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# DETERMINATION OF METHODS OF COLLECTING OIL AT A SUB-SURFACE LOCATION ABOVE A BLOWOUT

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## SUMMARY

The recent blowout of the Ixtoc-I well in Campeche Bay has focused attention on the severe problems a blowout of a large well can cause. With drilling taking place in deeper waters, blowout probabilities may increase. These facts have stimulated the formation of a research program to study and develop a technology for sub-surface collection of oil above a blowout. This proposal is for that study. The goal is the development of a technology that, if implemented, will allow collection of most of the oil above a blowout within a few days of the time that the blowout occurs. The proposed research and development program has three steps to be undertaken over a period of about three years, one year for each step. This proposal is for the first step which is a laboratory and theoretical study of the hydrodynamics involved in collecting most of an oil-water-gas plume (and possible devices for doing this) The second step, for which a formal proposal will be submitted in about 10 months, is an engineering study of possible system configurations to determine the most practical systems that can do the job. The third step is the preparation of detailed system design plans.

Proposal

For

# DETERMINATION OF METHODS FOR COLLECTING OIL AT A SUB-SURFACE LOCATION ABOVE A BLOWOUT

## 1. INTRODUCTION

Blowouts from offshore oil wells are infrequent, but catastrophic events. Ocassionally, the oil is introduced into the water near or at the ocean bottom as exemplified by the Santa Barbara blowout and the Campeche (Ixtoc) blowout. This latter incident is ongoing at the time of the writing of this proposal and is the incident which has focused attention on the problem. The risk of sub-surface blowouts is expected to increase in the future with the introduction of template drilling and more frequent operations in especially deep water.

This proposal is for the first part of a program whose final result is the determination of methods and the construction of the necessary equipment for collecting oil from such blowouts at a sub-surface location immediately above the well. The proposed work is to be done jointly by the Massachusetts Institute of Technology and Brown and Root, Inc. At the present time, Brown and Root, Inc. is working together with Petroleos Mexicanos (the company operating the blown out Ixtoc well) on the construction and installation of a "first attempt" at a device to do this job. This has been referred to in the press as the "steel sombrero" (sketched here in Fig. 1) and we will use that term here. Actually, the hat-shaped structure above the well-head is one of the smallest parts of the whole steel sombrero system, being about 40 ft. in diameter. This collector is held by a triangular shaped support which is about 200 ft. high and 200 ft. long. The "hypotenuse of this triangle" contains the outlet pipe from the collector which empties into a large gravity separator 75 ft. above the surface of the sea on the deck of a four-legged jacket platform. The gas outlet from the separator is introduced into a gas burner above the deck platform , the water is dumped overboard and the oil is pumped along a 350 ft. long bridge structure to a second jacket platform above which the oil is to be burnt. Thus, although the actual collector is relatively small, the entire system is massive and therefore, not suitable for rapid transportation to remote locations. There are five major requirements that must be met for the system to work:

1. The system must be installed with the collector immediately above the wellhead.

2. The turbulent flow within the collector must not be strong enough for the generation of a great many very small oil droplets with the driving of these droplets out below and to the side of the collector.

3. The oil is driven from the collector to the separator entrance (which is 75 ft. above the surface of the sea) by the "gas-lift" of the gas coming out of the well and rising through the riser pipe. Normally, in air-lift systems control of the air bubble size is possible and the desirable small size bubbles can be achieved. This control does not exist here. Secondly, little is known about the nature of air-lift systems in an inclined riser as is used here. For successful operations, the gas-lift system will have to operate successfully.

4. Adequate separation of the gas, oil and water will have to be achieved.

5. Ultimate disposal or collection of the oil, either by burning as planned, or by tank vessel shipment, will have to be achieved.

Whereas the steel sombrero can serve as a starting point for the proposed research here, it is very unlikely that it represents the optimum solution for the problem at hand. Its large size makes it cumbersome and difficult to transport. Only very limited research on the development on the collector shape was possible and essentially no work on learning on how to deal with the effects of turbulence could be done.

A small scale model of the collector was made at Brown and Root, Inc. but it was impossible to properly scale the relevant non-dimensional parameters in this model. Nevertheless, it was possible to see that in the model many small oil droplets were made and some of them were swept out beneath the collector.

The total proposed program contains three steps. The first step, which is the subject of this proposal is for the required research, including theoretical analysis, scale model studies , measurements on the steel sombrero and analysis of these measurements, initiation of studies of alternative system configurations and the preparation of the proposal for the second step. The second step is for the major part of the studies of alternative system configurations and for the development of plans for an actual collection system. It is possible that the first step will indicate the need for model studies at a larger scale than can be achieved during the execution of that step. If such larger scale model studies are needed they will be undertaken as part of step two. The third step is for the construction of the actual prototype system.

The first step will be done principally at M.I.T. with the aid of some Brown and Root personnel as consultants, particularly in the initiation of studies of optimum system configurations because of the familiarity of Brown and Root with offshore devices and structures. The second step, which is not part of this proposal, will be done principally by Brown and Root with the consultation of the M.I.T. personnel who are involved with step 1. U.S.G.S. support is sought for steps 1 and 2, although this proposal is only for step 1.

The third step will be done almost entirely by Brown and Root, Inc. since it will be in their area of major expertise with only a small amount of consulting effort on the part of M.I.T. Some plan for cost sharing between U.S.G.S. and Brown and Root (or other industrial support) appears to be the method of funding that will be sought.

## 2. RESEARCH PLAN FOR THIS PROPOSAL

### Basic Studies

This part of the work is aimed at determining basic operating concepts and predicted performance for sub-surface collectors. Some preliminary "engineering office studies" on sub-surface collection concepts have been undertaken by the Canadian Marine Drilling Co. and by Lockheed Petroleum Services, Ltd.

(New Westminster, B.C.), but no substantive reports of results are yet available. We will obtain as much information about these studies as we can to help guide our work.

For our measurement program, the starting point will be the steel sombrero. By measuring mean and turbulent velocities at one or two points in the collector as well as mean and turbulent pressure fluctuations at a point in the collector and at a point in the riser pipe, some full scale measure of operating conditons will be available. The chief problem in laboratory studies of a scale model collector is the impossibility of exact scaling. By having actual full scale data, we should be able to compare model measurements of some of the same parameters to determine how well the approximate scaling possible in a laboratory yields a flow which models the important aspects of the actual full scale flow.

For exact scaling, the following non-dimensional parameters must be identical for the full scale device and for the laboratory model:

| | |
|---|---|
| The Froude Number | $\frac{V}{\sqrt{gL}}$ |
| The Reynolds Number | $\frac{VL}{\nu_w}$ |
| The Pressure Ratios | $\frac{P_T}{P_B}$ |
| The Kinematic Viscosity Ratio | $\frac{\nu_w}{\nu_o}, \frac{\nu w}{\nu_g}$ |
| The Density Ratios | $\frac{\rho_w}{\rho_o}, \frac{\rho_w}{\rho_g}$ |
| The Weber Number | $\frac{T_{ow}}{\rho_w V^2 L^2}$ |
| The Interfacial Tension Ratios | $\frac{T_{ow}}{T_{og}}, \frac{T_{ow}}{T_{wg}}$ |
| The Flow Rate Ratio | $\frac{Q_o}{Q_g}$ |

where:

L = Characteristic length

V = Characteristic velocity

$g$ = Acceleration due to gravity
$\nu_w$ = Kinematic viscosity of the water
$\nu_o$ = Kinematic viscosity of the oil
$\nu_g$ = Kinematic viscoity of the gas
$\rho_w$ = Density of the water
$\rho_o$ = Density of the oil
$\rho_g$ = Density of the gas
$P_T$ = Absolute pressure at the surface
$P_B$ = Absolute pressure at the point of gas release
$T_{ow}$ = Oil-water interfacial tension
$T_{og}$ = Oil-gas
$T_{wg}$ = Water-gas
$Q_o$ = Oil flow rate
$Q_g$ = Gas flow rate

Obviously, it is impossible to simultaneously maintain the correct values for all of these parameters under the conditions where the size of the laboratory requires the laboratory size length scale to be about 1/15th of the full size length scale. One part of the proposed theoretical studies is for determining which parameters may be relaxed from their full scale values for accurate laboratory tests. For example, it is unlikely that it is necessary to accurately scale the gas density since the gravitational driving forces on a gas bubble will be determined by the difference in density between the water and the gas which will be nearly equal to the density of the water alone. However, it will be important to accurately scale the gas volume as a function of height and that is why proper scaling of the pressure ratio will be essential. This dictates the model apparatus will have to be operated under a partial vacuum.

For correct scaling of the Froude number, scaling of the Reynolds number is not practical and this has a bearing on the nature of the turbulence inside the collector. Since this turbulence has an important bearing on performance, the effect of the model Reynolds number being smaller than the full scale Reynolds number will have to be carefully studied.

The principal effect of the Weber numbers will be on the gas bubble and oil droplet sizes and behaviors. This is important because large bubbles and droplets will rise in the collector whereas small ones will be convected about by the turbulence with some of them escaping below and then beside the collector. The smallest bubbles and droplets are generated by the smallest turbulence eddies so that a study of the microscales of the turbulence will be required since exact dimensional similitude is impossible. The proposed principle investigator has had experience with a similar problem (Milgram, Donnelly, Van Houten and Camperman, 1978). The techniques proposed for studying the problem here are similar to those used in the reference.

It should be pointed out that some blowouts involve oil alone, some involve gas alone and some involve both oil and gas. Therefore, the proposed model tests will be carried out at a variety of oil-gas ratios from one extreme to the other. The other parameters which will certainly be varied in the model tests will be the shape of the collector, the distance of both the collector and the blowout source from the bottom, and the gas bubble size at the source.

In addition to measurements of actual system performance, such as successful gas lift in the presence of gas and amount of oil escaping from the collector into the open water, detailed measurements in the collector will be made. In particular, the distribution of turbulence within the collector will be studied. This is expected to reveal details of the turbulent flow which may be quite helpful in suggesting alternative concepts for collection. Furthermore, it should reveal how the collection efficiency depends both on collector size and the distance between the collector and the bottom. One subject needs which needs to be examined for collectors that are close to the bottom is the entrainment of bottom sediment into the rising flow within the collector and subsequent riser.

In the case of oil alone, without gas, or blowouts with only a minor amount of gas, utilizing gas lift to raise the oil to points high above the surface is impossible. Two alternatives present themselves here. One is to carry out the oil-water separation at a sub-surface location where the gravitational potential is sufficient for driving the oil to the top of the separator. The other alternative is to pump the fluid into the separator with a mechanical pump. Although this may permit a more optimized separator configuration, the increased oil-water emulsification caused by the pump detracts from ease of operation. Therefore, a tradeoff study needs to be made to determine whether or not pumping should precede separation when gas lift is not used. Along similar lines, we may find that the expanding gas bubbles in the gas lift system result in so much emulsification that the system is optimized by separating the gas from the liquid at a position near the blowout source and then using gravity rise to a sub-surface oil-water separator or pumped flow to an above water separator to obtain the oil.

One part of our effort will be the design and construction of the test apparatus. Some preliminary ideas for this are shown in Fig. 2.

System Configuration

The massiveness of the structure for supporting the steel sombrero and for holding auxiliary equipment makes that system difficult for transportation to a remote location. Can a smaller system that is more quickly transported and installed be used? What configuration might the device have? These are questions that must be answered in this program. Most of the studies leading to these answers are planned for the second year and will be done by Brown and Root, Inc. However, since the form and method of operation of the collector itself have large influences on the complete system, it will be useful to initiate the system configuration studies (including preparation of a Brown and Root proposal (for the second year) during the first year. The budget is written as if the consulting services Brown and Root provides to M.I.T. on the practical aspects of the basic research and the Brown and Root first year effort on the configuration studies are done under subcontract to M.I.T. If the sponsor prefers a separate first year contract with Brown and Root, this should be deleted from the M.I.T. budget.

Although the configuration of the final system cannot be predicted now, we can present a few thoughts about some matters to be considered in the configuration study. The steel sombrero is based on supporting jacket structures. The possibilities of using floating structures either with tension legs or with dynamic positioning will be examined here. Either of these alternatives would lead to more collector motion during use than the case with the rigidly located collector. Therefore, the use of a floating structure for holding the collector will necessitate a larger collector so that some positional inaccuracy can be tolerated. Thus, another tradeoff study is required to determine the relative practicalities of a rigidly held structure and of a floating collector. Because of the desired application in very deep water, system studies with floating devices are considered to be quite important.

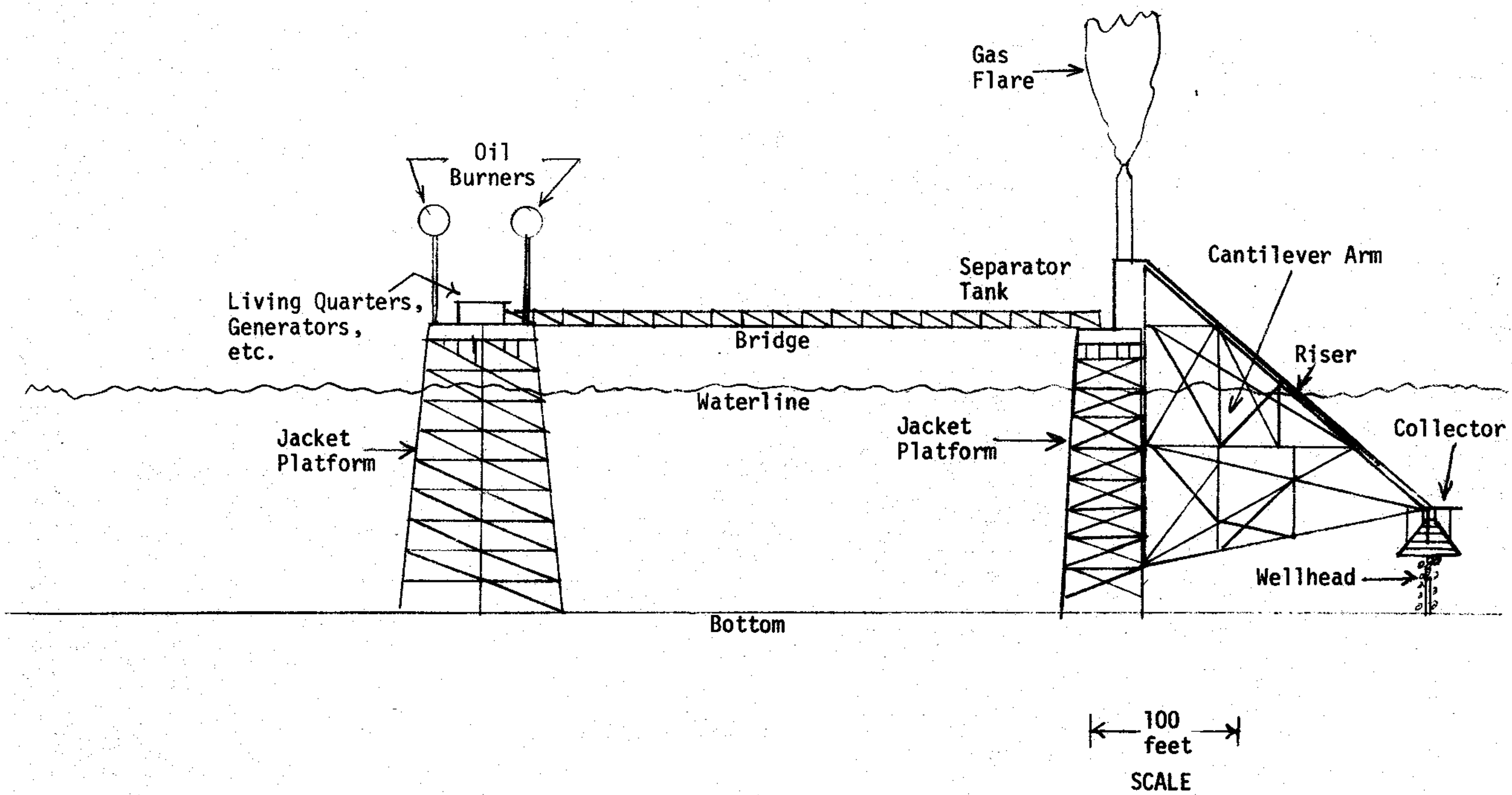


Figure 1. Diagram of the "Steel Sombrero" System

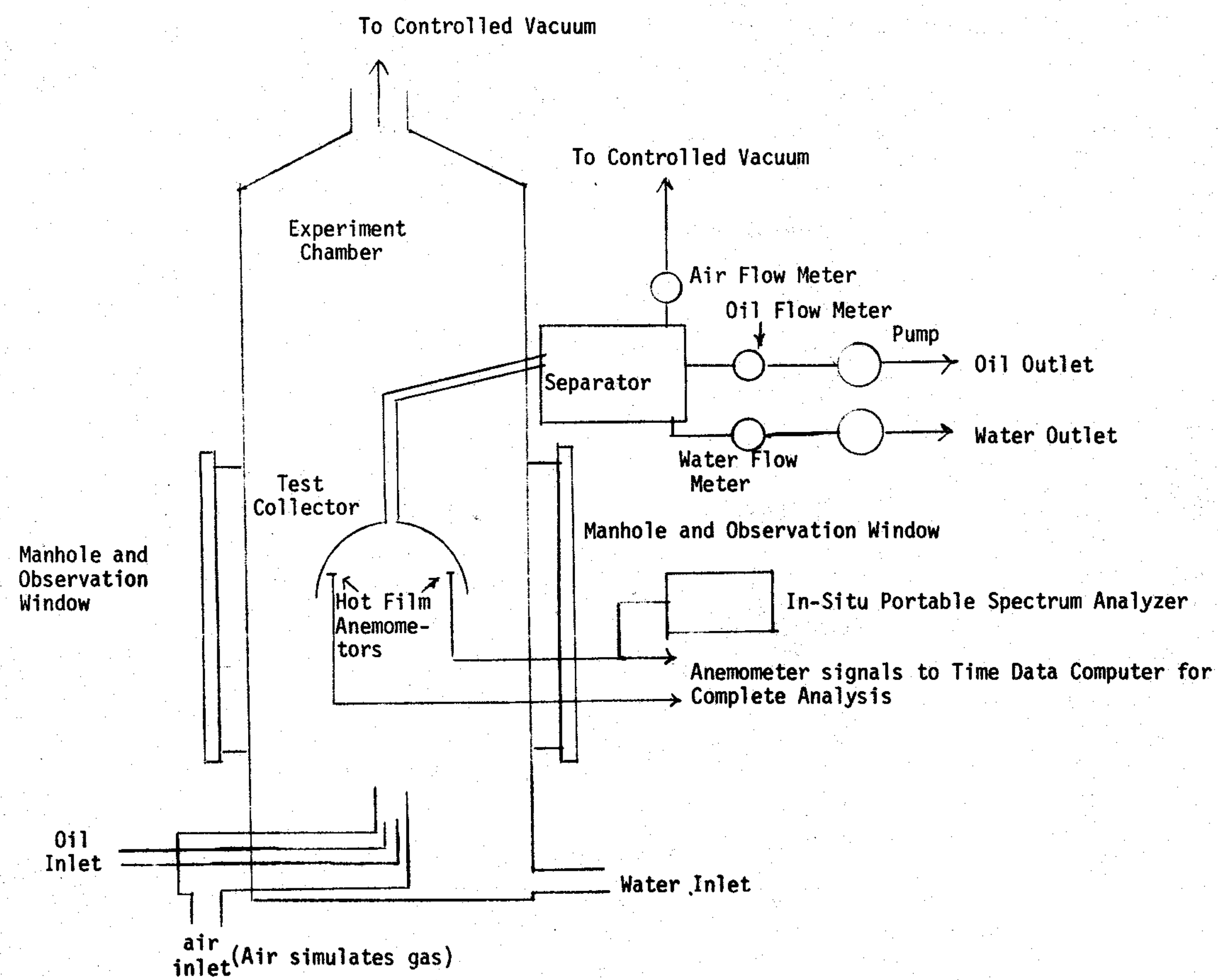


Figure 2. Diagram of Preliminary Concept of test Apparatus

## 3. JUSTIFICATION FOR A "SOLE SOURCE" CONTRACT

The proposed contractors, Massachusetts Institute of Technology and Brown and Root, Inc. are uniquely qualified for this work. Most of the fundamental studies on the hydrodynamics of the collection of oil spills at sea have been done in the Department of Ocean Engineering of MIT under the direction of Professor Milgram. He has also designed (and used) much of the equipment for collecting oil from large spills (see resume of Principal Investigator)

Brown and Root, Inc. is a leading company in the design, construction and installation of offshore structures. As a result, they have a wealth of experience of all aspects of the field, ranging from the highly analytical to the most practical. Of special importance here is their effort in being the designers, builders and implementers of the steel sombrero system.

At the time of writing this proposal, M.I.T. and Brown and Root are making plans and arrangements to obtain the full scale data from the steel sombrero system that will be of major value in the proposed work.

# 4. REFERENCE

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5. RESUME OF PRINCIPAL INVESTIGATOR

| | |
|---|---|
| Name: | Jerome H. Milgram |
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Education:

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| 1961 | S.B. in Naval Architecture and Marine Engineering, M.I.T. |
| 1961 | S.B. in Electrical Engineering, M.I.T. |
| 1962 | S.M. in Naval Architecture and Marine Engineering, M.I.T. |
| 1965 | Ph.D. in Hydrodynamics, M.I.T. Department of Naval Architecture and Marine Engineering. |

Professional Experience:

| | |
|---|---|
| 1977 - | Professor, M.I.T. Dept. of Ocean Engineering |
| 1970 - 1977 | Associate Professor, M.I.T. Dept. of Ocean Engineering |
| 1974 - 1976 | Research Associate in Biophysics - Harvard Medical School |
| 1967 - 1970 | Assistant Professor, M.I.T. Dept. of Naval Architecture and Marine Engineering (Now Dept. of Ocean Engineering) |
| 1965 - 1967 | President, Milgram and Hopkins, Inc., a sailmaking firm pioneering in computer aided design of sails. |
| 1961 - 1967 | Project Engineer at Block Associates, Inc., working on problems in hydrodynamics, ocean engineering, electronics and optics. |

Professional Experience (cont'd)

1961 Member of Applied Oceanography Group of Scripps Institution of Oceanography (summer seminar only).

Registered Professional Engineer, Commonwealth of Massachusetts Number 24876

Sponsored Research Projects Supervised Include:

1. The aerodynamics of high loaded lifting surfaces.
2. Section characteristics of thin, highly loaded lifting surfaces.
3. Wave forces on ocean structures.
4. Forces and motions of floating barriers.
5. Methods of evaluating floating barriers.
6. Forces on surface piercing lifting surfaces.
7. Wave effects on the containment and spreading of oil slicks.
8. Instrumentation for measurement of the seakeeping aspects of oil pollution control barriers.
9. Hydrodynamics of oil-water interfaces.
10. Evaluation of mooring line effects by mooring point impedances.
11. Dispersion of oil slicks by ocean waves and turbulence.
12. Mass transport of water and floating oil by waves.
13. Oil slick control in the offshore environment.
14. Design and construction of precision wave channel and flume.
15. Hydrodynamics of rapid reaction chemical reactors.

<u>Consulting Activities Include:</u>

1. Hard Sails, Incorporated, Islip, New York; on the analytical design of sails and on computer aided production methods.
2. Lamport Sail Fabric, Ltd., Putnam, Connecticut; on methods of the laboratory testing of textiles and the physical chemistry of textile production.
3. Simplex Wire and Cable Company, Hydrospace Division, Portsmouth, New Hampshire; on the ocean engineering of undersea power cables and pipelines.
4. Huyck, Incorporated; on the hydrodynamic analysis of paper making machines.
5. Northrup Corporation; on the motions of towed bodies in waves and currents.
6. Honeywell, Incorporated; on the motions of oceanographic instruments in waves and currents.
7. Chance and Company; on optimization of the rigs and sails for sailing vessels.
8. Cabot Corporation; on the hydrodynamics of surface coatings for ships and marine structures.
9. H.H. Westerbeke Corporation; on navigational instruments and marine evaporators.
10. Johns-Manville, Incorporated; as principal designer of the U.S. Coast Guard High Seas Oil Containment Barrier.
11. Murphy and Nye, Incorporated; on computer aided design and production of sails.
12. Offshore Devices, Incorporated; on refinement and production of U.S. Coast Guard High Seas Oil Containment Barrier.
13. Horizon Marine Enterprises, Incorporated; on computer aided design and construction of sails.
14. Arthur D. Little, Incorporated; on theory for dispersion of oil slicks at sea.

Consulting Activities (cont'd)

15. State of Marine Attorney General's Office; to provide expert witness services in field of containing and removing spilled oil.

16. New York State Attorney General's Office; on equipment for prevention and control of oil spills and for providing expert witness services on these subjects.

17. Exxon Production Research Company; on methods of evaluation of oil pollution control barriers.

18. United States Coast Guard; on evaluation of oil pollution control barriers.

19. Kennecott Exploration, Incorporated; on deep ocean mining; collection; transfer and transporation.

Other Professional Experiences:

1. Member of SNAME H-13 Panel on Sailing Vessels.

2. Member of SNAME H-5 Panel on Ship Waves.

3. Technical Advisor to Center for Law and Social Policy, on Oil Pollution Aspects of the Proposed Trans-Alaska Oil Pipeline.

4. Member of Panel on Data Buoy Technology of Marine Board of the National Academny of Engineering.

5. Chairman of Hydromechanics Group of Data Buoy Technology workshop (1973) of Marine Board of National Academny of Engineering.

6. Member of National Academny of Science Panel for Review of NOAA Data Buoy Office, 1978.

7. Member of U.S. General Accounting Office Panel for Review of U.S. Coast Guard response to oil spills.

8. Practicing Yacht Designer.

## Patents and Patent Applications

U.S. Patents Granted

1. #3,802,201 Rough Water Barrier, with D.P. Hoult; method and means for controlling floating pollutants in rough seas.

2. #3,938,704 Inflation Control Valves; method and means for remotely controlling release of a gas from a sealed contained to an inflatable device.

3. #3,943,720 Floating Oil Barrier; means for containing and controlling floating oil pollution in rough seas with no emulsion generating protruberances against the oil.

4. #4,059,962 Floating Skimming Barrier Assemblies; a practical combination of a pollution control barrier and skimmers in a single device to control, contain and collect floating oil pollution.

5. #4,131,397 Pumps, with U.S. Bartoo and B.H. O'Connor; double acting, self-priming hydraulically driven diaphragm pumps.

Applications in Process (Patents pending)

6. Self-reversing hydraulic control system and self-reversing pump incorporating such system.

7. Easily and compactly packaged oil pollution barrier.

8. High flow rate, oil-water-air separator which can handle floating debris and ice.

PROFESSIONAL

PUBLICATIONS

Jerome H. Milgram

[1] Milgram, J.H., "Studies on Making Wave Measurements in the Open Sea, "Block Associates Report, Cambridge, Massachusetts, 1964.

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[48) ____________, and Chance, B., "Studies of a Scale Model Rapid Reaction Apparatus", in preparation

6. ESTIMATED BUDGET FOR THE FIRST YEAR, 9-15-79 to 9-15-80

LABOR (see task descriptions)

| | | | |
|---|---|---|---|
| Principal Investigator | {25% of time in academic year and 1 month summer} $3\frac{1}{4}$ mos. | $11,447 | |
| Research Assistant | 11 months | 9,900 | |
| Secretary | 2 months | 1,800 | |
| Student labor | (UROP-no overhead) | 2,000 | |
| Employee benefits | (0.26 x $13,247) | 3,444 | |
| Overhead | (0.683 x $21,641) | 14,781 | |
| Labor, benefits and overhead | | $43,372 | New |

EQUIPMENT

| | | | |
|---|---|---|---|
| | Hot film anemometers for laboratory tests (see tabulation) | 5,000 | → 2500 |
| 2 | Laboratory pressure transducers (Schaevitz mod. P502) | 1,000 | same |
| | Spectrum analyzer (Spectral Dynamics Mod. 340) | 8,500 | ✓ |
| 2 | Flowmeters for field measurements (Signet Scientific Mods 314&315) | 2,000 | field } 3400 |
| 2 | Pressure transducers for field trails | 1,400 | field |
| | Instrumentation tape recorder (Tandberg Mod. 100) | 3,600 | same |
| | Subcontracted construction of test apparatus components | 4,500 | same |
| | General purpose power supply | 300 | |
| | Total Equipment | 26,300 | |
| SUBCONTRACT TO BROWN AND ROOT (see subcontract description) | | 18,000 | delete |

OTHER COSTS

| | | |
|---|---|---|
| Laboratory and field measurement materials and supplies (including $5,000 for electric cables for field use) | 11,000 | |
| Computer expense | 3,000 | 6000 |
| Office expense (including telephone) | 1,000 | Same |
| Travel (see tabulations) | 6,580 | |
| | $ 21,580 | |

TOTAL 109,252

APPENDIX TO BUDGET

Tabulation of Thermo Systems, Inc. Hot Film Anemometry Equipment
(for laboratory measurements of mean flows and turbulence)

| | | |
|---|---|---|
| 4 | Model 1750 anemometers at $300 | $1,200 |
| | Cables for above | 200 |
| | Power supply for above | 400 |
| | Linearizing equipment for above | 900 |
| 4 | Model 1472w hot film sensors at $150 | 600 |
| 2 | Model 1287w split film sensors at $350 | 700 |
| 2 | Model 1246w x-probes at $250 | 500 |
| 1 | Digital Voltmeter | 500 |
| | | $5,000 |

replace with Conductivity probe system

Tabulation of Proposed Travel Expenses

Trip to Houston, Texas to plan and install full scale instrumentation (10 days)

| | | |
|---|---|---|
| Airfare | $400 | |
| Car rental | $400 | |
| Misc. expenses | $200 | |
| 10 days per diem at $45/day | $450 | |
| TOTAL | | $1450 |

First trip to Mexico to check and operate instruments

| | | |
|---|---|---|
| Airfare | $400 | |
| Ground transportation | 100 | |
| 2 days per diem at $45/day | 90 | |
| Misc. expenses | 160 | |
| TOTAL | | $ 750 |

Trip to Corpus Christi and Houston to repair instrument cables and test instruments (two people)

| | | |
|---|---|---|
| Airfare | $1000 | |
| Ground Transportation | 300 | |
| 10 days per diem at $45/day | 450 | |
| Misc. expenses | 150 | |
| TOTAL | | $1900 |

Trip to Mexico to operate instruments and take operational data

| | | |
|---|---|---|
| Airfare | $ 400 | |
| Ground Transportation | 100 | |
| 4 days per diem at $45/day | 180 | |
| Misc. expenses | 120 | |
| TOTAL | | $ 800 |

Two trips to Houston for discussions with Brown and Root

| | | |
|---|---|---|
| Airfare | $ 400 | |
| Ground transportation | 100 | |
| 3 days per diem at $45/day | 135 | |
| Misc. expenses | 65 | |
| | | $ 700 x 2 = $1400 |

Two trips to Washington, D.C. (USGS) - One for discussion, one for giving seminar

| | | |
|---|---|---|
| Airfare | $ 100 | |
| Taxi fares | 30 | |
| Meals | 10 | |
| | $ 140 x 2 = $ 280 | |

TOTAL TRAVEL $6,580

## Task Descriptions for Labor Category

Principal Investigator. The principal investigator is the project leader. He will provide day-to-day administration of the work, will plan and do most of the theoretical studies, will plan overall aspects of the experiments and will monitor the experiments,and work on and supervise the project reports.

Research Assistant. The research assistant will help the principal investigator with the theoretical studies, will work out details of the experimental apparatus and the experiments themselves, will be in charge of conducting the experiments, will do most of the experimental work and data analysis and will work on the final report.

The secretary will handle all secretarial duties of the project including typing of all reports and letters, monitoring the telephone and checking the monthly statements.

The student employee will assist in building the apparatus,conducting experiments and take care of laboratory "housekeeping"

## Subcontract Work Description

Brown and Root, Inc. is to provide engineering consulting services to M.I.T. on the practicality of collector concepts. For example, certain concepts can increase well pressure near the top of the well that can lead to fracture of either the casing or the bottom geology. Furthermore, some concepts will have more fire risks than others.

Brown and Root, Inc. is to initiate the system configuration studies and carry them to the point of describing candidate systems for further study and of preparing a proposal (for year 2) for detailed system configuration studies and for preliminary design of the final system.