5 FIELD INSTALLATIONS AND OPERATIONS

Note: Abbreviations and conversion factors are listed after Table of Contents.

5.1 ALTERNATIVE CONCEPTS EVALUATION

Introduction

The proposed development scheme for Hod consists of a small, normally unmanned, steel wellhead protector platform tied back to Valhall "A" for control, processing and onward transportation. Metering and well testing will take place at Hod before the produced fluid is transported by pipeline to Valhall for processing. The lack of any major equipment at Hod permits normally unmanned operation of the platform. Maintenance and supply operations can take place during a visit to the platform by operating personnel from Valhall. The presence of minimal equipment and pertinent safety devices and process controls should ensure safe operation of the facility. It should be stated that Amoco has several years experience in operating such unmanned platforms in other offshore areas of the world, including the North Sea.

This chapter starts with a summary of historical evaluations of Hod Field development, followed by a detailed description of the recommended concept.

Background

After the Hod Field was discovered in late 1974, development was considered at several points in time. The relatively low reserves, formation properties and the location of the field made it natural and necessary to consider potential field development schemes in the light of the existing and planned infrastructure in the Ekofisk area and the Valhall Field development. Alternative gas export schemes were evaluated in conjunction with the Valhall Field development in 1976, and subsequently incorporated into the proposed Valhall gas export system.

A number of field development studies have been undertaken since the presence of producible hydrocarbons in the West Hod structure was proven by Well 2/11-2 in December 1974. The Valhall Field was developed with sufficient capacity to handle production from the Hod Field as well. Hence, all cases have assumed partial or full processing of the production stream at the Valhall Field. The Hod Field development concepts evaluated have ranged from self-contained platforms to subsea production systems. A drilling template was installed and a well drilled through it in 1981-82 as a result of one of these studies. Three alternatives representing the various historical approaches evaluated are described in more detail below.

The development of the Hod structure is now deemed economic under the proposed unmanned, minimum facility concept. To understand the significance of the current development scheme, it is appropriate to review the highlights of the previously considered schemes.

5.1.1 Combined Drilling/Production/Quarters Platform

The specific objective of this review is to make a scoping estimate of how much it would cost today to install a Hod development facility similar to what was envisioned in 1977. The first Hod field development study was completed and submitted to the Ministry of Industry on October 4, 1976. The development of the Hod structure was included as a subsequent development to the Valhall structure. The Valhall/Hod Development Study consisted of three main volumes. A fourth, supplemental volume entitled "Development Plans" was completed in January 1977. The details of the Hod development scheme were contained in the fourth volume.

At the time the 1976 Valhall/Hod Field Study was completed, only well 2/11-2 had been drilled on the Hod structure. Because of the complex geology and difficult geophysical analysis due to the presence of a gas cloud above the reservoir, the recoverable Hod reserves were estimated to range from 50 to 150 MMSTBO (8 to 24 million Sm^3). Although the reserves were uncertain, the conclusion was made that the Hod Field could be economically developed if a minimum of 70 MMSTB (11.1 million Sm^3) of oil and 100 BCF (2.8 billion Sm^3) of gas were contained within a 4000 acre (1620 hectare) platform drainage area.

The 1976 Valhall/Hod Development Study included a recommendation to drill one Hod structure delineation well in 1977 and a possible second delineation well in 1978. Subsequent development of the Hod structure was contingent on the Hod delineation wells' demonstrating a lack of solids flow. If this was not achieved, development of Hod would not take place until satisfactory production experience had been gained at Valhall.

The proposed development for the Hod structure consisted of a steel platform located at the Hod field with one liquid and one gas pipeline leading to Valhall 'A' via the tentative Valhall 'B' satellite platform. The Hod platform would include a self contained platform drilling rig but minimum production facilities. The production facilities on the Hod platform would be limited to a first stage separator and a test separator. Metering packages were to be installed on both vessels.

The number of development wells anticipated to be included on the Hod platform was twelve oil producers. Peak oil production was expected to be 20,500 BOPD (3260 Sm^3/day). The estimated capital expenditure for development of the Hod structure was $168.2 MM. The cost estimates were based on 1976 dollars and escalated at 10 percent per year in 1977/78 and 7 percent per year in 1979/80. No escalation was applied after 1980.

The breakdown of capital expenditures for Hod development was as follows:

Investment Cost Estimate	($ MM, 1976)
Mob/Demob	3.2
Delineation Wells	14.7
Platform and Drilling Rig	58.9
Development Wells	55.2
Pipelines	36.2
Total	168.2

Although not rigorously correct, one could take the $168.2 MM cost presented in 1976 and convert it to 1987 dollars. The cost estimates prepared in 1976 were done before the current Norwegian standards for offshore facilities were in place. Many of these standards were implemented during the construction of the Valhall facilities. The present proposed base case development of Hod includes 4 new development wells and one tie-back, but no delineation wells. Taking these factors into consideration the 'order of magnitude' estimate for the present day development cost of Hod with the facilities envisioned in 1977 becomes:

Investment Cost Estimate	($ MM, 1987)
Platform and Drilling Rig	216.5
Development Wells	33.5
Pipelines and Valhall tie-ins	116.0
Total	366.0

The conclusion reached at this point is that the present day installation cost for a self contained drilling platform with minimum production facilities in the Hod Field would cost at least $350 MM, including the drilling of four development wells and the installation of pipelines to Valhall.

5.1.2 Manned Wellhead Platform

In 1986 Kværner Engineering performed a Hod Field Development feasibility study for the NPD. In this study a manned wellhead platform concept was evaluated. The platform would have permanent living quarters for up to 70 people. All wells were assumed to be pre-drilled through the 12-slot template that had been installed in 1981. A workover rig would be installed that would allow various workover tasks, including sidetracking, to be performed. If additional wells were to be added, a jack-up drilling rig would be brought in.

Process facilities were designed to be minimal. A test separator would allow metering of individual wells, but the production would be routed directly to Valhall. On Valhall, the Hod production stream would be routed through a separator and fiscal metering equipment, and then to the first stage production separator.

The wellhead platform development concept was based on a peak production rate of 13,800 BOPD (2200 Sm^3/day) from four wells. Reserves were assumed to be 44 MMSTBO (7 million Sm^3). Total investments for this concept, including wells, pipelines and Valhall tie-ins, are estimated to be $279 MM in 1987 dollars (NOK 1,870 MM January 1986, escalated by 5 percent, exchange rate NOK 7.0/$). Contingency has been allowed for in this estimate. A breakdown of the estimate is given below.

Investment Cost Estimate	($ MM, 1987)
Platform	191.5
Wells	33.5
Pipelines and Valhall Tie-ins	54.0
Total	279.0

5.1.3 Subsea Production System

In the 1986 Hod Field Development feasibility study performed by Kværner Engineering, the following subsea alternatives were addressed for a 4 well case:

i) Separate flowlines for each subsea well
ii) A manifold system and only one pipeline
iii) A manifold system and two connected pipelines forming a continuous flowline loop.

All three alternatives were to make use of the template already installed on the Hod Field. Alternative i) was found to be preferable, mainly because of its flexibility in the case of well problems (e.g. solids production). A total of four wells were assumed, and continuous flowline loops would be established allowing for pigging from Valhall. A 4 inch (102 mm) service line would be installed to allow for chemical injection.

The Hod Field production would be processed on Valhall. As for the manned wellhead platform case above, oil and gas would be separated, and fiscal metering carried out, before entering the current Valhall processing equipment.

Total investment cost for the four well subsea concept is estimated to be $ 170 MM in 1987 dollars. (NOK 1,130 MM in January 1986 escalated by 5 percent, exchange rate NOK 7.0/$). Contingency has been allowed for in this estimate. A breakdown of the investments is given below:

Investment Cost Estimate	($ MM, 1987)
Subsea Equipment	40.5
Wells	49.5
Pipelines	34.5
Valhall Tie-ins	45.0
Total	169.5

Hod Field appraisal wells and Valhall Field production wells indicated the chalk formation in these reservoirs to be unconsolidated, allowing low drawdowns and resulting in production rates below initial expectations. Relatively frequent well intervention was required to keep the Valhall Field wells producing. Development of the Hod Field was in part dependent on that situation being improved. These aspects made a subsea solution for Hod unattractive due to the need for using a mobile rig to conduct such operations (cleaning out formation solids from the production string, re-stimulating the formation and recompleting wells). Thus, workovers on subsea wells would be more time consuming and expensive than those on wells that have been tied back to a fixed platform.

In addition to the negative aspect outlined above, the cost estimates show that subsea development would be more expensive than the proposed wellhead protector platform. Further evaluation of the subsea concept has therefore not been carried out.

5.1.4 Evaluation Process Since 1986

The changes to the tax regime enacted in 1986/87 resulted in improved economics for Hod development, such that the minimum facilities platform concept became economically acceptable. The subsea production concept was discarded, since this would involve several uncertainties and significant risk, especially in a multi-well system intended to produce from an unconsolidated reservoir such as Hod. Therefore, efforts were concentrated on minimizing the cost of a platform development. Due to the reduced reserves and hence the smaller number of wells required, a permanently installed drilling rig was not justified. Advances in the understanding of two phase flow resulted in the proposal for a single export pipeline, thus reducing costs even further.

The proposed concept is for a simple, fixed steel platform that would normally be unmanned. Personnel would only be required on board for maintenance tasks and non-routine operations. Basic monitoring and control would take place at Valhall. This concept fulfills all basic requirements at low development costs, and takes advantage of the available processing capacity at the Valhall Field and pipelines for onward transportation via Ekofisk. The following section describes the proposed development concept in detail.

5.2 FIELD INSTALLATIONS DESCRIPTION

This section describes the hardware required to develop the Hod Field, jacket, deck with facilities and pipeline, and also the modifications necessary for the Valhall Field to handle the production from Hod. The concept proposed for the Hod Platform has not been used in the Norwegian Sector of the North Sea previously and may set precedence for development of other fields. This description with associated drawings is therefore relatively detailed. The concept is however, already widely used throughout the rest of the world including the UK Sector of the North Sea, by Amoco and others.

5.2.1 Introduction

The Hod platform and facilities are reviewed in further detail in the "Hod Development Study" dated November 1987 which has previously been presented to the NPD and can be obtained from Amoco Norway.

The Hod platform will be a normally unmanned, minimum facilities wellhead protector platform. The platform will be installed over an existing 12 slot template. Eight well slots are included in the current design but access to 10 of the 12 template slots is possible with the designed jacket bracing. The platform jacket will be a 4-leg X-braced structure with one pile driven through each leg. The deck will consist of 2 levels, cellar deck and main deck, with an elevated cantilevered helideck.

Wells will be drilled and workovers will be performed by a cantilevered jackup drilling rig. The platform will support no drilling facilities. During drilling operations, all personnel will be accommodated in the quarters of the jackup drilling rig.

Apart from the drilling/workover mode, platform operation will be monitored at Valhall via telemetry and the platform facilities will be designed to operate without continuous manning. All critical operating functions can be shut down from Valhall. The platform will be attended occasionally for maintenance, well testing, and well wireline and/or coiled tubing work activities. Well testing is expected to occur about 48 hours per month, and maintenance operations are expected to occur once per week.

Access to the platform will be by helicopter. No provision will be made for accessing the platform directly from a supply boat.

All production facilities will be located on the south end of the cellar deck. Primary facilities are wellheads, a production/test header and a bypass header, a separator, a pig launcher, and interconnecting piping. Other auxiliary equipment such as sea sump pump, well equalization pumps, and meter prover are also located in the wellhead area.

The wellhead/production area will be separated from the utilities area by an H-O fire wall.

The primary utilities are a power generation and distribution system, a diesel fuel transfer system, a potable water system, sea water supply system, and an hydraulic power package. These systems will be designed to be as simple and reliable as possible to minimize the need for maintenance.

A small equipment module, located on the cellar deck north of the H-O fire wall, will contain a small shop, the main generator room, an electrical equipment room, a battery room, the emergency generator room, and the emergency switchgear room. The generator diesel day tanks will be located on the roof of the module.

The cellar deck will be partially protected by a wind screen; there will be openings along the top and bottom which will allow for natural ventilation.

Steel grating will be used for all primary deck areas. The use of grating will increase ventilation of the wellhead area and limit risk of potential damaging fires on the platform because flammable fluids and hydrocarbons from spills or leaks will not pool on the platform. Equipment which may contain hydrocarbons will be fitted with drip pans to contain any spillage and spillage will be routed to the sump.

There will be a shelter module on the main deck for personnel who, due to weather or emergencies, are forced to remain overnight on the platform. Basic facilities will be provided for ten persons in this small shelter.

The main deck will be clear (open) south of the shelter and helideck to allow free access for jackup drilling rig cantilever unit. The crane is also cantilevered on the east side of the main deck for drilling rig access.

One lifeboat sized for 20 men will be provided at the main deck. One pick-up craft/liferaft will also be provided on the east side of the platform at cellar deck level.

5.2.2 Process Design

5.2.2.1 Process Description

The Hod platform will have a single two-phase gas/liquid separator with meters located on gas and liquid outlet lines. No other process equipment will be located on the platform (See Exhibit 5.1,(Drawing P-5100 attached)). Product specifications are to be met through processing at Valhall.

During normal operations, all well fluids will be routed to the production header and into the separator. The gas and liquid phases of the produced fluid will be separated, metered, and recombined, before flowing through the pipeline to Valhall. Connections will be provided to allow the water phase to be separated and routed around the flowmeter should this be required in the future. The separator will serve only to permit metering of wellstream fluid, so that revenue can be allocated to Hod from the combined Hod and Valhall product measurements, taken at custody meters on the Ekofisk 2/4-G platform. Samples will be collected, automatically, on separator liquid and gas outlet lines, and laboratory analysis will be performed to determine BS&W and hydrocarbon composition.

During well tests, the separator will serve as a test separator. In the test mode, only the well being tested will flow into the separator. Production from other wells will be routed through a bypass header and around the separator. The pressure and temperature of wells routed through the bypass will be monitored for condition changes and allocation purposes. Flow from the separator and bypass line will combine, downstream of metering, and pass through the pipeline to Valhall. The platform will operate in this mode about 48 hours per month.

5.2.2.2 Process Equipment

Piping and instrument diagram (P&ID) legends are provided in Exhibits 5.2 and 5.3 (Drawings P-5110 and P-5112). Typical well details and connections to the production and bypass headers are shown on Exhibit 5.4, (Drawing P-5120). Piping from the wells to the main headers is designed for 5000 psig (344.7 bar), which exceeds well shut in pressure. Piping and valves downstream of the wing and including the header block valves will be rated ANSI 2500 lb or equivalent (maximum working pressure of 5815 psig (400.9 bar) at 165 degrees F (74°C)).

Both the production/test and the bypass headers will be built for six producing wells and can be extended for additional wells, if required. The headers will be rated ANSI 600 lb (1395 psig (96.2 bar) at 165 degrees F (74°C)).

The separator (V-501) will be a 5 ft (1.5 m) ID x 20 ft (6 m). seam to seam horizontal two-phase separator as illustrated on Exhibit 5.5, (Drawing P-5122). Design throughput will be 34.6 MBOPD (5,501 Sm^3/d) and 18.5 MMSCFD (0.524 million Sm^3/d) at 405 psig (27.9 bar), and 120 degrees Fahrenheit (49°C). Rated pressure and temperature will be 1395 psig (ANSI 600 lbs) and 165 degrees F (74°C), respectively.

Pigging facilities are provided and it is envisioned that pigging will be done routinely. The internal condition of the pipeline system can be inspected periodically.

5.2.2.3 Metering and Allocation

Metering facilities will be installed on the Hod platform to measure crude oil and gas quantities for allocation purposes. As far as practical, the equipment has been designed to meet NPD Regulations for fiscal metering. The few minor deviations are the result of the normally unmanned operation of the Hod platform and consequential need for simple and reliable equipment. For example, in-line densitometers require much operating and maintenance attention so Hod is designed to utilize continuous pressure and temperature measurements together with a suitable algorithm to calculate density.

Fiscal metering takes place at the Amoco/NOCO Group owned 2/4 G platform in the Ekofisk Center and it should be recognized that the Hod Field is not subject to Royalty. The proposed metering equipment is to be used for accurate allocation of products between the Valhall area fields only. A Supplement to the referenced Hod Development Study will be provided to NPD in the near future. This Supplement will provide additional details on the below described system and operation of the same.

Crude Oil Meter
A bank of three high resolution turbine meters will be provided, two for full production and one for individual well testing. All meter runs will be designed for the length required for a 4 inch (10 centimeters) flow-meter, providing extra flexibility. The production meters will each be 4 inch (10 cm) meters with a nominal range of 1900 to 42,000 BLPD (302 to 6677 Sm^3/d). The well test meter will be a 2 inch (5 cm) meter with a nominal range of 750 to 7700 BLPD (119 to 1224 Sm^3/d). Either size meters may be calibrated with the prover.

The meter prover will be a Brooks Compact prover utilizing the pulse interpolation method of meter calibration. In addition it is planned to perform monthly "proof checks" by taking one of the full flow meters to Amoco's 2/4G platform and proving the meter using the existing pipe prover loop. Once the accuracy and reliability of the compact prover is confirmed this "proof checking" will be terminated.

The continuous crude oil sampler will be flow proportional with the composite sample stored at a constant pressure. The sample will provide composition and sediment and water content. Pressure and temperature transmitters will be used in conjunction with algorithms based on PVT data from crude samples to determine the density of the crude oil.

Gas Meter
Two 6 inch (15 cm), dual chambered orifice meter runs will be used for full production and individual well tests. Each meter

will be able to handle the total gas flow. Dual, stacked differential pressure transmitters are included to obtain the flow range required. Pressure and temperature transmitters will be used in conjunction with standard density tables for the determination of the gas density. The continuous gas sampler will be flow proportional with a monthly composite sample stored at line pressure.

Computer

The flow computer is capable of calculating oil and gas flow in general compliance with NPD Regulations for Fiscal Measurement. The main exceptions are the lack of a back-up computer and remote proving capability. A single, dedicated 14-bit microprocessor is used instead of a 16-bit processor. The reasoning for these non-compliances are discussed in more detail in the previously referenced Hod Development Study dated November 1987.

Allocation Method

Products from the Hod Field will be delivered to the custody transfer meters at Ekofisk 2/4-G together with Valhall products. The method proposed for allocating the products between the fields will be in line with the principles employed for existing fields in the Valhall/Ekofisk area. The distribution is determined by performing a mass balance of individual hydrocarbon and non-hydrocarbon components. The metered flow and sample analyses at 2/4-G, at the Hod separator, and Valhall fuel and flare gas lines data are used in the allocation computations. Valhall allocated production will be calculated by difference. The planned allocation procedure is further described in the previously referenced Hod Development Study.

5.2.2.4 Pipeline Sizing

Hod produced fluids will be transported to Valhall for processing through one 12 inch (0.3 m) nominal bore, 13 kilometer long, multiphase line. The line size was selected based on results of process simulations, incorporating the Beggs and Brill multiphase pipeline pressure drop method and Eaton holdup correlation (see

Appendix I, Section 3 of the Hod Development Study for details). Results from the pipeline model indicate that a 12 inch (0.3 m) line will be most suitable for this installation.

Based on a nominal 12 inch (0.3 m) production line and slug velocity of 12 ft/sec (3.66 m/s) (maximum velocity at which large slugs are likely to be encountered), instantaneous Hod delivery rates to Valhall could approach 145 MBPD (23,053 Sm^3/d). At that rate, Valhall separator liquid residence time would approach 6 minutes, which is 300 percent of that needed for adequate gas/liquid separation.

5.2.2.5 Relief System

Pressure relief valves for thermal (fire) protection are located on the separator (V-501), pig launcher (V-502), and interconnecting piping. Full flow relief is provided at Valhall. The separator and piping relief valves are piped to a small vent at the Hod Platform. The pig launcher relief valve will be routed to the closed drain sea sump.

In accordance with API 14C and because of the low number of wells, simple flow scheme, and independently redundant instrumentation, a full flow relief system is not provided on the Hod platform. The provision of two independent shutdown valves (wing valve and upper master valve) each with an independent pressure switch high sensor connected to a separate relay and sensing point is an acceptable alternative to a pressure relief valve. The wells, chokes, and header block valves have a Maximum Allowable Working Pressure (MAWP) of 5000 psig (344.7 bar) which is higher than well shut in pressure. Downstream of the header block valves the platform piping and equipment have a MAWP of 1395 psi (96.2 bar). Normal operating pressure of the 1395 psig (96.2 bar) downstream equipment is less than 450 psig (31.0 bar). Independent high pressure switches are located on both the production and bypass headers. At 800 psig (55.2 bar), a pressure switch high will automatically initiate the closing of the wing valves. At 1000 psig (68.9 bar), a pressure switch high will initiate closing of the upper master and downhole safety valves. As additional protection, the thermal pressure relief valves would discharge at 1395 psig (96.2 bar) and the associated equipment (designed with a factor of safety greater than 3.0) will be hydrotested at 2092 psig (144.2 bar).

The maximum shut in pressure of the wells will decline rapidly as the wells are produced. Production estimates indicate, depending on the specific well, that the well shut in pressure will be below 1395 psig (96.2 bar) in a few years. Hence, after the decline, all the production facilities will be capable of handling full well shut in pressure.

5.2.3 Utilities

5.2.3.1 Generators and Diesel System

Three 100 kilowatt diesel engine powered generators will be provided as shown on Exhibit 5.6, (Drawing P-5130). A common diesel day tank (T-552) is provided for primary generators G-551 and G-552. A separate day tank (T-553) is provided for emergency generator G-553. Day tanks are sized to contain fuel for 24 hours continuous operation.

There is sufficient diesel oil storage capacity on the platform for approximately 17 days of normal operation. Instrumentation will keep operations personnel at Valhall informed of tank levels, and potential diesel oil supply problems are thus minimized.

5.2.3.2 Water Systems

5.2.3.2.1 Potable Water System

The potable water system is shown on Exhibit 5.7, (Drawing P-5140) and is designed for a normally unmanned platform. Potable water will be brought to the platform by supply boats. One pump is used to transfer the water to the potable water pressure tank (located in the shelter) and the end users. A chlorination package is provided upstream of the pressure tank. The water will supply the utilities in the shelter and equipment modules.

5.2.3.2.2 Seawater Supply System

The seawater system is supplied by the utility pump (P-561) located on the cellar deck north of the firewall. This is a 30 kilowatt pump supplying approximately 1000 liters/minute of seawater for utility or personnel fire protection (see also 5.2.6). The seawater supply pump will be an electric submersible pump which can be powered from either the main or emergency electrical distribution system.

5.2.3.3 Drain Systems

The open drain system consists of drains from the equipment module, drip pans underneath equipment, and connections from the diesel system and potable water tank. (Exhibit 5.8, (Drawing P-5142)).

Connections to the sump from the separator, pig launcher, and pig launcher pressure relief valve make up the closed drain system. Hydrocarbon liquids in the vented sump are pumped back into the line downstream of the separator by the use of the sump pump.

5.2.3.4 Chemical Injection

If required, wax dispersant and a biocide or corrosion inhibitor will be injected into the well stream fluids. Two positive displacement pumps are provided to inject the chemicals into the production piping system.

5.2.3.5 Electrical Generation and Distribution and Communications

5.2.3.5.1 Generators

Two diesel engine driven main (primary) generators will be provided and will generate power at 380 volts, 3 phase, 4 wire, 50 Hertz. Each unit will have a capacity of approximately 100 kilowatts at continuous duty. The emergency generator will also be a diesel engine driven unit with the same rating as the main generators. It will be housed in a separate room in the opposite end of the equipment module and its switchgear and controls will be in a room separated from the main switchgear.

5.2.3.5.2 Power Requirements

During unmanned operation the electrical load will be approximately 75 kilowatts. One 100 kilowatt unit will provide all power requirements of the platform control, communications, safety and ESD systems, telemetry, and minimal HVAC for the equipment and shelter modules.

When personnel are on board the Hod Platform, additional electrical capacity will be required for the shelter and for maintenance activities. The total load in this mode will be approximately 145 kilowatts and will be served by running the two main generators in parallel.

In the emergency mode, power is provided to safely shut down the platform, to maintain remote control and monitoring functions from Valhall, to meet emergency communications and navigation aids requirements, to maintain required emergency lighting, to run the seawater/firewater supply pump if necessary and to operate the emergency shelter for life support. Power requirements in this mode are approximately 70 kilowatts without the seawater supply pump and will be supplied by the emergency generator.

5.2.3.5.3. Electrical Distribution System

Refer to Exhibits 5.9 and 5.10 (Drawings P-5114 and P-5200).

380/220 Volt System

Electric power on the platform will be distributed by a 380/220 volt, 3 phase, 50 Hertz, 4 wire system. The distribution system will consist of two sets of switchgear and motor control centers - the main bus and the emergency bus. The two busses will be tied together through a bus tie breaker to ensure that any fault on one system will not damage the other. The two systems will be located in separate rooms. Under emergency conditions the bus tie breaker will open to completely isolate the emergency system from the main system.

24 Volt DC System

A 24 V DC system will be provided to serve miscellaneous controls. The batteries will be installed in a battery room next to the emergency generator switchgear room. Additional batteries will be provided specifically for the navigation aids and radio equipment. The battery chargers will be in the emergency generator switchgear room.

5.2.3.5.4 Emergency Power System

The emergency power system will consist of a battery charger, batteries and inverter to provide no-break AC power to emergency services. Battery capacity will provide for at least one half hour of operation at rated output.

5.2.3.6 Equipment Module

5.2.3.6.1 Introduction

An equipment module will be located on the cellar deck North of truss Row B. This module will contain the electrical generation and distribution equipment for both the main and emergency systems, control panels and batteries. The equipment module will be a single level steel building with approximate dimensions of 38 feet (11.6 meters) long, 25 feet (7.6 meters) wide and 15 feet (4.6 meters) high. The module will be shielded from the process area by an independent H-O firewall and the entire south wall of the module, and the roof, floor, and all walls enclosing the emergency generator and switchgear and battery rooms will be A-60 rated. (Reference Exhibit 5.11, (Drawing P-5010)).

5.2.3.6.2 Arrangement

Battery Room
The battery room will contain batteries for the AC no-break system, and the 24 VDC control battery. An extraction fan will prevent the accumulation of hazardous gasses caused by battery charging.

Emergency MCC and Switchgear Room
The emergency generator switchgear and control panel will be located in this room along with the emergency Motor Control Center (MCC), the essential services panel, any equipment associated with the emergency bus, and battery chargers and distribution panels.

Emergency Generator Room
This room will contain the diesel driven emergency generator. This unit will have a remote mounted radiator and fan unit. Combustion and cooling air will be drawn from a safe location on the North side of the building. Gas detectors will be provided to protect against the possible intrusion of combustible gasses.

Electrical Equipment Room
This room will contain the main generator switchgear, main Motor Control Center (MCC), platform control panel, fire and gas panel, ESD panel, wellhead control panel, remote terminal unit (RTU), public address system, and the normal distribution panel.

Main Generator Room
The two main diesel generators will be located in this room. The

generator sets will have a skid mounted radiator and cooling fan. The radiators will be located against louvers installed in the North wall. The louvers will open automatically when the engine is running and will close when the engine shuts down or when required by fire or gas detection in the generator room. The fans will draw cooling and combustion air into the room through automatic louvers in the East wall of the room. The area outside the East wall is a safe area; however, gas detectors will be located inside the room near the louvers to protect against entry of any combustible gas.

Shop

This room provides an area for minor maintenance work to be done such as repair or adjustment of instrumentation or electrical equipment. This room may also be used as a storage area for parts and supplies required for routine maintenance.

5.2.3.6.3 Ventilation

The Main Generator Room is designed to be ventilated by the engine cooling fans during normal operation. A small vent fan will operate as required if neither main generator is running. The remainder of the module will be served by two HVAC systems. One will cover the Electrical Equipment Room and the Shop and the other is for the Emergency Generator Room, Emergency MCC and Switchgear Room and the Battery Room. These systems will be designed to meet the NPD Regulations for this type of installation.

5.2.3.7 Communications and Telemetry

5.2.3.7.1 Overall Philosophy

The Hod Platform will normally be operated, monitored and controlled via telemetry link from the Valhall Platform, and it will be provided with all the normally required communications equipment.

5.2.3.7.2 Communication Network Plan

The communications network will consist of the microwave system (Hod to Valhall), SOLAS (Safety of Life at Sea), telephone system, public address system, power supply system, and the telemetry system.

5.2.3.7.3 Microwave System

The microwave system will be the primary link between the operators on Valhall and the Hod satellite platform. It will provide reliable communications from the control console on Valhall to the Remote Terminal Unit (RTU) on Hod. To assure that the most reliable communications link is provided, equipment redundancy and frequency and space diversity will be utilized. Experience with the Valhall-Ekofisk microwave link is that an availability in excess of 99.99 percent has been obtained. The equipment on Hod will operate from the no-break 220 volt system.

Loss of the Hod-Valhall microwave link will cause a production shutdown.

5.2.3.7.4 SOLAS Equipment

The radio equipment provided will meet the NTA (Norwegian Telecommunications Administration) requirements for SOLAS.

5.2.3.7.5 Telephone System

The microwave system will provide a connection to the Valhall telephone network. There will be two telephones on Hod utilizing this connection, one in the radio room and one in the electrical equipment room.

A sound powered telephone system with stations in the radio room, the electrical equipment room and at the lifeboat landing will also be provided.

5.2.3.7.6 Public Address (PA) System

The PA system will consist of control stations in the radio room and Motor Control Center (MCC) room and loudspeakers at various locations on the decks and in the emergency shelter.

Color coded status lights will be provided at appropriate locations on the platform. Color codes will be consistent with those used at Valhall.

5.2.3.7.7 Power Supply System

The standby MF/HF transmitter and receiver and the required radios will be connected to a 24 VDC battery supply capable of serving the load requirements for six (6) hours.

5.2.3.7.8 Hod to Valhall Remote Control Telemetry System

A Master Control Unit (MCU) will be installed in the Valhall control room and a Remote Terminal Unit (RTU) will be installed in the Hod Electrical Equipment Room. Communications between the two units will be via the microwave link previously described.

The Master Control Unit will be located in the Valhall control room and will consist of the MCU itself, a multiplexer to interface with the microwave system, a visual display unit with operator's keyboard, and a printer for producing data and event logs. The MCU will be a microprocessor based device which will process, store, and print data from Hod platform. The operator will be able to monitor and control the operation of Hod platform by watching the visual display and entering commands through the keyboard. Any alarms which occur on Hod will be recorded and audibly annunciated by the MCU.

The Remote Terminal Unit on Hod will be interfaced to the control and alarm panels to pick up the desired information. It will be possible to control separator pressure and level and to shut down any of the wells, and to initiate a platform shut down or ESD through the MCU on Valhall. Individual well chokes will be remotely adjustable. For reliability the RTU will be redundant. An operator interface will be provided on Hod so that personnel on Hod can take over control of the platform if so desired. This will be located in the electrical equipment room and will consist of a visual display and operator's keyboard similar to the one on Valhall. While the platform is under local control all data and status information will continue to be sent to Valhall.

5.2.3.8 Navigation Aids

The navigation aid lighting system will be designed to meet recommendations of the International Association of Lighthouse Authorities. The system will consist of two light assemblies each including one Main light (15 nautical miles white) and one Secondary light (10 nautical miles white). These light assemblies will be located on diagonally opposite corners of the platform and arranged so that the secondary light will be activated in the event of failure of the main light. In addition to the maritime aids to navigation, red aircraft obstruction lights will be provided on the extremities of the crane.

Main (2 nautical miles) and secondary (1/2 nautical mile) fog signals will be installed.

The navigational aids system will be supplied with a control panel which will monitor the status of all components of the system and provide alarms and indication in the electrical equipment room.

Four illuminated identification panels will be provided.

5.2.4 Platform Layout and Area Classification

5.2.4.1 Cellar Deck

The cellar deck layout is shown on Exhibit 5.12, (Drawing P-5000). The 75 ft x 70 ft (22.9 x 21.3 m) cellar deck is laid out with sufficient access to all equipment. In the wellbay area there are eight well slots.

The wellhead area is separated from the utility equipment by a class H-O firewall. Potable water storage tank (T-560), water pump (P-560), and the chlorination package (X-560) are located in the northwest section of the cellar deck. Diesel storage is contained in the crane pedestal (T-551). Seawater Supply Pump (P-561), diesel transfer pumps (P551 A and B) and a filter coalescer are located in the northeast portion of the platform.

The equipment module contains the normal and emergency diesel generators, the motor control center, emergency switchgear, battery room, control panels, telemetry equipment and a work shop. Additional information on the equipment module is contained in Section 5.3.6.

5.2.4.2 Main Deck and Helideck

The layout of the 75 ft x 70 ft (22.9 m x 21.3 m) main deck is shown on Exhibit 5.13 (Drawing P-5002) and the helideck details are shown on Exhibit 5.14 (Drawing P-5014). The main deck is clear to provide access for the drilling rig. The interior layout of the shelter is shown on Exhibit 5.15 (Drawing P-5012). The helideck is cantilevered and offset to provide drilling rig access and crane clearance.

5.2.4.3 Deck Elevations

Topside elevation views are shown on Exhibit 5.16 and 5.17 (Drawings P-5004 and P-5006). On Exhibit 5.16 (Drawing P-5004) the wind screens and firewall are evident on the cellar deck and the offsetting of the helideck is evident. The helideck offset permits utilization of the crane and better drilling rig access. Exhibit 5.17 (Drawing P-5006) illustrates the cantilevered equipment module, shelter module, and the helideck.

5.2.4.4 Area Classifications

Area classifications for the Hod platform were determined according to IEC 79-10 and API RP 500B.

The only hazard sources on the platform are located on the cellar deck and consist of the wellheads, the headers and piping, the separator, the meters, the pig launcher, the sea sump, and the vent which is located off the southeast corner of the platform. All hazard sources except the vent are considered secondary sources because they will release a flammable substance only during abnormal or infrequent operations. The area around these sources is therefore considered to be a Zone 2 area. Because of the open grating deck design and the openings at the top and bottom of the wind wall, sufficient natural ventilation will be present to preclude the necessity of upgrading the area within the wind walls to a Zone 1 area.

Layouts of the area classifications, which are superimposed over the deck plot plans and one deck elevation are shown on Exhibits 5.18, 5.19 and 5.20 (Drawings P-5050, P-5052 and P-5056). Note that the equipment and shelter modules are both located in unclassified areas and that appropriate Zone 1 and Zone 2 areas are shown around the vent.

5.2.5 Main Deck Facilities

5.2.5.1 Shelter Module

A shelter module will be located on the North end of the main deck under the helideck. When personnel travel to Hod from Valhall to work, the shelter will provide basic requirements for communications, for changing clothes, and for coffee breaks and small lunches. Should weather or other situations arise so that personnel must stay overnight at Hod, the shelter will provide basic accommodations in a designated area. Beds are provided for ten people and different sexes can be segregated. A layout of the shelter module is shown on Exhibit 5.15 (Drawing P-5012).

The South wall and roof of the module will be H-120 rated. The floor, which faces the utility (auxillary) area, will be A-60 rated. There will be no windows in the H-120 wall. The remaining three walls will be A-0 rated fire walls. All walls will be insulated to keep transmitted noise from the equipment module or the platform work areas to acceptable limits.

The normal module entrance and exit will be through a door on the North corner of the East wall. The emergency escape exit will be located in the West wall, on the opposite side of the module from the normal exit. Neither door will be located in a hazardous area.

The interior of the shelter is divided into five areas, or rooms.

A single change room provides facilities for changing/storing clothes and includes one lavatory unit (shower, washbasin, and toilet).

The snack room has been designed primarily for coffee and meal breaks. Its facilities include two tables, ten chairs, couches, refrigerator, microwave oven, hot plate, miscellaneous cooking utensils and an entertainment center. The radio room will contain all platform communications equipment except for lifeboat and liferaft radio(s) and certain platform telephones.

The utility room contains a pressurized potable water tank, hot water heater, cleaning supplies and equipment and dry food stores.

The dormitory room includes beds and lavatory facilities for ten people. There will be five two unit bunk beds, two lavatory units (incl. toilet, washbasin, shower) and ten lockers. The room is arranged with moveable (accordion type) partitions that span ceiling to floor so that the dormitory can be divided for housing males and females concurrently.

Fire protection will be provided in each shelter area by hand held fire extinguishers. Each area will have one or more heat, gas or smoke detectors.

The shelter module will be heated and ventilated by a dedicated HVAC system which will be designed to meet Amoco's standards and the NPD Regulations for heating and ventilation of permanent living quarters. The HVAC ducting will have gas detectors installed. The HVAC will shut down and dampers will close upon confirmed smoke or gas detection and a platform shutdown will be initiated. The above layout of the shelter module has been reviewed with and accepted by Amoco's Work Environment Committee.

5.2.5.2 Crane

It is intended to provide a reliable, low maintenance crane for this platform. The crane will be diesel engine driven and hydraulic powered and sized to lift 15 metric tons at 25 meters radius. The crane is located on the normal lee side of the platform.

5.2.5.3 Helideck

The helideck will basically be in compliance with NPD Regulations except the foam fire protection system which is designed in accordance with National Fire Protection Association (NFPA) 403 as previously discussed and submitted to NPD. Take off and approach sector requirements, deck size, loadings, surface conditions, and lighting requirements will comply with NPD Regulations. One clearly marked emergency exit will be provided in addition to the main helideck access. (See Supplement to the referenced Hod Development Study).

5.2.6 <u>Fire and Safety</u>

The safety study completed for Hod showed that the Hod Platform met NPD's safety criteria without water based firefighting capability. Reviews inhouse Amoco and by NPD resulted in requests for water based personnel protection systems for the wellbay areas and helideck as a contingency measure. Amoco responded to these requests by including the personnel protection system exemplified in the fire and gas layout drawings for the cellar deck (P-5060), the maindeck (P-5062) and the helideck (P-5068) (Exhibits 5.21, 5.22, and 5.23 respectively). These additions have been reviewed by Amoco's Safety Department, Work Environment Committee and NPD and found appropriate for the Hod development.

5.2.6.1 Fire and Gas Detection

The Hod platform fire and gas detection and control system will consist of several types of sensors (fusible loops, gas detectors, etc.) which will be monitored by a Fire & Gas control panel. The panel will interface with the Emergency Shut Down (ESD) panel, telemetry system, and platform control panel to initiate required actions and give the proper indications. This panel will be located in the electrical equipment room and will be powered by 24 VDC control power battery system.

The actions caused by detections of gas or fire are given in the Cause and Effect Diagrams, Exhibits 5.24, 5.25 and 5.26 (P-5210, P-5211, and P-5212).

5.2.6.2 Fire Fighting Equipment

Fixed fire fighting capability will consist of personnel protection systems in the process/wellbay area and the helideck. In the wellbay/process area there will be fixed water spray systems, connected to the fire and gas panel logic to cool burning equipment and protect personnel trapped in the area. Spray rates have been sized in accordance to NFPA 15 rules for exposure protection. Two hose reels located on the cellar deck can also be utilized for rescue purposes should that prove necessary. The helideck has been provided with fixed foam and dry powder systems designed in accordance to NFPA 403 heliport firefighting criteria. A hose reel at the base of the steps leading from the main deck to the helideck can also be used on the helideck as needed. Water supply for both wellbay and helideck systems comes from the seawater supply pump previously described (Section 5.2.3.2.2).

Portable fire fighting equipment will be provided throughout the platform. The equipment will consist of portable and wheeled fire extinguishers. The placement and number of extinguishers will equal or exceed normal National Fire Protection Association (NFPA) requirements. Two 150 lb (68 kg) wheeled extinguishers will be provided on each deck and numerous portable extinguishers will be placed on the deck and modules. Automatic halon units are provided in the main and emergency generator rooms.

5.2.6.3 Shutdown Logic and Activation

Shutdown logic will be contained in an Emergency Shut Down (ESD) panel located in the electrical equipment room. The function of this panel will be to monitor inputs from the Fire and Gas panel, manual ESD pushbuttons, process alarm and shutdown switches and the telemetry system from Valhall. The ESD panel will be a dual microprocessor based Programmable Logic Controller (PLC), which performs the logic functions and provides the required outputs. The logic will be in accordance with Cause and Effect Diagrams. Exhibits 5.24, 5.25 and 5.26 (Drawings P-5210, P-5211 and P-5212).

5.2.7 Platform Structural Design

5.2.7.1 Introduction

The conceptual design of the Hod platform jacket is shown in Exhibits 5.27, 5.28, 5.29 and 5.30 (Drawings P-5020, P-5030, P-5040 and P-5042). Member sizing in the jacket was based on an in-place analysis and preliminary progressive collapse analysis.

The major deck members were sized using a uniform load over the entire deck area and the environmental loads. No optimization nor any reanalysis due to minor frame geometry or deck plan changes was performed.

The Hod platform jacket is designed as a steel structure with 4 legs arranged in a square grid measuring 45 feet x 45 feet (13.7 m x 13.7 m) at the pile cutoff level which is 28 feet (8.5 m) above L.A.T. The legs are battered outwards from the pile cutoff elevation at 1 horizontal to 12 vertical (1:12) in two vertical orthogonal planes. One steel pile will be driven through each jacket leg. The annulus between each leg and its pile will be grout filled.

The jacket will be set over an existing 12 well drilling template and will be designed for the installation of 8 well conductors, with access for 10 conductors.

The deck is designed as a conventional 4-legged two level truss/plate girder structure which mates with the jacket at the pile cutoff elevation.

The platform structural weight is estimated to be:

Jacket	1700 Metric Tons
Deck	700 Metric Tons
Piles	1700 Metric Tons

The nominal platform life is 15 years.

The Hod Structural Design Criteria is given in Appendix III, Section 1.0 of the Hod Development Study.

5.2.7.2 Environmental Criteria

The environmental criteria proposed for the Hod Field have been taken from several sources. Four primary sources for the criteria are:

1. Marex Report No. 314 dated October 1977 "Environmental Conditions in the Norwegian North Sea - Valhall Field

Block 2/8 and Hod Field Block 2/11" (Appendix III, Section 2.0, Hod Development Study).

2. Amoco Production Company Research Report No. 87301ART0156 entitled "Extreme Wave Height and Wave Crest Elevation Estimates Ekofisk/Valhall Area" dated October 28, 1987 (Appendix III, Section 8.0, Hod Development Study).

3. Amoco Production Company Memorandum No. 87264ART0215 entitled "Directional Design Wave Heights for the Hod and S. E. Tor Platform Developments" dated September 21, 1987 (Appendix III, Section 9.0, Hod Development Study).

4. Amoco Production Company Memorandum No. 87274ART0202 entitled "Hydrodynamic Issues for Consideration in the Design of the Hod and S. E. Tor Platform Developments" dated October 1, 1987 (Appendix III, Section 10.0, Hod Development Study).

Storm Wave Description

Amoco has used storm hindcast results, calibrated by actual wave data measured at the Ekofisk Field, to statistically determine the value of the 100 year reoccurrence wave height. This wave height was calculated by Amoco to be 22.6 meters, with a wave period of 13 seconds. As explained in the Amoco Research report (reference item 2, above) much of the uncertainty and/or variability of selecting prediction parameters has been eliminated in Amoco's method.

As in the Valhall design criteria, Amoco intends to use the concept of wave directionality to design the Hod platform. In this method, storm data is hindcast to statistically determine the value of the 100 year wave height for each of 8 approach sectors. This method is discussed in reference 3 above. Wave parameters are given in Table 5.1.

The largest 100 year wave is from the NW sector, and the Hod platform will be oriented so that the pile foundation's maximum resistance is oriented to the NW-SE. The 100 year wave from each of the other sectors is used to verify foundation stability and jacket member strength.

Table 5.1: 100 Year Storm Wave, Current, Wind

Direction	Wave Height (m)	Wave Period (secs.)	Wind 1 min. mean (m/s)	Current Profile (meters/seconds) LAT	15m	30m	43m	67.1m
North	21.3	13	39.8	1.20	0.79	0.48	0.41	0.26
North East	15.4	11	33.2	1.21	0.86	0.46	0.36	0.36
East	17.2	11	34.8	1.05	0.67	0.46	0.34	0.34
South East	19.0	12	36.3	1.13	0.76	0.43	0.35	0.28
South	19.0	12	36.3	1.18	0.81	0.41	0.35	0.24
South West	20.1	12	35.3	1.21	0.86	0.51	0.42	0.26
West	21.3	13	37.9	1.18	0.80	0.54	0.46	0.29
North West	22.6	13	39.5	1.21	0.81	0.53	0.42	0.38

The design wind velocity is 90 percent of the 1 minute mean for 100 year return period at 10 meters elevation in each particular direction. The current velocities are 100 percent of the wind induced components plus 70 percent of the tidal and gradient drift components of the 5 minutes, average velocity for each direction.

Drag Coefficients

The proposed drag coefficients account for both marine growth effects and the over prediction of wave particle kinematics by Stokes fifth order wave theory.

Storm Conditions for Jacket and Deck

The Amoco 100 year storm condition combines the 100 year directional wave with reduced wind and tidal current values. On an average, measured winds were 87% of their maximum value and measured currents were 69% of their maximum value at the time the highest waves occurred.

After consultation with NPD Amoco has agreed to use an Environmental Load Factor of 1.15 combined with Amoco's 100 year wave for the area. (For additional details see Supplement to Hod Development Study and correspondence with NPD.)

Extreme Water Levels

The extreme water level of 14.8 m is the sum of the maximum total tide plus the calculated crest height of the 100 year storm wave. The crest height was determined by methods outlined in reference 2 above.

Air Gap

The 3.0 meters air gap allows a 1.5 meters clearance over and above a total subsidence contingency of 1.5 meters. The Hod platform will not be located over the producing reservoir but over the saddle between the East and West Hod lobes and Amoco's engineers do not predict measurable subsidence at the platform location.

Anode Loading

Amoco intends to account for the wave and current loading on anodes by applying a load factor to the total wave plus current load. The load factor is 5 percent, and is based on criteria Amoco is using in other North Sea developments.

As far as possible, the anodes will be located on the platform jacket so that they are shielded from the NW storm wave and current.

Marine Growth

The proposed marine growth values are based on the average marine growth thicknesses on the Valhall platforms as measured duringthe 1986 underwater inspection.

5.2.7.3 Foundation Criteria

Prior to the start of detail design engineering, a geotechnical engineering firm will develop the required foundation design data, (e.g., axial capacity curves, p-y curves). Amoco plans to use the Cone Penetrometer Test (CPT) method results in developing the appropriate capacity curves. The final pile size will be determined by considering both platform reactions for various load conditions and also pile driveability. Evaluation of available pile driving hammers, soil conditions and underdrive and overdrive allowances will determine the final piling makeup.

5.2.7.4 Fatigue Analysis

The fatigue analysis will consider the effects of in place wave loadings, the effects of wave slam forces on horizontal members in the splash zone, and vortex shedding vibration on members.

Minimum fatigue lives will be determined using calculated stress ranges. For members above the water line, the minimum life required is 15 years, the platform service life. These members are readily visible and accessible for inspection. The fatigue life for members below the water line will be required to be 30 years, or twice the design platform life. This conservatism is to account for the fact that underwater inspections are more difficult and that fatigue problems, if any, generally occur below the water line. Note that the platform has no horizontal bracing in the splash zone.

5.2.7.5 Boat Impact/Progressive Collapse Analysis

Amoco will use 3700 metric tons for the mass of a supply boat in the boat impact analysis. This is the size (with maximum cargo load) of the two supply boats Amoco has on long term charter at Valhall.

5.2.7.6 Dropped Object Analysis

Since all drilling operations will be done with a jack-up rig, the jack-up rig drill floor will be rated for the typical impacts that could occur during drilling. The BOP stack will be mounted by lifting it to the platform main deck area using an external crane and tuggers to locate it over the wellhead. Lift elevations above the deck will therefore be minimized.

After drilling, the only items that will be lifted in the wellhead area over the main deck are wireline units and coil tubing units. Amoco will establish an operating procedure, so that any equipment to be lifted/set over the wells will be lifted or lowered approximately 1 meter maximum height above the deck on the edges of the main deck and swung into or out of the wellhead area. Equipment will not be lifted to larger heights over the wellhead area. This procedure will greatly reduce the probability of deck damage due to an object being dropped.

5.2.8 Valhall Modifications

5.2.8.1 Introduction

Modifications on Valhall will be minimal. The only additions to the Valhall platform will be a pipeline riser, pig receiver, a tie-in to the existing piping system, and communications and telemetry equipment. In the original design of the Valhall Production/Compression Platform (PCP), provisions were made for additional production (including risers and pig receivers) from other fields. Current production levels at Valhall are substantially below the original design. The production rates, including the fluids from Hod, will still be significantly lower than the original design.

5.2.8.2 Process Design

Valhall facilities are designed to process 168,000 BOPD (26,709 Sm^3 oil/d) and 377 MMSCFD (10.7 million Sm^3/d) gas in two trains. The process system includes separation, compression, dehydration, cryogenic expansion, and stabilization. Specification quality gas and a NGL/crude oil mix are delivered by pipeline to Ekofisk. Forecasts indicate that Valhall production will approach 66,000 BOPD (10,493 Sm^3 oil/d) and 147 MMSCFD (4.16 million Sm^3 gas/d) in 1990 when Hod would be brought on stream. Hod production would be about 24,000 BOPD (3816 Sm^3 oil/d) and 27.5 MMSCFD (0.78 million Sm^3 gas/d). Total 1990 Valhall throughput would therefore be about 90,000 BOPD (14,309 Sm^3 oil/d) and 175 MMSCFD (4.95 million Sm^3 gas/d).

Pig receiver, piping, and separator information is shown on Exhibit 5.31 (Drawing P-5070). The only additional equipment to be added to the Valhall platform will be the pipeline riser, pipeline full flow relief valves, pig receiver, and associated piping for tying the Hod production into the separator headers. To accommodate this, the existing laboratory container must be relocated. In order to minimize the slug flow effect from the two-phase pipeline from Hod and improve flexibility in equipment utilization, the header upstream of the inlet separators will be modified such that the total flow can be split between the two separator trains.

The pipeline will have a maximum allowable design pressure above 1395 psig (221.8 bar). The pipeline full flow relief valve is set at 1120 psig (178.1 bar) which takes into account the maximum pressure drop through the pipeline, and allows the relief to discharge before pressure at Hod would exceed 1395 psig (221.8 bar). The relief is located upstream of the platform emergency shutdown valve, thus ensuring that the Hod platform is protected under all conditions.

Existing full flow relief valves on the piping and the separators provide additional insurance that the equipment will not be overpressurized. The existing piping full flow relief valves are set at 240 psig (16.5 bar), and the existing separator full flow relief valves are set at 150 psig (10.3 bar).

5.2.8.3 Utilities - Electrical and Instrumentation

5.2.8.3.1 Controls (Remote Control of Hod)

In order to provide remote control of the Hod platform from the Valhall platform, the following equipment will be required in conjunction with the central control room at Valhall: A Master Control Unit (MCU) and the associated telemetry and microwave equipment. This will also accommodate the Hod production data aquisition.

5.2.8.3.2 Communication and Telemetry

The telemetry and microwave equipment will be located in the existing Valhall radio equipment room. In addition to the telemetry equipment, the required additions will be made to the telephone system to provide for telephones on Hod. The telephone circuit will be carried on the microwave system.

5.2.8.3.3 Safety

A ESD valve will be provided on the Hod pipeline riser on Valhall PCP and will be integrated into the Valhall ESD logic.

5.2.8.4 Structural Design

The Valhall Production/Compression platform structure was designed for future installation of six 10 inch (0.25 m) nominal diameter risers and a riser guard. The 12 inch (0.3 m) nominal diameter riser from the Hod Field is the first riser to be retrofitted to the production platform.

5.3 DEVELOPMENT SCHEDULE AND ORGANIZATION

5.3.1 General

Amoco Norway Oil Company's Construction Department will be responsible for the construction work at Hod and modifications at Valhall associated with the Hod Development project. The Construction Department will be supported as appropriate by the rest of Amoco Norway's organization. In particular, the Internal Control, the Safety Department and the Production Department will be consulted so as to ensure a Hod development consistent with Amoco Norway's standard and the Norwegian Authorities requirements.

5.3.2 Project Schedule

Attached as Exhibit 5.32 is the Overall Project Schedule for the Hod Field Development. It anticipates Norwegian Authorities' approval of the Hod Field Development Project in May 1988 with Detail Engineering for the agreed concept being initiated immediately thereafter. Procurement of long-term delivery items are to begin during the autumn of 1988. Fabrication Contracts for jacket and deck fabrication will be awarded during the fall of 1988. Work in the yards should start during the latter part of the 4th Quarter 1988. Having built the facilities and the jacket, the jacket will be loaded onto a barge and moved to the Hod template site offshore and installed by a heavy lift crane vessel in the late spring of 1990. After having driven and grouted the four piles the deck with preinstalled equipment will be moved to the offshore site and installed immediately thereafter.

The pipeline from Hod to Valhall and the riser at Valhall is planned to be installed during the 3rd Quarter of 1989, followed by a tie-back to the Hod and Valhall risers in May-July 1990. Hydrostatic testing of the pipeline followed by cleaning and gauging pig runs will take place as soon as facilities at both ends of the pipeline are in place and functional.

The critical path events of the above outlined schedule are:

Date 1988	Event
1) February	Submit Field Development and Operating Plan
2) May	Obtain Norwegian Authorities approval of the above plan
3) May	Award Detailed Engineering contract
4) September	Initiate procurement of long term delivery items
5) October	Award fabrication contract
6) November	Initiate fabrication work

Improvement in the above schedule can be achieved if Detail Engineering can be initiated in late March/early April 1988, following either Ministry approval of the project or with the concurrence of the Norwegian Authorities for initiating such Detail Engineering. This can save up to two months on the above given schedule and will as such accelerate Procurement, Award of Fabrication contracts and Initiation of fabrication work by two months to July, August and September 1988 respectively.

5.3.3 Project Organization

The construction work on Hod will be organized with Amoco Norway providing technical direction to the project and employing one multidiscipline Engineering Contractor to do the Detail Engineering work under Amoco's Guidance.

To accomplish the above Amoco Norway will employ Senior Engineers in each of the technical disciplines needed. These Senior Engineers will work under the guidance of Amoco Norway's Construction Manager to ensure compliance with the approved Hod Development Concept and the Construction Department Quality Assurance Plan. Amoco's staff in the Houston General Office and Tulsa Research Center (USA) are available for additional expertise should it be needed. The Construction Department will make use of Amoco Norway inhouse expertise as needed. The Internal Control and Safety Department will be used to ensure/audit compliance with agreed standards, and use of an independent third party to verify the adequacy of the performed engineering will also be made.

Exhibit 5.33 provides the anticipated organization of Amoco Norway's Construction Department during the Detail Engineering Phase. As work is moved into the yards inspectors will be added to the staff to see to it that work is performed in a required manner. Two to three Amoco Site people per site are expected, hence anticipating two fabrication sites this will probably add 5-6 inspectors to the staff at the end of 1988.

On top of the above described Amoco Staff there will be the Engineering Contractor's Staff. However, with the simple concept used to develop Hod, this staff should be of a limited size and will be within the capacity of any medium sized Norwegian Engineering Company. Exhibit 5.34 presents the anticipated overall personnel requirement versus time.

5.3.4 Contracting and Procurement

Amoco Norway will follow previously established principles for the contracting and procurement activities. These services will be purchased based on bids and Amoco Norway will, as in the past, see to it that Norwegian Companies are given an opportunity to participate in such bidding procedures. Through the reporting routines to the Norwegian Authorities such practices can be verified and monitored.

Prior to awarding bid packages for engineering and procurement of essential equipment, the respective companies will be audited by Amoco Norway to ensure competency and adherence to specified standards including an ongoing and effective Quality Assurance System.

Detail Engineering
Amoco Norway will bid the detail engineering work to engineering companies located in Norway. It is expected that the major part of this work will take place during the summer and autumn of 1988. Follow-up work will then take place during the subsequent winter and spring of 1989.

Procurement
Again based on Amoco's normal bid procedure, procurement of some long term delivery items will begin during the early fall of 1988. However, the bulk of the purchase will take place during the winter of 1988/89. Amoco Norway will make an effort to encourage Norwegian bidders for these purchases. It should be noted that it is Amoco Norway's intent to purchase duplicates of proven

Valhall equipment where possible and considering the high Norwegian content in Valhall's purchases, this should ensure a large share for Norwegian goods and services.

Fabrication

The Hod jacket is of such a size, 80 meter tall, 14 by 14 meter at the top and 25 by 25 meter at the bottom, that it can be fabricated in many of the yards in Norway. Likewise the deck, 21 by 23 meter in size with very limited equipment installed can be fabricated by most Norwegian yards. Finally the two building modules are again small (10 x 12 meter) and can be fabricated in any qualified yard.

The above equipment is of such a size that Norwegian yards should have a good opportunity of securing the bids although foreign yards will be invited to tender also.

Installation

Current design calls for installation of the Hod jacket and deck via a semi-submersible heavy lift vessel. There are several of these vessels working in the North Sea.

Hook-up

Hook-up activity on the Hod platform will be insignificant (about a week duration) under current plans. Virtually all of the hook-up, commissioning, and testing will take place in the fabrication yard prior to load out. To minimize the number of interfaces and resultant errors and inefficiencies, Amoco Norway is planning to use the installation crew on the crane vessel to perform this minor amount of offshore hook-up work.

Supply Base and Transport

It is planned that Hod be supplied by the existing Amoco warehouse and transport organization located in Tananger, Norway. During the construction phase, Tananger will be utilized for some material storage but the bulk of material will be handled by the selected fabrication yards.

5.3.5 Quality Assurance and Internal Control

The Hod project "Quality Assurance Plan" is being prepared and will be administrated by Amoco Norway's Construction Department with input from Amoco Norway's Internal Control and Safety Department as appropriate. This manual is based on the Quality Assurance Plan recently employed with success during the 2/4 G Deck Elevation project and is consistent with Amoco Norway's previously approved "Quality Assurance Manual".

Amoco Norway's Construction Manager will be responsible for the quality assurance during the development phase. In addition to using a well qualified engineering staff, the use of independent third party verification of the engineering work performed and the use of qualified Amoco inspectors in the yards will ensure compliance with specified standards. Additionally the Internal Control and Safety Department will periodically audit the work being performed by the fabricator and Amoco's site people to confirm compliance.

For the period up until project approval by the Norwegian Authorities, bid documents for detail engineering will be prepared and the work bidded out but not awarded.

5.3.6 Commissioning and Hand Over

Most commissioning activities will be performed at the fabrication yard with only a minor amount left after installation offshore. It is our intention to have all equipment mounted on the deck prior to loadout from the fabrication yard. Commissioning will be the responsibility of the Construction Department with input from the Production Department. It is planned to divide the platform into systems, prepare check lists for commissioning, perform necessary tests and demonstrations, and then hand over to Production Operations for maintenance. When all systems are complete and commissioning check lists signed off, a formal hand over of the Hod platform from the Construction Manager to the

Production Manager will take place. Since the Hod platform has a minimum amount of facilities, commissioning activities, especially offshore commissioning will be very limited.

5.4 DRILLING AND WELL COMPLETION CONSIDERATIONS

A 12 slot template was installed on the Hod Field in 1981, positioned (N 56°10'35.52", E 03°27'36.62") mid-way between the East and West Hod structures. Well 2/11-6 (ST-1) was then directionally drilled through the template to the East Hod structure. Presently, the well is temporarily plugged and abandoned.

When the platform is installed over the 12 slot template, only 10 slots will be accessible. The jacket will be designed for the installation of 8 conductors. The current plan is to drill 4 additional wells on Hod. Some, or all, of these 4 wells may be predrilled through the template, and temporarily abandoned prior to installing the platform. Production testing is not planned. For any pre-drilling, either a jack-up unit or a semi-submersible rig could be used.

After installing the platform over the template, wells may be tied back and completed and any remaining wells drilled. This will be done using a jack-up unit, equipped for development drilling over the platform.

The question of whether the wells are pre-drilled will largely be an economic decision, weighing the value of earlier production against incurring drilling costs at an earlier stage.

Whichever method is adopted for drilling the wells, a simultaneous drilling and production situation will exist for some time. This aspect is considered in the overall system design as follows:

1. All drilling, casing and completion programs will be designed with the "two barrier" concept in mind. If one of the barriers is lost any producing wells will be shut in.

2. The wellhead protector platform's ESD equipment can be activated from an auxiliary panel placed on the jack-up rig.

3. A risk analysis will be performed to assess the ability of a jack-up to drill, complete and workover the wells safely while producing other wells on the wellhead protector platform. Based on this analysis, appropriate action will be taken. For example, an analysis of impact loading will be performed on both the platform and jack up rig to determine the criteria for shutting in wells during critical lifting operations.

Detailed simultaneous drilling and production procedures will be developed along the same lines as those which have proven successful on Valhall.

Representative drilling depths and times for the four planned additional Hod development wells are presented in Exhibit 5.32. The casing program is a conventional program, similar to that used previously in the Hod and Valhall fields. Setting depths are based on the pressure profile established for the area as illustrated in Exhibit 5.36. Casing sizes will accommodate the planned completion design, and will also provide sufficient flexibility for sidetracking wells, should this be required.

In order to reach both the East and West Hod structures from the template, the directional program specifies target departures of 1100-2800 m at 2600-2700 m true vertical depth sub-sea. Resulting maximum wellbore inclinations are in the range of 30-60 degrees. This is well within the directional drilling experience in the Valhall and Hod area. Kick-off point is planned in the 20 inch (508 mm) casing sections, with 4-8 degrees inclination at the 20 inch (508 mm) casing shoes. Inclination build-up is planned at a rate of 2 degrees per 30 m. Due to completion considerations, the wells will penetrate the reservoir at inclinations of 30 degrees or less. Drop rate is also 2 degrees per 30m.

With only 5 slots initially intended for use, slots may be selected to minimize well interference below the template.

The water sensitivity of the Tor and Hod reservoirs dictates the use of oil base drilling muds. Oil base mud is also considered necessary for drilling directional wells through the overlying shale formations in the 13 3/8 inch (340 mm) and 9 5/8 inch (244 mm) casing sections. The 20 inch (508 mm) casing sections will be drilled with water base mud.

In drilling the Hod wells, no major operational problems are anticipated. This is based on Amoco Norway's previous drilling experience in the Hod and Valhall area. Shallow gas is not anticipated, but appropriate precautions for handling any shallow gas will be taken. Gas-charged shale formations similar to those seen on Valhall are expected above the West Hod structure, and to a much lesser extent above the East Hod structure.

In the lower sections of the wells the range between pore pressure and fracture pressure narrows as illustrated by Exhibit 5.36. Therefore, carefully controlled drilling practices, similar to those developed at Valhall, must be followed to avoid loss of circulation.

Exhibit 5.37 presents a tentative completion design for a well producing form both Tor and Hod formations. The 5-1/2 inch (140 mm) tubing is equipped with a tubing retrievable surface controlled sub-sea safety valve as is used at Valhall, a mudline tubing hanger, a wireline plug nipple profile and a seal assembly, stung into the production packer. The production packer tailpipe consists of a sealbore extension, a second wireline plug nipple profile and 5 inch (127 mm) tubing inside the 7 inch (178 mm) liner. Wells completed in the Tor formation may have a gravel pack assembly installed across the perforations. Those wells completed in the Hod formation only are not planned to be gravel packed.

Planned well completion procedures are similar to those developed at Valhall. Tubing strings will be set in a clean, diesel-based completion fluid. Both the Hod and Tor formations will be stimulated with proppant packed hydraulic fractures, using a purpose-built stimulation vessel. In addition, the Tor formation is expected to be gravel packed under pressure conditions, using a snubbing unit with diesel as work fluid. Since the platform design does not allow for a drilling or workover fluid circulating system it will be necessary to have a jack up rig in place whenever snubbing or workover operation (except wireline and possibly coiled tubing work) are being undertaken. Initial clean up flows from wells would be routed via chiksan or Coflexip lines, through a portable choke manifold and to the jack-up rig's burner. Although we have assumed the above completion procedures for the purpose of this development plan, the possibility of using a different completion technique, such as acid fracturing, will also be investigated prior to drilling the wells.

The time estimates presented in Exhibit 5.35 for the Hod development wells are based on drilling and completion times experienced at the Valhall field. They are based on drilling 4 wells and completing 5 wells, including the presently suspended well 2/11-6 (ST-1) which is renamed E1.

5.5 FIELD OPERATIONS CONSIDERATIONS

5.5.1 Introduction

The plan for developing the Hod Field represents a new direction for field developments on the Norwegian Continental Shelf. Located in the Ekofisk-Valhall Area of the North Sea, the Hod Field is ready to make use of the already established infrastructure in the area. The Valhall "A" production/compression platform was designed to accommodate future small satellite field developments. Hence processing capacity in excess of that required for Valhall "A" was specifically included in the initial development. By taking advantage of these existing facilities, the development of Hod is both timely and less expensive than most other new developments. Provided a cost effective development of the Hod Field can be achieved other small prospects in the area may also be developed.

A concept that can give many of the advantages of both a subsea development and the production platform has been prepared. The concept is labelled as a "normally unmanned, wellhead protector platform" but can be likened to a subsea development with the wellheads elevated to the surface. The wells on this platform would produce unattended and flow, with a minimum of interposing actions, into the pipeline and on to Valhall "A" for processing. Both maintenance and operation of the wellheads can be performed by regular operators and maintenance-crew rather than divers.

By including necessary equipment for well control and metering only, the platform remains modest in size and hence provides for a safe and reliable operation. The above proposed facilities concept is commonly used throughout the world including the UK Sector of the North Sea.

The following section describes the operating philosophy for the platform, and is divided into two sections: production and workover.

5.5.2 Operating Philosophy

5.5.2.1 Production Operations

Once the jack-up is removed, the Hod platform will go into the normal production phase. There will be very little actual activity on the platform. In the normal operating mode, the wells will be flowing at a wellhead pressure of about 500 psig (34.5 bar), and routed to the pipeline via the separator. Later, choke adjustments can be made remotely from Valhall via telemetry.

In the unmanned mode, one generator will be left running with the other on standby to start automatically if the first one trips out.

If both generators are down and not able to start within a predetermined period, then the emergency generator will start automatically. The diesel fuel day-tanks on the generators are automatically fed from the diesel storage system in the crane pedestal. The generators, the ventilation system on the modules and the chemical injection pumps are the only continuously running machinery on the platform.

In the normally unattended mode, Hod will be continuously monitored via telemetry from Valhall. All essential status conditions, alarms, fire and gas indicators, associated shutdown devices, and equipment parameters can be monitored from the Valhall control room. Action to shut down all or part of the Hod platform can also be initiated from the Valhall control room. Choke adjustments and the opening/closing of the wing valves can be done remotely from Valhall via telemetry. Wellhead pressure, temperature, and status will be continuously monitored and relayed to Valhall and to shore.

The Valhall Platform Manager will be in charge of the Hod Platform, exercising his normal Platform Manager duties for this remote location.

There are very few activities which will create a need for people to visit Hod, and most of the activities described below will be coordinated and accomplished during one or two visits per week. These visits will involve a minimum of three people.

Routine maintenance will require one visit per week. Access platforms and convenient rig up will be provided to reduce the time that people have to spend at the Hod platform. While personnel are on the platform to perform maintenance they will refill storage vessels with potable water, chemicals, and diesel from supply boats. A supply vessel with fire-fighting capability will normally be available for support if the need arises while people are onboard the platform.

Another operational aspect which will require visits to the Hod platform will be to switch wells in and out of the separator for test. This is to be done manually with operators staying on board the platform for the duration of the well tests (4-6 hours each). During this time the operator will take samples for analysis of the produced fluid's sediment and water content. In addition the operators will undertake meter proving and routine checks while they are at the platform.

All of the above can be scheduled around inclement weather conditions.

Should personnel become stranded on the Hod Platform, their needs will be provided for. The shelter module will accommodate up to ten people with the dormitory being separated for male/female accommodation via accordion-type walls. Meal preparation facilities are provided as well as an ample supply of canned and dried food. A total of 16,300 liters of potable water are supplied for drinking and washing purposes. In each party sent to Hod, at least two members of the crew will be trained to supervise lowering and operation of the lifeboat, to give first aid, and to operate the radio equipment on board the platform. Direct telephone links between Valhall and Hod will be available and will be the primary means of communication while people are at Hod.

In summary, it is expected that for 5-6 days per week Hod will be unmanned and all operational decisions that may be required will be taken at Valhall.

5.5.2.2 Workover Operations

The fact that the Hod wells will likely be completed with propped fracture stimulations and gravel-packs should minimize the need for workovers. However, there may still be cases where well intervention is required for optimum management of the reservoir.

The workover phase can be divided into two categories. Those workovers requiring the use of a jack-up rig will be operated in the same manner as that described in the "Drilling and Well Completion Considerations", Section 5.4. Wireline and coiled tubing work can be done from the platform itself.

Wireline work would be done from the main deck. A fully self-contained logging unit including power pack would be brought to the platform and lifted onboard via the crane. One day can be used to rig up the unit and pressure test the lubricator so that the required wireline work can be completed the next day.

Coiled tubing work can also be done from the platform and would involve similar procedures to those for wireline work.

In both cases the complement of personnel would be kept below ten. The work schedule would be one or two twelve-hour shifts per day, with personnel being shuttled back and forth from Valhall. A stand-by vessel with fire-fighting ability would always be present during these operations.

Most stimulation jobs would be done as part of the initial completion when the jack-up rig is still present and able to support this work. The existing facilities are not designed for performing unsupported snubbing operations at Hod. Should snubbing work be required, this would be done from a jack-up rig.

5.5.3 Operations Organization

The present Valhall Production Operations Department will assume the responsibility for the operation and maintenance of the Hod Field installations following handover from the Construction Department. Once in the operating mode, the organization structure of the existing Production Operations Department will only be affected slightly by the addition of the unmanned Hod Platform tied in to the Valhall facilities.

The organizational changes will occur at the technician level at the Valhall installation, Exhibit 5.38. The various discipline supervisors will assign specific technicians to the operating and maintenance duties of the Hod facilities.

5.5.4 Maintenance Management

Maintenance on the Hod Field installations will be planned, organized and controlled utilizing the COMPASS system which is in operation for the Valhall Field operations.

During the detailed design phase, the Construction Department will draw on the resources in the Production Operations Department. Thus, the experience gained from the Valhall Field operations can be incorporated in the new installations, and to prepare for a smooth transition from the project to the operational phase. In specific cases, personnel from the Production Operations organization can be assigned duties in the project group.

5.5.5 Management and Contingency Manuals

The structure of the existing management manuals developed for the operation of the Valhall Field will be revised to incorporate the operation of satellite fields linked to Valhall. Appropriate sections covering the Hod Field will be included as required.

The structure of existing plans for emergency preparedness will be retained with the necessary additions and bridging documents included as appropriate depending on which phase the project is in (installation, drilling, production/maintenance and workover operations).

5.5.6 Supply Base and Transport

Satellite fields in the Valhall area will be served from the Tananger base facilities set up for the operation of the Valhall Field. The existing procedures for equipment purchase, storage, handling and transport will be used. The existing supply service has ample capacity and it is not anticipated that there will be a need for additional personnel as a result of the development of the Hod Field.

The helicopter transportation from shore to the fields will be operated out of Sola/Stavanger. The administration of flights will be handled by the existing organizations at Valhall and onshore. These in turn will coordinate with administrative personnel at the service vessels that may be located at the Hod Field in the different phases of operation (installation barges, drilling rig or other vessels).

Inter-field helicopter transportation may be conducted with regular flights or with dedicated shuttle helicopters located either at Valhall or within the Greater Ekofisk area.

6 SAFETY EVALUATION

6.1 INTRODUCTION

This Section represents a considerably abridged summary of the Conceptual Safety Evaluation Study conducted for Hod and included in Section 8.0 of the Hod Development Study dated November 1987. For further details reference should be made to the original study. Amoco's corporate Safety Department in Naperville, Illinois, USA was used to independently verify the assumptions, methods and calculations of this report. Their analysis is included at the end of the main Study. Further details on information requested by NPD in their response to the Hod Development Study will be addressed in a Supplement to the Hod Development Study.

6.2 PHILOSOPHY

Hod is intended to be a normally unmanned wellhead protector platform. It shall incorporate systems to limit the potential for loss of life, injury, pollution, or major structural damage. Reliable process safety and fire and gas detection/shutdown systems will, when combined with a limited hydrocarbon inventory and severely restricted areas where either liquid or gaseous hydrocarbons can collect, form the basis of an inherently safe design. Small water based personnel protection systems will be included in order to provide for an emergency contingency.

6.3 OBJECTIVE

The objective of the Conceptual Safety Evaluation was to show, through quantitative evaluation, that the philosophy described above is valid. The quantitative evaluation was carried out by first identifying potential accidental events, or hazards, then calculating the probabilities of such events occuring. Finally, the effect of these hazards, and an evaluation of their consequences was conducted. This allows conclusions concerning the acceptability, or otherwise, of accidental events based upon an acceptance criteria. In cases where assumptions were needed, or there were a range of estimates, the most conservative values were systematically and deliberately utilized.

6.4 ACCEPTANCE CRITERIA

The authorities have acceptance criteria relating to the safety of personnel, pollution and platform collapse. For the purposes of this Study the NPD's "Guidelines for Safety Evaluation of Platform Conceptual Design" was used to define the acceptance criteria for the risk of occurence of accidental events concerning any of the identified consequences. The acceptance of the risk of loss of capital investment or revenue is carried by the Amoco/NOCO Group.

6.5 HAZARD ANALYSIS PROCEDURE

The hazard analysis procedure is divided into three areas:

1. Identification of Hazards (accidental events)
2. Evaluation of Risks
3. Evaluation of Hazards

The hazards, or accidental events, that were evaluated in detail in the Study were defined through a series of meetings bringing together the experience of personnel from all areas - design, operations, and construction. It is believed that the hazards evaluated in the Study represent all accidental events which either have a known history of occurance, or which were considered to be sufficiently severe in terms of potential loss even if there is little history of occurance.

The evaluation of risk was applied to each of the accidental events. This was a two stage procedure requiring an estimation of the frequencies of each event, followed by calculation of probabilities for all possible outcomes. Both stages were represented in the form of Event Trees.

The evaluation of the hazards assumed that the event had occured, and then took the form of the calculation of quantitive models for each event. This typically took the form of a calculation to determine the radiant heat flux from, say, a hydrocarbon pool fire. Then, calculations were made which allowed the evaluation of the effect of the hazard on its surroundings. That is, for example, the temperature increase in an item of equipment due to incident radiant heat, the time to reach a steady state temperature, and the assessment of the consequences resulting from this temperature increase.

6.6 IDENTIFICATION OF ACCIDENTAL EVENTS

An accidental release of hydrocarbons from the system as represented in the conceptual design will result in one of the following; 1) release of liquid; 2) release of gas; or 3) release of a liquid/gas mixture. The way in which any release discharges to atmosphere is dependent upon the operating pressure, and the size and type of leakage source. At an operating pressure of between 1000 psi (69 bar) to 405 psi (28 bar) depending on area, any release will initially have a high momentum and therefore a gas release will form a jet of gas and a liquid release will form a "spout" of liquid.

Therefore, two types of hydrocarbon fire hazard can be identified. These are the liquid pool fire, and the gas jet fire.

Liquid Hydrocarbon Pool Fire

There are three items of process equipment under which drip pans will be provided. These are the production separator, meter prover and the pig launcher. Of these the production separator drip pan represents the more serious hazard, mainly due to the volume of hydrocarbon present in the separator, and the greater size of its drip pan. It should be noted that these drip pans are the only means whereby liquid hydrocarbons could collect on the Hod platform as the decks throughout the platform will be constructed of open steel grating.

Therefore, the only other conceivable scenario for a hydrocarbon pool fire would be where a leak collects on the surface of the sea beneath the platform and is somehow ignited. However, any oil spill onto the sea would be rapidly dispersed by wave action and by the wind. Also, the possibility of ignition of such a spill will be extremely small as the most common ignition sources are not present since there is no flare - a frequent cause of ignition.

Gas Jet Fire

The typical wellhead flowing pressure will be less than 1000 psi (69 bar) reducing, via choke valves on each flowline, to approximately 405 psi (28 bar) at the header and beyond.

The factors which directly affect the severity of any consequences as a result of a gas jet igniting are system pressure, leak size, release rate, length of jet formed and the orientation of the resulting flame.

Two events have been studied in detail.

1) A gas release from a wellhead or flowline, with the resulting flame impinging adjacent wellheads.

2) A gas release from the lower pressure part of the system, with the resulting flame impinging (or affecting through radiation) adjacent wellheads.

For each of these events (gas and oil leaks) various sizes of leak and different system pressures were investigated. In the case of the liquid pool fire the effects are assessed on the separator itself, the nearby wellheads and the escape routes. Likewise, the gas jet flame scenario was assessed by its effect on the wellheads, platform structure and the escape routes.

6.7 EVALUATION OF HELIDECK ACCIDENT

The frequency of accidents involving a helicopter is given by 3 x 10^{-7}/kilometer flown.
The distance from Valhall to Hod is 13 km and it has been estimated that up to 150 trips per year may be required. Therefore, approximately 26 km x 150 = 3900 km would be flown each year. This produces a probability of 1.17 x 10^{-3}. This value includes all accidents during flights as well as take-off and landing.

As the study was primarily concerned with accidents which occur during take-off and landing at Hod, the relative time used in landing and take-off at Hod has been used to calculate probabilities of such accidents occuring. Assuming 10% of flying time is spent during take-off and landing at Hod, the frequency becomes (1.17 x 10^{-3}) x 0.1 = 1.17 x 10^{-4} per year.

An event tree was produced to show the possible development of this event into various outcomes. For example, the probability of fatalities resulting from a helicopter crash onto the helideck was calculated to be 11.16 x 10^{-6} per year. The above calculated probabilities have been supported by additional calculations based upon actual statistics (numbers of offshore landings and take-offs, details of accidents combined with the helicopter accident frequency used above).

6.8 CONTINGENCY MEASURES (Water based Personnel Protection)

In order to comply with the requirements of "Emergency Preparedness" water based personnel protection systems will be provided on the platform. These systems are specifically designed to suit the purpose of emergency preparedness on Hod and consist of three small deluges systems in the wellbay/process area supplemented by three hose-reels (two outside the firewall on the cellardeck and one on the main deck next to the helideck stair.) In addition a two monitor foam system per NPFA 403 will be provided at the helideck, one at each exit.

The above water based contingency system is not accounted for in the herein described numerical safety assessment. But it should be clear that this water based personnel protection system will as a secondary affect also act as a fire-fighting system and hence reduce the impact of a fire on nearby equipment and structure.

6.9 EVALUATION OF EVACUATION SYSTEM AND EMERGENCY SHELTER SAFETY

6.9.1 Evacuation System

The facilities provided for the purpose of evacuation are as follows:

a) One lifeboat sized for 20 men. This lifeboat will be located at main deck level to the North of the shelter module and under the helideck. Launching will be done with the boat oriented to the North, away from the platform, to expedite escape.

b) One combined pick-up craft/liferaft will be located off the cellar deck level on the east side of the equipment module and will be davit launched.

c) At each of the above evacuation stations 5 life vests and 10 survival suits will be provided.

d) Two ladders from the cellar deck running down the North-East and North-West platform support legs to the spider deck level are provided to allow evacuation of personnel to the sea in the event that the other routes (as listed above) are not available.

Therefore there are four possible alternative routes for evacuation. The first evacuation route, by two separate stairs, is to the helideck. If a helicopter is not available, cannot land safely, or access to the stairs is blocked, then the next alternative, and primary escape route can be used. This is the lifeboat station behind the shelter module. As can be seen from Section 8.0 of the Hod Development Study this is well sheltered from the heat radiation expected from any fire in the wellhead/process area, and would give ample time to evacuate safely. Failing this the secondary escape route could be used. This is the liferaft station on the East side of the cellar deck. The effects of heat radiation due to a fire in the wellhead/process area, are fairly severe in this area (see Development Study), and unless evacuation were conducted rapidly serious burns could be possible. However, in the event of a fire in the wellhead/process area the main escape route would be from the lifeboat station on the main deck. Therefore, for personnel to be forced to use the liferaft a second fire or incident would have to occur simultaneously either at the North end of the cellar deck or the main deck.

In the extremely unlikely event of two simultaneous fires making the two main escape routes untenable, then either of the two ladders to the spider deck level could be used.

In summary, it is concluded that due to the low frequency of manning, the low numbers of personnel involved, a maximum of ten, the short escape distances due to the compactness of the platform, and since personnel would only be working on the platform if weather is good, the evacuation system provided is acceptable. An evaluation of the possible effects due to the weather on each of the escape modes will be conducted in a supplementary report to the Hod Development Study.

6.9.2 Emergency Shelter Safety

The only cause for concern with respect to the level of safety provided for the emergency shelter module is that no sprinkler system is provided.

As the lack of combustible material in such a module would limit the severity and duration of a fire the chances of a fire in this

module affecting anything outside are small. Therefore, sprinklers are not necessary for the protection of property as the loss of this module is considered as an acceptable risk by the Amoco/NOCO Group.
However, in such occasions where people can be asleep the use of sprinklers has a second function, the protection of life. It is considered that the only time where life would be at risk in the event of a fire in this module would be if the persons are asleep. As has been estimated there are only approximately 8 days per year where personnel might have to stay overnight due to bad weather. Therefore, the probability that the module is occupied by personnel overnight is 0.022 (8/365).

The maximum number of personnel that would be sleeping in the module is ten, although this is more likely to be less. Even ten people is a small group and would require only a minimal time to escape any fire.

The module is very small and provided with the necessary alternative escape routes, automatic detection equipment, and portable fire extinguishers. It should be noted that it is also intended to prohibit smoking within the sleeping area.

These facilities are considered to provide the necessary level of safety when the size of module, frequency of occupancy, small numbers of occupants, and the limited fire severity are taken into consideration.

6.10 CONCLUSIONS

As stated in Section 6.3, the objective of the Study was to evaluate, and ultimately to justify the conceptual design for the Hod platform.

This justification has its basis in quantitative analysis of the risks associated with the design and operation of the platform. From Section 6.4, the means to justify the risk is through comparison with an acceptance criteria. For risks concerning loss of life, pollution, or major structural damage (defined here as secondary effects) the acceptance criteria as defined in the NPD document, "Guidelines for Safety Evaluation of Platform Conceptual Design", has been applied. That is, the total probability of the occurance of any type of accidental event shall not exceed 10^{-4} per year.

Where accidental events do not cause loss of life, pollution or major structural damage the acceptance and financial consequences of such risks is carried by the Amoco/NOCO Group. From the probabilities calculated by the event tree method a summary of the results for each type of accidental event is produced below in Table 6.1.

TABLE 6.1

PROBABILITIES OF OCCURANCE (x10^{-6} per year)

Accidental Event	Reference *	Fatalities Nos. Killed	Fatalities Loss of Life	Pollution	Secondary Effects
Pin hole Leak (gas)	8.2.3.3.1.A Appendix 5A	0	0	N/A	0.81
Gasket Leak (gas)	8.2.3.3.1.B Appendix 5B	1	0.72	N/A	13.28
Inst. Conn. Leak (gas)	8.2.3.3.2.C Appendix 5C	1 or 2	1.83	300(air)	7.95
Pipe rupture (gas)	8.2.3.3.1.D Appendix 5D	2 or 3	0.02	0.37(air)	0.19
Blowout	8.2.3.3.1.E Appendix 5E	2 or 4	39.3	35.7 (sea)	13.00
Pin hole Leak (oil)	8.2.3.3.2.A Appendix 5F	0	0	N/A	0
Gasket Leak (oil)	8.2.3.3.2.B Appendix 5G	0	0	N/A	22.20
Inst. Conn. Leak (oil)	8.2.3.3.2.C Appendix 5H	0	0	270 (sea)	1.65
Pipe rupture (oil)	8.2.3.3.2.D Appendix 5I	1	0.02	0.34 (sea)	0.06
	Totals:		41.89	300.37: Air 306.04: Sea	
Helicopter Crash	8.2.5 Appendix 5J	2,4 or 8	11.16	N/A	7.50

* All references apply to Section 8.0 of the Hod Development Study dated November 1987.

In this table each different accidental event is listed down the margin and beside each event are listed the probabilities of occurence related to the three consequences (loss of life, pollution, secondary effects) which have been considered. Note that for significant pollution only leakages associated with instrument connection failures, or worse are considered.

Not included in this table are accidental events associated with ship impact, jack-up rig operation and the Valhall tie-in. In the original Study these items were not dealt with as they were considered to represent a sufficiently small level of risk. However, these events will be addressed in a supplementary report to follow.

The entries for loss of life, and pollution have been taken directly from the Hod Development Study. The third consequence, major structural damage, is not implicitly defined. Instead, a consequence indicated as secondary effects has been used. This consequence implies a domino effect leading from the initial event. Domino effects could mean that a wellhead is subjected to fire, or that a platform support leg is subjected to fire, etc. However, each of these need not necessarily cause major structural damage. For each accidental event the secondary effects predicted have been assessed in the Hod Development Study. Therefore, reference to the Study will reveal whether structural damage could be expected as a consequence of secondary effects for each accidental event.

From Table 6.1 it has been shown that no single type of accidental event, or even all types of accidental events examined to date (with the exception of pollution), exceed the NPD's limit of 10^{-4} per year. Additionally, the small inventory of hydrocarbons on the platform and in the pipeline limit the potential size of a oil spill to approximately 250 m^3.

As noted above, the only possible exception to the NPD's requirements is that of the significant sea pollution (3.06×10^{-4}).

However, the very pessimistic estimation of frequencies and probabilities used in the event trees should be remembered, and the order of magnitude is correct. NPD indicate that the 10^{-4} target should be considered as only being an indication of the required order of magnitude. Therefore, this event is also considered to meet the NPD's regulations.

Furthermore, it should be noted that where assumptions have been made in the study such assumptions have always been assessed pessimistically. Therefore, the results obtained are regarded as also being pessimistic, i.e. worse than would realistically be expected.

From the Hod Development Study many of the accidental events would take a considerable time (over 1 hour in some cases) to cause the major structural damage predicted. This time factor ignores the benefit of the water based personnel protection system which will limit the intensity of a fire and hence cool the nearby equipment and structural members. In addition structural damage could be avoided by the intervention of firefighting vessels from Valhall and elsewhere. These vessels are always available and the maximum time to reach Hod varies between 1/2 hour and 1-1/2 hours. Therefore, in many cases supplemental firewater from the supply boats would be available to mitigate the secondary effects. For many manning functions there will always be a boat actually on station at Hod.

In order to draw a comparison with other occupations the total probability of fatalities due to process accidents can be converted into an FAR number (Fatal Accident Rate). From Table 6.1, the total probability of a fatal accident resulting from such accidents is 41.89×10^{-6} per year. The total manhours expected to be worked on Hod in a typical year is 6264. Therefore, the FAR is given by $41.89 \times 10^{-6}/6264 = 0.60 \times 10^{-8}$ per manhour. The FAR numbers associated with fatal accidents resulting from helicopter take-off and landing manoeuvres is given by 11.16×10^{-6} (from Table 6.1) divided by 133.3 manhours (derived by assuming 5 minutes associated with taking-off and landing, and an average of 4 persons per trip) = 8.37×10^{-8} per manhour.

The equivalent statistic for general industry is 4×10^{-8}, or 12×10^{-8} for the construction industry. This is a clear indication that the life safety risk associated with working on Hod is low for such an environment.

The figure of 41.89×10^{-6} per year for fatal accidents presents a misleading picture because of the disproportionate contribution by the blowout scenario (39.3×10^{-6}). This is misleading as blowouts are generally a function of downhole tool integrity and drilling practices rather than platform design.

Finally, from the assessment of fatalities it is apparent that most fatalities predicted are as a result of a release igniting immediately and the personnel present not having time to escape. This is significant in that firewater systems would not be able to prevent such fatalities, as they cannot react quickly enough in such situations. However, the water based personnel protection system provided will protect people who are not able to escape, but survived the initial incident and will allow rescue of such personnel.

7 ECONOMIC EVALUATION

Note: Abbreviations and conversion factors are listed after Table of Contents.

Compared to other fields on the Norwegian Continental Shelf, the Hod Field is small in size, containing only 25.4 million barrels (4.04 million Sm^3) of recoverable oil. Despite this low reserve figure, the field can be developed economically because of two factors:

- Most of the transportation and processing facilities for the Hod Field are available in the form of the Valhall Production/Compression Platform and the Ekofisk pipeline and processing systems. This existing infrastructure helps to minimize the investments required to develop the field.

- The proposed unmanned platform development concept further reduces the capital and operating cost requirements compared to conventional concepts.

Economics for the field are based on the production profiles described in Chapter 4 and the field development concept described in Chapter 5. With capital investment on $85.8 million unescalated ($94.3 million escalated), and assuming an oil price of $17.50 per barrel and five percent per annum price and cost escalation, the development is expected to yield a relatively attractive internal rate of return (IRR) of 20 percent, and a present value at a 15 percent discount rate (PV15), of $8.7 million. This present value increases to $21.4 million at a discount rate of 10 percent (PV10). Base case economic results and sensitivities to those results are summarized in Exhibit 7.1, and Exhibit 7.2 is an annual data sheet showing revenues and expenditures on a yearly basis.

Economics for the Norwegian government are also attractive. Before taxes, the project earns an IRR of 35 percent for the Amoco/NOCO Group with a PV15 of $47.3 million and a PV10 of $70.1 million.

Escalated total taxes payable to the State amount to $75.7 million and have a PV15 of $38.6 million. In addition, the 10 percent Net Profit Share payable to Statoil totals $16.8 million (escalated). These economic results, explained below, indicate that the Hod Field may be developed profitably.

7.1 BASE CASE TECHNICAL ASSUMPTIONS

7.1.1 Sales Product Volumes

The Sales Product Volumes used in the Base Case economic analysis are tabulated in Exhibit 7.3 (English units in Exhibit 7.3a, and metric units in Exhibit 7.3b). These tables list the annual sales volumes as a daily average rate for each year. The Sales Oil volumes are generated directly from the reservoir model described in Section 4.5, after adjusting for downtime. The Sales Gas volumes are the model-generated produced gas volumes less fuel gas and NGL's recovered on Valhall. The Sales NGL volumes are generated from the produced gas volumes assuming the same NGL yield as the historical Valhall yield.

7.1.2 Capital Expenditures

The Base Case Investment Schedule for the Hod Field development is shown in Exhibit 7.4. All figures are in unescalated mid-1987 U.S. dollars. For the economic calculations, these costs have been escalated at 2.5 percent for 1988 and at 5 percent per annum thereafter.

The basis for this investment schedule is as follows :

A. Development Well Costs :

These costs of $33.4 million (unescalated) were estimated on the basis that four development wells would be drilled after installation of the platform in 1990, using a cantilevered jack-up rig. It is assumed that one of these wells, drilled on West Hod to try to prove up reserves in the Tor Formation, would not discover the Tor

Formation but would be completed as a Hod producer. The presently-suspended delineation well 2/11-6 (ST-1) on East Hod would also be tied back to the platform and completed in 1990.

However, the possibility of pre-drilling the wells in 1989 will also be investigated, and the more beneficial alternative will eventually be implemented.

B. Construction Costs :

These costs of $52.4 million unescalated were based on the concept of a normally unmanned platform. They are higher than those quoted in the cover letter transmitting the "Hod Development Study" report to the Norwegian Petroleum Directorate in November 1987. Subsequent discussions with the NPD have resulted in some design adjustments which have been reflected in the investment schedule shown in Exhibit 7.4 as the Base Case investment schedule.

7.1.3 <u>Operating Expense</u>

A tabulation of operating expenses by year is shown in Exhibit 7.5. These costs have been escalated in the same manner as the capital expenditures.

7.1.3.1 Workover and Well Repair

It is assumed that one workover will be required every year on one of the development wells, i.e. each well will be worked over once every five years. A jack-up rig would be mobilized to do the work. The cost of performing this work is estimated to be $5.5 MM (1987 $) per year.

Workover and Well Repair expenses are assumed to start in 1991 and end in 2002, i.e. two years prior to field abandonment. At this point it is believed that further workovers would not pay out. Escalated workover costs are shown in Exhibit 7.5.

7.1.3.2 Direct Production Expense

The figures assumed for Direct Production Expense are as tabulated below. These costs cover the following manpower and services requirements:

- Offshore Personnel Salaries
- Maintenance Costs
- Transportation
- Helicopter shuttling
- Materials and Supplies
- Jacket and Pipeline inspections
- Other offshore-related expenses

All the costs listed in the table below are in 1987 U.S. dollars. Escalated costs are shown in Exhibit 7.5.

Year	Expense ($ MM)
1987-1989	0
1990	2.3
1991	2.8
1992	2.6
1993-2001	2.4 per annum
2002	2.6
2003	2.7
2004	2.8

7.1.3.3 Indirect Operating and Administrative Expenses

This category of expenses covers the onshore manpower and services required for efficient development of the field. These costs are tabulated in Exhibit 7.5 (escalated).

7.1.3.4 Construction and Operating Insurance

Insurance costs are expected to be as follows (all figures in 1987 $) :

Construction:	Platform - $297 M
	Pipeline - $370 M
Operating:	Platform - $397 M per annum
	Pipeline - $ 59 M per annum

The escalated costs are shown in Exhibit 7.5.

It is envisaged that the Pipeline Construction premium would be paid in 1989 and the Platform Construction premium in 1990.

7.1.3.5 Tariffs

The tariff costs incurred for transportation and processing of produced hydrocarbons from Hod may be divided into two categories, viz.

- Third Party Tariffs
- Valhall Facilities Tariffs

The Third Party tariffs are paid to the various groups that own the Ekofisk Center, the oil and gas pipelines from Ekofisk to shore and the onshore terminals and processing plants. These tariffs have been calculated for Hod in the same manner as the equivalent tariffs for Valhall.

The Amoco/NOCO Group members have agreed that the issue of what tariff amount the Hod owners shall pay for transporting and processing the Hod production using the Valhall Facilities shall be finally decided by submission to a single arbitrator, and that the outcome of such arbitration will either be that Amoco/Amerada Hess/Texas Eastern's or NOCO's most recent compromise proposal goes into effect. These proposals are as follows: Amoco/Amerada/Texas Eastern have proposed that the Valhall Facilities Tariffs shall be based on a sharing of depreciation and operating costs of the Valhall Facilities on a relative production throughput basis for the processing of Valhall and Hod Field production. These tariffs will be paid by the Hod owners to the Valhall unit. NOCO, on the other hand has proposed that the Hod owners shall pay a fee based on operating expenses on a shared production throughput basis.

Exhibit 7.5 shows the values of the tariffs per unit volume for oil, gas and NGL, as well as total tariff costs based on the production profile in Exhibit 7.3a and 7.3b. Both Third Party tariffs and Valhall Facilities Tariffs are shown. The Valhall Facilities tariffs presented herein correspond to Amoco/Amerada Hess/Texas Eastern's proposal as outlined above. Whichever of the two proposals will be implemented, i.e. Amoco/Amerada Hess/Texas Eastern's proposal or NOCO's proposal, is subject to a final decision in the above-mentioned arbitration, and is not expected to have any significant impact on the economics.

7.1.3.6 Abandonment

The estimate for abandonment cost is $12.5 MM (in 1987 U.S. dollars) which is incurred in the year 2005. Exhibit 7.5 shows the escalated abandonment cost. The economics assume that the government will pay 67 percent of abandonment costs in lieu of a tax deduction.

7.2 BASE CASE ECONOMIC ASSUMPTIONS

Hod Field economics are calculated on a point-forward basis as of 1 January 1988, although some minor costs already incurred in 1987 have been included in the expenditures for 1988. All prices and costs are estimated in U.S. dollars, escalated to account for inflation, and cash flows are shown on the same basis.

Taxes are calculated as though all partners will be in a tax-paying position beginning in 1988 for both Corporation Tax and Special Tax. A sensitivity indicates somewhat less attractive economics for the project on a stand-alone basis, i.e. paying taxes beginning in 1991. Dividend deductions against State taxable income are included, and dividend withholding taxes of 15 percent were assumed. This taxation is intended to represent the approximate tax-paying situation for Amoco, Amerada Hess and Texas Eastern. NOCO's tax position would of course be somewhat different. Present values and IRR's are calculated using continuously compounded discount rates and assuming cash flows which are uniformly distributed throughout the year.

7.2.1 Prices

Several product price cases have been tested. For the Base Case, the oil price is forecast at $17.50 per barrel at the beginning of 1988 and is escalated at five percent per annum thereafter. In this forecast, investment and operating costs are escalated at the same five percent rate. A low price sensitivity forecasts $14 per barrel of oil with five percent escalation, and a high price sensitivity assumes that oil prices increase at seven percent per annum while costs increase at only five percent. A fourth price sensitivity assumes $17.50 per barrel with no price or cost escalation. Although economics are quite sensitive to price assumptions, the low price case still generates a rate of return of 11 percent, indicating that the project bears a fairly low risk for development.

Hod Field natural gas sales are subject to the terms of the existing contracts for the Valhall Field. Based on recent pricing experience for Valhall gas, the Base Case price for natural gas is set conservatively at 80 percent of the previous year's barrel of oil equivalent (BOE) price. One MCF is equal to 0.172 barrels of oil equivalent, or 1000 Sm^3 of gas is equal to 0.966 m^3 of oil equivalent. The 1991 price on this basis is $2.66 per MCF.

Hod gas prices will follow Valhall gas prices, which by contractual terms should average close to the BOE price with a time lag of 6 to 12 months. However, the gas is priced for European markets in several currencies, and market conditions or foreign exchange fluctuations can cause the price to deviate substantially from this trend. As a sensitivity, gas prices were set at the full BOE price for the previous year.

NGL prices are set at 50% of the previous year's oil price. This forecast is also based on recent experience and contractual provisions.

7.2.2 Rates of Exchange

Product prices are forecast and costs are estimated in U.S. dollars. For simplicity, rates of exchange are assumed constant at $1.00 equals 7.0 Norwegian kroner.

7.2.3 Financing Assumptions

For the purposes of evaluating the economics of Hod Field development, it was assumed that no debt financing would be employed. Each partner in the field would be expected to make its own decisions regarding the attractiveness of debt financing based on tax positions, attitudes toward debt, and the interaction of debt financing with dividend deductions which are assumed available in tax calculations for the economics.

7.3 FIELD DEVELOPMENT OPTIMIZATION

Since the discovery of the Hod Field in 1974, several evaluations of the development potential of the field have been carried out, involving different development concepts. Three representative cases are described in Section 5.1. These concepts are outlined below, together with an estimate of the peak production rates and capital costs in present-day money for each case. In cases where the development involved more wells than those presently envisaged, the capital costs have been prorated to reflect the current plan for five wells :

Case 1 - Drilling, Production and Quarters (DPQ) platform with 12 wells, minimum process facilities and separate oil and gas pipelines to Valhall.

Case 2 - Production and Quarters (PQ) platform with a workover rig, 4 wells, minimum process facilities and a single pipeline to Valhall.

Case 3 - Four subsea wells with individual pipelines to Valhall, plus a single service line from Valhall. All processing done on Valhall.

Case 4 - Present Base Case.

Case	Peak Annual Rate		Investment ($MM 1987)
	MBOPD	Sm^3/day	
1 (DPQ)	20.5	3260	366.0
2 (PQ)	13.8	2200	279.0
3 (Subsea)	13.8	2200	169.5
4 Present	14.5	2300	94.3

Note: Legend
D: Drilling
P: Production
Q: Quarters

The above table shows that the investment required for the least expensive of any of the previously considered development concepts is almost twice that of the present concept in 1987 money. This emphasizes even more strongly that, given all the information presently available, it is essential to maintain investment costs to a minimum for the project to remain economic. Any upgrading of the concept to something resembling cases 1, 2 or 3 would result in a large increase in capital expenditure, and the project would become uneconomic.

This argument applies equally well to the installation of secondary recovery and artificial lift facilities. Owing to the small size of Hod, any potential economic benefit from increased reserves due to these enhanced recovery projects would be outweighed by the large increase in capital and operating costs required to install and maintain these facilities. The optimum depletion strategy for Hod, from an economic viewpoint, is that proposed in this document.

As regards the number of wells to be drilled, Section 4.5.5.8 presents sensitivities on the number of wells drilled to develop the Hod reservoir. Economic runs were performed to evaluate these sensitivities versus the Base Case proposed (Section 7.4.2). These results show that the proposed number of wells is optimal for the anticipated reserves and production, but allows the flexibility to add wells to optimize results for higher reserves as more information about the reservoir becomes available during development.

Regarding the transportation of oil and gas from Hod, the proximity of Valhall dictates that pipeline export is the most economic method of transporting both oil and gas. A single pipeline is considered sufficient for this purpose and, since individual oil and gas pipelines would result in a significantly higher investment, the choice was made to use a single pipeline for hydrocarbon export.

7.4 RISK ANALYSIS BY SENSITIVITIES

To assess the impact of uncertainties in economic parameters on the profitability of the Hod project, sensitivities to the Base Case economics were run. These sensitivities addressed variations in the following parameters :

- Product prices
- Production rates and reserves
- Investment costs
- Operating costs
- Tax

The results of all the sensitivity runs performed are summarized in Exhibit 7.6.

7.4.1 Product Prices

The following sensitivities were run :

High Oil Price - $17.50/bbl in 1988, escalated at 7% p.a.
Low Oil Price - $14.00/bbl in 1988, escalated at 5% p.a.
No Escalation - $17.50/bbl in 1988, unescalated
High Gas Price - Base Case plus 25%

7.4.2 Production Profiles

Two main economic sensitivities were run in relation to the expected production profiles and ultimate reserves for the Hod Field.

High Reserve Case - Base Case profile plus 25%
Low Reserve Case - Base Case profile less 25%

In addition, economics were run on all the reservoir model results which investigated the effect of different numbers of wells on field recovery. These various cases are described in Section 4.5.5.8. The results of these economic sensitivity runs are shown in Exhibit 7.7, and they show that the Base Case five-well development is the most economic option regarding the number of wells.

7.4.3 Investment Costs

Two sensitivities were examined with respect to the investment costs of the Hod project, as follows :

High Investment Case - Base Case plus 15%
Low Investment Case - Base Case less 15%

7.4.4 Operating Costs

The following sensitivities were run on the operating costs for Hod, including tariff costs :

High Operating Costs - Base Case plus 25%
Low Operating Costs - Base Case less 25%

7.4.5 Tax

A final sensitivity was run to show the economics of the project if no taxes were payable.

7.4.6 Summary of Sensitivities

The low oil price and low reserves sensitivities resulted in rates of return of 11 and 12 percent, respectively. All other sensitivities resulted in rates of return equal to or greater than 15 percent, the highest being 26 percent for the high reserves case. The Amoco/ NOCO Group believes that these results justify proceeding with the development of the Hod Field as detailed in this document.

HOD FIELD ECONOMIC RESULTS

BASE CASE

Total Oil Production, MMSTBO	25.4
Total Oil Production, million Sm^3	4.04
Total Gas Production, BCF	31.2
Total Gas Production, million Sm^3	883.5
Total NGL Production, MMBBL	3.30
Total NGL Production, million Sm^3	0.52
Total Revenue from Sales, US$ million	769.8
Total Capital Expenditure, US$ million	94.3
Total Operating Expense, US$ million	537.0*
Total Corporation Tax, US$ million	54.7
Total Special Tax, US$ million	9.8
Total Dividend Withholding Tax, US$ million	11.1
Total Taxes, US$ million	75.7
Total Net Profit Share, US$ million	16.8
Total Net Equity Cash Flow, US$ million	62.9

* Excluding Depreciation

RESULTS :

Internal Rate of Return, percent	20
Net Present Value, 15% discount rate, US$ MM	8.7
Net Present Value, 10% discount rate, US$ MM	21.4
Net Present Value, 7% discount rate, US$ MM	31.3

EXHIBIT 7.1

HOD FIELD DEVELOPMENT AND OPERATING PLAN

Base Case Annual Data Sheet

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	TOTAL
FINANCIAL STATEMENT & CASH FLOW																			
Oil, Net MB/D	0.0	0.0	5.6	14.5	8.5	6.8	5.5	4.6	4.0	3.5	3.1	2.8	2.6	2.4	2.2	1.9	1.7	0.0	25.4
Gas, Net MMCF/D	0.0	0.0	4.6	18.7	9.9	7.5	6.3	5.6	5.0	4.5	4.1	3.8	3.6	3.4	3.2	2.8	2.4	0.0	31.2
NGL, Net MB/D	0.0	0.0	0.5	2.0	1.0	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.0	3.3
Crude Oil Price, $/Bbl	17.50	18.38	19.29	20.26	21.27	22.33	23.45	24.62	25.86	27.15	28.51	29.93	31.43	33.00	34.65	36.38	38.20	40.11	
Gas Price, $/MCF	2.07	2.41	2.53	2.66	2.79	3.93	3.08	3.23	3.40	3.57	3.74	3.93	4.13	4.33	4.55	4.78	5.02	5.27	
NGL Price, $/Bbl	7.50	8.35	9.19	9.65	10.13	10.64	11.17	11.73	12.31	12.93	13.57	14.25	14.97	15.71	16.50	17.32	18.19	19.10	
Revenue, $MM																			$MM
Oil	0.0	0.0	39.4	107.2	66.0	55.4	47.1	41.3	37.7	34.7	32.3	30.6	29.8	28.9	27.8	25.2	23.7	0.0	627.3
Gas	0.0	0.0	4.3	18.2	10.1	8.0	7.1	6.6	6.2	5.9	5.6	5.5	5.4	5.4	5.3	4.9	4.4	0.0	102.8
NGL	0.0	0.0	1.7	7.0	3.7	3.1	2.9	2.6	2.2	2.4	2.0	2.1	2.2	2.3	1.8	1.9	2.0	0.0	39.8
Total Revenue, $MM	0.0	0.0	45.4	132.4	79.8	66.6	57.0	50.5	46.2	42.9	39.8	38.1	37.4	36.6	34.9	32.0	30.1	0.0	769.8
Expenses, $MM																			
Tariffs	0.0	0.0	10.0	32.2	19.3	16.7	15.3	14.7	14.7	15.7	16.1	17.4	17.3	17.2	16.4	15.4	14.8	0.0	253.2
Operating Costs	2.9	3.9	7.5	14.4	14.6	15.0	15.7	16.4	17.2	18.1	19.0	19.9	20.9	21.9	23.4	12.8	13.7	0.0	257.3
Net Profit Share	0.0	0.0	0.0	1.3	4.6	3.5	2.6	1.9	1.4	0.9	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	16.8
Financial Book DD&A	0.0	0.0	5.5	20.1	11.8	9.4	7.6	6.4	5.5	4.8	4.3	3.9	3.6	3.3	3.0	2.6	2.4	0.0	94.3
Abandonment (After Tax)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	9.7
Total Expense, $MM	2.9	3.9	23.0	68.0	50.2	44.6	41.2	39.5	38.9	39.5	39.8	41.3	41.8	42.4	42.8	30.8	30.9	9.7	631.3
Income Before Tax, $MM	-2.9	-3.9	22.3	64.5	29.5	22.0	15.8	11.1	7.3	3.4	0.0	-3.2	-4.4	-5.9	-7.9	1.2	-0.8	-9.7	138.5
Norway Taxes																			
- Corporate Tax	-2.1	-4.7	4.5	27.6	9.7	5.7	3.2	2.9	4.8	2.8	1.2	-0.4	-1.0	-1.7	-1.5	2.3	1.4	0.0	54.7
- Special Tax	-1.4	-3.2	1.6	14.7	4.1	1.7	0.3	0.3	1.8	0.5	-0.5	-1.5	-1.9	-2.4	-3.0	-0.3	-0.9	0.0	9.8
- Dividend WH Tax	-0.2	-0.4	0.9	4.0	1.8	1.2	0.9	0.8	0.9	0.7	0.5	0.4	0.3	0.2	-0.5	-0.2	-0.3	0.0	11.1
- Deferred Tax	1.5	5.6	8.2	-3.5	3.2	5.1	5.1	2.0	-4.5	-3.9	-3.5	-3.1	-2.9	-2.7	-2.5	-2.1	-1.9	0.0	-0.0
Total Taxes, $MM	-2.2	-2.8	15.2	42.7	18.8	13.7	9.5	6.0	3.0	0.2	-2.2	-4.6	-5.5	-6.6	-7.5	-0.3	-1.7	0.0	75.7
Profit Contribution, $MM	-0.7	-1.1	7.1	21.7	10.8	8.3	6.4	5.1	4.3	3.2	2.3	1.4	1.1	0.7	-0.4	1.5	0.9	-9.7	62.9
Non-Cash Charges, $MM	1.5	5.6	13.8	16.6	15.0	14.5	12.7	8.4	1.1	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.0	94.3
Cash From Operations, $MM	0.8	4.5	20.9	38.3	25.7	22.8	19.1	13.5	5.3	4.1	3.1	2.2	1.8	1.4	0.2	2.0	1.4	-9.7	157.2
Less: Capital Expenditures, $MM	11.0	30.4	53.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	94.3
Net Equity Cash Flow, $MM	-10.2	-25.9	-32.1	38.3	25.7	22.8	19.1	13.5	5.3	4.1	3.1	2.2	1.8	1.4	0.2	2.0	1.4	-9.7	62.9
Cumulative Equity Cash Flow, $MM	-10.2	-36.1	-68.2	-29.9	-4.2	18.6	37.7	51.1	56.5	60.6	63.7	65.9	67.7	69.0	69.2	71.2	72.6	62.9	

EXHIBIT 7.2

HOD FIELD

PRODUCTION PROFILES

BASE CASE

YEAR	SALES OIL (STBOPD)	SALES GAS (MSCFD)	SALES NGL (BLPD)
1987	0	0	0
1988	0	0	0
1989	0	0	0
1990	5,600	4,600	500
1991	14,500	18,700	2,000
1992	8,500	9,900	1,000
1993	6,800	7,500	800
1994	5,500	6,300	700
1995	4,600	5,600	600
1996	4,000	5,000	500
1997	3,500	4,500	500
1998	3,100	4,100	500
1999	2,800	3,800	400
2000	2,600	3,600	400
2001	2,400	3,400	400
2002	2,200	3,200	300
2003	1,900	2,800	300
2004	1,700	2,400	300
CUMULATIVE PRODUCTION	25,400 MSTBO	31,200 MMSCF	3,300 MBBL

EXHIBIT 7.3a

HOD FIELD

PRODUCTION PROFILES

BASE CASE

YEAR	SALES OIL (Sm^3/D)	SALES GAS ($10^3 Sm^3$/D)	SALES NGL (TONNES/D)
1987	0	0	0
1988	0	0	0
1989	0	0	0
1990	890	130	40
1991	2,305	530	159
1992	1,351	280	79
1993	1,081	212	63
1994	874	178	56
1995	731	159	48
1996	636	142	40
1997	556	127	40
1998	493	116	32
1999	445	108	32
2000	413	102	32
2001	382	96	32
2002	350	91	24
2003	302	79	24
2004	270	68	24
CUMULATIVE PRODUCTION	4,044 $10^3 Sm^3$	883 $10^6 Sm^3$	264 10^3 Tonnes

CONVERSION FACTORS USED

OIL	1 STB	=	0.15897 Cubic meters
GAS	1 SCF	=	0.02832 Cubic meters
NGL	1 bbl	=	0.07937 Tonnes

EXHIBIT 7.3b

HOD FIELD INVESTMENT SCHEDULE

BASE CASE

All figures are in unescalated 1987 U.S. dollars (millions).

	1988	1989	1990	Total
Development Wells	-	-	33.4	33.4
Platform	5.6	15.4	1.4	22.4
Installation	-	-	10.2	10.2
Pipelines	1.8	8.0	1.4	11.2
Facilities	3.1	4.0	-	7.1
Valhall Modifications	0.2	0.8	0.5	1.5
TOTAL	10.7	28.2	46.9	85.8

Total Capital Expenditure (escalated) = US$ 94.3 million.

EXHIBIT 7.4

HOD FIELD DEVELOPMENT AND OPERATING PLAN

OPERATING EXPENSE PROFILE

All figures are escalated U.S.$MM (Gross)	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	TOTAL
CATEGORY																			
Workover and Well Repair	-	-	-	6.5	6.9	7.2	7.6	7.9	8.3	8.8	9.2	9.6	10.1	10.6	11.2	-	-	-	103.9
Direct Production Expense	-	-	2.6	3.3	3.2	3.1	3.3	3.5	3.6	3.8	4.0	4.2	4.4	4.6	5.3	5.8	6.3	-	61.0
Indirect Operating and Administrative	2.9	3.5	4.0	4.0	3.9	4.0	4.1	4.3	4.5	4.7	5.0	5.2	5.5	5.7	5.9	5.9	6.3	-	79.4
Insurances	-	0.4	0.9	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	-	13.0
Abandonment (net after tax)																		9.7	9.7
Unit Tariffs (Third Party)																			
- Oil ($/bbl)	-	-	1.30	1.22	1.38	1.56	1.69	1.93	2.12	2.56	2.94	3.29	3.57	3.83	4.46	4.86	5.42	-	
- Gas ($/MCF)	-	-	0.41	0.42	0.44	0.45	0.44	0.41	0.51	0.60	0.68	0.75	0.83	0.91	0.98	1.06	1.11	-	
- NGL ($/bbl)	-	-	8.31	8.00	7.79	8.33	9.04	9.92	11.36	12.67	14.28	15.99	16.91	18.90	21.09	22.79	25.51	-	
Unit Tariffs (Valhall)*																			
- Oil + NGL ($/bbl)	-	-	1.17	1.18	1.38	1.57	1.81	2.12	2.51	2.90	3.48	4.17	4.50	4.62	4.76	4.92	5.10	-	
- Gas ($/MCF)	-	-	1.50	1.46	1.61	1.76	1.95	2.18	2.48	2.96	3.47	4.17	4.14	4.19	4.28	4.38	4.50	-	
Total Tariffs ($ MM)																			
- Oil	-	-	5.1	12.7	8.6	7.7	7.0	6.8	6.7	7.0	7.2	7.6	7.7	7.4	7.4	6.8	6.5		112.2
- Gas	-	-	3.2	12.8	7.4	6.1	5.5	5.3	5.5	5.8	6.2	6.8	6.5	6.3	6.1	5.5	4.9		93.9
- NGL	-	-	1.7	6.7	3.3	2.9	2.8	2.6	2.5	2.9	3.2	2.9	3.1	3.4	2.8	3.0	3.3		47.1
Net Profit Share	-	-	-	1.3	4.6	3.5	2.6	1.9	1.4	0.9	0.5	0.1	-	-	-	-	-	-	16.8
TOTAL OPERATING EXPENSE (excl. depreciation)	2.9	3.9	17.5	47.9	38.5	35.2	33.6	33.0	33.3	34.7	36.1	37.3	38.2	39.0	39.7	28.1	28.4	9.7	537.0

* These unit tariffs are subject to final resolution in the arbitration mentioned in Section 7.1.3.5.

HOD FIELD ECONOMIC RESULTS

SENSITIVITIES TO BASE CASE

	IRR(%)	Net Present Value,$ MM 15 %	10 %	7 %
Base Case	20	8.7	21.4	31.3
High Oil Price (7% esc.)	23	16.1	32.8	46.2
Low Oil Price ($14/BO)	11	(5.7)	1.9	7.4
No Price or Cost Escalation	15	0.6	8.8	14.9
High Gas Price (+25%)	21	11.0	24.5	35.2
High Rates/Reserves(+25%)	26	22.4	39.8	53.5
Low Rates/Reserves(-25%)	12	(5.1)	2.9	8.9
High Investment Costs(+15%)	17	4.0	17.0	27.2
Low Investment Costs(-15%)	23	13.3	25.8	35.4
High Operating Costs(+25%)	16	0.9	10.1	16.9
Low Operating Costs(-25%)	23	16.3	32.4	45.2
Unconsolidated (Standalone) Tax Basis	18	4.7	16.3	24.9
No Taxes	35	47.3	70.1	87.2
Note: Present Value of Taxes (No Taxes Case - Base Case)		38.6	48.7	55.9

EXHIBIT 7.6

HOD FIELD ECONOMIC RESULTS

WELL SENSITIVITIES

A description of each of the cases studied below is found in Reservoir Engineering Section 4.5.5.8. The cases designated 'A' are sensitivities to the Base Case with no Tor Formation Present in West Hod. The cases designated 'B' address the possible developments if Tor Formation were present in West Hod as currently mapped.

Base - 2 wells in W.Hod, 3 wells in E.Hod

A1 - 1 well in W.Hod, 3 wells in E.Hod
A2 - 2 wells in W.Hod, 2 wells in E.Hod
A3 - 3 wells in W.Hod, 3 wells in E.Hod
A4 - 1 well in W.Hod, 3 wells in E.Hod
(no reserves west of major fault on West Hod)

B1 - 3 wells in W.Hod, 3 wells in E.Hod
B2 - 2 wells in W.Hod, 3 wells in E.Hod
B3 - 4 wells in W.Hod, 3 wells in E.Hod
B4 - 3 wells in W.Hod, 4 wells in E.Hod

Case	Well Cost $MM	W/O Cost $MM/yr	Reserves MMSTBO	$10^6 Sm^3$	IRR (%)	PV15 $ MM	PV10 $ MM	PV7 $ MM
Base	33.4	5.5	25.4	4.04	20	8.7	21.4	31.3
A1	26.4	4.4	24.1	3.83	19	7.7	20.2	30.0
A2	30.4	4.4	24.3	3.86	19	6.8	19.6	29.7
A3	40.2	6.6	25.7	4.09	19	7.8	20.1	29.4
A4	32.0	4.4	21.6	3.43	16	1.9	12.4	20.5
B1	42.6	6.6	37.1	5.90	31	33.5	54.0	69.9
B2	34.6	5.5	36.2	5.76	29	30.6	51.3	67.8
B3	50.6	7.7	38.0	6.04	31	34.8	55.1	70.6
B4	50.6	7.7	40.3	6.41	31	36.6	58.9	76.4

EXHIBIT 7.7

8 ENVIRONMENTAL AND SOCIO-ECONOMIC CONSEQUENCES

8.1 INTRODUCTION

In conjunction with the Field Development and Operating Plan (FD&OP) a Consequence Analysis is required. It is provided as a separate appendix in Norwegian (Konsekvensutredning). This document will be public and be used for the political evaluation of the application for developing the Hod Field. The Consequence Analysis gives a summary of the Field Development and Operating Plan and in addition provides description, evaluation and conclusions on the impacts the execution of the plan may have.

The Hod Field is an economically marginal field which demands cost-efficiency in development and operation. Development is made economic by the Valhall infrastructure already in place. The plan is to install a single wellhead platform above the existing drilling template with one well drilled. Only absolutely essential equipment will be included. The platform's equipment will be simple, straightforward and reliable. Produced oil and gas will be transported through a 13 kilometer pipeline to the Valhall Field for processing. Development of Hod was originally considered in connection with Valhall in 1977, so sufficient processing capacity was therefore provided for on the latter. The Hod platform will normally be unmanned, being monitored and controlled from Valhall.

Investment in field installations, including wells, is estimated to cost about NOK 600 million. Development of the Hod Field in 1988-89 may take advantage of and utilize idle, spare capacity in the construction industry in a period when investments on the Norwegian Continental Shelf will be at a relatively low level.

The operating organization and support functions will be integrated and coordinated with those existing for Valhall in all respects. This will keep operating cost to a minimum. The total operating costs for Hod are estimated to be about NOK 80 million per year.

8.2 ENVIRONMENTAL CONSEQUENCES

A mobile jack-up rig is envisioned for drilling of up to five wells in the base case. This will take less than one year and will result in discharge of oily drill cuttings. The concentrations of oil will not exceed the State Pollution Control Authority (SFT)'s pollution limits. The negative effects will largely be confined to organisms on the seabed in the immediate vicinity of the platform. There will be no continuous liquid or gas discharges from the Hod Platform.

Any produced water will be transported with the oil and gas to the Valhall Field for separation and treatment together with Valhall products. The potential increase in produced water discharge rate is not expected to cause any changes in or disturbances to the marine life.

Amoco will continue to measure hydrocarbon concentration of the discharges, and conduct biological surveys to monitor the biological and chemical environment around the Hod and Valhall platforms.

Any drilling and production operation constitutes a certain risk of larger oil-spills. If a major spill occurred, some seabirds would probably be killed. Number and species would depend on season and weather conditions. During a period of low mackerel stock a major oil spill may have long term impact on the stock, especially if a blow-out lasts through the majority of the spawning-season. Residual quantities of oil reaching shore may have negative effects during a shorter period for any fish-farming activities in the coastal districts affected. The probability for a major oil spill, however, is assesed to be low, and it is unlikely that hydrocarbons will drift to shore.

During normal operations on the continental shelf the negative impact on the fisheriecs would be the loss of fishing areas. Hod Field development will only result in a minor reduction in areas available for fishing, as the field is located in an already developed area. A template marked with a buoy has already been sitting on the seabed at the planned Hod platform location for more than 6 years.

8.3 SOCIO-ECONOMIC CONSEQUENCES

Development of Hod is expected to have positive socio-economic effects. The Hod project is considered to be socio-economically favorable in that it can make use of spare capacity and know-how during all phases (construction and operation) when activity within the offshore petroleum industry is predicted to be low.
While other operating organizations are expected to be on decline during Hod's projected time period, the Hod development will provide an opportunity to make use of existing operating capacities and expertise.

No potentially negative socio-economic consequences of the Hod development have been identified.