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RECOVERY OF OIL SPILLS USING VORTEX ASSISTED AIRLIFT SYSTEM

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RECOVERY OF OIL SPILLS USING VORTEX ASSISTED AIRLIFT SYSTEM

by

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for the

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

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ABSTRACT

Studies were conducted to determine the feasibility of a concept for recovery of floating oil slicks which utilizes a pump induced vortex and a vacuum suction or Coanda nozzle. The apparatus used for developmental experimentation comprised a pumping system for vortex production, a large water basin, a flapper type wave generator, and several configurations of the experimental assembly. The range of influence was smaller than was anticipated. Approximately a 25 foot influence diameter was achieved for the maximum strength vortex generated in this apparatus. Extrapolation of measured performance data showed that a 1/8 inch thick slick could be recovered at the rate of 960 gallons per hour. Experiments with and without a variety of oils showed that enhanced oil recovery rates with the vortex was due entirely to the surface current generated by the vortex. This effect was found to improve oil recovery by a factor of 7.9 above the rates achieved with a suction nozzle alone. The surface position of the vortex cavity was found to be sensitive to surface waves. The cavity moved in a circular path within three vortex cavity radii of the still water cavity location as a wave passed through the assembly.

Tests with a Coanda nozzle (a fluid attachment eductor) showed improved performance in surface waves. However, the recovered oil-water mixture was highly emulsified.

This report was submitted in fulfillment of contract 14-12-513 between Pacific Northwest Laboratories and FWPCA.

Key Words - Vortex, Coanda Nozzle, Wave Suppressor

CONTENTS

SECTION I

CONCLUSIONS

1. Recovery of floating oil slicks by means of a suction nozzle is technically feasible. The possible rate of recovery is strongly influenced by oil characteristics and by the precision with which the suction nozzle position is maintained relative to the liquid surface. Liquid recovery rates average about one percent of the air flow rate. The oil recovery rate of suction nozzles is degraded by the presence of waves. The use of a circular wave suppressor damped short period two foot waves by about 35 percent. This was not sufficient to allow efficient oil slick recovery.

2. Recovery of floating oil slicks by use of a low head-high flow surface attachment device (the Coanda nozzle) is of questionable practicality because the recovered oil is intimately mixed and emulsified with entrained water. This would greatly complicate subsequent steps in the recovery process compared to mechanical recovery methods which do not cause this effect. The emulsion formation results from atomization of oil and water as very small droplets during entrainment from the liquid surface.

3. The use of a vortex will expand the area of influence of an oil recovery suction nozzle up to a factor of 7.9 over a suction nozzle alone. With a four inch suction nozzle, such a vortex assisted system collected medium gravity crude oil at a rate of 960 gallons per hour in calm water conditions.

4. The position of the vortex cavity on a liquid surface is shifted as a wave passes. This shift in position is a transient circular displacement of the vortex cavity; the vortex cavity returns to the original centered position after a wave passes.

SECTION II

RECOMMENDATIONS

This program was limited to the investigation of a vortex assisted suction nozzle concept for floating oil slick recovery. It involved pilot scale experiments to test critical components, define limiting performance characteristics, and assess the effects of surface perturbations (waves) with regard to a reference system concept. While a vortex was found to enhance suction nozzle performance, the influences of waves on the overall system suggests that means other than a suction nozzle be sought for removal of surface oil. Specifically, it is recommended that a liquid pumping system be utilized whose suction head is in the form of a floating circular channel. The diameter of the circular head would be such that it would enclose the possible path of the vortex when it is subjected to wave action. The liquid pumping system would also be less vulnerable to malfunction, by flooding during surface disturbances, than air operated suction devices. Evaluation of this alternative could be efficiently accomplished by modification of the existing experimental apparatus.

Construction and sea testing of a full scale operational prototype oil recovery system is recommended contingent on successful implementation of a liquid pumping system. This phase of the work should incorporate evaluation under representative environmental conditions, spill materials, and with typical offshore supply vessels and work boats.

The interesting ability of the Coanda nozzle to atomize liquids as very fine droplets suggests that this might be a useful technique for efficiently burning oil collected by the system investigated in this study or by other techniques. While the limiting ratios of water to oil and oil to air for successful complete combustion are now unknown, a preliminary investigation of this possibility seems justified. Successful development of this technique would eliminate the need for large storage tankage for several oil recovery schemes under development and would thereby improve the economics and efficiency of these methods.

SECTION III

INTRODUCTION

Accidents resulting in massive release of petroleum products to the sea, such as the TORREY CANYON stranding and Santa Barbara Channel incidents, have elucidated, among other things: (a) the large expenditure required for emergency cleanup operations, and (b) the absence of satisfactory equipment to cope with relatively large volumes of released oil. Various mechanical and chemical techniques used to clean up small oil spills in the past were proven incapable of coping with large amounts of oil under open sea conditions.

The Battelle-Northwest Oil Spillage Study (1), performed for the U.S. Coast Guard, included a comprehensive review and critical evaluation of the state-of-the-art in oil spillage prevention, cleanup, control, effects, and disposal. Techniques were described which offered promise for further development. This study concluded that mechanical techniques are likely to be most effective when large amounts of oil are involved. Furthermore, mechanical techniques do not introduce additional insult to the environment such as that possible with the use of detergents or other treating agents. Commercial equipment is presently available or being developed, both mechanical and chemical, that can satisfactorily cope with small oil spills (less than a few thousand gallons) in sheltered waters; therefore the work described in this report was directed toward the development of equipment to mechanically recover large quantitites of oil from unprotected waters. Such a system would be applicable to smaller spills; however, it would not necessarily be the most optimum, economically, for small spills in sheltered waters.

Numerous mechanical approaches to recovery of oil spills from open waters have been tried and evaluated. Among these is the technique of lifting oil from the water surface by use of a suction nozzle. As air is sucked into a nozzle, a portion of the liquid surface layer in close proximity is entrained and collected in an air-liquid separator tank. The concept is analogous to a vacuum cleaner removing dust from a rug.

Recovery rates as high as 5 imperial gallons per minute have been reported for 3-inch suction nozzles[1]. Most types of oil can be lifted from the surface provided the oil flows as a continuous film to the suction nozzle. For heavy viscous oils, such as Bunker C, the rate of oil pickup is limited by the slow rate of spreading. Too rapid an air flow rate, necessary to attain high recovery rates, causes the oil slick to "tear" apart close to the nozzle. To continue recovery, one must wait until the oil spreads beneath the nozzle again or reposition the nozzle. Recovery rates for thin, rapidly spreading oils are limited by the thickness of the slick beneath the nozzle.

Oil recovery operations on the sea face the ever present perturbations of wind and waves. To function properly the nozzle must be maintained at a fixed position relative to the surface. Depending on the operating pressure, the working distance varies from one-half to one inch above the water surface. Such close proximity to the surface makes nozzles extremely sensitive to wave motion. Several methods may be used to circumvent this difficulty. In particular, high flow-low head devices (the Coanda nozzle is a classical example) capable of immediately shutting off when a wave washes over the nozzle appears to be a good approach. This technique was studied during the work reported herein.

The effective range of influence of suction nozzles, while theoretically very large, is only about five to ten nozzle radii. The term "effective range" is used here to indicate the furthermost point at which surface movement is caused by the action of the nozzle. One approach (the one used in this study) to increase the effective range is to generate a vortex directly beneath the nozzle. In the presence of a vortex, it was thought that the surface current generated would extend much further than that generated by a nozzle alone.

SECTION IV

SYSTEM INVESTIGATION

As a first step in the development program, operational requirements and system criteria were developed from review of oil spill histories, oil recovery equipment development and manufacture equipment specifications. The objective was to delineate the environmental conditions under which oil recovery systems must operate, physical constraints dictated by the characteristics of support vessels available at most harbors and ports, and the types of material most likely to be involved in a marine oil spill.

The spectrum of environmental conditions which may prevail during an oil spill incident is legend. However, environmental conditions under which oil recovery operations may logically be undertaken are determined by the need to limit the risk to life during storms; the fact that most spills from marine vessels occur within the mitigating influences of close land masses or in harbor or channel entrances, and; a significant portion of spill sources lie on land which ajoins the sea or waterways and would not require recovery operations under unlimited open sea conditions. In spite of these factors, of course, the ideal oil recovery system would be capable of operation under any conceivable combination of environmental conditions. However, to realistically reflect performance characteristics which are practically attainable, those factors mentioned above were combined with published materials[2,3] which list various typical environmental conditions during marine spill incidents.

The characteristics of boats and ships available for emergency or planned use in oil spill cleanup operations spans the range from small pleasure craft to large ships in the thousands-of-ton category. For this study, the types and characteristics of offshore work boats available for charter in ports and harbors was considered as typical. These boats are in the 90 to 140 foot range length, 80 ton displacement, have deck spaces on the order of 300 square feet, and are equipped with moderately sized liquid fuel tanks and pumping capacity. Limitations due to the work boat characteristics are minimal for the type of system considered in this study

Materials involved in marine spills would be expected to be predominately crude oils[3]. Attention must be given to equipment performance on other materials such as refined and residual fuel oils, however, to assure maximum utility of systems to be developed. The results of this phase of the systems study are summarized as follows:

ENVIRONMENTAL AND OPERATIONAL CHARACTERISTICS

A. Effective Wave Height and Spectrum - Random Sea

1. Height -- ∿4'
2. Period -- 5 sec
3. Current -- 0 - 1 knot
4. Wind Speed ∿ 18 mph
5. Debris Present - Kelp, seaweed and small logs and floating drift-wood
6. Temperature -- 50-100°F

B. Characteristics of Oil

1. Types -- Crude Oil, fuel and diesel, residual petroleum fuels
2. Density -- .85 - .92

C. Slick Thickness -- 0 - 1"

PERFORMANCE CRITERIA

A. Rate of Oil Removal

60-300 gpm

B. Suction Nozzle Characteristics

1. Air velocity -- 73-290 fps
2. Diameter -- 3-9 inch
3. Separation from water surface -- 1/4" - 1"
4. Geometry -- Fluted conical

C. Vortex Parameters

1. Flow -- to 6000 gpm
2. Intake depth -- 0-4 ft.
3. Intake diameter -- 18" max.
4. Diameter of effect -- ∿6.8 ft. - 20 ft.

D. Storage Capacity and Separation

1. Rate of oil removal -- 60-300 gpm
2. Oil water ratio -- (assume 20:1 mixture water; oil)

E. Buoyant Stability

1. Surface heaving $\lesssim 0.5''$

The experimental system intended to meet these criteria is outlined below:

Wave Suppressor Diameter	- 6 Feet
Intake Piping Diameter	- 18 Inches
Lower Cylinder Height	- 24 Inches
Vortex Flow	- 6000 gpm
Airlift Flow	- 5000 scfm
Minimum Airlift Head	- 200 Inches H_2O
Airlift Recovery Hose Diameter	- 9 Inches Maximum
Nozzle Proximity to Surface	- 1.0 Inches $\pm$ 0.5 In.

Nozzle proximity to the water surface can be maintained by adjustment of the mass volume ratio of the floating portion of the system.

Calculations were made to predict the amount of heaving expected of the system when operating in rough seas. To insure that a uniform cylindrical floating section does not heave more than 0.5" in 5 ft. waves, a weight to volume ratio of 5.7 lb/ft^3 is required. This ratio was determined by solving the equation of motion for a floating buoy with an overall dimension small compared to the wave length.(4).

The reference system envisioned to meet the performance and other criteria is sketched on Figure 1. It consists of a floating assembly connected to an offshore type work boat. Vacuum pumps for operation of the suction nozzles and liquid handling pumps for producing a vortex are mounted on the work boat and connected to the floating assembly by hoses. Tanks for receiving recovered oil are mounted on the work boat or towed. The floating assembly consists of a wave suppressor, the suction nozzle, and the vortex producing assembly. The latter would be the open end of a suction pipe with or without flow direction controlling vanes.

SECTION V

DESCRIPTION OF EXPERIMENTAL APPARATUS

Experimental apparatus was assembled for investigation of the various parameters expected to effect the reference system. A large water basin equipped with a wave generator was basic to the subsequent experiments.

The vortex generating apparatus consisted of an 18 inch diameter intake piping section with its open end located beneath the water basin surface. The depth of the intake was established from:

$$H = 2.64\ D^{1/2}\ V^{1/4}$$

where

H = Distance between the water surface and intake pipe
D = Intake pipe diameter
V = Mean velocity across the intake pipe

This equation was derived by Springer and Patterson[5]. Figure 2 shows a plot of this equation. This piping section was routed through a water tight fitting into the pump house and connected to the suction side of a 6000 gpm, 200 hp centrifugal pump. The pump discharge was fitted with facilities for pitot tube flow sensing and liquid sampling. The pump discharge was routed back into the water basin through a water tight fitting, discharging beneath the basin surface. Eighteen inch diameter gate valves were provided on both the pump suction and discharge lines for control of the system flow. Figure No. 3 shows a photograph of the 18-inch intake piping section, the wave suppressor and the supporting structure. The wave suppressor was a six foot O.D. circular slotted baffle fitted with angular plates to impart lateral motion to a particle of water entering on a radius to the vortex. An additional right cylindrical section with a closed bottom was provided to direct all or portions of the intake flow through the wave suppressor. Thus full control of the strength of the vortex was achieved by raising or lowering this lower cylindrical section in combination with water flow and water depth. The wave suppressor assembly was mounted on a four legged structure that provided a small deck space for personnel access around the unit. Figure 4 shows a sketch of the vortex generator and wave suppressor. The supporting structure for the wave suppressor and the vortex generator was located in the water basin at a distance of sixty feet from a wave generating machine with two foot high wave capabilities.

SECTION VI

CHARACTERIZATION OF VORTEX

The vortex assisted nozzle system is shown in Figure 5. In this figure, the main components are identified so that the reader may have a clear picture in mind as these terms appear frequently throughout this report. As an additional aid, operational capabilities such as air flow, water flow, etc. are also given in Figure 5. Flow control was accomplished by adjusting the gate valve on the discharge side of the pump. The water flow rate was determined by use of a calibrated pitot tube. The water level was controlled by pumping water into or out of the basin and noting the level by observing a marked gage bolted to the side of the vortex framework. The lower skirt was manually moved up or down to change the quantity of water entering the vortex from the side thus controlling the vortex size. Characterization of the vortex was by visual and photographic means. A grid work (2" x 2" square) was placed along a diameter of the vortex for the purpose of reconstructing the vortex profile from the photographs as shown on Figure 6. Such profiles are shown in Figure 7 along with the position of the nozzle with respect to the vortex. Additional tests were performed by moving the lower skirt down and allowing more water to be drawn from under the wave suppressor. The vortex size used for the oil recovery tests was smaller than the maximum capable of the system and was selected for its compatibility with the nozzle system based on nozzle diameter and air flow rate.

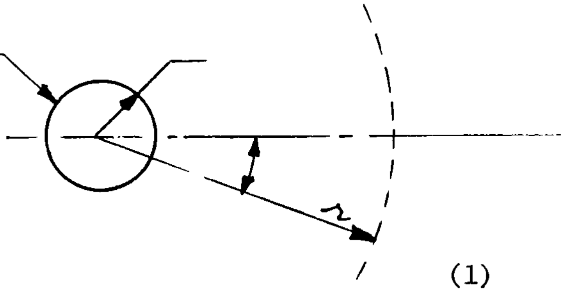
To this point, all of the vortex measurements were taken in calm water with little or no wind. The vortex was extremely stable and well suited as a possible assist to enhance the airlift technique for recovering oil slicks. To investigate the behavior of the vortex when subjected to wave motion, the preceeding experiments were repeated while two foot waves (average height) were present. The upper cylindrical slotted skirt suppressed the wave motion by about 35 percent, as indicated in Figure 8. The vortex responded to the dynamic state by meandering about its centered equilibrium (still water) position. Figure 9 is a sequence from a movie taken of this motion. In several instances, the vortex collapsed completely and then reformed at a later time (approx. 1 sec. after collapse). On the average, the vortex remained within a circle diameter of approximately 3 times the vortex diameter. This meandering motion was prevalent in all of the tests conducted in the wave motion experiments. It is believed, at least for this system, that it would be extremely difficult if not impossible to effectively damp out the motion of the vortex due to waves. Thus, to keep the nozzle above the vortex at all times one must employ a nozzle of sufficient size to cover the expected motion or to develop a feedback controlled nozzle to "follow" the vortex. The latter approach is very unrealistic from a practical point of view.

The wave generating machine used for these experiments consisted of a 338 hp hydraulically driven bottom hinged flapboard with two foot high wave capabilities. Control features are provided for both period and wave height.

SECTION VII

OIL COLLECTION EXPERIMENTS

The purpose of these experiments was to secure quantitative data on the area of influence of a vortex assisted airlift oil recovery system and on the efficiency of nozzles as a method for removing oil collected by vortex assistance. The method used to evaluate the effect of the vortex makes use of a continuity equation in which it suffices to measure surface current velocities. For example, the rate at which oil is recovered from a surface is proportional to the oil slick radial velocity and the thickness, at some point r multiplied by the circumference through r. This statement presupposes that the radial velocity ($\dot{r}$) is independent of θ, and that the oil thickness is sufficiently small to neglect velocity gradients through the thickness.



$$Q = -2\pi r \dot{r} h$$

$$\text{or} \quad \dot{r} = \frac{-Q}{2\pi r h} = \frac{K}{r} \qquad (1)$$

where

h = instantaneous slick thickness

Q = rate of oil recovery

$K = \dfrac{-Q}{2\pi h}$

R = nozzle radius

Thus, if r is taken to be some point where the surface velocity is small compared to the oil spreading velocity then the slick thickness (assuming a large oil slick area) remains relatively constant at least over some period of time. This "small" velocity will be termed the characteristic velocity V_c which for these studies was arbitrarily set equal to 0.01 ft/sec. It is apparent therefore that for a given oil slick the efficiency, as defined here, between different nozzles and vortex assisted nozzles can be estimated by merely noting the distances at which the characteristic velocity (V_c) is found. As an illustration, assume that (V_c) is found to be at 18 feet from the nozzle center for the vortex assisted nozzle while the same (V_c) is found to be at the 9 foot location for the unassisted nozzle. Then the vortex enhances oil pickup by a factor of two over the unassisted nozzle.

Time-distance data were taken on the movement of small floating particles for nozzle operation both with and without the vortex. These data taken with a variety of oil types and without oil show the range of influence to be due entirely to the surface current generated by the vortex. Typical values are presented in Figure 10. The oils used for these tests were 30 wt. motor oil 36°-38° API Canadian crude, 40°-42° API Canadian crude and diesel oil. To determine that the suction nozzle was capable of complete recovery of the oil gathered by the vortex system, samples of the discharge of the 6000 gpm pump were taken while the system was processing approximately a one-half inch thick slick of a 36°-38° API Canadian crude. Figure 11 shows the range of influence for three of the flow conditions investigated.

Comparison of the surface velocity data taken with that predicted by equation 1(K =-5.0) is shown in Figure 12. From this correlation, calculated values for oil recovery rates can be predicted and are presented in Figure 13. From these curves, the rate of oil recovery with the vortex assist and the lower cylinder installed is 7.9 times that of the airlift nozzle alone.

For the suction oil recovery experiments, the lower cylinder was removed to provide a forced vortex strength compatible with the 861 SCFM suction system. In these experiments, measured amounts of oil were administered over a specific area and the time for complete recovery recorded. Based on the nozzle recovery characteristics and these data, the oil-water ratio can be calculated as a function of slick thickness. Figure 14 presents these results. Although no tests were conducted in the presence of currents, it is believed that the presence of the vortex will still augment the operation of the suction nozzle.

The nozzle used for these tests was basically a truncated cone with a horizontal skirt added to the lower periphery (Figure 15). The addition of the horizontal skirt provided a longer residence time for the liquid surface to be acted upon by the negative pressure gradient in this region, facilitating a smoother removal of the surface liquid. Vertical positioning of the nozzle over the vortex was quite critical to achieve the objective - sufficient liquid recovery to insure 100 percent oil recovery in even relatively thick oil slicks and yet not over load the air hose with liquid during minor surface disturbances. This separation was one inch for the 861 SCFM air flow rate used for these tests and provided a 60 gpm liquid recovery rate. This is equivalent to approximately one percent by volume liquid. HIgher recovery rates were attempted but resulted in a significant loss of oil passing into the vortex generating system due to the nozzle periodically filling the suction line with water. This condition resulted in a pulsating type recovery flow.

Experiments were performed to determine if the range of influence of the vortex, both with and without oil was affected by the action of waves. Waves to two foot maximum height were generated during operation with a variety of vortex flow conditions and no change in the total area of influence could be observed. Although the area of influence during these tests did not appear to differ from the corresponding calm water test, it was observed that the center of the area moved toward the wave generating machine by some small amount. Due to the difficulty in measuring the velocity of a surface particle in the action of waves no quantitative data on this effect was gathered.

During both the calm sea and wave tests even relatively light winds (2-4 knots), had a strong influence on the migration of the oils being tested. Because of the low surface current velocities outside of the wave suppressor the pollutants would be blown down wind out of the range of influence of the vortex. The surface oil collected by the vortex was then generally limited to the areas immediately adjacent to the wave suppressor and up wind of it. During oil recovery operations these local breezes generated wind waves that were measured at up to two inches. No detrimental effect was experienced on the smooth flow of liquid from the surface from these small, short period waves.

SECTION VIII

COANDA NOZZLE EXPERIMENTS

The purpose of these experiments was to evaluate a Coanda eductor for use as an airlift oil recovery device.

One of the major faults of a conventional vacuum airlift system for recovery of oil from a water surface is its sensitivity to even small wave motion. The proximity to the liquid surface is very critical. If the airlift nozzle is submerged the system will fill with liquid to a height equal to its negative pressure. When the nozzle is again above the surface the distribution hoses, now filled with fluid, can be cleared. This natural process is relatively slow. A Coanda eductor, when subjected to the same wave motion will not fill its connecting hoses or piping with fluid, but will merely stop operating until the unit is above the surface again at which time it will instantly return to service. It was for this feature that it was selected for evaluation as an oil recovery device.

A three inch diameter, six inch long Coanda eductor was designed and fabricated for testing (Figure 16). The first experiments were performed to determine the optimum proximity of the nozzle to the liquid surface. For the three inch diameter unit this was 0.25 inches. The next series of experiments were performed to give the total liquid recovery as a function of air supply rate. Figure 17 presents these data. The final experiments established the oil-water recovery ratio as a function of oil slick thickness. It was found that the maximum oil recovery rate in an oil slick greater than 0.40 inches thick is 55.5 gal/hr. Figure 18 shows the maximum oil recovery rate as a function of oil slick thickness. Two oils were used for these tests, an SAE 30 motor oil and a Canadian crude (36° - 38° API). No measurable difference in recovery rates between these two materials was observed.

During the Coanda eductor tests, one feature was revealed that was considered objectionable from the standpoint of oil recovery. This feature was the emulsification of the recovered oil and water which required unusually long periods of time for coalescence to occur. It was observed during the testing that the performance of the Coanda eductor was somewhat sensitive to back pressure on the discharge hose. It is assumed that this feature would limit the length of the discharge hose transporting the recovered oil to a storage tank.

SECTION IX

ACKNOWLEDGMENTS

This report summarizes research conducted by Battelle-Northwest for the Federal Water Quality Administration, Department of the Interior under Contract 14-12-513.

The research team comprised:

J. D. Smith	Principal Investigator (Development Engineer - Systems Design and Development)
E. R. Simonson	Analytical Analysis (Development Engineer - Systems Design and Development)
P. L. Peterson	Scope and Principal Proposal Author (Development Engineer - Systems Design and Development)
P. C. Walkup	Project Director (Manager, Systems Design and Development)

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SECTION X

GLOSSARY

1. Vortex - A fluid having a whirling or circular motion tending to form a central cavity.

2. Vortex generator - Submerged intake piping connected to the 6000 gpm pump.

3. Wave suppressor - Circular-slotted baffel fitted with plates to induce circular motion to incoming water.

4. Suction nozzle - A truncated cone used for vacuum removal of oil.

5. Coanda nozzle - An eductor based on the fluid attachment principal.

6. Range of influence - That distance where surface motion attributable to nozzle or vortex action is just perceptible.

7. Basin - 209 ft x 432 ft, 16 ft maximum depth rectangular water pond.

8. Vortex assistance - Increasing the efficiency of nozzle by supplying a vortex directly beneath it.

9. Pollutant - Diesel oil, 36° - 38° API Canadian crude, 40° - 42° API Canadian crude, 30 wt. motor oil.

SECTION XI

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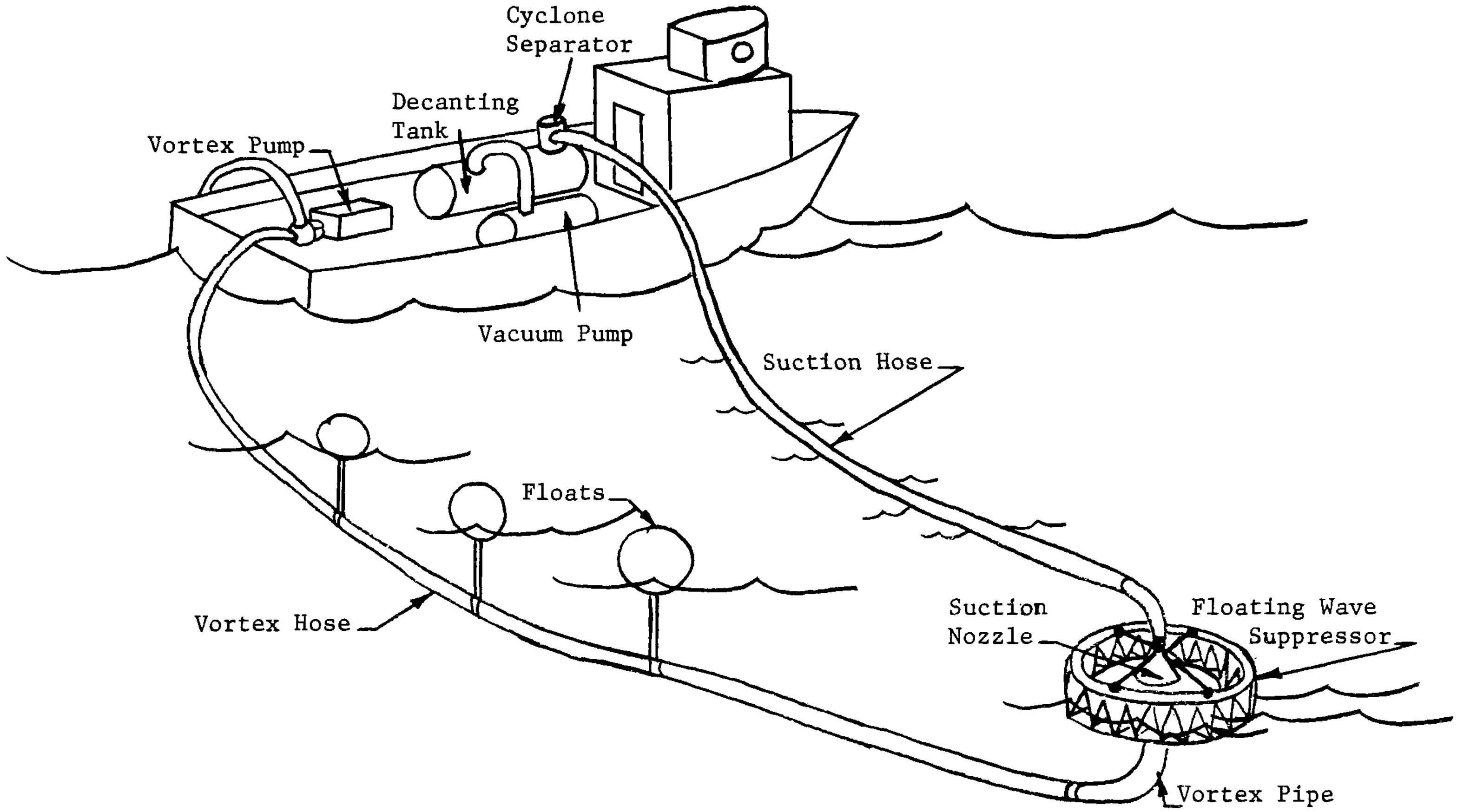


DEPLOYED REFERENCE SYSTEM

FIGURE 1

AN EMPIRICAL RELATIONSHIP FOR VORTEX FORMATION SHOWING THE CRITICAL SUBMERGENCE DEPTH VS FLOWRATE FOR AN 18 INCH DIAMETER DRAIN

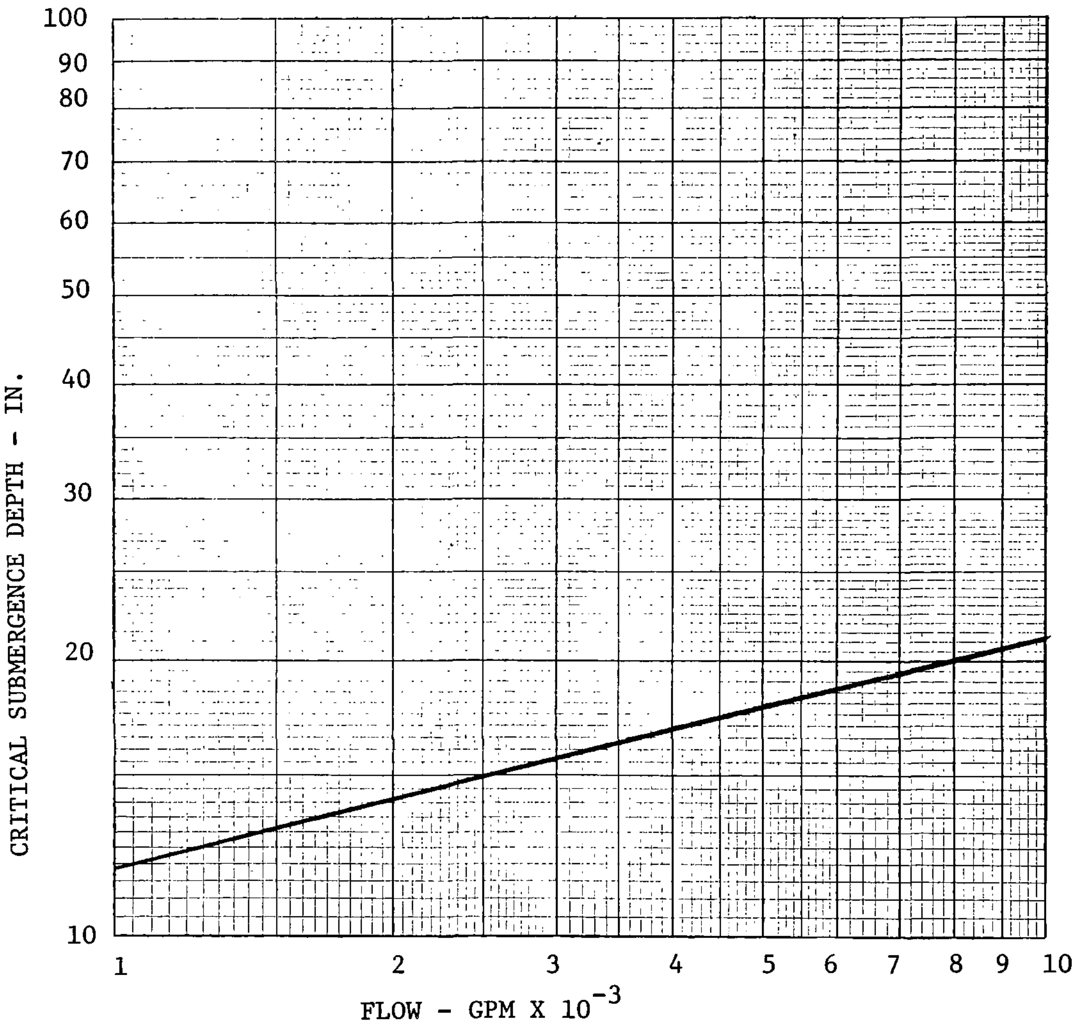


FIGURE NO. 2

VORTEX STRUCTURE ASSEMBLY

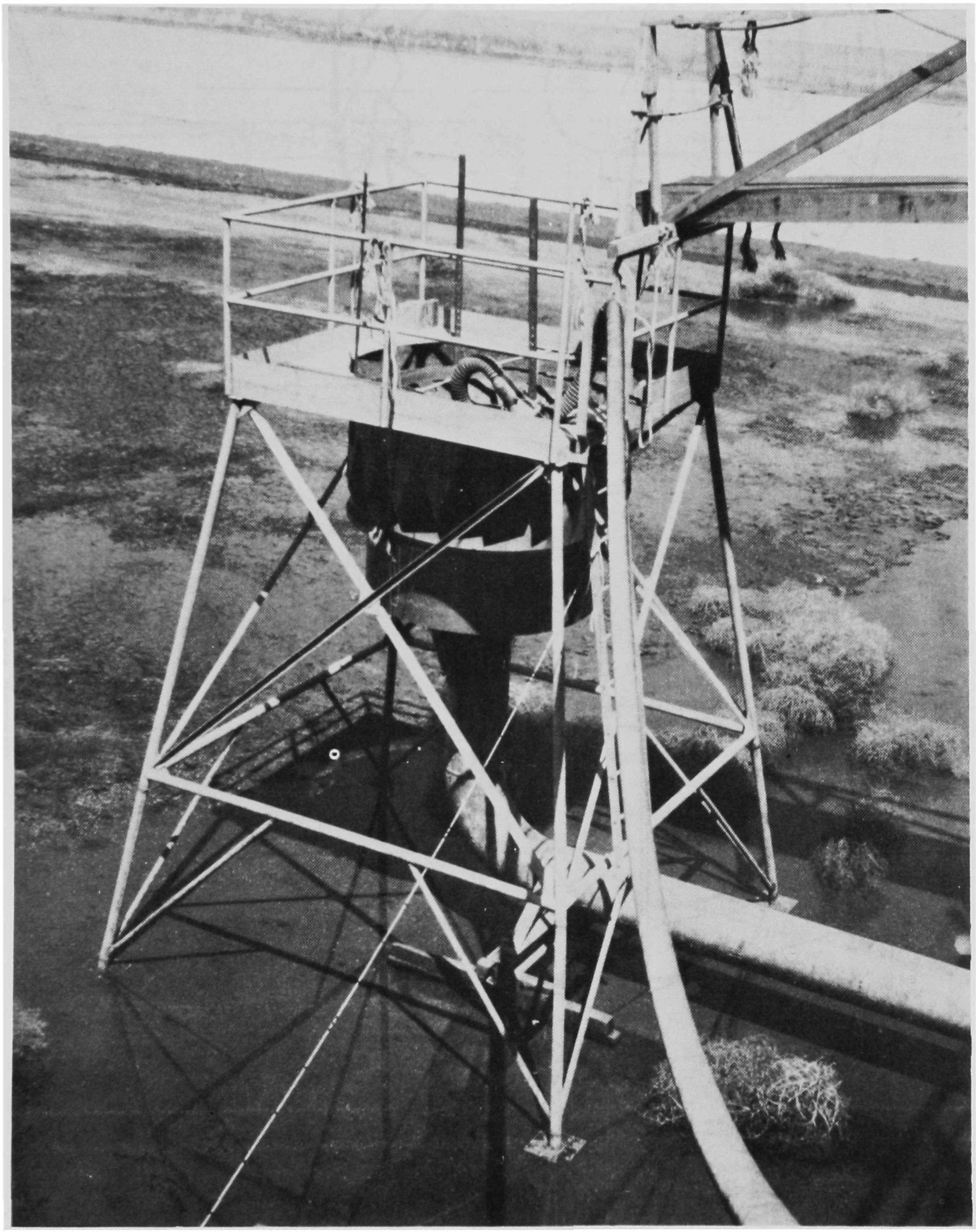
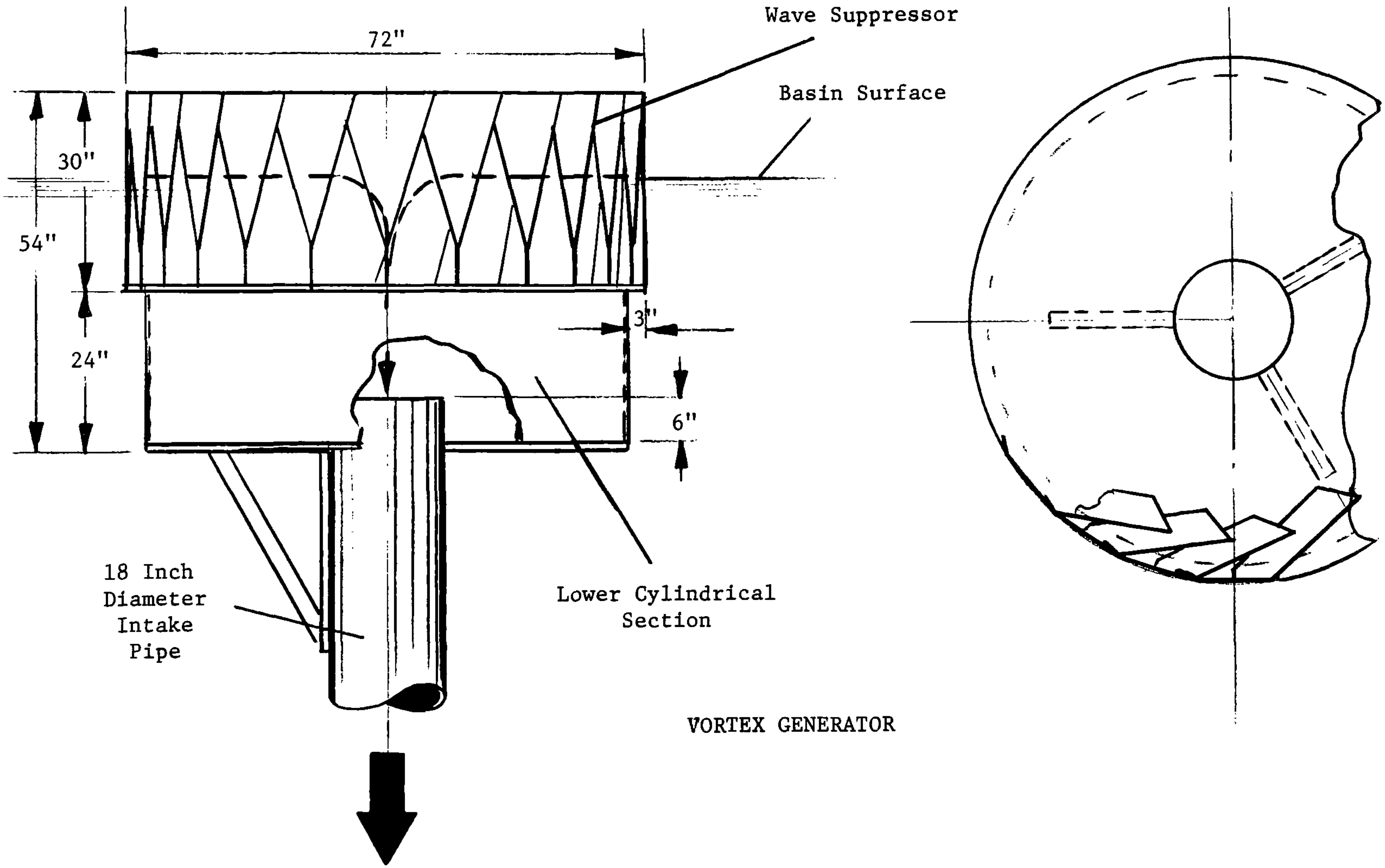
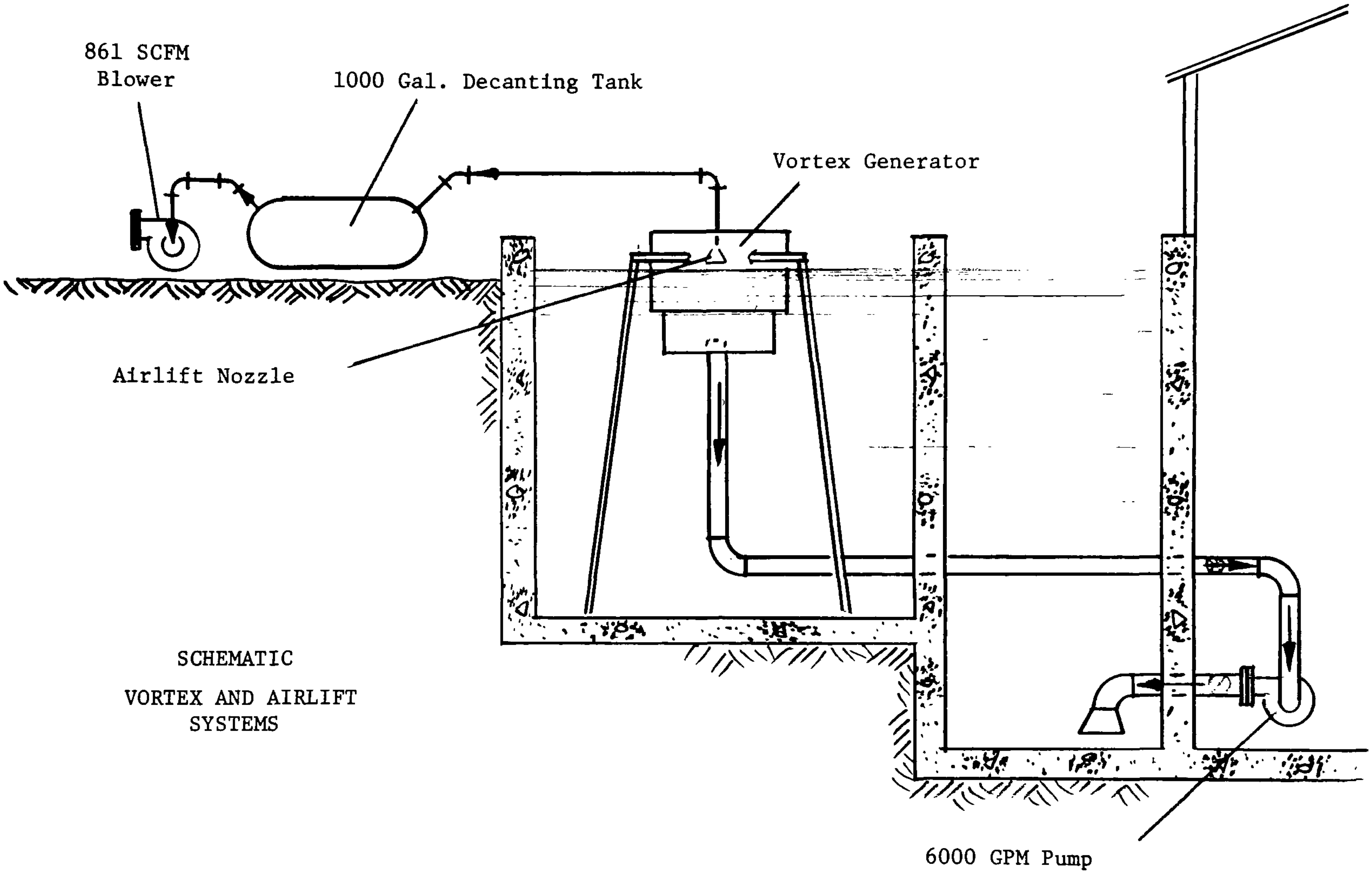


FIGURE 3



VORTEX GENERATOR

FIGURE NO. 4

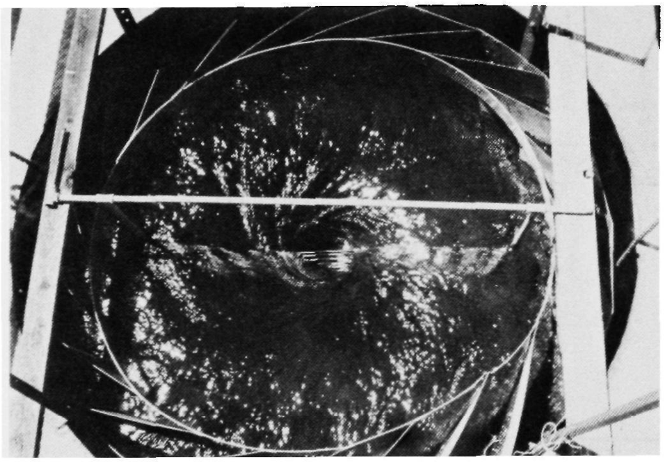


SCHEMATIC

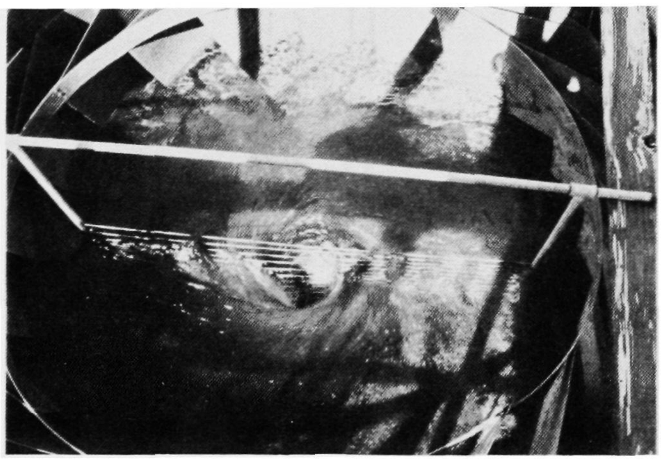
VORTEX AND AIRLIFT SYSTEMS

FIGURE NO. 5

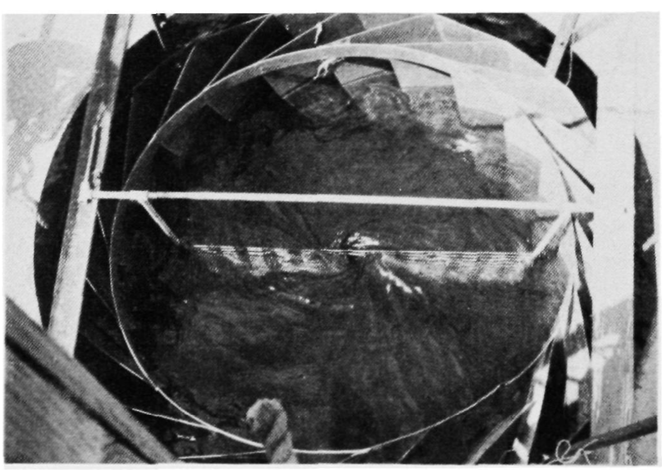
6000 GPM VORTEX



SUBMERGENCE
44 IN.



SUBMERGENCE
38 IN.



LOWER CYLINDER
REMOVED

SUBMERGENCE
38 IN.

FIGURE 6

VORTEX PROFILES

(one inch minor increments)

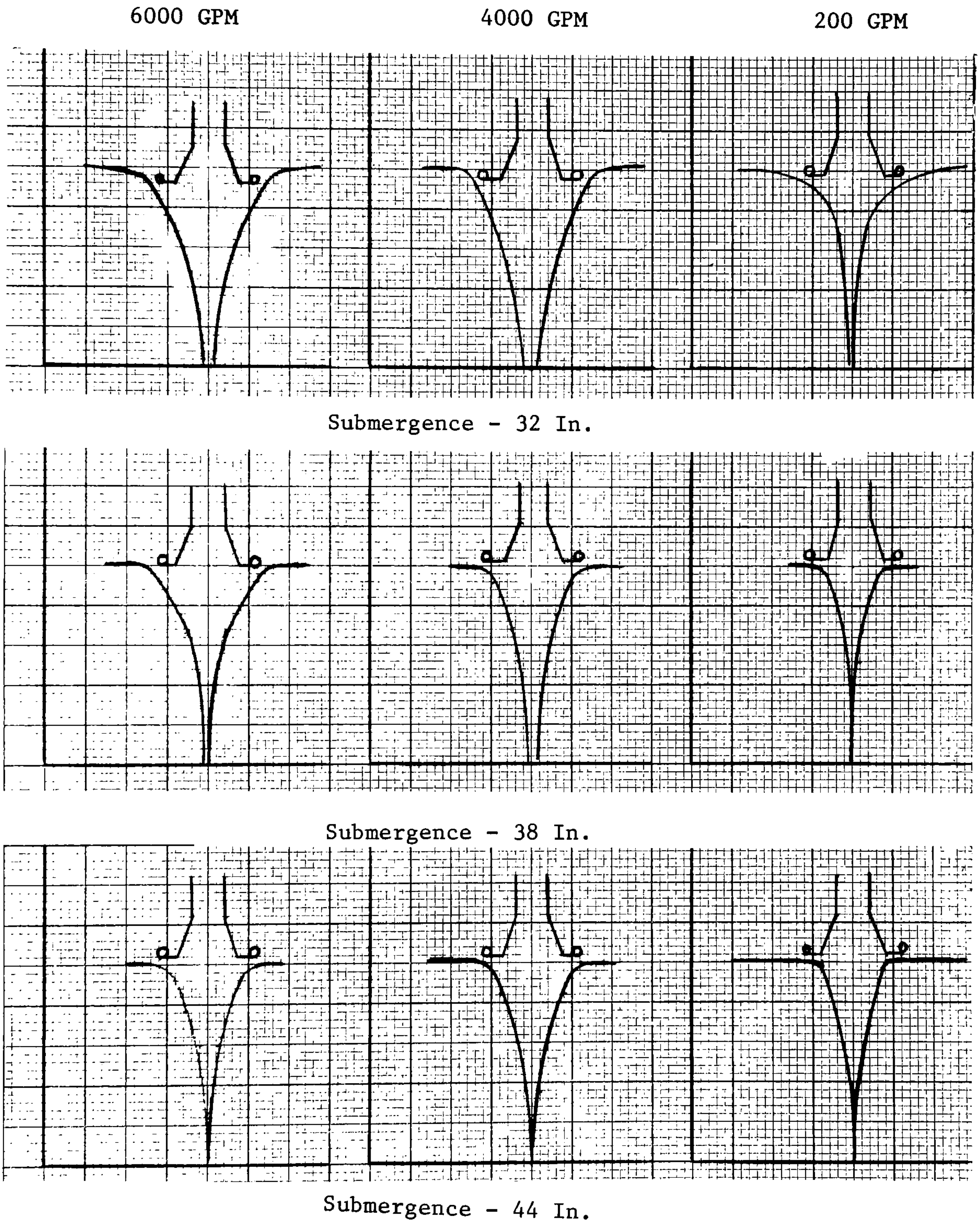


FIGURE NO. 7

WAVE SUPPRESSION
(SIX FOOT DIAMETER SLOTTED BAFFLE)

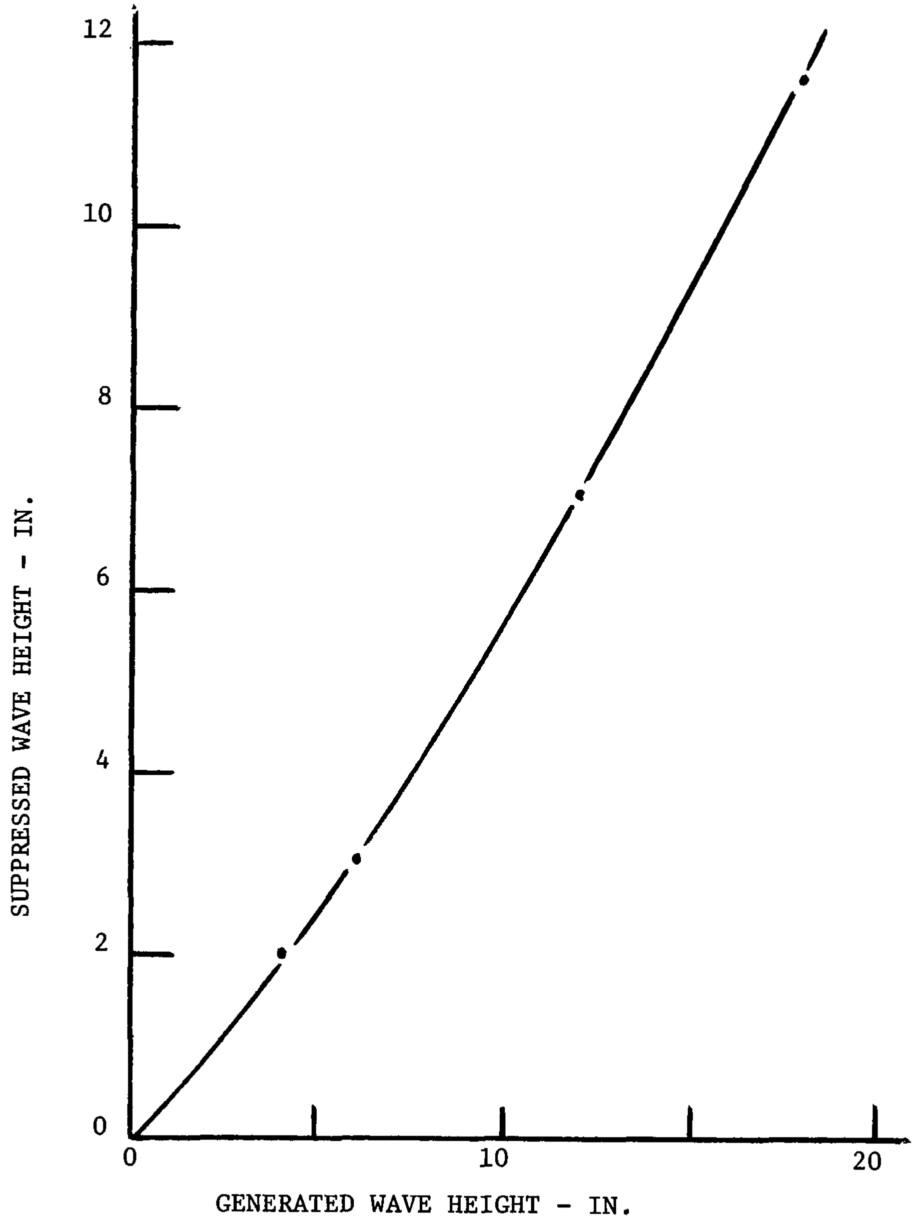
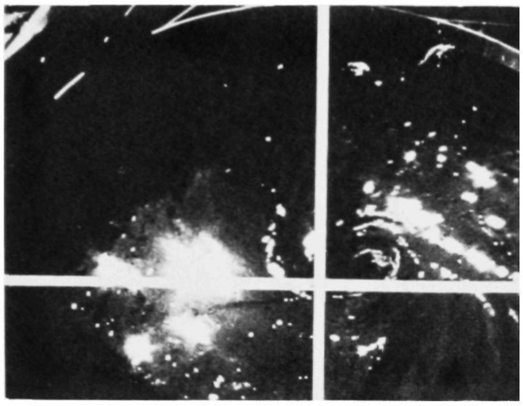


FIGURE NO. 8

VORTEX MOVEMENT
ONE SECOND INTERVALS



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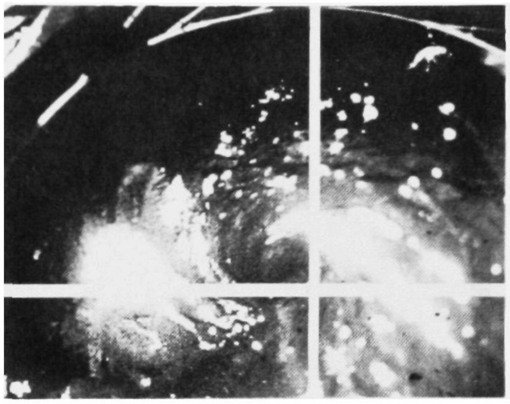

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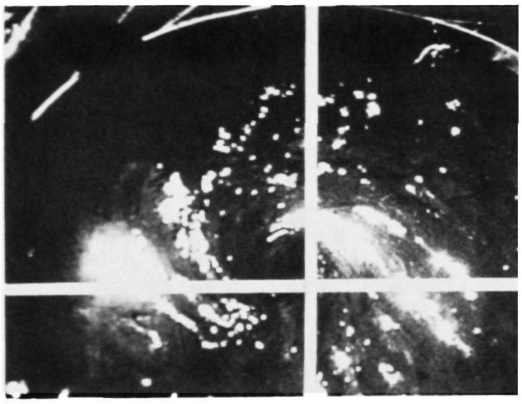

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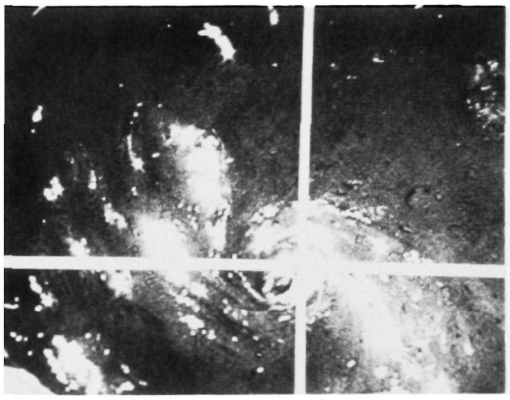

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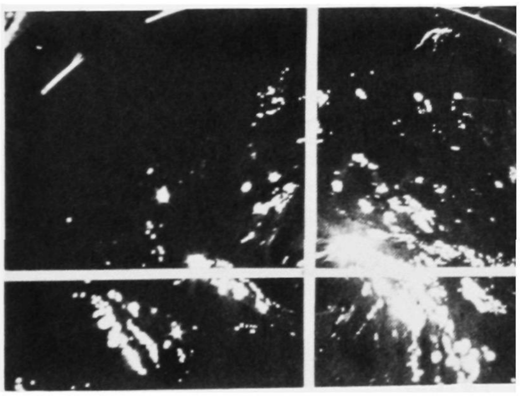

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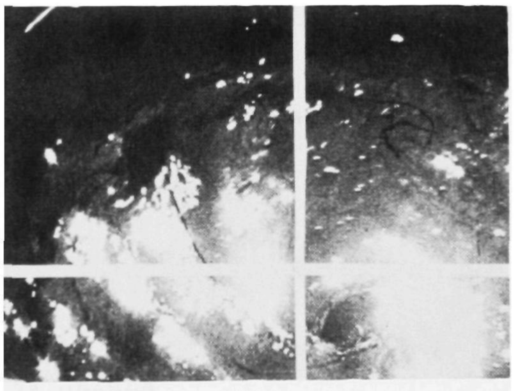


6

FIGURE 9

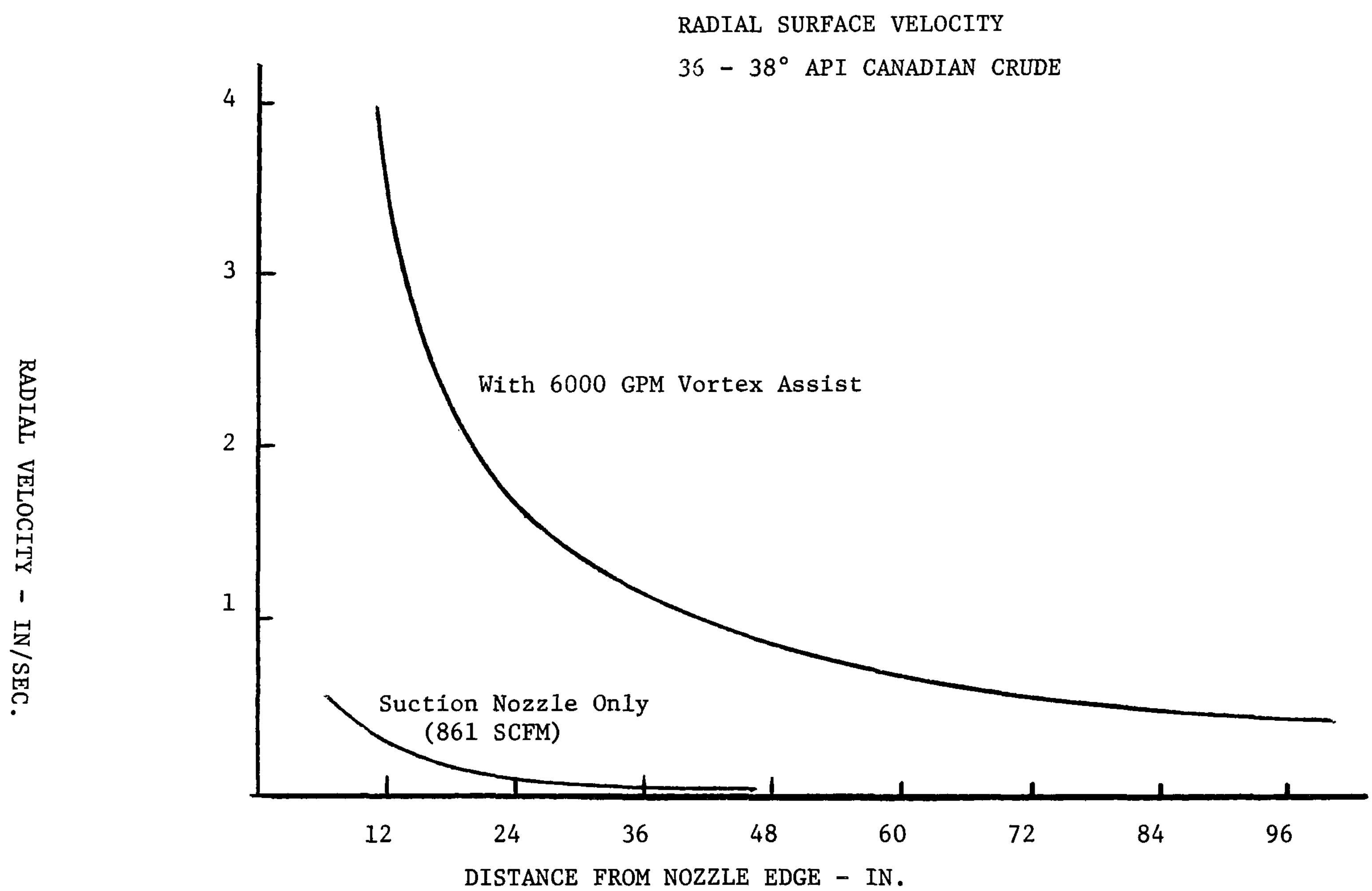

RADIAL SURFACE VELOCITY
36 - 38° API CANADIAN CRUDE
RADIAL VELOCITY - IN/SEC.
4
3
2
1
With 6000 GPM Vortex Assist
Suction Nozzle Only
(861 SCFM)
12
24
36
48
60
72
84
96
DISTANCE FROM NOZZLE EDGE - IN.

FIGURE NO. 10

EFFECTIVE RADIUS OF INFLUENCE

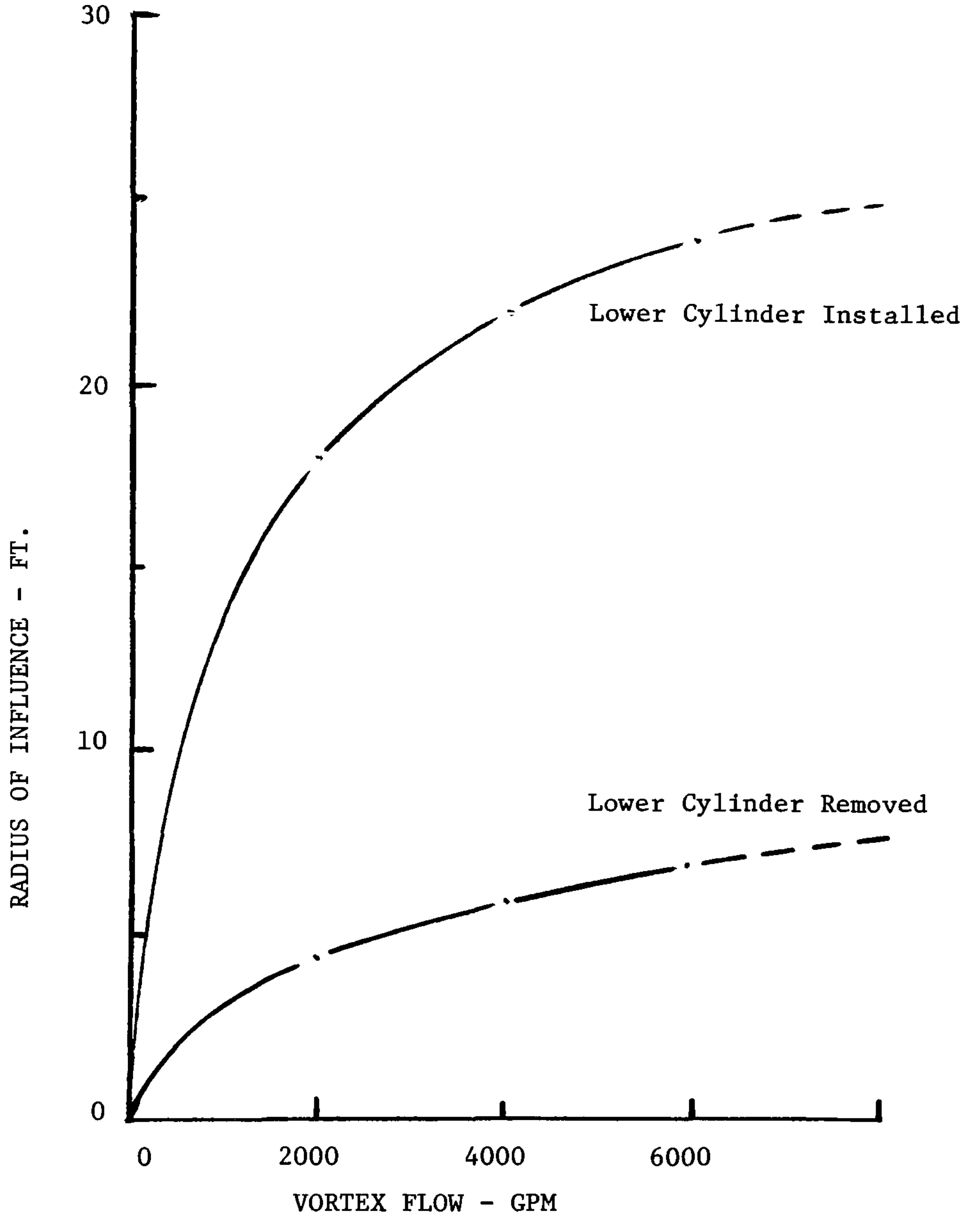


FIGURE NO. 11

RADIAL VELOCITY

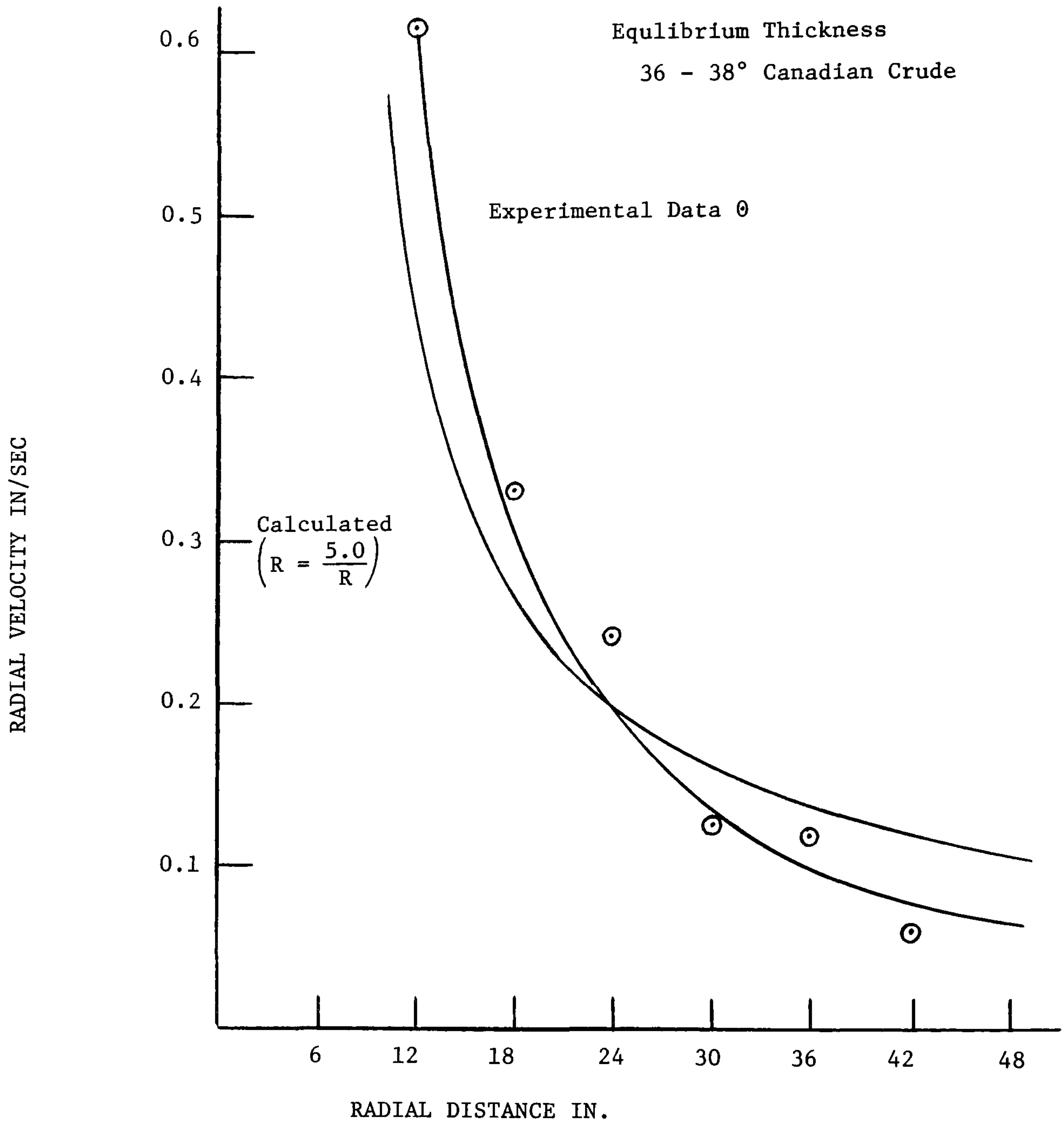


FIGURE NO. 12

CALCULATED OIL RECOVERY RATES FOR THE SUCTION NOZZLE ALONE AND WITH THE VORTEX ASSISTANCE FOR 36 - 38° API CANADIAN CRUDE OIL

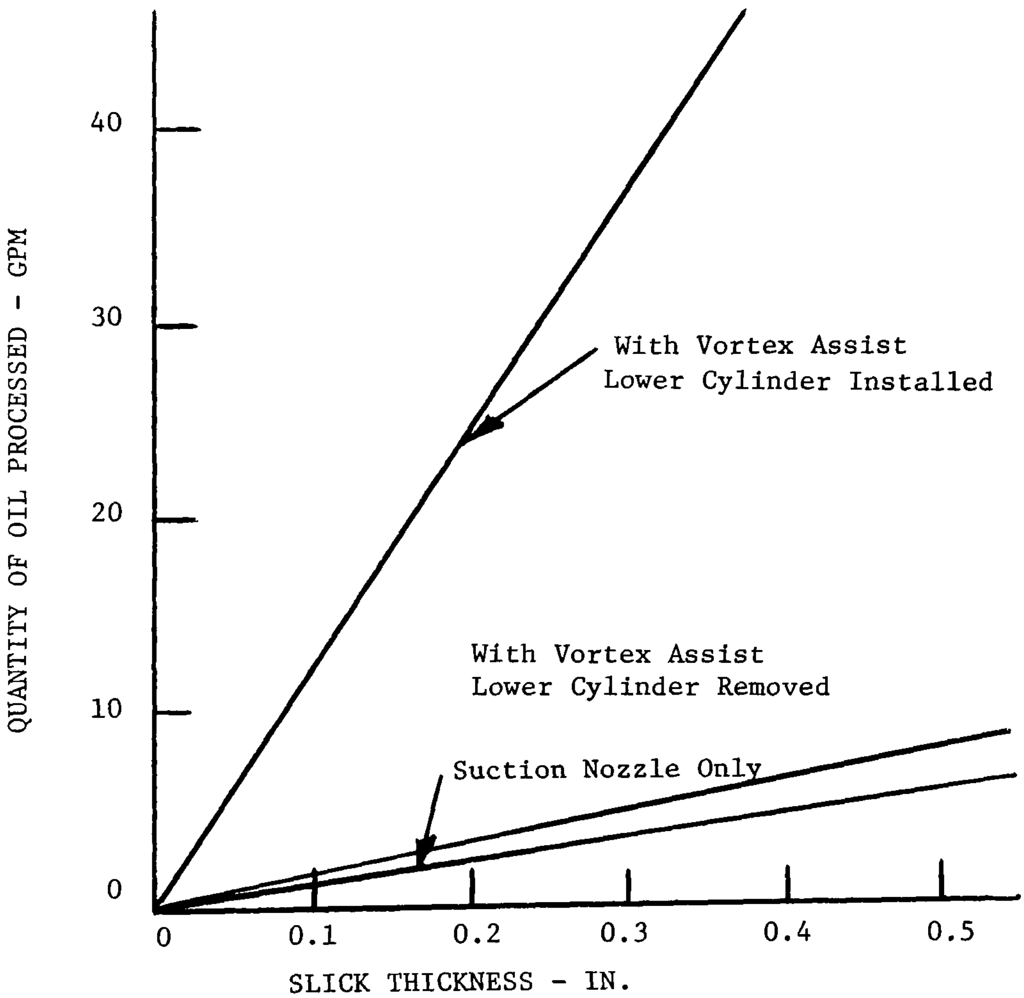


FIGURE NO. 13

CALCULATED OIL WATER RATIO VS SLICK THICKNESS
6000 GPM VORTEX - LOWER CYLINDER REMOVED

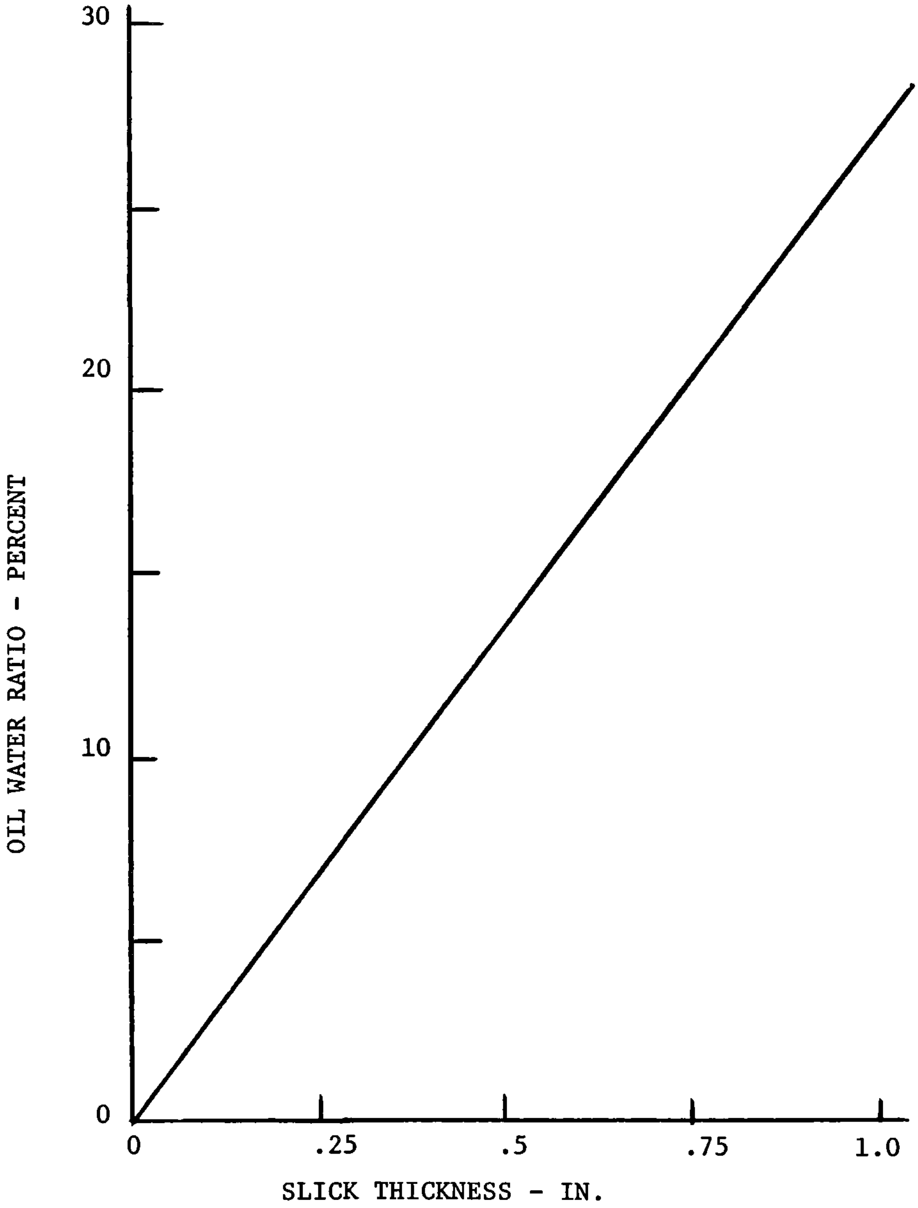
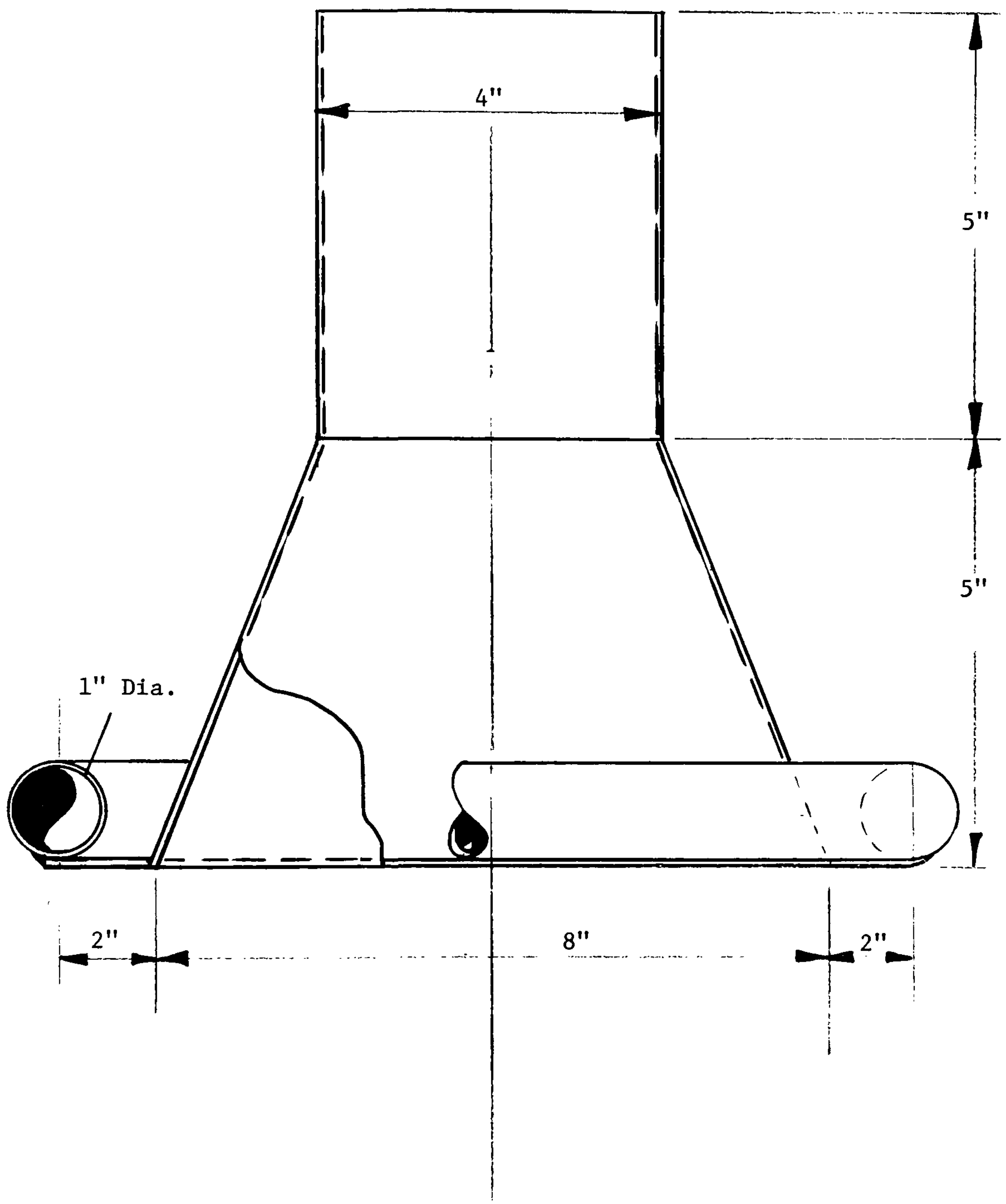


FIGURE NO. 14



AIRLIFT NOZZLE

FIGURE NO. 15

COANDA NOZZLE

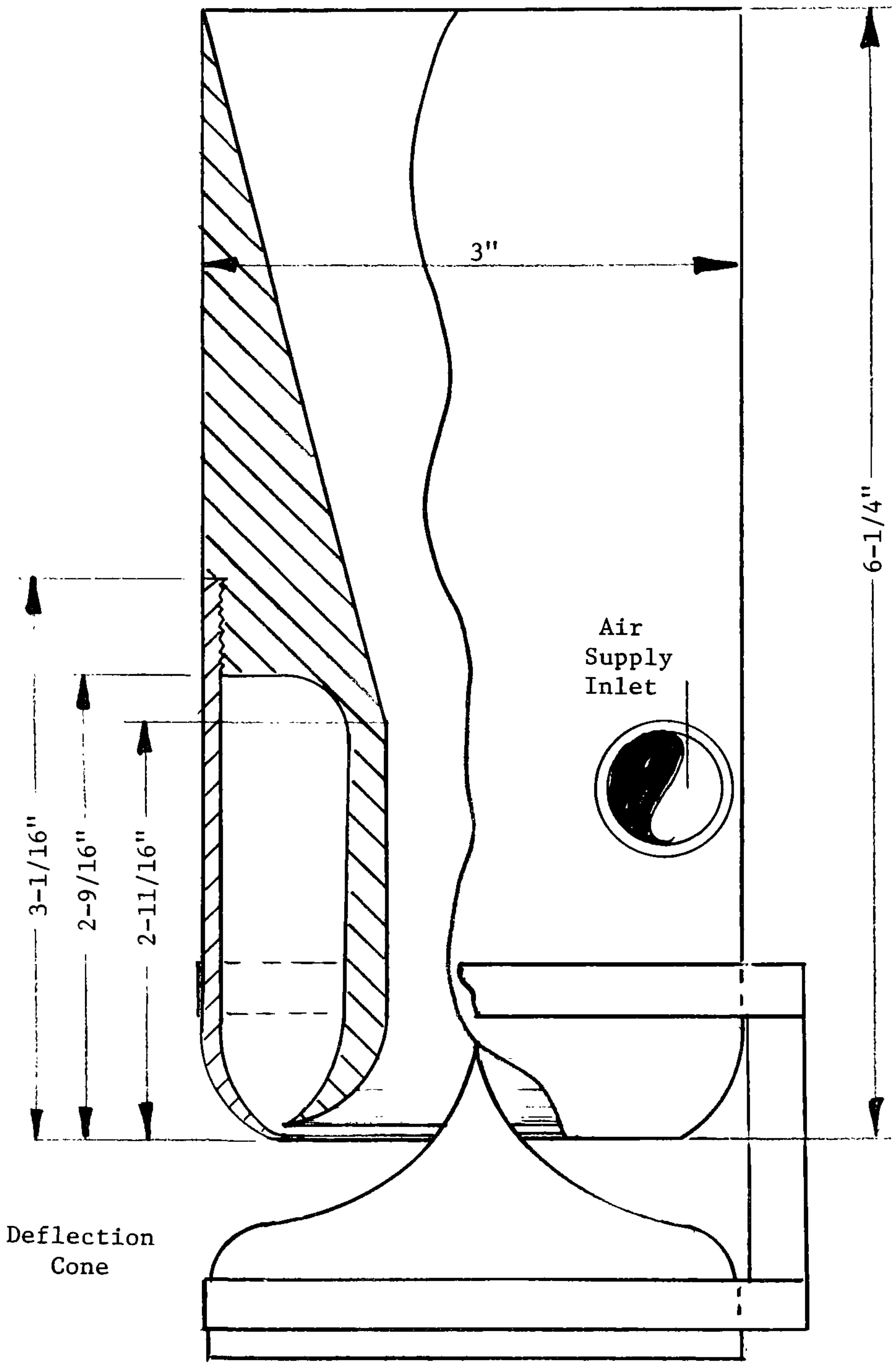


FIGURE NO.16

LIQUID RECOVERY VS AIR SUPPLY
THREE INCH COANDA NOZZLE

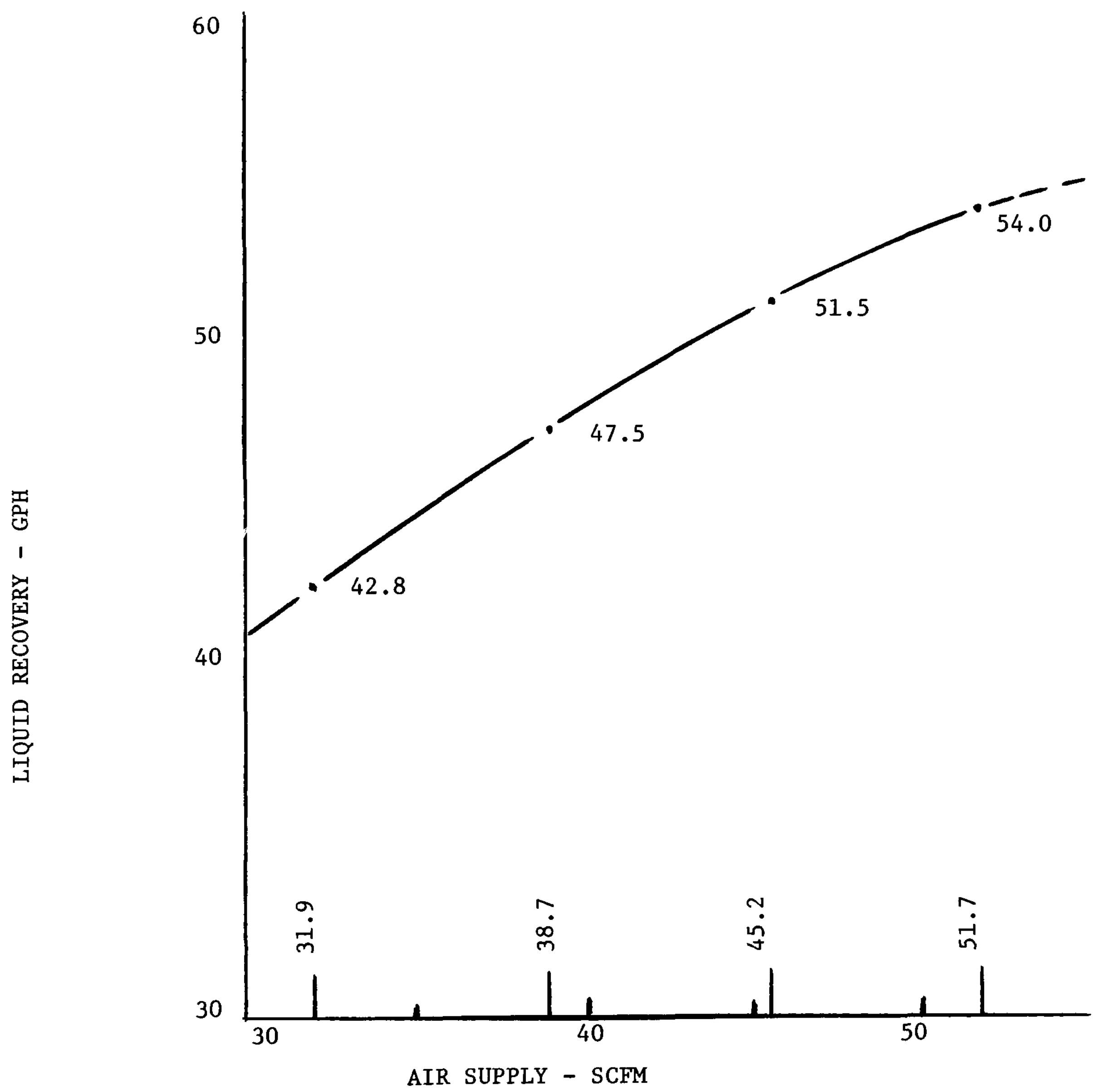


FIGURE NO. 17

OIL RECOVERY RATE VS SLICK THICKNESS
(THREE INCH COANDA NOZZLE)

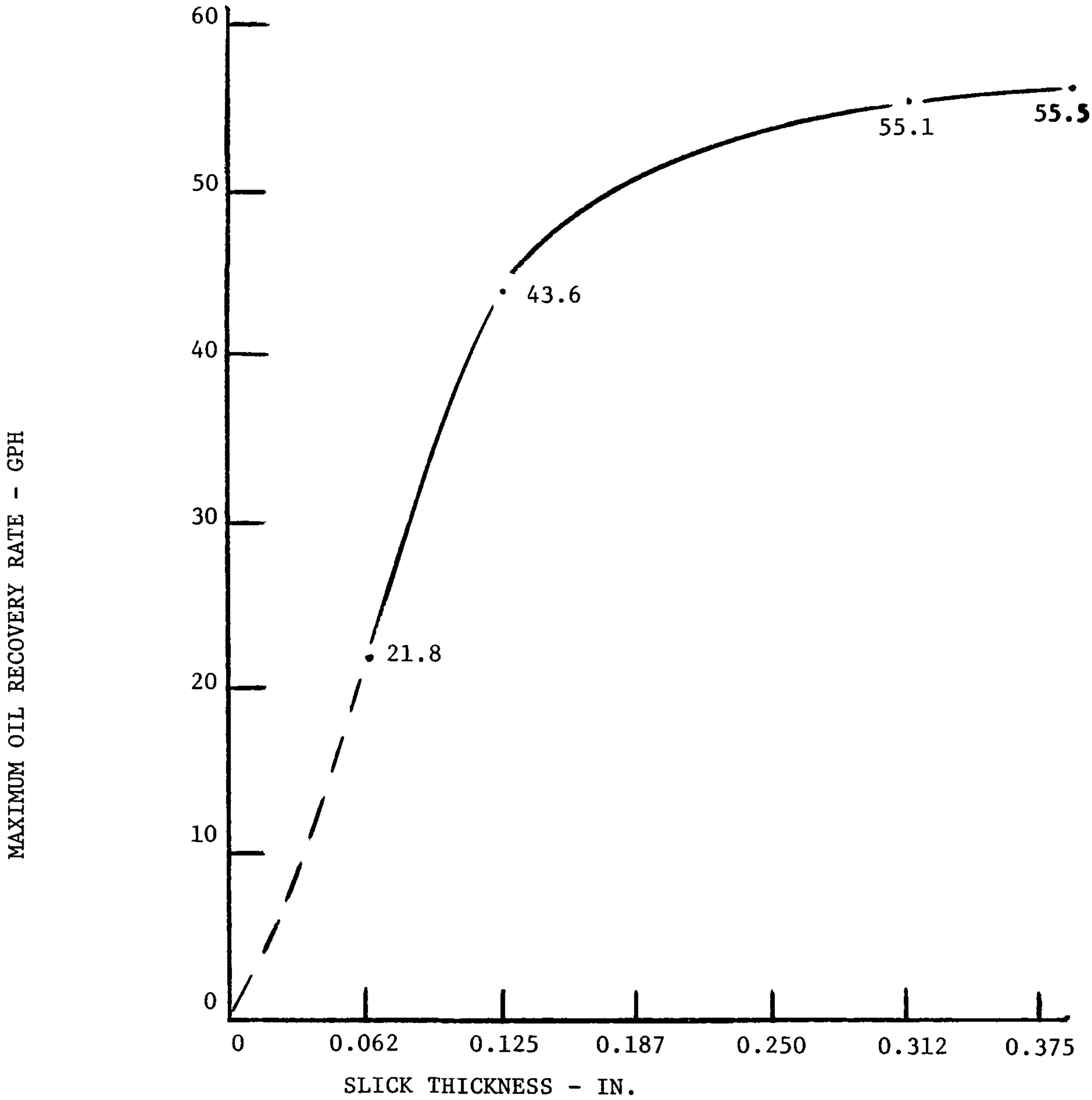


FIGURE NO.18

BIBLIOGRAPHIC:

Battelle Northwest, Recovery of Large Marine Oil Spills by Use of a Vortex Assisted Airlift System, Final Report FWPCA Contract No. 14-12-513, July, 1970

ACCESSION NO.

ABSTRACT

Studies were conducted to determine the feasibility of a concept for recovery of floating oil slicks which utilizes a pump induced vortex and a vacuum suction or Coanda nozzle. The apparatus used for developmental experimentation comprised a pumping system for vortex production, a large water basin, a flapper type wave generator, and several configurations of the experimental assembly. The range of influence was smaller than was anticipated. Approximately a 25 foot influence diameter was achieved for the maximum strength vortex generated in this apparatus. Extrapolation of measured performance data showed that a 1/8 inch thick slick could be recovered at the rate of 960 gallons per hour. Experiments with and without a variety of oils showed that enhanced oil recovery rates with the vortex was due entirely to the surface current generated by the vortex. This effect was found to improve oil recovery by a factor of 7.9 above the rates achieved with a suction nozzle alone. The surface position of the vortex cavity was found to be sensitive to surface waves. The cavity moved in a circular path within three vortex cavity radii of the still water cavity location as a wave passed through the assembly.

Tests with a Coanda nozzle (a fluid attachment eductor) showed improved performance in surface waves. However, the recovered oil-water mixture was highly emulsified.

KEY WORDS:

Vortex

Coanda Nozzle

Wave Suppressor

BIBLIOGRAPHIC:

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KEY WORDS:

Vortex

Coanda Nozzle

Wave Suppressor

1 Accession Number	2 Subject Field & Group	
	05G,08C	**SELECTED WATER RESOURCES ABSTRACTS** INPUT TRANSACTION FORM

5 *Organization*

Battelle Northwest Laboratories, Richland, Washington
Systems Design-Development Section

6 *Title*

Recovery of Oil Spills Using Vortex Assisted Airlift System

10 *Author(s)*

P. C. Walkup
J. D. Smith
E. R. Simonson

16 *Project Designation*

15080DJM07/70

21 *Note*

22 *Citation*

Battelle Northwest Research Report, July 1970, 40 p, 18 Fig., 17 Ref.

23 *Descriptors (Starred First)*

* Research and Development, *Water Pollution, *Water Pollution Control

*Vortices, *Oily Water

25 *Identifiers (Starred First)*

*Vortex, *Coanda

27 *Abstract*

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Abstractor John D. Smith | *Institution* Battelle Northwest (Smith-Battelle)