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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org


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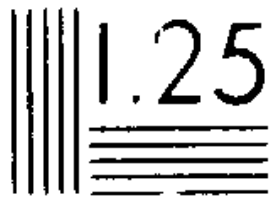
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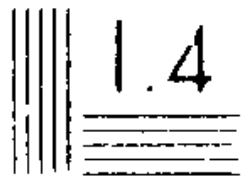
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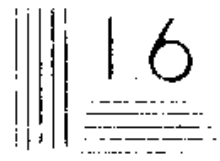
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5 May 1982
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India.

MODERNIZATION OF ENGINEERING DESIGN AND CONSULTANCY SERVICES

DP/IND/78/054

INDIA

Terminal report

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of R.T. Aliev,
expert in petroleum engineering

United Nations Industrial Development Organization
Vienna

V.82-25557

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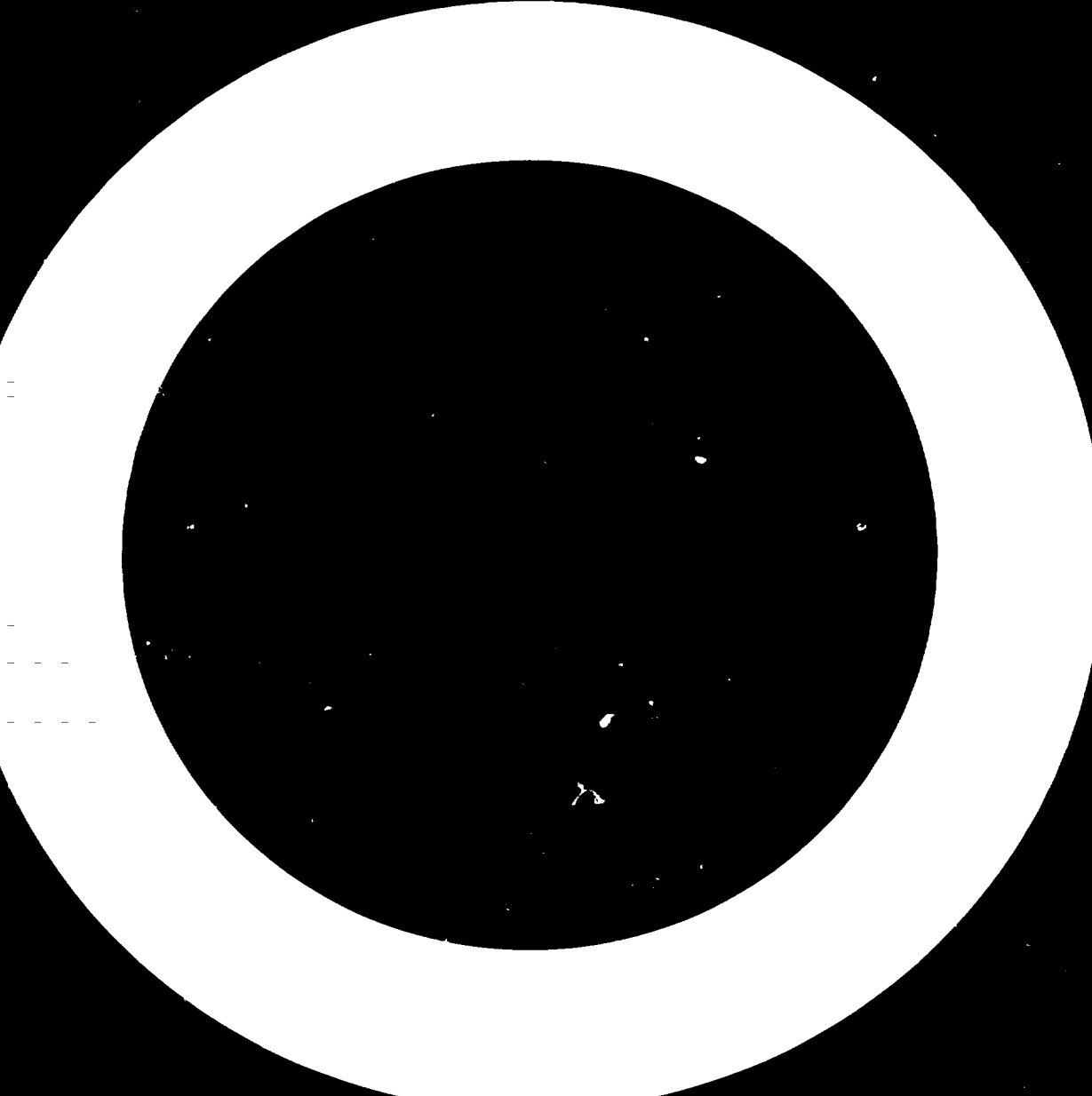
ABSTRACT

As part of the United Nations Development Programme (UNDP) project "Modernization of engineering design and consultancy services" (DP/IND/78/054), an expert in petroleum engineering was sent by the United Nations Industrial Development Organization (UNIDO), executing agency for the project, to assist in enhancing the engineering design and consultancy capabilities of Engineers India Limited (EIL), affiliated to the Ministry of Petroleum and Chemicals and operating in the field of offshore oil and gas development and production.

In the course of his five-month mission (November 1981-April 1982), the expert conducted a series of lectures and seminars for EIL engineers on problems related to oil and gas field development and secondary methods of recovering oil. He explored with EIL engineers the possibilities of increasing the capacity of existing submerged pipelines as well as the problems attaching to bringing offshore oil onshore.

At the request of its author, the Reservoir Engineering Department of the Compagnie Française du Petrole (CFP), the expert evaluated a report entitled "Bombay High LII Reservoir Development 3 D Model Study", and made a number of suggestions for its improvement. He also made a number of general technical recommendations, based on his observations. For example, factors governing development of the oil fields (flooding, rock temperature etc.) should be observed more systematically in order to facilitate regulation of the movement of the oil formation boundaries. Further, attention should be given to ensuring - particularly in the crestal regions - that rock pressure during production is greater than saturation pressure.



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INTRODUCTION

A major problem faced by many oil-producing countries is how to intensify recovery rates. It is a problem that has drawn the attention of thousands of scientific and technical personnel in the oil industry the world over.

Increasing offshore production, using secondary methods of recovery, has its own particular problems, such as the expense of the equipment needed and the high corrosion rate of much of that equipment. If, however, oil recovery plays an important role in the economy of a country, such problems must be faced. In any event, there are limits to the duration of the recovery process.

As part of the United Nations Development Programme (UNDP) project "Modernization of engineering design and consultancy services" (DP/IND/78/054), an expert in petroleum engineering was sent by the United Nations Industrial Development Organization (UNIDO), executing agency for the project, to assist in enhancing the engineering design and consultancy capabilities of Engineers India Limited (EIL), affiliated to the Ministry of Petroleum and Chemicals and operating in the field of offshore oil and gas development and production.

In the course of his five-month mission (November 1981-April 1982), the expert covered, in accordance with his work programme:

(a) Planning, designing and operation of offshore oil and gas production systems, including secondary recovery facilities;

(b) Reviewing and advising on various concepts to be developed by EIL;

(c) Conducting regular seminars and consultations with EIL engineers on problems related to development and production in oil and gas fields;

(d) Leading discussions after-examination of the basic issues-on various problems connected with secondary methods of oil recovery, and offering solutions to those problems;

(e) Conducting lectures and seminars for counterpart staff;

(f) Participating in discussions and meetings with EIL engineers on the problems of bringing offshore oil and gas, through pipelines, on-shore.

In the course of the discussions, the expert was asked to assess the possibilities of increasing the capacity of the existing submerged oil pipelines.

At the request of its author, the Reservoir Engineering Department of the Compagnie Française du Petrole (CFP), the expert evaluated a report entitled "Bombay High LII Reservoir Development 3 D Model Study", and made a number of suggestions for its improvement (chapter III below).

RECOMMENDATIONS

The following recommendations are made on the basis of the expert's discussions with EIL staff, his review of the CFP report, and his actual on-site observations:

(a) During the process of developing the oil fields, systematic observation of the development factors (e.g. flooding, quantity of gas in total production, rock pressure and temperature should be carried out in order to facilitate regulation of the movement of the oil formation boundaries;

(b) Oil reserves should be verified when new wells are being brought into production;

(c) During production, particularly in the crestal zone, rock pressure should be greater than saturation pressure;

(d) On the basis of the data collected, the productivity of the wells situated in the down-flank region should be determined in order to estimate future injection pressure requirements;

(e) In the crestal zone, investigations should be conducted at the monitoring well, with a view to regulating the functioning of the gas cap;

(f) The interrelationship between wells situated on the down-flank and in the crestal zone should be established;

(g) During injection of sea water, the interrelationship between sea water displacement and hydrocarbonate material, oil saturation, gas and rock water should be established;

(h) Consideration should be given to safeguarding the rock against micro-organisms (e.g. certain flora) in the sea water and the offshore equipment against corrosion.

I. OIL AND GAS FIELD DEVELOPMENT; SECONDARY METHODS OF RECOVERY

In the seminars he conducted and the consultations he held with EIL engineers on the problems of oil and gas field development and production and the implementation of secondary methods of oil recovery, the expert covered the following areas:

(a) Evaluation of relevant data and assessment of well capacity;

(b) Determination of rock porosity and permeability;

(c) Study of hydraulic interaction and piestic factors;

(d) Examination of schematics showing oil-gas deposits in the rock and determination of oil-gas zones;

(e) Preparation of field data for evaluation analysis;

(f) Analysis of oil field data;

(g) Calculation of the basic parameters for introducing a method of maintaining constant rock pressure;

(h) Calculation of injection pressures, quality of water to be injected, and other basic parameters for injection wells;

(i) Calculation of pressure maintenance in the "gas cap" and number of injection wells;

(j) Calculation on combined pressure maintenance (in oil deposit area and gas cap);

(k) Establishment of rheological models for oil recovery systems.

After examination of the basic questions, problems related to secondary methods of oil recovery were discussed and solutions put forward.

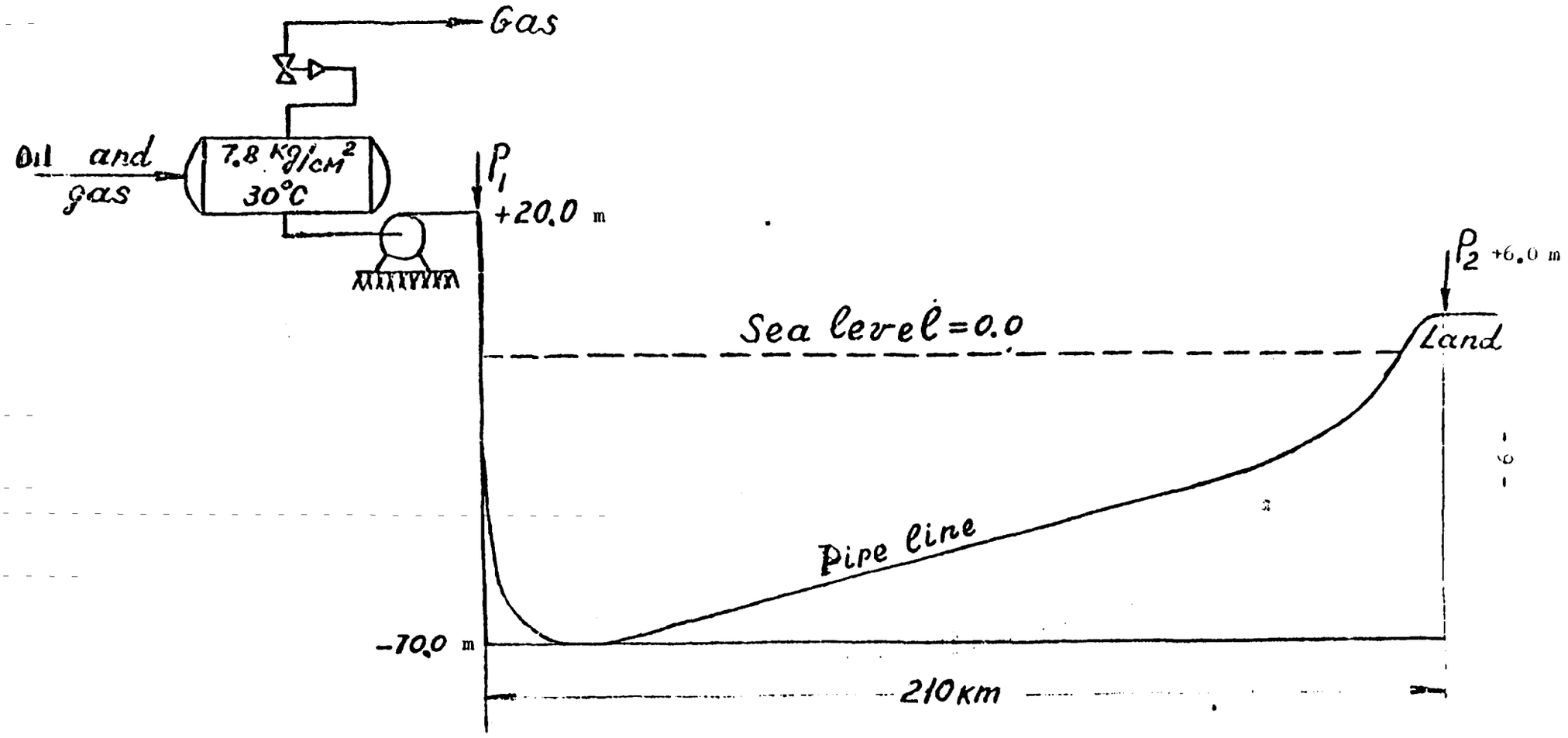
The problems of transporting offshore oil and gas through pipelines to the shore were also discussed with EIL engineers. At the request of that group, the expert assessed the possibility of increasing the capacity of the existing submerged oil pipelines. The following data were made available:

Oil

Density : 830 kg/m^3
Viscosity : 3 x 10^{-6} m^2/s @ 20°C and 8 x 10^{-6} m^2/s @ 26°C
Wax content : 15%

Pipeline

Length : 210 km
Internal diameter : 28.624 in (727.05 mm)
Welded pipes (not buried)



Layout of submerged oil pipeline

The layout of the submerged pipeline is shown in the accompanying illustration. The expert broke the problem down as follows (cases I and II):

	Case I	Case II
Capacity (m^3/h)	3 430	?
Pressure (gauge) (bar)		
Initial	?	80
Final	10	10

As data on the sea bed profile and other parameters related to the pumped oil (e.g. dynamic shear stress) were not available, the expert assumed a local hydraulic loss of 20 per cent for the purposes of his calculations. To evaluate the initial pressures that can arise in the process of pumping oil through pipelines, it is necessary to determine the parameters of oil relaxation, i.e. relaxation pressure and duration.

II. BOMBAY HIGH LII RESERVOIR

During the expert's tenure of work with EIL, he examined the report "Bombay High LII Reservoir Development 3D Model Study", prepared by the Reservoir Engineering Department of CFP. The report showed the results of an evaluation of the reservoir, prepared on the basis of laboratory and field data. It included the following chapters:

(a) Introduction, summary and recommendations;

(b) Description of the petrophysical models of the rock:

(c) Gas, oil and water boundaries and the distribution of water content;

(d) Characteristics of rock fluids:

(e) Description of rock models;

(f) The extent of the reservoir in 3D models of the rock.

The introductory chapter suggests that during the first phase of development of the LII, rock three productive platforms (NQ, NP and NS) should be brought into use. Wells are now being drilled under the platforms, and NQ and NS are scheduled to be commissioned by 1983. All three platforms are in the down-flank region of the LII, to enhance the possibility of exploiting layers B and C simultaneously with L III.

It is also shown that on investigation of the model built for the productive rock, gas-water-oil contact line calculations were found to be based on the limited field data available from production wells drilled on the LII line and on information relating to the wells of platform NP. For a more objective study of the productive conditions, and in order to formulate and implement the proper solutions, assessments should be made of:

(a) The oil rock condition after natural depletion (as well as an analysis of the change in the rock pressure with time);

(b) The advisability of using water injection to increase oil production from wells situated in the crestal zone of the reservoir during the second phase of production;

(c) The performance of central water injected through wells situated below the gas cap;

(d) Comparative well productivity and vertical permeability of the rock;

On the basis of his review of the CFP report, the expert has the following comments to offer.

With respect to the development of the oil field in question, the major problem in the near future will be to intensify oil production. A fall has been observed in the rock pressure and an increase of water and gas content in the

total produced. In such a situation, the solution is not only to use the inherent rock energy, but also to select an effective method of maintaining the pressure, e.g. from outside or inside the boundary; from outside and inside simultaneously; or by a real sweep method.

From this it will be seen that, using field and laboratory data, initial studies can be made of the properties of the productive zone. The material for model investigation and construction can be taken from the pre-development phase data as well as from rock samples from wells BH-1, BH-16, N1-2, N1-5, HK-1 and C2.

On the basis of the models developed, three different layers with similar petro-physical properties have been identified. The thickness of the layers is shown in isopach maps. In a similar manner, isoporosity maps can be developed. By assessing the rock sample and making a statistical analysis of the correlation between porosity and permeability, the concept of vertical permeability in the productive rock can be established. From this permeability, saturation curves can be drawn. Through interpolation, it is possible to establish the gas and oil depth in the rock. The water saturation in the well can be established using electro measuring and capillary devices.

The properties of rock fluids, as well as the compressibility of rock, oil, water and gas, were determined using PVT equipment. Moreover, based on the hydro-carbonate content in the rock, models of volumetric porosity for each layer, depending on the fluid saturation, were made. From this, it was possible to determine oil and gas saturation in the various zones. Initial production is to be realized through nine wells in platforms NP, NQ and NS. The NP platform is already in operation; the other two will be commissioned by 1983. The wells will all be situated in the oil saturation zone, between the gas oil contact boundary and the transition zone.

The CFP report indicates that on the basis of the investigations conducted and analyses made, the reservoir productions could be conducted using three alternative methods in the first phase. The first two alternatives assume different rates of recovery, reservoir depletion flooding, and an increase in the gas-water-oil ratio: thus it is necessary to employ water injection. In the third alternative, taking into consideration the presence of vertical permeability barriers in the crestal zone of the rock, it is recommended that production of the reservoir as a whole be conducted, along with the central zone.

This, therefore, provides the basis for various water injection alternatives, the injection being accomplished at certain stages of depletion, through the wells of platforms NP, NQ and NS and the two wells situated in the crestal zone.

The CFP report has been prepared by highly qualified scientific and technological personnel. It contains all that is required to prepare data for the production and post-production development processes. The following observations, therefore, should not in any way be seen as a reflection on the report.

Ideally, water injection should be undertaken when the rock consists of sand, uniformly distributed, and sandstone having a good degree of permeability and containing few faults.

Water injected into rock containing complex hydrocarbonates does not always give positive results. This is because certain areas are cut off from the canals of the system and cracks restrict the flow of fluids. In view of this, and taking into account the mobility factors of the fluids, it is difficult to calculate the exact ratio between the injection and production wells, or - very important - to determine beforehand the injection line. When the oil-water viscosity ratio nears 10, with a high degree of variability in the volume and permeability of the rock, it is even more difficult to predict.

As the CFP report observes, Bombay High refers to the second type of oil field. The productive area consists of hydrocarbonate rock with marked layers of limestone shale. From the porosity and permeability maps, using linear interpolation, it may be seen that the down-flank productive area consists of inferior total rock properties.

A better picture of the characteristics of fluid movement in various sections of the rock can be obtained using hydraulic interaction and piestic maps. In view of the limited pre-production data available, the maps should be drawn on the basis of isobar, isoposorosity and permeability charts.

During the first phase of recovery, according to the CFP report, the productive region should be strengthened by introducing in the down-flank part of the field platforms NQ and NS. Six wells are linked to these platforms and three to the already functioning NP platform. This solves the problem of how to intensify recovery. The distance between the recovery and the injection zones has been determined at 2.0-2.5 km. That means that well before the start of water injection, the injection line has been determined.

It should be pointed out that in all probability sea water will be used for injection. The interaction of this with hydrocarbonate rocks can introduce complications and requires special attention at every stage of production. With regard to selecting the injection line and determining the distance between the injection and recovery zones, the reliability of the projected external contour of the oil field and the characteristics of its movement are all-important.

Another problem was observed with respect to the crestal zone of the rock, where at present the wells differ markedly from each other in productivity.

The factors discussed above may change the whole philosophy of recovery in the future. The observations noted here, however, are based only on the expert's examination of the CFP report. It is difficult to suggest in advance solutions that will have universal application; the work being done at present, and which is to be continued, will no doubt contribute towards an understanding of the real situation.

Annex

JOB DESCRIPTION

DP/IND/78/054/11-02/32.1.F

Post title:	Petroleum engineer.
Duration:	Nine months (split mission: five months 1981 and four months 1982).
Date required:	As per schedule.
Duty station:	New Delhi, with travel within the country.
Purpose of project:	To enhance the engineering design and consultancy capabilities of Environmental Engineering Group of Engineers, India, Limited in offshore, oil and gas field development and production facilities.
Duties:	Specifically, the expert will be expected to: 1. Assist EIL in the planning, design and operation of offshore oil and gas production systems, including secondary recovery facilities and oil and gas distribution systems; 2. Review and advise on the various concepts which will be developed by EIL; 3. Give advice on the technology involved in planning and designing such facilities. The expert is also expected to prepare a final report, setting out the findings of the mission and recommendations to the Government on further action which might be taken.
Qualifications:	Post graduate degree in Petroleum Engineering/Chemical Engineering with extensive experience in planning, design and operation of oil and gas gathering and production facilities on offshore production platforms.
Language:	English.
Background information:	EIL is a Government undertaking, operating in the field of engineering design and consultancy. Over the last few years it has built up technical capabilities in the area of offshore oil and gas production facilities and offshore structures. EIL has always placed great emphasis on the adoption of appropriate technology and on the development of indigenous capabilities. It is felt that the services of an external expert with extensive experience in petroleum engineering will improve the capability to design offshore oil and gas field developemnt and production systems.