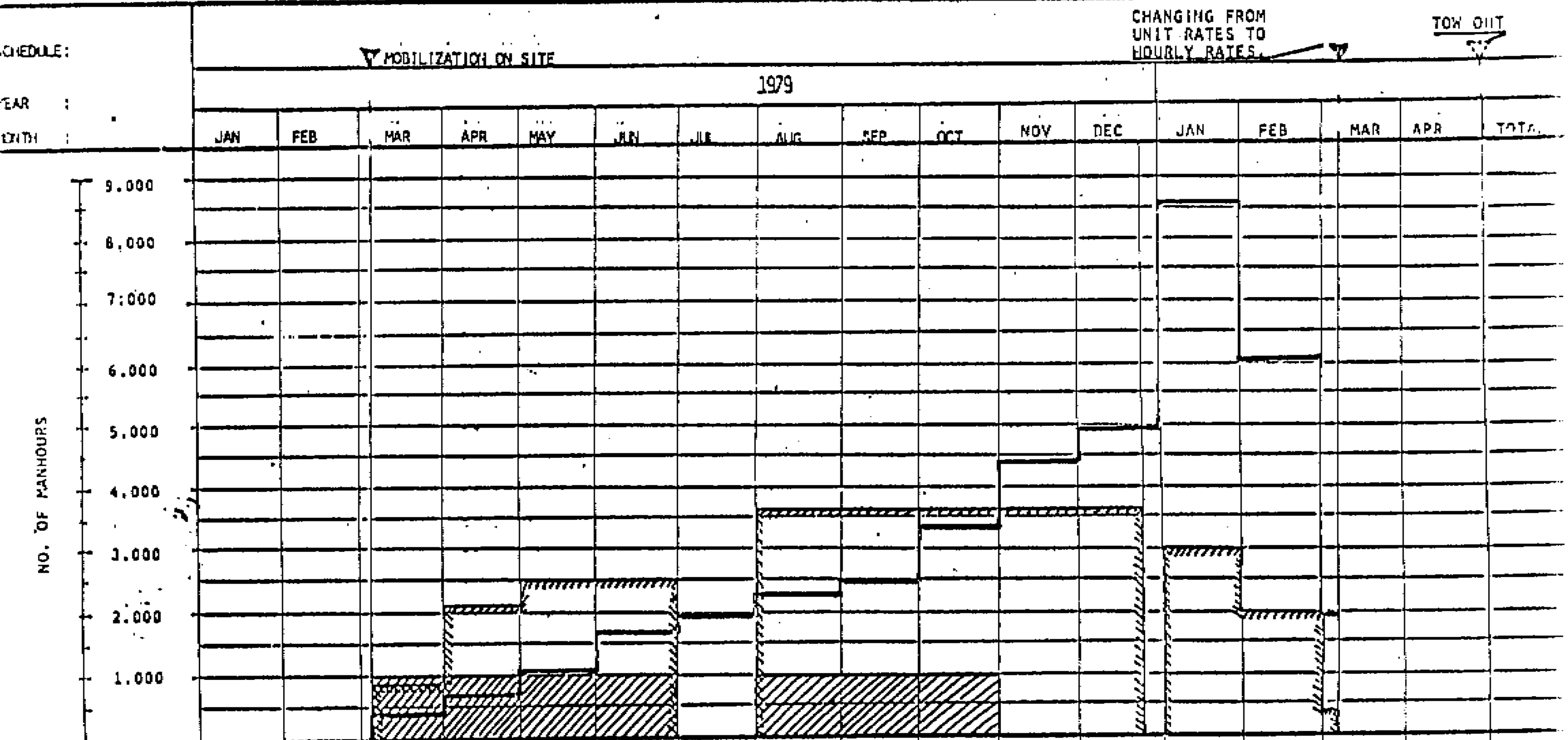
INSTRUMENTATION & ELECTRICAL

E. BGREY A/S - VCON A/S

(hatched top line) NO. OF PLANNED HOURS AFTER SUBSTANTIAL INCREASE IN SCOPE OF WORK.

(hatched bar) NO. OF ORIGINALY STATED CONTRACTUAL HOURS (BASE FOR ORIGINAL TENDER)

(solid line) NO. OF ACTUAL HOURS PERFORMED RESULTING FROM EXTERNALY INDUCTED LOW EFFICIENCY FACTOR.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	TOTAL
ACTUAL MHRS.			390	715	1024	1708	1942	2224	2445	3373	4416	4882	8563	6116	1995		39.79.
PLANNED MHRS.			800	2.200	2500	2500	[illegible]	3600	3600	3600	3600	3600	3000	2000	412		31.41.

4.3.4 Planning

4.3.4.1 Method

All planning issued by Elf and contractor have been presented as traditional bar-charts. The work has been split into activitites according to the physical production (i.e. prefabrication eastwall, insulating battery room, etc.) Each activity was given a code corresponding to the system it belonged to in order to allow the information to be sorted by computer as well. The start, duration and finishing date of each activity was based upon the availability of approved drwgs, material supply, manpower workshop and weather conditions.

4.3.4.2 Organization

COORDINATION PLANNING for all yards was issued by compression H.Q. in Stavanger, based upon information from yards, engineering, material-coordination, target dates from contractors, suppliers etc.
This planning served as infor. to the FRIGG-group and as a guideline for the yards.

YARD PLANNING served as an agreement between contractor and EAN 2, for the production on site. The yard planning was produced alternatively:

A) The coordination planning from H.Q. was transmitted to the contractor who was instructed to adjust his planning accordingly and issue it to Elf.

B) The contractor issued his planning on EAN 2 request. This planning was commented by EAN 2 and re-issued by contractor.

C) The planning was produced by EAN 2 and contractor in plenum.

COMMENTS:

Alternative A was used at the earlier stages of construction When the coordination planning started to indicate a completion date later than the contractual one (Nov. 1st 1979) this planning was kept confidentially within EAN2. Completion date was regarded as contractual matter and treatec on project management level (Elf/OIS).

Alternative B was used throughout the project and is the procedure stated in the contract. It was often difficult to obtain it from contractor as he was reluctant to issue it. It shoudl have been stated clearly in the contract how often the contractor had to issue his planning.

Alternative C was also used, but only as a guideline for contractor as the responsibility for planning is on him.

3-WEEK PLANNING.

As engineering has been going on at the same time as con--struction, it was always important to present sufficient amour of work to contractor. It was also of great importance to ensure that we were working with correct and approved drawings, hence avoiding vain-work.

By coordinating the different trades and their activities on such a detailed level throughout the project, lots of daily clashes were avoided to the benefit of both Elf and contractor.

The schedule was produced during a meeting every Friday between contractors and Elf's specialists and organized by Elf's planner.

During this meeting technical information was exchanged, problems discussed and a concrete schedule produced. The latest yard-planning was used as basic document when determining the time schedule. The previous 3-week schedule was updated with a situation line.

At the end of the construction period the contractor issued it and it was discussed when needed, during the weekly site meeting on Wednesdays organized by EAN site manager.

PUNCH-LISTS were issued when a discipline was approximately 90% finished. Punch-lists were used as basic documents when making the 3-week schedules.

4.3.4.3 Follow-up.

The progress had to be reported for the following reasons:

- As information on the present situation to the involved parties. (EAN yards, EAN project management, FRIGG-groups and contractors).
- As a basis for the monthly invoicing.

The progress was calculated in terms pf points. One point was defined as follows:

Contractual lump sum original total contractor's manhour est.

This gave 1 point = NOK 7739600/70650 hours = NOK 109,548

When scope of work was updated, the approved price was given a corresponding amount of points.

The progress was reported either as a percentage per discipline and area or as calculated number of points executed.

PROGRESS-REPORTING SYSTEM BY DISCIPLINE:

Main structure

Material take-off (MTO) from engineering was the basic document.

The ratio "approval points/ton of steel" was calculated for each area (pancake 40, 41, 44).

The points for each pancake was then split on the various structural parts (lower deck), upper deck, walls etc.).

This amount of points was then split on the construction stages such as:

Preparation 15% (shop drwgs 0,4t/hr, welding proc. 12.5 hr/t

Prefabrication 30% (cutting and assembling 2 hr/weld. meter, welding 2 hr/weld. meter, NDT 10% of welding).

Erection 45% (erection before welding, welding 2 hr/weld. me NDT9

"Safety" 10% (6% released when big prefabricated items were erected, 4% released when "as built" drwg was ready).

The weekly progress was determined by recording the weight cut, assembled or erected and meter of weld done.

Architectural fire walls was followed up on a separate sheet.

The area to be insulated and covered was split on walls, roof etc. according to surface. It was then split on:

- material. 20% when received (contractor's supply)
- pins for Rockwool. 10% when fixed
- Support for wall-sheets (Plannja) 20% when welded
- Rockwool (insulation) 10% when fixed
- Aluminium foil and wire-mesh. 25% when fixed
- Plannja sheets. 15% when erected.

SECONDARY STRUCTURE

Principally the same as main structure, but simplified.

INSTALLATION OF EQUIPMENT

All main equipment was listed and the points were distributed

on each equipment and it's various installation-stages at ratios agreed upon by EAN 2 and contractor. (Lifting/skiddin 70%, alignment 20%, precommissioning 10%).
The weekly progress was recorded as a % per item.

PIPING AND FITTINGS.

The lump sum points were distributed on the isometric drwgs. and points again split on:

Preparation (20%) all necessary drwgs. for piping and support

Prefabrication (50%) cutting, tack-welding, welding, NDT, erection, and dismantling.

Erection (20%) final erection, welding NDT.

Test (10%) all test, rectifications, as-built drwgs.

The weekly progress was reported as a % for each isometric drwg.

ELECTRICAL

The contractual lump sum at any time was split by items and the points distributed on each item no according to their unit-price and quantity.

For each item no, the estimated points were distributed as follows:

Prefabrication	appr.	20%	when applicable
Steelwork	"	44%	"
Erect. of equipment	appr.	25%	"
Cable pulling	"	70%	"
Connection	"	70%	"
Test	"	10%	"

Weekly progress was recorded as quantity or % executed.

INSTRUMENTATION

Principally the same as electrical.

VENTILATION

The points were distributed on the different items according to their material price. Weekly progress was recorded as % per item.

PAINTING

Approval points were distributed on the various construction parts according to the area to be painted.

Work done was reported as a % per coat for each construction part.

Example: P.41, lower deck inside: Coat 1 100%, coat 2,3,4 20% each.

The points were released as follows:

50% when sweepblasting and primer (coat no. 1) was applied.
15% more for coat no. 2
15% more for coat no. 3
20% more for final coat.

4.3.4.4 Intitial planning/progress

The sheet overleaf shows contractors first production schedul and actual progress.

4.3.4.5 Explanation of discrepancy

The delay of six months was generally due to late engineering and increase of scope of work (appr. 105% increase of cost.)

NOTES

OVERALL SCHEDULE

CONTRACTOR'S PLANNING

ACTUALLY DONE

elf aquitaine norge a/s

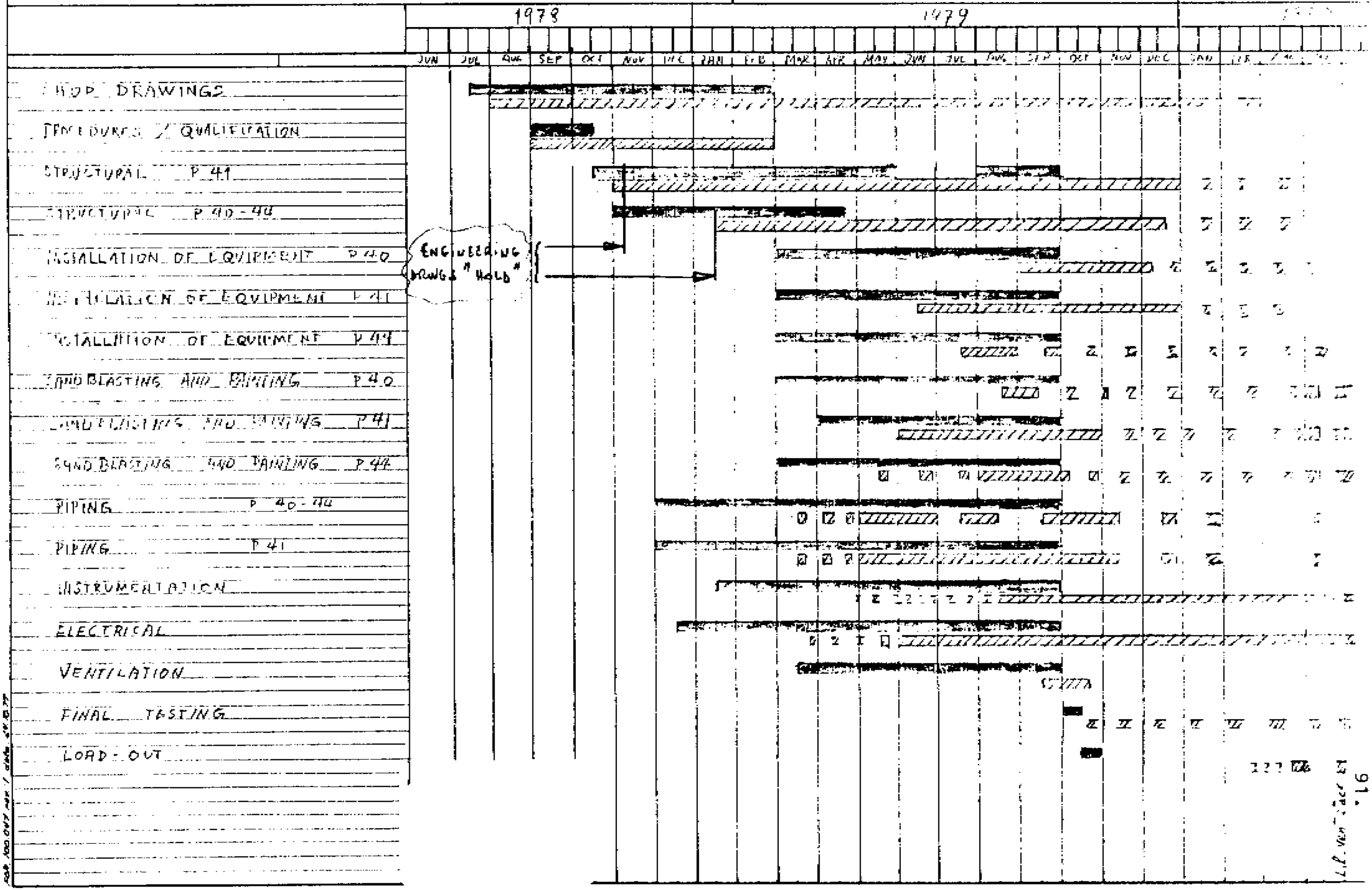
PROGRAMME

ref.:

by:

page of

rev.: date:



4.3.5 Comments

The n.// lump sum contract entered into as of June 28th 1978 by & between EAN and OIS was meant to cover the construction and load out in Kristiansand of 3 pancakes namely P. 40, P 41 and P. 44.

4.3.5.1 Yard opening.

At the negotiation of the contract and its signature, both parties believed from the evidence provided by the engineering and availability of materials that nothing would prevent the contractual object from being missed.

The reality was different and the object of the contract was compromised right at the yard opening and later on, the feaseable works amount at any time never represented more than one month ahead of what was in hand.

At the contract signature the lump sum was far from including the whole scope due to the very late engineering design at that stage.

The works shown on the tender drawings or itemised in the contractual take offs were in fact represented ca 20 % of the actual design completion.

The equipment list indicated the possible delivery of 3 turbo alternators as 2 have been actually installed. This example and the various disciplines charts of this report which record important quantity & quality changes are well illustrating this regrettable lack of definition.

Additionally, it came out that the 2 other yards were considered as priority holders.

- Yard 1 due to its contents and overall size.
- Yard 3 with its complementary equipment to the

Orkanger ones and due to its load out to be achieved prior to the yard 2 one on the same barge.

An incredible lack of contractor's suitability saved the engineering's face.

Contractually responsible to achieve the necessary welding procedures (w.p.) before starting the works in their shop, OIS - E.Ø contrary to all expectations was proved unable to sort out the first one before the beginning of November.

Any experienced contractor should have in these conditions produced all the W.P. within the shortest time placing the company in a very bad situation, leading to several months of postponement with an expensive overall stand-by.

Some very grave material problems came in addition to complicate the situation.

a) Long delays in the contractual Elf steel supplies (ref. the attached charts).

b) Shortages created by the various design changes obliging the yard to directly find 58 tons of plates and 74 tons of profiles in hurry. The ST 52 3N steel quality chosen by the engineering being somewhat special led to local chase of the equivalent materials to be approved piece by piece with additional time-consuming laboratory tests and welding procedures.

c) Unacceptable surface preparation of the Elf steel, ordered to the mills with an SA 3 preparation protected by a 20 μ to 50 μ zinc silicate primer coating.

The material department revealed unable to produce the surface preparation certificates and some coating proved to be of epoxy primer nature incompatible with the final Hempel chlorinated rubber system.

All Elf steel suppliers were therefore re-sandblasted on the yard, thus consuming ca. 800 hrs. spent over January and February 1979 and delaying all prefabrication work.

4.3.5.2 ENGINEERING

The contract amplifies in the overall object that time was of the essence, and the contractual delivery date of November 1st 1979 was the prime objective.

Within the construction period, the engineering never succeeded in improving the situation in any discipline, and the yard was obliged to proceed erratically up to the very end.

Bearing in mind the poor yard opening situation, KE/TP promised to meet the following main milestones during a coordination meeting held in Oslo on September 21st 1978.

- Structural 90 % of IFC drawings in November 1978.
- Piping 90 % of IFC drawings in December.
- Electrical 90 % of IFC drawings in January - February 1979.
- Instrument 90 % of IFC in January.

This engagement was not respected.

1 STRUCTURAL

Originally forecast from May - June 78 to October 78 the structural shop-drawings drafting turned out from August 78 to December 79 mainly due to overall "holds" which were kept on the engineering structural design as follows:

P. 40 up to W. 2 79
P. 41 up to W. 48 78
P. 44 up to W. 2 79

According to the first EAN guide schedule, the contractor was pressed to concentrate his efforts on P. 44, but unfortunately was obliged to switch on P. 41.

Structural wise the trickle of engineering output never allowed the mobilisation of more than one draftman to reduce the delays, and 35% of the drafting hours were spent on daily updatings up to December 1979.

2. PIPING

This part of the work was quite difficult to handle, and the yard suffered a permanent lack of sound definition.

The company was contractually in charge to supply all piping items, but most of its actual supplies delivered mid - January 79 just permitted the complete prefabrication of 2 Isos out of 53 for piping above 2 Inch diameter.

This situation arose from the fact that KE/TP did not issue the contractual material take-offs (ex - computer) in due time. When the yard received the document, so called IFC under rev. no. 7 by the end of January, it was in fact just concerning 12 Isos out of 53.

So as not to jeopardize the development of this trade, the yard was obliged to sort-out by hand all take-offs versus the not IFC design in hand to locally purchase the missing items in spite of an overall engineering hold kept up to the end of April.

Provided these yard actions, the work started in April with more than 3 months of delay, 10 Isos being still not KE/TP-issued beginning of May.

Contrary to all expectations, an additional scope concerning the Stal Laval interconnections was discovered in August inducing some 2000 hours of work.

3. MECHANICAL

If the mechanical items were delivered in time according to the contract indications, a lot of electrical or instrument panels were desperately postponed inducing some very awkward positioning.

Let us remind the reader that all heavy Nife items i.e. rectifiers and inverters were introduced in the P. 44 substation at the last moment when the pancakes were already loaded out on the barge. According to common sense, this operation was taking place one year too late.

In spite of adverse working conditions the yard had succeeded in achieving the positioning of the turbo alernators. The P. 41 structural status was at that time fully maximized with achieved internal coating and even the A 60 walls in the mezzanine control room.

Most of the problems which occured within this trade were due to:

- Not - finalized engineering studies
- Lack of vendors documentation (including the basic overall sizes most often received after the deliveries).
- Complete lack of main equipment installation scopes of work leading to the permanent presence of vendors representatives.
- Very deep lack of inspection and follow-up within the vendors workshop implicating by the erection time too numerous yard technical discussions about whatever detail, fitting or connection and resulting in a lot of small additional works.

Among other points, to be noted:

- The complete remake of the Stal-Laval fuel-gas knock - out pot package originally built without any supervision in Plenty's in England.

- The replacement of most of the equipment junction boxes (due to wrong type or sizes) and cable glands not certified.

- The permanent rejection of the diesel generator room electrical hoist far too big to be installed within the available space.

4. ELECTRICAL & INSTRUMENT

The summary concerning the drawings dispatching, shows that the engineering documentation was issued too late and too frequently revised.

Together with the above, the erratic material deliveries (ref. summary) resulted in:

- Appreciable schedule changes with inefficiency and lost hours.

- Work priorities shifting.

- Open air activities slide into winter conditions.

- Extra mobilization and demobilization, overmanning and high production costs.

- Irrational work due to partial deliveries.

4.3.5.3 Actual yard performance

Taking large profit of the construction period extent up to mid - May 1980 (ca. 8 additional months), the revised scope assigned to the yard was achieved by the barge departure except:

a) about 500 hours of feasible works
   - 200 hours of gas detectors connections
   - 100 hours of earthing
   - 200 hours of painting

b) The installation of non-delivered company items, supplied ca. 6 months later, on board TCP2 during the hook-up phase

   - ca 2000 meters of cables
   - the ESD panel S. 53.44.4.24
   - 9 interconnection junction boxes
   - 4 start - stop push buttons

75 workers bustled aaound the completion task up to the ultimate time with quite good efficiency even if "a priori" such a sustained end of yard activities sounds not suspicious

This noticeable result has been reached in spite of a final extremely tight schedule thanks to the contractor's willingness and toughness.

Should the original contractual date of November 1st 1979 have been confirmed the late engineering and material deliveries would have most certainly limited the works progress to:

$\frac{85500}{161125} \times 100 = 53\%$ of the final result.

4.3.5.4 E.77 CONTRACT APPRECIATION

The engineering progress was not allowing a yard opening on September 1st 1978, but probably on February 1st 1979.

It is also undeniable that the contract documents were so scamped that it was impossible to define unequivocally the tasks and quantities details covered by the lump sum.

The basic indications scattered over the various volumes, and regrettably incomplete, were given under too many conflicting headings.

As a result of this, it was very awkward to obtain from the contractor the material he had to furnish without additional payment, as it was defined during the negotiations.

The agreement of compensation was therefore somewhat tricky, and the differences of opinion regarding the contract interpretation and working procedures were obvious early in the project.

85 claims were OIS - E.Ø. issued related to quantity or quality changes.

Quantity wise EAN 2 issued and updated the various take-offs on a permanent basis, and this preparation allowed the settlement of the corresponding claims without problems.

Quality wise the situation was far different due to the engineering changes or delays and to the material shortages. EAN was actually led to compensate the inefficiency due to the frequent work-schedule changes and associated erratic construction.

In a certain way the contractor aimed at maximising his gain from the deviation versus the contract, and naturally EAN minimised creating a conflictual atmosphere throughout the lump sum period (1978 & 1979).

However, considering that the acceptable quality changes were settled at justified cost within the course of the construction, the final claim settlement payment of 1,500,000 NKR meant to cover the various known and unappreciated disturbances, this being in other words to be also understood as an EAN gesture of good will to reward the contractor for their good performance.

4.4 Report on Yard 3 (OIS NYMO Lot. no. 3)

4.4.1 Organization

Basically the organization scheme was the same as the one for Yard 2.

OIS was the contractual responsible while the work was performed by NYMO at the GRIMSTAD yard.

4.4.2 Scope of work

The scope was the construction of 6 pancakes socalled "utilities pancakes":

- fresh water cooling medium
- sea water cooling medium
- plant air
- fire houses

The prefabrication and erection of the sea water pipework, made of cupro-nickel alloy was excluded from the contract but executed directly by a third party: Yorkshire Imperial Work, with the assistance of Nymo.

4.4.3 Statistics

4.4.3.1 Production ratios

- Structural
    - weight 300 T
    - productive manpower 44700 Hrs
    - ratio: 149 hrs/ton
- Mechanical
    - number of units 12
    - Productive manpower 4800 hrs
    - ratio: 400 hrs/item.

- Piping

    - Weight 112 T
    - Productive manpower 3600 hrs
    - Ratio 320 hrs/ton (average diameter 6")

- Painting

    - surface (structural + piping) 7130 m^2
    - productive manhours 18000 hrs
    - ratio 2,5 hrs/m^2

- Electrical/instrumentation

    - productive manhours 25000 hrs.

4.4.3.2 S.curves and manpower histogramme.

See enclosures overleaf.

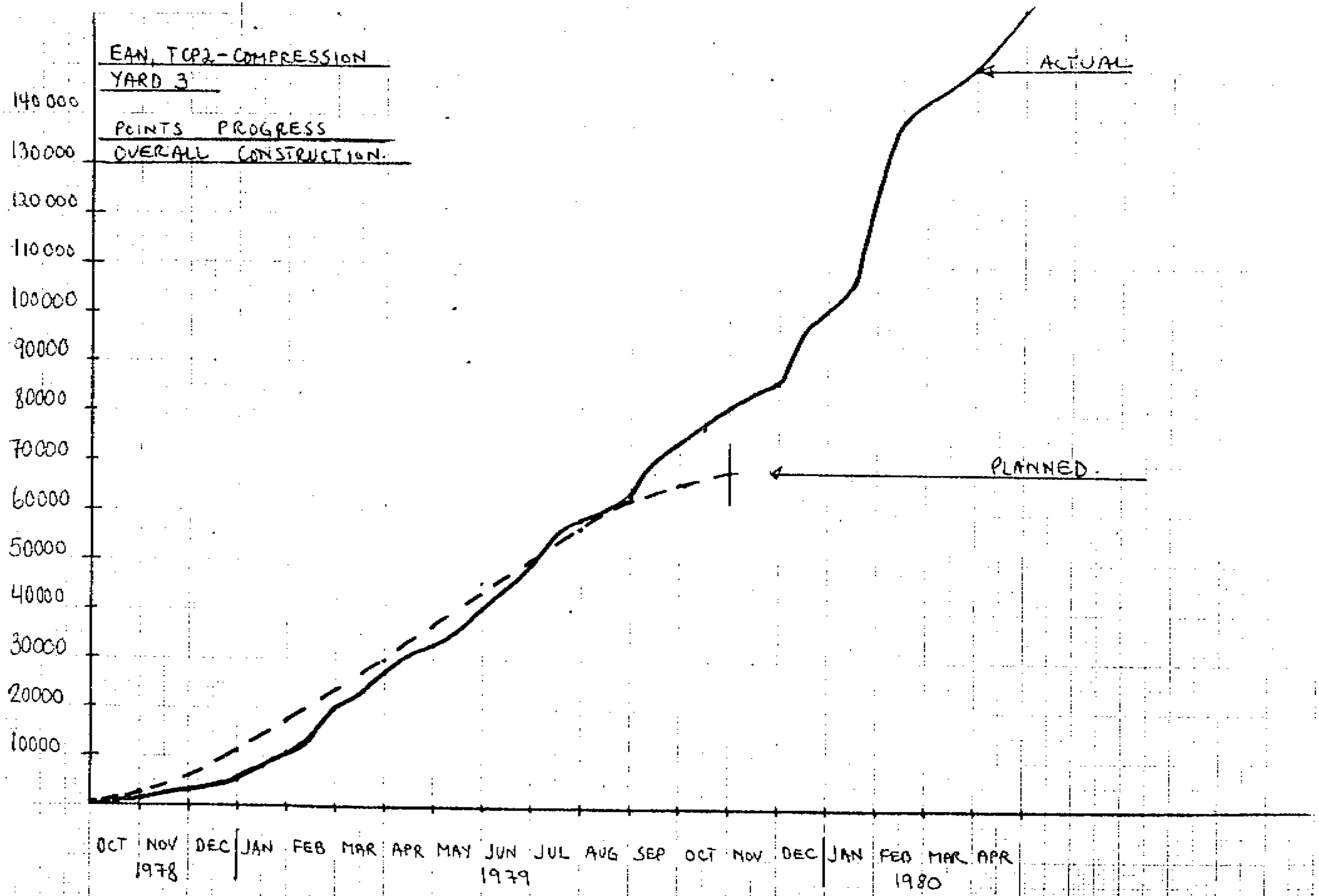
4.4.4. Planning

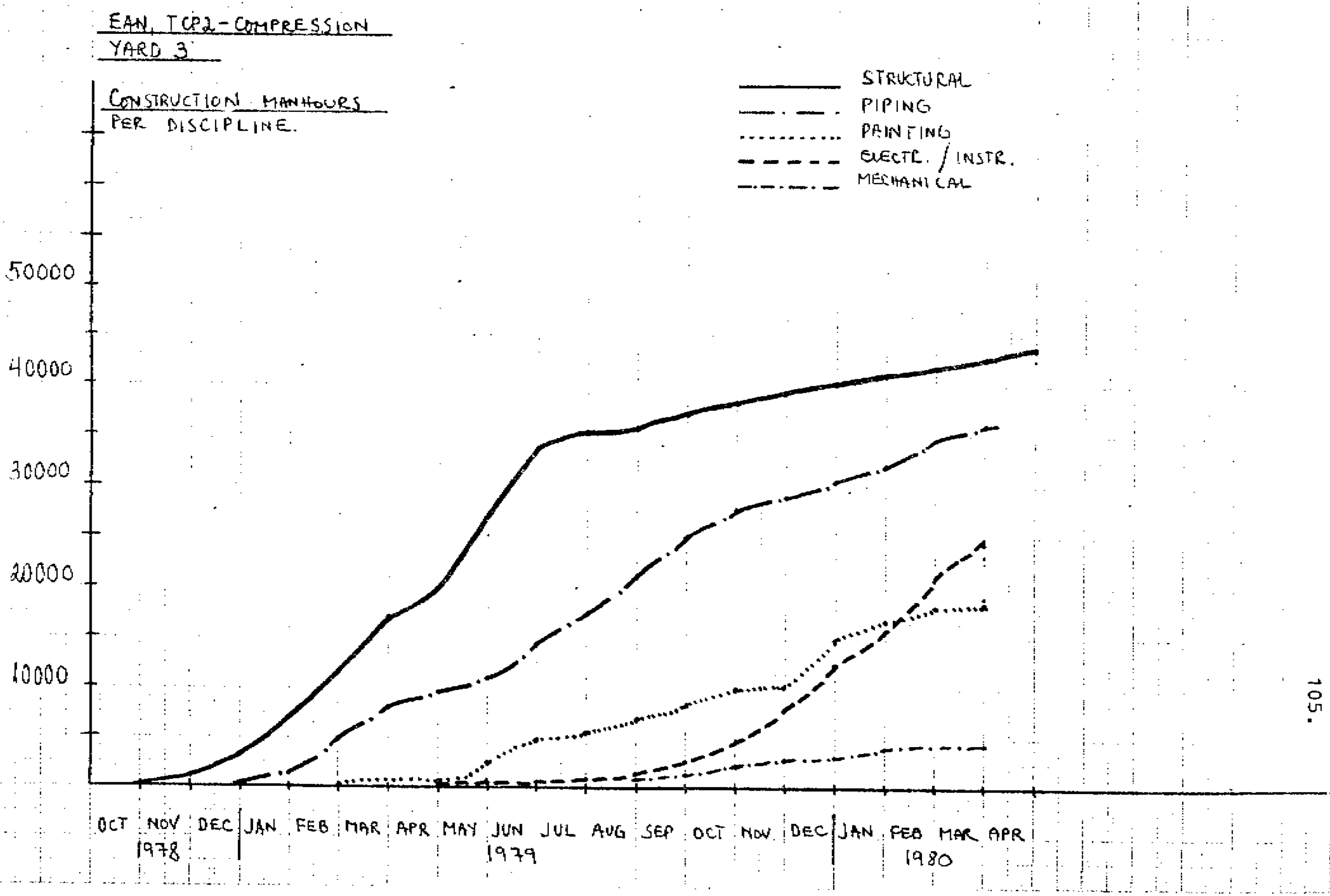
- Contract award 28th of June 1978
- Yard opening 15th of September 1978
- Work completed on 14th of March 1980

Some remaining works (electrical, instrumentation)were completed on board the cargo barge during the loadout of the lot 2' pancakes.

4.4.5 Comments

Contractor's weakness in piping and coordination of disciplines was saved by a high contribution of the supervision team.


EAN, TCP2 - COMPRESSION
YARD 3
POINTS PROGRESS
OVERALL CONSTRUCTION.
ACTUAL
PLANNED.
140 000
130000
120 000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
OCT NOV DEC
1978
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1979
JAN FEB MAR APR
1980



EAN. TCP2 - COMPRESSION
YARD 3
CONSTRUCTION MANHOURS
PER DISCIPLINE.
STRUCTURAL
PIPING
PAINTING
ELECTR. / INSTR.
MECHANICAL
50000
40000
30000
20000
10000
OCT
NOV
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1978
JAN
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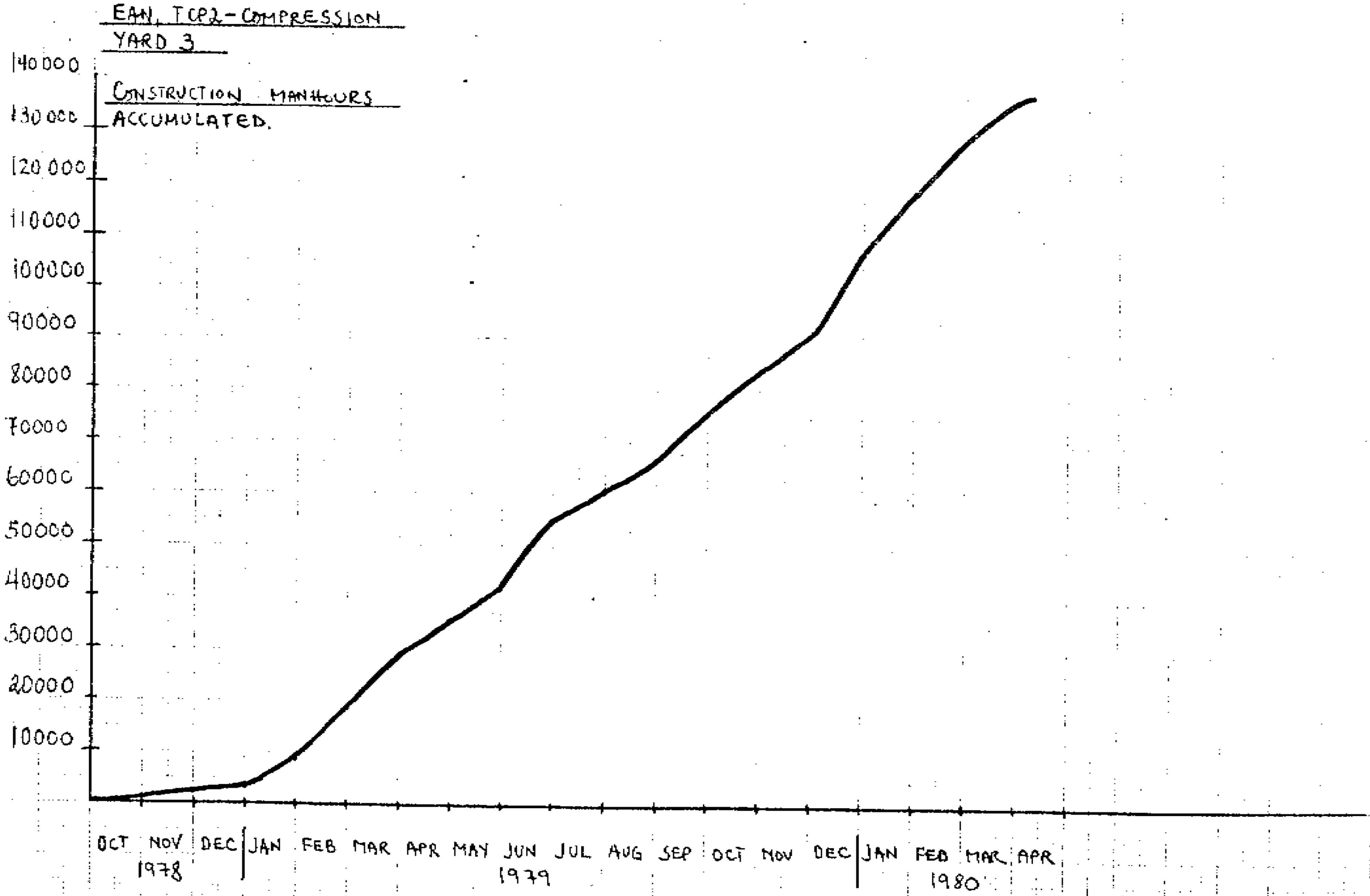
EAN, TCP2-COMPRESSION
YARD 3
CONSTRUCTION MANHOURS
ACCUMULATED.
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
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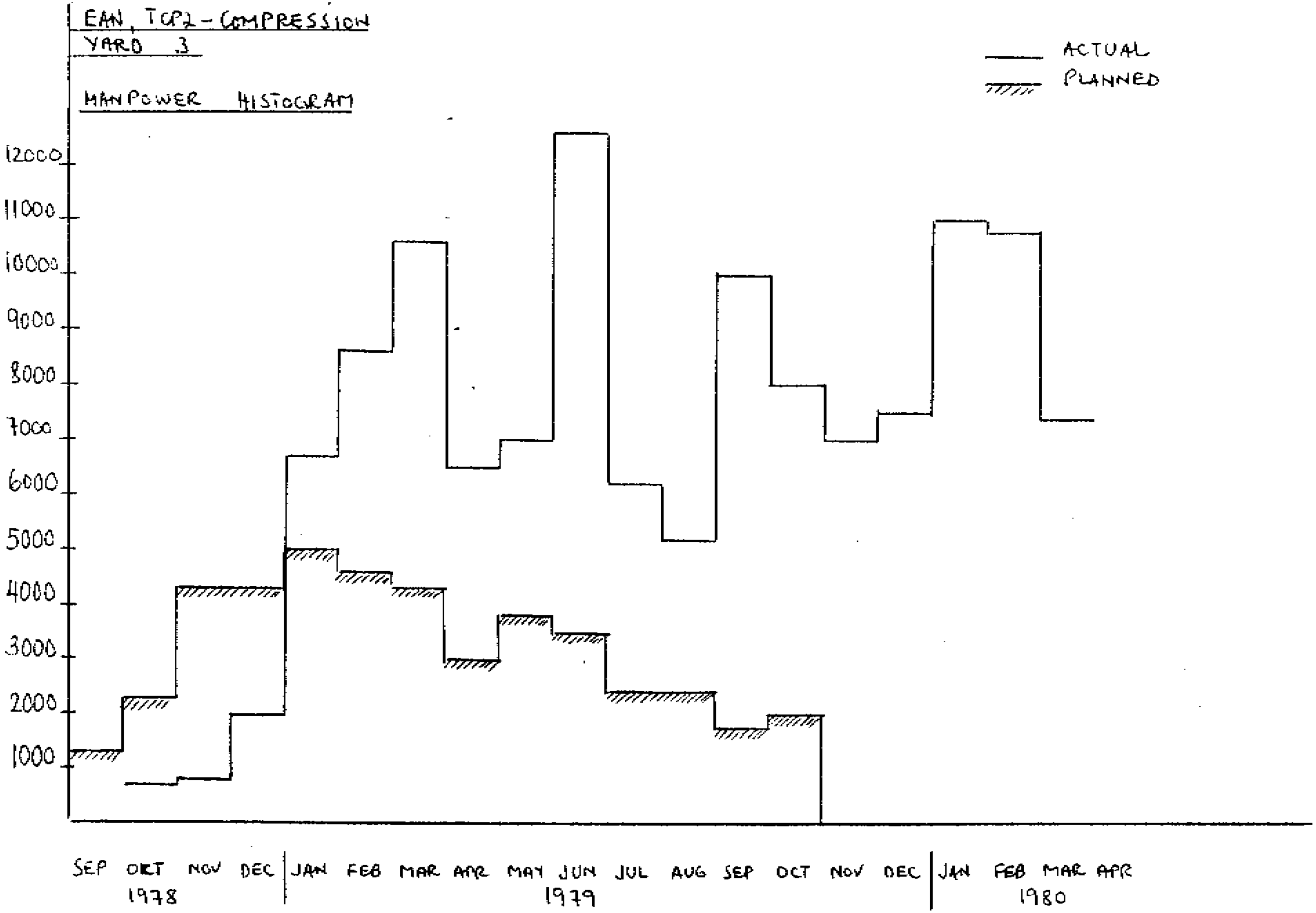
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR
1978
1979
1980



PLANNED	1280	2240	4320	4320	4960	4640	4320	3040	3800	3520	2400	2400	1760	2000							45000
ACTUAL	—	700	800	2000	6700	8600	10600	6500	7800	12600	6200	5200	10000	8000	7000	7500	11000	10800	7400		128600

4.5 Report on construction of off-site facilities.

Some construction were undertaken in 1979 in order to build temporary pancakes such as:

- one office and ware-house module (M. 948)
- two pancakes for storage areas (P. 945 and P. 946)

M. 948 was designed in order to provide office space (165 m^2) lavatories and toilets, and heated warehousing (107 m^2) from the very beginning of hook-up works.

Its use is valuable as it saved the installation and hook-up of several office containers during the hook-up and start-up works, and it is still used as a permanent facility by the field operators.

P. 945 and 946 are flat storage areas designed to fill in the empty spaces at the main deck level of the support frame and provide storage areas for heavy equipment.

Construction started at HJELMELAND, small construction site in STAVANGER area. The work was hampered by the Contractor bankrupcy at the beginning of 1980. EAN succeeded in removin what was erected, and committed MARITIME GMC to complete the work in due time.

4.6 General comments.

Very serious difficulties were encountered on the yards during the onshore construction period for several main reasons.

4.6.1 The yards were opened in September 1978 when the progress in drafting given by KE/TP was estimated at: 61,2%.

In fact this figure was completely wrong due to a large underestimate of the engineering work and the opening of the yards was done with a total progress in drafting less than 40% mainly for structure and piping.

4.6.2 The planning proposed by KE/TP for completion of the engineering work was never respected. A permanent slippage was noticed in spite of numerous actions against the engineering management.

In the same time the quality of the document was very low and we had to check in detail the final issue. The consequence of a such situation was a permanent uncertainty for ordering the right material, in quality and quantity, with the evident delays in the deliveries and the impossibility for the yards to prepair and organize their work correctly, without the final documents available and accurate knowledge of the material received.

4.6.3 The contractual delivery date for the three yards was November 1st 1979 at the latest. With this schedule a maximum of the works should have been done in the summer season allowing a better productivity. Due to the delays in engineering and procurements many extra difficulties were encountered for welding, cables pulling, hydrotest, sand blasting and painting in outside location with bad weather conditions.

4.6.4 The contracts were awarded to the contractors on a lump sum basis for the works which were defined at that time, knowing that some supplementary works would be added later on. These additional works not covered by the lump sum price or due to changes were included in a unit rates list, including all subjections.

This was theoretically perfect and motivating, if the scope of work was clearly defined and the amount of the extra works remained at an acceptable level in front of the lump sum works, which could be organized in the most efficient way by the contractor.

In fact the insufficient definition in the call for bid, a wide underestimate of the work, the delays for engineering completion, the changes in electricity and instruments or delays in material deliveries, created very serious disturbances in the normal progress. The result was a big amount of claims, more or less justified, and a lot of time was spent in detrimental discussions for a good atmosphere on the yards, without a satisfactory agreement.

4.6.5 The splitting of the onshore construction in three yards located at a long distance from Stavanger created a lot of extra difficulties:

- dispatching of documents, materials and equipments
- necessity of a careful coordination in order to guarante the coherence and compatibility between the elements built in different places.
- uneasy communication.

4.6.6 The performances of the yards for the general organization of the work were very low:

- lack of management and underestimate of the job
- poor coordination interdisciplines
- questionable skill of manpower in certain cases
- very bad preparation of the work
- incapacity to perform the detailed engineering as foreseen.

- follow-up of material arrivals on site, storage and delivery for erection totally inadequate and badly managed.

The negative effect of the reasons here above mentioned was less perceivable on the small yards, 2 and 3, where the EAN team was more integrated in the contractor team who accepted comments and advices easier than the yard 1.

4.6.7 As a conclusion one can say that it was probably too much ambitions to manage properly a lump sum contract with a widely insufficient definition of the scope ow work at the call for bid stage, the contractor's capabilities and turn of mind. The permanent slippage in engineering was an additional factor giving the contractors the possibility of contestations which was used at a maximum level in spite of all efforts made by the EAN teams which were initially organised for quality and progress control only.

This was proved by the improvement obtained when the form of the contract was amended and the work completed on an hourly rate basis, allowing a more directive function to the EAN staff and the peace of mind to the contractors on their productivity wise or costwise.

5. TRANSPORT AND LIFTING

The towing from the yards to Frigg, the preparation of TCP2 platform, the lifting and installation of 4 modules and 9 main pancakes for a total weight of about 5000 tons have been managed by the EAN Offshore Construction Department in Stavanger.

5. REPORT OF OPERATION

5.1 PRECALL FOR BID

5.2 CALL FOR BID

5.3 LIFTING ENGINEERING

- a) Padeye
- b) Rigging arrangement
- c) Rigging platform
- d) Tugger padeyes
- e) Cleaning
- f) Positioning

5.4 TOWING AND LOAD OUT ONTO CARGO BARGE

- a) Grimstad
- b) Kristiansand
- c) Hjelmeland
- d) Orkanger
- e) Weighing

5.5 LIFTING OPERATION

- a) Onshore lifting
- b) Offshore lifting

5.6 DESCRIPTION OF PACKAGE

- a) 32
- b) 30.31.33
- c) 41
- d) 42-43
- e) 40-44-45
- f) 46-63.1-63.2,40-1,40.2

5.7 POSITIONING RESULT

5.8 GENERAL COMMENTS ON THE PROJECT

5.1 PRECALL FOR BID:

A precall for bid was sent on February 23th 1979, in order to have a first selection of the barge able to perform the lifting of the module 32 which was the most critical compression module to be lifted (due to its weight, its volume, its rigging arrangement).
No satisfactory result came out the different bidders answers, but nevertheless after analysis the different answers we came across the following points.

a) if a SSCV was used, the 4 modules could not be skidded onto their final position.

b) if a conventional vessel used the Aker crane had to be lifted separately to module 32.

By May the 10th complementory informations about skidding procedure were asked to the bidders who intend to skid the module in final position.

5.2 CALL FOR BID

The call for bid was sent on June the 20th and the answers was requested at the latest on July the 27th 1979.
The different lifting company contacted were ETPM - MICOPERI - UGLAND - BROWN AKER - NOC - OCEANIC - HEEREMA.

ELF did not find any satisfactory answers (due to some missing points in the paragraph called "Lump sum rates" and due to too many qualifications). It was then decided that a second round was to be sent to bidders on August 15th 1979. The answers were requested for end of that month.

The comparative study of the bid showed that Heerema and this submersible crane vessel "Balder" 5000^T lifting capacity, 8000^T deck capacity, was the most qualified bidder to perform our work.

The order to start engineering was sent to Heerema on November 6th 1979 and the final contract was signed on January 8th 1980.

5.3 LIFTING ENGINEERING:

a) Padeye:

The calculation note of the padeyes has been performed by ELF and HEEREMA approved the design (Thickness - hole diameter) during the meeting held on December 12th 1979.
HEEREMA according to the COG location given by chart PEA 00001 B gave us the padeye angle as follows:

Module 32.42.43	padeye release on December 19th 1979.
Module 46	padeye release on December 19th 1979.
Module 41.45	padeye release on December 13th 1979.
Module 44	padeye release on January 7th 1980.
Module 40	padeye release on January 16th 1980.
Module 30.31.33	padeye release on January 18th 1980.
Module 948.945.946.	the sling arrangement proposed by ELF was accepted by HEEREMA on December 12th 1979.

b) Rigging arrangement:

Based on COG and weight according to chart no. PEA 00001.B The rigging arrangment for modules 30.31.32.33.40.41.44 and 45 was given by HEEREMA during meeting on February 2nd 1979. The spreader frame calculation note for modules 32.41.43. was given to ELF on March 3rd 1980 and approved by NDA on March 13th 1980. Design criteria used by ELF for the calculation of rigging gear.

Safe working load = 2,15 static load.
Design criteria used by HEEREMA for the calculation of spreader frame bea - sling.

P lifted : 1,2 static P
Safe working load = 75% of the P lifted is taken on one diagonal.

i.e.: The figure given by the 4 padeyes of one package is a scare. The COG is at the geometric center of the 4 padeyes.

Load to be considered in the design

ELF: Load in one padeye

$L = \frac{P}{4} \times 2,15 = 0,54 \underline{P} = SWL$

HEEREMA:

$L = \frac{1,2P}{2} \times 0,75 = 0,45\underline{P} = SWL$

c) Rigging_platform: needed only for module 30.31.33.

They were defined by HEEREMA during the meeting held on 02.02.80 and approved by HEEREMA in the meeting held on 07.03.80.

d) Tugger_padeyes: accepted by HEEREMA during the meeting on 07.03.80.

e) Cleaning: HEEREMA gave ELF the preliminary procedure during the meeting on 16.01.80 and the final procedure was included in the operation manual.

f) Positioning: ELF supplied HEEREMA with the as built survey of the support frame, the as built survey of each module, and the theoretical position as ELF wanted to have the modules onto TCP2 support frame HEEREMA accepted during the meeting on 02.02.80 the principle of the feasibility study to position the modules with in the accuracy of ± 25 mm and then decided to use stabbing guides welded underneath the packages.
The final positionning of these stabbing guides was included in the operational manual.

5.4 LOAD OUT ONTO CARGO BARGE AND TOWING.

The load out was under construction yard responsibility.
The yard had to supply the skidding beams till the quay and had to supply as well if necessary the articulated beam between the quay and the cargo barge.
The cargo barge was supplied by the lifting Contractor.
The skidding beam onto the cargo barge was supplied by the lifting Contractor.
The calculation note of the sea fastening was performed by HEEREMA. The prefabrication and installation of the sea fastening was under HEEREMA responsibility.

a) Grimstad:

The barge H107 from HEEREMA arrived at Grimstad on January 3rd 1980. The load out procedure was done by OIS. The first module (42) was loaded by skidding it on teflon shoes on 28. The 2nd module (43) was loaded by skidding it on teflon shoes on 29. The pulling devices was 2 air winches on board the flotting crane, no articulated beam was used.
The module 45 was loaded by means of 1 floating crane "Flevick" and the pier crane of the yard on January 31st 1980.
Packages 63.1, 63.2, were loaded by the pier crane on January the 31st. Package 46 was loaded by the pier crane during the first half of February. The calculation note of the seafastening was issued by HEEREMAon December 16th 1979.
The seafastening calculation note was approved by Noble Denton during meeting held in Stavanger on January the 11th 1980.

The barge H107 left Grimstad to Kristiansand on March 16th 1980. The towing tug was the "Bever" 60^T bollard pull. The barge arrived at Kristiansand the same day in the afternoon but due to heavy ice in the dry dock the barge was driven into the dry dock on March 19th only.

b) Kristiansand

The load out procedure was done by Øgrey.
The 3 modules were loaded by skidding them on teflon shoes. The pulling device was 2 electrical winches, (fixed on the opposite quay) equipped with 50^T wire, one 1,5 m long articulated beam was used.
The pancake 41 was loaded on March 26th 1980.
The pancake 44 was loaded on March 28th 1980.
The pancake 40 was loaded on March 31st 1980.

The LP vent stack was loaded by lifting it onto the cargo barge, HEEREMA calculation note of sea fastening was issued on January 16th 1980, and approved by Noble Denton on February 4th 1980.
The barge H107 left Kristiansand on May 9th 1980 and arrived in Stavanger on May 10th 1980 at noon.
The towing tug was the "Fairplay 9" 57^T bollard pull.

c) Hjelmeland

Due to the bankrupcy of Hjelmeland Industri, the modules were loaded on March 13th 1980 onto the cargo bare "Maersk 7" in order to be towed to the Maritime GMC yard where they were finished to be built.

d) Orkanger

Load out procedure was done by Spie Batignolle - Vigor.
The barge H108 arrived in Orkanger on April 14th 1980, but was expected on April 8th. The towing tug the "Helgeland" was only 2130 BHP, and here is the reason of this late arrival.
The modules 30.31.32.33 were loaded by rolling them on a a system of roller box. The pulling device was 2 hydraulic winches, one 5 m long articulated beam was used.
Module 30 was loaded on April 17th 1980.
Module 31 was loaded on April 21st 1980.
Module 32 was loaded on April 24th 1980.
Module 33 was loaded on April 29th 1980.

HEEREMA's calculation note was issued on February 4th 1980 and approved by Noble Denton on February 2nd 1980.
The barge H108 left Orkanger on May 10th 1980 at 3 p.m.
The towing tug was "Wrestler" 6000 IHP, 65^T bollard pull.
The barge arrived in stavanger on May 13th 1980 at 16.00.

e) Weighing of module on yard:

The result of the weighing is shown on sketch no 5423 W 10.18.SK. in the column called "Final lifting weight before towout".

Grimstad:	Weighing was done during week 10
Kristiansand:	weighing was done during week 12
Orkanger:	weighing was done during week 13

5.5 LIFTING OPERATION:

a) Onshore lift

The 2 barges H107 and H108 were alongside the quay of Norsea base in Dusavik.
The "Maersk 7" was alongside Maritime GMC quay on Saturday May 10th, the HEEREMA tug "Njord" towed the "Maersk 7" alongside the "Balder". The packages 948, 945, 946, beam for 947, were loaded on board the "Balder". The "Maersk 7" was demobilized on Staruday evening 10.05.80. On Thursday 15th, the "Njord" towed the H107 alongside the "Balder". All the packages were loaded onboard the "Balder". The H107 was demobilized on May 17th 1980.
On Friday afternoon May 16th, the barge H108 was brought alongside the "Balder". The 4 modules 30.31.32.33. were loaded onboard the "Balder". The barge H108 was demobilized on May 19th 1980.
The "Balder" was anchored in the Byfjorden in front of ELF office.

LOADING ONTO "BALDER" SEQUENCE:

	Module	Date	Time		From barge
1	948	10.05.			Maersk 7
2	945				"
3	946				"
4	42	15.05.		13hoo	H107
5	43	15.05.	4h30	17h30	"
6	45	15.05.	10h00		"
7	46)	Night			"
8	63.1)	15 to			"
9	63.2)	16			"
10	LP vent				"
11	40.1				"
12	41	16.05	10h30	11h15	"
13	44	16.05.	13h00	13h30	"
14	40	16.05.	17h00	18h00	"
15	Manitowoc				
16	31	17.05.	23h00		H108
17	30	18.05.	12h00	12h30	"
18	32	18.05.	14h00	14h30	"
19	33	18.05.	15h30	16h00	"
20	40.2	18.05			

As at the time of the loading of module onto the "Balder" all the slings expected to be used were not available some modifications in the rigging were done.
The 4 modules from Orkanger were lifted horizontal.
All the pancakes were lifted with an angle:
- due to a mistake in the rigging for 41. 42. 43.
- due to COG location for 45-40.

During the towing to Frigg field, the result of the first lift (loading on board the "Balder") was integrated in the rigging calculation note of the tilted packages and some modifications were done in the final arrangement in order to have a horizontal lifting offshore.

The removal of anchors in the Byfjorden started Thuesday morning May 20th. The "Balder" left Stavanger to Frigg on May 20th at 13h00 p.m. The "Balder" arrived at Frigg on May 21st at 2 p.m. The running out of anchors was completed at 10h00 p.m. The barge was alongside TCP2 ready to work, on May 22nd at 00h00 o'clock.

b) Offshore lift

OFFSHORE LIFTING SEQUENCE:

Module	Day	Time		Weight *(given by load indication of crane (incl. rigging))
32" valve	22.05.	9h35		
46	22.05.	13h55	14h40	82
40	23.05.	6h21	7h44	141
948	23.05.	8h40	8h55	198
41	23.05.	15h55	16h30	548
947	23.05.	19h00	19h16	68
43	24.05.	2h30	2h45	230
942	24.05.	13h25		
42	24.05.	14h25	13h55	525
44	24.05.	19h30	14h45	140
969	24.05.	20h25	19h42	120
63.1	24.05.	20h25	20h40	27
63.2	24.05.	20h55	21h25	25
945	24.05.	21h40	22h00	50
45	25.05.	10h35	11h00	115
32	25.05.	18h10	19h15	1172
33	26.05.	1h00	1h37	802
31	26.05.	2h45	3h00	809
30	26.05.	5h00	6h30	836
946	26.05.	8h50	9h00	
40.1 40.2	26.05.	9h40	9h45	
manitovoc	26.05.	17h15	17h25	168

*I will recommend to consider the weigh given above as an indication only and to use the weight given by weighing as the official one.

5.6 DESCRIPTION OF PACKAGES

You will find after on the 3 sketches the rigging arrangement which was used, package by package.

a) Module 32

The padeyes were located at lower deck level.
4 vertical slings - 1 spreader frame - 4 tilted slings were used. Due to the position of the padeyes this module was the first of the 4 big modules, to be lifted.
After the positioning of module, the padeyes and the padeye protection had to be cut before starting the lifting of modules 31 and 33.

Guiding syste:

- In the north - south direction the guides was done by means of bumpers welded on the steel support frame reinforcements.
- In the east - west direction the guiding was done by means of stabbing guides.

b) Module 30-31-33

The padeyes were located at the upper deck level.
4 tilted slings were used.
The design of the padeyes and the clearance between the modules were the reason why module 32 was damaged during the lifting of module 31 and 33.
Some small items as cable tray - speaker - electrical junction box were damaged during the removal of the slings.

Guiding system:

- In north - south direction the guiding was done by using the module already lifted on one side and by using a bumper on the other side.
- In the east - west direction the guiding was done by using stabbing guides undereath packages.

c) Pancake 41

The padeyes were located at roof level. One spreader frame temporary included on the roof was used to lift this package 4 tilted slings were then used.

Guiding system:

- The first guiding was done by means of 4 channel guide. The clearance between pancake and channel guide was ± 60 mm.
- The final guiding was done by means of stabbing guides welded underneath the pancake. Clearance was ± 25 mm.

d) Pancake 42-43

The padeyes were located at the lower deck level. 4 vertical slings - 1 spreader frame - 4 tilted slings were used. The first and final guidings were done by using the same system as for PC 41 but the channel guides installed by HEEREMA were too small and so were useless.

e) Pancake 40-44-45

The padeyes were located at the lower deck level. 4 inclined slings - 1 spreader beam + 2 inclined slings were used.

Guiding system:

- For the first guiding of pancake 44 only the channel guides were used but it was not a success because of interference between shackles and SSF upper beam. Pancakes 45 and 40 were lifted without these channel guides.
- The final guiding was done by means of stabbing guides.

f) Pancake 46-63.1-63.2-40.1-40.2

Lifted without any guiding system.

5.7 POSITIONING RESULT

All the compression packages were lifted within an accuracy of ± 25 mm but for module 31 which is out of 20 mm.

5.8 GENERAL COMMENTS ON THE PROJECT

PRELIMINARY

Four main points further to the performance of the lifts can be retained:

- Lifting pre studies were done late compared to the evolution of the compression project despite the efficiency of the structural engineer who was not a lifting specialist.

- Engineering and lifting procedures were performed by the lifting contractor which is a cheap solution on one hand but implies a risk associated with a lump sum contract on the other hand.

- The lifting contract on lump sum basis, left the contractor with too much freedom of choice.

- The lifts performed by such a perfect tool like "Balder" has balanced a weak engineering.

1. LIFTING PRE STUDIES

They have started within ELF Aquitaine Norge end 1978 for an installation late spring 1980.

Even then:

- The structural part of the modules
- The positions of super structures
- The positions of the lifting padeyes

were freezed at this date.

These pre studies have shown that:

- Construction of spreader bars and spreader frames were required to adjust the position of the lifting pad eyes at the deck bottoms.

- Position of some equipment has to be altered to avoid interferences with the slings. In spite of these precautionary measures some equipment were damaged at the upper part of the modules.

- Installation of the slings on the yard for the pancakes had not been possible without adding huge temporary structures.

  Taking into consideration the above comments it would be advisable to get expertise from a lifting specialist at the design phase in order to study all questions connected to the lifting operation (skidding, transportation, lifting etc...).
  This procedure should normally avoid solutions which would make hazardous operations.

2. <u>LIFTING - STUDIES</u>

2.1 The detailed engineering was done by the lifting contractor (HEEREMA). This engineering was done in a way to minimize the cost of the operations (included in the lump sum).
It must be emphasized that at the time of the call for tender, some critical points have to be included in the technical specifications such as "in yard" slinging in order to avoid too many operations.

2.2 In the frame work of the lifting contract a significant part of the engineering was conditioned by preliminary studies provided by ELF Aquitaine Norge (weights, position of the centers of gravity, measurements on platform and modules).

In order to avoid difficulties and delays during the progress of the engineering, it seems desirable but difficult to bring into operation to make the lifting contractor responsible of all matters concerning weights, position of centers of gravity, measurements control...
This difficulty is due to the fact that the construction contract is different of the lifting contract.

Should a solution be investigated during the conduct of a project the best could be to subcontract these matters (weights, position of the centers of gravity, overall dimensions etc.) to the lifting contractor.

2.3 Technical comments.

2.3.1 Do not wait recommendations from the lifting contractor to secure and protect our equipments.

2.3.2 As far as it is possible, do not install padeyes on the bottom deck of the modules (ref. photograph of mod 32).

2.3.3 The spreader frames must be avoided. They could be replaced by temporary compression bars integrated to the modules.

2.3.4 External equipment compared with respect to the partition walls of the modules must be eluded.

2.3.5 The rigging platforms must be over sized in order to better protect the surrounding equipments.

2.3.6 The equipment have to be protected against the possible swinging of the slings during slinging and de-slinging operations.

2.3.7 The modules must not be set too near from each other (30 cm is a too much constraint).
The width of the modules and the dimensions of the various adjusting pieces shall take this constraint into consideration.

3. <u>CONTRACT S.940 (EAN - HEEREMA)</u>

This contract written with general specifications left the lifting contractor with a freedom of choice. On the other hand this had avoided the marginal costs and possible claims and in addition has allowed the closure of the contract immediately after the end of the operations.

Furthermore the three hereunder considerations have made easier the execution of the contract:

3.1 All safety aspects very detailed in the contract have left the lifting contractor with no possibility to read the rules (NPD rules).

3.2 The "Warranty Surveyor" clause have made HEEREMA dependent upon Noble Dentor decisions through Elf Aquitaine Norge.

3.3 The lifting contractor was fully responsible for the sea fastening of the modules on the cargo barges: No cost argument has occured between EAN and the construction yards what so ever.

Possible improvements:

- Insurance and responsibilities:
  HEEREMA has refused to be responsible of the possible damages of which the cost of repair is under the accidental damage excess in spite of our long negociations to include this clause. In fact each time we are facing this problem with a skilled contractor there is no possibility to have this clause written in the contract.

- The skidding and loading of the modules on to the cargo barges was entirely managed by EAN for each yard.
  A late delivery to the lifting contractor for transportation and offshore lifting could therefore occur in case of failure. A particular clause shall be written in the contract to cover this purpose.

4. OPERATIONS

The choice of the lifting contractor must be connected with the quality of the derrick barge proposed.

The engineering made by HEEREMA onshore was sharply criticized by the operational people of the Balder.
This is quite usual, and the coordination between engineering and operation is always difficult.
Nevertheless, in spite of the fact that the contract is on lump sum basis it should be well advised to call out some coordination meetings during the engineering phase and two months before the

operations. Perhaps it's a quick wish.

The difficulties encountered during the lifts were mainly due to:

- Complicated slinging arrangments of the modules

- Position precision on the platform with an accuracy out of the usual range (± 1 in)

- Direct installation of the modules too near from each other (10 inches) and were overcome by the quality of the Derrick Barge and the skilled personnel.

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We can summarize the main features of the "Balder":

- Semi submersible crane vessel with very high stability capable to work with significant swell and wind.

- Large deck area which allows the loading of the modules. All the modules were loaded "in fjord" on the Derrick Barge.

- Large lifting capacity with 2 cranes (one module on lift, the other under preparation).

The enclosed report will summarize the whole operation from March 1979 to May 1980.

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5. <u>TRANSPORT AND LIFTING.</u>

INDEX OF PICTURES

1. TCP2 platform without compression facilities

2. Skidding module 32 - Yard 1 - Orkanger

3. Modules 30, 31, 32, 33 on the barge H108 - Stavanger

4. Pancakes 40, 41, 44 on the barge H107 - Stavanger

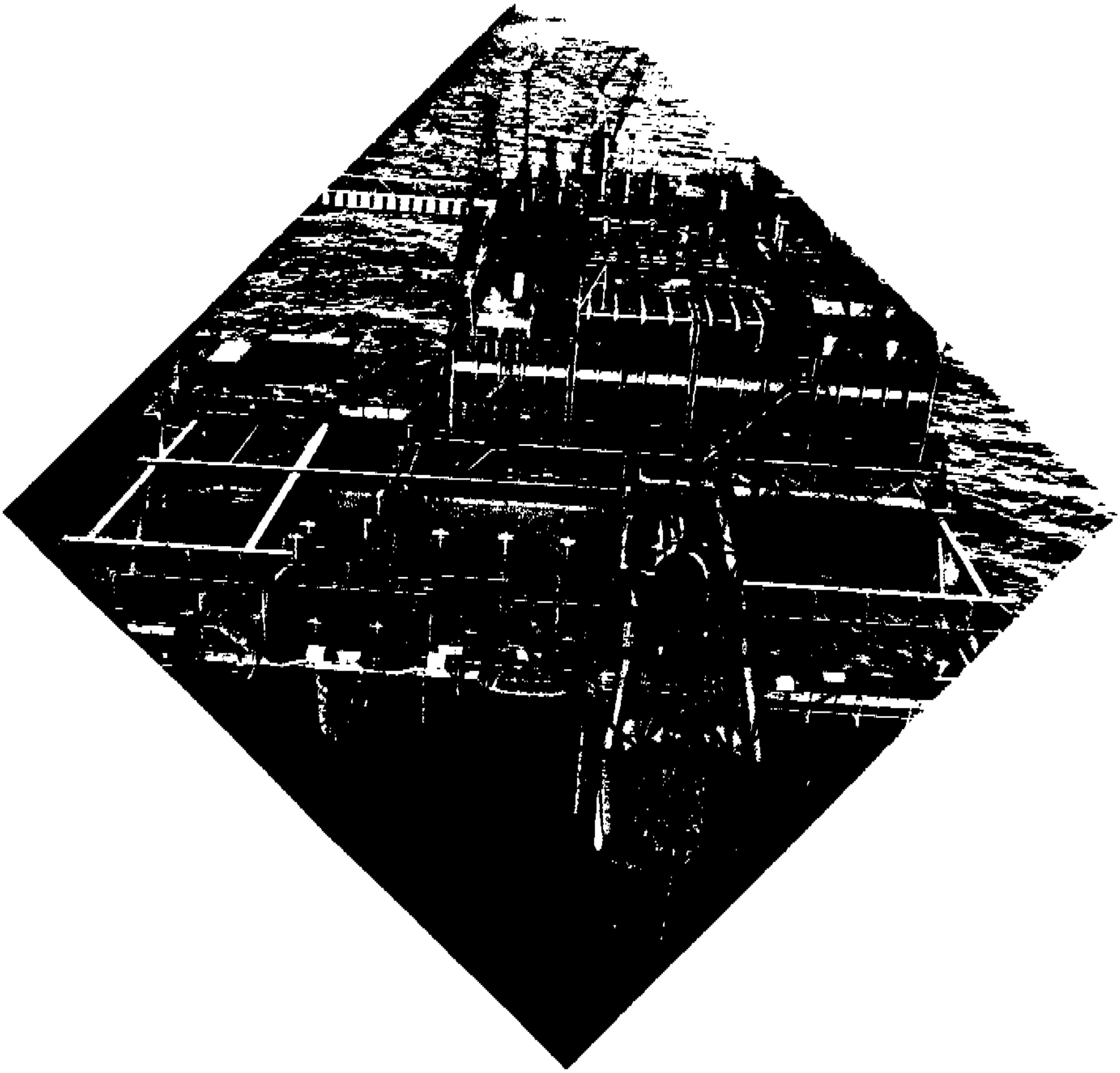
5. "Balder" in the fjord before loading - Stavanger

6. Bumpers for module 32 - Frigg

7. "Balder" in position at Frigg

8. Lifting module 32 - Frigg

9. Lifting pancake 42 - Frigg.



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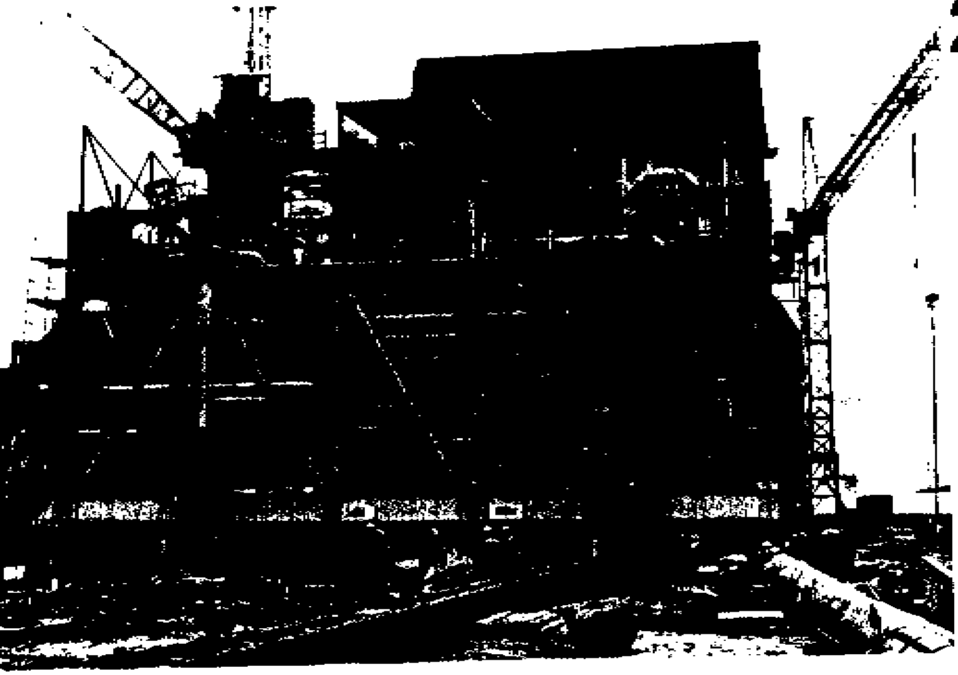
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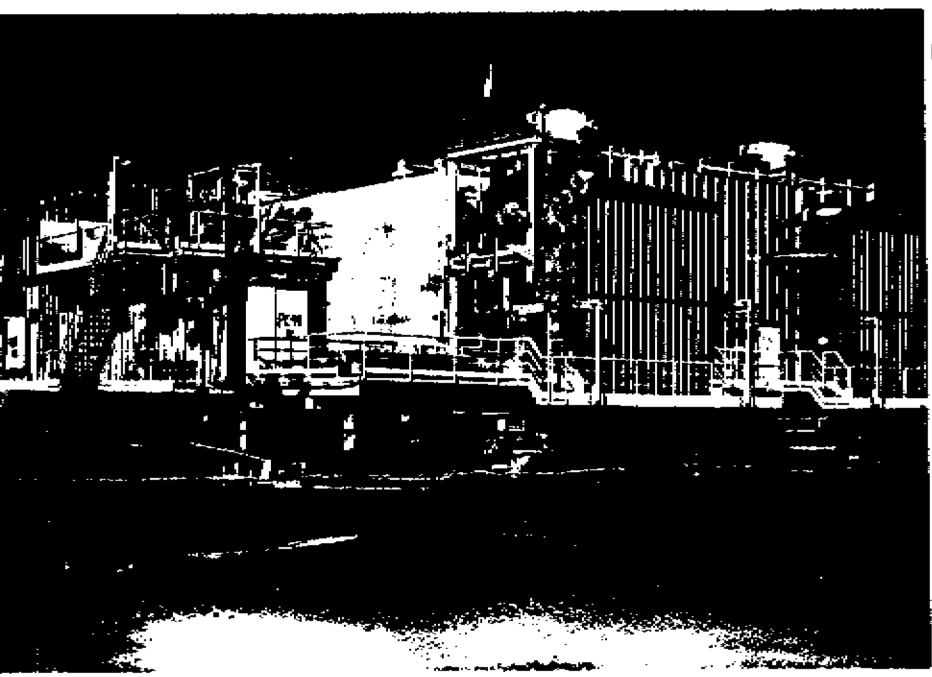
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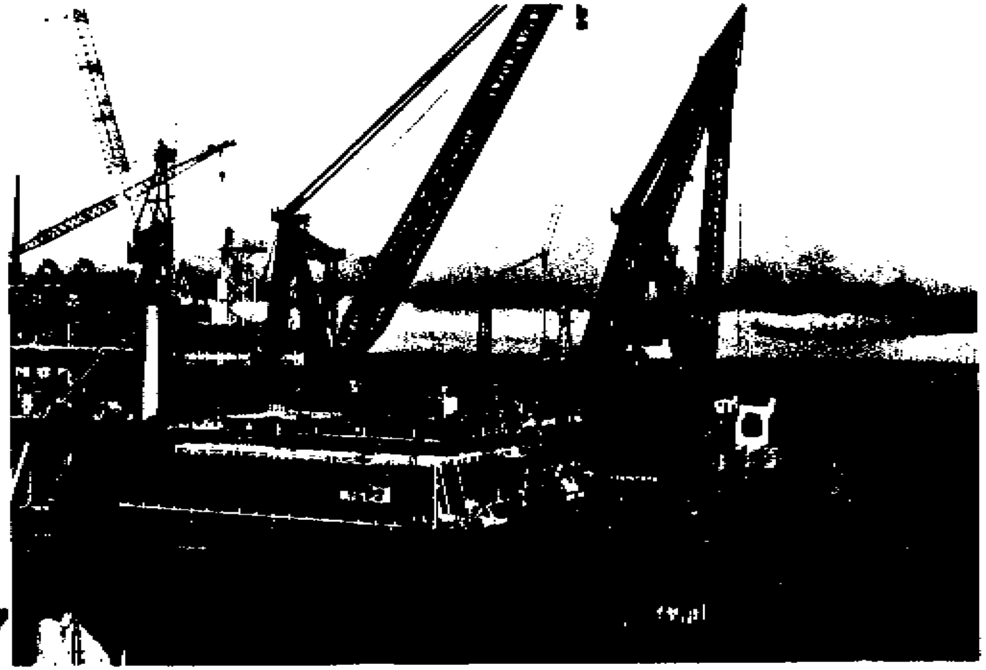
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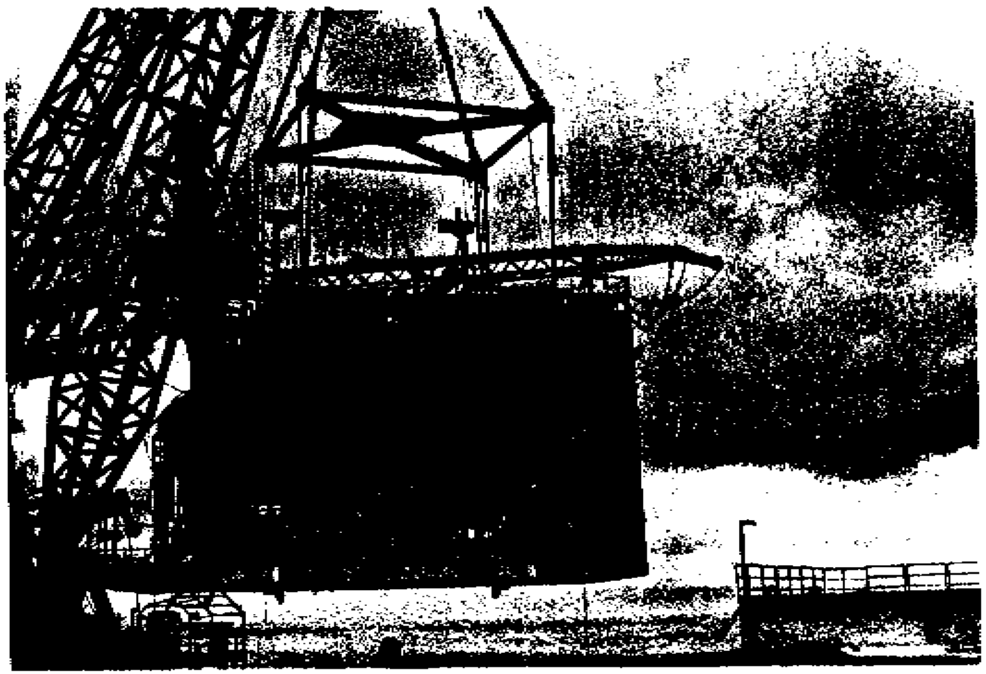
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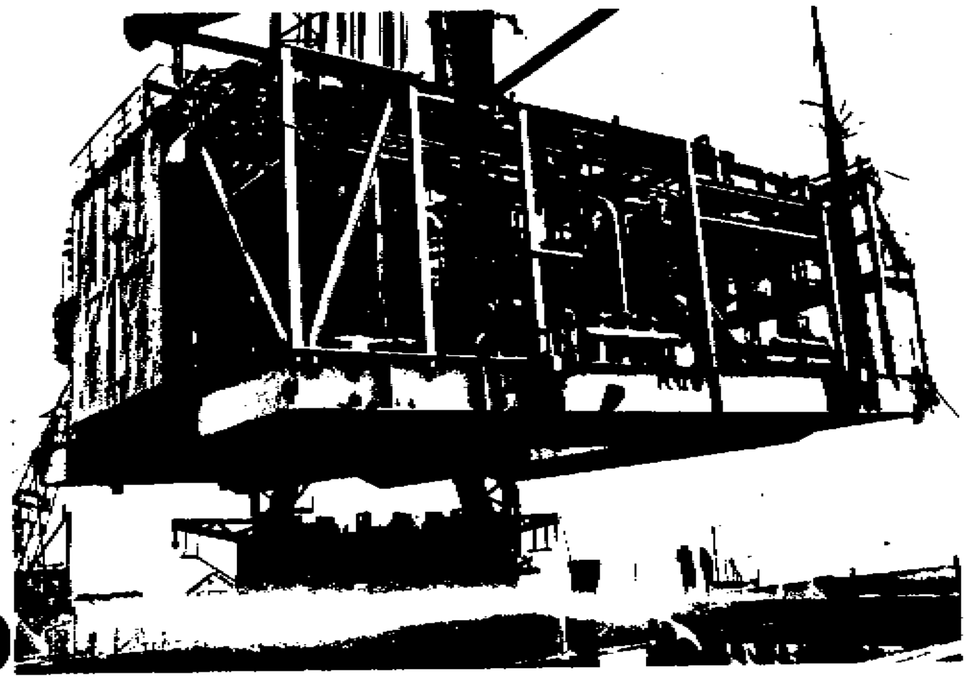
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