"BACKGROUND" - TO THE PIPER ALPHA TRAGEDY

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The purpose of this paper is to provide the background to the circumstances which led to the tragic loss of the Piper Alpha Platform on 6th July 1988. It is hoped that this will assist delegates to focus on areas where lessons may be learnt for the future.

THE TRAGEDY

On 6th July 1988, at about 22:00 hours, an explosion rocked Occidental's Piper Alpha Platform. Within seconds a major crude oil fire developed and all but the lower parts of the platform and wellhead area were engulfed in a choking black smoke.

Many of the 226 persons onboard were trapped in the accommodation areas, unable to make their way to the survival craft because of the smoke and initial fires. Twenty minutes into the fire, a major failure of a riser occurred, i.e. the pipeline connecting the Piper Alpha with the Texaco's Tartan Alpha platform. A fireball, in excess of 150 metres diameter, engulfed and rose above the platform. The subsequent fires caused the structure to sag, further risers and equipment to fail and eventual collapse during the next few hours. By the morning only the wellhead module remained standing.

In the disaster, 167 persons tragically lost their lives. Of these, 165 were persons onboard the platform and two were members of the crew of a fast rescue craft which was lost as one of the risers failed. The loss is likely to exceed £1,000 million.

THE PLATFORM AND PROCESS

The Piper field is located in Block 15/17 of the North Sea, some 125 miles north east of Aberdeen. The field was discovered in January 1973 and during that year the design of the platform commenced. The basic design of the topsides was based on those used in the Gulf of Mexico. Oil production commenced in December 1976.

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The general elevations of the topsides are shown in Figures 1 and 2. At the 84 ft. level there were four Modules A,B,C and D. The southern most Module was "A" which comprised the wellhead (36 slots) to which two angled flare booms were attached. Module B contained the manifolds, test and main production separators and main oil line export pumps; see Figure 3.

Module C contained the original gas compression equipment which comprised three centrifugal compressors which recompressed the gas from the separator pressure of 155 psia to about 675 psia. In Phase 2, i.e. normal operation, the flow would be directed to the Gas Conservation Module (GCM) located at the 107 ft. level, where it was passed through dehydration molsieve towers and compressed further. However, at the time of the accident, the GCM was down for maintenance and the operation had reverted to the original Phase 1 operation. In this operating mode, the gas from the Centrifugal compressors was directed to the first stage of the two reciprocating compressors located in the centre of Module C, and compressed to approximately 1465 psia. The pressure was then reduced to 635 psia through a JT valve and the condensate liquid formed was collected in the JT Flash Drum, which was located beneath Module C at the 68 ft. level. The gas from this vessel was returned again to Module C and compressed to about 1735 psia in the second stage of the reciprocating compressors and used for gas injection of a number of wells.

The condensate collected in the JT Flash Drum was pumped into the main oil line for export to the Flotta Terminal by the use of booster pumps and condensate injection pumps (commonly called the "Condy" pumps), which raised the pressure to approximately 1100 psia. All this equipment was located at the 68 ft. level beneath Module C (see Figure 4).

Module D was the northern most module and contained the Control Room, workshops, electrical power generation, some of the switchgear and emergency diesel generator. The accommodation modules were located essentially above Module D. The Mud, Sacks and PODS Modules were at the 107 ft. level located above Modules C and B on the west side, and the Utility Module and GCM were similarly located on the east side. The Diesel storage tanks were located principally in the deck space above Module C but beneath the PODs module etc.

Modules A,B,C and D were separated by firewalls, which were not rated for explosion overpressure. The firewall between Modules C and D was specified with an 6 hour fire rating whilst that between B - C, and A - B were specified for 4.5 hours (see Figure 3).

The Piper Platform was central in the Piper field with respect to the communication systems and the pipeline export network (see Figure 5). The pipelines/risers connecting Piper to other installations were as follows:-

		Diameter	Length	Hydrocarbon Inventory
o	Main Oil Line to Flotta Terminal	30 inch	127 miles	70,000 tonnes (approx)
o	Gas Import from Texaco Tartan	18 inch	11.5 miles	450 tonnes
o	Gas Export to Total MCP-01	18 inch	33.5 miles	1,280 tonnes
o	Gas Import/Export to Claymore	16 inch	21.5 miles	260 tonnes

The location of the risers on Piper are shown in Figure 4. Each pipeline had an emergency shutdown valve located in close proximity to their respective Pig Trap. During Phase 1 operation, at the time of the accident, no Piper Gas was being exported. Tartan gas was being imported but was exported to the Total Oil Marine Compression Platform, MCP-01, independently of any Piper process.

EVENTS PRIOR TO 6th JULY

The Gas Conservation Module was shutdown and changeover to Phase 1 operation occurred on 3rd July, so that the molecular sieves could be replaced. At the same time some pressure safety valves and other equipment were to be inspected or changed out, the work having been planned several months previously.

The Claymore pipeline had been packed with dry Piper gas to approximately 1000 psi prior to the changeover. After the changeover and during Phase 1, the pipeline pressure was maintained by topping up with gas from the Tartan pipeline.

It was recognised that during Phase 1 operation, without gas dehydration, there would be a greater tendency for hydrate formation and consequently additional methanol was being injected, for example, upstream of the JT valve, at the second stage reciprocating suction scrubbers and at the condensate booster and injection pumps. Also the function of the JT Flash Drum altered in Phase 1 when, instead of acting merely as a surge vessel for condensate, it became a separator downstream of the JT valve. As such, it operated at the higher pressure of 635 psia instead of 250 psia under Phase 2 operation.

The evidence given to the Inquiry indicated that a number of problems occurred during, or after, the changeover. For example, a problem was found with one of the isolation valves for a Centrifugal Compressor, which meant that it was not until the 5th July that all three compressors were operational. On 4th July a small leak occurred at a pressure switch on condensate injection pump 'B' and was repaired on the 5th July by fitting a new switch with a higher pressure rating. On 5th July a small leak was found on one head of the methanol injection pump and was repaired the same day.

It was recorded in handover notes on 5th July 1988, that the plant was running well in Phase 1.

EVENTS OF 6th JULY

The following is an abstract of the evidence given to the Inquiry by a number of witnesses.

Prior to the 6th July a decision was taken to shutdown condensate injection pump A in order to carry out work on the variable speed coupling which was experiencing high vibrations. At the same time it was planned to undertake 24 month preventative maintenance (PM) work on the pump. Pump shutdown occurred on 6th July. There was much time spent at the Inquiry determining whether the actual maintenance shutdown was for the 24 month PM or the work on the coupling; the importance being that some personnel would adopt different isolation philosophies for the two tasks. However, on the morning of 6th July a Permit to Work (PTW) was taken out to perform maintenance work on Pump A. In their submission on Day 130 of the Inquiry, the Crown concluded that the evidence suggested that the pump would have been electrically and mechanically isolated, but not spaded.

The pressure safety valve for Condensate Injection Pump A (PSV-504) was the last PSV to be recertified on the Platform. Therefore, the opportunity was taken to remove PSV-504 and recertify the valve. It appears that a separate PTW was taken out for this work, the authorised 4th copy being recovered from the accommodation module. PSV-504 was located in Module C and thus, it would be normal practice, for the PTW for this work to be kept in the control room but placed in the pigeon hole for Module C. The pump maintenance PTW would have been placed in the corresponding pigeon hole for the 68 ft. level.

PSV-504 was removed during the early afternoon and it was normal practice for blank flanges to be installed on the open-ended pipes. The PSV was recertified, however there was not enough time to refit the valve and therefore the PTW for PSV-504 was returned to the Control Room, apparently during the period of Shift Handover, and the work suspended. Normal practice was for suspended permits to be filed in the Safety Office under the Contractor during the job.

During the afternoon of the 6th July, another leak was noticed on the methanol pump from one of the heads supplying methanol to the JT valve. It appears that the repair took between 16-00 and 20-00 to affect, during which time the methanol supply to the JT valve was approximately halved.

The initial explosion occurred at about 22-00 hours. According to survivors, no major problems had been encountered that day, until some 10 to 15 minutes before the explosion, when condensate injection pump B tripped. The reason for the trip is not clear. However, within several minutes, the control room operator accepted a "common" alarm indicating a condensate system malfunction, which he concluded to be high level in the JT Flash Drum (This would have meant that the level in the drum was only about 30%, but condensate was still being produced and thus the level was rising). In the meantime, an operator went to investigate the situation.

There is evidence to indicate that in response to the developing problems the operators unloaded the reciprocating compressors, thereby significantly reducing the quantities of condensate entering the JT Flash Drum.

Much evidence was heard at the Inquiry regarding the knowledge that the night-shift personnel had of the removal of PSV-504 and whether Condensate Injection Pump A would have been recommissioned. It is known that a production supervisor entered the Control Room, collected a PTW for Pump A and signed it off in preparation to recommission the Pump. A little later the maintenance supervisor also signed off the PTW. It appears therefore, that attempts were made to restart Pump B and that a course of action had been embarked upon to bring Pump A back into service.

Shortly before the initial explosion, the Control Room Operator responded to a number of trips and alarms namely:-

o Two of the Centrifugal Compressors tripping simultaneously.

o Low gas alarm associated with Centrifugal Compressor C (This occurred about one or two minutes prior to the explosion).

Then seconds before the explosion:-

o Low gas alarms associated with Centrifugal Compressors A and B.

o Low gas alarm for Module C East.

o High gas alarm associated with a Centrifugal Compressor.

o During this latter sequence of alarms the third Centrifugal Compressor tripped.

Just prior to the explosion, it is known that there was activity associated with the Condensate system at the 68 ft level. Further an operator had left that area and went upstairs to Module C to investigate the cause of the initial low gas alarm. Also it is possible that operators were attempting to return gas from the Claymore pipeline to the discharge piping of the Centrifugal Compressors to provide fuel gas for the platform in the event the third Centrifugal Compressor tripped.

INVESTIGATION OF POSSIBLE CAUSES

On behalf of the Crown, a substantial part of Cremer and Warner's initial work was to investigate the potential cause of the disaster and to ensure that all aspects were fully identified and examined by the Inquiry. A team of specialists was assembled covering such diverse areas as, for example, explosion modelling, fire dynamics, compressor design, hydrate formation, thermodynamic predictions, gas detection, wind tunnel modelling, noise predictions, leak rate and pipeline mass balance analysis, to name but a few. In all, some 60 organisations and companies had to be co-ordinated to provide, either specialist analysis using "state-of-the-art" technology, or reports, which were submitted to the Inquiry.

The principle difficulty with the investigation was the fact that it was deemed impractical to recover the equipment for forensic examination. Further nobody witnessed directly the gas cloud or the explosion which occurred in Module C, and survived the accident.

The UK Department of Energy prepared an Interim Report (Ref 1) in September 1988. This investigation identified two possible causes:-

Scenario A — Whilst attempting to recommission Condensate Pump 'A' a condensate leak occurred from the joint where a blind flange had been fitted to pipework at the location of a Pressure Safety Valve (PSV-504). [The pump was located on the 68 ft level, but the PSV was located in Module C above].

Scenario B — Liquid entered the second stage of the reciprocating compressor, after being carried over from the JT Flash Drum, and caused a major failure of one or more of the cylinders.

It was important not to concentrate solely on just two possible causes, as initially other causes were identified as being possible and had to be examined at the Inquiry. These additional scenarios included such mechanisms as, for example, hydrate blockage, overpressurisation, brittle fracture, auto-ignition, fatigue failures and human error.

It is part of Lord Cullen's remit to make a finding (if possible) as to the cause, based on the evidence presented at the Inquiry. However, in the closing submission for the Crown (Day 130) it was concluded that many of the scenarios (including Scenario B) could be discounted based on the burden of the evidence presented to the Inquiry. The Crown concluded that it was open to the Inquiry to find that the initial explosion could have been caused as a result of the sequence of events described in Scenario A. Further it concluded that there was a theoretical possibility that auto-ignition of a condensate-air mixture in the relief line could have dislodged a properly fitted flange or damaged the relief line, thereby causing a leak at the site of PSV-504. This possibility is described more fully in the paper by Dr. Richardson.

One scenario was developed as a result of undertaking hydrate prediction tests in a dynamic simulator, described by Hans Johnsen in the paper that follows. This scenario postulated that hydrates were formed in the condensate system during the afternoon and early evening, when methanol supply to the JT Valve was reduced. The hydrates survived and accumulated in the system and were the cause of the condensate pump 'B' tripping before the explosion. Whilst attempting to restart the pump, the downstream piping of the PSV (PSV-505), associated with the pump, became blocked with hydrates and the valve was overpressurised and failed. The Crown concluded (Day 130) that this scenario was technically feasible but evidence from survivors pointed against it being the cause, as well as it involving a complex chain of events.

Whatever the final judgement of Lord Cullen as to the cause, the various scenarios raised many interesting technical issues and examined many procedural matters, such as the operation and effectiveness of Permit to Work systems and Shift Handovers.

ESCALATION OF THE INCIDENT

An important issue identified during the Inquiry was the mechanism by which the initial explosion escalated to cause such loss of life and damage to the platform. Presented below are the likely major steps in the escalation, drawn from the evidence presented by Cox, Drysdale, Bakke, Smyllie and others, to the Inquiry and the review presented in the Crown's submission.

- o The initial explosion occurred in Module C and may have involved a flammable mass of as little as 45 kg; most likely being condensate vapour. (Time 22-00 approx).
- o The overpressure generated caused failure of the firewalls between Modules C-D and C-B.
- o The failure of the Module C-D firewall caused extensive damage to the Control Room, loss of electrical power and many emergency power supplies, loss of communication systems and possible loss of the firewater distribution system. (However, the fire pumps were isolated at the time).
- o The failure of the Module C-B firewall generated a number of fragments (missiles) which fractured small bore pipework associated with the crude oil metering and export system and a 4" condensate export line (upstream of its tie-in to the Main Oil Pipeline).

- o Some 10 to 20 seconds after the initial explosion, the fireball seen at the west face of Module B was caused by the burning of the 100kg, or so, expelled from the ruptured condensate export line.
- o Within seconds, a crude oil fire developed which produced copous quantities of smoke reducing visibility at all locations on the platform, except at the 68 ft level and Module A/derrick area.
- o A small fire occurred adjacent to the accommodation block (ERQ) on the north face. This arose from the venting of unburnt hydrocarbon fuel from Modules C and B.
- o Within minutes a running fire occurred beneath Module C as crude oil commenced spilling over, or through the decking. A pool fire developed on the Dive Skid (58 ft level) beneath Module B. [See Figure 4].
- o It is possible that the emergency shutdown valve (ESV) on the Main Oil Export line (MOL) failed to fully close and backflow from the MOL contributed to fuelling the fire in Module B.
- o Many of the persons on board were already in, or attempted to reach, the muster station at the top level of the accommodation block, to await helicopter evacuation. Access to the survival crafts was impossible due to smoke.
- o At 22-20, flame impingement from the fire on the dive skid caused the Tartan Riser to fail, resulting in a massive torch flame to develop beneath the whole platform (i.e. 68 ft level and below).
- o During this period, if not before, the diesel tanks were breached contributing further hydrocarbon fuel to the fire. (Total inventory was some 170 tonnes).
- o The inventory of the Tartan pipeline continued to sustain a major fire beneath the platform.
- o At 22-50 hours (approx) the MCP01 riser was breached and a major fireball developed.
- o Throughout this period, the HP flare had been burning steadily following the depressurisation of equipment within minutes of the initial explosion. The source of fuel was suspected to arise from the Claymore Pipeline via an ESV which is suspected not to have closed. It is possible that a small contribution to the flare load was from the MCP01 pipeline via an ESV which may not have fully seated.
- o Between 23-00 and 23-30, the Claymore Riser and MOL Risers failed, the derrick collapsed and the centre of the platform sagged. Shortly thereafter, the main accommodation block toppled into the sea.

The speed at which the accident escalated and the impact on the means of evacuation, escape and rescue hold important lessons for the future.

ESCAPE AND RESCUE

The first person to be rescued was the chemist, who had been in the Oil Lab at the 68 ft level and had reached the 20 ft level beneath Module A, where he was rescued after some 5 minutes by the Fast Rescue Craft (FRC) from the standby vessel, the "Silver Pitt".

Divers and personnel who were either at the 68 ft level, or located at the control room at the time of the explosion were able to reach the lower parts of north west corner of the platform which initially was not smoke logged. They climbed down knotted ropes to the 20 ft level and were rescued by Fast Rescue Craft (FRC). This continued until 22-20 when the Tartan Riser failed and the fireball forced a number of people to jump from the 68 ft level. Some thirty survivors escaped via this route.

The muster point was the galley on the 4th Floor of the main accommodation module (ERQ) just beneath the Helideck. Between the time of the Tartan and MCP-01 Riser failures, a number of people attempted to leave the ERQ. Of these, 8 survivors made their way to the SW corner and escaped down a hose or jumped into the sea. A group had made their way to the helideck, but were caught by the fireball and 5 survivors jumped from 174ft into the sea. It was at this time that the Sandhaven FRC was destroyed with the loss of 2 of its 3 man crew, together with some six men rescued from the SW corner.

A number of personnel who managed to leave the ERQ, took shelter in the "White House" which was on the Piper Deck adjacent to the accommodation modules. Between 23-00 and 23-30, the Platform suffered a major collapse which affected the structure of the White House. The pipedeck had collapsed to the west and was at an angle of up to 45 degrees. At this stage some 13 survivors jumped from the 107 ft level into the sea on the west side of the platform and two jumped, probably from the east side, into the sea.

All of the 61 survivors were subsequently transfered, or taken directly to the MSV Tharos.

"LESSONS TO BE LEARNT"

Part 2 of the Inquiry concentrated on the "Lessons to be Learnt", the general topics considered being:-

- o Avoidance of explosions and mitigating their effects
- o Fire protection systems
- o Emergency shutdown systems
- o Pipeline Risers
- o Integrity of Electrical and Emergency Systems
- o Accommodation and Safe Refuges
- o Work Permits and Shift Handovers
- o Formal Safety Assessments
- o Management of Safety
- o The Offshore Regime.

Some 47 days of evidence and three days of closing submissions were devoted to this Part. In all, the Inquiry sat for 180 days, heard from some 260 witnesses who spoke in excess of 6 million words in evidence under cross examination from eleven QC's and their juniors.

I trust that the imminent publication of Lord Cullen's Report, together with venues such as this Conference, will highlight the lessons to be learnt from such a tragic loss.

References

(1) "Piper Alpha Technical Investigation - Interim Report" UK Department of Energy; September 1988.

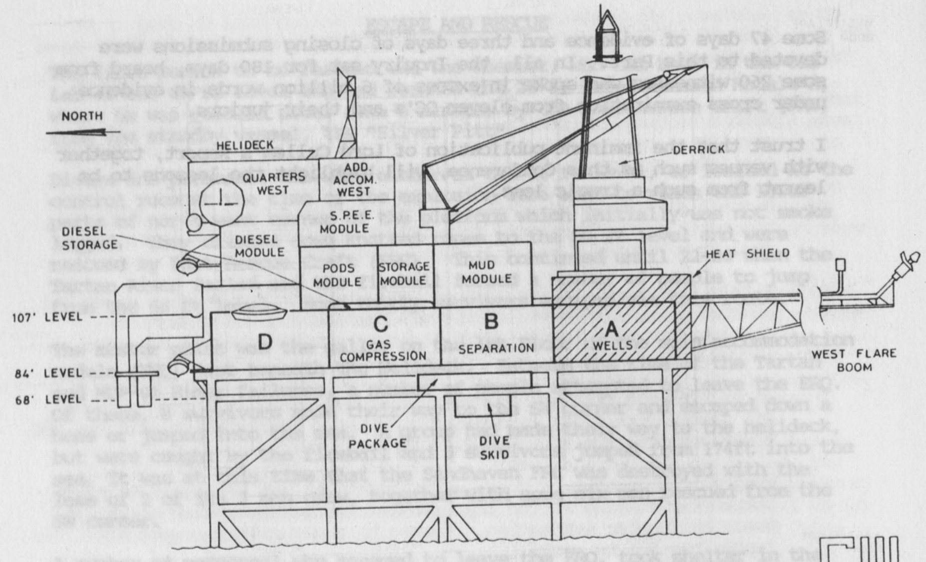

FIGURE 1 PIPER ALPHA - WEST ELEVATION

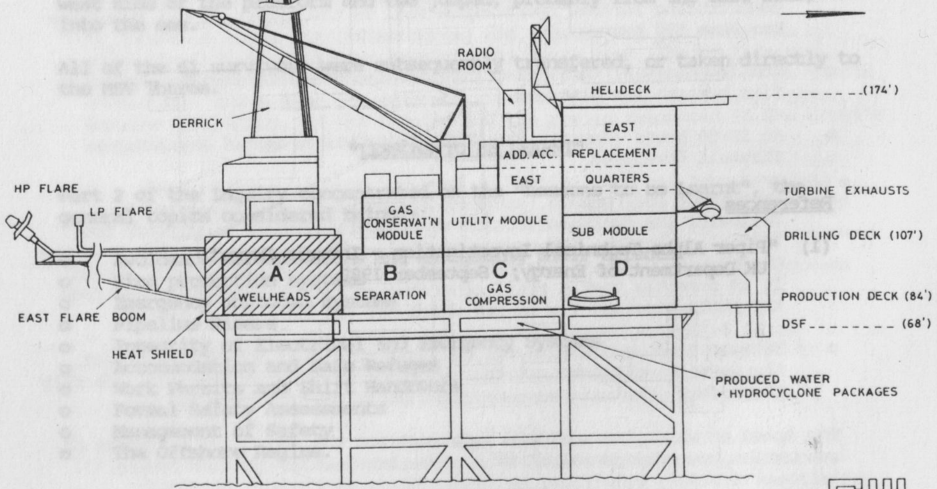

FIGURE 2 PIPER ALPHA - EAST ELEVATION

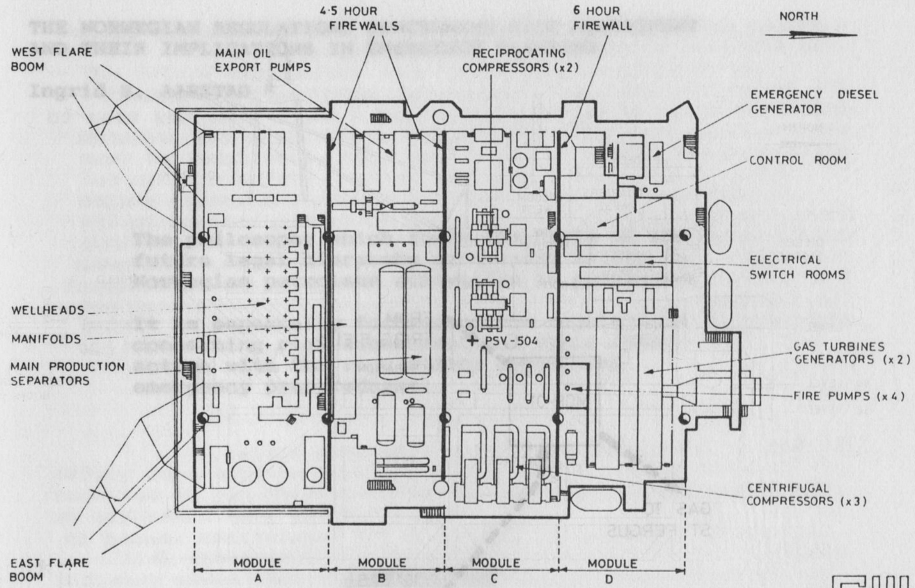

FIGURE 3 PIPER ALPHA - PRODUCTION (84 ft) LEVEL

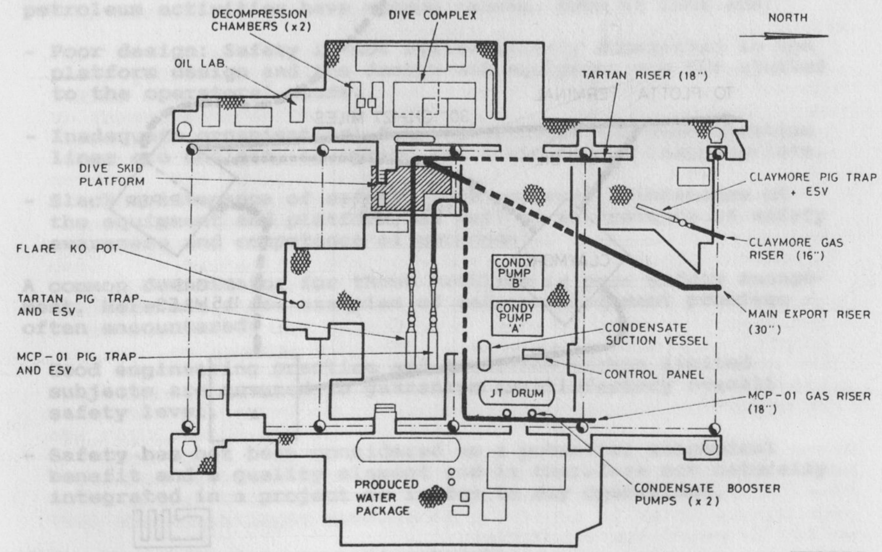

FIGURE 4

PIPER ALPHA - DECK SUPPORT FRAME (68 ft LEVEL)

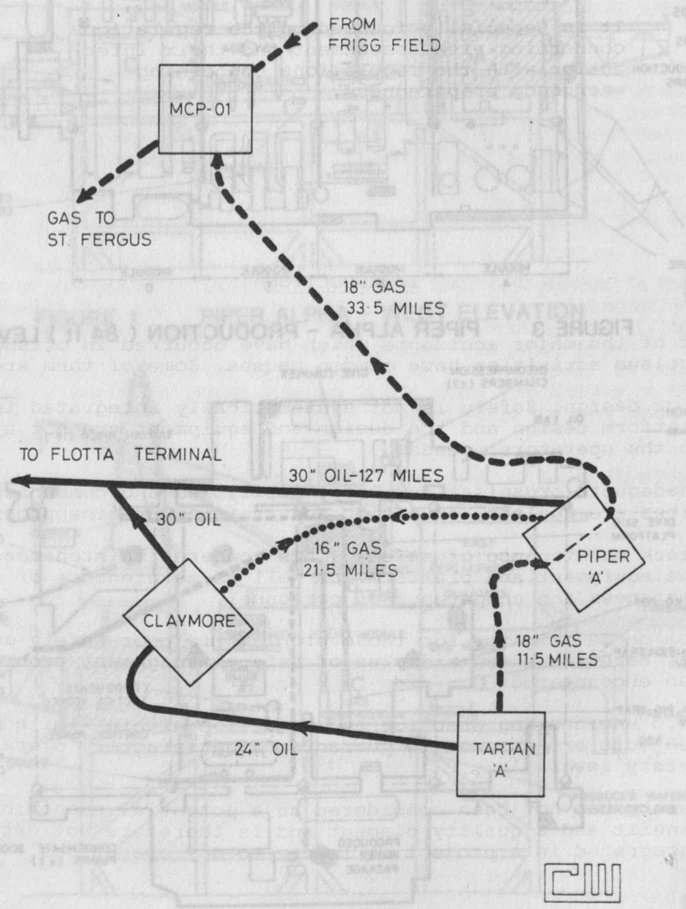

FIGURE 5 PIPER ALPHA - OIL & GAS PIPELINES

THE NORWEGIAN REGULATIONS CONCERNING RISK ASSESSMENT AND THEIR IMPLICATIONS IN EMERGENCY PLANNING

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The philosophy which forms the basis of the future legal hierarchy concerning safety in Norwegian petroleum activities is presented.

It is especially focused on the regulations concerning risk assessment and their interaction with the regulations concerning emergency preparedness.

INTRODUCTION

Most of the major accidents which have occurred in offshore petroleum activities have common causes. Some of them are:

- Poor design: Safety is not systematically integrated in the platform design and the design and equipment are not ajusted to the operators' needs.
- Inadequate organisation: Responsibilities and communication lines are unclear, education and training are inappropriate.
- Slack maintenance of safety: This concerns maintenance of the equipment and platform, as well as maintenance of safety awareness and competence of personnel.

A common denominator for those problems is poor safety management. Here are a few examples of safety management problems often encountered:

- Good engineering practice and tradition within limited subjects are assumed to guarantee a satisfactory overall safety level.
- Safety has not been considered as a potential economical benefit and a quality element and is therefore not naturally integrated in a project or in day to day operations.

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