DRAFT

ELF AQUITAINE NORGE A/S

FRIGG FIELD DEVELOPMENT

PREPARED BY :

ELF AQUITAINE NORGE

WITH THE ASSISTANCE OF :

TECHNIP - GEOPRODUCTION, FRANCE.

SUMMARY

CHAPTER I

ABSTRACT

1- LARGEST OFFSHORE GAS FIELD DEVELOPMENT

The Frigg Field, discovered in 1971, besides being the world's largest offshore gas-field, with proven reserves of almost 270 x 10^9 std m^3, is located in an extremely unfavourable natural environment : it is distant from the coasts (190 km from Norway, 190 km from the Shetland Islands, 360 km from Scotland) and is situated in the open Northern North Sea, where sea conditions are severe and the weather window for carrying out marine installation work is reduced to few months a year.

Furthermore, the field extends over both sides of the Norwegian-British boundary, involving two groups of partners. The developers of the field had to tackle the difficult problem of how to split the reserves between the two countries, and a number of complicated problems arose in connection with the development of the field and the landing and utilisation of the gas. An independent expert was engaged to make a proposal regarding the split of the reserves. The results of his studies, (60.82 per cent of the Frigg reserves lying on the Norwegian side and 39.18 per cent on the British side), were accepted by all the partners and by the authorities of the two countries.

In 1973 the licence holders on both sides of the median line agreed that all the permanent installations on the field should be built, operated and financed as one unit. ELF Aquitaine Norway was appointed operator for this part of the project. The decision to develop the British part of the field was taken in July 1973 and the Norwegian part one year later, following negotiations for the sale of gas to British Gas Corporation (B.G.C.) and, agreement with British, then Norwegian authorities.

The development program was launched, with the decision to build the first drilling and production platform, DP1, to be followed by 4 other platforms, 1 flare, and interconnecting flowlines and cables.

To adhere to the overall development schedule, engineering and construction had to be scattered among various engineering contractors and fabrication yards in Europe.

Things were further complicated by the financial instability prevailing in Europe during that time, so that existing cost control techniques to cope with inflation and unstable currency exchange rates had to be reviewed.

The related organisation and management tasks were enormous and involved a great industrial effort in which Norway took an important role. Field installation activity, which started in 1975, reached its peak in 1976 and 1977, enabling the completed and tested facilities to deliver commercial gas to Britain before the contractual date of October 1, 1977. More than one word would deserve to be spent on the tremendous human effort that was the keystone of this success, much more so because the timely achievement of a project of such magnitude is not so commonly seen in the difficult North Sea Theatre.

Technical innovations played an equally important role : first, a combination of difficulties due to unconsolidated sand reservoir and extremely high well production had to be overcome, for which a specific knowhow, unavailable at that time, had to be acquired.

Secondly, various skilled solutions and technological innovations, showing EAN'S pioneering attitude and creative vocation, have boosted the steps of development : use of a concrete drilling platform ; use of an articulated flare ; use of the pulling method for tying flowlines to concrete platforms ; hyperbaric flowlines welding ; new seismic and satellite localisation techniques ; development of sophisticated steel support frames ; self-erection of modules dispensing from the use of a derrick barge, ...

Also from the professional point of view, Frigg has been an important achievement : operations are now run by the same personnel who were involved in the early stages of commissioning and testing of the facilities and therefore the qualitiy of the knowledge they acquiered contributes towards safe exploitation.

The Norwegian personnel, after meticulous training contribute greatly to the successful running of the operations.

FRIGG | FRIGG FIELD IN NORTH SEA

2 - CONTENTS OF THE REPORT

This report is divided into 7 chapters :

-=-=-=-=-=-=-

CHAPTER II

DISCOVERY OF THE FIELD

1 - HISTORY OF SNEA (P) NORTH SEA EXPLORATION

It was the prospect of finding natural gas which first set off the international off-shore search for petroleum in the North Sea during the early 1960s. The discovery of a series of major gas fields in the southern part of the U.C. North Sea, off Lincolnshire and East Anglia, first proved that major accumulations of hydrocarbons existed off the coast of North-West Europe and enabled the gas industry in Britain to revolutionize its supply base and market possibilities.

As the search moved north, off the coasts of Scotland and Norway, even greater accumulations of both oil and gas were found. SNEA (P) and Total were themselves pioneers in the exploration of the prolific Viking Graben in the treacherous seas between the Shetland Islands and the west Norwegian coast. And it is Elf and Total's discovery and development of the Frigg gas field in such basin which was to provide a crucial new boost to the British Gas Corporation's supplies and to open a new and important chapter in the history of gas in the North Sea.

2 - THE AWARD OF BLOCKS 25/1 AND 10/1

When the second Norwegian licensing round took place in 1968-69, the oil companies had only a rudimentary knowledge of the Northen North Sea area, most companies having only sparse or incomplete seismic grids. A more detailed study of the Frigg area was persued, and as this study indicated the presence of a large structure, the Petronord Group (Elf Aquitaine, Total and Norsk Hydro) decided to apply for the Norwegian blocks 25/1 and 25/2.

With a five percent state interest, the group was awarded the two blocks in 1969. A year later the TOM Group was awarded the neighbouring block 10/1 on the U.K. side of the border line. Of primary interest to the geologists and geophysisists was a large "beautiful" structure which today is made up of the finds Frigg, Odin, North East Frigg, East Frigg and South East Frigg. At that time it was thought to be one continuous structure and the sand in this formation was identified as Eocene sands.

3 - THE DISCOVERY

The first well was spudded on April 2, 1971 by the Operator Elf on the Norwegian block 25/1 awarded to the Petronord group. The rig used was "Neptune 7", which in June encountered gas then oil. The well 25/1-1 was completed on July 22, 1971, and through a 5/8 inch choke, the well produced 23,8 million standard cubic feet of gas per day : Frigg was discovered.

"Neptune 7" continued with a second well (25/1-2) spudded on July 23 and plugged in August 25, which was a confirmation of the Frigg Field.

On December 31, 1971 the rig "Ocean Traveler" spudded the first well on block 10/1 in U.K. waters but this well was to be abandonned on February 8, 1972 due to a storm and "Ocean Traveler" spudded a new well on February 27.

This well 10/1-1A came in as a gas producer in late April and was plugged as a confirmation of the Frigg discovery, on May 7, 1972, proving that the Frigg structure extended over the median line.

The Frigg field was then the most northerly known petroleum reservoir in the North Sea.

-=-=-=-=-=-=-

4 - THE ASSOCIATIONS

The above discovery made it clear that the Frigg field straddled the border line between U.K. and Norway. Consequently the development of the field involved two Associations :

a) U.K. Association for the 10/1 block

French Group (100 %)

. ELF AQUITAINE Group, represented by :

- ELF OIL EXPLORATION AND PRODUCTION (U.K. Ltd) 4/9

- AQUITAINE OIL (U.K.) Ltd 2/9

. TOTAL Group, represented by :

- TOTAL OIL MARINE Ltd (operator) 3/9

FRENCH INTERESTS 100 %

b) Norwegian Association for the 25/1 block

Franco-Norwegian Petronord Group (95 %)

. ELF AQUITAINE Group represented by :

- ELF NORGE A/S (operator) .... 27.613 %

- AQUITAINE NORGE A/S 13.807

. TOTAL Group, represented by :

- TOTAL MARINE NORSK A/S .... 20.710 %

FRENCH INTERESTS 62,13 %

. NORSK HYDRO A/S...................... 32.870 %

OTHER INTERESTS (5 %)

- DEN NORSKE STATS OLJESELSKAP (STATOIL) .... 5.000 %

NORWEGIAN INTERESTS 37,87 %

CHAPTER III

DEVELOPMENT DECISION AND ORGANIZATION

1 - DECLARATION OF COMMERCIALITY : THE ANGLO/NORWEGIAN AGREEMENT

It was clear from 25-1/1 discovery well data and the seismic interpretation that the Frigg structure straddled the median line between the Norwegian and the United Kingdom Continental Shelf. Consequently, as early as mid 1971, preliminary discussions took place between the Petronord group and the UK group to consider the commercial aspects of the discovery. Without waiting for additional well results, it was then decided by Norwegian and British Associates to immediately perform preliminary studies, within the one year period from mid 1971 up to mid 1972 while appraisal wells on both sectors had to be drilled.

These studies executed and controlled by the two operators, ELF AQUITAINE NORGE and TOTAL OIL MARINE, gathered enough technical data to support a conclusion stating that the Frigg discovery was a commercial field.

This conclusion was officially disclosed by the Norwegian Ministry of Industry on April 25, 1972 and led NORSK HYDRO on the same day, to increase its share in the Petronord Group by exercising its double option, as provided by the Agreement between partners on Licence 024 (Block 25/1).

A month later, in May 1973, the Norwegian State decided to acquire an interest of 5% in the above licence.

- before a decision to develop the field could take place, several problems had to be solved for the following reasons :

. the size of the structure : apparently one of the biggest offshore gas deposits ever discovered,

. the water depth : important, ranging around 100 m.

. the hostile environment of the Northern North Sea,

. the international aspect of the field, straddling the border between the UK and Norway which was an unprecedented occurence in the North Sea,

. the sale of the gas,

. the financing of the huge development costs

The first step was to clearly define the responsibilities of both Operators and establish a very close cooperation between them.

ELF NORGE was entrusted with the responsibility for developing and producing the whole field, TOM being in charge of the transportation system.

In a second step, a Management Committee was created between all partners with the purpose of negociating Frigg specific Agreements to be submitted to the approval of the UK and Norwegian Governments.

From the very beginning, observers from both governments attended Management Committee meetings, which allowed a free flow of information. Whenever a decision was taken, they had the opportunity to comment and register the reasons for such decision.

At these meetings, partners submitted all problems for discussion and the following Agreements were concluded and later approved by the UK and Norwegian Governments and attached as appendix to the Frigg Treaty :

- <u>In May 1973</u>

The Frigg Field Expert Agreement appointing an independent expert to determine the limits of the Frigg Field reservoir and evaluate gas reserves in place and the sharing of such reserves between the Norwegian and the UK sectors.

- <u>In July 1973</u>

The Frigg Field Main Agreement considering the Field as a unit and regulating the conditions of its development and exploitation.

- <u>In July 1974</u>

The Frigg Transportation Agreement establishing a close coordination between the Norwegian and UK Associations.

- <u>In conclusion</u> :

The development of the Frigg Field was divided between two Asscociations, British and Norwegian (Petronord) and governed by the regulations of the two countries involved. Consequently, it was organized as follows :

- field unitized with respect to the individual interests of British and Norwegian partners,
- field operated by Elf Aquitaine Norge (5 platforms, supporting facilities, flare, connecting flowlines, cables and compression fecilities),
- transportation divided between U.K. and Norway as follows :
    - . 1 U.K. 32" pipeline from Frigg to St Fergus,
    - . 1 Norway 32" pipeline from Frigg to St Fergus,
    - . 1 intermediate booster platform located midway between Frigg and St Fergus
    - . 1 shore terminal in St Fergus

    divided approximately 50 % U.K. and 50 % Norway
- transportation and shore terminal operated by Total Oil Marine Ltd (TOM).

2 SALE OF FRIGG GAS TO BRITISH GAS CORPORATION

One of the priorities was to find a market for the Frigg gas. It was soon clear that although the FRIGG Field contains a sizeable amount of oil underneath the gas, it would be very difficult to produce that oil from the very thin and stretched out pay-zone (10 metres). Therefore, gas development only was recommended.

The sales market opened to the owners of the large gas field was limited. First of all, it seemed impossible to bring the gas ashore to Norway because of the Norwegian Trench, and because Norway had restricted market possibilities. Moreover, part of the field was in British waters, and British Gas Corporation had a monopoly in the U.K. The Continent was considered, but discarded because of the distance. The Shetland Islands were then left as the nearest landing place, but a pipeline to Shetland would necessitate a liquefaction plant and NGL transport. The only alternative was therefore Scotland.

Negociations were carried out, it was envisaged to transport the Frigg gas by pipeline to Scotland and the British market. It must be remembered that in 1972 the Phillips Group was also in the process of negotiating the sale of gas from Ekofisk to the Continent. Since British Gas lost the Ekofisk contract, they were eager to negotiate for the Frigg gas. One of the reasons why Ekofisk gas was not sold to U.K. was that Phillips obtained better prices from buyers on the continent.

It is also clear that if the gas prices negociated for the southern British gas fields had been applicable to Frigg, the field could not have been developed, as the income from gas sales could not have recovered development costs for Frigg, (including pipeline investment). On Dec. 13, 1973, a contract was signed for the sale of the British part of Frigg gas to BGC.

A two phase development plan was presented : first the British side, and secondly for the Norwegian side.

It was also evident that the Norwegian authorities wanted a closer look at the possible sale of the Frigg gas. Although the Storting exercised the five percent state participation option on May 25, 1973, the gover-nment wanted some benefits from Frigg production to come to Norway.

However, when the first gas sale contract for the British gas from Frigg was signed, the owners of the field had a sellers' option to sell the remaining Norwegian gas to BGC. After long negociations the Norwegian government recommended the sale of the Frigg gas to the U.K., but retained the right to request a small diameter pipeline to be laid to Karmoy in Norway. This option has to be exercised before the end of 1978. The Petronord Group accepted this condition and the Norwegian Storting approved the sale in May 1974. A contract for the sale of the Norwegian portion of the Frigg gas was signed in July 1974. Subsequently a third contract was signed, "Tripartite agreement", as an "umbrella" over the two sales contracts.

3 - UNITIZATION OF THE FIELD

A number of other problems remained to be solved before Frigg could be brought on stream. The first platform was ordered in 1973. It was subsequently decided that the complete field development should involve five platforms and a flare on the field, with an intermediate booster platform on the pipeline midway between Frigg and St. Fergus. Another question to be settled was the unitization of the field. A number of problems arose from such unitization such as to clear up the reserves question, sort out jurisdiction problems, find practical application for penal and taxation laws, etc.

Norway and the U.K. signed a treaty in 1965 which defined the median line and also laid down provisions for cases like Frigg. Without such treaty unitization of the field would have been much more intricate or even impossible. It is also clear that the ensuing Frigg treaty could set a precedent for future unitization agreements.

The question of splitting the reserves between the two countries was more difficult because of the enormous economic interests involved. The idea of soliciting an independent consultant, de Golyer & Mc Naughton to prepare a report on this question was suggested by Norsk Hydro and supported by Statoil.

The annexed Table summerizes the results of the de Golyer & Mc Naughton study on the initial volumetric estimate of gas reserves in place in the Frigg Field reservoir ; it has to be noted that as more reservoir data become available from additional wells this estimate could be subject to further modifications.

GAS RESERVES in PLACE
in the
FRIGG FIELD in NORWAY and UNITED KINGDOM
NORTH SEA
as of
20 OCTOBER 1976

Country Block	Reservoir Area (hectares)	Average Gross Pay Thickness (meters)	Gross Reservoir Volume (cubic meters x 10^3)	Average Net Pay Thickness (meters)	Net Reservoir Volume (cubic meters x 10^3)	Areal Average Porosity (percent)	Areal Average Gas Saturation (percent)	Gas Expansion Factor (cubic meter/cubic meter)	Initial Gas Reserves in Place (cubic meters x 10^9)
NORWAY									
25/1	6,391.3	49.3	3,150,108	47.2	3,014,120	29.48	92.00	199.238	162.873
30/10	87.0	12.1	10,557	12.1	10,538	30.65	83.57	199.238	0.538
Total	6,478.3		3,160,665		3,024,658				163.411
UNITED KINGDOM									
4/26	3.7	4.0	148	2.5	93	29.20	78.50	199.238	0.094
9/5	31.5	46.6	14,673	39.5	12,440	26.61	92.52	199.238	0.610
9/10	221.6	43.8	97,129	42.1	93,204	27.76	93.97	199.238	4.844
10/1	3,125.9	68.0	2,126,719	63.1	1,971,168	28.04	87.99	199.238	96.896
10/6	97.5	56.2	54,804	55.6	54,225	28.28	94.69	199.238	2.893
Total	3,480.2		2,293,473		2,131,130				105.247
TOTAL FIELD	9,958.5		5,454,138		5,155,788				268.658

CHAPTER IV

THE FRIGG RESERVOIR

1 - STRUCTURE

The Frigg field is located on the western flank and not very far from the deepest part of the Viking tertiary embayment, in an area where tectonic is very quiet and structural features very flat.

On seismic maps, the structure appears like a low amplitude, lobate, fan-shaped anticline, with a southwestern apex and three main lobes trending to the East, North-East and North.

The shape of the structure itself, is strongly suggestive of a submarine fan (fig. 1).

2 - SEDIMENTOLOGY

Reservoir rock consists of sands from the Eocene age separated from the underlaying COD sand by a small bed of volcanic tuffs, the extent of which is large but perhaps not continuous. Communication between the two sand banks is likely at least in the aquifer area.

The deposits coming from the land or from the continental shelf are carried away through a canyon up to a slope where they run down into some channels ending into a fan.

On each side of the channels, embankments allow only the finest sediments to flow over them. The Frigg field is located in the channel zone divided into several branches. It is likely that bad rock characteristics will be found between the channels, i.e. on the flanks of the structure.

3 - ROCK CHARACTERISTICS

The log interpretation showed the Frigg reservoir to consist of a massive, generally clean sand of uniform quality. Some increase in shaliness and the presence of tight calcareous sections are noted at the top of the pay. However the presence of these tight and shaly sections has little effect on the recoverable hydrocarbons, 98 per cent of which lie in the area of the clean sand. The ratio of net to gross pay is close to 90 %. A very uniform 10 metre layer of oil separates the gas from the underlying aquifer. Fluid contacts are extremely clear in all logs, and indicate that the fluid interfaces are effectively horizontal accross the field. Water saturations in the gas pay average 3-5 per cent. This unreducible value is reached approximately 15 metres above the oil-water contact (5 metres above the gas-oil contact). The low connate water values and the sharp transition zone indicate high permeability.

Porosities averages 29 per cent, with extremes of 25-32 per cent.

Well 10/1-2 showed the lower Eocene sand to be much reduced in thichness and extremely tight and shaly. The well is effectively dry and marks a western limit to the field. The gross reservoir sand varies between 60 and 200 metres thickness accross the field and carries a maximum logged gross hydrocarbon thickness of 152 metres.

Cores were taken in the pay sand in some 8 wells. No exact correlation between cores and well logs could be obtained due to incomplete recovery and the extreme friability of such sand as was recovered. Core description and inspection of the cores confirmed the findings of the logs (Enclosure 3.1.).

Due to sand friability, only a small number of cemented samples could be obtained for porosity and permeability determination. However, the samples do show that high permeability values of one darcy or greater are very probable in the main pay sand. Both vertical and horizontal permeabilities were measured in the consolidated cores. The few samples tested showed no significant difference between horizontal and vertical values.

Special core analysis was carried out on a number of samples giving values of residual hydrocarbons (both oil and gas). It seems that the average value of Sgr = 20 % is a realistic one. (Enclosure 3.2.)

Capillary pressure curves were obtained for a selection of core samples. Water saturation depth curves, derived from these results, were compared with log saturation profiles and confirmed that permeabilities of one darcy or greater could be expected.

4 - PRODUCTION TEST DATA ANALYSIS

Gas production tests were attempted on the discovery well 25/1-1. (Enclosure 4.1).

The test was designed as a three point absolute open flow test with a conventional build-up. Eight metres of clean gas sand, representative of the hydrocarbon reservoir in the well, were opened for testing. The formation of gas hydrates in the system prevented the full potential of the well being tested. The maximum rate achieved was 673. 000 m3/day for a reservoir drawdown of 11 psi. The pressure build-up was instantaneous.

The tests made on 3 other appraisal wells 10/1-1, 25/2-1, 25/1-4 indicated abnormal behaviour. Flowrates and pressures were very instable with sharp variation of more than 30 psi while flowing through the same choke. It was obvious that there was an effect of sand bridging behind perforations due to inadequate completion. On the latest appraisal well tested, 25/1-5, completed with a special screen, the results were already better : 800.000 m3/day with a pressure drop of 17 psi.

After having put the first 11 wells into production, it is now obvious that sand control by the special screen used is satisfactory. All the wells have a very high potential, above 2 x 10^6m3/day. As an example, the pressure drop measured on 10/1-4 well at a rate of 2,2.10^6 m^3/day is only 9 psi (fig. 2).

6 - RESERVES

The estimation of the gas originally in place (G.P.I.P.) has been done by both the operator EAN and the expert DGMN.

The result are very close :

- EAN : 286×10^9 std m3
- DGMN : 269×10^9 std m3.

The principles of the methods used are similar :

- evaluation of the gas-impregnated rock volume using the seismic map at the marker near the top of the gas-bearing formation.

- calculation from the log and drawing of the corresponding isovalue map for :

  . the net pay/gross pay ratio

  . the porosity

  . the gas saturation

In order to obtain average values for the whole field or for the different concession blocks, the most debateable point is how to extrapolate the results of the calculation for the existing wells to the area where no well exists, especially in the flanks or in the north.

The amount of recoverable gas depends mainly on production technique. Depending on various hypothesis the recovery factor ranges between 72,5 % and 87,5 %.

7 - COMPLETION WITH SCREEN

Special attention has been paid to the sand control. The very high rate of production expected from the wells, 2 to 4 x $10^6 m^3$ / day, has never been obtained before in such loose sand.

The knowledge of the exact sand granulometry was a major data. EAN elected some core sample (fig.3) and disregarded all the samples obtained during production (fig.4) which are very different and therefore not representative.

To define the most suitable equipment, materials and procedures to solve the problem, EAN built a special testing device using the gas of the LACQ field. Tests have been run during 18 months on 3 different kinds of screen. The one selected had the following characteristics :

- outer diameter 7 5/8"
- screen in INOX 316 L, slots 12/1000"
- inner tube 6 5/8".

The first test in the field was carried out on well 25/1-5 where it proved to be satisfactory but where difficulties arose with the completion fluid and packer setting.

Studies have therefore been conducted very intensively to define the completion fluid in the laboratory and test it in 6 wells in France.

Though production time is still short, it appears from the results of the first 11 wells that the completion device and fluid is very satisfactory, the well productivity being much better than that obtained on discovery and appraisal wells.

No skin, nor turbulence effects have come to light. A bottom pressure control has shown that the major part of the screens is interested by the gas flow, implying a relatively low gas velocity through the screens (fig.5).

To calculate the water incroachement and then the pressure of the field, these data have been introduced into a special numerical model called TRIGAS.

The horizontal grid is composed of 11 x 16 = 176 irregular blocks. Two layers are sufficient to represent the whole aquifer : the lower one simulates the Cod sands and the upper one the Frigg sands. The vertical fluid communication is regulated by the permeability value kz = 2 md, introduced between superposed blocks.

. Simulation of the future performance

The main purpose of the study was to estimate the time at which the tubing head pressure limit of 140 bars will be reached, requiring compression. The maximum gas velocity in the tubing is 15 m/sec.

This has been done with a given production schedule corresponding, after the 2 first years, to a maximum daily rate of 54 x 10^6 Std m3/day in winter and a minimum of 29 x 10^6 Std m3/day in summer according to BGC contract.

To cover all possibilities, 3 cases of well daily rate have been taken into consideration : 1,5 - 2 - 2,5 x 10^6 Std m3/day.

The results of the evolution of the well head flowing pressure are given in fig.7 and 8 versus cumulative production and time.

It appears in fig. 8 that the pressure limit of 140 bars will be reached during the winter of 1980 - 1981. This implies that the sales contract with BGC can only be respected if the compression facilities have been installed on the Frigg field well before this period.

For determination of the pressure drop at the well, it has been assumed that well productivity law include an important skin effect and takes into account turbulence effect. According to actual results of the 11 first development wells this seems to be pessimistic. If this good productivity is confirmed, it will be possible to postpone to summer 1981 the installation of the compressors.

8 - GAS PRODUCTS FORECASTS - COMPRESSION

. Aquifer characteristics

The future performances of Frigg Field will depend to a large extent on the behaviour of the surrounding common aquifer.

In reponse to the pressure drop in the gas pool, this aquifer will react by providing a source of water encoachement, the rate of which will be related to the shape, the size and the compressibility of the water-bearing rocks.

According to the results of some thirty wells which have been drilled up to now in the Frigg basin, these water-bearing rocks are composed of three formations :

- Frigg sands (lower Eocene) which contain the Frigg pool
- Cod sands (upper Paleocene) with contain the Heimdal pool
- Danian sands (lower Paleocene)

Electrical logs have shown that the volcanic tuff formation lying between Frigg and Cod sands may be considered as permeable in a vertical direction but that the communication between Cod and Danian sands is probably nil. Thus, the Danian sands have not been taken into consideration for the water influx calculation.

The map of Frigg and Cod sands is shown on Fig. 6.

It appears that the extent of the Cod sands is much larger than the one of Frigg sands and that, on the west side, the boundary of Cod sands is not well defined. It may extend up to tye outcrop. Consequently though the amount of water in the Cod sands is quite large due to the bad communication between the Cod and Frigg sands, the Frigg aquifer has to be considered as a limited one.

The sand thickness varies considerably, the average value being equal to 70 m for Frigg sands and 150 m for Cod sands.

The average porosity for Cod and Frigg sands is respectively 25 % and 29 % the horizontal permeability being 250 md and 1200 md. The ratio of the vertical to horizontal permeability is 1/4.

In the case of the limited aquifer, the permeability of the Volcanic Tuff, layer between Cod and Frigg sands, is estimated equal to 2 md. In the case of no aquifer it is zero.

ENCLOSURE 3.1. CORES FRIGG FIELD

WELL	CORE	INTERVAL DRILLERS DEPTH (m)	RECOVERY %
25/1-1	K 1	1868 - 1877	66.6
	K 2	1877 - 1895	19.0
	K 3	1895 - 1910	66.0
	K 4	2686 - 2694.5	95.0
	K 5	2825.3 - 2842.4	100.0
	K 6	2993 - 2997.8	
25/1-3	K 1	1951 - 1969	80
	K 2	1969 - 1987	80
	K 3	1987 - 2005	80
	K 4	2563 - 2568	50
25/1 - 4	K 1	1922 - 1935.5	81.5
	K 2	1935.5 - 1953.5	78
	K 3	1953.5 - 1970.5	100
	K 4	1970.5 - 1984	44
	K 5	1984 1 1993	67
	K 6	1993 - 2001	75
	K 7	2001 - 2010	100
	K 8	2010 - 2028	75

ENCLOSURE 3.2. FRIGG SAND DATA

WELL NUMBERS	10/1-1	10/1-3	10/1-4	25/1 - 1	25/1 - 2	25/1 - 3	25/1 - 5	25/2 - 1
Elevation - Rotary table	27	25.9	24.1	23.5	23.5	23.5	25.0	24.0
Log depths less true vertical depth	27.0	25.9	Deviated	25.0 at top 25.5 at GOC	26.0	25.0	29.6	24.0
Top of Marker	-1848.7	-1909.1	-1814.4	-1813.0	-1895.5	-1918.1	-1877.4	-1880.5
Top of Sand	-1851.8	-1927.3	-1826.0	-1821.8	-1921.8	-1931.6	-1883.9	-1891.5
Gas/oil contact	-1943.8	-1947.2	-1950.2	-1944.7	-1948.2	-1948.0	-1946.2	-1947.5
Gross Pay metre - h	95.10	38.10	136.1	131.7	52.7	29.9	68.8	56.1
Net pay metre	86.30	14.60	113.9	123.4	39.3	16.2	61.1	56.1
Net/Gross ratio -	0.9075	0.3832	0.8369	0.9749	0.7457	0.5418	0.8881	1.0000
Porosity - decimal Ø	0.2750	0.2561	0.2955	0.2906	0.3016	0.3034	0.3046	0.2921
Gas saturation decimal Sg	0.9385	0.7812	0.8885	0.9369	0.9065	0.9436	0.9365	0.9353
factor = x Ø x Sg dimensionless	0.2342	0.0767	0.2197	0.2711	0.2039	0.1551	0.2533	0.2732
Equivalent gas heights metre	22.27	2.92	29.90	35.70	10.75	4.64	17.43	15.32

All depths are true vertical subsea depths in meter.

ENCLOSURE 4.1.

WELL 25/1-1

Choke inch	Flowrate Gas Std.m3/day	Well Head Pressure		Bottom Hole Pressure	
		PSI	BARS	PSI	BARS
56/64	673 000	1620	111.7	2833	195.3
32/64	417 400	2285	157.6	2832	195.3
16/64	95 750	2460	169.6	2841	185.9
Well shut in	-	2465	169.96	-	196

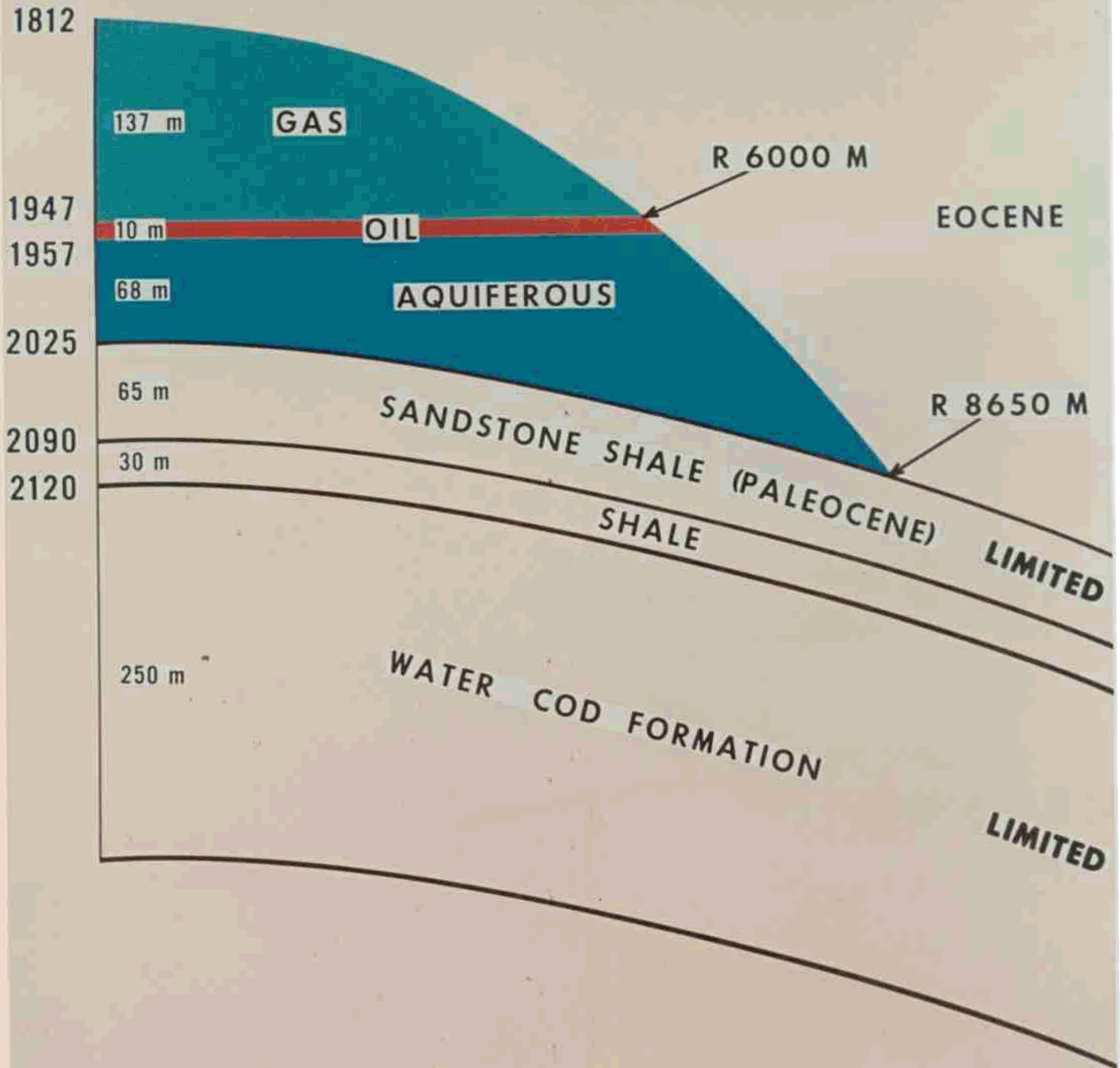
25/1-1

Choke inch	Gas Flowrate Std.m3/day	Condensate g/std m3 gas	Well Head Pressure		Bottom Hole Pressure	
			PSI	BARS	PSI	BARS
48/64	597 000	4.39	2070	142.7	2828	195
56/64	828 000	3.94	1815	125.3	2815	194.1
Well shut in	-		2458	169.5	2833	195.3

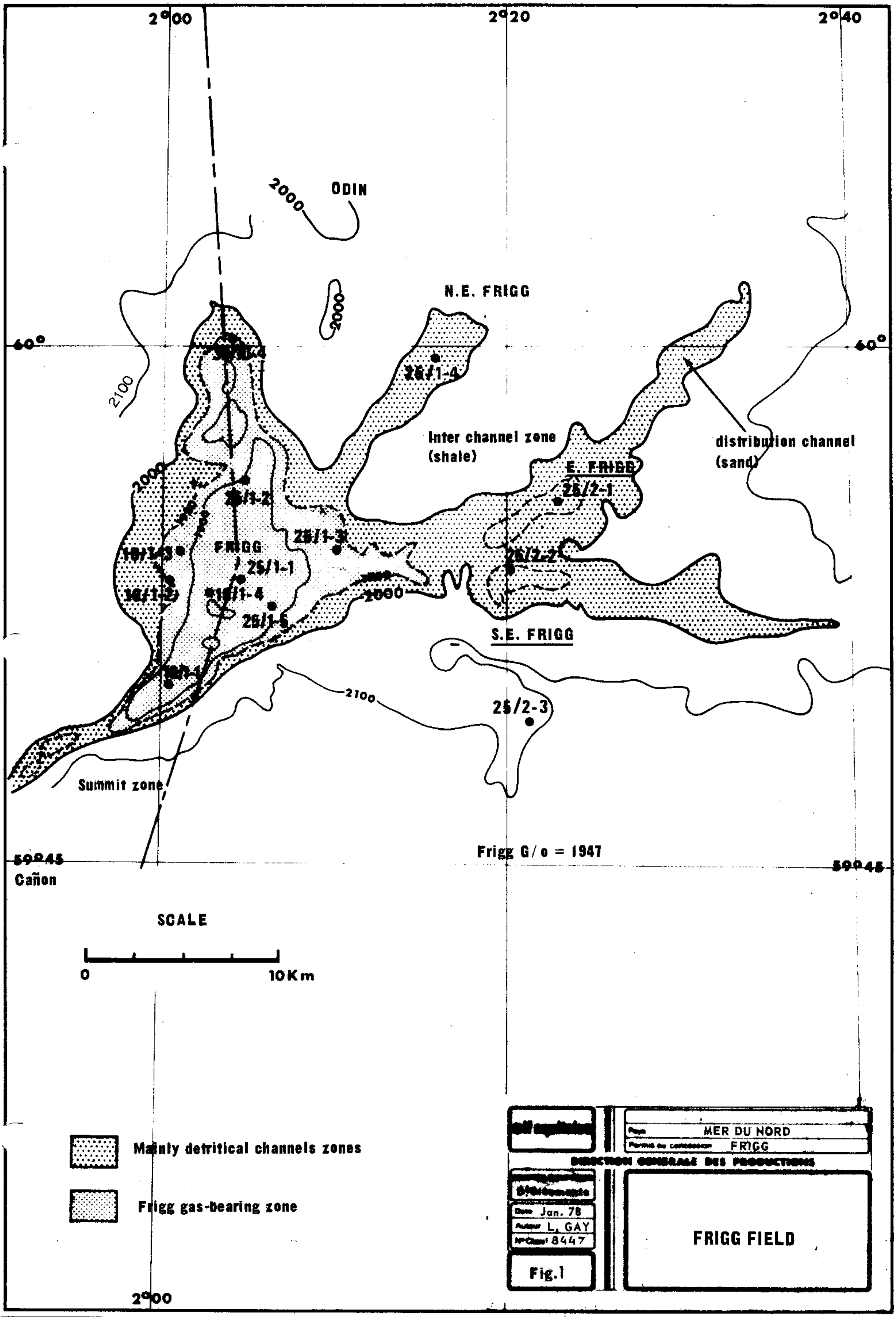
10/1-3

Choke inch	Gas Flowrate Std.m3/day	Condensate g/std m3 gas	Well Head Pressure		Bottom Hole Pressure	
			PSI	BARS	PSI	BARS
48/64	536 000	3.67	1910	131.7	2839	195.7
40/64	407 200	2.91	2164	149.2	2842	195.9
56/64	638 300	3.04	1660	114.4	2830	195.1
Well shut in	-		2445	168.6	2853	196.7

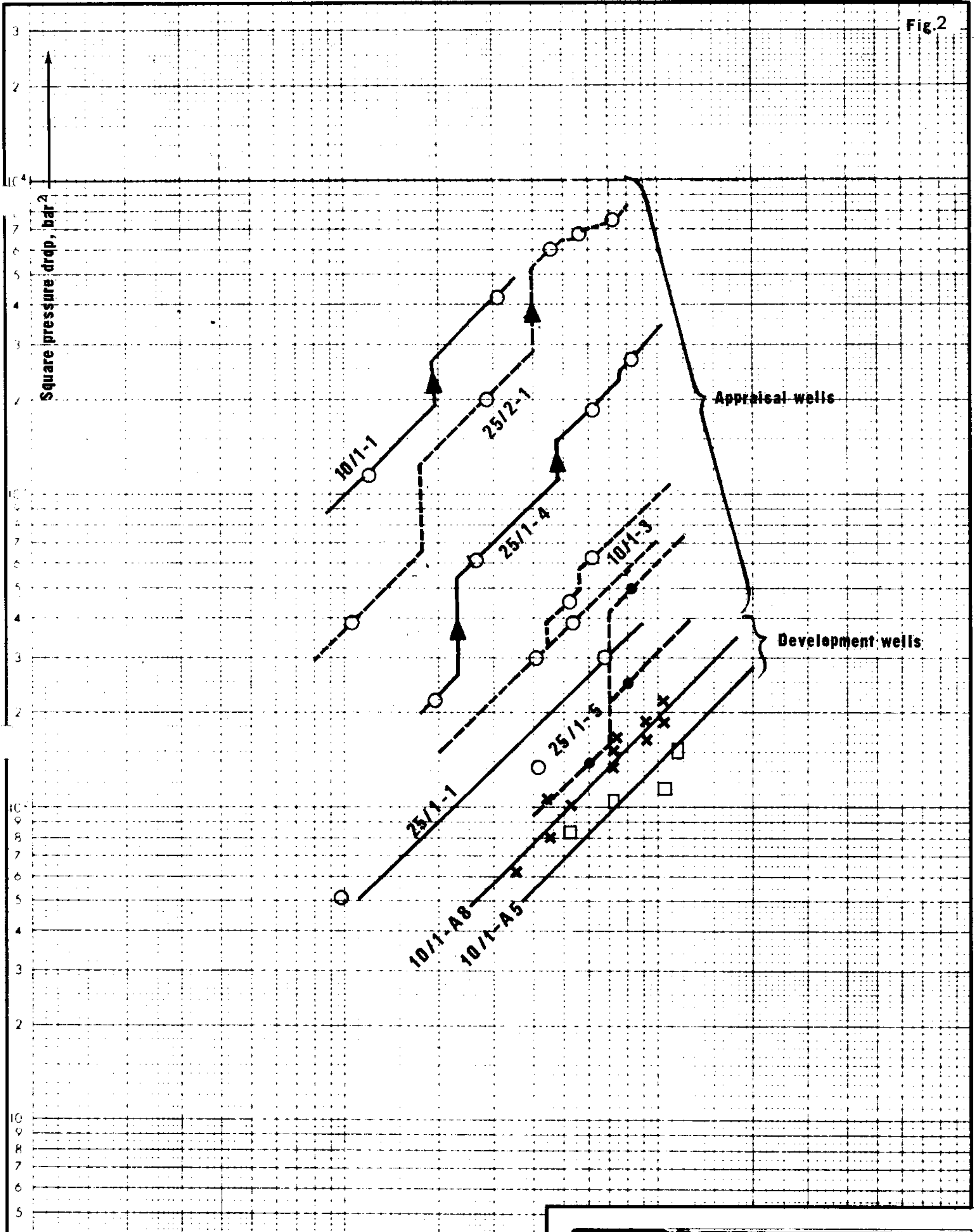
FRIGG | FORMATION CUT



	H	α	Ø	KH	KV	EXTENSION
EOCENE	215	0.8	0.31	2000	500	8650 M
PALEOCENE	65	0.55	0.25	500	6	LIMITED
SHALE	30				0.5	LIMITED
COD	250	0.55	0.25	250	2	LIMITED
	M		%	MD	MD	



2°00
2°20
2°40
60°
60°
59°45
59°45
Cañon
ODIN
2000
2000
2100
N.E. FRIGG
25/1-4
Inter channel zone
(shale)
distribution channel
(sand)
E. FRIGG
25/2-1
2000
25/1-2
FRIGG
25/1-3
10/1-3
25/1-1
10/1-2
10/1-4
25/1-5
25/2-2
2000
S.E. FRIGG
2100
25/2-3
Summit zone
Frigg G/o = 1947
SCALE
0
10Km
Mainly detritical channels zones
Frigg gas-bearing zone
MER DU NORD
FRIGG
Jan. 78
L. GAY
8447
Fig.1
FRIGG FIELD
2°00



elf aquitaine

Pays MER DU NORD

Permis ou concession FRIGG

DIRECTION GENERALE DES PRODUCTIONS

DIRECTION EXPLOITATION

D^t Gisements

Date jan. 78

Auteur L. GAY

N° Class^t 8447

Fig.2

BACK PRESSURE CURVES ON FRIGG WELLS

N 269

Fig. 3

SAND GRANULOMETRY (CORES)

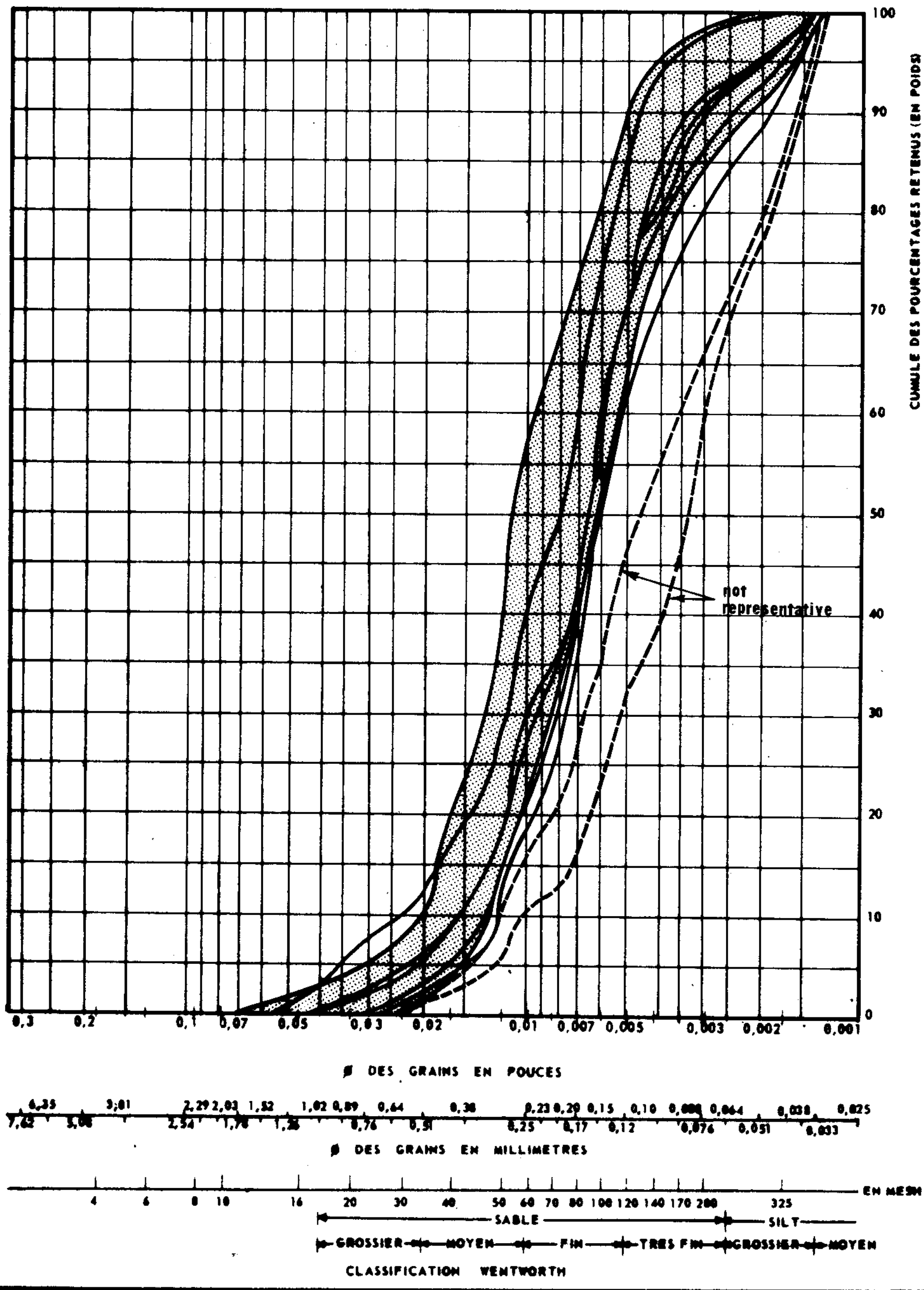
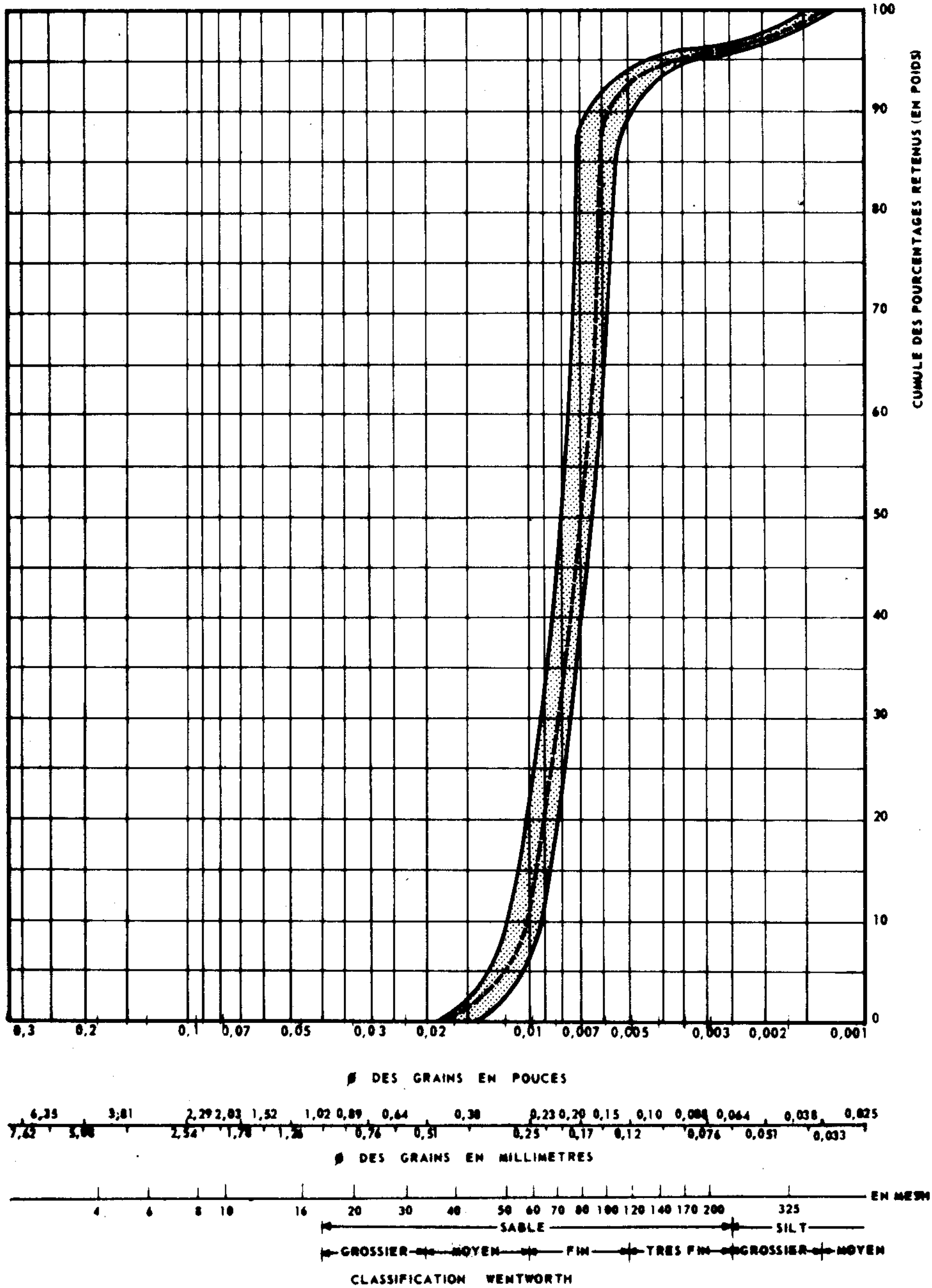


Fig. 4

SAND GRANULOMETRY (PRODUCTION SAMPLE)



10/1 - A 11 - RESERVOIR FRIGG SAND

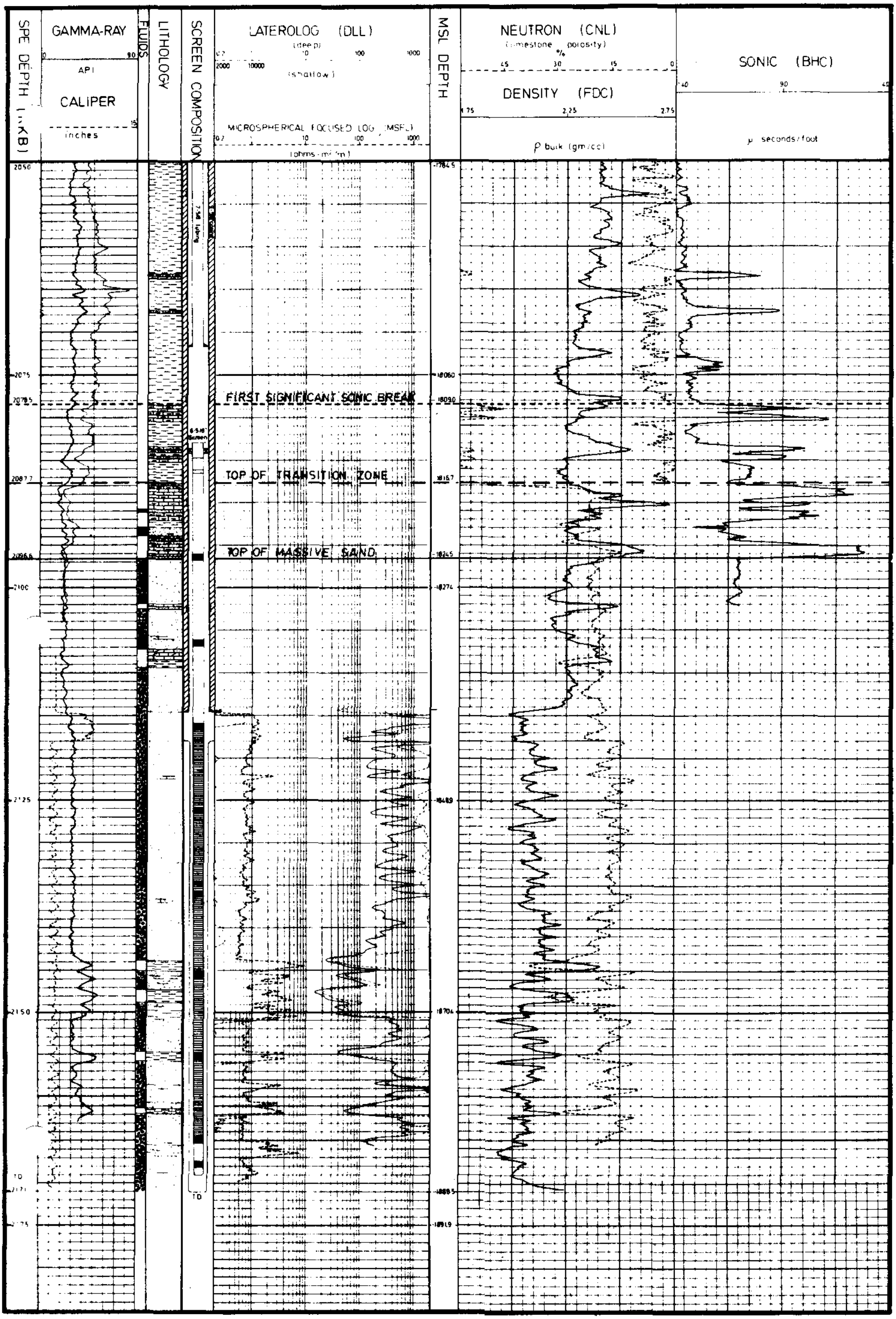
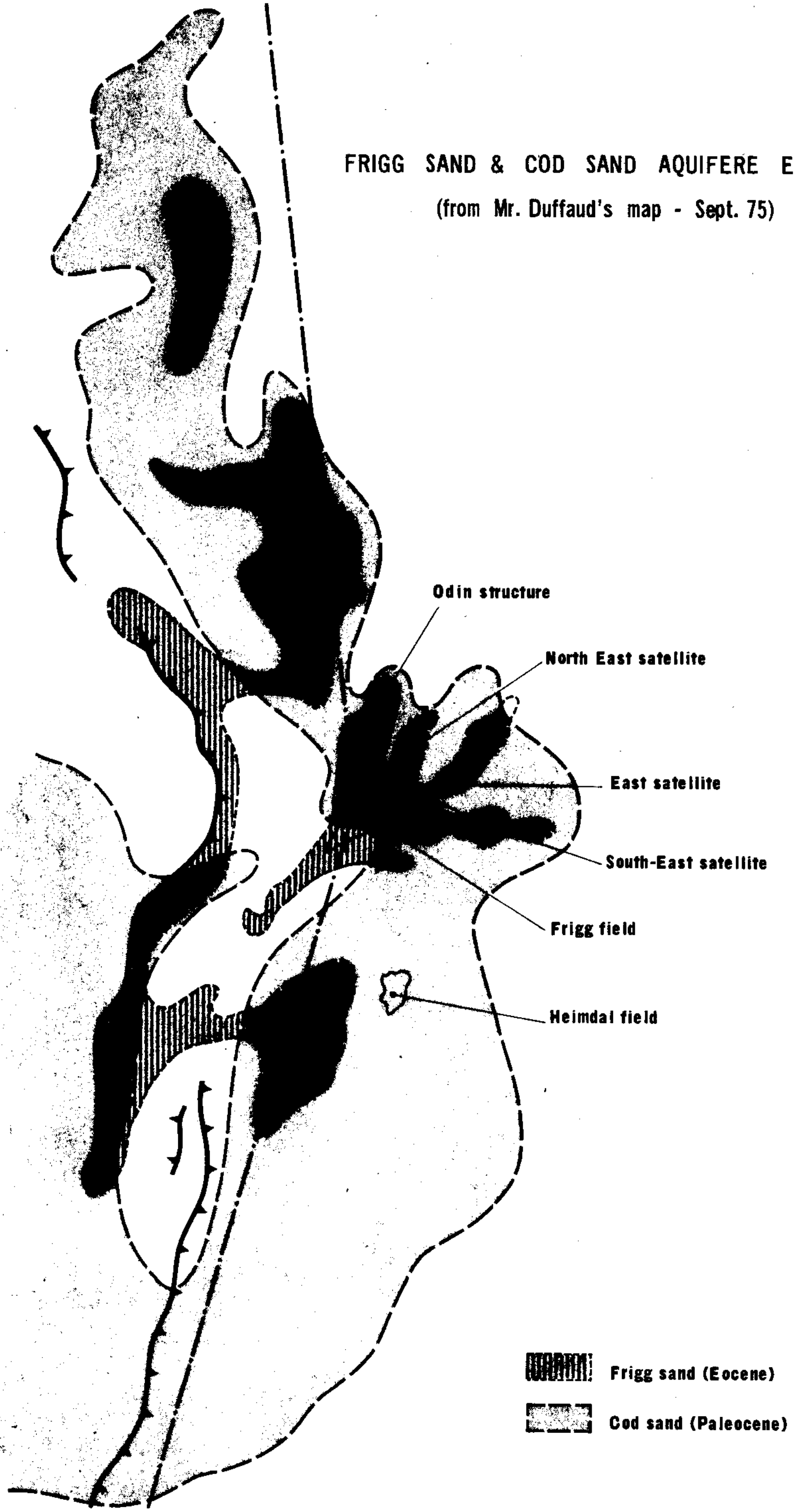
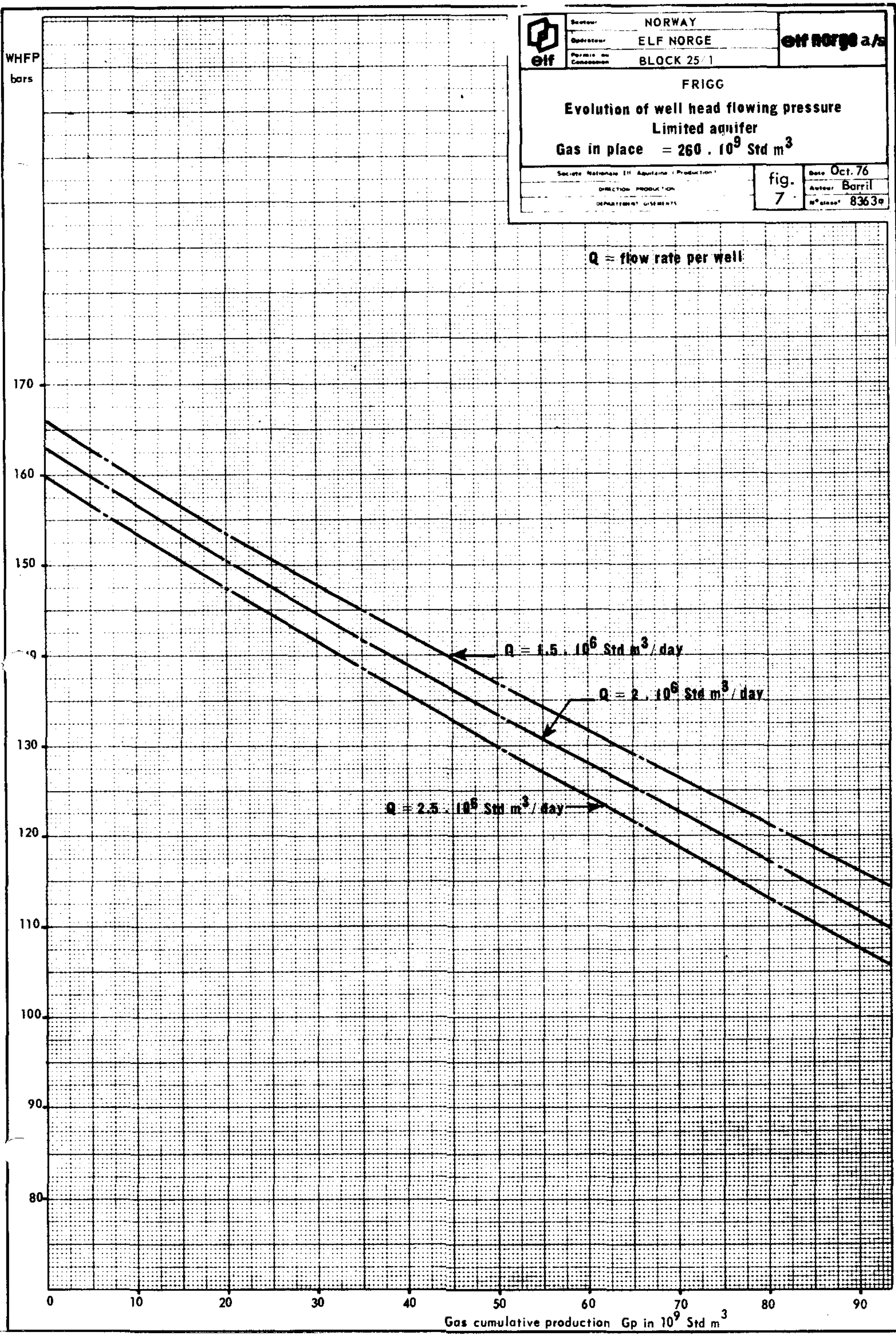


Fig. 6

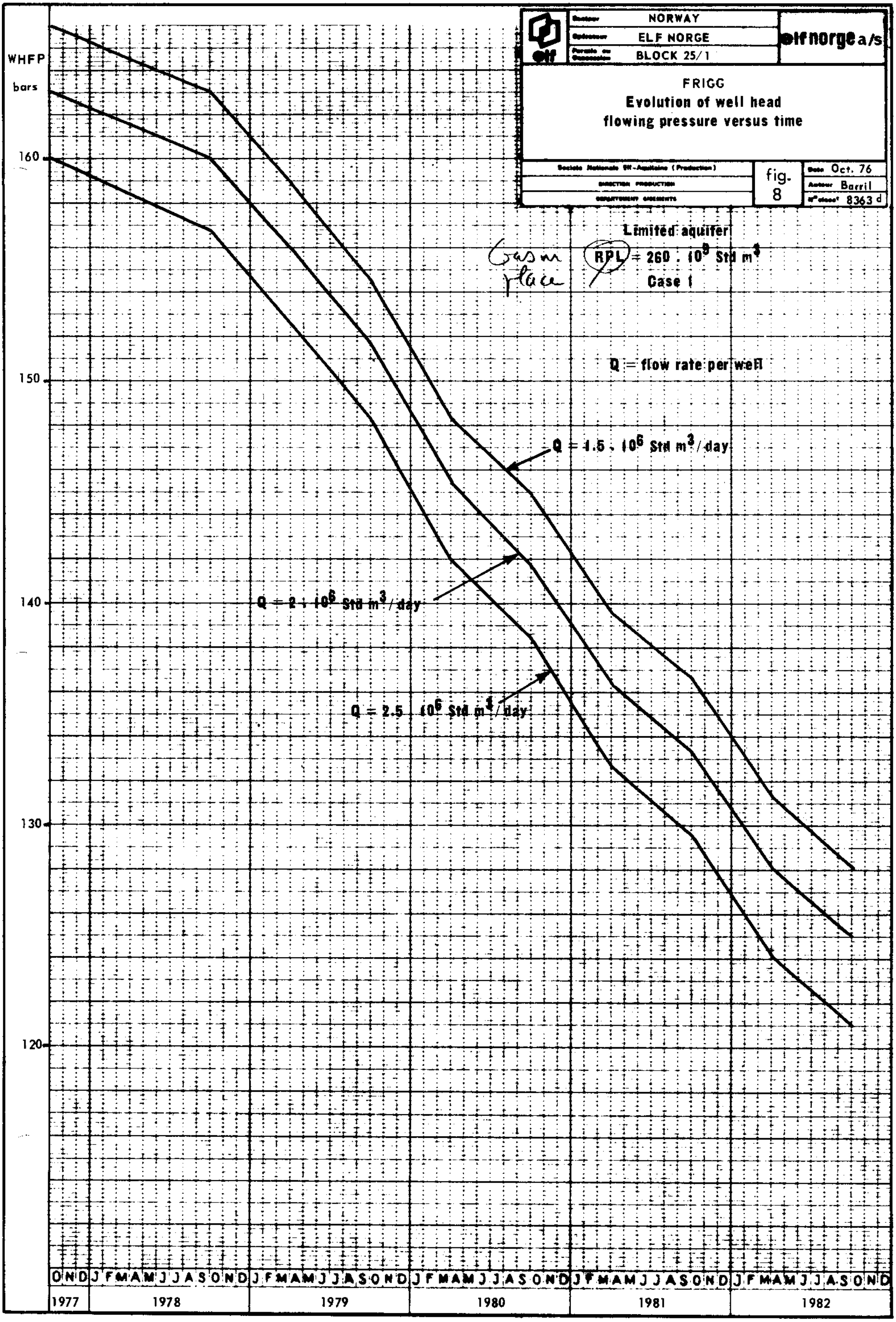
FRIGG SAND & COD SAND AQUIFERE EXTENT

(from Mr. Duffaud's map - Sept. 75)





Secteur NORWAY
Opérateur ELF NORGE
Permis ou Concession BLOCK 25/1
elf
elf norge a/s
FRIGG
Evolution of well head flowing pressure
Limited aquifer
Gas in place = 260 . 10^9 Std m^3
Société Nationale Elf Aquitaine (Production)
DIRECTION PRODUCTION
DEPARTEMENT GISEMENTS
fig. 7
Date Oct. 76
Auteur Barril
N° classt 8363
Q = flow rate per well
WHFP bars
170
160
150
130
120
110
100
90
80
Q = 1.5 . 10^6 Std m^3/day
Q = 2 . 10^6 Std m^3/day
Q = 2.5 . 10^6 Std m^3/day
0
10
20
30
40
50
60
70
80
90
Gas cumulative production Gp in 10^9 Std m^3



NORWAY
ELF NORGE
BLOCK 25/1
elf norge a/s
FRIGG
Evolution of well head flowing pressure versus time
Societe Nationale Elf-Aquitaine (Production)
DIRECTION PRODUCTION
DEPARTEMENT GISEMENTS
fig. 8
Oct. 76
Barril
8363 d
WHFP bars
160
150
140
130
120
Limited aquifer
Gas in place
RPL = 260 . 10^9 Std m^3
Case 1
Q = flow rate per well
Q = 1.5 . 10^6 Std m^3/day
Q = 2 . 10^6 Std m^3/day
Q = 2.5 . 10^6 Std m^3/day
O N D J F M A M 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 S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1977
1978
1979
1980
1981
1982

CHAPTER V

DEVELOPMENT PROGRAM

1 - GENERAL

The Frigg Field straddles across the median line of the Northern North Sea, between approximately 59°48' and 60° of latitude N and 2° and 2°15' of longitude E.

Water depth ranges from 96 to 106 meter LAT.

As an accurate knowledge of the meteo oceanographical conditions and soil characteristics governs to a large extent the safety of any offshore fixed installation, a particulary accurate analysis necessary to establish the basic premises for the design of FRIGG facilities (platforms, pipelines, articulated flare, etc...) was carried out, utilizing the services of several experts in geotechnical and meteo-oceanographic investigation.

2 - ENVIRONMENT

The general environmental design criteria on which all fixed platforms have been based are summarized as follows :

1. Water depth

Ranging from	: 96 to 106 m LAT

2. Tide

Astronomical	: 1.80 m
Storm (extreme)	: 0.60 m

3. Storm conditions

Wave height	: 29 m
Wave period	: 16 s
Current velocity at surface	: 1.35 m/s
Current velocity at 30 m above seabottom	: 0.70 m/s
Current velocity at seabottom	: 0.30 m/s
Max. 1 min sustained wind velocity	: 55 m/s

4. Operating conditions

Wave height	: 17 m
Wave period	: 11.2 s
Current velocity at surface	: 1.00 m/s
Current velocity at 30 m above seabottom	: 0.58 m/s
Current velocity at seabottom	: 0.30 m/s

5. Ambient air temperature

Between	: - 15°C and + 32°C.

6. Water temperature

Between	: + 14°C and + 17°C.

3 - THE FOUNDATION SOIL

3.1. Basis of foundation design

From the geotechnical investigations it can be seen that all sub-bottom layers on Frigg Field are over consolidated, but important lateral variations were revealed even on a decametric scale due to the presence of several buried erosion valleys.

Below 3 to 13 meters of fine dense sand (size : 0.1 to 0.2 mm ; effective friction angle : 39°), foundation conditions can be entirely different from one platform to another (ex : horizontal shear strength varies between 9 and 20 t/m^2 at a given level). This subbottom consists of mixed or interbedded layers of fine sand, silt and clay to about 40 m depth. Deeper layers are either very hard clay (with cohesion 40 to 80 t/m^2) or fine sand if there is a deep erosion valley. Consequently, bearing capacity conditions were good except below TCP 2 platform.

The main soil problems were the following :

- risk of liquefaction of the top fine sand under storm conditions,
- clay "fatigue" under the slab cyclic loading induced by storms waves,
- safety against cratering of the gravity structure foundation without skirts, CDP 1, during underslab drilling, particularly when pilot hole drilling for the conductor pipes installation, taking into account the Norwegian regulation of no permanent hole through the conductor pipe,
- stability of drilled hole walls for insert piling.

Erosion predictions were verified on site and the phenomena fully controlled.

3.2. Monitoring of foundation design

Elf Aquitaine Norge decided to install a complete set of innovative structural, geotechnical and oceanographical instrumentation (to systematically gather the so-called E and P data) on the platforms One year's preliminary results indicated that, even under storm conditions with a 12 m significant wave height, the pore pressure increase was low in the top sand and negligeable in deeper clay layers. Consequently, the theoretical risks of liquefaction and fatigue were overestimated.

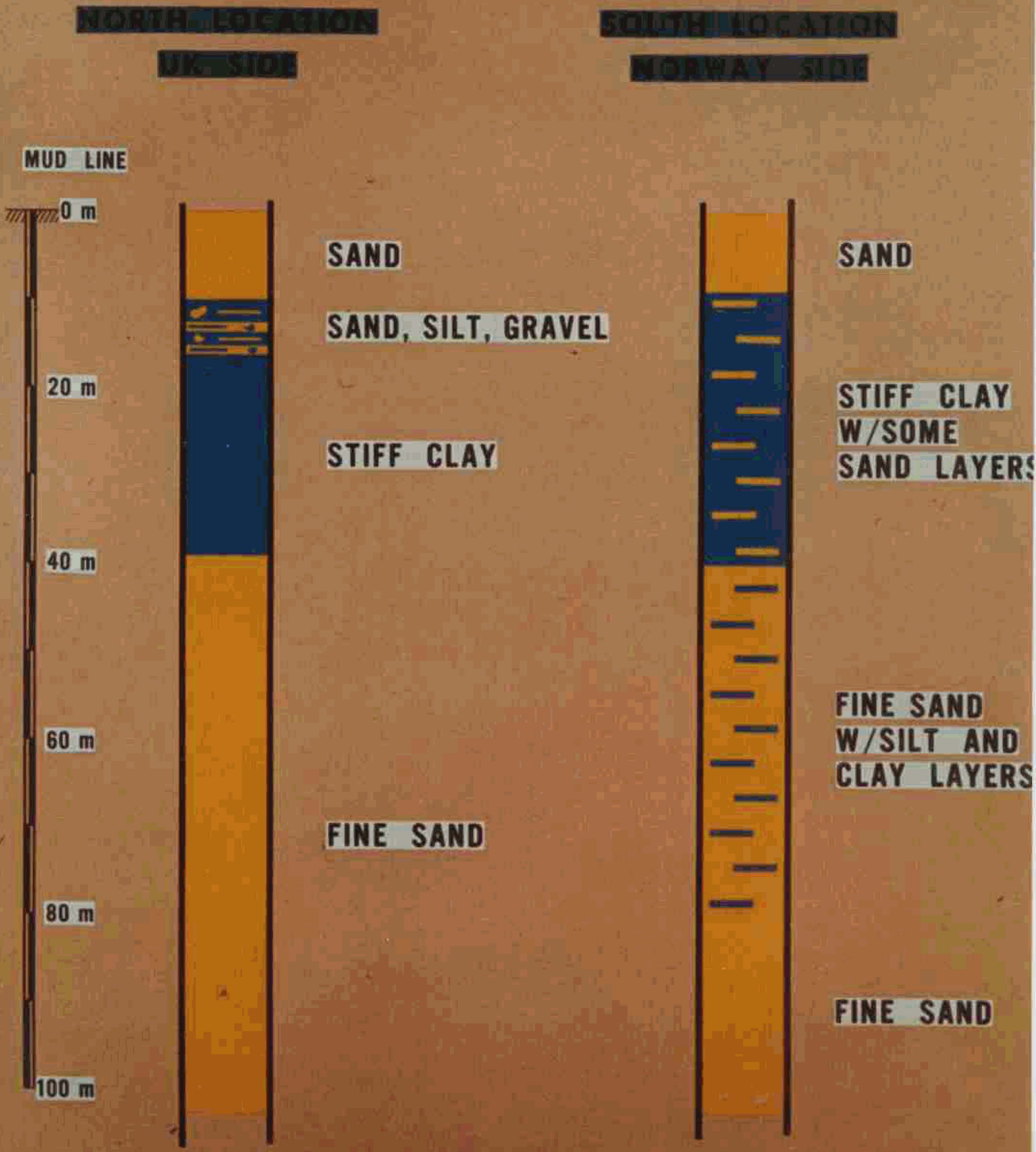
Note that different observations since the installation of the Frigg platforms also tend to indicate that design calculations for foundations were conservative

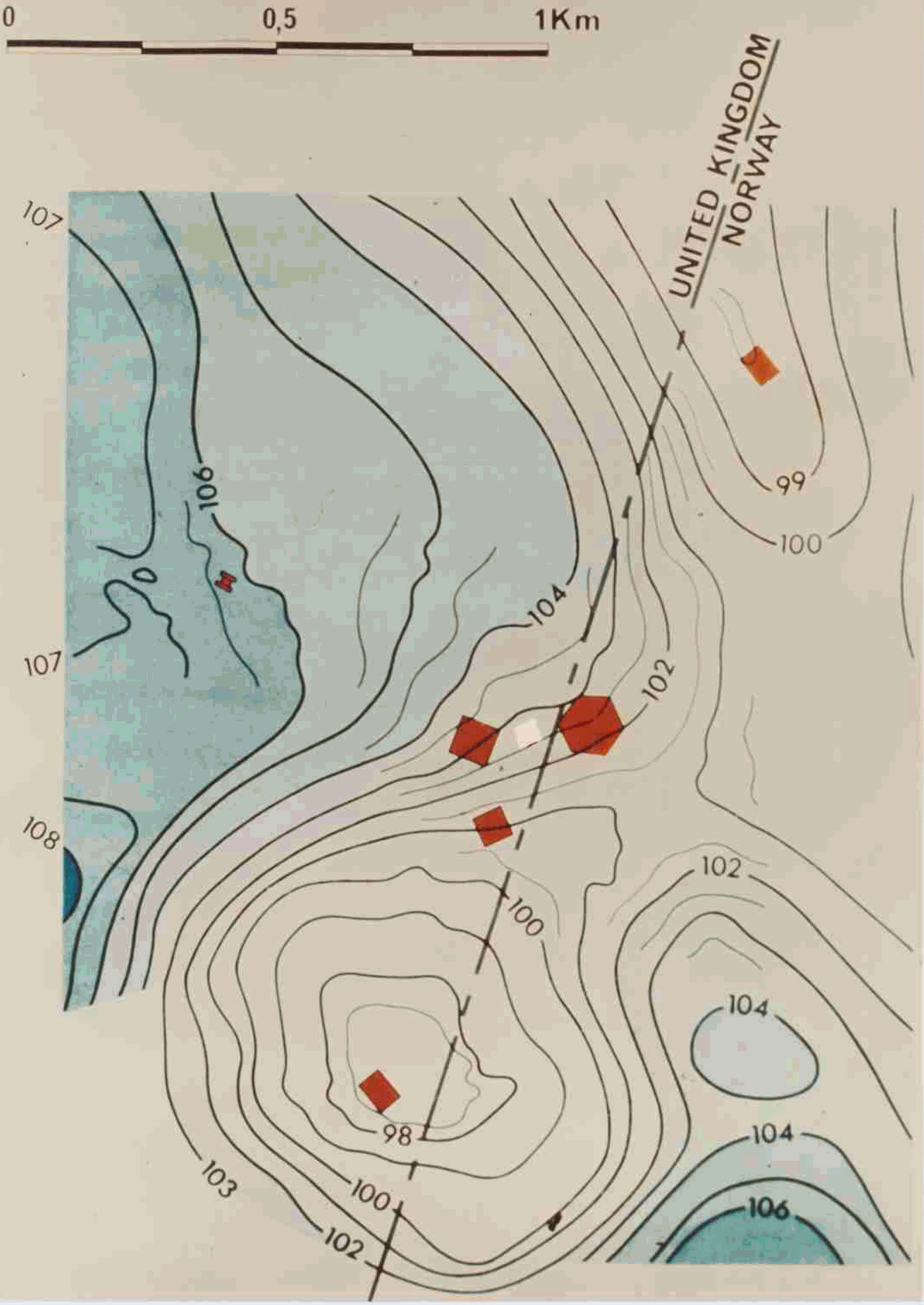
Drilled hole stability problems for insert-piles and conductor pilot holes were solved by a special mud developed by EAN. An original procedure of mud column weight control was successfully applied to install the conductor pipe without foundation disturbance. Production drilling below these conductor pipes was accomplished without any trouble for the structure.

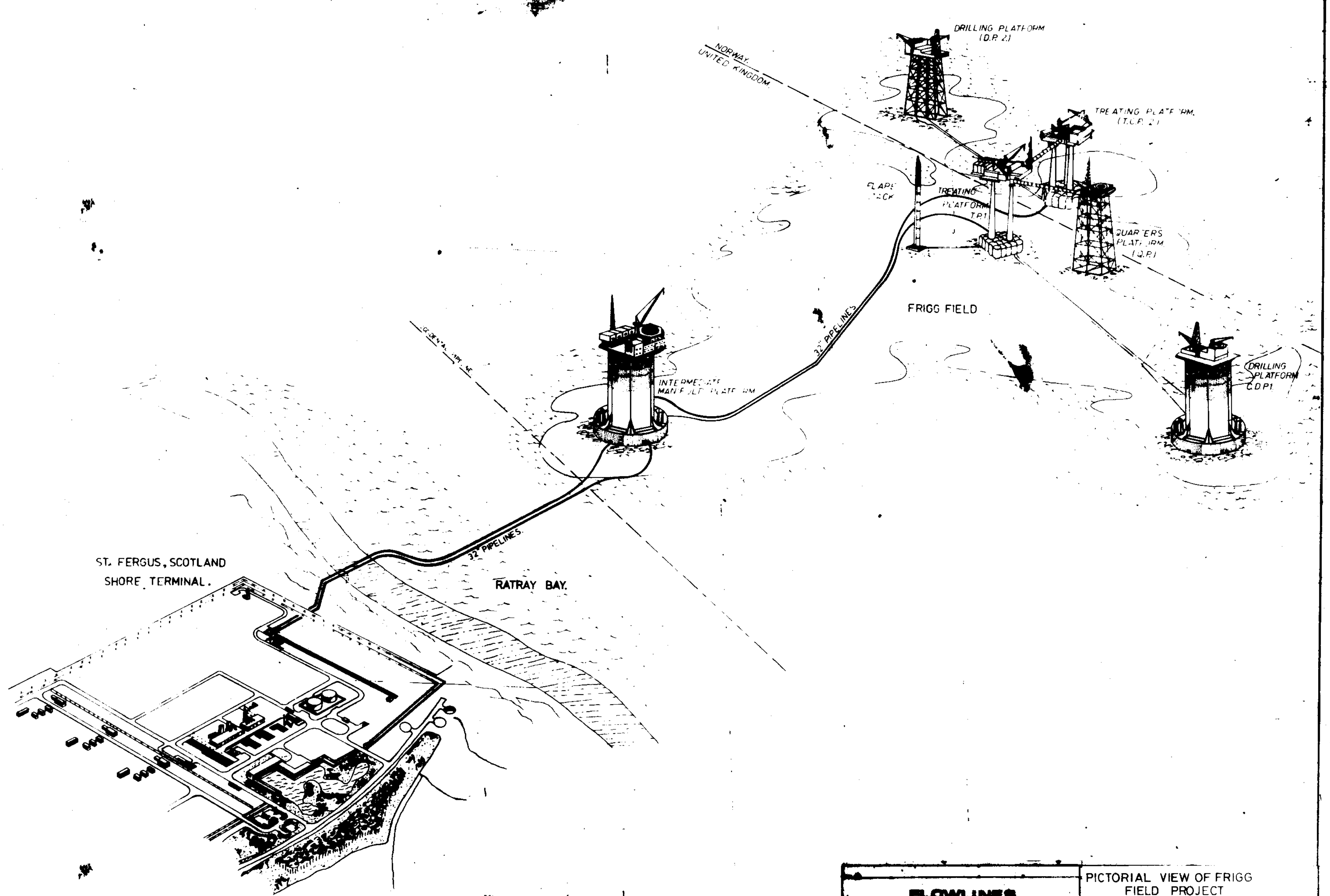
The development of Frigg Field represented an opportunity to use the most recent equipment for sea-bottom and subbottom surveying and, at times, to innovate (bathymetry, logging, ...).

FRIGG | PLATFORM DESIGN

SOIL DATA




0
0,5
1Km
UNITED KINGDOM
NORWAY
107
107
108
106
104
102
102
100
99
100
98
100
102
103
104
104
106



FLOWLINES

PICTORIAL VIEW OF FRIGG FIELD PROJECT

Brown & Root De France
Engineers Constructors
PARIS, FRANCE

ELF . NORGE - A/S

FRIGG FIELD DEVELOPMENT PROJECT

REFERENCE DRAWINGS NUMBER	TITLE	REV.	REVISION	BY	DATE	CKD
		0	FOR INFORMATION ONLY	AC	30/7/76	JJS

	DRAWN	CHECKED	CHECKED	APPROVED
BY	AC	J.J.S		
DATE	30 7 76	30/7/76	30	

SCALE	PROJECT No.	DRAWING NUMBER	REV.
N.T.S		AI-PL-A-112	0

5 - PROGRAM

It must be remembered that The Licence'Joint Venture group had agreed to share the responsibility for the development and operation of the Frigg field and for the transportation system required. EAN has been given the responsibility for the development and production of the gas from the Frigg field, and TOM has been given the responsibility for the construction of the pipeline to Scotland, booster platform and shore terminal.

The Frigg field is surrounded by several other minor gas discoveries which are under evaluation. These are East Frigg, North/East Frigg, Odin. Should these deposits be produced, the gas could be conveyed to the Frigg field facilities.

The development of the Frigg Field, to include production and pipeline facilities, was originally to be completed in three phases as outlined below.

5.1. Phase I - Construction completed in 1977

Phase I is the development of the Frigg field production facilities and the pipeline facilities for the exploitation of the U.K. zone. This phase includes up to 24 gas wells and dehydration treatment facilities located at the Frigg field site, one 32 inch diameter pipeline some 360 kilometers in length, one intermediate platform and one shore terminal with processing and gas metering facilities. It will maintain both hydrocarbon and water dew point control and flow of 30.5 x 10^6 Std m^3/day with an annual delivery of 8.5. x 10^9 Std m^3.

5.2. Phase II - Construction to be completed by 1978

Basically, the Norwegian zone adds approximately twenty four (24) gas wells, related platform production equipment and additional processing facilities within the shore terminal complex to the system. The second 32 inch pipe line parallels the first line and utilises the previously completed intermediate platform for pig receiving, launching and future compression. It is designed for maximum daily flow of 30.5 x 10^6 Std m^3/day with an annual delivery of approximately 8.5 x 109 Std m^3 .

5.3. Phase III - Construction to be completed by 1981

To transport and treat the gas produced for delivery onshore at the contractual pressure of about 44 bars, it is necessary to maintain pressure on the field at 150 bars throughout the life of the field, by the use of adequate compression facilities.

The difficulty, and the novelty, was to design platform TCP 2 suitable to house both the phase II treatment trains and the future compression system.

The design of the compression facility was obviously dependent upon the load carrying capacity of TCP 2 and upon the largest size of gas turbines of an already proven technology.

The unit size finally chosen was 38 000 hp.

Installation was planned in two stages, each of 114 000 hp,

comprising 2 units chain mounted plus one back up compressor, in order to compress a quantity of 60 Mm^3/day initially at 100 bars, then at a pressure ranging from 65 to 150 bars.

5.4. Program changes

Due to one major accident and certain other difficulties, the initial phase of the original plan was shifted accordingly.

However, after the loss of DP1, by using the experience gained previously, a revised plan was set in motion in December 1976. From that date the schedule of facilities fabrication, installation and completion was satisfactorily adhered to, as well as gas delivery target date (see attached planning chart).


PLATFORMS
1975
1976
1977
1978
1979
J F M A M J J A S O N D
CDP 1
TP 1
DP 2
QP
TCP 2
FLARE
FLOW - LINES & CABLES
WELLS COMPLETED
HOOK-UP
COMMISSIONING
REMAINING WORKS
CERTIFICATE OF FITNESS
TRANSFER TO PRODUCTION
START - UP
GAS DELIVERY
EAST CLUSTER
WEST CLUSTER
SHUT-DOWN
TIE-IN
DEMOBILISATION OF TEMPORARY EQUIPMENTS
TCP2 COMPRESSION 1980
TRANSPORT LIFT
HOOK-UP
COMMISSIONING
TEST
START-UP
TOW & SET
COMMISSION
MISC. WORKS
OFFICIAL INAUGURATION
STABILISE LINES
POWER CABLES
CONTROL CABLES
TP1 - FLARE CABLE
CDP1
DP2
Basic hypothesis
On CDP 1 - drilling & production simultaneously
On DP2 - possible production on one cluster while drilling on another cluster
- Hook-up & drilling simultaneously
elf norge a/s p.o. box 168 - 4001 Stavanger
elf
OVERALL
FRIGG FIELD
SCHEDULE
FF.000.100.036
10.4.78
9

6 - ENGINEERING

6.1. General

a) Multiple platform arrangement

Governed by the principle of unitisation, the development of the Frigg Field by the Unit Operator Elf Aquitaine Norge, was divided into three separate phases : the first covered the western side or the field, the second the eastern sector, the third gas recompression.

The development involved the engineering, fabrication and installation of five major platforms, the use of an articulated structure and an intricate task of connecting pipelines and facilities.

Each platform had to be designed to withstand the unusually rough conditions of the Northern North Sea and to last the full life of the field (an estimated 15 to 20 years).

b) Steel or concrete

Steel or concrete ? A comparative study was made in April 1973 that ruled out the choice of a concrete drilling platform in favour of a steel one for the following reasons :

- at that time no concrete drilling platform had yet been used in the North Sea,
- sea bottom stability assured by a piled foundation was considered more reliable than gravity type stability, which was particularly important for a drilling platform, due to the presence of the wells conductors linking soil to structure,
- economy.

Subsequently, the doubt about uncertain stability disappeared, as was proved by the choice of concrete for the treatment platforms.

French technology in prestressed concrete has always been advanced which has undoubtedly played a role in encouraging the choice of this material, against steel in the severe North Sea environment.

All the arguments in favour of concrete have now achieved practical demonstration : when the steel drilling platform DP 1 was lost, the concrete manifod platform MP 1 had to be modified in order to be equipped with 24 well conductors. Substantial other modifications had also to be made on the base, the structure and the modules. MP1 was then successfully operational as a drilling platform.

In the case of Frigg, EAN has installed platforms of both the more conventional steel jacket-type, and the more recent concrete design. The steel structures, used for the quarters platform (QP) and the second drilling platform (DP2), were towed out on barges, launched, settled on the seabed, piled and then topped with decks lifted by crane barges. The concrete platforms adopted for the first drilling unit (CDP1) and the two treatment and compression units (TP1 and TCP 2), were towed out to the site, and set on the seabed by the usual flooding procedure.

In addition to these platforms, which are interconnected (above sea level by bridges and at seabottom/by flowlines) to provide back-up mud, electricity and other services, the field has a common quarters platform (QP) providing accomodation, the central control, and service facilities to serve the whole field.

The flare stack of novel conception, designed to burn off gas in emergencies, was installed in October 1975, 500 metres apart from the other installations for safety reasons.

The campaign of offshore platform installation, hook-up, and pipeline laying has employed more than 1,500 people at the same time on the field itself. Completion of the second phase is scheduled for the summer of 1978 and will bring Frigg production to its full capacity .

c) On Site Gas Treatment

. C.1 Gas characteristics

It can be said that Frigg gas is very close to pure methane : as a matter of fact, it only accounts for 95 % of the gas, the remaining 5 % being the heavier paraffins. Analysis of these heavier components proves to be unusual. From the table of gas composition shown below, it can be seen that Frigg gas lacks intermediates, such as pentane up to hexane but contains heavy ends. Even if it is a very lean gas, a low condensate content exists and total liquid recovery comes close to 5 g/m3. A study of pressure and temperature effects indicates a retrograde behaviour.

This description of Frigg gas composition would not be complete if no mention was made of the complete absence of sulfur compounds.

This gas is at its dew point in the reservoir at the following conditions :

- pressure = 198 bars (initial pressure)
- temperature = 60 °C

and fluid has the following analysis :

Comp.	% moles	Comp.	% moles
N2	0.4491	C7	0.00043
CO2	0.3371	C8	0.00071
C1	95.037	C9	0.00427
C2	4.061	C10	0.00903
C3	0.037	C11	0.01592
iC4	0.007	C12	0.01651
nC4	0.004	C13	0.01136
iC5	0.003	C14	0.00418
nC5	0.00002	C15	0.00121
C6	0.00008	C16 +	0.00108
		TOTAL	100

Average molecular weight	16.8728	
Pseudo critical pressure	46.555	bars
Pseudo critical temperature	195.569	° Kelvin
Specific gravity	0.582	
C16 + molecular weight	220	
C16 + density	875	kg/m3

. C.2 Alternates for transportation and treatment

The development scheme was intended to solve two problems :

- transporting the gas to shore, some 360 kilometers apart from field site to feed the British Gas Corporation network ;
- delivering a sales gas under contractual specifications of :

. water dew point	= 17°C at 41 bars gauge
. hydrocarbon dew point	= - 12 °C for pressures below 69 bars gauge.

Therefore three development schemes were investiga-ted. They are briefly described before the selected solution is enlarged upon.

1. Field processing to meet sales specification

In this scheme, gas transmission is single phase and no processing facilities are necessary on shore. Condensate is removed off shore by cold frac process at low pressure and temperature and gas boosting compressors are installed right from the start. Condensate is either evacuated through a separate sea-line or loaded off shore.

2. Two phase-transportation and on shore treatment

Condensate facilities are located on shore. There remains an off-shore hydrate prevention system, involving dehydration or methanol inhibition. Installing of compressors can be delayed. Gas transportation is two phase.

.../...

3. Composite solution

Another possibility consists of moderately cooling the gas off shore to unable single phase transportation, and carrying out main processing on shore.

Alternates 1 and 3 need huge and expensive off shore processing facilities, compression units and condensate disposal. The two phase transportation scheme is economically interesting but slug problems are particularly annoying. Nevertheless, it was adopted. This was a calculated risk and the choice proved to be successful.

C.3. Process description

The gas and liquids stream from reservoir is saturated with water so that any simple injection into the sea-line would undergo severe hydrate formation and line blockage. On site processing must then be designed to prevent hydrate from forming during transportation to shore. Owing to unacceptable corrosion rates, methanol injection was rejected and dehydration by triethylene glycol was chosen. A value of water dew point for the gas and liquid mixture was agreed upon by both producer and carrier. This value was fixed to 0°C at 140 bars and was the only specification that this process had to meet.

As gas and liquids follow different circuits in the process, the corresponding treatments will be separately described.

C.3.1. Gas stream

The two phase output is separated in individual well head scrubbers-desanders, where liquid is removed and sand carry-over filtered. Gas phase is transported through two 26 " sea-lines to the treating platform. In normal operation, no hydrate formation occurs in these lines. Nevertheless, methanol injection can be supplied during start-up phase. Gas production enters three identical trains comprising :

- a WKO to remove liquid condensed during transmission and which can accomodate liquid slugs ;
- a contactor where triethylene glycol strips gas of its water and where dew point is completed ;
- a glycol regeneration package ;
- a metering system where gas output is metered before entering the pipeline ;

Each train has a treatment capacity of 15 million cubic meters of gas. Two of the trains are normally in service, with the third used as a spare. Overall capacity installed on the two treating platforms exceeds contractual delivery, so that part of the equipment stays available for new field connections.

C.3.2. Liquid stream

Liquid phase removed in desanders is flashed at low pressure and dispatched to the treating platforms through a 4" line.

Various liquid streams are then collected and dehydrated in one unit consisting of :

- a low pressure separator where water is removed ;
- a booster pump unit ;
- a coalescer where residual water is stripped off, an outlet coalescer, where condensate water dew point drops to - 5°C ;
- a high pressure pumping unit to inject into pipeline ;

C.4. Controls

The gas flow system has 3 primary operating controls points :

- water content ;
- gas flow rate entering the pipeline to St. Fergus;
- pressure of the gas pipeline at Frigg platform ;

Each will be discussed separately.

. The water content of outlet unit gas must be less than 67.5 parts per million which is equivalent to a dew point temperature of - 5°C at 140 bars. It is controlled by regulating glycol flow rate and concentration entering the contactor. The water content of gas leaving each train is measured with a moisture analyser and recorded in the control room.

. Flow is regulated through each train by setting the flow controller at the desired rate and adjusting the wellhead chokes so that pressure drop across flow controller is 5-15 bars.

. Frigg gas must be delivered to the BGC at St. Fergus at a pressure of about 44 bars. The process facilities on shore have a pressure drop of approximately 5 bars.

Consequently the gas which arrives on shore must have a pressure of 49 bars. In order to arrive at St. Fergus at 49 bars, gas pressure at Frigg must equal 49 bars plus the pressure drop in the 32 " line.

But condensate in the line will settle out in low spots if velocity does not exceed 4 meters per second.

Therefore, sealine pressure at Frigg must fall within two limits :

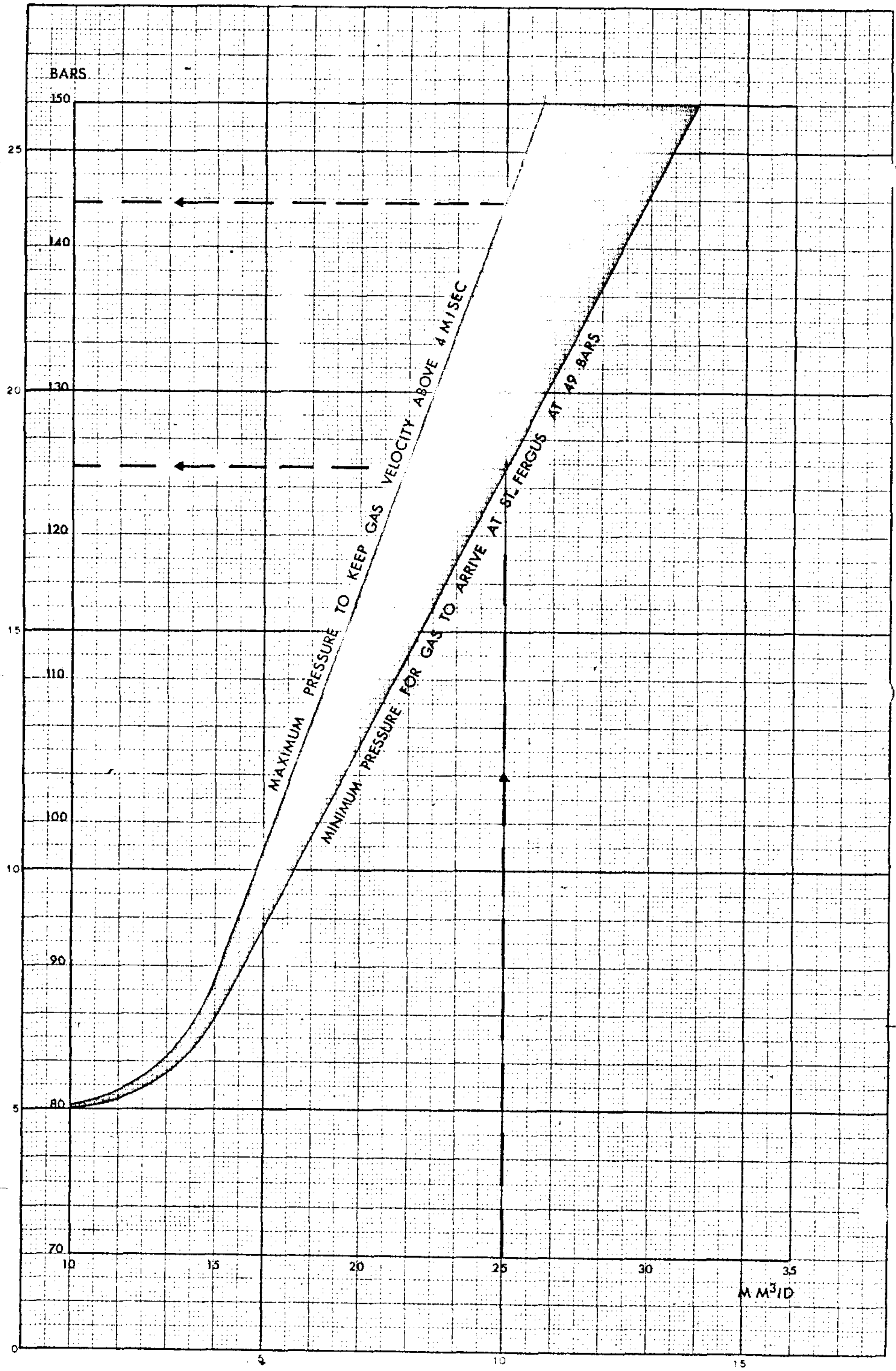
- the minimum pressure required to assure 49 bars at St Fergus ;
- the maximum pressure corresponding to a 4 m/s velocity ;

Pressure is controlled by varying the flow rate of gas entering the pipeline at Frigg.

. <u>Control of liquid system</u>

Because of condensate dumping into pipeline, it is imperative to control its water dew point continuously so that mixture remains below specification. This is achieved by means of a BS & W device that senses water content and monitors production recycling if water content exceeds 2 %.

DRILLING PLATFORM
TREATING PLATFORM
DESANDER 1
DESANDER 12
DESANDER 13
DESANDER 24
WELL 1
WELL 12
WELL13
WELL 24
PIG TRAP
26" SEA-LINE
4" SEA-LINE
FLASH DRUM 1
FLASH DRUM 2
TO FLARE
LIQUID KNOCK OUT 1
LIQUID KNOCK OUT 2
LIQUID KNOCK OUT 3
GLYCOL CONTACTOR
COOLER
STRIPPER
REBOILER
HEAT EXCHANGER
GLYCOL SURGE TANK
METERING
HEAT EXCHANGER
LTS
FUEL GAS
TO CONDENSATE SYSTEME
32"
TO SAINT-FERGUS
CONDENSATE SURGE TANK
FLASH DRUM
WATER TO SKIMMER
CONDENSATE BOOSTER PUMP
COALESCER
PIPELINE PUMP
FLOWMETER


BARS
150
140
130
120
110
100
90
80
70
10
15
20
25
30
35
MM³/D
MAXIMUM PRESSURE TO KEEP GAS VELOCITY ABOVE 4 M/SEC
MINIMUM PRESSURE FOR GAS TO ARRIVE AT ST. FERGUS AT 49 BARS
LES PAPIERS CANSON . FRANCE

d) Operating and Safety System

d.1. Operating and computer assistance

Running the Frigg plant means in fact fulfilling two conditions :

- to deliver to the pipeline a flow rate fixed within a defined range of pressures ;

- to deliver a treated gas.

Delivery conditions are notified by on shore dispatcher. They must fit with on shore plant operations and BGC requirement. For a given flow rate, gas must be supplied in a range of pressures as shown in the attached figure. Three ways exist to control the system :

- use of flow controller to regulate pipeline pressure. In this way pressure will override flow rate ;

- use of pipeline pressure to regulate flow rate. Flow rate will then override pressure ;

- combination : flow rate control on one unit, pressure control on the other ;

Quality of outlet gas in obtained by adjusting operating parameters of glycol unit, mainly reboiling temperature. There are furthermore, plenty of secondary parameters to be adjusted to optimize operations. For these, operator can get help from computer.

d.2. Computer assistance

On Frigg field, data under permanent control are thousands, since production wells are approximately 48 in number. Alarm and safety amount is related to field giant dimensions. In one word, no condition is missing for a computer assistance.

The selected computer is a 56 K memory TELEMECANIQUE 1600 equipped with :

- 2 synoptic display terminals ;
- 2 converse terminals ;
- 1 terminal for soft-ware modification ;
- 1 card reader ;
- 1 printer ;
- 1 teletype ;

It has been conceived to assist field superintendent in 3 ways :

- permanent information of field operating data ;
- anticipated information ;
- recording and reporting ;

At any time, operators can oversee field activity through colored screen flow sheets where required information is reported and every minute up-dated. They can be informed of general information as well as details on part of one unit. During start-up period, specialized programmes are available. They display changing of parameters on a selected unit. Alarms are recorded.

Anticipated information is helpful for transient periods when delivery rates are going to be changed. The computer provides an overall field simulation that enables operators to define optimum operation parameters.

Bi-hourly reports and daily production returns are routinely printed out and delivery flow rates continously computed.

d.3. Safety

- Process safety system

The process safety system is quite complex. But to summarize, it can be said that it was designed to react against possible occurrence of the principal malfunctions listed herebelow :

- Inlet treating platform :

. Abnormal pressure in transmission line between platforms that involves stopping of gas inlet treating units :

- Inside treating platform :

. Abnormal liquid levels in vessels that block in unit and shut down glycol system ;

. High moisture that stops gas delivery ;

- Outlet treating platform :

. Abnormal pressure in 32" pipeline that shuts down production.

Emergency shut down system

The emergency shutdown system protects personnel and equipment in the event of a fire or gas leak on the platform. It results in a partial or total platform shutdown as shown below :

	Blocks in	Action on generators	Action on equipmen
Level 1	Entire FRIGG-FIELD	Turn off	Depressurization
Level 2	One treating platform	Turn off	Depressurization
Level 3	One treating platform		
Level 4	One gas train		

Emergency shutdown is triggered either by pushbuttons in central control room and strategic locations or by fire or gas detection. Fire detection devices (ultraviolet light detectors, infrared light dectectors, smoke detectors) are located so that every square meter of the platform is monitored by at least two devices. If one trips, it will sound fire alarm and start firewater pumps. If a second one trips from sensing fire in the same area, emergency shutdown system is activated and fire extin-guishing and/or water sprinkler systems are actuated.

Gas detecting elements are located in all parts of the platforms.

d.4. Vent systems

There are two systems for relieving pressure in process equipment : a low pressure vent system to relieve pressure in equipment operating at a pressure below 15 bars, a high pressure vent for values above.

The high pressure vent system terminates at a remote flare connected to the platform by a 26" underwater line. To hold a stable flame, the flare line is continously purged with fuel gas. The high pressure vent system collects gas from following sources :

- relief valves and ruptures discs ;
- emergency shutdown valves ;
- hand depressurized equipment ;
- outlet treating unit when gas is out of specification ;

The low pressure vent system has equivalent functions for low pressure gases.

d.5. Diagrams

A diagram and a syntetic description of some of the safety systems is attached :

d.5.1. H.P. relief system,

d.5.2. Schematic shut down diagram

d.5.3. Fire water system,

d.5.4. Detection logic system.

d.5.1. HP relief system

Any abnormal stream production from the HP treatment system of platforms TP1 and TCP2 is gathered in the HP relief system and burnt on two 42" flare stacks located on the articulated flare platform (FP) at a safe 500 m from TP1.

The abnormal venting situations that could occur are :

- start-up transient time to match gas specifications in each unit,
- automatic safety relief due to fire occurence,
- accidental overpressure in one point of the system, originated, for instance, by a flow interruption, that activates automatic relief valves,
- shut down and decompression of a treating unit. After the shut down and decompression control has been manually activated, the automatic opening of decompression valves occurs.

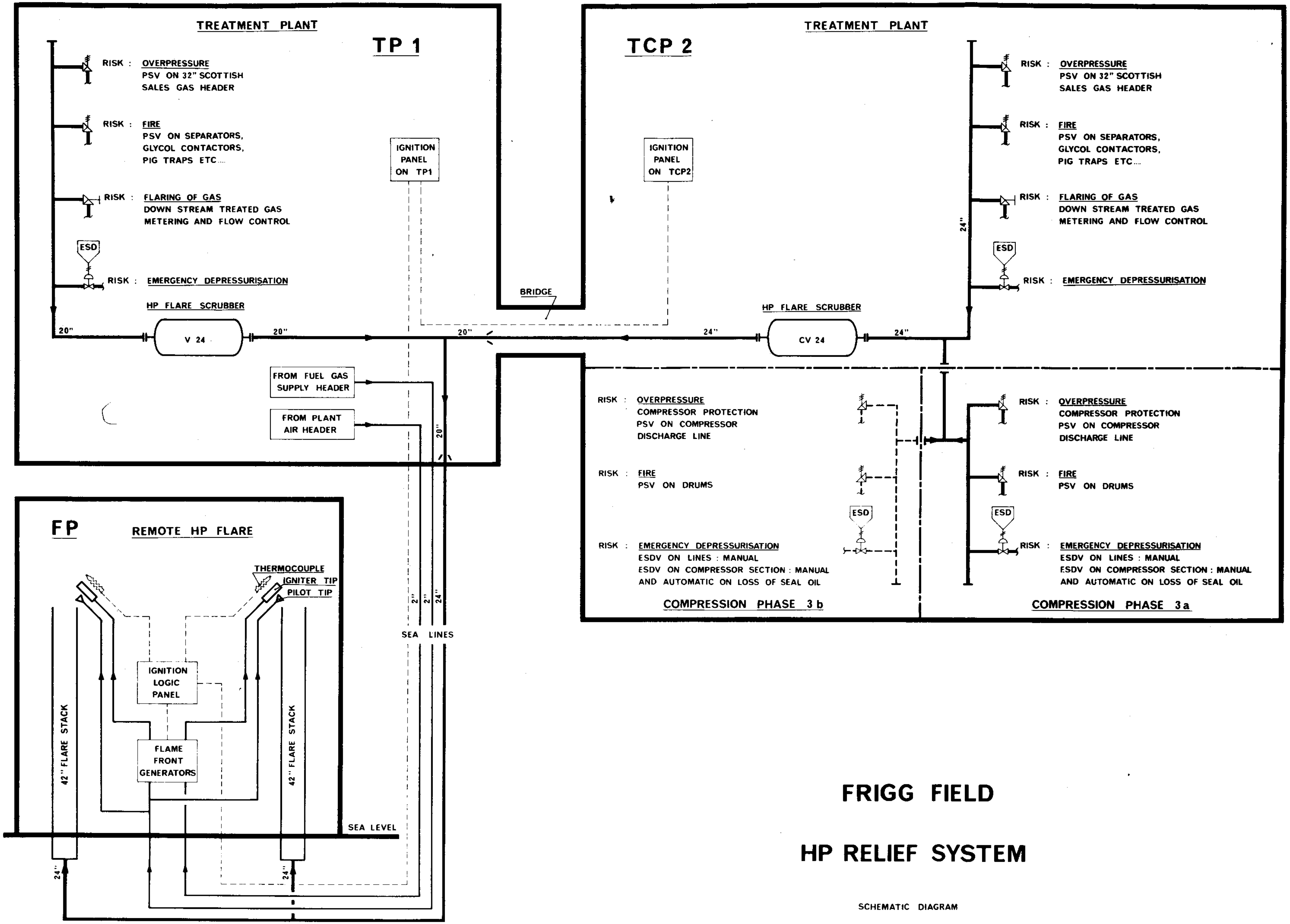
A scrubber is provided downstream the safety and depressurization valves on both TP1 and TCP2 platforms, which separates from the gas stream any condensates.

The gas so treated is sent through a 24" underwater flowline to the 42 " flares stacks of platform FP.

The vented gas is lighted by pilot burners that equip the flare tip.

The pilot burners in their turn are lighted by front flame ignitors activated from any of the platforms TP1, TCP2.

The pilot burners and the ignitors are fed by two 2" sealines, one for fuel gas and one for air, from platform TP1.



FRIGG FIELD

HP RELIEF SYSTEM

SCHEMATIC DIAGRAM

AVRIL 78

d.5.2. Schematic shut-down diagram

The system has been designed on a five level basis. The features are summarized herebelow.

First level : Manual general shut-down.

Manual general shut-down of the Frigg field (QP, CDP1, TP1, DP2 and TCP2 platforms) is activated by one push-button on the QP platform.

Second level : Manual shut-down (and decompression) of each platform from QP, TP1 and TCP2.

Manual shut-down and decompression of TP1 and/or TCP2 by push-buttons on QP.

Manual shut-down and decompression of TP1 by push-button on TP1. Manual shut-down of CDP1 by push-button on TP1.

Manual shut-down and decompression of TCP2 by push-button on TCP2. Manual shut-down of DP2 by push-button on TCP2.

Third level : Manual shut-down from each platform. Fire detection and gas detection actions.

On each platform CDP1, TP1, DP2 and TCP2 manual shut-down without decompression is activated from the corresponding platform by local push-button.

On each platform CDP1, TP1, DP2 and TCP2 manual shut-down without decompression is activated from push-button on QP.

On each platform CDP1, TP1, DP2 and TCP2 automatic shut-down, fire pumps starting and deluge valves opening are activated from gas and fire detectors.

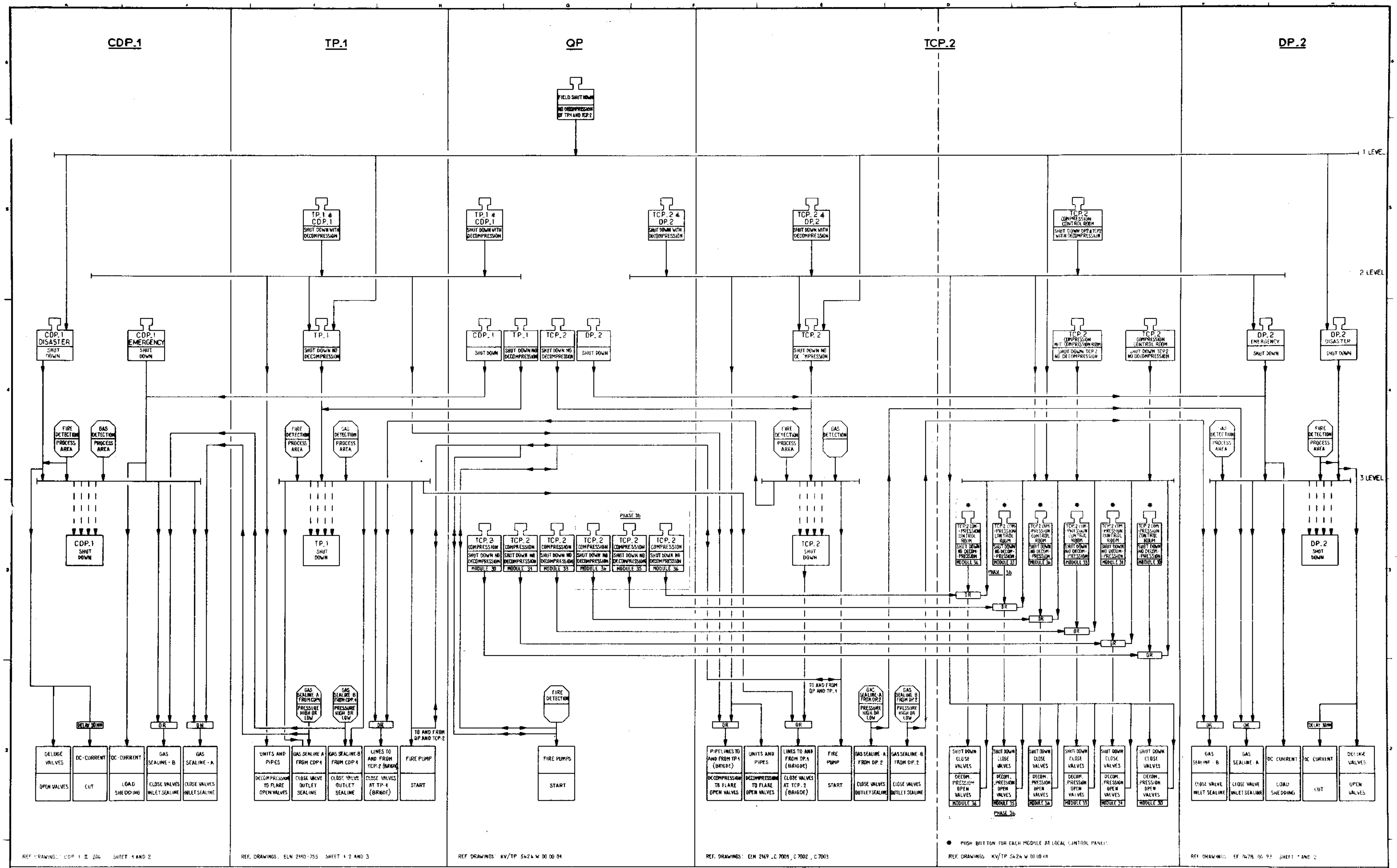
Fourth level :

Shut-down by local or remote push-buttons of one (or all by simultaneous operation) of the three parallel trains of gas treatment for the TP1 and TCP2 platforms.

Shut-down by local pressure switch of one (or all by simultaneous operation) of the three parallel trains of gas treatment for the TP1 and TCP2 platforms.

Fifth level :

Selective shut-down automatically from detection of abnormal process conditions.



FRIGG FIELD
SCHEMATIC SHUT DOWN DIAGRAM

APRIL 1978 _ PRELIMINARY

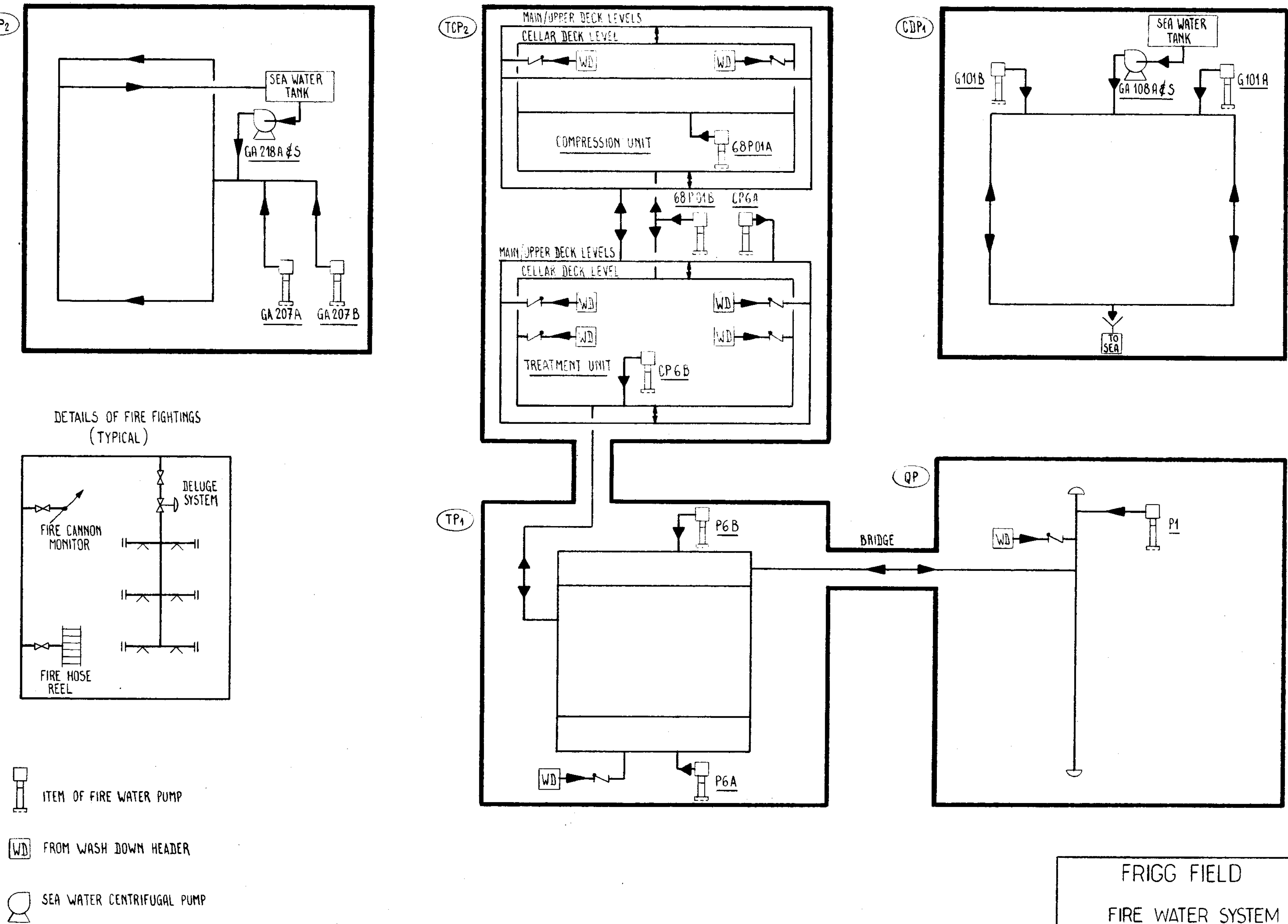
d.5.3. Fire water system

Each platform has a fire water system composed of a piping grid and 2 diesel pumps, 1 operational, 1 spare (however, QP has only one). Fire detectors of all types (UV, IR, heat detectors, smoke detectors) are strategically located around the decks and start up diesel driven fire water pumps.

Both manual and automatic fire fighting equipment is provided on all platforms. Some stations and rooms are specially protected by automatic deluge valve (or halon). Fire monitors and hose reels are located at various stations on all levels, so that any point can be covered from any one or two stations.

TCP2, TP1 and QP platforms fire water systems are interconnected through the bridges, hence all fire pumps can supply any requirement on any of these platforms, thus assuring redundancy in the system. The fire water system design is based on a permanent sea water filling of the lines, thereby saving precious seconds when required. Fire water main loop is filled up under pressure with interconnections on general wash down loop.

CDP1 and DP2 platforms have an independent fire water system, pressurized by centrifugal sea water pumps (jockey pumps).



FRIGG FIELD

FIRE WATER SYSTEM

AVRIL 1978

d. 5.4. Detection logic system

TCP2 : (treatment unit only)

Activation of any fire detector (infrared, heat, smoke, ultraviolet) or gas detector (electrocatalytic filament) results in :

- indications on the platform and on the fire and gas detection mimic panel of QP,
- alarms via the QP public address system,
- actions : fire pumps starting on the three platforms TCP2, TP1 and QP,

In certain instances ESD is initiated :

- by fire detection in process areas,
- by a high level of gas concentration,

In certain areas simultaneous activation of several detectors will cause the release of extinguishment, halon or water.

TP1 : Detection logic systems for TP1 and TCP2 are similar.

QP : Activation of any fire detector (same type as for treatment platforms) results in :

- indications on the fire and gas detection mimic panel,
- alarms,
- actions : fire pumps starting on the three platforms, QP, TP1 and TCP2,
- heating and ventilating shut down,
- ESD system initiating.

Activation of any gas detector results in :

- indicators and alarms,
- fire pumps starting on the three platforms.

In case of high level of gas concentration, heating and ventilating shut down will be initiated.

CDP1 : Two separate detection systems are installed, one for the production area, the other one for the drilling area. They are interlinked by annunciation system that indicates fire, gas, shut downs.

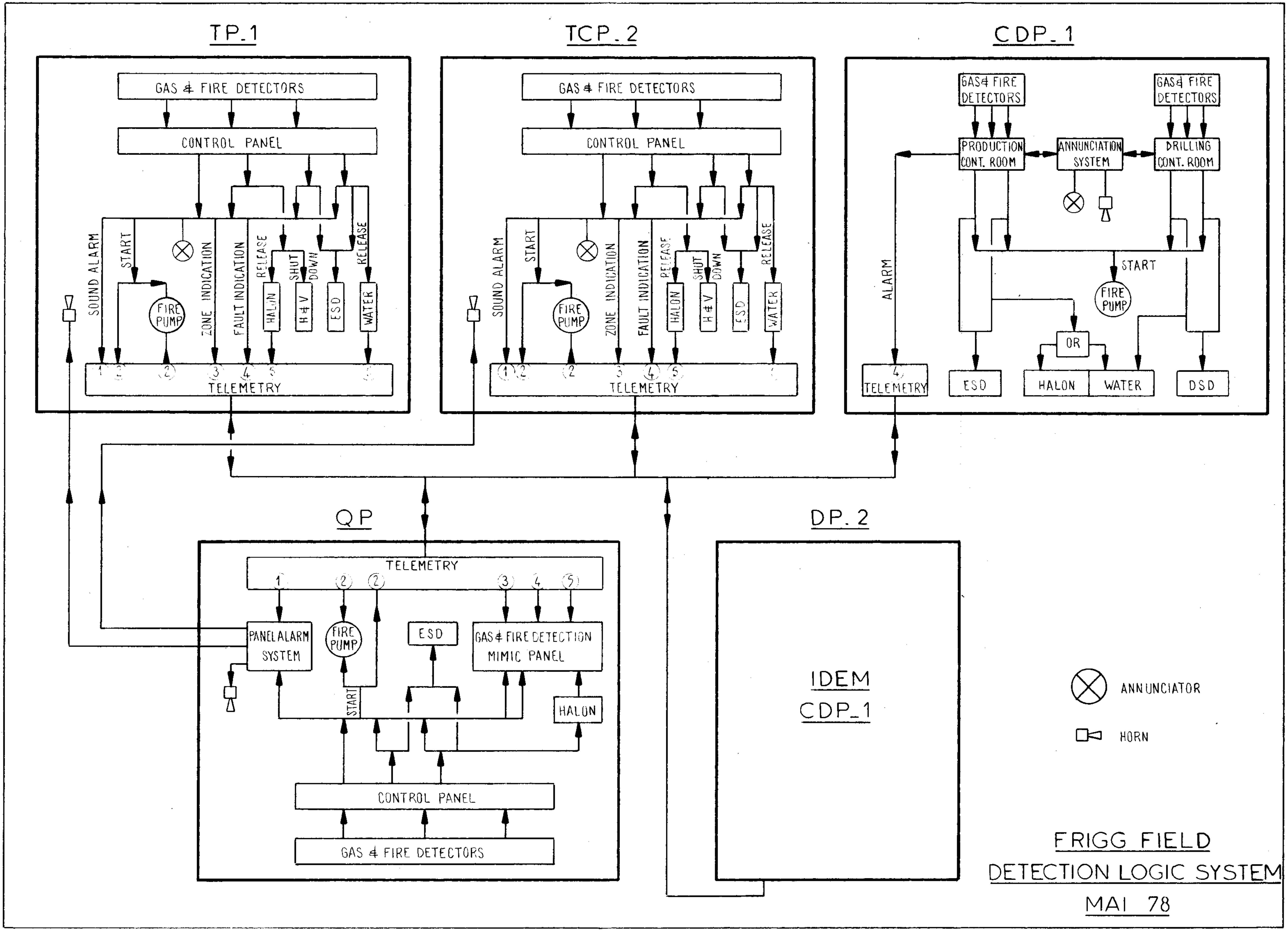
Gas detection : automatic action is initiated only by two simultaneous sensor's activation and a high level of gas concentration.

Fire detectors (smoke, heat rise, fusible plugs) when activated will initiate :

- indicators and alarms,
- fire pumps starting.

In certain instances simultaneous activation of several detectors will cause the release of halon.

DP2 : The detection logic system of this platform is conceptually simular to that of CDPI.



FRIGG FIELD
DETECTION LOGIC SYSTEM
MAI 78

6.2. Description of the platforms and interconnecting flowlines

Introduction : engineering premises

The basis of Frigg field development, as explained in paragraph 4, was the adoption of a multiple platform arrangement, with living quarters separate from treatment platforms.

However, it has appeared economically and technically desirable to group phase 2 treatment facilities and phase 3 compression facilities on one single platform (TCP2). Therefore, we present a detailed engineering description of this platform, which has given the opportunity to develop original concepts in the domain of integrated platforms, amongst which :

- use of a sophisticated support frame,
- equipment located inside the columns (pumps, risers, storage tanks ...)

A synthetic engineering description of the Frigg facilities, in the chronological order of installation is presented herebelow :

6.2.1.	QP
6.2.2.	CDP1
6.2.3.	FP
6.2.4.	DP2
6.2.5.	TP1
6.2.6.	TCP2
6.2.7.	Flowlines and cables

6.2.1.Living quarters platform (QP)

The QP platform is a 4 leg steel jacket (1) which was positioned on site in July 1975, and on which are set two living quarters modules, each comprising three levels (2). The platform supports also an aerial Telecommunications mast with its summit over 100 meters above sea level. A huge helideck, as well as a hanger for a small service helicopter is also provided.

All personnel working in the Frigg field are accommodated on the QP platform : this therefore include "residential" rooms : restaurant, recreation room, winter garden, 60 bedrooms (for 120 persons) and the various auxiliary rooms : kitchen, cold storage rooms, laundry, first-aid room, etc...

The following service facilities are also located on the QP platform :

- central operating and control room for the whole field,

- radio telecommunications rooms : remote control of platforms CDP1 and DP2 ; telecommunications with Norway and Scotland; communications with vessels, helicopters, etc.

- offices and conference room,

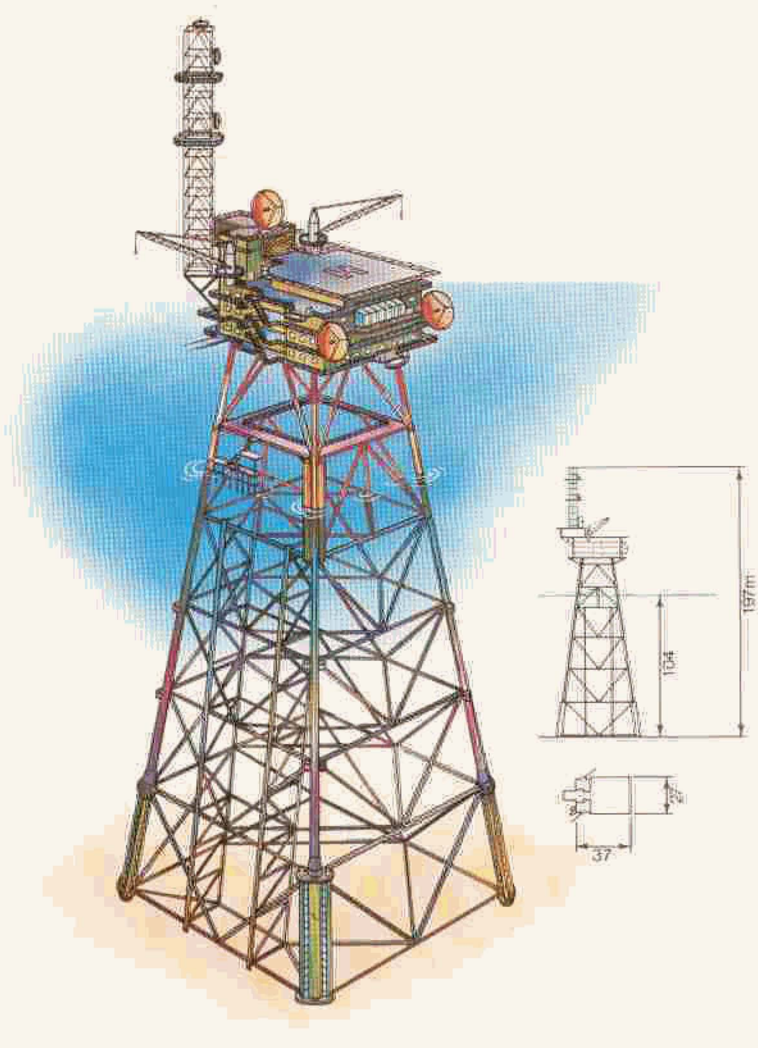
- services and auxiliaries : workshop, gas analysis laboratory, emergency generators, air-conditioning unit, sewage disposal, etc...

- various storage vessels,

(1) Fabricated in Cherbourg by UIE (Union Industrielle et d'Entreprise.

(2) Fabricated in Bordeaux by Chantiers de la Garonne.

QUARTERS PLATFORM



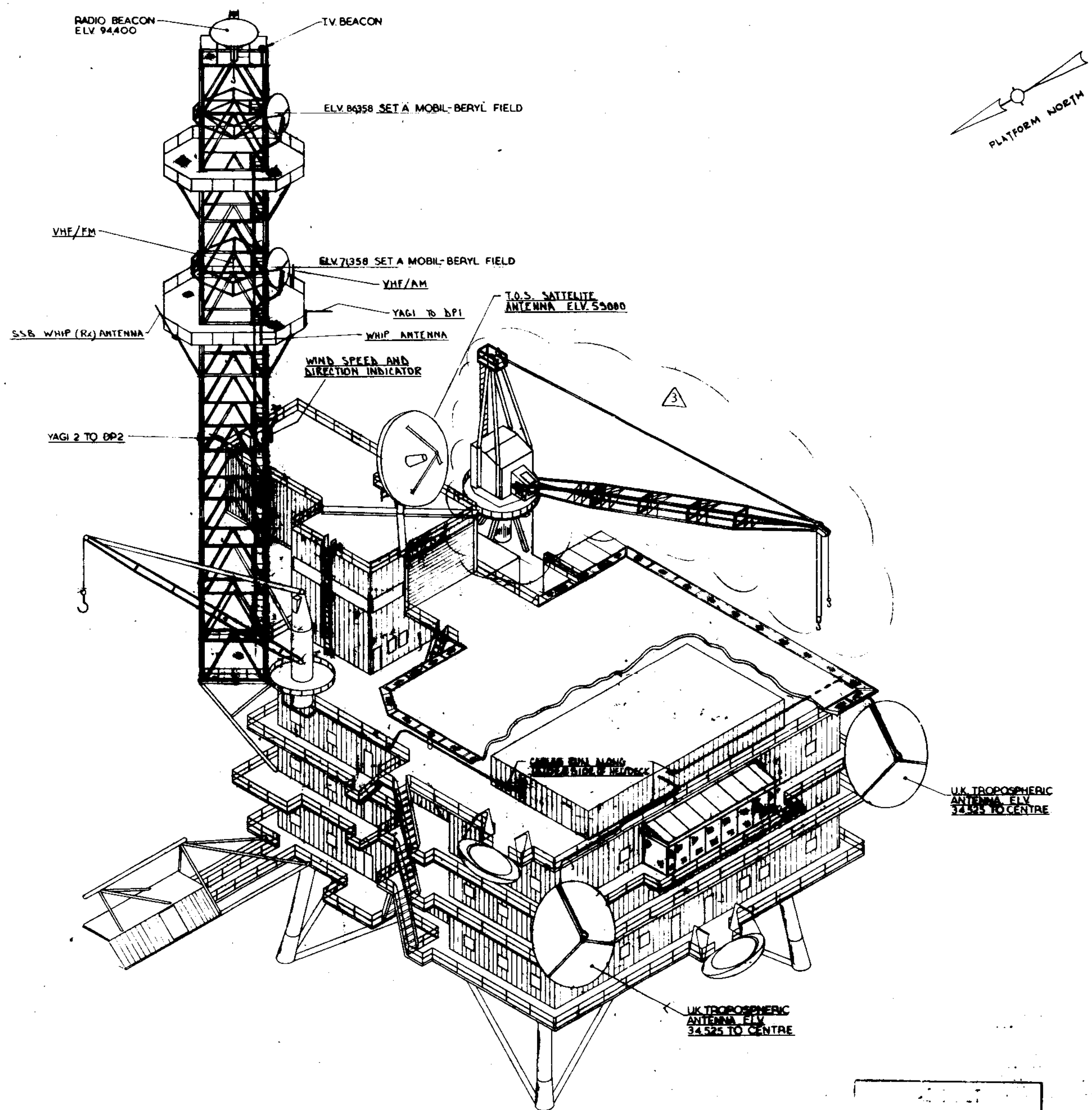
QP

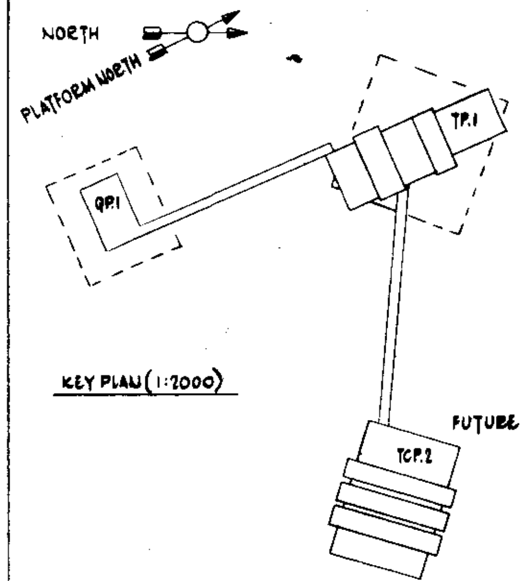
August 1976

QP platform

SHEET NO. 782

DWG 2111





REFERENCE DRAWINGS

DRG Nº	SHT Nº	TITLE
ELN2111	741	COMMUNICATION AERIALS PLAN
"	751	" CABLES ISOMETRIC

ELF – NORGE
FRIGG FIELD

QUARTERS PLATFORM
NORTH SEA JOB 1-40-D2 W.D.104M

McDERMOTT – HUDSON
LONDON – ENGLAND

DRAWN BY	SCALE	DATE
L.T. WARREN.	N.T.S.	4th OCT 74
DESIGNED BY		

ANTENNAE CABLE ROUTE TO U.K. COMMUNICATIONS

APPROVED
McDERMOTT – HUDSON
DATE: 4 Feb 75

ENGINEERS APPROVAL

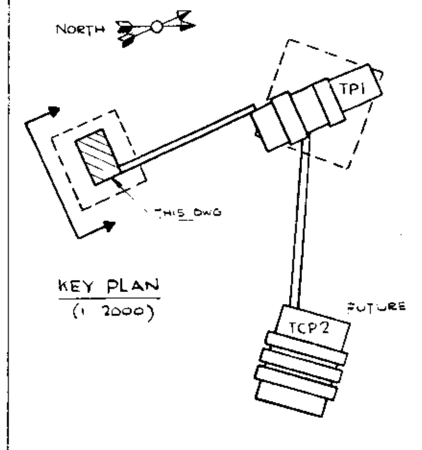
JES	BY	DATE
PROJECT		1-3-75
STRUCTURAL		
PROCESS		3-2-75
MECHANICAL		
ELECTRICAL		4/2/75
INSTRUMENT		
FAB. CHECK		
PROF. CHECK		

CUSTOMER APPROVAL
BY
DATE: 12/3/75

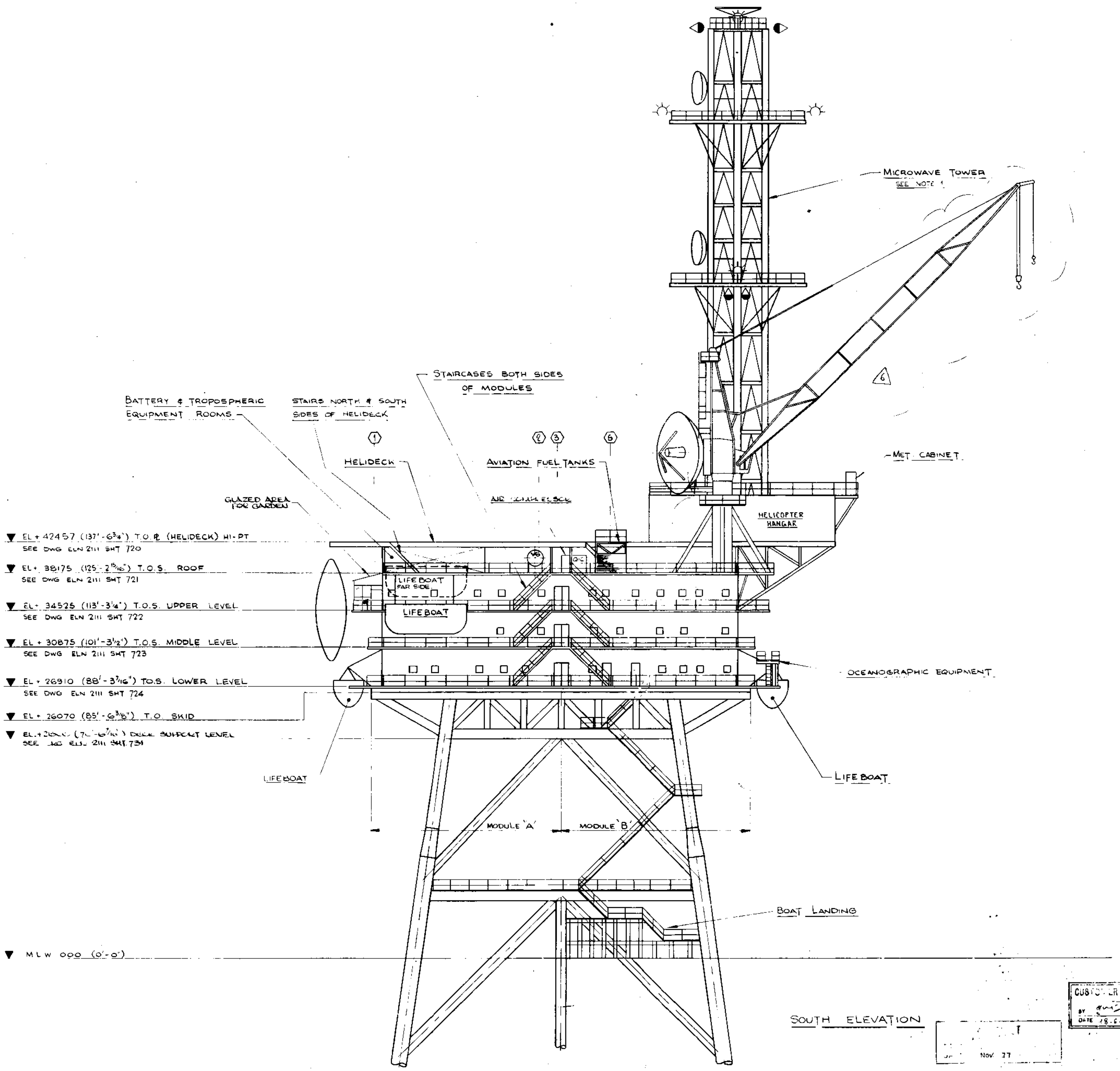
RECEIVED
NOV 77

FAB. STDS. REQ'D. THIS SHT

DESIGN	ELEC	INSTR	PIPING	STRUCT	NO	BY	DATE	REVISIONS	DATE	APP
					3	D.M.	13-9-77	CRANE REVISED AS SHOWN & ISSUED AS BUILT.		
					2	D.M.	29-7-76	BACKGROUND & CABLE ROUTING UPDATED		
					1	GR	25-2-75	ISSUED FOR CONSTRUCTION	3-3-75	
					0	TRG	24-1-75	ISSUED FOR CLIENT APPROVAL	28-1-75	



GENERAL NOTES



SOUTH ELEVATION

CUSTOMER APPROVAL
BY
DATE 18.6.75

Nov 77

'9 JUN 80'

REFERENCE DRAWINGS

DRG Nº	SHT. Nº	TITLE
ELN 2111	717	FIRE & SAFETY LAYOUT - LEGEND
ELN 2111	719	" - EAST ELEV.
ELN 2111	720	" - HELIDECK
ELN 2111	721	" - ROOF
ELN 2111	722	" - UPPER FLOOR
ELN 2111	723	" - MIDDLE FLOOR
ELN 2111	724	" - LOWER FLOOR
ELN 2111	731	" - DECK SUPPORT LEVEL

MK	BY	DATE	REVISIONS	DATE	APP
6	DM	18.11.77	CRANE REVISED AS SHOWN AND DRAWING ISSUED AS BUILT.		
5	JEP	3-3-77	OPEN LAUNCH CHANGED TO LIFEBOAT	3-3-77	
4	S.C.	29-4-76	TOWER-FLOOD LTS ADDED & NAV LTS POSS CHANGED	5-7-76	
3	D.M.	1-11-75	FLOODLIGHT SYMBOLS ADDED		
2	TW	27-7-74	REF. DRG. ADDED.		
1	DA	18-6-75	ISSUED FOR CONSTRUCTION	18/6/75	
0	T.W.	10.4.75	ISSUED FOR APPROVAL	10/4/75	

APPROVED
McDERMOTT — HUDSON
DATE 10/4/75

ENGINEERS APPROVAL

	BY	DATE
PROJECT	SS	
STRUCTURAL		
PROCESS		
MECHANICAL		
ELECTRICAL		
INSTRUMENT		
FAB CHECK		
PROP CHECK		

ELF - NORGE
FRIGG FIELD

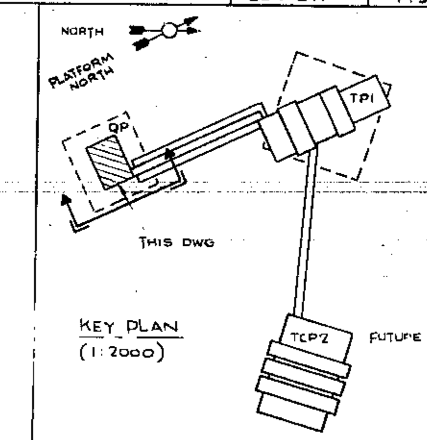
QUARTERS PLATFORM
JOB 1-40-D2

NORTH SEA

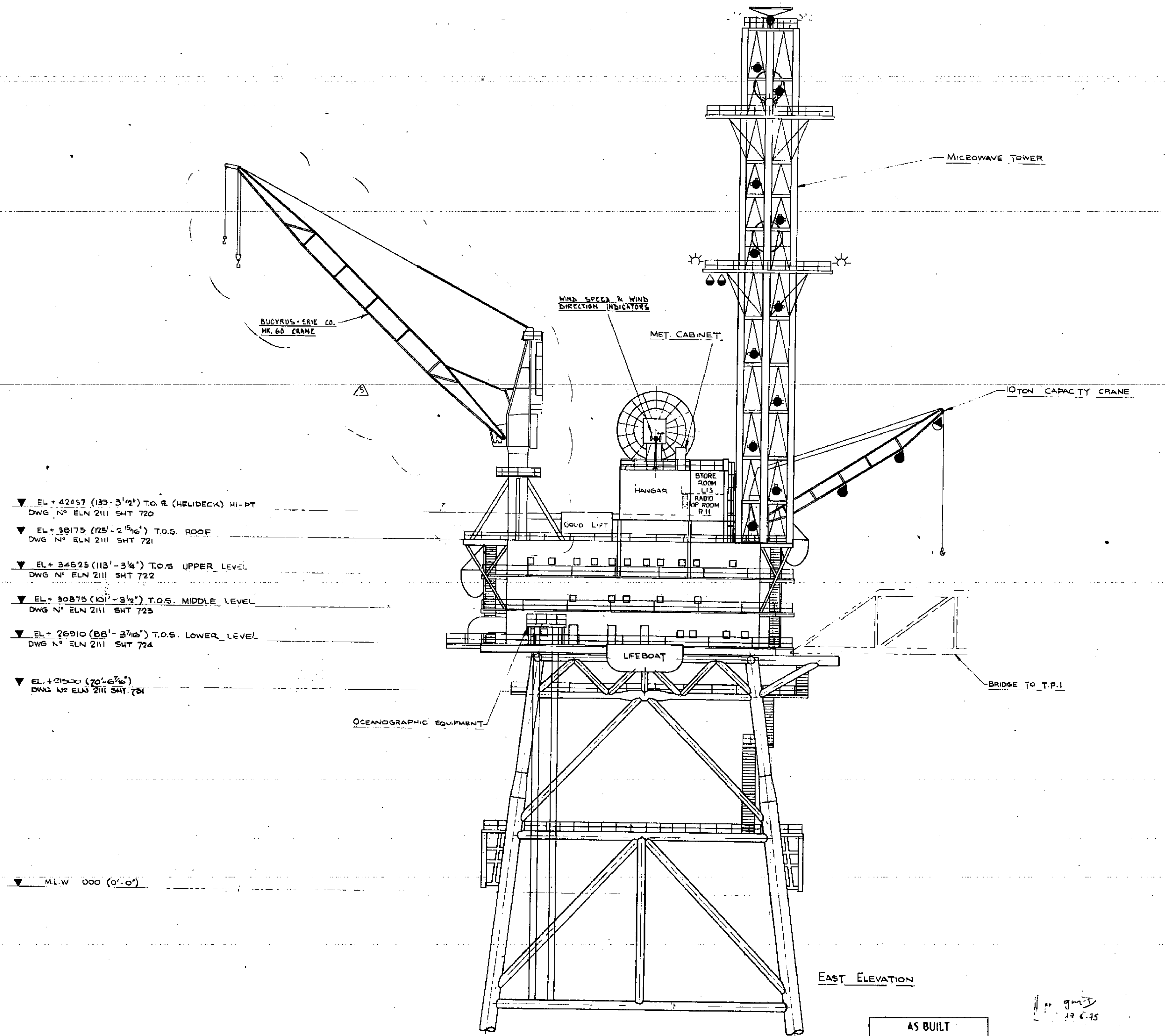
McDERMOTT - HUDSON
LONDON — ENGLAND

DRAWN BY	SCALE	DATE	DWG NO
C.A. GRIFFITHS	1:150	27th JAN '75	ELN 2111
DESIGNED BY			SHEET NO
A. WORSFOLD			718

FIRE & SAFETY LAYOUT - SOUTH ELEVN



GENERAL NOTES.



REFERENCE DRAWINGS		
DRG Nº	SHT Nº	TITLE
ELN 2111	717	FIRE & SAFETY LAYOUT - LEGEND
ELN 2111	718	" - NORTH ELEVN
ELN 2111	720	" - HELIDECK
ELN 2111	721	" - ROOF
ELN 2111	722	" - UPPER FLOOR
ELN 2111	723	" - MIDDLE FLOOR
ELN 2111	724	" - LOWER FLOOR
ELN 2111	731	" - DECK SUPPORT LEVEL

AS BUILT
JP TJ NOV. 77

19.6.75

MK	BY	DATE	REVISIONS	DATE	APP
5	BM	28-11-77	CRANE REVISED AS SHOWN DRAWING ISSUED AS BUILT		
4	FC			5.7.2	
3	D.M	1-11-75	FLIGHT. SYMBOLS ADDED. NOTE DELETED		
2	T.W.	27-7-75	REF. DWG. ADDED		
1	DA	18-6-75	ISSUED FOR CONSTRUCTION	18/6/75	
0	T.W.	10.4.75	ISSUED FOR APPROVAL	10/6/75	

FAB STDS REQ'D THIS SHT.

APPROVED
Tony Dawson
McDERMOTT – HUDSON
DATE 10/4/75
ENGINEERS APPROVAL

ELF – NORGE
FRIGG FIELD

QUARTERS PLATFORM
NORTH SEA **JOB 1-40-D2** WD 104 M

McDERMOTT – HUDSON
LONDON — ENGLAND

DRAWN BY	SCALE	DATE	DWG NO
C.A. GRIFFITHS	1:150	28th JAN '75	ELN 2111
DESIGNED BY			SHEET NO
A. WORSFOLD			719

FIRE & SAFETY LAYOUT - EAST ELEVATION. 5

6.2.2. Concrete drilling platform 1 (CDP 1)

This platform was originally conceived for use as an intermediate boosting platform, midway along the Frigg-St Fergus gasline; it was modified for installation on the actual Frigg field to replace the steel drilling-production platform DP1 which was lost during installation operations in 1974.

A pre-stressed concrete gravity structure (1), the CDP 1 platform was installed on site in September 1975. Its deck, also of concrete, supports the modules containing the drilling (2), production and processing (3)equipment and related utilities; this equipment was installed with the aid of an 800 ton travelling gantry erected for this purpose on the very deck of the platform.

The following operations are carried out from this platform :

- drilling of up to 24 wells;
- pretreatment of the gas : sand removal, drying, extraction of condensates.

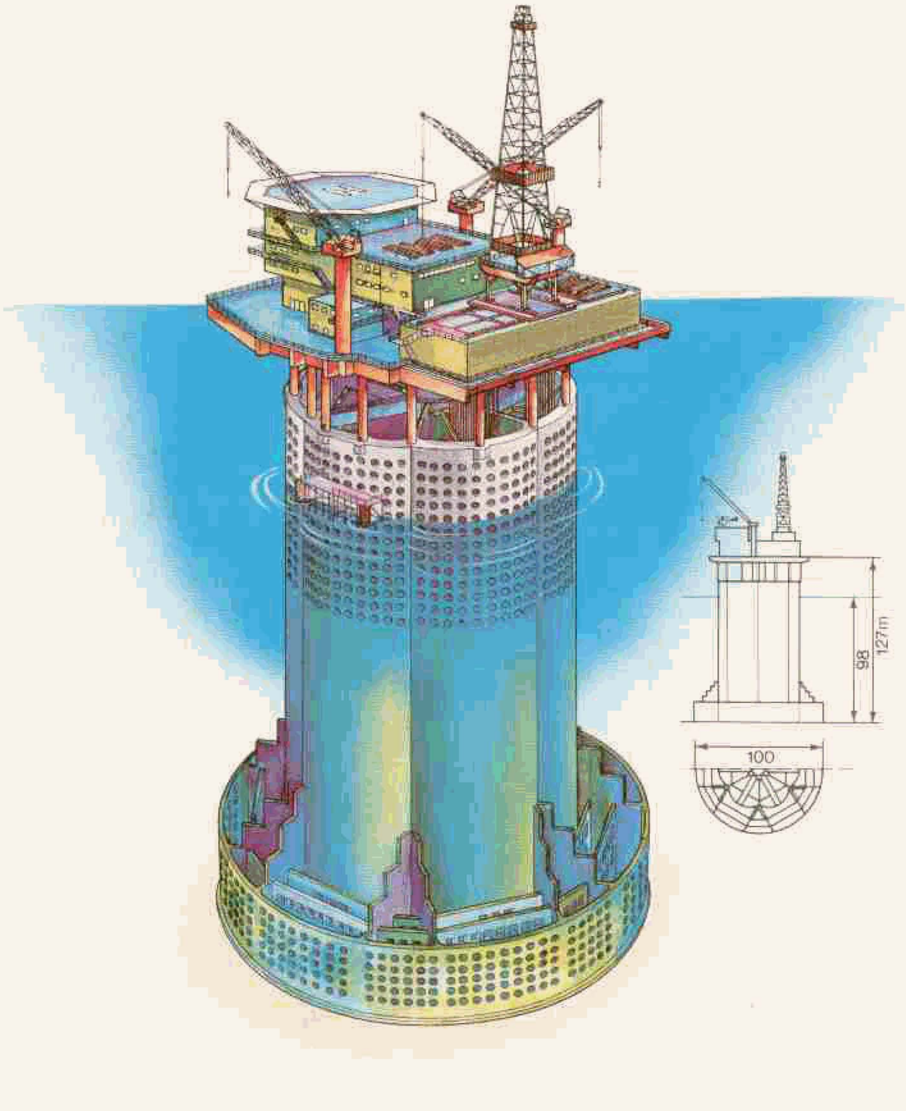
After glycol injection to prevent hydrates formation the gas flows to the treatment platform TP 1 by means of two 26" pipelines ; a 4" pipeline is installed to carry condensates to the same platform.

(1) Designed by the DORIS-HOWARD Franco-British organization and fabricated in Andalsnes (Norway) by the NORWEGIAN CONTRACTORS group.

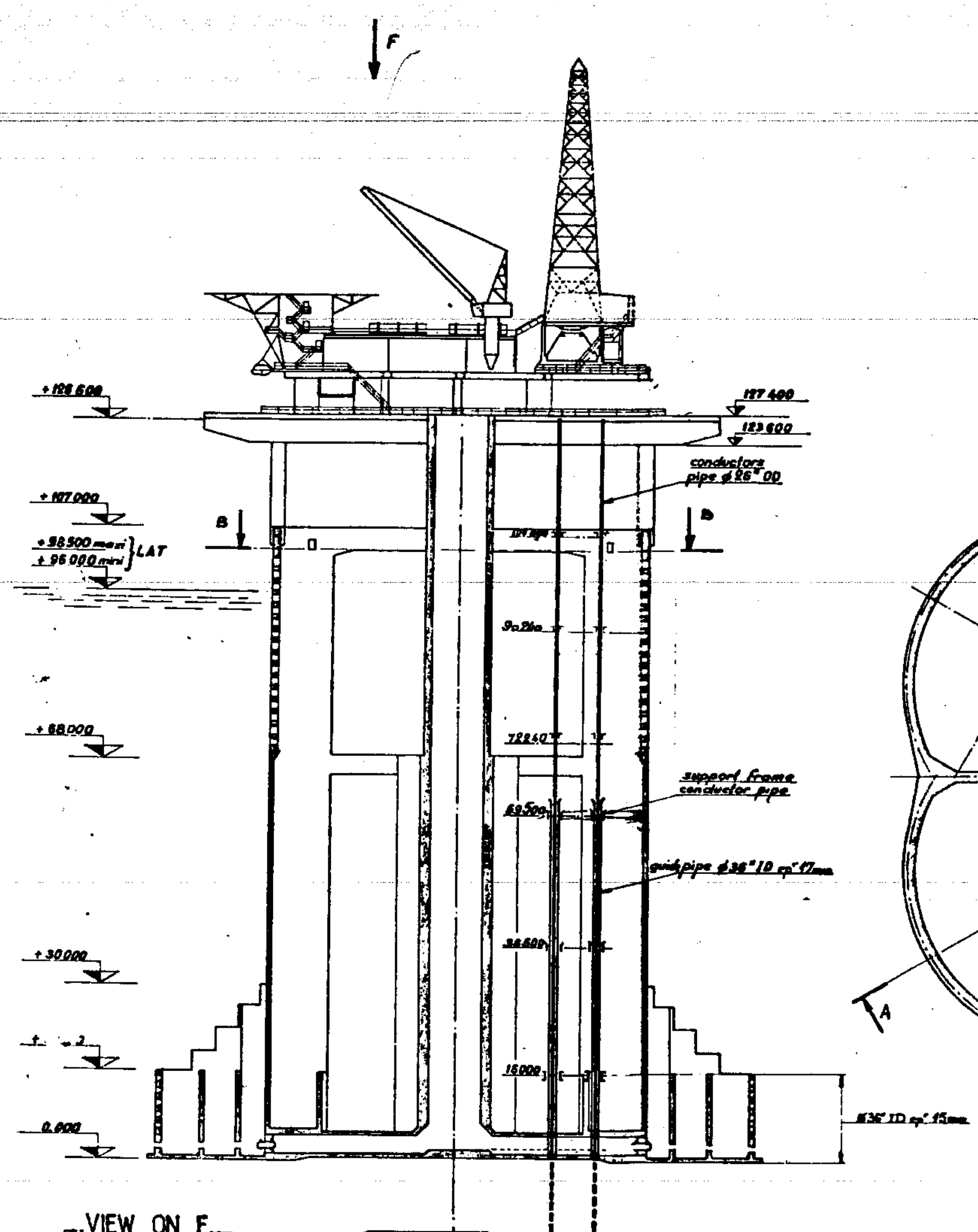
(2) Supplied by the Italian firm SAIPEM.

(3) Designed by the two engineering firms of LUMMUS FRANCE and COMSIP.

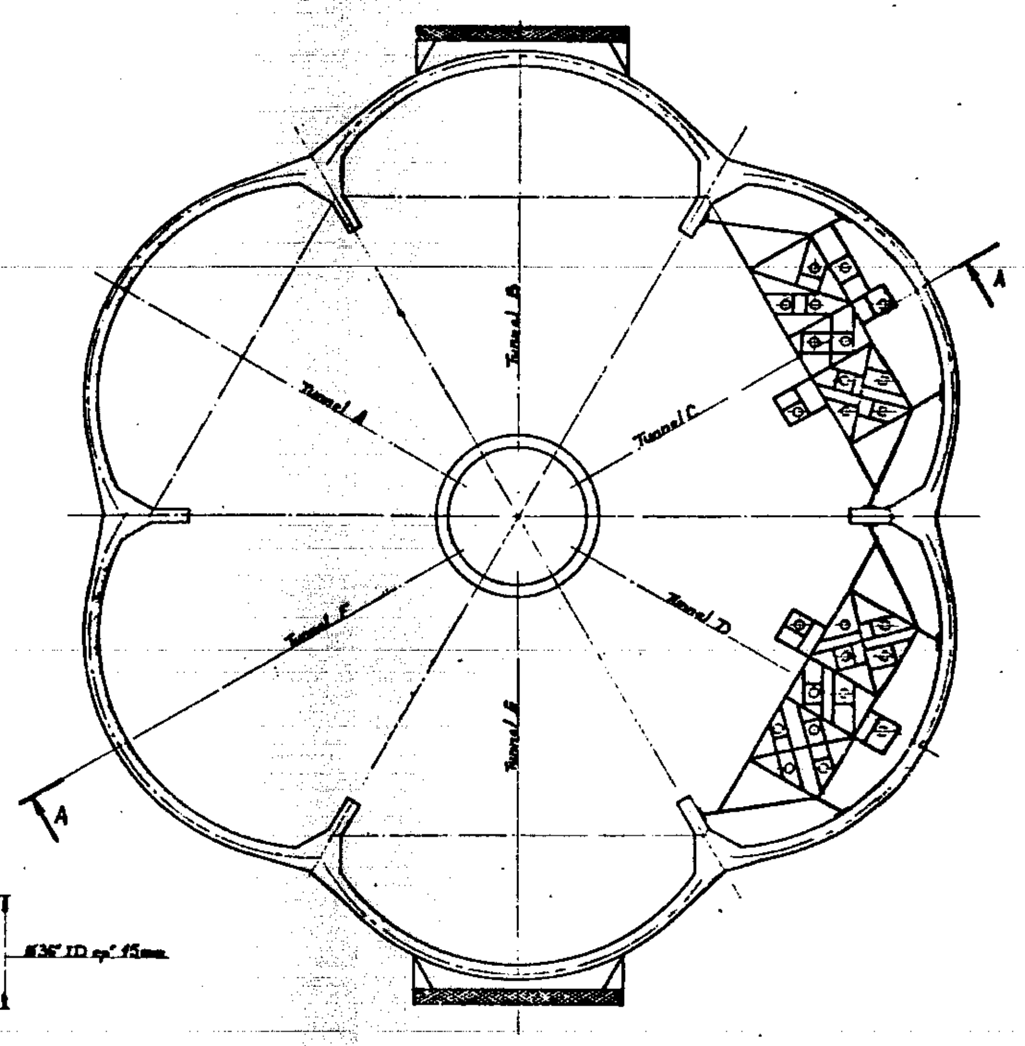
CONCRETE DRILLING PLATFORM I



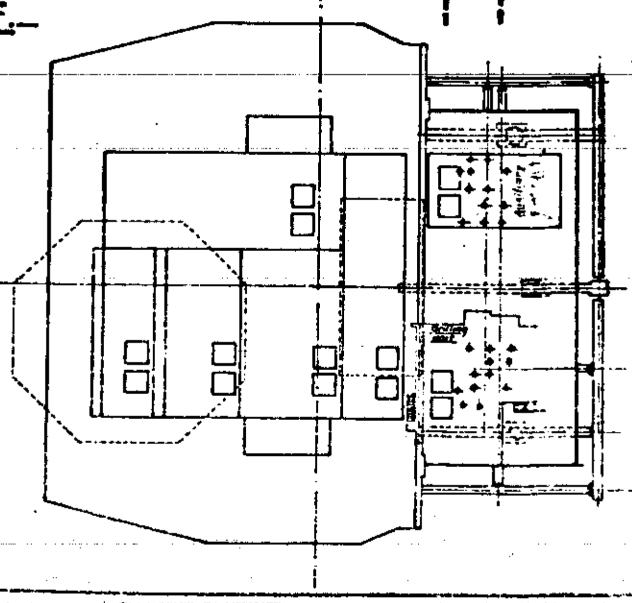
VERTICAL SECTION AA



SECTION BB



VIEW ON F



NUMBER	TITLE	0	1	2	3	4	5	6	7	8	9
A1. MP. OR2032	LOCATION OF DRILLING HOLES		12.11	6.12	28.1						
A1. MP. OR2033	LOCATION OF DRILLING HOLES		12.11	6.12	28.1						
A1 MPQF 1016	GENERAL VIEW FOR MODIFICATION OF THE PLATFORM		[illegible]	[illegible]							
A1. MP. OM 5051	LOCATION OF BASE PLATES FOR GUIDE PIPES										
A1. MP. QF 1005	SUPPORT OF GUIDE PIPES . LEVEL + 15000										
A1. MP. QF 1017	SUPPORT OF GUIDE PIPES . LEVEL + 15000										
A1. MP. QF	SUPPORT OF GUIDE PIPES . LEVEL + 38 500 .										
A1. MP. QF	SUPPORT OF GUIDE PIPES . LEVEL + 59000										
A1. MP. QF	SUPPORT OF GUIDE PIPES . LEVEL + 71240										
A1. MP. QF	SUPPORT OF GUIDE PIPES . LEVEL + 88500 .										
A1. MP. QF	SUPPORT OF GUIDE PIPES . LEVEL + 98240										
A1. MP. QF	SUPPORT OF GUIDE PIPES . LEVEL + 106000										

REFERENCE DRAWINGS NUMBER	TITLE	REV NO	REVISION	BY	CHECKED	DATE
		1	FOR APPROVAL			
		2	UP DATING			
		3	UP DATING			

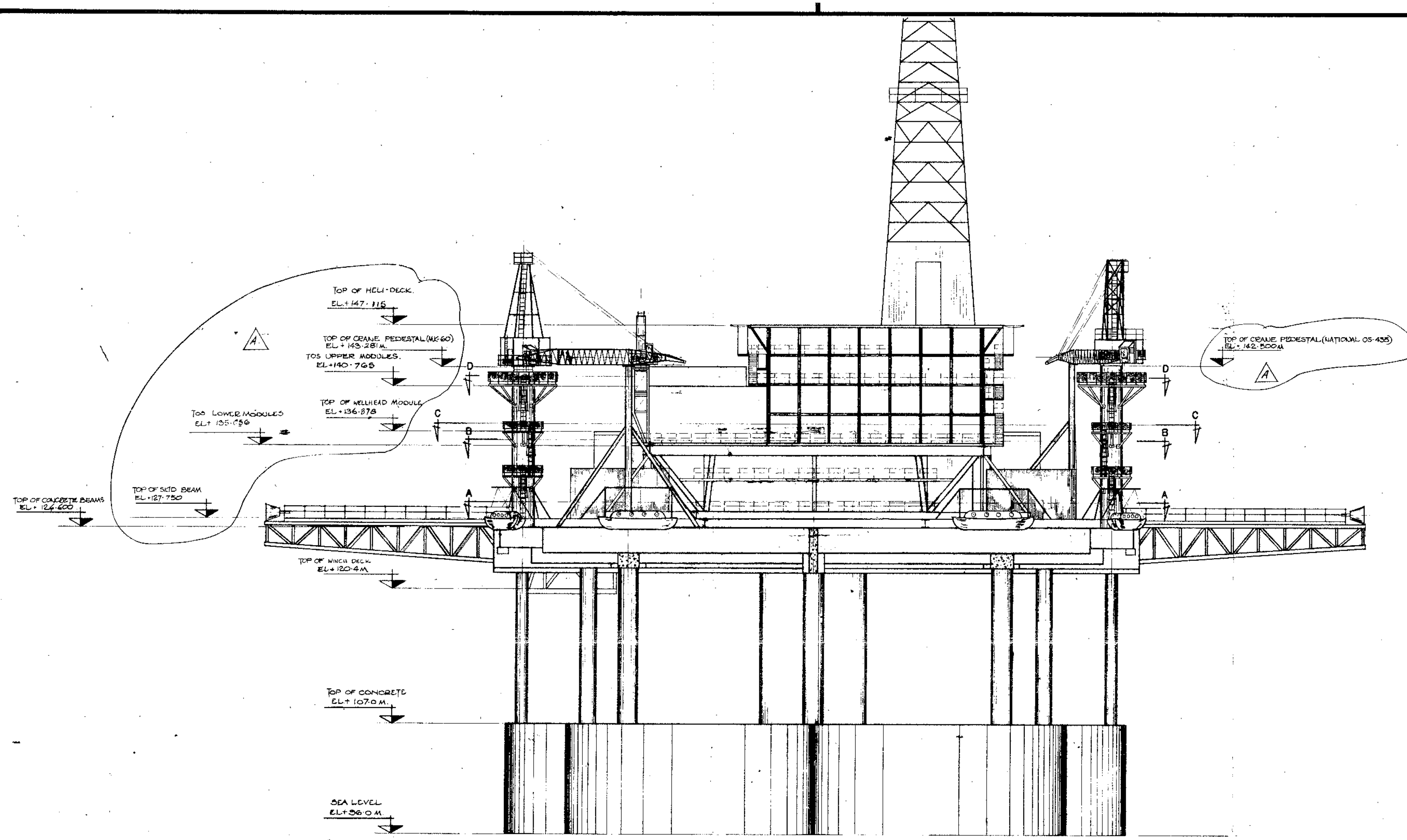
C.G DORIS
John Howard

TOTAL OIL MARINE LIMITED
LONDON
Frigg field to Scotland pipe line
Intermediate manifold platform

814 . 01 . 1016

GENERAL VIEW FOR MODIFICATIONS OF THE PLATFORM

DRAWN	CHECKED	CHECKED	APPROVED	SCALE	PROJECT Nº	DRAWING Nº
T.H. 20.01.1975				1/500 : 1/250		A1. MP. QF 1016 3



PROPRIETARY INFORMATION

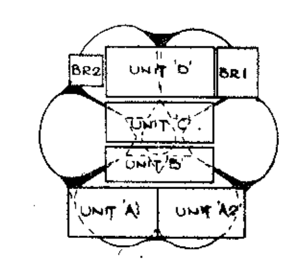
This drawing/report/document contains proprietary information belonging to Brown & Root, Inc. and may not be wholly or partially reproduced nor disclosed without prior written permission of Brown & Root, Inc.

BROWN & ROOT (UK) LTD REF DRGS.

EN-AA-002 EAST ELEVATION ON MODULES
EN-AA-004 G.A. OF MODULES ON PLATFORM.
EN-AA-005 UPPER MODULE ROOF PLAN EL+140·765 M
EN-AA-006 UPPER MODULE FLOOR PLAN EL+135·565 M
EN-AA-007 LOWER MODULE ROOF EL+135·065 M.
EN-AA-008 LOWER MODULE FLOOR PLAN EL+128·541 M
EN-AA-009 MAIN DECK: CONCRETE BEAM LAYOUT EL+126·600
EN-AA-010 PLAN ON SERVICE DECK EL+120·4 M.
EN-AA-016 FLOOR PLAN ON MODULES BR1 & BR2 EL+128·541 M
EN-AA-017 WEST ELEVATION ON MODULES
EN-AA-018 CRANE AND LIFE BOAT POSITIONS

A

NORTH ELEVATION



KEY PLAN

A

NOTES	REVISION · BY · DATE	REVISION · BY · DATE
		A. LEVELS AMENDED WJY. 6.10.75

Brown & Root, (U.K.) Ltd.
Engineers - Constructors
LONDON, ENGLAND.

DRAWN BY: R FOURNEL
DATE 30.1.75
CHK'D. BY:
DATE
SCALE: 1:200

APPROVED

APPROVED

SEAL

TITLE OF DRAWING: NORTH ELEVATION
MPX TO DP1 CONVERSION
NAME OF OWNER: [redacted]
LOCATION OF PROJECT: [redacted]

CONTRACT [redacted]
DRAWING [redacted]
SHEET [redacted]

6.2.3. Flare platform (FP)

The original swivelling platform design has been adopted to support the emergency flare (1). The FP frame is articulated on a ballasted base and from bottom to top consists of a triangular section lattice girder, a cylindrical stabilizing float and a cylindrical stack of lesser diameter, surmounted by two flare vents (2). Each vent is equipped with a pilot burner. The ignition system and the control and monitoring units are housed in compartments within the stack.

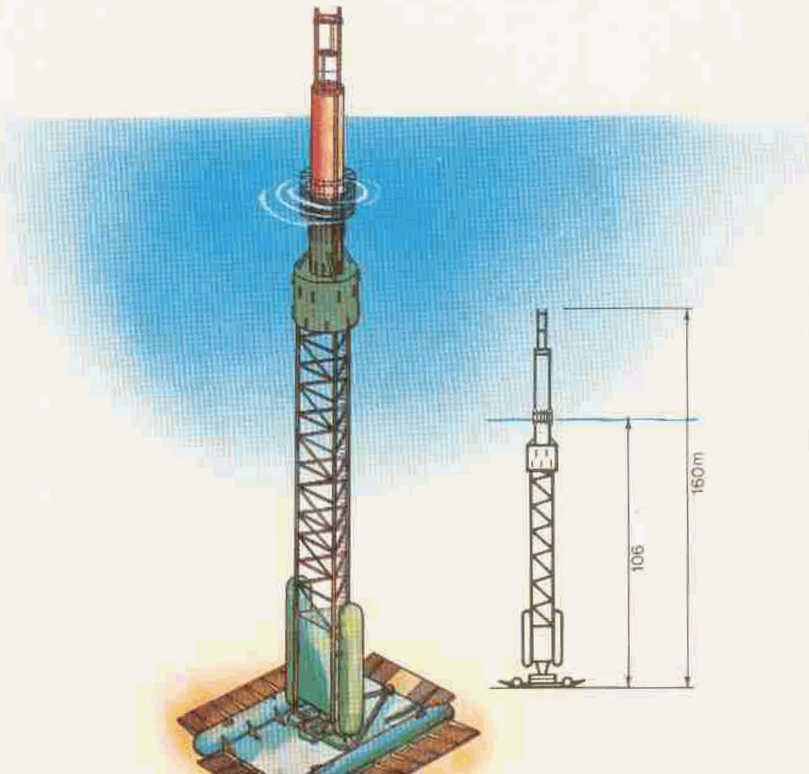
The platform is connected to TP 1 by means of a single 24 inch duct, which divides at the base to form two circuits each terminating at one of the vents via the universal articulation, the torsional seals, the framing, the float and the stack. Reinforced elastomer torsion sleeves provide the necessary flexibility at the forkpiece (See photograph).

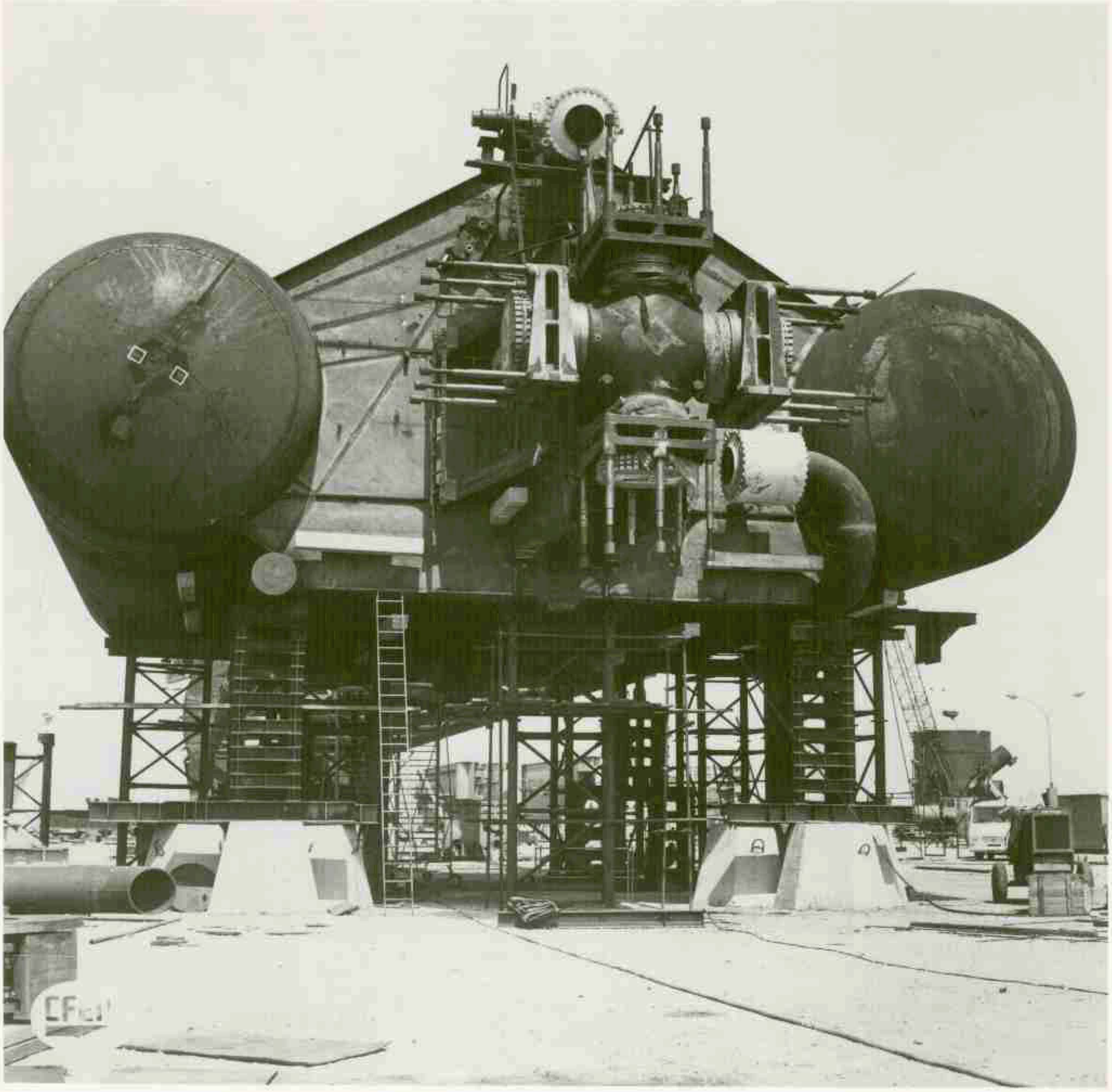
Pilot burners are fed by two 2" independent circuits, one for gas, one for air, from TP1.

(1) Designed by ELF AQUITAINE and CFEM (Compagnie Française d'Entreprises Metalliques), this type of platform was successfully tested in the Bay of Biscay between 1968 and 1971 (ELF OCEAN test oscillating platform).

(2) The base and the column were prefabricated by CFEM in Rouen, assembled in Dunkirk, and transported separately to Stavanger. After final assembling the platform was towed to Frigg in the upright position (see photographs).

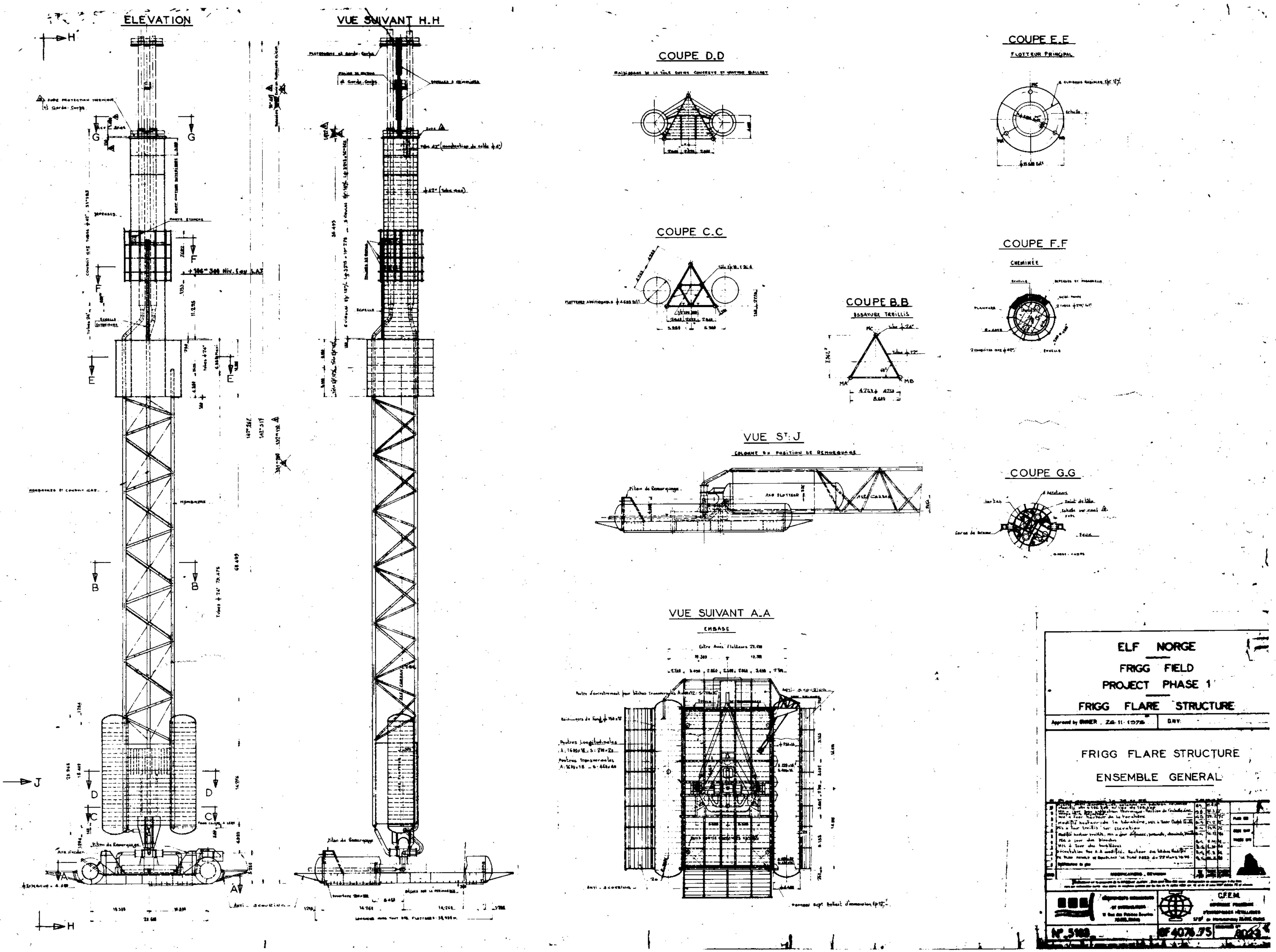
FLARE PLATFORM






BUGSIER
ELF
CFEM


10/1-FP



ELEVATION
VUE SUIVANT H.H
COUPE D.D
COUPE C.C
COUPE B.B
OSSATURE TREILLIS
COUPE E.E
FLOTTEUR PRINCIPAL
COUPE F.F
CHEMINÉE
COUPE G.G
VUE St. J
COLONNE EN POSITION DE REMORQUAGE
VUE SUIVANT A.A
EMBASE
ELF NORGE
FRIGG FIELD
PROJECT PHASE 1
FRIGG FLARE STRUCTURE
FRIGG FLARE STRUCTURE
ENSEMBLE GENERAL
C.F.E.M.

6.2.4. Drilling Platform 2 (DP2)

The DP2 drilling-production platform is an eight leg steel jacket (8 000 tons), fixed to the seabed by means of twenty piles (4 400 t) (2) topped by a support-frame (8 00 t) (2) that supports the prefabricated modules containing the equipment for drilling (3), processing (4) and services (approximately 2 500 tons in total).

Installation of structure, piling, lifting of modules and hook-up was carried our successfully according to plan and schedule.

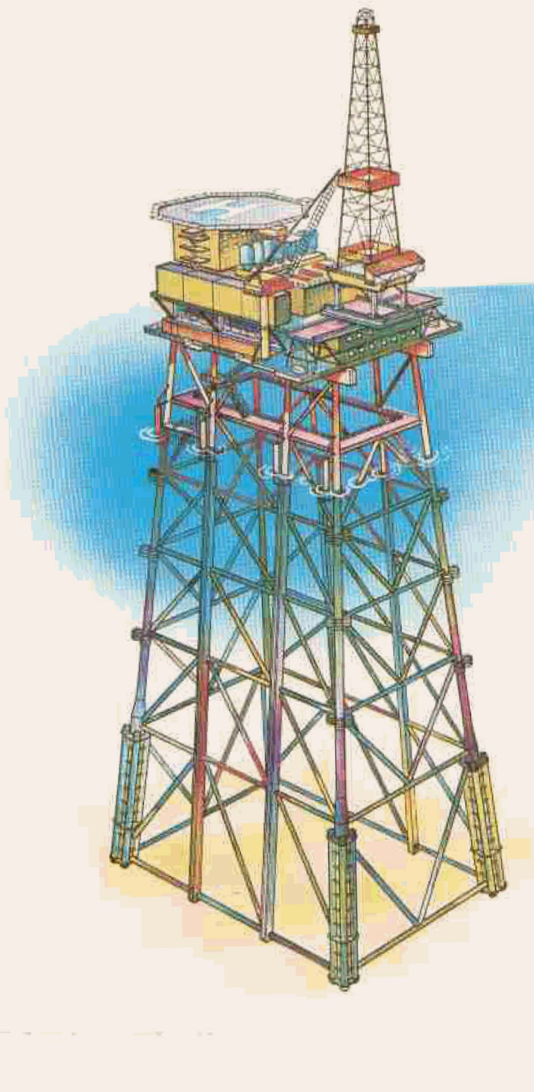
(1) Fabricated at Cherbourg by UIE (Union Industrielle d'Entre-eprises).

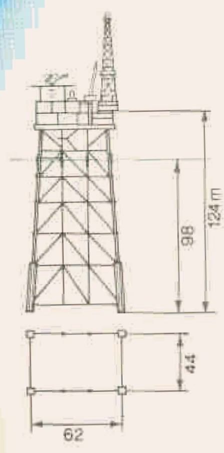
(2) Fabricated at St. Wandrille by UIE.

(3) Supplied and installed by the French firm FOREX.

(4) Designed by LUMMUS FRANCE, COMSIP Entreprise and UIE : fabricated in St. Wandrille by UIE.

DRILLING PLATFORM 2

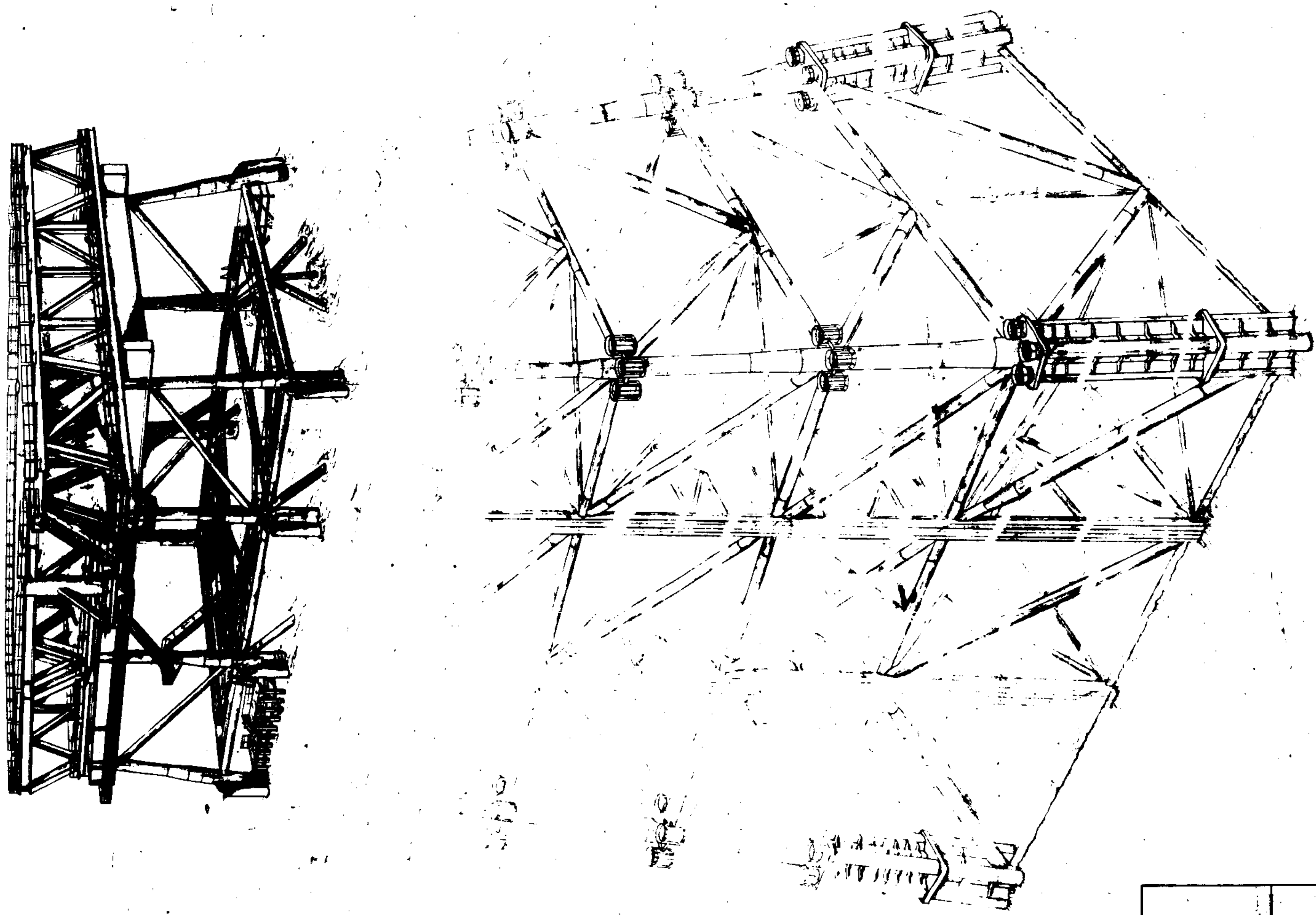





elf UIE

DP2 PLATFORM

DWG NO ELN 2144 SHEET NO. 001



ELF – NORGE A[illegible]
NORWAY

DRILLING PLATF[illegible]

APPROVED

ENGINEERS A[illegible]

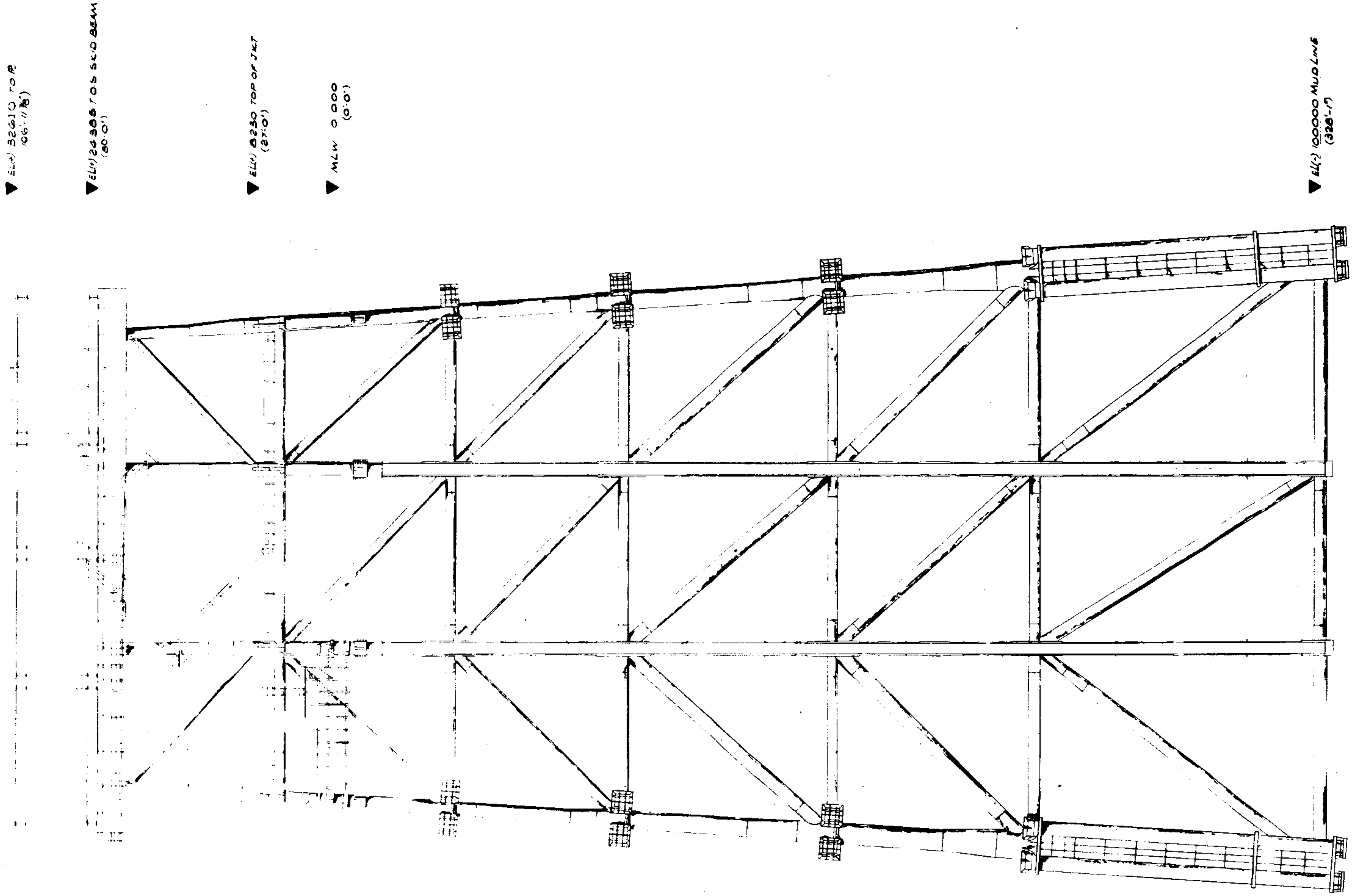
McDERMOTT – HUDSON
LONDON – ENGLAND

DRAWN BY	SCALE	DATE
[illegible]	[illegible]	JULY 74

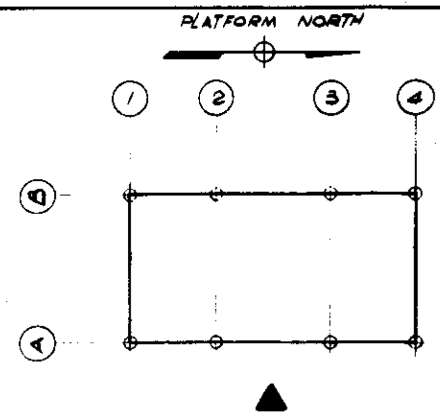
FAB. STDS. REQ'D. THIS SHT

DESIGN	ELEC	INSTR	PIPING	STRUCT	NO.	BY	DATE	REVISIONS	DATE	APP.	DESIGN	ELEC	INSTR	PIPING	STRUCT	NO.	BY	DATE	REVISIONS	DATE	APP

DWG ? 2144 SHEET NO 002



ELEVATION A



ELEVATION A
KEY PLAN

REFERENCE

DATE 2[illegible]

FAB STDS REQD THIS SHT		DRG	ELE	INSTR	PIPING	STRUCT	NO	BY	DATE	REVISIONS	DATE	APP	DESIGN	ELEC	INSTR	PIPING	STRUCT	NO	BY	DATE	REVISIONS	DATE	APP

APPROVED Robt Sov
McDERMOTT — HUDSON
DATE 19-3-75

ENGINEERS APPROVAL

	BY	DATE
PROJECT	[illegible]	19-3-75
STRUCTURAL	[illegible]	19-3-75
PROCESS		
MECHANICAL		
ELECTRICAL		
INSTRUMENT		
FAB CHECK	JC	18 MAR 7[illegible]
PROD MECH		

ELF-NORGE A/S NORWAY

DRILLING PLATFORM No.2

NORTH SEA — FRIGG FIELD — W.D. 100 M

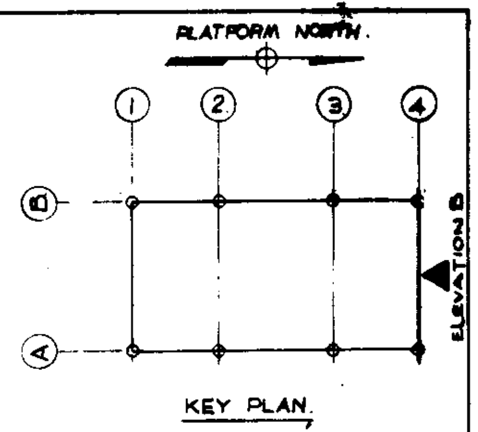
McDERMOTT — HUDSON

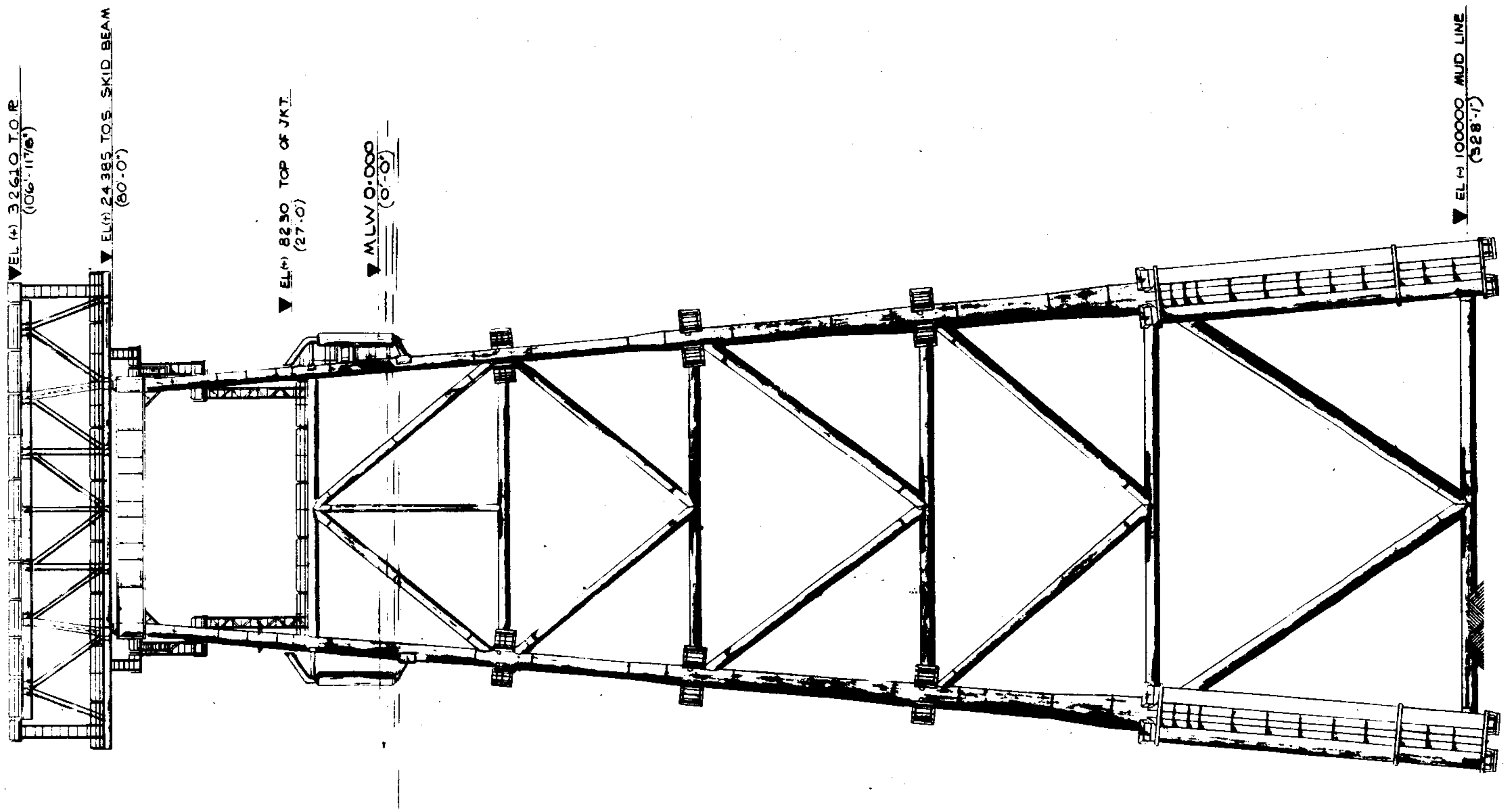
LONDON — ENGLAND

DRAWN BY	SCALE	DATE	DWG NO
M PHILPOT	1:250	24 JULY 74	ELN 2144
DESIGNED BY			SHEET NO
			002

ELEVATION A

DWG No E' 2144 | SHEET No 003





ELEVATION B

REFERENCE

DATE 27 FEB 1978

ELF-NORGE A/S
NORWAY

DRILLING PLATFORM No 2

NORTH SEA FRIGG FIELD

McDERMOTT — HUDSON

LONDON — ENGLAND

DRAWN BY	SCALE	DATE	DWG NO.
D.MURPHY	1 : 250	8 JULY 74	E.N. 2144
DESIGNED BY			SHEET No. 003

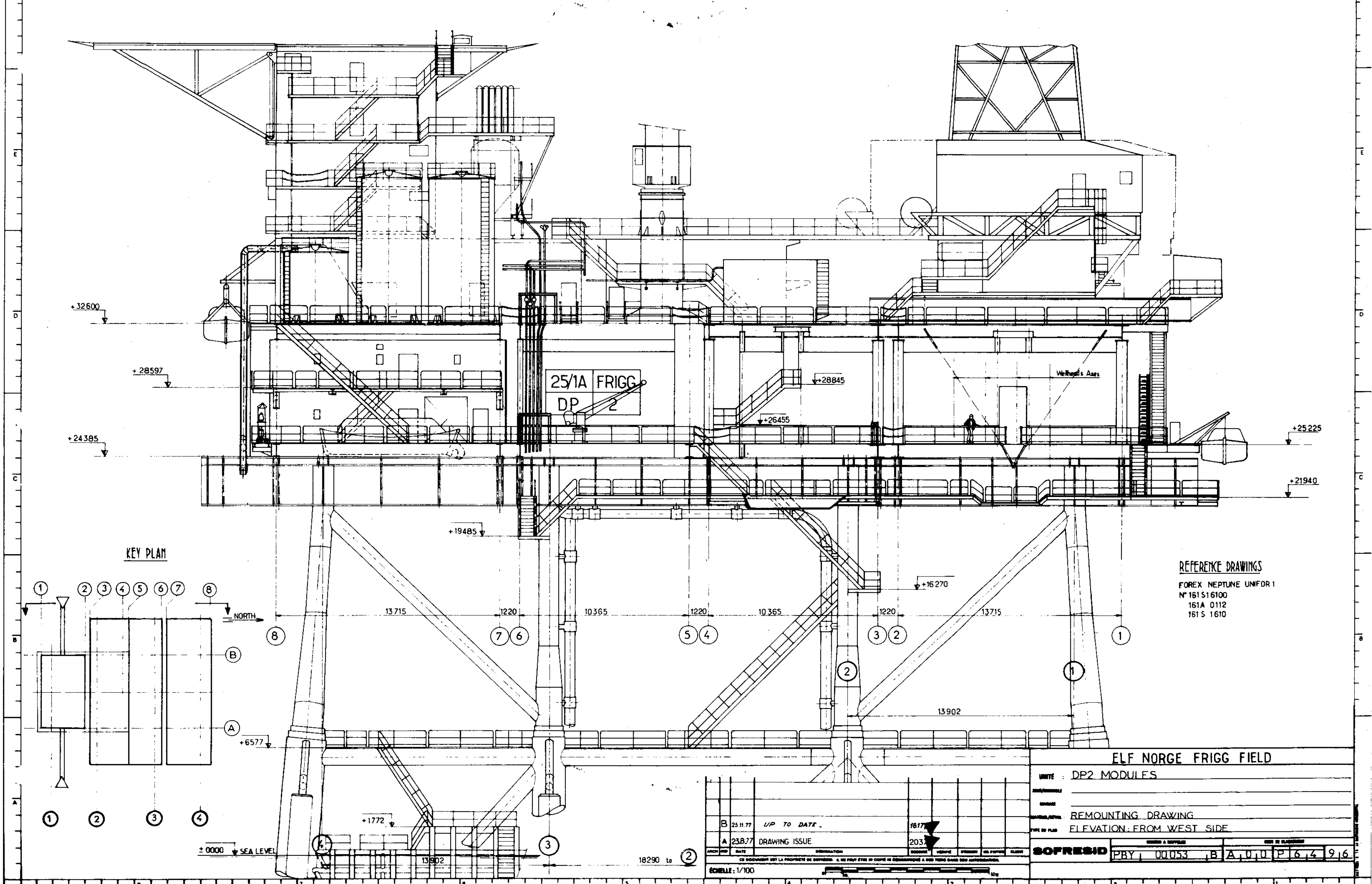
ELEVATION. B

APPROVED
McDERMOTT — HUDSON
DATE
ENGINEERS APPROVAL

	BY	DATE
PROJECT		
STRUCTURAL		
PROCESS		
MECHANICAL		
ELECTRICAL		
INSTRUMENT		
FAB. CHECK	JC	
PROP CHECK		

FAB. STDS. REQ'D. THIS SHT

DESIGN	ELEC	INSTR	PIPING	STRUCT	NO	BY	DATE	REVISIONS	DATE	APP	DESIGN	ELEC	INSTR	PIPING	STRUCT	NO.	BY	DATE	REVISIONS	DATE	APP



B	25.11.77	UP TO DATE.	1817
A	23.8.77	DRAWING ISSUE	2037
ARCH.	IND.	DATE	DÉSIGNATION

ÉCHELLE: 1/100

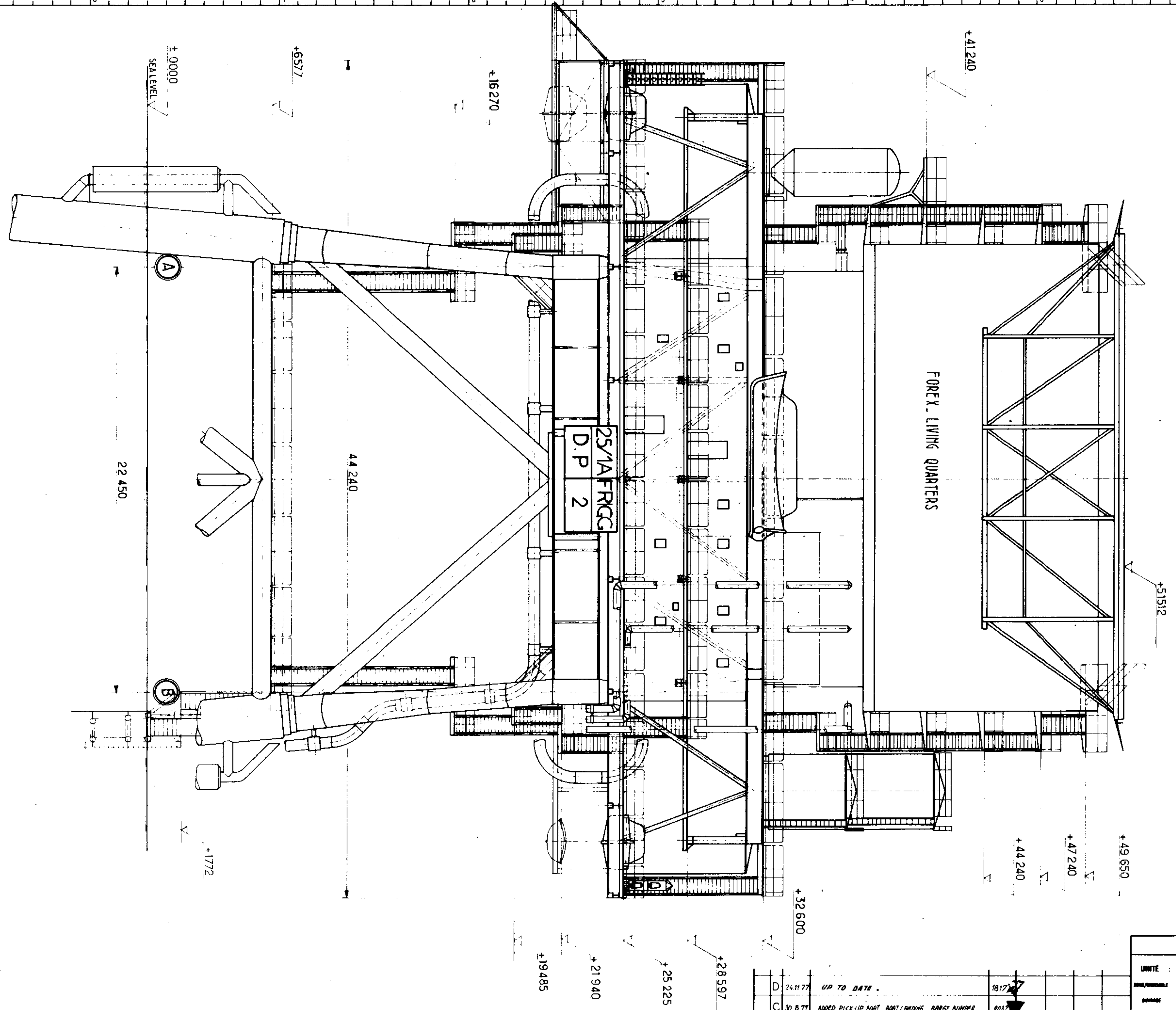
ELF NORGE FRIGG FIELD

UNITÉ : DP2 MODULES

REMOUNTING DRAWING

ELEVATION: FROM WEST SIDE

SOFRESID PBY 00053 B A 0 0 P 6 4 9 6

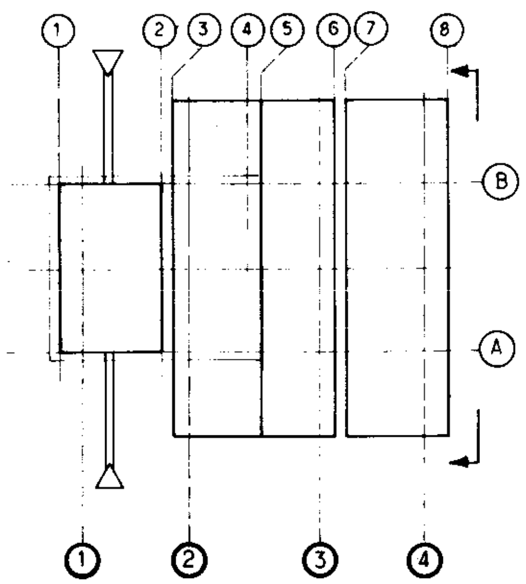


REFERENCE DRAWINGS

Mc DERMOTT		UIE
003	7478 04	104
149		105
171		106
191		120 A & B

FOREX NEPTUNE UNIFOR 1
161 A 0002
161 A 8901

KEY PLAN



IND	DATE	DÉSIGNATION	DESSINÉ
D	24.11.77	UP TO DATE.	1817
C	30.8.77	ADDED PICK-UP BOAT. BOAT LANDING. BARGE BUMPER	2037
B	2.8.77	TO BRING UP TO DATE	2037
A	6.6.77	DRAWING ISSUE	2612

CE DOCUMENT EST LA PROPRIÉTÉ DE SOFRESID. IL NE PEUT ÊTRE NI COPIÉ NI COMMUNIQUÉ A DES TIERS SANS SON AUTORISATION.

ÉCHELLE 1/100

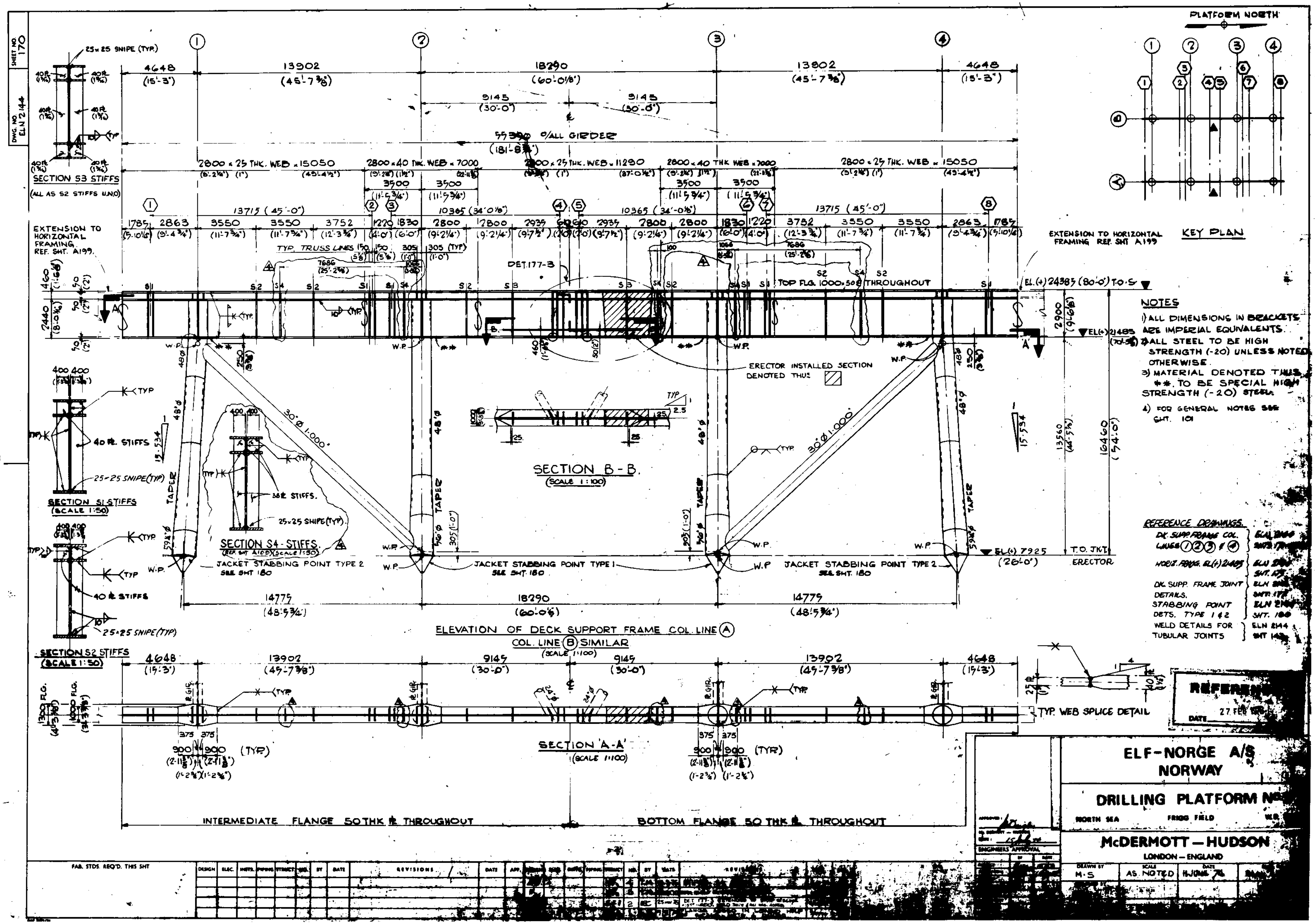
ELF NORGE FRIGG FIELD

UNITÉ : DP 2 MODULES

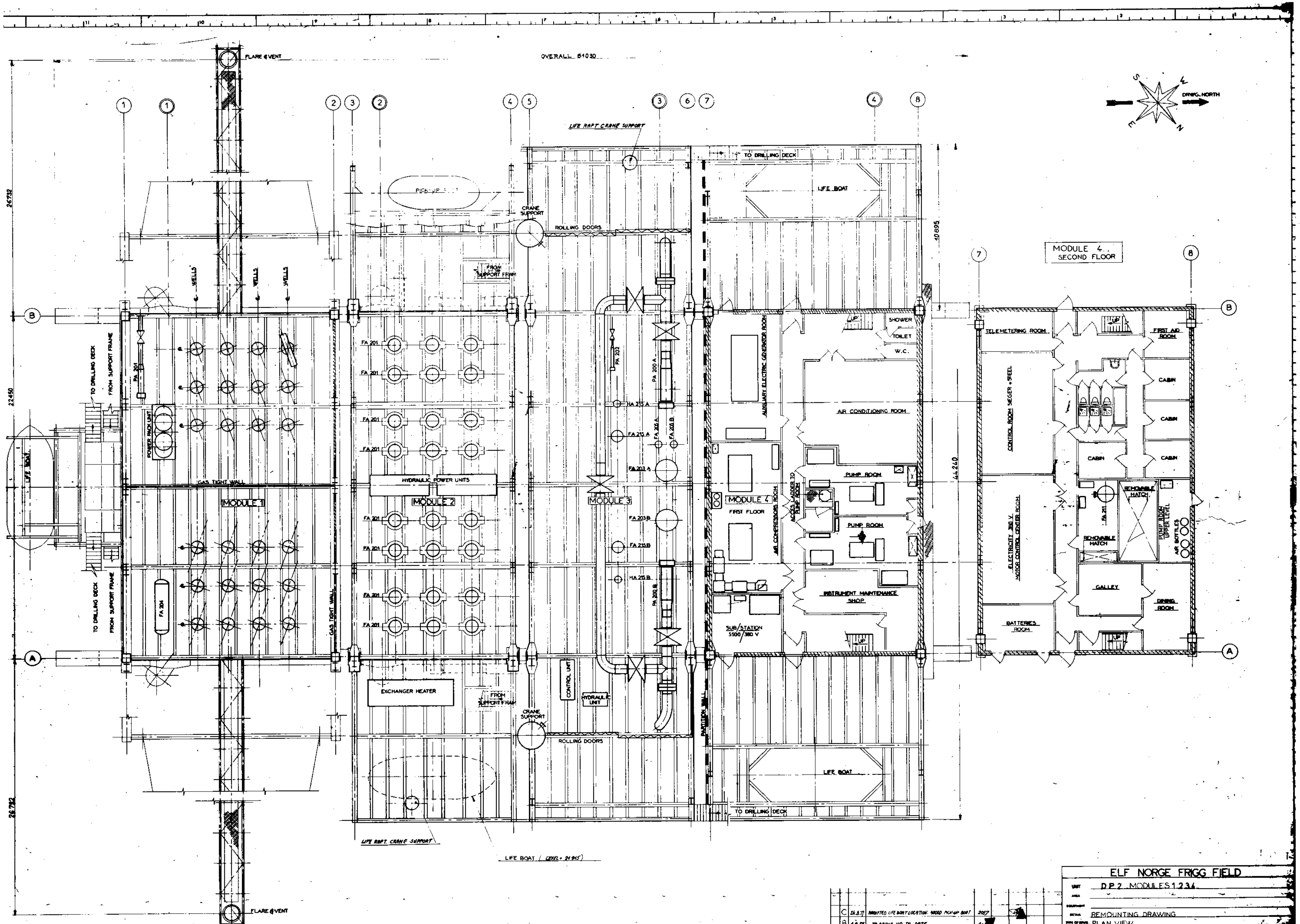
REMOUNTING DRAWING
ELEVATION: FROM NORTH SIDE

SOFRESID

PBY 00031 D A 0 0 P 6 4 9 6



SHEET NO 170
DWG. NO. ELN 2144
PLATFORM NORTH
KEY PLAN
SECTION S3 STIFFS
(ALL AS S2 STIFFS U.N.O)
25×25 SNIPE (TYP.)
55390 O/ALL GIRDER
(181'-8⅞")
2800 × 25 THK. WEB × 15050
2800 × 40 THK. WEB × 7000
2800 × 25 THK. WEB × 11280
2800 × 40 THK. WEB × 7000
2800 × 25 THK. WEB × 15050
EXTENSION TO HORIZONTAL FRAMING REF. SHT. A199.
EXTENSION TO HORIZONTAL FRAMING REF. SHT A199
TYP. TRUSS LINES
DET.177-3
TOP FLG. 1000×50 THROUGHOUT
EL.(+) 24385 (80'-0") T.O.S.
ERECTOR INSTALLED SECTION DENOTED THUS
SECTION B-B
(SCALE 1:100)
SECTION S1 STIFFS
(SCALE 1:50)
40 ℄ STIFFS
25×25 SNIPE(TYP)
SECTION S4-STIFFS
(REF. SHT A199)(SCALE 1:50)
38 ℄ STIFFS.
25×25 SNIPE(TYP)
SECTION S2 STIFFS
(SCALE 1:50)
30"Ø 1.000"
48"Ø
TAPER
W.P.
JACKET STABBING POINT TYPE 2 SEE SHT 180
JACKET STABBING POINT TYPE 1 SEE SHT. 180
JACKET STABBING POINT TYPE 2 SEE SHT. 180
EL.(+) 7925 (26'-0")
T.O. JKT. ERECTOR
14775 (48'-5¾")
18290 (60'-0⅛")
14775 (48'-5¾")
ELEVATION OF DECK SUPPORT FRAME COL. LINE Ⓐ
COL. LINE Ⓑ SIMILAR
(SCALE 1:100)
NOTES
1) ALL DIMENSIONS IN BRACKETS ARE IMPERIAL EQUIVALENTS.
2) ALL STEEL TO BE HIGH STRENGTH (-20) UNLESS NOTED OTHERWISE.
3) MATERIAL DENOTED THUS ** TO BE SPECIAL HIGH STRENGTH (-20) STEEL.
4) FOR GENERAL NOTES SEE SHT. 101
REFERENCE DRAWINGS.
DK. SUPP. FRAME COL. LINES ①②③ & ④
HORIZ. FRMG. EL.(+) 21485
DK. SUPP. FRAME JOINT DETAILS.
STABBING POINT DETS. TYPE 1 & 2
WELD DETAILS FOR TUBULAR JOINTS ELN 2144 SHT 142
TYP. WEB SPLICE DETAIL
SECTION 'A-A'
(SCALE 1:100)
INTERMEDIATE FLANGE 50THK ℄ THROUGHOUT
BOTTOM FLANGE 50 THK ℄ THROUGHOUT
REFERENCE
27 FEB
ELF-NORGE A/S NORWAY
DRILLING PLATFORM
NORTH SEA
FRIGG FIELD
McDERMOTT — HUDSON
LONDON — ENGLAND
ENGINEERS APPROVAL
DRAWN BY M.S
SCALE AS NOTED
DATE 14 JUNE 74
FAB. STDS. REQ'D. THIS SHT
REVISIONS



REV	DATE	DESIGNATION	DRAWN BY	CHECKED	APPROVED	PRAJ. MR	CLIENT
C	24.8.77	MODIFIED LIFE BOAT LOCATION. ADDED PICK-UP BOAT	2037				
B	4.8.77	TO BRING UP TO DATE	2037				
A	2.6.77	DRAWING ISSUE	3561				

SCALE 1/75

ELF NORGE FRIGG FIELD

UNIT: DP2 MODULES 1 2 3 4
AREA:
EQUIPMENT:
DETAIL: REMOUNTING DRAWING
TYPE OF DRWG: PLAN VIEW

SOFRESID PBY 00052 C A

6.2.5. Treatment platform 1 (TP1)

The concrete structure (1) of the TP1 platform consists of a cluster of 25 cells erected on a rectangular raft supporting two tapered columns.

49 000 cubic meters of reinforced and prestressed concrete were used in the construction. The steel support frame (2) weighs 2 000 tons and supports 6 000 tons of equipment (3) distributed over an area of 2 500 square meters. The fully equipped platform, ballasted, weighs 176 000 tons.

TP1 treats the gas from CDP1 (and if necessary from DP2) through three drying trains (two operational, one reserve) with a unit daily capacity of 15 million cubic meters (4). Gas and condensates are then piped through one of the two 32" sealines connecting Frigg to St. Fergus.

The killing mud unit is installed on this platform and connected by two pipelines to the drilling-production platforms CDP1 and DP2.

The TP1 platform is connected by sealines to CDP1 drilling platform. The new "tunnel" concept to pull lines inside of platform and tie them to the riser in dry and atmospheric conditions were used extensively for the first time on TP1, CDP1 and TCP2.

The TP1 platform is connected to the QP quarters platform by a gangway.

The platform was positioned on site on June 5, 1976.

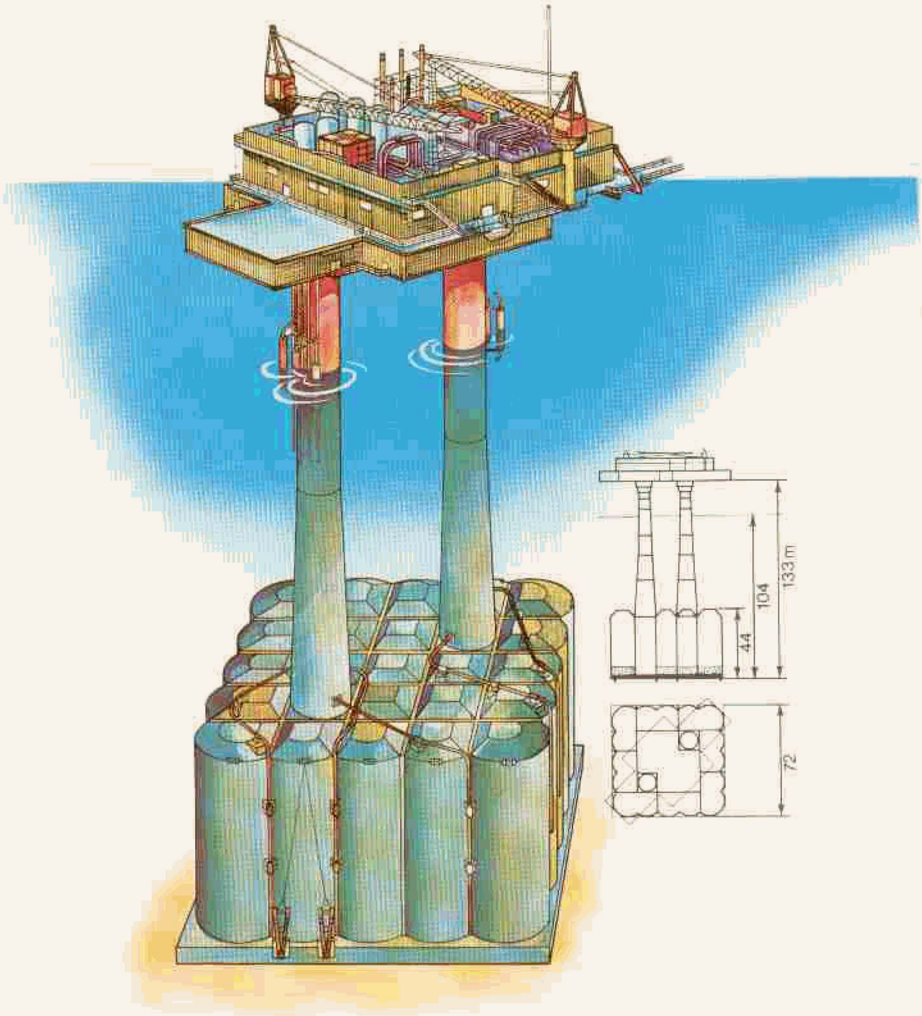
(1) Fabricated in Ardyne Point, Scotland, by the Franco-British SEA TANK CO-MAC ALPINE consortium.

(2) Fabricated at Dunkerque, France, by CONSTRUCTIONS METALLIQUES DE PROVENCE.

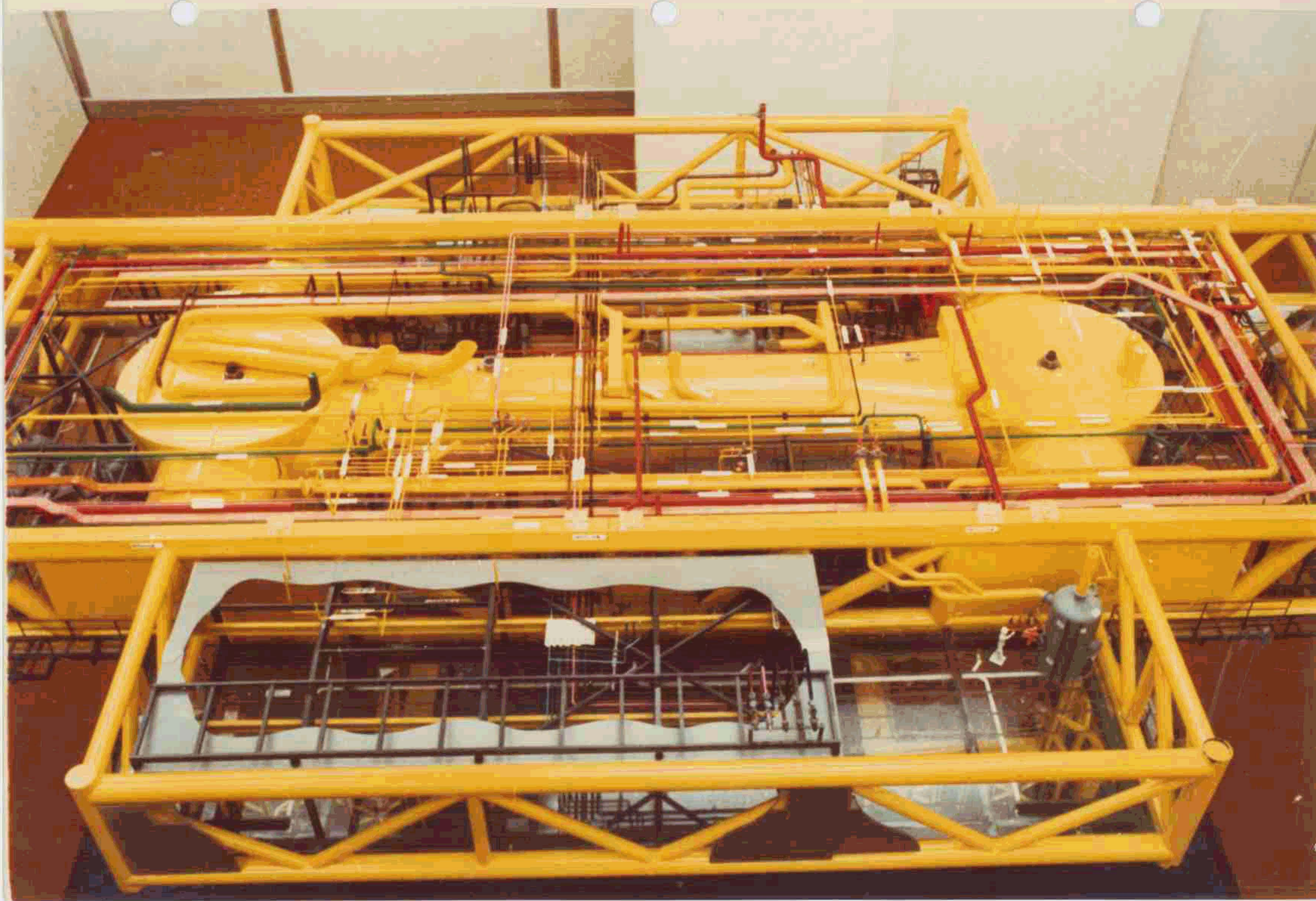
(3) Constructed at Antwerp, Belgium, by MERCANTILE MARINE ENGINEERING.

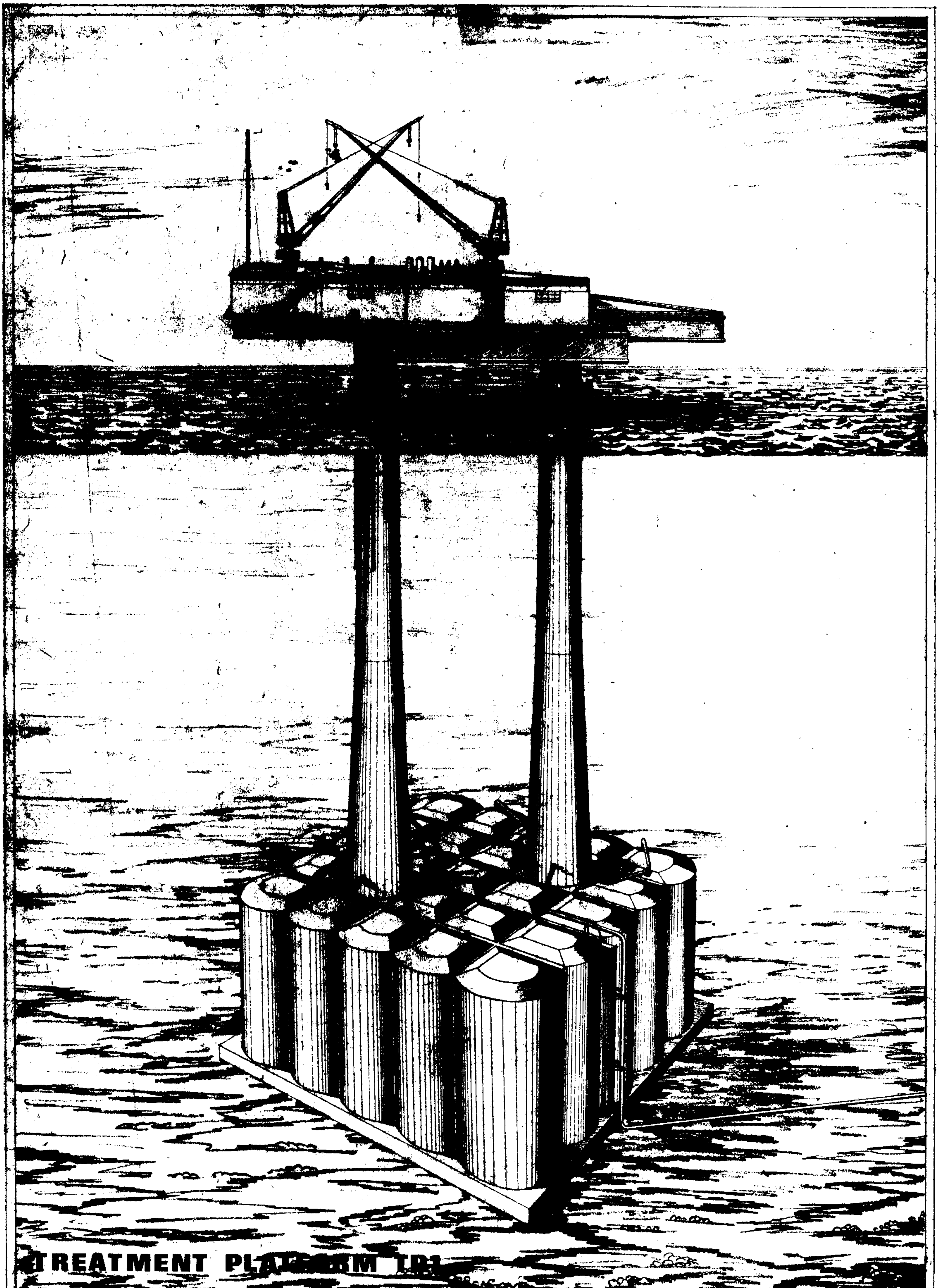
(4) Each train includes a gas/liquid separator, a glycol contactor and a glycol regeneration unit.

TREATMENT PLATFORM N° 1

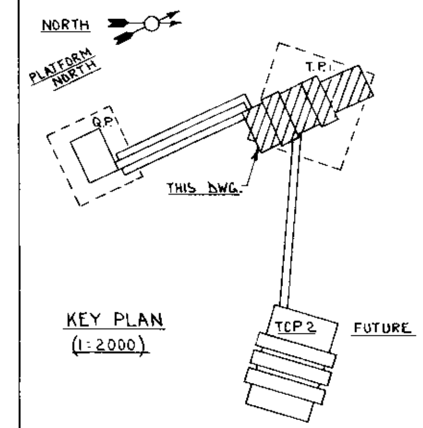



TP1

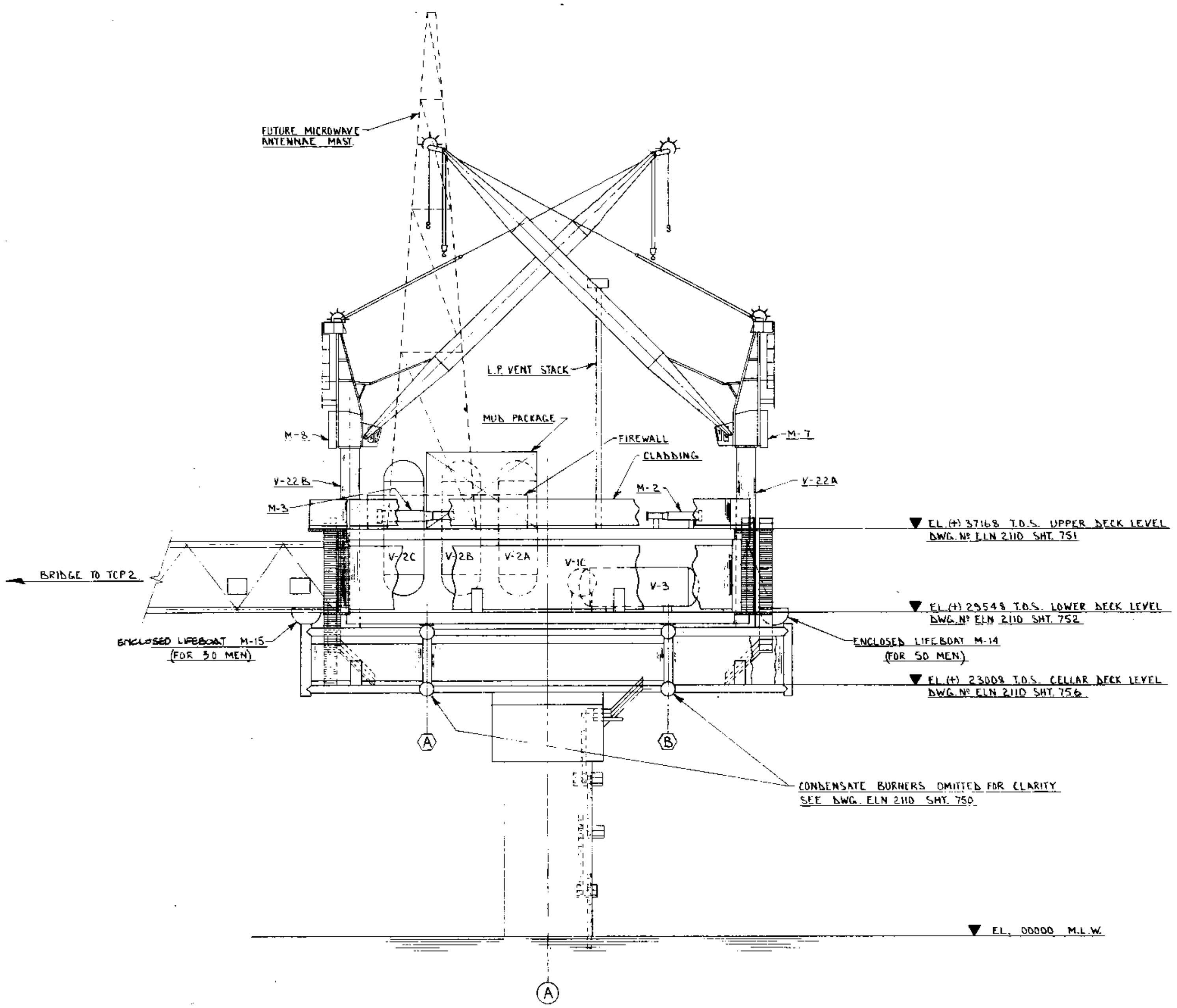



TREATMENT PLATFORM TP1

ELN 2110 | 749



KEY PLAN
(1:2000)



ELEVATION LOOKING SOUTH
(SIDING & FUTURE COMPRESSORS OMITTED FOR CLARITY)

LEGEND

GENERAL NOTES

(1) ALL DIMENSIONS ARE IN MM.

REFERENCE DRAWINGS

DWG. Nº	SHT. Nº	TITLE
ELN 2110	748	FIRE & SAFETY LEGEND
ELN 2110	750	FIRE & SAFETY LAYOUT ~ NORTH ELEV.
ELN 2110	751	FIRE & SAFETY LAYOUT ~ UPPER LEVEL
ELN 2110	752	FIRE & SAFETY LAYOUT ~ LOWER LEVEL
ELN 2110	756	FIRE & SAFETY LAYOUT ~ CELLAR DECK

AS BUILT
TO INFORMATION RECEIVED UP TO AUG 1977

MK	BY	DATE	REVISIONS	DATE	APP
3	IN	7.10.77	ISSUED AS BUILT		
2		4.12.75	REVISED TO ENGINEERS COMMENTS	19/12	
1	DA	9.6.75	ISSUED FOR CONSTRUCTION		JJ
0	D.M.	2.4.75	ISSUED FOR APPROVAL		JJ

FAB STDS REQ'D THIS SHT

APPROVED
McDERMOTT — HUDSON
DATE

ENGINEERS APPROVAL

	BY	DATE
PROJECT	JJ	
STRUCTURAL		
PROCESS		
MECHANICAL		
ELECTRICAL		
INSTRUMENT		
FAB CHECK		
PROP CHECK		

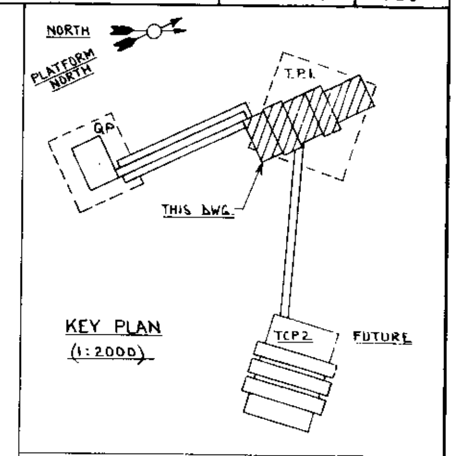
ELF-NORGE
FRIGG FIELD

TREATMENT PLATFORM Nº1
NORTH SEA **JOB 1-40-C2** W.D.104 M

McDERMOTT – HUDSON
LONDON — ENGLAND

DRAWN BY	SCALE	DATE	DWG NO
D. MOORE	1:200	7-2-75	ELN 2110
DESIGNED BY			SHEET NO
			749

FIRE & SAFETY LAYOUT- NORTH ELEVATION 3

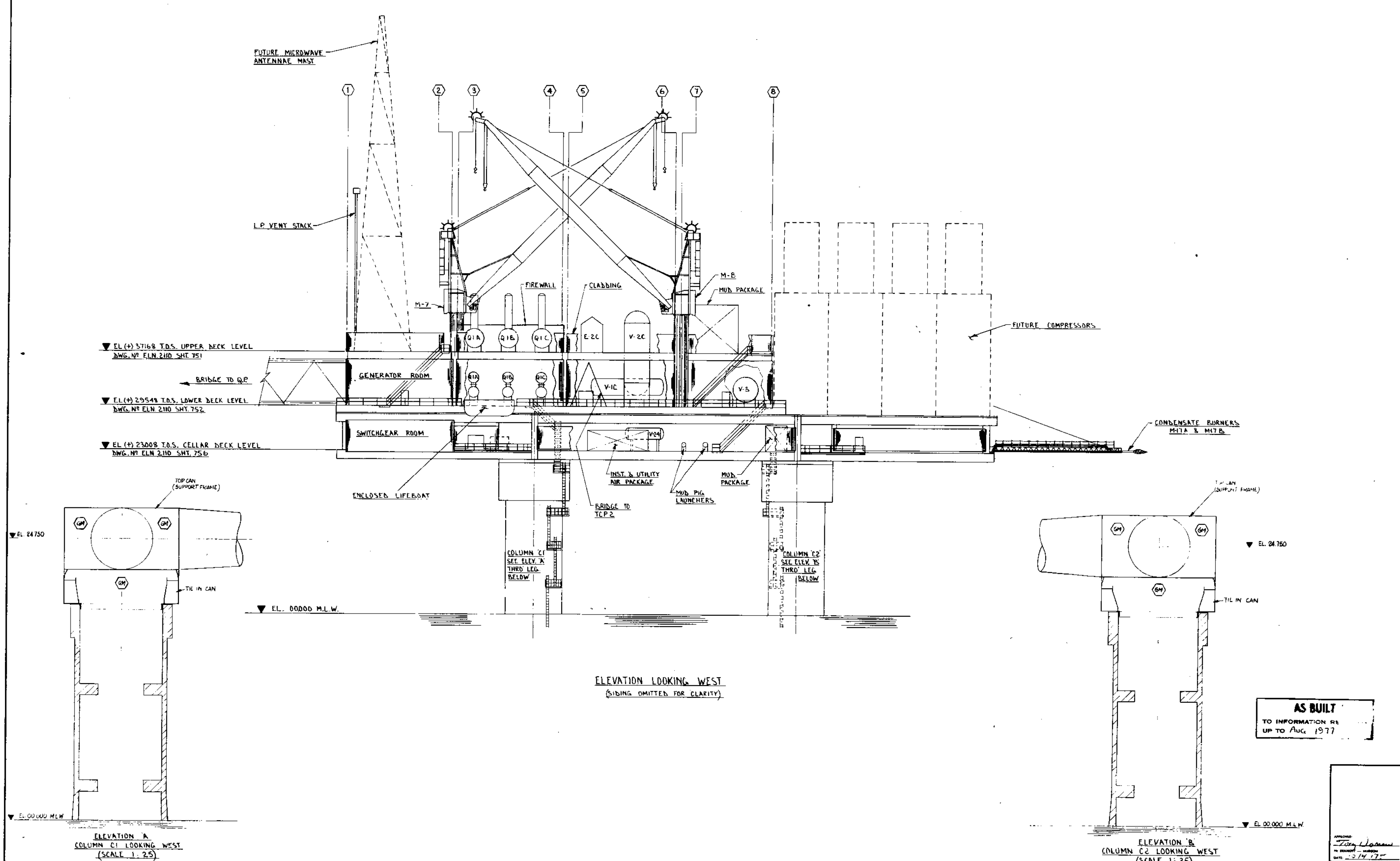


KEY PLAN
(1:2000)

LEGEND

GENERAL NOTES

(1) ALL DIMENSIONS ARE IN MM.



ELEVATION LOOKING WEST
(SIDING OMITTED FOR CLARITY)

ELEVATION 'A'
COLUMN C1 LOOKING WEST
(SCALE 1:25)

ELEVATION 'B'
COLUMN C2 LOOKING WEST
(SCALE 1:25)

AS BUILT
TO INFORMATION RE
UP TO Aug 1977

REFERENCE DRAWINGS

DWG. Nº	SHT. Nº	TITLE
ELN 2110	748	FIRE & SAFETY LEGEND
ELN 2110	749	FIRE & SAFETY LAYOUT - NORTH ELEV.
ELN 2110	751	FIRE & SAFETY LAYOUT - UPPER LEVEL
ELN 2110	752	FIRE & SAFETY LAYOUT - LOWER LEVEL
ELN 2110	756	FIRE & SAFETY LAYOUT - CELLAR DECK

DESIGN	STRUCT.	PIPING	ELEC.	MK.	BY	DATE	REVISIONS	DATE	APP
				3	I.N.	7-10-77	ISSUED AS BUILT		
				2		4-12-75	REVISED TO ENGINEERS COMMENTS		
				1	DA.	17-6-75	ISSUED FOR CONSTRUCTION	18-6-75	
				0	D.M.	2-4-75	ISSUED FOR APPROVAL	10-4-75	

FAB STDS REQ'D THIS SHT

18-6-75

APPROVED
McDERMOTT — HUDSON
DATE: 3/4/75

ENGINEERS APPROVAL

	BY	DATE
PROJECT		
STRUCTURAL		
PROCESS		
MECHANICAL		
ELECTRICAL		
INSTRUMENT		
FAB CHECK		
PROP CHECK		

ELF - NORGE
FRIGG FIELD

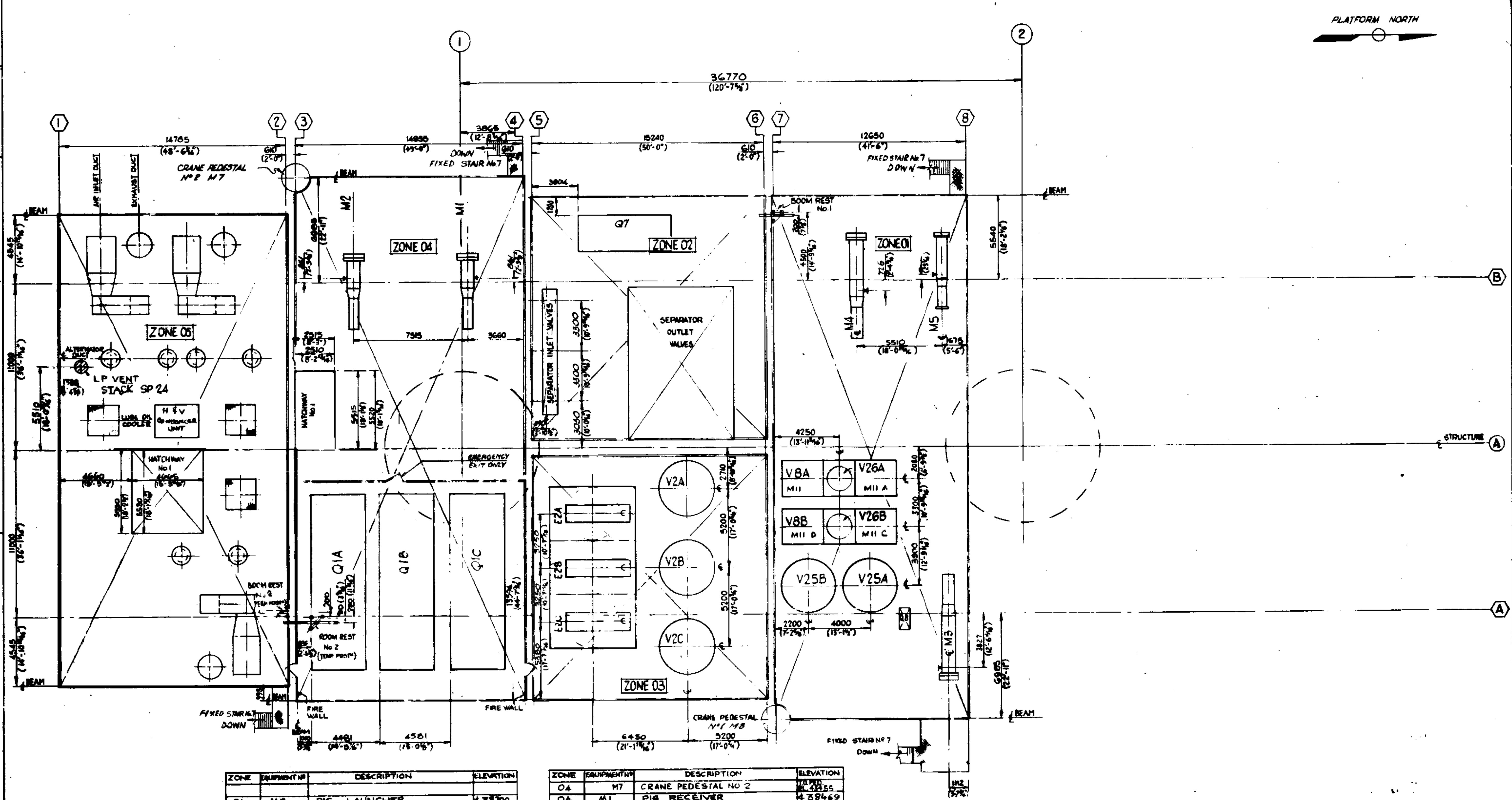
TREATMENT PLATFORM Nº1
NORTH SEA — JOB 1-40-C2 — W.D. 104 M

McDERMOTT — HUDSON
LONDON — ENGLAND

DRAWN BY	SCALE	DATE	DWG NO
D. MOORE	1:200 & 1:125	4-2-75	ELN 2110
DESIGNED BY			SHEET NO
			750

FIRE & SAFETY LAYOUT — EAST ELEVATION

DWG NO ELN 2110 SHEET NO 421



ZONE	EQUIPMENT Nº	DESCRIPTION	ELEVATION
01	M3	PIG LAUNCHER	℄ 38700
01	M4	PIG RECEIVER	℄ 38700
01	M5	PIG RECEIVER	℄ 38500
01	Q8	REMOTE CONTROL STATION FOR PIGS	T.O.℄ 37168
01	V8A/B	MUD MIX TANK	T.O.℄ 37168
01	V25A/B	MUD & MUD/CEMENT BULK HOPPER	T.O.℄ 37168
01	V26A/B	MUD SURGE TANK	T.O. SKID EL. [illegible]
01	M8	CRANE PEDESTAL No. 1	T.O. PED. EL. 43455
01	M11 A/B/C/D	[illegible]	
02	Q7	CENTRAL HYDRAULIC UNIT	T.O.℄ 37168
03	E2A/B/C	GLYCOL AIR COOLERS	T.O.℄ 37168
03	V2A/B/C	GLYCOL CONTACTORS	SEE LOWER LEVEL

ZONE	EQUIPMENT Nº	DESCRIPTION	ELEVATION
04	M7	CRANE PEDESTAL NO 2	T.O. PED. EL. 43455
04	M1	PIG RECEIVER	℄ 38469
04	M2	PIG RECEIVER	℄ 38460
04	Q1A/B/C	GLYCOL REBOILERS	T.O.℄ 37168
05	SP 24	LP VENT STACK	U/S BASE EL. 37168

TOP OF PLATFORM ELEVATION ~ 37168.

INDICATES ERECTOR INSTALLED EQUIPMENT

ELF NORGE
FRIGG FIELD

TREATMENT PLATFORM Nº 1
JOB 1-40-C2

WD 104 M

McDERMOTT — HUDSON
LONDON — ENGLAND

DRAWN BY	SCALE	DATE	DWG NO
C. GRICE	1:125	23.5.74.	ELN 2110
DESIGNED BY	CHECKED BY J.T. YOUNGS		SHEET NO 421

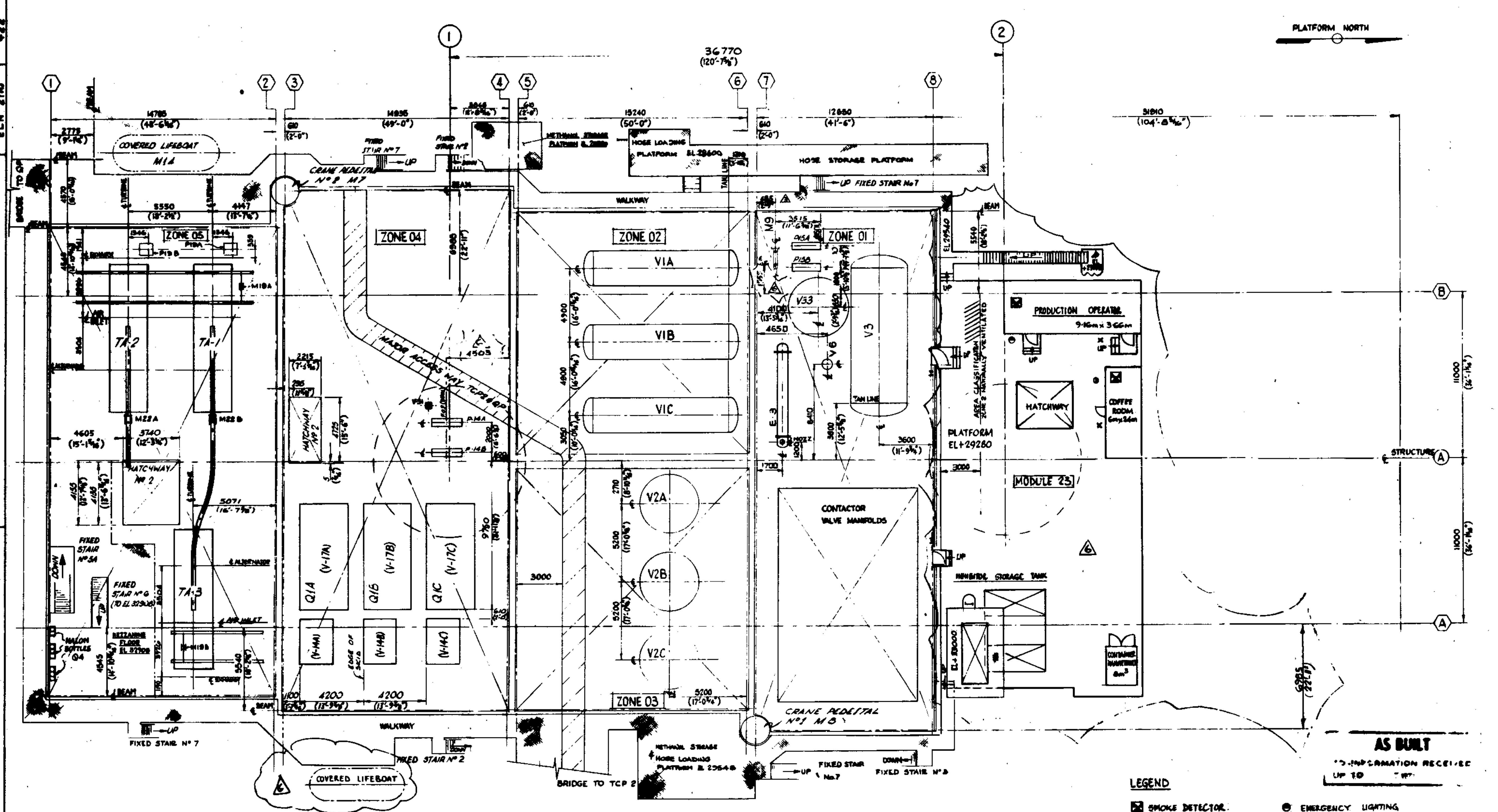
PLOT PLAN – UPPER LEVEL

Oct. 17, 1974
ENGINEERS APPROVAL

FAB. STDS. REQ'D. THIS SHT

NO.	BY	DATE	REVISIONS	DATE	APP
7	[illegible]	4/1/77	[illegible]	4.1.77	[illegible]
6	RS	14/1/76	REVISED AS NOTED. THIS DWG INCLUDES REV 6A	10.4.76	[illegible]
5	[illegible]	2-11-75	REVISED AS INDICATED	11.11.75	[illegible]
–	[illegible]	28.8.75	[illegible]	[illegible]	[illegible]

NO.	BY	DATE	REVISIONS	DATE	APP
3	K.C.	1-9-75	REVISED AS INDICATED	12.9.75	[illegible]
2	RC	13-3-75		24.3.75	JAJ
1	AJH	9-10-74	APPROVED FOR CONSTRUCTION	16 OCT	[illegible]
8	VA	12-8-77	AS BUILT	[illegible]	[illegible]



ZONE	EQUIPMENT Nº	DESCRIPTION	ELEVATION
01	P15A&B	CONDENSATE RECYCLE PUMP	T.O.P EL.29548
01	E3	FUEL GAS EXCHANGER	℄ 30615
01	M9	CONDENSATE PIG RECEIVER	℄ 30548
01	V3	CONDENSATE SURGE TANK	℄ 32298
01	V6	FUEL GAS SEPARATOR	TAN EL 30810
01	V33	CONDENSATE STORAGE TANK	T.O.P 29548
01	M-8	CRANE PEDESTAL Nº1	T.O. PED. EL. 43458
02	V1A/B/C	FWKO SEPARATORS	℄ 32348
05	P-19 A&B	MAIN DIESEL OIL FUEL PUMP	

ZONE	EQUIPMENT Nº	DESCRIPTION	ELEVATION
05	P19A & B	MAIN DIESEL OIL FUEL PUMP	
03	V2A/B/C	CONTACTORS	TAN 33748
04	Q1A/B/C	GLYCOL REGENERATION UNIT	TO P 29548
04	M-7	CRANE PEDESTAL Nº2	T.O. PED. EL. 43433
04	V-51	GLYCOL CHARCOL FILTER	
04	P-14A & B	GLYCOL INJECTION PUMPS	U/S BASE EL 29548
	M14	COVERED LIFEBOAT	
		COVERED LIFEBOAT	
05	M19A/B	2 TON HOIST	
05	M22A/B	10 TON HOIST	
05	TA-1/2/3	GENERATOR PACKAGE UNIT	TOP 29548
05	Q4	FIRE DETECTION / EXTINGUISH SYSTEM	

TOP OF PLATFORM ELEVATION - 29548

INDICATES ERECTOR INSTALLED EQUIPMENT

LEGEND

SMOKE DETECTOR

EMERGENCY LIGHTING

× 2 PORTABLE WATER EXTINGUISHERS (10 LITRES)

FAB. STDS. REQ'D. THIS SHT

DESIGN	ELEC.	INSTR.	PIPING	STRUCT	NO.	BY	DATE	REVISIONS	DATE	APP
					6	AB		AS BUILT	17/1/77	
					5		7/12/76	ADDED P-19A&B MAIN DIESEL OIL FUEL PUMP	4-1-77	
					4	RS		REVISED AS NOTED. THIS ALSO INCLUDES REV 4A	10.9.76	

DESIGN	ELEC.	INSTR.	PIPING	STRUCT	NO	BY	DATE	REVISIONS	DATE	APP
					3	K.C.	1-8-75	REVISED AS INDICATED		
					2	RGU	17.8.75	REVISED AS INDICATED		
					1	AJM	9-10-74	APPROVED FOR CONSTRUCTION		

APPROVED
McDERMOTT - HUDSON
DATE: Oct 14, 1974

ENGINEERS APPROVAL

	BY	DATE
PROJECT		
STRUCTURAL		
PROCESS		
MECHANICAL		
ELECTRICAL		
INSTRUMENT		
FAB CHECK	AJM	9 OCT 74
PROP CHECK		

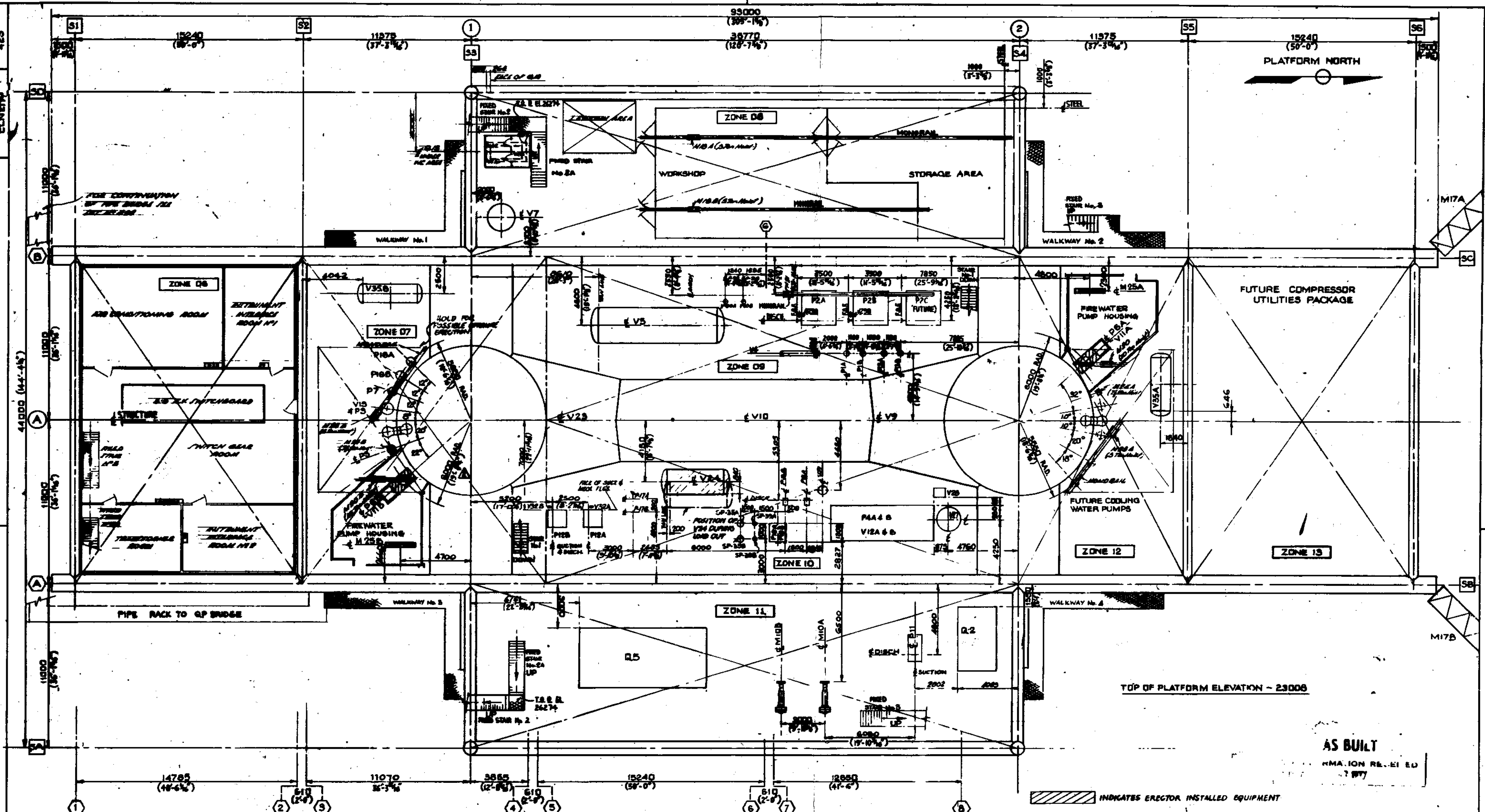
ELF - NORGE
FRIGG FIELD

TREATMENT PLATFORM Nº1
JOB 1-40-C2

McDERMOTT — HUDSON
LONDON — ENGLAND

DRAWN BY	SCALE	DATE	DWG NO
J.C.GRICE	1:125	6-MAY-1974	ELN 2110
DESIGNED BY	CHECKED BY J.T.YOUNGS		SHEET NO. 422

PLOT PLAN - LOWER LEVEL



ZONE	EQUIP'T	DESCRIPTION	ELEVATION	ZONE	EQUIP'T	DESCRIPTION	ELEVATION	ZONE	EQUIP'T	DESCRIPTION	ELEVATION	ZONE	EQUIP'T	DESCRIPTION	ELEVATION
07/12	V35A/B	AIR START VESSEL	℄ EL 23796									10	SP33A&B	DIESEL OIL FILTER	℄ INLET EL 23646
07/12	M30 A&B	10 TON HOIST		07/12	M23 A&B	5 TON HOIST		07/12	M24 A&B	7½ TON HOIST		10	P18A&B	DIESEL OIL PUMP	℄ SUCTION EL 23460
07	P3	SUMP PUMP		09	P1A&B	CONDENSATE BOOSTER PUMPS	[illegible]	09	V30A&B	SLOPS OIL PULSATION DAMPENERS		10	V28	SLURRY TUB	
07	P5	MUD WATER PUMP	℄ HOLD	09	P2A&B	CONDENSATE RETURN PUMPS	[illegible]	08	Q 13	WASTE TREATMENT UNIT	[illegible]	09	M 21	5 TON HOIST	
07/12	P6A&B	FIREWATER PUMPS	℄ [illegible] 23440	09	P9A&B	SLOPS OIL PUMPS		10	P4A&B	MUD PROCESS PUMPS		10	V32A&B.	METHANOL PULSATION DAMPERS.	
07	P7	WASHDOWN PUMP	DISCH. 23208	09	P15A&B	GLYCOL FILL PUMPS	[illegible]	10	P8A&B	DIESEL PUMPS	℄ SUCT 23460	10	P17A&B	METHANOL TRANSFER PUMPS	[illegible]
07	P16A&B	WATER CURTAIN PUMPS	DISCH. 23208	09	V4	COALESCER	℄ 24380	10	P12A&B	METHANOL METERING PUMPS	[illegible]	11	M10A/B	MUD PIG LAUNCHERS	℄ 23750
07	V13	SUMP CAISSON		09	V5	OIL SKIMMER	℄ 25106	08	M16A&B	5 TON HOIST		11	P 11	MUD RECIRCULATION PUMP	℄ SUCT. 23453
07/12	V11A/B	FIREWATER DIESEL DAY TANKS		09/10	V9	GLYCOL STORAGE TANK	℄ 24750	10	V12A&B	MUD PUMPS DAY TANKS		11	Q 2	MUD AIR COMP. PACKAGE	
07/12	M25A/B	TEMP. EMERGENCY START N2 BOTTLES	[illegible]	09/10	V10	DIESEL STORAGE TANK	℄ 24750	10	V21	DIESEL FILTER		11	Q5	INST. & UTILITY AIR COMP. PACKAGE	
08	V7	LP VENT SCRUBBER	BOT. TAN 24008	09/10	V23	METHANOL STORAGE TANK	℄ 24750	10	V24	HP FLARE SCRUBBER	℄ 25446	10	SP35A&B	DIESEL OIL COALESER	℄ INLET EL 23666
06	Q4	FIRE DETECTION/EXTINGUISH SYSTEM		09	V29 A&B	CONDENSATE PULSATION DAMPENERS		10	V27	CEMENT SURGE TANK		13	M17A&B	CONDENSATE BOOM & BURNERS	

FAB. STDS. REQ'D. THIS SHT

NO.	BY	DATE	REVISIONS	DATE	APP.
4	T.L.	9/10/75	REVISED AS INDICATED 4	15-10-75	JJ
5	R.S.	1/9/76	REVISED AS NOTED, THIS ALSO INCLUDES REVS 5A & 5B	10-9-76	JJ
6		12/76	ADDED P18A&B SP-33A&B & 35A&B DIESEL OIL TO GENERATOR	4-1-77	
7		1/77	[illegible]		
3	K.C.	1-8-75	REVISED AS INDICATED 3	12-8-75	JJ
2	P/C	5-3-75	REVISED AS INDICATED 2	26-4-75	TAJ
1		3-10-74	APPROVED FOR CONSTRUCTION		
8			AS BUILT	17/10/77	

ELF-NORGE
FRIGG FIELD

TREATMENT PLATFORM No 1
NORTH SEA JOB 1-40-C2

McDERMOTT – HUDSON
LONDON – ENGLAND

APPROVED
DATE 29 Oct 1974
ENGINEERS APPROVAL

DRAWN BY	SCALE	DATE	DWG NO
C.E. REEVE	1:125	27 SEPT '74	ELN 2110
DESIGNED BY J.T. YOUNGS.			SHEET NO. 425

PLOT PLAN ~ CELLAR DECK

6.2.6. Treatment compression platform 2 (TCP2)

a) General

The concrete structure (1) of the TCP2 platform consists of a cluster of 19 cylindrical cells erected on a hexagonal raft, supporting three columns.

60 000 cubic meters of reinforced and prestressed concrete were required for its construction. The support-frame which is of steel (2) and weighs 3 500 tons, will support the 18 000 t of processing equipment distributed over some 4 500 square meters of area. The platform thus equipped and ballasted weighs about 440,000 t dry weight or 188,000 t wet weight.

With the exception of the mud center (which is installed on the TP1), equipment provided for the treatment of gas and condensates and for the service facilities (3) is similar to that of the TP1 : 3 drying trains for the gas ; a 32" pipe for conveyance of the gas and condensates ; electrical power capacity redundant for both TCP2, DP2 and if necessary for the TP1 and QP platforms.

Recompression of the gas will be necessary when pressure at the well head becomes inadequate after a certain field depletion. Future facilities for recompression of the total gas production of the field may reach a total installed power of 230 000 hp ; they will be installed in two steps.

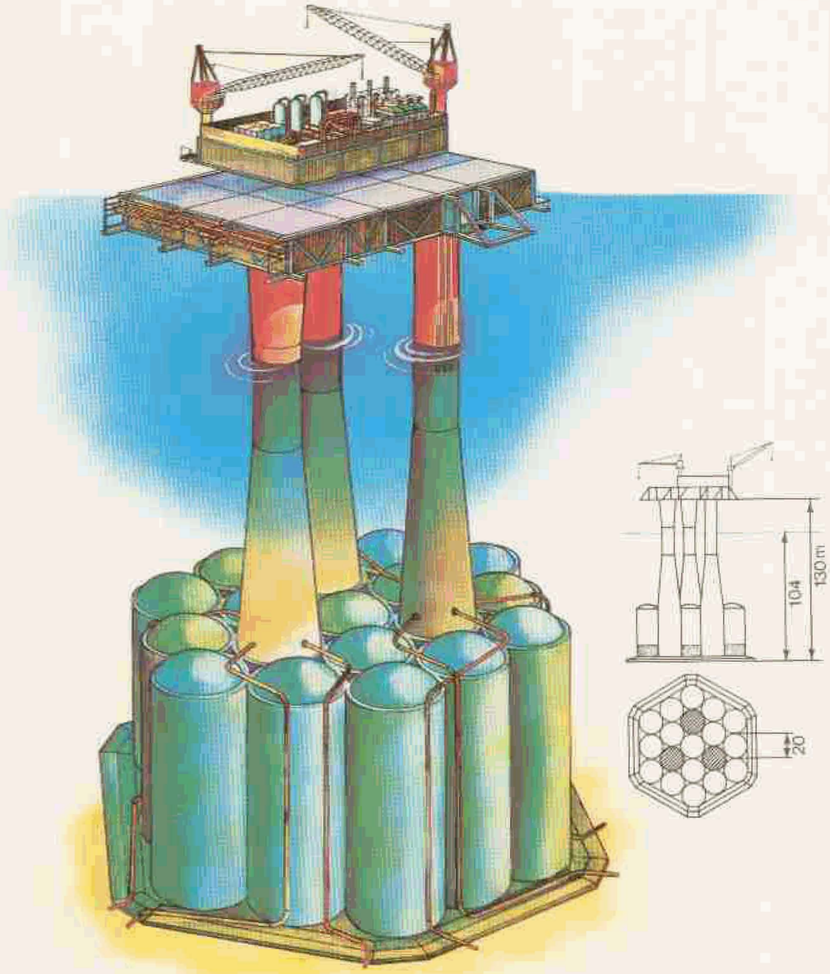
A gangway links TCP2 to the TP1 platform, which is itself connected by gangway to QP.

(1) Designed according to the Norwegian CONDEEP (Concrete Deep-water Structure) conception and fabricated in Andalsnes, Norway, by the NORWEGIAN CONTRACTORS consortium.

(2) Fabricated in various european Yards, assembled in Cherburg on UIE yard.

(3) Fabricated in Orkanger, Norway, by the Franco-Norwegian SPIE-VIGOR partnership.

TREATMENT COMPRESSION PLATFORM 2



b) Support frame

Area : 84 x 63 = ... 5.300 m2.

Overall dimensions :

- length .... 84 m.
- width .... 63 m.
- height .... 9,60 m.

Total weight including accessories .....approximatly 3.500 tons.

The steel support frame is made of cross-braced trusses : the chords, diagonals and vertical members are box beams of welded steel plate.

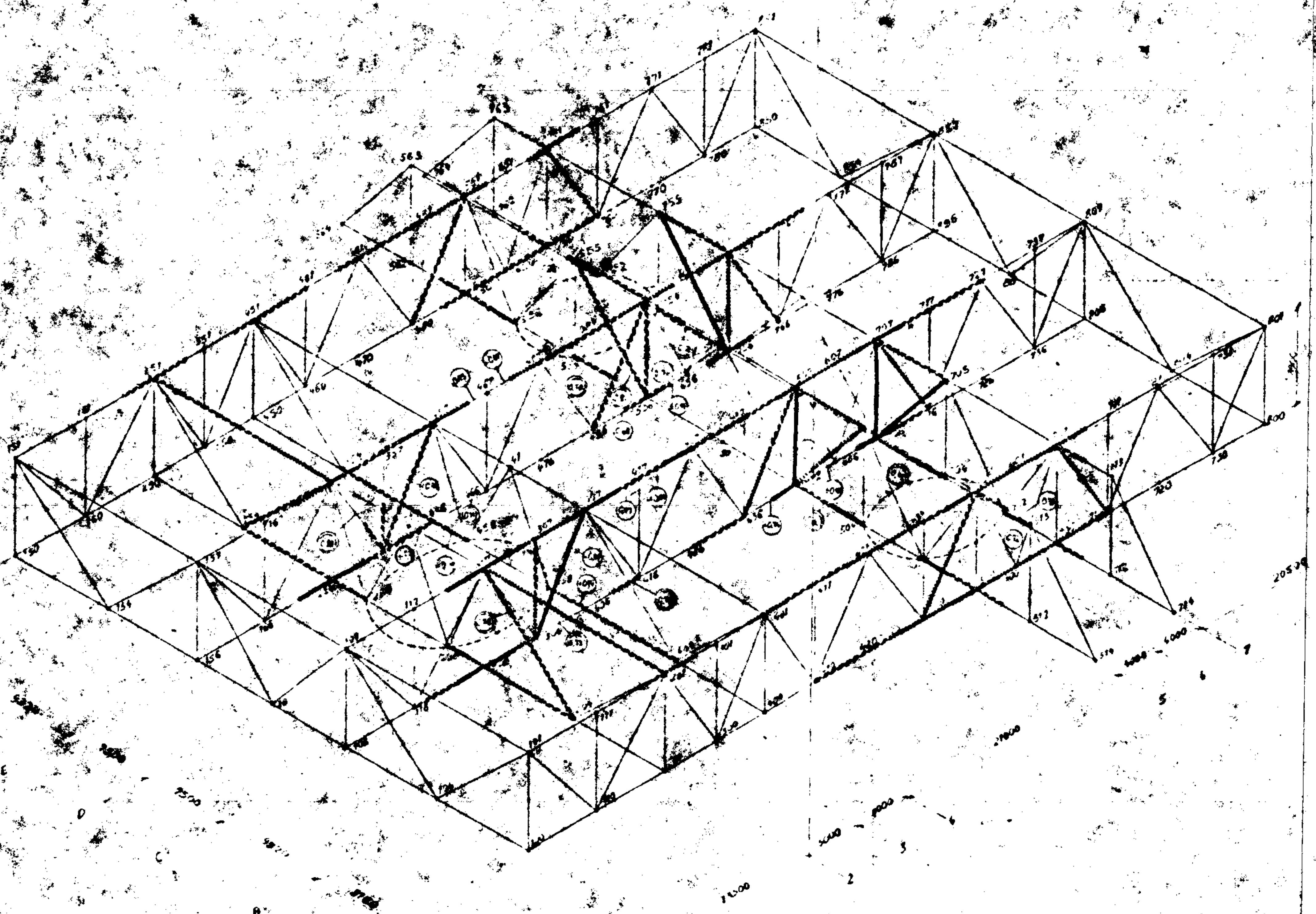
The deck is supported by the 3 concrete columns of the base through 3 concrete junction pieces.

Structural calculations have been carried out by the finite elements analysis (DIANA program) . Fatigue analysis has been carried out as well.

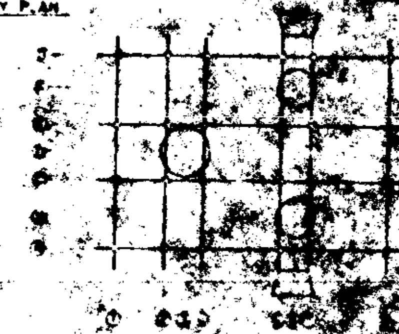
Regarding the structural elements, the complete support frame has required :

- 238 design and engineering drawings
- about 800 shop drawings

All calculations, design and shop drawings were checked by an independent organization before being submitted to DNV for approval.



KEY PLAN



ISSUED FOR INFORMATION	
CONDEEP production platform	ELF – NORGE A/S ... FRIGG – TCP 2 – STEEL FRAME
MOYER	STRUCTURAL ANALYSIS USAGE FACTORS FROM FATIGUE ANALYSIS STRESS LEVEL FOR ... AND ...
	UC 3337 0449 · 20

- Steel

The structural steels used for the fabrication of the support frame are :

SHSS = Special High Strength Steel at - 20°C for thickness $<$ 30 mm or - 40°C, for thickness $\geq$ 30 mm according to EAN specifications.

The maximum plate thickness used in the support frame is 100 mm.

- Fabrication

The fabrication of the 3 500 tons of structural steel corresponds to a considerable amount of shop welding, since every member is made out of steel plate. The nodes of the trusses are generally of complicated design.

With respect to the welding procedures, the fabricator was requested :

- to carry out C.O.D. tests at - 10°C on the thicknesses exceeding 50 mm ;

- to obtain a root impact value for these thicknesses of 3.6 kg x m at -40°C.

In order to get satisfactory C.O.D. results, all parts of the structure involving important thicknesses (60, 80 and 100 mm) required preheating and stress relieving.

- Final assembly

The whole deck has been entirely assembled and completed in U.I.E. yard in CHERBOURG, France. It has then been loaded out (by skidding) into a 120 x 30 x 7,5 m cargo barge and seafastened for open sea transportation.

- Transportation

The barge and the seafastened deck were towed by 2 tugs up to the fjord where the concrete base was under construction (Andalsnes, Norway).

- Matching of support frame to base

Installation of the support frame on the concrete base has been accomplished by lowering the concrete platform in a deep sheltered site, and placing the support frame, straddling between two cargo barges.

Duration of studies
(calculations, drawings, etc).................. about 20 months

Duration of fabrication .... about 16 months.

b) <u>Program of construction and final assemblying</u>

At the beginning of the project, ANDALSNES fjord was selected for the construction of the concrete structure for the following reasons :

- site well sheltered
- town served by railway,
- easy access by sea,
- very deep fjord (about 250 m) although far from the coast (about 60 km),
- several Condeep type platforms had already been built in this fjord.

The concrete structure was built under favourable conditions and within the required time.

Platform assembling was carried out as follows :

- steel deck mating to concrete columns,
- lifting and positioning of temporary and permanent equipment on deck,
- carrying out of hook up works and preparation for the tow out to Frigg field.

The support frame on two NORBARGE barges was trimmed along the quay of ANDALSNES harbour, with a view to load the first modules.

The permanent equipment for gas treatment to be installed on the support frame before deck mating operation reached ANDALSNES on March 18th.

It was loaded on DINO I barge, coming from ORKANGER (Norway) where it had been fabricated by SPIE BATIGNOLLES VIGOR .

On March 24th, 1977, BROWN & ROOT temporary equipment, accommodation units, helideck, generators set, etc... arrived as well. This equipment was fabricated in HAMBURG, Germany, and towed to ANDALSNES on 5 MORLAND barges.

From March 28th to April 6th, 4 000 tons of equipment were installed onto the support frame by the E.T.P.M. 701 derrick barge, of 700 t lifting capacity.

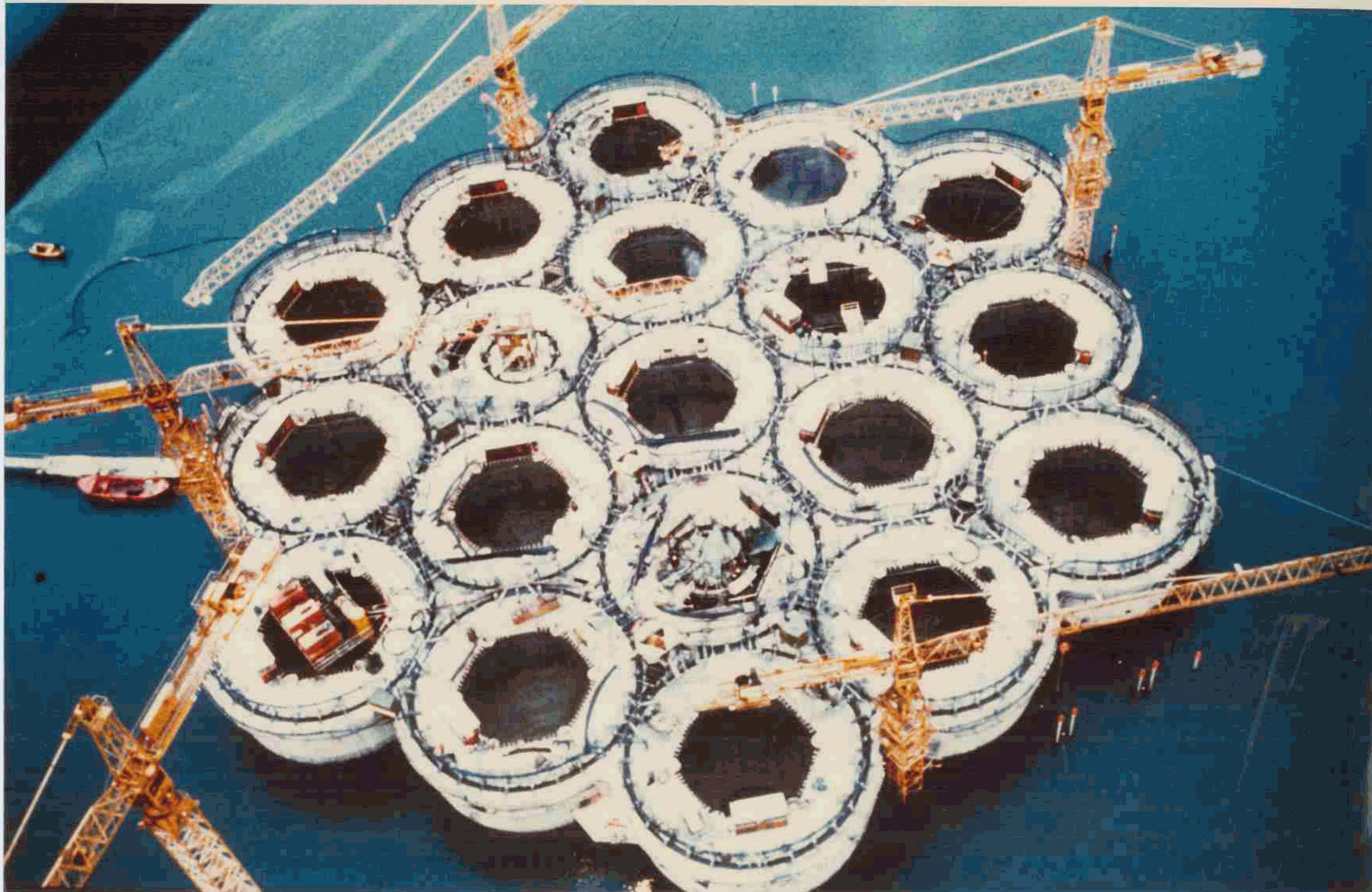
Over 20 % of the hook up of the treatment modules was achieved before departure, and the temporary equipment (accommodation, equipment, generators, etc...) was operational on the date of the departure to Frigg.

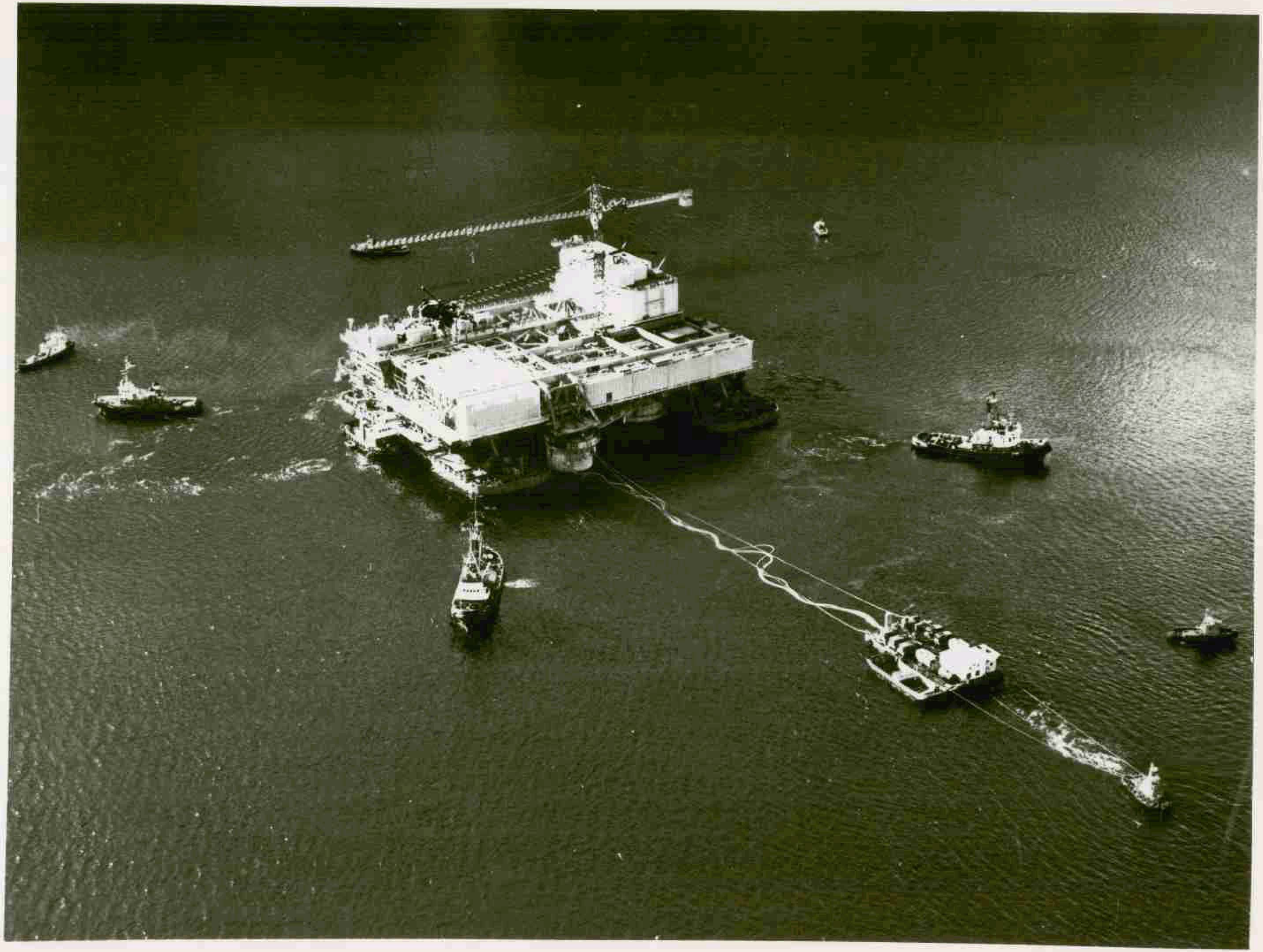
During this second phase, treatment modules, accmmodation module, helideck, were positioned by means of E.T.P.M. 1601 derrick barge of 1 600 t maximum lifting capacity.

During the works in ANDALSNES, 2 stability tests were performed. The first was performed after the deck mating operation and after positioning of the second set of equipment on the deck. The second was performed before loading the last modules. These tests determined a GM of approximately one meter, corresponding to a weight close to 12 600 t.

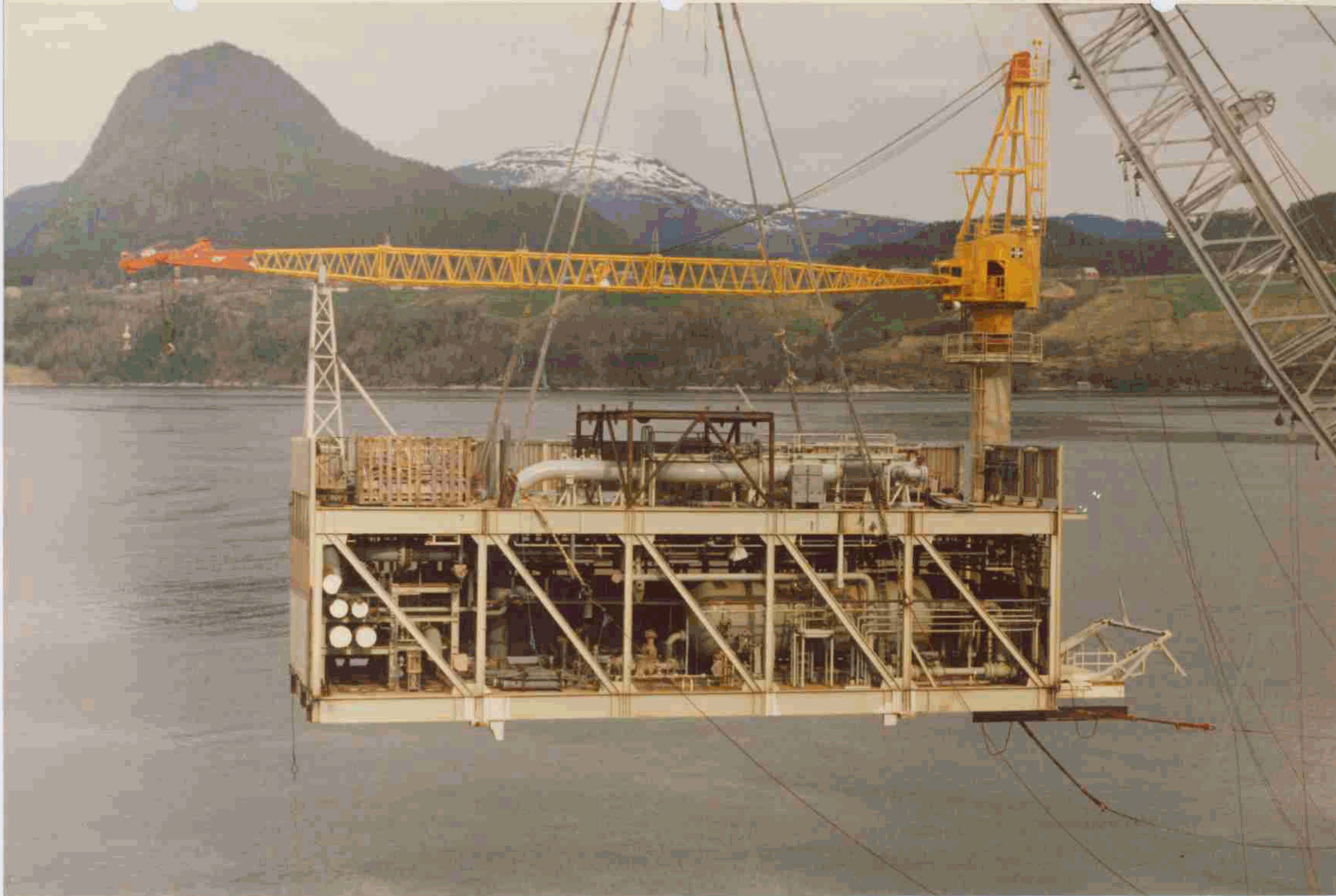
The platform left ANDALSNES site on Wednesday June 8th, that is one week before the scheduled date.

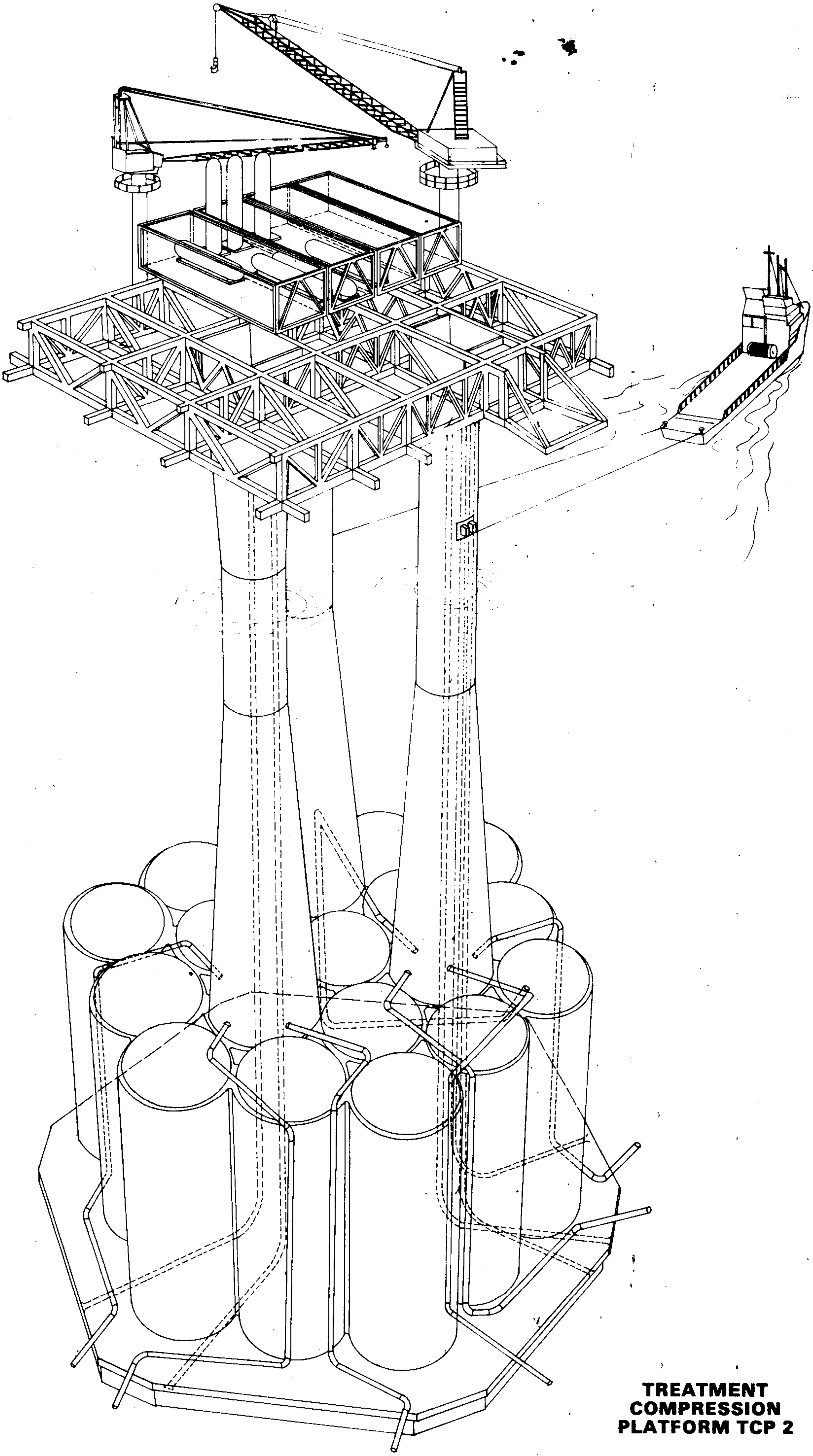
Five tugs, totalling 62 000 HP, towed the platform to Frigg field, at a 2 knot average speed : it reached its final site on June 22nd, 1977, after 8 days of stand-by in the Frigg field due to weather.



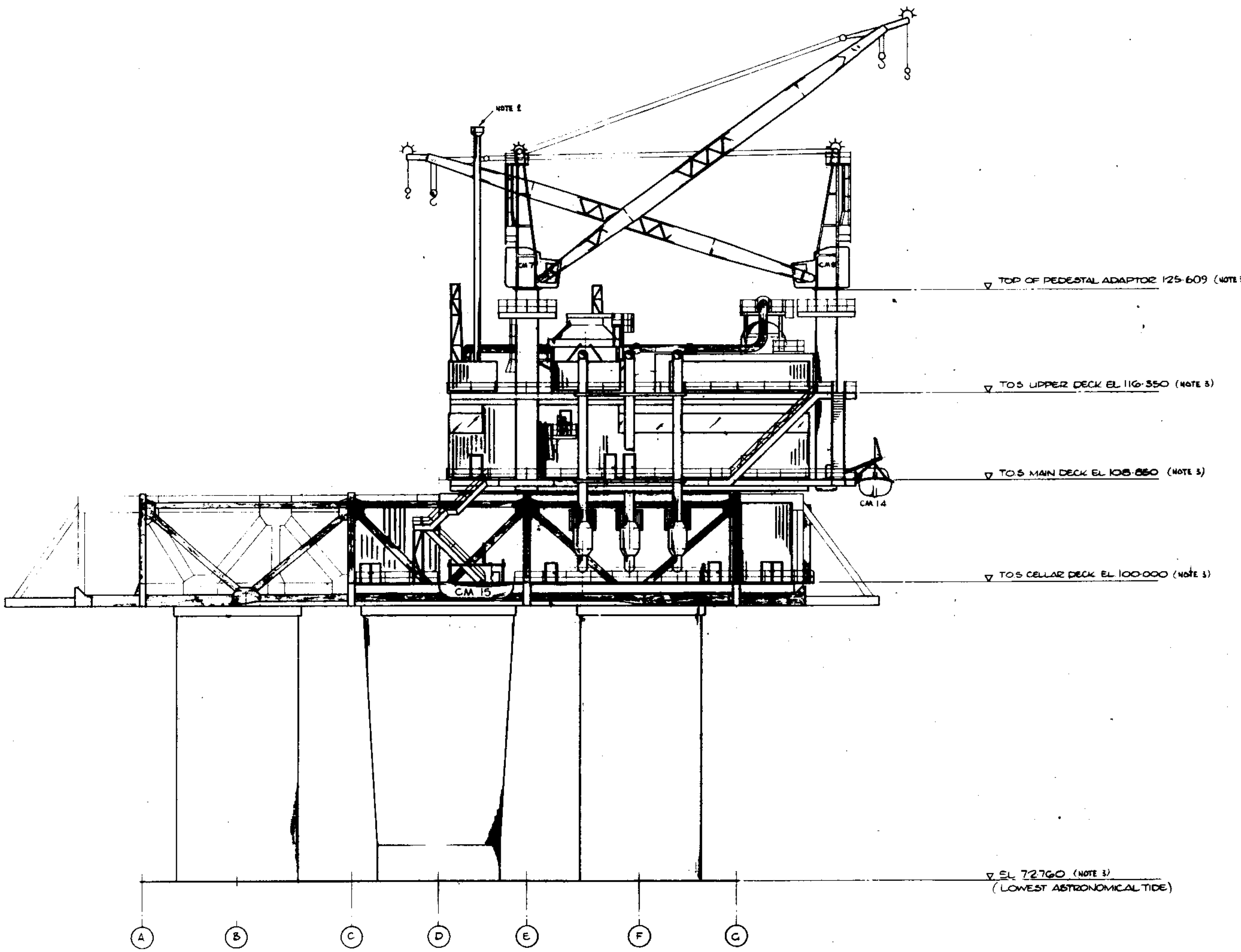



2

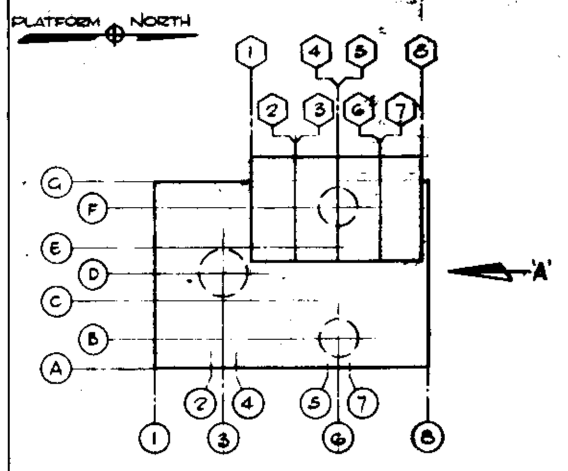




TREATMENT
COMPRESSION
PLATFORM TCP 2



VIEW ON ARROW 'A'
(SEE KEY PLAN)



— KEY PLAN —

NOTES:-

1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. THE TOP OF THE L.P. VENT STACK WILL BE ILLUMINATED BY A SPOTLIGHT, SUPPLIED WITH EMERGENCY ELECTRICAL POWER.
3. PLANT REFERENCE IS TAKEN AS 100,000 AT POINT SHOWN. THIS CORRESPONDS TO 27,240 ABOVE L.A.T.

APPROVED FOR CONSTRUCTION
REVISED PRINT, DESTROY ALL PREVIOUS COPIES.

18 MAY 1977

DESIGN	ELEC	INSTR	PIPING	STRUCT	NO	BY	DATE	REVISIONS	DATE	APP.
					O	C.P.	13-5-77	APPROVED FOR CONSTRUCTION		
		—		—	A	EM	28-1-76	ISSUED FOR APPROVAL		

J. Bartel 12.05.77

ELF - NORGE
FRIGG FIELD

TREATMENT / COMPRESSION PLATFORM No.2

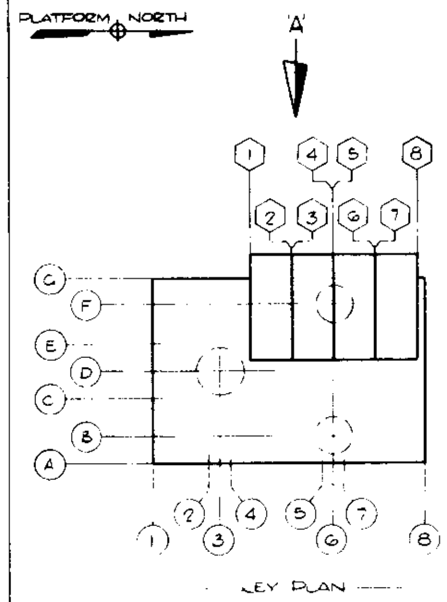
NORTH SEA — JOB 1-40-E2

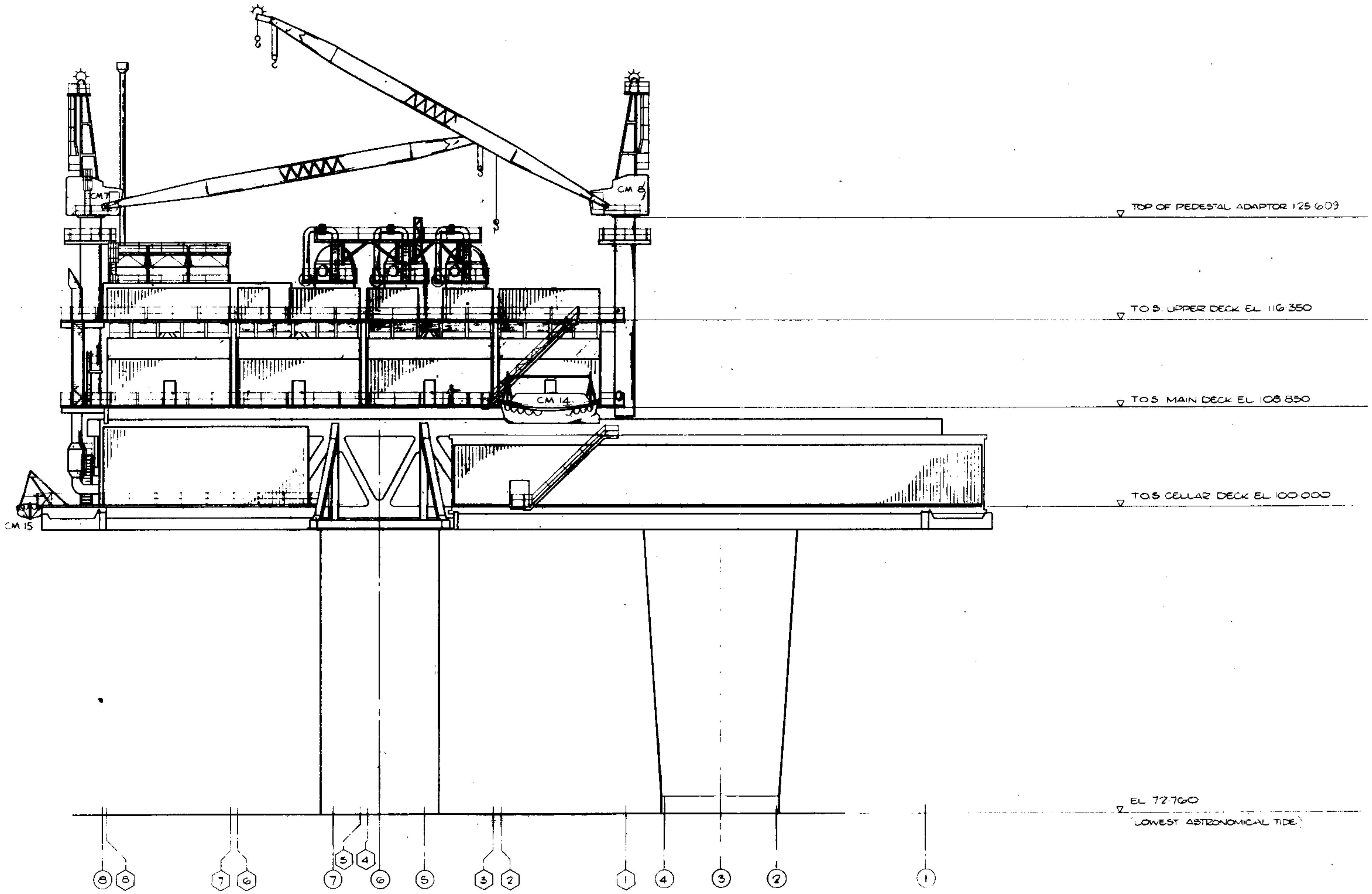
McDERMOTT — HUDSON
LONDON — ENGLAND

ENGINEERS APPROVAL

DRAWN BY	SCALE	DATE	DWG NO
EDWARD H.	1:150	26 JAN 1976	ELN 2165.
DESIGNED BY: MB Wine			SHEET NO: C7382

FIRE & SAFETY LAYOUT NORTH ELEVATION





VIEW ON ARROW 'A'
(SEE KEY PLAN)

NOTES -

1. SEE NOTES ON DRAWING No. ELN 2169 - C7382.

APPROVED FOR CONSTRUCTION
REVISED PRINT. DESTROY ALL PREVIOUS COPIES.

DESIGN	ELEC	INSTR	PIPING	STRUCT	NO	BY	DATE	REVISIONS	DATE	APP
					0	CP	29.3.77	APPROVED FOR CONSTRUCTION	18/6	
			-		-	A	EH	28.1.76	ISSUED FOR APPROVAL	24/1/76	

ELF-NORGE
FRIGG FIELD

TREATMENT / COMPRESSION PLATFORM No.2

NORTH SEA JOB 1-40-E2 WD 104-M.

McDERMOTT — HUDSON
LONDON — ENGLAND

ENGINEERS APPROVAL

DRAWN BY	SCALE	DATE	DWG. NO
EDWARD H.	1:150	26 JAN 1976	ELN 2169
DESIGNED BY			SHEET NO
			G7383

FIRE & SAFETY LAYOUT WEST ELEVATION

J. Bo[illegible] 12.05.77

7 - MANAGEMENT OF CONSTRUCTION

7.1. General

Like any big offshore project, Frigg has been developed in three steps :

- a 2 years conception and engineering phase, started in 1971,

- a construction phase, from 1972 to 1977,

- a marine installation phase, from 1975 to 1978, in the course of which commercial gas delivery to BGC has started (in 1977), with the program of reaching its full capacity in 1979.

SNEA (P)'s approach to an offshore project is the following :

- the conception phase, which requires direct contact between project management and specialists, is carried out in France,

- the engineering/construction phase is managed by a Project Group that handles all technical, juridical, coordination aspects of the project : this group, based in France in the case of the Frigg Project, will in future projects be based in the country where the Operator is based,

- the marine installation phase is managed on site where installation takes place.

7.2. Engineering and construction organization

7.2.1. General

In general terms, the Frigg facilities have been developed by the Project Group, their construction farmed out to fabricating contractors and then delivered to EAN, for the offshore installation, seafastened on the cargo barges departing from the fabrication yards docks (all steel jackets, decks, production modules and bridges have been treated in this manner).

However, for the self installing structures (gravity platforms), i.e., the flare, TP 1 and TCP 2, the Project Group has managed, besides the design fabrication, also the tow out and marine installation.

This is explained by the fact that offshore installation of a gravity platform is dependent on decisions taken during design and fabrication, and is done under the same contract as onshore fabrication.

Thus the Project Group, composed of Elf personnel and hired personnel under Elf supervision, had the overall responsibility, from engineering to technical acceptance.

7.2.2. Project Group organization evolution

An independent Project Group, as described above, guarantees a smooth management, able to cope with hybrid technical choices, and diversified fabrication and logistical problems.

At the commencement of the Frigg project, due to Elf's limited previous experience in the management of projects of such magnitude, management tasks were contracted to various international engineering contractors (Brown and Root, Mc Dermott, UIE, Lummus,...).

This eventually led to certain unsatisfactory effects :

- on the management side :
  - . unsatisfactory cost control technique,
  - . " " planning technique,
  - . " " outlook of difficulties.
- on the technical side :
  - . unsatisfactory technical choices,
  - . " " internal task-splitting.

These were countered by the progressive growth of Elf's own management involvement and engineering checking activity.

This policy started very early in the Project and grew rapidly, so that the management organization reached an optimun size and efficiency during fabrication and installation of TCP 2.

Inside the Project Group, a team of engineers has treated directly some TCP 2 engineering and management tasks such as :

- definition of basic choices :

  . loading conditions on support frame,

  . load analysis on support frame during transportation,

- scheduling and cost control,

- coordination of the 4 different engineering contractors (for platforms, decks, risers, temporary modules, permanent modules),

- choice, appointment and supervision of the appropriate experts for :

  . detailed check of vital components such as base structures, support frame, ballasting installation procedure, in parallel with the checks carried out by official agencies (DNV, Insurances,...).

  . orientation studies, allowing changement of scope of work without adversely effecting cost and delivery schedule.

The team was not only successful in monitoring the different components of the project as they were taking shape, but was able to reorganize the fabrication of two important components.

This type of organization has proven its efficiency in facing the technical and industrial difficulties evidenced during construction of an integrated platform.

Moreover, only a team responsible for both onshore construction and offshore installation of all facility could guarantee the optimum overall preparation of critical offshore work.

The homogeneity of conception and management of platform TCP 2 can be testified by the following achievements :

- precision-setting of TCP 2 close to TP 1 (length of gangway = 75m) unattained before between two concrete platforms,

- installation at site of a fully operational platform (with power and compressed air generation, quartering for 250 people,..) able to give immediate support to hook-up and flowline tie-in operations,

- carrying out of an important amount (20 %) of hook-up work while in the fjord, in parallel with main construction work, without shifting the tow-out date.

8 - PLATFORMS OFFSHORE INSTALLATION AND HOOK UP

8.1. General

Before explaining in detail in paragraph 9 what were the main rules of EAN offshore works organization in 1976 and 1977, it must be said that the efficiency of this organization has been proved by the fact that from April 1st, 1976 to September 30th, 1977 (that is to say over a 18 month period) :

- three platforms (TP 1 - DP 2 - TCP 2) were installed in the field,
- two platforms (QP - CDP 1) that were half installed were completed,
- 71 process modules, for a total weight of 24.730 metric tons were lifted and installed,
- 11 connecting lines and 4 cables were laid and connected,
- two 32" pipelines to SCOTLAND were connected to TP 1 and TCP 2,
- 7 hyperbaric welds (six 26" and one 32") were performed in the field area,
- the four 26" connecting lines and the two 32" pipe-lines were either buried or protected in the field area,
- four platforms (CDP 1 - QP - TP 1 - DP 2) were completely hooked up with a total of 3.395.000 offshore manhours over this period,
- the first phase was brought into production on schedule with the gas flowing to SCOTLAND from nine completed wells,
- the cost of the construction works over this 18 month period was 74,2 % of the total offshore construction cost.

For the hook up works this ratio is 66,8 %.

8.2. Offshore installation

As long as only one derrick or/and lay barge is working in an offshore field to install a platform or lay a pipe there is little coordination to be done.

Problems start when the simultaneous use of two or three barges is required, since, for safety reasons, only one barge can be moored within a circular area of about 1 km radius.

In order to solve the problem of the simultaneous presence of two or three derrick barges, it was attempted :

- to minimize the use of barges by modifying the installation procedures (gantry crane for module lifting on CDP 1, self-contained modules for insert piling on QP, semi-submersible assistance for insert piling on DP 2) ;

- to specialize the barges (one derrick barge to lift modules, one to lay pipeline and perform underwater welding). When one barge was working, the other was one mile off location making ready for the next operation.

The two barges extensively employed were the "ETPM 1601" and the "L.B. MEADERS". During the 1976 summer season it was possible to have in addition the "DB 22" installing the DP 2 jacket, which required a coordination effort in order to :

- follow the preliminary schedule based on the coordination of the barge work ;

- organize the mooring operations and vessels traffic in the field area.

The attempt was successful because :

- EAN's representatives on barges and platforms were fully aware of the schedule requirments and the priority order of each operation,
- the two or three barge superintendents were cooperative,

- frequent contacts with the onshore base made easier a detailed follow-up of the operations and the immediate modification of the instructions when required,

A "Frigg traffic office" (two senior captains equipped with radio and radar facilitities) were coordinating 24 hours per day the mooring operations and the vessel traffic (there were up to 30 different boats in the field including barges, tugs, supply vessels and stand-by vessels).

8.3. Hook up and start up

The coordination requirements for this type of operations are completely different. It is no longer a matter of 2 barges but of 2.000 men, no more a matter of mooring interferences but of logistic interferences complicated by the simultaneity of ten or twenty activities on one platform and the transfer of material and equipment from one team to the other.

Early in the hook-up stage it became necessary to modify the installation organization. Part of the onshore management was transfered offshore and a site Manager was placed permanently on board the quarters platform with full authority over all of the offshore personnel. From this stage all the short term decisions regarding the priorities, scheduling, logistics, offshore organization were taken by this site Manager assisted by the platform managers, the barge supervisors and the logistics supervisors. This transfer of authority from the onshore base to the offshore site was one of the key factors for the successful and timely performance of the job.

8.4. Logistics

It was evident that a heavy logistics organization was needed as early as May 1976 when more offshore beds were required to accomodate personnel working on the platforms offshore. From this very moment, and throughout the hook-up period, accomodation and transportation were a permanent worry for the operations managers.

a) Accomodation

The number of offshore personnel reached the highest level during the 1977 spring with about 1.300 persons working on the platforms, making a total of more than 1.850 when including the crews of barges and vessels.

To accomodate these 1.300 workers two solutions were found :

- installation on the platforms of as many temporary quarters as permitted by safety and available deck space. On each platform two rig officers were assisting the platform manager for bed allocations,

- chartering of semi-submersible accomodation rigs fitted with additionnal temporary quarters, each of these rigs being under the authority of a EAN supervisor assisted by two rig officers and reporting directly to the site manager.

Three rigs were at different times moored in the field vicinity to finally reach a total of 670 "floating beds" available to field personnel :

- West Venture
- Treasure Hunter, then Treasure Finder,
- Sedco 135 C.

The allocation of beds on platforms and accomodation rigs between the different contractors was made by the site manager in accordance with the actual progress of the works and the order of priorities.

b) Personnel transportation

Every day but on Sundays and Mondays charter plane(s) were flying from either France or Scotland to Stavanger where a direct connection with helicopters was arranged in order to have a quick rotation of personnel.

The fact that, in 1977, there were a total of 11.612 hours of helicopter flying gives an idea of the importance of the air traffic.

In addition to this, the extensively used accomodation rigs led to a heavy helicopter shuttling every morning and evening to and from the platforms. One Sikorsky S61 and one Bell 212 were involved in this shuttling for a total of up to 700 passengers daily. In August 1977, more than 34.000 passengers were shuttled in the field.

This air traffic was handled onshore by an air traffic group (three persons full time) and offshore by air traffic officers located on the West Venture under the authority of the EAN supervisor on board.

The offshore assignment of a total of 5 helicopter pilots and mechanics made possible the permanent availability of the stand by Bell 212, giving a guarantee for safety flights to Stavanger in case of emergency.

c) Equipment transportation

The Frigg traffic office, already mentioned previously was working in connection and under the authority of an onshore marine transportation group (three senior captains and one barge mechanic).

This group handled in the summer of 1976 12 tugs, 15 cargo barges, 2 tender-vessels and 11 supply-vessels directly chartered by EAN.

d) Telecommunications

Apart from the standard radio facilities which were used for telephone calls and telexes throughout the construction period, special equipment was installed to facilitate the contacts between the site and the base :

- one radio channel was specially allocated to EAN. It was used to communicate with the barges,

- V.H.F. sets were installed on the fixed platforms and rigs,

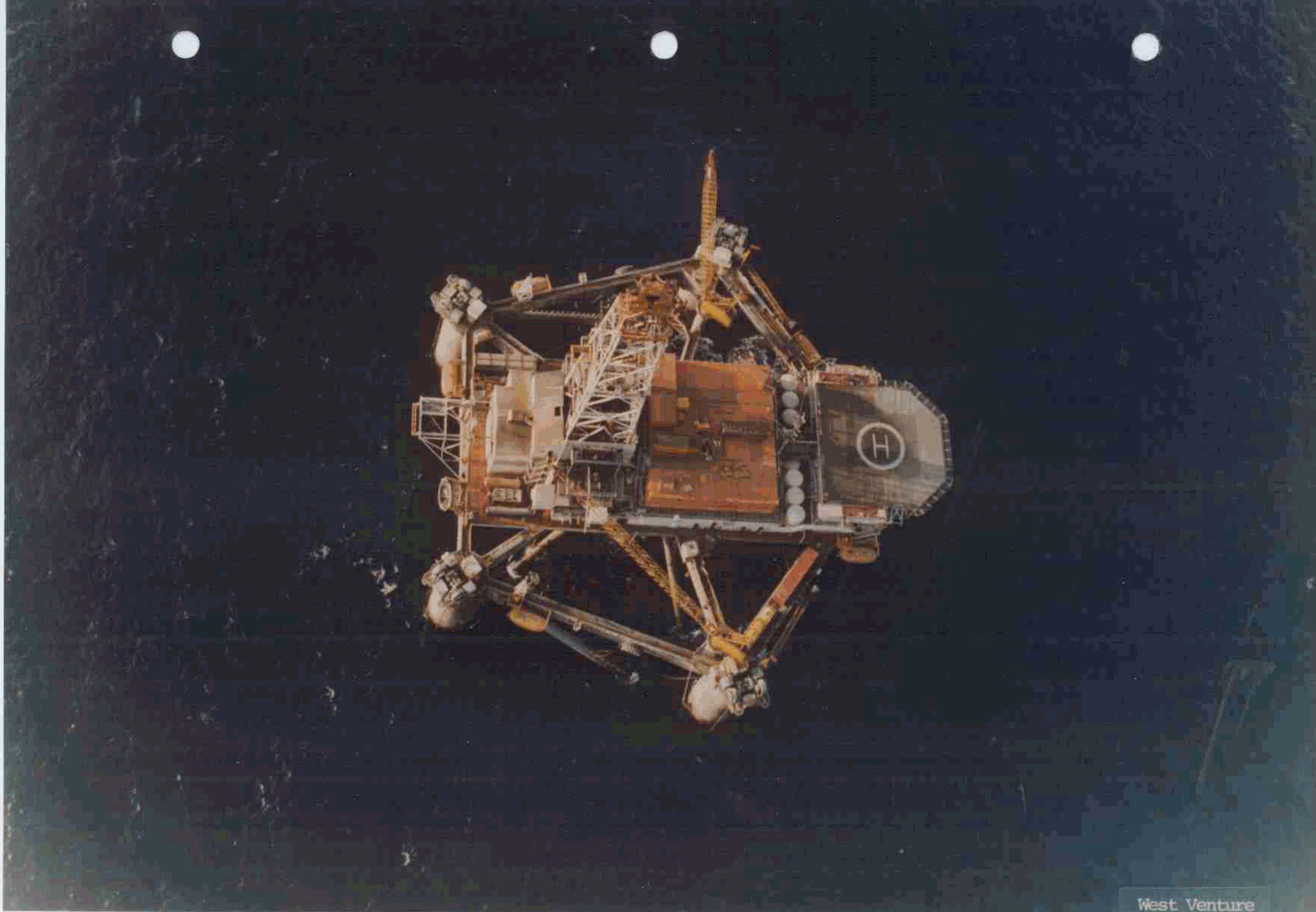
- facsimile machines were used for immediate transmission of reports,

- and, from June 1977, satellite telecommunications were available allowing the offshore management to reach immediately, through the Norwegian link, any place in the world.

e) Conclusion

It can be concluded that the success of the development of a large offshore field is strongly dependent on how the work is organized.

What was done in the Frigg field between April 1976 and September 1977 is one example of a suitable approach to this size of operation and for the Elf Group represents clear experience in handling big projects.



West Venture


Treasure Hunter and DP2 platform

9 - MARINE OPERATIONS ORGANIZATION

To support the marine operations, a massive management organization was required.

At first E.A.N. which was at this time not fully experienced in handling this type of project in the North Sea area called on management contractors having a world-wide reputation, such as BROWN and ROOT and Mc DERMOTT to organize and direct the offshore works. Besides these contractors a small E.A.N. team of skilled personnel was assigned to STANVANGER to follow the progress of these works.

After a few months it clearly appeared that, due to the complexity of the project, this structure was not suitable to reach a high degree of efficiency and, at the beginning of 1976, a new organization was set within E.A.N. in accordance with the following principles :

- E.A.N. personnel directly in command of all the operations in the STAVANGER base as well as in the Frigg field.

- Experienced personnel, issued from various companies but temporarily hired to E.A.N., included in the E.A.N. team as specialists in their own field of activities.

- Scheduling, determination of priorities, selection of contractors and equipment , logistics under full control of this team.

- Management contractors only in charge of the detailed work preparation and control of execution, as required by E.A.N..

- Large delegation of authority to the personnel in charge of the main functions in order to allow an immediate action when required.

Although the detailed organization was progressively modified according to actual work progress, the general frame remained the same over 1976 and 1977 with the following departments, all located in the E.A.N. offices in STAVANGER :

- operations departments (one per platform for construction work, one for hook-up work, one for the connecting lines),

- five additional departments for assistance to the others in matters of logistics, contracts, cost control, engineering and certification.

Every operations department had permanently on site, either on barge, or on platform one or several representatives. For critical barge operations (jacket launching, heavy lifts) or hook-up work the offshore representative was a senior engineer able to take immediate decisions if required.

In addition to the personnel assigned to STAVANGER, various specialists belonging to the ELF AQUITAINE Group were called by the operations departments for specific assistance in various activities such as : platform positioning, pile driving, corrosion, underwater welding, gas processing, production equipment, power generation, telecommunications, etc..., the typical example of the use of SNEA (P) background being the assignment, within the commissioning team, of experienced production and maintenance supervisors from the SNEA (P) gas complex in LACQ and different refineries in FRANCE.

10 - COMMISSIONING AND START-UP

For the offshore commissioning, each platform was conventionally subdivided into a number of systems.

A team of EAN personnel (40 units) was sent to the platforms and split according to the systems.

Following a preestablished check list, each system was verified and tested.

The same personnel that did the commissioning, constitutes now the core of the exploitation personnel.

Furthermore, the start-up personnel was extracted from the commissioning personnel, with the addition of site managers transferred from onshore to offshore for the purpose.

11 - MAJOR DIFFICULTIES ENCOUNTERED

1.1. Coordination

It is easily realized that the development of a project of the Frigg complexity, split among a dozen of major engineering companies and contractors and hundreds of minor service suppliers, has posed a huge coordination task for the Operator.

The selection of contractors, both for the engineering, the onshore fabrication and the offshore installation, had to be based upon many criteria, cost, reliability, availability, nationality and this was in itself a one-way basic management choice. Subsequently, the coordination of these various contractors, in geographically displaced sites (France, U.K., Belgium, Norway) and the planning and supervision of the offshore installation could be possible only at a price of a very massive organization.

The establishment and efficient running of such an organization is a substancial international management achievement for ELF.

The organization that has made possible the coordination task is described in paragraph 8.

1.2. Unforeseen

One of the setbacks in the Frigg development was the loss of the steel jacket of Drilling Platform 1, which sank on October 14, 1974. This platform was planned to be the first to be set in and it was also envisaged that DP 1 should have completed most of the 24 wells it was scheduled to drill before Frigg was brought on stream.

Due to the approaching winter, all efforts to salvage the platform were fruitless. Finally another platform of the concrete gravity type was used in its place and a new booster platform built.

In the meantime, the DP 1 jacket was salvaged in July 1975, and is now placed in such a way that it does not hamper the activity at Frigg nor sea navigation.

The episode, although a severe blow to the morale in the project at the time of happening, has proven the extreme flexibility of the operational organization to adjust to changing circumstances.

The concrete platform originally conceived as manifold platform underwent substantial modification, was renamed CDP 1, and was successfully installed on site.

Drilling from this platform was thus commenced within the modified planning framework.

1.3. Cost Control

Since the engineering and fabrication of the various components of the Frigg facilities (platforms, jackets, decks, modules, etc...) was taking place in different European Countries in a particularly unstable economical moment, it was a major difficulty for the cost control function to handle the numerous rates of inflation and currency rates variation.

To solve the problem EAN have decided to adopt a fixed rate of exchange for currencies during all the duration of the project. According to actual expenses paid, it was possible to know at the end of each month the difference with the estimate. This difference had been followed up as a "differential of exchange", giving the possibility, with the forecast of rates for coming years, of a permanent readjustement and a revised final cost.

On this basis, the different functions of the Cost Control could be accomplished on a fairly realistic basis :

1. estimate of the cost of the different parts of the project,
2. approval of the estimate, transformed into budget commitment,
3. follow up of commitments. Before commitment of any contract, the information of the amount forecast on the pertinent budget item, the amount already committed and thus the amount available is given by the cost control to the responsible of the budget.

This clear knowledge of the commitment has permitted accurate monthly payment forecasts to be made, which proved very important for a project of the Frigg magnitude, for which monthly payments have been around 250 MNOK during some months.

It also had other beneficial side effects :

- good knowledge of final cost, step by step,
- accurate calls for funds to Partners,
- proper cash management.

4. check of invoices,

5. analysis of the differences between estimated and actual costs.

The experience gained by ELF in the Frigg cost control management is giving birth to a computarized cost control system, that will lead to a better analysis and understanding of the economics of future big projects.

12 - NEW TECHNIQUES

INTRODUCTION

The problems encountered in the North Sea, and particularly on the Frigg field, were of such scale and difficulty that without some techniques, developed recently, and even specially developed for this particular project, it would have been impossible to develop this field.

12.1. Seismics and logging

Although classic type seismics were used initially on the Frigg field prospect, it was the first time it had been possible to demonstrate the "bright spot" phenomenon in the North Sea, i.e. direct evidencing through seismics of the presence of gas.

The phenomenon was proved successfully on the Frigg field prospect by the French Group, both on the Norwegian and British sides, and the method is now in current use.

The extension of exploration beyond the Cretaceous and down to the Jurassic encountered problems related to lack of compaction of clays associated with high pressure layers.

These problems were overcome by devising new techniques for appraising pore pressure, based on reading instanteneous logs.

12.2. Localization by satellite

In order to locate the field precisely, the novel technique of localization by satellite was used, which was absolutely essential in order to ensure correct split of reserves between Norway and U.K.

Until 1973, sea fixes were made by means of various Decca radio chains and classical topographical means along the coast lines covering practically the whole of the North Sea.

In the case of Frigg, as the reservoir was spread across the median line between the British and Norwegian Continental Shelves, the split of reserves not only involved the interests of two associations, but also of two nations.

As radiolocalisation was not sufficiently precise, the relatively new method of satellite positioning was used, thus reducing the margin of error from tens of meters to meters.

A further application of this method was to enable a direct link between the British and Norwegian geodesic surveys.

12.3. Directional drilling from a floater

Due to proximity of permanent installations of Frigg field and for safety reasons, the delineation well 10/1-4 in the British Sector had to be drilled from a location about 1 000 m apart from the expected target.

This was successfully accomplished from a floating drilling unit through a 30" conductor.

This was the first time that a French Group had drilled a directional well from a floater.

12.4. Prestressed concrete platforms

French pre-stressed concrete technology has always been on the forefront of progress. Therefore this material was used for the Frigg platforms in the North Sea, where it is particularly suited to the severe weather conditions.

With the use of concrete, very simple methods, but on a grand scale (such as slip forming) were used, thus ensuring regular quality and firm delivery commitments, which would not have been possible with, for instance, welding of steel members.

Because of the sheer weight of pre-stressed concrete, deep foundations were not necessary, and this in turn facilitated the installation of the structures ; the expression "gravity" was attribued to this type of structure, with the two extreme variations of the slender TCP 2 and the more massive CDP 1.

12.5. Articulated flare

The flare stack of the Frigg field is an articulated platform.

This represents a new category of permanent marine structures. The design is based on the fact that a steel column, connected by a swivel joint to a base placed on the sea floor, can be maintained in a sub-vertical position by a buoyancy compartment located on the upper part of the structure, at sea level.

Such a structure swings freely in the swell, with the swing characteristics governed by its configuration (volume of buoyancy), swell, and applied external horizontal load (if any).

In waterdepths around 100 m, the combined external load can reach several hundred tons, which lends itself to uses such as flarestacks (Brent and Frigg), or as exposed tanker loading buoy.

The special feature of the system, which also appears to be its weakest point, is the universal joint, but the experience gained from the Elfocean platform in 1968-1971, and the first articulated platforms application in the North Sea, appears to confirm the reliability of this mechanical component.

The hydraulic connections for production operations are assured by means of lines built into the actual body of the universal joint, and flexibility is provided by means of tension sleeves made of reinforced elastomer.

Other means for transferring fluids could also be incorporated into the universal joint, such as axial flexible lines.

12.6. Novel underwater pipeline connections

- Automatic welding

While in previous North Sea operations the sealines had always been welded manually on the laying barge deck, for the Frigg sealines automatic welding, by the CRC process which necessitated long and careful studies, was rapidly adopted in wiew of the many advantages gained, not only in time saving but also in quality.

From the time-saving point of view, this was of the order of 50 %, which cut substantially barge costs.

As for quality, this was brilliantly demonstrated by the hydrostatic tests carried out in 1976 on the 3 sections laid at that time, and which showed that all 45 000 automatic welds were satisfactory.

Automatic CRC welding is carried out by two different types of machine :

- machine that does the root pass from the inside,
- one or more machines that fill the bevel from the outside.

Welding is carried out electrically, under argon or CO_2, with a thick welding rod, continuous and uncoated.

- Hyperbaric welding

Lenghts of flowlines laid at different times by different contractors were joined at the sea bottom by a special technique.

The welding process consists of installing around the pipes to be welded a chamber, which is brought to seafloor pressure by means of a mixture of helium an oxygen. For Frigg this pressure, unattained before, was 15 bars.

This process allows the welders to work in a dry atmosphere, in complete freedom (they nevertheless must undergo all the preparations required for deep diving operations).

A long testing programme was carried out by Taylor Diving and Comex in order to optimize the welding process in a high pressure atmosphere.

It was thus possible to use this system instead of the mechanical coupling method which is normally used, but which has a higher failure ratio.

The six (6) connections on the 26" flowlines carried out with the new technique have, at the present time, undergone successfully all the pressure tests.

12.7. <u>Flowlines tie-ins to platforms</u>

The link between the submarine pipelines and the risers on the platforms, pre-installed inside the concrete platforms, both of the Doris and Seatank types, was carried out by means of an entirely new method.

The end of the pipeline to be joined, which can be placed either on the laying barge or on the sea bed, is drawn towards the riser by means of a winch placed on the platform deck.

By drawing in this way, the section of pipe is fitted into the column on the platform through an horizontal access tunnel provided for this purpose on the platform base.

Watertightness is thus assured by a series of joints along a section of pipe between the riser column and the outside, and water expelled.

The pipe and riser can then be welded together from inside the platform.

This technique is far better than the normal underwater connection methods outside the platforms, which are always long and difficult to perform, whether they are done through mechanical connectors or hyperbaric welding.

Moreover, with the section of pipe to be connected lying on the sea floor, it is possible to work despite bad weather, maximise the use of laying barges, thus ensuring greater ease in working, and a wider safety margin.

12.8. Equipment modules self-erection

A special technique was adopted for the marine installation on CDP 1 deck of the drilling and production modules.

As the work barges LB Meaders and DB 22 were engaged in operation respectively on TP 1 and DP 2, a solution was devised that dispensed from the use of floating cranes for lifting and positioning the modules on the concrete support frame of CDP 1.

The installation sequence, that took approximately one month of summer 1976, is illustrated herebelow (see photographic sequence).

Step 1

A mast (conceived by Buzzichelli and Doris, prefabricated in Le Havre, and installed on the deck of CDP 1 at Andalsnes) had originally the function of erecting the production deck equipment modules on what was meant to be the manifold and compression platform.

Step 2

A gantry crane (engineered and prefabricated by CFEM) was lifted in sections from tender barges and assembled using the mast.

Step 3

The Buzzichelli mast was disassembled using the gantry crane.

Step 4

The drilling and production modules were lifted and positioned using the gantry crane.

Step 5

The gantry crane was disassembled and offladed in sections using a Manitowac 400 t ringer crane mounted on the top of a deck module.

Step 6

The Manitowac 400 t ringer crane was disassembled and offloaded into tender barges using the platform service cranes.

The merit of this technique resides in the possibility of speeding-up offshore lifting work in conditions of unavailability /inacessibility of floating cranes.

CDP1

8 MAY 1976


CDP1
JUNE 2, 1976

12.9. Data collection and processing

A systematic recording of data is carried out from the platforms of the Frigg field.

These data can be classified, according to their nature, into two groups :

1. environmental data ("E" Data)
2. platform data ("P" Data)

These two groups of data are to be submitted regularly to the Norwegian Authorities.

In this connection, it is to be remarked that ELF had anticipated the need and introduced the recording system in the early stage of the platform design, before Norwegian Authorities introduced the obligation to the Operators to equip their platforms with such a recording system.

Environmental Data (platform QP)

The following information is recorded on tape on a time basis for 20 continuous minutes at 3 hrs intervals :

- significant wave height,
- current velocity at sea surface
  at sea bottom,
- water temperature at sea surface
  at sea bottom,
- water level
- wind speed and direction
- air temperature
- atmospheric pressure
- humidity.

Some of the above quantities, such as wind speed, velocity, wave height, etc... are also measured in real time and used to help marine operations.

The general synoptic of the QP data acquisition system is shown in the attached table.

The data are summerized in a monthly report, copy of which is diffused to the Norwegian Authorities.

The information thus collected finds three main fields of application :

- aid to marine operations (helicopter, service vessels, works offshore, etc...) through the data available in real time, as already mentioned,

- improvement of the knowledge of the marine environment on the site,

- updating the premises used for the platform design (100 years wave height, wind and current, tide, etc...).

Platform data

The other platforms of the FRIGG field are equipped to record on tape, through structural and geotechnical instrumentation, located as schematically shown on the attached tables, the following data for 20 continuous minutes at 3 hrs intervals :

- wave height,
- columns horizontal displacement,
- stress level at base and top of columns,
- wave shock,
- settlement,
- horizontal displacement,
- soil pressure.

If a certain threshold of these parameters is exceeded, recording becomes uninterrupted until the variable falls below such threshold value : furthemore, if certain values are exceeded, an alarm is activated that warns the platform personnel.

Each month the tape is sent ashore for data processing.

The data are summerized in monthly and yearly reports, copy of which, for the platforms in the Norwegian side, is diffused to the Norwegian Authorities.

The information thus collected finds three main fields of application :

- real time detection of abnormal situtations by automatic alerting of the platform personnel,
- design calculations check through correlation of marine action with stress levels in structural members and soil,
- fatigue analysis through dynamic response of platforms.

To comply with NPD safety requirements, EAN is presently commissioning to DNV the lay down of specifications for the "In Service Inspection System".

These specifications will be based on the availability of the platform data described hereabove.

12.10. Remote controlled operations

Automation, in the widest sense, of offshore installations, is essential in order to reduce personnel to a minimum, to service the installations, which are often difficult to reach or exposed, and to assure maximum possible safety.

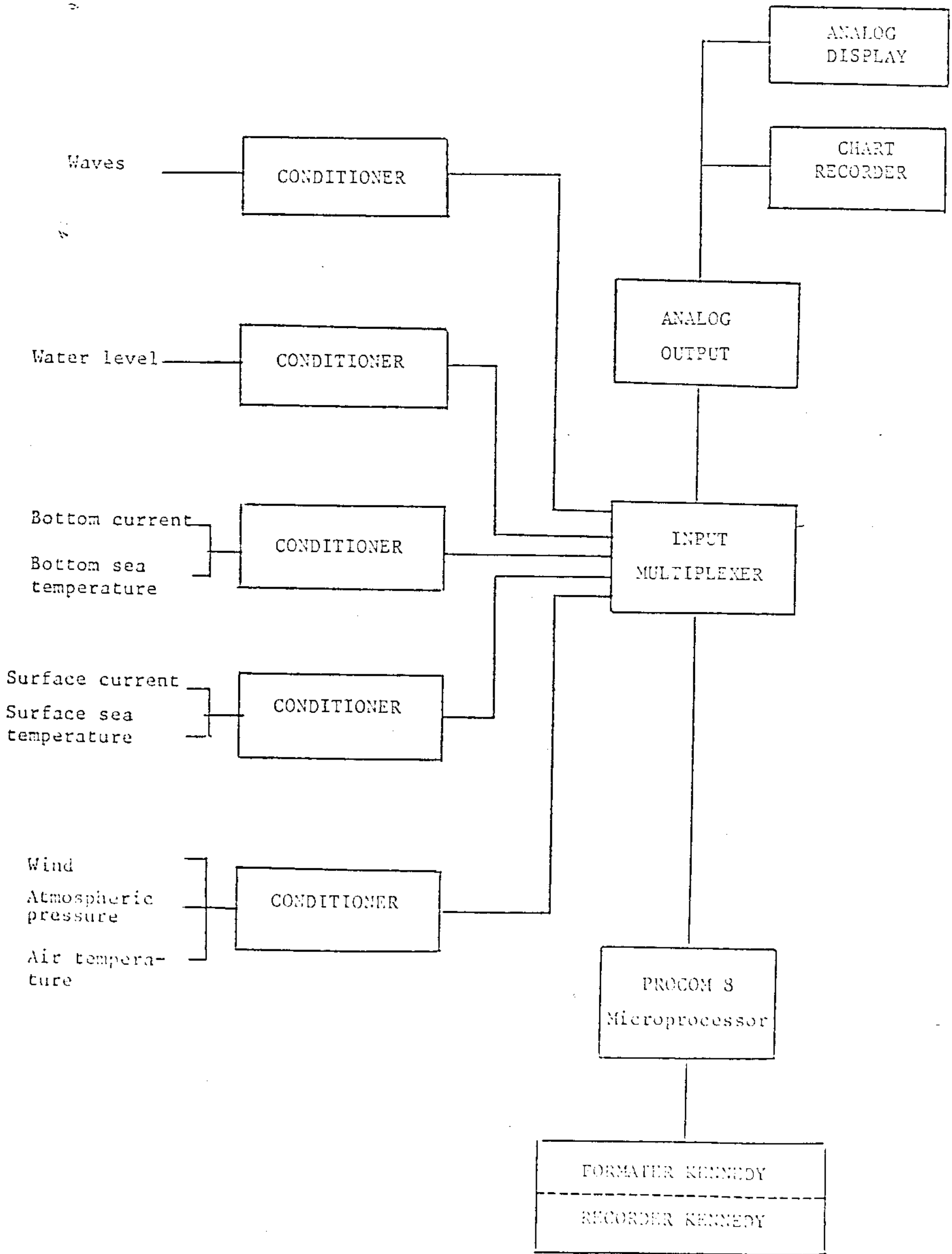
Therefore, not only were the controls either automated or manually remote-controlled, but the information collected from the various sources was re-transmitted and fed into a computer.

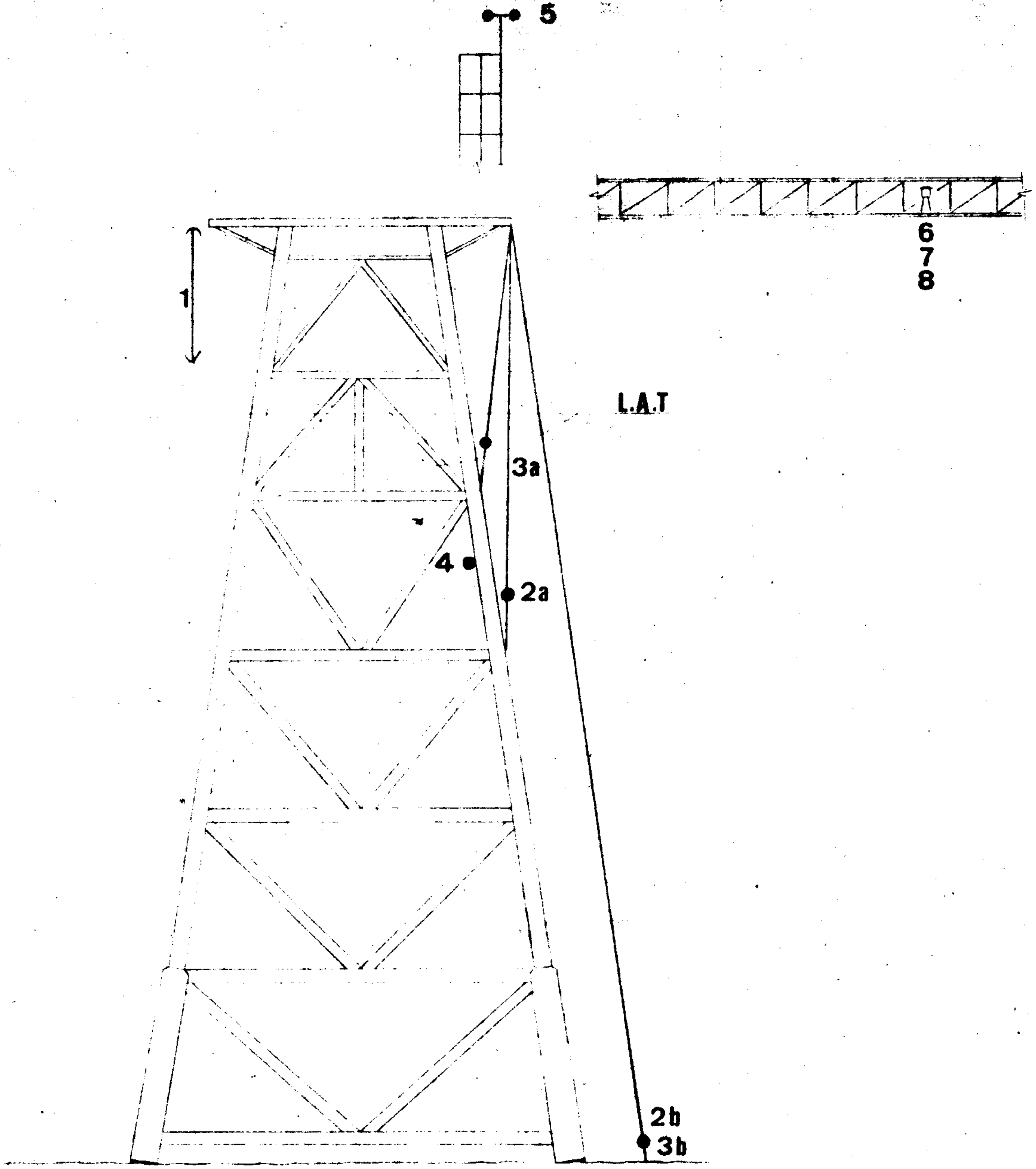
On the Frigg Field, some 4 000 indications, measurements, readings or alarms, can be read, either continuously or periodically, both as recorded information or spot visualisation.

Forecast information can also be obtained which sets the working parameters for a given production requirement.

Finally, when the models used have been adjusted according to working experience in the field, the informations will be retransmitted to the installation in the form of automated running instructions.

GENERAL SYNOPTIC OF THE QP DATA ACQUISITION SYSTEM

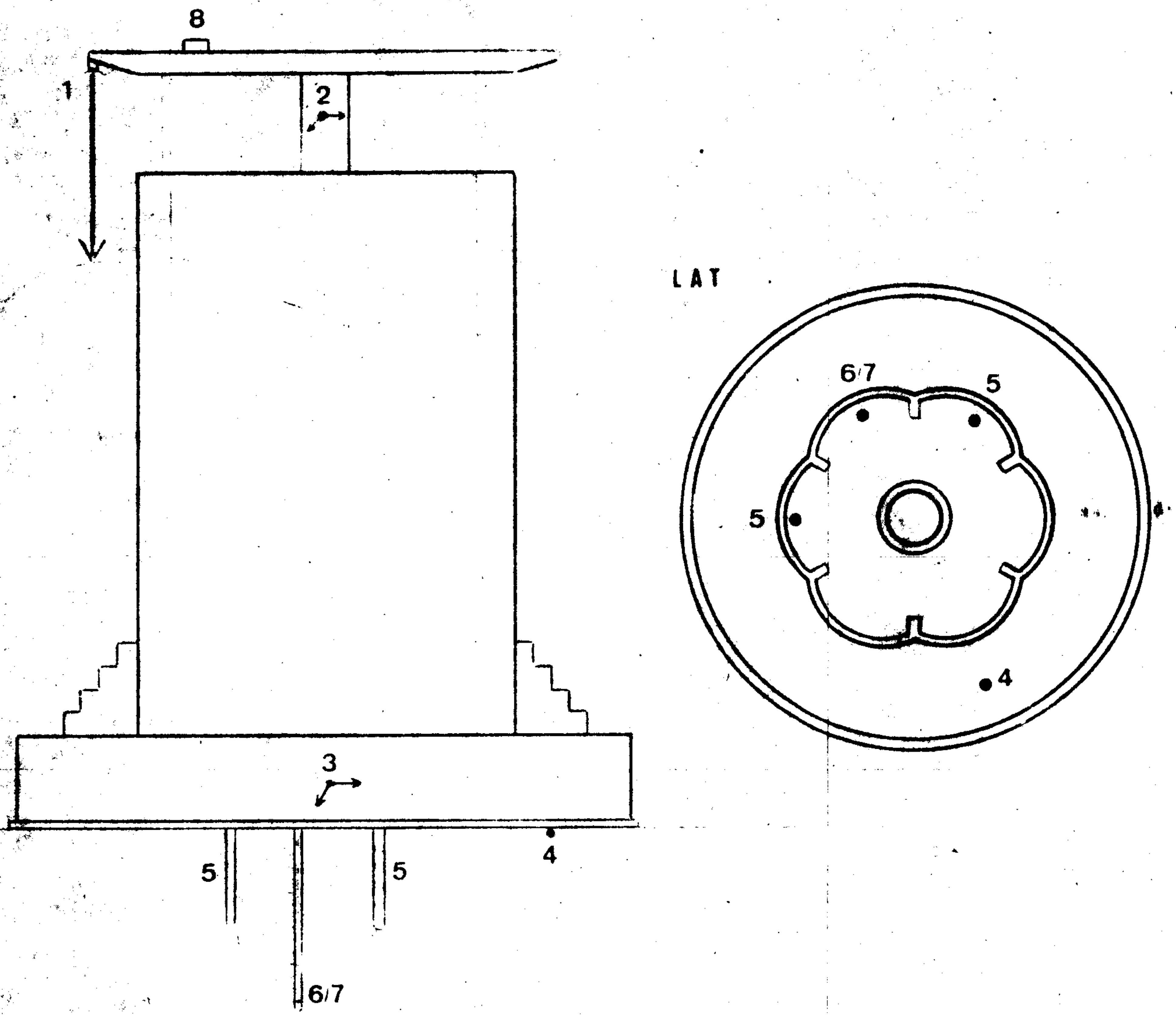




1 . WAVE HEIGHT
2 . CURRENT VELOCITY
a AT SEA SURFACE
b AT SEA BOTTOM
3 . WATER TEMPERATURE
a AT SEA SURFACE
b AT SEA BOTTOM
4 . WATER LEVEL
5 . WIND SPEED AND DIRECTION
6 . AIR TEMPERATURE
7 . ATMOSPHERIC PRESSURE
8 . HUMIDITY

QP PLATFORM

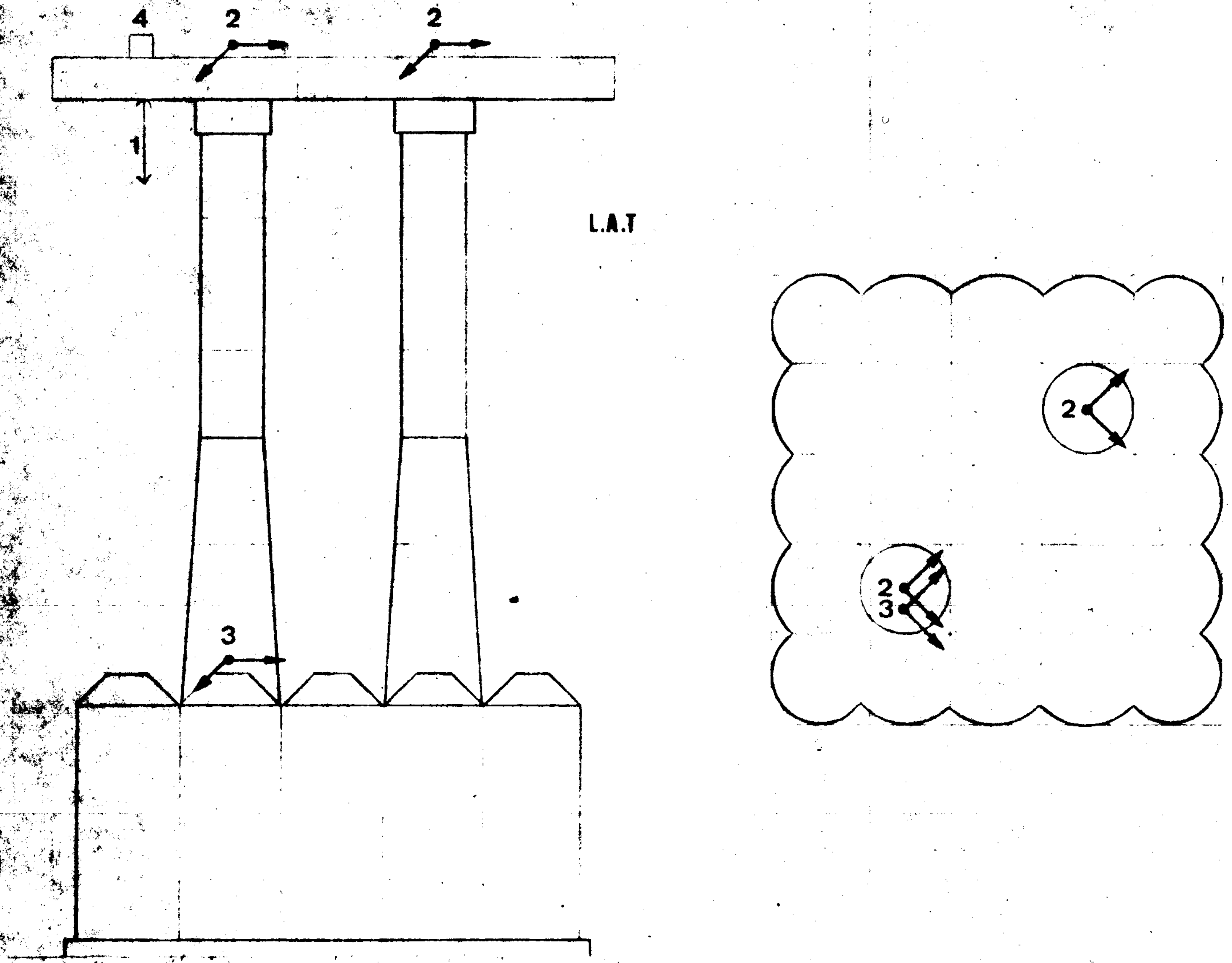
Instrumentation for "E" data collection



1. WAVE HEIGHT
2. DECK ACCELERATION
3. SLAB ACCELERATION
4. TOTAL PRESSURE
5. DEEP PORE PRESSURE
6. SETTLEMENT
7. HORIZONTAL DISPLACEMENT
8. DATA ACQUISITION SYSTEM

CDP1 PLATFORM

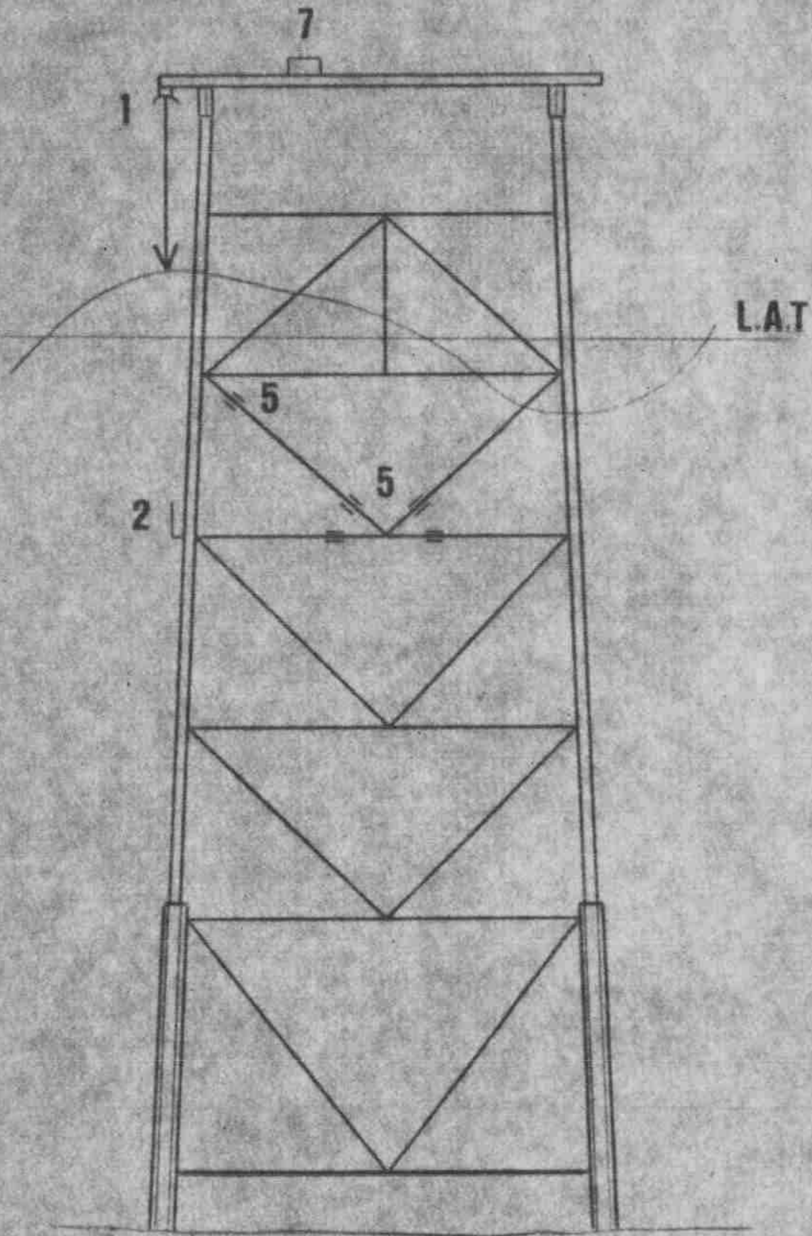
Instrumentation for
" P " data collection

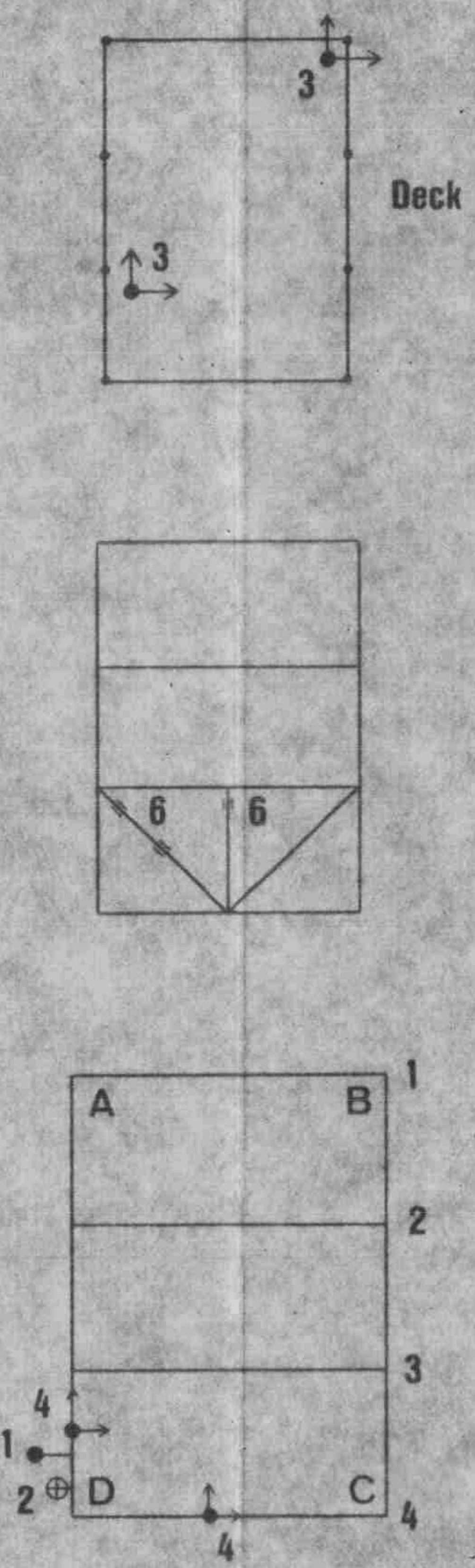


1 . WAVE HEIGHT
2 . DECK ACCELERATION
3 . CAISSON ACCELERATION
4 . DATA ACQUISITION SYSTEM

T P 1 PLATFORM

Instrumentation for
" P " data collection

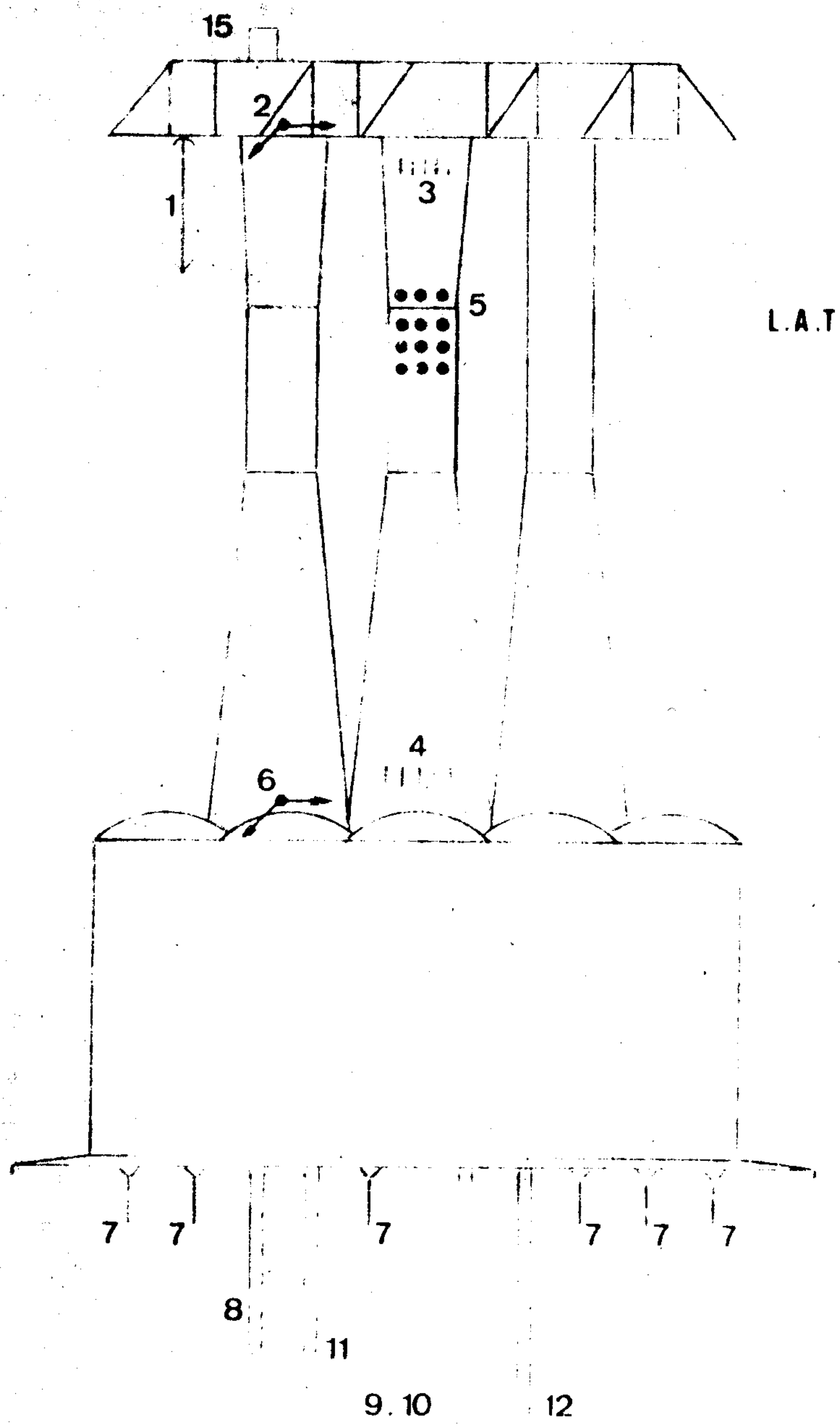


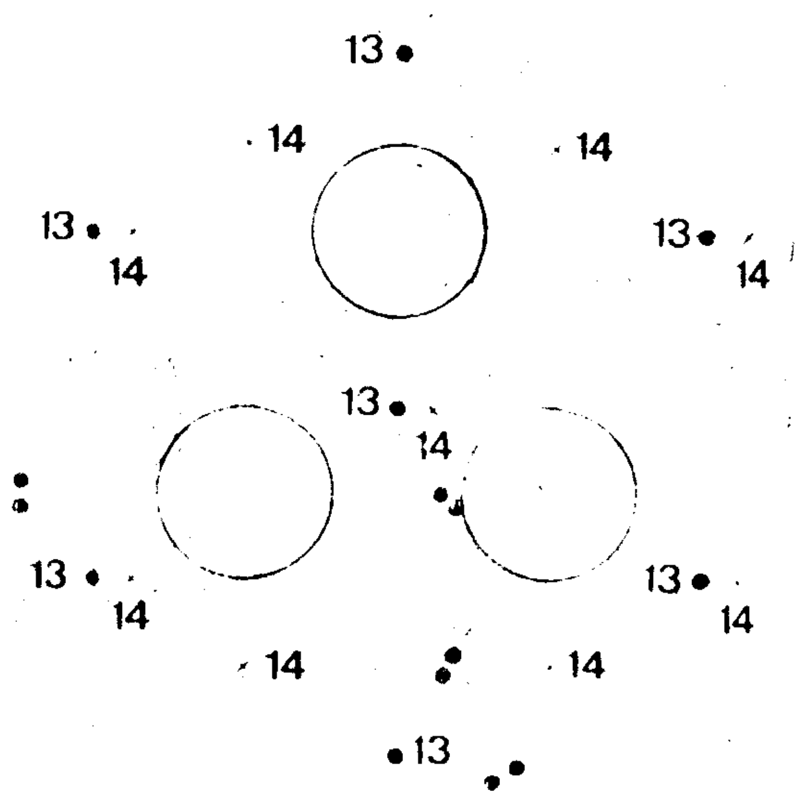


1 . WAVE HEIGHT
2 . WAVE DIRECTION
3 . DECK ACCELERATION
4 . BASE ACCELERATION
5 . JOINT STRESS
6 . WAVE SLAMMING
7 . DATA ACQUISITION SYSTEM

DP 2 PLATFORM

Instrumentation for "P" data collection





1 . WAVE HEIGHT
2 . COLUMN BENDING
3 . STRESS IN CONCRETE
4 . STRESS IN CONCRETE
5 . WAVE SLAMMING
6 . CAISSON ACCELERATION
7 . SHALLOW PORE PRESSURE
8 . DEEP PORE PRESSURE
9 . SETTLEMENT
10 . HORIZONTAL DISPLACEMENT
11 . PRESSURE
12 . PRESSURE
13 . SOIL PRESSURE
14 . STRESS IN CONCRETE CELL
15 . DATA ACQUISITION SYSTEM

TCP 2 PLATFORM

Instrumentation for "P" data collection

13 - THE INVOLVEMENT OF NORWEGIAN INDUSTRY

Since the decision to develop the Frigg field, ELF has sought participation of the diversified capabilities of the Norwegian industry, and this participation has been steadily growing with the Project.

This growth is evidenced by the analysis of the expenditure and committments of the various Phases of the Project : the analysis shows a steady increase in the Norwegian participation, that has somewhat doubled from Phase to Phase, to exceed, in Phase 2, 50 % and to reach, in Phase 3, 75 % of the Norwegian part in the Project.

This was done in spite of the fact that the established Norwegian Industry had limited technological experience in some areas of offshore equipment, such as high power gas compressors. This experience was acquired through licensing from other countries.

It may also be pointed out that the joint Venture Nylands Verksted/Stal Laval, initiated for the Frigg project purpose, has induced for Nylands Verkstel orders from other petroleum operators for very significant amounts of industrial equipment.

An analytical summary of the financial source of expenditure is given in the Attachment.

Although not shown in the Attachment, it may be noted that the involvement of Norwegian Industry in production and maintenance operations reaches approximately 75 % of the needs.

ATTACHMENT

FINANCIAL SOURCE OF EXPENDITURE

INVOLVEMENT OF NORWEGIAN INDUSTRY

(Estimate Fall 1977)
All Figures in MNOK

	NORWEGIAN PART	TOTAL COST
PHASE I		
Construction	340	2814
Wells	40	285
Sea Works	340	1640
Hook-up	65	570
Miscellaneous	200	645
Sub Total Phase I	985	5954
%	17 %	100 %
PHASE II		
Construction	602	1963
Sea Works	437	1240
Hook-up	185	360
Supervision	80	250
Miscellaneous	51	258
Sub Total Phase II	1355	4071
%	33 %	100 %
PHASE III		
Construction	343	716
Sea Works	50	100
Hook-up	81	108
Miscellaneous	87	134
Sub Total Phase III	561	1058
%	53 %	100 %
TOTAL PHASES I + II	2340	10025
%	23 %	100 %
TOTAL PHASES I + II + III	2901	11083
%	26 %	100 %

CHAPTER VI

DRILLING AND PRODUCTION OPERATIONS

1 - GENERAL DEVELOPMENT DRILLING PLAN

Development drilling in the Frigg field is being carried out from two permanent platforms, CPD 1 located in the U.K. side sector of the North sea, DP 2 in the Norwegian sector of the North Sea.

The drilling slots on each platform are 24 and have received a serial numbering from 1 to 24 : the wells are named according to this numbering.

2 - DRILLING SCHEDULE

2.1. CDP 1 Platform

The CDP 1 wells are divided in two group : Cluster West and Cluster East, separated by a fire protection wall.

Each cluster has 12 available drilling slots. One vertical and 23 directional production wells will be drilled to an approximate total depth of 1880 m TVD. (MSL).

EAN's plan is to drill and produce simultaneously from CDP 1 platform (but not from the same cluster) to match the gas delivery schedule.

To perform these operations with a maximum of safety EAN has proceeded as follows :

a) all 18"5/8 casings were set on each cluster before starting the build-up,

b) the vertical well was drilled first and then the directional wells located at the external boundary of the cluster, i.e. those having the highest kick off points were drilled in priority,

c) when drilling and producing at the same time, the producing wells were those having their slots located at the maximum possible distance from the slot of the well to be drilled,

d) individual approval was requested for each development well before drilling in 17"1/2.

Phase 1 - Cluster West

1. Drive 12 conductor pipes of 26 inches diameter,

2. set 12 18"5/8 surface casings,

3. drill and complete the vertical well n° 8 (cut core in the pay-zone : about 60 meters),

4. drill and complete in rotation 9 wells : 11,5, 2, 3, 1, 10, 12, 9, 6,

5. well n° 8 was gradually tested through permanent test facilities and the gas flared.

Phase 2 - Cluset East

1. Drive 12 conductor pipes,

2. set 12 18"5/8 surface casings,

3. drill and complete in rotation wells n°s 20, 23, 22, 14 13, 15, 17, 24, 21, 18.

Slots 4 and 7 (Cluster West) 19 and 16 (Cluster East)

The wells corresponding to these slots were drilled and completed later on, according to B.G.C.'s needs and actual progress at DP 2.

2.2. DP 2 Platform

The DP 2 wells are divided into two groups, Cluster West and Cluster East, separated by a fire protection wall. Each cluster has 12 available drilling slots : 1 vertical, 22 directional production wells and 1 observation well will be drilled.

The observation well will be converted into production well later on.

To perform these operations with a maximum of safety the operator has proceeded as follows :

- all 20" casing were set on each cluster before starting the build-up,

- the vertical well was drilled first and then the directional wells located at the external boundary of the cluster, i.e. those having the highest kick off point were drilled in priority,

- individual approval was required for each development well before drilling in 17"1/2.

Phase 1 - Cluster East

- drive 12 (twelve) 30" conductor pipe,
- set 12 (twelve) 20" surface casings,
- drill and complete the vertical well n° 20 (cut core in the pay-zone : approx. 60 m),
- drill and complete the deviated wells n° 23 and n° 17. Put the wells in safety position.

Note : after completion of these wells they were kept as back up producing wells, i.e. if any trouble occurs with the producing wells on CDP 1, these wells could be put into production to meet the gas delivery requirements.

Phase 2 - Cluster West

- skid rig to cluster west and drive 12 30" conductor pipes,
- set 12 20" surface casings,
- drill and complete 7 to 12 wells in the following order : wells n° 3, 1, 4, 2, 6, 7, 8, 5, 10, 9, 12, 11.

Phase 3 - Cluster East

- skid rig back to Cluster East,
- drill and complete the remaining 9 wells in the following order : wells n° 21, 22, 24, 13, 18, 19, 16, 20, 14.

Phase 4 - Cluster West

- skid rig back to Cluster West,
- drill and complete the remaining wells

3 - GENERAL DRILLING PROGRAM

3.1. CDP 1

a) Location

Block 10/1 (U.K. Continental Shelf)

Coordinates : 02° 03' 41,75 East
59° 52' 31,39 North

b) Drilling Rig

SAIPEM. Rig Emsco C3.

c) Water Depth

Reference : LAT 96 m
RKB- Sea Bottom : 144 m

d) Estimate Well Total Depth

Approximately : 1880 m (vertical depth : TVD MSL)
or 1928 m (vertical depth : TVD RKB)

e) Geological Data

Depth (RKB)	Geological Stage	Formation
0- 851	Upper tertiary	Sand
851- 1855	Tertiary	Clay
1855 and below	Eocene	Sand
1995		Gas-Oil Interface

f) Drilling Program

In order to exactly control overburden pressure in safe conditions, the wells have a heavy program with one extra surface casing 18"5/8.

Casing shoes 9"5/8 were later on positioned on top of the pay-zone in order to reduce to a minimum the fall of expandable clays behind the liner.

F.1.) Casing Program

Hole	Casing	Weight	Grade	Approximate vert. setting depht RKB.
Driven	26"	267 lbs/ft	X52	180 m
23"	18"5/8	87,5lbs/ft	K55	450 m
17"1/2	13"3/8	68 lbs/ft	K55	950 m
12"1/4	10"3/4 9"5/8	47 lbs/ft 55,5	N80 N80	1850 m 190 m
8"1/2	Screens 7"1/2	-	-	-

Note : in order to minimize the weight on the 26" conductor pipe :

- mud line suspension were set at 180 m (on 13 3/8" casing),

- the upper part (down to about 190 m) of the tapered production casing is 10" 3/4" size in order to allow an emergency landing of the 7" 5/8 tubing flutted hanger and to have enough room in the annulus casing/tubing for the 1/4" control line operating the mud line safety valve.

F.2.) Cementing Program

- 18" 5/8 casing cemented up to the 26" shoe CP, with diacemoil or equivalent cement classe "G" (SG = 1,50),

- 13" 3/8 casing cemented up to the surface in two stages with diacemoil or equivalent cement class "G" (SG = 1,55),

- 9" 5/8 casing cemented up to 800 m with class "G" cement (SG = 1,88).

F.3.) Directional drilling program (except 1st well)

An example of deviated well is attached (10/1-A 14) showing the drift angle, departure, Kick off Point and azimuth.

Gyroscopoc survey inside 18"5/8 casing computed by Sperry Sun.

Build up in 17"1/2 phase using motor-drill in the string. While drilling the built-up, control continuously the position with the magnetic steering tool.

Drill 12"1/4 straight hole with stabilized string. Surveys to be made by "single shot".

After setting of each casing, Gyroscopic survey to be run.

All survey to be computed by Sperry Sun - computer installed on the platform.

3.2. DP 2

a) Location

Block 25/1 (Norwegian Continental Shelf)
Coordinates : 02° 04' 20.60" E
59° 53' 10.07" N

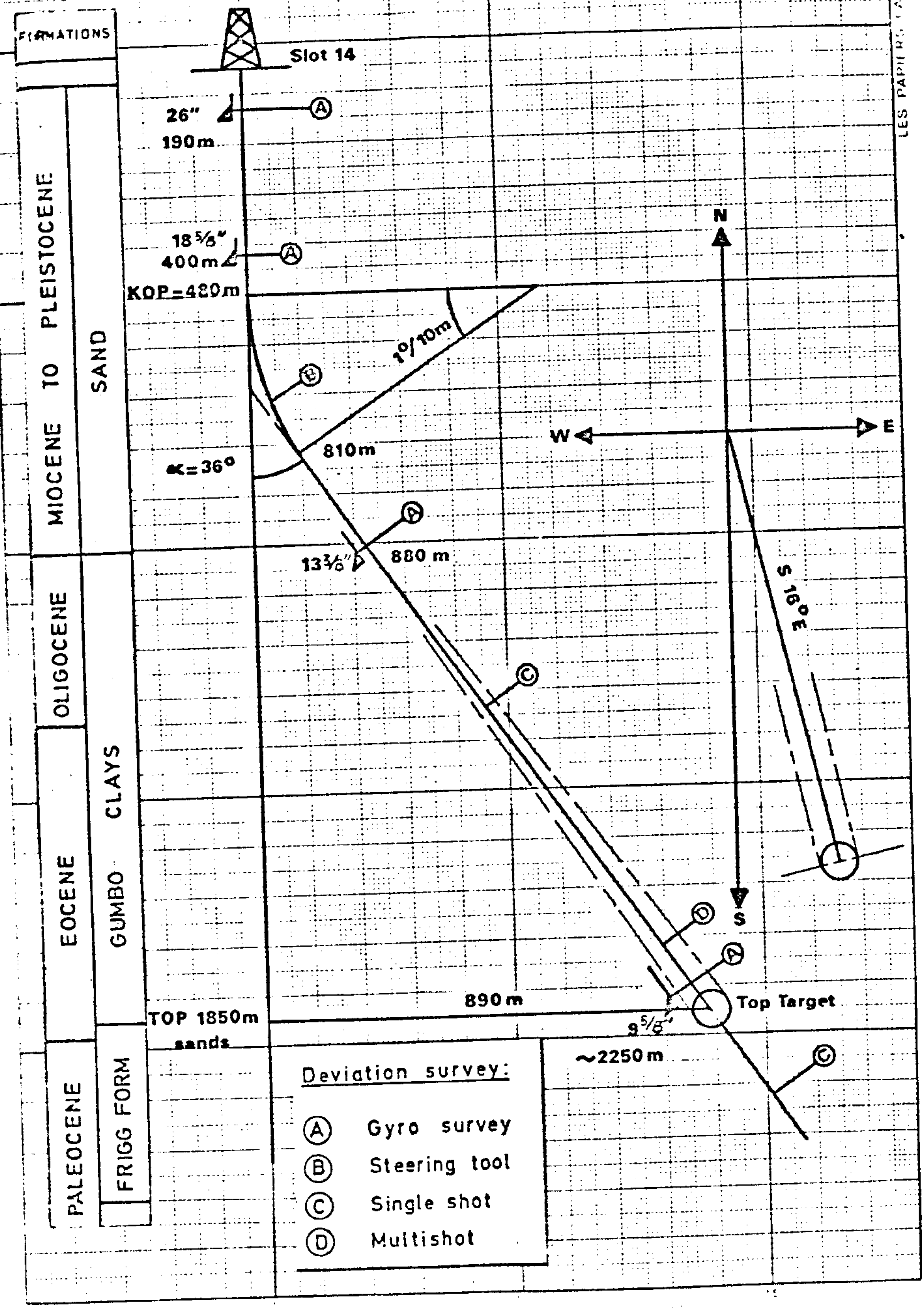
b) Drilling Rig

Unifor 1

c) Water Depth

Reference : LAT 98 m
RKB - Sea Bottom : 141 m

DEVIATION PLAN Excmple: FRIGG 10/1-A-14



d) Estimated well Total Depth

1923 m (TVD - RKB)

e) Geological Data

Depth (RKB)	Geological Data	Formation
0 - 750 m	Pleistocene to Miocene	Sand
750 - 1860 m	Oligocene to Eocene	Gumbo clays
1860 -	Eocene	Sand

f) Casing Program

Hole	Casing	Weight	Grade	Approximate vertical setting depth (RKB)
Driven	30"	310 lbs/ft	X52	177 m
26"	20"	106.5 lbs/ft	K55	450 m
17"1/2	13"3/8	68 lbs/ft	K55	950 m
12"1/4	(10"3/4 9"5/8	55.5 lbs/ft 47 lbs/ft	N80 N80	190 m 1855 m
8"1/2	Screens 7"1/2			TD

Note : the upper part (down to about 190 m) of the tapered production casing is 10"3/4 size in order to allow an emergency landing of the 7"5/8 tubing flutted hanger and to give enough room in the annulus casing/tubing for the 1/4" control line operating the mud line safety valve.

g) Cementing Program

- 20" casing cemented in two stages up to the wellhead module with light cement SG = 1.53,
- 13"3/8 casing cemented up to 150 m above 20" shoe with light cement SG = 1.53.,
- 935/8 casing cemented up to 800 m with class "G" cement SG = 1.88.

h) Mud Program

- 26" phase	- Mud Sea Water + Polymer	
	Weight	= 1.03 SG
	Viscosity	= 120
	Water loss	= 5.
- 17"1/2 phase	- Sea Water + Polymer	
	Weight	= 1.10 SG
	Viscosity	= 70 - 75
	Water loss	= 3.
- 12"1/4 phase	- Mud FCL + Dextrid + Sea Water	
	Weight	= 1.15 - 1.25.
	Viscosity	= 45 - 50
	Water loss	= 2.
	Solids	= 9 %
- 8"1/2 phase	- FCL + Dextrid + Sea Water	
	Weight	= 1.15 SG
	Viscosity	= 45 - 50
	Water loss	= 2.
	Solids	= 4 %

i) Logging Program

General :

- Phase 12"1/4 : GR - ISF - SP
  CBL after setting of 9"5/8 casing
- Phase 8"1/2 : DLL - MSFL - SP - GR.

Vertical well

- Phase 12"1/4	:	GR - ISF - SONIC - SP CBL after setting of 9"5/8 casing
- Phase 8"1/2	:	DLL - MSFL - SP - GR - FDC - CNL - ISF - SONIC.

j) Sampling Program

450	-	700 m	:	10 m interval
700	-	950 m	:	5 m interval
950	-	1500 m	:	10 m interval
1500	-	TD	:	5 m interval

k) Coring Program

About 70 m were cut in the pay-zone on the vertical well.

l) Deviation Control Program

An example of deviated well is attached (25/1 A-23) showing the drift angle, departure, KOP and azimuth.

Giroscopic survey inside 20" casing computed by Sperry Sun.

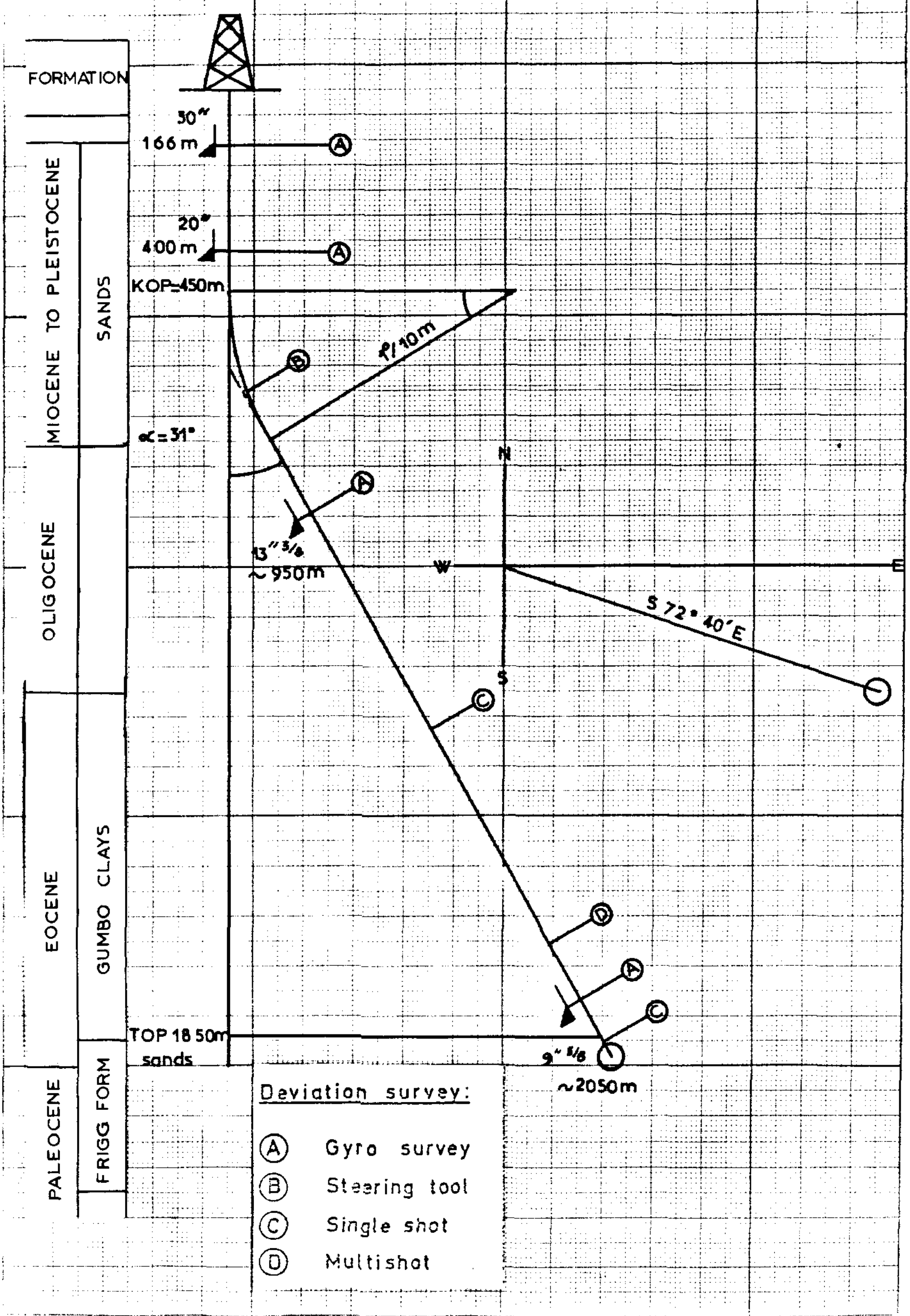
Build up in 17" 1/2 phase using motor-drill in the string. While drilling the build-up, control continuously the position with the magnetic steering tool.

Drill 12" 1/4 straight hole with stabilized string. Surveys to be made by "single shot".

After setting of each casing Gyroscopic survey to be run.

All surveys to be computed by Sperry Sun - Computer installed in the field.

DEVIATION PLAN Example: FRIGG 25/1A-23



4 - FORMATION CONTROL AND WELL EQUIPMENT

The Frigg reservoir is mainly composed of massive sand-reservoir. Characteristics are good : porosity = 30 %, permeability > 1 Darcy. Hydrocarbons in place are gas (pay thickness : max 152 m) and oil (pay thickness : 10 m).

As soon as the very short production tests of the discovery well 25/1-1 (year 1971) were over, it was obvious that an adequate completion had to be studied to prevent sand production.

It was realized that little experience existed worldwide in high flowrates from gas reservoirs composed of non consolidated sands. This forced EAN to look for a new design and led to a systematic program of studies and experimentations as from 1972.

Based on the conclusions of these works, the following criteria were established as the basis of the completion :

- self gravelled sand (filtering element in 316 L Inox welded on a 6" 5/8 preperforated casing - slots 0,3 mm (12/1000"),
- an hydroxyethyl cellulose C base fluid fully degradable by itself,
- a 7" 5/8 tubing string,

The following completion program was set :

- changing of mud when 9" 5/8 casing string is set at the top of massive sand,
- penetrating into the reservoir (partial penetration 8" 1/2" hole),
- logging,
- running of the sand screen liner,
- running of the 7" 5/8 tubing string,
- surface assembly,
- cleaning up on flare at a gradual flowrate.

This type of completion has already been used on 11 wells on CDF 1 between February and December 1977 and will likely be extended to all wells.

Production started on September 1977, and up to Spring 1978 inspections carried out to check any sand effects on manifolds and on some sections of the welleads did not reveal any trace of erosion.

Furthermore, check of sand traps (one scrubber per well) showed only unsignificant amounts of sand, proving the sand screen efficiency.

The top sediment control in the checking well (1-8) has not improved since the beginning (March 1977). Undertaken operations to check gas origin (logging production, pressure measurements on the check well) have demonstrated that the whole of the sand screen is involved in production.

The objective has been reached. All wells completed by 31.12.77 were able to produce 2,2 x 10^6 m^3/day without any significant sand occurence.

As an example, well equipment of well 10/14 is presented in the attached drawing.

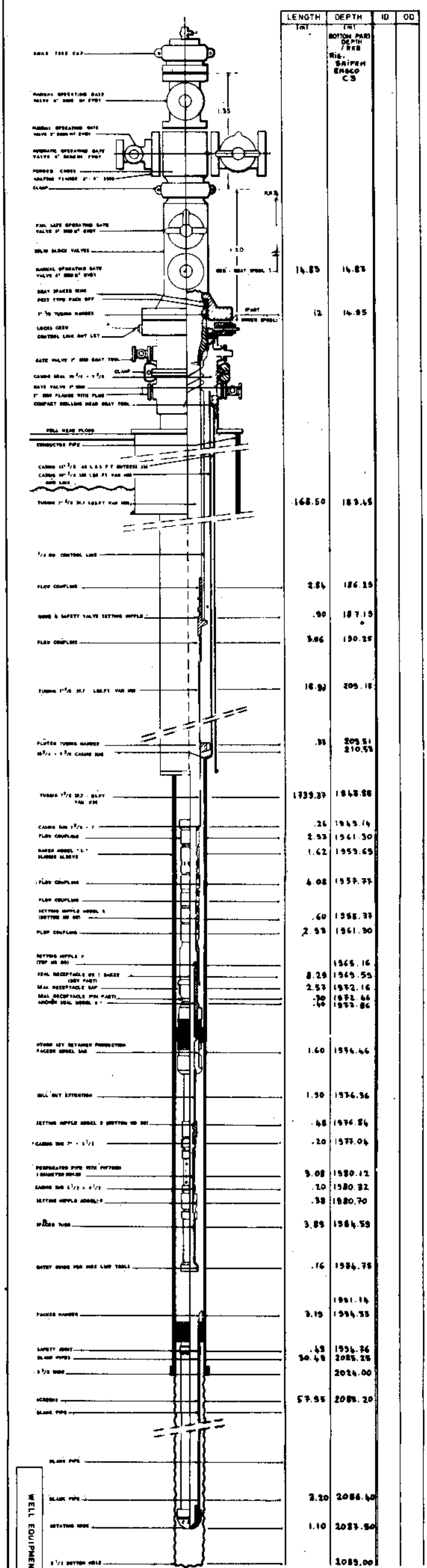
Fig. 5

COMPLETION

FRIGG FIELD

WELL EQUIPMENT

CDP 1 10/1A -



DEPARTEMENT GISEMENTS N°8447

COMPLETION

FRIGG FIELD

WELL EQUIPMENT

10.1A.12

CDP1
WEST. CLUSTER

	LENGTH (m)	DEPTH (m) BOTTOM PART DEPTH / RKB	ID	OD
XMAS TREE CAP			7"1/8	
MANUAL OPERATING GATE VALVE 6" 5000 Mc EVOY			7" 1/8	
MANUAL OPERATING GATE VALVE 3" 5000 Mc EVOY				
AUTOMATIC OPERATING GATE VALVE 6" 5000 Mc EVOY			7" 1/8	
FORGED CROSS				
ADAPTOR FLANGE 6"x 3" 5000			7" 1/8	
CLAMP			7" 1/8	
FAIL SAFE OPERATING GATE VALVE 6" 5000 Mc EVOY			7"1/8	
SOLID BLOCK VALVES			7" 1/8	
MANUAL OPERATING GATE VALVE 6" 5000 Mc EVOY			7" 1/8	
GRAY SPACER RING FEST TYPE PACK OFF				
7" 5/8 TUBING HANGER			6" 1/2	13" 1/2
LOCKS CREW				
CONTROL LINE OUTLET			2"	
GATE VALVE 2" 5000 GRAY TOOL			1/8"	1/4
CASING SEAL 10 3/4 x 9 5/8			11" 1/2	13"
GATE VALVE 2" 5000			2"	
2" 5000 FLANGE WITH PLUG				
COMPACT DRILLING HEAD GRAY TOOL				
WELL HEAD FLOOR			24"	26"
CONDUCTOR PIPE			28"	30"
CASING 13" 3/8 68 LBS FT BUTRESS J55			12" 500	13" 3/8
CASING 10"3/4 55.5 LBS FT VAM N80			9" 500	10"3/4
MUD LINE				
TUBING 7"5/8 29.7 LBS.FT VAM N80			6"875 6"750	7"5/8
1/4 OD CONTROL LINE				
FLOW COUPLING	2.93	184.58	6" 75	8" 500
MODE B SAFETY VALVE SETTING NIPPLE	0.90	185.48	6"375	9"
FLOW COUPLING	2.92		6" 75	8" 500
TUBING 7"5/8 29.7 LBS.FT VAM N80				
FLUTED TUBING HANGER	0.33	202.81	6"7'5	9", 5
10 3/4 x 9 5/8 CASING SUB		203.21	8.681	11.750
TUBING 7 5/8 29.7 LBS.FT VAM N80				
CASING SUB 7 5/8 X 7	0.26	1808.07	6"059	8" 126
FLOW COUPLING	2.93	1811.00	6"	7" 5/8
BAKER MODEL "L" SLIDING SLEEVE	1.48	1812.48	5" 500	8" 504
FLOW COUPLING	2.93		6"	7" 5/8
FLOW COUPLING	2.93	1818.34	6"	7" 5/8
SETTING NIPPLE MODEL R (BOTTOM NO GO)	0.59	1818.93	5"250	7" 5/8
FLOW COUPLING	2.92	1821.85	6"	7" 5/8
SETTING NIPPLE F (TOP NO GO)		1823.89	4"562	
SEAL RECEPTACLE ER 1 BAKER	8.59		4"562	8" 375
SEAL RECEPTACLE GAP				
ANCHOR SEAL MODEL K	0.36	1832.84	4"750	
HYDRO SET RETAINER PRODUCTION PACKER MODEL SAB	1.60	1833.54	4"750	8"350
MILL OUT EXTENTION	1.90	1836.34	6"	7"
SETTING NIPPLE MODEL R (BOTTOM NO GO)	0.48	1836.82	4"562	7" 618
CASING SUB 7" x 5 1/2	~~0.24~~	~~1837.06~~	4"778	7"657
PERFORATED PIPE WITH FIFTEEN 1 DIAMETER HOLES	3.09	1840.15	4.778	5"1/2
CASING SUB 5 1/2 x 4 1/2	0.13	1840.28	3"958	6"051
SETTING NIPPLE MODEL F	0.37	1840.65	3"812	5"200
SPACER TUBE	3.87		4"	4"500
ENTRY GUIDE FOR WIRE LINE TOOLS	0.16	1844.68	4"	5"200
PACKER HANGER		1856.09	6".05	8" 350
SAFETY JOINT	0.43	1859.05	6".05	8"
BLANK PIPE			6".05	6 5/8
9 5/8 SHOE		1892.50		
SCREEN			6".05	7.76
BLANK PIPE	NONE		6".05	6 5/8
BLANK PIPE	NONE		6".05	6 5/8
BLANK PIPE	3.25		6".05	6 5/8
ROTATING SHOE	1.10	1960.00		8"
8 1/2 BOTTOM HOLE		1962.00		

WELL EQUIPMENT

5 - COMMERCIAL PRODUCTION

Frigg's commercial gas production, started on September 13, 1977 (17 days ahead of schedule and before the beginning of the first BGC contractual year), has been satisfactorily running without major problems ever since.

The main reasons for this successful performance can be explained as follows :

- production personnel is mostly the same that has been involved in operations from the early stage of commissioning, start-up, testing, establishment of procedures, emergency drills, etc...

- active participation in the establishment of modifications on CDP 1 and TP 1 process equipment. Although basic conception done by the engineerings was correct, many details had to be field-modified to better suit operations and safety, and this notwithstanding the severe North Sea environment. Among the field modifications, already carried out or under course, we mention the following :

. Shut down system : shut down temperature diminished,

. Condensate system : study under way to improve the regulation system (quantities, slug,...),

. Draining system : study under way to improve operational conditions,

. Maintenance safety by-pass on CDP1 : study under way to improve maitenance conditions,

. Fire water system : fire water pumps interchangeable,

. Vibrations : analysis and cure,

. Noise : analysis and cure,

. Inhibitor injection into the 32" pipelines

. Fire detection system : improvement on UV-IR detectors

. Heat-tracing : heat-traced additional lines,

. Temperature measurements : from measurement, the real gas temperature in the HP relief system was found in accordance with the theoretical one.

. Metering : disconnection of metering from stream control and regulation to improve operation of each function.

- EAN's systematic field exploitation approach :

. early mobilization (1 year ahead of start-up) of competent Group personnel having already practical experience in gas field exploitation,

. due consideration to all espects of safety, by which accidents and shutdowns were prevented rather than cured,

. efficient operations running, giving power to the operators in the field to carry out spot modification to improve the systems,

. gradual implementation of Norwegian Personnel after an accurate training carried out according to a programme suited to Frigg and established in close liaison with the exploitation personnel,

. decision power attributed to functional people offshore : high caliper production experts for the running of production operations, experienced technicians during drilling operations.

6 -TELECOMMUNICATIONS , CONTROLS AND SAFETY

6.1- GENERAL

Frigg field is operated from a control room located on the second level of quarters platform QP. It has therefore been necessary to install means of data centralization and means of automatization of the greater part of the production equipment.

In view of the use of highly advanced technical equipment, particular emphasis has been laid on the problems of automatic safety systems as well as on reliability of the transmission systems for the remote control of production equipment.

The quantity and variety of data (measurements, states, alarms, etc) centralized in the control room is considerable. To assist the operator in his task, it is necessary to use the most up to date means of data processing (computer) as well as an intregrated conception of the functions of data acquisition and automatic control.

Furthermore, in view of the remote and distant locations of the different treatment and production platforms, it is necessary to install means of internal communication between the platforms (telephone, radio) as well as long distance connections with the mainland, Great Britain and Norway (telephone, telex and automatic data links).

6.2 - MEANS OF COMMUNICATIONS AND TRANSMISSION

There are two main telecommunications problems :

- internal field communications between the different platforms and, in particular, communications from the production platforms to the Quarters Platform and to the control room.

- external communications, i.e. long distance connections with Great Britain and Norway and connections with ships, coastal stations and helicopters.

2.1. Internal communications

2.1.1. Means of communication

Frigg field comprises five platforms and one articulated flare :

- two drilling platforms CDP1 in the U.K zone and DP 2 in the Norwegian zone), both situated more than 500 m from QP.

These two platforms are connected to the quarters platform QP (U.K. zone) by two means of communication :

. Main equipment : submarine cable enabling the transmission of a multiplex signal comprising telephone and date links.

. Emergency equipment : Micro-wave link on the 1500 MHz frequency band, equipped with low gain directional aerials (distances around 1000 metres).

- two gas treatment and compression platforms : TP 1 (treatment- U.K. zone) and TCP 2 (treatment and compression- Norwegian zone) with bridge connections to QP.

These two platforms are connected to the Quarters platform QP by two multi-conductor cables providing telephone and data links (cables laid along connecting bridges).

- quarters platform QP on which the field control room is installed. This platform is the centre of both internal and external field telecommunications.

- an articulated flare situated in the U.K. zone. Its supervision and some remote control operations are carried out from QP and TP 1 by means of a sub-marine multi-conductor cable link.

2.1.2. Organization

There are two methods of internal field communication :

- telephone links through a network enabling direct conversation between users.

- Data links enabling automatic centralization of information in the control room (QP platform) and remote control of production equipment from the control room.

2.1.2.1. Telephone links

For direct communications (conversation) there are two distinct networks with different functions :

- telephone network

It consists of a grid network linking up all the platforms and enabling a considerable number of users to contact each other.

The network includes 3 exchangers located on platforms QP, DP1 and DP 2 and approximately 150 extensions throughout the field.

The exchanger on QP connects all the extensions on QP (60) on TP 1 (15) and on TCP 2 (20).

The DP 1 and DP 2 exchangers connect about 20 telephone extensions on each of these platforms.

The telephones are of the standard type (with dial). Calls are made by dialling a four-figure code. Some of the telephones are of the mural type and some are watertight, according to their location.

Three conversations can take place simultaneously between CDP1 and any of the other platforms (the same applies to DP 2).

- Intercom network

Direct lines provide point-to-point links between the QP control room, the TP 1 and the TCP 2 Transducer Rooms and the DP 1 and DP 2 control rooms;

These direct lines are equipped with intercom devices and communications are made by a simplified push-button system.

The central switchboard installed on QP is multidirectional and enables simultaneous contact with all the other intercoms connected to the network (conference network).

The CDP1, DP2, TP 1 and TCP 2 switchboards are uni-directional and only allow contact with the QP control room.

All the intercoms are equipped with microphone and loudspeaker enabling users to converse with their hands free.

The central switchboard in the QP control room is equipped for 12 lines, taking into account the future extension of this network (on Frigg field or neighbouring fields).

2.1.2.2. Data links

All data necessary for operation of the field from the QP control room are automatically transmitted by special data links equipped with MODEM.

The teletransmission equipment enables automatic scanning and data acquisition and sending and checking of remote control commands. This equipment is divided into main stations (situated on QP) and sub- stations (situated ou CDP1, DP2, TP1 and TCP2). The main station controls scanning and updating of data and also performs validity and redundancy checks. The sub-stations serve to transcode data and receive remote control commands.

Some safety control signals are sent twice in order to increase the reliability of the system.

The transmission of actual data is accomplished at a speed of 200 bauds (200 elementary data per second) on several channels in parallel, multiplexed on a standard telephone channel (300-3400 Hz).

A telephone channel is used for each link :

QP- CDP 1

QP- DP 2

QP- TP 1

QP- TCP 2

With regard to the connections between CDP 1 and DP 2, the data links are, in addition, multiplexed with the telephone network channels and the intercom links so that they can be transmitted by the same medium.

The teletransmission equipment installed on QP is directly connected to the computer, enabling automatic acquisition of data by the computer as well as permitting the scanning and control functions to be taken over by the computer itself where necessary.

2.2. External communications

2.2.1. Means of communication

All the equipment enabling external communications with the Frigg field is centralized on the quarters platform QP. This equipment is divided into four different groups :

- Frigg - Great Britain links
- Frigg - Norway links
- Radio maritime station
- Radio helicopter station

2.2.1.1. Frigg-Great Britain links

Communications with Great Britain can be transmitted in two ways :

- Tropo - scatter radio link using a diversity system (space and polarization) and using 2 large diameter aerials (8 meters) fixed onto the side of the QP platform modules. The corresponding ground station is situated in the Shetland Isles.

The supply system for this equipment is equipped with a non-break safety device ensuring continuity of the contact.

There is a special room fitted out on the quarters platform for the switchboard equipment.

- Direct transmission micro-wave link connecting QP platform to BERYL Field, situated to the south of Frigg Field.

Communications are then conducted to St Fergus by a tropo-scatter system. The system is thus a looped circuit : Frigg-Shetland-St Fergus Beryl-Frigg.

A diversity system is also used for the micro-wave link : the 2 aerials are mounted on a mast set up in the North West corner of QP platform.

In order to make the tropo-scatter connection with Great Britain an economic proposition, it is also planned to use QP as a relay station for telecommunications with future fields situated near by in the U.K. zone. To this end, the telecommunications mast is designed to receive other aerials similar to those used for connection with Beryl fied.

2.2.1.2. Frigg- Norway links

Frigg Field is connected to Norway by a radio link with relay by satellite. An offshore station is located on the quarters platform, equipped with a 1.5 KW transmitter and a low noise parametric receiver.

An 8 meter-diameter aerial set up on the roof of the helicopter hangar enables focusing on two different satellites, one situated over the Atlantic, the other over the Indian Ocean. An automatic tracking system ensures stable focusing and corrects the slight displacements of the satellite (satellite virtually stationary).

A ground station located in Norway in the Elk region and equipped with a 13 meter-diameter aerial provides the links with Frigg and other fields in the North Sea (in the immediate future, at least 3 stations will be operational in the North Sea : Frigg, Ekofisk and Statfjord).

In a similar way to the tropo-scatter system with Great Britain the Frigg offshore satellite station is equipped with a non-break emergency supply which ensures uninterrupted contact.

The Frigg-Norway satellite link is completed by an emergency VHF band serving as a link in case of breakdown or temporary unavailability for maintenance work on the satellite station.

2.2.1.3. Radio maritime and aeromobile station

Frigg field is equipped with a standard radio maritime and aeromobile station situated on QP platform.

This station has the following equipment :

- AN SSB telephone transmitter-receiver covering the marine frequency bands 400 KHZ- 27 MHZ
- A 2182 KHZ watch receiver.
- A radio-telephone on the 156 - 174 MHz band.
- A portable VHF Tranceiver.
- A aircraft VHF transceiver for helicopters traffic.
- A ADF transmitter (radio beacon)
- A radar of 48 NM range.

2.2.2. Organization of external communications

There are several types of external communications with Frigg fied.

2.2.2.1. Telephone links

The following telephone links can be established :

- Frigg-Norway

The telephone network described previously is connected by the satellite and VHF link with Norway, on the one hand to the EAN base in Stavanger and on the other hand, to the Norwegian public network.

The interconnection is by means of a switchboard on QP platform. All the extensions on the field have access to Stavanger but only a few priveleged extensions can obtain the Norwegian public network.

- Frigg - Great Britain

Some extensions on the quarters platform QP are linked with Great Britain by the tropo-scatter system.

These extensions are quite different from those used for the internal telephone network and for connection to Norway. The British and Norwegian networks have absolutely nothing in common and are two entirely separate systems.

The following links can be established with Great Britain :

- Point-to point link between the QP and St Fergus control rooms.

- "Working" or maintenance link with St Fergus switchboard.

- Direct telephone link with British public network.

- telephone link connecting St Fergus switchboard to a few extensions on QP.

- telephone contacts with helicopters.

2.2.2.2. Telegraphic links

The telegraphic links Frigg-St Fergus and Frigg-Stavanger are provided by the tropo-scatter system for Great Britain and by the satellite for Norway.

Two telegraph channels are used in each direction :

- point-to point link between teleprinters installed respectively on Frigg field (QP control room) and at St Fergus.

- telex link connected to the British Public network.

- point-to-point link between teleprinters installed respectively on Frigg field (QP) and at Stavanger.

- telex link connected to Norwegian Public network.

The telex and the teleprinter terminals linked to the Elf base in Stavanger are installed in a special room on the quarters platform (telex room).

2.2.3.3. Data link

An automatic data link is used between QP platform on Frigg field and St Fergus. Information (measurements, situations, alarms) collected at Frigg and transmitted to St Fergus is coded and supplied to the transmission system by the computer installed on QP. This data is delivered automatically and at regular intervals with display in the QP control room.

The teletransmission system multiplexes the data on a 1 200 bauds channel. The main station is situated at St Fergus and interrogates the Frigg sub-station at regular intervals.

A return data link from St Fergus to Frigg is available and could be used later on (instructions, remote control commands, etc.) for the automatic reverse transmission of data.

This data link uses the tropo-scatter system as a medium of communications.

For the moment, there is no data link with Norway.

2.2.2.4. Facsimile channels

A telephone channel between Frigg field and the Stavanger base via the satellite is reserved for the automatic transmission of printed or handwritten facsimile documents-drawings, sketches, etc.

This channel is in fact grouped with the other channels providing telephone communications by the satellite link medium.

At the present time, three facsimile terminals are planned :

- a terminal at the Stavanger base
- a terminal in the teleprinting room on QP platform.
- a terminal in the control room of the first drilling platform CDP1.

The latter will be used during the drilling and start up phase and can subsequently be installed on DP2.

The speed of transmission on these facsimile channels is fixed at 1200 bauds. An A_4 document can be sent in 2 - 3 minutes.

6.3. OPERATION AND CONTROL OF THE FIELD

The control room situated on the QP platform is the vital centre of Frigg operations.

All the telecontrol, telemetry and remote control equipment is grouped in this control room, as well as the calculation centre equipped with 2 computers which can take over the automatic control of production operations.

The operators have the choice between two methods of controlling the production installations :

1. Entirely manual control by the operators who are aided by the computer for supervising the installations and decision taking. With this system, the operators do not take the computer into account and it serves solely as a supplementary aid for controlling operations.

2. Supervision of operations by the computer which can take certain decisions in respect of controls and warn the operator should any production problem arise. It can also command changes of flow rate. All these operations are conducted in accordance with a pre-established programme.

To ensure proper control (whether manual or automatic), the control room is equipped with two units which are virtually independent of each other and can be entirely disconnected from each other.

- A unit comprising control panel, indicators, recorders, console desk which are unrelated to the computer. This unit is directly connected to the data link system.

- An integrated data processing system using two computers with the possibility of switching from one to the other. The dialogue terminals enable the operators to switch off the computer and to take over running and control of operations.

3.1. Centralized manual control

In order to operate the field from the QP control room, the operator must have access to means of supervision and control enabling him to survey the installations and to be warned of any alarm. He must also have the means of remote control enabling him to act from distance to make any necessary adjustments or modifications, or simply to ensure correct functioning of the production units.

3.1.1. Supervision

An extremely wide variety of information is displayed, screened or recorded in the control room. This information can be classified into three categories.

- physical measurements : temperature, pressure, flow rate...
- configuration of field : state of valves (open or closed,) pumps working or not....
- alarms, operating deficiencies.

All this information is collected by the data link system which transmits different information to the various panels and recorders in the control room.

A control panel facing the operators pools all the data separately for each platform. The upper section of the panel consists of a mimic panel representing the production installations of the platform concerned. The lower section comprises all the annunciators, indicators and recorders (measurements).

The true position of the valves, the states of certain items of equipment (pumps) and the alarm processes are displayed on the mimic panel.

The mimic panels representing CDP1 and DP2 do not show the entire group of wells but only two wells at a time. However, the operator can select on a keyboard the required data concerning any one of the 24 wells on either of the platforms.

For TCP2, the mimic panel is divided into two distinct sections-the treatment units and the compression units.

A special control panel pools all the information relative to utilities (electric power, in particular).

All the data received in the control room are systematically updated and the acquisition time is a few seconds.

3.1.2. Telemetry and remote control

- CDP 1 and DP 2 drilling platforms

From the control room on QP the operator has the means of remote control enabling him to modify certain production parameters. These are mainly :

- shut down of one or several wells

- control of certain important valves : well head valves, sea line outlet valves

- starting and stopping of methanol injection pumps

- independent adjustment of chokes on each well

On the other hand, the wells can only be opened from the platform itself.

All remote control operations are carefully checked by the tele-transmission system to avoid any false interpretation or inadvertent actuating of apparatus.

All data is returned to the control room operator enabling him to check that his commands have been executed correctly. The control positions of all the chokes of the 24 wells is permanently displayed.

- TP1 and TCP2 treatment platforms

As the treatment platforms are situated close to QP platform where the control room is located, remote control operations are restricted to controlling the flow rate of each treatment unit.

The flow rate set point can be adjusted in three ways :

- at the controller itself

- by remote control (by manual operation from the QP control room).

- by remote control (automatically by the central computer)

For the constant flow rate units with override pressure, it is necessary to establish the following parameters :

- low pressure threshed at which an alarm is sent to St Fergus.

- high pressure threshold defining the limit above which override pressure goes into action (in this case an alarm is also sent to St Fergus.

These thresholds are a function of the total flow in the pipeline and should be readjusted after each change of flow rate. These operations can be carried out by remote control from QP control room.

3.2. <u>Operator aids and automatic control</u>

This paragraph concerns the use of an integrated data processing system and use of the computer to take over the control of flow rates and pressures (chokes and flow rate controllers).

The computer also aids the operator in defining certain functions, calculating control variables and in producing daily reports and operating documents.

6.4. - Automated safety devices

The centralized control of production equipment from the control room on QP platform necessitates the installation of an integrated security system enabling action to be taken anywhere on the installations, in accordance with a pre-established plan (programmed automation). The protection of the equipment and the personnel is thus ensured.

Each production platform (CDP1, DP2, TP1, and TCP2) has its own security system which can operate independently. The safety control operations (shut-down of production, decompression of units, etc.) are however interconnected in the field and can interact between several platforms.

According to how serious the deficiency is, the security system reacts on all or part of the installations and it can thus be described in relation to the importance or number of units involved. In this way, several stages of action can be defined, the most drastic being the total shut-down of the field and the minimum action necessary concerning the safety of a specific device or unit.

4.1. Safety equipment

4.1.1. Equipment for supervision of installations

The permanent supervision of the production installations is mainly aimed at detecting three possible types of deficiency :

- gas detection

Gas detectors are installed in all parts of the production platforms. The presence of gas containing 20 % of explosive mixture is considered abnormal (alarm) and 60 % is the danger point when the safety system goes into action.

- Fire-detecting equipment

The alarm must be given immediatly in case of fire in the processing areas to prevent its spreading and to avoid explosion.

Fire detecting equipment is installed in all the hazardous areas of the production platforms. The detectors are based on a system of detec-ting any sudden increase in temperature, or the presence of flames or smoke. They enable the extent and importance of the fire to be assessed immediately.

- Production parameters

The production installations are equipped with threshold measurement transmitters which indicate immediately when a production parameter is exceeded to a dangerous extent.

These parameters include high and low pressure alarms, high temperature, high or low levels.....

4.1.2. Equipment for protection of installations

In order to protect the installations and to enable the safety system to eliminate or minimize any risk due to one of the deficiencies mentioned above, the following equipment is installed :

- fire fighting equipment

Fire pumps and automatically operated hoses, flame proof walls, etc.

Isolation of production equipment by sector, or isolation of the entire platforms by the systematic use of automatic safety valves.

Decompression of units, connection lines, pressurized vessels, can be automatically carried out by safety valves connected to a vent line

4.2. Field safety (SD 1)

Should a serious incident arise necessitating the shut-down of the entire field production and decompression of the installations, all the safety systems on the production platforms can be operated by one action.

This command, which is given by manual operation only, can be actuated from the following points :

- control room on QP platform
- transducer rooms on TP 1 and TCP 2.

This represents the highest protection level. Its effects are :

. isolation of all the platforms

. decompression of all the installations

. fire-fighting at any point

. shut-down of the central electric plant.

4.3. Individual platform safety systems

4.3.1. CDP1 and DP2 drilling platforms

The safety systems offer three levels of protection enabling the automatic shut-down of well production and fire-fighting operations.

Level 1 : Total shut-down of production and fire-fighting.

Level 2 : Partial shut-down of production, in clusters of 12 wells.

Level 3 : Shut-down of any one of the 24 wells in case of failure on an individual well.

A fourth protection level concerns the intrinsic safety of individual equipment (pumps, pressurized vessels, sea lines etc..).

4.3.2. TP1 and TCP2 treatment platforms

In view of the proximity of these platforms to the QP control room, the safety system is operated manually for the most drastic situation and the automatic controls are reserved for gas and fire detection.

Similarly to the drilling platforms, three levels of protection are defined :

Level 1 : Complete shut-down of production- fire fighting- decompression of installations.

The command at this level can be given from the control room on QP or from the platform concerned itself (by push-button or automatically by the gas or fire detectors).

Level 2 : Complete shut-down of production without decompression of installations.

This in an automatic command initiated by the gas or fire detector.

Level 3 : Closing of a treatment line from the QP control room or from the platform itself, by push-button.

A fourth level of protection goes into action when production parameter thresholds are exceeded. An automatic command closes certain safety valves, shuts down some units or isolates certain gas lines.

4.4. Safety supervision and control

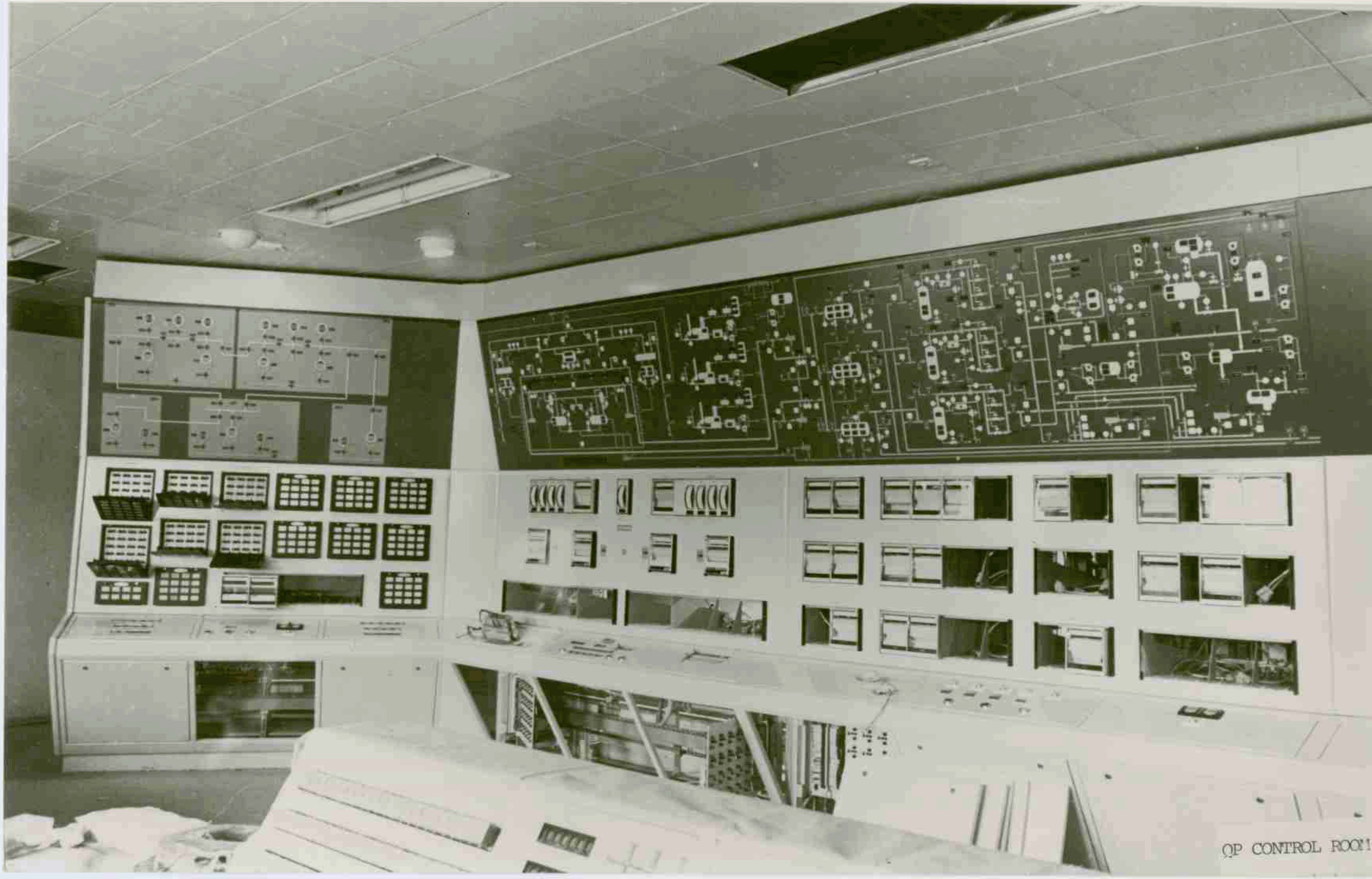
All the information concerning detection of deficiencies, production parameter alarms and automatic commands are centralized in the QP control room.

The operator has visual alarms which flash a warning as soon as any technical incident occurs on the field.

A special control panel for the gas and fire detectors is provided.

In the case of an alert, an alarm is sounded (klaxon) and the operator can immediately see where the failure lies by a red signal flashing on one of the control panels.


TREATMENT PLATFORM Nº1
COMPRESSION



QP CONTROL ROO!!

7 - MAINTENANCE

In addition to routine maintenance on the various structural and equipment components of the field, a special schedule of inspection has been planned in the aim of detecting any faults in the platforms and risers.

The purpose of this structural inspection is to make sure of the safety and good status of the platforms and risers in order to continue production, and at the same time respect the legislation and certification laws.

For this purpose, the Frigg Field facilities have been grouped as follows :

- steel platforms (QP, DP2 and FP articulated flare stack),
- concrete platforms (CDP1, TP1, and TCP2),
- underwater risers and pipelines.

The inspection plan is directed firstly towards more extensive surveillance of those parts of the structures considered to be the weakest. The weaker parts of the platforms were determined after an intensive study of the environmental conditions, hypotheses and calculation sheets, final drawings, construction and erection reports.

Through this EAN was able to locate the areas where a concentration of stress existed, those subject to corrosion, or deterioration, those not in compliance with construction specifications, those that had posed problems during construction and those that underwent repairs.

The second way to follow the overall integrity and to direct the inspection is by an efficient and permanent instrumentation system installed on the different parts of the structure.

On the site the inspection itself is conducted first by a visual survey of the overall structure. The underwater inspection is carried out by divers, submarines, and recorded and transmitted by television. In so doing a general idea of the condition of all the components is achieved. The evolution of fouling of the different zones and mainly at the foundation, structure and risers can thus be observed. The risers are also given special attention at the jacket supports.

Certain surfaces of the structures are cleaned by divers to enable a more extensive check-up. Then thickness measurements are taken and non destructive tests are made to detect the evidence of internal cracks or to follow the evolution of already existing cracks (by underwater television and ultrasonics) and to study the resistance of the concrete (porosity, hardness). The corrosion is given particular attention : follow up of the sacrificial anodes, potential and resistivity.

These underwater inspections take approximately one hundred days per year. This means a support of several service vessels with entire saturated diving equipment and remote control underwater apparatus. A submarine for part time observation is also needed.

Systematically, the results of the underwater inspection campaign and those given by instrumentation will be carefully collected and noted in order to check the integrity of the structures and risers. The analysis of these results will direct the maintenance programme and repairs.

The inspection team will maintain close contact with the Authorities (mainly DNV) for the implementation of the inspection programme and the renewal of the Certificate of Fitness.

======

CHAPTER VII

FRIGG'S FUTURE POSSIBILITIES

1 - FRIGG'S PRODUCTION

Maximum steady production of the Frigg Field will be close to 60×10^6 M^3/D in 1979.

2 - TYING-IN WITH CONTIGUOUS FIELDS

The treating capacity of Frigg's production platforms TP 1 and TPC 2 is well above the figure given under point 1.

Furthermore, an extra 1 000 m2 of deck space has been provided on each of the Frigg production platforms to support future equipment in connection with increase of gas production.

Such additionnal space could be needed at a later stage if, for instance, it is decided to bring into production some contiguous gas fields and/or to let other gas go through.

For this purpose, two spare risers are available on TP 1 (32" and 24" respectively) and 4 on TCP 2 (24", 20", 18" and 16").

3 - TRANSPORTATION

Two 32" sealines convey Frigg gas to St Fergus. The transportation capacity complies with the production figure given under point 1. Such capacity can be substantially increased by providing boosting equipment on an intermediate manifold platform (MCP1) or/and a third pipeline.