PROCEEDINGS OF THE SECOND DREDGING SEMINAR

November 21, 1969

June 1970

TAMU-SG-70-113

CDS Report No. 126

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The Proceedings were assembled and edited by Dr. John B. Herbich and Dr. David R. Basco.

The Seminar was partially supported by the National Science Foundation Sea Grant Program Institutional Grant GH-59 to Texas A&M University.

Conference participants view the Center's new laboratory

It's a Dynamic "Magna Power" variable speed drive (50-1800 RPM)

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WELCOMING REMARKS

By

Dean Fred J. Benson
College of Engineering
Texas A&M University

Dean Benson welcomed the participants and indicated the University's continuing interest in the development of the Center for Dredging Studies as a College of Engineering--Industry cooperative program. He reviewed briefly the progress made during the past year in the development of the facilities for the Center and implementation of the research program.

Dean Benson discussed the importance of the Gulf of Mexico to the State of Texas and discussed the relative lack of interest in inland areas of Texas in the development of Texas coastal zones and ocean resources. He felt that the situation would improve and that Texans of the future would be much more knowledgeable of and sensitive to the importance of the ocean to the welfare of the people of the State. In particular a probable increased interest in dredging activities and the effect of such activities will arise and it is important that the Dredging Industry be abreast of this development and be in position to respond. A good research program will be beneficial to the industry in responding to potential criticism.

Dean Benson indicated that it was most important that better methods be developed for predicting the effect of engineering developments along the coast (and in the bays and estuaries) upon these coastal areas. Physical, ecological and environmental effects must be considered.

SECOND DREDGING SEMINAR - 1969

Sponsored jointly by the Gulf Chapter of World Dredging Association and the Center for Dredging Studies, Texas A&M University.

Place: Memorial Student Center, Texas A&M University, College Station, Texas

Date: Friday, November 21, 1969

Time: 9:30 A.M. - 5:00 P.M.

9:15 A.M. Late Registration

9:30 A.M. *Welcoming Remarks* - Dean F. J. Benson, College of Engineering

9:45 A.M. *"Pollution Control and Dredging"* - Mr. Carl B. Hakenjos, Williams-McWilliams Company

10:15 A.M. *"The McFarland, 2-1/2 Years After"* - Colonel F. B. Moon, U. S. Army Engineers, Galveston District

10:45 A.M. Break

11:00 A.M. *"Effect of Air Content on Dredge Pump Performance"* - Dr. J. B. Herbich, Texas A&M University

11:30 A.M. *"The Hofer System"* - Mr. Frank F. Waldeck, Hofer Automatic Relief Valve Systems

12:15 P.M. Lunch
Speaker: Dr. Richard A. Geyer, Head, Oceanography Department Texas A&M University

2:00 P.M. *"Dredge Pump and Pipeline Energy Losses"* - Mr. David M. Frazier, Erickson Engineering Associates

2:30 P.M. *"Cavitation in Dredge Pumps"* - Dr. C. J. Garrison, Texas A&M Univ.

3:00 P.M. *"The Challenge Ahead: Change or be Changed"* - Mr. R. Alderdice, Offshore Magazine

3:30 P.M. General Discussion

4:00 - 5:00 P.M. Tour of Facilities - Hydromechanics Laboratories

POLLUTION CONTROL AND DREDGING

By

Carl B. Hakenjos
Texas A&M University

Gentlemen:

We in the Dredging Industry are presently being confronted with a very serious problem concerning the rules and regulations that are being enacted upon us by Government, State and Local Agencies, which deal with the disposition or disposal of our hydraulic dredge spoils. Being dredging specialists, we are all familiar with the various aspects of the behavior of certain type materials, and how they act when pumped overboard or into confined areas. It is on this problem of handling material, once excavated, that I would like to speak this morning.

Since the enactment of the Water Pollution Control Act, we have seen legislation on top of legislation, and act after act passed with, at times, little or no regard as to the consequences, other than to stop polluting our air, stop polluting our water, stop polluting our Country, or soon we will all be walking around with gas masks on our faces or hip boots on our feet. The word Pollution has been kicked around so hard within the past years, that few people take sight of its true meaning. The word Pollution has become such a political catch word that to quote a recent publication, "One would sooner be against Motherhood than be in favor of Pollution".

The problem of clean rivers and streams should be approached with reason. Right now, however, there is entirely too much emotion in this matter. I'll state a good example. In early October of this year, after months of political pulling, the House passed and sent to the Senate, a Bill giving the Federal Water Pollution Control Administration, 600 Million Dollars for treatment plant grants. This was triple the Nixon's Administration Budget of 214 Million Dollars; however, and this is the crux of the issue, the amount of the Bill was down from One Billion Dollars, which was originally fought for on the Floor and would have passed because a Bipartisan Citizen Group had collected pledges of support from 220 of 290 House Members, until it was learned that there was insufficient engineering manpower available to handle the work One Billion Dollars would generate.

Gentlemen, this industry must bring our legislators to analyze the situation on a sound and realistic basis. One of the biggest problems, I believe, is defining and understanding Pollution. Throughout our Country today, you will find individuals, organizations and judicial powers, all using the word Pollution to fit their particular needs.

A fitting example of this can be shown by the remarks of Mr. Carl D. Felzer, which were stated in the Report on Pollution at the National Rivers and Harbors Congress in May of this year, and where Mr. Felzer is concerned with the relationship of pollution to agriculture, and I quote "Sediment is a Pollutant. Volume-wise, it is the most important pollution in the Nation's Rivers". The dictionary defines the work Polluted, as to make impure, foul, contaminated, offensive, harmful and even to poison. In my estimation, the Mississippi River, for example, is not extremely polluted, but rather has a high turbidity level. Turbidity is the stirred-up sediment or amount of solid matter that is suspended in water. I wish you would keep this matter of turbidity in mind because it has, I believe, a direct bearing on the problem confronting this industry, and I will touch on it again later.

Present existing Law declares it to be the intent of Congress, that all Federal Departments and Agencies comply with water quality standards. This declaration of intent has proved unsatisfactory. Recent legislation is now requiring that all activity over which Federal Government has direct control, be carried out in a manner to assure compliance with applicable water quality standards.

Originally, sections 16 (a) and 16 (c) of the Water Quality Act, would have adversely affected dredging operations essential to navigation. Initially, under these provisions of the Bill, all dredging, Federal, State or Private, would be subjected to the same standard:"..compliance with applicable water quality standards". In enacting the Water Quality Act, Congress directed that Water Standards be prepared on, and I quote, "Their use and value for public water supplies, propagation of fish and wild life, recreational purposes and agricultural and other legitimate uses". We can readily see from this that originally there were no provisions made for navigation, which is the life blood of our industry. However, recent legislation has added language to the Act to specifically include navigation. So now, we have a "Water Quality Standard" which has to include navigation.

You will recall, earlier, I referred to Turbidity as being the amount of stirred-up sediment or amount of solid matter suspended in the water. Under existing Federal Water Quality Standards, Turbidity is included as a measure of water standards, but with one very important exception, which states that such standards were not drawn to accomodate or otherwise consider temporary turbidity resulting for dredging and disposal of dredge spoil. Consequently, criteria should be provided for the establishment of standards for temporary turbidity based on the location and characteristics of various waterways within specific locations of the Country.

We have all read or heard about the serious pollution problem occurring in the Great Lakes Area with respect to waste disposal and dredging, but I am certain that there can be no correlation of the establishment of standards for temporary turbidity resulting from dredging in this area, to the dredging conditions that we have along the entire Gulf Coast and even up into the Mississippi Valley. Most of us, I am sure, are familiar with all the conditions

I refer to; Dredging the mud from miles and miles of the Gulf Intracoastal Waterway, with the spoil being deposited within areas adjacent to the waterway; dredging the silt and fine sands from the Mississippi River with spoil generally being discharged overboard; dredging the mud and silt from the Lake Charles, Mississippi River Gulf Outlet, Gulfport, Pascagoula and Mobile Ship Channel, where spoil is deposited within confined and /or overboard spoil areas; dredging the silt of the Atchafalaya Basin, and countless other adjacent related waterways. The dredging of these materials which have been deposited recently, or which have existed in their natural state and the disposal of these materials whether for navigation or for other hydraulic dredging projects does not constitute a violation of applicable water quality standards.

Also, I would like to point out that nothing in the recent Bill can be construed as requiring the disposal of all dredge spoil on land. Where spoil is determined to be non-polluting and where turbidity does not cause long-term environmental damage, and where a short time after discharging in water the spoil ceases to cause turbidity, this material may be properly discharged into lakes or rivers.

In addition to establishing a basic standard of determination of pollution concerning dredging, the problems in evaluating existing water quality standards are being further compounded by the mounting opposition of narrow-minded conservationists. Their approach to our mutual problems are almost always single-minded and uncompromising, and leave little or no room for reasonable reconciliation of differences. Their views on pollution are hard-fixed and despite straightforward and sound factual information, they show ignorance and prejudice.

Many conservation groups start out assuming that business won't cooperate. Even when a company participates in an environmental plan, they seldom receive any credit for their efforts. A very good example of this is the recent case where a company, American Metal Climax, Inc., a 600 Million Dollar natural resources developer, has participated in just such a plan to an almost unrivaled degree.

At its new Henderson mine high in the Rockies, 50 miles West of Denver, to avoid the usual drab appearance of mining installations, the buildings are being designed with colored siding to match the surroundings. Access roads have been rerouted to preserve as many trees as possible. Some 6,000 acres of woodland have been thrown open for hunting, hiking, and camping.

AMAX's biggest concession to the environment, however, is its system for handling "tailing" - finely ground ore waste that leaves the mill hydraulically in the form of 60% water and 40% solids. For convenience, tailing is normally stored in ponds near the mine. At Henderson, however, this would have placed it very close to a major highway. AMAX Engineers are therefore tunneling 9.3 miles through Red Mountain, building a 13 mile railroad at a cost of 25 Million Dollars, and putting their tailing pond far from the public's and conservationists' view.

However, Dr. Beatrice Willard, an ecologist and one of the more militant members of a large private conservation group, is impressed with results thus far, but she feels there are still several matters to be ironed out. "I want to do considerably more research on wind patterns around the tailing pond", she says, "If wind lifts the tailing into the air and drops it on plants, we can have all kinds of problems". Whatever her research shows, I feel certain that AMAX already knows which way the wind is blowing.

Gentlemen, we believe we also know which way the wind is blowing, and should defend ourselves against this narrow-minded approach to pollution. In contrast, the Corps of Engineers is employing technical assistance in evaluating both the real and potential pollution problems associated with dredging and the disposal techniques, analysis of dredging and spoil disposal techniques, analysis of areas and materials to be dredged, and the effects of disposal of spoil in submerged areas.

It is time we impress our legislators that we are willing to cooperate to preserve the beauty of our environment, but not in line with the inflexible belief of our conservationists, that change always means destruction, and that to preserve the beauty of our environment means complete abandonment of economic progress.

Water is a precious commodity. It is becoming more apparent each year that we cannot afford to waste, pollute, or in any way destroy this natural resource. Thus, we must plan the use of our Nation's water supplies to provide maximum benefits to all purposes...........providing outdoor recreation opportunities, fish and wild life conservation and enhancement, in conjunction with dredging to maintain existing navigation, provide for new navigation, and also assure the control of floods in our Country.

THE McFARLAND, 2-1/2 YEARS AFTER

by

Colonel Franklin B. Moon
Galveston District, Corps of Engineers
Department of the Army

INTRODUCTION

In April 1967, the Corps of Engineers placed in service a new concept in hopper dredging, the dredge McFARLAND, with the ability to:

First, perform conventional hopper dredging with bottom dumping in deep water.

Second, perform side-casting or boom discharge dredging, wherein the material is continuously thrown to one side of the channel as it is dredged, and

Third, perform pump-ashore work where bottom dumping is not feasible or where beach nourishment is desired. There were various other innovations and modern features in the McFARLAND designed to increase efficiency such as a single hopper in lieu of the previously used multiple hopper arrangements, larger hopper door area to facilitate faster dumping of material, hydraulically-controlled adjustable hopper overflow or loading levels to improve material retention while eliminating excess water in the hoppers, reversible pitch propulsion propellers, reversible pitch bow thruster, swell compensators for the drag arms to provide uniform draghead pressures on the bottom materials, greater suction pipe cross section to increase vacuum at the dragheads, and an unprecedented degree of production instrumentation.

DESCRIPTION OF DREDGE

For those of you who are not familiar with the dredge, a brief description may be in order. The McFARLAND is 300 feet long, has a 72-foot beam, a

33-foot molded depth, and can be safely loaded to a maximum draft of 23 feet. The loaded displacement is 9,720 long tons. Hopper capacity is 3,140 cubic yards. 6,000 horsepower of propulsion power is supplied to the twin 13.5-foot diameter Bird-Johnson reversible pitch propellers by 4 Alco diesel engines, with direct drive through Lufkin reduction gears. There are two 34-inch inside diameter dragarms, one on each side, capable of dredging to a maximum of 55 feet, each connected to its own dredging pump. The pumps are electrically driven, with a maximum of 2,800 horsepower per pump to allow for pump-ashore operations, but normally utilizing not over 1800 horsepower per pump. Dragarms are retractable to the weather deck to reduce water friction when moving to and from the dumping area or between ports, and to facilitate repairs, adjustments and docking. The 222-foot all aluminum side-casting boom supports a 35-inch discharge pipe, rotates from the stern to either port or starboard in three minutes and will cast material approximately 165 feet from the side of the dredge. The 75-man crew has modern air-conditioned quarters, private or semi-private, each room with its own full bath. The dredge can carry sufficient fuel, food and other supplies to enable it to operate in excess of a month or travel 8500 miles without stopping for replenishment.

In general arrangement, the vessel includes a forward area which is the site of the pilot house, dragtenders houses, pumpout control house, quarters for deck officers and men, recreation rooms and pump room. Amidships are located the hoppers, discharge boom turntable and the dragarm hoisting equipment. The aft section contains generating and propulsion equipment as well as quarters for engine officers and crew, galley, mess rooms, hospital space, and shop spaces.

The rotunda-type pilot house contains a central process control console, which includes a visual diagram of all process piping, with lights to indicate both the proper and the actual valve positions for each mode of dredging and discharge. Controls for each valve are included. Available arrangements for pumping ashore include both single and double pipe discharge to either port or starboard.

A special feature is an air-conditioned, soundproofed engine control room, which includes controls to start and stop the engines from this central location, stripchart instruments to monitor the operation of all engine exhaust temperatures and lube oil pressures, and speakers to monitor high fidelity microphones located in the engine spaces.

Other features of the vessel include a galley with cafeteria-type service, a machine shop, electrical shop, welding and iron shop, ship's office, radio room, chart room, a laundry, and automatic mooring winches. The McFARLAND has twin screws and twin rudders for the high maneuverability required of hopper dredges and the complete navigation, communication, and other equipment as required for "Ocean" certification.

Two 32-foot aluminum launches are provided, one outfitted as a crew boat and the second for surveys. The launches are each powered with twin two hundred horsepower diesel engines and have a cruising speed of approximately 30 miles per hour. The launches are handled in gravity type davits, one port and one starboard.

PERFORMANCE OF DREDGE

As my subject title indicates, the McFARLAND has now been in operation for approximately two and a half years. The dredge has been subject to, and tested by, a wide variety of project conditions at nine different locations, extending from Brazos Island Harbor, Texas, near the Mexican Border to Charlotte Harbor, Florida. It has reopened three channels which were seriously shoaled by hurricanes: Brazos Island Harbor and the Corpus Christi

Ship Channel in Texas, following hurricane "Beulah" in September 1967, and Pascagoula Harbor, Mississippi, following hurricane "Camille" in August 1969. A wide variety of materials have been encountered, including various grades or types of clays, sands and silts. Both virgin and shoaled material have been removed, employing both the conventional bottom dump and side-casting dredging modes. Let us now examine the dredge's performance under these varying conditions.

As a general statement, I will say that all projects have been handled very successfully and that the McFARLAND can readily dredge and dump all types of materials which have been encountered. But to properly evaluate performance, we must consider production and costs, since the basic function and mission of the dredge is not only to remove and dispose of materials from the waterways, but to do so efficiently and economically. The quantities in all production figures quoted hereinafter are as computed from before and after dredging surveys.

Overall, the McFARLAND has dredged approximately 26.5 million cubic yards of material at a cost of slightly under $6,000,000, an average of approximately 22.6¢ per cubic yard. This is a rather economical average price, considering that approximately 50 percent of the total was virgin material, primarily sand and medium to stiff clay, and that all dredging has been in exposed locations, principally in the open Gulf of Mexico, with an average haul distance from the project to the disposal area of approximately 2 miles. The price includes all applicable costs, such as depreciation, travel between projects, surveys and overhead, labor, fuel, subsistence, repairs, etc.

Breaking the production down in another manner, if we deduct approximately 3.2 months that the dredge has been in the shipyard or on cessation

OVERALL PRODUCTION IN FIRST 2.5 YEARS

QUANTITY ---------------------- 26,500,000 CU. YD.

COST ------------------------------------ $ 6,000,000

AVERAGE UNIT PRICE -------- 22.6 ¢ PER CU. YD.

MATERIAL
- 50% VIRGIN (SAND AND MEDIUM TO STIFF CLAY)
- 50% SHOALING (SAND AND SILT)

AVERAGE DISTANCE TO DISPOSAL AREA ---- 2 MI.

during the Christmas -New Years Holiday period, we find the dredge has been "on project" 26.8 months or almost 90 percent of the entire two and a half years, and has produced almost 1,000,000 cubic yards per elapsed month while "on project." Or based on only "effective" working time (pumping, turning, to and from dump, dumping and /or side-casting), production has been approximately 48,777 cubic yards per 24 hour day, slightly less than 1,500,000 cubic yards per "effective" month. This difference between 1,000,000 yards per elapsed month and 1,500,000 yards per effective month is mostly due to a shortage of qualified crew members. The crew shortage has occurred partially from Government-imposed hiring limitations, but is mainly due to a general shortage of licensed officers available to the maritime industry. The shortage of crew members has resulted in the dredge working principally on a 5-day week, in lieu of a 7-day week, the latter being far more productive and efficient.

So, overall production has been very good and can be expected to improve with more operating experience and with a longer operating week.

SIDE-CASTING OPERATIONS

Although the Galveston District has been attempting to concentrate on new work dredging at Galveston Harbor and at the Sabine-Neches Waterway, which requires bottom dumping, the dredge has been used 3.8 months on side-casting operations. We are particularly pleased with the results of side-casting operations, as this is the first Corps of Engineers dredge constructed with this capability. Some of this work was experimental, just to see how the dredge would perform in various materials and channels, and was not expected to be especially productive. It was anticipated, and subsequently proven, that this mode of dredging is particularly effective in shoaled silty materials, where favorable cross currents exist, as in portions of the Sabine-

ADDITIONAL DATA — FIRST 2.5 YEARS

TIME ON PROJECT ------------------ 90 %
(26.8 OF 30 MONTHS)

AVERAGE PRODUCTION PER
MONTH ON PROJECT ------ 1,000,000 CU. YD.

AVERAGE PRODUCTION PER
EFFECTIVE DAY (LAY TIME
AND LOST TIME DELETED) ---- 48,777 CU. YD.

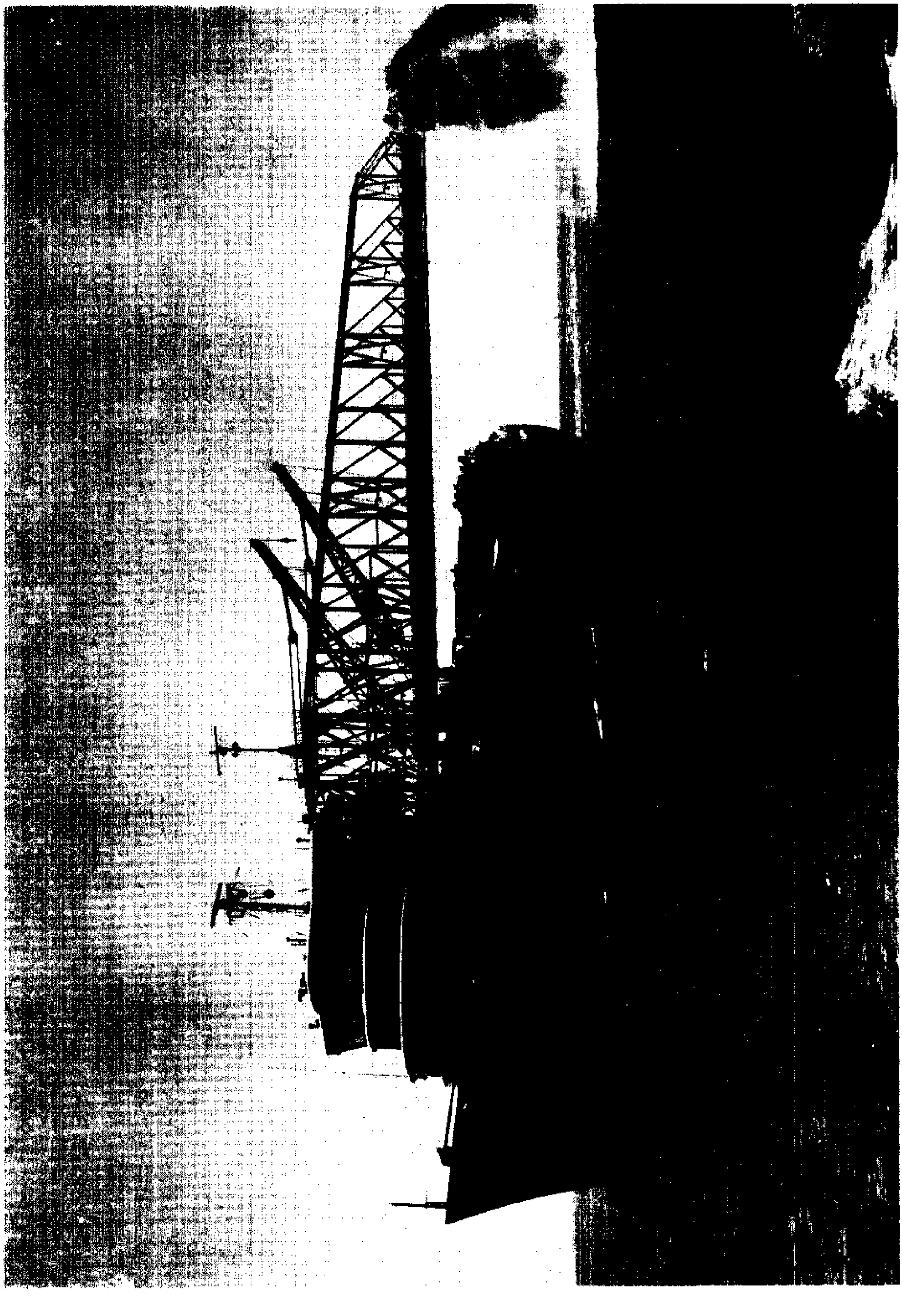
AVERAGE PRODUCTION PER
EFFECTIVE MONTH ---------- 1,500,000 CU. YD.

Neches Waterway, Texas, Calcasieu River and Pass, Louisiana, and at other entrance channels on the Gulf coast farther east. Approximately 8,700,000 cubic yards, or about one-third of total production to date, have been removed by this method, and in Fiscal Year 1969, side-casting shoal material in the Sabine-Neches and Calcasieu River projects, the McFARLAND removed approximately 6,000,000 cubic yards at a unit cost of 6.75¢. It is evident that the McFARLAND is a remarkable piece of equipment for this type of work.

PROBLEMS ENCOUNTERED

But operating the dredge during its first two and a half years has not been all pure joy. In many ways, the McFARLAND is a sharp departure from previous hopper dredge design and thus is somewhat experimental. Predictably, numerous difficulties, or "bugs," arose during the early months of operation. These involved principally small construction deficiencies; adjustments of machinery, controls and instrumentation; and learning how to properly operate a considerably more complex excavating machine. Most of the "bugs" were easily and readily corrected by the builder under the guarantee within the first few months after delivery. However, some were not easily resolved, the most serious being the excessive vibration experienced initially.

This vibration was caused mostly by cavitation, or an interference with the adequate and smooth flow of water to the propellers. In constructing the vessel, considerable concern had been expressed over its short wide shape and large block coefficient, which were required to enable the dredge to turn in the narrow waterways and still provide proper transverse stability for the side-casting boom. Model tests indicated that no steering difficulties would be encountered if adequate 45° skegs were provided port and starboard aft. In actual practice, though, it was found that the skegs were too extensive and that they caused hull vibration by "starving" the propellers for water. When the skegs were cut back sharply, and fairing pieces between



SIDE—CASTING DREDGING

TOTAL REMOVED, INCLUDING EXPERIMENTAL
(IN 3.8 MONTHS) -------------- 8,700,000 CU. YD.

FISCAL YEAR 1969 PRODUCTION
(SABINE-NECHES WATERWAY, TEXAS,
CALCASIEU RIVER & HARBOR, LA.)

QUANTITY -------------------------- 6,000,000 CU. YD.

UNIT COST PER CUBIC YARD -------------- 6 3/4 ¢

the tailshafts and hull were removed, vibration was reduced sharply and, unexpectedly, steering actually improved. In fact, the vessel steers excellently maneuverable.

Another equally vexing but not so serious problem has been leakage of lubricating oil from the stern tubes. The after portions of the propeller shafts run immersed in an oil bath. At the propeller end there is a patented seal, composed of a series of spring-loaded graphite segments. Despite renewal of these seals several times, lubricating oil leakage of varying amounts has continued intermittently. New spring-loaded rubber seals have now been designed and constructed similar to those with which excellent results have been experienced on another hopper dredge, the LANGFITT. These new seals are split to permit installation without disturbing the reversible pitch propellers. The seals will be installed and operating within the next two weeks and are expected to completely stop the leakage.

Problems with the process instrumentation, which were very prevalent when excessive vibration was being experienced, were largely alleviated when the vibration was eliminated. The remaining instrument problems are largely due to lack of qualified maintenance personnel. Some of the recording, totalizing, and integrating instruments furnished by the prime contractor were of laboratory quality. Sophisticated instrumentation and unsophisticated fingers just do not mix well.

Another problem encountered was in the after ventilating system. The problem arose due to the necessity of keeping the exhaust stacks low, to permit the side-casting boom to swing over the stacks. We found that under certain wind conditions, the fumes tended to remain low instead of rising and dispersing, and the ventilating system then picked up and recirculated a small portion of these fumes to the after quarters and engine rooms. Correction was effected by installing an air intake plenum running to the extreme aft of the vessel, well away from the diesel exhaust stacks.

A separate ventilation problem involved leakage of fumes back through stand-by or non-operating engines that were connected to common exhaust lines with operating engines. The lines were valved, but the valves generally failed to seat properly due to the high temperatures encountered in diesel exhaust lines. This was corrected by installing additional individual exhaust lines.

PERFORMANCE OF NOVEL EQUIPMENT

Conversely, several innovations or new features on this dredge have operated remarkably well, far better than generally expected. For example, there have been no problems with the all-aluminum side-casting boom or with its operating mechanism. The 222-foot boom moves smoothly on a large roller bearing and is rotated to port or starboard from its stowed position aft by an electrically driven wildcat and chain drive. Vessel list when using the boom is approximately a maximum of 3 or 4 degrees, which for practical purposes is negligible. Also, the thrust of material leaving the boom has failed to produce any noticeable crabbing, as had been a problem with certain privately-owned side-casting vessels operated in South America. The vessel continues to track on a true course when side-casting.

The swell compensators on the drag hoist gear work so well in decreasing dragtender work and increasing production that similar units are being designed or planned for installation on older dredges. The idea is relatively simple, consisting of running the drag hoist cables in a loop over a sheave attached to a hydraulically-loaded cylinder, which retracts or extends as more cable is needed. These units maintain a predetermined, but adjustable, draghead pressure on the channel bottom, paying out or retracting cable to compensate for wave action, bottom variation, and vessel loading. Since these automatic devices keep the draghead in continuous contact with the material, the dragtenders do not have to continually adjust for the varying depth to the channel bottom, and production is continuous instead of intermittent. After seeing it operate so well, one wonders, as with many innovations in various fields of endeavor, why didn't someone think of it sooner?

The davits and mecanisms to retract the dragarms to the weather deck have proven to be definitely superior to any system previously used on other dredges for this purpose. The units have worked smoothly and effectively with a minimum of maintenance and keep complete control over the dragarms at all times. As the davits pivot downward, the trunnion rolls down a 45° inclined track, until it enters the guide channels on the side of the vessel, wherein it is lowered by the cables until it wedges and seals over the pump suction opening. Thus, the trunnion is held securely at all times, and rolling of the vessel in a seaway does not interfere with the trunnion operation. Mechanisms on older dredges required the trunnion to be reinserted in its track on the side of the vessel with the dragarms hanging on cables, free to swing. This made insertion of the trunnion difficult and hazardous except in calm water conditions.

The Bird-Johnson bow thruster with its 13,000 pounds of transverse thrust has proven to be very effective in docking, undocking and in turning the vessel and has operated with a minimum of maintenance. Similarly the Bird-Johnson reversible pitch propellers for propulsion have continually operated reliably with only minor adjustments.

Despite the larger than normal hopper doors on the vessel (to facilitate dumping) the hopper door operating mechanisms have presented no problems. Particular attention has been given to these doors since an earlier version of the mechanism, on another vessel, presented some bearing wear and door leakage difficulties. The McFARLAND doors do not leak, and there is no indicated need for adjustment due to bearing wear. Pilot house control of dumping operations is very effective and trouble-free.

The two Corps of Engineers-designed 26-inch dredging pumps have operated efficiently and smoothly, without cavitation or excessive wear.

The ten Alco diesel engines used for propulsion, pumping, and auxiliary power have been fully reliable. Maintenance has been negligible to date.

SUMMARY

In summary, the McFARLAND has been very productive and has dredged both virgin material and shoaled material at economical costs. Despite the "bugs" and other early difficulties, the dredge has been "on project" approximately 90 percent of these first two and a half years, the remaining 10 percent being lost due to shipyard work and Christmas-New Years Holiday time. While some problems and corrections can be expected in any new and somewhat experimental vessel, and while those actually encountered have caused inconvenience, no major system has ever failed to operate and the vessel has continued to dredge effectively even while adjustments or repairs were being arranged. Certain new systems have been so successful that their installation on both existing and future dredges can be expected. In short, it is evident that the vessel remains a style-setter, completely suitable and efficient for the work for which it was designed. On balance, the McFARLAND is an unqualified success.

EFFECT OF AIR CONTENT ON CHARACTERISTICS OF A MODEL DREDGE PUMP

By

Dr. John B. Herbich
Texas A&M University

And

Robert E. Miller
University of Nevada (Reno)

INTRODUCTION

In dredging operations in harbors and estuaries the dredge pump encounters mixtures of liquids, solids and gases. The ratio of these constituents can vary widely depending on the bottom material and the method of dredging. Large gas content in dredged material is highly undesirable for many reasons and its effect on dredge pump performance largely unknown.

There were several investigations conducted during the past thirty years on the flow of gas-liquid mixtures in pipes[1]. However, in most cases the mechanics of flow within the pipe walls were of great interest to the investigators and not the effect on pump performance.

The effect of solids-water mixtures on pump performance was studied on projects sponsored by the U.S. Army Engineers and by the National Bulk Carriers[2,3,4] No serious problems occur unless the material in the suction pipe is of too high density and the pump begins to choke and the discharge drops off. The occurrence of gas in the dredged material can cause the pump to unload in a manner similar to the choking due to excessive solids. The main difference is that in gas unloading the vacuum is reduced while in solids unloading the vacuum is increased.

EXPERIMENTAL STUDIES

The pump selected for study was a 1:8 model of a dredge pump installed on the U.S. Army Engineers dredge ESSAYONS.

Test Facility

The test facility consisted of a storage tank, suction pipe, discharge pipe, discharge tank, and a return pipe all connected in a continuous flow loop. External to this flow system was the pump motor and an air compressor. (Figures 1 and 2)

The Model Dredge Pump

The pump selected for study was a 1:8 model of a dredge pump installed on the U. S. Army Engineers Dredge ESSAYONS. It was powered by a 40HP D.C. motor. The impeller had the following characteristics

Diameter: 10 1/2 inches

No. of vanes: 5

Vane shape: involute

Inlet angle: 45°

Exit angle: 22 1/2°

The suction pipe made of plexiglas has a 4.5 inch diameter and steel discharge pipe had a 4 inch diameter. The compressed air was filtered and cooled before injection into the suction line. The air injection was accomplished at the periphery of a "drag head" end of the suction pipe.

Pump Characteristics

Pump characteristics were first obtained without air injection for comparison with subsequent studies with varying air content. Figure 3 present the pump characteristics in a dimensionless form. The specific speed is defined by the following equation

$$N_s = \frac{N \sqrt{Q}}{H^{3/4}}$$

where N = pump speed in RPM
Q = rate of flow in GPM
H = head in feet of water

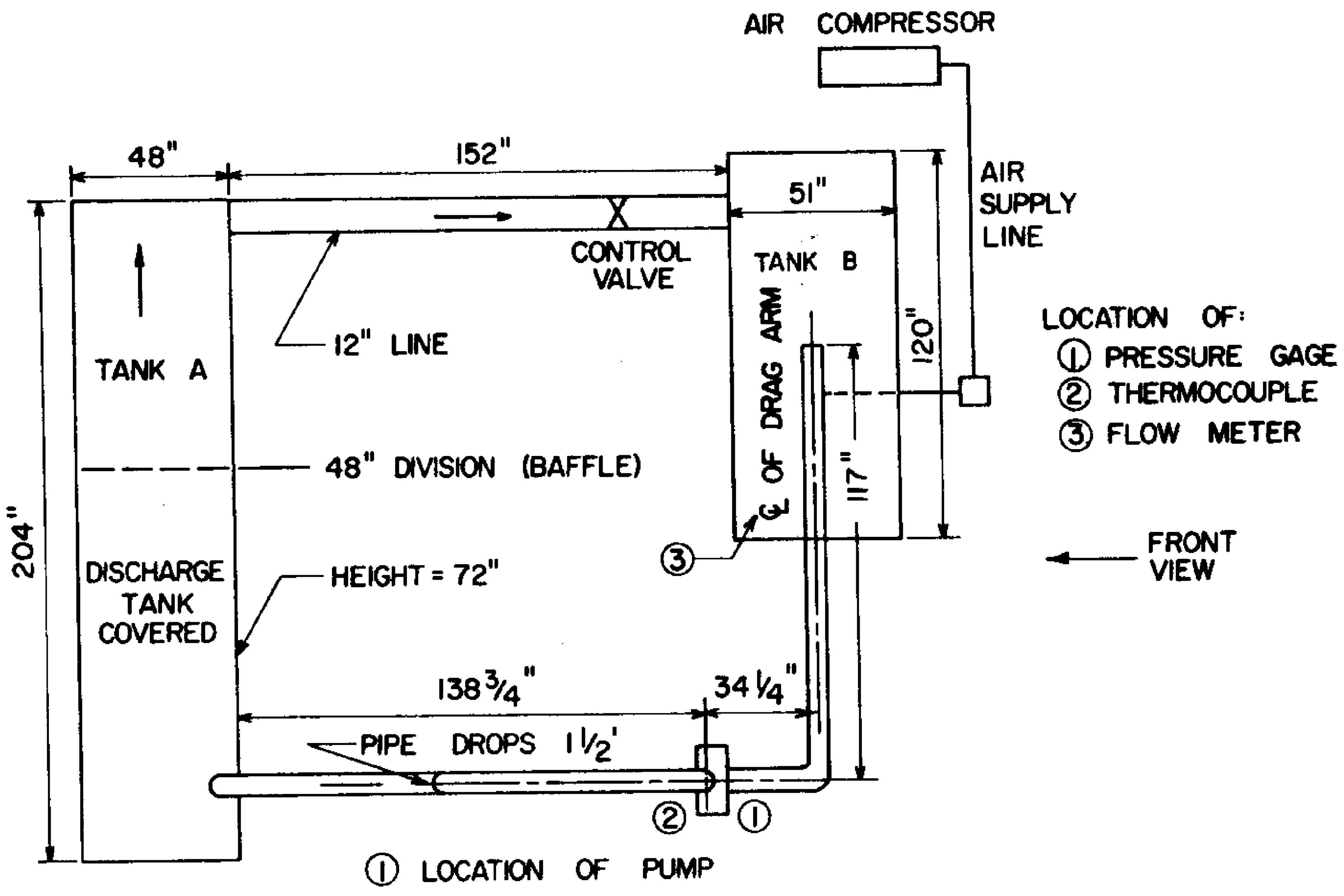


FIGURE I PLAN VIEW OF EXPERIMENTAL FACILITY

① LOCATION OF DISCHARGE TANK A

② SUPPLY TANK B WITH PLEXIGLASS WINDOWS

③ POINT OF AIR INJECTOR

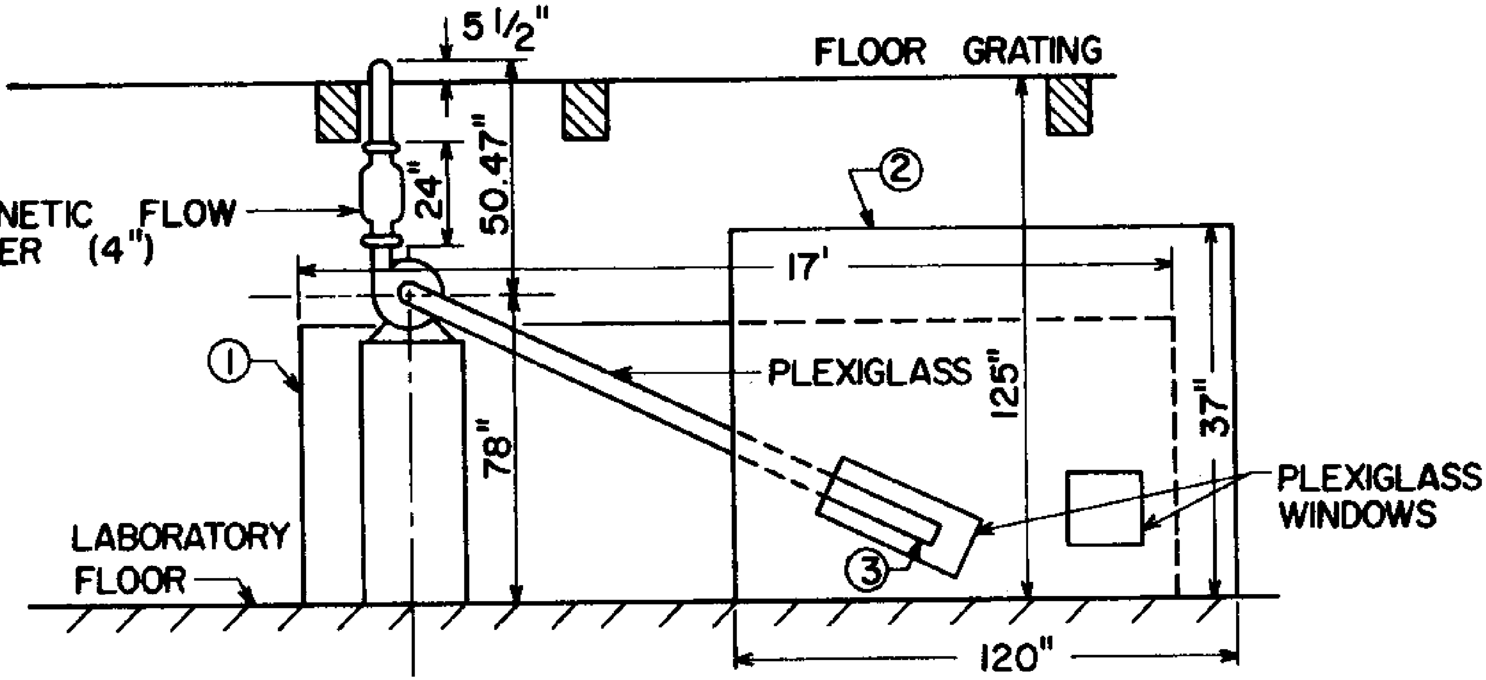


FIGURE 2 FRONT VIEW OF EXPERIMENTAL FACILITY

was 2030 rpm. The dimensionless specific speed defined as

$$N_s = \frac{n \sqrt{q}}{(gh)^{3/4}}$$

where n = pump speed in radians per second
L = rate of flow in cubic feet per second
g = acceleration due to gravity in feet per second square
h = head in feet of liquid

was 150.

Study Parameters

The primary variables in the study were the fluid discharge, air injection rate and pump speed.

Test Procedures

In general, steady-state flow was established in the recirculating test loop for the desired rate of flow and pump speed. After all readings of discharge, speed, suction and discharge pressures and power input were taken, the desired air content was injected into the suction line and new readings recorded. The air rates of flow were increased in steps until the model dredge pump collapsed.

RESULTS OF STUDY

Presentation of Results

The results of the study are presented in a dimensionless form so that the characteristics may be predicted for any size of pump having similar geometry. Following the modern practice the head developed in the model pump were equal to that in the prototype pump.

(a) Dimensionless head

The dimensionless head is defined as follows:

$$H_{Dim} = \frac{gh}{N^2D^2}$$

where d = impeller diameter.

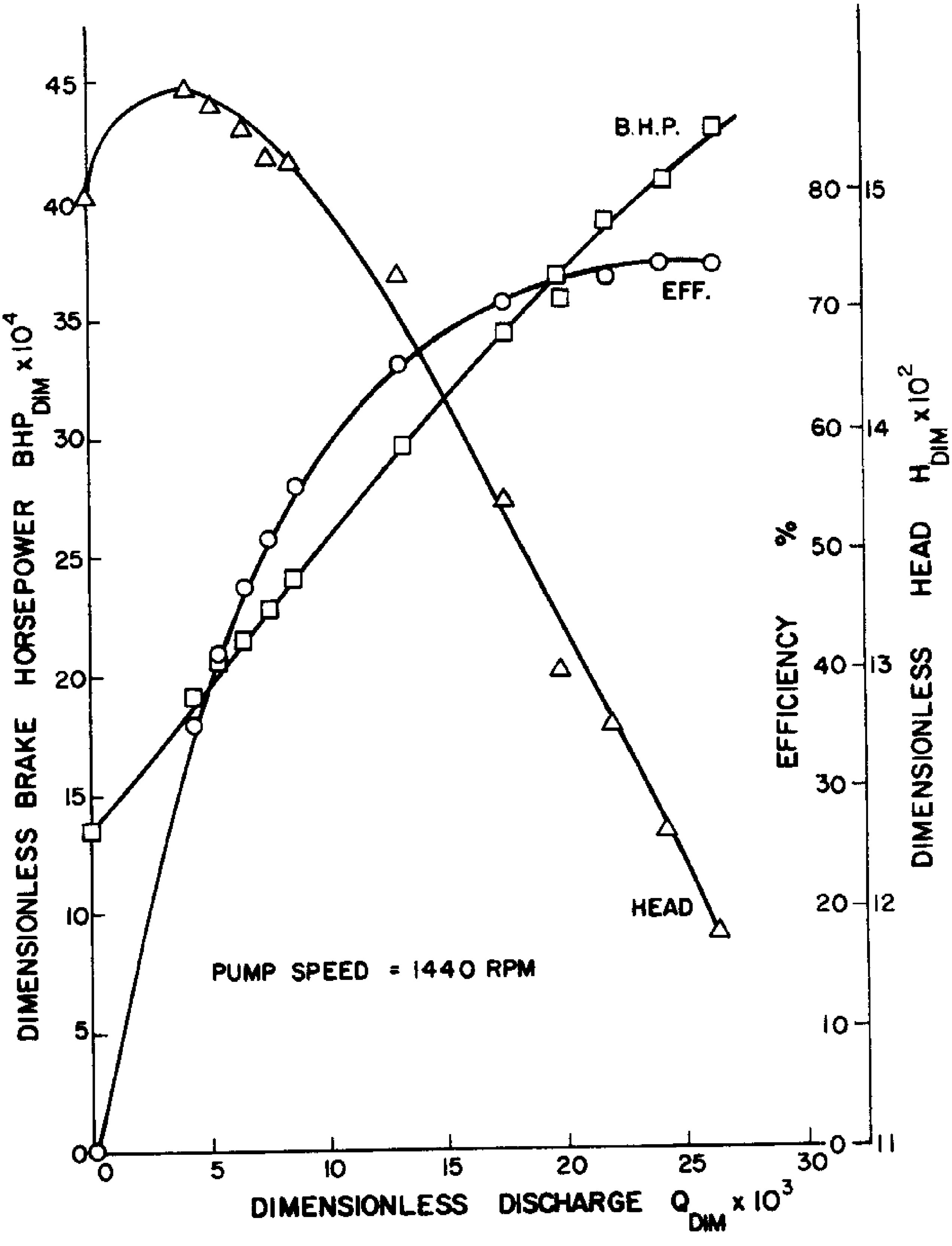


FIGURE 3 DIMENSIONLESS PUMP CHARACTERISTICS (NO AIR IN THE FLUID)

When the values of dimensionless head in the model are equated to those in the prototype and if the model studies are conducted at the same head as the prototype head, the speed in the prototype (n_p) is equal to one-eighth of the model speed, or

$$n_p = \frac{n_m}{8}$$

(b) Dimensionless discharge

The dimensionless discharge is defined as follows:

$$Q_{Dim} = \frac{q}{nd^3}$$

When the values of model and prototype dimensionless discharges are equated and the model and prototype heads are equal the following relationship results

$$q_p = 64\ q_m$$

or the prototype discharge is equal to sixty-four times the model discharge.

Effect of Air Volume on Water Discharge

Figure 4 shows the effect of air percentage on water discharge. There was very little reduction in water discharge for air content of less than 2 percent. However, for greater air contents the discharge fell off markedly until the pump collapsed.

Effect of Air Volume on Total Head Developed

Figure 5 shows the effect of the injected air on the total head of the pump in a dimensionless form. The plot is a summary a great number of tests conducted in the laboratory.

The head was reduced by only a small amount for air contents less than 2 percent, but an air flow of 3 to 4 percent caused an appreciable drop in total head. For air percentages greater than 4 percent the reduction in head was considerable.

Pump Collapse

The actual amount of air volume which causes the pump to collapse could not be predicted with accuracy. However, visual observation of flow in the transparent suction pipe indicated that the air flow gradually progressed into a slug flow in which the air was no longer all entrained in water. A slug of water with some air would eventually be followed by a slug of air which completely fills the suction pipe. Pump collapse would follow shortly after this condition was reached. In most cases the pump collapsed when the air content reached 10 percent.

CONCLUSIONS

1. Low rates of air injection have only a small effect on pump performance. Even at low discharge rates the pump can operate effectively with a 2 percent air flow.

2. The pump discharge decreases as the amount of air injected increases. This reduction in discharge is gradual up to about 2 percent air flow, then the discharge drops off rapidly.

3. Excessive amounts of air will cause a complete collapse of the pump. At an initial model discharge of 1000 gpm (64,000 gpm prototype) the pump will collapse at 10 percent air flow.

4. The length of time that air is injected had no effect on the pump performance.

5. The useful pumping range is extended from an air flow of 3 percent to an air flow of 4.5 percent if the model pump speed is increased from 1300 to 1600 rpm. (prototype pump speed of 163 to 200 rpm)

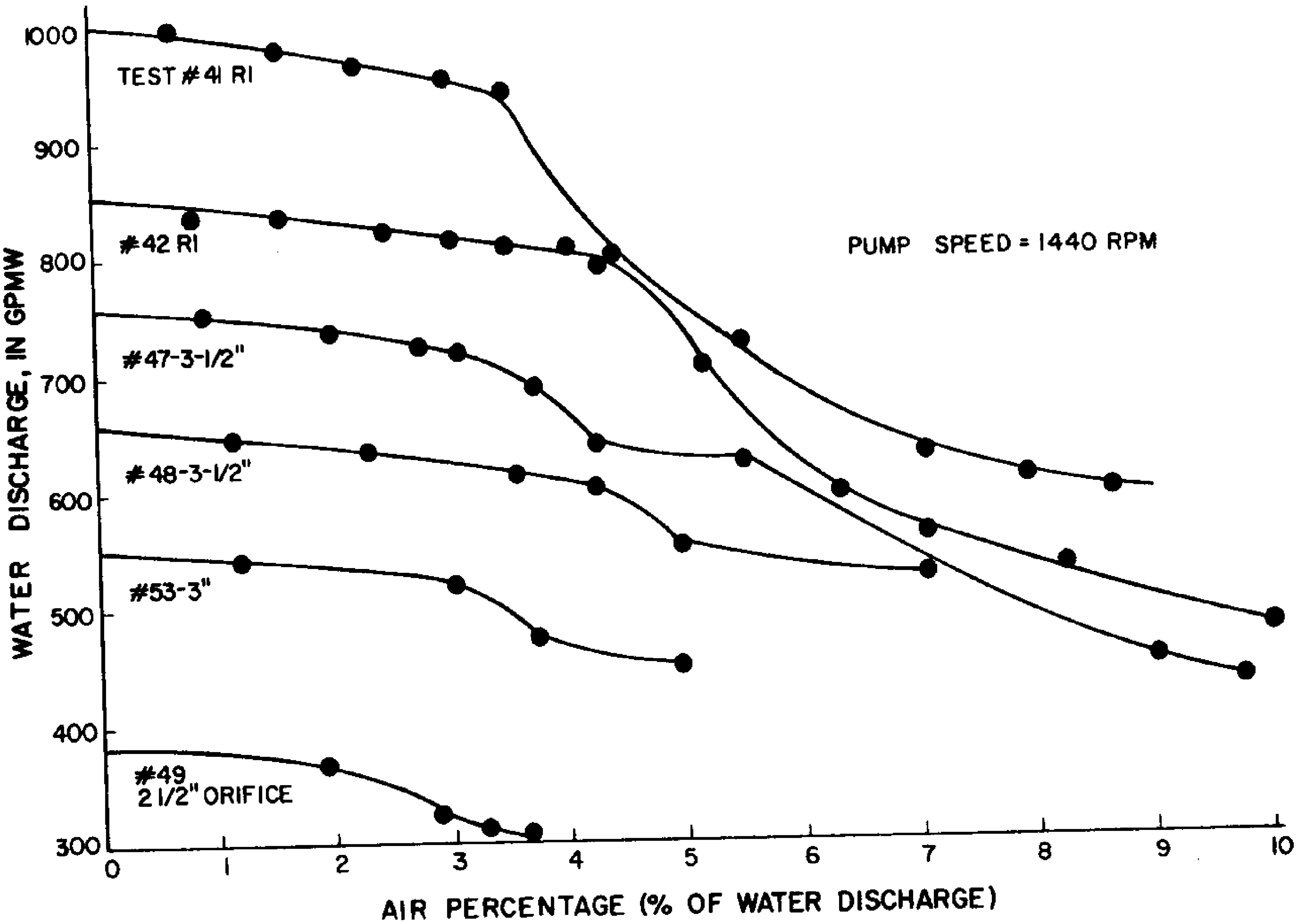


FIGURE 4 WATER DISCHARGE AS A FUNCTION OF AIR PERCENTAGE

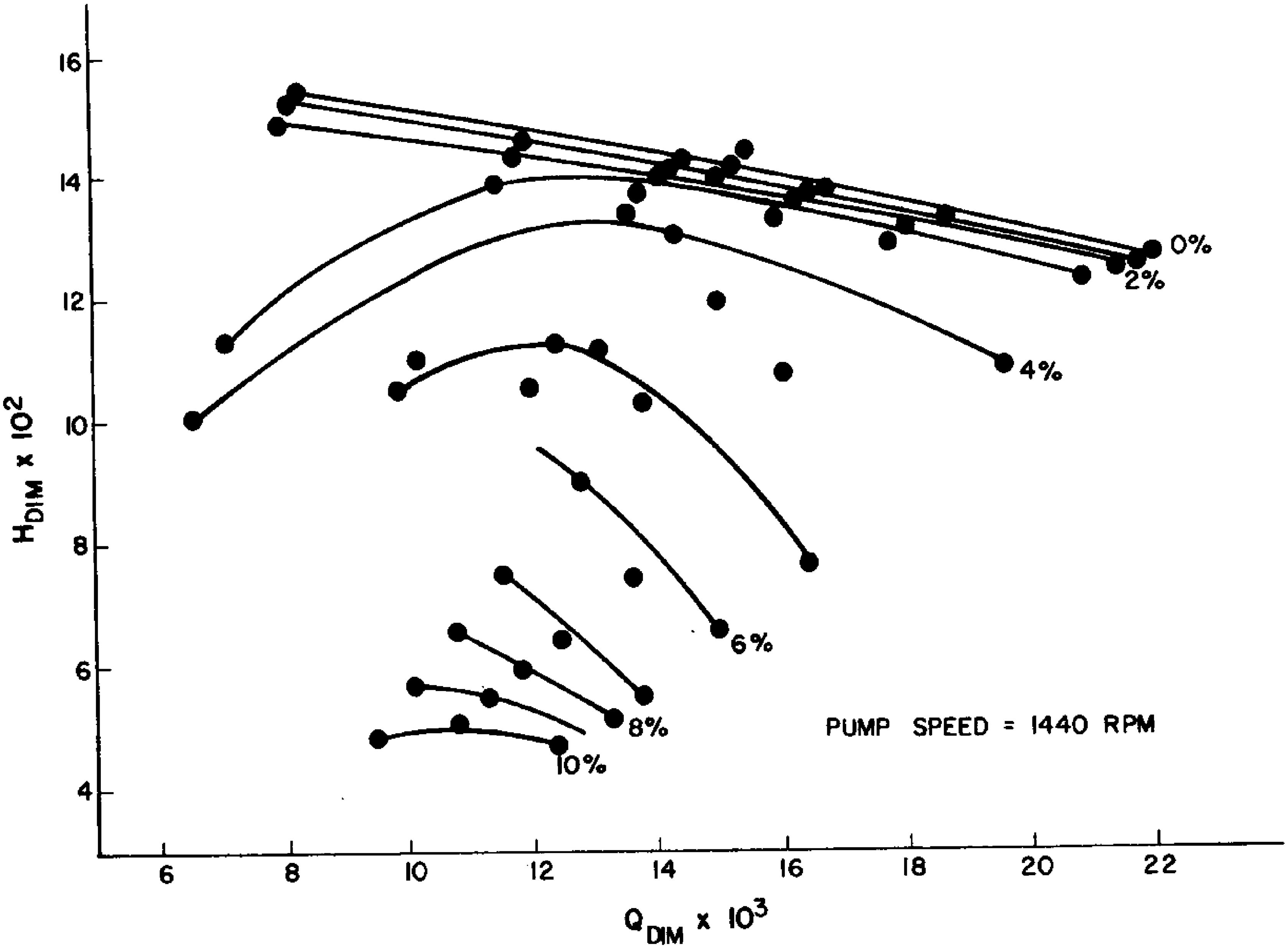


FIGURE 5 DIMENSIONLESS HEAD VERSUS DIMENSIONLESS DISCHARGE AS A FUNCTION OF DISCHARGE AIR CONTENT.

References:

(1) Mathers, L. J., "Effect of Slope on Friction of Air-Water Mixtures in Pipe Flow", Washington State University, M. S. Thesis in Hydraulic Engineering, 1960.

(2) Herbich, J. B., "Effect of Impeller Design Changes on Characteristics of a Model Dredge Pump", A.S.M.E., Paper No. 63-AHGT-33, March 1963.

(3) Warnock, R. G., J. B. Herbich, "Efficiency of Pumping and Piping Layout", Lehigh University, Fritz Engineering Laboratory Report No. 294.1, October 1962.

(4) Herbich, J. B., J. R. Adams and S. C. Ko, "Gas Removal System Part III", Model Study, Lehigh University, Fritz Engineering Laboratory Report No. 310.21, February 1969.

THE HOFER AUTOMATIC RELIEF VALUE SYSTEM

by

Frank F. Waldeck

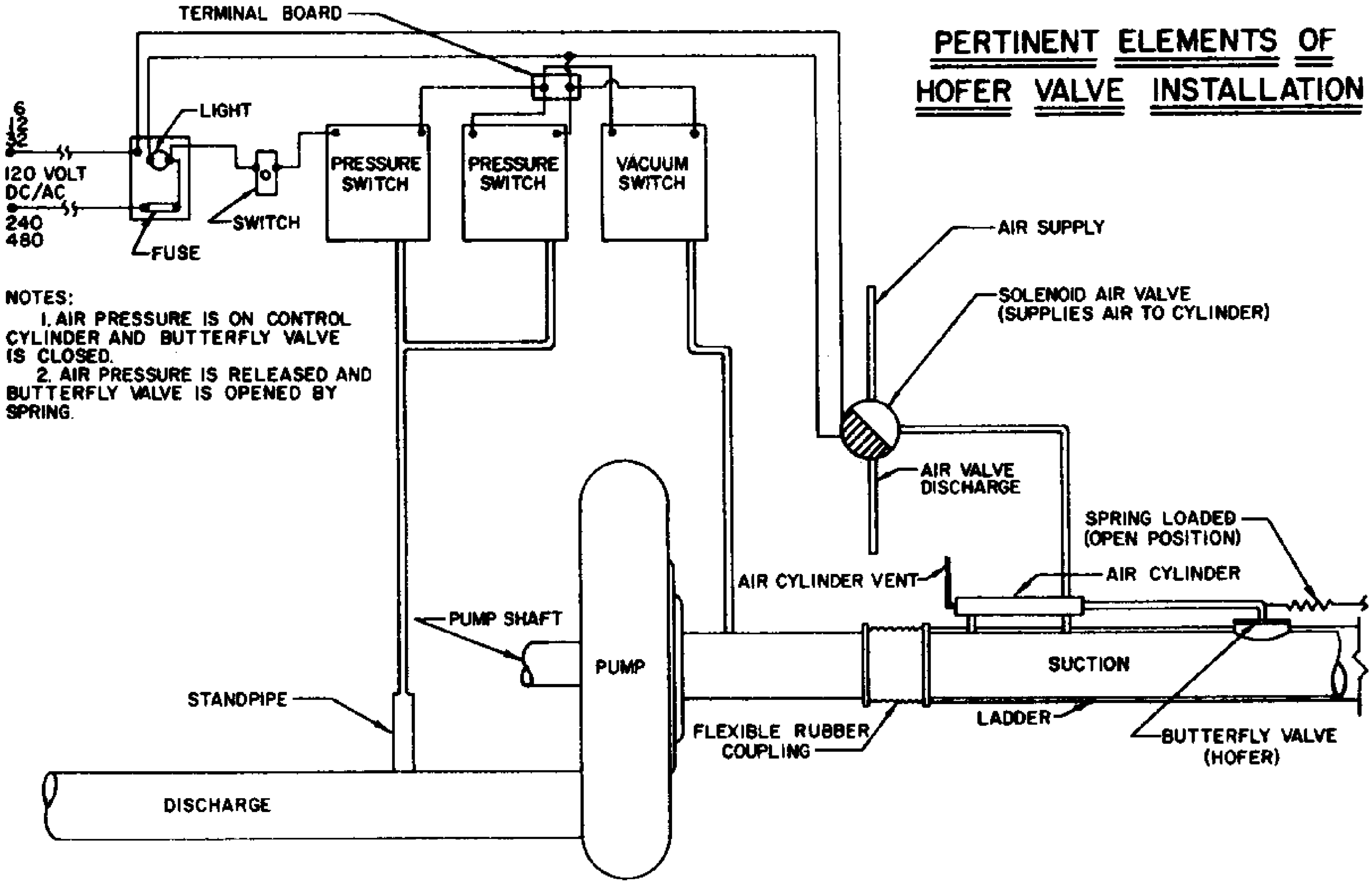
Synopsis

During normal dredge pump operation near maximum capacity a "choke off" condition may result in which momentary flow stoppage occurs in the suction line. Major contributing factors are the dredging conditions, suction load, material consistency or gas pockets and the pump essentially loses its prime for a short period. Manual control of the dredging operation is usually not responsive enough to prevent the occurrence of this uneconomical and potential damaging phenomena.

Mr. D. L. Hofer reasoned that if water could be automatically admitted to the suction flow at the instant the "choke off" condition began the pump would operated more normally during the cycle. The operator would then have more time to react to the conditions and take appropriate action.

A schematic diagram of the essential elements are shown on the enclosed sketch. A quick acting butterfly valve emitted a limited quantity of water to the suction pipe during the stalled condition. The "automatic switch" controlled the valve operation through pressure and vacuum signals from the discharge and suction sides of the pump, respectively. The switch setting was determined by trial and error from field tests.

PERTINENT ELEMENTS OF HOFER VALVE INSTALLATION



NOTES:
1. AIR PRESSURE IS ON CONTROL CYLINDER AND BUTTERFLY VALVE IS CLOSED.
2. AIR PRESSURE IS RELEASED AND BUTTERFLY VALVE IS OPENED BY SPRING.

Willis H. Clark
Assistant Director
Sea Grant Program Office
Texas A&M University

On October 15, 1966, President Johnson signed Public Law 89-688, The National Sea Grant College and Program Act, for the purpose of accelerating national development of marine resources through support and encouragement to academic institutions, research institutes, and laboratories. This legislation is the basis of the Sea Grant Program which we in the university environment regard as a very important step in the development and exploitation of our marine resources. This legislation is now coming to the attention of community leaders and people such as yourselves who are interested in the future of our country and your communities.

Let me ask that you recognize one thing as I discuss this subject. Whenever a major new program is initiated, by the Federal government, or by state government, or within the framework of a major corporation, it is usually accompanied by a lot of high-sounding phrases which seem to convey the notion that this particular undertaking will be the basis of salvation of all mankind. Certainly the Sea Grant Program has been cast in this light at times. The Program is still in its infancy and we who are involved in it believe that it will be an excellent vehicle for accomplishing some of the fine objectives which have been set forth by the Congress and people in high offices. We recognize too, that there are many hurdles to be crossed and all the problems are not going to be solved overnight.

The term "Sea Grant" was chosen to emphasize the parallel between the present need for ocean resource development and the need for development of the land at the time of the Morrill Act of 1862, which established the land-grant program. I am sure that most of you are aware of this land-grant program and you will recall that through this program, many of the major institutions of this nation were developed or brought into being. Texas A&M University became the land grant institution of the State of Texas, and it has, throughout the years, been an example of the excellence which can be obtained by a university in a major program such as this.

While the Sea Grant Program follows the pattern of the land grant program only to a very limited extent, perhaps more in the name than in reality, it does embrace the principal concept, that of providing a means through which scholars and their institutions of higher learning can apply their competence and knowledge to the practical needs of the nation and of the world.

The Act itself seems to summarize its purposes in two paragraphs which read as follows:

> "That federal support for the establishment, development and operation of programs by Sea Grant Colleges and federal support of other programs designed to achieve the gainful use of marine resources, offers the best means of promoting the programs toward the goals set forth and should be undertaken by the federal government, and also, in view of the importance of achieving the earliest possible initiation of significant national activities related to the development of marine resources, it is the purpose of this act to provide for the establishment of a program of sea grant colleges and education, training, and research in the fields of marine science, engineering, and related disciplines."

The Act then went on the state that "the provisions of this Act shall be administered by the National Science Foundation." As is characteristic of major new programs of this nature, it was sometime before the Congress made any appropriations to support the authorizations that had been made in the original Act. It was during this period then that the National Science Foundation organized and established a separate office which is identified as the Sea Grant Program Office. Dr. Robert Abel who had previously been Executive Secretary of the federal Inter-agency Committee on Oceanography, was selected to be the Director of this office and, by early 1967, he and a few assistants were deeply involved in establishing the ground rules for setting up sea grant programs.

When we examine the subject today we see that for operational purposes, the National Sea Grant Program has been divided into two distinct elements. They are referred to as Sea Grant Institutional Support and Sea Grant Project Support.

Sea Grant Institutional Support is focused in institutions which are engaged in comprehensive marine resource programs that include research, education and advisory services. These institutions are to provide leadership and scientific and technological resources for marine activity within their geographical regions.

Sea Grant Project Support, on the other hand, has the purpose of aiding individual projects in marine resource development. In general, these projects will be single, well-defined research, study, education, advisory, or training activities. Whereas only a few institutions will receive the institutional support, many more institutions will receive the project support. Thus a wide variety of institutions would have an opportunity to participate according to their interests and their competence.

A third term of common usage is the Sea Grant College. The Act defines a Sea Grant College as "an institution of higher education which has major programs devoted to increasing our nation's utilization of the world's marine resources. The National Science Foundation will, from time to time, designate as Sea Grant Colleges certain institutions of higher education which have demonstrated a sustained excellent performance along a broad front and have received some major support under this Act."

In the first year of the program, the National Science Foundation, made institutional grants to six universities. These were: The University of Washington; Oregon State University; the University of Rhode Island; the University of Hawaii, the University of Wisconsin; and Texas A&M University. In the second year the University of Michigan and Miami University were added. All eight of these institutions are well known because of a lengthy past history in marine science or oceanography.

In the first year of the program, 27 sea grant project awards were made and in the second year there were about 25.

The present plan of the National Science Foundation is to carry on with the institutional and project awards for a period of years before taking steps to designate any institution as a Sea Grant College. Before this award was ever made, there would have to be several years' history of excellent performance in broad institutional programs involving research, education, and advisory service activities.

I will not go into any detail on financial matters but I think you should realize that it is quite a task for a university to go about establishing a large scale program such as we have in the case of the Sea Grant Program. There are many details to be worked out with respect to the distribution of funds and the sources of funds required in the way of institutional contribution. Consider for a moment that at Texas A&M University we have a College of Engineering, a College of Science, a College of Geosciences, a College of Agriculture, a College of Veterinary Medicine, a College of Business Administration, a College of Liberal Arts, a College of Education and a College of Architecture, all located on our main campus. In addition we have the Texas Engineering Experiment Station and the Texas Engineering Extension Service. We have the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service. We have the Water Resources Institute, we have the Remote Sensing Center, the Center for Dredging Studies and we have Chemurgic Research Lab with its work in fish protein concentrate. And there are many others. Yet the problems of the seas and our coastal and estuarine areas are not unique to any one of these organizations and we find that in one way or another we would like to bring each one of these groups into the program. The proposal which was generated in the first year of the Sea Grant program requested over one and half million dollars from the National Science Foundation. When you add the institutional contributions to this you can see that a program with a price tag exceeding 2 million dollars was being suggested for the first year alone. Yes, we had to trim things back and we did. But, as we went through the proposal cycle for the second year of the program, we were faced with the same kind of a situation because we had interests from all of the major organizations throughout the campus.

The focal point for the Sea Grant work at Texas A&M University is the Sea Grant Program office. Dr. John C. Calhoun, Jr., is director of the program, and the head of the Program Office. He is also a Vice President at Texas A&M University and Dean of the College of Geosciences. For the past two years he has been Chairman of the Committee of Oceanography of the National Academy of Sciences. In years past he was Dean of the College of Engineering at Texas A&M University and he served a one year tour as science advisor to Secretary Udall, Secretary of Interior.

I serve as Assistant Director for this program. Mr. Don Walsh, who has a Master's Degree in Oceanography, is in our office. His principal duty is that of working with individuals throughout the campus in the formulation and execution of each task.

The Program itself, as I have indicated from time to time, is broken down into the major categories of Education, Extension and Advisory Services, and Research.

In the field of education and training, we have several activities underway. We take note of the fact that there are many academic subject areas which have a particular association with marine resources; for example, recreation, economics, geography, law, and business administration. If there were courses available in some of these areas, more students would be interested in a career related to marine resources development. The purpose of this project is to identify two or three potential areas for course development.

Under the heading of "Coastal and Ocean Engineering", we are seeking to strengthen the curriculum and to develop new graduate courses in this field including a course in "Continental Shelf and Deep Ocean Dredging." The Sea Grant Program partially supports faculty members who have been relieved from some of their normal duties in order to prepare the requisite courses. The effort is managed principally by representatives of the Civil Engineering Department.

Technician Training is a very vital part of our Sea Grant Program, and one which is being brought into being from the ground up. Sea Grant sponsored training programs being conducted at the Texas State Technical Institute at Waco and at Galveston College in Galveston. There are two programs, one for oceanographic instrument technicians and one for deck and fishery technicians. The curricula will include both theory and practice necessary to equip the graduates to perform useful work aboard oceanographic vessels and fishing boats. Technicians are to be trained to be useful in ship operations, in making emergency repair to rigging, machinery, and electronics equipment, and in assisting the scientists and engineers in operating instruments and recording and reporting data.

Turning to the broad area of "Extension and Advisory Services", we find two major projects under the Sea Grant Program. One effort under the Texas Agricultural Extension Service is directed toward demonstration and application of research information in the development of commercially feasible systems of marine life production, principally involving shrimp, crab and oysters. A number of field demonstrations are being established and the results will formulate the basis for educational programs to be conducted throughout the coastal region. Also, small scale conferences or meetings will be held throughout the coastal region in order to examine the nature of specific problems in the fishing industry and other marine resource activities.

Another effort in this area has to do with determining the adequacy of current literature and information services. It is planned that some specific area such as the aquatic food industry, marine engineering, or marine biology will be selected and an automated information system designed to meet the needs of this group. The basic objective here is to improve the literature awareness of those who work in these selected areas.

Finally we come to the broad area identified as research. This constitutes about 60% of our effort, dollar wise. Since there are about 30 research activities, I will not attempt to go into any detail on any one of these. Rather, I will merely tell you the major fields in which we are working, and give you an idea of who is participating.

Under "Fishery Science", we have one project from the Biology Department of the College of Science, and three from the Veterinary Microbiology Department of the College of Veterinary Medicine.

Under the heading of "Coastal Engineering", we have three projects from the Civil Engineering Department including a project on "Cavitation of Dredge Pumps." Under the heading "Pollution", we have two projects from the Civil Engineering Department. Under the heading "Aquaculture", there is one project in the Wildlife Science Department. Under "Marine Economics", one project from the Economics Department. Under the heading "Marine Geochemical Analysis", there is one project from the Activation Analysis Laboratory of the Engineering Experiment Station and one project from the Oceanography Department. Under "Acoustics", one project from the Electrical Engineering Department of the College of Engineering. Under "Marine Bio-Engineering", one project from the Chemical Engineering Department. Under the heading "Marine Activities Inventory", one project from the Industrial Economics Division. Under the heading "Estuarine Technology", one project from the Recreation and Parks Department.

You see, therefore, that we have participation from most of the Colleges of the University, from the Experiment Stations, from Texas State Technical Institute, from the Marine Laboratory at Galveston, and Galveston College. We have a broad program which involves the participation of many people, yet by grouping them under the principal headings as I have done, we are showing an effort to develop a focus to our work. In our overall program management we must continually press for such a focus for we have been advised by the National Science Foundation that they expect the universities participating under the broad institutional programs to capitalize on their greatest strengths in the development of their programs. But the strengths of the institutions necessarily have to be matched to the needs of the region. We recognize this factor also, and are taking this matter into consideration. I think I can say, with a considerable degree of certainty that our future work will tend to emphasize the educational and training and extension and advisory service activities more than the research programs, which predominated during the first year. Research is essential, or course, but what we would like to do is to draw more on the outputs of research activities which could be conducted in the normal course of events or through separate programs and to use our Sea Grant funding to put greater emphasis on the application of the results of the research. This means greater emphasis on education, training, extension and advisory services.

By way of summary, I have given you a broad picture of the Sea Grant Program, first explaining how it came into being, then describing various characteristics as we see them today and, finally, I have given you a sketch of what our work at Texas A&M is like.

DREDGE PUMP AND PIPELINE ENERGY LOSSES

By

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Of all the system components which limit the production of a hydraulic dredge none has received so much attention as the dredge pump. Yet with all this attention there is still an aurora of mystery, superstition, and misconception related to solids pumps and pipelines. The scientific world has been unable to provide reliable formulae or information which can be broadly projected into estimates of system performance. The majority of technicians and researchers are no more able to predict performance than experienced field men. Mr. Henry Babcock, a well known researcher in the art who is with the Colorado School Mines Experimental Station, expressed the problem well. "The most important technical problem facing the designer of a hydraulic haulage system is estimation of the head loss under various opertion conditions." ---------"Although no reliable correlation of all the variables exists, pipelines still must be built and since scientific knowledge of how to design them is, to say the least, inadequate, the engineer finds himself at the interface between an irresistable commercial demand and a scientific void."

While I agree with Mr. Babcock's observation, I also believe that the fundamental understanding can be substantially improved upon with little difficulty. With few exceptions those researchers in solids transport have ignored pump theory and performance, and as a consequence they have unnecessarily complicated the identification of the many variables.

The practitioners of the two-phase art continue to measure system energy losses in terms of pipeline head loss. To understand energy loss phenomena (energy loss being a conversion process) it is necessary to work within the framework of energy rather than head.

The dredging fraternity has through years of experience and error, developed some very useful rules of thumb which in many instances have been adequate. Some of these coincide very closely with the results of a much more sophisticated estimating technique. Unfortunately empirical rules of thumb cannot be safely projected beyond their experience source. Adequate theory can be projected. Present rules of thumb are inadequate for estimating head losses on long pipelines, high static lifts, suction performance for deep dredging, dredging unusual materials or exceptional concentrations. By dredging and pumping more efficiently new markets can be opened for an industry with too many dredges and too few projects.

With this in mind I shall review some of the fundamental concepts of material and energy which are frequently ignored when estimating pump and pipeline power requirements.

First, one should separate the pump from the pipeline when analyzing any system. Dredge pumps have a highly predicable performance even when pumping solids. This is particularly true when pump curves are available. Unfortunately, most dredge pumps are not tested for performance and the curves furnished by the manufacturer are frequently a figment of someone's imagination, or a projection of some prototype unit. When this is the case the impeller and volute provide sufficient clues to estimate the pump performance reasonably well.

On the other hand, pipeline energy requirements are subject to many variations depending upon size of material, concentration, velocity, elevation, shape of the solid particles, and specific gravity of the solids. Theory is available to explain pump performance, but no theory has been offered which is adequate to explain all the variables of pipeline energy requirements.

Fortunately, however, many pipeline problems can be identified in terms of qualitative performance, and many empirically developed rules of thumb do just this.

The dredging industry, as well as the others who pump solids, is accustomed to judging pump efficiency in terms of head pressure developed rather than the pump's efficiency as a pressure energy generator. A pump's only function, regardless of its type, is to continuously provide a source of pressure energy. Pressure energy moves through the closed system in the direction of flow and at the speed of sound, about 4800 feet per second in water. The pump's function can be considered analogous to an electric generator. The fact that liquid flows through the pump under most circumstances does not alter this similtude. The pressure energy speeds to the point where conversion to some other form of energy takes place. This conversion can be to the heat of friction, to the kinetic energy of increased velocity, or to the potential energy of position associated with an increase in elevation of the mixture.

A pump can generate pressure with no flow, which is similar to a generator producing an electrical pressure, expressed in volts. In either instance until a flow has been established there is no work being done. The amp is the measure of electrical flow, while lbs. of water is a measure of hydraulic flow. The watt, electrical power, is a function of voltage, amps and time; hydraulic power, water horsepower, is a function of pounds of water, pressure and time.

Another fundamental physical concept is that solids can neither possess or transmit pressure energy. This means in very simple terms that the hydraulic power flowing from a pump is reduced by the volume of solids in transport. For example, if a pump were pumping 4000 GPM of water at a 200 foot head pressure it would be supplying 200 WHP to the pipeline. Similarly, if the pump was pumping the same volume of slurry containing 20%

solids by true volume, and at the same discharge pressure, the pump would be supplying 20% less WHP to the pipeline, or 160 WHP.

It is also a well established fact that with centrifigual pumps the SHP requirements increase relative to the specific gravity of the mixture. Assuming that the above pump were 70 percent efficient pumping water the prime mover must supply 285 SHP. To generate an identical 200 WHP at the pump discharge when pumping 20% sand requires 382 SHP. When pumping this concentration of solids the pump's efficiency as a pressure energy generator of solids is but 42% compared to its efficiency of 70% pumping water.

It has been the practice in the past to call this pump 70 percent efficient when pumping solids, and to attribute the required power increase to the presence of solids to pipeline losses. Losses due to the volume and weight of the solids present are pump losses not pipeline losses when pumping a horizontal pipeline. The specific gravity of the mixture is an additional energy requirement when pumping vertically. Erroneously attributing the loss of pump efficiency to pipeline losses is of no importance when pumping horizontally, as there is a double error which is canceling. However, when calculating vertical lifts the story is different. The power and pressure requirements are much higher than present formulae allow. This has led to dredgers' tales that pressure on the suction of the pump is only half as efficient as on the discharge, and many similar beliefs. When it is realized that centrifigual pumps have these efficiency characteristics when pumping solids improved pumping and material handling techniques can be evolved. (Figure 1). In addition, when the fundamental process of energy conversion is understood it becomes apparent that the centrifigual pump, the positive displacement pump, and the jet pump have different internal loss characteristics when pumping solids. Figure 2 shows the efficiency comparison of the three types of pumps on a theoretical level pumping 35 percent solids by volume. Limited performance and test data tend to

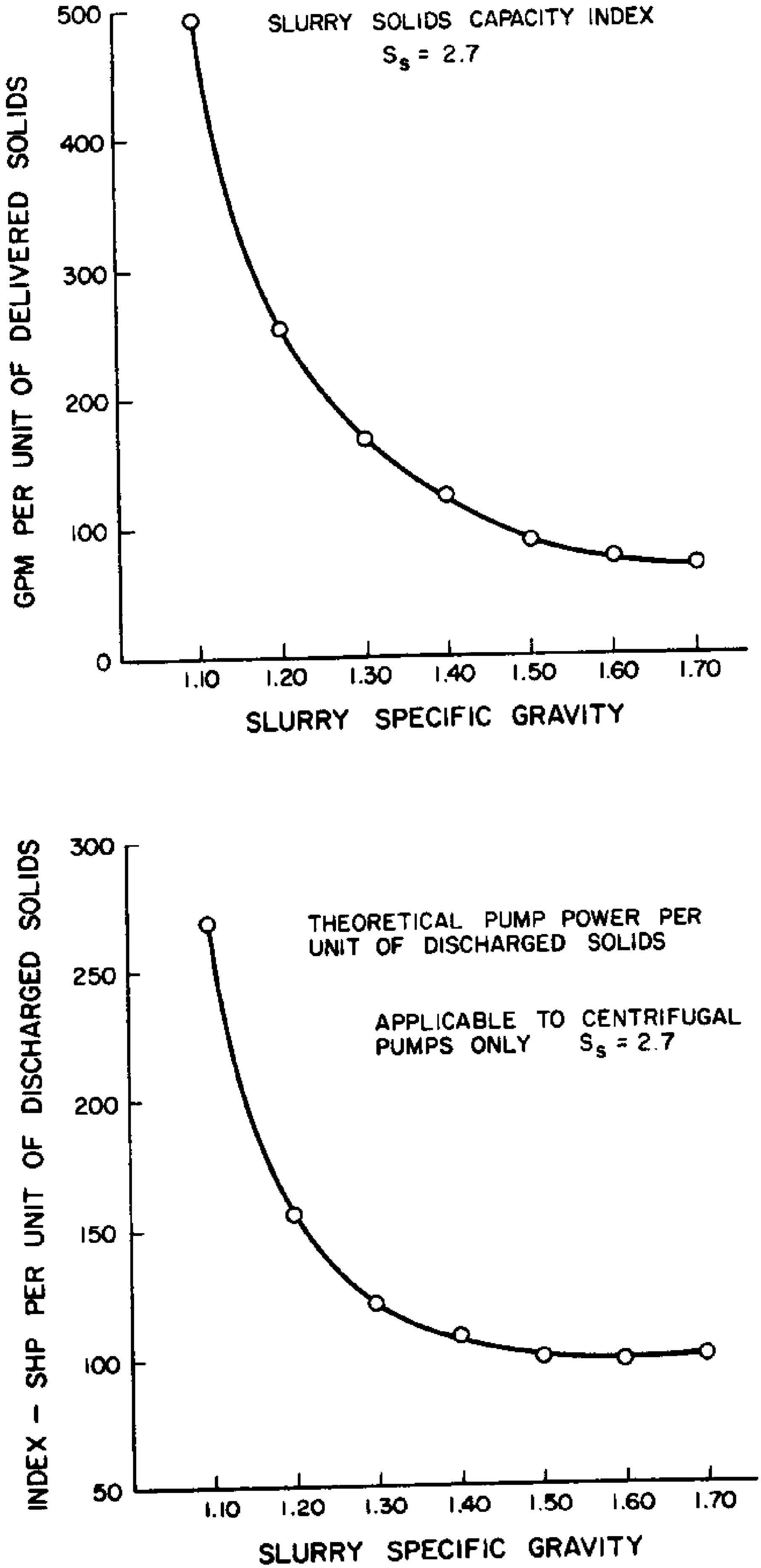
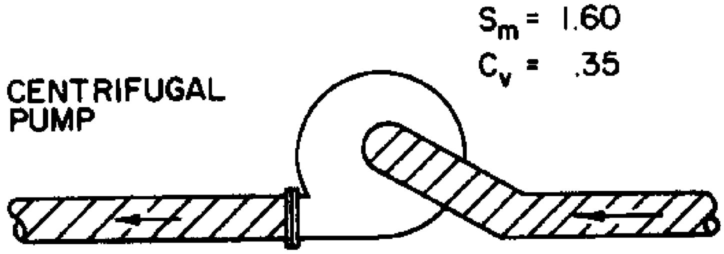
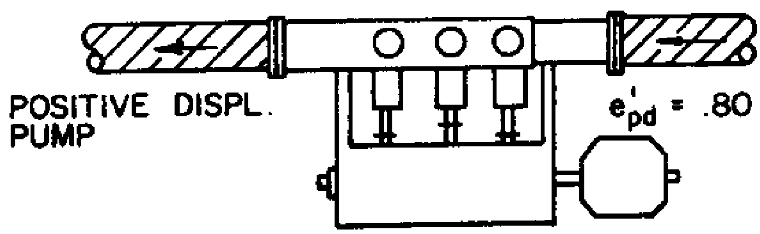

SLURRY SOLIDS CAPACITY INDEX
S_s = 2.7
GPM PER UNIT OF DELIVERED SOLIDS
500
400
300
200
100
0
1.10
1.20
1.30
1.40
1.50
1.60
1.70
SLURRY SPECIFIC GRAVITY
THEORETICAL PUMP POWER PER UNIT OF DISCHARGED SOLIDS
APPLICABLE TO CENTRIFUGAL PUMPS ONLY
S_s = 2.7
INDEX – SHP PER UNIT OF DISCHARGED SOLIDS
300
250
200
150
100
50
1.10
1.20
1.30
1.40
1.50
1.60
1.70
SLURRY SPECIFIC GRAVITY

FIGURE 1

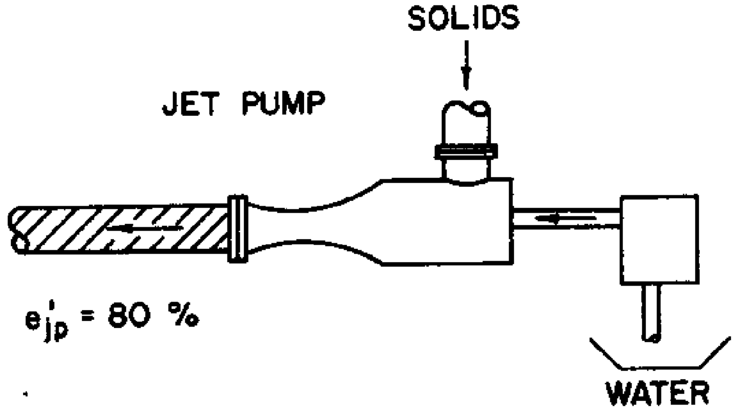
SLURRY PUMPING ARRANGEMENTS



$$e'_{cp} \quad \frac{.70 \times (1 - .35)}{1.60} = 28.4\ \%$$



$$e'_{pd} = .80 \times (1 - .35) = 60\ \%$$



$$e'_{jp} = 80\ \%$$

FIGURE 2

support the theoretical relationships.

Further support of the volumetric loss portion of the theory is given Mr. Henry Babcock in a presentation given last year at the International Symposium on Two Phase Flow. The Colorado School of Mines Research Foundation ran statistical research on data obtained from numerous slurry line test loops. The findings were that the only consistant predicable influence on pipeline head losses was the volumetric concentration of solids, when flow was in the homogenous regimes. Where material moves by saltation or heterogenously other factors increase the friction loss.

Frequently the presence of heavy concentractions of solids or thixotropic materials such as Kaolin, bentonite clays, phosphate matrixes actually reduces the energy required below that when pumping water. These phenomena are explained in different ways. In some instances the threshold of turbulent flow is increased, in other cases it appears that there is a turbulence suppression. Most dredging contractors have experienced this type flow when pumping silt and light mud.

The centrifigual pump is inherently the most inefficient pump when pumping solids. The reasons for this are that feeding solids introduces two losses which are not present when pumping liquid. The first loss is the kinetic energy imparted to the solids present. This kinetic energy is radial to the pump shaft and is never recovered by conversion to pressure energy as is the case with the liquid present. Thus the total of this energy is lost and shows up as an increased shaft horsepower requirement. This additional power is directly proportional to the specific gravity of the mixture. The second loss is due to internal hydraulic and mechanical friction. This loss is usually equal to or more than the energy loss when pumping clear liquid. Since these fixed losses must be supplied by a diminished quantity of liquid the loss per unit liquid is greater by the volumetric ratio of the solids present.

A positive displacement pump has an efficiency loss equal to the volume of solids, but because there is no centrifigual force involved the specific gravity is not a detriment to the efficiency. The jet pump functions on a momentum exchange principle and has no inate theoretical energy losses due to the presence of solids, as is the case with both the centrifigual and positive displacement pump.

Even though the centrifigual pump is the least efficient from the energy generation point of view it is at the present time the only practical means for dredging on long pipelines. The more complete understanding of pump theory helps point to means of making the most efficient use of the pump for the purpose intended. It is seen that all things being equal the most economical concentrations are 1.40 to 1.70 specific gravity when pumping sand, silt and clay sizes. The Dutch pump sand for land fill several miles at very low cost. The writer recently observed a 65 cm (25.5 inches) system pumping over seven miles and delivering an average of 3000 cubic yards per hour; the pump horsepower was 8500. Discounting the obvious advantages of increased production and lower unit labor, the power required per unit production was less than half that of the long pipe-lines which were recently in use for road fill in Louisiana.

When the nature of the centrifigual pump and pipeline losses is generally understood competition will force the American dredging industry to improve solids concentrations by one means or another.

CAVITATION IN DREDGE PUMPS

By

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Introduction

During recent years increased attention has been focused on the phenomenon of cavitation in pump impellers. This increased interest has originated from the increased tendency toward cavitation which accompanies the higher impeller rotative speed of modern turbomachinery.

The term cavitation refers to the formation of vapor filled cavities in the liquid owing to the local pressure reduction. In the eye region of an impeller local pressure reductions occur at the leading edges of the vanes and if this reduction is large enough the liquid "boils". As the vapor filled cavities move into the higher pressure regions of the impeller they collapse violently causing extreme stresses in the impeller surfaces which can erode the metal. A second and very important consequence of cavitation is the large reduction in performance, i.e., drop in head and flow rate, which accompanies fully developed cavitation. Recognizing these effects as most undesirable to a dredge pump operation, attention must be given to the cavitation characteristics in design, selection and operation of dredge pumps.

The purpose of the present paper is to discuss the various parameters which are used to describe the cavitation characteristics of a dredge pump and to present some typical results from model tests.

Fundamentals

There are many different ways of presenting both the performance and cavitation characteristics of a pump. At times such parameters as head, efficiency or cavitation index are plotted against discharge rate, a dimensionless flow coefficient or sometimes a specific speed. Any of these plots are valid methods of representation but certain forms are, at times, more instructive than others.

A simple dimensional analysis of the variables involved in a pump shows very clearly what parameters can be used and represented as a function of others. For any pump the rise in total pressure, i.e., energy, between the suction and discharge side can be represented as a function of the impeller rotative speed, flow rate, impeller size and density of the fluid being pumped as

$$\Delta P = f_1(Q, W, D, \rho) \tag{1}$$

where

ΔP - rise in total pressure across the pump, lb/ft^2.

Q - discharge rate, ft^3/sec

D - characteristic length scale of the impeller; refers to the impeller eye diameter in this paper, ft.

$\frac{\gamma}{g} = \rho$ - density of fluid being pumped, $slugs/ft^3$.

W - rotative speed of impeller $= 2\pi N/60$, where N = rotative speed, RPM

γ - specific weight of the fluid being pumped, lb/ft^3.

According to the basic concepts of dimensional analysis these five variables can be arranged into two dimensionless groups. One possible form of the two parameters appears as

$$\frac{gHD^4}{Q^2} = f_2\left(\frac{Q}{WD^3}\right) \tag{2}$$

where $\Delta P/\gamma$ occurring in the first dimensionless term has been replaced by the symbol H which is called the total head and expressed in feet of the fluid involved. Other possible forms of the two dimensionless parameters might appear as:

$$\frac{gH}{W^2D^2} = f_3\left(\frac{Q}{WD^3}\right) \quad \text{or} \quad f_4\left(\frac{WQ^{1/2}}{(gH)^{3/4}}\right) \tag{3}$$

where the parameter gH/W^2D^2 is called the specific head, Q/WD^3 the specific capacity and $WQ^{1/2}/(gH)^{3/4}$ the specific speed. The specific capacity and specific speed are generally used as abscissa when plotting the performance characteristics of a pump.

In attempting to relate the parameters involved in the description of the cavitation characteristics of a pump the dimensional analysis approach can again be used. When the minimum local pressure within an impeller reaches the vapor pressure of the liquid involved, cavitation will result provided sufficient nuclei are available in the fluid. In the case of dredge pumps the solid particles in the slurry provide an extremely good source of nuclei so that this hypothesis should be valid. Thus, one can reason that the difference between the pressure at some reference station (taken at the pump inlet) and the vapor pressure of the liquid when cavitation begins, should be related to other pertinent variables as

$$P_S - P_V = f_5 (Q, W, D, \rho) \qquad (4)$$

where

P_S - total pressure at the suction side of the pump

P_V - vapor pressure of the liquid

and the other variables are the same as defined previously. Arranging these variables into two dimensionless groups yields, as one possible combination,

$$\frac{gH_{SV}}{W^2D^2} = f_6 \left(\frac{Q}{WD^3}\right) \qquad (5)$$

where $H_{SV} = (P_S - P_V)/\gamma$ is the total suction head above the vapor pressure and is expressed in feet of fluid being pumped.

Using eq. (3) and (5) a number of possible forms for the relationship between a cavitation coefficient and independent parameter on the right-hand side of the equation can be derived. There are basically four different forms of cavitation coefficient and two different forms of the independent variable on the right-hand side of the equation that are in common usage, all of which can be obtained from eqs. (3) and (5). The cavitation parameter

$$H_{sv}/(u^2/2g) \tag{6}$$

where u is the peripheral velocity of the impeller at the impeller eye, has been in common usage in Europe since the days of Hermann Foettinger in the early 20's It may be noted, however, that since the impeller peripheral speed is proportional to WD the form of the coefficient on the left-hand side of eq. (5) is equivalent to this. During the same period the so-called Thoma parameter

$$H_{sv}/H \tag{7}$$

which is probably the most widly used form of cavitation parameter was introduced by Dieter Thoma. A third parameter proposed by G. F. Wisclicenus, R. M. Watson and I. J. Karassik [1] is the "suction specific speed"

$$S = \frac{W\sqrt{Q}^{1/2}}{(gH_{sv})^{3/4}} \tag{8}$$

analogous to the familiar specific speed

$$N_s = \frac{W\sqrt{Q}^{1/2}}{(gH)^{3/4}}$$

but with the absolute inlet head above vapor pressure substituted for the usual head, H, across the pump. A fourth form of cavitation parameter also in common use is the cavitation index[1] ,

$$K = \frac{H_{sv}}{\dfrac{Q^2}{2g\ (\pi D^2/4)^2}} \tag{9}$$

or, equivalently, in terms of the meridional velocity at the pump inlet reference station

$$K = \frac{H_{sv}}{C^2m/2g} \tag{10}$$

Any one of these cavitation coefficients indicated in (5-10) may be used to represent the cavitation characteristics of a pump when plotted against an independent dimensionless parameter. Two forms of this independent dimensionless parameter can be used, the specific speed,

$$N_s = \frac{W\sqrt{Q}^{1/2}}{(gH)^{3/4}} \tag{11}$$

or the flow coefficent,

$$\phi = \frac{Q}{WD^3} \tag{12}$$

However, since the impeller peripheral speed is proportional to WD and the inlet meridional velocity is proportional to Q/D^2, the flow coefficient indicated in (12) is equivalent to the form

$$\phi = \frac{Cm}{U} \tag{13}$$

which is also in common usage.

In representing the cavitation characteristics of a pump any one of the parameters listed in eqs. (5-10) may be plotted as a function of either of the forms of the independent dimensionless parameters indicated in eqs. (11-13). Often it is a matter of convention as to which parameters are chosen but there seems to be some merit in the use of the forms which do not involve the total head, H, across the pump. That is, the use of any one of the parameters on the left side of eq. (14) plotted as a function of either parameter on the right side of the equation is particularly suited to the representation of cavitation in pumps because both parameters then will involve variables which are associated only with the eye design of the impeller.

$$\begin{bmatrix} \dfrac{gH_{sv}}{W^2D^2} \text{ or } \dfrac{H_{sv}}{U^2/2g}, \\ \dfrac{W\sqrt{Q}}{(gH_{sv})^{3/4}}, \\ \dfrac{H_{sv}}{Q^2/2g(\pi D^2/4)^2} \text{ or } \dfrac{H_{sv}}{C^2m/2g} \end{bmatrix} = f \begin{bmatrix} \dfrac{Q}{WD^3} \\ \\ \dfrac{Cm}{U} \end{bmatrix} \tag{14}$$

As discussed by Gongwer [2], the eye design and relative flow in the eye is the most critical aspect with regard to cavitation and , accordingly, the parameters indicated in equation (14) are most appropriate in representing cavitation performance.

The two parameters on the right side of eq. (14) are equivalent since the impeller peripheral speed is proportional to WD and the meridional velocity is proportional to Q/D^2. These parameters are the most appropriate for use in plotting cavitation performance of an impeller because their value is proportional to the relative angle of incidence of the fluid at the eye of the impeller. If the impeller is properly designed there will be some value of Q/WD^3 or Cm/U at which the angle of the fluid velocity vector relative to the vane leading edge will be zero. This point will generally correspond to the point of best efficiency as well as best cavitation performance. That is, the cavitation index, $H_{SV}/[Q^2/2g(\pi D^2/4)^2]$, will have a minimum at this optimum point with increasing values on either side.

Experimental Procedure

Model tests are often carried out in order to determine the cavitation characteristics of prototype pumps. Testing is usually achieved using a closed loop wherein the system pressure can be regulated (See figure (1)). The flow and impeller speed are set and the pressure is then reduced by use of a vacuum pump until the cavitating condition is reached. A typical plot of the pump head and torque versus system pressure is shown in Fig. (2). As the pressure is reduced a point is reached at which a rapid breakoff in head and torque occurs. Cavitation inception is usually referred to as the point of .5% drop in head and complete cavitation as the point where the head rise curve drops essentially vertically. The exact definition is, however, not too critical for low specific speed pumps near the point of best efficiency since the two are very close together.

Presentation of Experimental Data

Pump cavitation data may be represented in dimensionless form by any pair of parameters listed in eq. (14). Typical centrifugal pump results presented in terms of the parameters $H_{SV}/[Q^2/2g(\pi D^2/4)^2]$ and gH_{SV}/W^2D^2 as a function of Q/WD^2 are presented in figures (3) and (4). Point A indicated on these figures corre-

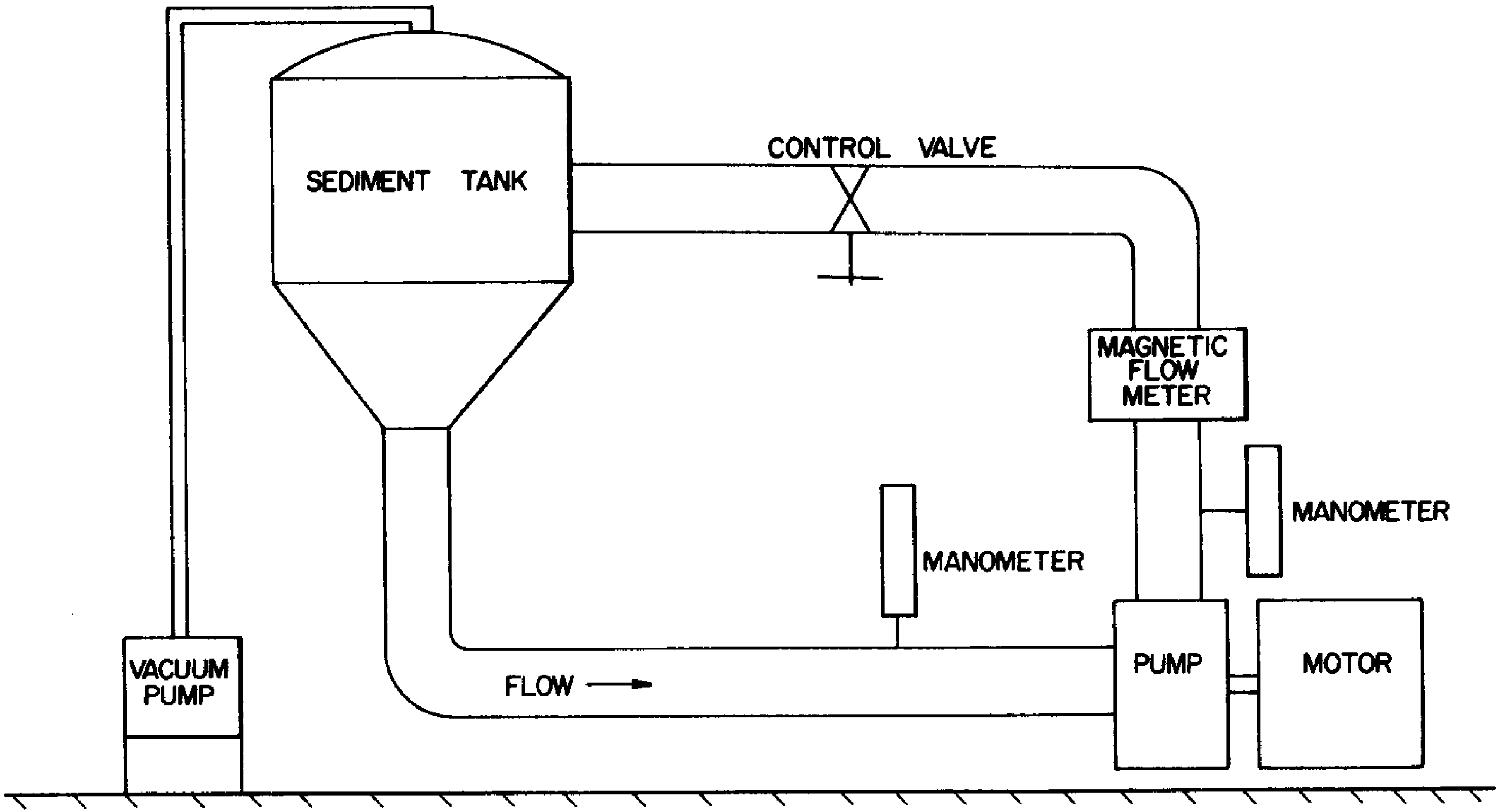


FIGURE I DREDGE PUMP TEST LOOP

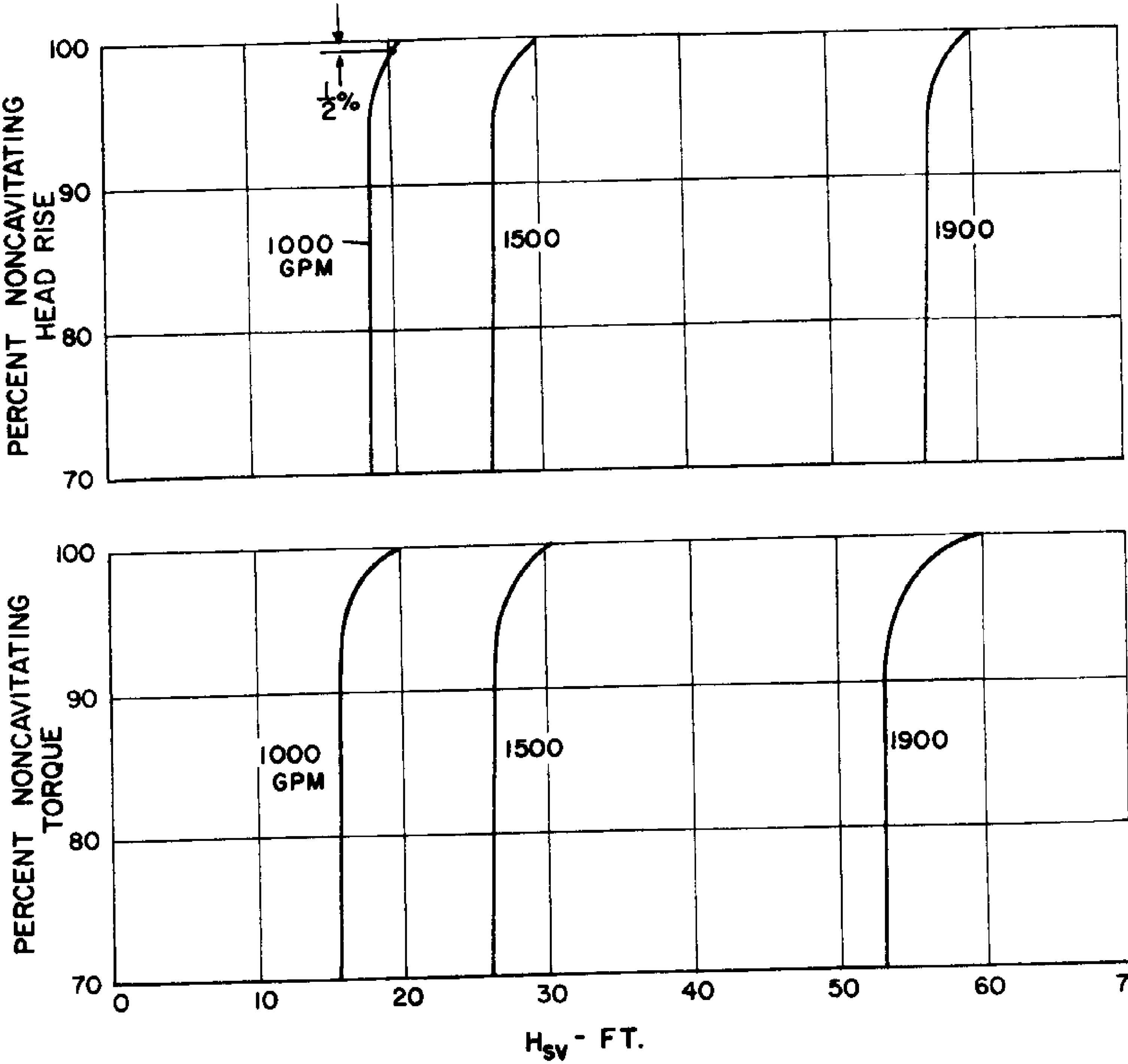


FIGURE 2 TYPICAL CAVITATING TORQUE AND HEAD VERSUS H_{SV}

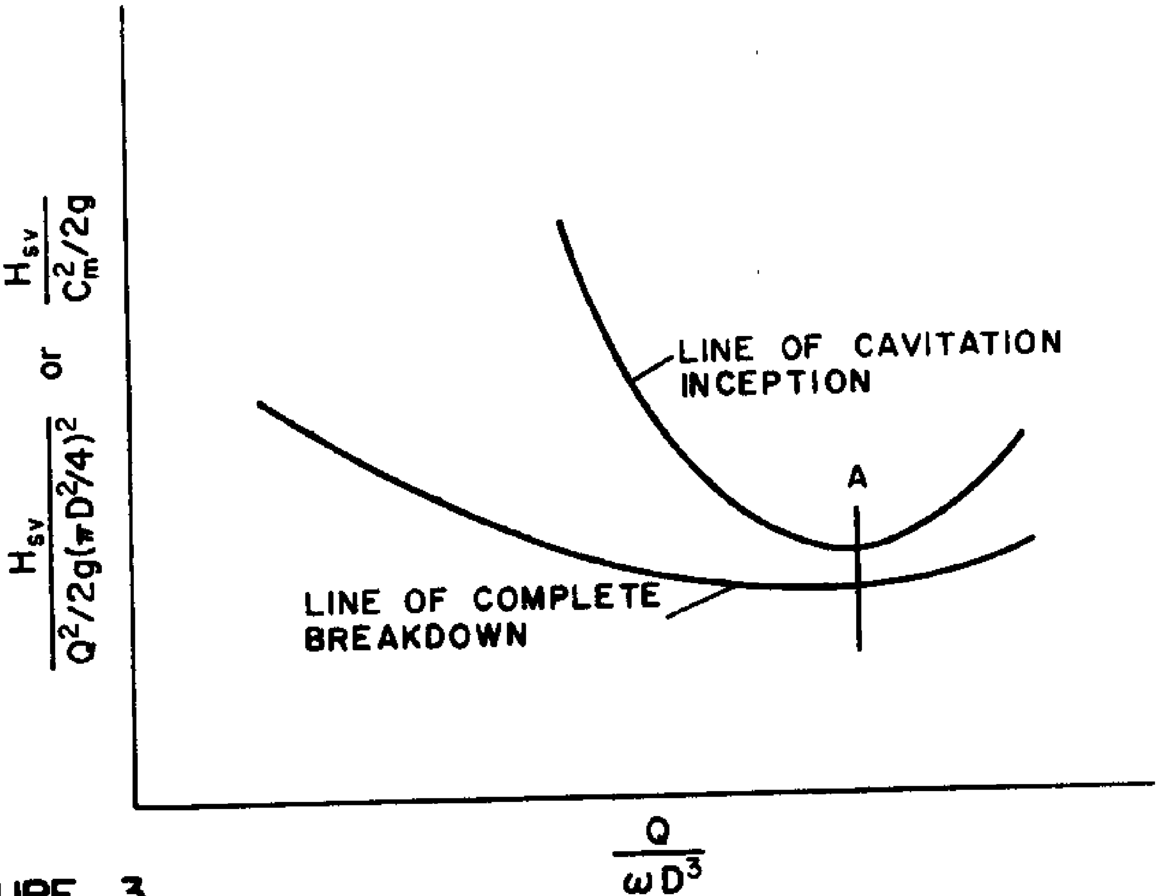


FIGURE 3

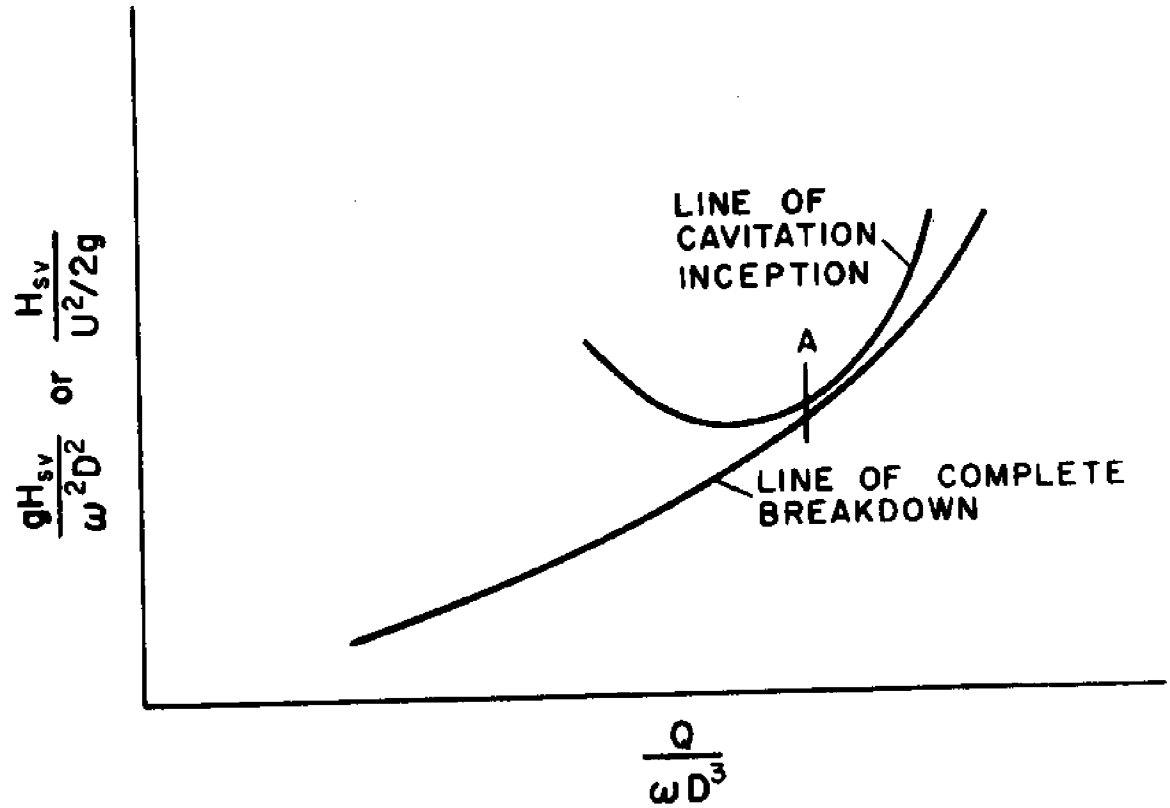


FIGURE 4 TYPICAL CAVITATION PERFORMANCE PLOTS

sponds to the condition where the impeller is operating at zero relative angle between the vanes and the flow at the impeller eye. Near this point a reduction in H_{SV}, other things being constant, results in a rapid breakoff in head whereas at off-design conditions the process is much more gradual.

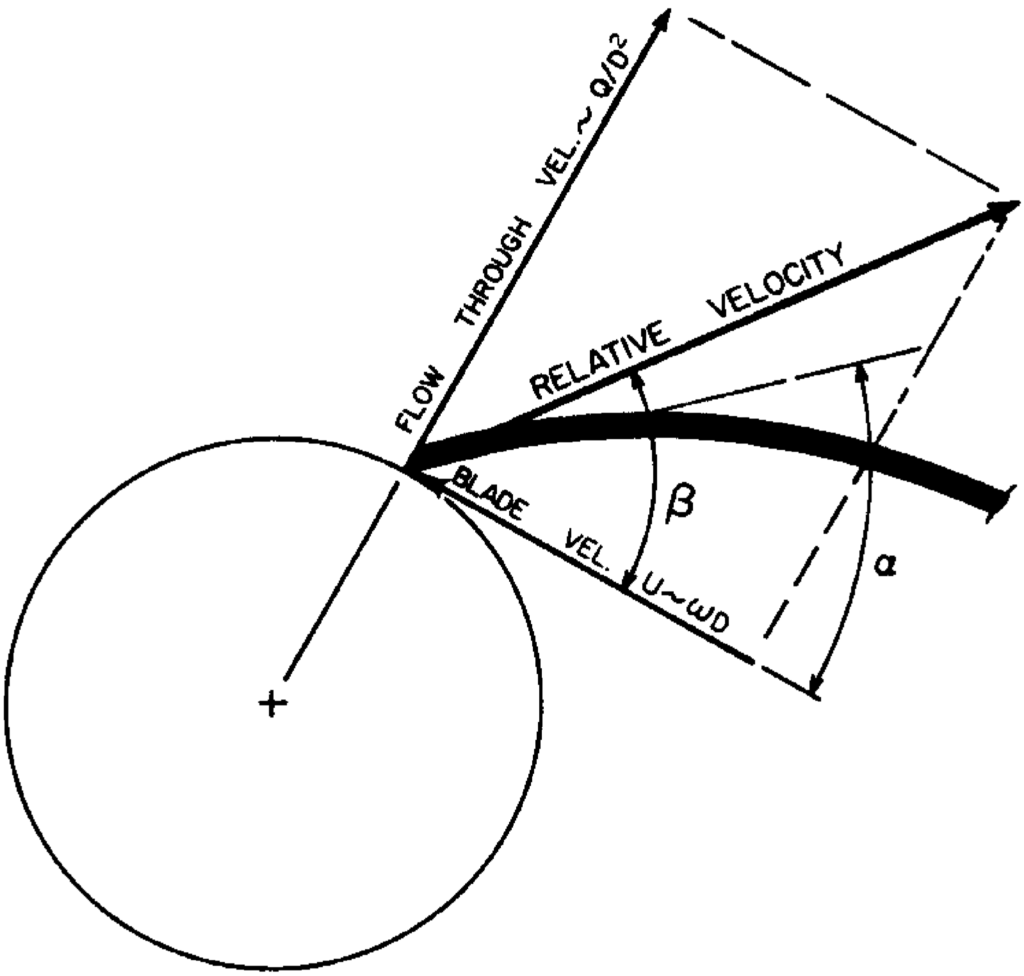
Figure (5) indicates the significants of the parameter Q/WD^3 (which Gongwer has termed the "angle of entry index") for representing cavitation performance in showing its relationship to the vane incidence angle. From the geometry indicated on the figure it is evident that the angle β is related to the flow coefficient by the relationship.

$$\beta = \tan^{-1}\left(\frac{Q}{WD^3}\right)$$

Thus, the angle of the incidence of the fluid relative to the vane leading edge is $(\beta-\alpha)$ and the zero incidence condition is reached when $\beta=\alpha$. This condition corresponds to the point of best cavitation performance denoted by point A on figures (3) and (4) and is generally at or very near the point of maximum efficiency.

Effect of Fluid Density

The primary fundamental difference between water pumps and dredge pumps is the kind of fluid pumped. Although little data is available on the effects of the slurry mixture limited test results from a model test using three different slurry mixtures showed no noticable effect on cavitation performance provided the results were presented in dimensionless form and heads were measured in feet of the fluid pumped. A typical plot of the cavitation index as a function of the flow coefficient for three different fluids ranging from specific gravity 1.0 to 1.31 is shown in figure (6). These data were taken from ref. [3] and represent model tests of the Corps of Engineers hopper dredge Essayons. Clearly, no effect of the fluid density is present and, therefore, available results on water pump cavitation should be of use in dredge pump design. One must remember, however, that according to the dimensional analysis, heads H and H_{SV} are defined as total



$$\text{TAN } \beta = \frac{Q/D^2}{\omega D} = \frac{Q}{\omega D^3}$$

0° INCIDENCE WHEN $\beta = \alpha$ (POINT A)

FIGURE 5 VELOCITY TRIANGLE AT EYE

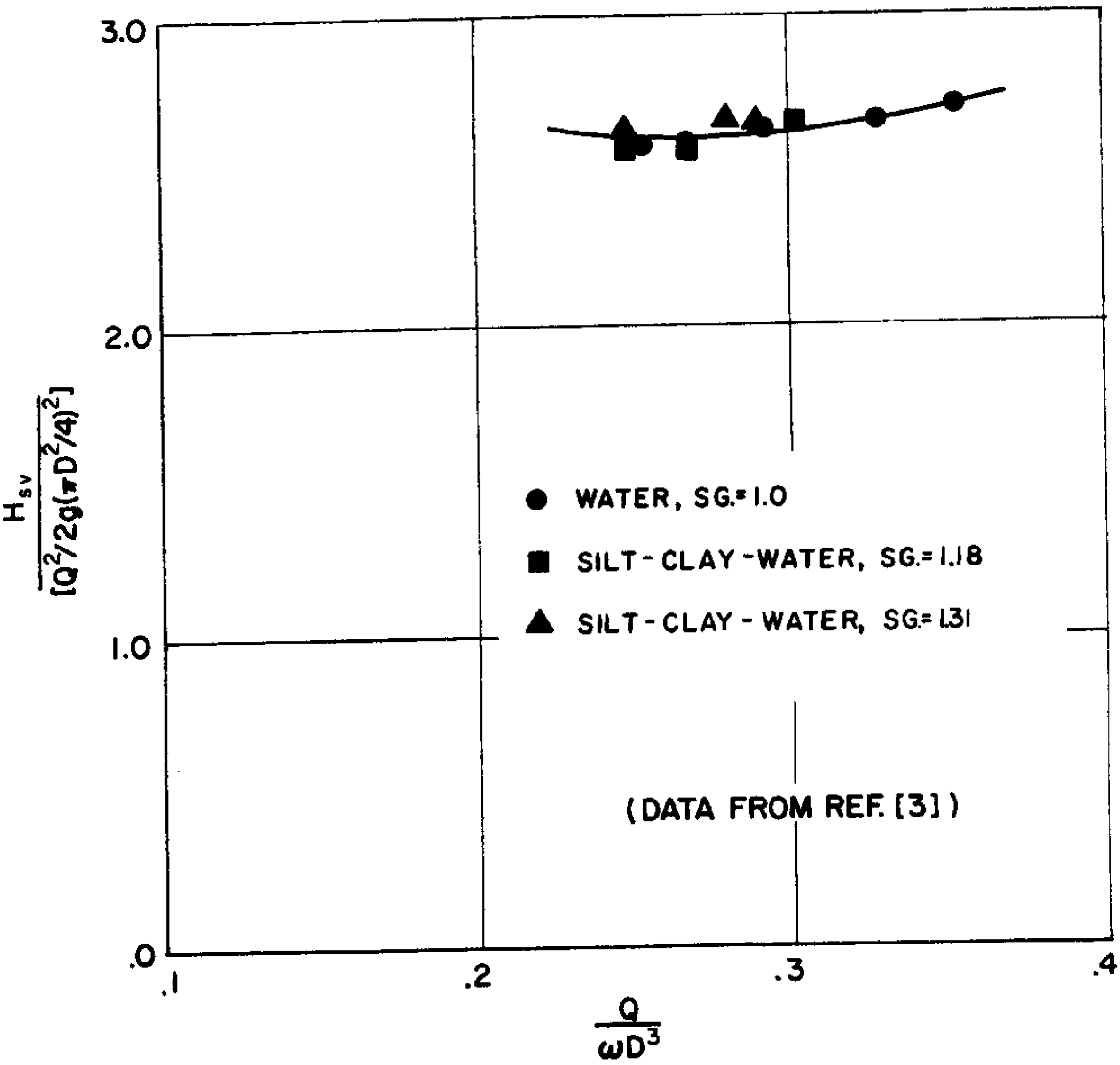


FIGURE 6 EFFECT OF FLUID DENSITY. (IMPELLER TD-7).

heads measured in feet of the fluid involved.

The conclusions regarding density effects of the slurry mixture were reached on the basis of experimental evidence associated with mixtures of very fine solids. Courser solids may have a sizable influence on cavitation.

Comparison of Cavitation Indices

Previously a plea was made for plotting cavitation indices, which do not involve total pump head, against the flow coefficient Q/WD^3. This was because cavitation is primarily dependent on the nature of the flow at the eye and has little to do with the over-all pump head. Figures (7) and (8) show the same data from three slightly different impellers but with the same eye design plotted in two different ways. Figure (7) shows the data presented in the form of the Thoma cavitation parameter against the specific speed while figure (8) shows the cavitation index which is independent of head plotted against the flow coefficient. The Thoma plot shows scatter of approximately 20% owing to the fact that the impellers were all similar in eye design but operated at slightly different heads. The cavitation index not involving H plotted on figure (8) against Q/WD^3 shows only 11% scatter and, therefore, is preferred for representing cavitation performance.

Factors Affecting Cavitation Performance

The most important factor affecting the cavitation performance of a centrifugal pump is the geometry of the passage and vanes in the inlet or eye region of the impeller. The radius of curvature of the shroud in the eye region as well as the vane shape, thickness and number are important. At the point of fully developed cavitation the influence of the angle α is strongly bound to those of blade thickness t and blade number z by the contraction number

$$\frac{tz}{2\Pi r \sin\alpha}$$

where r is the radius of the observed point at the inlet. Experience [4] shows

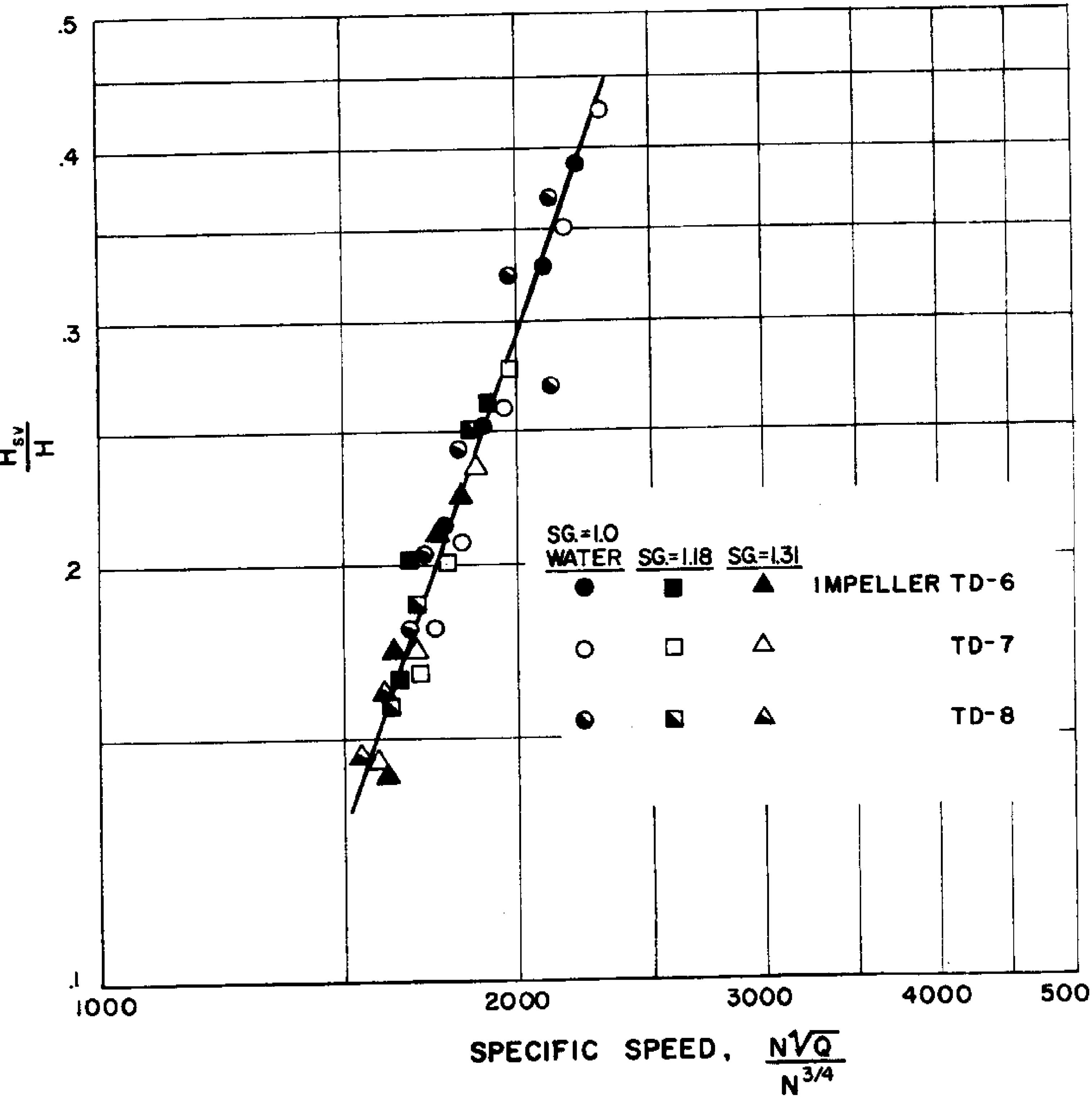


FIGURE 7 CAVITATION CHARACTERISTICS OF THREE IMPELLERS WITH THREE FLUIDS

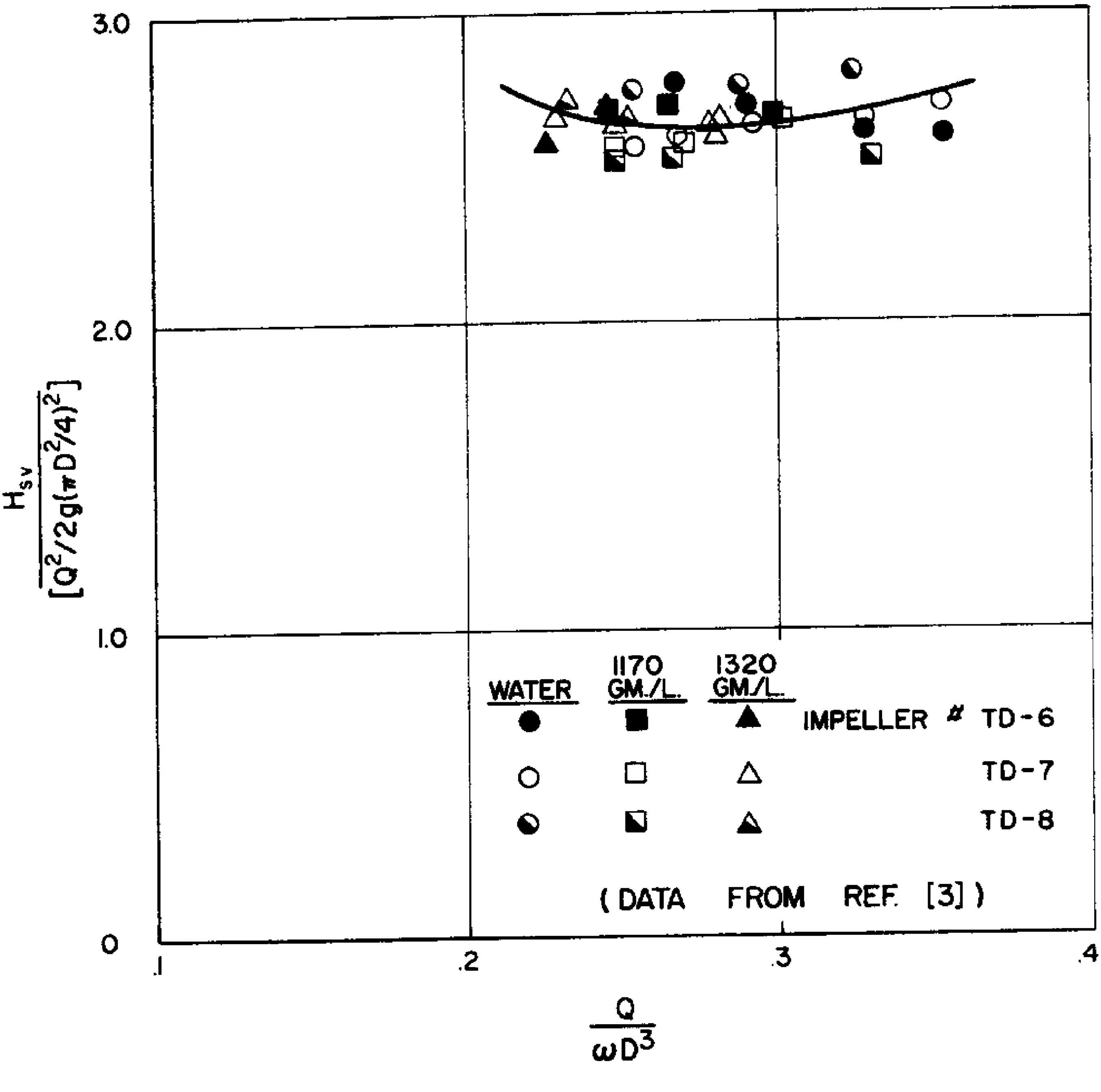


FIGURE 8 CAVITATION CHARACTERISTICS OF THREE IMPELLERS WITH THREE FLUIDS

that constant contraction number does not affect the cavitation index near the point of minimum cavitation index. Increasing the contraction number tends to increase the tendency toward cavitation and corresponds to increasing values of the cavitation index while decreasing the contraction number has the opposite effect.

Gongwer [2] has developed an impirical expression to relate the minimum value of the cavitation index as a function of the angle-of-entry index in the form

$$\frac{H_{SV}}{Q^2/2g(\pi D^2/4)^2} = 1.4 + .085\ (1 + \frac{\pi^2/64}{(\frac{Q}{WD^3})^2}$$

This expression was developed on the basis of test results from a series of impellers of similar eye design and, consequently, does not reflect any effect of vane thickness or number. It is interesting to note, however, that if tz/r in the contraction number is held constant the contraction number is directly related to the angle-of-entry index since $\alpha \quad \tan^{-1} (\frac{Q^2}{WD^3})$. This shows that Gongwer's imperical expression is in accord with the conclusion that the minimum value of the cavitation index is soley dependent on the contraction number.

Experience also has shown that sharpening the leading edge of the vanes has a sizable effect on cavitation. European experience reported by Raabe [4] shows that a large reduction in the minimum value of the cavitation index can be achieved by sharpening both the pressure and suction side of the vanes at the leading edge. If blade inlet edge is removed only on the suction side, the point of best performance changes to lower rates of flow. Sharpening the pressure side of the blade inlet edge diminishes the minimum cavitation index.

The effects of noncondensable dissolved gas content on cavitation in general has been the subject of many investigations and it is commonly agreed upon that air content affects incipient or limited cavitation. For example, results of some German tests reported by Raabe [4] shows that in the case of incipient cavitation in centrifugal pumps air content has a sizable effect. However, these same tests show that the effect of air content on fully developed cavitation is very unimportant and can be ignored. There seems to be no reason that these same conclusions cannot be applied to dredge pump.

Conclusions

1) Cavitation causes loss in performance and erosion of flow passages.

2) Best cavitation performance corresponds to the value of Q/WD^3 where the relative flow angle is zero.

3) The effect of the slurry mixture shows no noticable effect in limited test results provided the results are plotted in dimensionless form.

4) Cavitation is primarily dependent on the flow at the eye and, therefore, the cavitation index $H_{sv}/[Q^2/2g(\pi D^2/4)^2]$ and flow coefficient Q/WD^3 are preferable parameters to use in presenting the data.

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(1) G. F. Wislicenus, R. M. Watson and I. J. Karassik, "Cavitation Characteristics of Centrifugal Pumps Described by Similarity Conditions", Trans. A.S.M.E., Vol. 61, 1939, pp. 17-24.

(2) C. A. Gongwer, "A Theory of Cavitation Flow in Centrifugal - Pump Impellers", Trans. A.S.M.E., Vol. 63, 1941, pp. 29-40.

(3) V. Richard Mariani and John B. Herbich, "Effect of Viscosity of Solid-Liquid Mixture on Pump Cavitation", Central Water and Power Research Station Poona Golden Jubilee Symposia, Vol. 2 No. 51, January 1966.

(4) J. Raabe, "Cavitation Effects in Turbomachinery - European Experiences", Cavitation State of Knowledge, A.S.M.E., Fluids Engineering and Applied Mechanics Conference, Northwestern University, Evanton, Illinois, June 16-18, 1969.

THE CHALLENGE AHEAD: CHANGE OR BE CHANGED

by

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It is a real pleasure for me to appear before this group today. Because here in Texas, it's very easy to recognize dredging's contribution to marine industry and our local economy. The Texas Almanac of 1857 notes the award of public lands to the Galveston and Brazos Canal Company for development of commerce with the mainland.

At that time, coastal commerce was a leisurely ... and costly affair. Most foodstuffs and cargo reached Galveston Island aboard small coastal sloops putting out from Harrisburg and from Liverpool at the headwaters of Chocolate Bay. The trip took over 15 days!

That same year, an advertisement for the first steamboat on the Texas coast -- the Laura -- indicated that shippers and passengers could expect arrival at Sabine Pass 18 to 22 days after putting out from the Laura's home port near Jasper, Texas.

Today, the Sabine-Neches Waterway, the Houston Ship Channel, the "new" Brazos, the Port Lavaca Channel, the Corpus Christi Channel, and dozens of others join the Intracoastal Waterway to form one of the nation's most vital transportation nets.

Dredging can share the credit for the tremendous change occurring in the 110 years since the Laura first steamed up Buffalo Bayou. But that's past history!

More change will take place in the ten years just ahead than in the entire previous one-hundred-and-ten years.

For those of us in marine business, the 1970's represent a truly historic opportunity. We now stand at the outset of ocean development with existing corporate organizations, existing machinery and equipment, and generations of experience in the marine environment.

If we are to take advantage of our opportunity, however, we must begin now to plan for our future. Already, we can see some of the new things ahead for us.

This year, OFFSHORE Magazine performed a nation-wide survey of the dredging industry...to determine its capability to participate in tomorrow's offshore mining activities. As pointed out then, mining is basically digging...and digging under water is dredging!

Offshore mining is a controversial subject. Jamison Moore, head of an independent west-coast management research firm, said, "Nothing so excites the imagination as the quest for precious metals or the endless potential of manganese and phosphorite nodules. Something happens to normally rational people when the prospect of dredging wealth from the ocean floor is mentioned. The deep-water potential of offshore mining remains more than several years ahead of us."

Most offshore businessmen agree with Moore. The immediate future will see offshore mining limited to production of placer deposits in less than 400 feet of water.

But at this point, I have three questions for you to ponder:

Can you visualize in your mind how <u>much</u> unexplored real estate lies just off our coasts in less than 400 feet of water? We'll be developing this huge piece of geography during the next ten years.

Secondly, if a potential customer came to you in, say, June of 1971 and asked you to bid on an offshore job in open water of 250-foot depth could the equipment you now have on order perform the work?

And lastly, if Moore is right that nothing intrigues men so much in 1969 as the thought of dredging wealth from the deep-ocean floor...what intrigued man just as much only ten years ago?

I imagine your answer to the latter would be the rather dreamy thought of putting a man on the moon!

The OFFSHORE Magazine survey was not designed to determine the extent of offshore mining. Instead it determined the extent to which the dredging industry was involved in offshore mining.

We discovered that only one-third of the surveyed dredging companies considered themselves as in the mining business. Another 38 percent indicated that they produced mined products, but did not think of themselves as being in the mining business. Here is an indication that the dredging industry as a whole is not contemplating a role of leadership in offshore mining.

Offshore construction is another future industry having a potential for dredging. Recently, we have talked with companies interested in putting entire process plants on offshore platforms. This interest springs from two economic considerations: the rising cost and scarcity of coastal lands for new-plant construction, and the desireability of offloading deep-draft supertankers directly into the process-plant production streams.

To contain a complete process plant of only modest size, an offshore platform would need to be as large as 20 to 50 acres. To accommodate the supertankers, they'll need to be constructed in around 100 feet of water. Some engineering experts believe that platforms of this large size will require foundation excavations similar to those for large onshore construction projects.

And, there are supertankers and bulk carriers on the drawing boards that are so large that they will seldom even come within sight of land on their routine voyages. This means that offshore terminals will be constructed to accommodate their laden drafts of 80 to 100 feet.

These are only a few examples of future business the dredging industry might seek out and profitably undertake. But today's problem is the very difficult task of planning ahead. It's not easy.

In marine industry...as well as in all other industry...techniques of business planning that have held true for decades now fail to provide adequate answers. And there are threatening new forces in society itself that have little precedent in American business history.

Many "futurists" have published their view on the 1970's...and beyond. But businessmen have often found them to be intolerably conflicting.

If these various portraits of the future are viewed collectively,it can be seen that the inaccuracies may stem from the specialized viewpoints of the artists. Urban planner, ocean scientist, architect, computer specialist -- each tends to award undue influence to his own speciality in shaping his view of the years ahead. In actuality, these separate forces will continue to tug against each other and our economy will remain a dynamic balance of them all.

But the marine businessman of 1969 can be assured of three factors that will affect his business for the decade ahead. These are:

GROWTH

CHANGE

RESTRUCTURING

Let's consider each factor for a moment.

GROWTH: Nothing short of world-wide atomic annihilation can deter growth of world population. It will almost double in the next 30 years... to over 6-billion people. Sociological problems aside, this population growth will have the effect of doubling the available market for each and every product and service industry provides today.

Hopefully, we will be able to find a way for each of these new citizens to make a living on his own...especially here in America.

If we do, the basic yardstick of American economy will grow along with the population -- the Gross National Product. Before 1975, just five years from now...our GNP will reach $1-trillion. Only twenty-five years later, it will reach the second $-trillion.

For the marine businessman, this has special meaning. I've heard no one dispute the fact that we will develop the continental shelves during the next thirty years. These amount to about 20 percent of the total area of the United States...depending on whose definition of the continental shelf you use.

If my Aggie friends will excuse me, I'll quote Dr. George Kozmetsky, Dean of the School of Business Administration at the University of Texas He speculates, "If the continental shelf is 15-20 percent of the total area of the U. S., is it not feasible that by 1985 (which is the beginning of the 21st Century), 15 or 20 percent of the U. S. Gross National Product should arise from the exploitation of these offshore resources?"

If Dr. Kozmetsky is correct, there is a real possibility that more than $200-billion in new business will be available to the marine industry in the next 15 years!

I personally believe this view is overly optimistic. Let's slash it drastically...cut it in half. Let's say that only $100-billion will arise from marine industry by 1985.

If we accept that very conservative 1985 goal, it means that every part of the marine industry -- dredging included -- will have to find the money, the men and the equipment to build three more industries with the ability to perform as much work as today's marine industry.

That $100-billion goal just fifteen years ahead represents a four-fold growth. The President's Commission on Marine Science, Resources and Engineering measures the marine industry by its contribution to the Gross National Product...the same yardstick we have just used to pick our goal. Their total figure for 1968: $21.4-billion.

Congressman Richard T. Hanna described the components of this total figure for the Ocean and The Investor Conference sponsored by the American Society of Oceanography last year. Here's where the money comes from:

Transportation	$11.280-billion
Recreation................................	3.855-billion
Marine Engineering........................	2.320-billion
Mining & Petroleum........................	1.704-billion
Defense & Space...........................	1.319-billion
Health & Welfare..........................	.372-billion
Food & Agriculture........................	.345-billion
Research & Development....................	.232-billion
Miscellaneous.............................	.010-billion
Total.....................................	$21.400-billion

Congressman Hanna went on to note, "In all this presentation of figures, it should be obvious that the bulk of the market for oceanic goods and services will remain where it has historically been. That is, dominance will be in shipping, defense, and in oil extraction with a continued substantial position for fisheries and related sea foods."

For dredging and the rest of the classical marine industries, this is good news. It underscores our growth potential and gives us confidence in our conservative figure of $100-billion by 1985.

There are other sources that assure us of dredging growth potential in even its most basic activities. Mr. F. A. Mechling of Mechling Barge Lines says, "If public demand for freight services continues to expand at its present rate, the industry will have to supply twice as much service in 1980 as it provides today. That means, in effect, an opportunity to build a new transportation system equal in capacity to the one we have now. A vast expansion of inland water transportation will be built into this expanded system."

And finally, the October issue of Business Management Magazine carries an excellent survey of the entire oceanographic market. It notes that the single factor of "Harbor and Coastal Improvements" will double -- from $300-million annual expenditures to $600-million -- over the next five years!

Thus, we are assured of fantastic growth in our own marketplaces during the decade ahead.

Now, let's consider the next factor upon which the business planner can depend in considering the 1970's.

CHANGE: We can be pretty sure that, fifteen years from now, our marine industries will be producing four times as much revenue as today; but who will be doing the work? In today's industry, change is the product of technology. And here, progress will brook no delay.

Let me give you a classic example. In electronic circuitry, the vacuum tube and the transistor perform exactly the same operational function. In 1950, a handful of well-established, large manufacturers produced 100 per cent of our nation's vacuum tubes. There was no transistor, at least, in commercial production.

By 1954, several new companies such as Texas Instruments, Transitron and Fairchild were producing transistors for the commercial marketplace. The tube manufacturers elected to concentrate on improving the vacuum tube, thereby saving their large capital investments in tube-manufacturing facilities.

By 1960, there were no more vacuum tubes.

And not one single tube manufacturer was a significant factor in the transistor market. The tube manufacturers' confident 1950 predictions about the ten-year potential of the electronics market had come true. They just weren't doing the work.

Now, lest the example of the tiny transistor seem too far removed from a mighty dredge, let me mention the emergence of the new tug/supply vessels being constructed for offshore oil operators. This totally new type of vessel has been developed to fill the void created when the U.S. towing industry could not economically provide the towing services needed. Why?

Most U. S. towing companies are local or regional operations. When the oil companies moved out of the Gulf into far-flung waters, the towers could provide the tow out okay, but were faced with dead-heading it all the way back to the States. Thus, they had to bid the tow based on costs for running outbound under tow plus inbound running free. Only a few large foreign firms have been able to establish world-wide sales functions providing some assurance of inbound profit also.

Dr. Claude Hocott of Esso Production Research commented on technological change in the 1970's when he said, "The rate of change has already accelerated to the extent that it is impossible to accurately project current thinking only a few years into the future. Today, the half-life of truth is only ten years!"

The message is clear. Everyone in every business -- on the sea and on land -- must take advantage of every technological development available to him at the earliest possible moment.

Now the last factor:

RESTRUCTURING: The inevitable restructuring of both industries and markets is the result of growth and change. Heretofore, economic growth has consisted of expanding existing business practices and technology into "virgin" new territories. Today, there is little virgin territory left in the world

So business must begin to expand by improving existing business practices in areas they are already serving. There is a parallel in the contrast between the frontier woodsman timbering the natural forests and today's timber-farming industry with deep vertical integration.

But let me give you an example from the marine industry.

A marketplace or industry can be defined as a group of customer companies being supplied by another group of seller companies. The chain can be two or three or more links long.

Historically, the maritime industry consisted of ship chandlers selling goods to ship builders who sold ships to ship operators. When the oil companies developed extensive marine operations, they needed specialized vessels of their own. Thus, chandlers and builders found themselves with a new set of customers. Because of their technology, which was geared by and large, to the needs of ocean shipping, they were slow to develop the new types of boats needed by the rapidly diversifying ocean industry. As a result, systems-oriented aerospace companies began to fill the gap with submersibles, high-speed gas-turbine crew boats and other specialized vessels. Many of the suppliers to the aerospace industry have never before been involved in the marine market.

At this point, not only do chandlers and shipbuilding firms have a new segment of customers, maritime operators and oil companies have a new set of suppliers also -- the aerospace companies!

This is a fine example of the restructuring to be expected in the decade ahead.

Thank you for bearing with me through this sales pitch for the future. I know I have covered much territory that is not new to you, but perhaps by tying the facts together in this manner, I have given you an added measure of confidence in your future...and mine. It's not an easy time we face just ahead. But it will be an exciting time. A time when those who are able, will reap the rewards of years nurturing a modern ocean business.

We'll see growth: at least four-fold growth in the next fifteen years. The chances are, it'll be much greater.

We'll see change born of new technology. And the space age has taught us to take advantage of every development just as soon as we are financially able.

And, we'll see our old marketplaces change. New customers will arise for our existing services while we find new services to provide our old customers.

Change, we can. And change, we must.

Thank you.

TOUR OF FACILITIES IN
HYDROMECHANICS LABORATORIES

The recently expanded Hydromechanics Laboratories house the facilities of:

1) Undergraduate Fluid Dynamics Laboratory
2) Coastal and Ocean Engineering Laboratories
3) Center for Dredging Studies

The laboratories have 15,000 sq. ft. of floor space in use at the present time and proposed plans for additional space at the Texas A&M Research Annex, west of the main campus.

Undergraduate Fluid Dynamics Laboratory

The undergraduate laboratory consists of experiments in basic fluid dynamics and hydromechanics. Some of the equipment used in these experiments is:

1) Velocity distribution in a conduit
2) Gilkes pump - pump characteristics
3) Hele-shaw apparatus
4) Parshall flume
5) Pipeline meters - flow rate measurement
6) Falling sphere apparatus
7) Variable slope flume

Coastal and Ocean Engineering Laboratory

The Coastal and Ocean Engineering Laboratory consists of:

1) 2' x 3' x 120' 2-dimensional wave tank
2) 2' x 32' x 86' 3-dimensional wave tank
3) 5' x 10' x 150' 2-dimensional wave tank and towing tank (under construction)
4) 2' x 4' x 150' Variable slope flume
5) Large 3-dimensional wave basin, Texas A&M Research Annex. (proposed)

Research is conducted in the following areas:

1) Effect of Surface Roughness of the Wave Forces on a Cylindrical Pile

2) Biological Response to Organic Chemicals in Estuaries

3) Bottom Sludge Accumulation and Oxygen Demand in a Polluted Estuary

4) An Analytical Solution for the Dynamic Response of a Laterally Loaded Pile

5) Digital Computer Model of Base Flow of the Brazos River

6) Effects of Roughened Slopes on Regular and Irregular Wave Run-Up on Composite Beach Sections

7) Some Characteristics of Waves Broken by a Longshore Bar

8) Numerical Calculation of Wave Refraction by Digital Computer

9) Scour Around a Circular Pile due to Oscillatory Motion

10) Galvanic Corrosion of Structural Aluminum Coupled with Mild Steel

11) Wave Forces on Underwater Storage Tanks

Center for Dredging Studies

A proposal was prepared as a result of discussions between staff members in the civil engineering department, random sampling of representatives of the dredging industry and the discussions with the Sea-Grant representatives of the National Science Foundation. The proposal was presented to the Board of Directors of Texas A&M for their consideration and approval. The Center was officially created in June 1968 in the College of Engineering with administrative and fiscal responsibility for research and operational activities in areas involving the development of efficient dredging systems for shallow- and deep-water dredging. The Center works through the Civil Engineering Department in developing appropriate graduate teaching activities.

The goals of the Center are:

(1) To establish a first-class dredging laboratory incorporating:

(a) a large dredge pump test loop.

(b) a cutter-head towing tank.

(c) a four-dredge pump dredging system loop.

(d) a pipeline loop system.

(e) a small dredge pump wear and erosion test stand.

(2) To conduct basic and applied research to improve:

(a) dredge pump efficiency.

(b) dredge pump cavitation characteristics.

(c) cutter-head efficiency, etc.

(3) To study the use of jet pumps in suction lines of dredge pumps to increase dredging depth.

(4) To develop design criteria for

(a) dredge pumps.

(b) jet-assist pumps.

(c) drag heads.

(d) gas removal systems.

(e) multiple-dredge pump systems.

(f) booster pumps, etc.

(5) To determine more accurate information on pipe friction losses for various materials pumped and head losses in elbows, eyes, ball joints, etc.

(6) To publish a quarterly newsletter and abstracting service covering all recent publications of interest to dredging industry.

(7) To provide an industrial testing facility to solve specific problems of any given firm.

Financial Support

The financial support for operation of the Center is currently being solicited.

The support may be given in a variety of ways:

(1) A grant for the operation of the Center and for support of basic research of interest to the Dredging Industry. The level of support of between $1500 and $7000 per year, depending on the size of Company, with initial commitment for two years with remittance on a yearly basis. Any company granting funds of this type will nominate a representative to the Advisory Board of the Center. Consultations with the Advisory Board will determine the most pressing research needs, and projects will be conducted to provide answers to general problems.

(2) Service-to-Industry type projects will be conducted for a company (or several companies who may wish to join forces) which desires to solve a particular problem. A lump sum grant will be accepted in this case to fund the study. The cost of the study will in general be the actual direct costs plus indirect costs (overhead). The actual length of the study will be determined in each case.

(3) Donations in the form of equipment for development of facilities will also be accepted.

(4) An abstracting service covering all recent publications will be provided free of charge to those contributing to the operation of the Center. A subscription charge to all others will be $40 per year.

The quarterly newsletter will be available free to those who indicate a wish to receive it.

Facilities

The center is housed in the new 6440 sq. ft. addition to the Hydromechanics Laboratories. Two test facilities are presently available.

1) A large dredge pump test loop.

2) A pipeline loop system

One additional facility is under construction:

1) Errosion test stand

The large dredge pump test loop consists of three main parts:

1) Vacuum tank

2) Pump and drive unit

3) Instrumentation

The vacuum tank is 11 feet in diameter and 15 feet tall with a volume of 800 cubic feet. It was designed to withstand a vacuum of 29 inches of mercury. The tank will also serve as a reservoir for the system.

The pump and drive unit consists of three parts:

1) Motor

2) Variable speed coupling

3) Pump

The motor is a 200-HP, 440 V, 1775 RPM Continental Electric Motor. The variable speed coupling is a Dynamatic 200-HP, 50-1750 RPM eddy current coupling. The pump presently being tested is a Morris, type 6JC14, slurry pump. On hand is a Pekor, 6" x 8", model DV pump which will be tested next.

The instrumentation for the system includes:

1) Vacuum pressure on the tank by absolute manometer
2) Suction side pressure by manometers and pressure transducer
3) Discharge side pressure by gage and pressure transducer
4) Discharge by Fischer & Porter, 6" magnetic flowmeter
5) Temperature and density of the flowing fluid
6) Shaft horsepower to the pump
7) Pump speed by magnetic pickup and Strobotac
8) Plexiglas suction side cover to be used when high speed movies are taken

The first research project to be conducted in the large dredge pump test loop is the "Effect of Viscosity on Cavitation of Dredge Pumps". Water, sand-water mixtures, clay-water mixtures and polymers added to water will be used as fluids for the test. The pump will be run at several speeds, discharges, and suction side vacuum pressures on the tank. Several pumps will be run, each with different design characteristics to see if these characteristics affect the cavitation of the pump with changes in the fluid viscosity.

The pipeline test loop consists of three 180 foot test lines; 4", 6", and 8" in diameter. The lines will be monitored along their length by manometers connected to a common reference point to obtain the head losses along the line. The same fluids used in the dredge pump test loop will be used in the pipeline loop. The loop is presently under construction and will be operational by December 1969.

The erosion test stand will be used to study the erosion patterns in several different dredge pumps. The test stand is presently under construction and should be operational by February 1970. From this study, the erosion and wear characteristics of several pumps will be studied and efforts made to improve upon them.

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