TECHNICAL REPORT HL-88-2

US Army Corps of Engineers

PUMPING STATION INFLOW—DISCHARGE HYDRAULICS, GENERALIZED PUMP SUMP RESEARCH STUDY

by

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February 1988

Final Report

Approved For Public Release; Distribution Unlimited

HYDRAULICS LABORATORY

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Technical Report HL-88-2	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAEWES Hydraulics Laboratory 6b. OFFICE SYMBOL (If applicable) WESHS-S	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39180-0631	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING / SPONSORING ORGANIZATION See reverse 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Pumping Station Inflow--Discharge Hydraulics, Generalized Pump Sump Research Study

12. PERSONAL AUTHOR(S)
Fletcher, Bobby P., Triplett, Glenn R., Grace, John L., Robertson, John J.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final report	FROM ______ TO ______	February 1988	374

16. SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Automatic data acquisition system Microcomputer (Continued)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report contains the first phase of a continuing sump research study for typical small pumping stations (capacities less than 200 cfs) with relatively low submergences. The facility consists of three operational mixed-flow pumps and one suction or dummy pump. An automatic data acquisition system is housed in an environmentally controlled building. Comparison testing was conducted with an operational pump and the dummy pump. Optimum location of the pump within the sump was determined by a wide range of testing. Surface vortex suppressors and other appurtenances were tested to improve approach inflow conditions and diminish vortex action.

The improved sump design with optimum pump location was used for repetitive tests to determine base data to plot performance "signature" curves for each of the three operational pumps. The coordinates of these signature curves were installed in the permanent memory of the microcomputer for comparison of subsequent sump designs. An 0.8D- to 2-D-high
(Continued)

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

8a. NAME OF FUNDING/SPONSORING
ORGANIZATION (Continued).

DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington DC 20314-1000

18. SUBJECT TERMS (Continued).

Pumping stations
Pump location
Pump performance
Scale effects
Submergence
Sump appurtenances
Sumps
Vortex suppressors
Vortices

19. ABSTRACT (Continued).

vertical drop was located across the sump approach at varying distances from the pump. Test results showed only minor deviations from the signature data; when the distance was equal to or greater than 2D, the flow was in the lateral plane, and the submergence was equal to or greater than 0.47D.

Criteria for similarity of surface vortices in pump station models are discussed using a search of the literature. Similarity of submerged vortices is investigated in physical models of different size.

PREFACE

The continuing pumping station sump investigation reported herein was authorized by the Office, Chief of Engineers (OCE), US Army. Project monitors were Messrs. J. S. Robertson and R. L. Kinsel. Mr. R. Malm, OCE, was instrumental in obtaining initial funding for computer software.

This phase of the study was conducted in the Hydraulics Laboratory of the US Army Engineer Waterways Experiment Station (WES) under the direction of Messrs. H. B. Simmons and F. A. Herrmann, Jr., former and present Chiefs of the Hydraulics Laboratory; and under the general supervision of Messrs. J. L. Grace, Jr., Chief of the Hydraulic Structures Division, and N. R. Oswalt, Chief of the Spillways and Channels Branch. Technical instrumentation support was provided by Messrs. B. W. McCleave, H. C. Greer, S. W. Guy, and L. B. Smithhart of the Instrumentation Services Division. Drs. Roger Multer, of the WES Hydraulic Analysis Division, and Dr. B. James, of the Coastal Engineering Research Center, Fort Belvoir, Maryland, developed the modified algorithms presented in Part IV. Support for computer software development was provided by Drs. Multer and L. L. Daggett, also of the Hydraulic Analysis Division, and Mr. P. K. Senter, Chief, Information Research Center, Information Technology Laboratory (ITL). Project Engineers for this phase of the study were Messrs. G. R. Triplett and B. P. Fletcher, Spillways and Channels Branch. This report was prepared by Messrs. Triplett, Fletcher, Grace, and J. J. Robertson, former Chief, Electrical and Mechanical Branch, Engineering Division, Directorate of Engineering and Construction, OCE, and edited by Mrs. Beth F. Burris, Information Products Division, ITL.

During the investigation, the following visitors were at WES to discuss various aspects of the program and test results: Dr. J. Choromokos, Jr., Director of Research and Development, OCE; BG C. Edgar, Deputy Director of Civil Works, OCE; J. J. Robertson, R. L. Kinsel, S. B. Powell, R. Malm, T. Munsey, and W. E. Roper, OCE; and numerous other representatives from Corps of Engineer Districts; universities; Federal, State, and local governments; pump manufacturers; and from the countries of Egypt, France, Pakistan, Colombia, Sweden, Taiwan, Philippines, Israel, Federal Republic of Germany, People's Republic of China, Canada, Korea, Portugal, and Italy.

COL Dwayne G. Lee, CE, is the Commander and Director of WES. Dr. Robert W. Whalin is the Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENTS

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
degrees (angle)	0.01745329	radians
Fahreheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
foot-pounds (force)	1.355818	metre-newtons
gallons (US liquid)	3.785412	cubic decimetres
horsepower (550 foot-pounds (force) per second)	745.6999	watts
inches	2.54	centimetres
pounds (force) per foot	14.5939	newtons per metre
pounds (force) per square inch	6.894757	kilopascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds-square feet (moment of inertia)	0.04214011	kilograms-square metre
square feet	0.09290304	square metres
square inches	6.4516	square centimetres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9) (F - 32). To obtain Kelvin (K) readings, use: K = (5/9)(F - 32) + 273.15.

PUMPING STATION INFLOW--DISCHARGE HYDRAULICS

GENERALIZED PUMP SUMP RESEARCH STUDY

PART I: INTRODUCTION

Need for Research

1. This research was initiated due to the absence of adequate design criteria for sumps and sump approaches for flood-control pumping stations that are required to operate at low submergences. An investigation conducted by the US Army Corps of Engineers (Fletcher 1979) revealed that approximately 50 percent of all sumps for flood-control pumping stations designed and constructed by the Corps needed some sort of postconstruction modification to improve the flow conditions to the pumps. These modifications were costly and in most cases did not correct the problem but improved the conditions only slightly. For the Corps to continue to design sumps without improving them in any way was unthinkable. Consequently, this research program was initiated to provide the information needed to permit the Corps to design pumping stations that would be acceptable not only from a hydraulic standpoint but also from an operational and maintenance standpoint.

Purpose and Scope of Sump Research Study

2. The purpose of this research was to develop the criteria needed to design the approach conditions and sumps for small flood-control pumping stations with some degree of assurance that they will be trouble-free. Because site-specific model studies are costly, they are generally recommended only for pumping stations with capacities larger than 200 cfs* or those stations having a sump with a unique design. This study pertains to generalized pumping stations with smaller discharges (less than 200 cfs). A microcomputer system and appropriate software were developed to enhance the depth and accuracy of the study. Evaluation techniques were developed to compare the

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* A table of factors for converting non-SI units of measurement to SI (metric) units is found on page 4.

many variations of sumps tested. Some of these variations included pump intake location, surface vortex suppressor beams, vertical drops in the approach, and other appurtenances.

PART II: TEST FACILITY

3. The planned test program required an experimental facility sufficiently flexible to handle inflow from simulated channels, ponding areas, and conduits. To satisfy this need the test facility shown in Figure 1 was constructed.

Flume

4. The 45-ft-long, 35-ft-wide, and 4-ft-deep flume (Figure 1a) is raised 3.8 ft above the floor to facilitate observation and general working conditions and to reduce the minimum head against which the pumps must operate. A weir is constructed across the upstream end of the flume to provide evenly distributed flow from the return flow pumps. An 8-in. rock baffle wall is also constructed across the flume just 3.5 ft downstream from the weir to further baffle the return flow pumped from the rear reservoir. The flume itself is constructed of wood and leveled on steel support structures. The wooden construction facilitates approach flow and sump geometry modifications.

Rear Reservoir

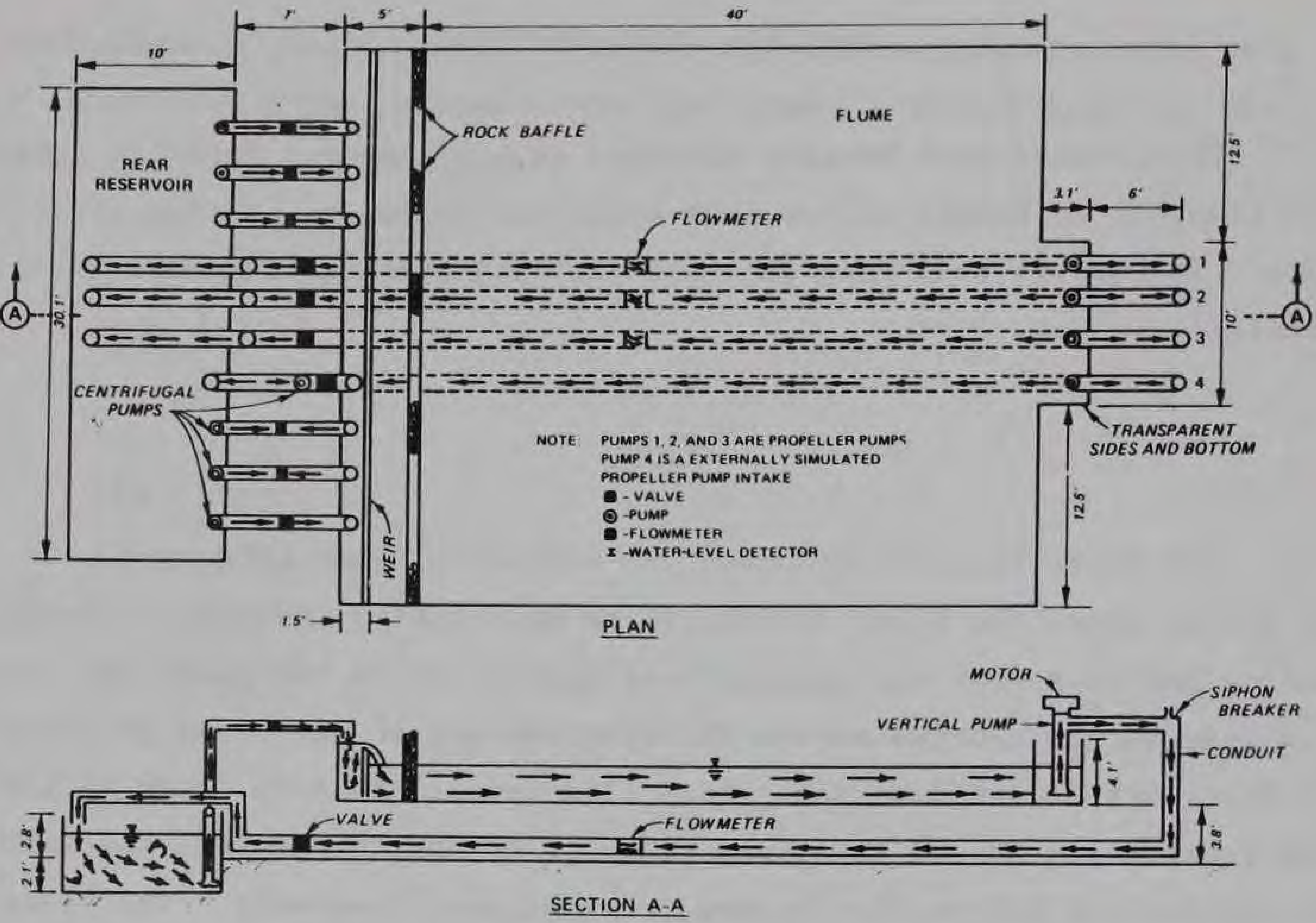
5. The 30.1-ft by 10-ft by 4.9-ft-deep (Figures 1a and 1d) rear reservoir is partly recessed into the ground so that the water-surface level is below the pump bell intake plane. This allows pumping against a static head as low as -1.65 ft (total head of 5.68 ft).

Sump

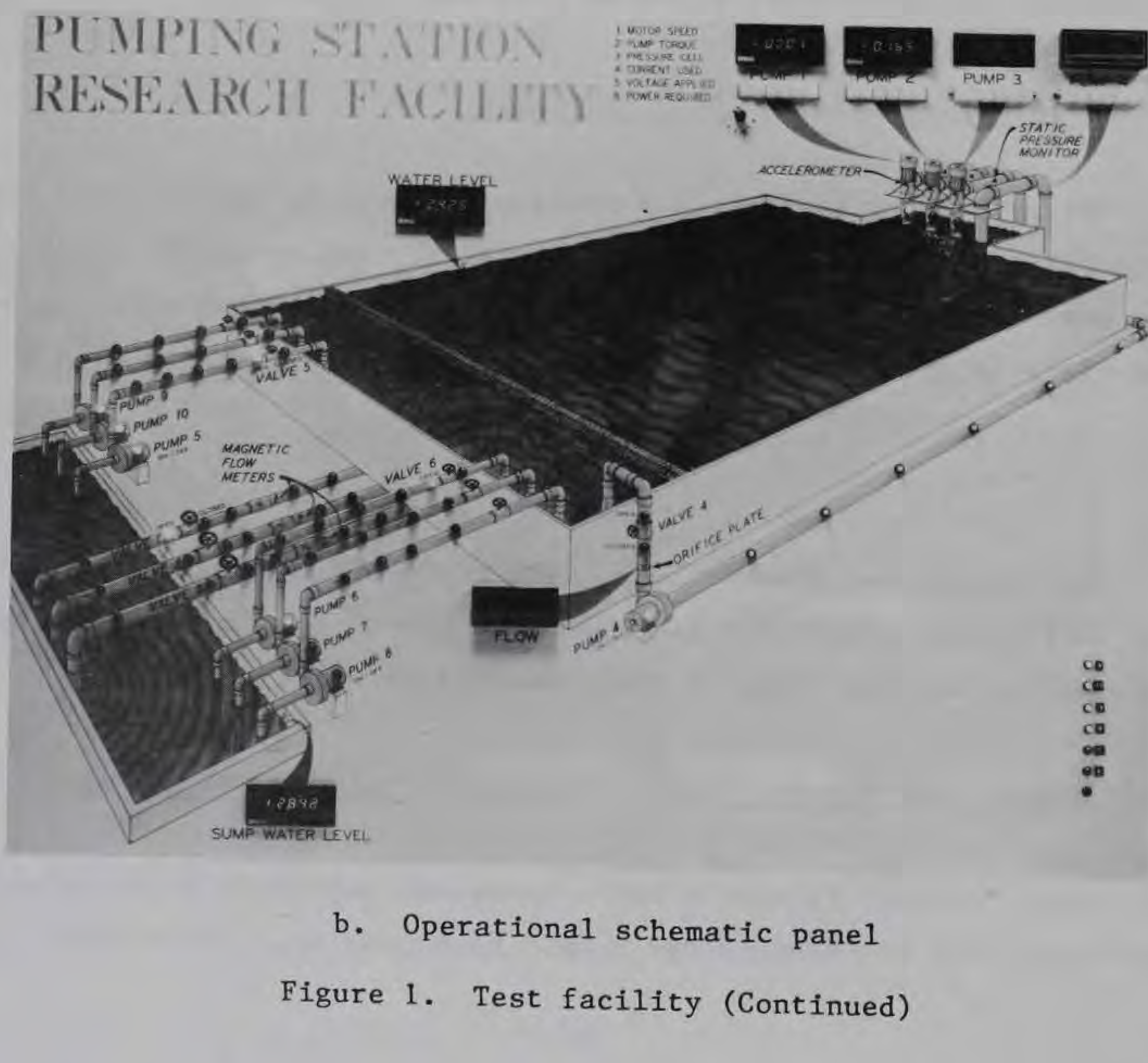
6. The transparent plastic sump, located in the downstream end of the flume, is 10 ft wide, offset 3.1 ft beyond the end of the flume, and symmetrically located between the sides of the flume (Figure 1a).

Pumps, Pump Motors, Support Structure, Valves, and Piping

7. Three vertical Fairbanks Morse pumps are supported by an independent steel structure over the transparent sump. Each pump is a 10-in.-diam,



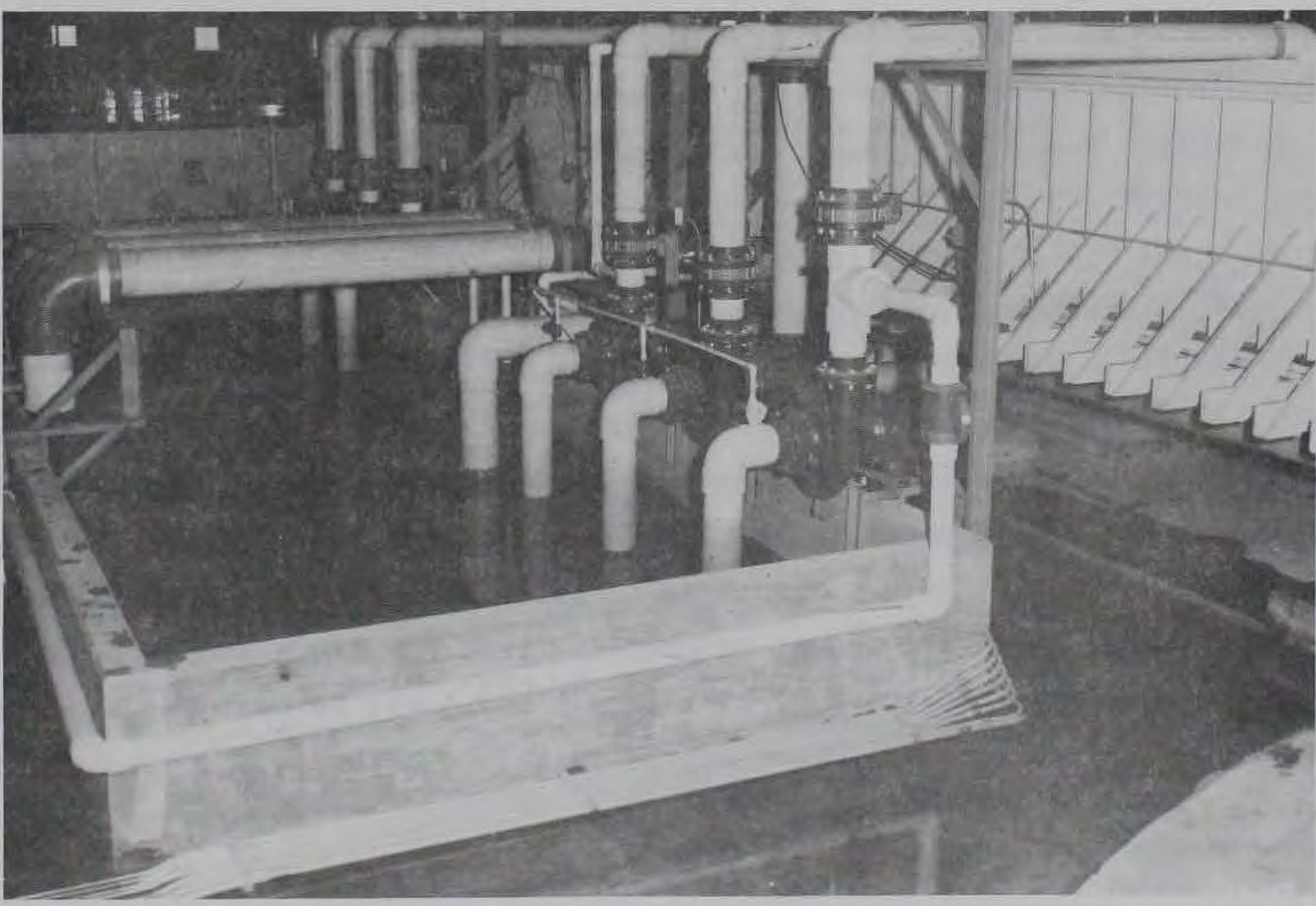
a. Plan and profile



b. Operational schematic panel

Figure 1. Test facility (Continued)

c. Instrument room, primary pumps, and flume



d. Rear sump and recirculating pumps

Figure 1. (Concluded)

single-stage, mixed-flow pump with a maximum discharge capacity of approximately 2,800 gpm at zero static head. Each pump is model 8312 equipped with the B1432T propeller and operates at 1,770 rpm (Figure 2). The steel structure for the pumps and motors is separate from the flume structure in order to minimize the transfer of vibrations from the motors and pumps to the flume. Each of the three Fairbanks Morse pumps is driven by a 15-hp, 460-v, three-phase, 60-Hz, 1,750 rpm motor manufactured by US Electrical Motors. The three Fairbanks Morse pumps are numbered from left to right (1, 2, 3) looking downstream (Figure 1a).

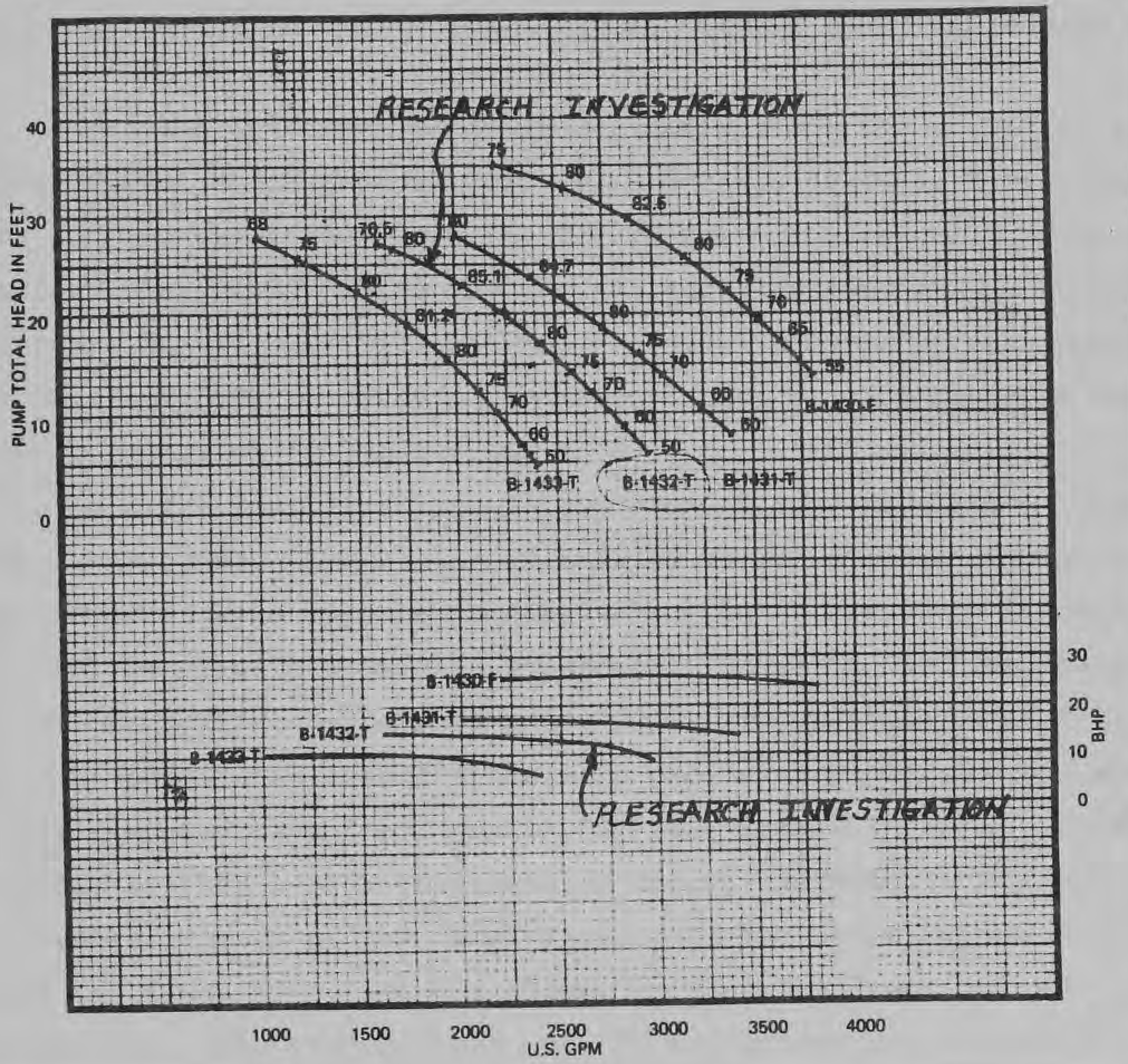
8. Pump 4 has a transparent suction bell and several feet of transparent intake piping. The suction bell is located just to the right of pump 3 (Figure 1a) and is connected to a centrifugal, Jacuzzi pump model 40F118T/E driven by a Gould Centry, 40-hp motor, model G 323058-1, 1,765 rpm, 60 Hz, 230/460 v located on the floor at the opposite end of the flume (Figure 1b). An overhead crane is available to reposition pumps 1-4 within the sump area (up, down, backward, forward, and sideward). Manual gate valves are installed in the conduit downstream from pump 4 to allow recirculation of water from the rear reservoir or the flume. The capacity of pump 4 is approximately 2,000 gpm.

9. Pumps numbered 5-10 are used to recirculate water from the rear reservoir to the flume (Figure 1b). These pumps are Jacuzzi centrifugals, model 15 EM 5-T/E. Pumps 5, 9, and 10 are driven by 15-hp Gould Centry motors, model 6-321227-03, 230/460 v; pumps 6, 7, and 8 are driven by US Electrical Motors model 254 JD (A-1), 15 hp, 1,755 rpm.

10. Keystone motor-driven valves, model 770-600, have been installed in the piping from pumps 1, 2, 3, 5, and 6 (Figure 1b). All of these valves are activated from the control panel. The valves allow the head and discharge on each pump to be varied. The valves in the piping from pumps 3 and 5 allow a portion of the pumped water to be returned to the rear reservoir without shutting off any pumps. The net result is to allow flow from the rear reservoir to the flume to be exactly equal to the flow from the flume (pumps 1, 2, 3, or 4) to the reservoir. Adjustment of valves 5 and 6 may be operated manually or automatically from the instrument control panel to maintain a constant water-surface elevation in the flume.

8000 PROPELLER PUMPS
PUMP PERFORMANCE

1800 RPM - 1 - 1
8312



10"
8312

1770
RPM

1
STAGE

10"
COLUMN

10"
CAST IRON
ELBOW

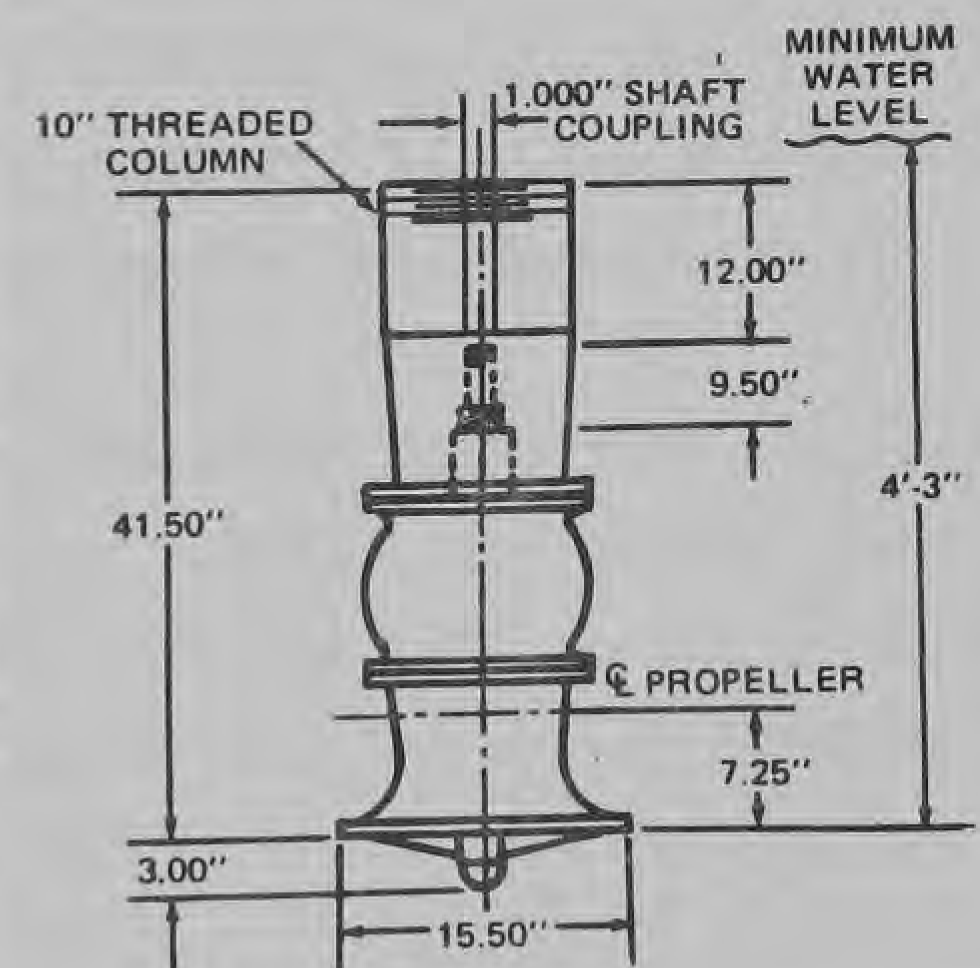
1"
LINESHAFT

1-1/2"
ENCLOSING
TUBE

DATA	VALUE
PUMP SHAFT DIAMETER	1.1875 IN.
MAXIMUM SPHERE SIZE	1.5 IN.
K_t (THRUST FACTOR)	20 LBS./FT.
K_a (TOTAL ROTOR WEIGHT)	17 LBS.
K_s (SETTING CONSTANT)	2.8 LBS./FT.
WK^2 (MOMENT)^2	1.1 LBS.-FT.^{2}
BOWL ASSEMBLY WEIGHT	265 LBS.
EYE AREA: PROPELLER NO. B-1430-F	41.0 SQ. IN.
PROPELLER NO. B-1431-T	41.0 SQ. IN.
PROPELLER NO. B-1432-T	41.0 SQ. IN.
PROPELLER NO. B-1433-T	41.0 SQ. IN.
PROPELLER NO.	
PROPELLER NO.	

HYDRAULIC PERFORMANCE IS CONTINGENT ON FURNISHING THE PUMP WITH SPECIFIED AMOUNT OF CLEAR, FRESH, NON-AERATED WATER NOT TO EXCEED 85° F.

PUMP PERFORMANCE SHOWN IS BOWL ASSEMBLY WITH 10 FEET OF COLUMN INCLUDING A STANDARD ABOVE GROUND DISCHARGE ELBOW. ADDITIONAL COLUMN LOSSES SHOULD BE ADDED WHEN SETTINGS ARE DEEPER THAN 10 FEET AND/OR FOR OTHER DISCHARGE ARRANGEMENTS.



FAIRBANKS MORSE PUMPS

Figure 2. Pump characteristics as furnished by Fairbanks Morse

11. Pumps 1, 2, and 3 use 10-in. polyvinyl chloride (PVC)* piping. All return flow pumps (5-10) use 6-in. PVC piping. Pump 4, the suction pump, has a transparent suction bell and 2 ft of 10-in. conduit; the remainder is 8-in. PVC pipe.

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* For convenience, symbols and abbreviations are listed in the Notation (Appendix A).

PART III: DATA ACQUISITION, ANALYSIS, AND RECORDING SYSTEM

Pressure Transducers and Sensors

12. All instrumentation except the sensors is located in an environmentally controlled room located near the pump test facility (Figure 1c). The room and entire facility are located in the north end of a large metal building (Building 3100) within the Hydraulics Laboratory at the US Army Engineer Waterways Experiment Station (WES). A block diagram of the instrumentation system, including sensors, is shown in Figure 3. Locations of some of the sensors are shown in Figures 1a and 4.

13. The pump discharge is measured in a 10-in. Foxboro Magnetic Flow Tube, model 2800. The signal is relayed to the digital display panel and the microcomputer by a Foxboro Magnetic Flowmeter Transmitter model 696A. Periodic calibrations are made to the Foxboro magnetic flow measuring system by use of the Foxboro calibrator model 8120. In addition, volumetric verifications of the system accuracy are made periodically by timing a measured volume of water pumped from the flume to the rear reservoir. The reliability and accuracy of this system have been repeatedly verified. The magnetic flow tube is located in each of the three pipes from the three Fairbanks Morse pumps under the flume approximately midway between the pumps and the rear reservoir (Figure 1a). The transmitters and the calibrator are located in the instrument room behind the instrument control panel.

14. The torque transducer (Lebow model 1114-1K) and the tachometer pickup are both located on the pump propeller shaft 0.8 ft below the pump motor. A digital reading of each is displayed at the instrument control panel.

15. Noise is measured by a microphone, B&K model 4125, with a preamplifier B&K model 2642 using a B&K model 2810 power supply. The microphone is located 0.8 ft from the pump column and 3.4 ft from the bell intake of each of the Fairbanks Morse pumps (see "Acoustic," Figure 4). The noise signal is transmitted to the microcomputer through the WES amplifier and calibration network.

16. Pump vibration is measured in the longitudinal plane by use of a velocity transducer, Vibrometrics model 124. The transducer is attached to the pump column (Figure 4). The signal is relayed to the microcomputer

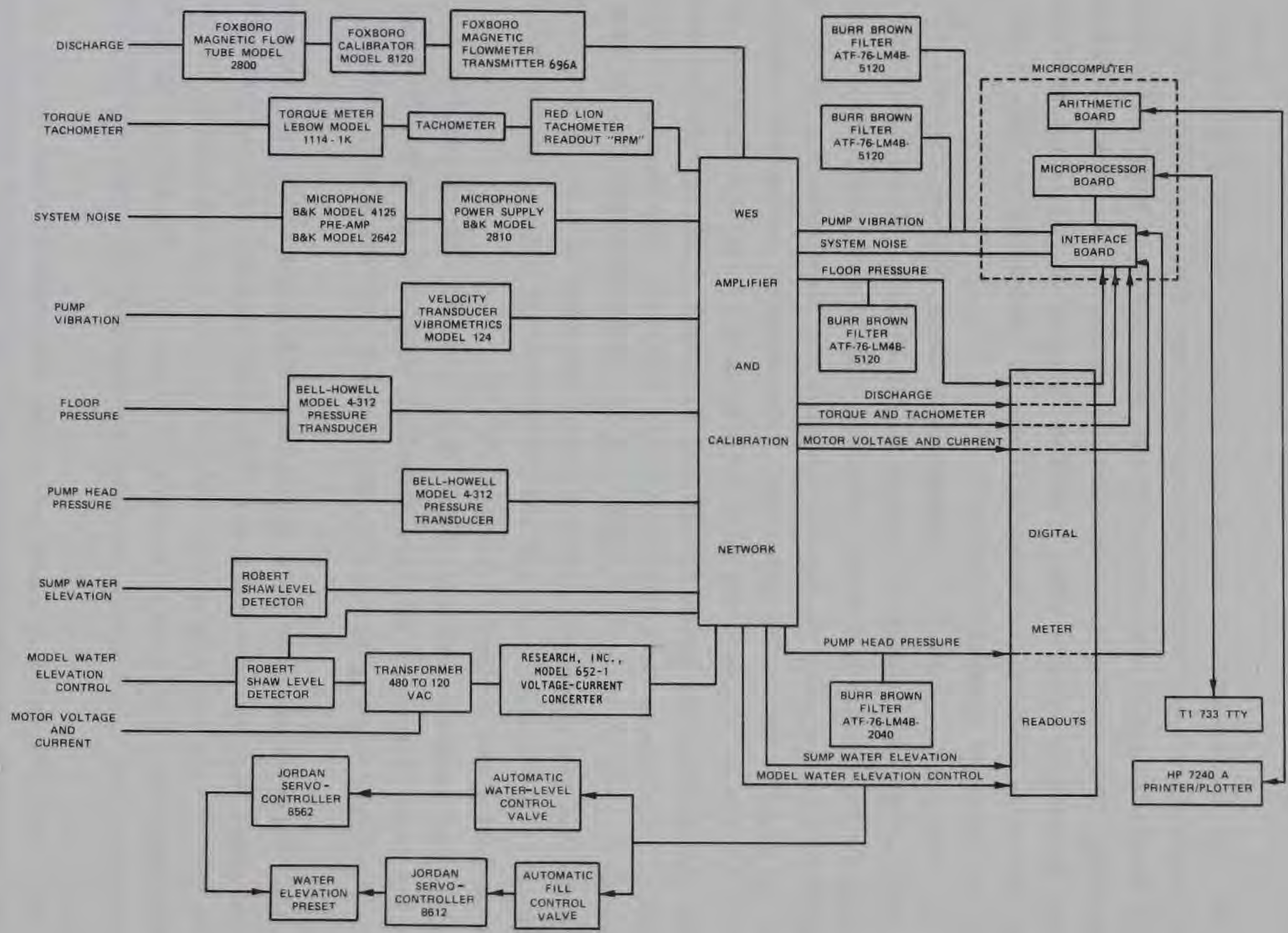


Figure 3. Instrumentation block diagram, pump sump research facility

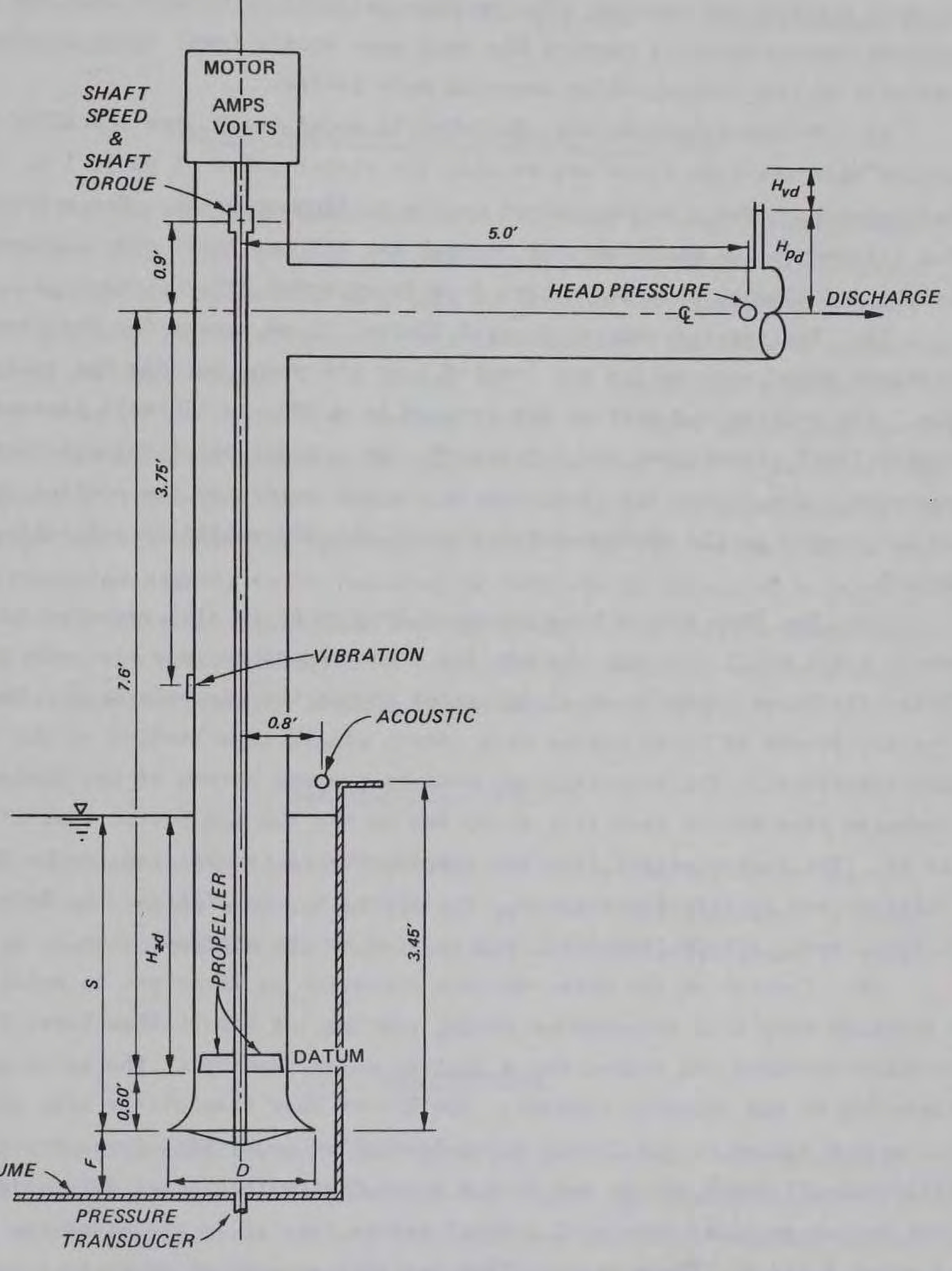


Figure 4. Propeller pump sensor locations

through the WES amplifier and calibration network. In earlier research, vibration was measured in the transverse direction also. The values were so nearly the same that the transverse direction of vibration was eliminated from the data acquisition process. The maximum velocity is plotted with the performance characteristics curves; the root mean square (rms) value is also available in the corresponding research data tables.

17. Pressure transducers, Bell-Howell model 4-312, are installed flush-mounted with the sump floor and beneath the center point of pumps 1-4. A digital meter provides a value readout on the instrument panel. The signal is also relayed to the microcomputer through the WES amplifier and calibration network and through a noise filter, Burr Brown model ATF-76-LM4B-5120.

18. Voltage and current General Electric gage meters for the three Fairbanks Morse pump motors are located near the pumps outside the equipment room. The voltage and current are reduced by a 480- to 120-volt alternating current (VAC) transformer and a Research, Inc., model 652-1 voltage-current converter. The values are displayed by digital meters on the control panel and are routed to the microcomputer through the WES amplifier and calibration network.

19. The pump static head pressure (Figure 4) is also measured by Bell-Howell model 4-312 pressure transducers. Four pressure taps are made in the 10-in. discharge pipes at equal distances around the circumference. The four taps are joined by Tygon tubing to a common single tube leading to the pressure transducer. The four taps are made at top and bottom of the horizontal discharge pipe and on each side at 90 deg to the top and bottom taps (Figure 4). The analog signal from the transducers is transmitted to the WES amplifier and calibration network. The signal is then filtered by Burr Brown Filters, model ATF-76-LM4B-2040, and relayed to the microcomputer.

20. Control of the water-surface elevation is important in maintaining a constant pump bell submergence during testing. A Robert Shaw Water Level Detector provides the signal for a digital meter reading of the water-surface elevation to the operator console. The Robert Shaw transmitter also provides the analog signal to the Jordan Servo-Controller model 8612 for automatic fill/shut-off valve and to two Jordan Servo-Controllers model 8562 which control two automatic water-level control valves located in the discharge lines of pumps 5 and 6. These valves allow variable amounts of water to be recirculated back to the rear reservoir when the flume water level rises above the

preset level. The water level preset dial relay allows the operator to select the desired surface water level for constant submergence operation or for automatic filling of the flume when an attendant is not available to observe filling progress and to close the water fill line when the desired water depth has been obtained.

The WES Amplifier and Calibration Network

21. The WES amplifier and calibration network is composed of printed circuit boards (PCB) that contain the amplifiers, potentiometers, switches, and other electronic components necessary to receive the transducer signals and condition them for reception by the microcomputer. The balance potentiometers allow residual signals to be zeroed out. The amplifiers provide the necessary boost in the signals to desired levels to be used as scaling factors to convert to equivalent engineering units. The method used to calibrate the linear gages provides for three input voltage levels to the microcomputer that relate gage voltage output to engineering units. The PCB switches allow the actual transducer signals to be replaced by calibration reference voltage levels or calibration step (amplified) voltage levels. The third voltage level is zero, i.e., the actual readings of the gages are observed and balancing potentiometers allow residual signals to be adjusted to zero.

System Power Supplies

22. Various voltage levels are required for operation of the microcomputer. Power supply modules and 110 VAC provide these voltages. A block diagram of these values and how they interface with other equipment is shown in Figure 5.

The Microcomputer

23. The microcomputer contains three primary boards: microprocessor, interface, and arithmetic. The microcomputer system along with the computer terminal and printer/plotter allowed data analysis and report-quality graphs and tables to be produced without any help from a mainframe computer or plotter. Prior to this system, the analog data were recorded on magnetic tape

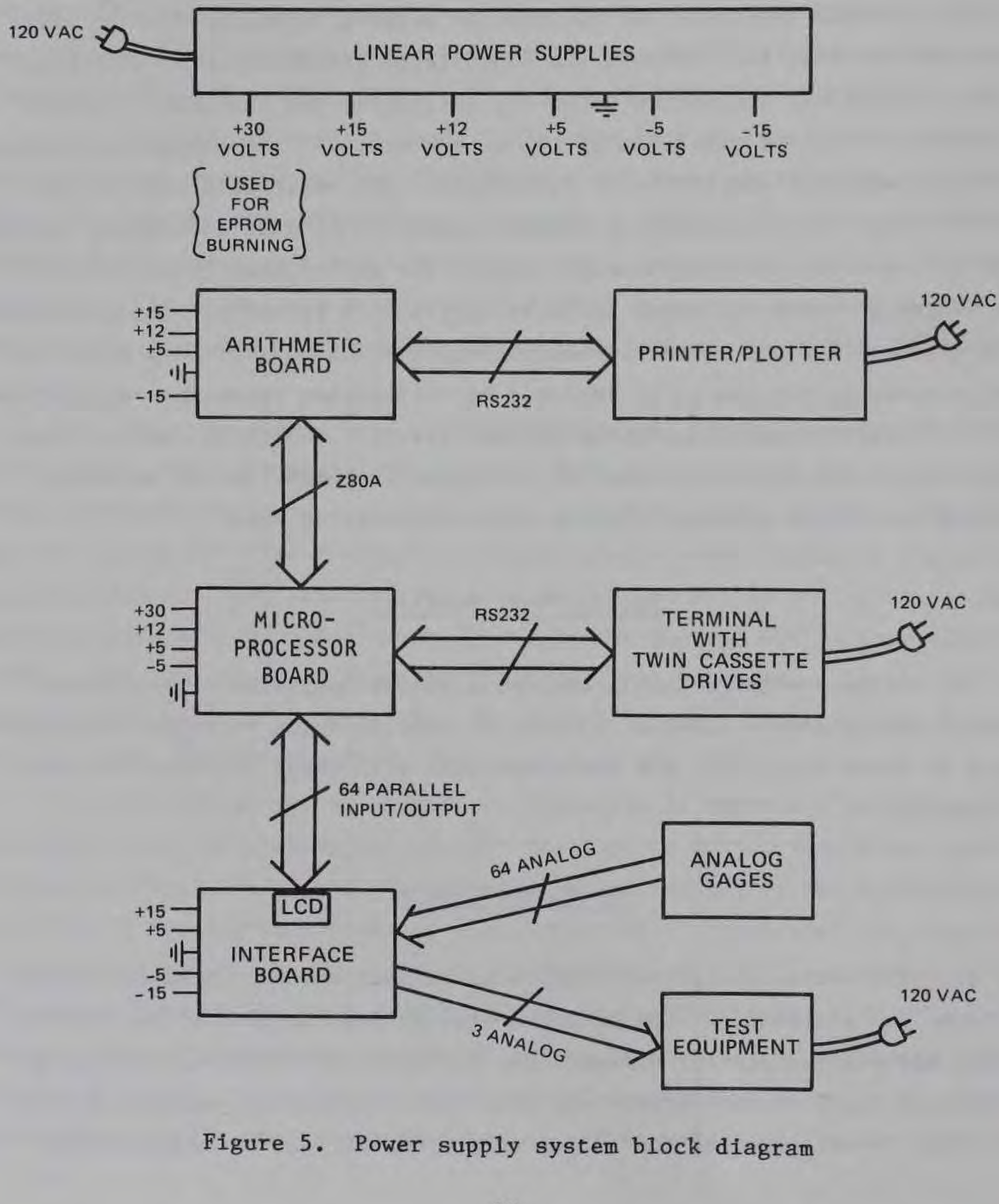


Figure 5. Power supply system block diagram

during testing. The tape recorder used a frequency modification recording technique that gave good linearity from direct voltage to frequencies in the tens of kilohertz. The analog data were "digitized" (converted from analog to digital format) and recorded on digital magnetic tape. The digital magnetic tape provided to the mainframe computer allowed subsequent tables and graphs to be obtained. This system had problems in time scheduling for the data reduction equipment and personnel. The accuracy of the system was also marginal. The analog tape recorders can frequently have problems with bias noise of 25 to 40 mv (with a maximum range of 4 v). The new system using direct digital acquisition devices (analog to digital conversion) has low inherent noise (less than the least significant bit value--2.5 mv for a 10-v, 12-bit range). The temperature and time stability are several orders of magnitude better with the direct digital acquisition devices. Data acquired digitally on site by the 12-bit system are therefore significantly more accurate than the previously used analog recording method. The new system also operates more proficiently and more expediently because the project engineer is able to observe the data during testing time. Problem areas can be identified and corrected without expending long hours of testing and data reduction before the data can be examined.

The microprocessor board

24. The microprocessor board is the heart of the microcomputer. This board, model MPS 94-1, is a commercially available board made by Quay Corporation of Freehold, New Jersey. The board, shown in Figure 6, measures 8 by 16 in. The model MPS 94-1 board consists of a Z80A microprocessor, 66,560 bytes of random access memory (RAM), 14,336 bytes of erasable-programmable-read-only memory (EPROM), 64 bidirectional parallel input/output (I/O) lines, 4 timers, 1 asynchronous communications port, and an onboard EPROM programmer. The Z80A is operated at a clock frequency of 4 MHz. The address lines are buffered by 74LS367 buffers that are tristated during direct memory access (DMA) operations. All data lines have bidirectional buffering using 74LS367 buffers. Control logic allows read-and-write operations, tristate DMA operation, and read-on vectored interrupt operation (mode 2). Z80A interrupt mode 2 requires that the interrupting device place the lower 8 bits of the interrupt vector address on the data lines when the Z80A central processing unit (CPU) issues I/O requests during the first memory cycle (MI). There are two clock circuits of the basic linear type oscillator onboard. One runs at

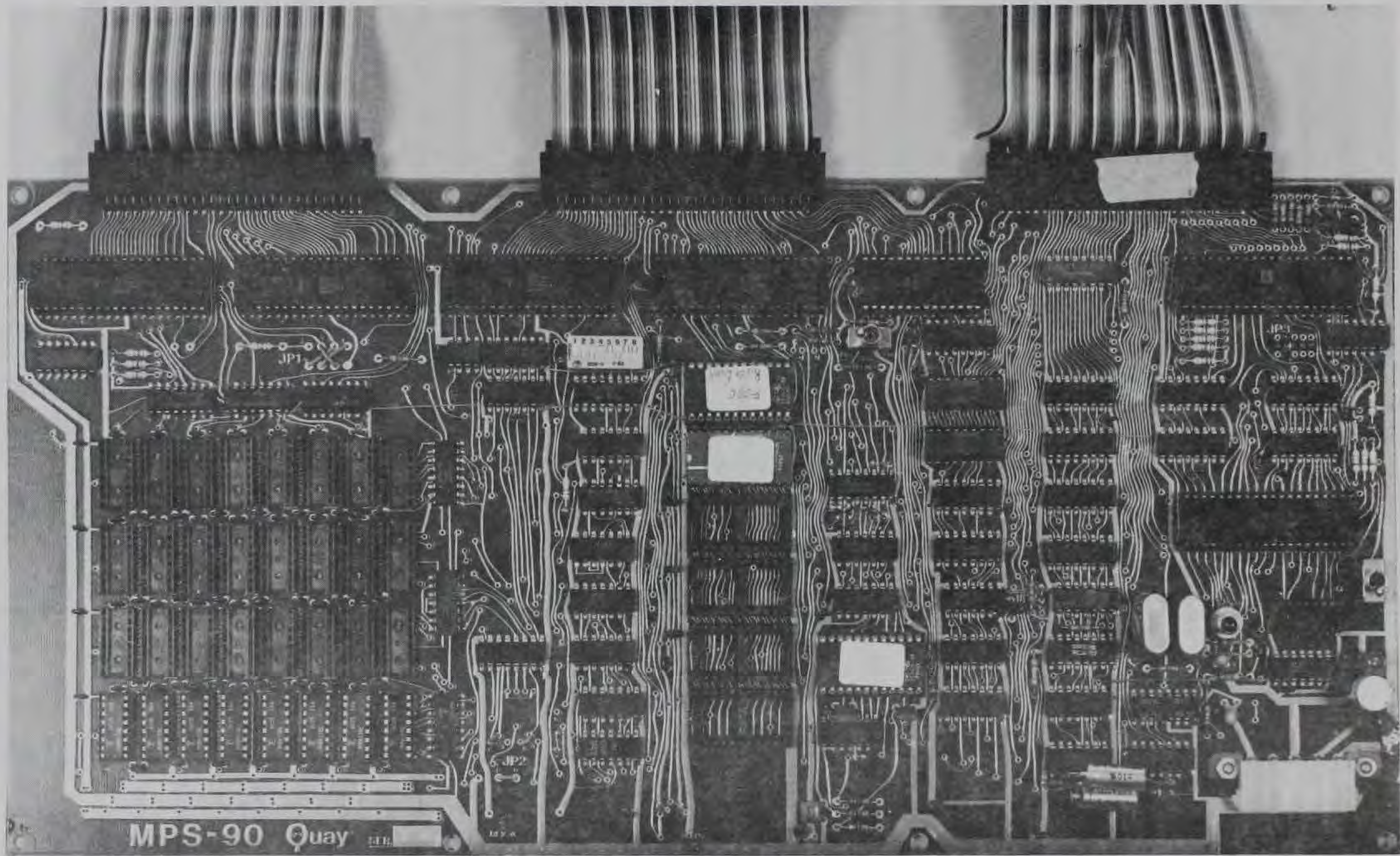


Figure 6. Microprocessor

2.4567 MHz and is used by the baud rate generator circuitry for the universal asynchronous receiver transmitter (UART). The other runs at 4 MHz and feeds all the circuitry except the UART. The board is automatically reset on power-up by resistor/capacitor delay circuit feeding a series of gates that square up the pulse produced. The 3-sec delay allows the power supplies to stabilize before reset is issued. A manual reset button is also incorporated. The board contains circuitry to allow instructions to be single-stepped, to allow break and snap (dynamic break) points, and to allow dumping of CPU registers. Sockets are provided for all memory chips so that the power consumption can be limited by removing any unneeded chips. The board uses 60-pin bulkhead connectors to greatly increase system reliability over the more common edge-connector configurations.

The interface board

25. The interface board (Figure 7) was designed to provide the interface between the Quay microprocessor board and the rest of the system which consists of (a) analog input, (b) analog output, (c) operator switches, (d) liquid crystal diode (LCD) display, and (e) digital cassette recorder. The interface board's dimensions are the same as those of the microprocessor board (8 by 16 in.). Diagrams are available for the overall circuitry for implementation of the board. The board has three analog outputs. These outputs can also be used to drive strip chart recorder traces for run-time display of selected input channels. Reliability was of major concern in the design of the interface board. Since edge connectors are a common cause of system failure (due to corrosion), gold-plated bulkhead connectors (of the same type used on the microprocessor board) were selected for system interconnection. Ribbon cables with insulation displacement-type connectors were chosen for most of the system's wiring to reduce assembly costs and to eliminate the possibility of connector solder joint failure. To further improve reliability, large-scale integrated circuits were selected whenever possible to reduce the number of component connections (common failure points). A large ground plane and heavy power lines were "printed" on a double-sided plated-through card, and gold-plated turret-type wire-wrap sockets were used to increase reliability, reduce system noise, and allow ease of servicing and modification. The channel address of the analog-to-digital converter (ADC) circuit is output by the Z80A. The lower 3 bits go through a 7442 demultiplexer (Z28) and a 7404 inverter (Z27 and Z31) to enable one of the eight

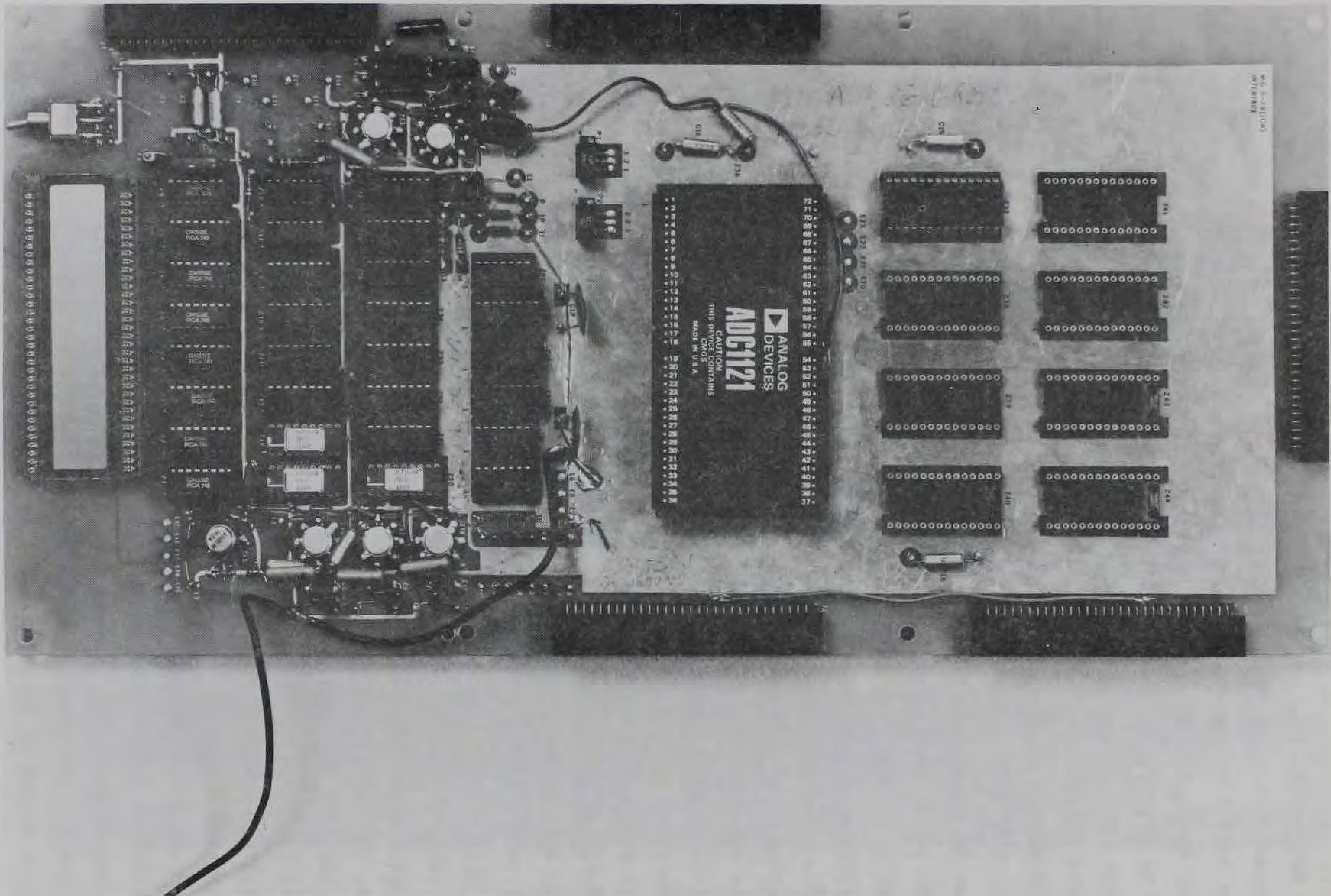


Figure 7. Interface board

AD7507's. The AD7507 is an 8-channel dual input complementary metal oxide semiconducter (CMOS) analog switch network with differential outputs (Sheingold 1972). The switches have internal Transistor/Transistor Logic (TTL) to CMOS converter/demultiplexers/drivers and an enable input. The CMOS switches are followed by a differential amplifier circuit. The operational amplifier, AD509 (Z33) with 40-kohm resistors, performs the differential to single-ended conversion. The system uses an ADC 1102 converter that is operated at 15 v and takes 8 μsec with the input range set to be ±10 v. The ports are connected to Z80A-PIO chips through tristate buffers so that the ADC outputs can share the same ports as the digital-to-analog converter (DAC or D/A) inputs. Capacitors are installed across the strobe inputs to the DAC latches to prevent glitches from causing their outputs to change. Each DAC has 12 type 74174 latches (Z21-Z26) between the Z80A-PIO outputs and its inputs. The strobe latches the inputs to the DAC (causing the DAC to behave as a zero-order hold device). The AD7541 DAC's (Z18-Z20) are CMOS ladder networks that multiply a ±10-v reference (provided by an AD581-Z45) times a divider network. A Schottky diode is tied to the outputs of the DAC's to prevent operational amplifier reverse spikes from damaging the DAC's. The interface board also contains circuitry to support time-of-day display and initialization.

The arithmetic board

26. The arithmetic board (Figure 8) is a standard 8080 Intellect system board (pin interconnecting wiring) made by Advanced Microcomputers model AMC 95/6011 (Advanced Micro Computers 1978). The main component is the Advanced Micro Devices 9611A floating-point chip. The 9611A is actually a special-purpose 16-bit microprocessor that does most common mathematical operations (such as addition, division, logarithms, exponentials, powers, and trigonometric). It handles three standard formats: 16-bit fixed, 32-bit fixed, and 32-bit floating point. The board also contains the bus receiver and driver, clock divider, and address decoding circuitry. Since the board was specifically designed to interface with a different system, several modifications were made on the board. The Z80A handshake lines vary slightly from the 8080 lines so some gating modifications were made to produce the 8080 IOREAD and IOWRITE from the Z80A MEMORY/IO and READ/WRITE lines. Several noise problems were discovered with the board inputs so pull-up resistors were added on the clock and address input lines on the board. Also the 7407 clock input receiver was replaced with a 7414 to square up the clock via

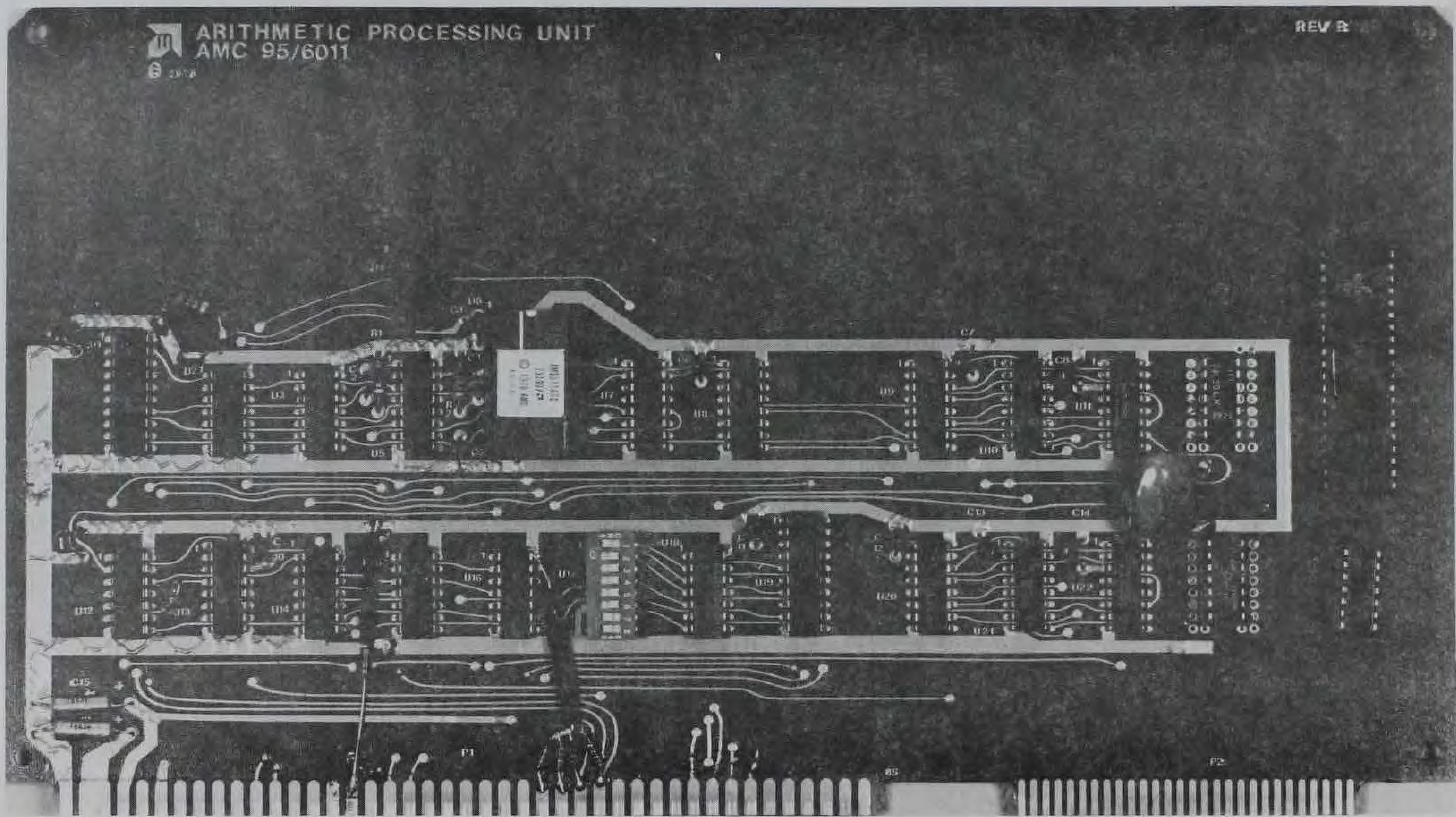


Figure 8. The arithmetic board

Schmitt-triggers. The divide-by-5 counter chip was modified to give divide-by-2 so that the 4-MHz Z80A clock could be halved for use with the 2-MHz 9511A chip. The board was designed to interface directly on the microprocessor bus as I/O ports.

Computer Terminal

27. The Texas Instrument Silent 700, model 733 ASR/KSR, electronic data terminal is used as the system keyboard and data storage device. The operator may enter information from either keyboard or cassette. Test parameters may be entered from one drive and data may be written to the other drive in a time-interleaved manner. The terminal also provides hard copy via a 5-by-7 dot matrix, 80-column thermal printer. The terminal is driven at 1,200 bits per second (120 characters per second) via a serial Electronic Industries Association (EIA) RS232 port on the microprocessor board. The cassettes and keyboard can operate at 120 characters per second, but the printer can be driven at only 30 characters per second and must receive special treatment (discussed under software).

Printer/Plotter

28. The Hewlett Packard Model 7240A printer/plotter is interfaced through an addition to the arithmetic board. An INS*250 UART[10] provides serial TTL input/output, with TTL to EIA level conversion performed by one DS1489 (EIA to TTL) and one DS1488 (TTL to EIA). Existing spare gates on the board are used for address decoding. The 2-MHz clock on the board is input to the UART which is software programmable by means of internal 16-bit counter/divider circuitry to give a variable number of baud rates. The highest rate at which the printer/plotter can accept characters (2400 baud) is used. The printer/plotter combines a dot matrix thermal printer with a vector-type plotter. The dot matrix characters may be printed in any of four directions (the paper may move up or down and the print head left or right). The plot width is limited to 10.2 in. and the length to 16.5 ft. The plotter portion has many built-in functions, which are normally done in the computer software with a Calcomp type package. These include (a) software character generation with continuously selectable size, rotation, and slant; (b) vector commands;

(c) plot and rotate commands; (d) axis generate and label commands with tick marks; and (e) circle and arc commands. The rotate and scale commands, for example, were used to scale and position the Corps of Engineers castle insignia shown on all curve-plotted sheets in this report.

Intelligent Buffer

29. The Angel intelligent buffer accumulates data from the computer, stores it, and relays it to the printer/plotter at a speed it can accept. This allows the computer to continue with other operations without waiting for the printer.

Reference Comprehensive Description

30. A more comprehensive description of the data acquisition, analysis, and recording equipment is contained in a separate report (McCleave 1984).

PART IV: COMPUTER PROGRAMS

31. The computer software is designed to interact with the user in a conversational manner. The user is instructed as to which cassettes to install and the appropriate time to install them. The user is asked if he wants to input the gage description and test conditions from keyboard or cassette and is also asked to input time and date and sequence of calibration. The option is also given to use calibration step values for scaling. A subsequent opportunity is given to input new engineering values or make corrections. After each of the calibration readings is taken, the analog signal values are printed in volts. The user can verify the validity of these values. After each reading (calibration or data), the user is given the option of printing the engineering units for each gage. The user also has the option after checking the data to put it on the test cassette tape or make corrections and take a new reading. An additional option available is the amount of data to print for review: all, overall, or selected. When the "all" option is requested, the terminal prints out the results of analyses of the data in memory to determine rms, standard deviation, and mean maximum and minimum values for each variable and each pump that is operating. When the "overall" is asked for, the terminal prints out the results of the analyses to determine rms for the noise, the maximum value for velocity (vibration), and the mean value for the remainder of the variables pertinent to each pump operating. For "selected," specific values of each variable may be listed.

Header or Identification Information

32. Basic information that determines options throughout the data acquisition, plotting, and recording process is entered on the data cassette in a prescribed format. This basic information is referred to as identification (ID) or header information (Figure 9). The first line contains the title. The computer obtains the title for all subsequent graphs and tables from this location. Also on the first line and near the right margin are two numbers that indicate the number of gages and the sampling rate. In the sample shown in Figure 9, there are eight gages and the data are randomly sampled 500 times for each of five data values in each category (rms, standard deviation, mean, maximum, and minimum) for each gage (Figure 10). The sixth data

```
Pump Sump Research Station                                                                  8      500
Discharge Flow-1        1     1GPM       4    31Torque     Torq-1    1   1In-Lb    5       31
Voltage  E-1            1     1Volts     6    31Current    I-1       1   1Amps     7       31
Velocity V-1            1     1IPS       8    31Noise-1    Mike-1    1   1PSI      9       31
Stat Head Stat-Hd-1     1     1Feet     10    31Floor Cell FC-1      1   1Feet    11       31
/* EOF
/* EOF
/* EOF
```

Figure 9. Sample header or ID information

RM	4.408E- 5	4.325E- 5	4.275E- 5	4.608E- 5	4.368E- 5	4.398E- 5
ST	4.405E- 5	4.323E- 5	4.274E- 5	4.607E- 5	4.368E- 5	4.398E- 5
ME	-1.563E- 6	1.456E- 6	7.357E- 7	5.375E- 7	-3.137E- 7	1.706E- 7
MA	1.236E- 4	1.254E- 4	1.309E- 4	1.493E- 4	1.162E- 4	1.493E- 4
MI	-1.506E- 4	-1.479E- 4	-1.433E- 4	-1.479E- 4	-1.405E- 4	-1.506E- 4

Figure 10. Sample raw data for noise

value in Figure 10 represents a composite of all 2,500 (5 × 500) random data samples for the pertinent category. The header information (Figure 9) also contains the name of each gage parameter, its engineering units, a designated serial number identification, and the gage number. These values are also taken from here when used in the graphs and tables. The user has the option of which data categories (rms, standard deviation, mean, maximum, or minimum) that he wants to record on tape. The user designates this by the quantity shown in the extreme right column. In Figure 9 this value is 31 indicating that all categories are to be recorded for each parameter. The last of the header information is "EOF" (end of file) statements to inform the computer that this is the end of the header information.

33. The software programs contain more than 8,000 lines of code. A more comprehensive description of the software along with program listings are contained in a separate report (McCleave 1984). Many of the subroutines are general and are used in most of the application programs. Only the more important subroutines will be discussed in this report.

Time and Date

34. Time-of-day is kept in the software of the Z80A microprocessor based on interrupts at a fixed interval from the Z80A clock-timer chip (CTC). The chip contains four timers; time 1 (clock 0) is used for time-of-day

interrupts. The time is displayed as day/hour/minute on an LCD display driven by the Z80A and updated once per second. Time after power-up may be entered either from binary coded decimal (BCD) thumb-wheel switches or from keyboard. Years are not kept; however, Julian days are allowed to go from 0 to 999 (to allow tests to run into the next year, recycling to 0 after 999).

35. Handshaking occurs between the application program and the time-of-day routine to be sure the application program does not retrieve information during the updating of the software counters. To read, the time-of-day routine maintains a separate buffer from the applications program. If the application program has set a flag indicating it is reading the buffer, the time-of-day routine will not update the buffer. When the applications program finishes retrieving the time-of-day, it resets the flag and the buffer is once again kept current. The time and date are recorded on cassette each time a set of raw data is recorded.

Electronic Data Terminal and Cassette Driver

36. The primary operator interface is a data storage and data entry device, the Texas Instruments Silent 700 model 733ASR/KSR electronic data terminal. The routines, which communicate with the terminal, transfer variable length blocks of ASCII characters. The keyboard entry routine INBUF is used by INFLT2 and INBCD to get a block of characters representing a floating-point number or a fixed-point number, respectively. INBUF is also used for character entries of model parameters such as test name. The routine passes the length of the buffer and checks to see that too many characters are not entered. When the buffer is full, the routine issues a carriage return/line feed and terminates. If the operator wishes to delete all entries from the time the last carriage return was entered, he types a "rubout." If the routine detects a rubout, it reinitializes all parameters and issues a carriage return/line feed and beep. The operator may backspace by use of the "Control H" key. The routine backspaces two characters (the "Control H" and the previously entered character) each time "Control H" is entered, and outputs a carriage return/line feed and beep, and reinitializes the parameters. The number of characters entered is returned as a parameter in the IX register. The routine issues a beep upon entry to cue the operator that keyboard entry is required.

37. The Silent 733 also allows cassette input. The Z80A routine INCAS disables the keyboard, enables the cassette playback, and reads in a block of characters. The "Remote Device Controller" option allows the Z80A CPU to automatically select and control the printer, keyboard, cassette reader, and cassette recorder electronics. The routine accepts characters until an attempt to exceed the buffer length is made or a "Control S" character is sensed. The "Control S" character causes continuous playback to end. To begin reading a record (i.e., on entry), the routine issues a "Control R" character. Before terminating, the routine disables the cassette playback electronics and enables the keyboard.

38. When printing characters, the PRINT routine conforms to the peculiarities of the Silent 733. All data transfers are at 120 characters per second (1200 baud); however, the printer can print only 30 per second. So each printable character output is followed by output of three rubouts. Following the output of a carriage routine, a delay of about 0.2 sec is incorporated to allow the carriage to settle so that characters will not be missed. When a binary zero or carriage return character is detected in the input buffer, a carriage return/line feed is issued and the routine is terminated.

Calibration and Statistical Subroutines

39. The statistical subroutines deal with floating-point numbers and are quite lengthy and complex. Rather than a discussion of the actual implementation of the routines in detail, the formulas used are derived in mathematical terms. Since the calibration (cal) technique must be understood before the statistical formulas will be meaningful, the order of presentation is (a) calibration of gages, (b) statistical data acquisition, and (c) statistical data reduction.

Calibration of gages

40. The linear gages are calibrated to input three voltage levels that relate gage voltage outputs to engineering units. The first two levels, calibration reference (cal ref) and calibration step (cal step), usually are input reference voltages that replace the gage (via a switching network) as input to the microcomputer. The difference between these two voltages is equivalent to a given engineering value span and is used to obtain the slope term m in the linear equation of a line:

$$y = mx + b \tag{1}$$

where y is in engineering units, x is the A/D reading, and b is the y-intercept value.

$$m = \frac{\text{Cal Step Engineering}}{\text{Cal Step A/D Reading - Cal Ref A/D Reading}} \tag{2}$$

where m is the ratio of engineering to A/D reading units. The third voltage level is the output of the gage under no excitation. This value is usually equivalent to some known engineering value (normally zero). Another way of writing Equation 1 is

$$y = m(x - x_o) + y_o \tag{3}$$

where

y = unknown engineering value

x = acquired A/D value representing a data point

x_o = acquired gage output corresponding to a known engineering value $\left(\text{PRETEST}_{A/D}\right)$

y_o = known engineering value corresponding to an acquired gage output x_o $\left(\text{PRETEST}_{ENG}\right)$

All necessary information is therefore available to the microcomputer to compute the engineering value of any gage reading. The voltages all pass through the same electronic circuitry, so the computation technique is independent of any gains or offsets occurring in the ADC circuitry (as long as linearity is propagated throughout).

41. Unfortunately, some gages are known to give a certain engineering value at zero volts out, but do not return to a known state when unexcited. In these cases, the known point is used for x_o and y_o rather than the gage unexcited output. To accomplish this, the cal ref is forced to be ground and the cal ref is used as x_o. This assures that any offset in the ADC circuitry is not a factor. The disadvantage is that an offset in the gage circuitry prior to the cal/gage switch point becomes a source of error (so any amplifiers in the gage circuit must be accurately zeroed). For further discussion the three calibration voltage levels will be referred to as

(a) reference, (b) step, and (c) pretest. With some gages, pretest zero is ignored (computed for printout, however) and cal ref is used in its place in Equation 3. The slope m will be referred to as RATIO.

Statistical data acquisition

42. To reduce memory requirements, each individual data point is not saved. The sum, maximum, minimum, and sum of the squares of the n data points are saved for each gage. To save time and increase accuracy, these values are computed and saved in the 12-bit binary form as it is read from the ADC. The conversion to engineering units occurs after the data acquisition period but prior to printout or plotting. If the ratio of engineering values to A/D values is negative, the minimum A/D value is used to compute the maximum engineering value (conversely). The maximum and minimum values are obtained from one data point (rather than the average of several) and are converted by Equation 3. For future discussion, the sum of n data points will be referred to as SUM. The sum of the squares of n data points will be referred to as SUMSQ.

Statistical data reduction

43. The statistical values computed are rms, mean, and standard deviation (SD). These values are desired in engineering units. The values cannot be computed in A/D readings and then calibrated by Equation 3. The values should be converted to engineering units and then "plugged" into statistical equations. Unfortunately, the actual data have been lost and only overall values of SUM and SUMSQ are available in A/D units. These values are all that are needed if the equations are derived in terms of these values.

44. To compute the rms, begin with this equation (Bowker and Lieberman 1972):

$$\text{rms} = \left(\sum_{i=1}^{n} \frac{y_i^2}{n} \right)^{1/2} \tag{4}$$

where

$$y_i = m(x_i - x_o) + y_o$$

where

y_i = engineering units of the subsequent data value

x_i = corresponding A/D value

Substituting Equation 3 for y_i yields

$$\text{rms} = \left\{ \sum_{i=1}^{n} \left[\frac{(x_i - x_o)\, m + y_o}{n} \right]^2 \right\}^{1/2} \tag{5}$$

Squaring the substitution for y_i yields

$$\text{rms} = \left\{ \sum_{i=1}^{n} \left[\frac{m^2 x_i^2 + 2(my_o - m^2 x_o)\, x_i + y_o^2 + m^2 x_o^2 - 2mx_o y_o}{n} \right] \right\}^{1/2} \tag{6}$$

Removing the summation term by substituting the available data values yields

$$\text{rms} = \left[\left(\frac{C_1 \text{SUMSQ} + C_2 \text{SUM}}{n} \right) + C_3 \right]^{1/2} \tag{7}$$

where C_1 , C_2 , and C_3 are constants defined as follows:

$$C_3 = \left(\text{PRETEST}_{\text{ENG}}\right)^2 + (\text{RATIO})^2 \left(\text{PRETEST}_{\text{A/D}}\right)^2 - 2(\text{RATIO}) \times \left(\text{PRETEST}_{\text{ENG}}\right)\left(\text{PRETEST}_{\text{A/D}}\right) \tag{8}$$

$$C_1 = (\text{RATIO})^2 \tag{9}$$

and

$$C_2 = 2\left(\text{PRETEST}_{\text{ENG}}\right)(\text{RATIO}) - \left(\text{PRETEST}_{\text{A/D}}\right)(\text{RATIO})^2 \tag{10}$$

45. To derive the equation for standard deviation, assume that n is large enough so that n may be substituted for $n - 1$ in the exact equation (Bowker and Lieberman 1972):

$$SD = \left(RMS^2 - MEAN^2\right)^{\frac{1}{2}} \tag{11}$$

to give the expanded equation

$$SD = \left[\frac{\sum_{i=1}^{n} x_i^2}{n} - \left(\frac{\sum_{i=1}^{n} x_i}{n}\right)^2\right]^{\frac{1}{2}} \tag{12}$$

Substituting the previously found rms value and the sum term yields

$$SD = \left((rms)^2 - \left\{\frac{\left[(RATIO)(SUM) + (n)(C_4)\right]^2}{n^2}\right\}\right)^{1/2} \tag{13}$$

where

$$C_4 = \left(PRETEST_{ENG}\right) - (RATIO)\left(PRETEST_{A/D}\right)$$

To derive the equation for MEAN (Bowker and Lieberman 1972), begin with

$$MEAN = \sum_{i=1}^{n} \frac{x_i}{n} \tag{14}$$

and substitute to yield

$$MEAN = \left[\frac{(SUM)(RATIO)}{n}\right] + C_4 \tag{15}$$

with C_4 as previously defined.

Arithmetic Board Driver

46. The arithmetic board performs most of the necessary mathematical operations. To cause the arithmetic board to perform its inherent

mathematical functions, software simply outputs data to the data port, outputs a command to the command port, checks for the "operation complete" bit of the status port, and inputs data from the data port.

Fixed-point numbers

47. Fixed-point multiplication and division routines were first written in software using the Z80A double-add and double-subtract instructions; however, after addition of the AMD9511 chip to the circuit, these routines were replaced by hardware. The AMD9511 chip handles both 16- and 32-bit "two's complement" binary integers. It has conversion routines between these two formats and its 32-bit floating-point format.

Floating-point numbers

48. All floating-point mathematical operations are done by the AMD9511 chip. The AMD9511 chip acts as a scientific calculator on a chip in that it has, in addition to the common arithmetic operations, many of the transcendental functions (trigonometric, logarithmic, etc.). A number of software routines had to be written to utilize the chip effectively. Routines were written to convert from 12-character ASCII (P format) to 32-bit floating point and vice versa. These routines utilize the AMD9511 for most of the mathematical operations. The 32-bit integer format is used for conversion operations dealing with the mantissa to maintain maximum precision through the additional guard bits. A powers-of-10 table spanning from -20 to +19 is used during the conversion process. The ASCII to floating-point conversion routine (ASCFLT) multiplies each of the BCD digits of the mantissa by a power of 10 (32-bit integer) from 5 to 0 from left to right and sums the results. The sum is then converted to floating point and multiplied by 10^{-5} to complete the mantissa. The value of the exponent is obtained from the table. The table entry is then multiplied by the mantissa and the sign changed, if necessary, to give the final number.

Plotter Driver

49. A National Semiconductor INS8250 UART (with external TTL to EIA level converters) was added in a blank area on the arithmetic board (the board had already been modified extensively in connection with this project) because the plotter requires an RS232C interface. The INS 8250 UART has 10 internal registers to allow programmable versatility. The UART is initialized to 2400 baud (via the Z80A output commands) by the subroutine UARTIN.

50. Two undesirable phenomena may occur when a continuous phenomenon is sampled at a constant interval: aliasing and hidden oscillations. Aliasing involves the folding of energy at a given frequency back to a lower frequency. Hidden oscillations involve the total loss of energy at a particular frequency. The first phenomenon is shown in Figure 11, the second in Figure 12.

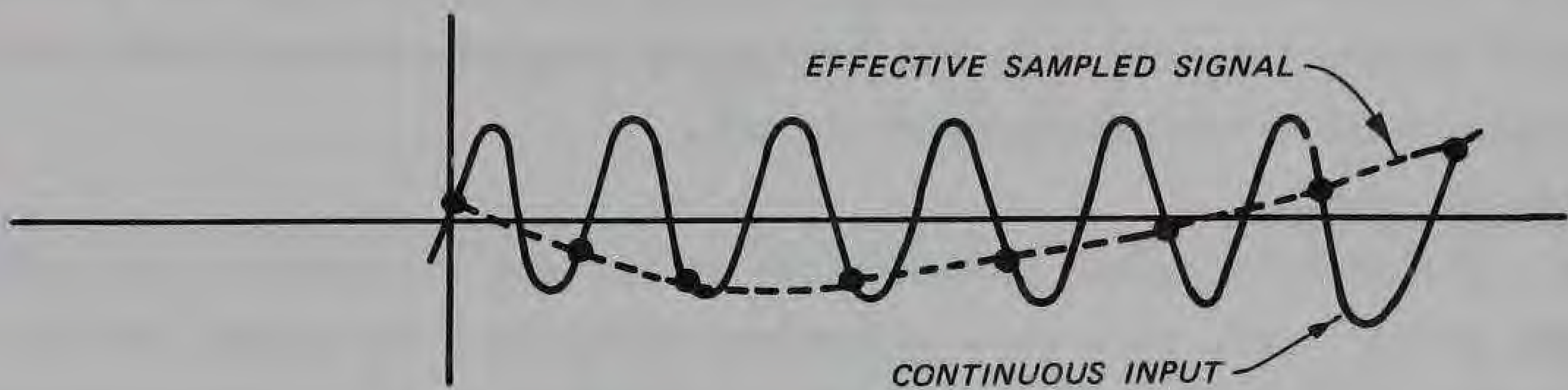


Figure 11. Aliased data

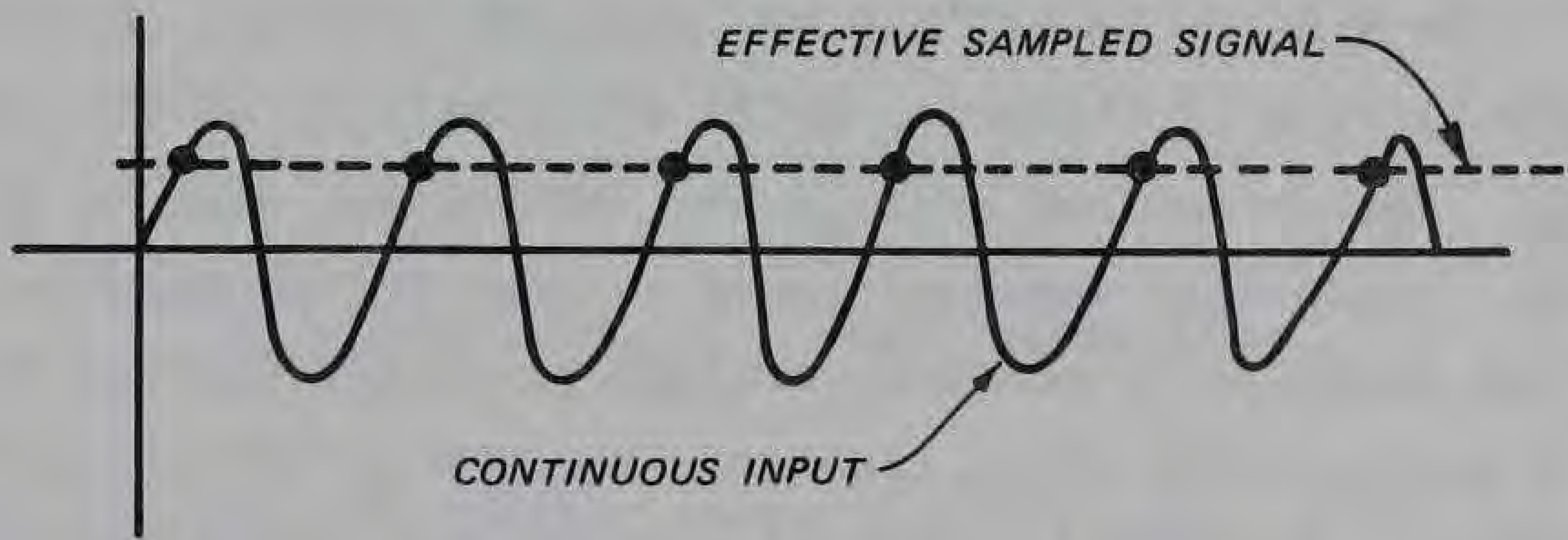


Figure 12. Hidden oscillations

51. These two undesirable phenomena may be prevented by three methods: (a) sampling the highest input frequency at least twice, (b) varying the sampling period randomly, or (c) low-pass analog filtering of the signal prior to digitization to reduce its highest frequency to less than half that of the sampling rate. A frequency investigation was performed to determine levels of extraneous noise. Analog bypass filters were installed accordingly (Figure 3). Digital filters are of no use at this stage because the harm is already done by the time they are implemented. High-frequency components were present in the signals coming from the gages such that sampling at least twice the highest input frequency was impossible. The highest sample rate of the ADC was 100,000 samples per second, which, when divided by the number of channels multiplexed, turned out to be lower (per channel) than twice the noise

frequency (per channel). All of the high-frequency components could have been removed by analog low-pass filters placed between the gages and the computer's multiplexer inputs, but the investigation results indicated that some of these components were of interest. Sampling method (a) was investigated varying the sampling period. Since aliasing and hidden oscillations are caused by a constant digitizing frequency, "beating," or heterodyning of twice the digitizing rate with the data frequency yields the

$$\text{alias frequency} = \text{data frequency} - 2 \times \text{digitizing rate} \tag{16}$$

The terms beating or heterodyning are borrowed from communications theory where a local oscillator (LF) "beats" with a higher frequency input radio signal (RF) to produce two output frequencies.

$$OF1 = RF - LF \tag{17}$$

and

$$OF2 = RF + LF \tag{18}$$

OF1 is an intermediate lower frequency (IF) that can then be processed by a band-limited tuner.

52. Since aliasing occurs because of a constant sampling interval, one way to prevent it is to make the sampling interval vary randomly. The more the sampling interval approaches a Gaussian distribution, the less likely aliasing is to occur. The time needed to sample a test would have increased significantly if a band-limited Gaussian-type sampling arrangement had been provided by mathematically varying the sampling interval based on a random number generator. The floating-point "multiply and addition routines" used by the microcomputer varied considerably in time required for computation with the magnitude of the numbers multiplied or added. The sampling interval was caused to vary randomly by dynamically computing the sum, sum of squares, maximum, and minimum while the data were being collected and by sampling the next point as soon as the sum, sum of squares, maximum, and minimum were updated by the previous point. The effectiveness of this technique for use with pump sump data was verified experimentally. Data were collected on analog

tape and the same analog signal was applied to both high-speed (twice the highest input frequency) sampling and the low-speed random method proposed. Statistical analysis of sampled records from the two approaches showed them to yield results with less difference than the inherent error of the gages being used. Therefore the random sampling approach was chosen for this project.

53. Statistical analysis is somewhat immune to bias due to aliasing because frequency is of little concern unless it is low enough that only a portion of a cycle is included in the sample record. The results are biased if only a portion of an aliased cycle is used in statistical calculations. The more serious problem is the hidden oscillation phenomenon where sampling data of a frequency that is an exact harmonic of the sample rate produces a zero order bias (DC). Random sampling is a time-proven statistical method for removing bias when choosing a representative sample record from an ensemble. The central-limit theorem could be applied to the method used on the pump sump project to produce randomness of sample interval. It could be stated in this application, since the distribution of the sum of a sufficiently large number of random sample intervals tends to be Gaussian, even if the distributions of the individual random sample intervals are not Gaussian. In the pump sump program, the overall statistical values are produced from 2,500 individual random sample intervals, a large enough number to cause the distribution of the sample intervals to approach Gaussian. For example, consider that 50 groups of 50 sample intervals have their distributions summed; the sum would approach a Gaussian distribution. Therefore the sample method used should tend to remove bias due to hidden oscillations quite effectively.

Randomly Ordered Data

54. Both the MJ chord algorithm (used for curve fitting) and the low-pass digital filter (used for curve smoothening) require ordered input (i.e., $X_{I-1} < X_I < X_{I+1} < X_{I+2}$) . The pump sump data as acquired are not always ordered. Generally, the data are not reordered physically; rather, an order buffer is created and consulted by algorithms to obtain points indirectly in an ordered manner. An assembly language subroutine called ORDER searches the buffer to be used as the abscissa (one point at a time) comparing each point with all previously order-determined points. It then adjusts the order buffer values, causing the new point to take on the index value of the point

immediately larger and all points with greater than or equal index values to have their respective indexes incremented by one. The routine is quite general in that it can accept any input buffer, nonmultiplexed or multiplexed in any manner, with the first point at any depth in the buffer. The MJ and FILTER routines then use the index from the order buffer to compute the relative buffer depth for obtaining abscissa and ordinate values. This technique assumes that the values in the two buffers are ordered the same. The buffers can otherwise be structured differently by calling the address calculating subroutines XCALC and YCALC. XCALC calculates the address of X from

$$\text{XADD} = \text{XBUFF} + 4\left[(\text{XFRST} + \text{XMUX})(\text{XDEPTH})\right] \tag{19}$$

where

XADD = address of the location in which X is stored
XBUFF = base address of the X buffer
4 = number of bytes occupied by each X value
XFRST = buffer index of the first X point
XMUX = number of channels multiplexed
XDEPTH = index value from the order buffer

The subroutine then fetches the value of X and returns it to MJ or FILTER. YCALC calculates the address of Y in a similar manner, fetches Y , and returns it to MJ or FILTER. The Y address is calculated from

$$\text{YADD} = \text{YBUFF} + 4\left[(\text{YFRST} + (\text{YMUX})(\text{XDEPTH})\right] \tag{20}$$

where

YADD = address of the location in which Y is stored
YBUFF = base address of the Y buffer
YFRST = buffer index of the first Y point
YMUX = number of channels multiplexed

Note that in both cases, XDEPTH is an integer between 0 and N-1 , where N is the number of points in the order buffer.

Curve Fitting

55. The previous curve-fitting technique was based on the adjustment of

data points to evenly spaced discharge increments for subsequent input to a nonrecursive digital filter similar to the one used presently as well as with the original MJ chord algorithm (which worked only with evenly spaced points). The projection of the data was planned to be accomplished by linear extrapolation at each end of the input data, and by linear interpolation where data points were available on either side of the evenly spaced increment. Due to a programming error, however, projection was always done by extrapolation using the two preceding data points. Rather than just correct the programming error, which would only partially solve the less than satisfactory fit problem, it was decided to modify both the filter and the MJ algorithm so that they would deal with the original data on its unevenly spaced increments. Also the previous method did not allow for randomly ordered data. It assumed data were always collected in descending order of discharge. During the rewrite, randomly ordered data were assumed in all algorithms, as described previously.

56. During testing, data points are plotted as the data are acquired. The printer/plotter then fits a curve through the data points, after the complete test is finished, using the MJ chord algorithm. This algorithm uses a separate cubic polynomial to describe the curve through a series of intervals. The slope of the approximating function for each interval is controlled at both ends of the interval by interpolation routines and causes the concatenation of cubic polynominals to be a continuous function. The use of the MJ chord algorithm resulted in improved curve fitting over the previously used least squares method. The MJ chord algorithm method of curve fitting is a recent development and may require additional refinements for this application. A more comprehensive explanation of the MJ chord algorithm and interpolation routine for this project is contained in a separate report (McCleave 1984).

Curve Smoothening by Digital Filtering

57. Pump sump data are digitally filtered by an elementary nonrecursive filter prior to input to the MJ chord algorithm. It uses the present point and the point to either side of the present point and sums their weighted values to produce a filtered point that is a weighted average of the three. The higher the weight applied to the present point with respect to the weights applied to the points on either side, the less the data are filtered. If the

sum of the three weights is one, the gain of the filter is one. The filter used averages the weighted point prior to the present one with the weighted point after the present one. It then weights this value and sums it with the weighted present point. The sum of these two weights is one for unity gain. The computer operator has control of the selection of these two weights. The first weight α is applied directly to the present point (e.g., α values approaching 1 imply less filtering while α values approaching 0 imply more filtering). The other weight β is weighted by the relative distance the two neighboring points are away from the present one to derive the portion of β to be applied to each of these two points. A more comprehensive explanation of the digital filtering used with this project is contained in a separate report (McCleave 1984).

PART V: SUMP EVALUATION TECHNIQUES

Pump Performance

58. Procedures are discussed and illustrated for data analysis and comparison of sump performance based on six pump parameters: discharge, head, efficiency, horsepower, vibration (velocity), and noise for each of the three vertical-propeller pumps. Relative pump performance is used as an indicator of sump performance. A schematic, typical of the three pumps used (Figure 13), indicates the various heads and dimensions used in computing pump performance as shown in Figure 14. Five pump parameters are measured for each pump relative to various discharges and plotted as shown in Figure 14. The solid lines in the plot represent the pump signature curves which were obtained with a base (signature) sump design that provided a submergence S (Figure 13) of 3.1 ft and evenly distributed approach flow to the pump intake. The dashed lines in the plot represent the pump performance curves obtained with a test approach and sump design. The position and amount the test curves vary from the signature curves indicate the test approach and sump hydraulic effect on pump performance relative to the signature sump. A comparison of the test and signature curves over a range of discharges permits a qualitative evaluation of the hydraulic performance of the test sump relative to the signature sump.

59. Typical test results are analyzed to illustrate how the pump performance curves were obtained and how a test curve is compared with a signature curve. The basic data used for this sample analysis, obtained from the model by means of meters and gages, are listed by the printer/plotter in Figure 15 (underlined) and are also tabulated in Figure 16. An analog plot of a typical signal detected by the microcomputer (Figure 17) shows the type of values measured. The performance curves for vibration (velocity) and noise (Figure 14) were obtained by plotting the calculated rms values for noise (Figure 16), and the maximum values F_{MAX} (Figure 16) for vibration versus discharge. The values listed under vibration (max) and noise (rms) in Figure 16 provide one point on their respective performance curves as indicated by the vertical dashed line in Figure 14. The values of the parameters that define the performance curves for head, efficiency, and power delivered to the pump were developed by the microprocessor from the basic data and are listed

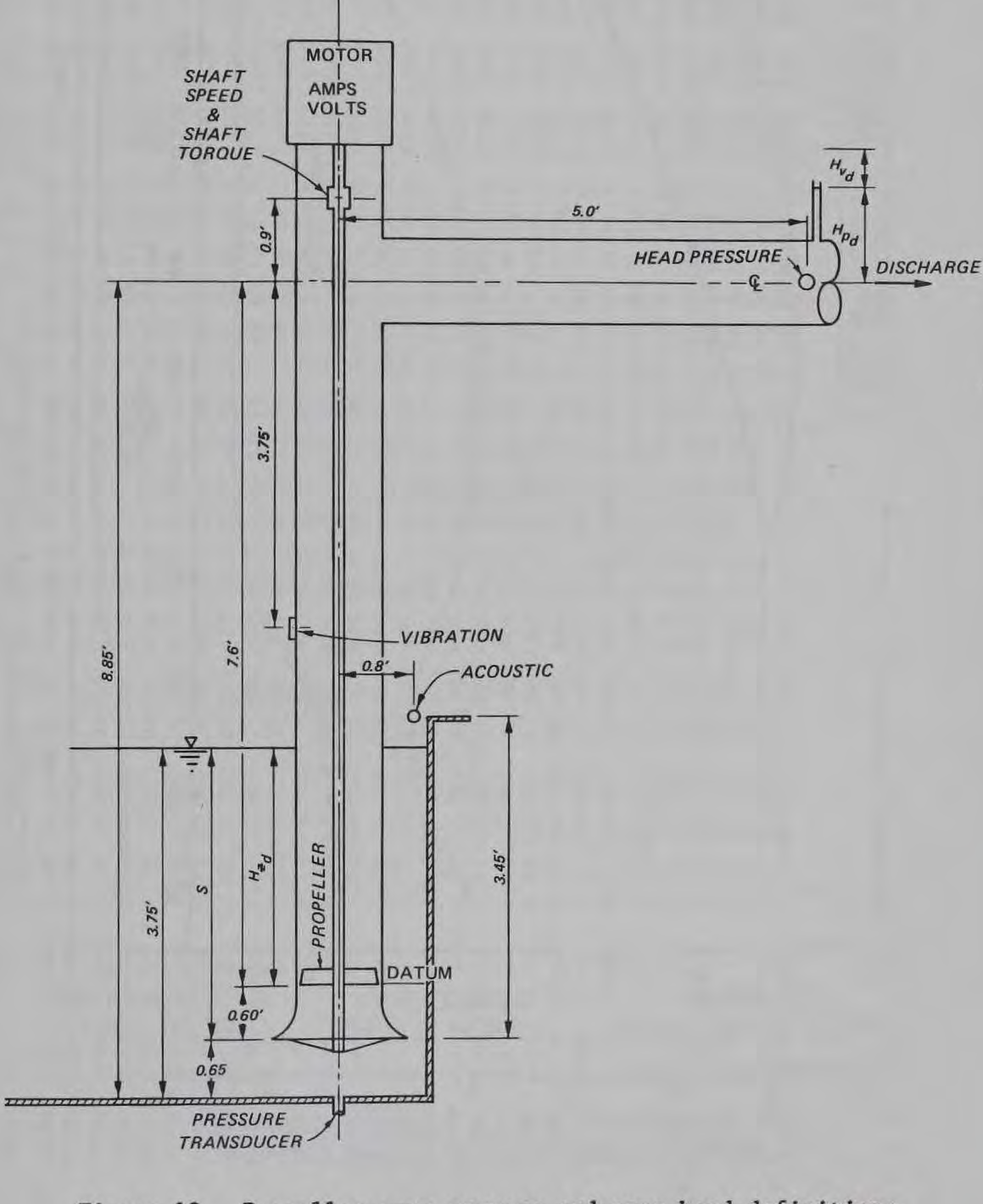


Figure 13. Propeller pump sensors and pump head definitions

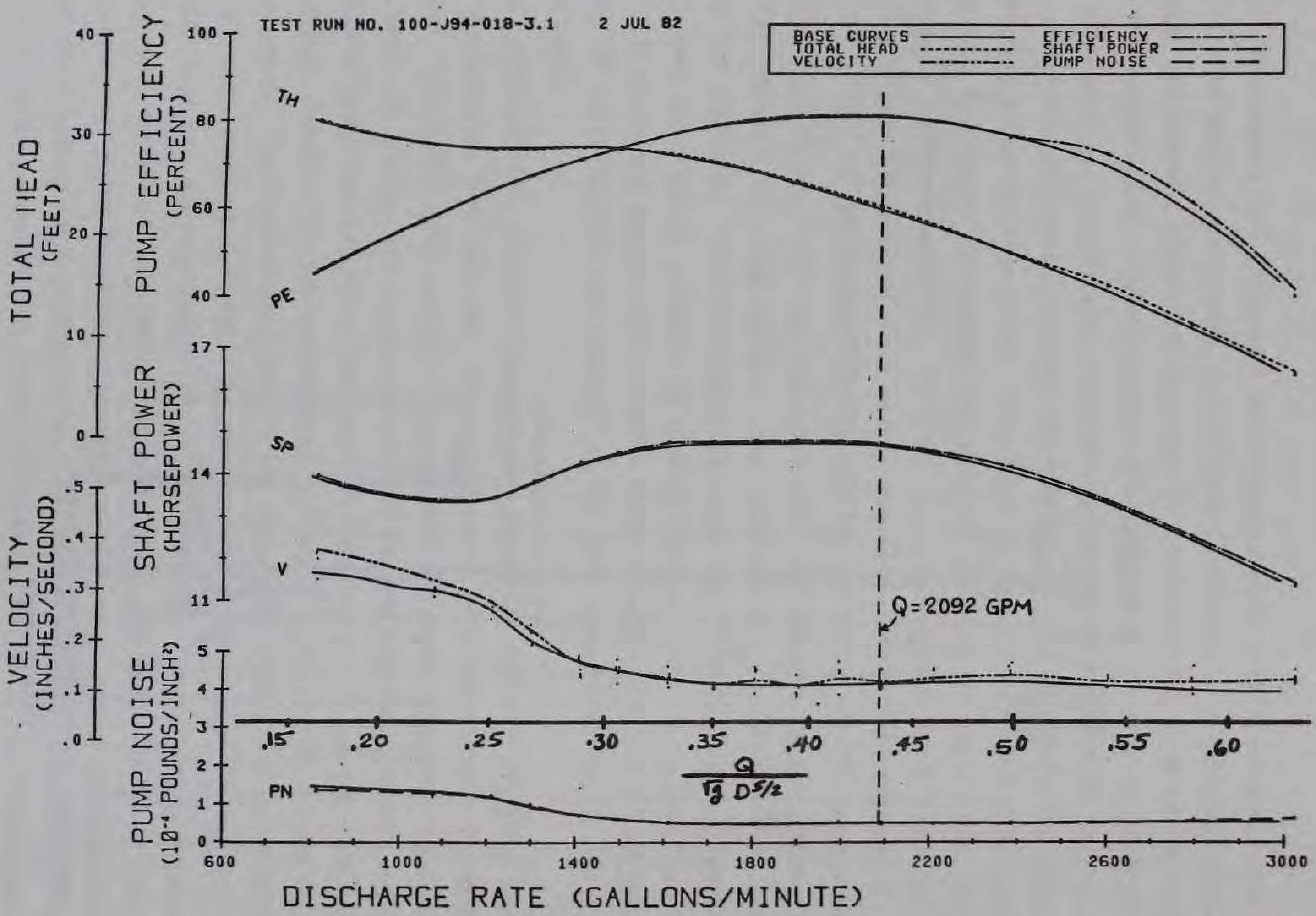


Figure 14. Performance characteristic curves; pump 1, Test J94, sump 018, submergence 3.1 ft

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	3036	3.10	-1.63	2.39	5.858	33.42	478	15.9	17.68	11.30	4.50	63.89	39.8	1775	.044	.137	.000062	3.49	3.74
1	3036	3.10	-1.67	2.39	5.812	33.54	478	16.0	17.70	11.34	4.46	64.06	39.4	1775	.040	.119	.000061	3.60	3.73
1	3035	3.10	-1.66	2.39	5.827	33.57	478	16.0	17.71	11.34	4.47	64.07	39.4	1775	.040	.113	.000060	3.56	3.74
1	3036	3.10	-1.66	2.39	5.830	33.49	478	15.9	17.67	11.32	4.47	64.03	39.5	1775	.041	.123	.000060	3.47	3.72
1	3037	3.10	-1.67	2.39	5.813	33.41	478	15.9	17.67	11.29	4.46	63.89	39.5	1775	.040	.109	.000060	2.97	3.73
2	2793	3.10	3.62	2.02	10.749	36.98	477	16.4	18.12	12.50	7.59	68.96	60.7	1775	.038	.100	.000053	3.10	3.69
2	2794	3.10	3.66	2.03	10.787	36.94	477	16.4	18.11	12.48	7.62	68.94	61.0	1775	.035	.088	.000054	3.58	3.72
2	2792	3.10	3.62	2.02	10.750	36.98	477	16.4	18.12	12.50	7.59	68.96	60.7	1775	.042	.120	.000053	3.37	3.70
2	2790	3.10	3.68	2.02	10.804	37.08	477	16.4	18.13	12.53	7.62	69.15	60.8	1775	.041	.117	.000052	3.60	3.71
2	2797	3.10	3.60	2.03	10.732	36.98	477	16.4	18.11	12.50	7.59	69.00	60.7	1775	.043	.144	.000057	3.58	3.71
3	2601	3.10	7.73	1.75	14.586	39.57	479	16.6	18.51	13.37	9.59	72.25	71.7	1775	.040	.100	.000045	3.25	3.72
3	2601	3.10	7.75	1.76	14.613	39.55	479	16.6	18.51	13.37	9.61	72.22	71.9	1775	.041	.102	.000045	3.58	3.70
3	2605	3.10	7.73	1.76	14.590	39.61	479	16.6	18.51	13.39	9.61	72.31	71.8	1775	.044	.125	.000048	3.59	3.72
3	2605	3.10	7.74	1.76	14.607	39.58	479	16.6	18.51	13.38	9.62	72.29	71.9	1775	.037	.101	.000049	3.49	3.71
3	2605	3.10	7.75	1.76	14.618	39.62	479	16.7	18.51	13.39	9.63	72.35	71.9	1775	.042	.119	.000048	3.61	3.71
4	2385	3.10	11.22	1.48	17.804	41.94	480	17.0	18.93	14.17	10.73	74.89	75.7	1775	.045	.134	.000047	3.52	3.71
4	2384	3.10	11.23	1.47	17.810	41.92	480	17.0	18.92	14.17	10.73	74.87	75.8	1775	.036	.097	.000041	3.63	3.72
4	2381	3.10	11.19	1.47	17.767	41.89	480	17.0	18.92	14.16	10.69	74.82	75.5	1775	.038	.143	.000043	3.62	3.72
4	2389	3.10	11.22	1.48	17.807	41.96	480	17.0	18.93	14.18	10.76	74.89	75.9	1775	.049	.150	.000046	3.58	3.72
4	2386	3.10	11.23	1.48	17.815	41.86	481	17.0	18.92	14.15	10.75	74.77	76.0	1775	.050	.127	.000049	3.61	3.70
5	2210	3.10	14.22	1.27	20.595	43.00	480	17.1	19.07	14.53	11.51	76.20	79.2	1775	.045	.135	.000041	3.39	3.72
5	2210	3.10	14.26	1.27	20.630	43.07	480	17.1	19.07	14.56	11.53	76.33	79.2	1775	.038	.115	.000045	3.21	3.70
5	2208	3.10	14.26	1.27	20.627	43.04	479	17.1	19.06	14.55	11.52	76.33	79.2	1775	.043	.111	.000046	3.60	3.72
5	2208	3.10	14.23	1.26	20.595	43.02	479	17.1	19.05	14.54	11.49	76.31	79.1	1775	.041	.117	.000043	3.55	3.73
5	2212	3.10	14.26	1.27	20.629	43.07	479	17.1	19.06	14.56	11.53	76.39	79.2	1775	.047	.139	.000046	3.46	3.74
6	2092	3.10	16.17	1.14	22.411	43.56	480	17.2	19.12	14.72	11.86	76.99	80.5	1775	.039	.102	.000045	3.61	3.71
6	2092	3.10	16.16	1.14	22.400	43.58	480	17.2	19.13	14.73	11.85	77.00	80.4	1775	.054	.138	.000049	3.54	3.71
6	2090	3.10	16.16	1.13	22.402	43.54	480	17.2	19.13	14.72	11.84	76.93	80.4	1775	.040	.106	.000048	3.63	3.72
6	2091	3.10	16.17	1.13	22.405	43.52	480	17.2	19.13	14.71	11.84	76.87	80.5	1775	.040	.100	.000041	3.56	3.72
6	2088	3.10	16.23	1.13	22.460	43.62	480	17.2	19.16	14.74	11.86	76.95	80.4	1775	.042	.097	.000046	3.58	3.73

TEST RUN NO. 100-J94-018-3.1   2 JUL 82

Figure 15. Research data; pump 1, Test J94, sump 018, submergence 3.1 ft

BASIC DATA

PUMP 1, TEST J94, SUMP 018, SUBMERGENCE 3.1 ft

READING NO. 6a

VARIABLE	SYMBOL	MAGNITUDE	UNITS	VALUE
DISCHARGE	Q	2092	GPM	MEAN
SUBMERGENCE	S	3.10	FT	MEAN
PRESSURE (STATIC HEAD)	H	16.17	FT	MEAN
SHAFT TORQUE	T	43.56	FT-LBS	MEAN
VOLTAGE	E	480	VOLTS	MEAN
CURRENT	I	17.2	AMPS	MEAN
SHAFT SPEED	η	1775	RPM	MEAN
PUMP COLUMN VIBRATION (RMS)	F_{RMS}	0.039	IN/SEC	RMS
PUMP COLUMN VIBRATION (MAX)	F_{MAX}	0.102	IN/SEC	PEAK
NOISE	N	4.5	$\#/IN^2$	
PRESSURE (MINIMUM)	P_{MIN}	3.61	FT	PEAK
PRESSURE (MAXIMUM)	P_{MAX}	3.71	FT	PEAK

Figure 16. Basic data

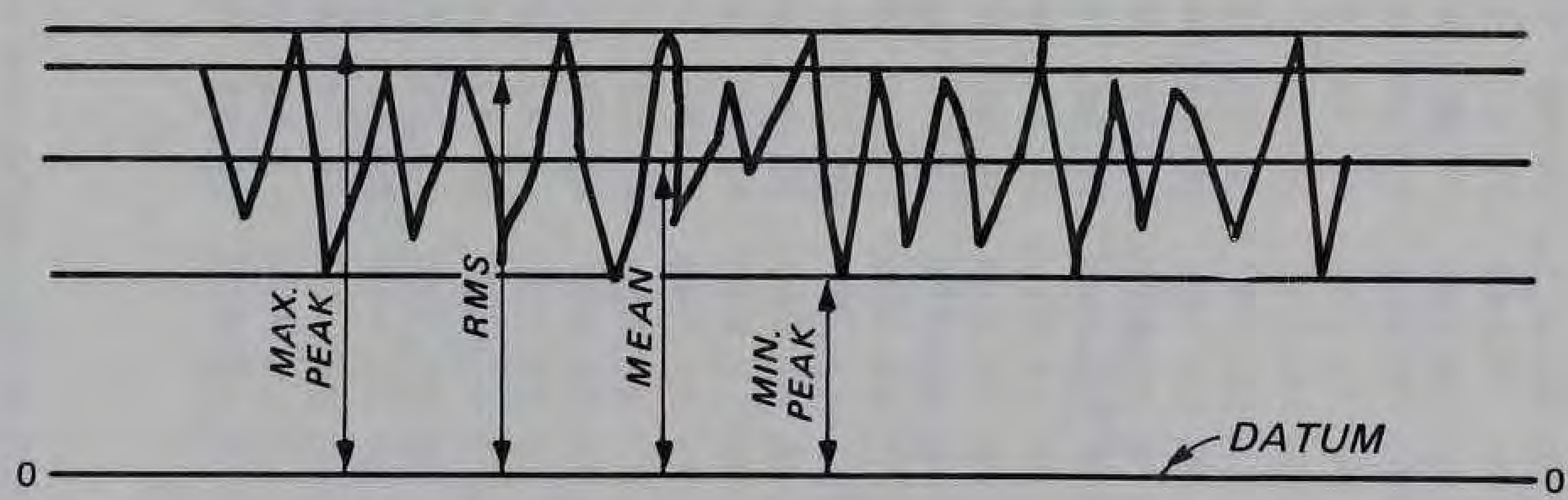


Figure 17. Typical analog record not to scale

COMPUTED VALUES

PUMP 1, TEST J94, SUMP 018, SUBMERGENT 3.1 FT

READING NO. 6a

VARIABLE	SYMBOL	MAGNITUDE	UNITS
VELOCITY HEAD	H_v	1.14	FT
TOTAL PUMP HEAD	H	22.4	FT
POWER DELIVERED TO DRIVER (MOTOR POWER)	P	19.1	h_p
POWER DELIVERED TO PUMP (SHAFT POWER)	P	14.7	h_p
PUMP POWER OUTPUT (WATER POWER)	P	11.8	h_p
DRIVER (MOTOR) EFFICIENCY	η	77	DIMENSIONLESS
PUMP EFFICIENCY	η	80	DIMENSIONLESS

Figure 18. Computed values

in Figure 15 (underlined) and are tabulated in Figure 18. The following equation illustrates how the basic data are utilized by the microcomputer to compute pump head, horsepower, and efficiency:

$$A = \pi r^2 = \pi(0.417)^2 = 0.545 \text{ ft}^2 \tag{21}$$

$$V = \frac{Q}{A} = \frac{2{,}092 \text{ gpm}}{0.545 \text{ ft}^2} \times \frac{1 \text{ ft}^3/\text{sec}}{448.30 \text{ gpm}} = 8.55 \text{ ft/sec}^2 \tag{22}$$

where

A = inside area of discharge conduit, ft^2

V = average velocity in discharge conduit, ft/sec

Q = discharge in conduit, ft^3/sec

$$H_v = \frac{V^2}{2g} = \frac{8.55 \text{ ft/sec}^2}{64.4 \text{ ft/sec}^2} = 1.14 \text{ ft} \tag{23}$$

where

H_v = velocity head in discharge conduit, ft

g = acceleration due to gravity in ft/sec^2

$$H = H_d - H_s = H_{p_d} + H_{v_d} + H_{z_d} \; ; \quad H_s \text{ assumed} = H_{z_s} \tag{24}$$

$$H = H_{p_d} + H_{v_d} + 7.6 - H_{z_s} = 16.17 \text{ ft} + 1.14 \text{ ft} + 7.6 \text{ ft} - 2.5 \text{ ft} = 22.4 \text{ ft} \tag{25}$$

where

H = total pump head, ft

H_d = discharge head, ft

H_s = suction head, assumed to equal H_{z_s}

H_{p_d} = static head in discharge conduit, ft

H_{v_d} = velocity head in discharge conduit, ft

H_{z_d} = vertical distance from datum to water surface, ft

H_{z_s} = elevation head, ft

$$P_i = \sqrt{3}\ E\ \frac{I}{0.746} = \sqrt{3}\ 0.480 \text{ kV } \frac{17.2 \text{ amps}}{0.746} = 19.1 \text{ hp} \tag{26}$$

where

P_i = power delivered to driver, hp

E = voltage, kV

I = current, amps

$$P_s = \frac{T\omega}{550} = \frac{43.56 \text{ ft-lb} \times 1{,}775 \text{ rpm} \times 1 \text{ min} \times 2\pi\text{rad} \times 1 \text{ hp}}{\frac{550 \text{ ft-lb}}{\text{sec}} \times 60 \text{ sec} \times 1 \text{ rev}} = 14.7 \text{ hp} \tag{27}$$

where

P_s = power delivered to pump, hp

T = shaft torque, ft-lb

ω = angular rotation, rad/sec

$$P_w = \frac{\gamma QH}{550} = \frac{62.4 \text{ lb/ft}^3 \times 2{,}092 \text{ gpm} \times 22.4 \text{ ft} \times (1 \text{ hp})(\text{ft}^3/\text{sec})}{\frac{550 \text{ ft-lb}}{\text{sec}} \times 448.8 \text{ gpm}} = 11.8 \text{ hp} \tag{28}$$

where

P_w = pump power output, hp

γ = specific weight of water, lb/ft^3

Q = discharge, ft^3/sec

$$\eta_d = \left(\frac{P_s}{P_i}\right)100 = \frac{14.72 \text{ hp}}{19.1 \text{ hp}} = 77\% \qquad (29)$$

where

η_d = driver efficiency, dimensionless

P_s = power delivered to pump, hp

P_i = power delivered to driver, hp

$$\eta_p = \left(\frac{P_w}{P_s}\right)100 \left(\frac{11.8 \text{ hp}}{14.7 \text{ hp}}\right) = 80\% \qquad (30)$$

where η_p is the dimensionless pump efficiency.

60. A visual comparison of the test curves with the signature curves in Figure 14 permits an evaluation of how the pump performs in the test sump relative to the signature sump. A more precise comparison of the test curves with the signature curves is provided in Figure 19. The data in Figure 19 indicate, for discharges between 1,500 and 2,500 gpm, the amount each test curve deviates above and below each signature curve and the maximum and minimum values for each test curve. With visual inspection of the test relative to the signature curves in Figure 13 or the values in Figure 19, a sump could be evaluated as indicated in Figure 20.

61. Results tabulated in Figure 20 indicate no definite trend, and the test curves only slightly deviate from the signature curves. Therefore, based on pump performance, it can be concluded that the test sump for the established conditions creates no disturbances that affect the performance of the pump.

Visual Observations, Current Velocities, and Pressure Fluctuations

62. Visual observation of subsurface current flow patterns and

TEST RUN NO. 100-J94-018-3.1 2 JUL 82 ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	5.2847 IPS*GPM	.2612 IPS*GPM	.134251 IPS	1500 GPM	.106275 IPS	1900 GPM
TOTAL HEAD	101.80 FT*GPM	8.72 FT*GPM	28.11590 FT	1500 GPM	16.18160 FT	2500 GPM
PUMP NOISE	.00000 PSI*GPM	.00263 PSI*GPM	.0000568 PSI	1500 GPM	.0000444 PSI	2250 GPM
SHAFT POWER	53.954 HP*GPM	.000 HP*GPM	14.80910 HP	1880 GPM	13.77360 HP	2500 GPM
PUMP EFFICIENCY	130.97 % * GPM	78.30 % * GPM	80.51590 %	2040 GPM	73.33090 %	1500 GPM

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

Figure 19. Statistical comparison, pump 1, Test J94, sump 018, submergence 3.1 ft

SUMP PERFORMANCE

PARAMETER	SUMP PERFORMANCE RELATIVE TO SIGNATURE CURVES		
	BETTER	WORSE	NO CHANGE
VELOCITY		YES	
TOTAL PUMP HEAD	YES		
PUMP NOISE	YES		
SHAFT POWER		YES	
POWER EFFICIENCY	YES		

Figure 20. Sump performance

turbulence by injection of dye or other flow indicators is a proven method for evaluating approaches to sumps and sump performance. Surface flow patterns approaching the pump intakes are traced with confetti sprinkled on the water surface.

63. Surface and subsurface (submerged) vortices (Figures 21-23) are

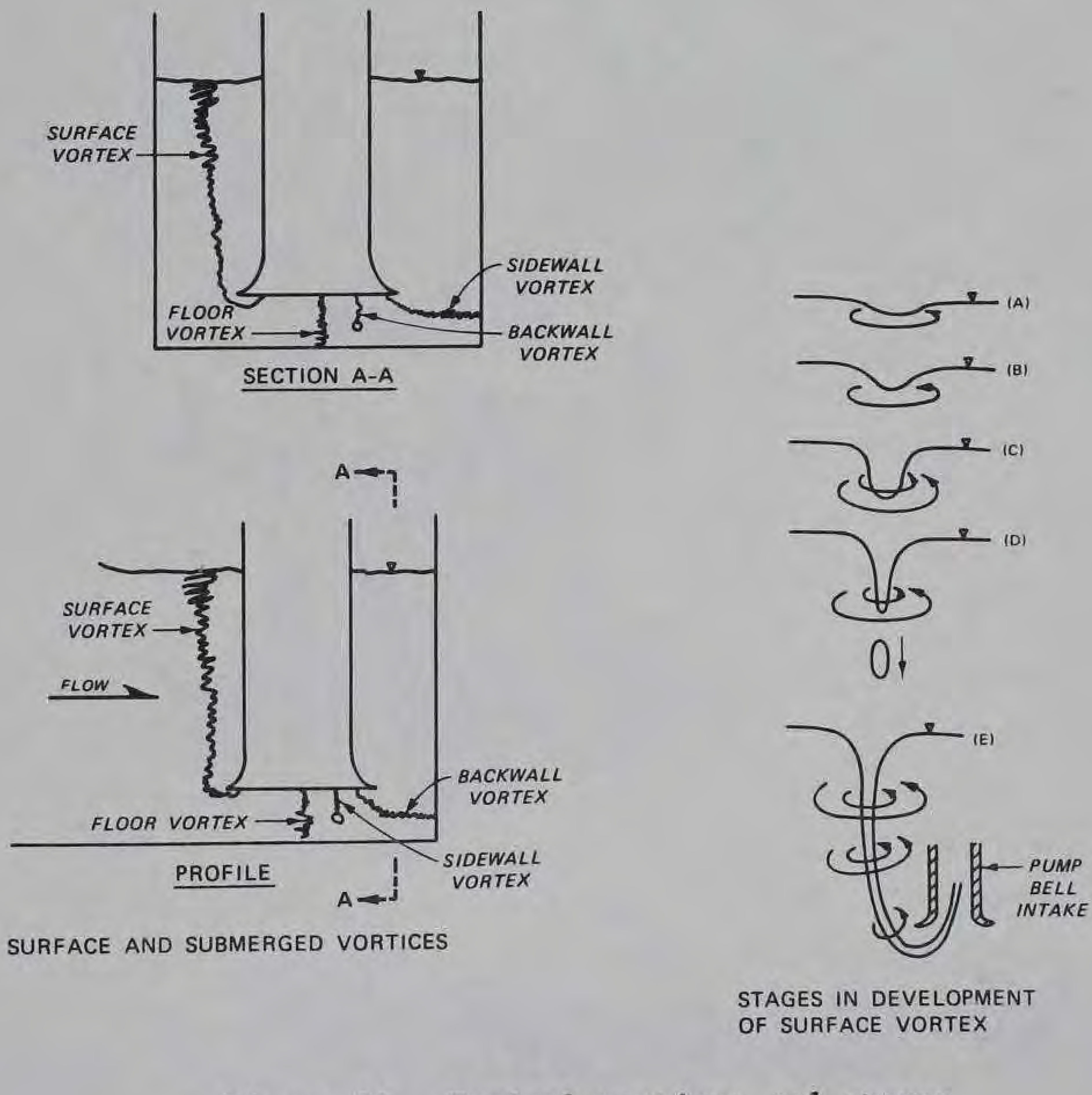


Figure 21. Typical vortices and stages

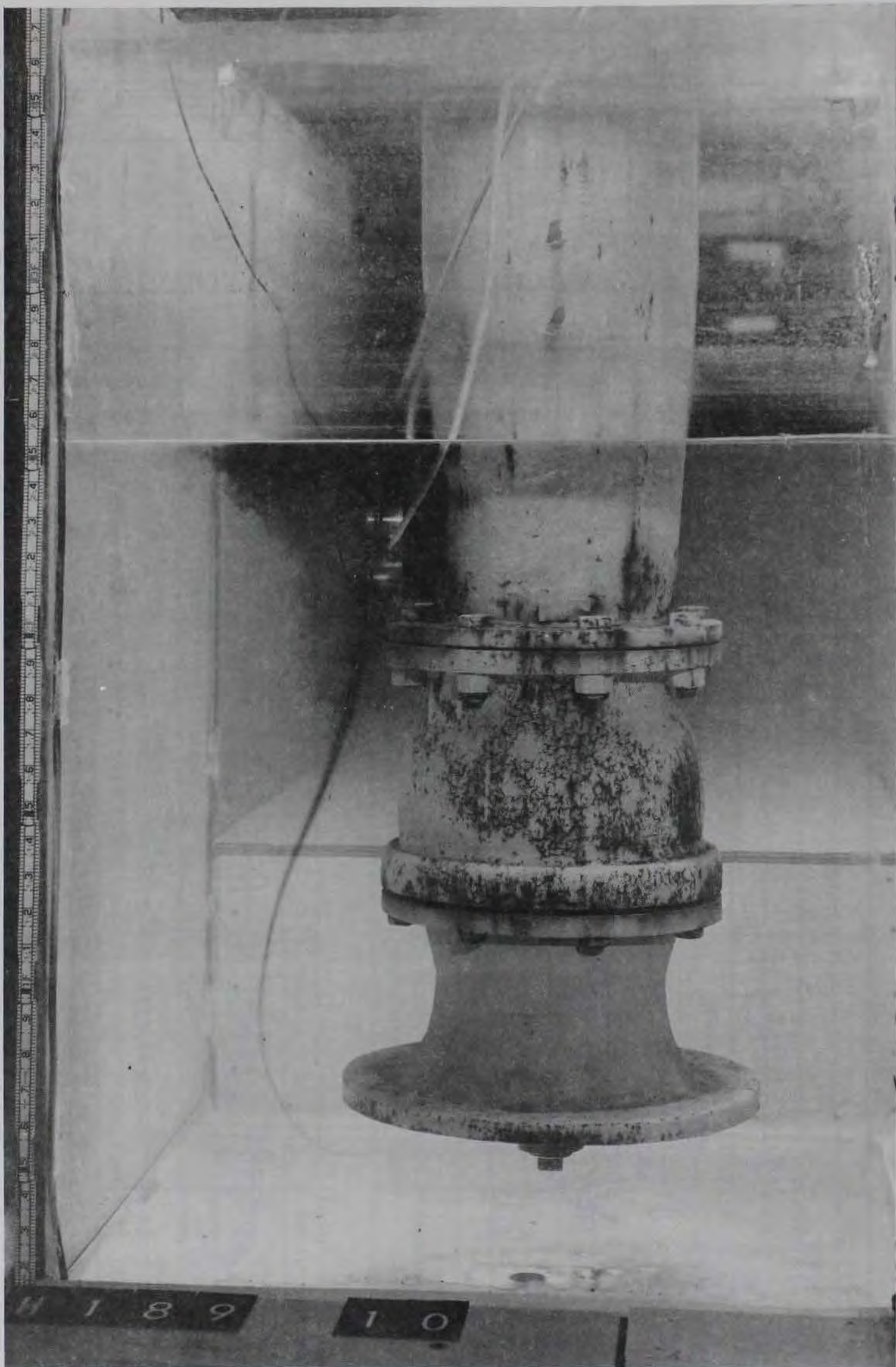


Figure 22. Type 2 sump, pump 1, discharge 1,300 gpm, submergence 1.3 ft

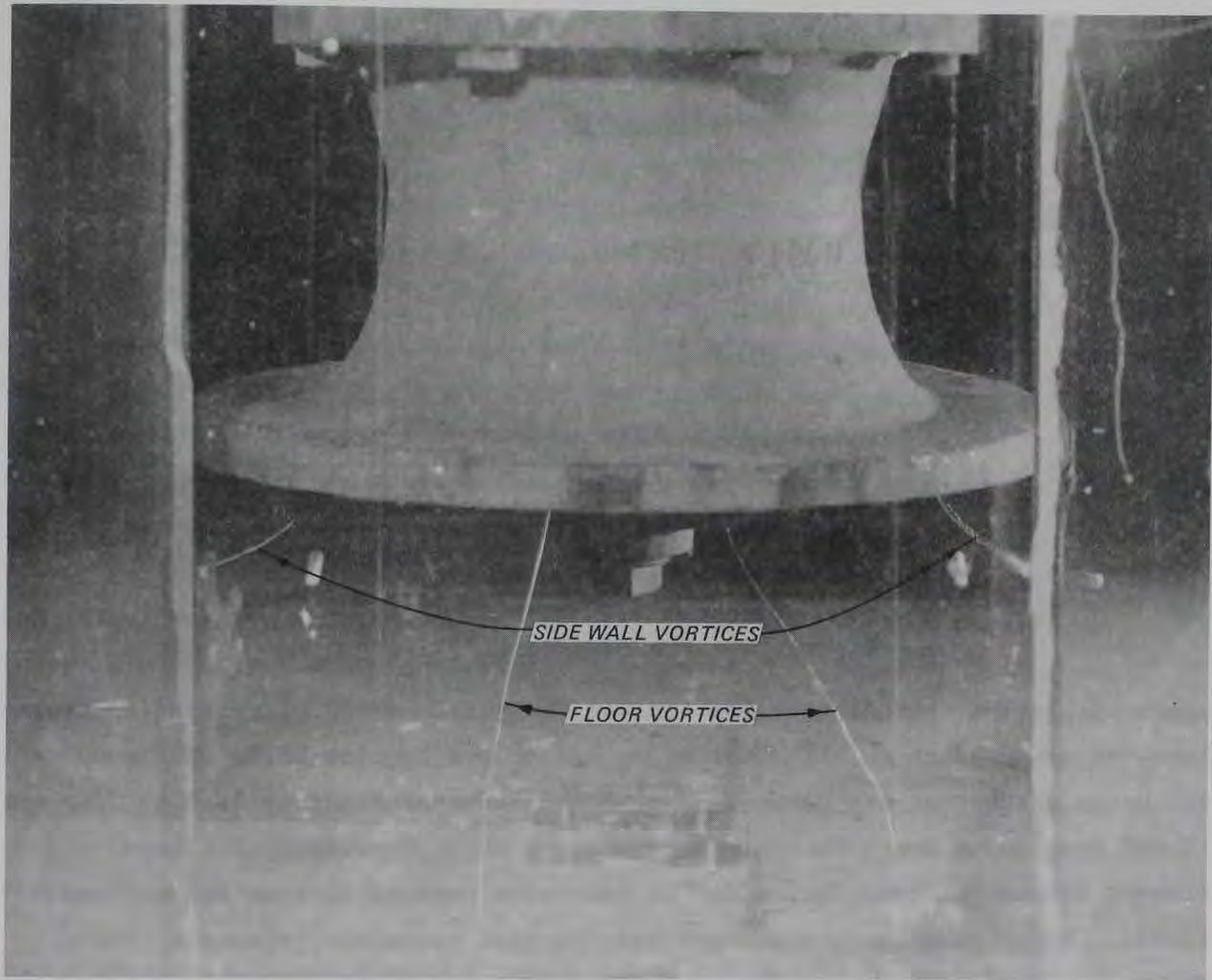


Figure 23. Submerged vortices

observed through the transparent sidewalls. The stages used in evaluation of air-entraining surface vortices are shown in Figure 21. The stages C, D, and E surface vortices are considered unacceptable.

64. Flow distribution in the approach to the sump and in the sump itself was determined by measuring current velocities with a velocity meter Pitot tube and turbine current meter. These measurements are not made for all tests but can be very helpful when a change of pattern occurs in a series of tests or if other investigation parameters indicate a necessity for them.

65. Pressure fluctuations at each pump intake were measured by a 0.25-in.-diam electronic pressure cell (Figure 24) mounted flush with the floor of the sump directly below the center line of the pump column. It has been established that pressure fluctuations greater than 4 ft are

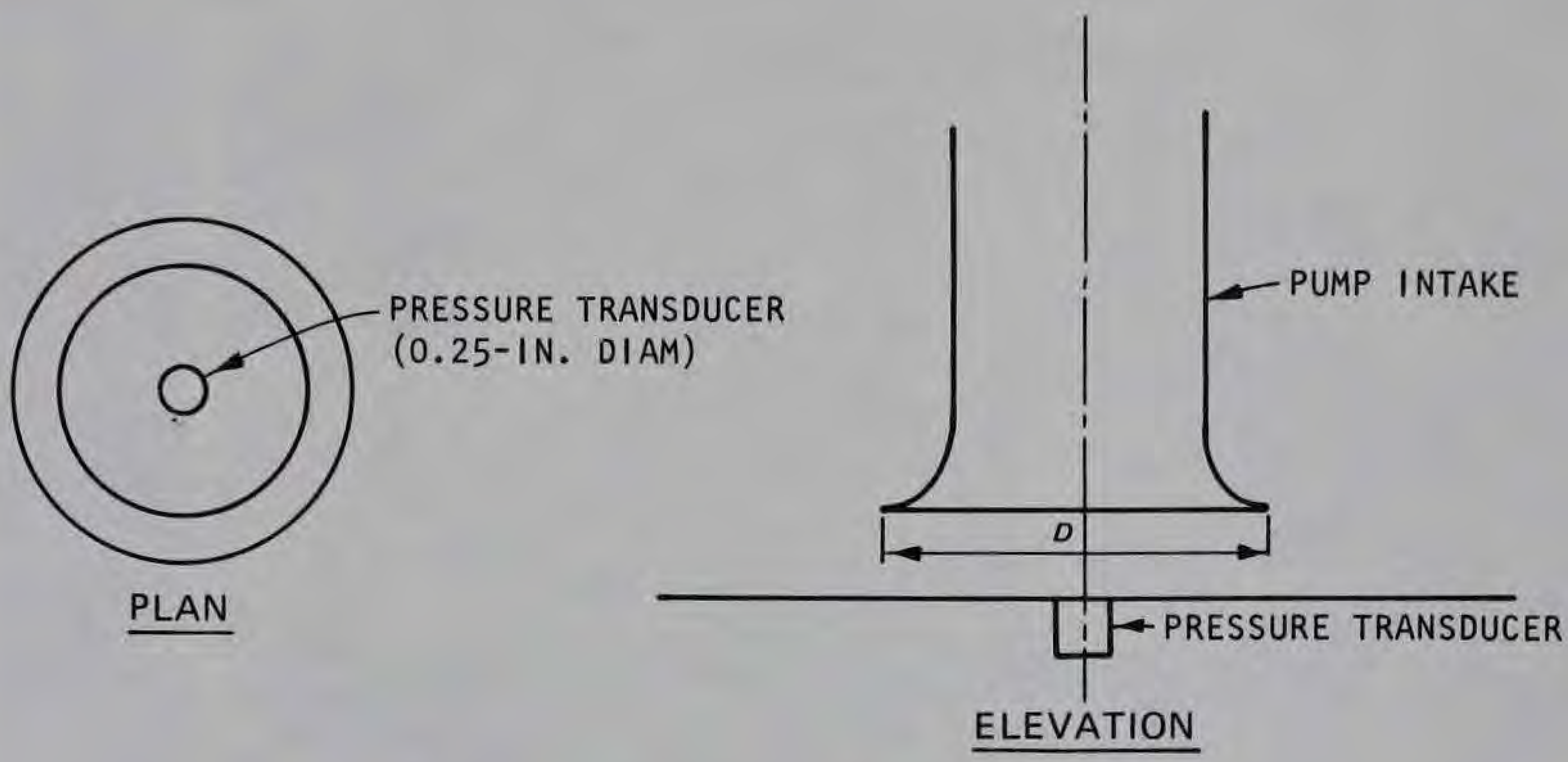


Figure 24. Pressure cell location

unacceptable. A typical test for a given design consisted of setting a water level or submergence relative to the bottom of the suction bell. The pump discharge was set at its maximum $Q/g^{1/2}D^{5/2}$ of approximately 0.60 (2,890 gpm) and reduced in various increments to approximately 0.15 gpm (lowest discharge investigated due to excessive pump vibrations and cavitation). The submergence was changed and the same procedure repeated. These tests permitted, for a given sump configuration or appendage, determination of values of various parameters relative to $Q/g^{1/2}D^{5/2}$ that preceded vortex development.

66. Many considerations are involved in the determination of which types of testing techniques should be accomplished and at what stage of testing it should be done. Many times the answers may be obvious based on experience in site-specific model testing and engineering judgment. At other times, opinions of district engineers and others with prototype experience are solicited. Sometimes unplanned trial-and-error testing provides solutions.

PART VI: SIMILARITY OF PUMP STATION MODELS

Introduction and Objectives

67. Pump station models will reproduce prototype conditions if consideration is given to the proper model size and method of model operation. The objective of this part is to provide guidance for the design and operation of pump station models. Pump station models are built geometrically similar and operated according to the Froudian criteria. This ensures that the flow distribution approaching the pump intakes will be similar in model and prototype. However, surface vortices are one of the important items of study in a pump station model and surface vortices are affected by viscous forces. The relatively greater viscous forces present in scale models can inhibit surface vortex formation in the model. A wealth of information relative to surface vortex similarity can be found in the literature, particularly literature of the past 15 years. One more study comparing surface vortices in various model sizes would be of limited value. An analysis of past surface vortex similarity work is needed to see if any general agreement can be found in achieving similarity of surface vortices in pump station models. That analysis is the first objective of this part.

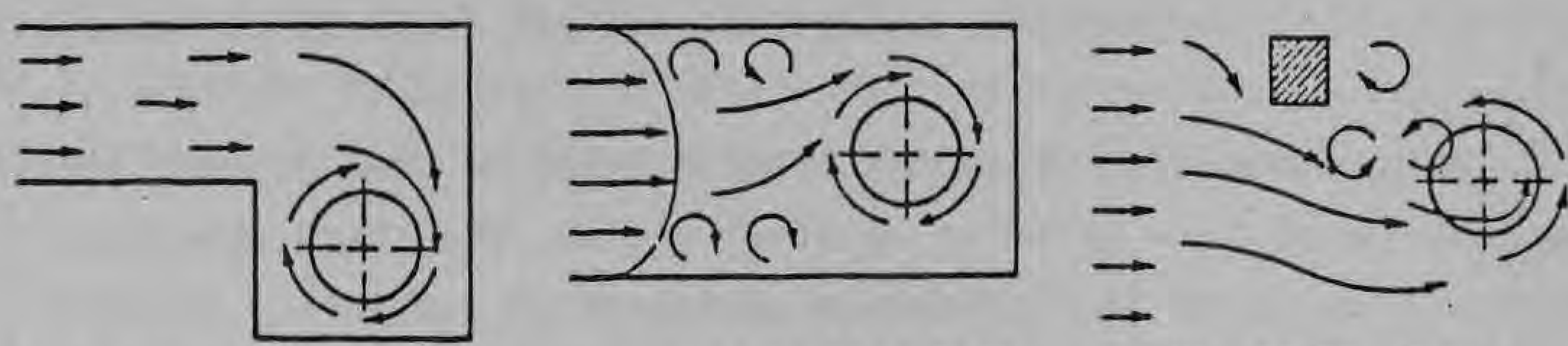
68. Submerged vortices, another important item of study in pump station models, have received little attention in past work relative to similarity between model and prototype. This lack of attention may be due to the fact that submerged vortices are difficult to detect in prototype installations. The second objective of this part is to evaluate pertinent literature on submerged vortex similarity and to conduct a model investigation of various model pump sizes and compare the occurrences of submerged vortices in the different sizes. This study is applicable to vertical wet pit pumps of the propeller type.

69. Swirl is a third important item of study in pump station models that has been shown to be affected by model scale. The third objective of this part is a review of the literature pertinent to similarity of swirl.

70. References on pump station modeling cited in this report are provided at the end of this report; references not cited in this report are included in the Bibliography.

Surface Vortices: Analysis of Pertinent Literature

71. Similarity of surface vortices has been studied extensively to define the magnitude of the scale effects and the size of model or method of operation required to obtain the best similarity between model and prototype. To offset the viscous scale effects, some investigators have used geometrically similar models but have operated these models at velocities greater than that required by the Froudian criteria even up to the prototype velocity. Amphlett (1978) developed a relationship between a circulation number and a radial Reynolds number that shows the effect of viscosity on vortex formation. This relationship allows determining whether a model is affected by viscous effects and how much the model Reynolds number (i.e. velocity) must be increased to achieve similarity with respect to vortex formation. Chang (1979) conducted vortex similarity tests in rectangular pump sumps and found significant scale effects with respect to formation of fully air-entraining vortices at model pump sizes less than 6 in. in diameter. A Froude-scale multiplying factor was developed that varied with floor clearance, submergence, and model size. Denny and Young (1957) reported on a limited comparison of model and prototypes that indicated similarity of air-entraining vortices is attained only when prototype velocities are used in the model. Durgin and Hecker (1978) discussed the three types of vorticity sources shown in Figure 25. In the first type, viscosity does not affect the vorticity flux to the inlet. The last two sources are influenced by viscosity and may be Reynolds number dependent. Durgin and Hecker go on to point out that the flow at the inlet itself is dependent on Reynolds number regardless of the sources of the vorticity. Durgin and Hecker used elevated model temperatures and small increases in flow rate to achieve high model Reynolds number and found that the model



I. OFFSET INTRODUCTION   II. VELOCITY GRADIENTS   III. OBSTRUCTION

Figure 25. Sources of vorticity (from Durgin and Hecker 1978; courtesy of American Society of Civil Engineers)

indicated a relatively weak vortex at normal temperatures, but strong vortices were found at elevated temperatures and flow rates. They report that a strong vortex is probably more dependent on Reynolds number than weak vortex activity. Holtorff's (1964) theoretical development of vortex flow showed that velocities in excess of those required by Froudian scaling are required for surface vortex similarity. Haindl (1959) conducted vortex similarity tests over a limited range of sizes and concluded that Froude law is not valid for vortex similarity. Iversen (1953) conducted a model-prototype comparison of an 18.25-in.-diam prototype and a 6.375-in.-diam model pump intake. The percentage of air drawn into the pump was compared, and the model percentage of air was considerably lower than the prototype. No results were presented comparing the types of vortices present in the model and prototype. Zajdlik (1977) conducted tests with pump intakes in rectangular sumps and concluded that the amount of velocity increase required to obtain similarity with respect to initiation of vortices increases with increasing length ratio as well as with decreasing submergence.

72. However, use of increased velocities in a free-surface model results in violating the criteria necessary for the proper flow distribution and circulation approaching the pump intakes. Much of the developmental work in using increased velocities was conducted in circular tanks or straight rectangular pump sumps. It is likely that increased velocities do not significantly change flow distribution for these cases. Flow distribution in relatively complex sump geometries may be distorted by increased velocities. Spurr (1980) in his discussion of a paper by Tullis (1979) presents an additional factor to be considered when using increased velocities. According to Spurr,

> "If turbulence levels in a model are artificially high, the over-all rates of diffusion could disproportionately increase. This, in turn, may hinder the initial organization of the vorticity within the upstream fluid shear layers...and prevent the formation of a vortex which may otherwise have formed, as well as to significantly reduce the ability of an already organized vortex to persist, or, even to diffuse the phenomena altogether."

73. A second method of adusting scale models to account for increased viscous effects has been proposed by Jain, Raju, and Garde (1978). Instead of using increased velocities to offset viscous scale effects, Jain, Raju, and Garde propose a factor that is used to correct the submergence predicted by the model which is operated according to the Froudian criteria. This factor

K relates the required submergence for a prototype without scale effects to the submergence predicted by a model having scale effects. K is a function of both Reynolds and Froude numbers of flow in the pipe intake (Figure 26). The investigation of Jain, Raju, and Garde was conducted in a circular tank and may not apply to complex sump geometries.

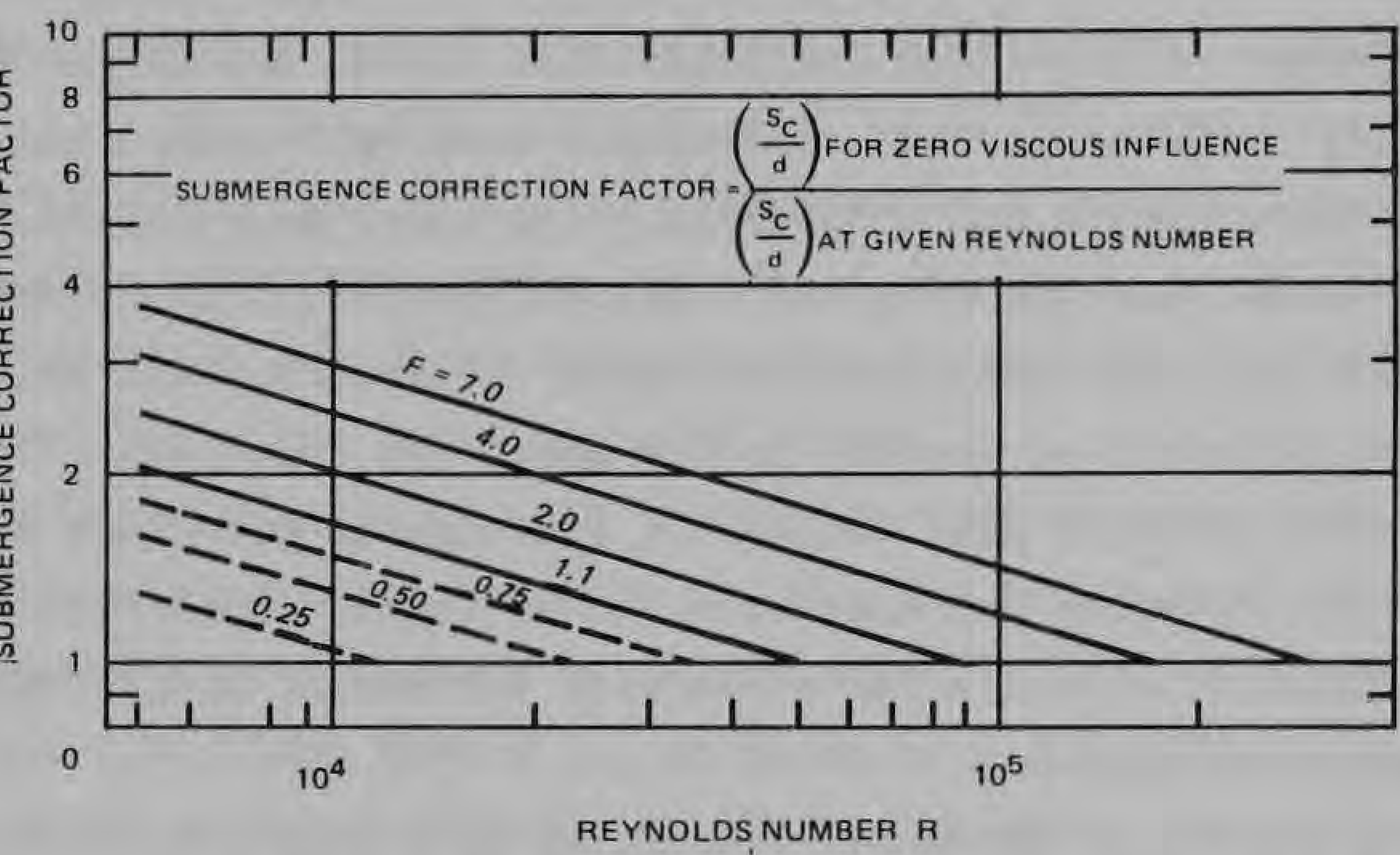


Figure 26. Variation of submergence correction factor with Reynolds number and Froude number (from Jain, Raju, and Garde 1978; courtesy of American Society of Civil Engineers)

74. The third method of accounting for scale effects in models is to find limiting criteria at which models must be built or operated to achieve similarity of surface vortices while operating at Froudian velocities; only similarity of the type of vortex is needed. The relative size of the model vortices or amount of air drawn into the intake through the vortices is rarely important in pump station modeling. Anwar (1968) reported that similarity of narrow air cores or deep dimples does not depend on radial Reynolds number R_r

$$R_r = \frac{Q}{\nu S} \tag{31}$$

where

ν = kinematic viscosity of water

S = submergence

if R_r is greater than 10^3. Anwar also reported that similarity of a strong vortex does depend on R_r. Anwar's tests were conducted in a circular tank with a vertically inverted pipe similar to a pump suction pipe. Anwar and Amphlett (1980) found that a nondimensional circulation parameter and air-core vortices formation become independent of fluid viscosity when the radial Reynolds number is greater than $3(10)^4$. Anwar and Amphlett conducted their study in a rectangular flume and included the extensive data collected by Chang (1979) whose work was also conducted in a rectangular sump.

75. Daggett and Keulegan (1974) found that surface vortex formation becomes independent of viscous effects at Reynolds number R'

$$R' = \frac{Q}{r\nu} \tag{32}$$

where r is orifice radius if R' is greater than $5(10)^4$. Daggett and Keulegan conducted their tests in a circular tank with an orifice at the bottom of the tank.

76. Hecker (1981) presented a model-prototype comparison of free-surface vortices. Of 19 projects where model studies were conducted with velocities scaled according to the Froudian criteria (where F_m, the model Froude number, equals F_p, the prototype Froude number), 5 exhibited stronger or more persistent vortices in the prototype than in the model. The remaining 14 had model and prototype vortices essentially equal. Of three projects where model studies were conducted at $F_m = 2$ to $4.5 \times F_p$, two exhibited model and prototype vortices essentially equal and one exhibited vortices stronger in the model than in the prototype. Hecker's general findings were that final intake designs developed from Froude-scale models (large enough to satisfy criteria set forth by Daggett and Keulegan (1974) and Anwar and Amphlett (1980)) were vortex-free in the prototype and those having weak vortices in the model had weak vortices in the prototype.

77. The submergence correction factor K developed by Jain, Raju, and Garde (1978) is shown to be equal to 1 (no scale effects) at a point that is dependent on both the model pipe Reynolds and Froude numbers (Figure 26). The investigation of Jain, Raju, and Garde was conducted in a circular tank with a drainpipe vertically down from the center of the tank. Blaisdell (1979), in his discussion of the paper by Jain, Raju, and Garde (1978), reported that to eliminate the effects of viscosity, models should be operated such that

$$R > 5(10)^4 F \tag{33}$$

where R and F are the Reynolds and Froude numbers of the pipe intake, respectively.

78. Pump station model studies at WES are conducted such that the pipe Reynolds number is greater than 10^5 and defined as

$$R = \frac{Vd}{\nu} \tag{34}$$

where

V = average velocity

d = pump column intake diameter (not bell diameter)

79. Summarizing these various criteria for limiting Reynolds number for surface vortex similarity yields two separate criteria. Daggett and Keulegan (1974); Jain, Raju, and Garde (1978) (for $F \leq 2$ which includes most flood-control pumping stations); Blaisdell (1979) ($F \leq 2$), and WES guidance are essentially equivalent and can be expressed as

$$R = \frac{Vd}{\nu} \text{ must be } \geq 10^5$$

The second limiting criterion that should be checked in determining model size is the radial Reynolds number as defined by Anwar and Amphlett (1980)

$$R_r = \frac{Q}{\nu S} \text{ must be } \geq 3(10)^4$$

Submerged Vortices

80. The second objective of this investigation is an evaluation of similarity of submerged vortices.

Review of literature

81. Submerged vortices can occur on the floor, sides, and backwall (Figure 21) of a pump sump. Generally, they become less severe with increasing distance between the pump and the sump boundaries. According to Tullis

(1979) the floor vortex is found in most installations. Tullis reports that when circulation is present within the sump, the floor vortex is usually strong and stable. If flow is generally uniform with little circulation, the floor vortex can be unstable or possibly two vortices might exist with opposite rotation. Tullis reports that in models, the subsurface vortices can have sufficient strength that they self-aerate by drawing air out of solution due to the low pressure at their centers. This brings up the possibility that the observance in models of subsurface vortices may depend on the concentration of dissolved gas in the water which may vary with such factors as temperature.

82. Amphlett (1978) reports that submerged vortices are generally associated with shallow submergence depth and high intake velocity. Chang and Laursen (1980) used a 45-deg floor fillet along the bottom of the backwall to reduce the potential for submerged vortices.

83. Dicmas (1978) found that a vertical splitter installed between the sump backwall and suction bell was useful for breaking up submerged vortices. A suction cone was also found to eliminate submerged vortices almost completely. Dicmas concluded that an approach velocity in excess of 2 ft/sec will encourage severe submerged vortices. Hattersley (1965) reports that subsurface vortices can be eliminated by developing a sump system having zero swirl.

84. This review of the literature has shown that submerged vortices are suspected of being detrimental to pump performance, and several methods of preventing them have been suggested by different investigators. However, the effects of scale on similarity of subsurface vortices is largely unknown.

Model investigation

85. A series of tests were undertaken to compare the occurrence of submerged vortices in various size models. Suction pumps with column diameters of 0.67 and 0.35 ft were used having suction bell diameters of 1.29 and 0.68 ft, respectively. The test facility for the 1.29-ft suction pump is shown in Figure 1a. The test facility for the 0.68-ft suction pump is shown in Figure 27. Both facilities resulted in essentially zero swirl at the pump intakes. Sump and suction pump details are shown in Figure 28. Water was recirculated in the flumes by means of pumps, and discharges were measured by venturi and elbow meters. Submergence was varied from a minimum of 0.5D above the suction bell to a maximum of 2.0D above the suction bell. Backwall,

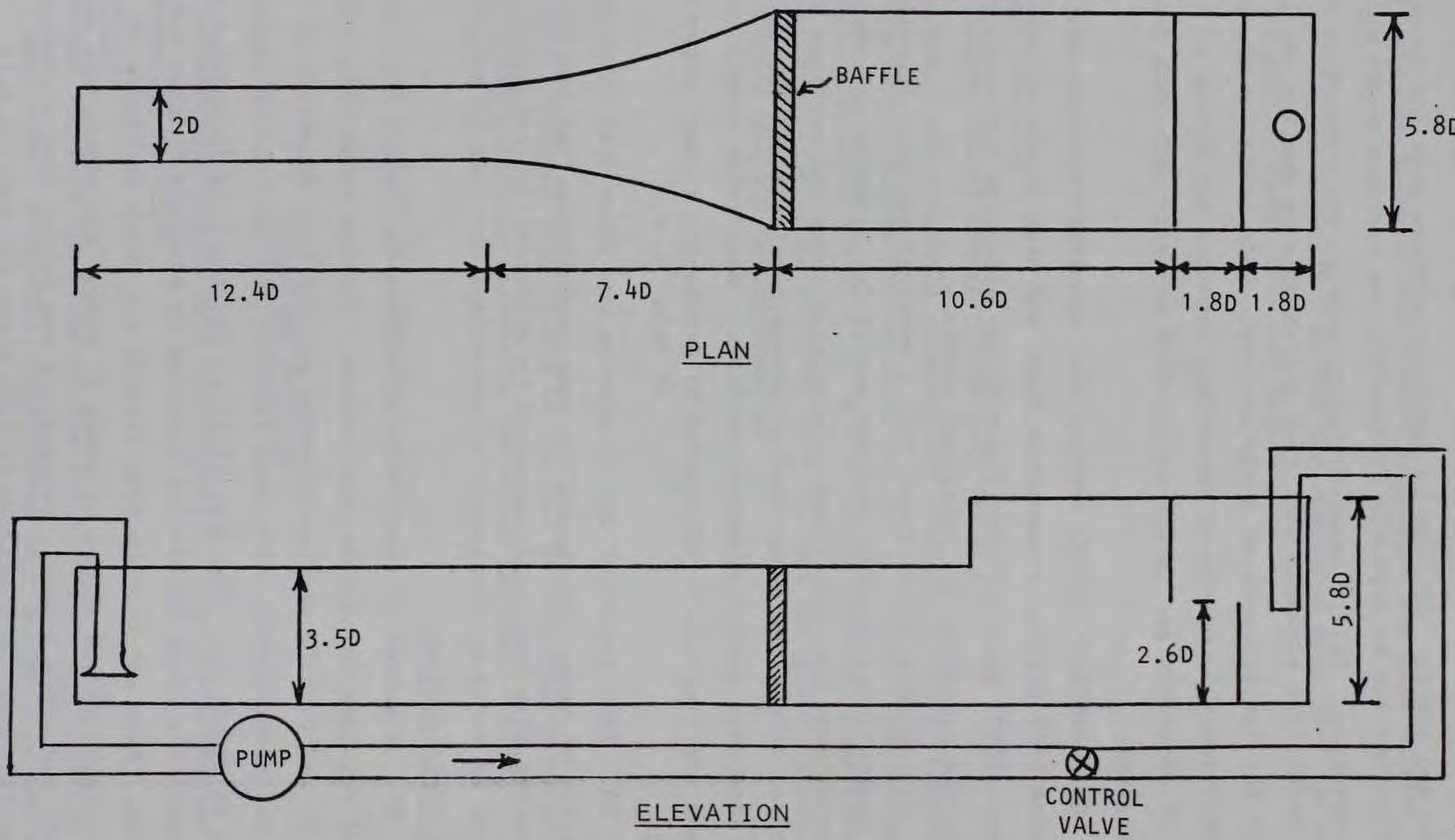
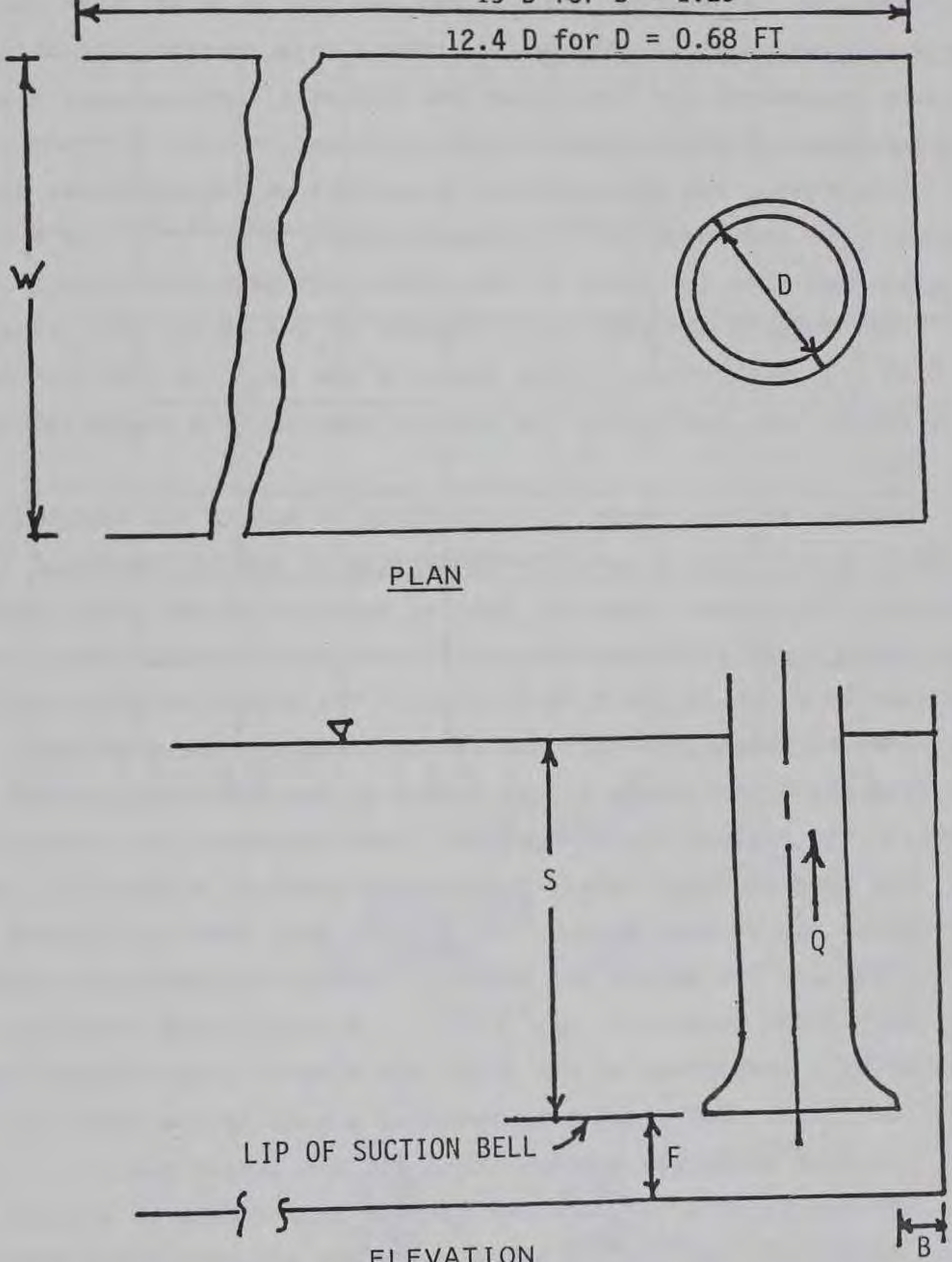


Figure 27. Test facility for 0.68-ft bell diameter



D suction bell diameter
S submergence at lip of suction bell
Q distance
W sump width = 2D
F distance from floor - 0.33D
B distance from backwall = 0.05D

Figure 28. Sump and suction pump details

sidewall, and floor clearances were chosen to ensure the formation of backwall and floor vortices. Discharge in the model was initially set high and gradually decreased until no submerged vortices were present. In this manner, the incipient conditions for both floor and backwall vortices were determined for each pump size and for a range of submergences.

86. Submergence and discharge are presented as dimensionless parameters by the terms S/D and $Q/g^{1/2}D^{5/2}$, respectively. $Q/g^{1/2}D^{5/2}$ is a dimensionless parameter that is useful in describing the pump discharge.

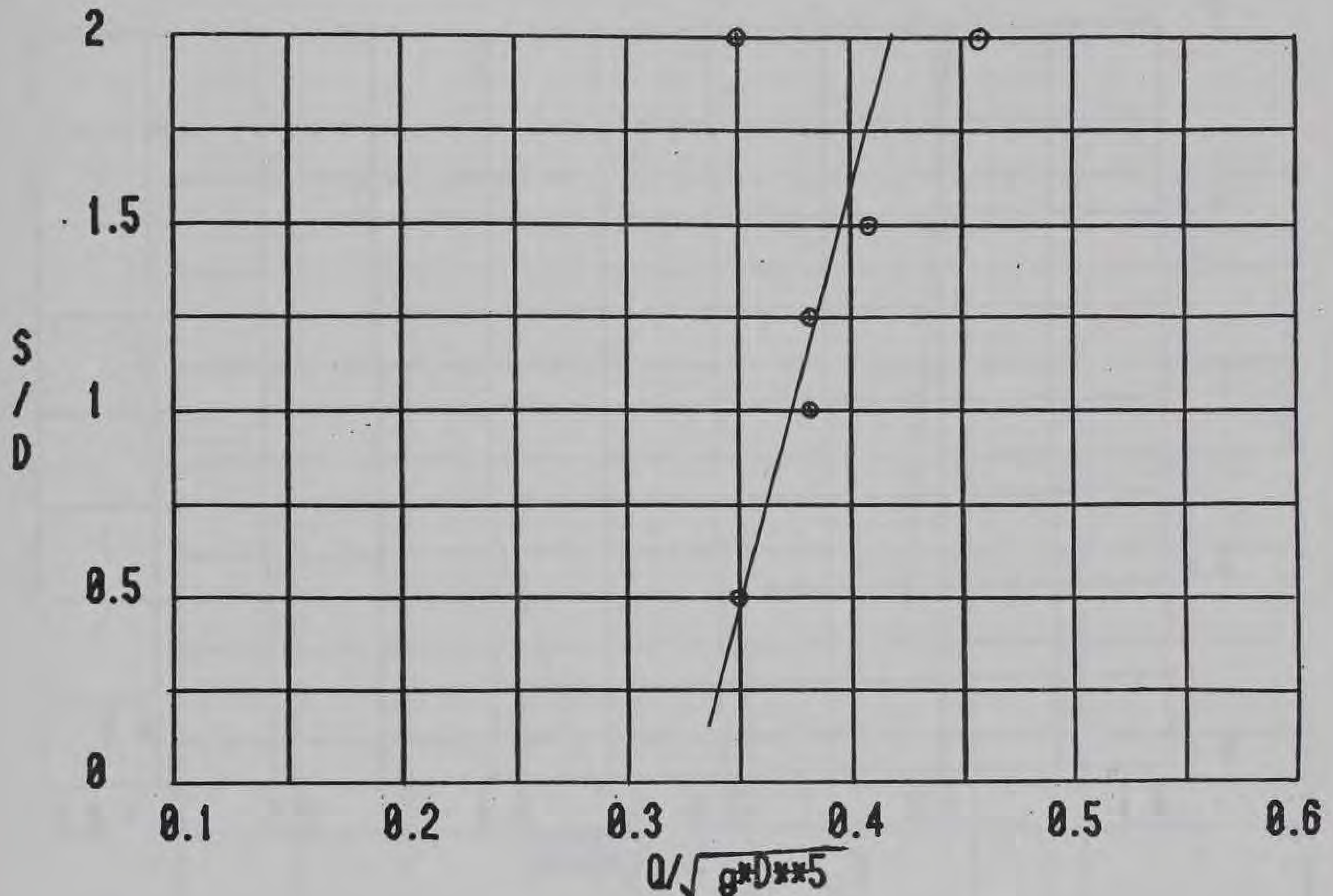
87. Test results are plotted in Figures 29 and 30 for bell diameters of 1.29 and 0.68 ft, respectively. Also shown is the best-fit line for each pump size. A straight line assumption was made to simplify the comparison of the different sizes.

88. During testing, large concentrations of minute air bubbles occurred in the 0.68-ft model; only a small concentration of bubbles occurred in the 1.29-ft model. The reason these air bubbles occurred in the small flume and not in the large flume is likely due to the more rapid recirculation of the smaller volume of water in the 0.68-ft model. The effect of these air bubbles on formation of the submerged vortices was not known. Therefore tests were conducted with the 0.68-ft pump intake placed in the facility used for the 1.29-ft pump. The appropriate sump width, floor clearance, and backwall clearance were used in these tests; results are shown in Figure 31. Significant differences are present between the 0.68-ft pump with and without the minute air bubbles. The minute air bubbles resulted in submerged vortices forming at much lower values of $Q/g^{1/2}D^{5/2}$. A significant variation due to size is shown by a comparison of the 0.68- and 1.29-ft pumps without bubbles present in the flume. The small pump required a much larger value of $Q/g^{1/2}D^{5/2}$ to form submerged vortices than did the larger pump.

89. Dye was injected beneath the 1.29-ft pump intake to analyze flow patterns at values of $Q/g^{1/2}D^{5/2}$ below which the air-core floor vortices occur. The dye indicated that the rotating core of fluid is present at very low values of $Q/g^{1/2}D^{5/2}$ even with essentially no swirl in the pump intake.

Swirl

90. Swirl is a general term referring to the rotation of flow as it travels up the pump column. Indicated swirl is quantified by measuring the

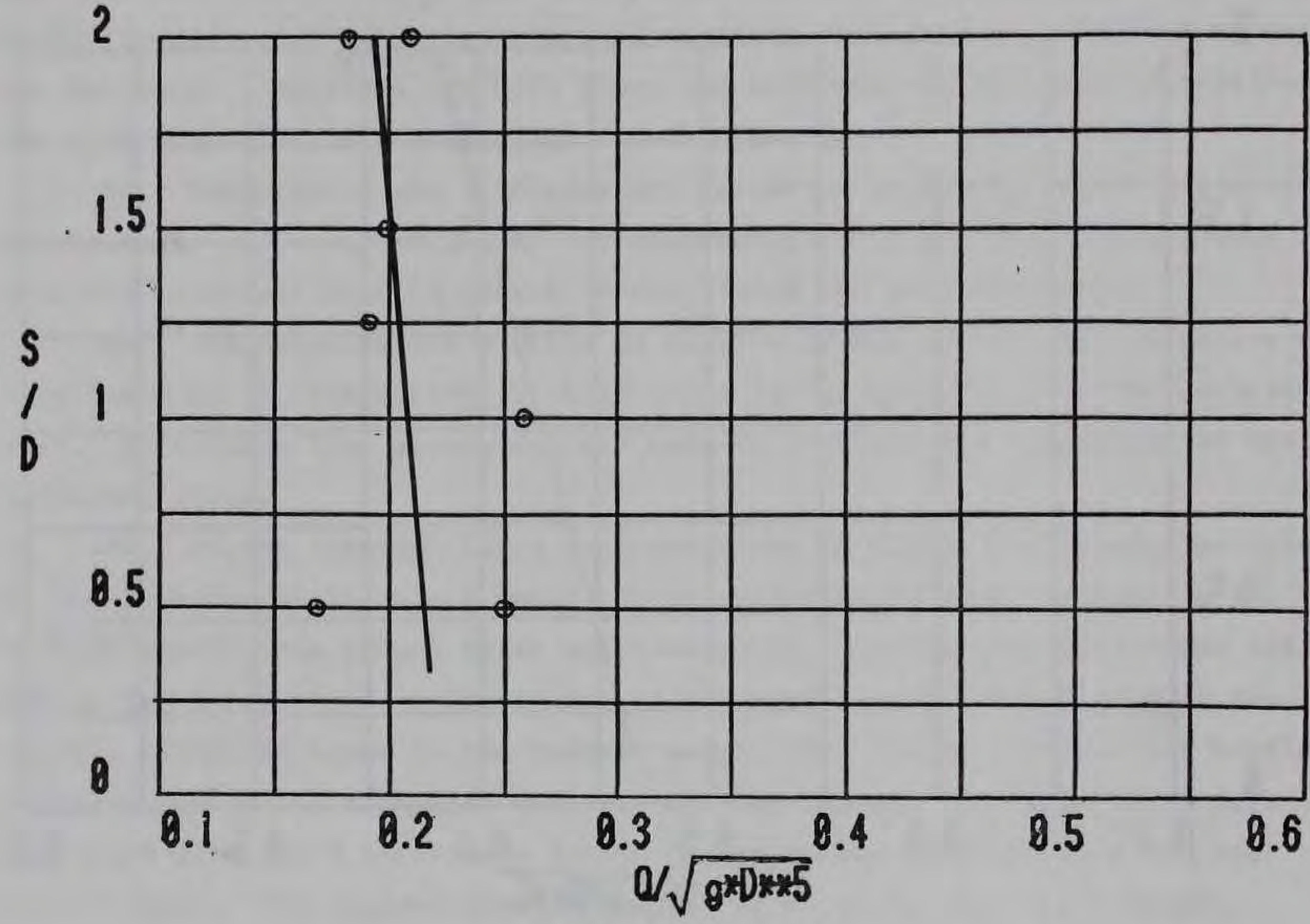


BASIC DATA

Q/√(g*D**5)	S/D
0.35	0.50
0.38	1.00
0.41	1.50
0.35	2.00
0.35	0.50
0.38	1.25
0.46	2.00

a. Floor

Figure 29. Submerged vortices, D = 1.29 ft , incipient vortices (Continued)

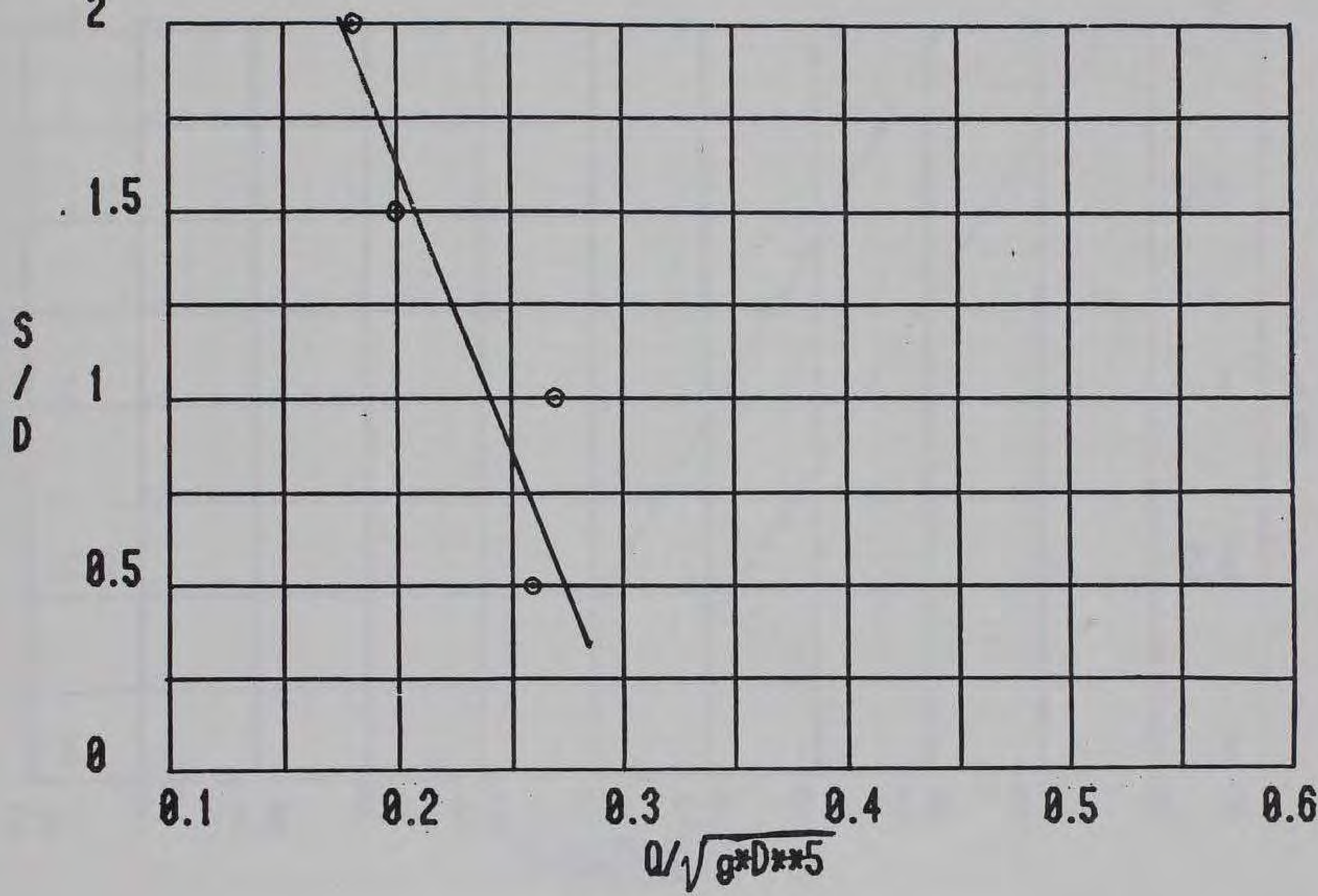


BASIC DATA

Q/√g*D**5	S/D
0.25	0.50
0.26	1.00
0.20	1.50
0.18	2.00
0.17	0.50
0.19	1.25
0.21	2.00

b. Backwall

Figure 29. (Concluded)

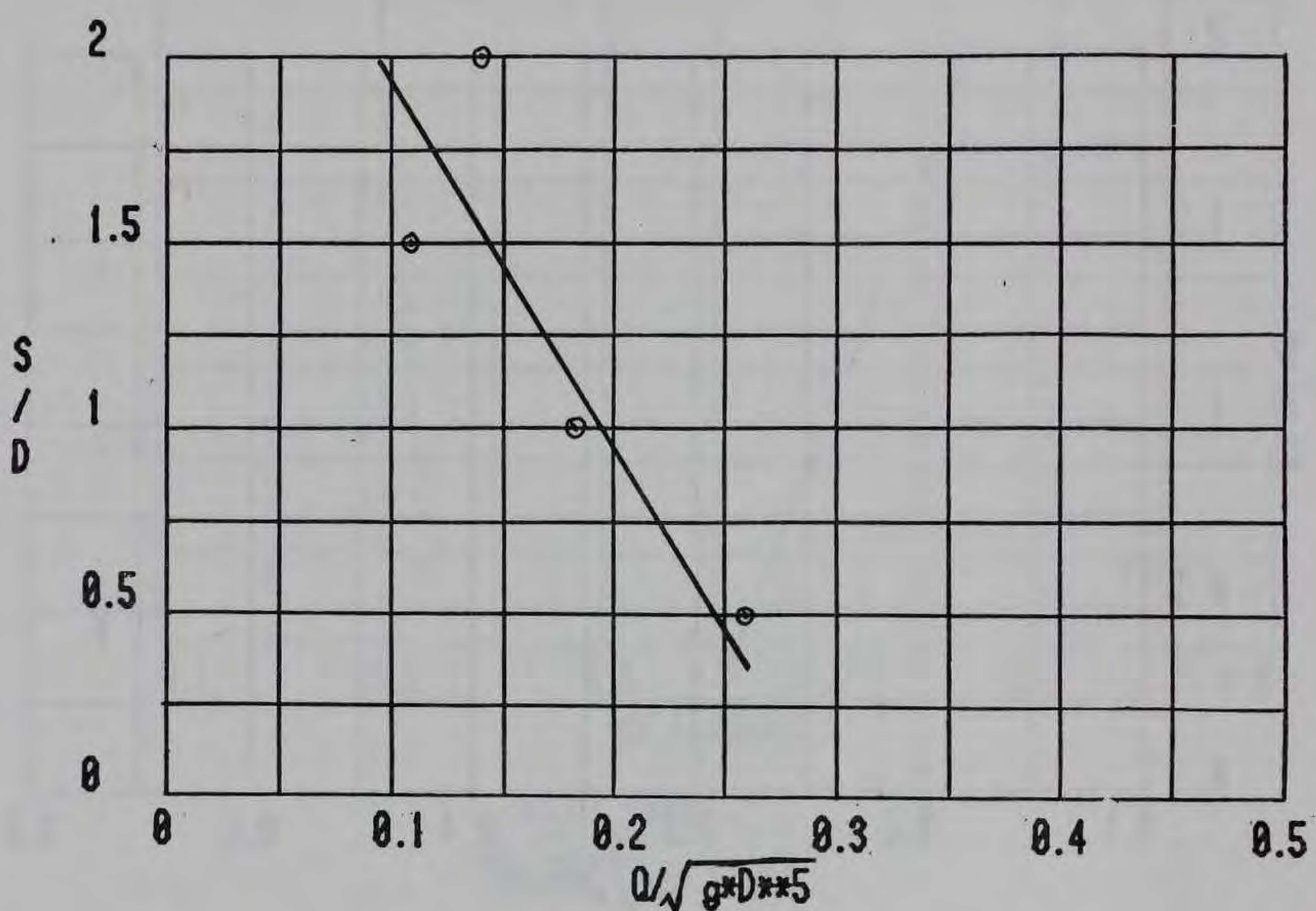


BASIC DATA

Q/√g*D**5	S/D
Ø.26	0.50
Ø.27	1.00
Ø.20	1.50
Ø.18	2.00

a. Floor

Figure 30. Submerged vortices, with air bubbles; D = 0.68 ft , incipient vortices (Continued)

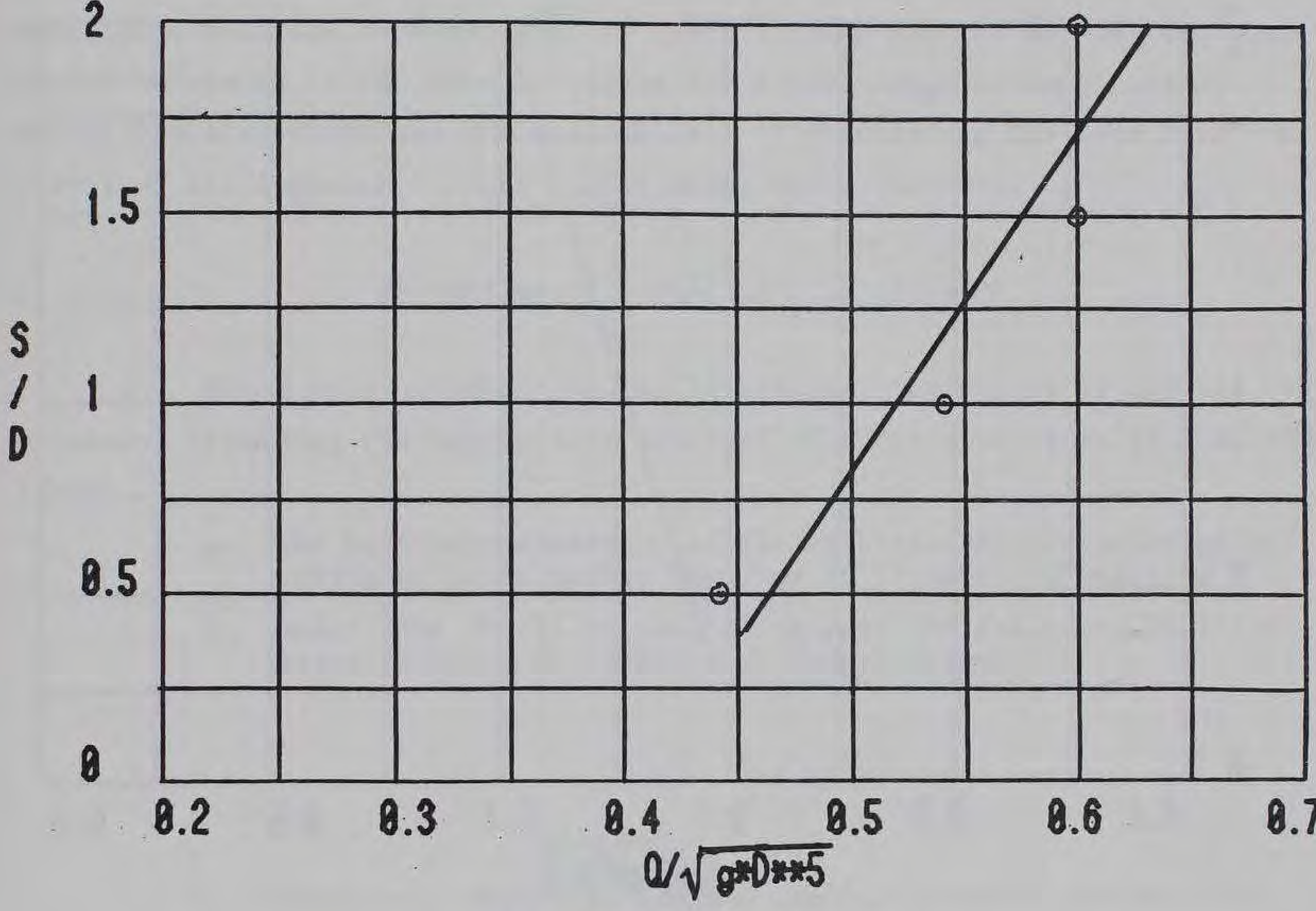


BASIC DATA

Q/√ g*D**5	S/D
0.26	0.50
0.18	1.00
0.11	1.50
0.14	2.00

b. Backwall

Figure 30. (Concluded)

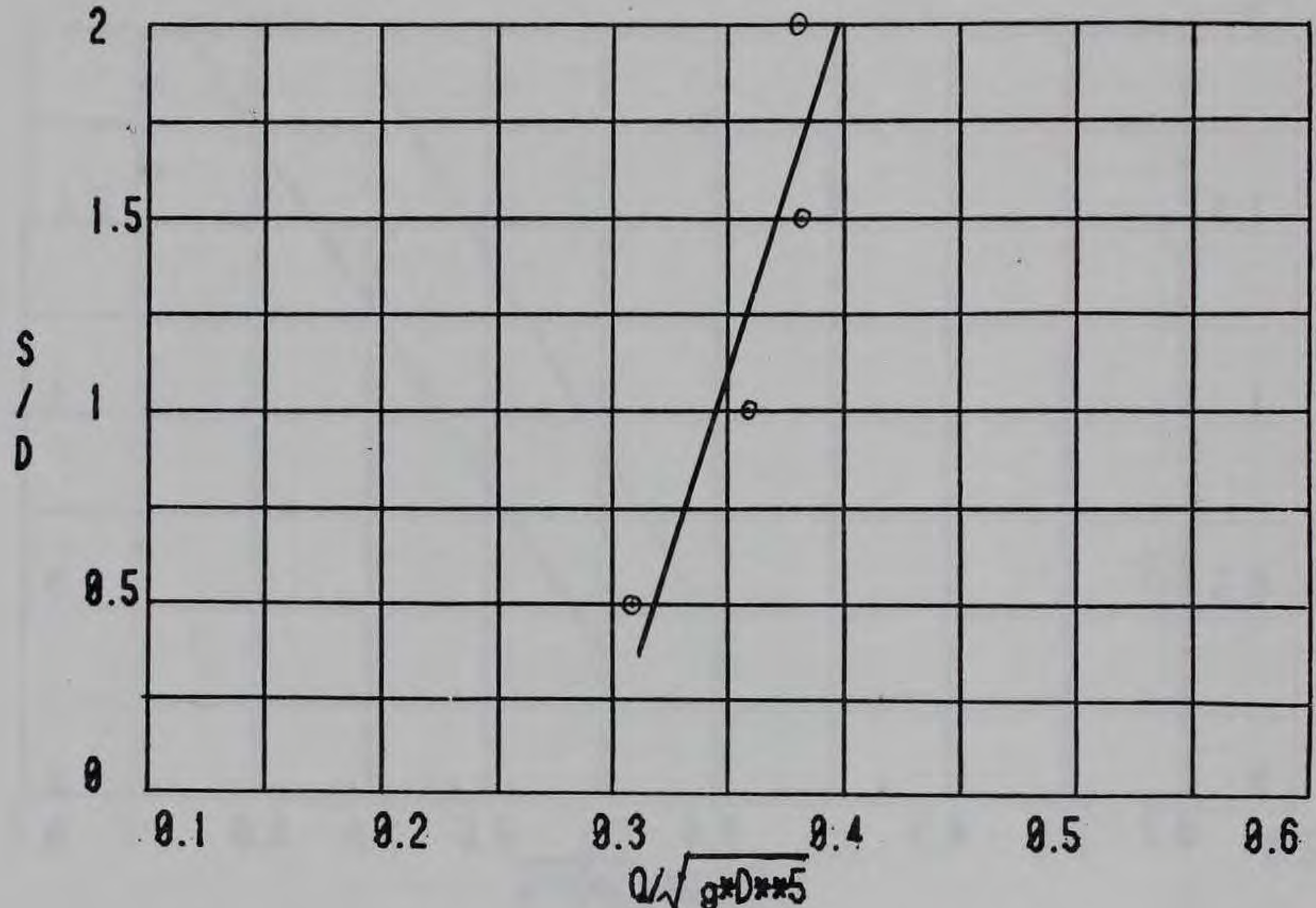


BASIC DATA

Q/√g*D**5	S/D
0.44	0.50
0.54	1.00
0.60	1.50
0.60	2.00

a. Floor

Figure 31. Submerged vortices, without air bubbles; D = 0.68 ft , incipient vortices (Continued)



BASIC DATA

Q/√g*D**5	S/D
Ø.31	Ø.5Ø
Ø.36	1.ØØ
Ø.38	1.5Ø
Ø.38	2.ØØ

b. Backwall

Figure 31. (Concluded)

rotation of a zero-pitch vane placed inside the pump column. Hattersley (1965) found that swirl in a pump station model is accurately reproduced only when the model exceeds a critical value of the parameter $R\sqrt{f}$ where R is the model Reynolds number for the approach channel and f is the friction factor for the model approach channel walls. Hattersley's work was the only work found relative to similarity of swirl in pump station models, but recommended values of $R\sqrt{f}$ were not given for a full range of model sizes. Hattersley also discusses the desirability of maintaining the same friction factor of the approach channel in the model and prototype.

Discussion of Results and Conclusions

91. Based on examination of the literature, the following results are presented regarding the appropriate modeling of surface vortices in pump stations:

a. The best representation of flow distribution is achieved by utilizing large models operated at Froudian velocities.

b. Model size should be checked against the following limiting criteria based on intake size and velocity:

$$R = \frac{Vd}{\nu} > (10)^5$$

c. Model size should be checked against criteria developed by Anwar and Amphlett (1980)

$$R_r = \frac{Q}{\nu S} \geq 3(10)^4$$

d. Dimples and vortices with narrow air cores are less affected by scale effects than are fully air-entraining vortices.

e. Increased velocities may significantly distort flow patterns and possibly inhibit vortex formation (Spurr 1980). Their use should include measured velocity distributions to show that flow patterns are not altered at exaggerated velocities.

92. A search of the literature reveals that no information is available relative to modeling and scale effects of submerged vortices. The following conclusions are presented based on this model investigation of submerged vortices:

a. The presence of minute air bubbles in the flow had a significant effect on the formation of submerged vortices. The presence of the air bubbles may be associated with high concentrations of dissolved air in the water. Submerged vortices in the 0.68-ft pump with air bubbles occurred at much lower $Q/g^{1/2}D^{5/2}$ than compared with either the larger 1.29-ft pump or the 0.68-ft pump without air bubbles.

b. A significant variation due to model size is present. Comparison of the 0.68-ft pump without the air bubbles and the 1.29-ft pump shows incipient submerged vortices at much larger $Q/g^{1/2}D^{5/2}$ in the smaller model. No evidence is available that shows that even the 1.29-ft pump accurately reproduces submerged vortices in larger prototypes. It is safe to say that if the 0.68-ft pump (which is close to the minimum size used in pump station models) will not reproduce the submerged vortices in the 1.29-ft pump, then the 0.68-ft pump is not representative of submerged vortices in large prototype pumps. This deviation with model size is not surprising. Air-core submerged vortices are the result of a localized low-pressure zone that brings air out of solution in scale models and may be strong enough to form vapor cavities in large models and the prototype. This low pressure will decrease with an increase in model size. The absolute pressure at which air comes out of solution or at which vapor cavities form will not change with model size. From this analysis, it is seen that similar flow conditions in two different size models can easily produce air-core submerged vortices in the larger model that are not present in the smaller model. This leads to the possibility that there is no limiting model size which can be defined that is similar to the prototype with respect to incipient air-core submerged vortices.

c. Dye injections show that the rotating core of fluid is present at low $Q/g^{1/2}D^{5/2}$ in sump installations where swirl is essentially zero.

d. Pump station modeling should attempt to minimize the strength and occurrence of organized submerged vortex motion as indicated by dye injection. The criteria of no visible air-core submerged vortices should not be used.

93. Swirl is another item of study in pump station models. Hattersley defines a parameter that can be used to determine if swirl is accurately reproduced. However, recommended values for a full range of model sizes are not available.

PART VII: PUMP INTAKE LOCATION

Objective

94. Tests were conducted to determine the optimum pump intake (suction bell) location relative to distance from backwall, sidewall, and floor that would permit the lowest submergence and maintain satisfactory operation without surface or submerged vortices.

Test Facility

95. The test facility was modified for the pump location tests. The modifications consisted of constructing a rectangular pump bay 24.0 ft long and 2.6 ft wide for pump 1. The rectangular approach to pump 1 was designed to provide uniform approach flow and permit testing of various discharges and submergences with the pump intake located various distances from the backwall, sidewall, and floor.

Typical Test

96. A typical test for a given pump location consisted of setting a maximum submergence S of 3.2 ft (2.48D) relative to the bottom of the suction bell. The pump discharge was set at its maximum value of approximately 2,895 gpm ($Q/g^{1/2}D^{5/2} = 0.6$). The head pressure on the pump was increased in increments by closing a value in the discharge line. Vortexing conditions were identified visually at the corresponding decrements in discharge. The submergence was lowered in decrements and the procedure was repeated for each level of submergence. The tests for a given pump location allowed definition of flow conditions that induced submerged and surface vortices.

Distance from Bell to Floor

97. The distance from the bell to the floor F was investigated with the bell located 0.05D, 0.25D, 0.50D, and 1.50D from the backwall.

Surface vortices

98. Critical flow rates $Q/g^{1/2}D^{5/2}$ for surface vortices are shown in Figures 32-35. The curves in Figures 32-35 indicate that for bell distances from the backwall B of 0.05D, 0.25D, and 0.50D and various submergences S, the bell distance from the floor has an insignificant effect on the development of surface vortices. With the bell located 1.50D from the backwall and various distances from the floor, the curves in Figure 35 indicate an erratic pattern in the development of surface vortices.

Backwall vortices

99. The critical flow rates $Q/g^{1/2}D^{5/2}$ for backwall vortices are shown in Figures 36-38. The plots indicate that backwall vortices are not significantly affected by varying the bell distance from the floor.

Floor vortices

100. The critical flow rates for floor vortices are shown in Figures 39-42. The plots indicate that for distances from the backwall of 0.05D, 0.25D, and 0.50D and given submergences, the floor vortices decrease as the distance from the floor increases. For a distance of 1.50D from the backwall, the bell distance from the floor has less effect on the tendency for formation of floor vortices.

Sidewall vortices

101. Sidewall vortices occurred only at the minimum submergence investigated (S = 0.47D). The plot in Figure 43 indicates an increase in the tendency for sidewall vortices as the distance from the floor increases.

Distance from Bell to Backwall

102. The distance from the bell to the backwall B was investigated with the bell located 0.25D, 0.33D, 0.50D, and 0.66D from the floor.

Surface vortices

103. The critical flow rates for surface vortices are shown in Figures 44-47. The plots indicate that for a given distance from the floor, the tendency for surface vortices increases as the suction bell is moved from 0.05D to 0.50D from the backwall. As the bell is moved farther than 0.50D from the backwall, the plots indicate less tendency for development of surface vortices.

Backwall vortices

104. The critical flow rates for backwall vortices are shown in Figures 48-51. Figures 48 and 51 indicate that with the pump located 0.25D or 0.66D from the floor, the tendency for backwall vortices decreases as the pump is moved away from the backwall. Figures 49 and 50 indicate that with the pump bell located a distance of 0.33D or 0.50D from the floor and 0.25D from the backwall, there was less tendency for backwall vortices.

Floor vortices

105. Floor vortices are not significantly or consistently affected by varying the distance from the pump intake to the backwall as indicated by the random data patterns in Figures 52-55.

Sidewall vortices

106. Sidewall vortices occurred only at the minimum submergence investigated (0.47D) with the suction bell located 0.50D from the backwall and either 0.50D or 0.66D from the floor. The data points obtained with the bell located various distances from the floor are presented in Figures 56-58.

Pump Bay Width

107. The pump intake was located 0.50D from the floor and 0.25D from the backwall, and tests were conducted to determine the most feasible pump bay width W for the approach to the pump intakes.

Surface vortices

108. The plots in Figure 59 indicate that surface vortices are not significantly affected by bay width for submergences equal to 1.26D and 2.02D. The tendency for surface vortices decreases as submergence increases.

Backwall vortices

109. The critical flow rates, $Q/g^{1/2}D^{5/2}$, for backwall vortices are shown in Figure 60. For a submergence of 0.47D the critical submergence increases at a significant rate for values of W/D greater than 2.00 (Figure 60).

Floor vortices

110. The critical flow rates for floor vortices are shown in Figure 61, which indicates that the critical flow rate increases as the bay width, W/D, increases from 1.5 to 3.0.

Sidewall vortices

111. Sidewall vortices occurred at bay width equal to 1.5D and did not occur for bay widths equal to or greater than 2.0D (Figure 62).

Discussion

Distance from bell to floor

112. Results of tests indicate that surface, backwall, and sidewall vortices are not significantly affected by varying the distance from the pump intake to the floor. Floor vortices are affected by distance from pump intake to the floor. The plots in Figures 39-41 indicate that floor vortices will be reduced to a minimum if the pump intake is located 0.50D from the floor.

Distance from bell to backwall

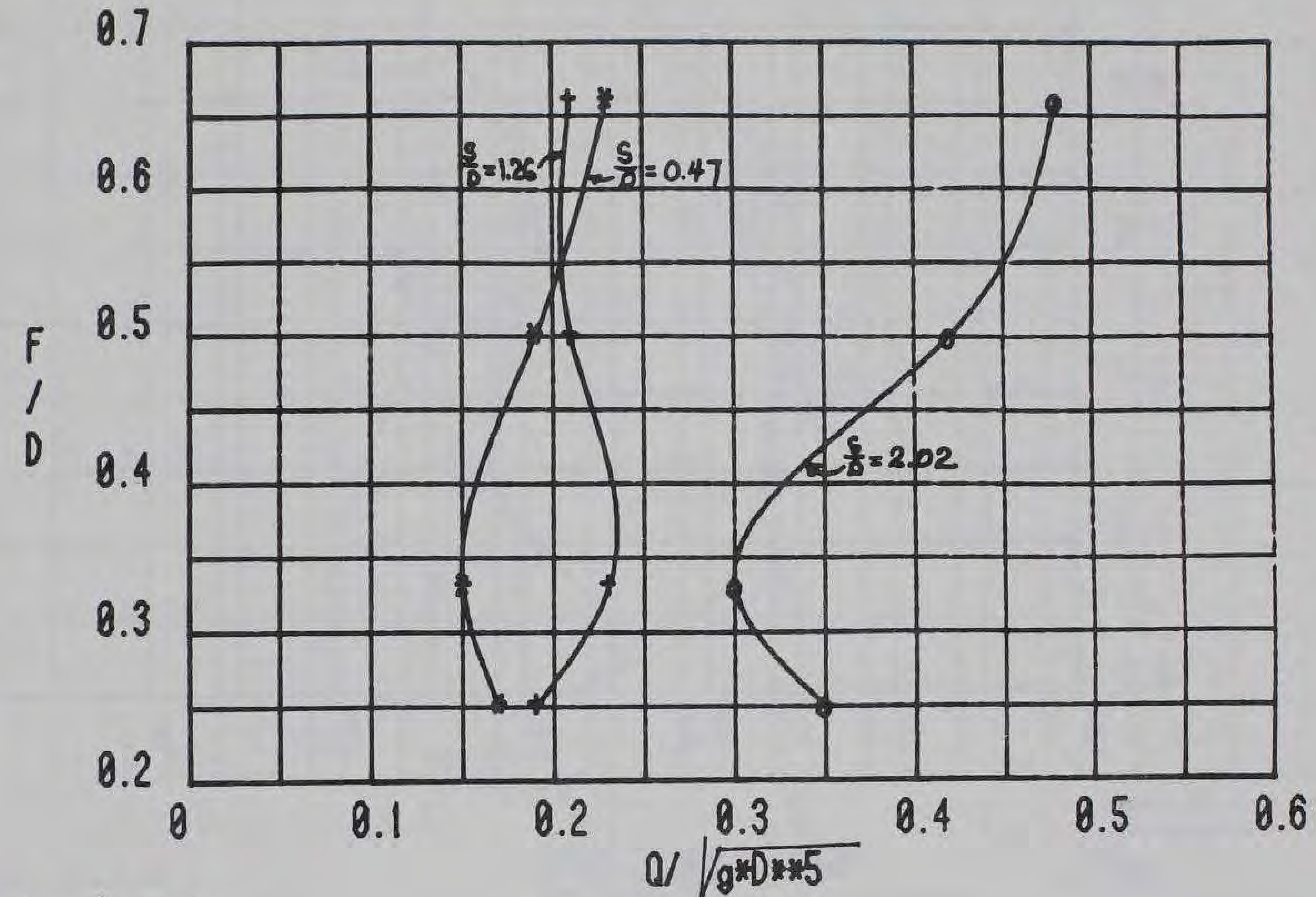
113. Floor and sidewall vortices are not significantly affected by distance from the pump intake to the backwall. Surface vortices increase as the pump is moved from 0.05D to 0.50D from the backwall. Backwall vortices tend to decrease as the pump is moved away from the backwall. With the pump intake located 0.50D from the floor (0.50D from the floor is recommended in paragraph 112), the optimum distance from the suction bell to the backwall is 0.25D.

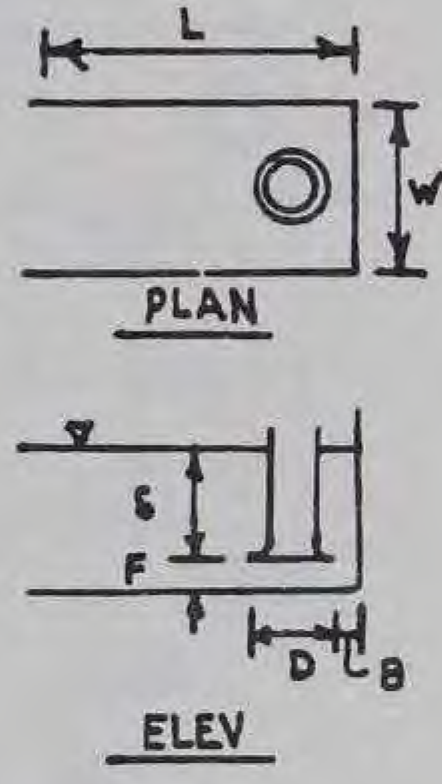
Pump bay width

114. Test results indicate that surface vortices are not significantly affected by varying the bay width between 1.5D and 2.5D. A pump bay width of 2.0D is recommended due to the tendency for backwall, floor, and sidewall vortices to increase significantly for bay widths less than 2.0D.

115. A pump intake should be located as follows:

Distance from backwall	B = 0.25D
Distance from floor	F = 0.50D
Pump bay width	W = 2.00D



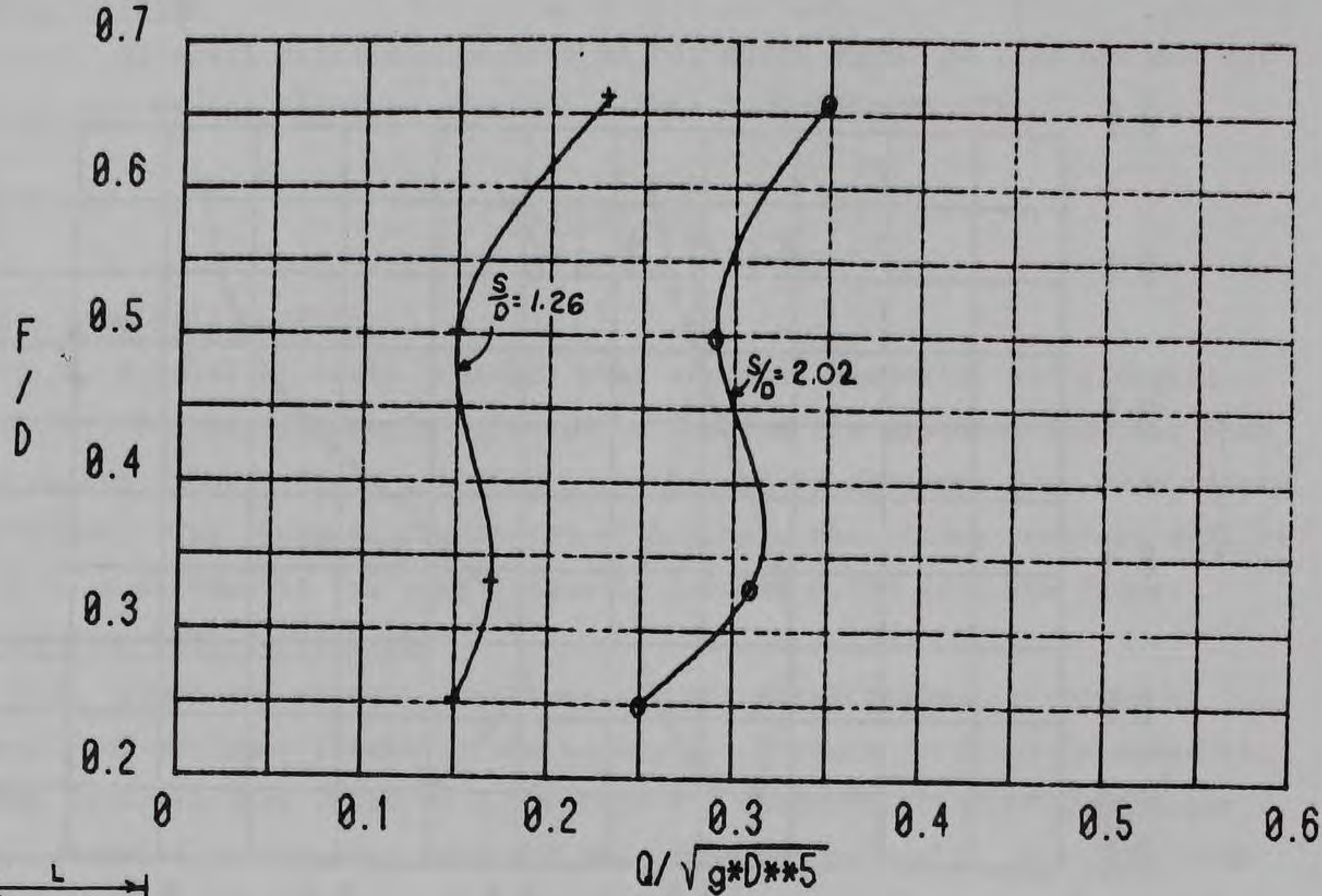


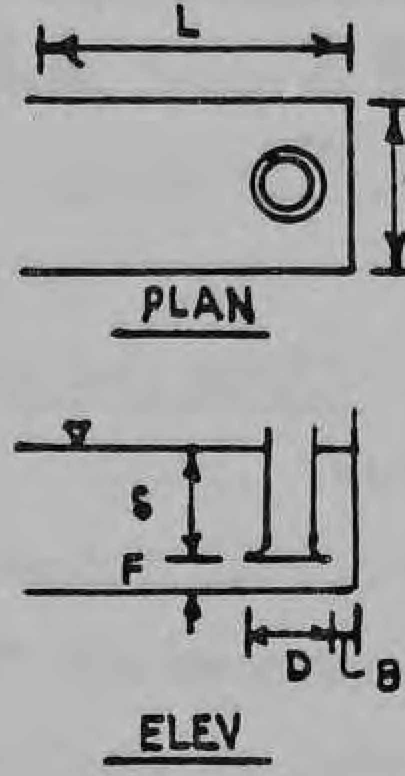
TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	F/D	S/D
*	0.17	0.25	0.47
*	0.15	0.33	0.47
*	0.19	0.50	0.47
*	0.23	0.66	0.47
+	0.19	0.25	1.26
+	0.23	0.33	1.26
+	0.21	0.50	1.26
+	0.21	0.66	1.26
o	0.35	0.25	2.02
o	0.30	0.33	2.02
o	0.42	0.50	2.02
o	0.48	0.66	2.02

Figure 32. Distance from floor versus flow rate, surface vortices, incipient stage C vortex (propeller pump), B/D = 0.05





TEST CONDITIONS

D = 1.29 FT

L = 18.6 D

W = 2.0 D

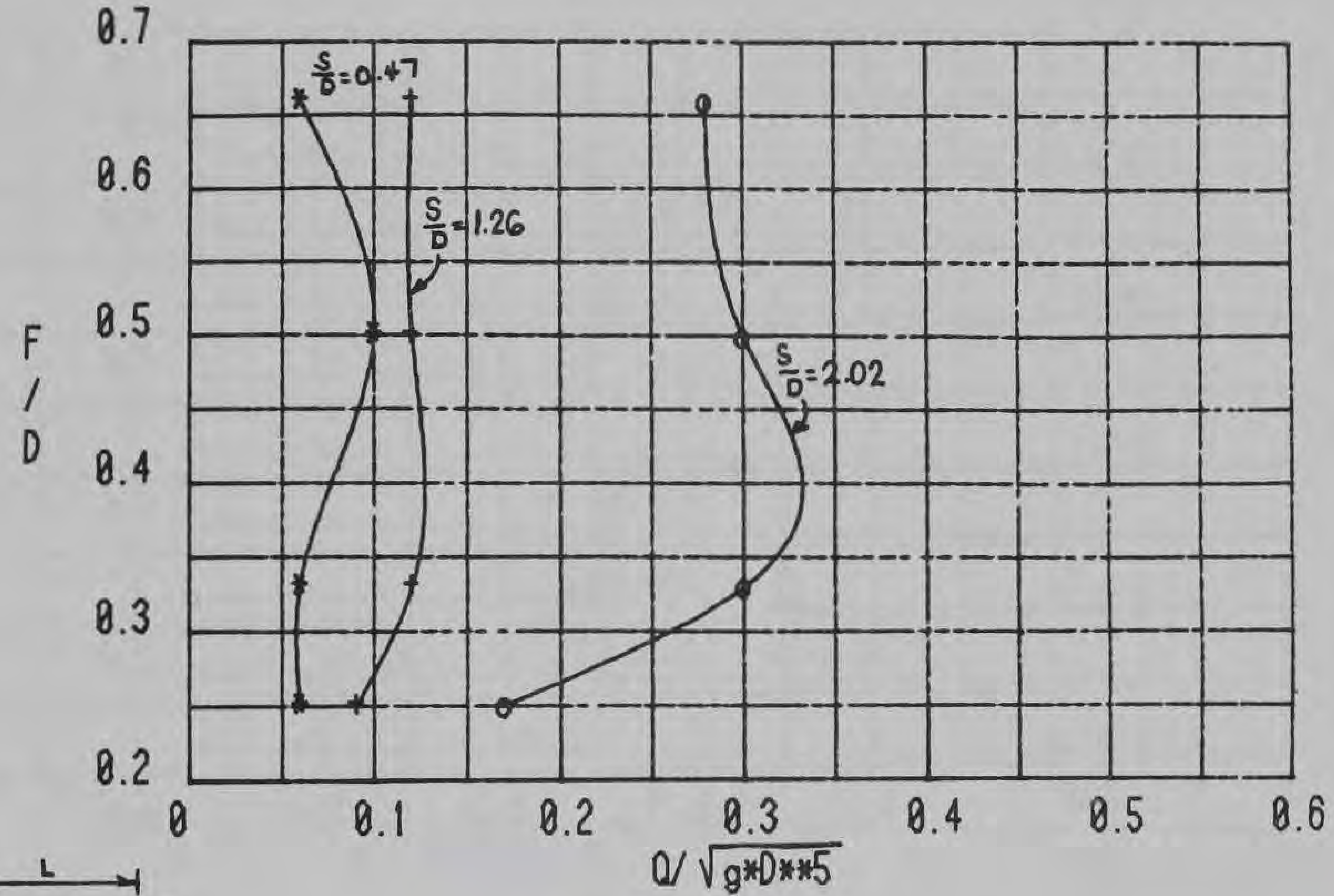
— VORTICES WERE OBSERVED AT A MINIMUM PERMISSIBLE

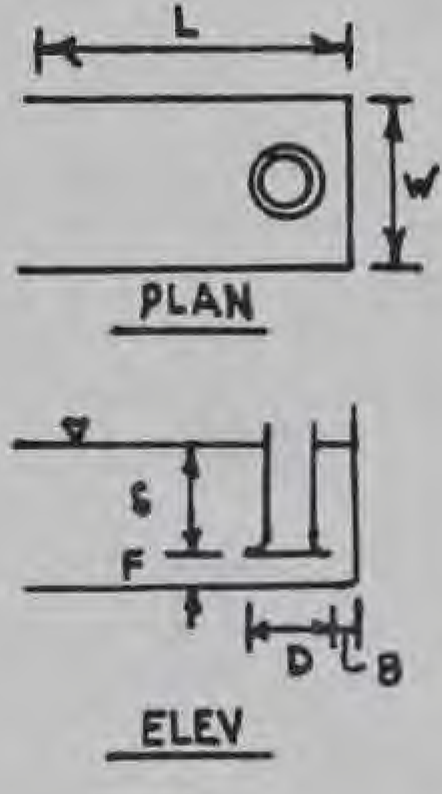
$$\frac{g}{D^{5/2} g^{1/2}} = 0.06$$

BASIC DATA

SYMBOL	Q/√g*D**5	F/D	S/D
*	-	0.25	0.47
*	-	0.33	0.47
*	-	0.50	0.47
*	-	0.66	0.47
+	0.15	0.25	1.26
+	0.17	0.33	1.26
+	0.15	0.50	1.26
+	0.23	0.66	1.26
o	0.25	0.25	2.02
o	0.31	0.33	2.02
o	0.29	0.50	2.02
o	0.35	0.66	2.02

Figure 33. Distance from floor versus flow rate, surface vortices, incipient stage C vortex (propeller pump), B/D = 0.25

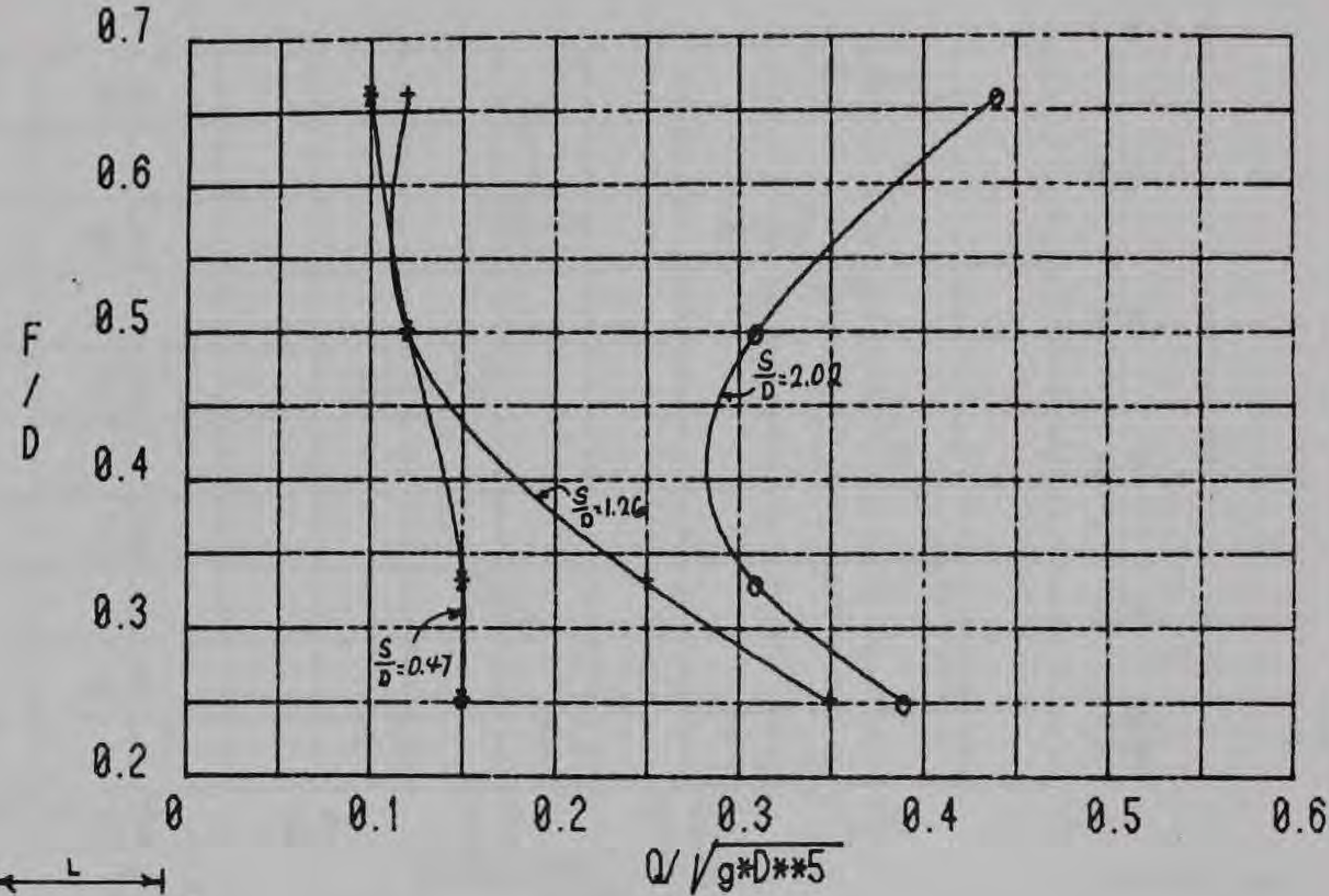


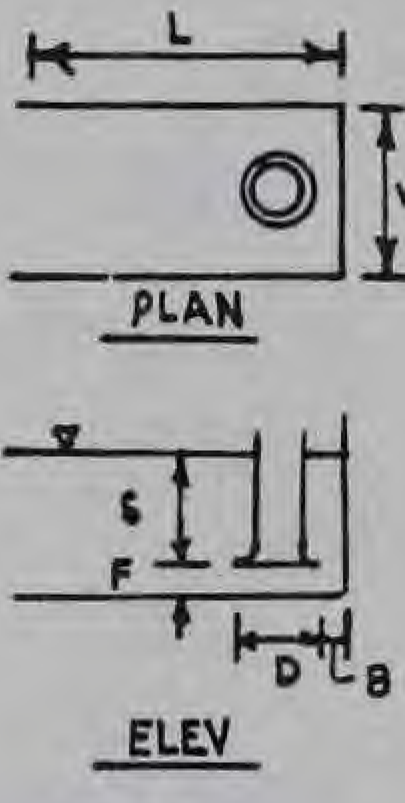


BASIC DATA

SYMBOL	Q/√g*D**5	F/D	S/D
*	0.06	0.25	0.47
*	0.06	0.33	0.47
*	0.10	0.50	0.47
*	0.06	0.66	0.47
+	0.09	0.25	1.26
+	0.12	0.33	1.26
+	0.12	0.50	1.26
+	0.12	0.66	1.26
o	0.17	0.25	2.02
o	0.30	0.33	2.02
o	0.30	0.50	2.02
o	0.28	0.66	2.02

Figure 34. Distance from floor versus flow rate, surface vortices, incipient stage C vortex (propeller pump), B/D = 0.50



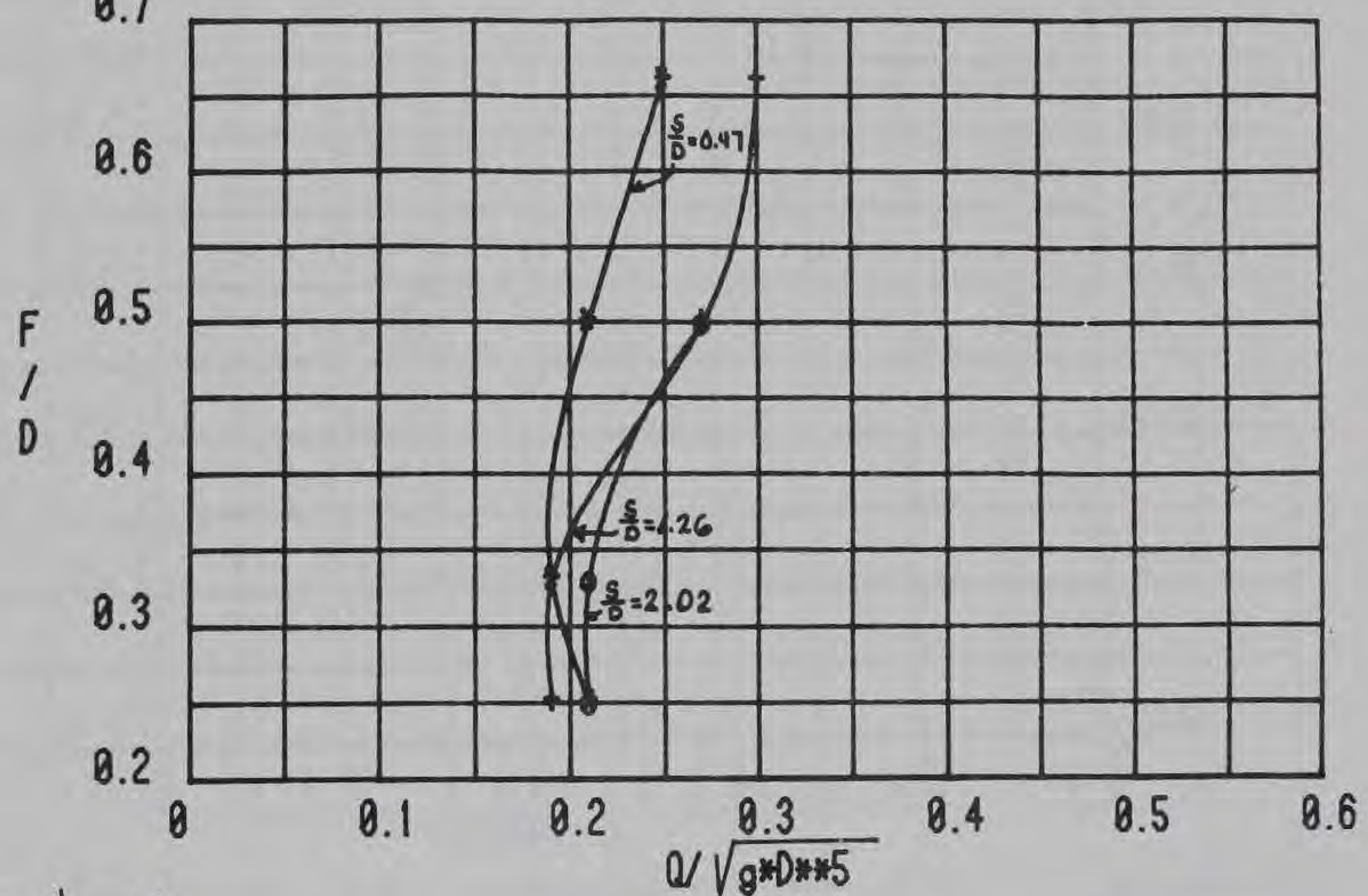


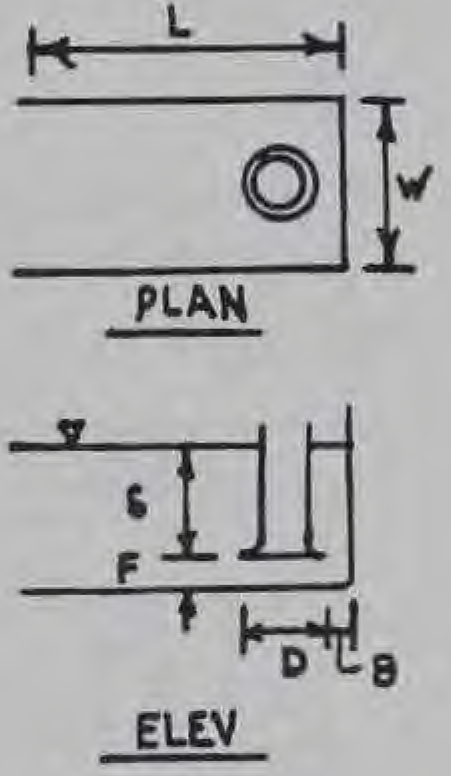
TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	F/D	S/D
*	0.15	0.25	0.47
*	0.15	0.33	0.47
*	0.12	0.50	0.47
*	0.10	0.66	0.47
+	0.35	0.25	1.26
+	0.25	0.33	1.26
+	0.12	0.50	1.26
+	0.12	0.66	1.26
o	0.39	0.25	2.02
o	0.31	0.33	2.02
o	0.31	0.50	2.02
o	0.44	0.66	2.02

Figure 35. Distance from floor versus flow rate, surface vortices, incipient stage C vortex (propeller pump), B/D = 1.5



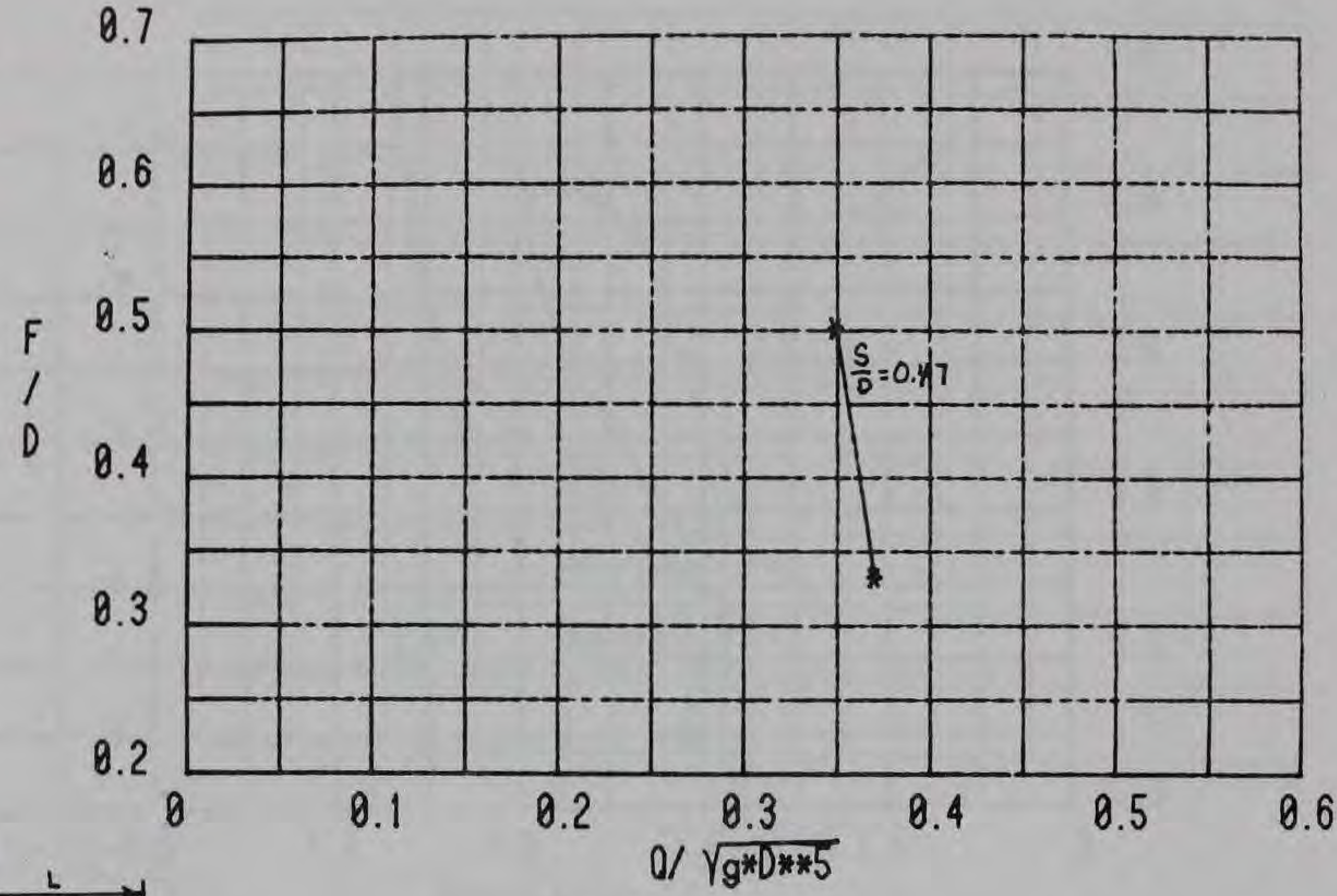


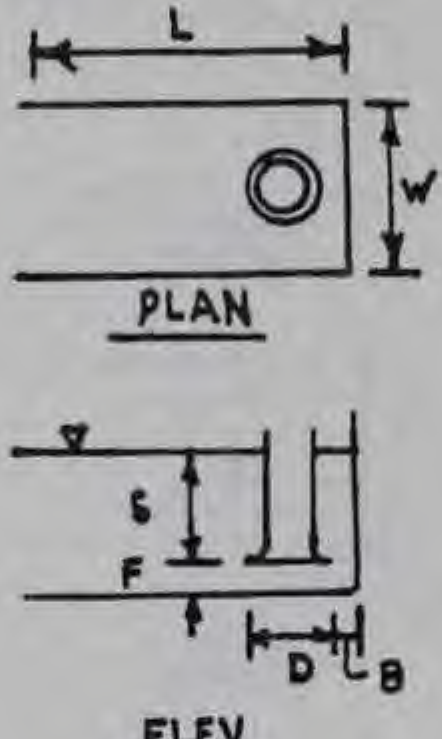
TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	F/D	S/D
*	0.21	0.25	0.47
*	0.19	0.33	0.47
*	0.21	0.50	0.47
*	0.25	0.66	0.47
+	0.19	0.25	1.26
+	0.19	0.33	1.26
+	0.27	0.50	1.26
+	0.30	0.66	1.26
o	0.21	0.25	2.02
o	0.21	0.33	2.02
o	0.27	0.50	2.02

Figure 36. Distance from floor versus flow rate, backwall vortices, incipient air core (propeller pump), B/D = 0.05





TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

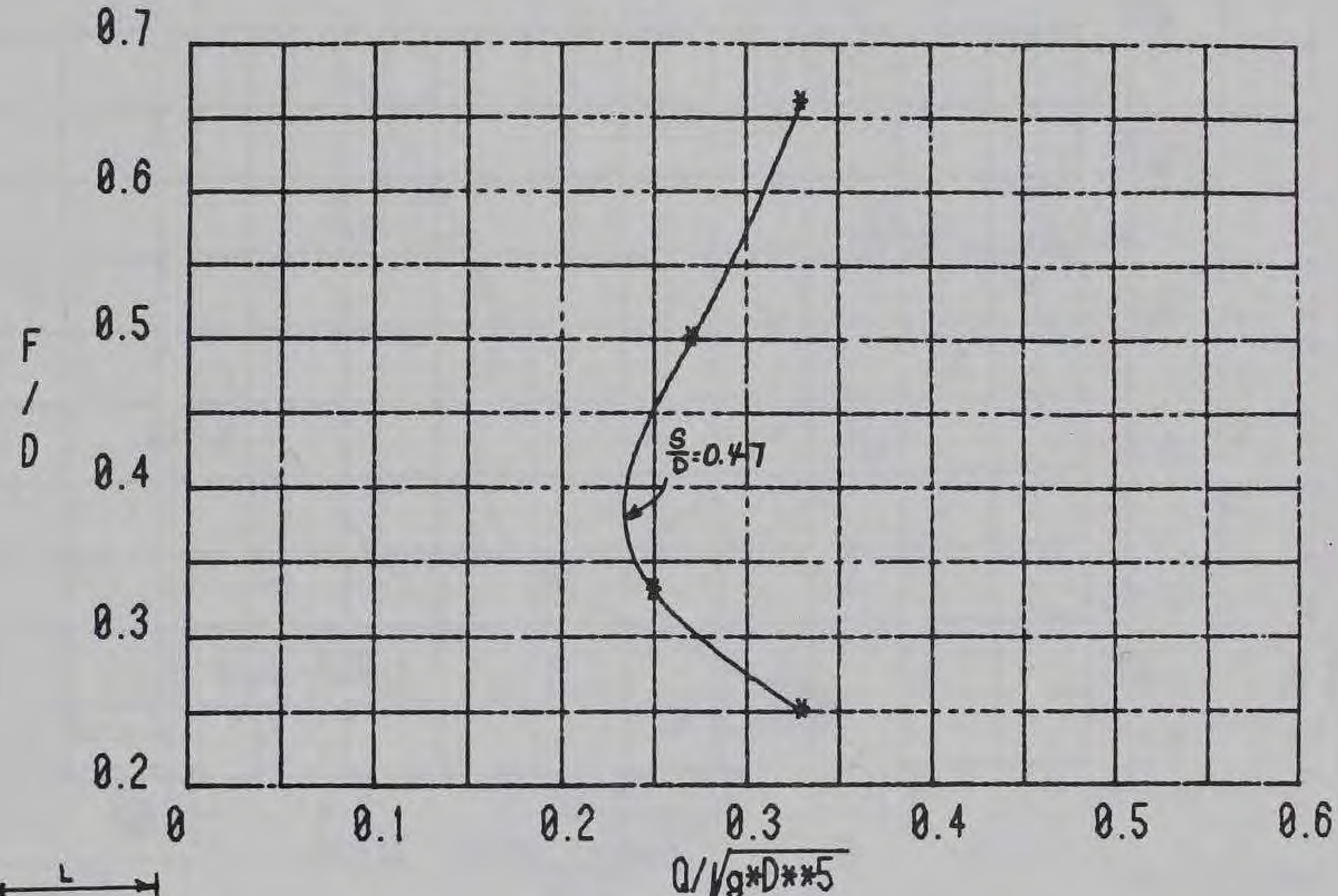
SYMBOL	Q/ √g*D**5	F/D	S/D
*	0.37	0.33	0.47
*	0.35	0.50	0.47
*	-	0.25	0.47
*	-	0.66	0.47

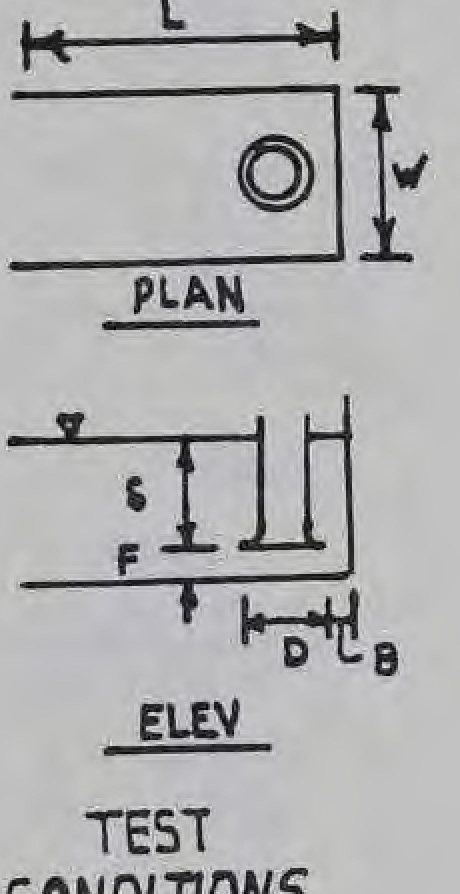
TEST WERE CONDUCTED AT A S/D OF 1.26 AND 2.02 FOR VARIOUS VALUES OF F/D AND VORTICES DID NOT OCCUR FOR THE MAXIMUM PERMISSIBLE $\frac{Q}{D^{5/2} g^{1/2}} = 0.6$

—— VORTICES DID NOT OCCUR FOR MAXIMUM PERMISSIBLE

$$\frac{Q}{D^{5/2} g^{1/2}} = 0.6$$

Figure 37. Distance from floor versus flow rate, backwall vortices, incipient air core (propeller pump), B/D = 0.25





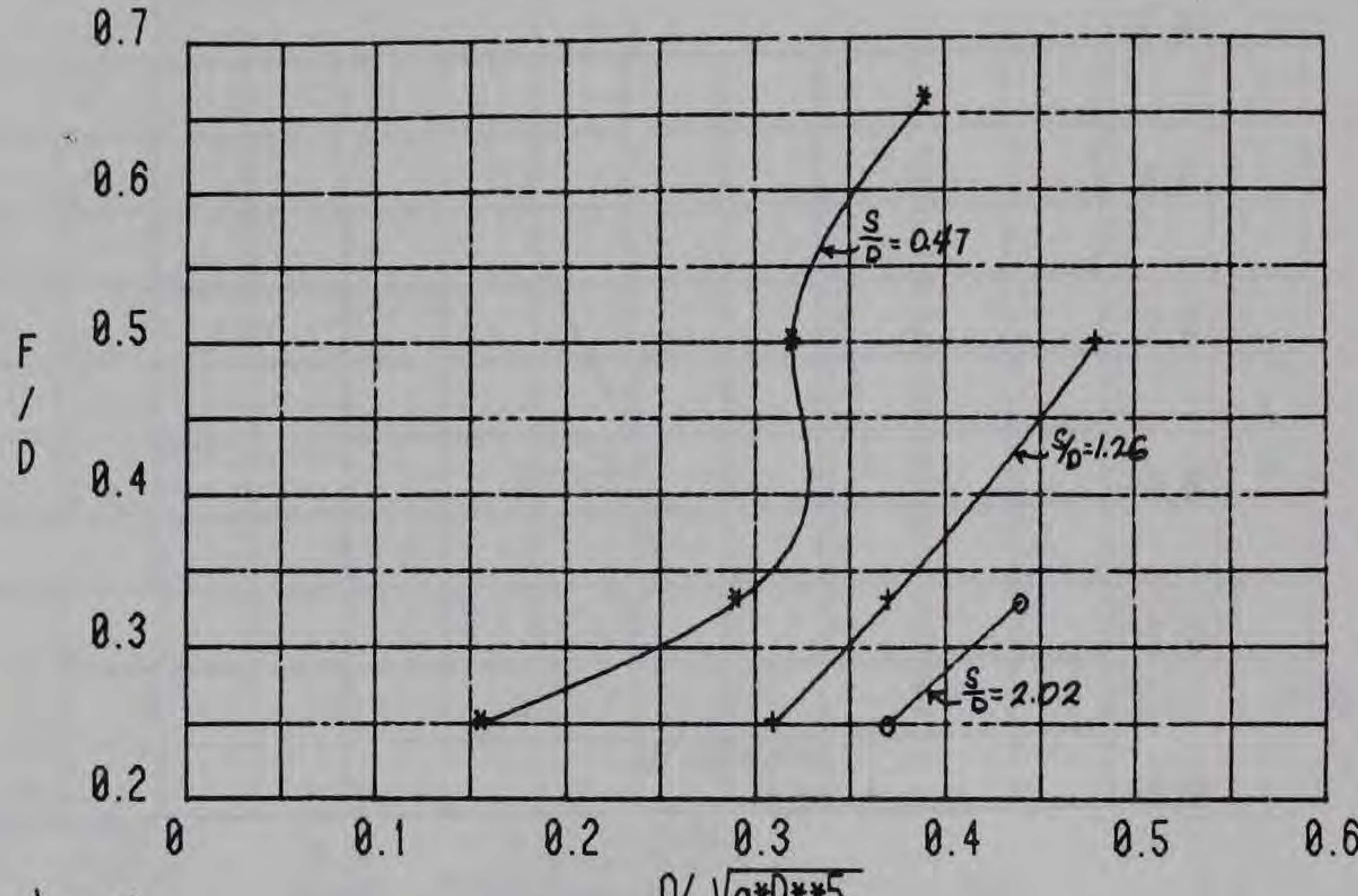
TEST CONDITIONS
D = 1.29 FT
L = 18.6 D
W = 2.0 D

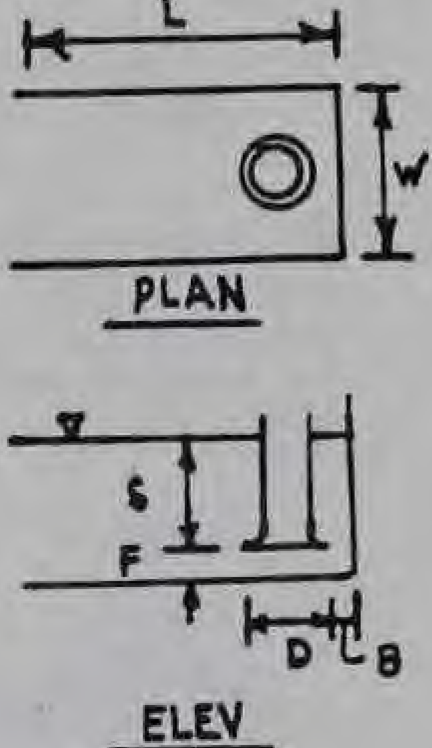
BASIC DATA

SYMBOL	$Q/\sqrt{g*D**5}$	F/D	S/D
*	0.33	0.25	0.47
*	0.25	0.33	0.47
*	0.27	0.50	0.47
*	0.33	0.66	0.47

TESTS WERE CONDUCTED AT A $\frac{S}{D}$ OF 1.26 AND 2.02 FOR VARIOUS VALUES OF F/D AND VORTICES DID NOT OCCUR FOR THE MAXIMUM PERMISSIBLE $\frac{Q}{D^{5/2} g^{1/2}} = 0.6$

Figure 38. Distance from floor versus flow rate, backwall vortices, incipient air core (propeller pump), B/D = 0.50



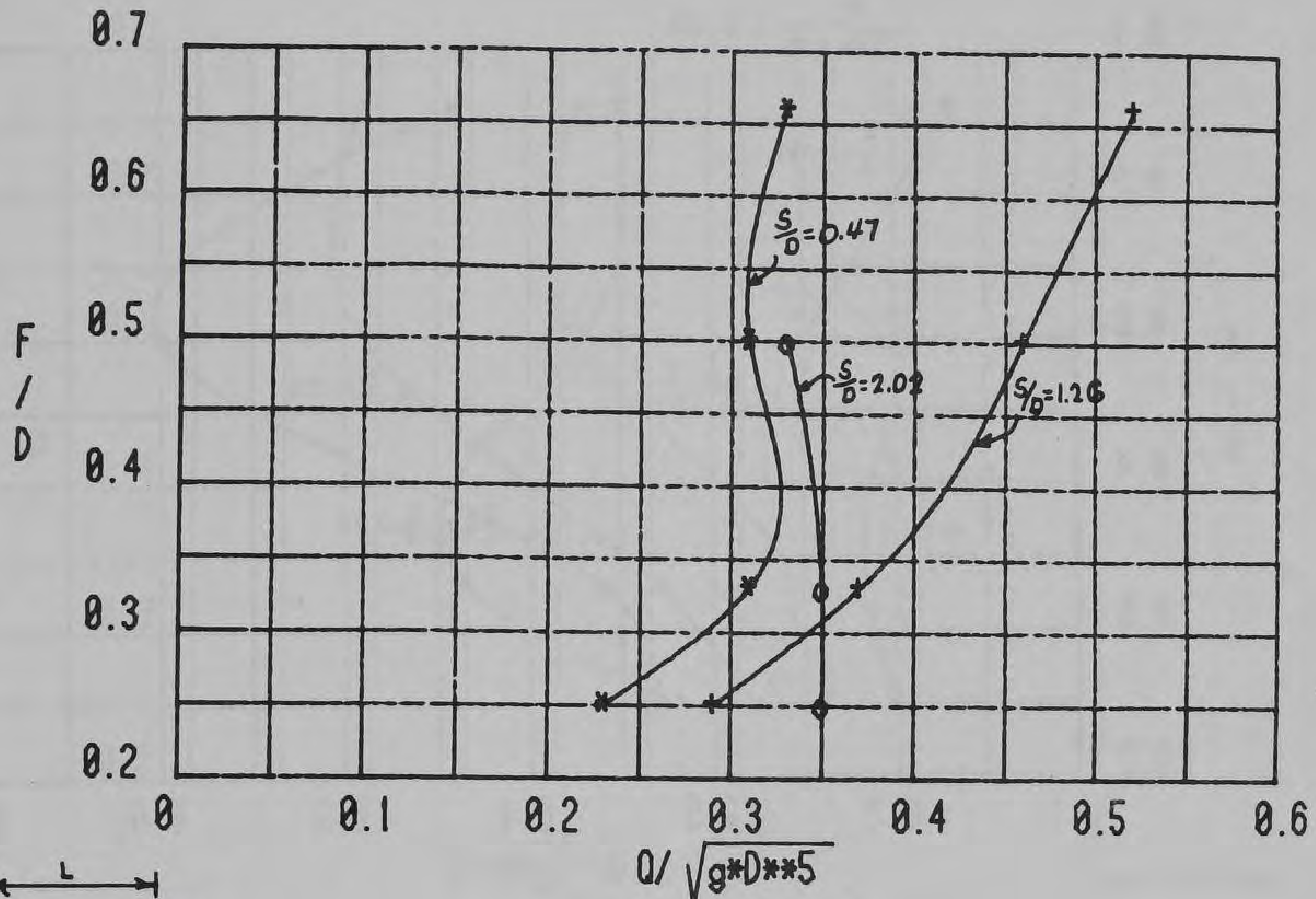


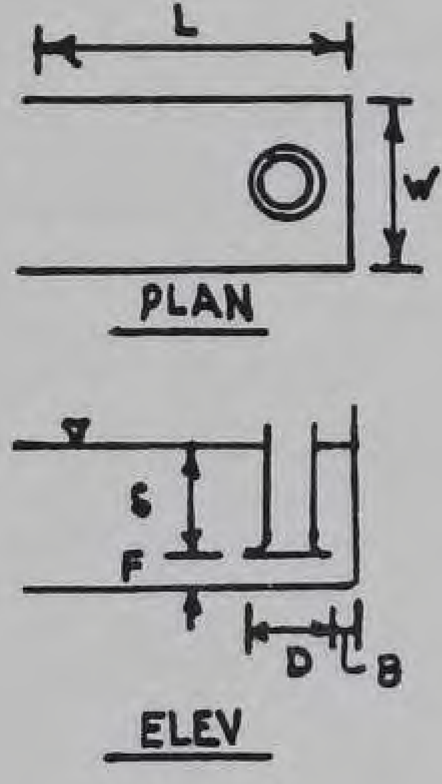
TEST CONDITIONS
D = 1.29 FT
L = 18.6 D
W = 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	F/D	S/D
*	0.16	0.25	0.47
*	0.29	0.33	0.47
*	0.32	0.50	0.47
*	0.39	0.66	0.47
+	0.31	0.25	1.26
+	0.37	0.33	1.26
+	0.48	0.50	1.26
o	0.37	0.25	2.02
o	0.44	0.33	2.02

Figure 39. Distance from floor versus flow rate, floor vortices, incipient air core (propeller pump), B/D = 0.05



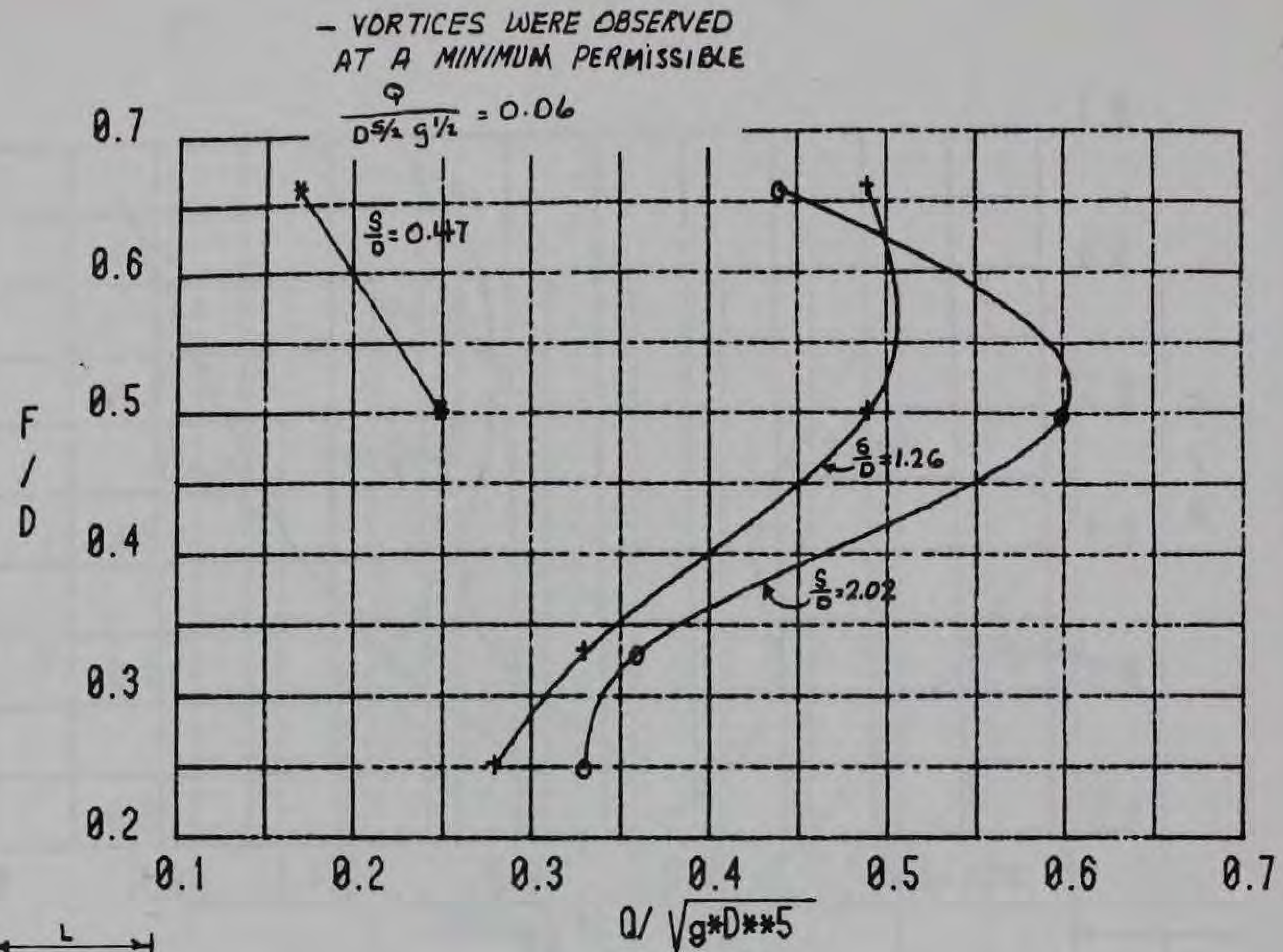


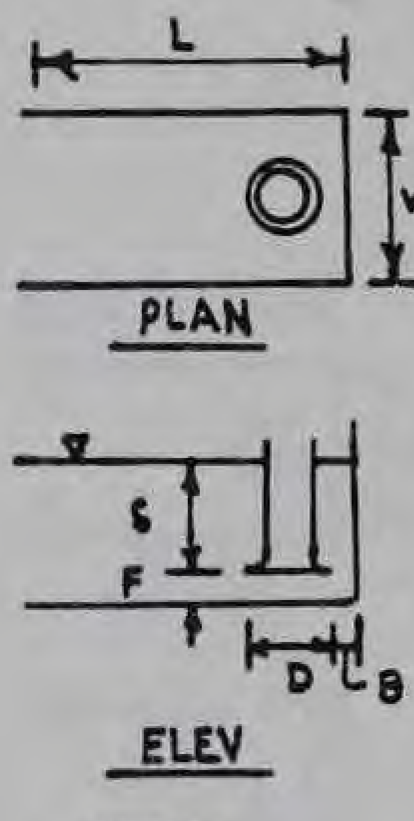
TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	F/D	S/D
*	0.23	0.25	0.47
*	0.31	0.33	0.47
*	0.31	0.50	0.47
*	0.33	0.66	0.47
+	0.29	0.25	1.26
+	0.37	0.33	1.26
+	0.46	0.50	1.26
+	0.52	0.66	1.26
o	0.35	0.25	2.02
o	0.35	0.33	2.02
o	0.33	0.50	2.02
o	-	0.66	2.02

Figure 40. Distance from floor versus flow rate, floor vortices, incipient air core (propeller pump), B/D = 0.25



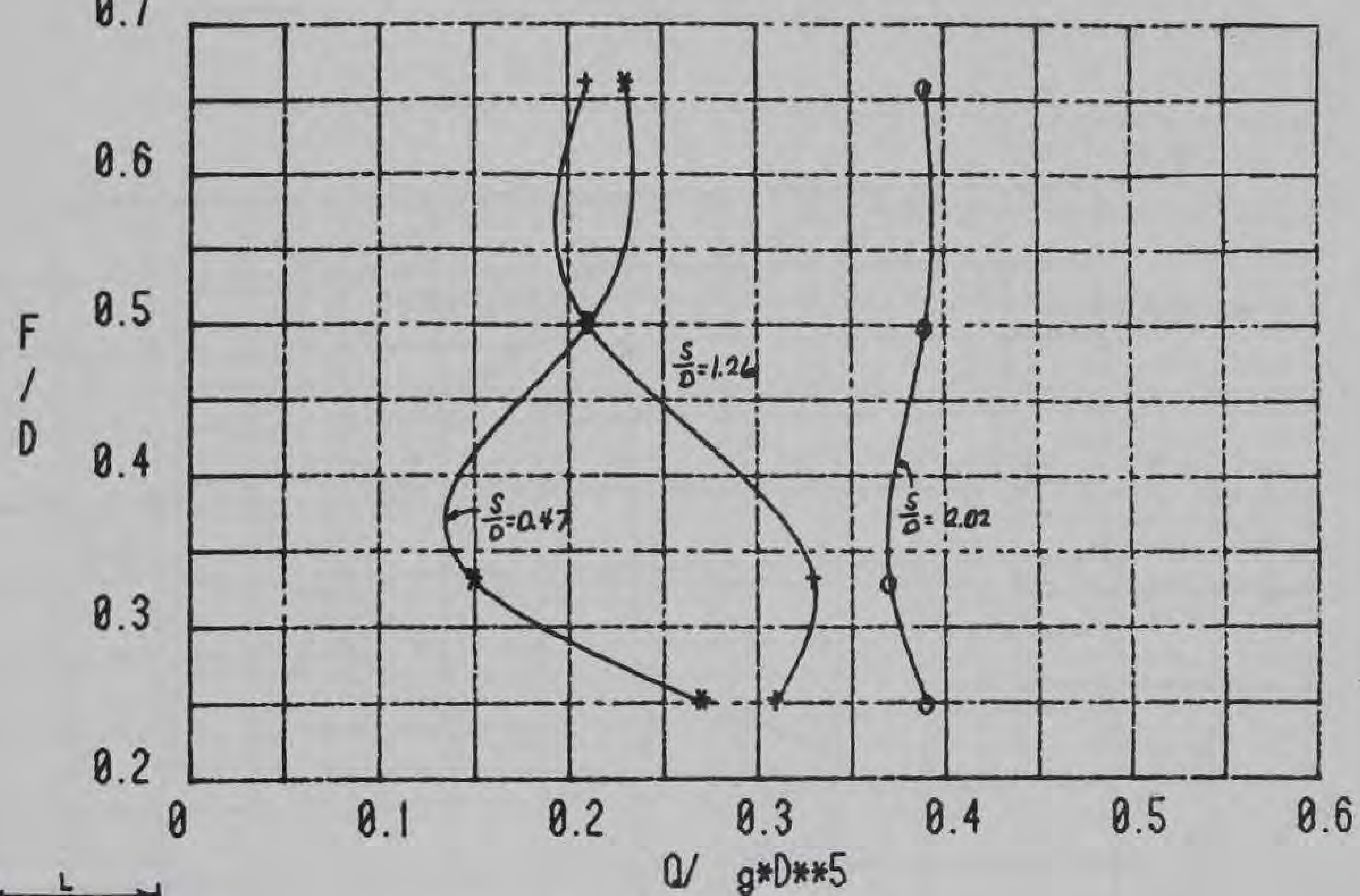


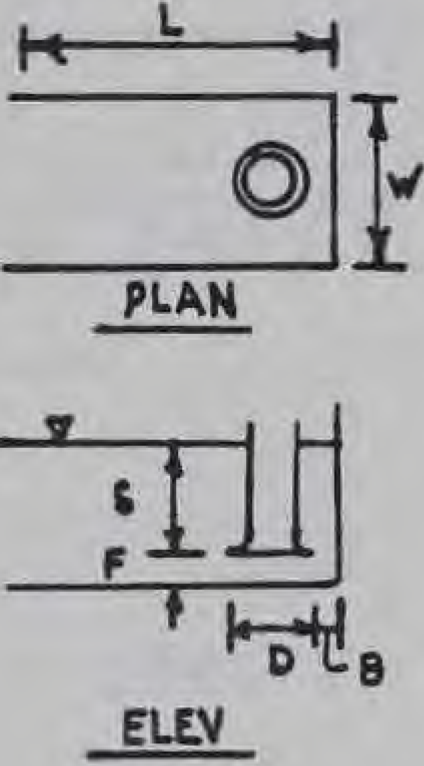
TEST CONDITIONS
D = 1.29 FT
L = 18.6 D
W = 2.0 D

BASIC DATA

SYMBOL	$Q/\sqrt{g*D**5}$	F/D	S/D
*	0.25	0.50	0.47
*	0.17	0.66	0.47
*	-	0.25	0.47
*	-	0.33	0.47
+	0.28	0.25	1.26
+	0.33	0.33	1.26
+	0.49	0.50	1.26
+	0.49	0.66	1.26
o	0.33	0.25	2.02
o	0.36	0.33	2.02
o	0.60	0.50	2.02
o	0.44	0.66	2.02

Figure 41. Distance from floor versus flow rate, floor vortices, incipient air core (propeller pump), B/D = 0.50



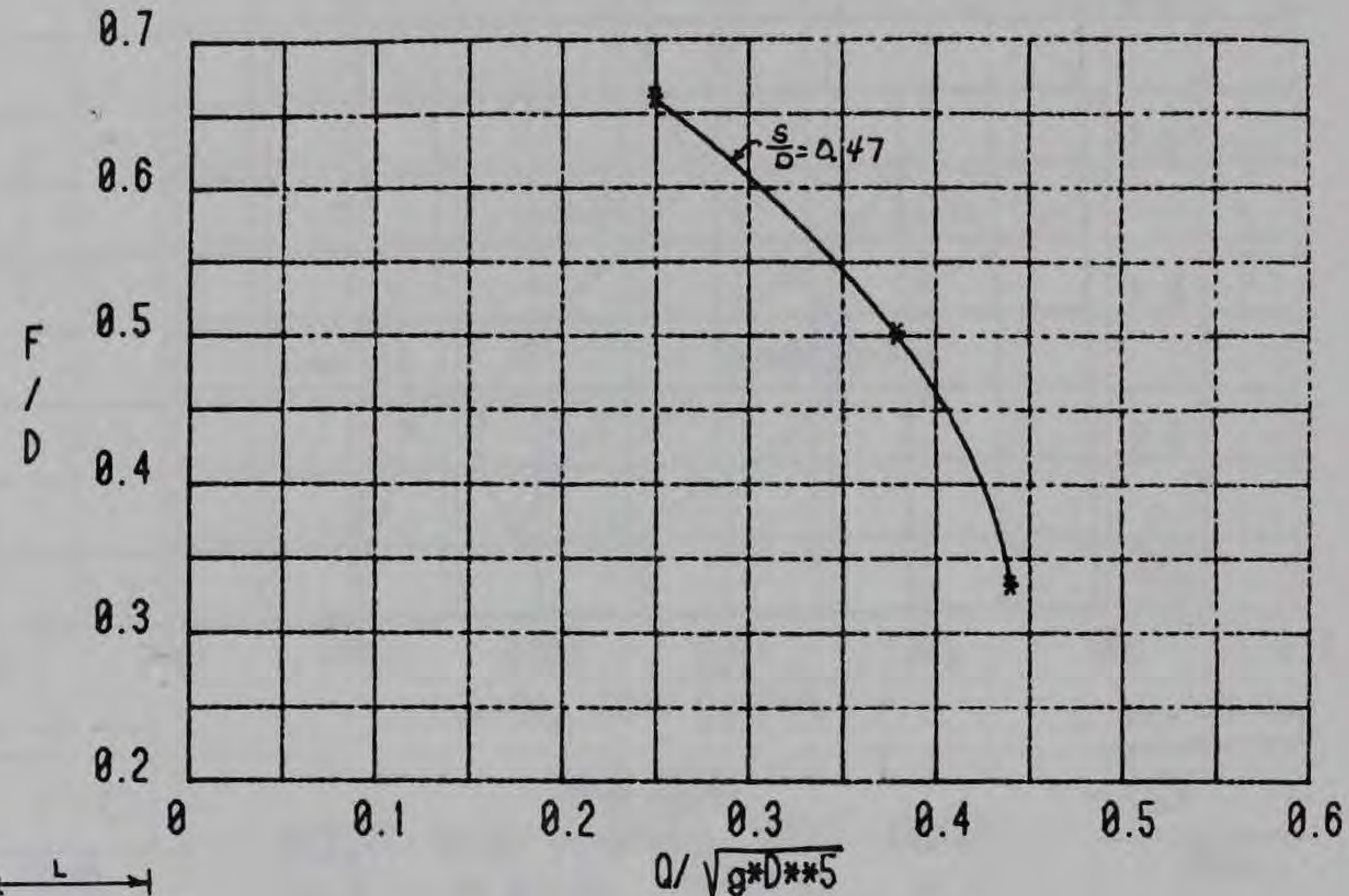


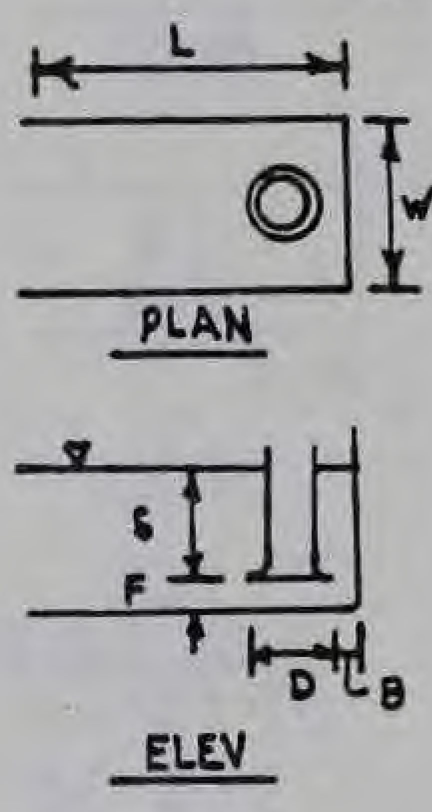
TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

SYMBOL	Q/ g*D**5	F/D	S/D
*	0.27	0.25	0.47
*	0.15	0.33	0.47
*	0.21	0.50	0.47
*	0.23	0.66	0.47
+	0.31	0.25	1.26
+	0.33	0.33	1.26
+	0.21	0.50	1.26
+	0.21	0.66	1.26
o	0.39	0.25	2.02
o	0.37	0.33	2.02
o	0.39	0.50	2.02
o	0.39	0.66	2.02

Figure 42. Distance from floor versus flow rate, floor vortices, incipient air core (propeller pump), B/D = 1.50





BASIC DATA

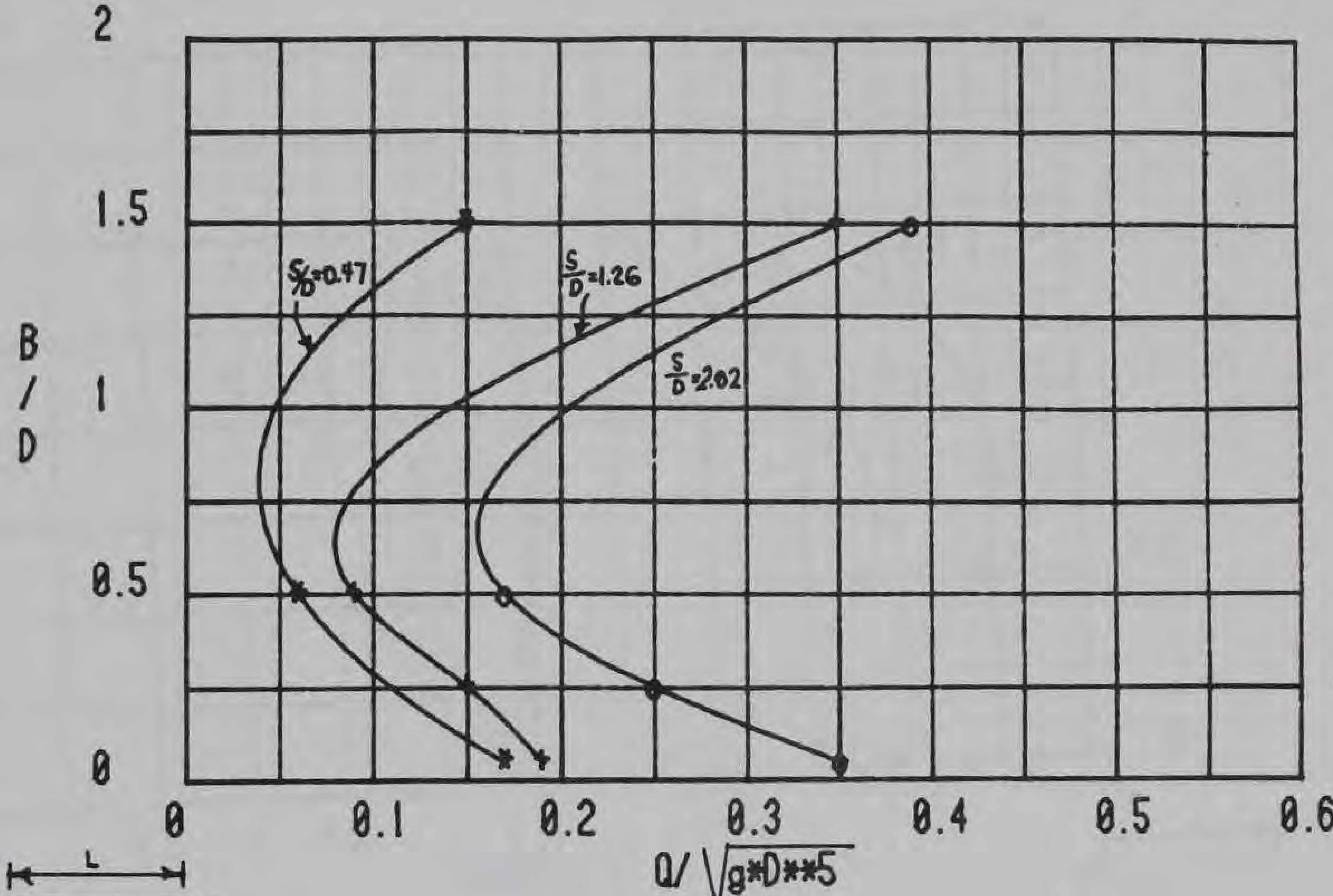
SYMBOL	Q/ √g*D**5	F/D	S/D
*	0.44	0.33	0.47
*	0.38	0.50	0.47
*	0.25	0.66	0.47
*	-	0.25	0.47

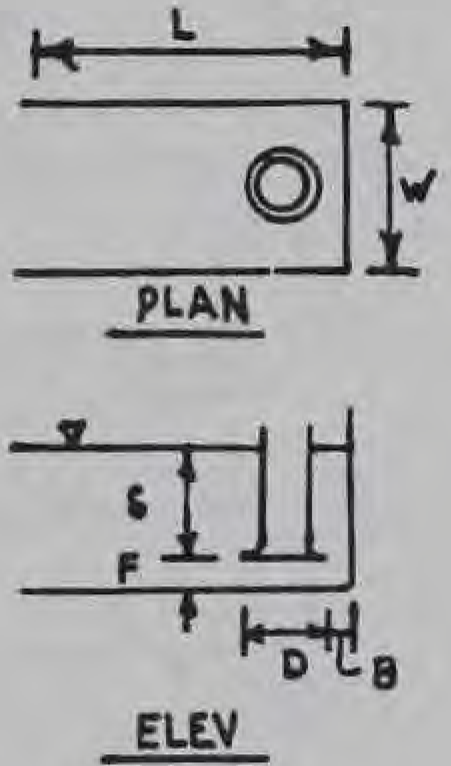
TEST CONDITIONS
D = 1.29 FT
L = 18.6 D
W = 2.0 D

TESTS WERE CONDUCTED AT A S OF 1.26 AND 2.02 D AND VORTICES DID NOT OCCUR FOR THE MAXIMUM PERMISSIBLE $\frac{Q}{D^{5/2} g^{1/2}} = 0.6$

— VORTICES DID NOT OCCUR FOR MAXIMUM PERMISSIBLE $\frac{Q}{D^{5/2} g^{1/2}} = 0.6$

Figure 43. Distance from floor versus flow rate, sidewall vortices, incipient air core (propeller pump), B/D = 0.50



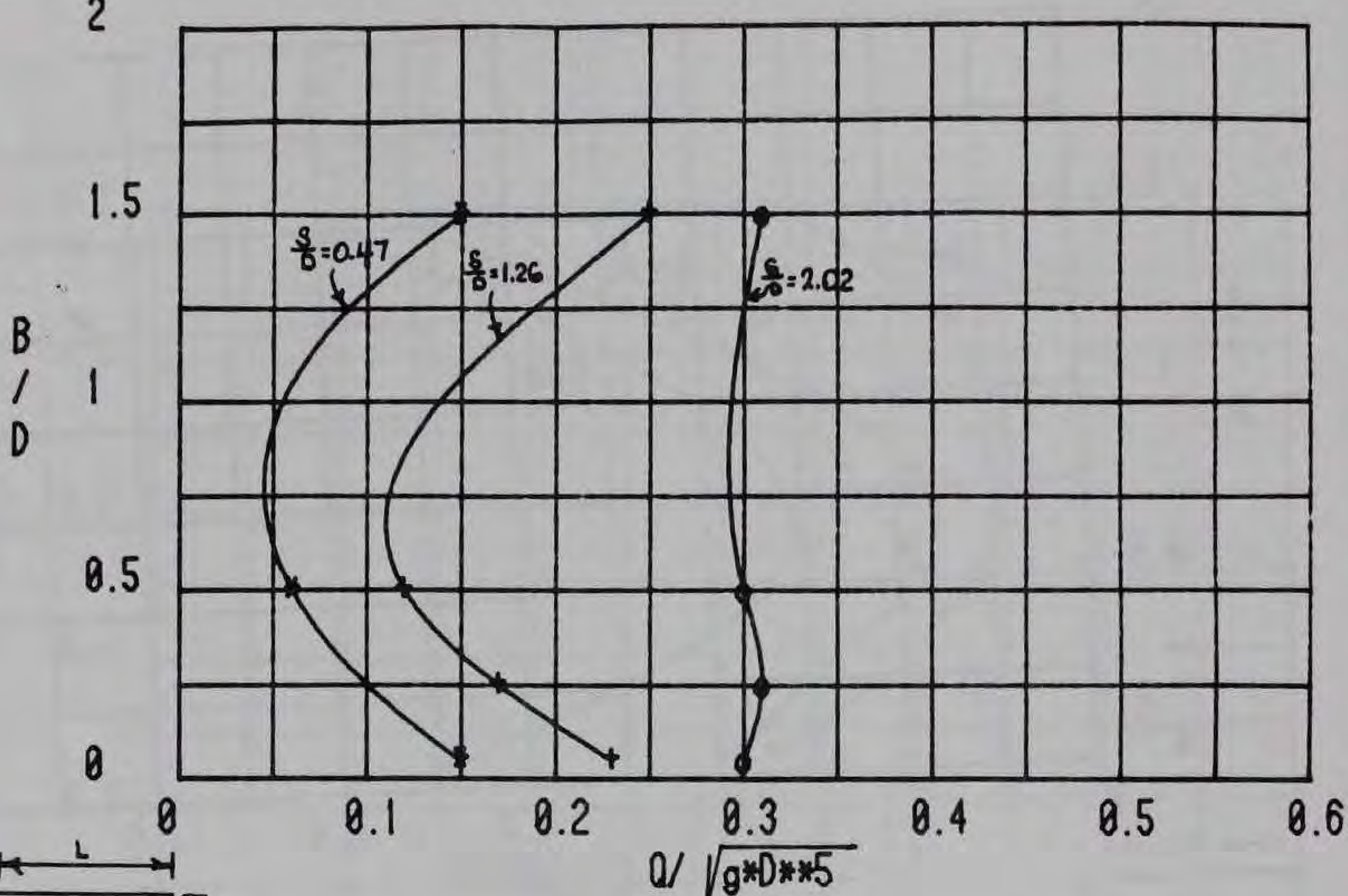


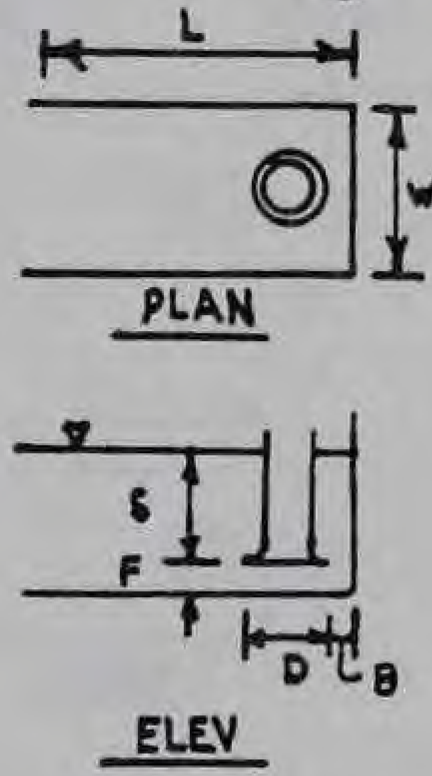
TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.17	0.05	0.47
*	0.06	0.50	0.47
*	0.15	1.50	0.47
*	-	0.25	0.47
+	0.19	0.05	1.26
+	0.15	0.25	1.26
+	0.09	0.50	1.26
+	0.35	1.50	1.26
o	0.35	0.05	2.02
o	0.25	0.25	2.02
o	0.17	0.50	2.02
o	0.39	1.50	2.02

Figure 44. Distance from backwall versus flow rate, surface vortices, incipient stage C vortex (propeller pump), F/D = 0.25



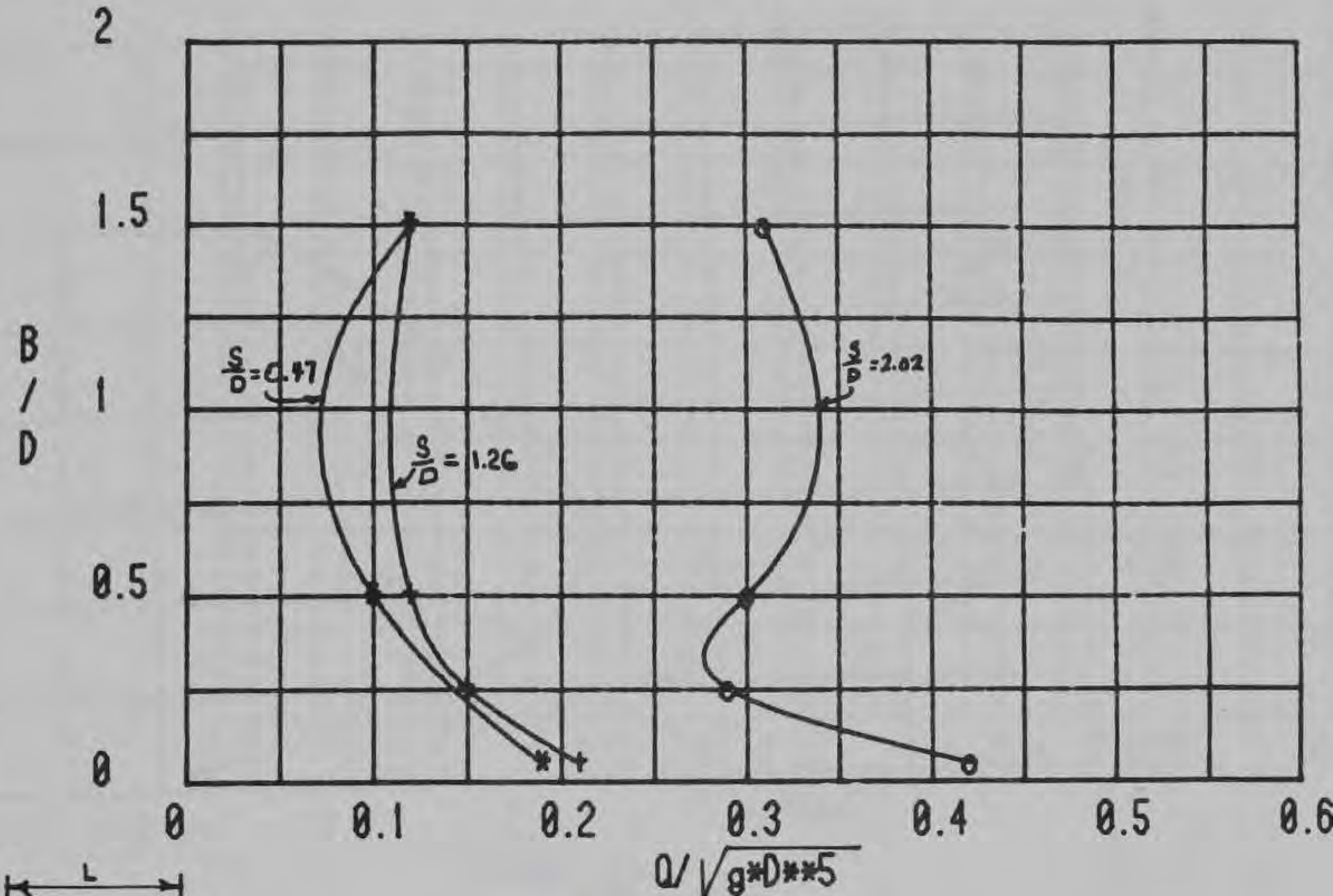


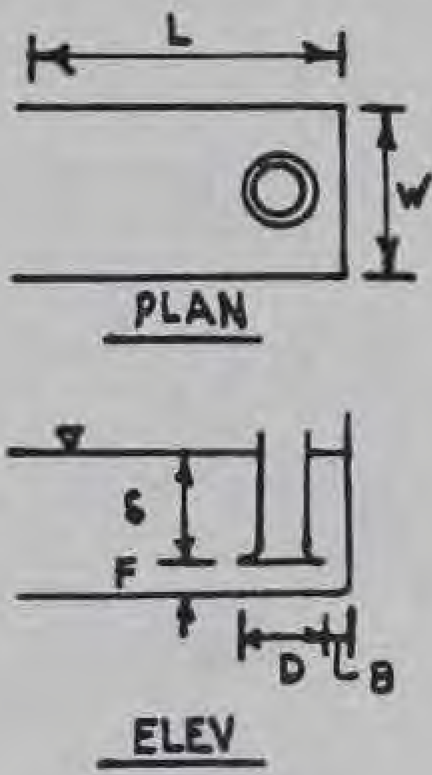
TEST
CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.15	0.05	0.47
*	0.06	0.50	0.47
*	0.15	1.50	0.47
*	-	0.25	0.47
+	0.23	0.05	1.26
+	0.17	0.25	1.26
+	0.12	0.50	1.26
+	0.25	1.50	1.26
o	0.30	0.05	2.02
o	0.31	0.25	2.02
o	0.30	0.50	2.02
o	0.31	1.50	2.02

Figure 45. Distance from backwall versus flow rate, surface vortices, incipient stage C vortex (propeller pump), F/S = 0.33



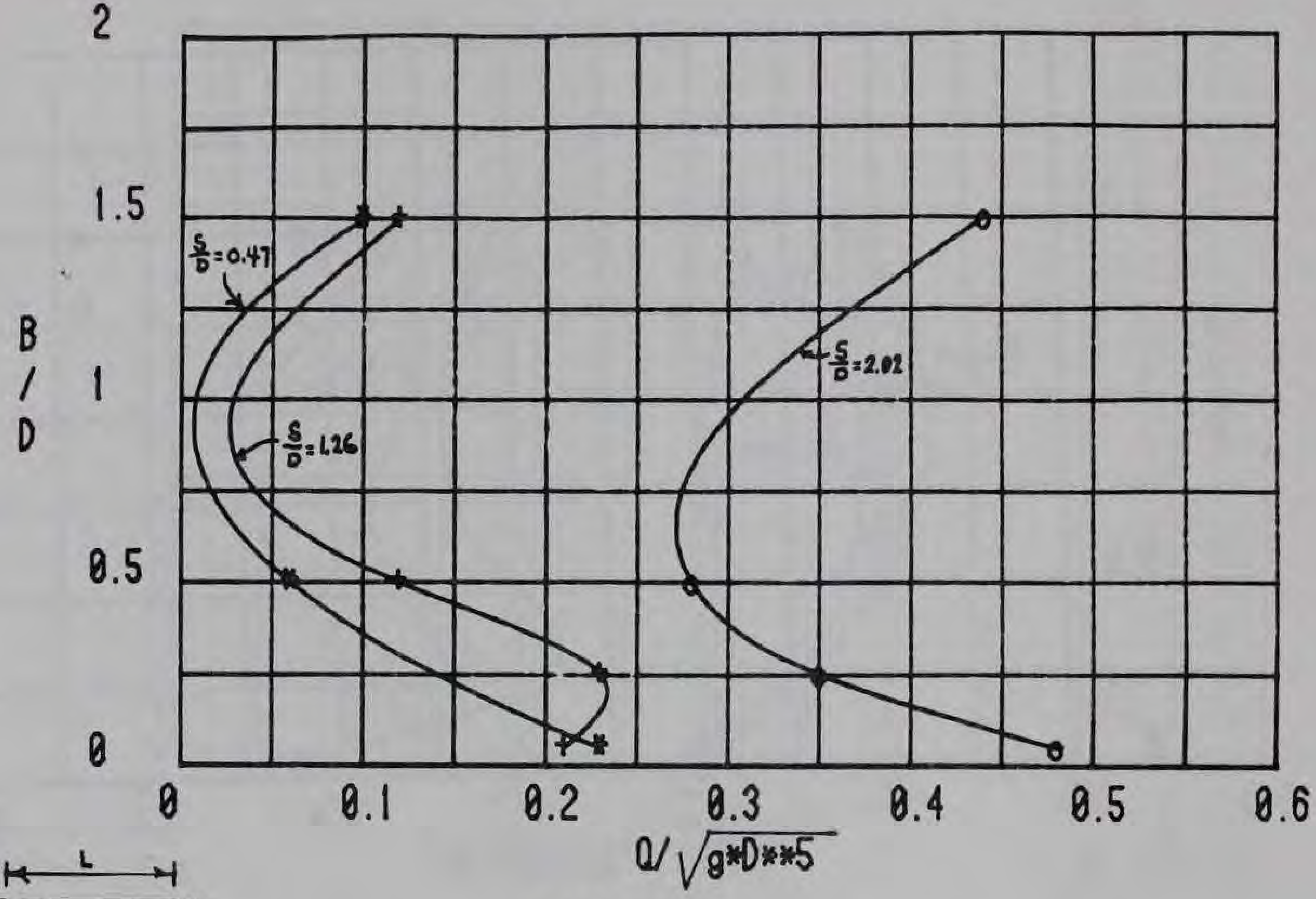


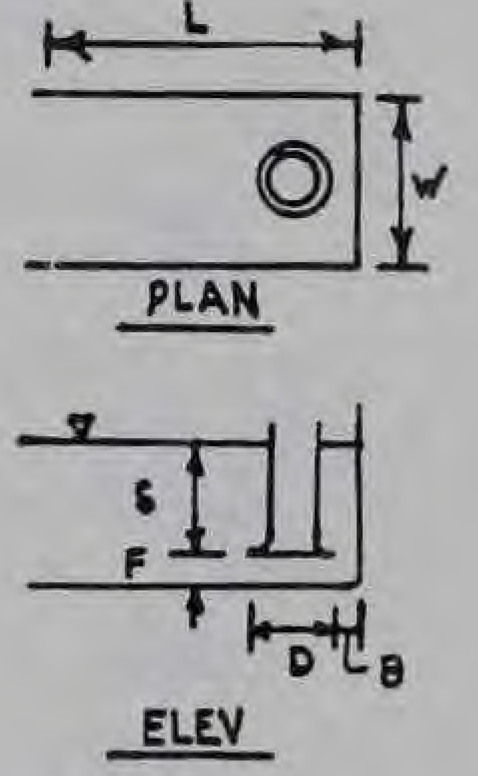
TEST CONDITIONS
D = 1.29 FT
L = 18.6 D
W = 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.19	0.05	0.47
*	0.10	0.50	0.47
*	0.12	1.50	0.47
*	-	0.25	0.47
+	0.21	0.05	1.26
+	0.15	0.25	1.26
+	0.12	0.50	1.26
+	0.12	1.50	1.26
o	0.42	0.05	2.02
o	0.29	0.25	2.02
o	0.30	0.50	2.02
o	0.31	1.50	2.02

Figure 46. Distance from backwall versus flow rate, surface vortices, incipient stage C vortex (propeller pump), F/D = 0.50



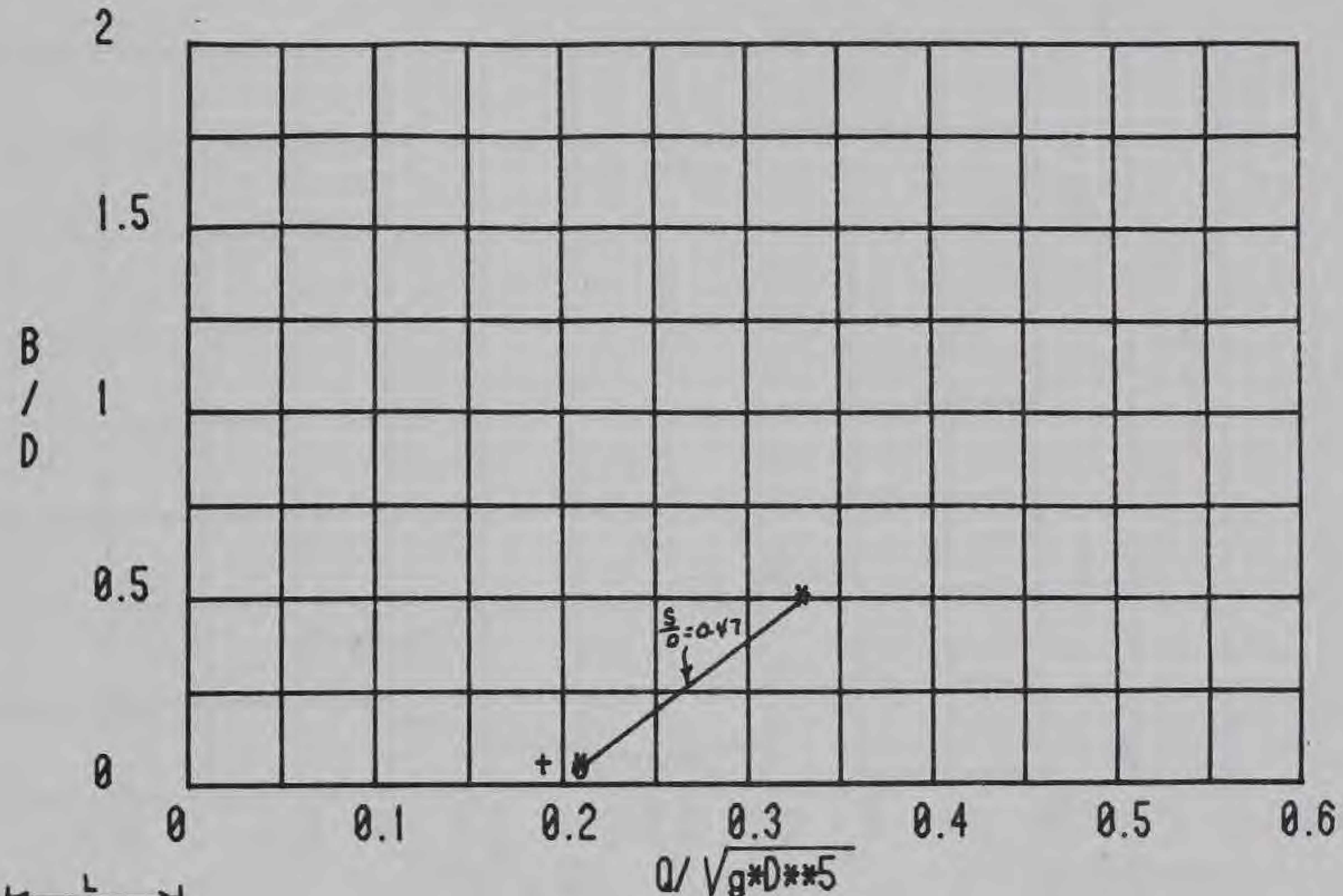


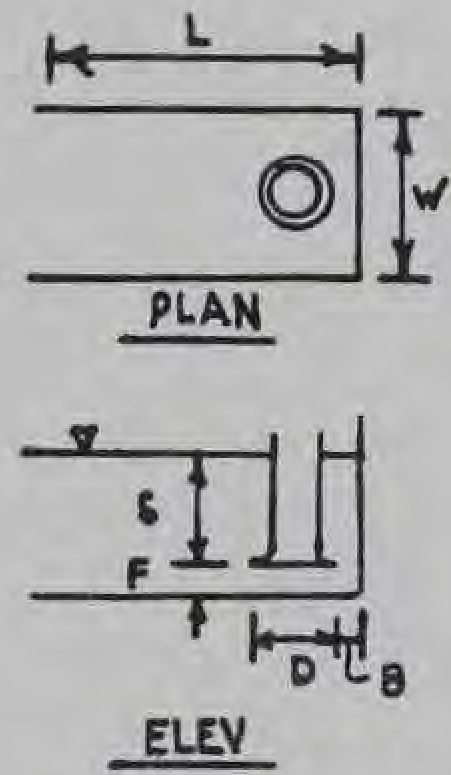
TEST CONDITIONS
D = 1.29 FT
L = 18.6 D
W = 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.23	0.05	0.47
*	0.06	0.50	0.47
*	0.10	1.50	0.47
*	-	0.25	0.47
+	0.21	0.05	1.26
+	0.23	0.25	1.26
+	0.12	0.50	1.26
+	0.12	1.50	1.26
o	0.48	0.05	2.02
o	0.35	0.25	2.02
o	0.28	0.50	2.02
o	0.44	1.50	2.02

Figure 47. Distance from backwall versus flow rate, surface vortices, incipient stage C vortex (propeller pump), F/D = 0.66





BASIC DATA

SYMBOL	$Q/\sqrt{g*D**5}$	B/D	S/D
*	0.21	0.05	0.47
*	0.33	0.50	0.47
*	-	0.25	0.47
+	0.19	0.05	1.26
+	-	0.25	1.26
+	-	0.50	1.26
o	0.21	0.05	2.02
o	-	0.25	2.02
o	-	0.50	2.02

TEST CONDITIONS

D = 1.29 FT

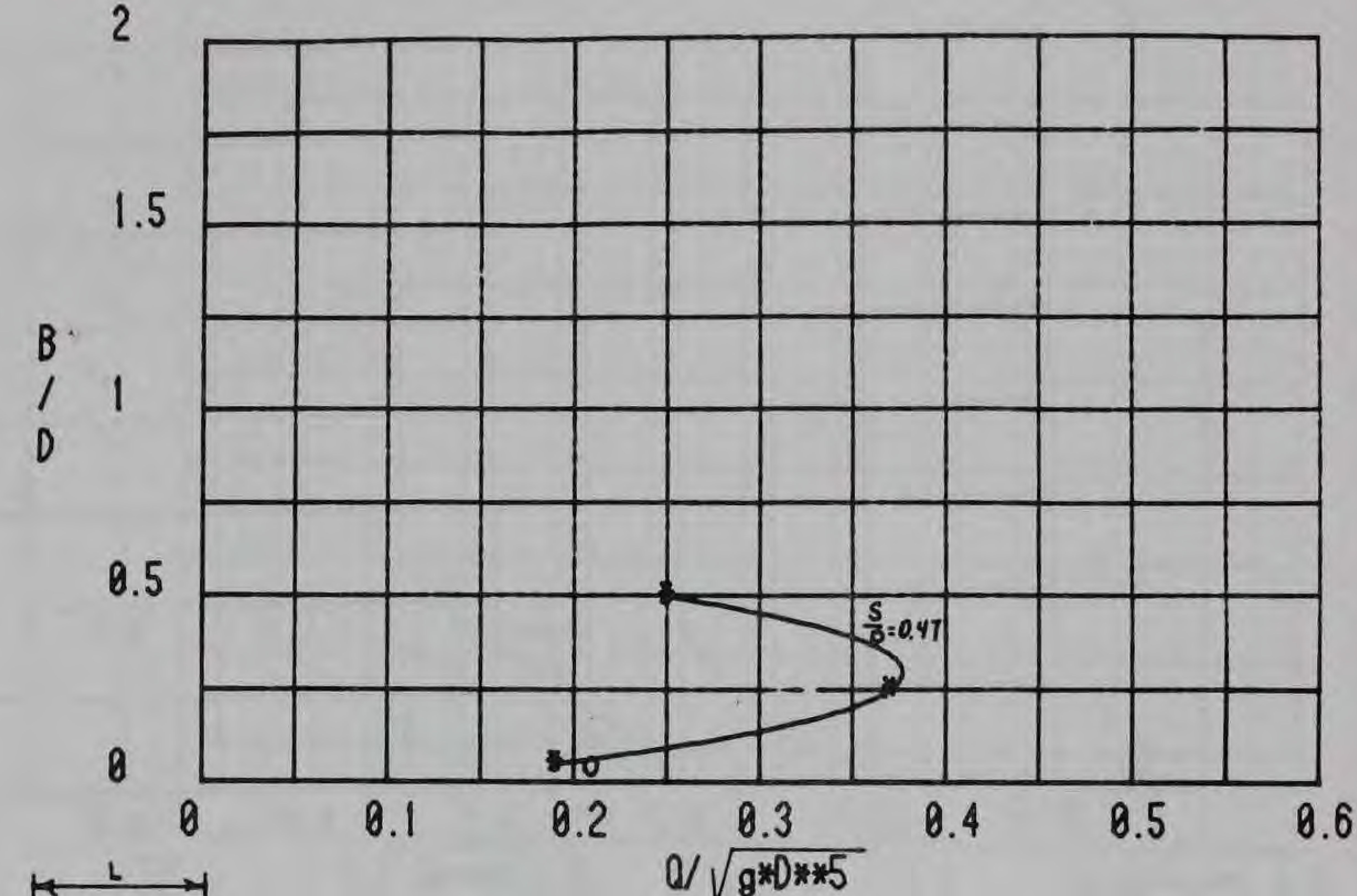
L = 18.6 D

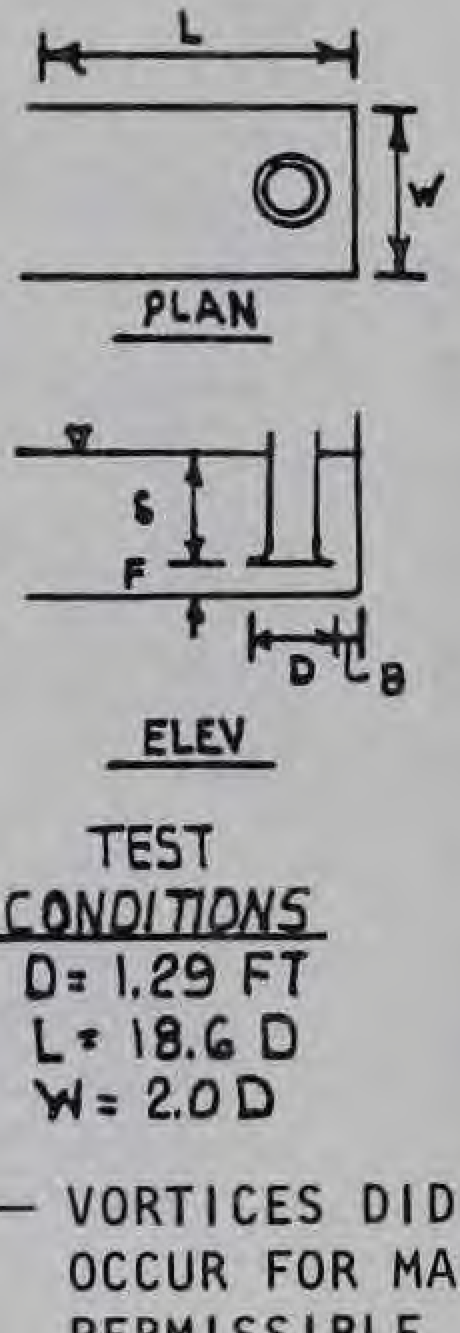
W = 2.0 D

—— VORTICES DID NOT OCCUR FOR MAXIMUM PERMISSIBLE

$$\frac{Q}{D^{5/2} g^{1/2}} = 0.6$$

Figure 48. Distance from backwall versus flow rate, backwall vortices, incipient air core (propeller pump), F/D = 0.25





TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

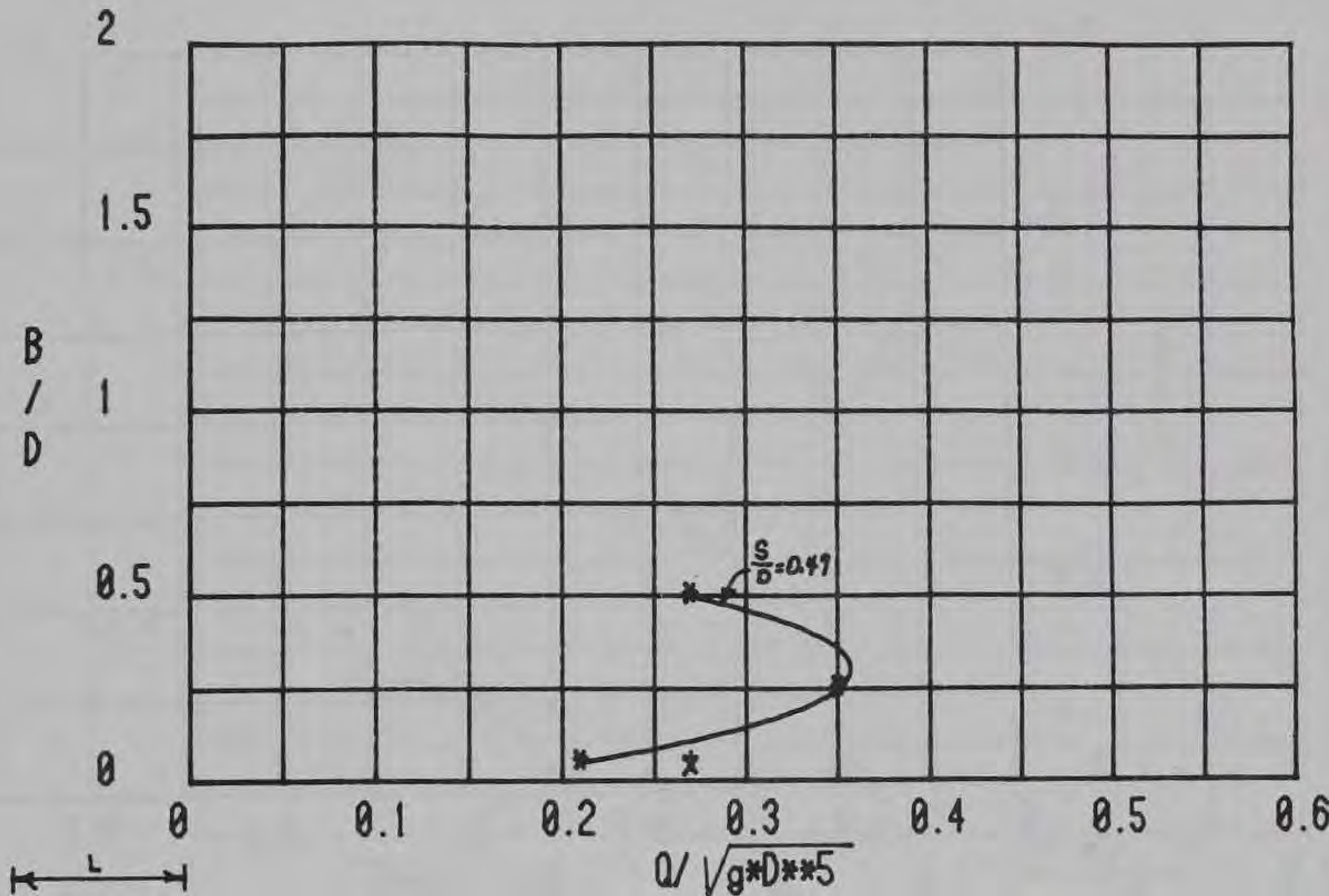
BASIC DATA

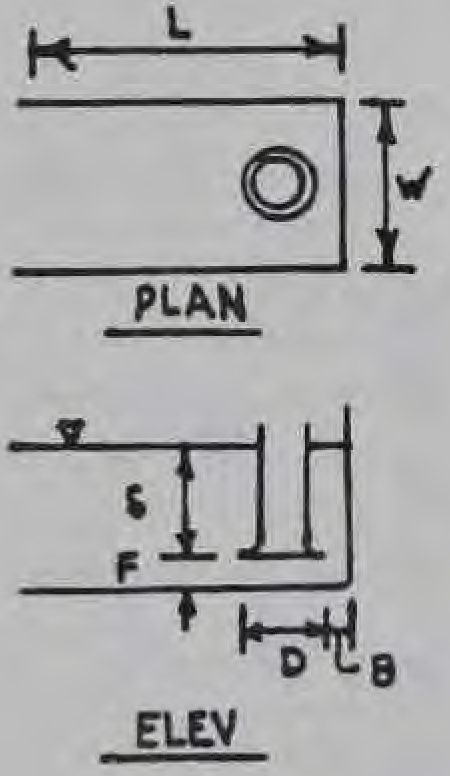
SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.19	0.05	0.47
*	0.37	0.25	0.47
*	0.25	0.50	0.47
+	0.19	0.05	1.26
+	-	0.25	1.26
+	-	0.50	1.26
o	0.21	0.05	2.02
o	-	0.25	2.02
o	-	0.50	2.02

—— VORTICES DID NOT OCCUR FOR MAXIMUM PERMISSIBLE

$$\frac{Q}{D^{5/2}g^{1/2}} = 0.6$$

Figure 49. Distance from backwall versus flow rate, backwall vortices, incipient air core (propeller pump), F/D = 0.33





TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

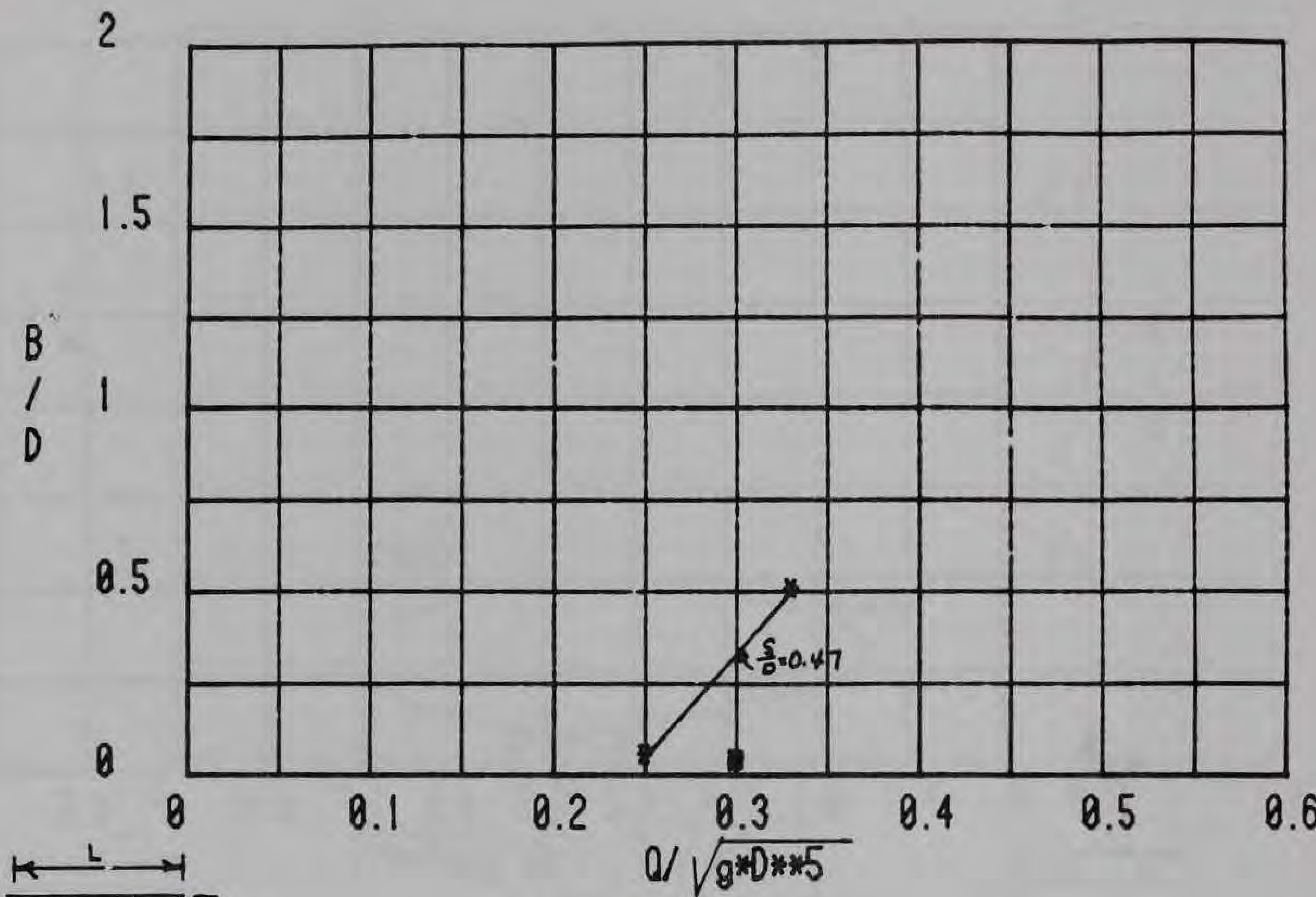
BASIC DATA

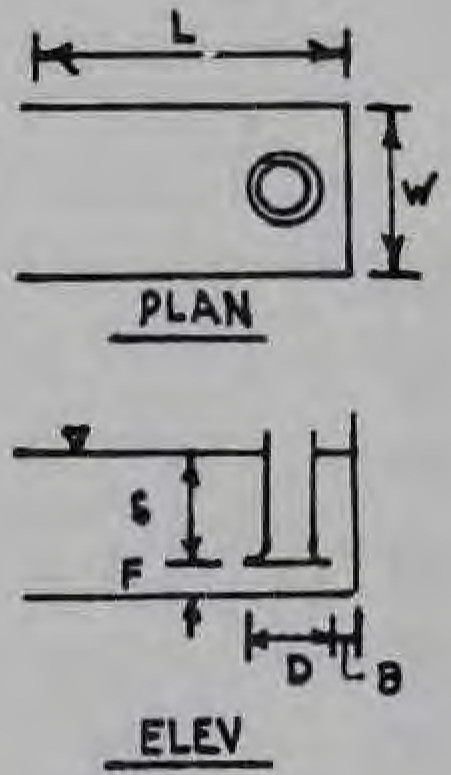
SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.21	0.05	0.47
*	0.35	0.25	0.47
*	0.27	0.50	0.47
+	0.27	0.05	1.26
+	-	0.25	1.26
+	-	0.50	1.26
x	0.27	0.05	2.02
x	-	0.25	2.02
x	-	0.50	2.02

— VORTICES DID NOT OCCUR FOR MAXIMUM PERMISSIBLE

$$\frac{Q}{D^{5/2} g^{1/2}} = 0.6$$

Figure 50. Distance from backwall versus flow rate, backwall vortices, incipient air core (propeller pump), F/D = 0.50





TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

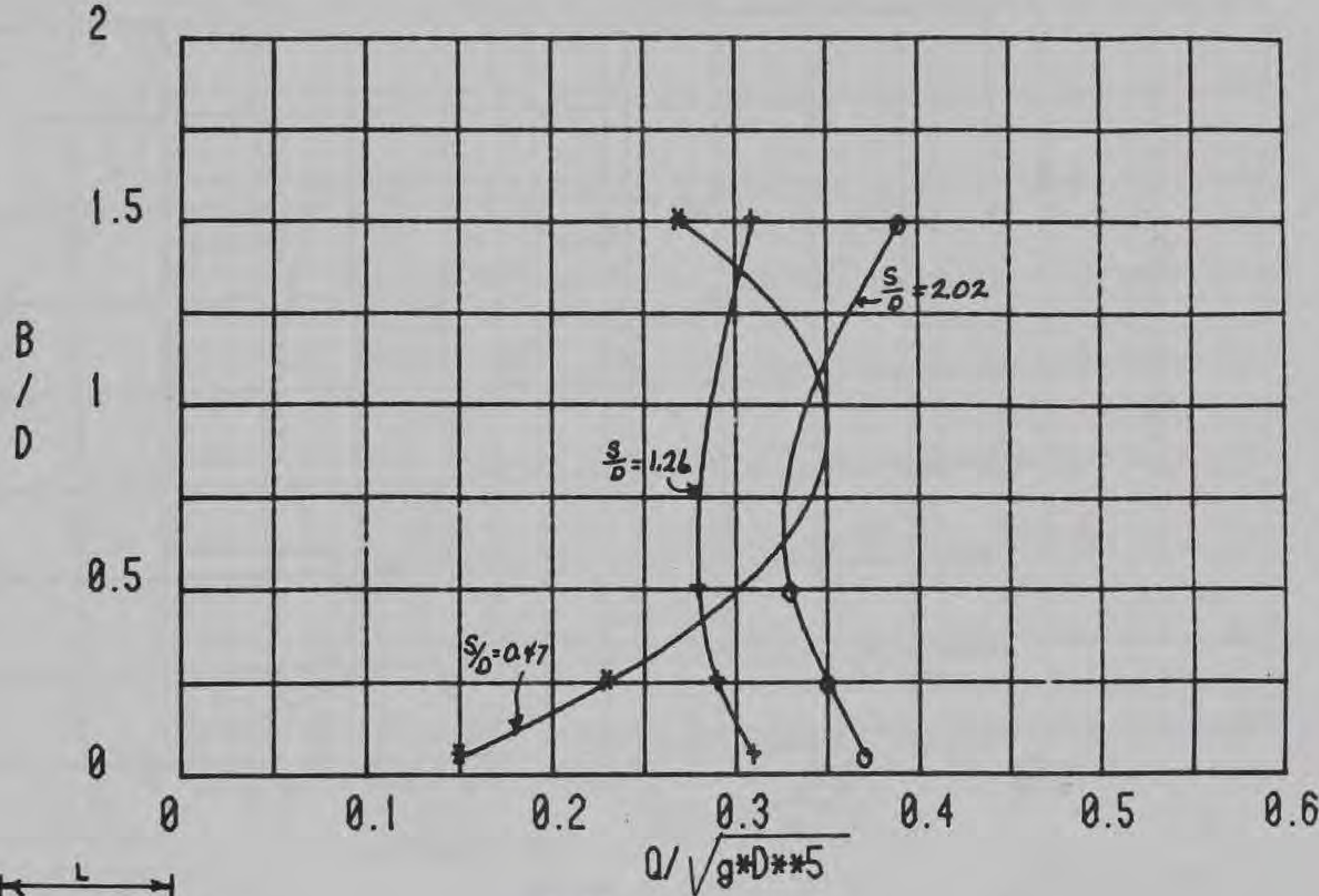
BASIC DATA

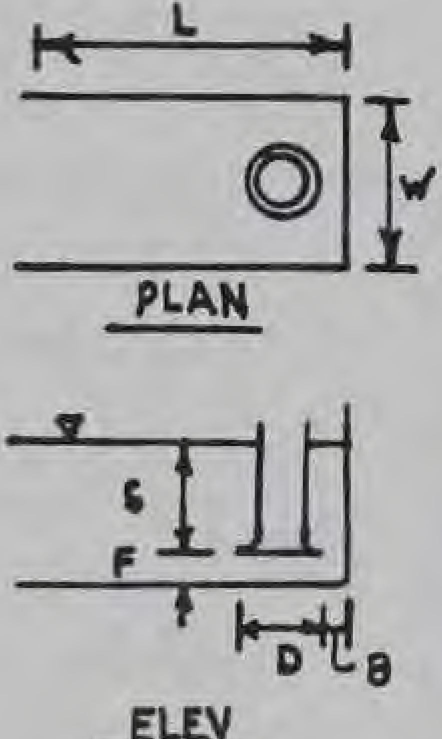
SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.25	0.05	0.47
*	0.33	0.50	0.47
*	-	0.25	0.47
o	0.30	0.05	1.26
o	-	0.25	1.26
o	-	0.50	1.26
x	0.30	0.05	2.02
x	-	0.25	2.02
x	-	0.50	2.02

— VORTICES DID NOT OCCUR FOR MAXIMUM PERMISSIBLE

$$\frac{Q}{D^{5/2}g^{1/2}} = 0.6$$

Figure 51. Distance from backwall versus flow rate, backwall vortices, incipient air core (propeller pump), F/D = 0.66





TEST CONDITIONS

D = 1.29 FT

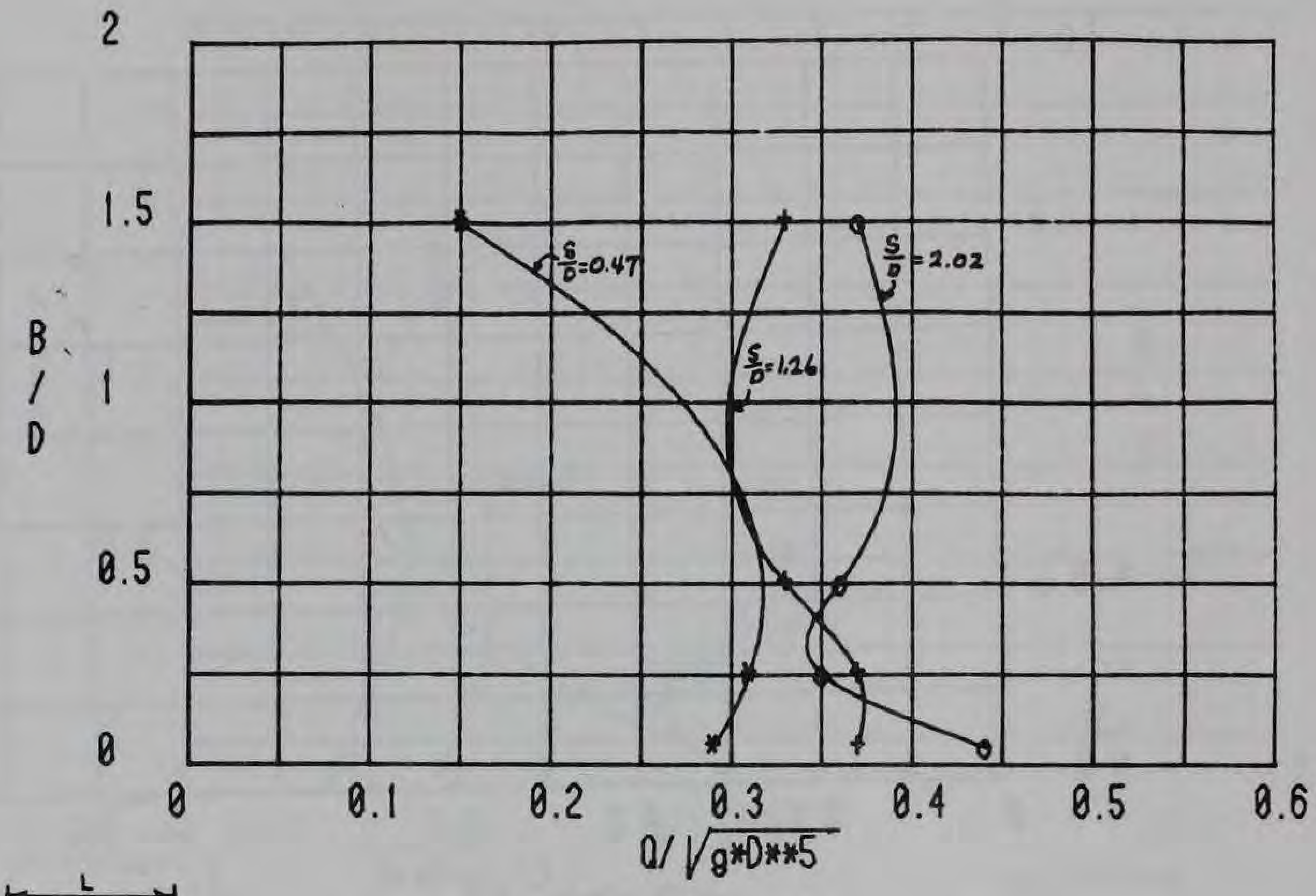
L = 18.6 D

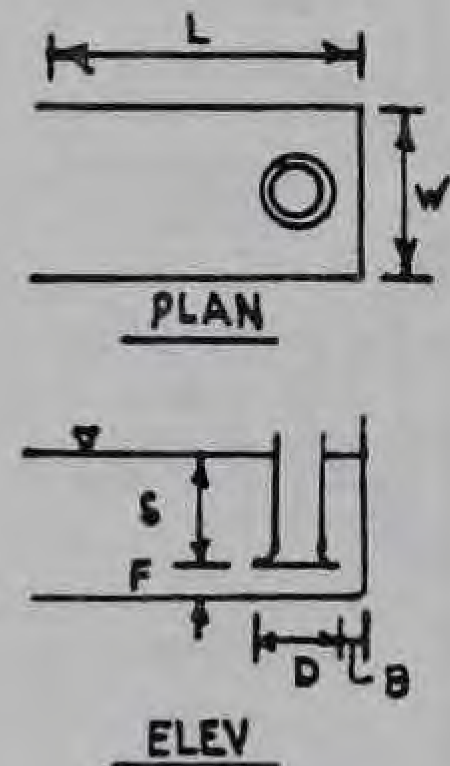
W = 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.15	0.05	0.47
*	0.23	0.25	0.47
*	0.27	1.50	0.47
*	-	0.50	0.47
+	0.31	0.05	1.26
+	0.29	0.25	1.26
+	0.28	0.50	1.26
+	0.31	1.50	1.26
o	0.37	0.05	2.02
o	0.35	0.25	2.02
o	0.33	0.50	2.02
o	0.39	1.50	2.02

Figure 52. Distance from backwall versus flow rate, floor vortices, incipient air core (propeller pump), F/D = 0.25



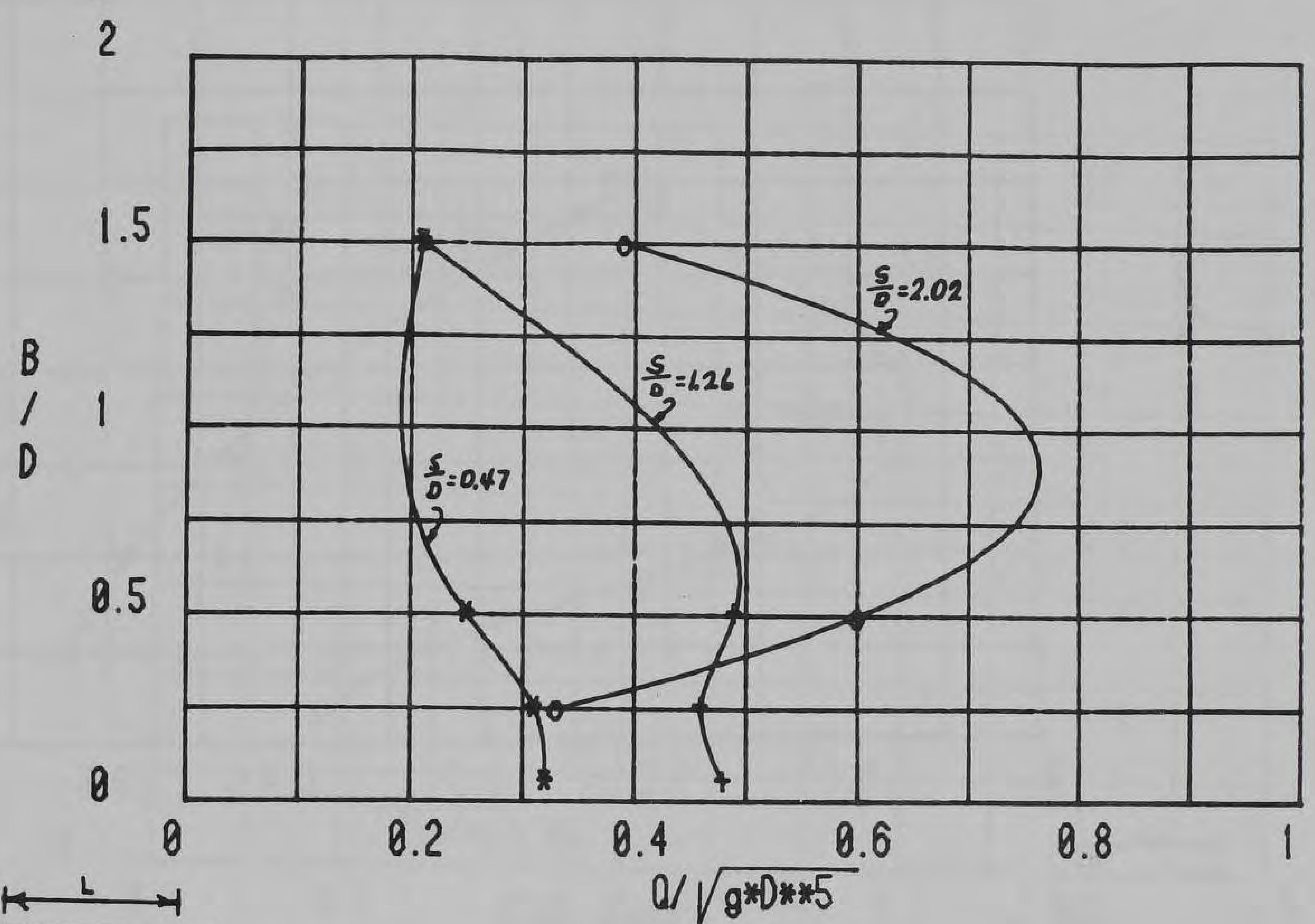


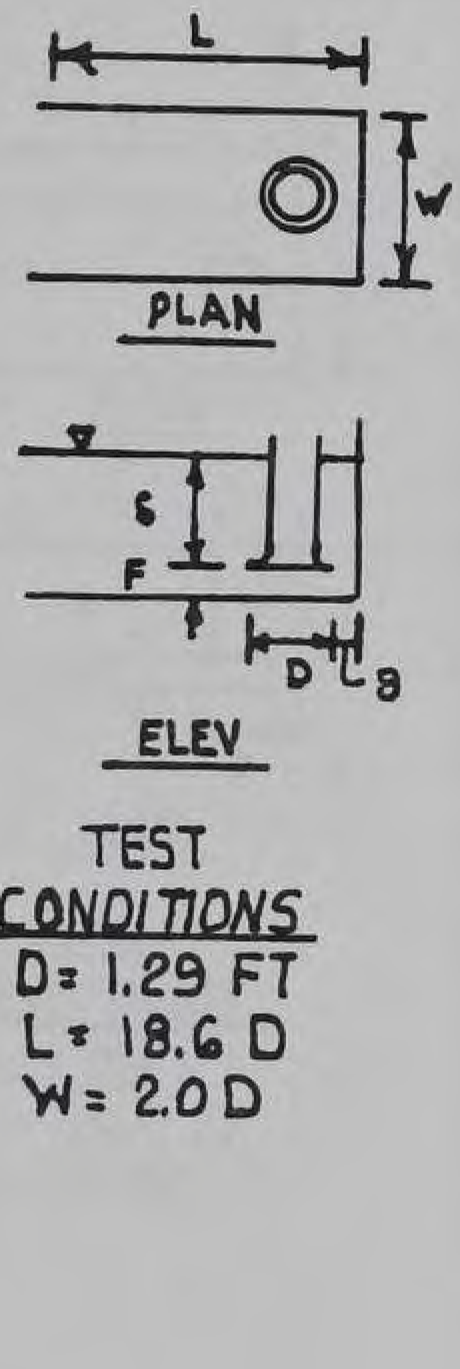
TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.29	0.05	0.47
*	0.31	0.25	0.47
*	0.15	1.50	0.47
*	-	0.50	0.47
+	0.37	0.05	1.26
+	0.37	0.25	1.26
+	0.33	0.50	1.26
+	0.33	1.50	1.26
o	0.44	0.05	2.02
o	0.35	0.25	2.02
o	0.36	0.50	2.02
o	0.37	1.50	2.02

Figure 53. Distance from backwall versus flow rate, floor vortices, incipient air core (propeller pump), F/D = 0.33

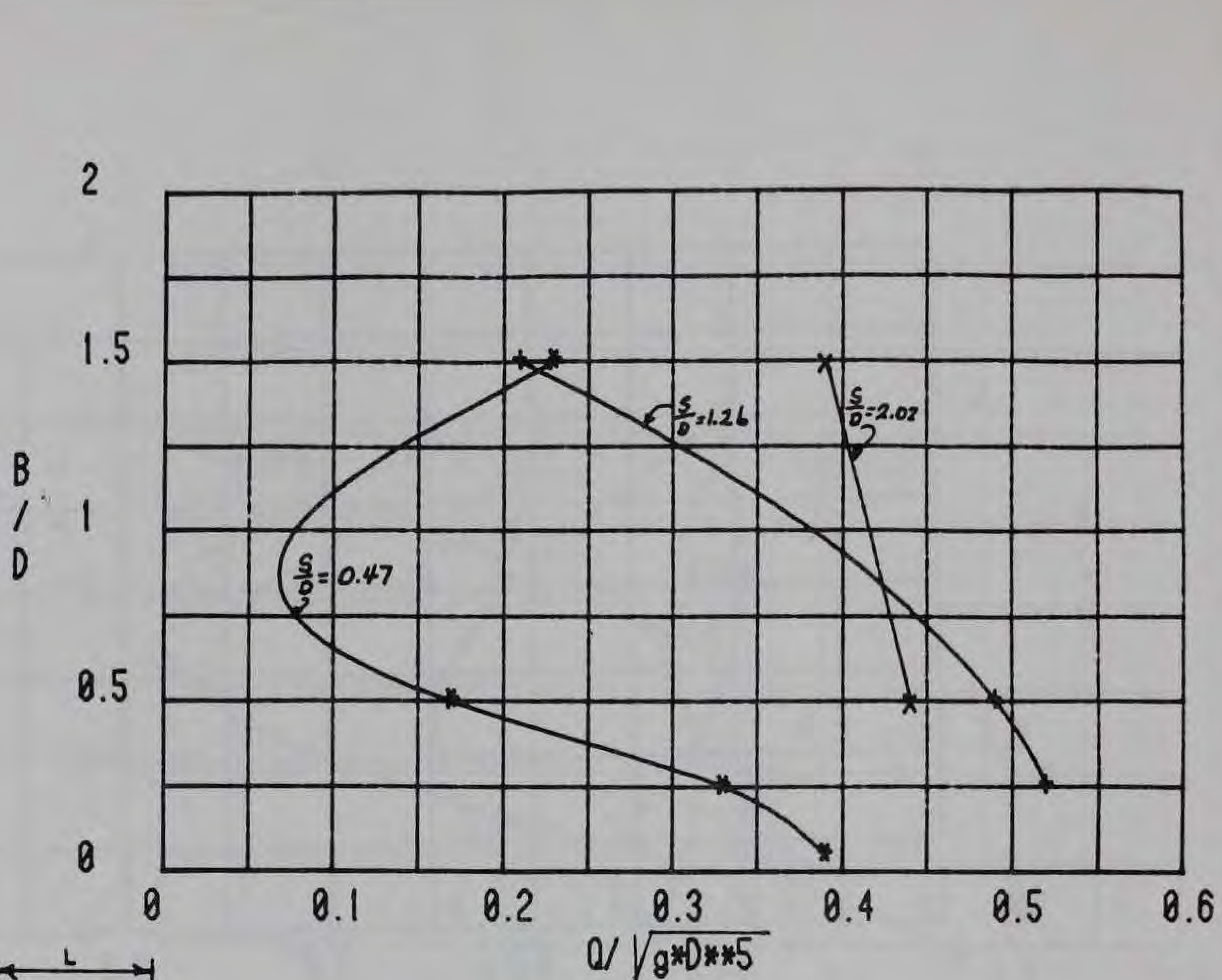


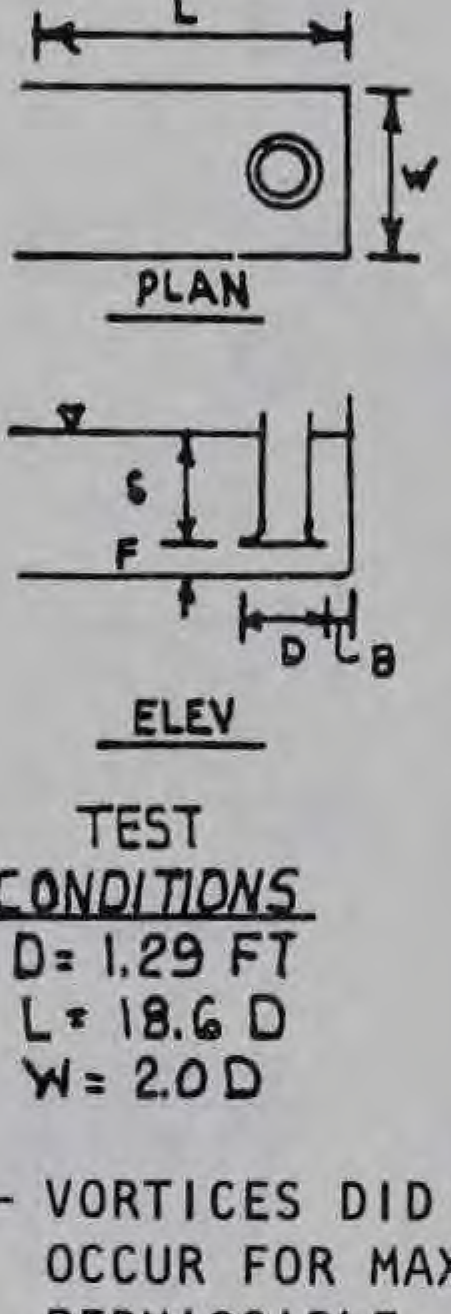


BASIC DATA

SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.32	0.05	0.47
*	0.31	0.25	0.47
*	0.25	0.50	0.47
*	0.21	1.50	0.47
+	0.48	0.05	1.26
+	0.46	0.25	1.26
+	0.49	0.50	1.26
+	0.21	1.50	1.26
o	0.33	0.25	2.02
o	0.60	0.50	2.02
o	0.39	1.50	2.02
o	-	0.05	2.02

Figure 54. Distance from backwall versus flow rate, floor vortices, incipient air core (propeller pump), F/D = 0.50





TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

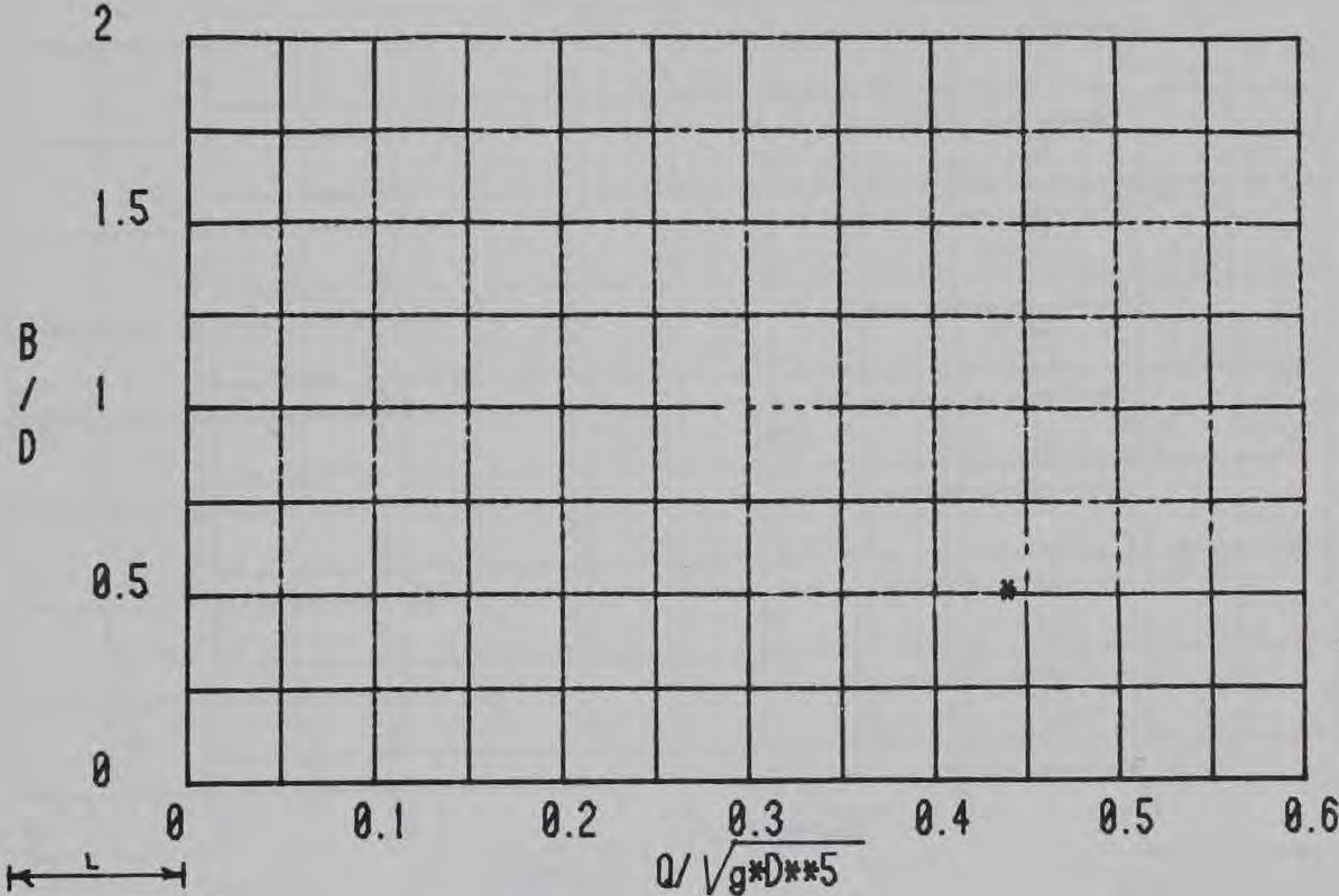
— VORTICES DID NOT OCCUR FOR MAXIMUM PERMISSIBLE

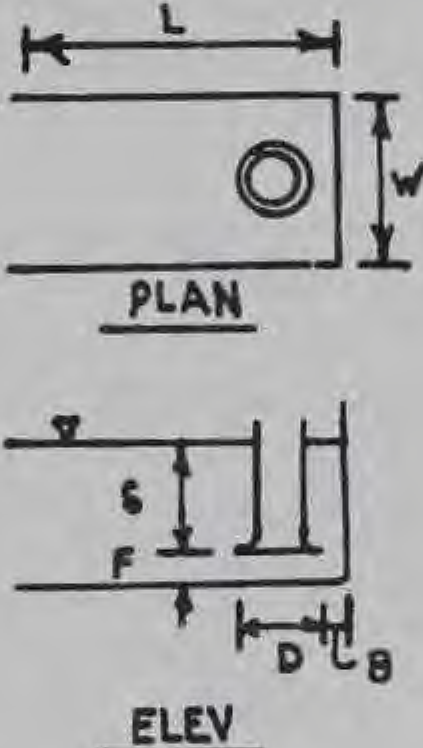
$$\frac{Q}{D^{5/2}g^{1/2}} = 0.6$$

BASIC DATA

SYMBOL	Q/ $\sqrt{g*D**5}$	B/D	S/D
*	0.39	0.05	0.47
*	0.33	0.25	0.47
*	0.17	0.50	0.47
*	0.23	1.50	0.47
+	0.52	0.25	1.26
+	0.49	0.50	1.26
+	0.21	1.50	1.26
+	-	0.05	1.26
x	0.44	0.50	2.02
x	0.39	1.50	2.02
x	-	0.05	2.02
x	-	0.25	2.02

Figure 55. Distance from backwall versus flow rate, floor vortices, incipient air core (propeller pump), F/D = 0.66





TEST CONDITIONS
D= 1.29 FT
L= 18.6 D
W= 2.0 D

BASIC DATA

SYMBOL	$Q/\sqrt{g*D**5}$	B/D	S/D
*	0.44	0.50	0.47

NOTE:
FOR VALUES OF $\frac{S}{D} > 0.47$
VORTICES DID NOT
OCCUR FOR MAXIMUM
PERMISSIBLE $\frac{Q}{D^{5/2} g^{1/2}} = 0.6$

TESTS WERE CONDUCTED AT
A S OF 1.26 AND 2.02 D
AND VORTICES DID NOT
OCCUR FOR THE MAXIMUM
PERMISSIBLE $\frac{Q}{D^{5/2} g^{1/2}} = 0.6$

Figure 56. Distance from backwall versus flow rate, sidewall vortices, incipient air core (propeller pump), F/D = 0.33

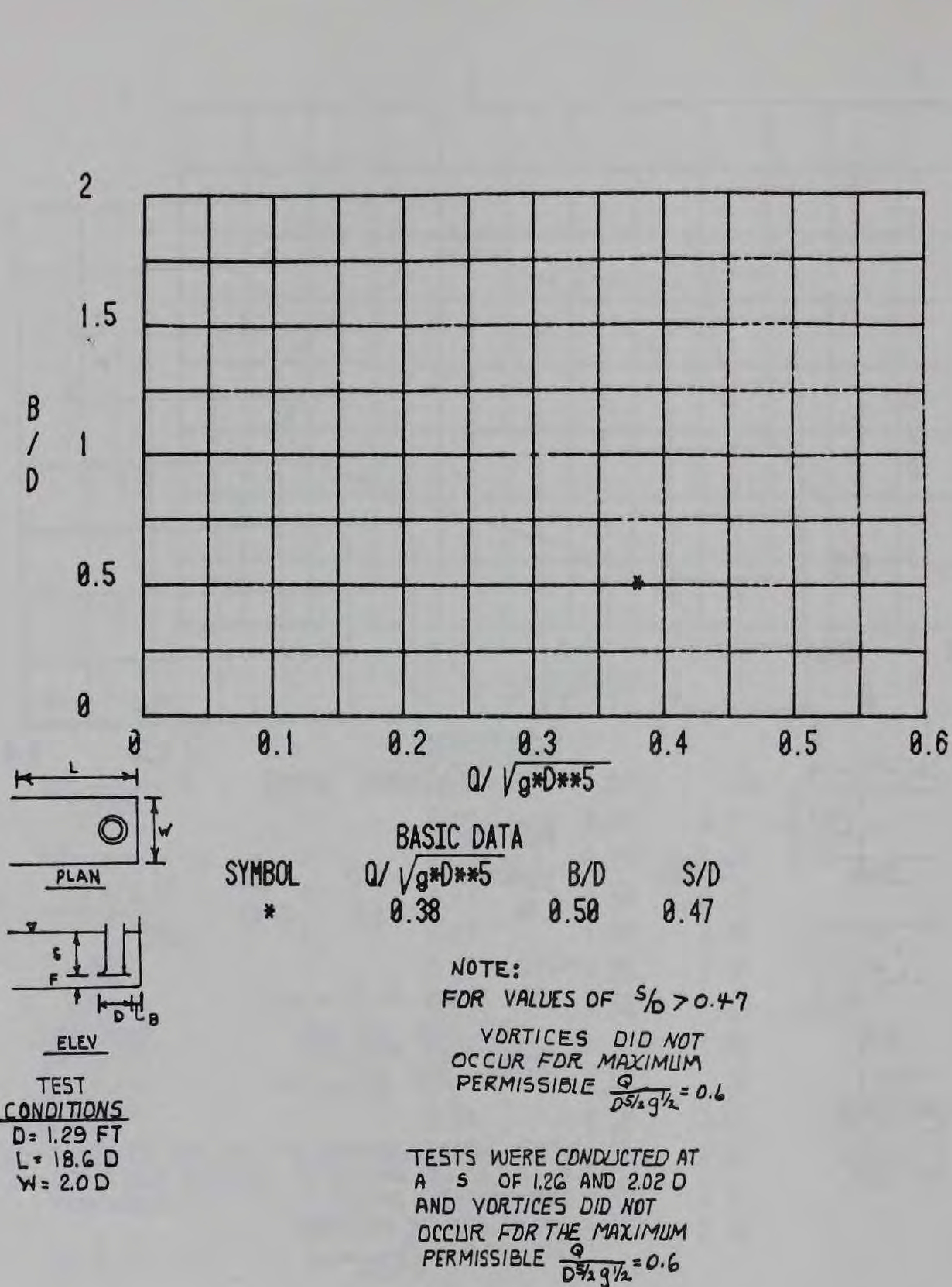
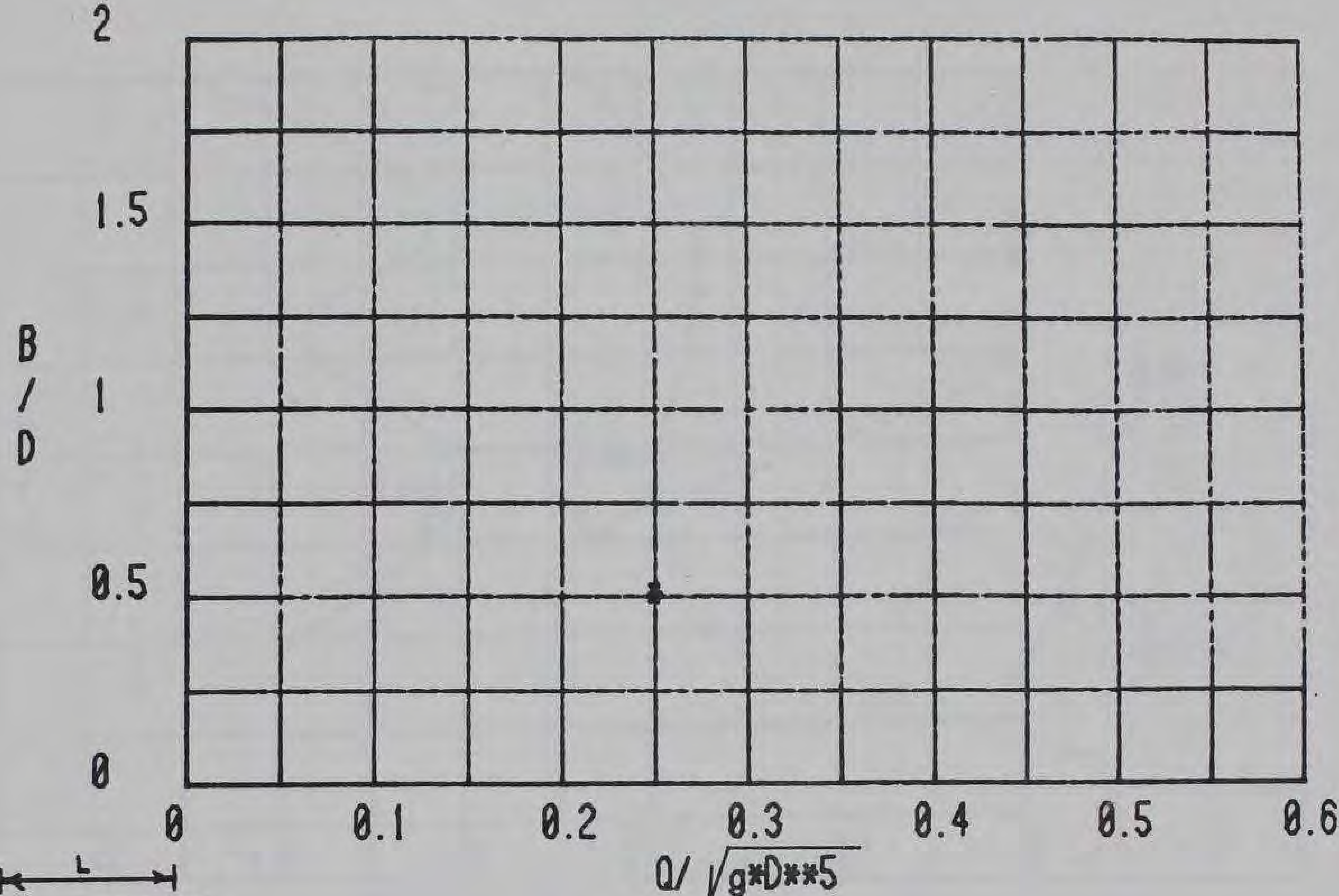
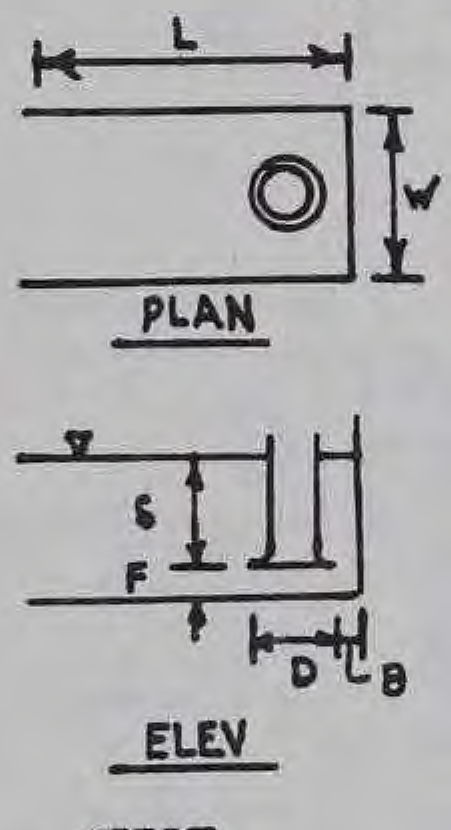


Figure 57. Distance from backwall versus flow rate, sidewall vortices, incipient air core (propeller pump), F/D = 0.50





BASIC DATA

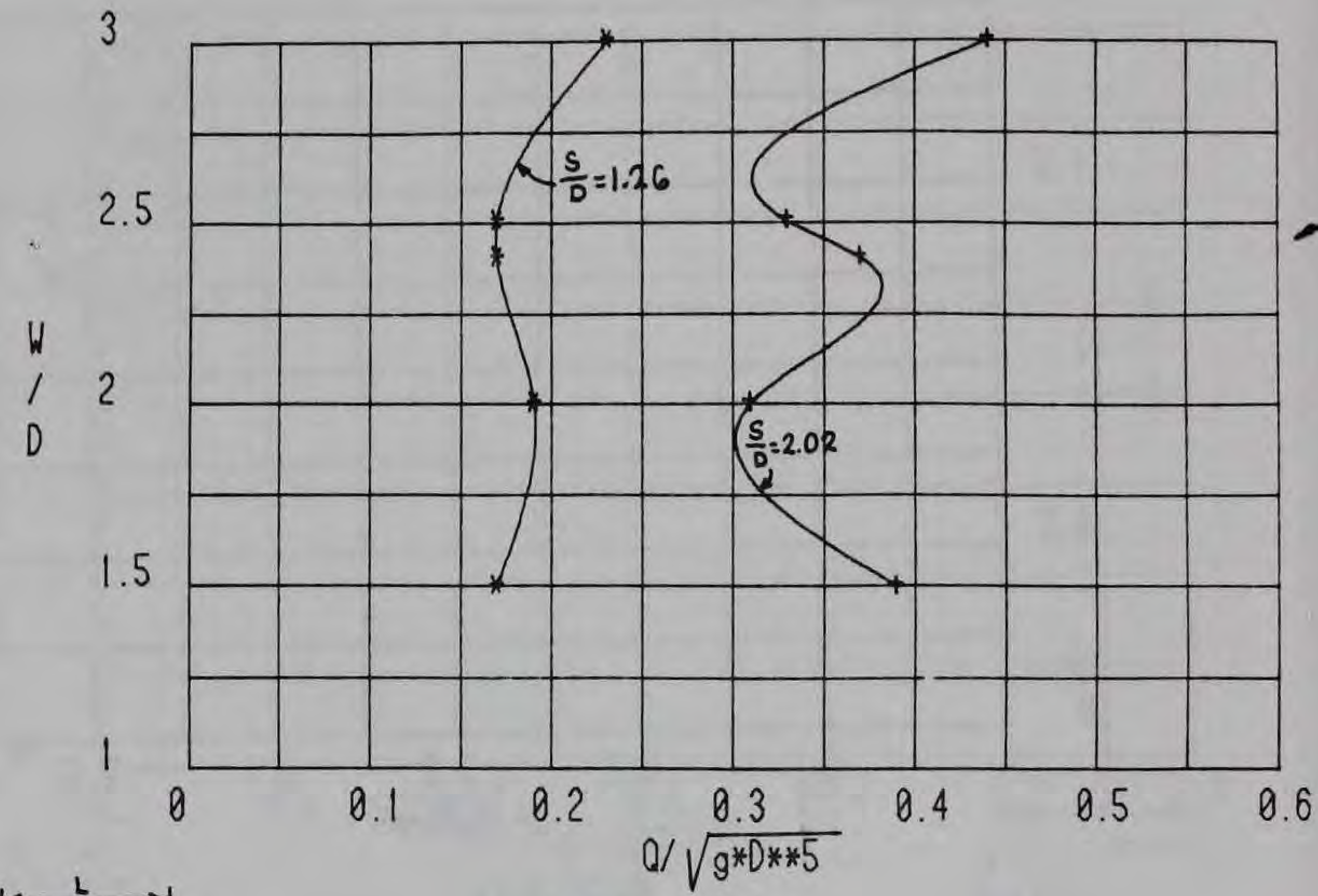
SYMBOL	Q/ √g*D**5	B/D	S/D
*	0.25	0.50	0.47

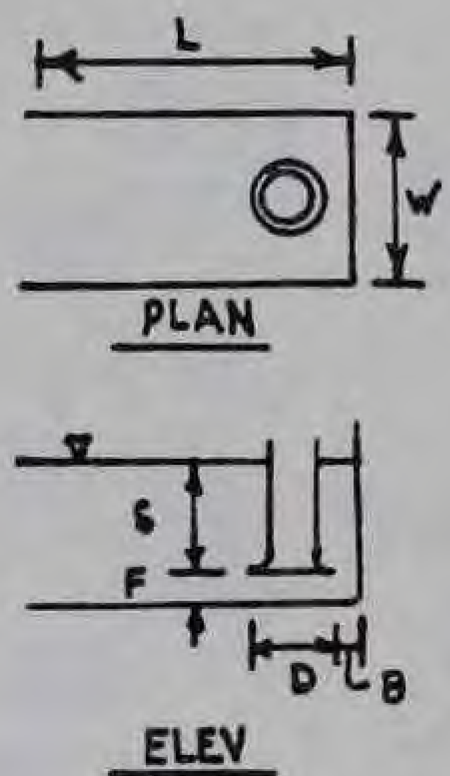
TEST CONDITIONS
D = 1.29 FT
L = 18.6 D
W = 2.0 D

FOR VALUES OF $S/D > 0.47$ VORTICES DID NOT OCCUR FOR MAXIMUM PERMISSIBLE $\frac{Q}{D^{5/2} g^{1/2}} = 0.6$

TESTS WERE CONDUCTED AT A S OF 1.26 AND 2.02 D AND VORTICES DID NOT OCCUR FOR THE MAXIMUM PERMISSIBLE $\frac{Q}{D^{5/2} g^{1/2}} = 0.6$

Figure 58. Distance from backwall versus flow rate, sidewall vortices, incipient air core (propeller pump), F/D = 0.66



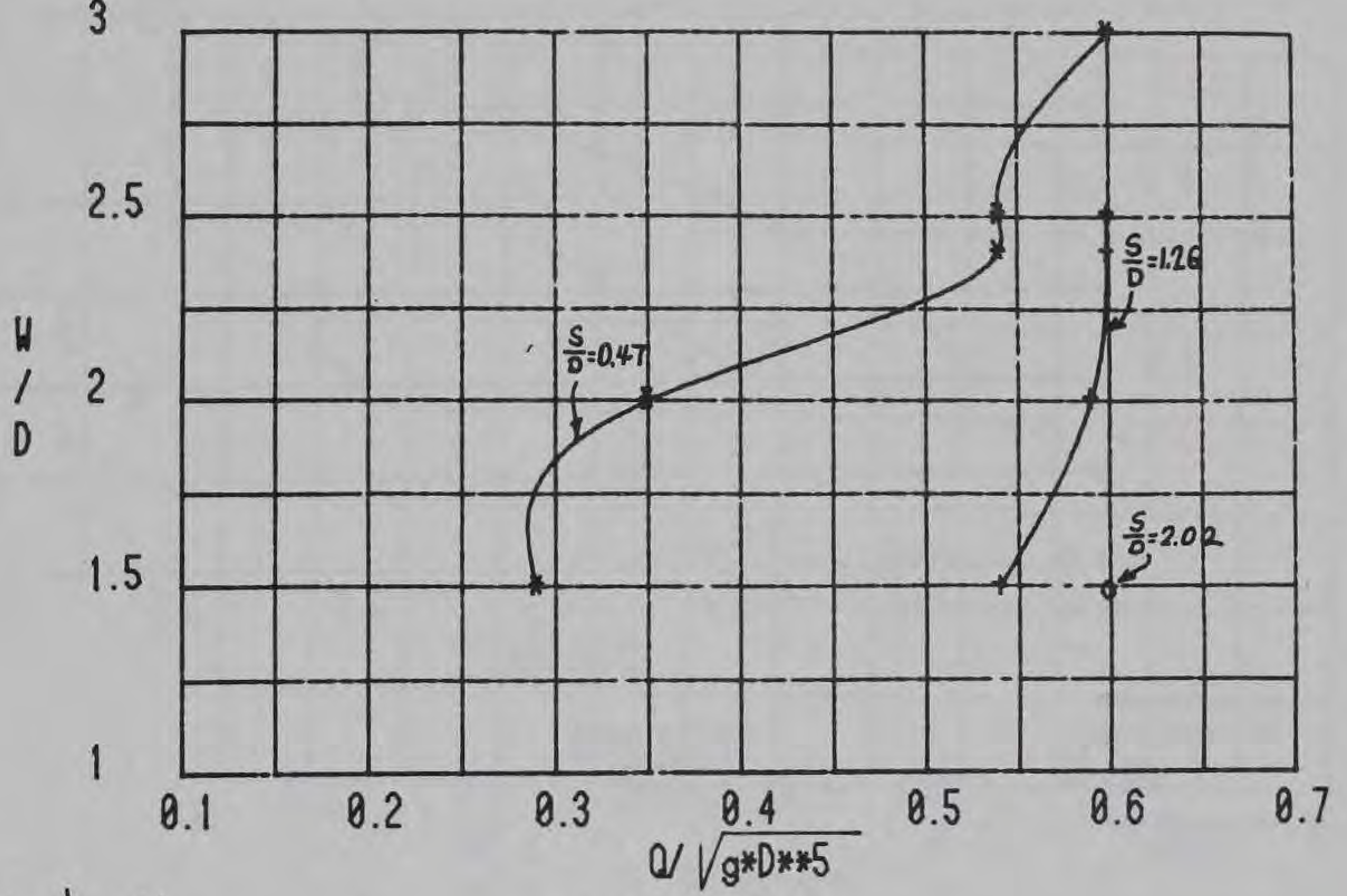


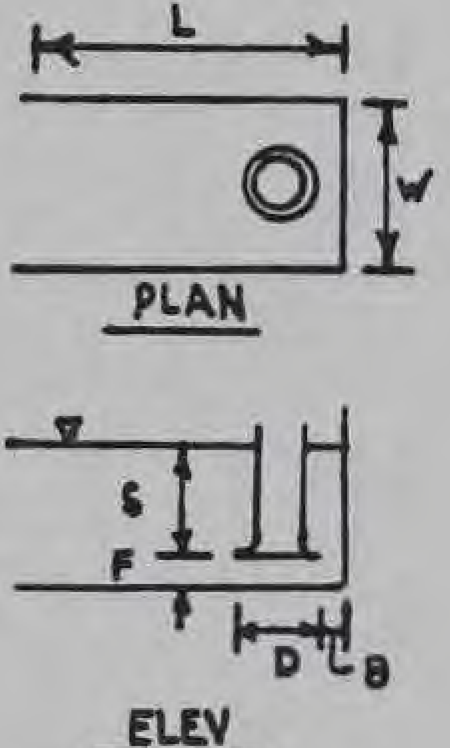
BASIC DATA

SYMBOL	Q/ √g*D**5	W/D	S/D
*	0.17	1.50	1.26
*	0.19	2.00	1.26
*	0.17	2.40	1.26
*	0.17	2.50	1.26
*	0.23	3.00	1.26
+	0.39	1.50	2.02
+	0.31	2.00	2.02
+	0.37	2.40	2.02
+	0.33	2.50	2.02
+	0.44	3.00	2.02

FOR A S/D = 0.47 VORTICES WERE OBSERVED AT A MINIMUM PERMISSIBLE $\frac{Q}{D^{5/2} g^{1/2}} = 0.06.$

Figure 59. Bay width versus flow rate, surface vortices, incipient stage C vortex (propeller pump), B/D = 0.25 ; F/D = 0.50

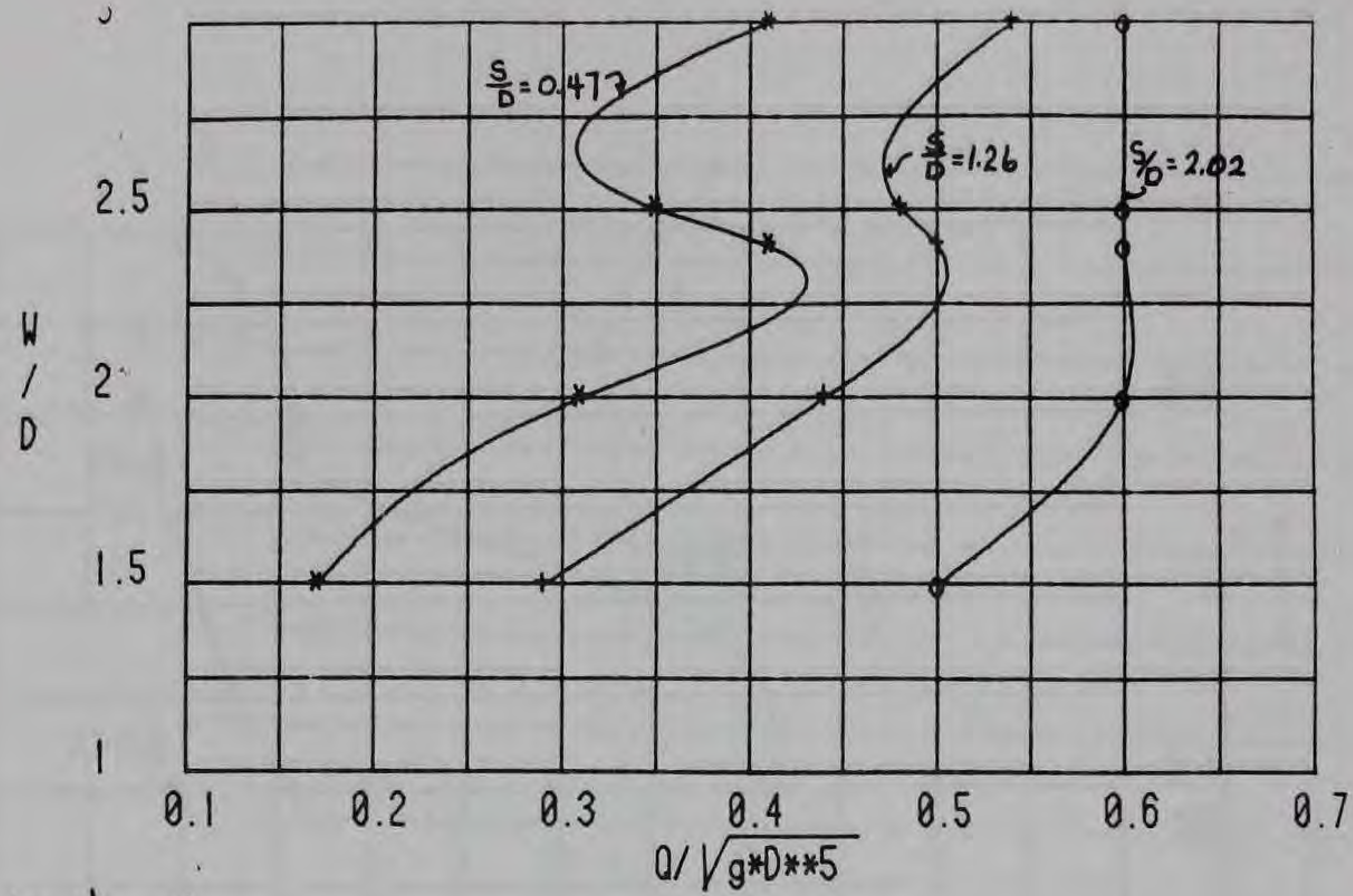


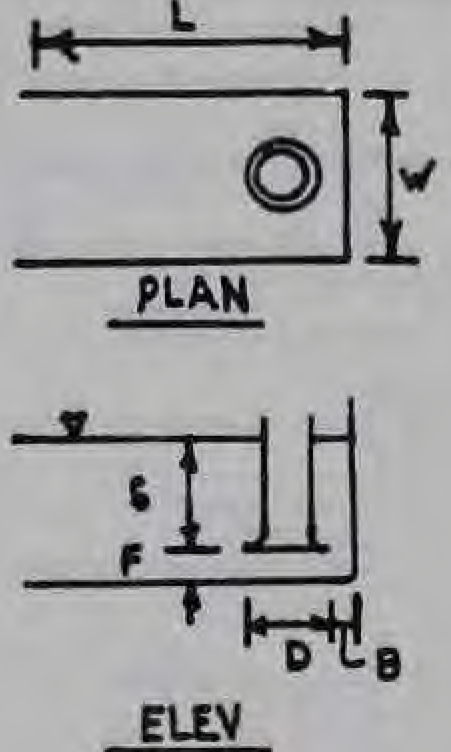


BASIC DATA

SYMBOL	Q/ √g*D**5	W/D	S/D
*	0.29	1.50	0.47
*	0.35	2.00	0.47
*	0.54	2.40	0.47
*	0.54	2.50	0.47
*	0.60	3.00	0.47
+	0.54	1.50	1.26
+	0.59	2.00	1.26
+	0.60	2.40	1.26
+	0.60	2.50	1.26
o	0.60	1.50	2.02

Figure 60. Bay width versus flow rate, backwall vortices, incipient air core (propeller pump), B/D = 0.25 ; F/D = 0.50

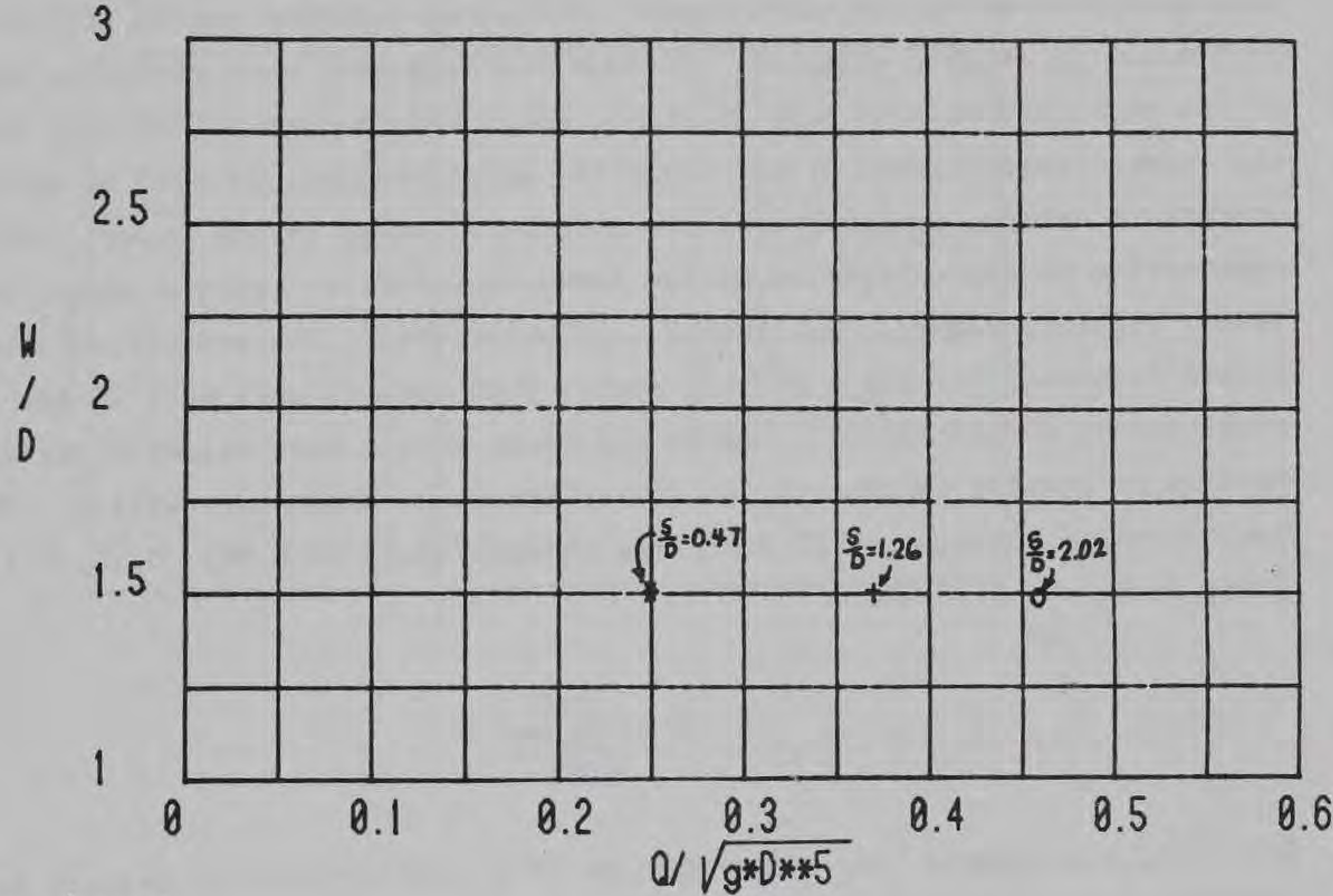


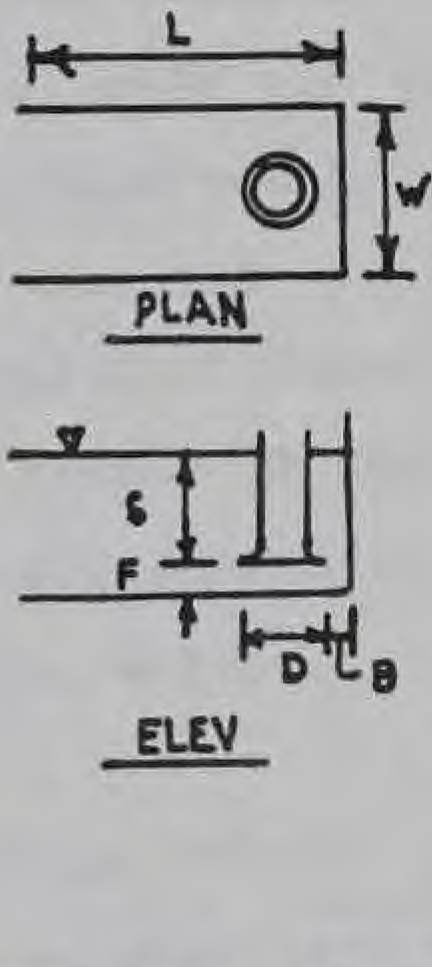


BASIC DATA

SYMBOL	Q/ √g*D**5	W/D	S/D
*	0.17	1.50	0.47
*	0.31	2.00	0.47
*	0.41	2.40	0.47
*	0.35	2.50	0.47
*	0.41	3.00	0.47
+	0.29	1.50	1.26
+	0.44	2.00	1.26
+	0.50	2.40	1.26
+	0.48	2.50	1.26
+	0.54	3.00	1.26
O	0.50	1.50	2.02
O	0.60	2.00	2.02
O	0.60	2.40	2.02
O	0.60	2.50	2.02
O	0.60	3.00	2.02

Figure 61. Bay width versus flow rate, floor vortices, incipient air core (propeller pump), B/D = 0.25 ; F/D = 0.50





BASIC DATA

SYMBOL	Q/ √g*D**5	W/D	S/D
*	0.25	1.50	0.47
+	0.37	1.50	1.26
o	0.46	1.50	2.02

SIDE WALL VORTICES DID NOT OCCUR FOR BAY WIDTHS, W > 1.5 D

Figure 62. Bay width versus flow rate, sidewall vortices, incipient air core (propeller pump), B/D = 0.25 ; F/D = 0.50

PART VIII: SURFACE VORTEX SUPPRESSOR BEAMS

116. Surface vortex suppressor (SVS) beams are horizontal members placed across the sump just upstream from the pump. The purpose of the beams is to create sufficient surface turbulence to break up circular motion that usually progresses to surface vortices. Surface vortices (SV) were virtually ignored in the tests determining pump location, described in Part VII of this report. The reason, demonstrated by site-specific model studies, is that in all but exceptional cases, surface vortices can be eliminated by SVS beams. Various combination of six categories of SVS beams were tested: single stage, single level, slotted, sloping, multistage, and multilevel. The evaluation techniques discussed in Part V of this report were used in this part of the report with certain modifications. Common discharge ratios were selected during testing to provide continuity for comparison with subsequent testing. These ratios are as follows: full discharge (usually 0.58 to 0.60), 0.50, 0.42, 0.35, 0.29, and 0.23 where

$$R = \frac{Q}{\sqrt{gD}^{5/2}} \qquad (35)$$

The data, for example, may state that an FV (floor vortex) was present for a discharge range of $0.6 \leq R \leq 0.42$. This means that the pump was first operated at a discharge ratio R of 0.6 and then at decremental (or decreasing) ratios of 0.5, 0.42, 0.35, etc. The FV was visible at $R = 0.42$ but not at $R = 0.35$. The FV may have been visible also at some ratio beyond 0.42 but prior to 0.35; but since the pump was not operated at any other R values in between, this is not known. The same philosophy was used in selecting submergence ranges in increments of 0.5D or 0.25D. These data points provide sufficient data for reliable evaluation.

117. Sump type 28 (Figure 63) was used for the majority of SVS testing (all except SVS type 56). Sump type 18 was used for the remaining testing (SVS type 56). The only difference in the two sumps is that the width is 2.5D for type 28 and 2D for type 18 (Figure 63).

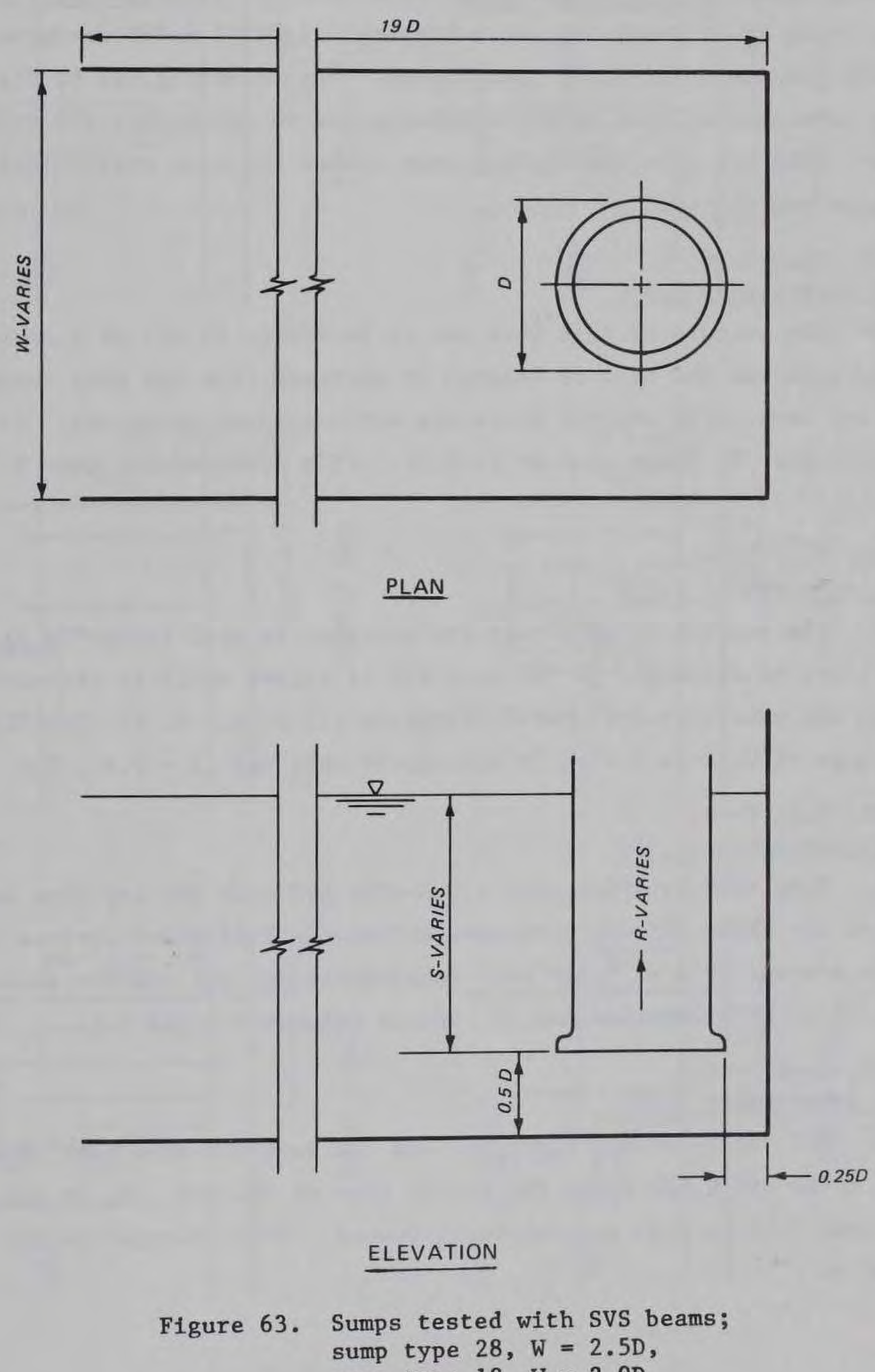


Figure 63. Sumps tested with SVS beams; sump type 28, W = 2.5D, sump type 18, W = 2.0D

Single Beams Located 1D Upstream from Pump

118. Initial tests were conducted to investigate the effect of height and upstream location of a single beam for a range of submergences. For the first two tests (I-38 and I-39), an arbitrary height of 0.75D was selected (Figure 64) and tested at 1.97D submergence. The reasoning was to start at an arbitrary submergence, then decrease submergence as successful SVS types were determined. The SVS type was changed when either the size or the location of the SVS beam was changed.

Type 1 SVS, Test I-38,
pump bell submergence 1.97D

119. The purpose of this test was to determine if all SV's could be eliminated when the SVS beam is located 1D upstream from the pump column center line and vertically extends above the water-surface elevation. No SV occurred for the R range of 0.60 to 0.31. FV's occurred for the R value of 0.6.

Type 2 SVS, Test I-39,
pump bell submergence 1.97D

120. The purpose of this test (in addition to that stated in paragraph 119) was to determine if the same SVS is raised until it protrudes only 0.27D into the water, it will still eliminate all SV's. No SV occurred for the R range of 0.60 to 0.23. FV's occurred only for R = 0.6 .

Type 3 SVS, Test I-40,
pump bell submergence 1.97D

121. This test verified that a 0.5-high SVS with the top edge located 0.27D below the water surface continues to provide sufficient surface turbulence to prevent SV's at 1.97D bell submergence and for the aforementioned values of R . FV's occurred for R values between 0.6 and 0.5.

Type 4 SVS, Test I-41,
pump bell submergence 1.22D

122. The water-surface elevation and the 0.5D SVS were both lowered. The water level was 0.22D above the bottom edge of the SVS. No SV occurred for R range 0.60 to 0.23 as previously stated. FV's occurred in the R range 0.60 to 0.46.

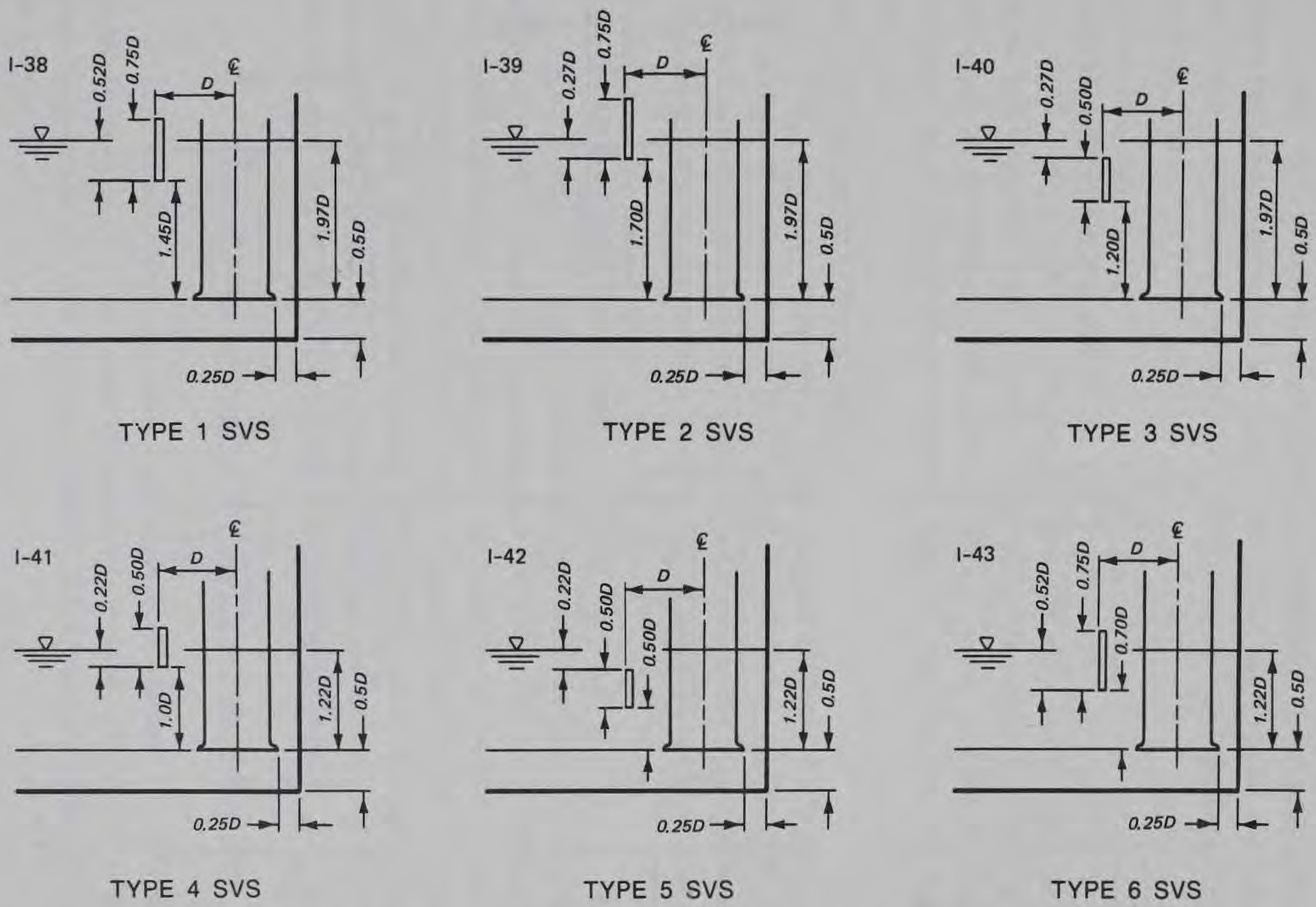
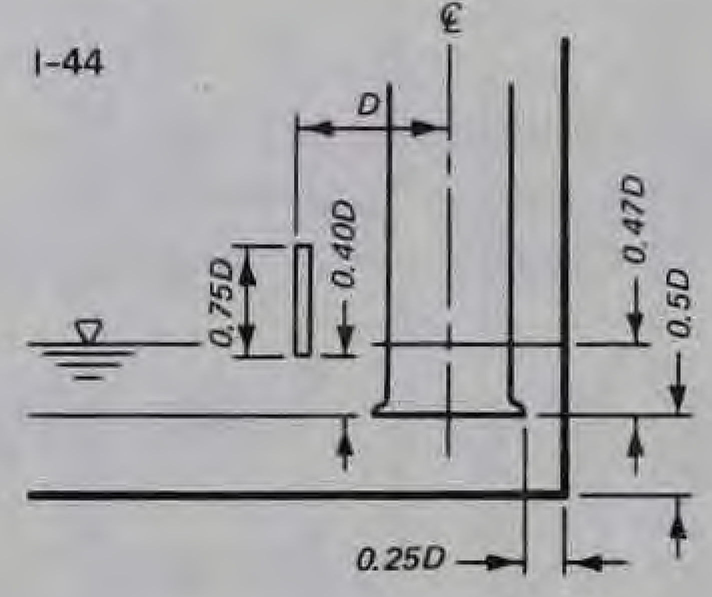
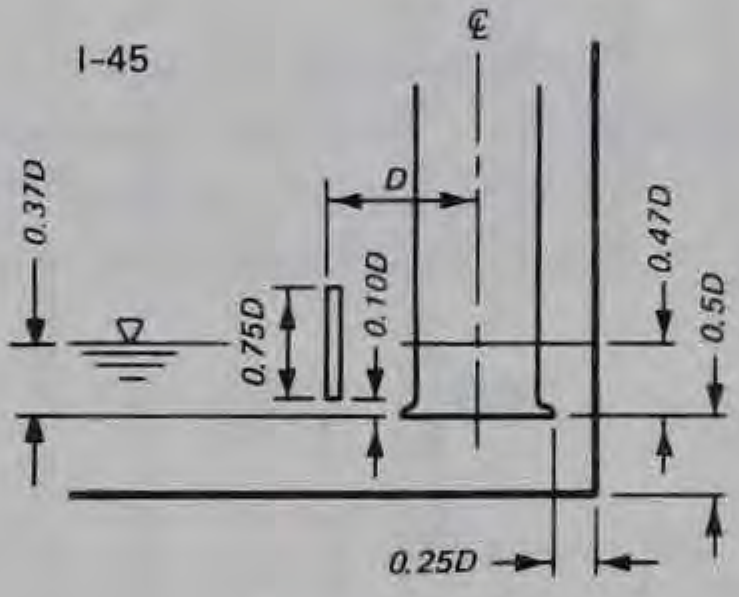


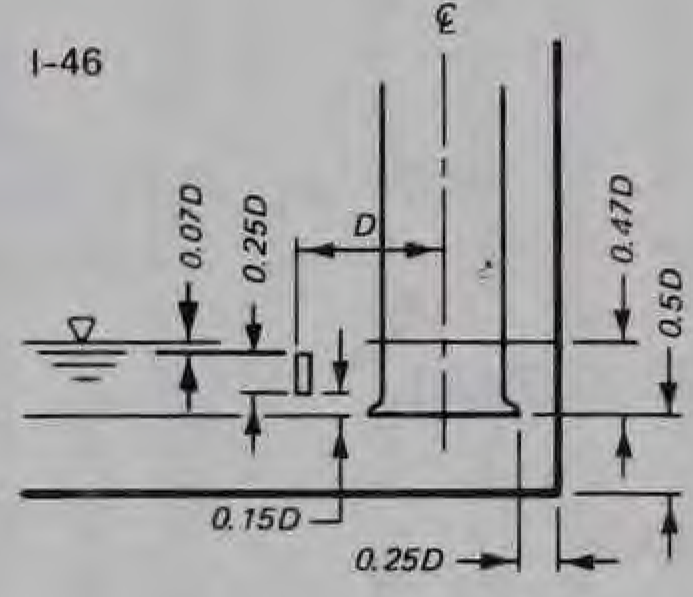
Figure 64. Surface vortex suppressors; single beam located 1D upstream from center line of pump, Tests I-38 through I-52, sump type 28; SVS types 1 through 14 submergence varies, discharge ratio varies (Continued)



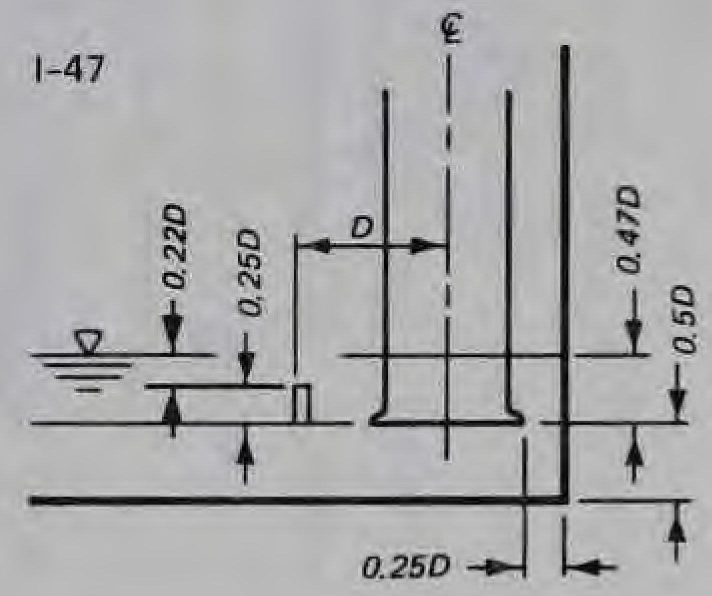
TYPE 7 SVS



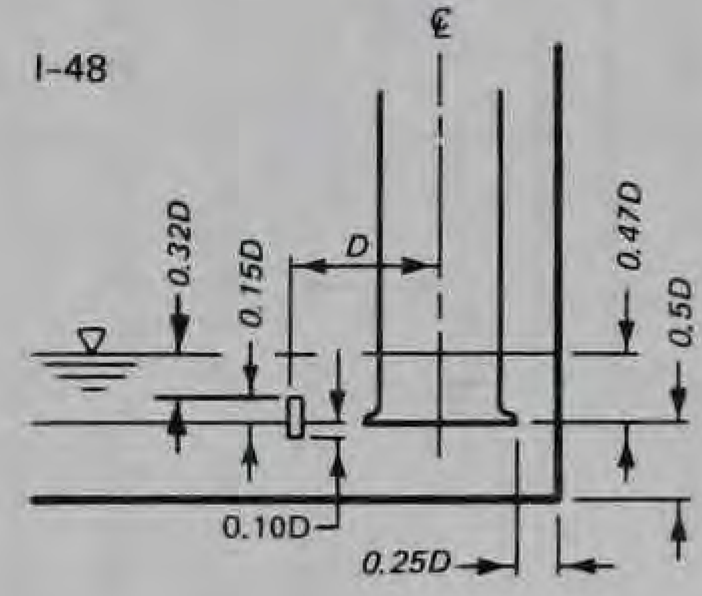
TYPE 8 SVS



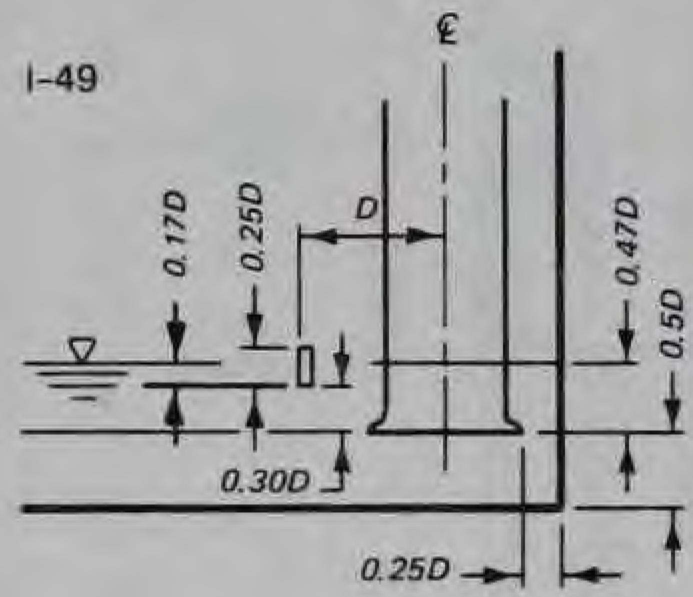
TYPE 9 SVS



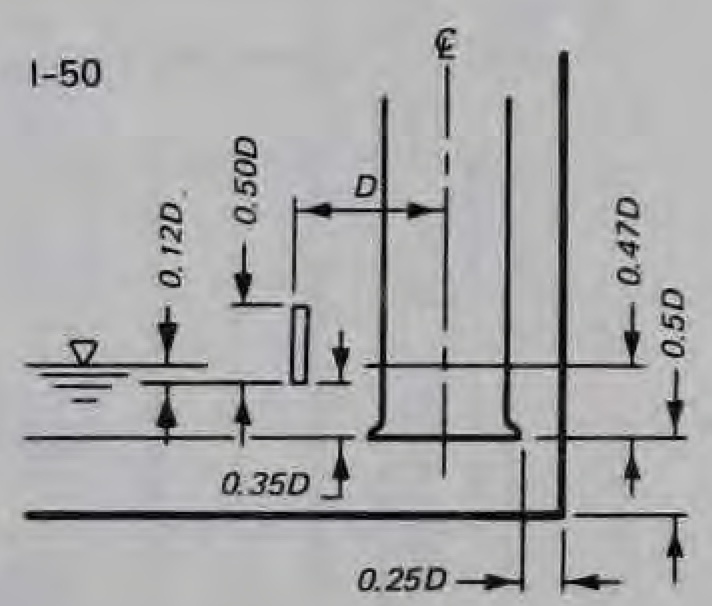
TYPE 10 SVS



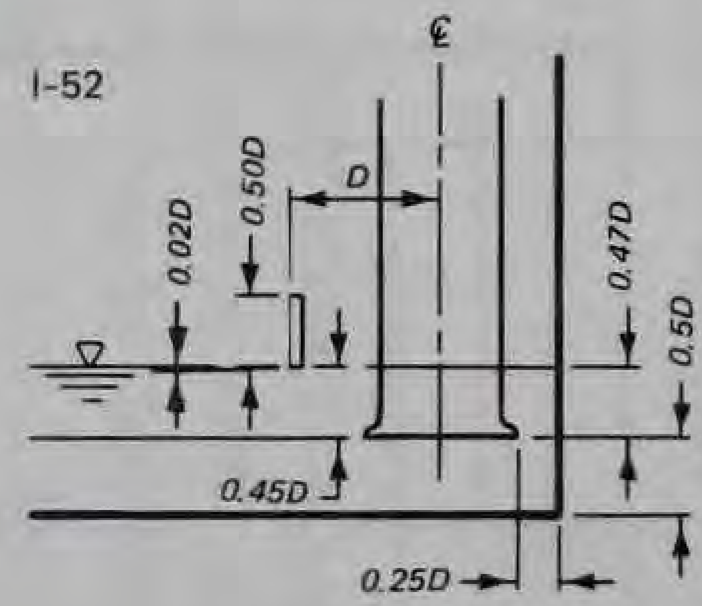
TYPE 11 SVS



TYPE 12 SVS



TYPE 13 SVS



TYPE 14 SVS

Figure 64. (Concluded)

Type 5 SVS, Test I-42,
pump bell submergence 1.22D

123. The 0.50D SVS was lowered an additional 0.50D while the pump bell submergence was maintained at 1.22D. The water depth above the top of the SVS was 0.22D. No SV occurred but the FV remained for a wider range of R of 0.60 to 0.37.

Type 6 SVS, Test I-43,
pump bell submergence 1.22D

124. The 0.75D-high SVS was reinstalled with its bottom edge 0.70D above the pump bell lip. It was tested at 1.22D pump bell submergence; therefore it protruded 0.23D above the water surface and 0.52D below the water surface. No SV occurred and the FV's remained only for the R range of 0.60 to 0.42.

Low pump bell submergence (0.47D)

125. The next eight tests (I-44 through I-50 and I-52) were conducted for various SVS types (7-14) but were unsuccessful in eliminating SV's at low (0.47D) pump bell submergence. The turbulences conducive to SV are so strong that they override any surface turbulence intended to break up the SV.

Conclusions for single beam
located 1D from bell center line

126. The 0.50D and 0.75D single beams at this location are effective in eliminating SV at pump bell submergences of 1.22D and 1.97D when the beam is vertically located so that the top of the beam is not more than 0.27D below the water surface or when the bottom of the beam protrudes below the water surface 0.22D or more. SVS beams 0.50 high or higher at these low submergences produce favorable conditions for FV to occur. Future studies will be made to determine the cause of the FV and action required to minimize them.

Single Beams Located 2D Upstream from Pump Center Line

127. These tests and test conditions were similar to those conducted for beams located 1D upstream from the pump center line. The purpose was to obtain data for comparison with previous tests. SVS types for these tests are shown in Figure 65.

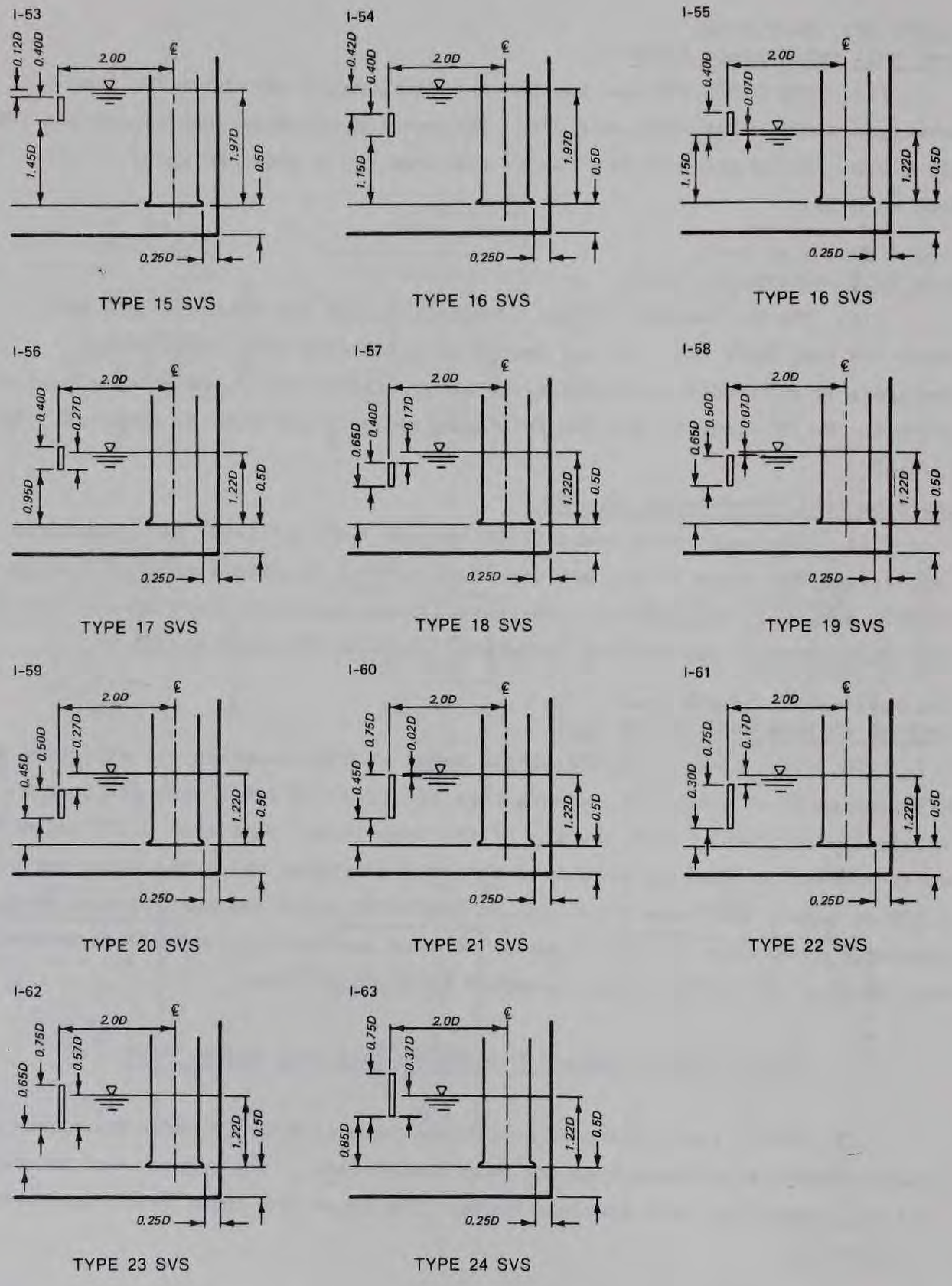


Figure 65. Surface vortex suppressors; single beam located 2D upstream from center line of pump, Tests I-53 through I-72, sump type 28; SVS types 15 through 32, submergence varies, discharge ratio varies (Continued)

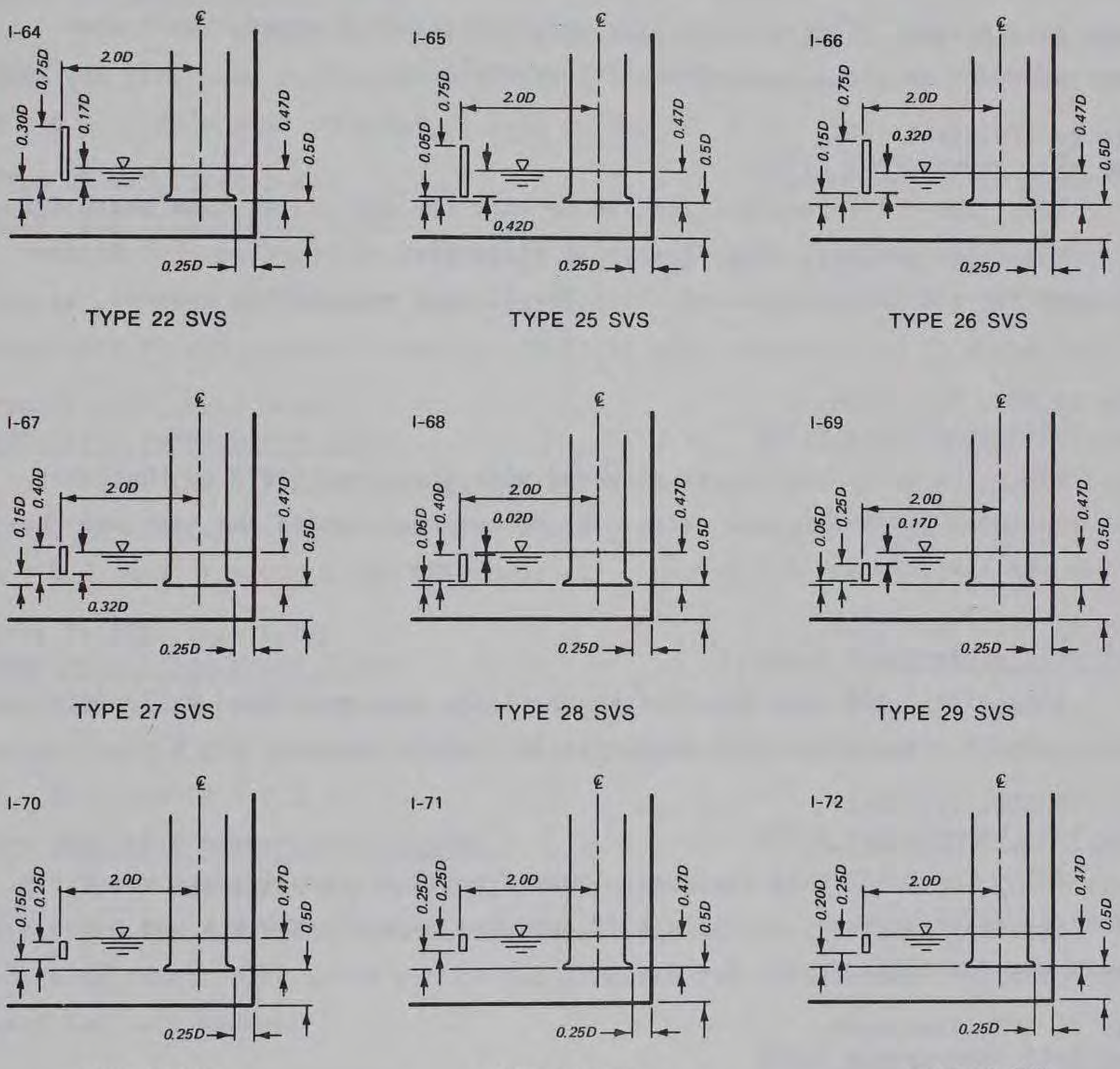


Figure 65. (Concluded)

Type 15 SVS, Test I-53, pump bell submergence 1.97D

128. During this test, the top of the 0.40D beam was 0.12D below the water surface. No SV occurred but an FV was visible at the high discharge R value of 0.6 only. This was not attributed to the beam since the FV also occurred under the same conditions without the beam.

Type 16 SVS, Test I-54, pump bell submergence 1.97D

129. The 0.40D beam was lowered so that the top of the beam was 0.42D below the water surface. The SV was not eliminated at R = 0.6 but it disappeared for all lower values of R . The FV also was visible only at R = 0.6 .

Type 16 SVS, Test I-55, pump bell submergence 1.22D

130. The water surface was lowered with the type 16 SVS so that the beam protruded 0.07D into the water. No SV occurred during the test and the FV was visible only at R = 0.6 .

Type 17 SVS, Test I-56, pump bell submergence 1.22D

131. The 0.40D beam was lowered until the beam protruded 0.27D into the water. No SV occurred and the FV was still visible only at R = 0.6 .

Type 18 SVS, Test I-57, pump bell submergence 1.22D

132. The 0.40D beam was again lowered until its top surface was 0.17D below the water surface. A stage A SV occurred between R = 0.6 and 0.42 . The FV was visible only at R = 0.6 .

Type 19 SVS, Test I-58, pump bell submergence 1.22D

133. A larger SVS beam was installed with its lower surface located 0.65D above the bell lip. This location with respect to the lower surface is the same as the previously tested 0.40D beam. The top surface of the taller SVS (0.50D) was therefore only 0.07D below the water surface. No SV's occurred but FV's appeared at R values of 0.6 and 0.4.

Type 20 SVS, Test I-59, pump bell submergence 1.22D

134. The 0.50D SVS was lowered so that it was submerged 0.27D below the

water surface. A stage B SV occurred at R = 0.6 and a stage A SV occurred at R = 0.4 . An FV occurred for R values between 0.4 and 0.6.

Type 21 SVS, Test I-60,
pump bell submergence 1.22D

135. The height of the SVS was increased to 0.75D so that the top surface was very near the water surface. A stage A SV occurred at R = 0.6 and R = 0.4 . FV's also occurred at both values of R .

Type 22 SVS, Test I-61,
pump bell submergence 1.22D

136. The 0.75D SVS was lowered until its top surface was 0.17D below the water surface. A stage B SV occurred at R = 0.6 and R = 0.4 . There also were FV and backwall vortices (BWV) at both values of R (0.6 and 0.4).

Type 23 SVS, Test I-62,
pump bell submergence 1.22D

137. The 0.75D SVS was raised until the lower portion protruded 0.57D into the water. A stage A SV occurred at R = 0.6 and FV's occurred at R = 0.6 and R = 0.4 . No BWV occurred.

Type 24 SVS, Test I-63,
pump bell submergence 1.22D

138. The 0.75D SVS was again raised. During this test the beam extended only 0.37D into the water. No SV occurred but FV's were observed at R = 0.6 and R = 0.5 .

Low pump bell submergence (0.47D)

139. The next nine tests (I-64 through I-72) were conducted for various SVS types (22 and 25-32) but were unsuccessful in eliminating SV, sidewall vortices (SWV), BWV, or FV due to the unstable flow conditions caused by the very low submergence.

Conclusions for single beam
located 2D from bell center line

140. The general conclusions for the previously discussed 1D location also apply here except for low values of R . As R decreases, surface turbulence decreases and diminishes the effectiveness of the beam. SV's have a tendency to try to form upstream from the pump rather than at the usual location between the pump and the backwall. In general, the beam here must baffle more water to produce the equivalent amount of turbulence in the vortexing

area, i.e., the height of the beam or the amount extending below the water surface must be greater than when the beam was located closer to the pump.

Single Beams Located 1.5D Upstream from Pump Center Line

141. Two sizes (0.250D and 0.50D) of SVS were tested (Figure 66) for low submergence (0.47D) at several vertical positions (SVS types 33-38) but none was successful in eliminating SV. FV and SWV also occurred during each

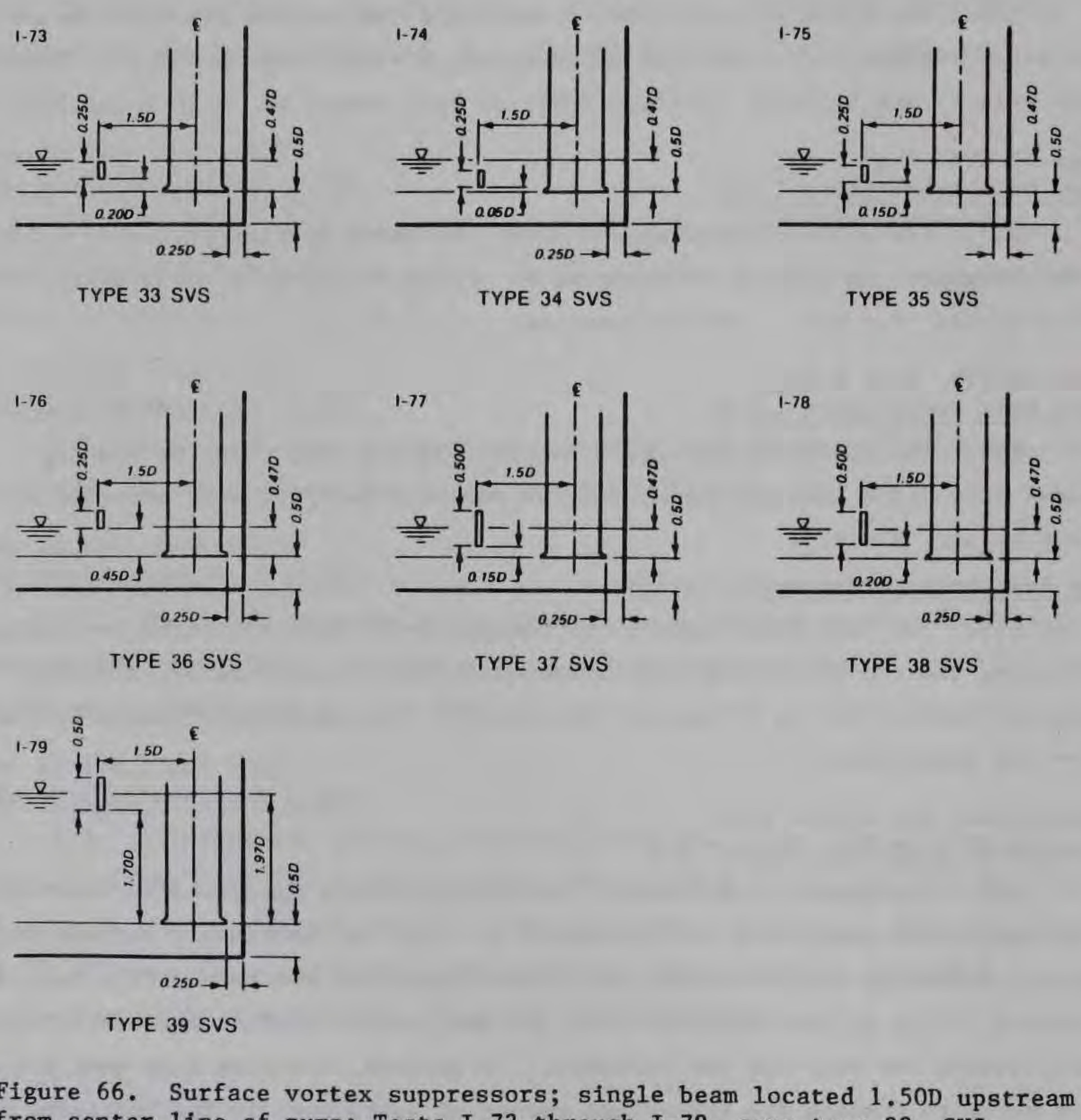


Figure 66. Surface vortex suppressors; single beam located 1.50D upstream from center line of pump; Tests I-73 through I-79, sump type 28, SVS type 33 through 39, submergence varies, discharge ratio varies

test. BWV occurred during tests I-73, I-74, I-76, and I-78, but none was observed during I-75 and I-77.

142. One test (I-79) was conducted at a pump bell submergence of 1.97D with a 0.50D high SVS (type 39 SVS). The beam was located vertically so that it penetrated the water surface by 0.27D (Figure 66). No vortices of any kind occurred. These are the best results of the three horizontal single beam locations tested.

Single Beams Located 1.75D Upstream from Pump Center Line

143. Two tests were conducted with a 0.50D-high SVS located horizontally 1.75D upstream from the pump center line (Figure 67). The tests were conducted at two submergences (1.97D and 1.22D) but in both cases the SVS was positioned vertically so that it penetrated the water surface by 0.27D. No SV appeared during either test at the high discharge ratio except where R = 0.6 .

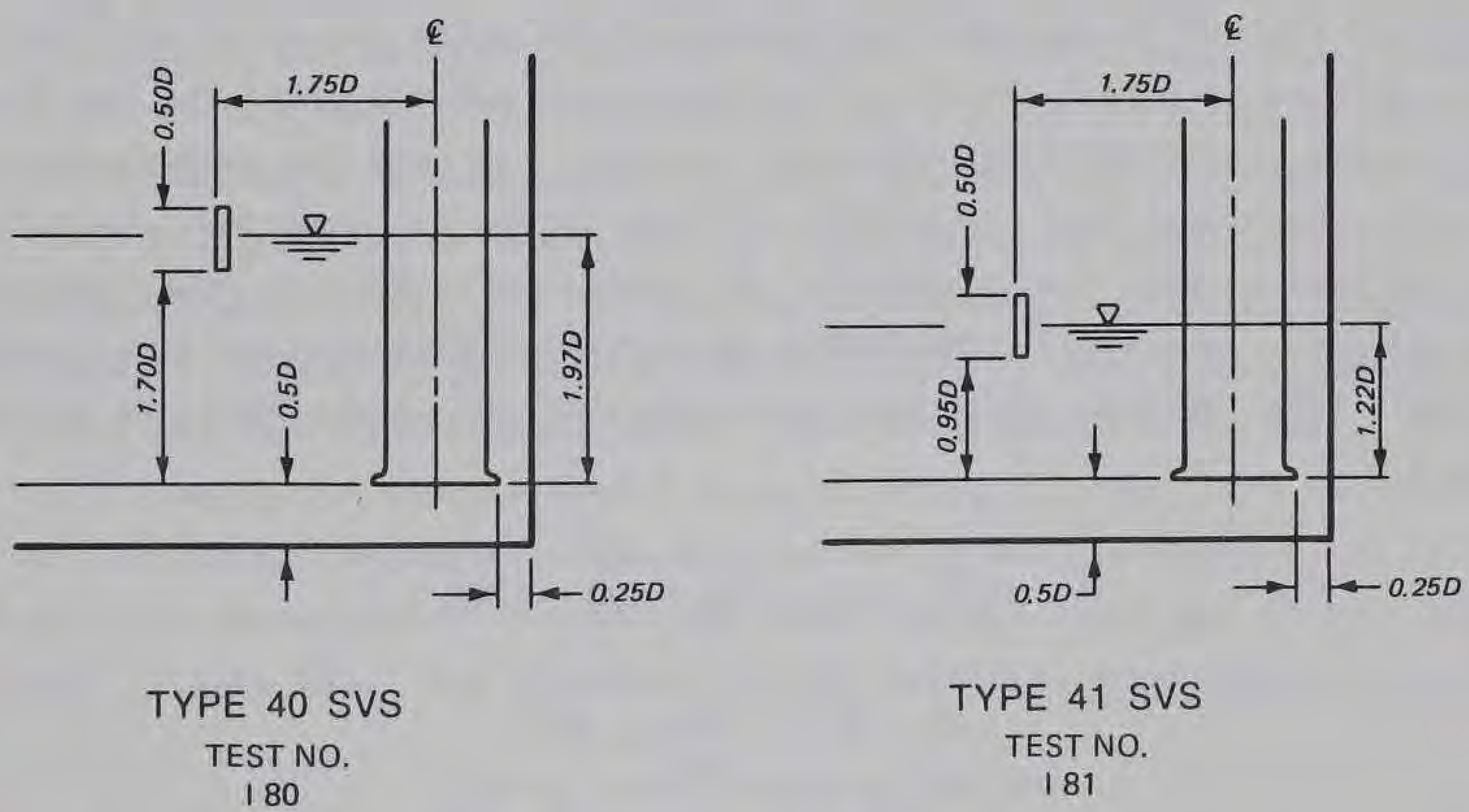


Figure 67. Surface vortex suppressors; single beam located 1.75D upstream from center line of pump, Tests I-80 and I-81, sump type 28; SVS types 40 and 41, submergence varies, discharge ratio varies

Conclusions for Use of Single SVS Beams

Horizontal location from pump bell center line

144. A single SVS beam is generally effective when located in the area of 1D to 2D upstream from the center line of the pump bell. SV's generally occur near the pump column; therefore surface turbulence must be sufficiently strong in this area in order to break up the SV. The strength of surface turbulence is influenced by R ; the turbulence is stronger at higher values of R . At lower values of R (<0.3) the SVS beam should be closer to the pump (approximately 1D from the pump center line) to produce adequately strong surface turbulence to break up the SV that occur near the pump column. At higher values of R , (>0.5) the SVS beam may be located as far as 2D upstream from the pump center line and still generate sufficiently strong turbulence to break up SV in the proximity of the pump column.

Vertical location above pump bell intake plane

145. A single SVS beam is generally most effective when it is located vertically so that it extends approximately 0.25D below the water surface. The beam continues to be effective for a rising water surface until the top of the beam is more than 0.25D below the water surface. At very low submergences $(S < 1D)$ a beam with more than 0.25D to 0.50D height can sometimes obstruct flow and produce flow conditions that are conducive to FV's or other subsurface vortices. A general submergence guideline for single-stage flow blockage allowable (FBA) without producing conditions that are conducive to FV is as follows:

$$0.50 \leq S \leq 0.7D \; ; \; FBA \leq 20\% \tag{36}$$

$$S > 0.7D \; ; \; FBA \leq 30\% \tag{37}$$

The FBA is determined as a percentage of the total flow cross-sectional area in the vertical plane in which the SVS beam is placed. Subsequent discussions pertain to SVS beams and submergence that fall outside these guidelines.

Single-Stage, Trilevel SVS Beams

146. Three beams were located at different heights (trilevel) in a single vertical plane (single-stage) with respect to the pump bell intake. The vertical plane aligns the upstream face of the SVS beams at a horizontal location of 1.75D upstream from the pump bell center line. This phase of testing is the beginning of an effort to determine effective multiple beam SVS configurations for low submergence ranges. Arbitrary increments of 0.50D and 0.25D were selected to vary the submergence through a range of 1.97D to 0.47D. The lowest submergence tested (0.47D) for reducing SV is only a goal since no single beam SVS was found that would completely eliminate all SV (see previous sections on single beam testing) for this submergence.

Slotted SVS beams 0.25D high

147. The type 43 SVS design consisted of three slotted beams (Figure 68) 0.25D high with the lower surface of the bottom beam located 0.2D above the pump intake plane and the top of the top beam's surface located 2.3D above the pump intake plane. This implies a submergence testing range from 0.47D to more than 2.3D (Figure 69). Experience with single beam testing indicates that the type 43 SVS is influential for reducing SV for a submergence range from 2.05D to just over 2.3D (see paragraph 145). This series of tests therefore was conducted at a submergence of 0.47D, and at 0.50D submergence increments (0.97D and 1.47D) to 1.47D, and at 0.25D increments (1.72D and 1.97D) to a submergence near 2.05D. SVS testing was performed at specific submergence increments (0.50D and 0.25D) throughout this study so that comparisons with subsequent testing results can be made. With SVS type 43, only Test I-86 for the 1.97D submergence was successful in eliminating all SV. As a whole, the type 43 SVS was unacceptable, primarily because it was ineffective for eliminating SV at submergences at which the water-surface level was between the SVS beams (Figure 69). The additional baffle effect of more than one beam

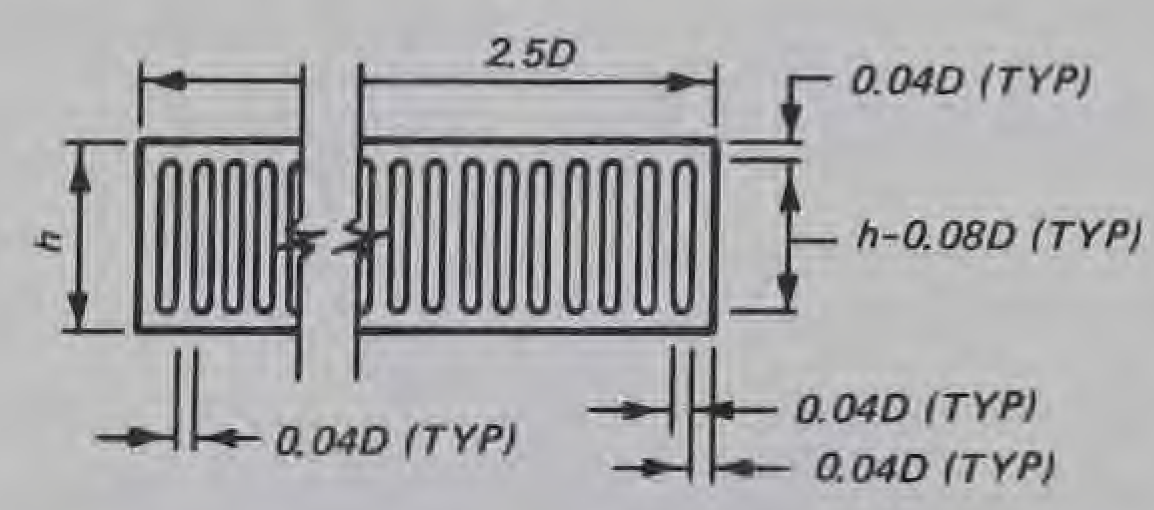
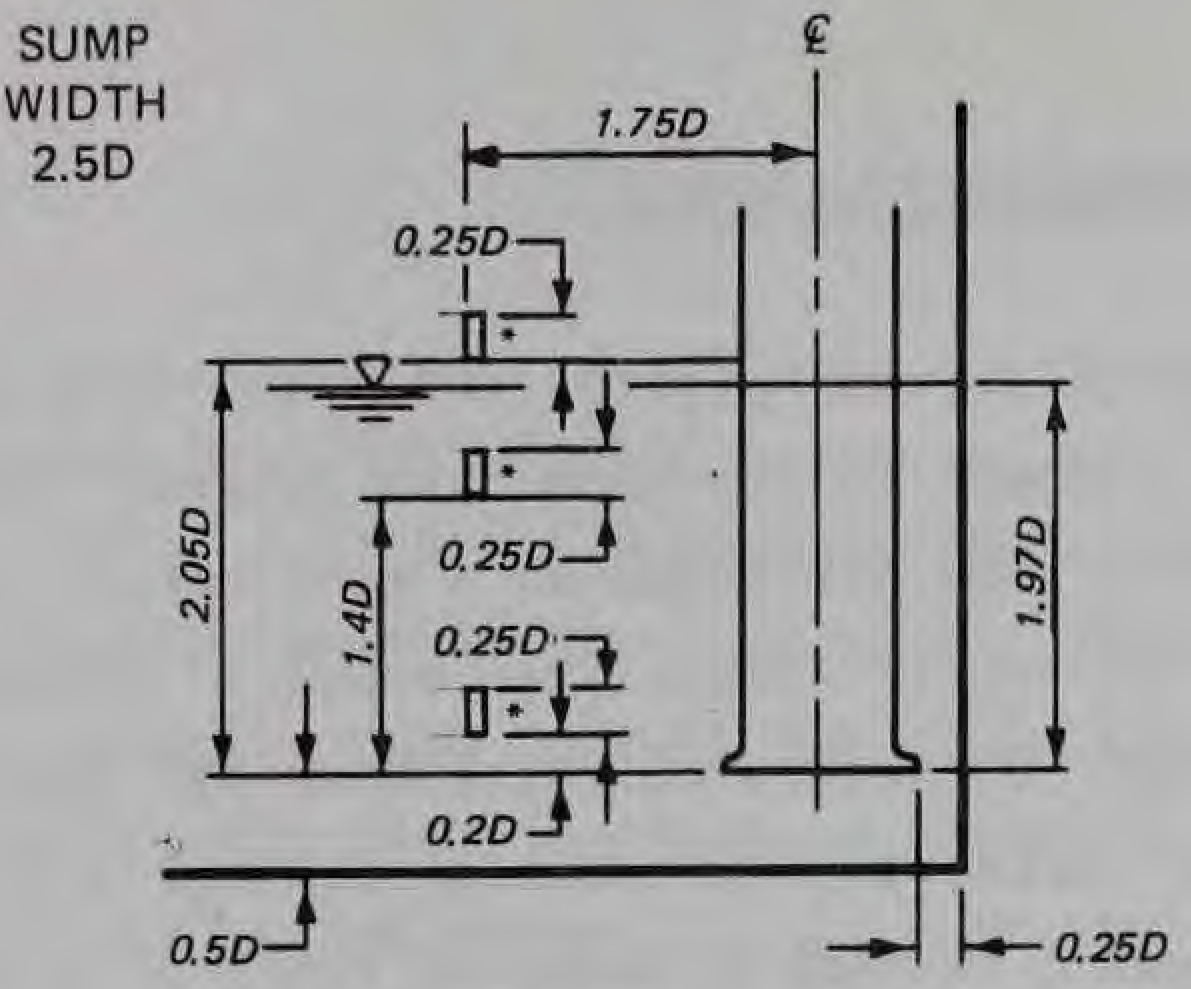
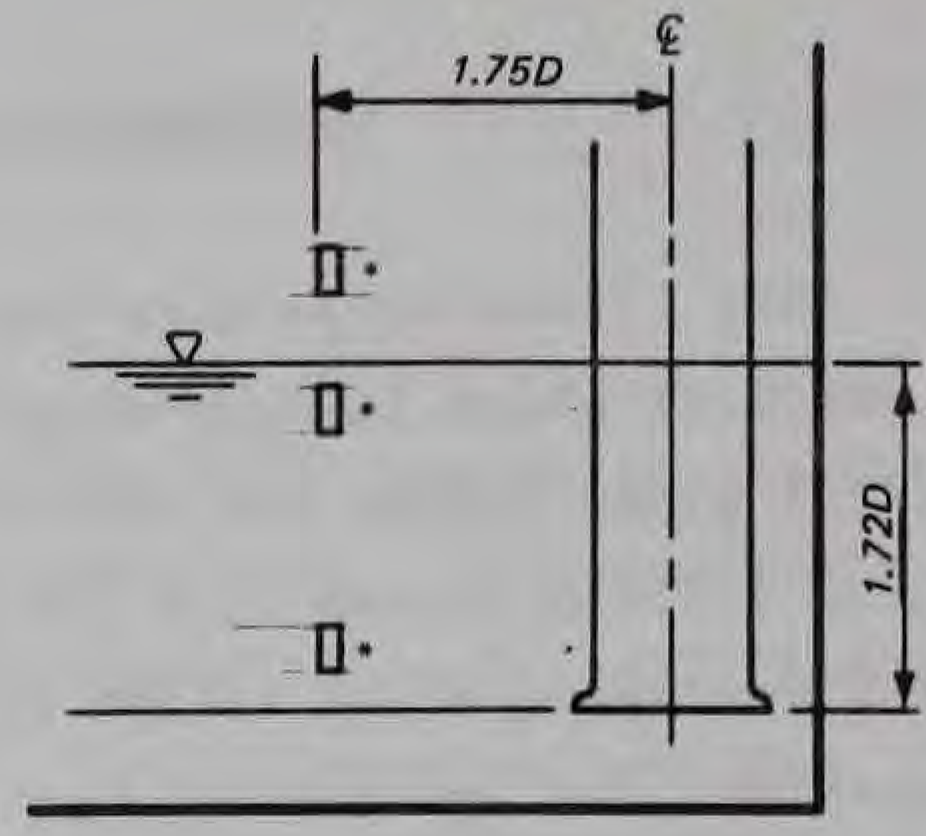


Figure 68. Typical slotted SVS beam



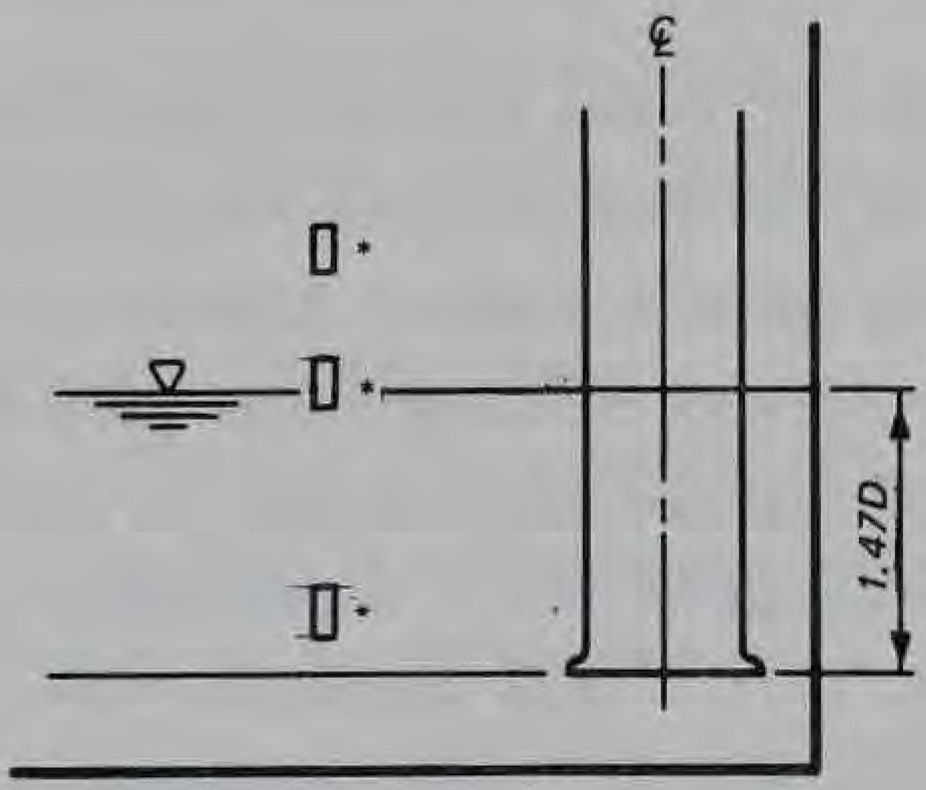
TEST I-86

FV AT R = 0.6
NO OTHER VORTICES



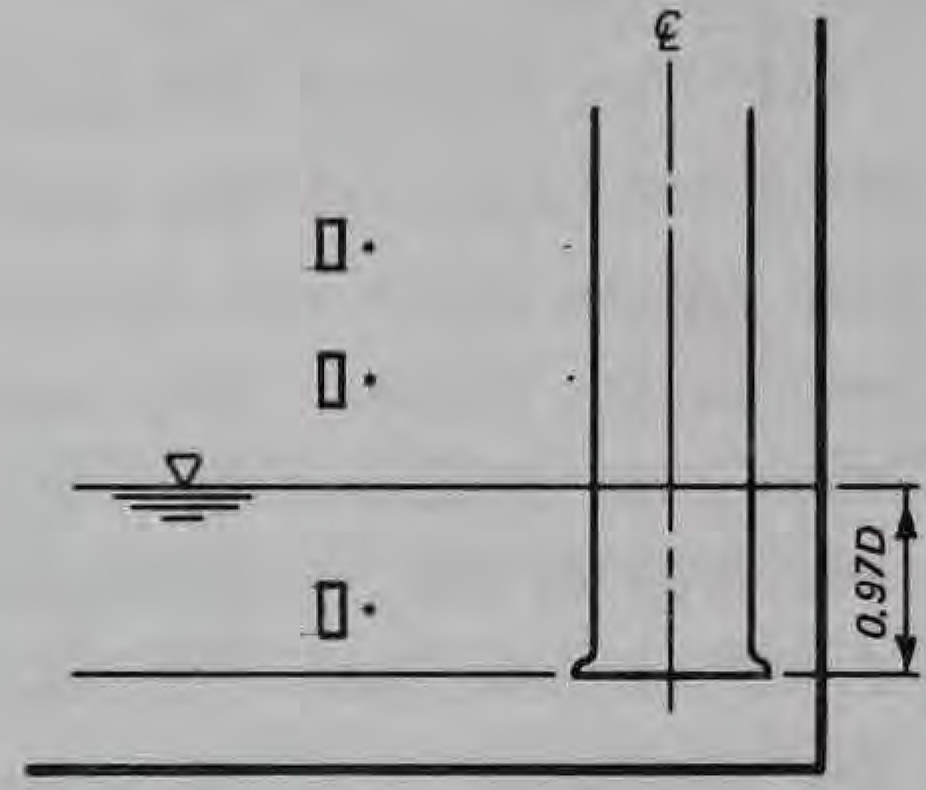
TEST I-85

FV AT 0.5 ≤ R ≤ 0.6
SV STAGE C TO A AT 0.23 ≤ R ≤ 0.6



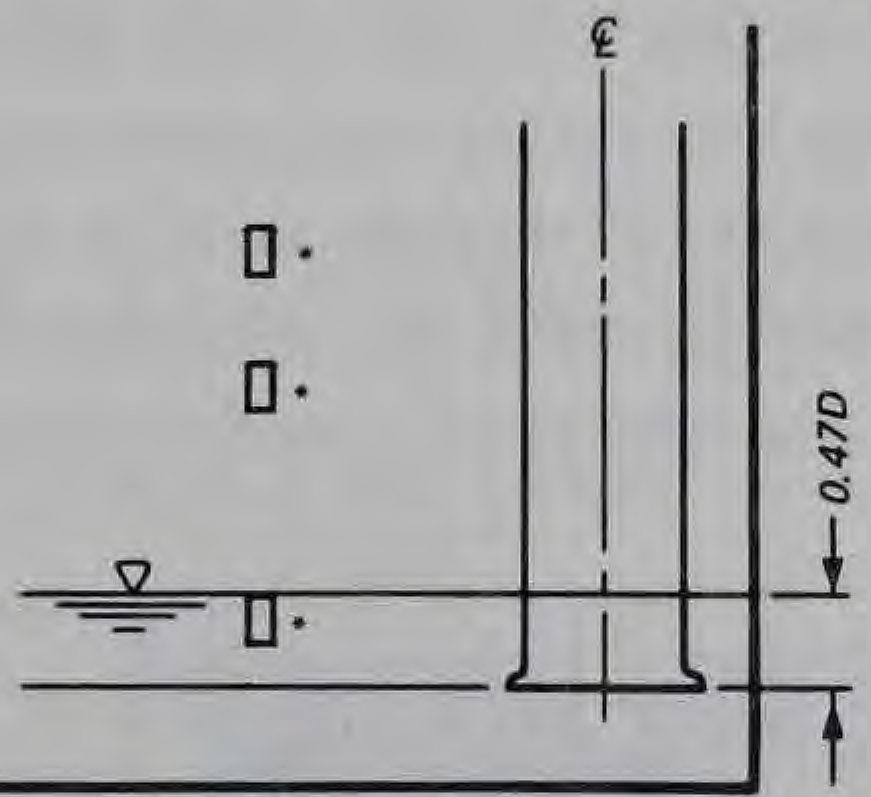
TEST I-84

FV AT 0.5 ≤ R ≤ 0.6
SV STAGE D TO B AT 0.23 ≤ R ≤ 0.6



TEST I-83

FV AT 0.35 ≤ R ≤ 0.60
BWV AT R = 0.6
SV STAGE D TO B AT 0.23 ≤ R ≤ 0.42



TEST I-82

FV AND SV STAGE E AT 0.2 ≤ R ≤ 0.6
BWV AND SWV AT 0.35 ≤ R ≤ 0.6

Figure 69. Surface vortex suppressors; trilevel, single-stage, *slotted, sump type 28, SVS type 43, Tests I-82 through I-86, all dimensions typical except submergence which varies, discharge ratio varies

submerged was not sufficient to provide the necessary turbulence required to break up SV that occurred during tests in which the water-surface level was between beams. The slotted pattern (Figure 68) in the lower beam did not produce any significant differences in test results, at submergences below the second beam, from single beam tests for comparable submergences.

148. The slotted pattern (Figure 68) reduces head loss and the amount of flow diverted downward and thus the tendency to form more FV. The occurrence of FV tends to increase as the amount of blockage increases (paragraph 145). Figure 70 shows the dye pattern flows for both conditions with and without an SVS beam. Without the beam, the flow arrives in the vicinity of the pump column, then makes more of a vertical downward flow pattern to the periphery of the pump bell intake. With the beam, the downward flow force under the beam interrupts the equal distribution peripheral flow pattern, pushing more of the flow toward the backwall. In comparing conditions where there was a FV without the beam, for the same sump with the beam the FV is moved nearer to the backwall. By the same reasoning an FV has more of a tendency to occur as the amount of blockage increases, i.e., as the height of the beam increases relative to the submergence. At lower submergences the volume of flow is less; therefore, less blockage is required to produce conditions conducive to FV than is required at higher submergences.

149. The type 44 SVS is a trilevel, single-stage arrangement similar to the type 43 except that the height of the type 44 SVS has been increased to 0.4D (Figure 71). The location of the bottom surface of each beam and the upstream face of each beam is the same as the type 43 SVS. The height of the type 44 SVS was increased to 0.40D to obtain additional turbulence for SV suppression and to decrease the spacing between the beams, hopefully without increasing the tendency for FV. Obviously, the 0.40D SVS did increase the blockage somewhat more than the 0.25D SVS; however, with the hole cutouts, the tendency for FV did not seem to be significantly increased. The type 44 SVS did not provide a significant improvement over the type 43 SVS; therefore, it, too, was unsatisfactory. Tests I-87 through I-93 results are shown in Figure 71 for comparison.

150. Tests I-94 through I-96 were conducted with the type 45 SVS (Figure 72). This SVS design (type 45) has the same size and slots as the type 44 SVS design and is located the same distance upstream from the center line of the pump (1.75D). The vertical location of the upper two beams, however, is

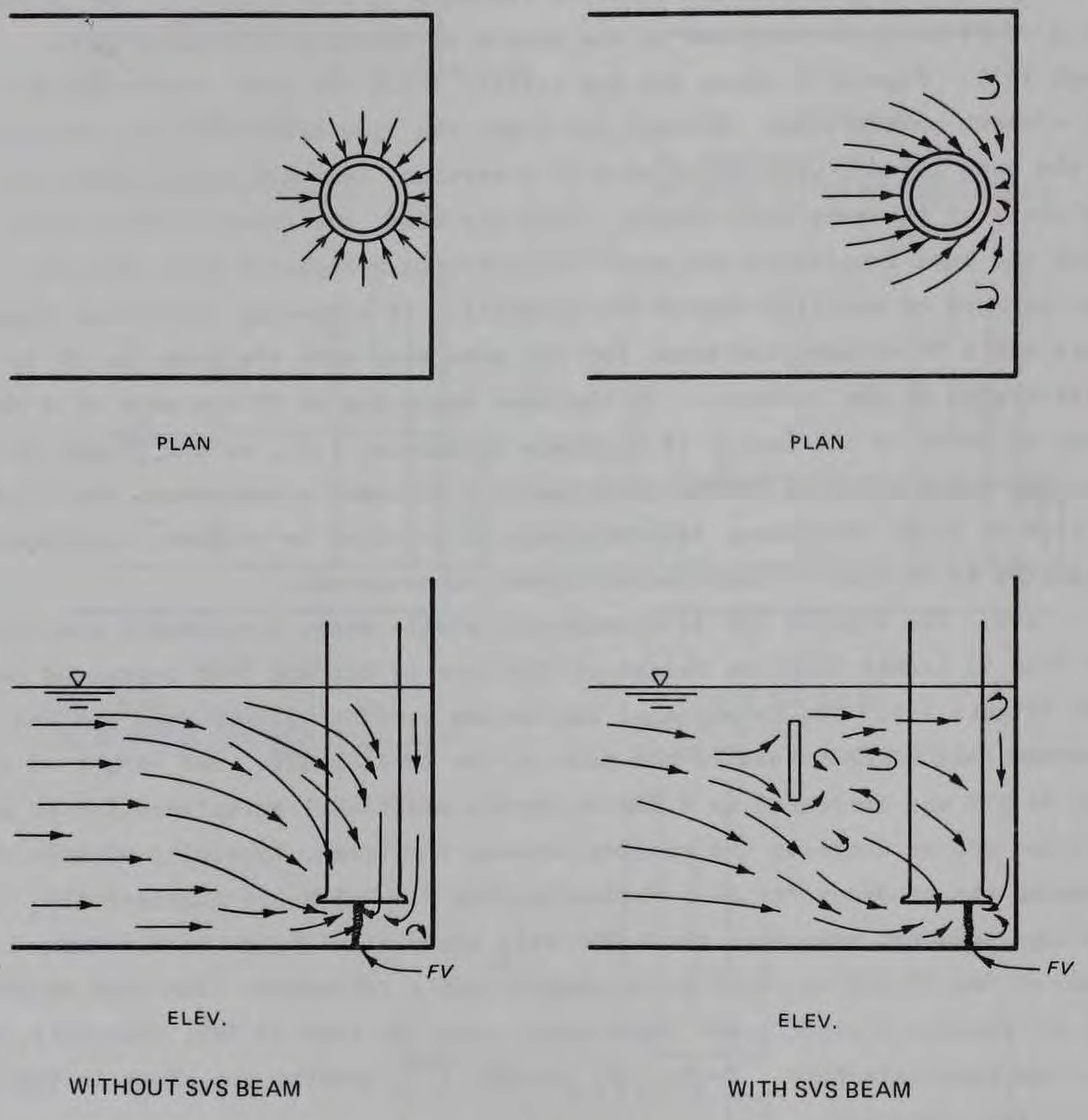


Figure 70. SVS beam effects on FV

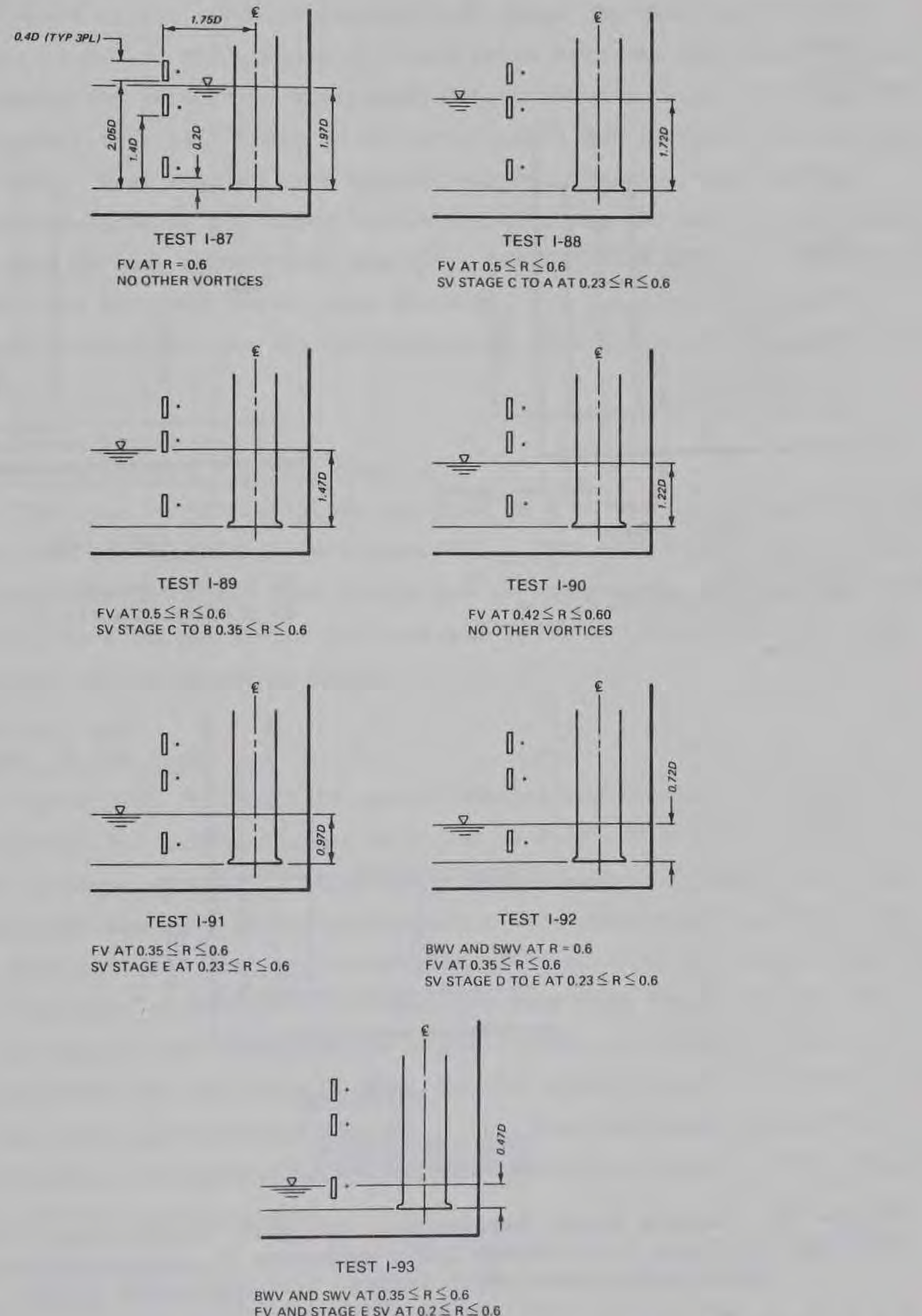


Figure 71. Surface vortex suppressors; trilevel, single-stage, *slotted SVS type 44, Tests I-87 through I-93, sump type 28; all dimensions typical except submergence which varies, discharge ratio varies

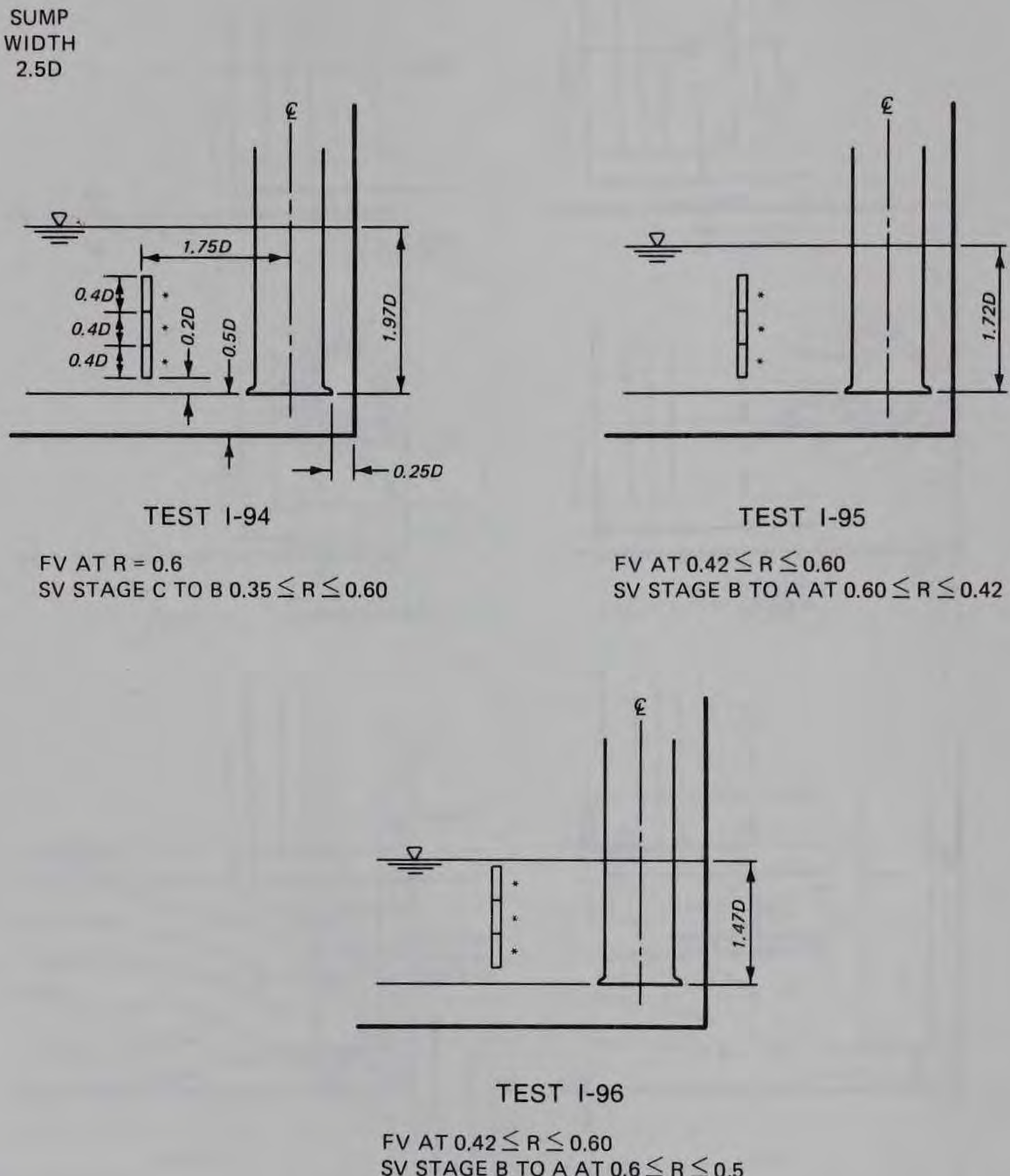


Figure 72. Surface vortex suppressors; trilevel, single-stage, *slotted, SVS type 45, Tests I-94 through I-96, sump type 28, all dimensions typical except submergence which varies, discharge ratio varies

different. In the type 45 SVS design, the beams are stacked (no space between them); the bottom of the stack is located 0.2D above the pump intake plane (same as type 43 SVS). The purpose of these tests with the type 45 SVS design was to determine the effective water-level height above a relatively high SVS beam (1.2D total) that will break up SV and yet will not increase the tendency for FV to occur. Test results were unsatisfactory. Insufficient surface turbulence was created at all three levels tested above the beams, and yet the FV results were worse. Apparently, the slots in the beams were not sufficient to eliminate head loss and lessen flow blockage, yet the slots were sufficiently large to diminish the intended turbulent effect that is necessary to break up SV.

Alternate slotted beams (top and bottom), three 0.40D-high stacked beams

151. The type 46 SVS design is the same as the type 45 design except the middle beam does not contain slots (Figure 73). This change was made to generate additional turbulence. This design was an improvement in SV at the three higher submergences tested (Tests I-97 through I-99) but FV and SWV were generally worse at all submergences tested.

Sloped, slotted, and stacked beams, 0.50D high

152. Tests J-05 through J-11 were conducted for the type 47 SVS for submergences of 1.97D and decrements of 0.25D to 0.47D (Figure 74). The type 47 SVS is three slotted, 0.50D-high beams stacked at an angle of 20 deg with the vertical and with the upstream face of the forward edge of the beam located 1D upstream from the pump center line (Figure 74). The lower edge of the beam arrangement is located 0.2D above the pump bell intake plane. Results of the three middle submergences tested (1.22D, 0.97D, and 0.72D) were generally improved from the type 46 SVS, and the results of the 0.47D submergence test were approximately the same. The sloping design type 47 SVS design is therefore considered to be unsatisfactory for a single stage design for varying but low submergences.

Sloped, alternate slotted, and stacked beams, 0.50D high

153. The type 48 SVS design is also a 20-deg sloping beam identical in size and location with the type 47 except that the type 48 SVS design does not

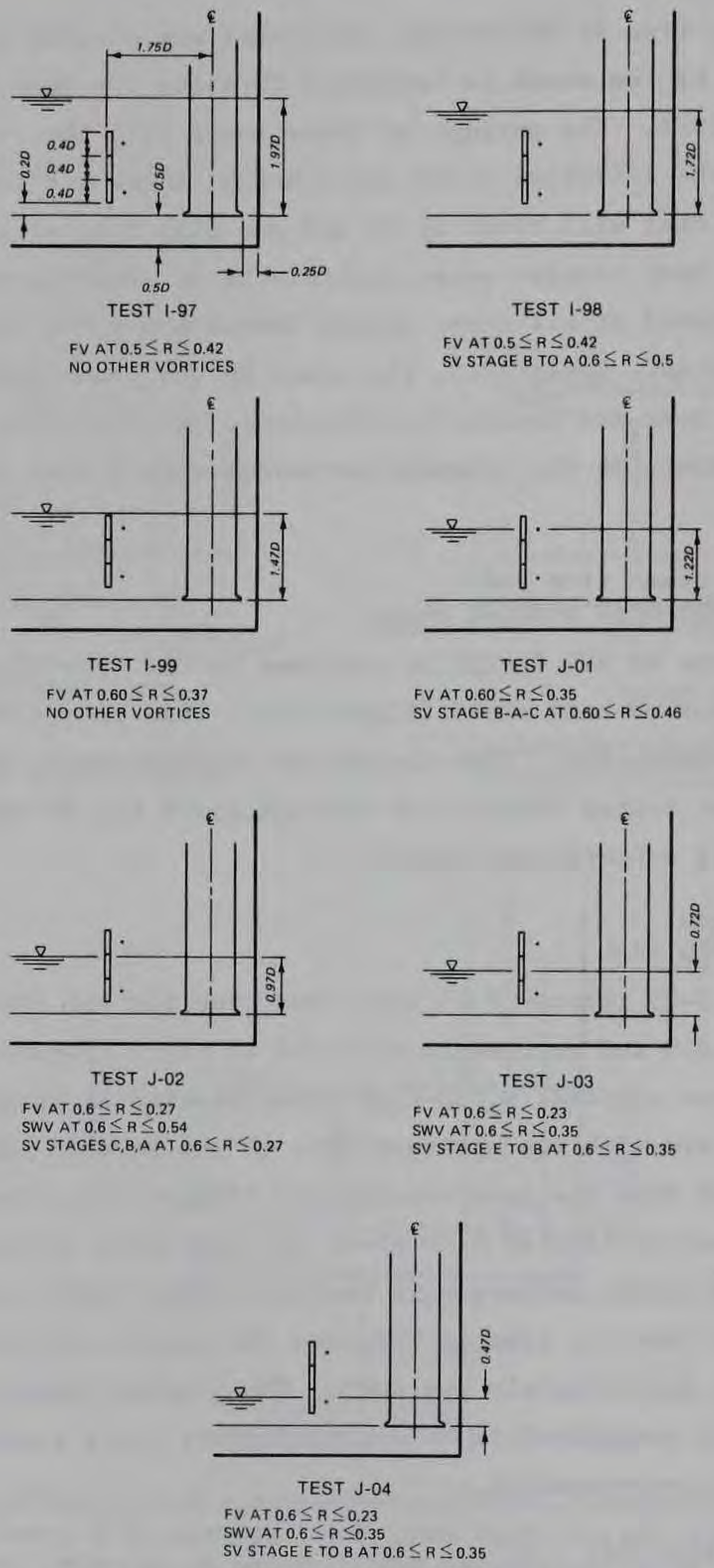


Figure 73. Surface vortex suppressors; trilevel, single-stage, stacked, alternate beams, *slotted, SVS type 46, Tests I-97 through J-04, sump type 28, all dimensions typical except submergence which varies, discharge ratio varies

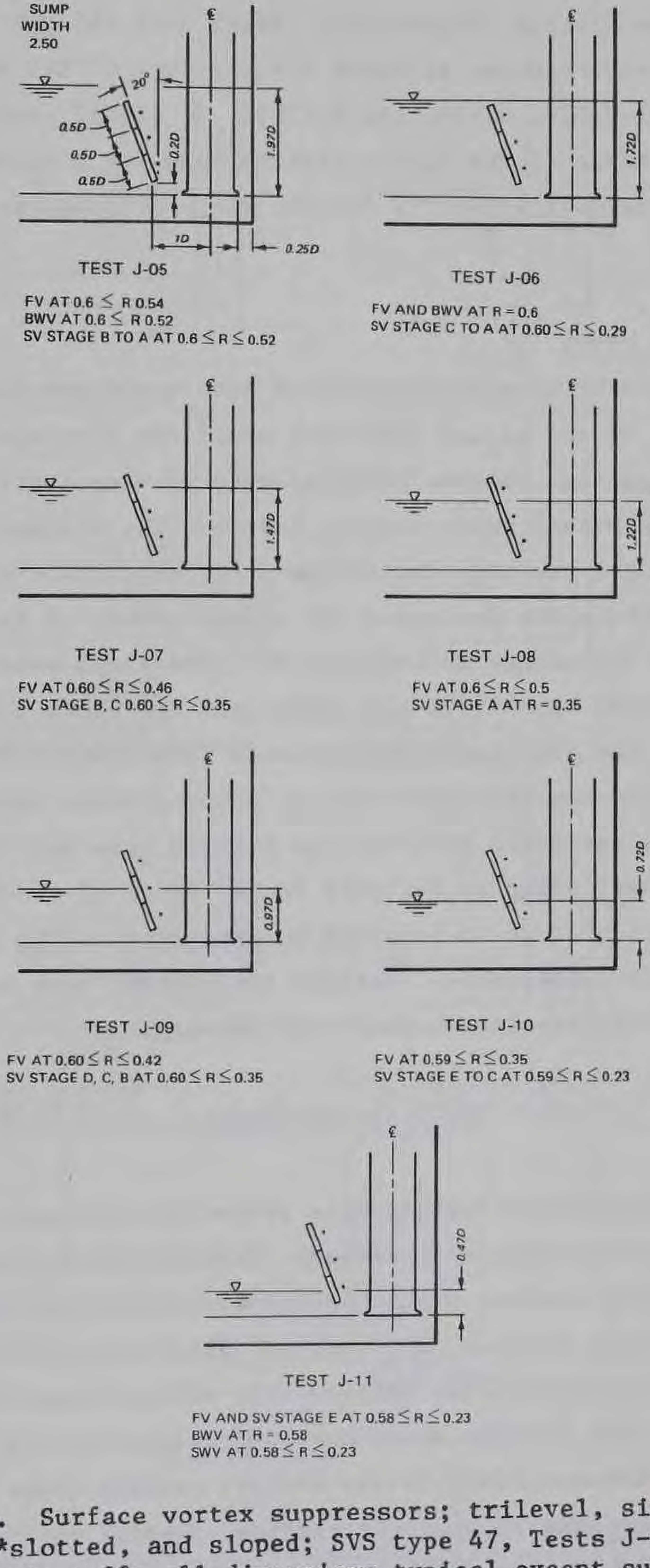


Figure 74. Surface vortex suppressors; trilevel, single-stage, stacked, *slotted, and sloped; SVS type 47, Tests J-05 through J-11, sump type 28; all dimensions typical except submergence which varies, discharge ratio varies

have the middle beam slotted (Figure 75). Tests J-12 through J-18 were conducted at the same submergences as those for the type 47 SVS design (1.97D, 1.72D, 1.47D, 1.22D, 0.97D, 0.72D, and 0.47D). No significant improvement was obtained by the exchange of the middle slotted beam for a solid beam. The type 48 SVS design is unsatisfactory for the range of submergences and discharges tested.

Conclusions--single-stage, trilevel SVS beams

154. No proper balance was determined that would provide adequate turbulence to break up SV and at the same time avoid the blockage that produces a tendency for FV. Spacings between beams allowed SV when tests were conducted at those (in between beams) water-surface levels. The stacked beams caused too much flow blockage, creating the tendency for subsurface vortices. The relief provided by the slots decreased the effectiveness of the beams to generate the necessary turbulence to break up SV. The slots were a low-priority tool anyway since field experience has shown that the slots tend to accumulate debris which blocks the flow and causes adverse flow distribution or a head differential. In site-specific model tests, sloping beams have been effective in some instances by serving a dual role as a guide vane and SVS. The sloping beam results were unsatisfactory for this tested range of discharge and submergences. This series of tests provided an extension of the single-beam testing for the 0.47D submergence. Neither the slotted beam nor the sloping beam produced favorable results at the 0.47D submergence.

Two-Stage SVS Beams

155. The two-stage SVS designs were tested for the same objective as that of the slots in the beam (as previously tested)--to decrease flow blockage while continuing to produce ample surface turbulence for breaking up SV. A second stage of beams, located in a vertical plane at a different dimension upstream from the pump center line (Figure 76), allows beams to be located with less vertical space between them, i.e., turbulence can be generated for a continuous range of water-surface levels without causing undue flow blockage in the cross-sectional area of a single vertical plane.

156. Tests J-19 through J-24 were conducted with the SVS type 49 design (Figure 76). Knowledge of general flow behavior has increased as SVS testing

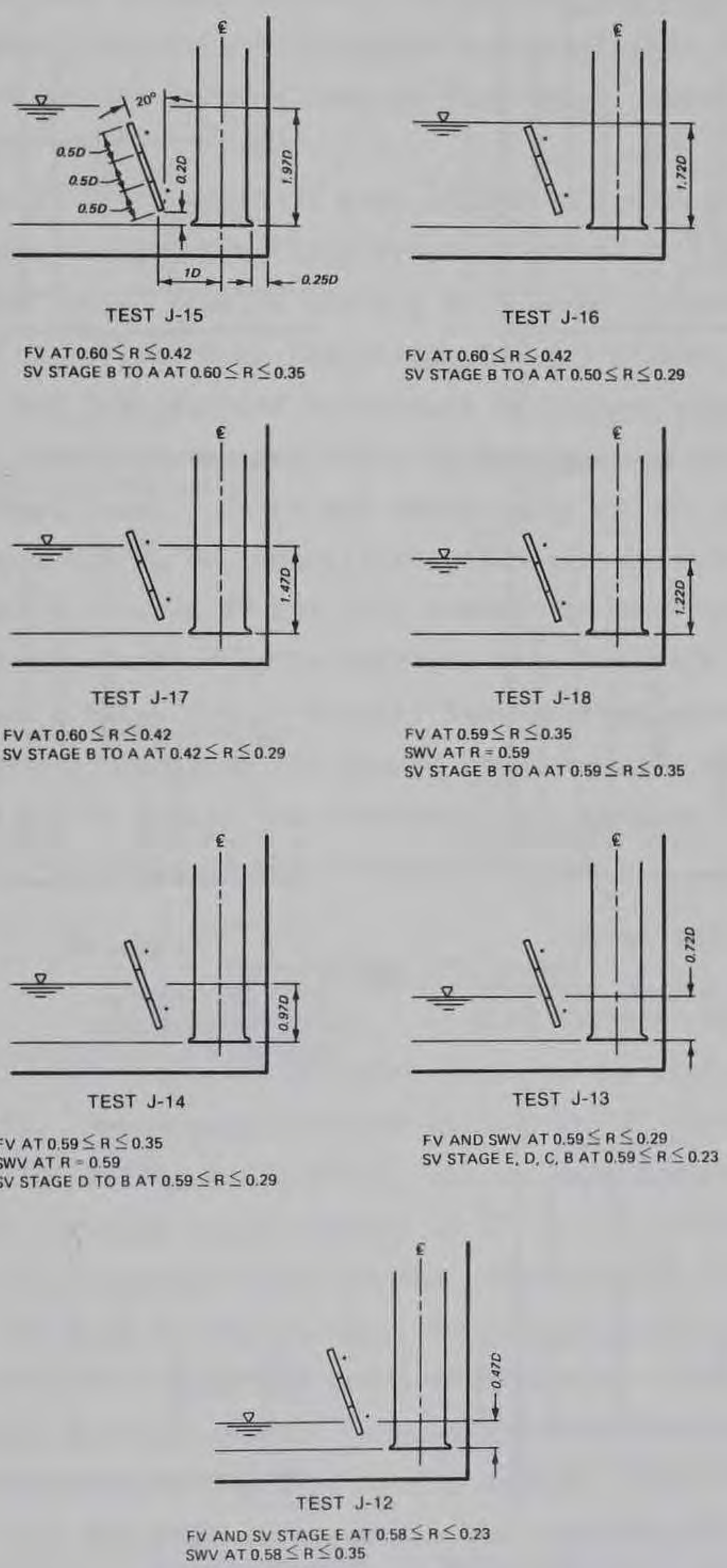
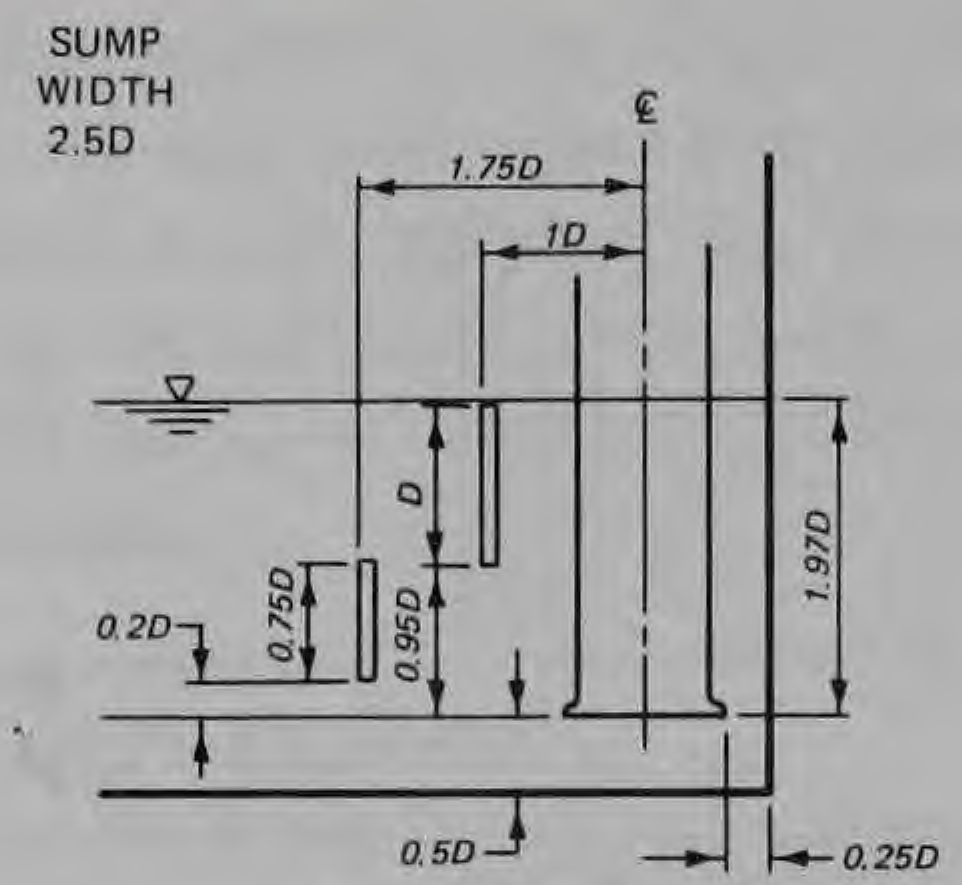
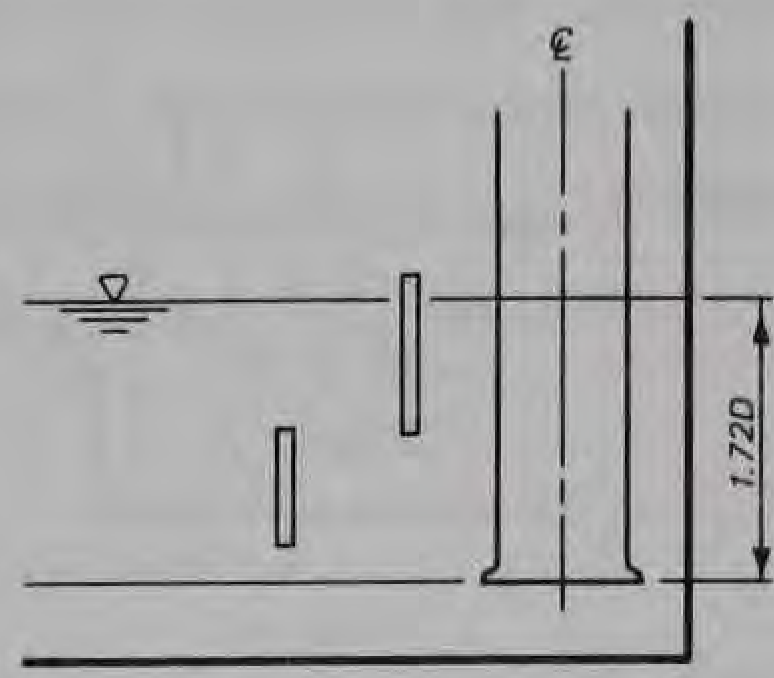


Figure 75. Surface vortex suppressors; trilevel, single-stage, stacked, alternately *slotted, and sloped, SVS type 48, Tests J-12 through J-18, sump type 28; all dimensions typical except submergence which varies, discharge ratio varies



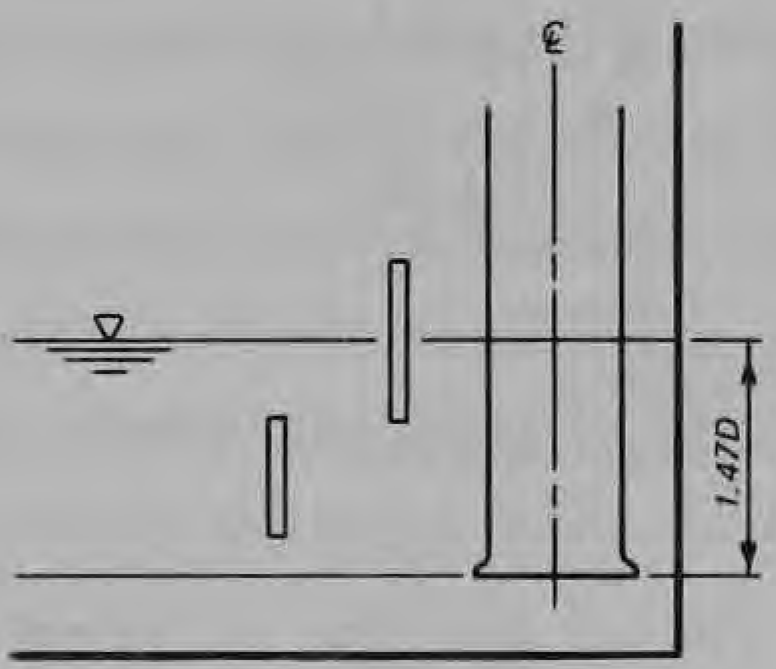
TEST J-19

FV AND SV STAGE B TO A AT 0.6 $\leq$ R $\leq$ 0.35



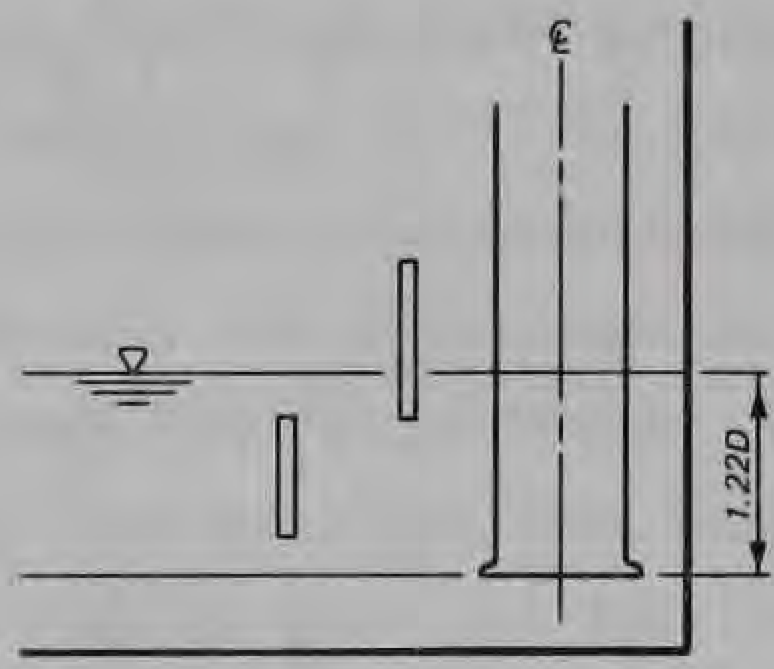
TEST J-20

FV AT 0.60 $\leq$ R $\leq$ 0.35
SV STAGE A AT 0.60 $\leq$ R $\leq$ 0.42



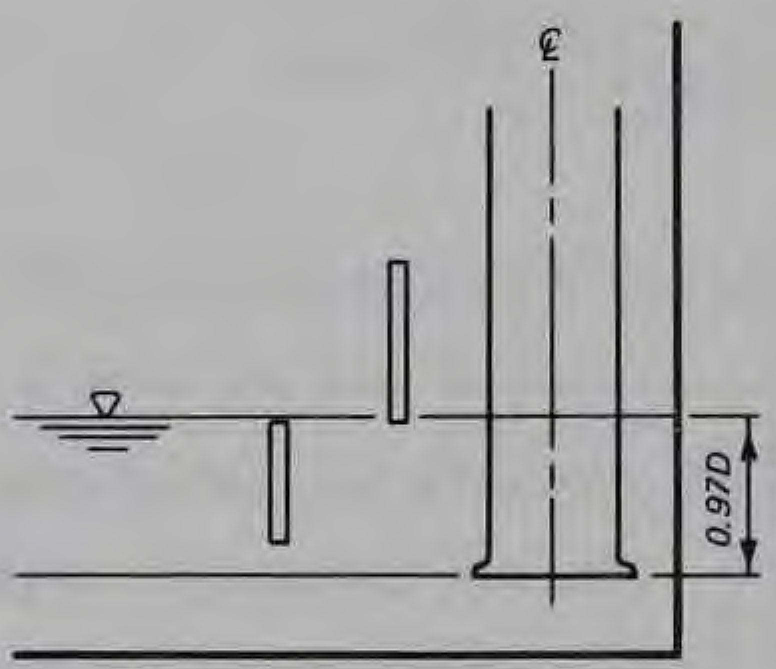
TEST J-21

FV AT 0.60 $\leq$ R $\leq$ 0.42
SV STAGE B TO A AT 0.60 $\leq$ R $\leq$ 0.35



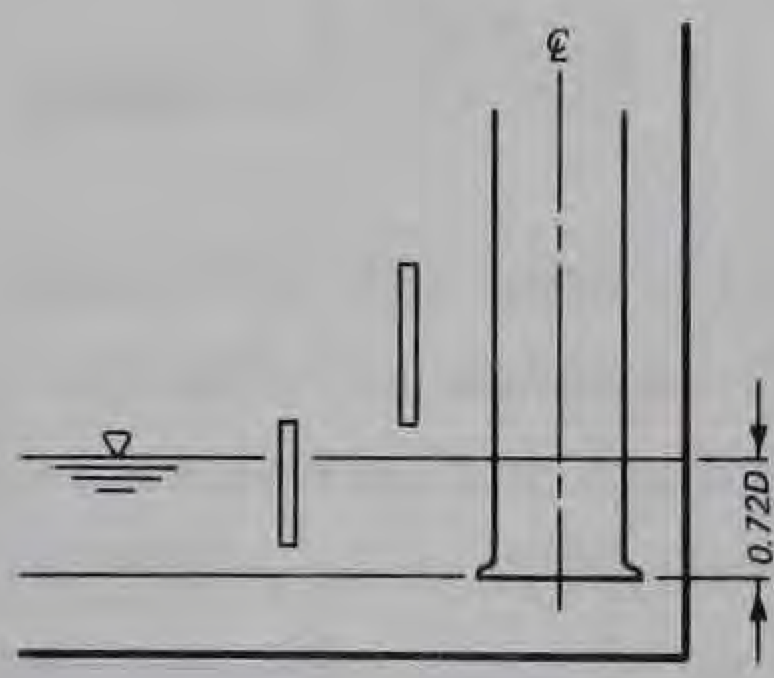
TEST J-22

FV AT 0.59 $\leq$ R $\leq$ 0.29
SWV AT 0.59 $\leq$ R $\leq$ 0.35
SV STAGE B TO A AT 0.59 $\leq$ R $\leq$ 0.35



TEST J-24

FV AND SV STAGE D TO A AT 0.59 $\leq$ R $\leq$ 0.23
SWV AT 0.59 $\leq$ R $\leq$ 0.42



TEST J-23

FV AND SV STAGE D TO A AT 0.59 $\leq$ R $\leq$ 0.23
SWV AT 0.59 $\leq$ R $\leq$ 0.35

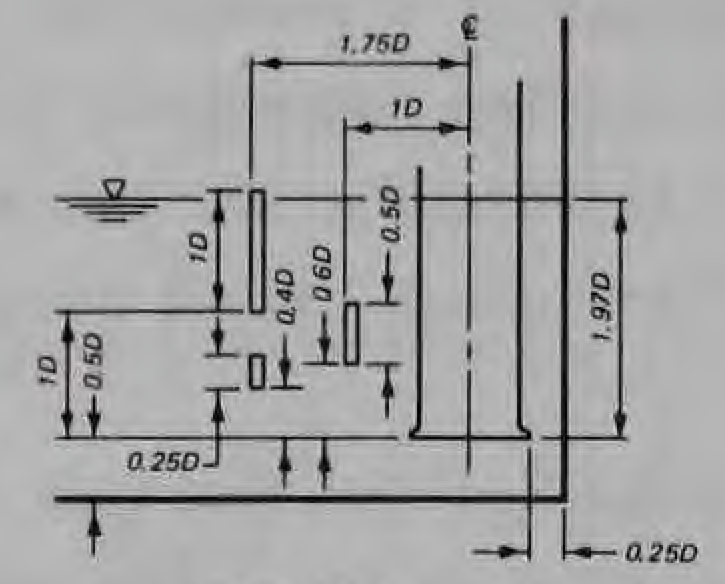
Figure 76. Surface vortex suppressors; two-stage, SVS type 49, Tests J-19 through J-24, sump type 28; all dimensions typical except submergence which varies, discharge ratio varies

has progressed. For example, the flow blockage of a relatively large (height) SVS beam near the pump is more critical in causing subsurface vortices. The type 49 SVS results indicate good progress in reducing SV, but the design is unsatisfactory due to the induced adverse flow which caused additional subsurface vortices.

157. Tests J-25 through J-31 were conducted for the type 50 SVS design. This is a two-stage design with three beams (Figure 77). The second stage has two beams with the larger beam at the top to increase turbulence and the smaller beam at the bottom where the velocities are higher, some turbulence is already present, and less induced turbulence is needed. The first-stage beam is positioned to handle flows with water-surface elevations falling between the two second-stage beams. There was improvement in the FV problem at submergences 1.22D and 0.97D, but overall the changes were not significant from the previous results of type 49 SVS with respect to the reduction of SV and subsurface vortices. These results indicate that positive results were obtained by locating a large (1D in height) beam farther upstream from the pump, and moving the larger beam from the second stage to alleviate flow blockage there. The SVS type 50 design was unsatisfactory because of the FV induced by the excessive flow blockage of the 1D-high SVS beam.

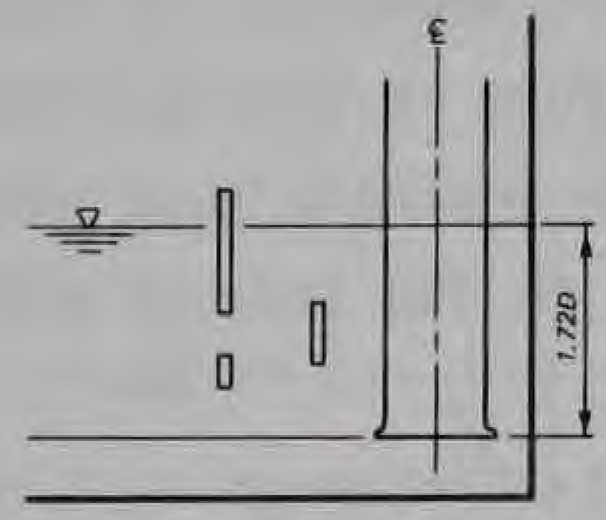
Three-Stage SVS Beams

158. Tests J-32 through J-37 were conducted to study the type 51 SVS design (Figure 78). Submergences tested with this SVS design were 1.97D, 1.72D, 1.47D, 1.22D, 2.22D, and 2.47D. Various experimental test results at WES indicate that strength and frequency of SV are proportional to the flow velocity and inversely proportional to the submergence. Concentration of study, prior to the type 51 SVS design, was limited to a submergence range from 0.47D to 1.97D, the reasoning being that SV are easier to suppress at higher submergences (above 1.97D). Two additional submergence levels (2.22D and 2.47D) were tested with the type 51 SVS design. This design was unsatisfactory for the full range of submergences and discharges tested; however, a significant improvement was recognized in Test J-36 for both SV and FV at the 1.47D submergence. This test series raised additional questions. Are the stages farther apart then necessary? Should the shorter (in height) beams be progressively nearer to the pump and vertically lower or nearer the pump bell



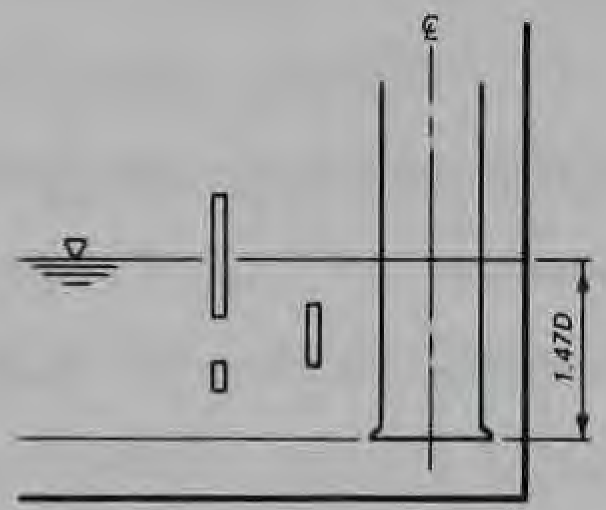
TEST J-25

FV AT 0.60 ≤ R ≤ 0.42
SV STAGE B TO A AT 0.60 ≤ R ≤ 0.35



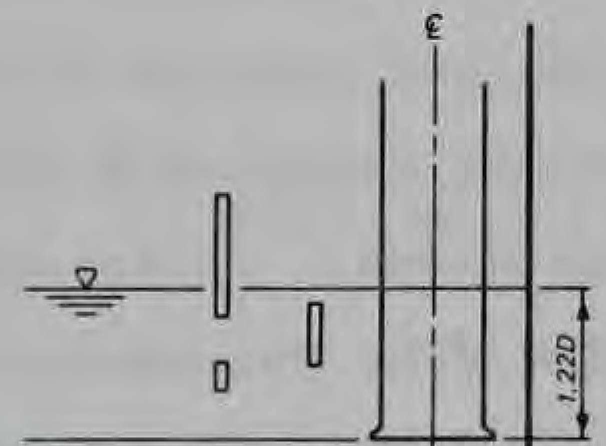
TEST J-26

FV AND SV STAGE B TO A
AT 0.60 ≤ R ≤ 0.35



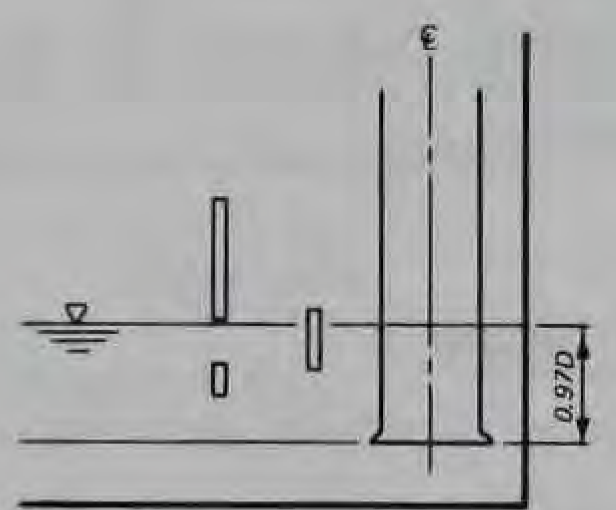
TEST J-27

FV AT 0.59 ≤ R ≤ 0.35
SV STAGE B TO A AT 0.59 ≤ R ≤ 0.29



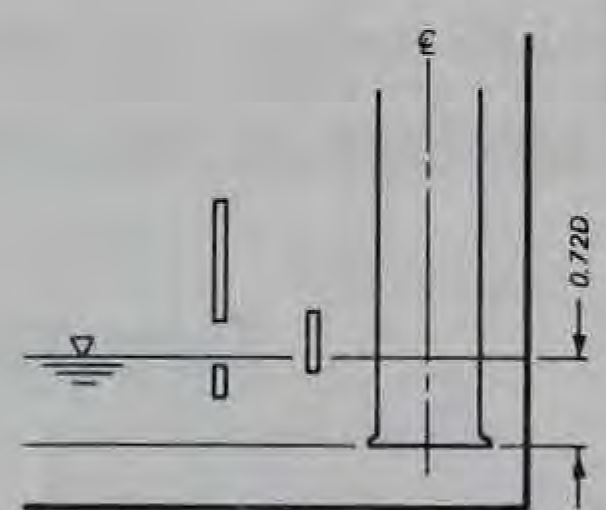
TEST J-28

FV AT 0.59 ≤ R ≤ 0.35
SV STAGE B TO A AT 0.59 ≤ R ≤ 0.29



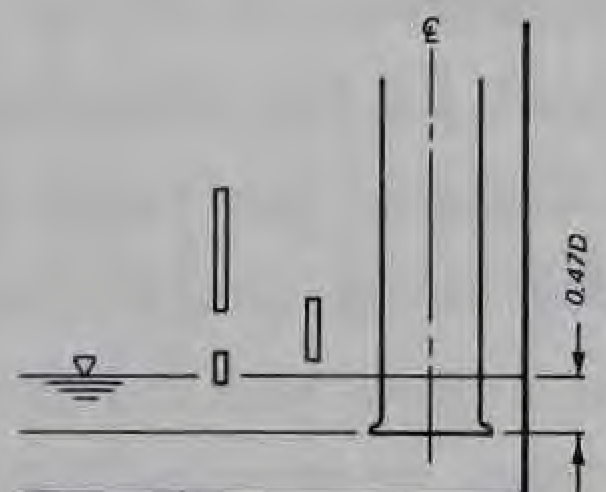
TEST J-29

FV AT 0.59 ≤ R ≤ 0.35
SWV AT R = 0.59
SV STAGE B TO A AT 0.59 ≤ R ≤ 0.29



TEST J-30

FV AND SV STAGE D TO A AT 0.58 ≤ R ≤ 0.23
SWV AT R = 0.58



TEST J-31

FV AT 0.58 ≤ R ≤ 0.29
SWV AND SWV AT 0.58 ≤ R ≤ 0.50
SV STAGE E AT 0.58 ≤ R ≤ 0.23

Figure 77. Surface vortex suppressors; two-stage, SVS type 50, Tests J-25 through J-31, sump type 28; all dimensions typical except submergence which varies, discharge ratio varies

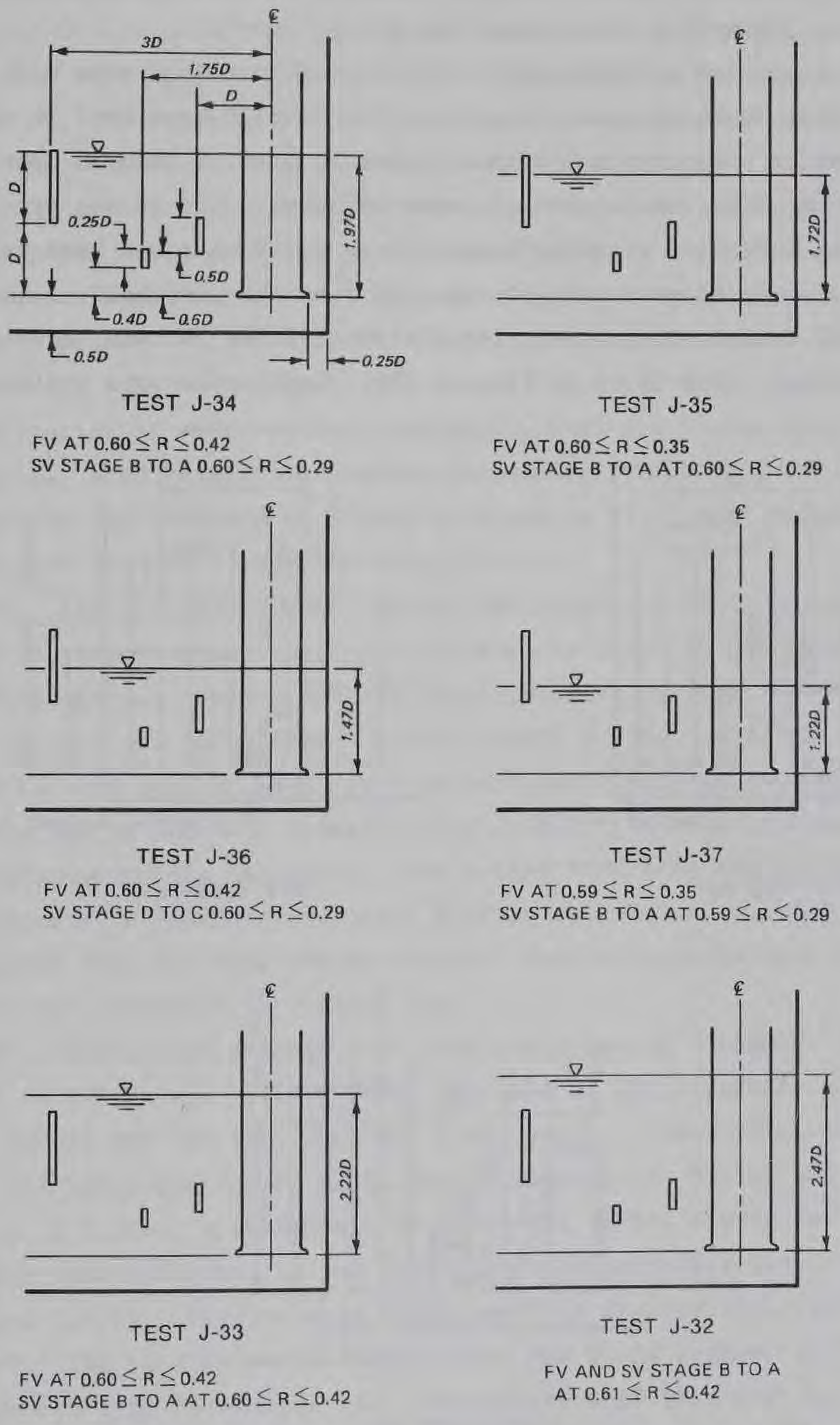


Figure 78. Surface vortex suppressors; three-stage, SVS type 51, Tests J-32 through J-37, sump type 28; all dimensions typical except submergence which varies, discharge ratio varies

intake plane? Can beams be effective in reducing SV when the beam is located more than 3D upstream from the center line of the pump?

159. A number of multibeam and multistage SVS arrangements were observed for varied discharges and recorded. The 1D-high beam used in the type 51 SVS design was moved to various distances greater than 3D upstream while keeping the first two stages of beams stationary (as in the type 51). Flow conditions indicated no significant change to SV when the beam was relocated at distances of more than 3D upstream from the pump bell center line. The type 52 SVS design changed only the distance of the 1D beam, as located in the type 51 design, from 3D to 2D (Figure 79). Testing results indicated

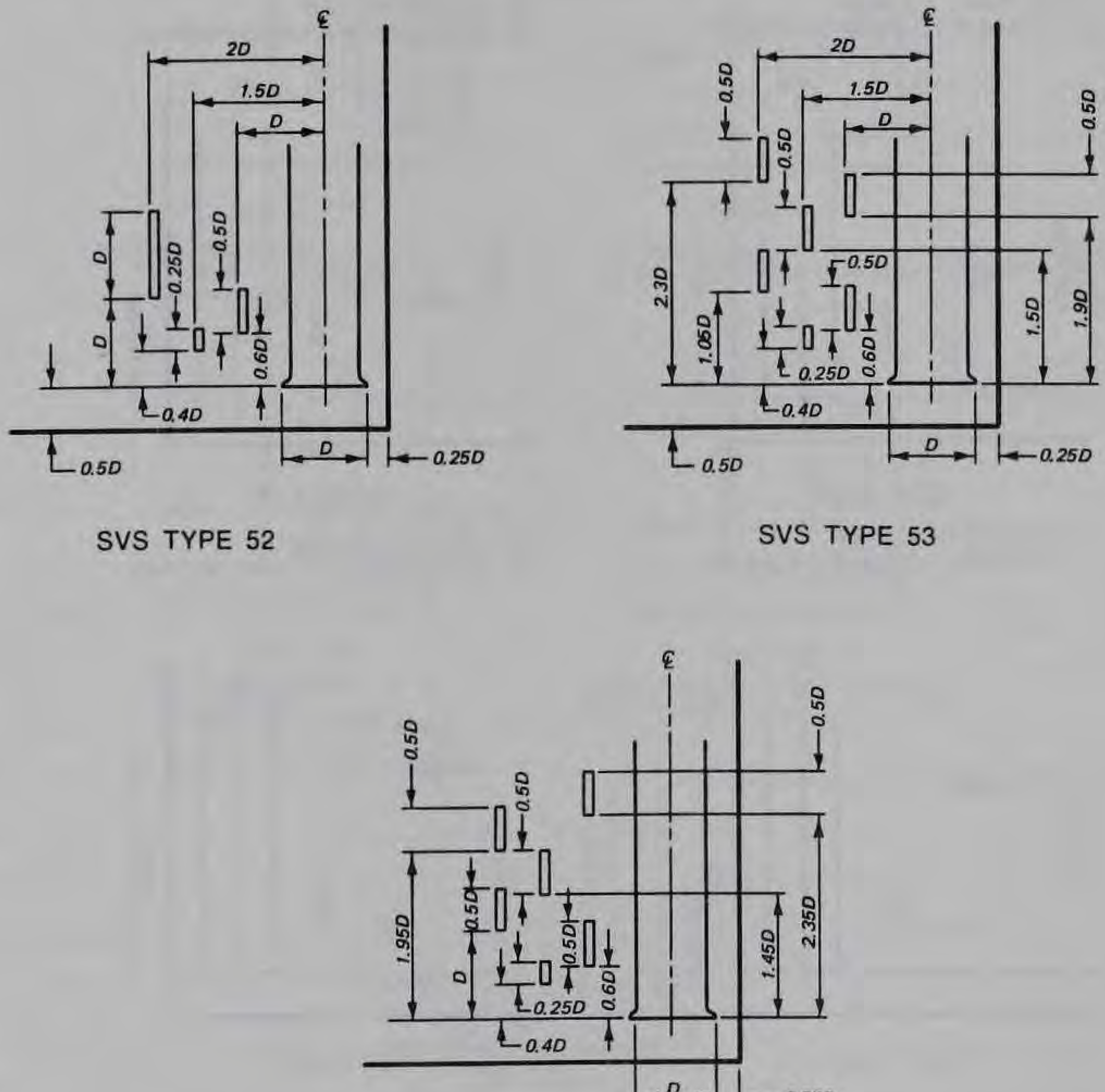


Figure 79. Surface vortex suppressors; three-stage, multiple-beam designs, sump type 28, submergence varies, discharge ratio varies

excessive flow blockage and a possible need to reduce the height of the 1D beam and to compensate by increasing the number of beams in each of the stages. The test results from SVS type 53 (Figure 79) indicated much improvement with FV. The type 53 SVS design contained two beams in each of the three stages. The beams were staggered to minimize flow blockage at any one stage. The vertical arrangement was such that operation at any submergence between 0.40D and 2.80D would provide some penetration below the water surface for surface vortex suppression. Vertical spacing from bottom to top, the overlap of one beam to the next, was 0.05D, 0.05D, 0.05D, 0.10D, and 0.10D. All of the beams were 0.50D high except the bottom beam, which was 0.25D high. During operation at water-surface elevations near the bottom beam (below 0.70D submergence), high velocities produce turbulence; therefore, less induced turbulence by the SVS beam is needed to break up SV. Lower height SVS beams are also less conducive to subsurface vortices.

160. SVS type 54 (Figure 79) was the result of minor changes in the vertical spacing (overlap) between the beams as given in the type 53 SVS design. The vertical spacing between beams (overlap) in the type 54 SVS design (bottom to top) was as follows: 0.05D, 0.10D, 0.05D, 0.00D, and 0.10D. These adjustments were made in an attempt to manipulate surface turbulence during pump operation at specific water-surface levels. Results indicate that additional refinements are necessary. The second beam from the bottom (vertically) appears to generate excessive surface turbulence, possibly because of its location near the pump (first stage). Excessive turbulence contributes to vibration and therefore is undesirable.

161. Tests J-67 through J-75 were conducted to determine the effect of the type 55 SVS design (Figure 80). The type 55 SVS design is similar to the type 54 except for vertical overlap of the beams. These values were adjusted so that all beams overlap by 0.10D except between the bottom two beams, where the value is 0.05D. Results were the best yet tested with respect to SV. Results were unsatisfactory at the three lower submergences tested (0.97D, 0.72D, and 0.47D). Results were not as good as desired with reference to FV.

162. The vertical overlap dimension was 0.05D between all consecutive beams for SVS type 56 design. All other dimensions were the same as those for the type 55 SVS design (Figure 81). Tests J-76 through J-84 were conducted to evaluate this design for submergences between 2.47D and 0.47D in 0.25D decrements. There was little difference in data results for these two SVS designs

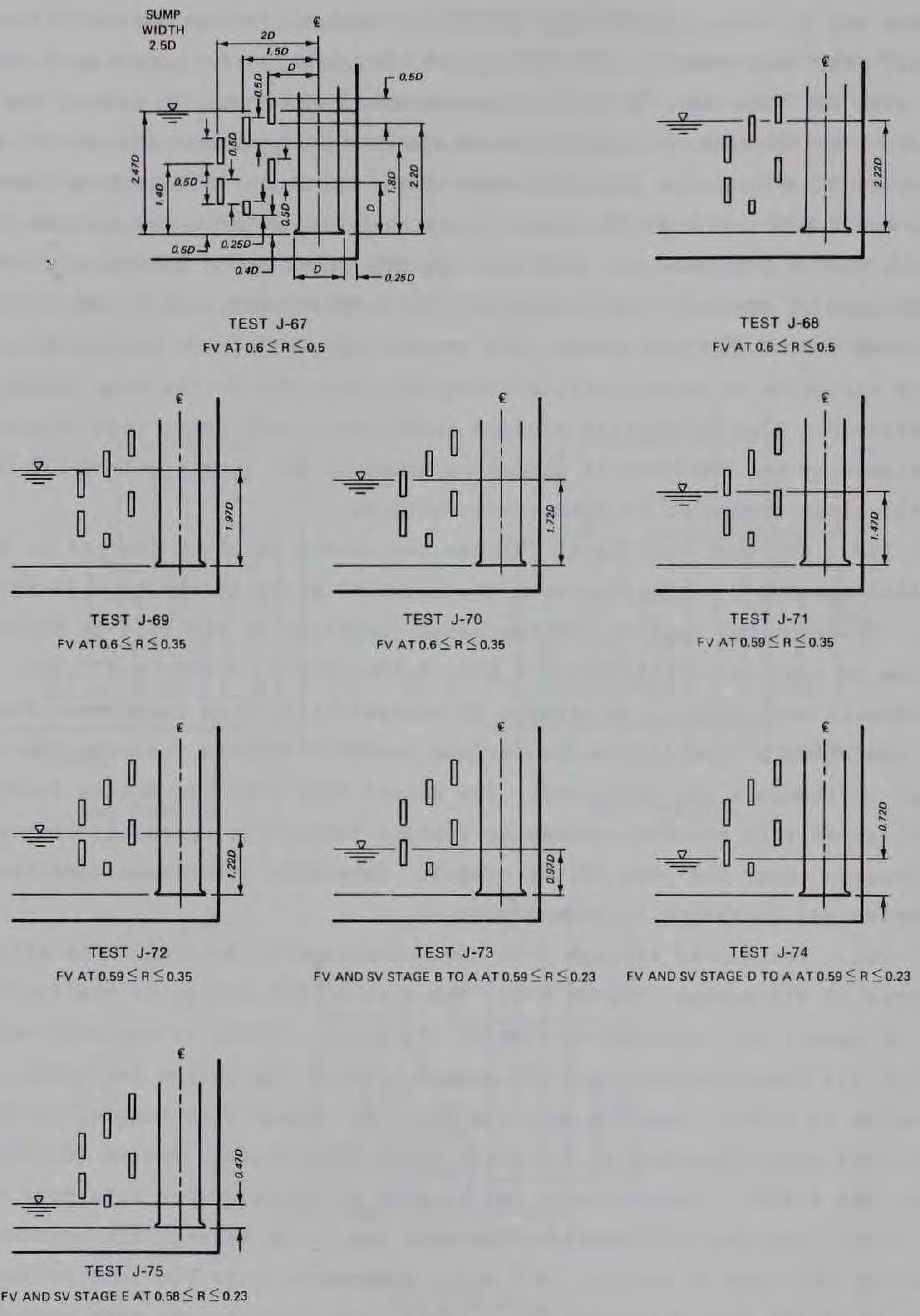


Figure 80. Surface vortex suppressors; three-stage, multiple-beam, SVS type 55, Tests J-67 through J-75, sump type 28; all dimensions typical except submergence which varies, discharge ratio varies

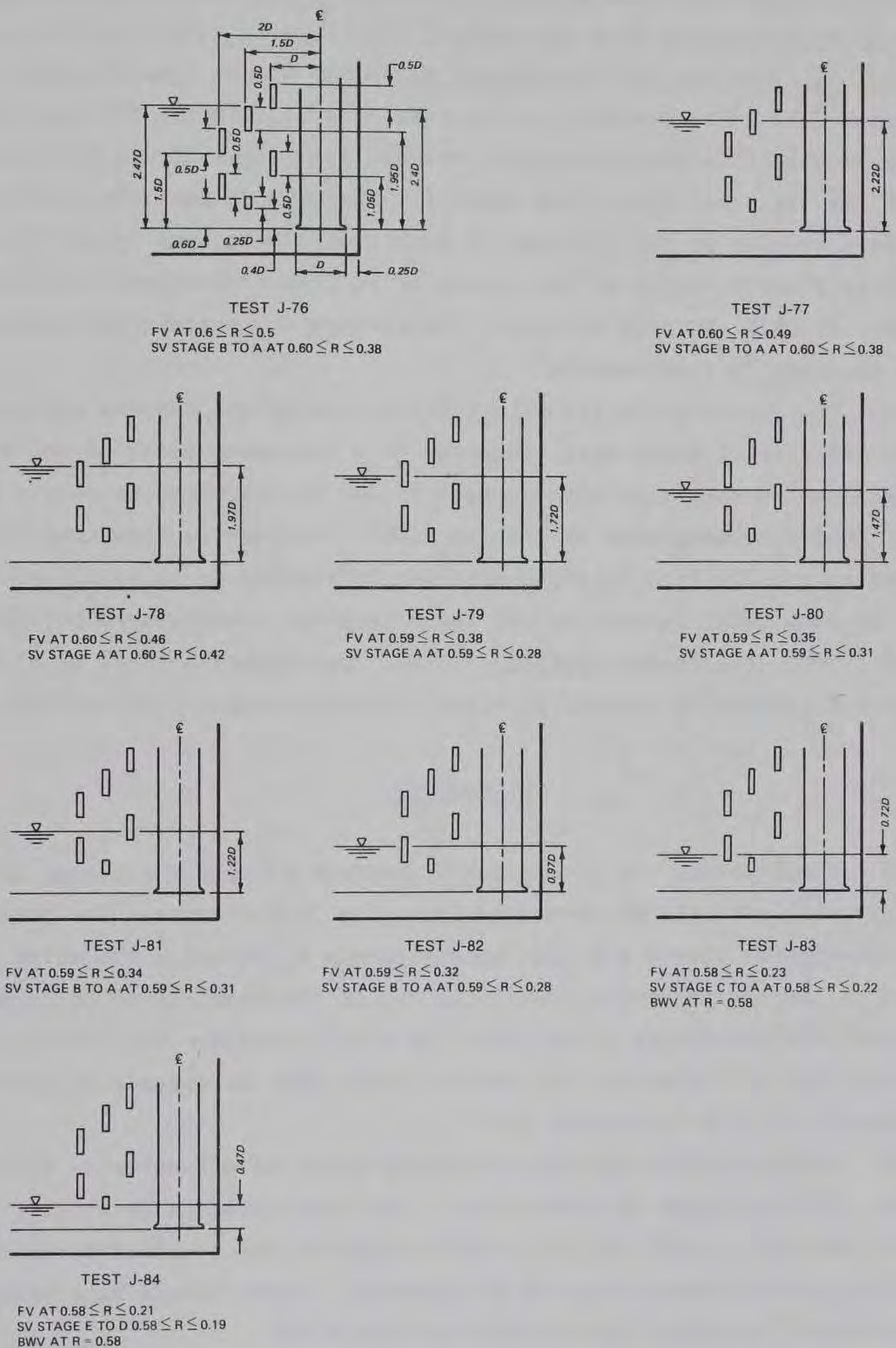


Figure 81. Surface vortex suppressors; three-stage, multiple-beam, SVS type 56, Tests 7-76 through J-84, sump type 28; all dimensions typical except submergence which varies, discharge ratio varies

(types 56 and 55) with respect to FV. The type 56 was less satisfactory than the type 55 as there were more (in number) mild SV's (stages B and A).

163. All previous SVS testing was performed in the type 28 sump. Tests J-85 through J-93 were conducted in the type 18 sump with the SVS type 56 design (Figure 63). The only difference between sump types 18 and 28 is that the width for the type 18 is 2.00D while for the type 28 sump the width is 2.50D. Data results of the SVS type 56 design with both sump types (18 and 28) indicate a small degree of deterioration in flow conditions (a few more SWV at low S) with the type 18 sump. The savings in construction cost should outweigh the loss in flow benefit.

164. The depth of the research facility limits the maximum submergence to 2.47D. Additional tests were conducted in a 1:2 scale model of the research facility to determine what changes if any are required to obtain satisfactory flow for submergences as high as 4.00D. No adverse flow conditions were observed and the type 56 SVS design was determined to be satisfactory for the type 18 sump (with respect to SV) for a range of submergences between 0.72D and 4.00D. Subsequent testing of other appurtenances (Part IX of this report) was conducted to correct problems related to subsurface vortices.

Discussion

165. Single beams can successfully suppress SV when the change in submergence is small and the minimum submergence is 1.0D or more. The beam at minimum submergence should protrude approximately 0.25D below the water surface, and at the maximum water level, the top of the beam should be no more than approximately 0.10D to 0.20D below the water surface. Care should be taken not to get the height of the beam so large that it creates an environment conducive to FV's (paragraph 145).

166. Two-stage multiple beam arrangement can be effective in eliminating SV for a larger range of submergence. The same care, as previously mentioned, should be taken not to get the height of the combined beams sufficiently high to contribute to an FV environment. There should be a minimum 0.05D overlap of the beams in the vertical direction.

167. The type 56 SVS design can be used for still greater submergence ranges. No satisfactory SVS design was found for submergences under 0.75D, but some improvement was gained with SVS type 56. The sump width and bell

location as shown by sump type 18 is adequate for the SVS type 56 design. When practical, the sump width may be increased to 2.50D with the type 56 SVS design to reduce SWV at extremely low submergence (<0.75D) and high discharge ratios.

PART IX: APPURTENANCES

Objective

168. The objective of this series of tests was to evaluate various appurtenance designs in the sump that would complement or replace the SVS designs by permitting satisfactory pump operation at submergences below 1.00D.

Tests

169. Tests were conducted to evaluate various types of appurtenances located in the types 18 (W = 2.00D) and 28 (W = 2.50D) sumps (Figure 63) with and without the type 51 SVS design (Figure 82) to determine effectiveness of the appurtenances in improving the hydraulic performance of the sump. The type 51 SVS design provided the best results for a three-stage design with only a single beam in each of the three stages. Appurtenance testing was conducted at this time to determine if a satisfactory sump design could be found (with type 51 SVS design plus an appurtenance) without the necessity of continued testing with more complex SVS designs (multibeam and multistage). The type 51 SVS design was considered sufficiently representative for appurtenant testing. The appurtenance tests were conducted in the same portion of the test facility as the pump location tests (Figure 1a).

Fillets

170. The type 51 SVS (Figure 82) was installed in the type 28 sump (W = 2.50D) and tests were conducted to evaluate fillets located in the sidewalls and backwalls. Various fillet designs investigated are shown in Figures 83-93.

- a. The type 1 appurtenance induced submerged vortices to attach to the surface of the fillet (Figure 82).
- b. The type 2 appurtenance (Figure 83) induced the formation of submerged vortices that attached to the surface of the fillets.
- c. The types 3 and 4 appurtenances (Figures 84 and 85) did not have a significant effect on the performance of the sump and were therefore unsatisfactory.
- d. The types 5 and 6 appurtenances (Figures 86 and 87) were undesirable because submerged vortices attached to the surface of the fillets.

e. The types 7 and 8 appurtenances (Figures 88 and 89) did not have a significant effect on the hydraulic performance of the sump and were therefore unsatisfactory.

f. The type 9 appurtenance (Figure 90) was undesirable because of the tendency for submerged vortices to attach to the face of the fillet.

g. The types 10 and 11 appurtenances (Figures 91 and 92) had no significant effect on the hydraulic performance of the sump and were therefore unsatisfactory.

171. Test results of appurtenances 1-11 SVS and the type 28 sump with uniform approach flow indicate that fillets do not reduce the tendency for surface vortices and increase the tendency for submerged vortices. Submerged vortices were more frequent and intense if the horizontal distance from the surface of the fillet to the edge of the intake was less than 0.25D and/or if, along the vertical center line of the pump intake, the vertical distance from the surface of the fillet to the horizontal plane of the intake was less than 0.50D.

Converging sidewalls

172. Tests were conducted in the type 28 (W = 2.50D) sump with the SVS removed and converging sidewalls installed for evaluation of their effect on sump performance. Initially the walls were located as shown in Figure 93 (type 12 appurtenance), and tests were conducted to define flow conditions for surface and submerged vortices.

173. The converging sidewalls were moved closer to the edge of the suction bell (type 13 appurtenance) as shown in Figure 94. A comparison of Figures 93 and 94 indicates that moving the sidewalls closer to the sides of the suction bell increased the tendency for backwall and sidewall vortices, with smaller changes in SV and FV.

174. The edge of the suction bell was located a distance of 0.05D from the sidewalls and backwall (type 14 appurtenance) as shown in Figure 95. A comparison of the plots in Figures 94 and 95 again indicates that the submerged vortices increased as the suction bell was moved closer to the walls; however, the frequency and intensity of surface vortices decreased. Observation of dye injected into flow approaching the pump intake indicated that with the converging sidewalls and backwalls located 0.05D from the pump intake, flow upstream of the intake was directed downward toward the pump intake as shown in Figure 96 (compare Figures 96a and 96b). The downward flow component

induced the formation of submerged vortices. Surface vortices were attenuated because there was only a relatively small amount of flow directed vertically downward along the rear side of the pump column as shown in Figure 96b (compare Figures 96a and 96b). With the converging sidewalls located $\geq$0.08D from the edge of the suction bell, performance was similar to that observed in the type 28 sump without converging sidewalls.

175. Test results indicated that the converging sidewalls and backwall should be about 0.05D from the edge of the suction bell to be effective in attenuating SV. However, test results also indicated that the frequency and intensity of submerged vortices increased considerably when the walls were located 0.05D from the edge of the suction bell. Therefore it was concluded that with evenly distributed approach flow, converging sidewalls were not effective in improving sump performance. It should be noted that in some prototype and model sumps that had severe SV due to adverse flow distribution approaching the pump intakes and values of $Q/g^{1/2}D^{5/2}$ less than 0.28, converging sidewalls were appropriate devices for eliminating severe SV.

Umbrellas

176. The effects of flat plate umbrellas on surface and submerged vortices were investigated. The umbrellas were tested in the type 18 design sump, which was 19.0D long and 2.0D wide. Four umbrellas were tested; their geometries are shown in Figure 97. The type 15 design appurtenance had an umbrella diameter of 1.30D and a backwall clearance of 0.10D. The type 16 design appurtenance had a diameter of 1.50D with the umbrella's back cut such that the backwall clearance was 0.10D. The type 17 design appurtenance had a diameter of 1.80D with the umbrella's back cut such that the backwall clearance was 0.10D. The pump center line was moved forward with the type 18 design appurtenance so that the umbrella could be circular with a diameter of 1.80D and wall clearances of 0.10D (Figure 97). The umbrellas were also tested in combination with the type 56 design vortex suppressor. The type 56 vortex suppressor (see Part VIII, this report) is effective in reducing SV. The umbrellas were tested with suction bell submergences between 0.50D and 2.50D and flow rates (in terms of the dimensionless parameter $Q/g^{1/2}D^{5/2}$) between 0.18 and 0.60. Test results are plotted in Figures 98-106.

177. The purpose of umbrellas is to reduce SV activity. Umbrellas spread the flow entering the suction bell and reduce the magnitude of downward velocity vectors. Flow patterns with an umbrella, and with both an umbrella

and vortex suppressors, are shown in Figure 107. Significantly more flow enters the pump from the back of the suction bell without the vortex suppressor beams.

178. The effect of the umbrellas on SV activity was determined. Critical bell submergences for eliminating SV activity (stage C) for the four umbrellas tested, the type 18 design sump with no appurtenances and the type 56 design vortex suppressor, are compared in Figure 108. The SV activity decreased as the umbrella diameter increased, but the umbrellas were not nearly as effective as the type 56 design vortex suppressors.

179. The occurrence of submerged vortices appeared to be independent of suction bell submergence with the umbrellas. The location of the critical submerged vortex moved between the floor and backwall, depending on the umbrella's geometry. Submerged BWV were critical with the type 15 and 16 design appurtenances and occurred when $Q/g^{1/2}D^{5/2}$ was 0.32 and 0.25, respectively. Submerged FV were critical with the type 17 and 18 design appurtenances and occurred when $Q/g^{1/2}D^{5/2}$ was 0.30. The apparent lack of influence of submergence on the occurrence of submerged vortices with umbrellas is distinctly different from tests with no appurtenances and the type 56 design vortex suppressors. In the latter case, the occurrence of submerged vortices--specifically FV--was influenced by suction bell submergence.

180. Surface and submerged vortices determined critical bell submergence in the sump with no appurtenances (type 18 design sump). Submerged FV determined critical bell submergence with the type 56 design; all classifications of vortices were used to determine the critical bell submergence with the umbrellas. Surface vortices were generally critical with submergences below 2.00D and submerged vortices were generally critical with submergences above 2.00D. Critical bell submergence for vortex-free sumps (both surface and submerged) are shown in Figure 109. The type 56 design vortex suppressor was the most effective in eliminating vortices.

181. Umbrellas were tested in combination with the type 56 vortex suppressors to determine if sump performance could be improved. In these tests, the vortex suppressor locations remained constant with respect to their distances from the backwall. SV, located just upstream from the vortex suppressors, occurred more frequently as the umbrella diameter increased. The most severe surface vortices occurred at a suction bell submergence of 1.22D. It is possible that SV activity could be improved by relocating the vortex

suppressors; however, this was not evaluated in these tests. The critical submerged vortices were FV which decreased with an increase in suction bell submergence for the type 15 and 16 design appurtenances, but were essentially independent of suction bell submergence with the type 17 and 18 design appurtenances. Critical bell submergences for the umbrellas in combination with the type 56 design vortex suppressors are compared with the type 56 design vortex suppressors alone in Figure 110. Submerged vortices can be reduced with the type 17 and 18 design appurtenances when used in combination with the type 56 design vortex suppressors at suction bell submergences less than 2.00D.

182. It can be concluded from these tests that umbrellas are effective in reducing the level of SV activity in sumps with straight approaches, where $Q/g^{1/2}D^{5/2}$ is between 0.2 and 0.6. The effectiveness of the umbrella increases with its diameter. However, the umbrellas tested were not as effective as the type 56 design vortex suppressors in reducing surface vortices. The vortex suppressors are also more effective in providing for a sump free from both submerged and surface vortices.

Discussion

183. Test results obtained with evenly distributed approach flow and various appurtenance designs (fillets, converging sidewalls, and umbrellas) indicated that none of the appurtenances provided sump performance as satisfactory as that provided by the type 56 SVS.

184. The fillets did not attenuate SV and induced the formation of submerged vortices that attached to the surface of the fillets.

185. Converging sidewalls located 0.05D from the edge of the suction bell were effective in reducing SV. However, the converging sidewalls were undesirable due to severe submerged vortices that attached to the sidewalls.

186. Umbrellas were effective in reducing SV, but not as effective as the type 56 vortex suppressor. Umbrellas were ineffective in reducing the frequency or magnitude of submerged vortices.

187. Evaluation of the three types of appurtenances has resulted in a recommendation that they not be used in a sump with evenly distributed approach flow.

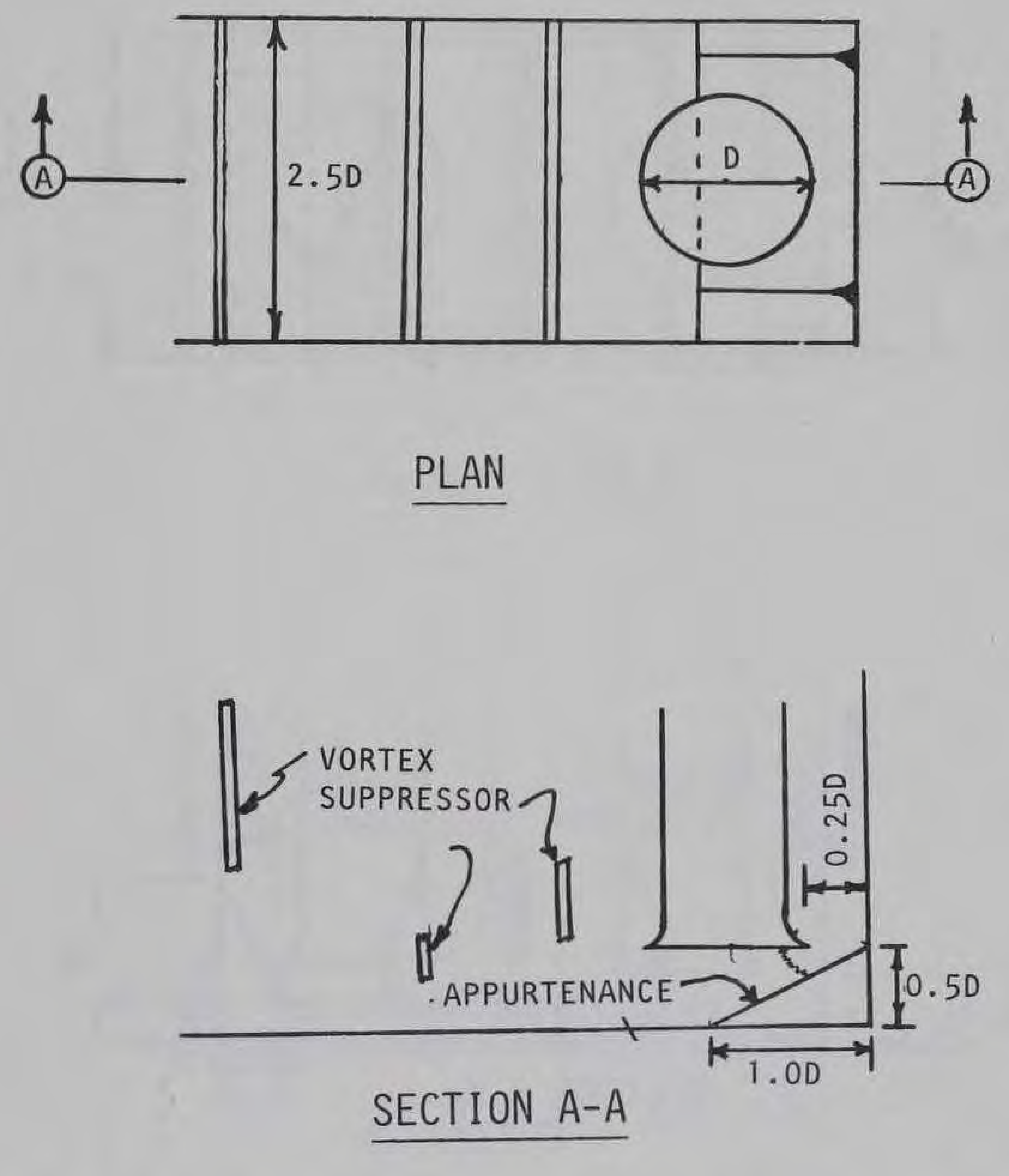


Figure 82. Type 1 appurtenance, type 28 sump, type 51 SVS

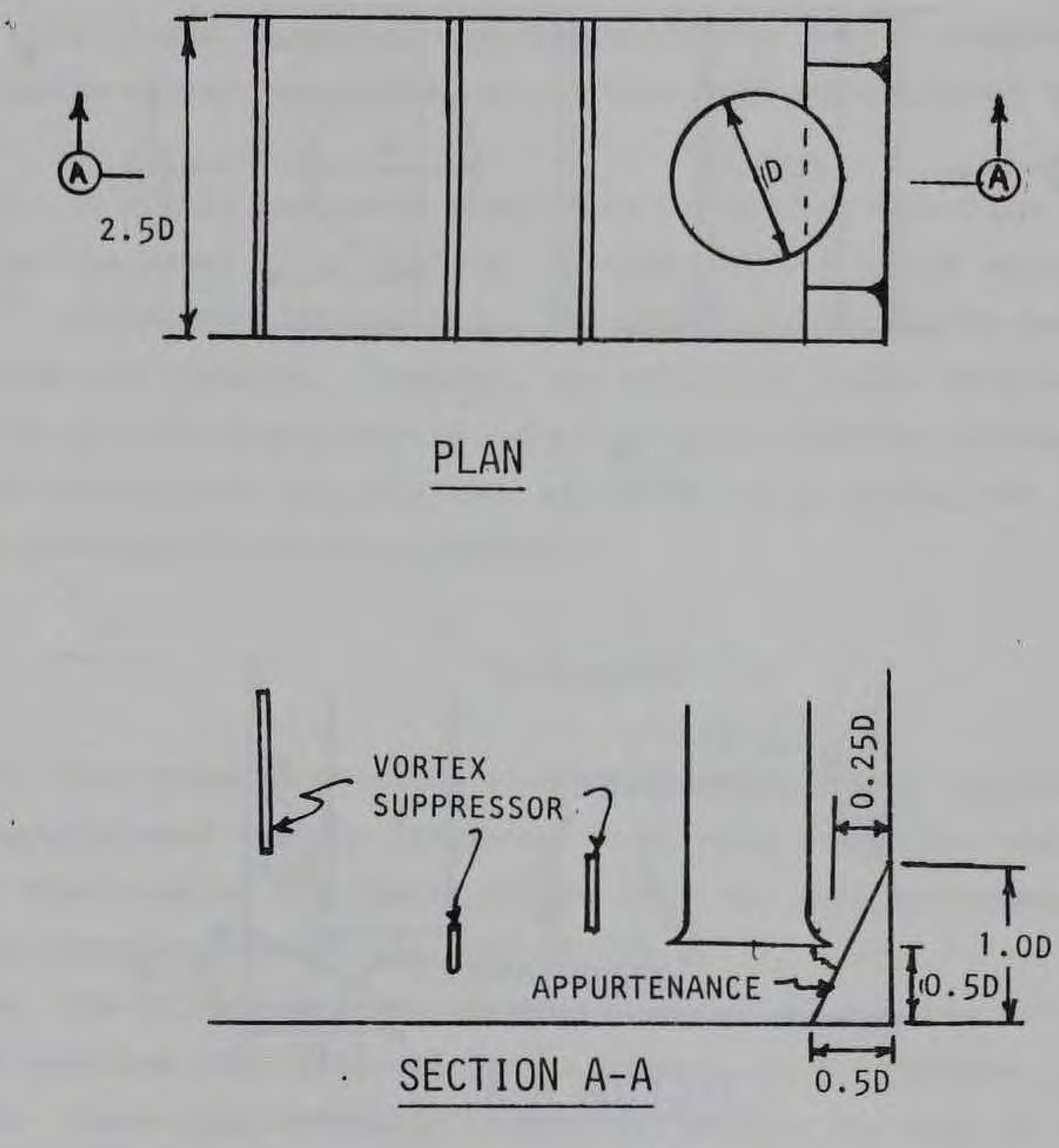


Figure 83. Type 2 appurtenance, type 28 sump, type 51 SVS

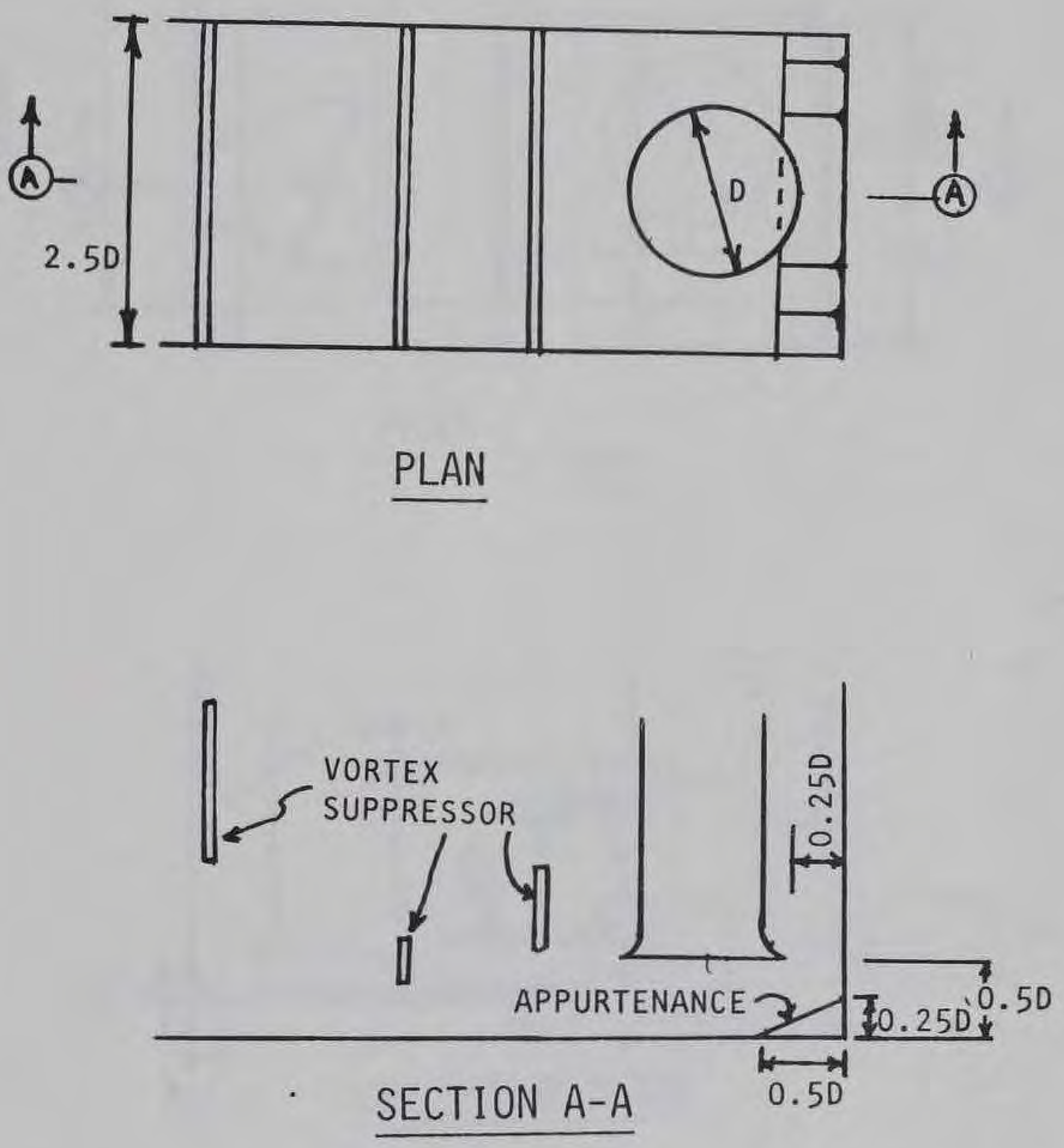


Figure 84. Type 3 appurtenance, type 28 sump, type 51 SVS

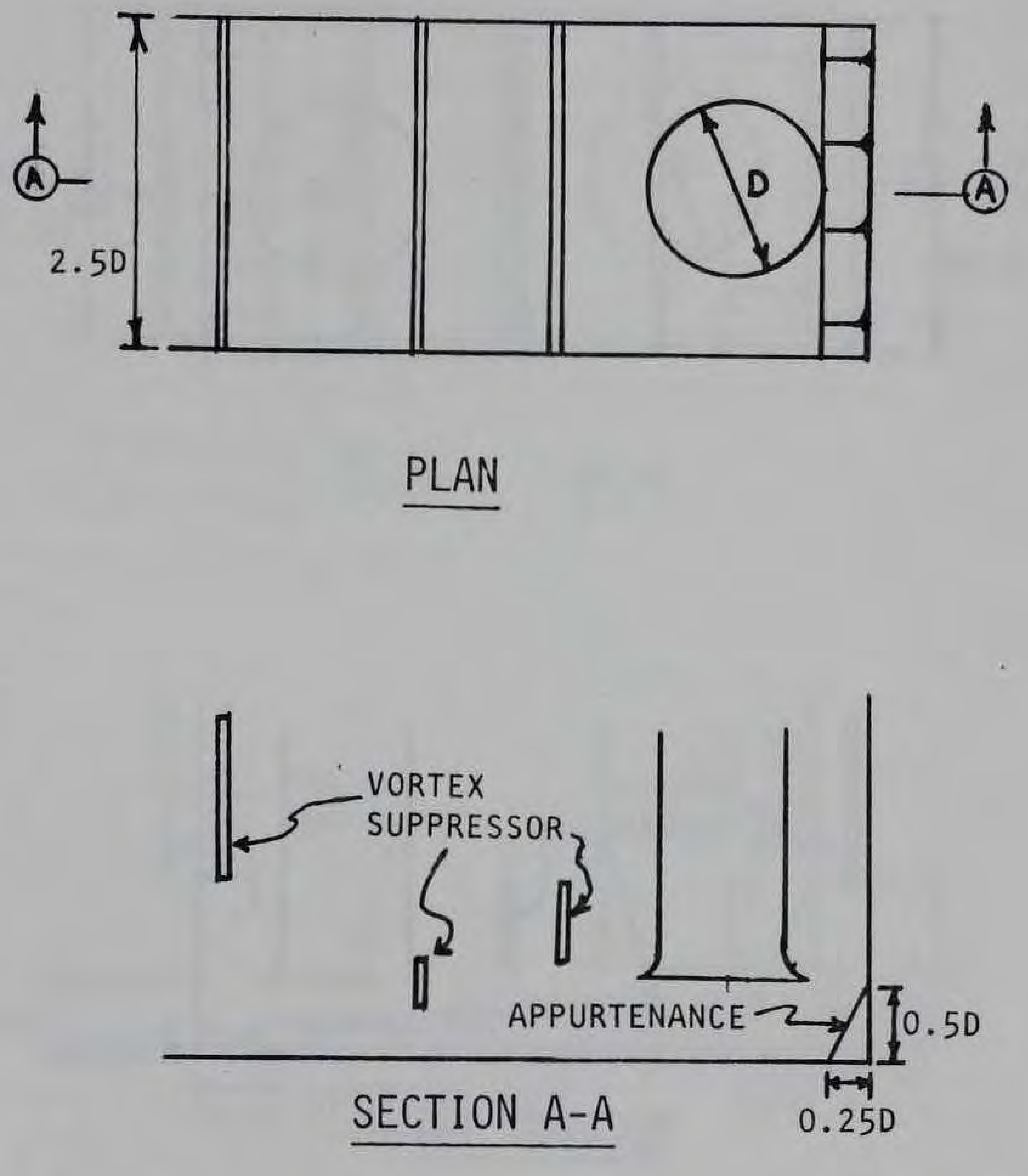


Figure 85. Type 4 appurtenance, type 28 sump, type 51 SVS

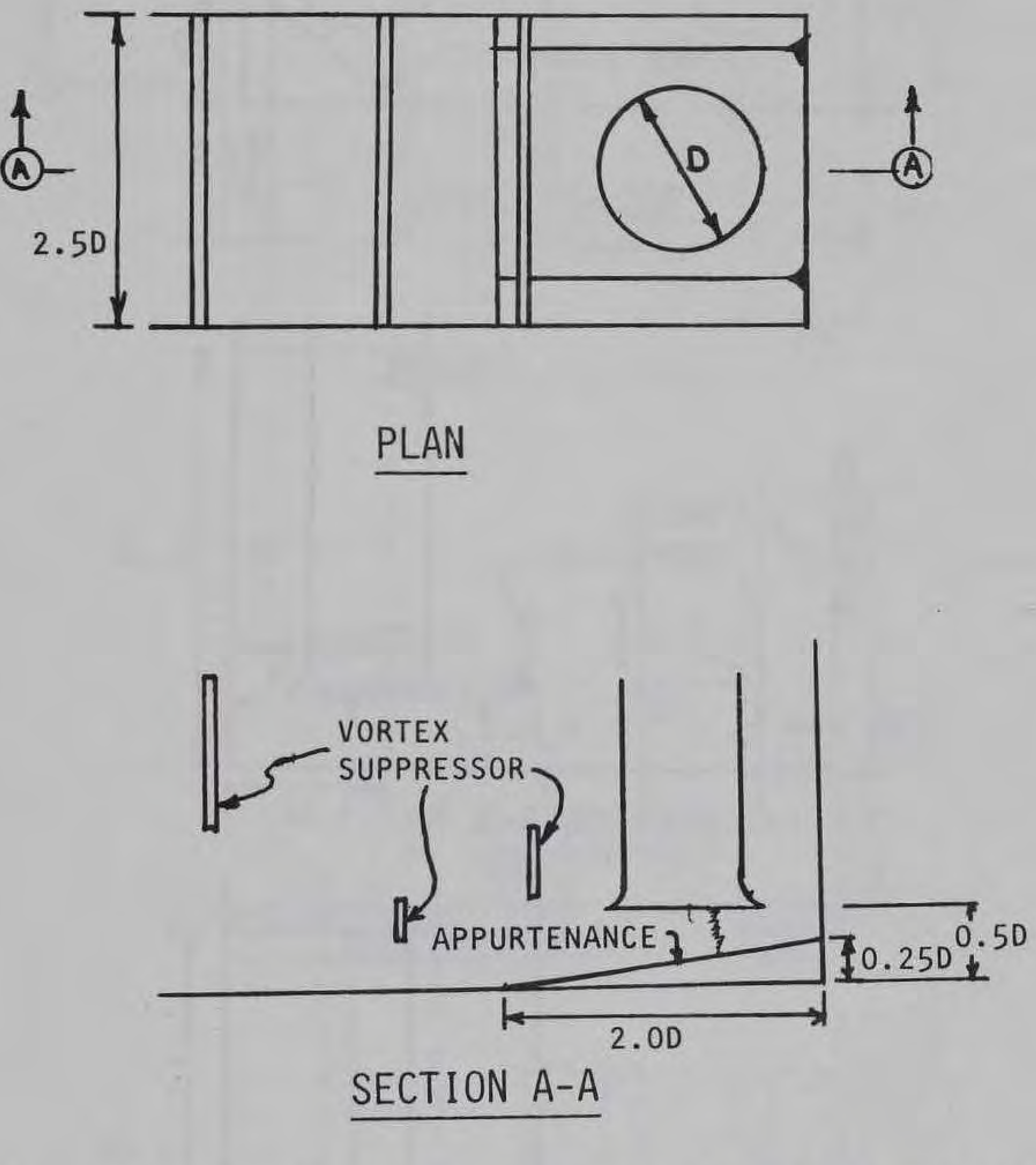


Figure 86. Type 5 appurtenance, type 28 sump, type 51 SVS

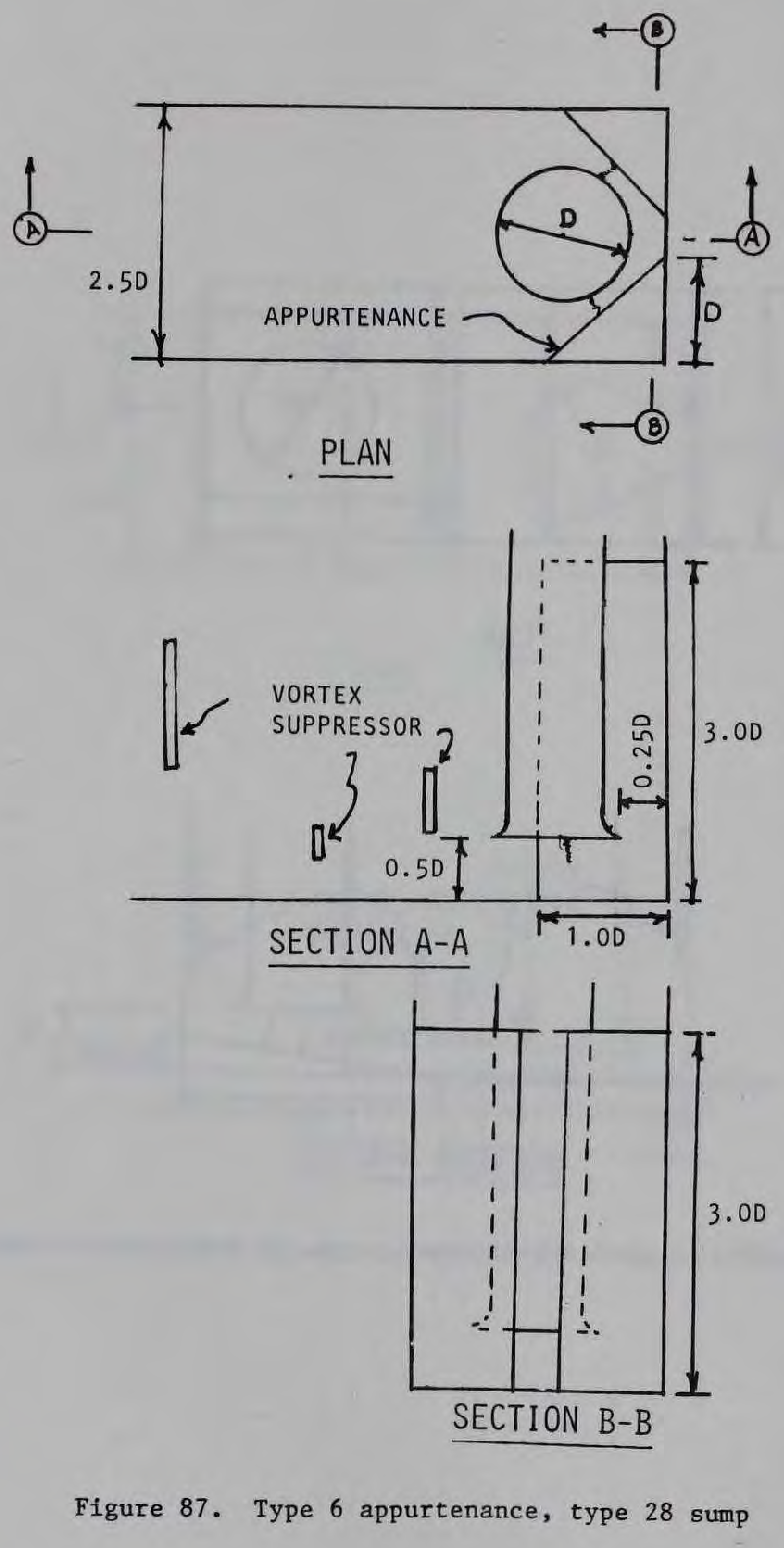


Figure 87. Type 6 appurtenance, type 28 sump

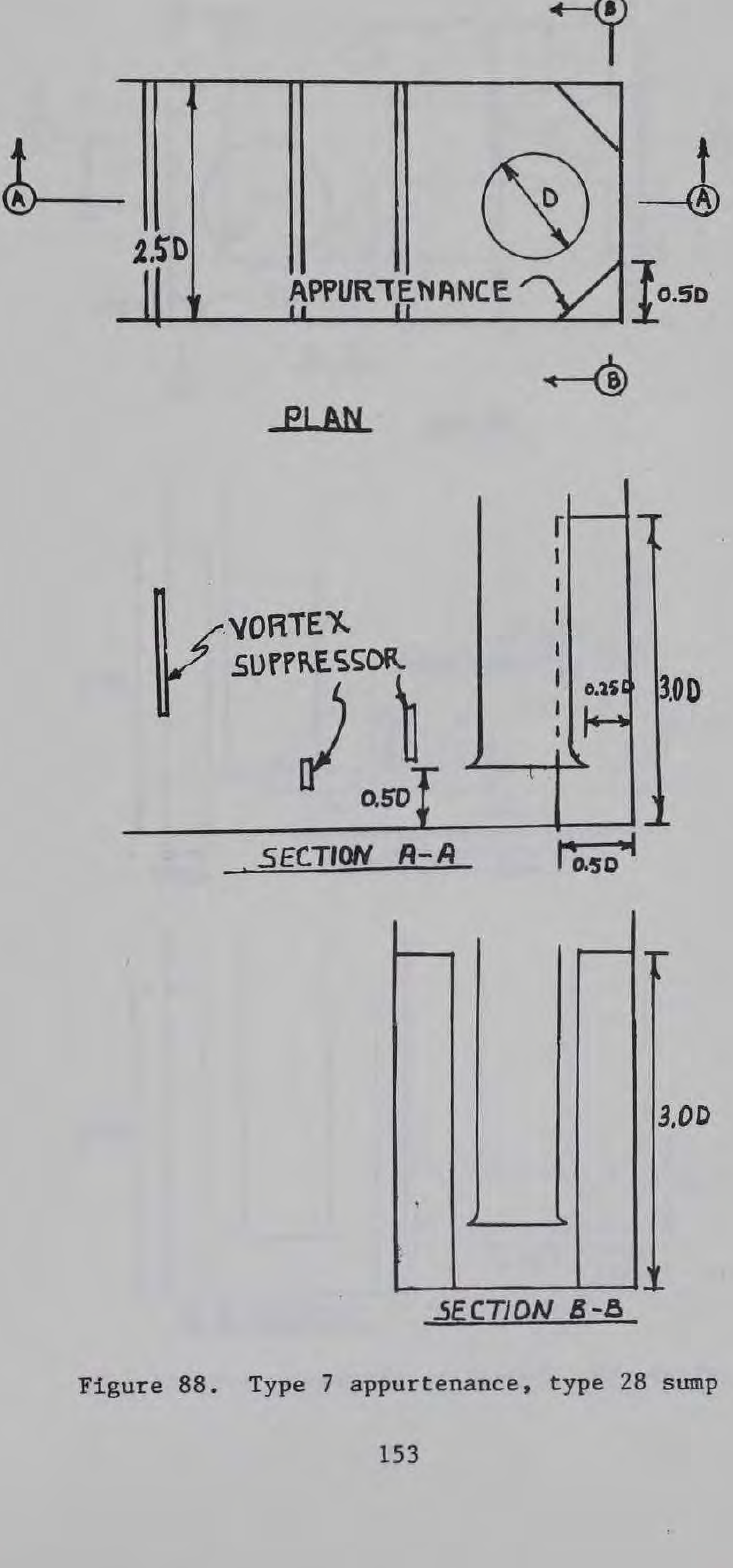


Figure 88. Type 7 appurtenance, type 28 sump

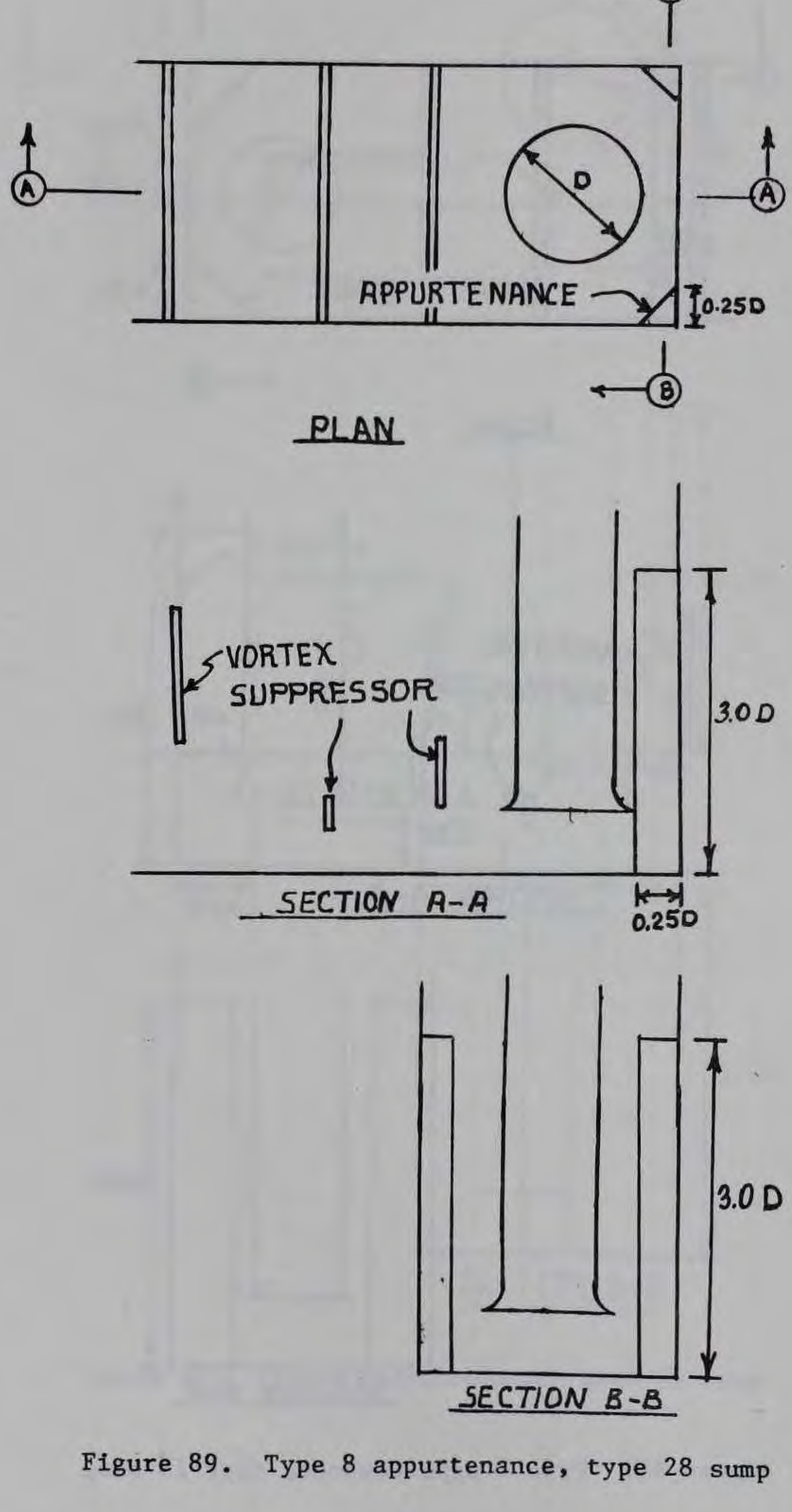


Figure 89. Type 8 appurtenance, type 28 sump

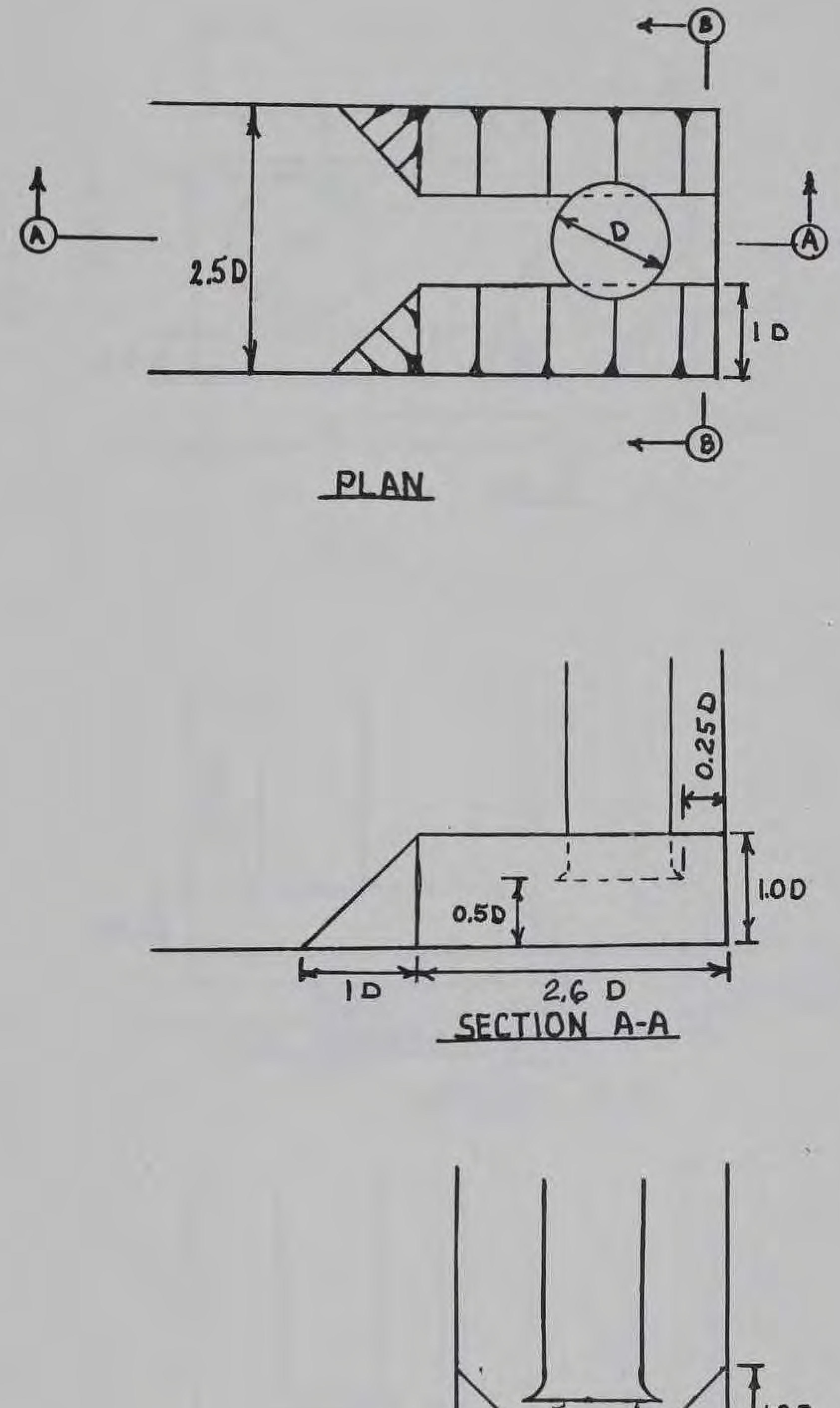


Figure 90. Type 9 appurtenance, type 28 sump

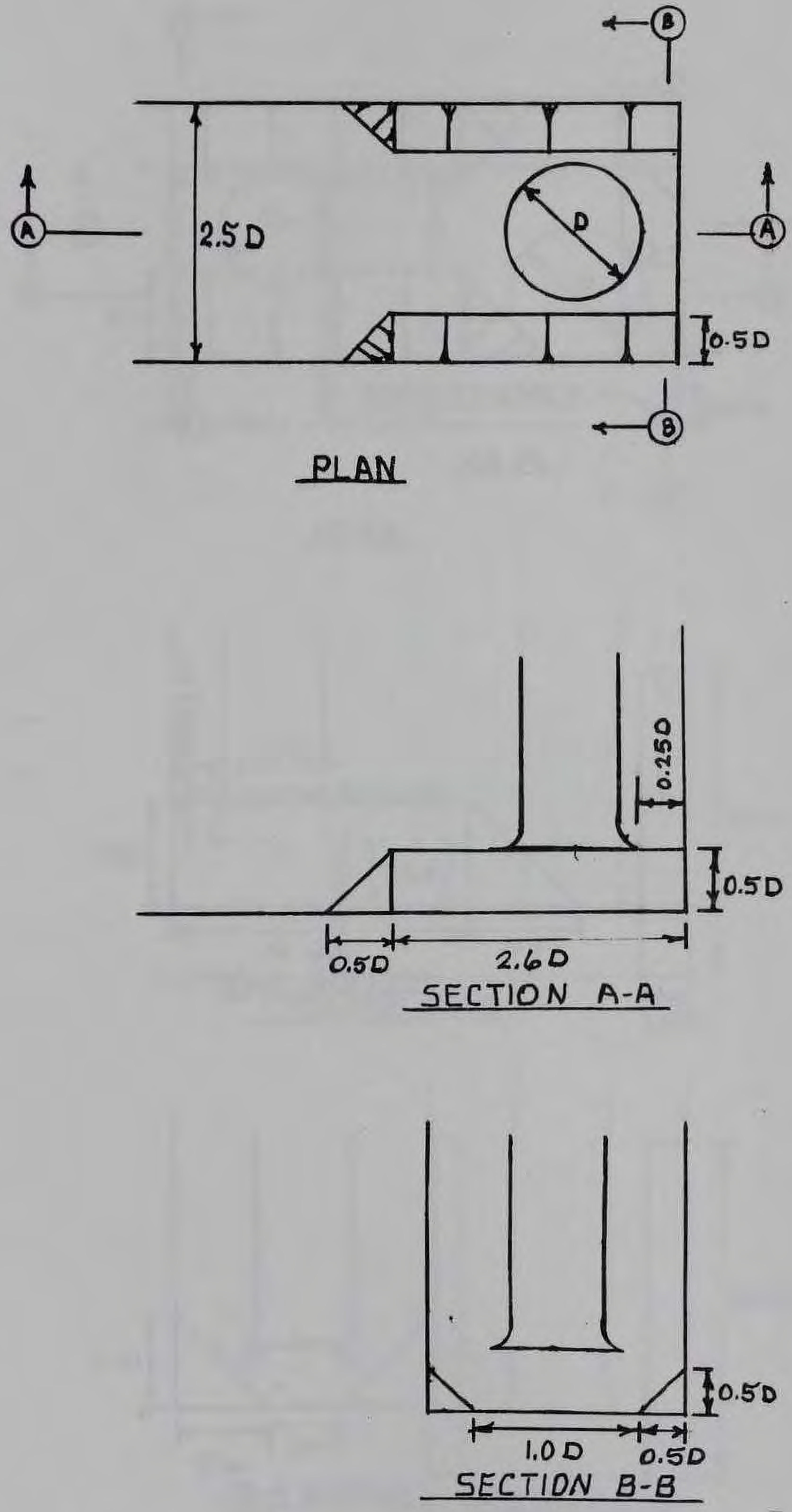


Figure 91. Type 10 appurtenance, type 28 sump

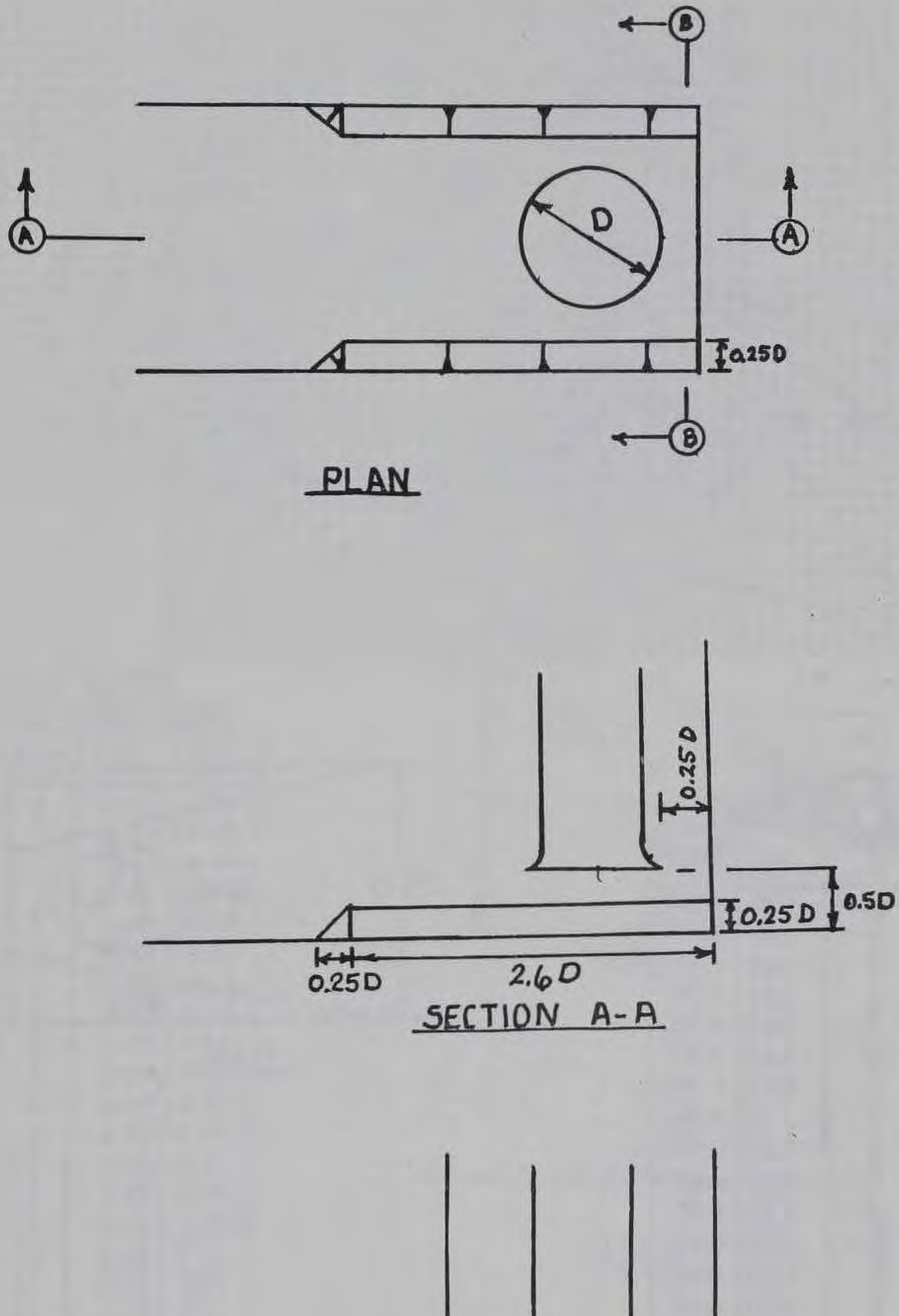
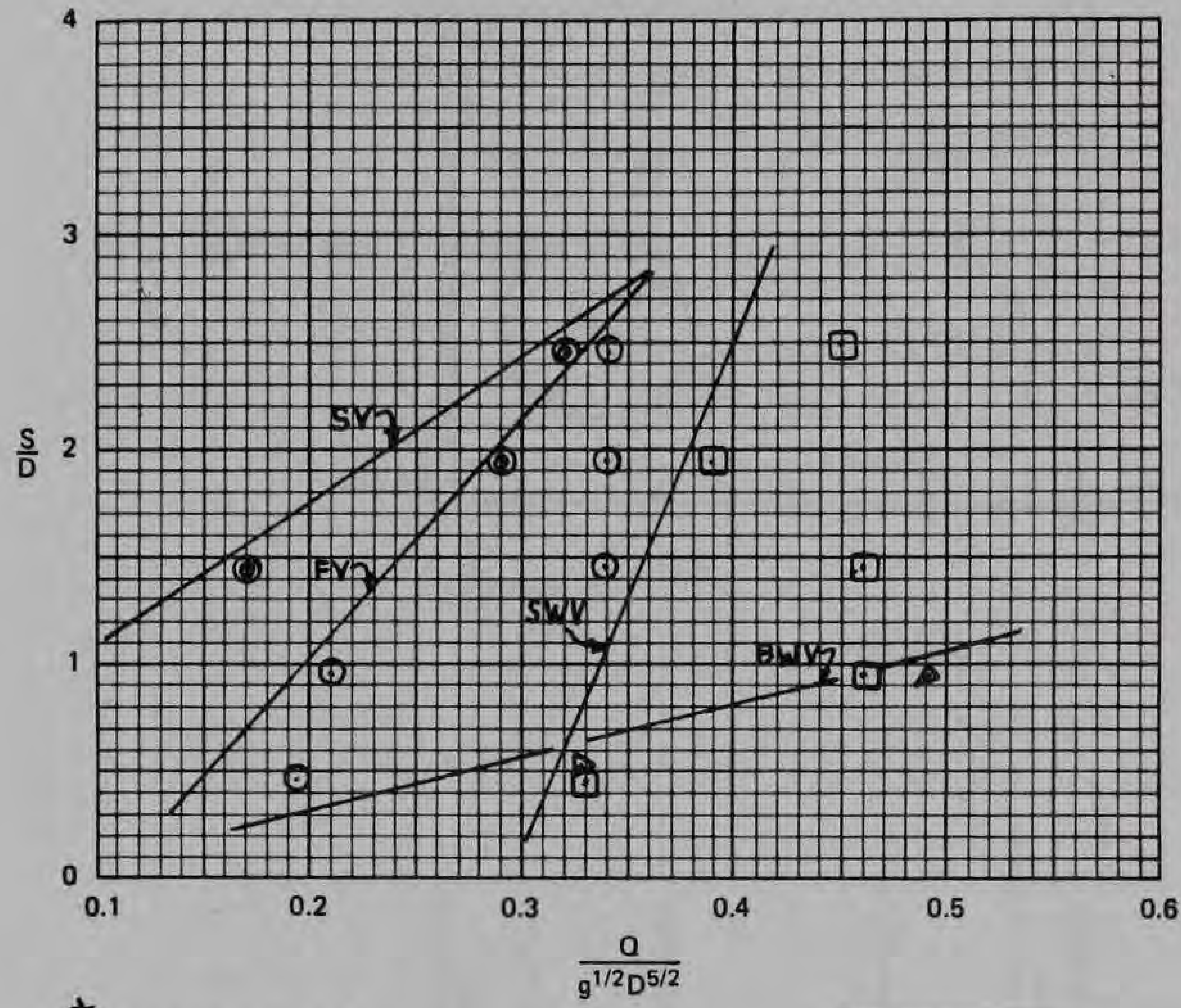


Figure 92. Type 11 appurtenance, type 28 sump



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BASIC DATA

MIXED FLOW PUMP

TYPE VORTEX	SYM.	S/D	$Q/g^{1/2}D^{5/2}$
FV	⊙	0.47	0.19
↓	↓	0.97	0.21
		1.47	0.34
		1.97	0.34
		2.47	0.34
SWV	⊡	0.47	0.33
↓	↓	0.97	0.46
		1.47	0.46
		1.97	0.39
		2.47	0.45
BWV	△	0.47	0.33
↓	↓	0.97	0.49
SV	◎	1.47	0.17
↓	↓	1.97	0.29
		2.47	0.32

* INCIPIENT VORTICES

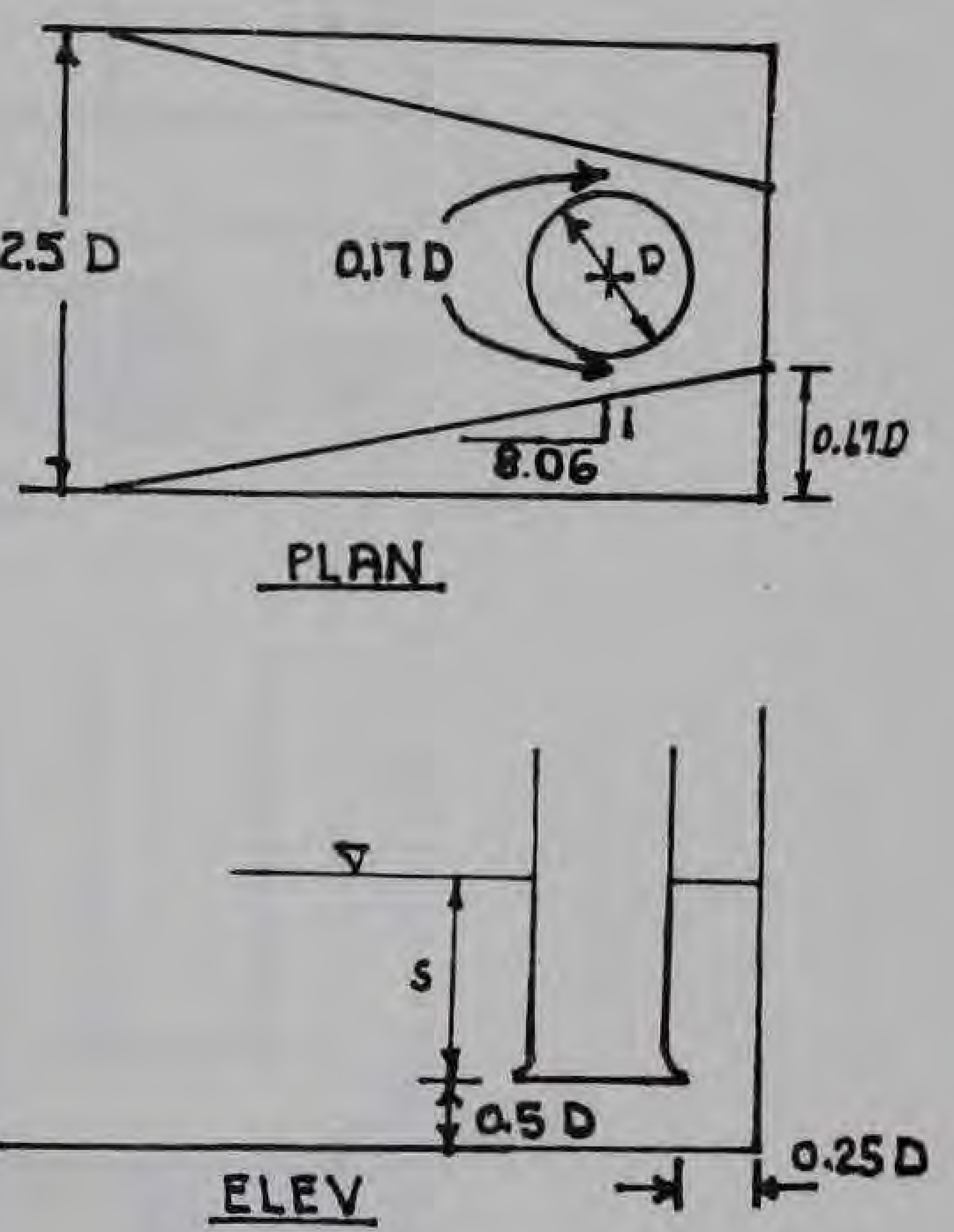
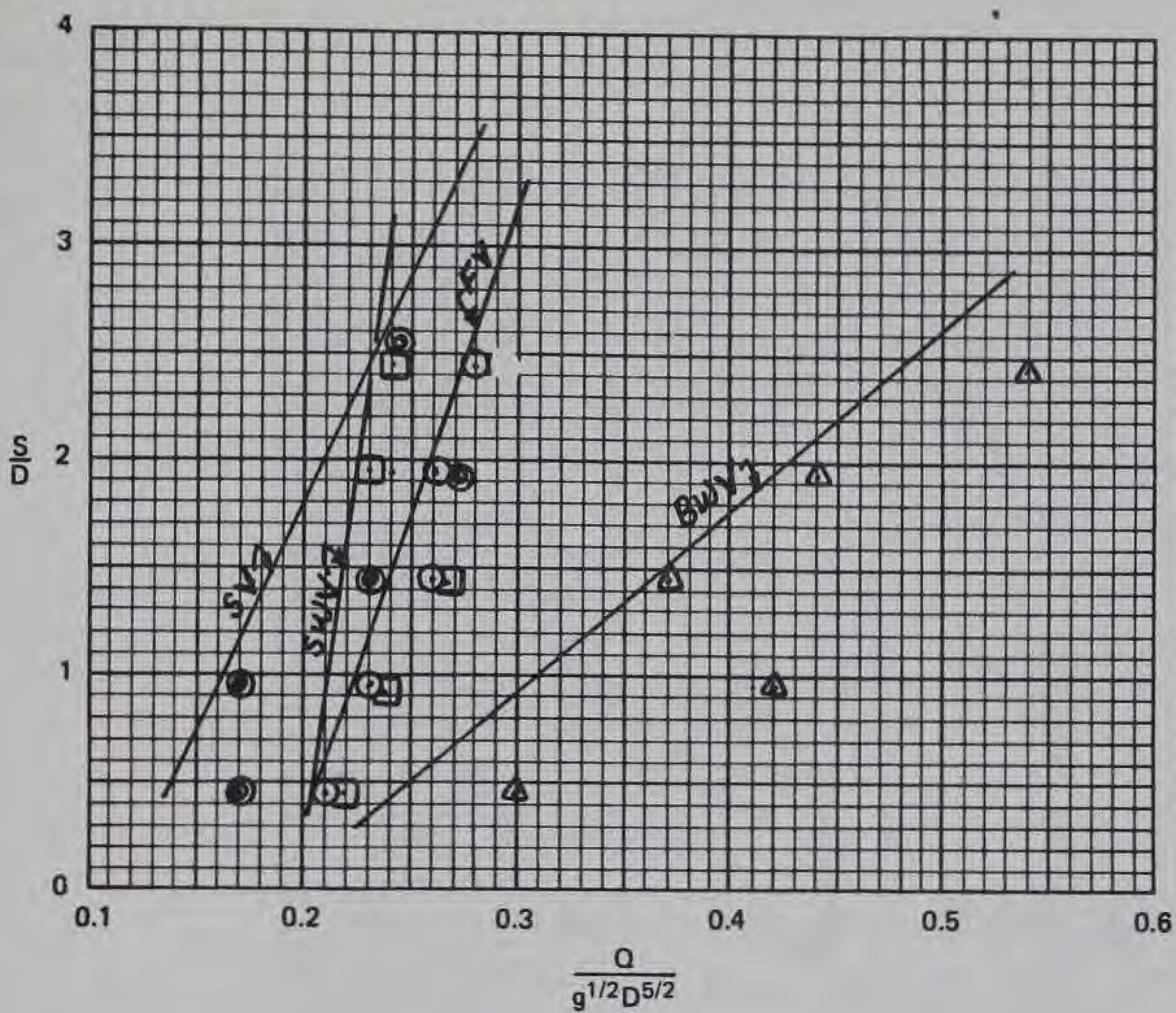


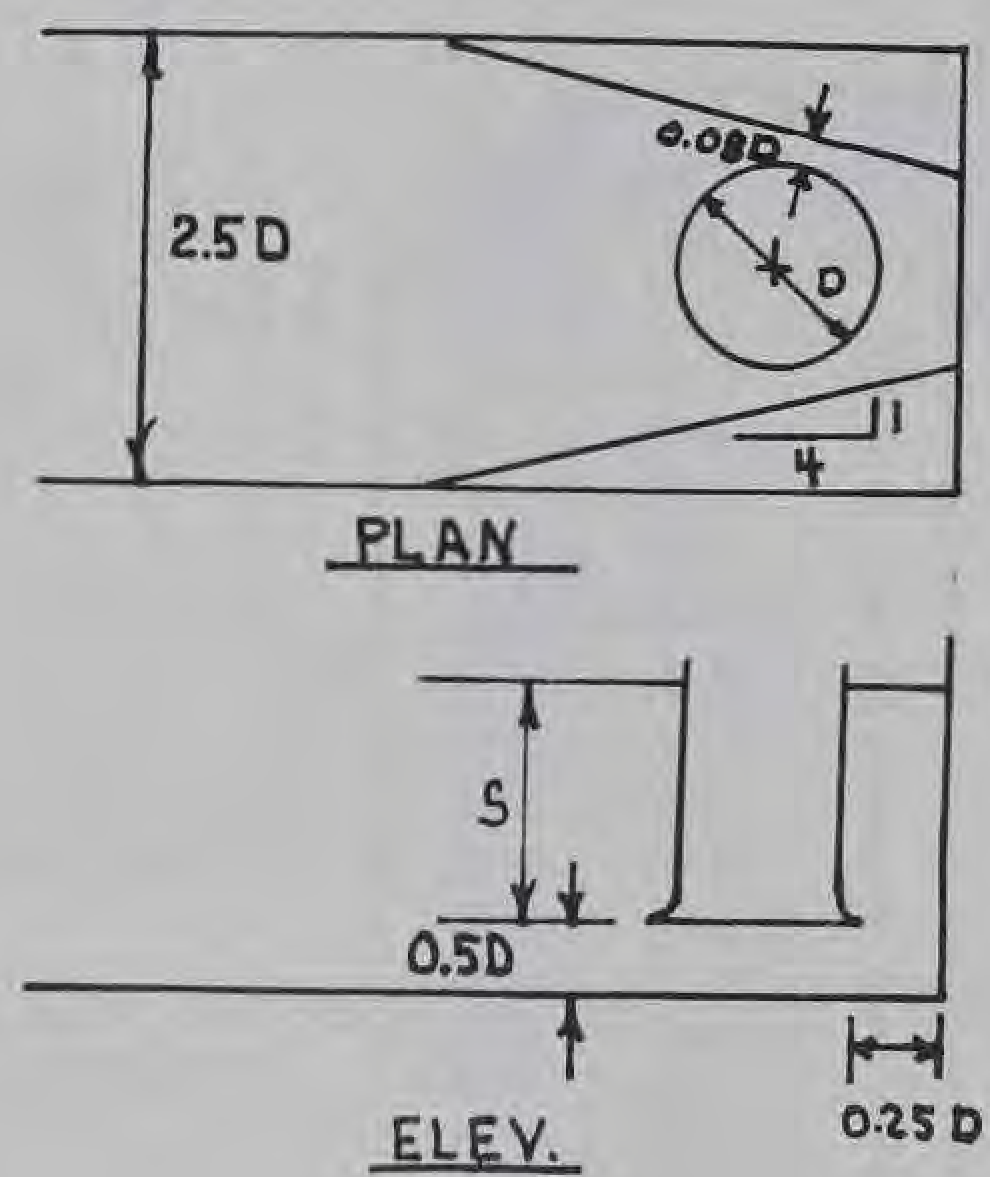
Figure 93. Critical bell submergence S , vortices, type 28 sump, type 12 appurtenance



* BASIC DATA

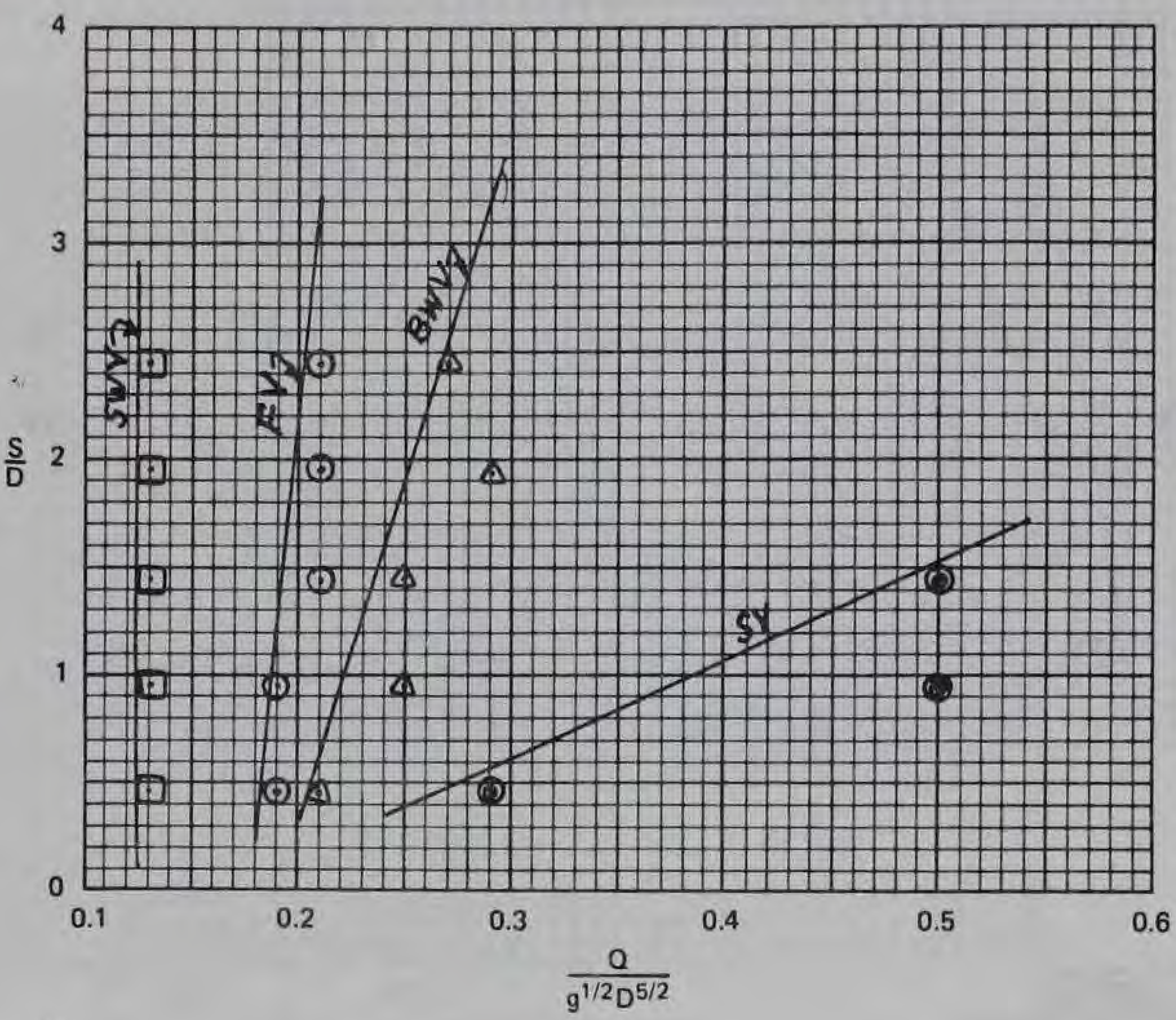
MIXED FLOW PUMP

TYPE VORTEX	SYM	S/D	$Q/g^{1/2}D^{5/2}$
FV	⊙	0.47	0.21
		0.97	0.23
		1.47	0.26
		1.97	0.26
		2.47	0.28
SWV	⊡	0.47	0.21
		0.97	0.23
		1.47	0.26
		1.97	0.23
		2.47	0.24
BWV	△	0.47	0.30
		0.97	0.42
		1.47	0.37
		1.97	0.44
		2.47	0.54
SV	◉	0.47	0.17
		0.97	0.17
		1.47	0.23
		1.97	0.26
		2.47	0.24



* INCIPIENT VORTICES

Figure 94. Critical bell submergence S, vortices, type 28 sump, type 13 appurtenance



* BASIC DATA

MIXED FLOW PUMP

TYPE VORTEX	SYM.	S/D	$Q/g^{1/2}D^{5/2}$
FV	⊙	0.47	0.19
↓	↓	0.97	0.19
		1.47	0.21
		1.97	0.21
		2.47	0.21
SWV	⊡	0.47	0.13
↓	↓	0.97	0.13
		1.47	0.13
		1.97	0.13
		2.47	0.13
BWV	△	0.47	0.21
↓	↓	0.97	0.25
		1.47	0.25
		1.97	0.29
		2.47	0.27
SV	◉	0.47	0.29
↓	↓	0.97	0.50
		1.47	0.50

* INCIPIENT VORTICES

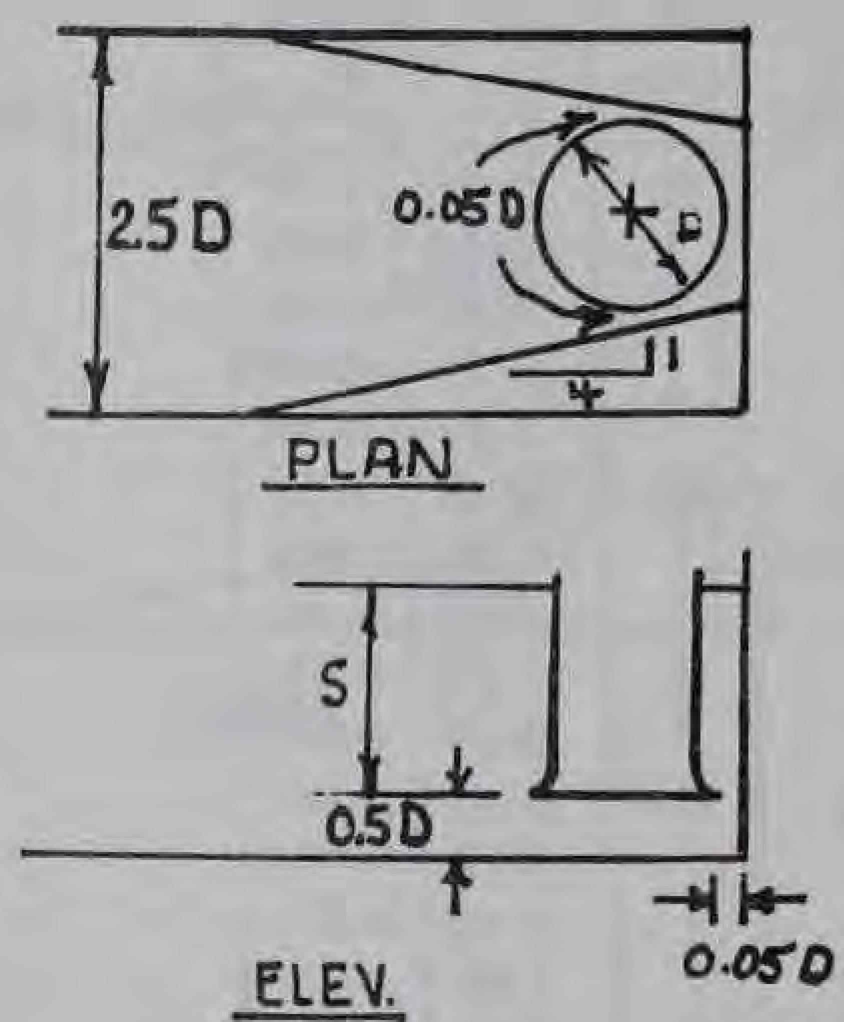
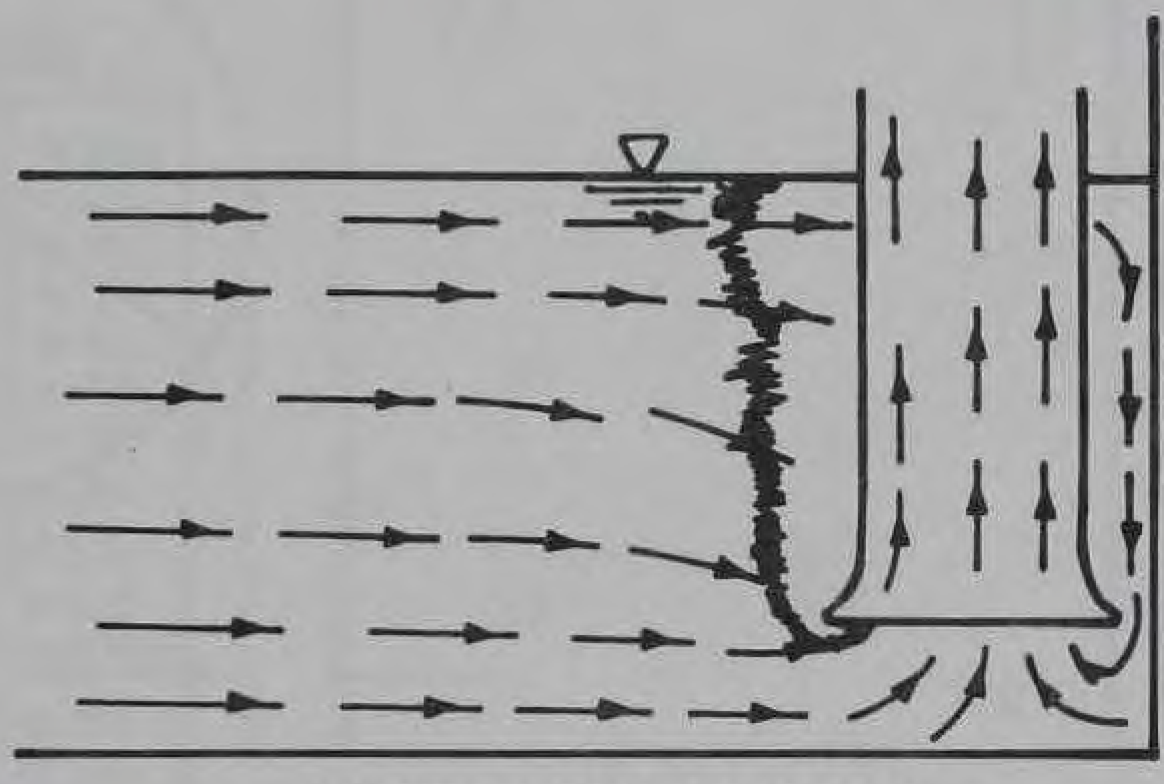
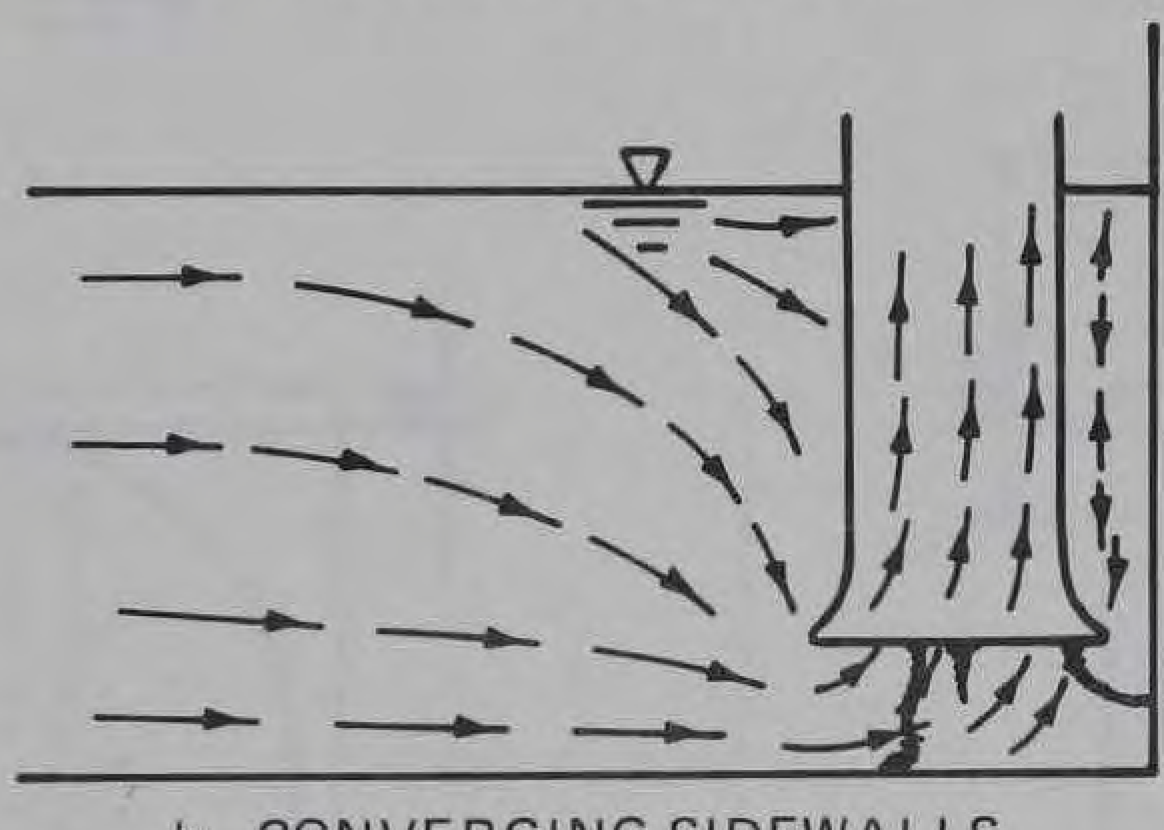


Figure 95. Critical bell submergence S , vortices, type 29 sump, type 14 appurtenance



a. RECTANGULAR SUMP



b. CONVERGING SIDEWALLS

Figure 96. Typical flow conditions, rectangular sump and converging sidewalls

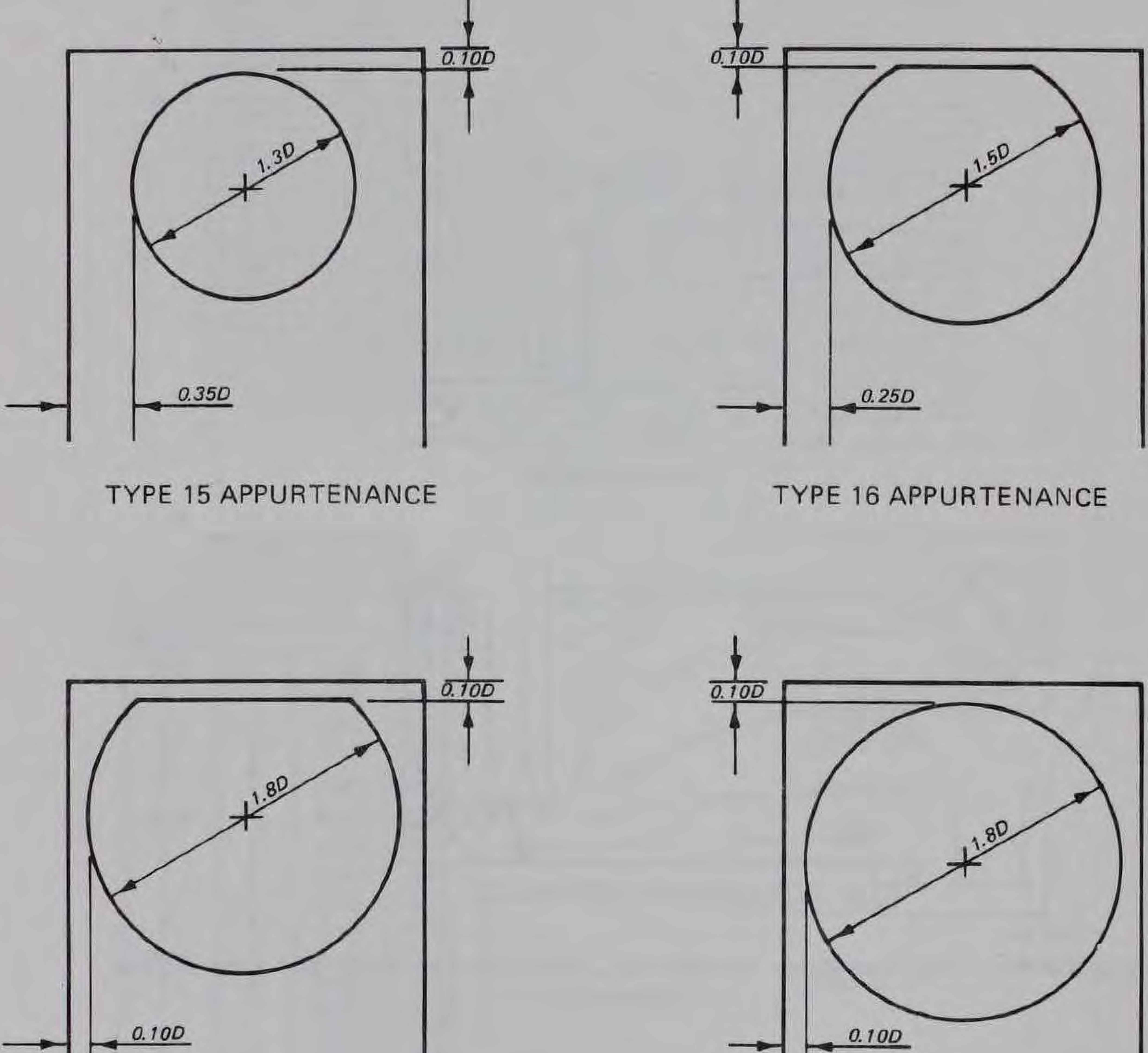


Figure 97. Umbrellas

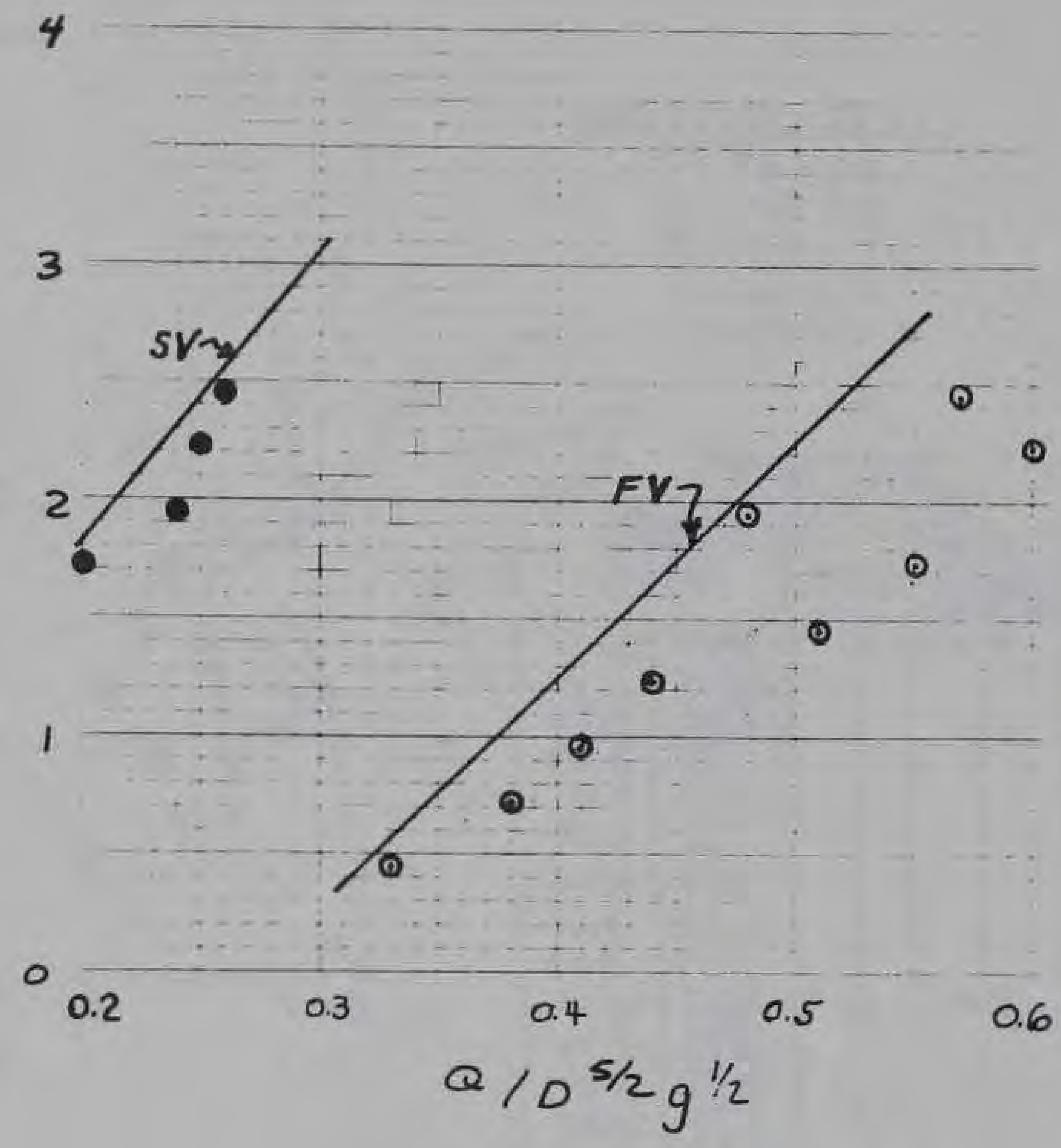
TEST CONDITIONS

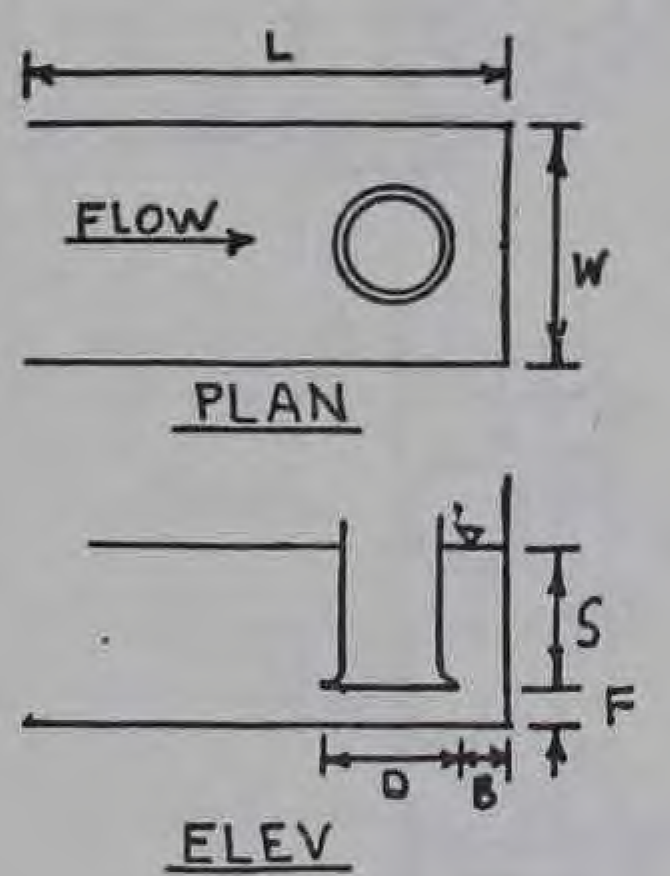
D = 1.29 FT
B = 0.25 D
F = 0.50 D
W = 2.0 D
L = 19.0 D

BASIC DATA

MIXED FLOW PUMP

TYPE VORTEX	SYM.	S/D	$Q/D^{5/2}g^{1/2}$
FV	⊙	0.47	0.33
		0.72	0.33
		0.97	0.41
		1.22	0.44
		1.47	0.51
		1.72	0.55
		1.97	0.48
		2.22	0.60
		2.47	0.57
SV	●	1.72	0.20
		1.97	0.24
		2.22	0.25
		2.47	0.26





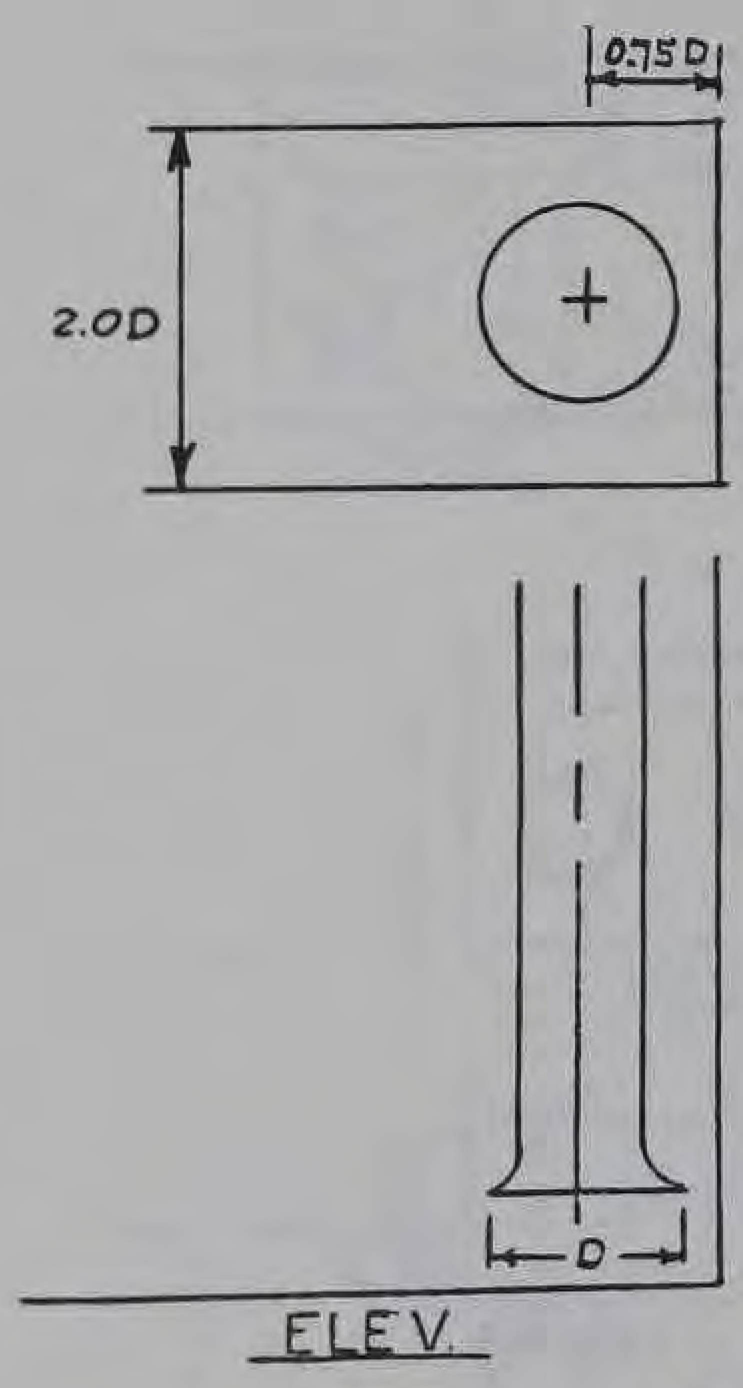


Figure 98. Critical bell submergence S, vortices, type 18 sump

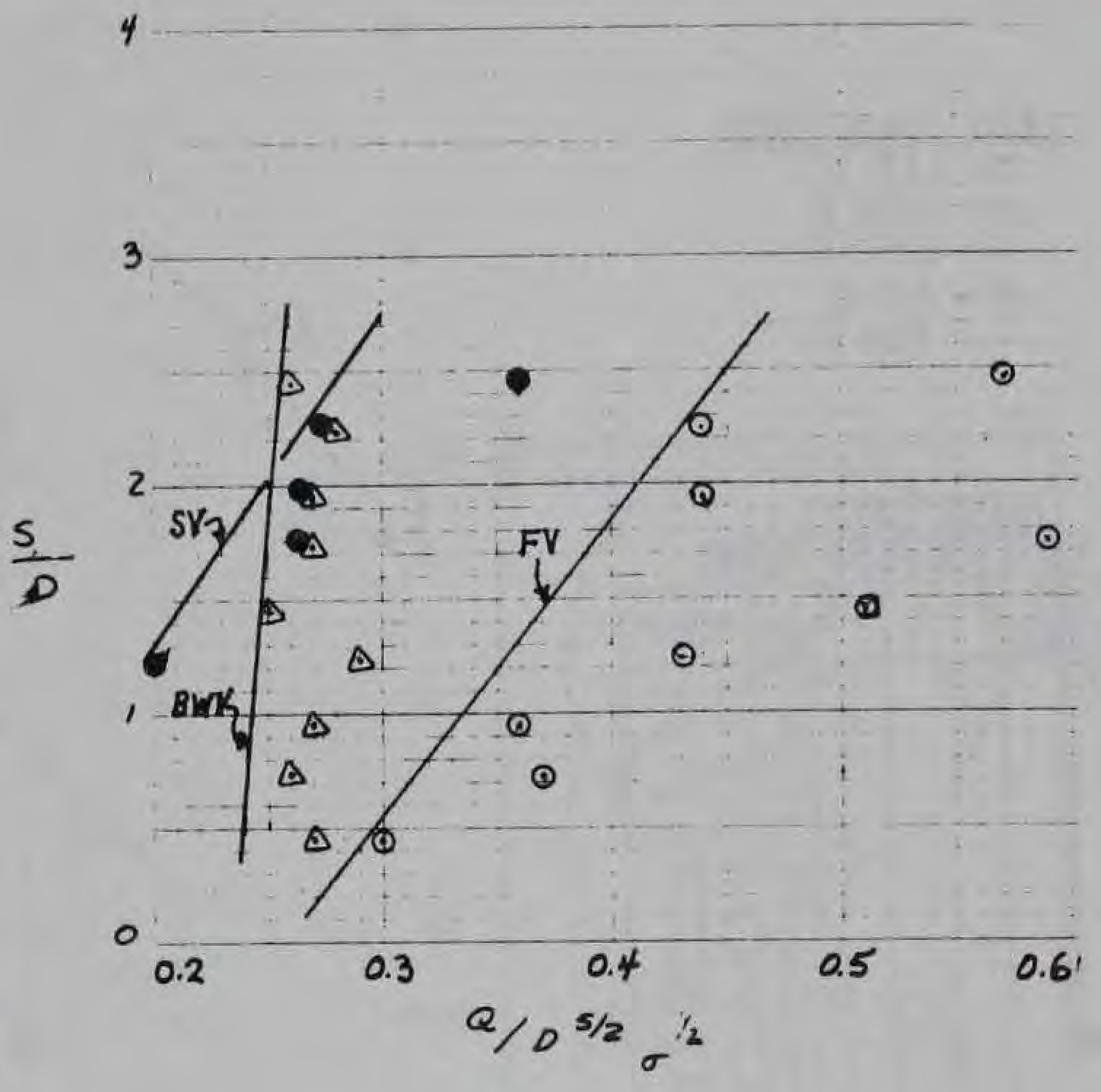
TEST CONDITIONS

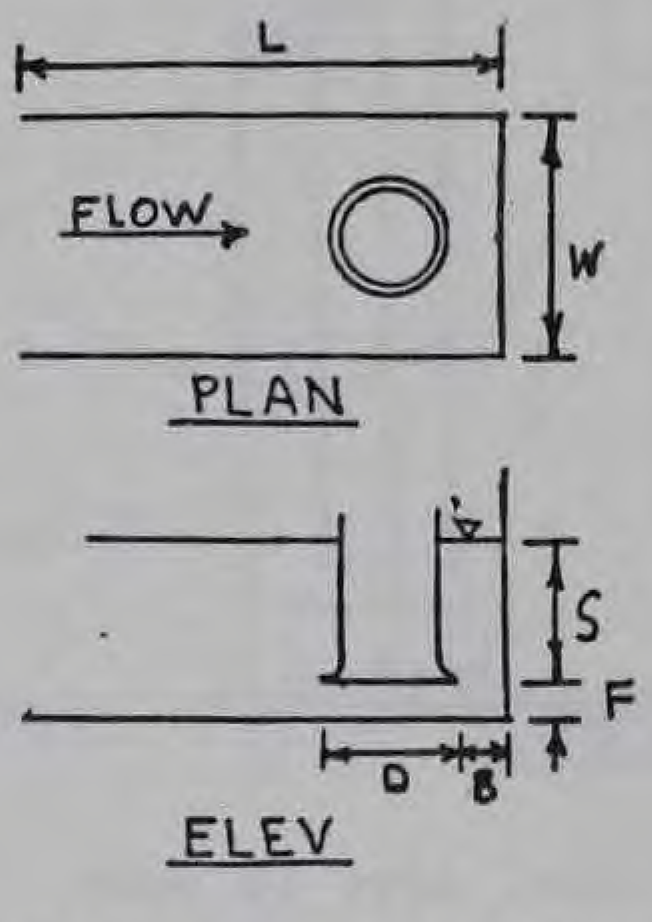
D = 1.29 FT
B = 0.10 D
F = 0.50 D
W = 2.0 D
L = 1[illegible].0 D

BASIC DATA

MIXED FLOW PUMP

TYPE VORTEX	SYM.	S/D	Q/
FV	⊙	0.47	0.30
		0.72	0.37
		0.97	0.36
		1.22	0.43
		1.47	0.51
		1.72	0.59
		1.97	0.44
		2.22	0.44
		2.47	0.57
BWV	△	0.47	0.27
		0.72	0.26
		0.97	0.27
		1.22	0.29
		1.47	0.25
		1.72	0.27
		1.97	0.27
		2.22	0.28
		2.47	0.26
SV	●	1.22	0.20
		1.72	0.27
		1.97	0.27
		2.22	0.28
		2.47	0.36





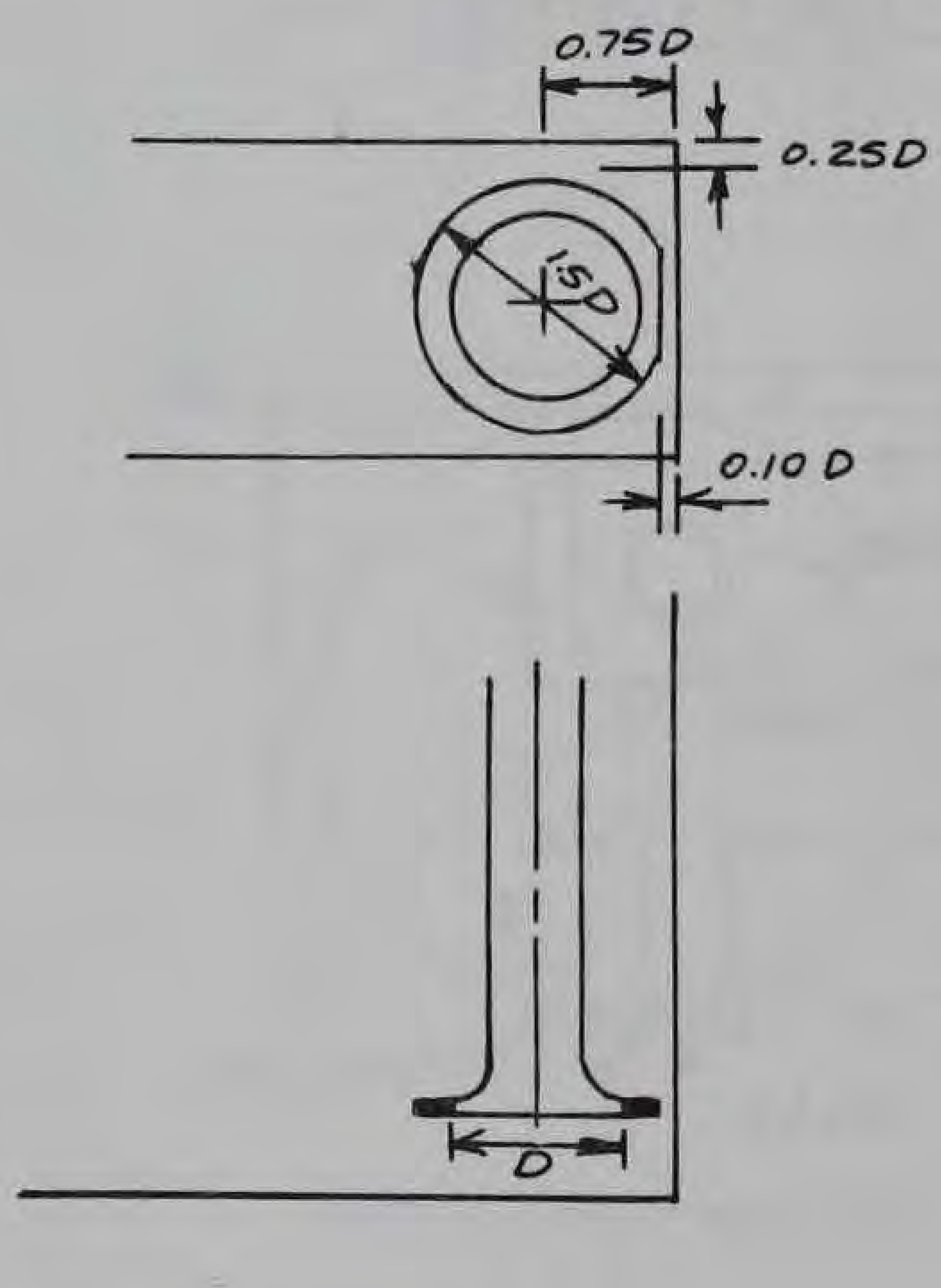


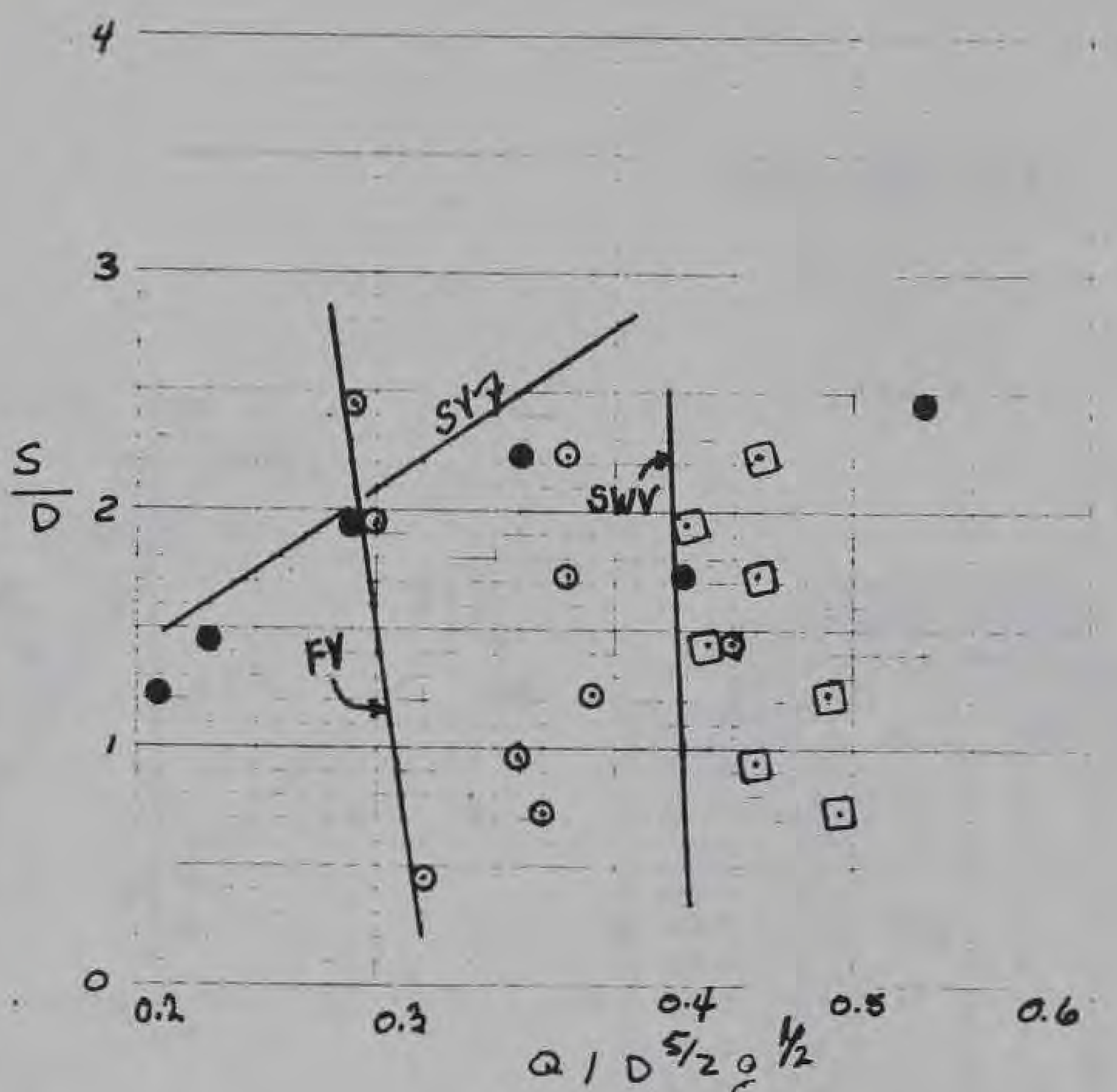
Figure 99. Critical bell submergence S , vortices, type 18 sump, type 15 appurtenance

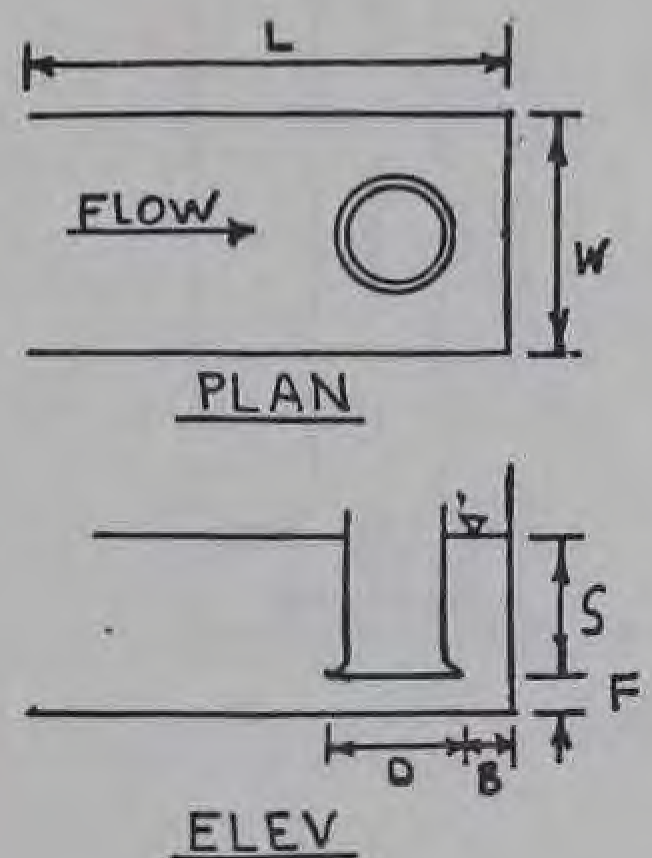
TEST CONDITIONS

D = 1.29 FT
B = 0.10 D
F = 0.50 D
W = 2.0 D
L = 19.0 D

BASIC DATA
MIXED FLOW PUMP

TYPE VORTEX	SYM.	S	$Q/g^{1/2}D^{5/2}$
FV	⊙	0.47	0.32
		0.72	0.37
		0.97	0.36
		1.22	0.39
		1.47	0.45
		1.72	0.38
		1.97	0.30
		2.22	0.38
		2.47	0.29
SWV	⊡	0.72	0.49
		0.97	0.46
		1.22	0.39
		1.47	0.34
		1.72	0.36
		1.97	0.33
		2.22	0.36
		2.47	0.29
SV	●	1.22	0.21
		1.47	0.23
		1.72	0.43
		1.97	0.29
		2.22	0.36
		2.47	0.53





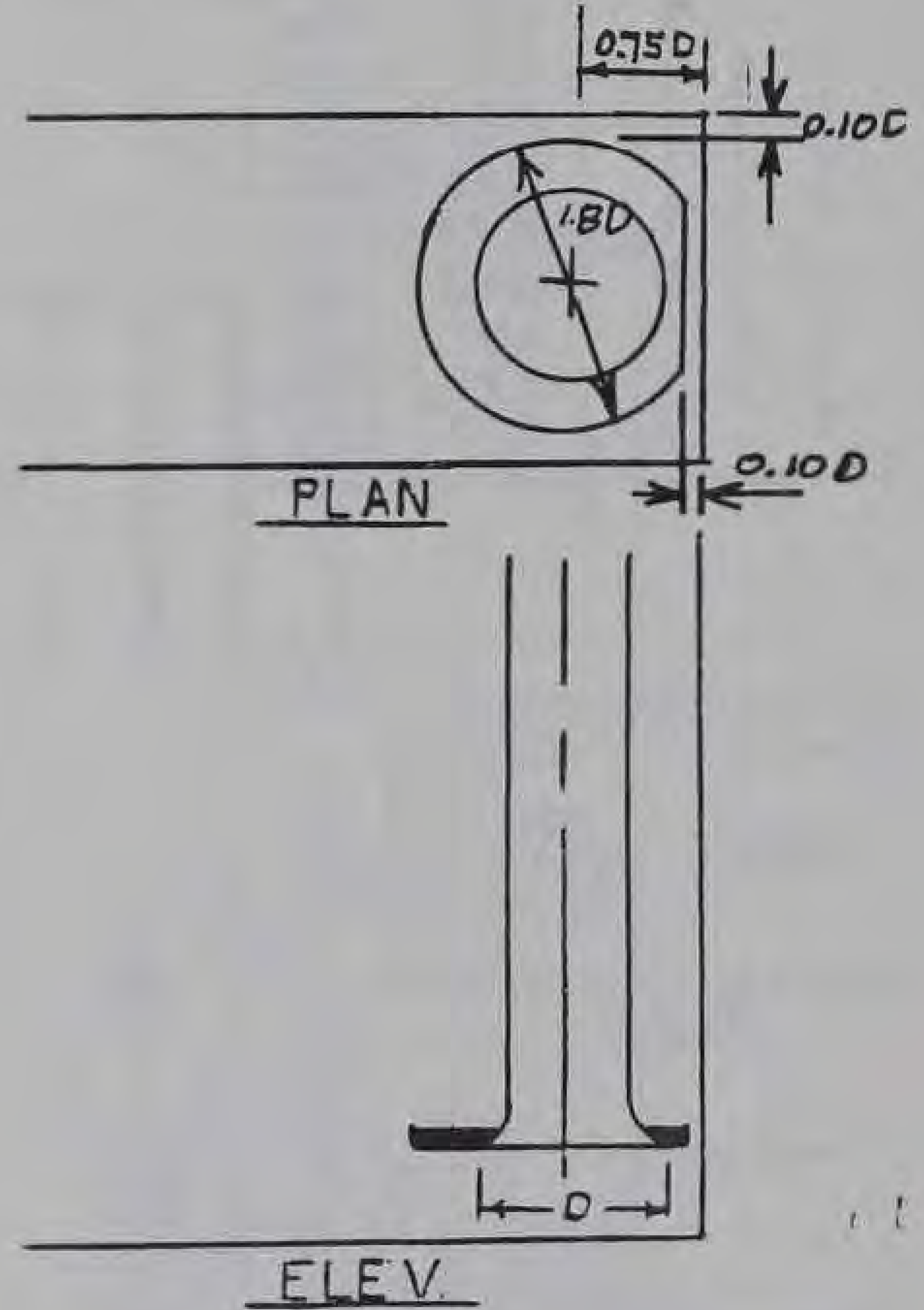


Figure 100. Critical bell submergence S , surface vortices, type 18 sump, type 16 appurtenance

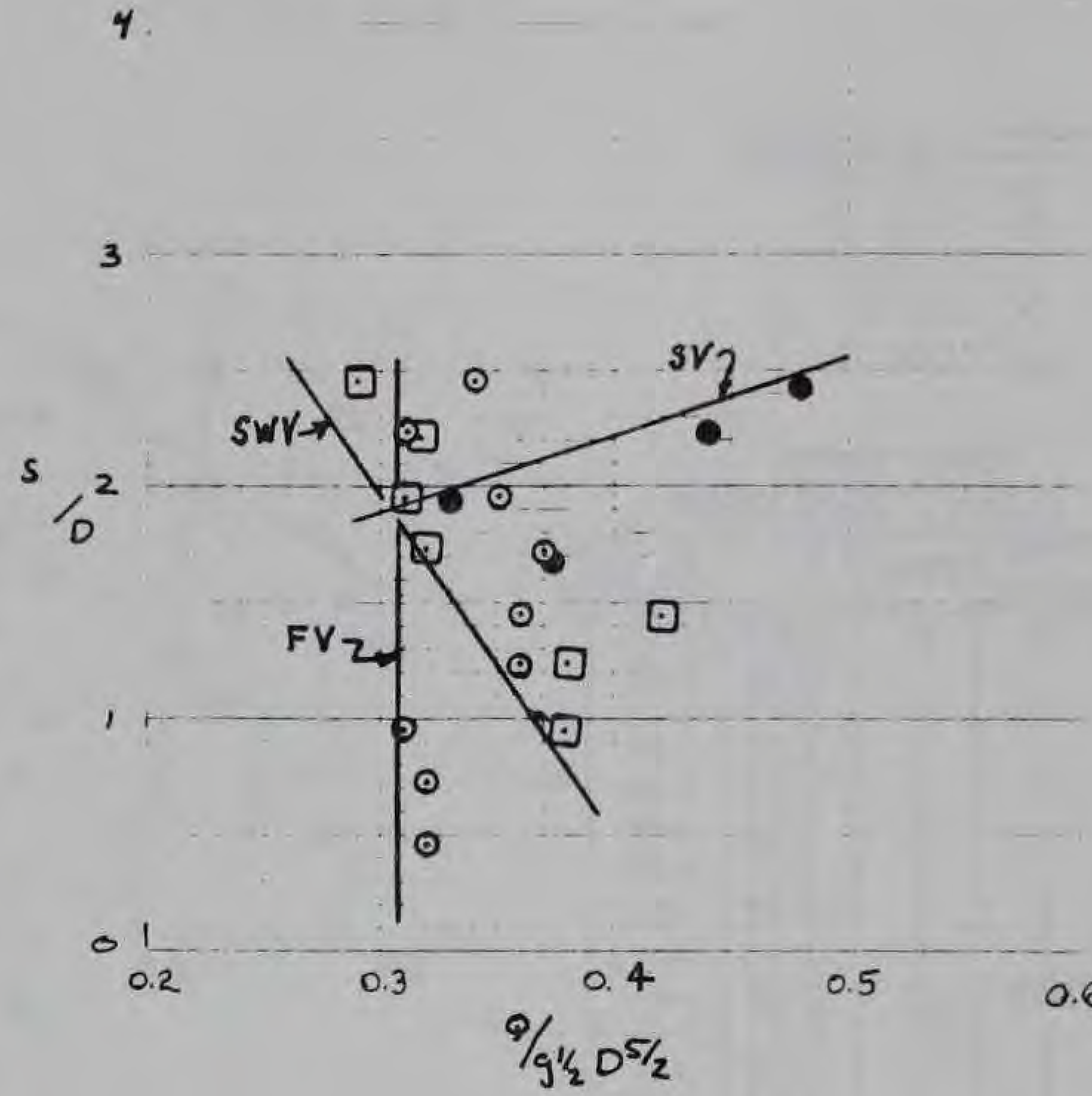
TEST CONDITIONS

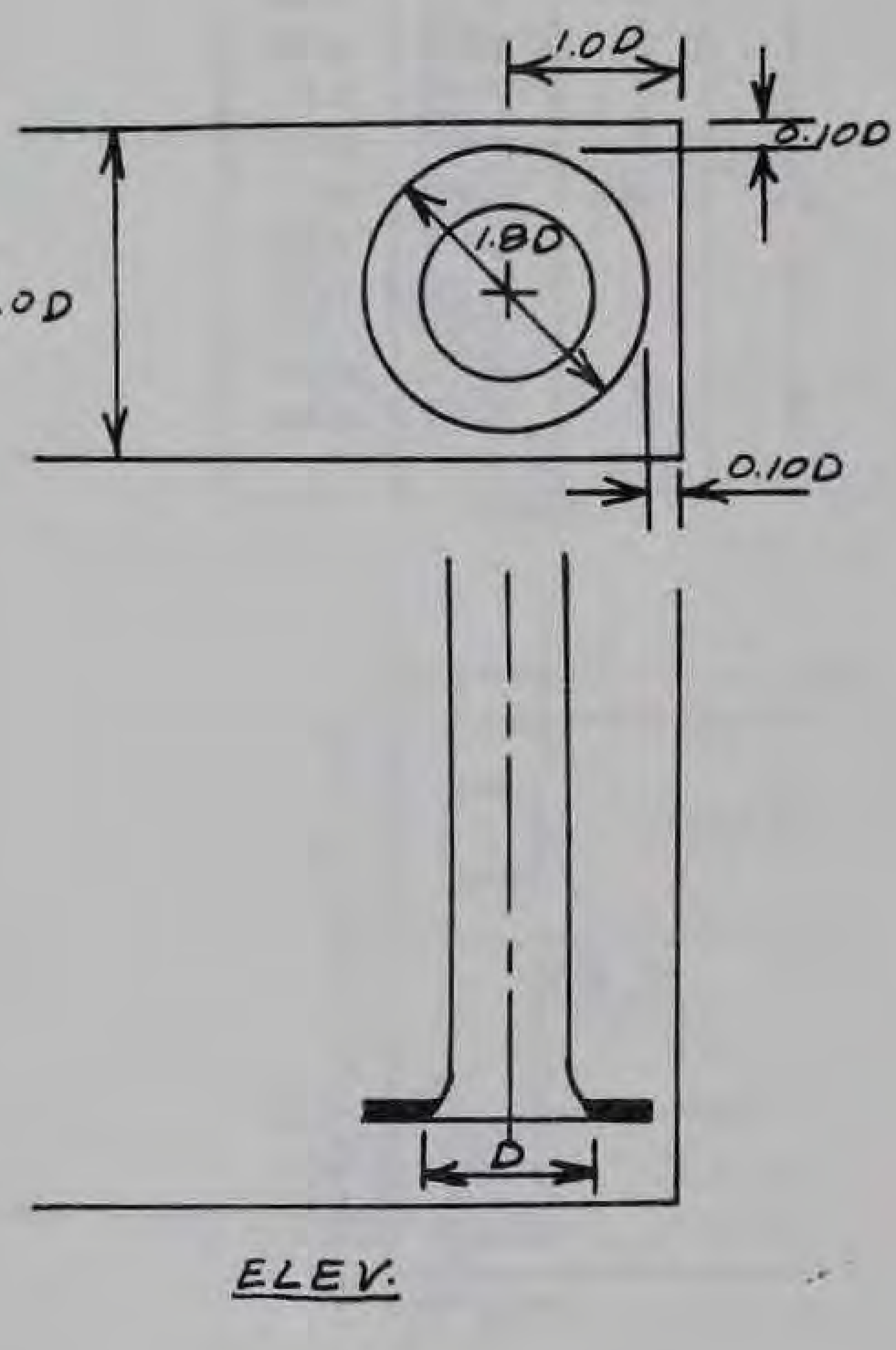
D = 1.29 FT
B = 0.10 D
F = 0.50 D
W = 2.0 D
L = 19.0 D

BASIC DATA

MIXED FLOW PUMP

TYPE VORTEX	SYM.	S/D	$Q/g^{1/2}D^{5/2}$
FV	⊙	0.47	0.32
		0.72	0.32
		0.97	0.31
		1.22	0.36
		1.47	0.36
		1.72	0.37
		1.97	0.35
		2.22	0.31
		2.47	0.34
SWV	⊡	0.97	0.38
		1.22	0.38
		1.47	0.42
		1.72	0.32
		1.97	0.31
		2.22	0.31
		2.47	0.29
SV	●	1.72	0.37
		1.97	0.30
		2.22	0.44
		2.47	0.48





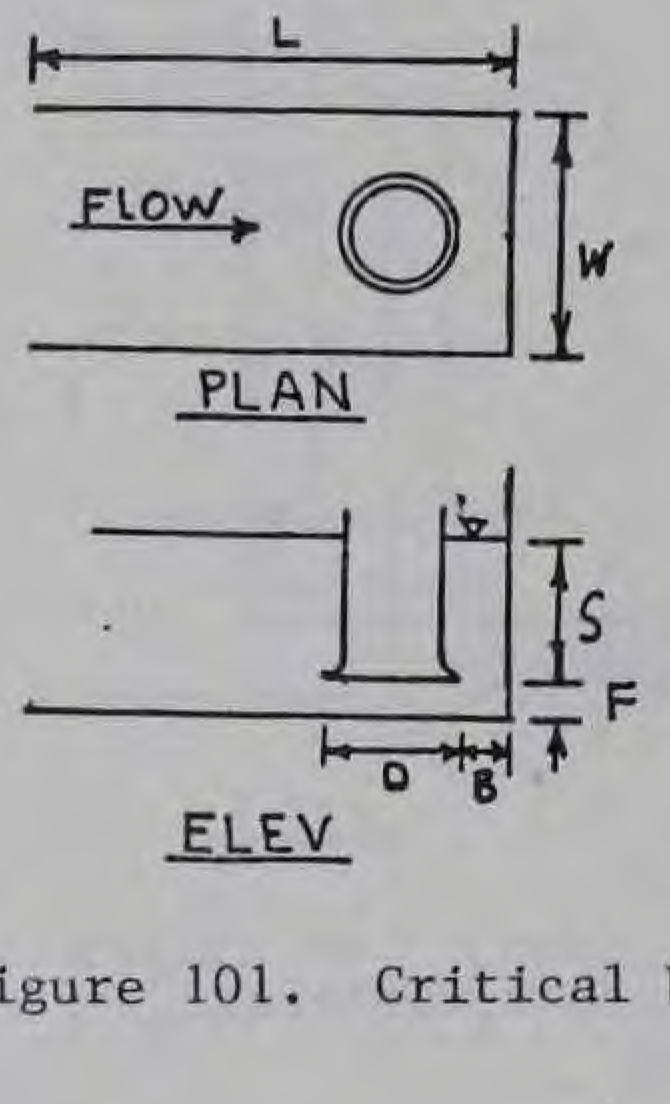


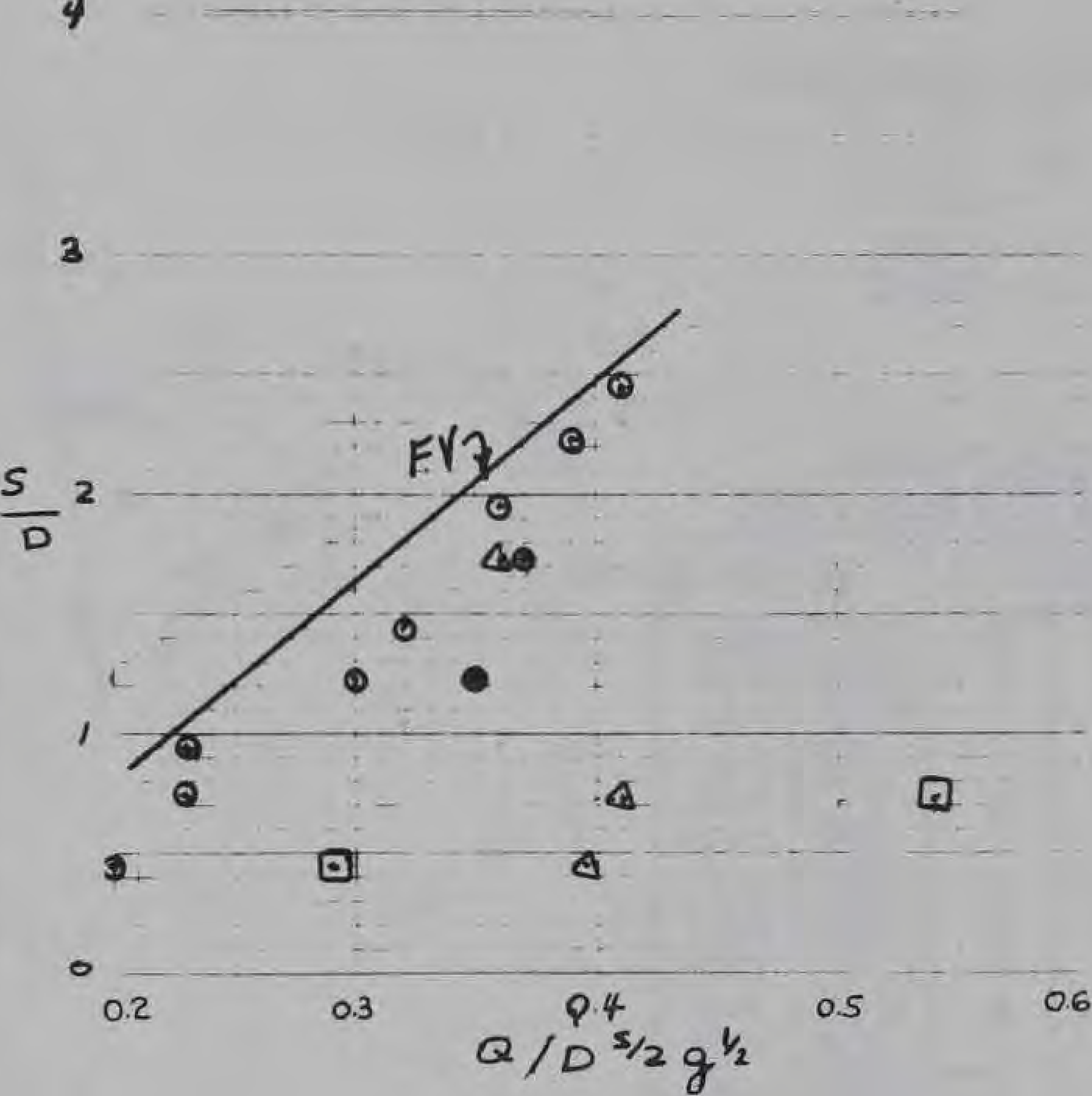
Figure 101. Critical bell submergence S , surface vortices, type 18 sump, type 17 appurtenance

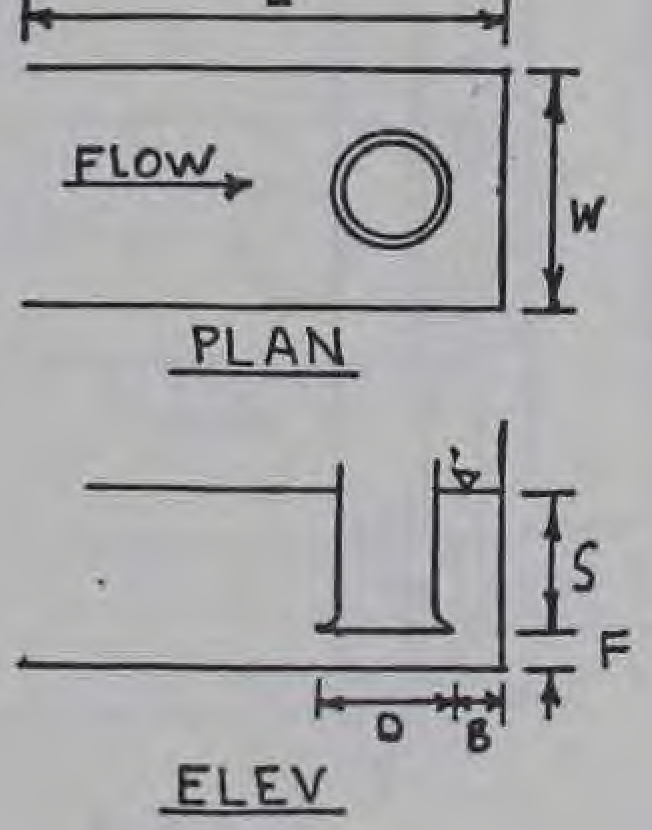
TEST CONDITIONS

D = 1.29 FT
B = 0.25 D
F = 0.50 D
W = 2.0 D
L = 19.0 D

BASIC DATA
MIXED FLOW PUMP

TYPE VORTEX	SYM.	S/D	$Q/D^{5/2}g^{1/2}$
FV	⊙	0.47	0.19
↓	↓	0.72	0.23
↓	↓	0.97	0.23
↓	↓	1.22	0.30
↓	↓	1.47	0.32
↓	↓	1.72	0.37
↓	↓	1.97	0.36
↓	↓	2.22	0.39
↓	↓	2.47	0.41
SWV	⊡	0.47	0.29
↓	↓	0.72	0.54
BWV	△	0.47	0.39
↓	↓	0.72	0.41
↓	↓	1.72	0.36
SV	●	1.22	0.35





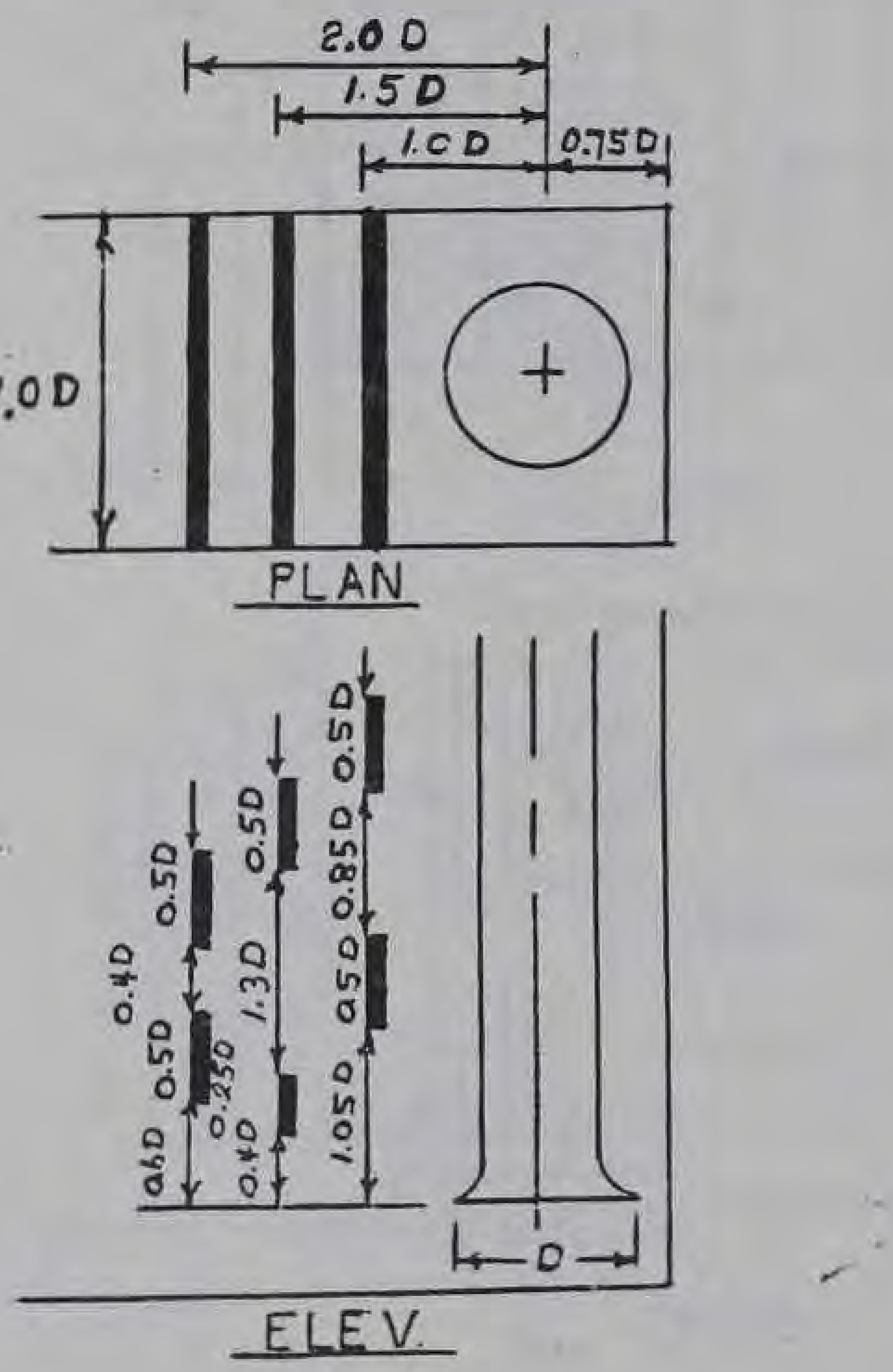
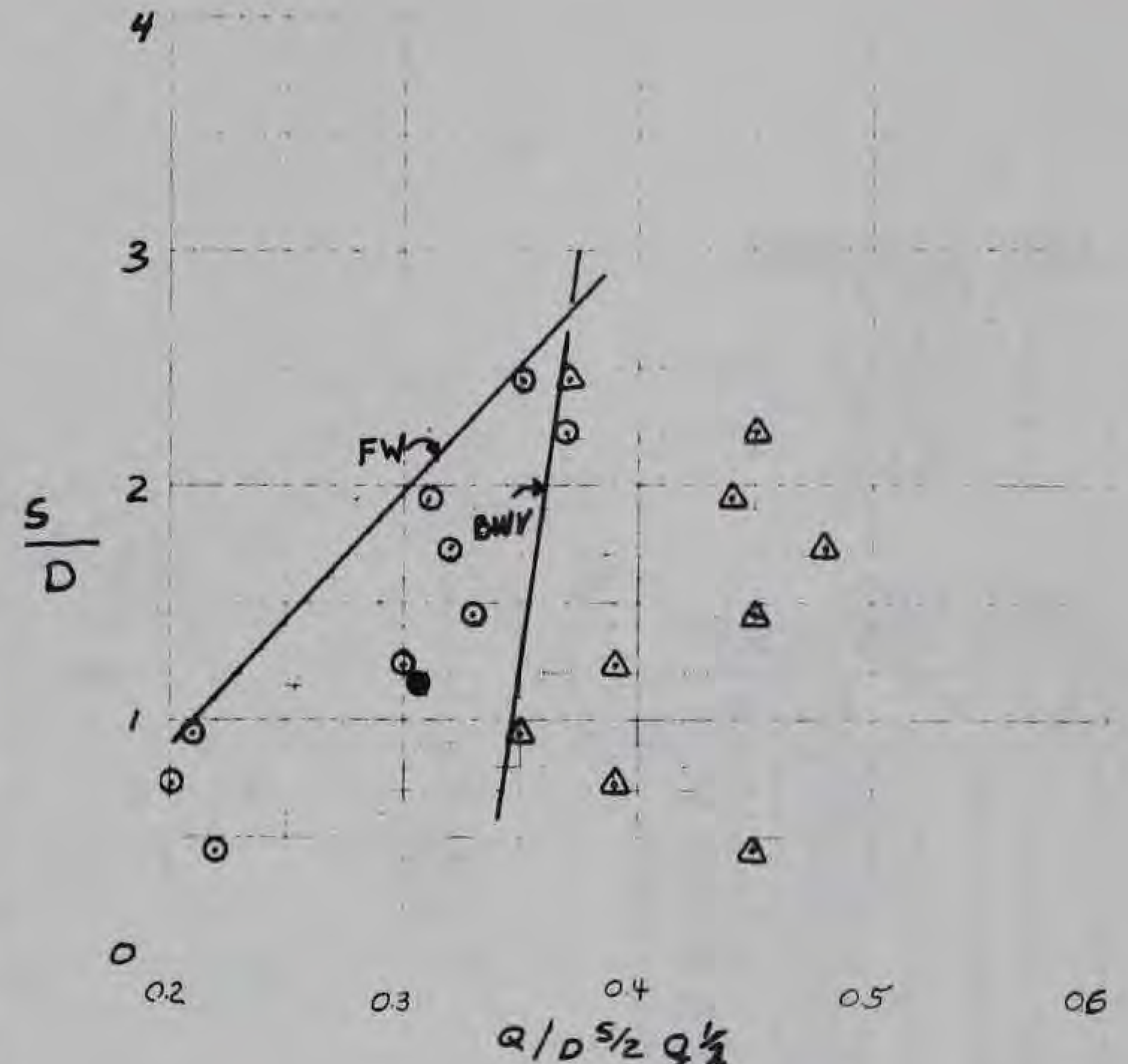


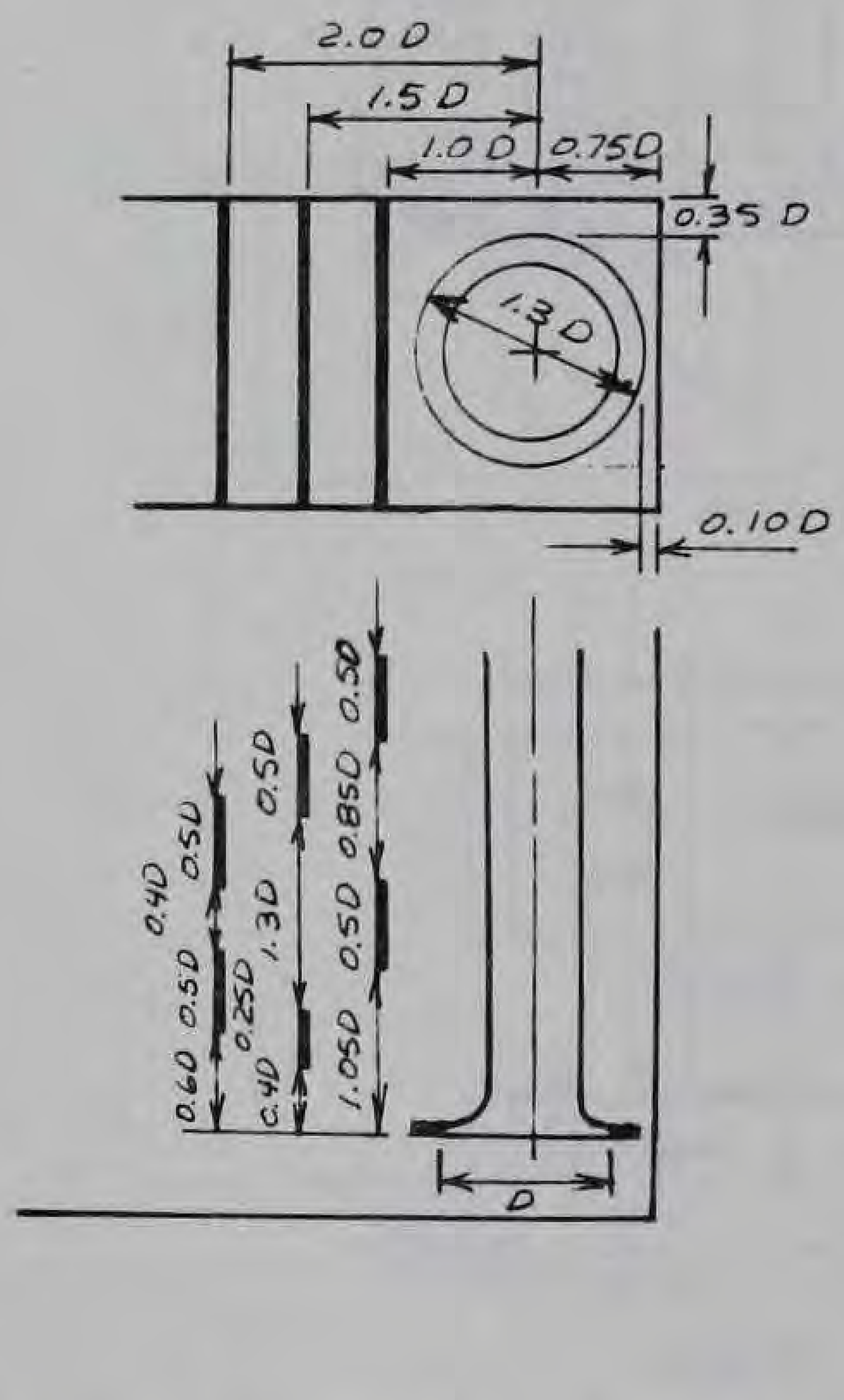
Figure 102. Critical bell submergence S, vortices, type 18 sump, type 56 surface vortex suppressor

TEST CONDITIONS
D = 1.29 FT
B = 0.10 D
F = 0.50 D
W = 2.0 D
L = 19.0 D

BASIC DATA
MIXED FLOW PUMP

TYPE VORTEX	SYM.	S/D	$Q/D^{5/2} g^{1/2}$
FV	⊙	0.47	0.22
		0.72	0.19
		0.97	0.21
		1.22	0.30
		1.47	0.33
		1.72	0.32
		1.97	0.31
		2.22	0.37
		2.47	0.38
BWV	△	0.47	0.45
		0.72	0.39
		0.97	0.35
		1.22	0.39
		1.47	0.45
		1.72	0.48
		1.97	0.44
		2.22	0.45
		2.47	0.37
SV	●	1.22	0.30





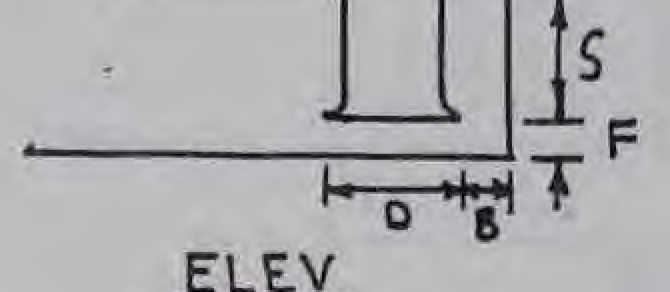


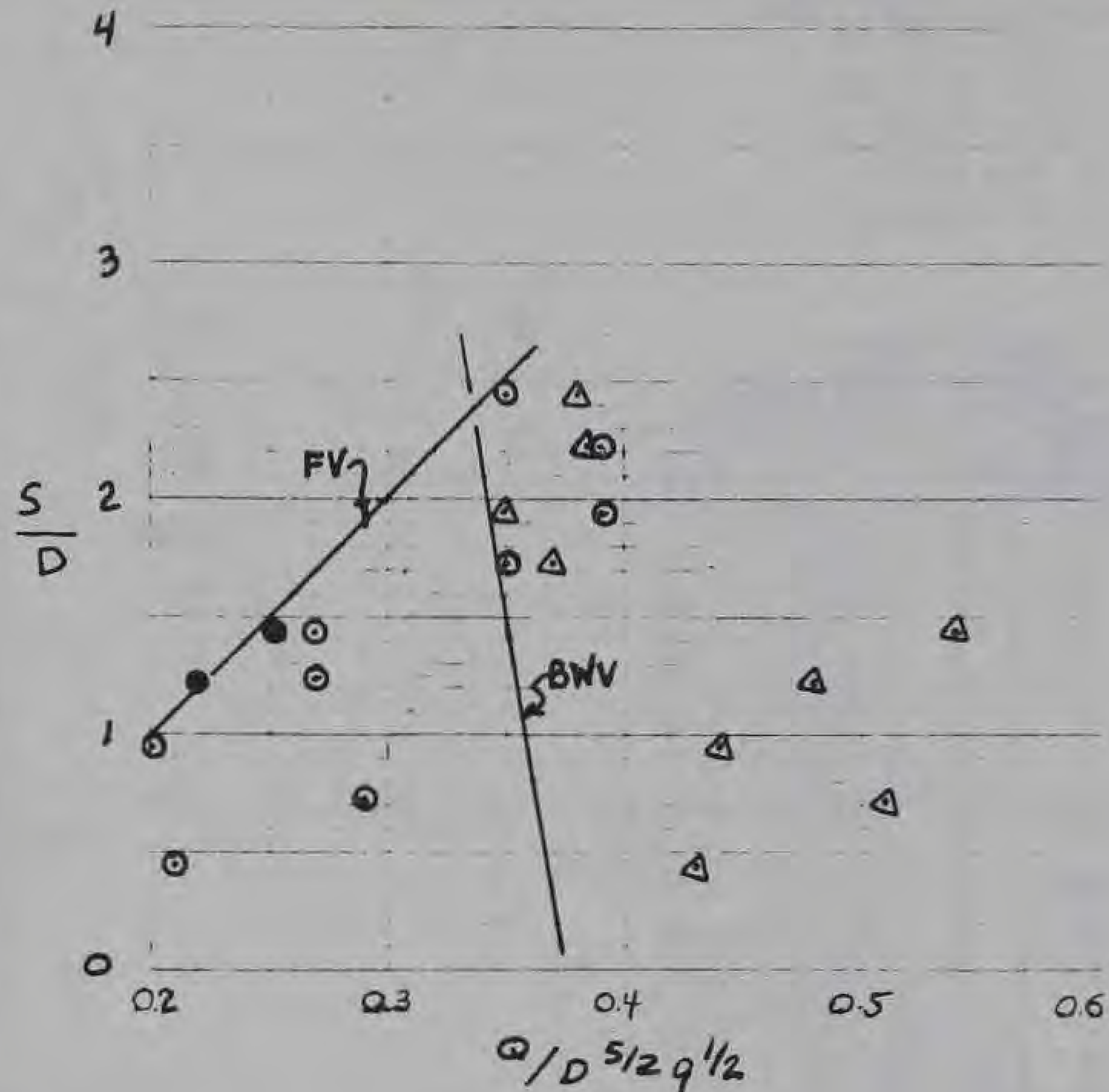
Figure 103. Critical bell submergence S, vortices, type 18 sump, type 56 surface vortex suppressor, type 15 appurtenance

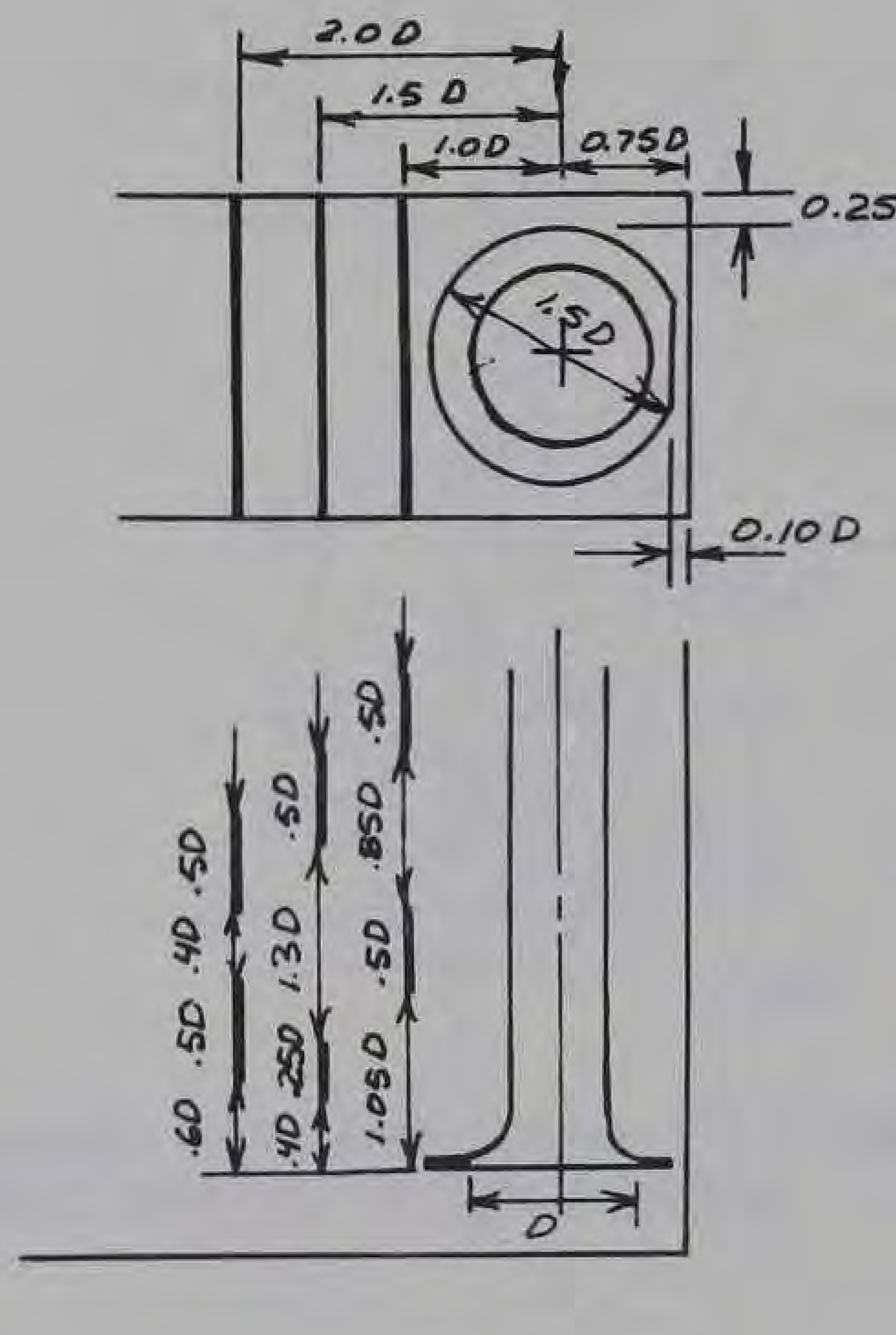
TEST CONDITIONS

D = 1.29 FT
B = 0.10 D
F = 0.50 D
W = 2.0 D
L = 1?.0 D

BASIC DATA
MIXED FLOW PUMP

TYPE VORTEX	SYM.	S/D	$Q/D^{5/2}g^{1/2}$
FV	⊙	0.47	0.21
		0.72	0.29
		0.97	0.19
		1.22	0.27
		1.47	0.27
		1.72	0.35
		1.97	0.39
		2.22	0.39
		2.47	0.35
BWV	△	0.47	0.43
		0.72	0.51
		0.97	0.44
		1.22	0.42
		1.47	0.54
		1.72	0.37
		1.97	0.35
		2.22	0.39
		2.47	0.38
SV	●	1.22	0.22
SV	●	1.47	0.25





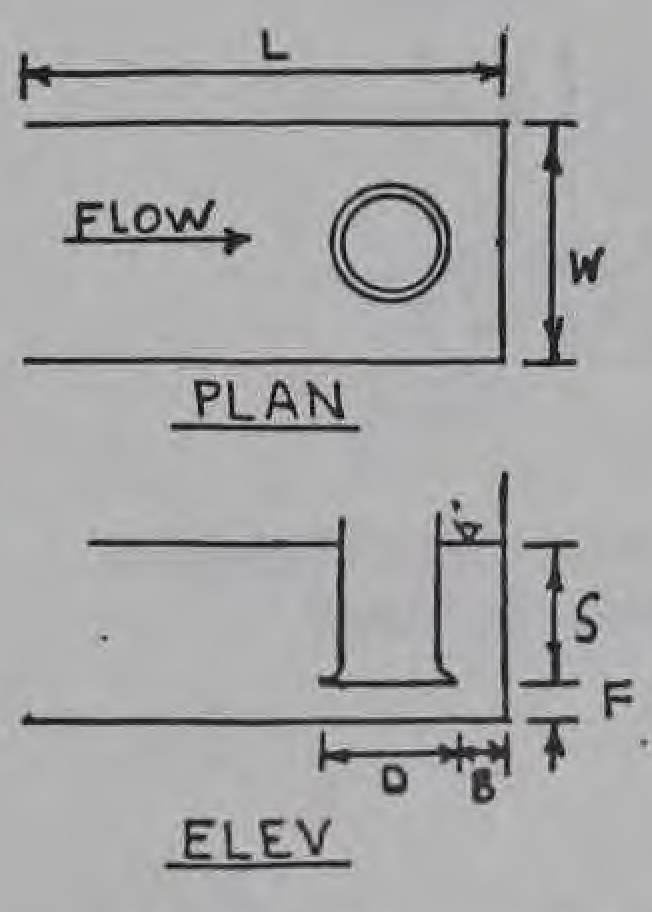
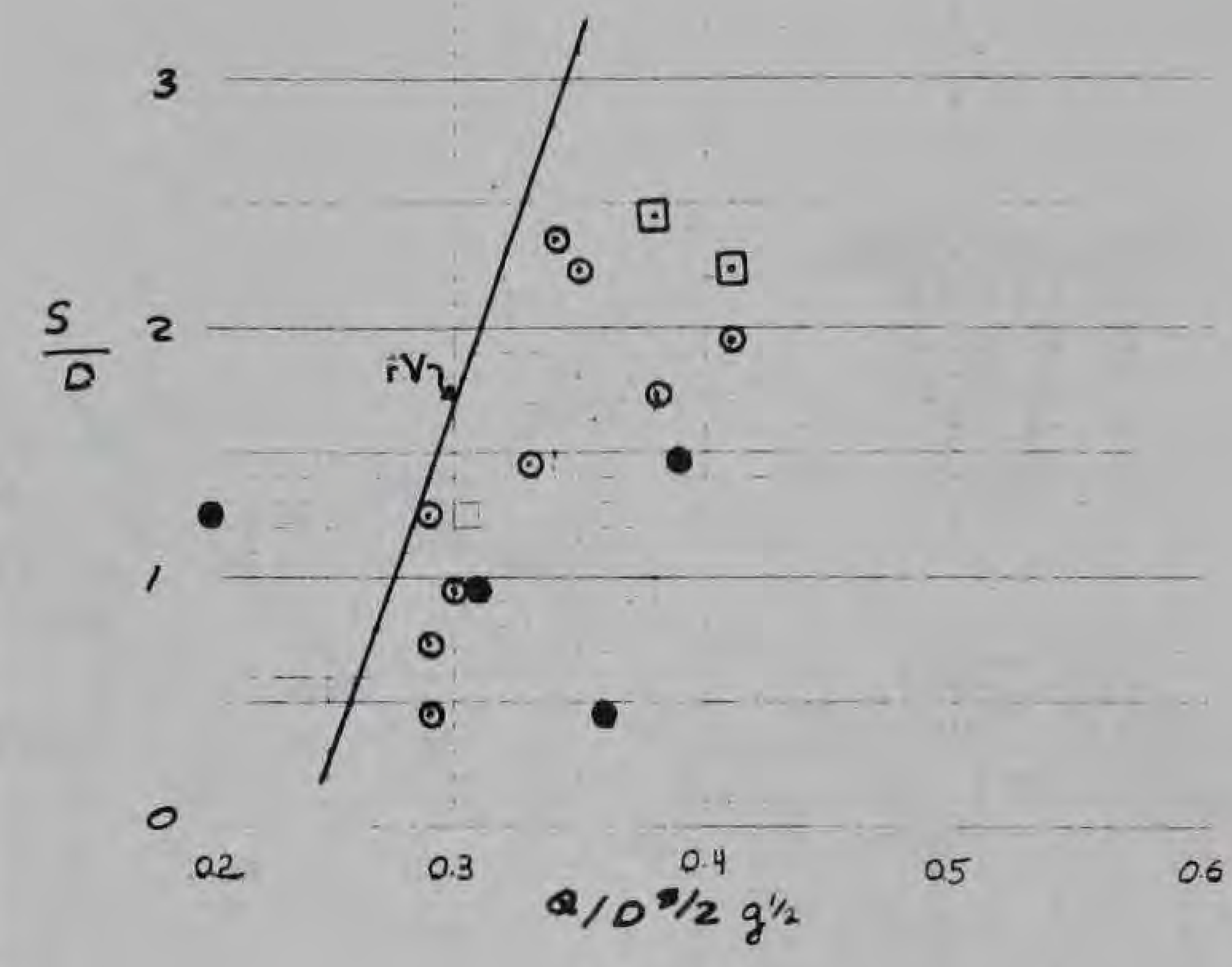


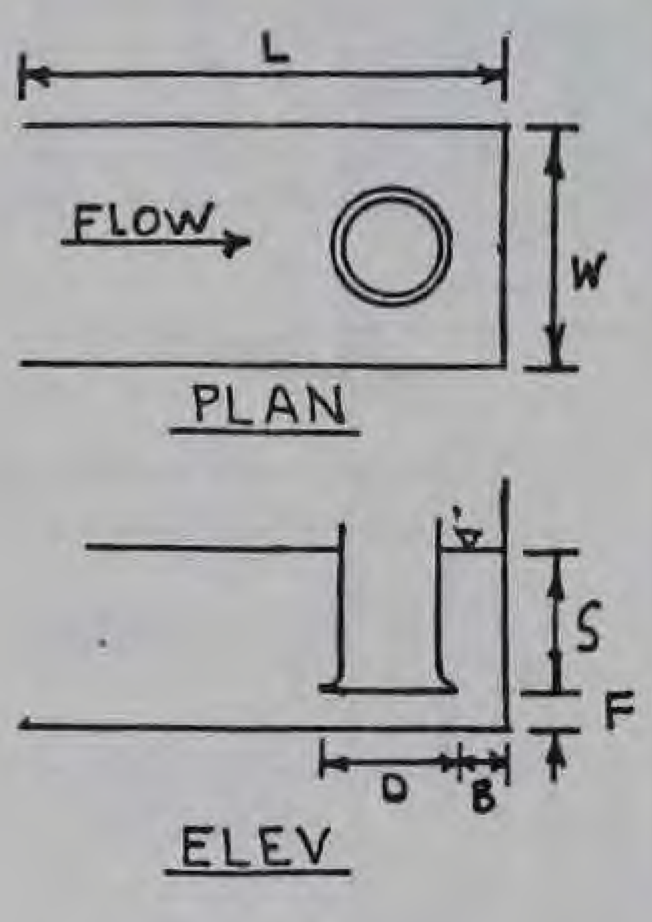
Figure 104. Critical bell submergence S , vortices, type 18 sump, type 56 surface vortex suppressor, type 15 appurtenance

TEST CONDITIONS
D= 1.29 FT
B= 0.10 D
F= 0.50 D
W= 2.0 D
L= 19.0 D

BASIC DATA
MIXED FLOW PUMP

TYPE VORTEX	SYM.	S_{bc}/D	$Q/D^{5/2}g^{1/2}$
FV	⊙	0.47	0.29
		0.72	0.29
		0.97	0.30
		1.22	0.29
		1.47	0.33
		1.72	0.38
		1.97	0.41
		2.22	0.35
		2.47	0.34
SWV	⊡	2.22	0.41
		2.47	0.38
SV	●	0.47	0.36
		0.97	0.31
		1.22	0.20
		1.47	0.39





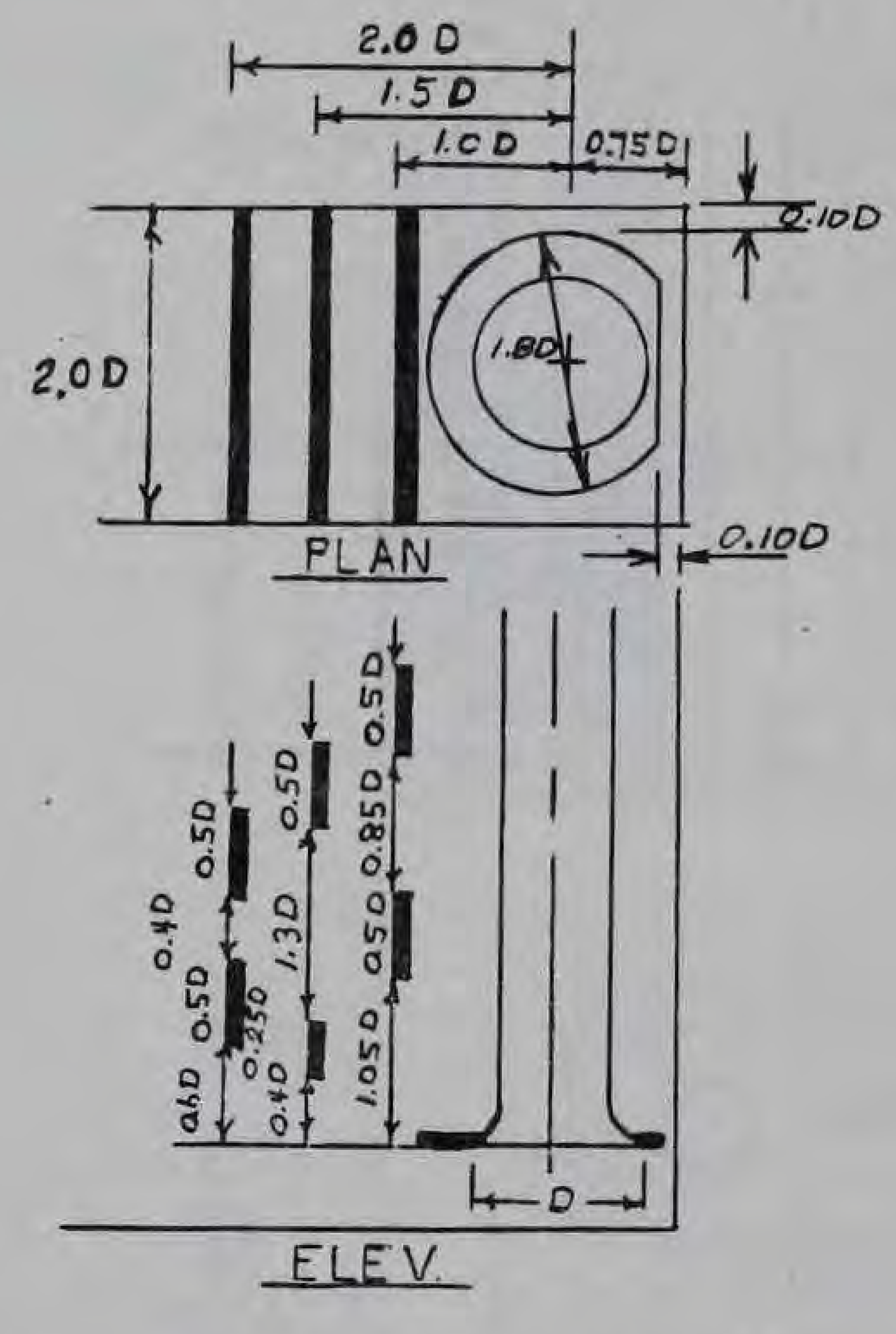
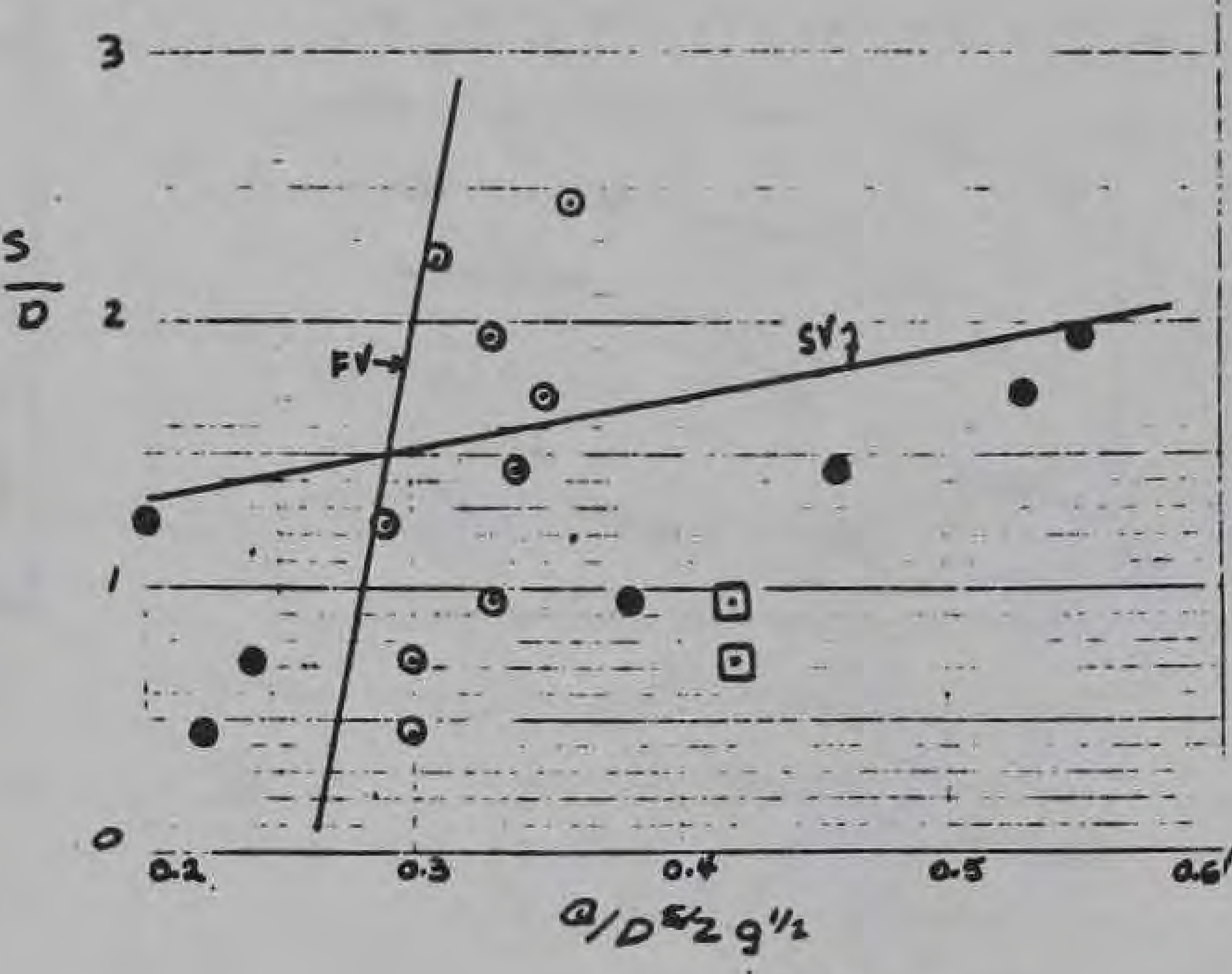


Figure 105. Critical bell submergence S , vortices, type 18 sump, type 56 surface vortex suppressor, type 16 appurtenance

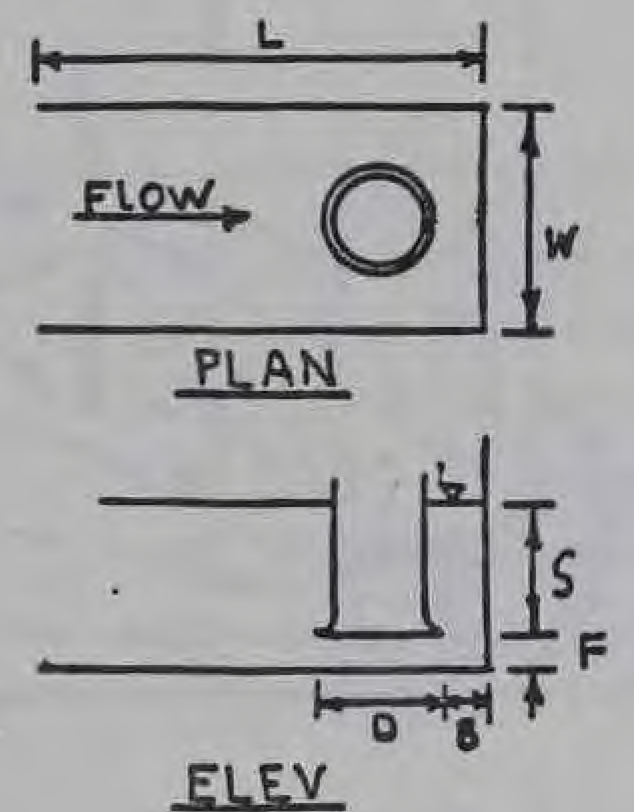
TEST CONDITIONS

D = 1.29 FT
B = 0.10 D
F = 0.50 D
W = 2.0 D
L = 19.0 D



BASIC DATA
MIXED FLOW PUMP

TYPE VORTEX	SYM.	S/D	$Q/D^{5/2}g^{1/2}$
FV	⊙	0.47	0.30
		0.72	0.30
		0.97	0.33
		1.22	0.29
		1.47	0.34
		1.72	0.35
		1.97	0.33
		2.22	0.31
		2.47	0.36
SWV	⊡	0.72	0.42
		0.97	0.42
SV	●	0.47	0.22
		0.72	0.24
		0.97	0.38
		1.22	0.26
		1.47	0.46
		1.72	0.53
		2.47	0.55



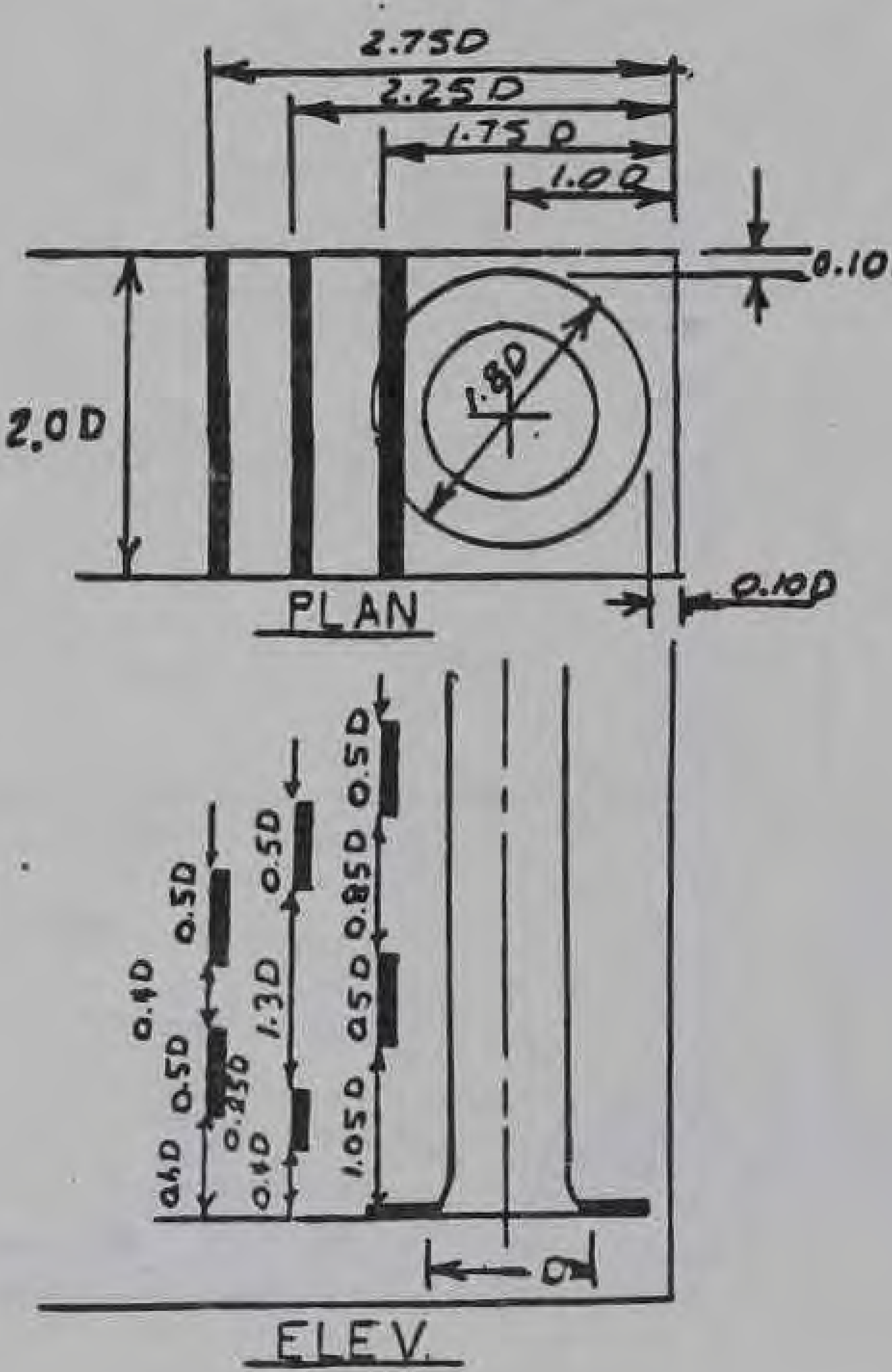
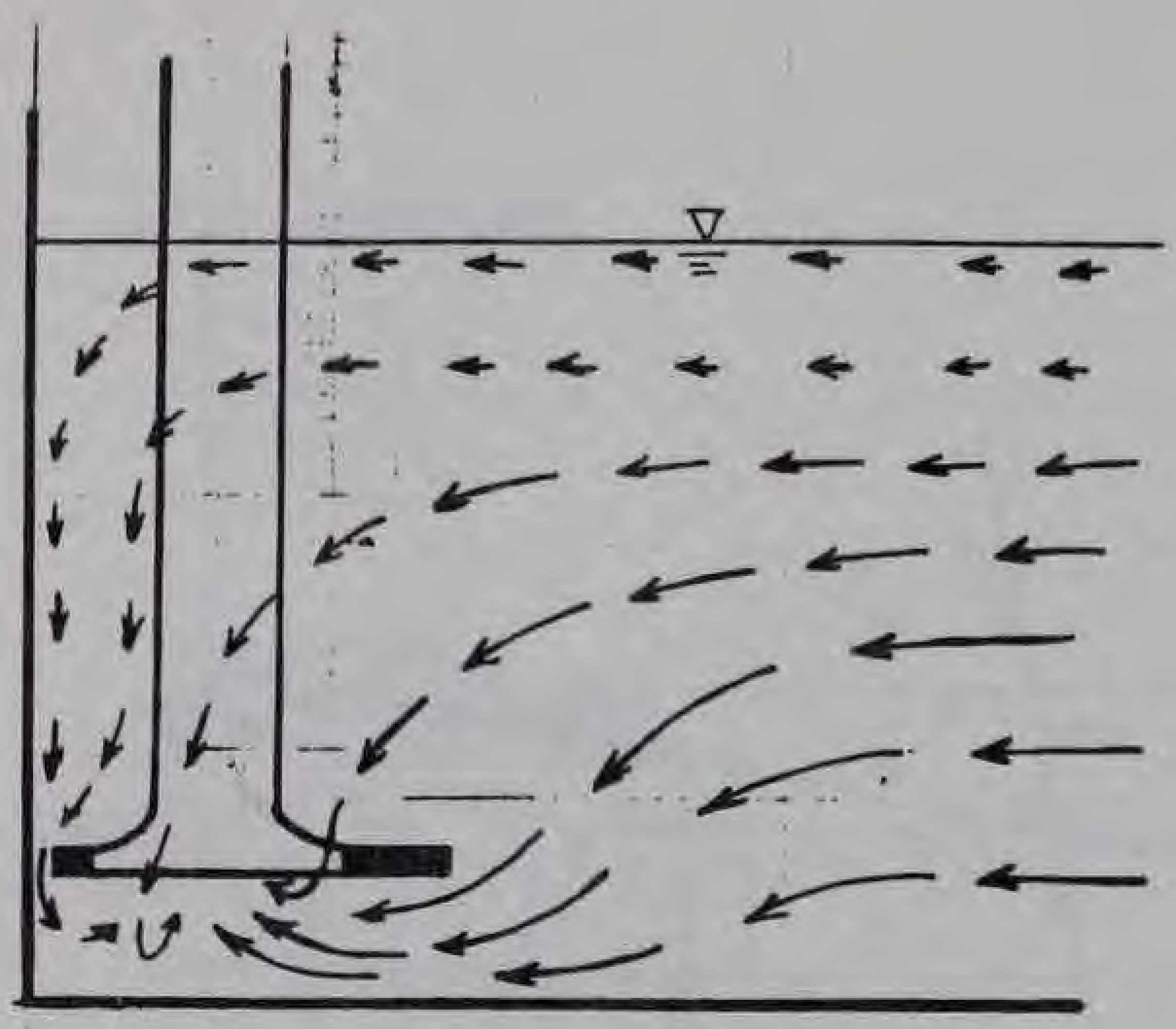
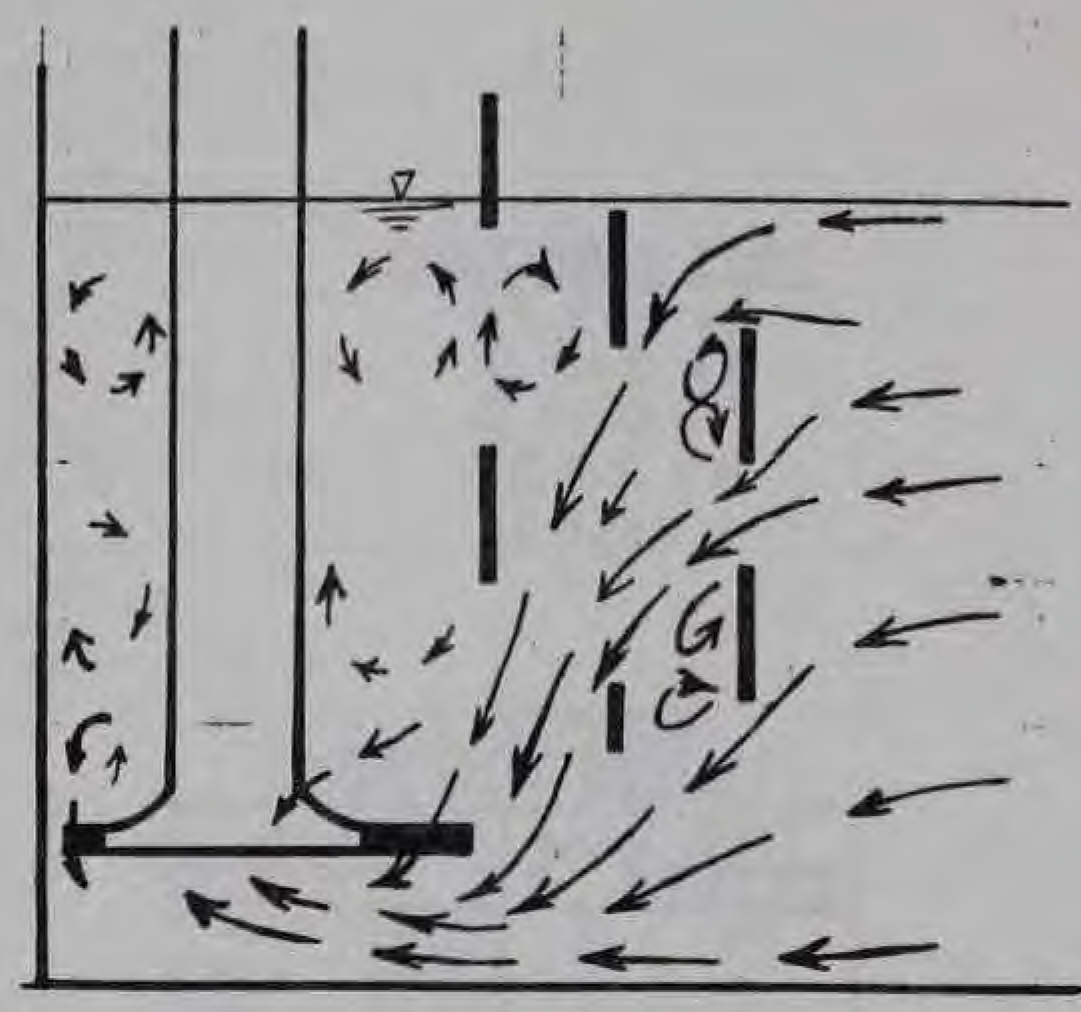


Figure 106. Critical bell submergence S , vortices, type 18 sump, type 56 surface vortex suppressor, type 17 appurtenance



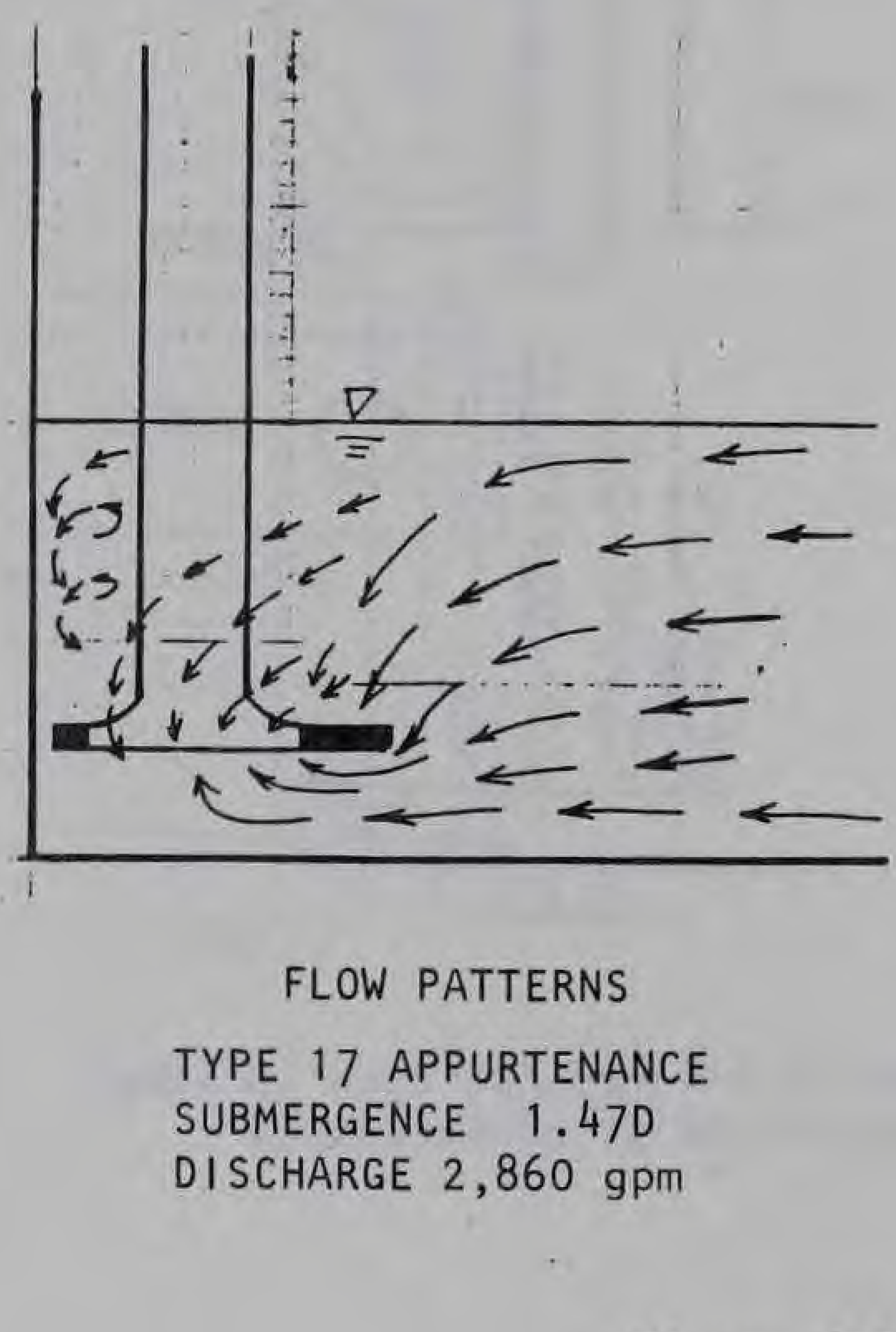
FLOW PATTERNS

TYPE 17 APPURTENANCE
SUBMERGENCE 2.47D
DISCHARGE 2,860 gpm



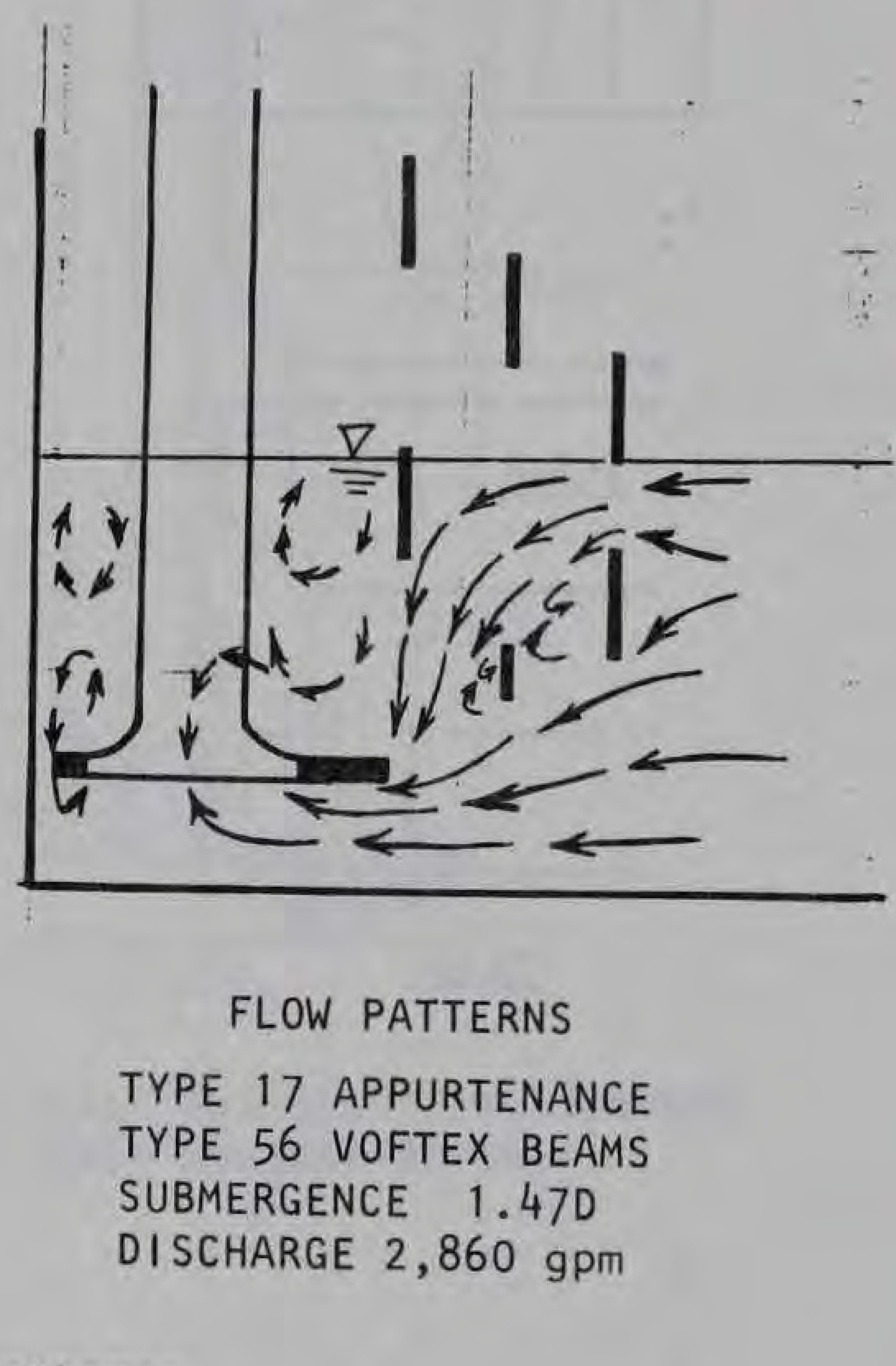
FLOW PATTERNS

TYPE 17 APPURTENANCE
TYPE 56 VORTEX BEAMS
SUBMERGENCE 2.47D
DISCHARGE 2,860 gpm



FLOW PATTERNS

TYPE 17 APPURTENANCE
SUBMERGENCE 1.47D
DISCHARGE 2,860 gpm



FLOW PATTERNS

TYPE 17 APPURTENANCE
TYPE 56 VOFTEX BEAMS
SUBMERGENCE 1.47D
DISCHARGE 2,860 gpm

Figure 107. Flow patterns

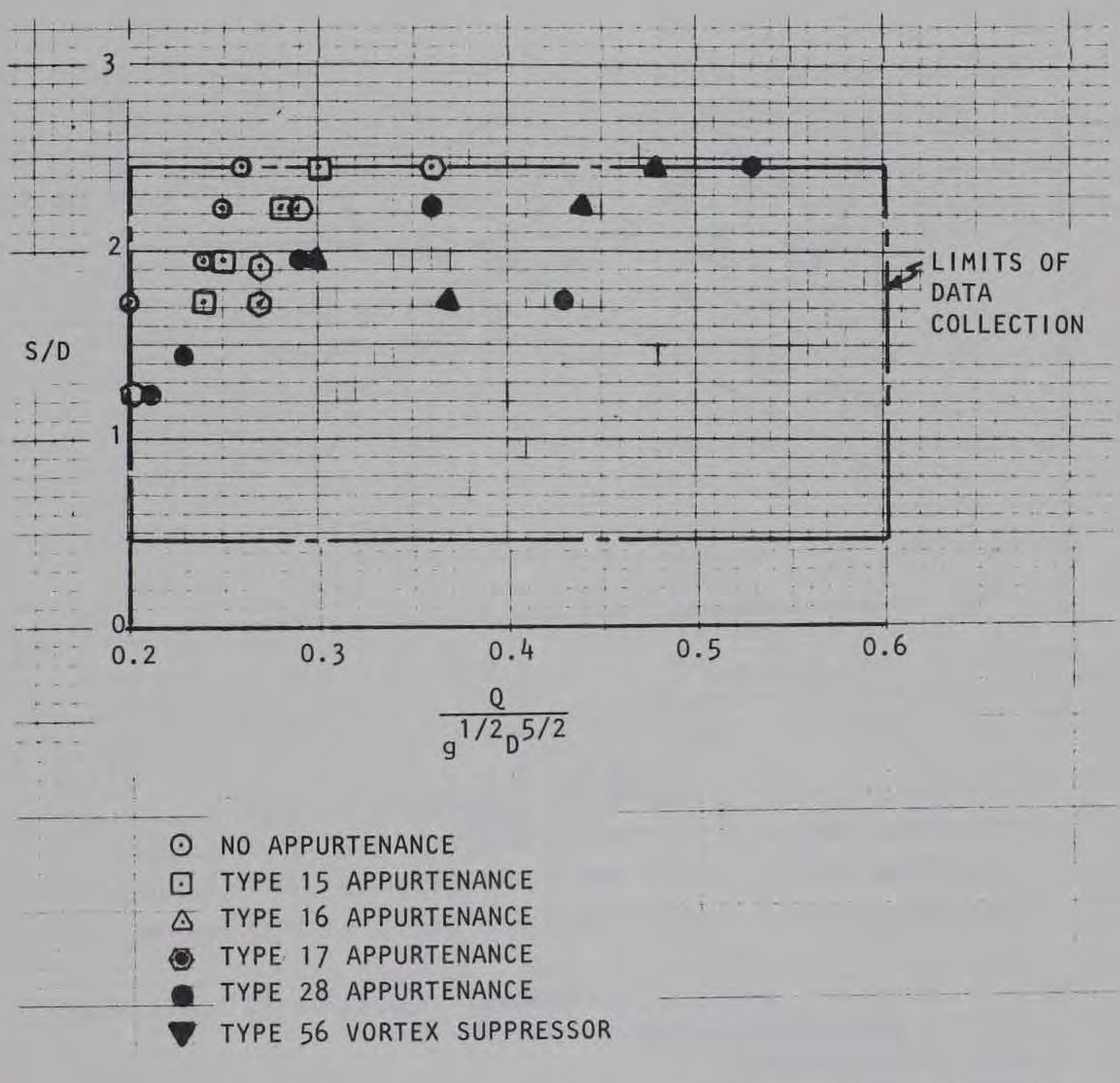
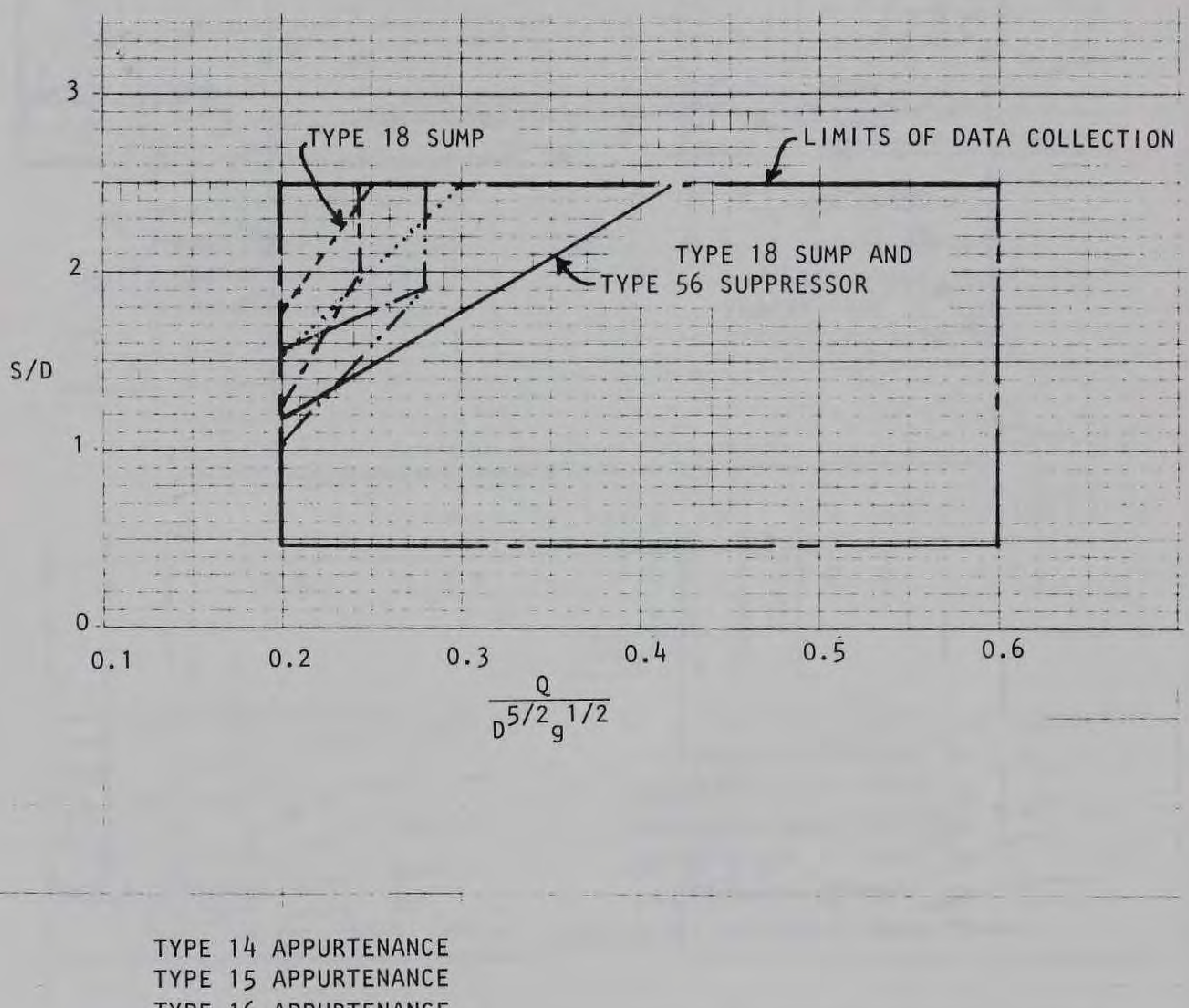


Figure 108. Critical bell submergence, surface vortices, type 18 sump



TYPE 14 APPURTENANCE
TYPE 15 APPURTENANCE
TYPE 16 APPURTENANCE
TYPE 17 APPURTENANCE

VORTEX-FREE SUMP TO LEFT OF LINES.

Figure 109. Critical bell submergence, vortex-free sump, type 18 sump

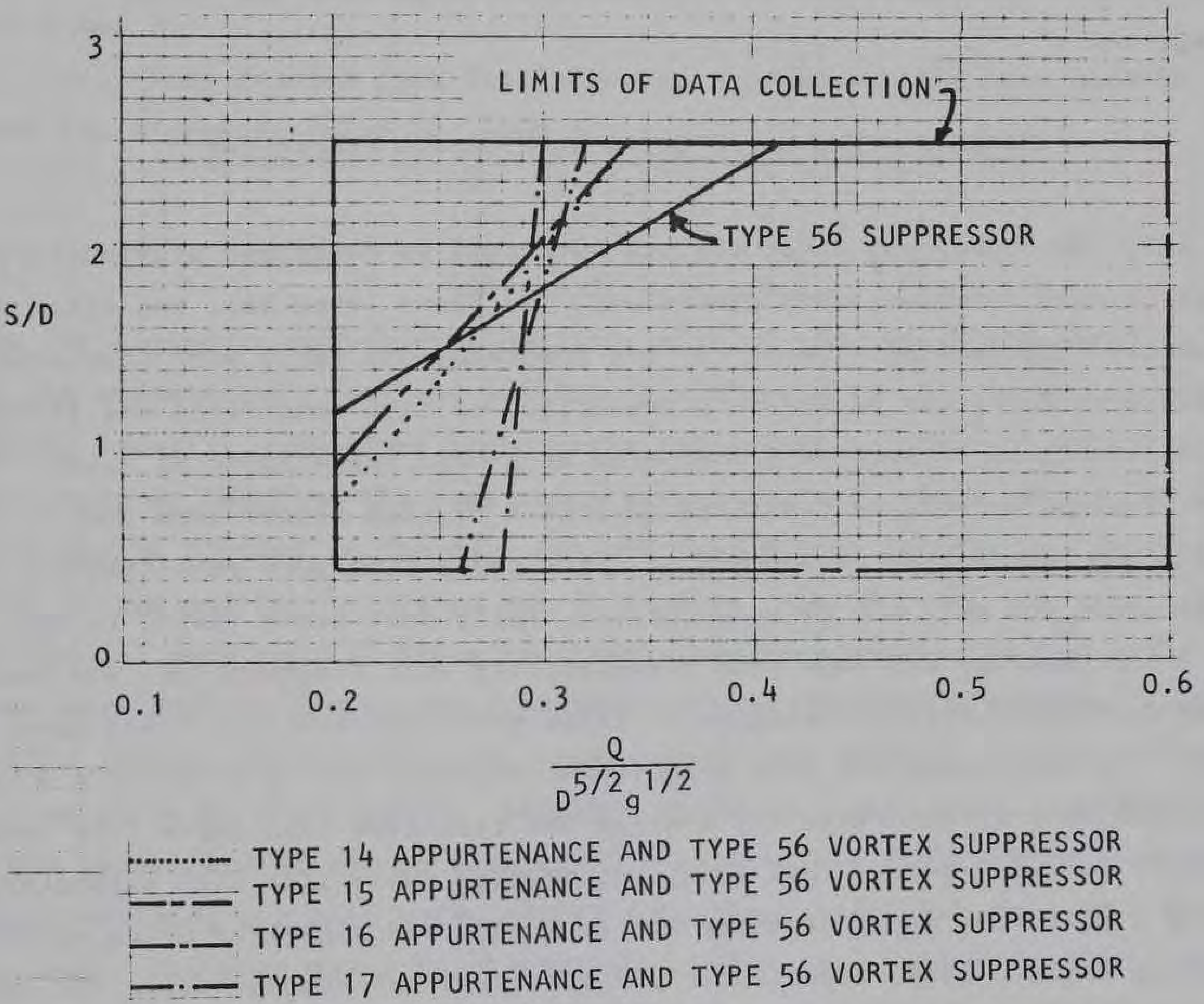


Figure 110. Critical bell submergence, submerged vortices with type 56 vortex suppressor

PART X: SIGNATURE CURVES

188. The purpose of obtaining pump performance signature curves for each of the Fairbanks Morse pumps is to establish a standard for evaluating the hydraulics of future sumps. The pump performance curves are developed for a base sump with evenly distributed approach flow, with optimum pump location, with SVS beams installed, and with a relatively high (for the Corps) submergence.

Signature Tests and Curve Development Procedures

189. The base sump (type 18) was developed as described previously with respect to pump location, sump dimensions, SVS beams (type 56), and other appurtenances (Figure 111). Three to five comprehensive tests were completed for each pump to obtain an accurate repetition of flow conditions and instrumentation. All base tests were completed at a bell submergence of 2.40D. The sump evaluation techniques described in Part V of this report were used to evaluate the base tests. A minimum of three tests with good repeatability was a requirement for each set of base curves. Early base tests (prior to the third test) that did not show good repeatability were disqualified, and testing was continued until the minimum of three good repeatability tests were obtained. The base tests for each pump (three minimum) were plotted on a single sheet (overlaid) to determine the average one resultant base curve (for each parameter) for each pump. This resultant average curve (for each parameter) was then traced to a separate sheet for each pump and digitized using an Altec digitizing table. These coordinates for the resultant average curve for each pump (and each parameter) were typed into the microcomputer, recorded on cassette, and became the signature curves for each pump for subsequent comparisons with adverse sumps. The base sump as referred to in this report is that sump configuration which was used to develop the signature curves. After development of the signature curves, then terminology for base curves and signature curves is used interchangeably to mean those curves which represent the pump performance parameters for the base sump.

Pump 1 Signature Curves

190. Pump performance curves provide a quick visual comparison of a base sump to any future sump tested. Other tools and methods provide a deeper and more exact comparison of sumps. A thorough discussion is made of these tools and methods for pump 1; then brief references are made of them for pumps 2 and 3.

191. Test results from the following four base tests were used to derive the signature curve for pump 1:

100 - J-94 - 18 - 3.1
100 - J-95 - 18 - 3.1
100 - J-96 - 18 - 3.1
100 - J-97 - 18 - 3.1

After the signature curves were derived, each of the base tests (used to derive the signature curves) was plotted on a sheet with the signature curves (Figures 112-115). The base tests coordinates were recorded on magnetic cassette tapes at the time the base tests were performed. Data points for the curves may be plotted as the data are obtained during testing or the entire set of curves may be plotted at any later date from the data cassette. Figures 112-115 were plotted after the tests were completed since the tests themselves were used to derive the signature curves. Signature curves are shown as solid lines, and the individual base curves are shown as dotted or dashed lines as given by the legends. Standard deviation, rms, mean, maximum, and minimum values are stored on cassette for each of the eight gages (discharge, torque, voltage, current, noise, vibration, head, and floor pressure) read for each pump. The mean value is plotted for discharge, shaft horsepower, and head; the rms value is plotted for noise; and maximum is plotted for vibration (velocity).

Statistical comparisons

192. Statistical tables provide a quantitative comparison of any curve to the signature curve. The microcomputer calculates the area between the signature curve and the comparison curve for an arbitrarily selected discharge range from 1,500 to 2,500 gpm. This range was selected as the discharge corresponding to a likely operating head range of 16 to 29 ft (see H versus Q curve). The statistical comparisons are shown in Figures 116-119 for Tests J-94 through J-97, respectively. These comparisons made between the signature and the individual base test curves (used to derive the signature

curve) provide an indication of the allowable margin of the system.

193. Vibration (velocity). The vibration varies from a maximum area of 5.2847 ips × gpm above the signature (J-94) curve to a maximum area of 12.8324 ips × gpm below the signature curve (J-97) (Figures 116 and 119, respectively). This indicates an allowable system margin for vibration of ±13 ips × gpm. For individual interest, the maximum and minimum vibration values are also given in this table with respect to the discharge. The maximum values of all four base tests were less than 0.14 ips in the specified discharge range (1,500 to 2,500 gpm). The maximum values for all four base tests occurred at 1,500 gpm. This is largely due to the cavitation that tends to increase as the head pressure increases. The minimum vibration occurred between 1,660 and 2,000 gpm for the four base tests for pump 1. This range is at maximum efficiency and toward higher head pressure.

194. Total head. The area above the signature curve in the discharge range of 1,500 to 2,500 gpm for the four base tests varied from 0 to 148.37 ft × gpm. The area below the signature curve for the same four base tests for the same discharge range varied from 8.72 to 375.28 ft × gpm. This indicates an allowable system margin of approximately ±400 ft × gpm. The maximum total head for the designated discharge range for the base tests for pump 1 varied from 27.9 to 28.4 ft, and all occurred at the lower discharge limit of 1,500 gpm. The corresponding minimum head varied from 15.3799 to 16.1816 ft and occurred at the upper discharge limit of 2,500 gpm.

195. Noise. The area above the signature curve for pump 1 noise for the designated discharge range (1,500 to 2,500 gpm) for the base curves varied from 0 to 4.1×10^4 psi × gpm. The corresponding area below the signature curve varied from 14.7×10^4 to 42.3×10^4 psi × gpm. This indicates an allowable pump 1 system noise margin of approximately $\pm 45 \times 10^4$ psi × gpm. The maximum noise for the pump 1 base tests for the designated discharge range varied from 0.538 to 0.576×10^{-4} psi, and all occurred at the lower discharge limit (1,500 gpm) where cavitation begins. The minimum noise level (for the same base tests and discharge range) varied from 0.432×10^{-4} to 0.448×10^{-4} ft and occurred at discharges of 1,880 to 2,250 gpm. This is near the peak and to the right of maximum efficiency.

196. Shaft horsepower. The area above the shaft horsepower signature curve (but below the four base curves) for pump 1 varied from 0 to 53.954 hp × gpm. The corresponding area below the signature curve (from Figures 116-119)

varied from 71.4 hp × gpm to 0 hp × gpm. This would indicate a pump 1 horsepower system allowable margin of approximately ±75 hp × gpm. The maximum horsepower varied from 14.6834 to 14.8091 hp and occurred between 1,710 and 1,880 gpm. This is just left of the maximum efficiency zone. The minimum horsepower varied from 13.5687 to 13.7736 hp--all occurred at the upper discharge limit where the horsepower continues to drop as the head is decreased.

197. Efficiency. The area above the signature curve varied from 0 to 865.94 percent × gpm for the four base tests. The area below the signature curve varied from 0 to 1,160.54 percent × gpm. This indicates an allowable system margin of ±1,160 percent × gpm for pump 1 efficiency. The maximum efficiency range for the four base tests was from 79.3983 to 81.4386 percent and occurred in the discharge range of 1,970 to 2,040 gpm, which is near the optimum operating range for this pump. The minimum efficiency range for the four base tests was 71.2032-73.5902 percent. One of the low efficiency points occurred at the low discharge (1,500 gpm) limit (high head) and the other three minimum efficiency points were at the upper discharge (2,500 gpm) limit (low head).

Research data

198. The pump 1 research data tabulations (Figures 120-123) include both raw data and calculated data for the four pump 1 base tests. The raw data were collected simultaneously from all gages at each reading. The research data sheets list five lines of data at each reading; each of these lines of data is the result of 500 random data samples. The reasons for the high random sampling rate are explained in Part IV of this report. Details of the calculated data methods are given in Part V of this report. Correlations may be made between readings of the research data figures and the statistical comparison figures to obtain more exace evaluations of sumps.

Pump flow pattern

199. Figure 124 shows the flow pattern for the pump 1 base sump. The flow pattern is for the dimensionless discharge ratio $Q/g^{1/2}D^{5/2}$ of 0.4. The pattern does vary with a change in the value of the ratio; however, this value was selected as a typical value for comparison with future sumps. This flow pattern alone is interesting, but its true value will become more apparent when it is compared with future sump patterns at the same discharge ratio.

Visual observation notes

200. The visual observation notes for two of the pump 1 base tests are

shown in Figures 125 and 126. These notes were not recorded on all four of the tests because the results were so nearly identical. This is understandable since the operating conditions were as nearly identical as could be controlled.

201. A review of the visual notes for Test J-97 will show some of its value for sump comparisons (Figure 126). The test was begun on 8 July 1982 at hour 0800. The temperature of the water was 79° F and the air temperature was 75° F. The barometric pressure was 29.92 in. Hg. At reading 1, pump 1 was operating at full discharge--approximately 2,870 gpm (Figure 123). Intermittent FV and intermittent BWV were visible. The intermittent BWV had disappeared at reading 3 (approximately 2,395 gpm), and the intermittent FV were gone at reading 7 (approximately 1,895 gpm). The test was completed at 1000 hours (Figure 126). The air temperature was 84° F, the water temperature was 80° F, and the barometric pressure was 29.93 in. Hg. See Figure 126 for more details of visual observation notes. The reading numbers may be correlated with the discharge values in the research data (Figure 123) to obtain numerical values of corresponding parameters.

202. The indicated allowable system margins for sump 1 (between 1,500 and 2,500 gpm) judging from all four base tests are as follows:

Vibration (velocity)	±13 ips × gpm
Total head	±160 ft × gpm
Pump noise	$\pm 42 \times 10^{-4}$ psi × gpm
Shaft horsepower	±72 hp × gpm
Pump efficiency	±1,160 percent × gpm

A visual knowledge of these values is obvious from Figure 127 where all four base tests are plotted on the same sheet along with the resultant signature curve.

Pump 2 Signature Curves

203. The following base tests were used to derive the signature curves for pump 2:

020 - J-98 - 18 - 3.1

020 - J-99 - 18 - 3.1

020 - K-06 - 18 - 3.1

The graphic comparison of each of these tests with the newly developed signature curves is shown by Figures 128-130, respectively. The quantitative differences between each of the base curves and the signature curve for pump 2 are shown in Figures 131-133, respectively. The base curve for all three of the base tests are plotted on a single sheet (Figure 134) along with the pump 2 signature curves. This provides a relative idea of the allowable system margin for pump 2. These quantitative values are as follows:

Vibration (velocity)	±6 ips × gpm
Total head	±125 ft × gpm
Pump noise	$\pm 92 \times 10^{-4}$ psi × gpm
Shaft horsepower	±50 hp × gpm
Pump efficiency	±790 percent × gpm

The research data tabulations for pump 2 are shown in Figures 135-137. The sump 2 flow pattern and the visual observation notes are shown in Figures 138 and 139, respectively. The visual observation notes were recorded only for Test J-99 (Figure 139) because the observations were almost identical as were the operating conditions for each of the two base tests.

Pump 3 Signature Curves

204. The following base tests were used to derive the signature curves for pump 3:

003 - K-03 - 18 - 3.1

003 - K-04 - 18 - 3.1

003 - K-05 - 18 - 3.1

Comparison of each base test curve with the signature curve is shown in Figures 140-142, where the signature curves are shown by solid lines alongside the base test curves (shown by dashed lines). The statistical comparisons, for the discharge range from 1,500 to 2,500 gpm, are shown by Figures 143-145. An approximation of the allowable system margins can be seen from these by selecting the maximum deviations of areas above and below the signature curve as follows:

Vibration (velocity)	±7 ips × gpm
Total head	±160 ft × gpm
Pump noise	$\pm 105 \times 10^{-4}$ psi × gpm
Shaft horsepower	±24 hp × gpm
Pump efficiency	±494 percent × gpm

These differences may be more easily visualized from Figure 146 which has all three base tests superimposed on the same sheet alongside the signature curves. The research data tabulations are shown in Figures 147-149. The pump 3 flow pattern is shown in Figure 150 and the visual observation notes in Figure 151. The notes and flow pattern were only recorded for one of the base tests since the operating conditions of all three of the pump 3 base tests were identical or as nearly as could be controlled.

System Allowable Margins

205. The amount of the base curve deviation from the signature curves has been tabulated for each of the pumps in the preceding paragraphs. This deviation represents the maximum areas between the base tests and the signature curve. The maximum area deviation above or below the signature curve is then designated plus or minus--allowing that a maximum deviation, if base testing continued, could occur alternately above and below the signature curves. For future test curve comparisons, it would not be expected that a sump could be classified adverse on the basis of the signature curve comparison alone if an area deviation of its corresponding signature curve was less than that for any of the corresponding base curve comparisons. For that reason, the following system allowable margin guidelines are extractions of the maximum area deviations considering the whole of the 10 base test comparisons for all three pumps:

Vibration (velocity)	±13 ips × gpm
Total head	±160 ft × gpm
Pump noise	$\pm 105 \times 10^{-4}$ psi × gpm
Shaft horsepower	±72 hp × gpm
Pump efficiency	±1,160 percent × gpm

These data values alone are not firm criteria for rejection of a particular sump as a bad sump, but do provide some guidelines to be used with the other tools discussed in this section: visual observation notes, sump flow patterns, research data, and the curves themselves.

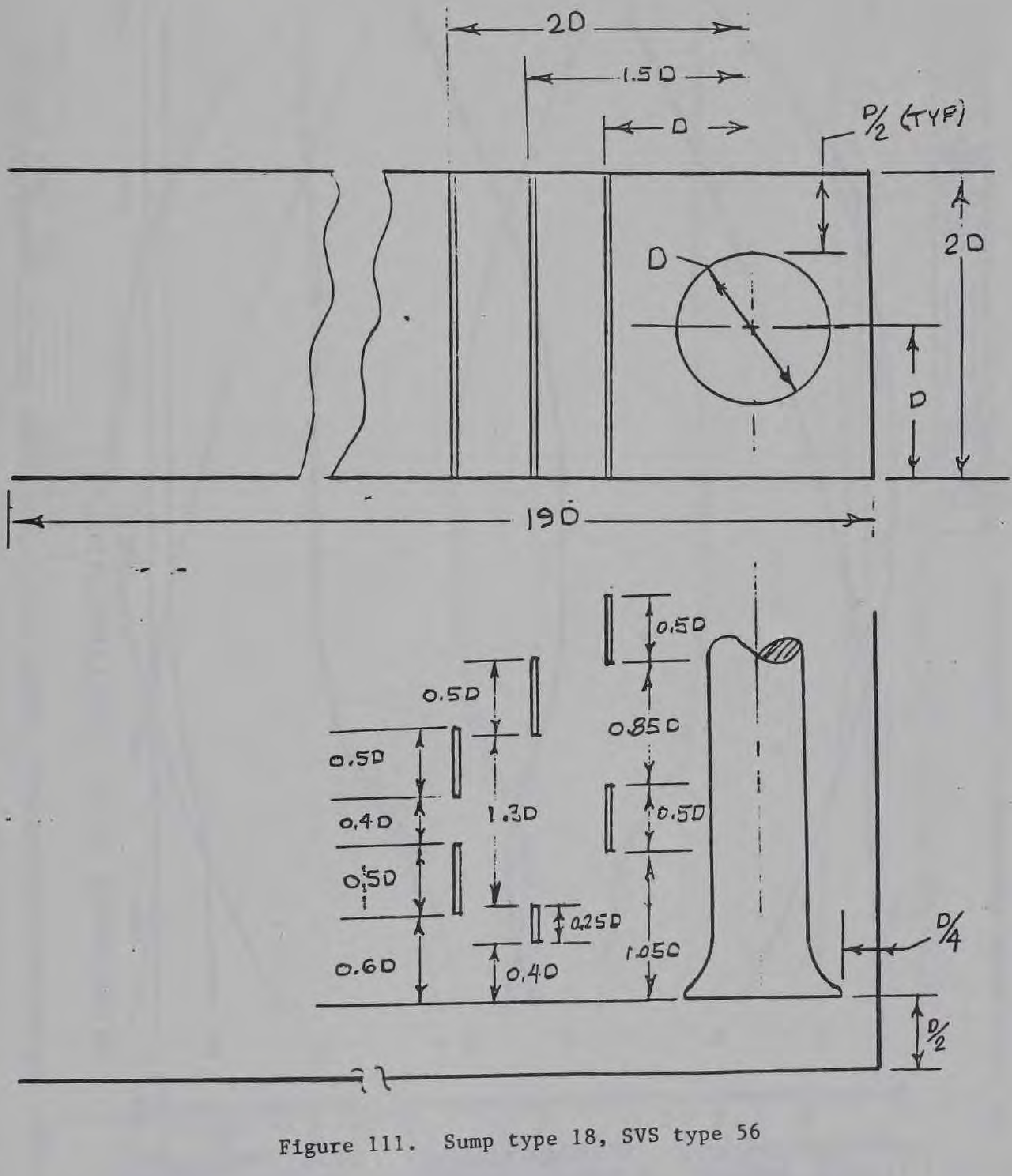


Figure 111. Sump type 18, SVS type 56

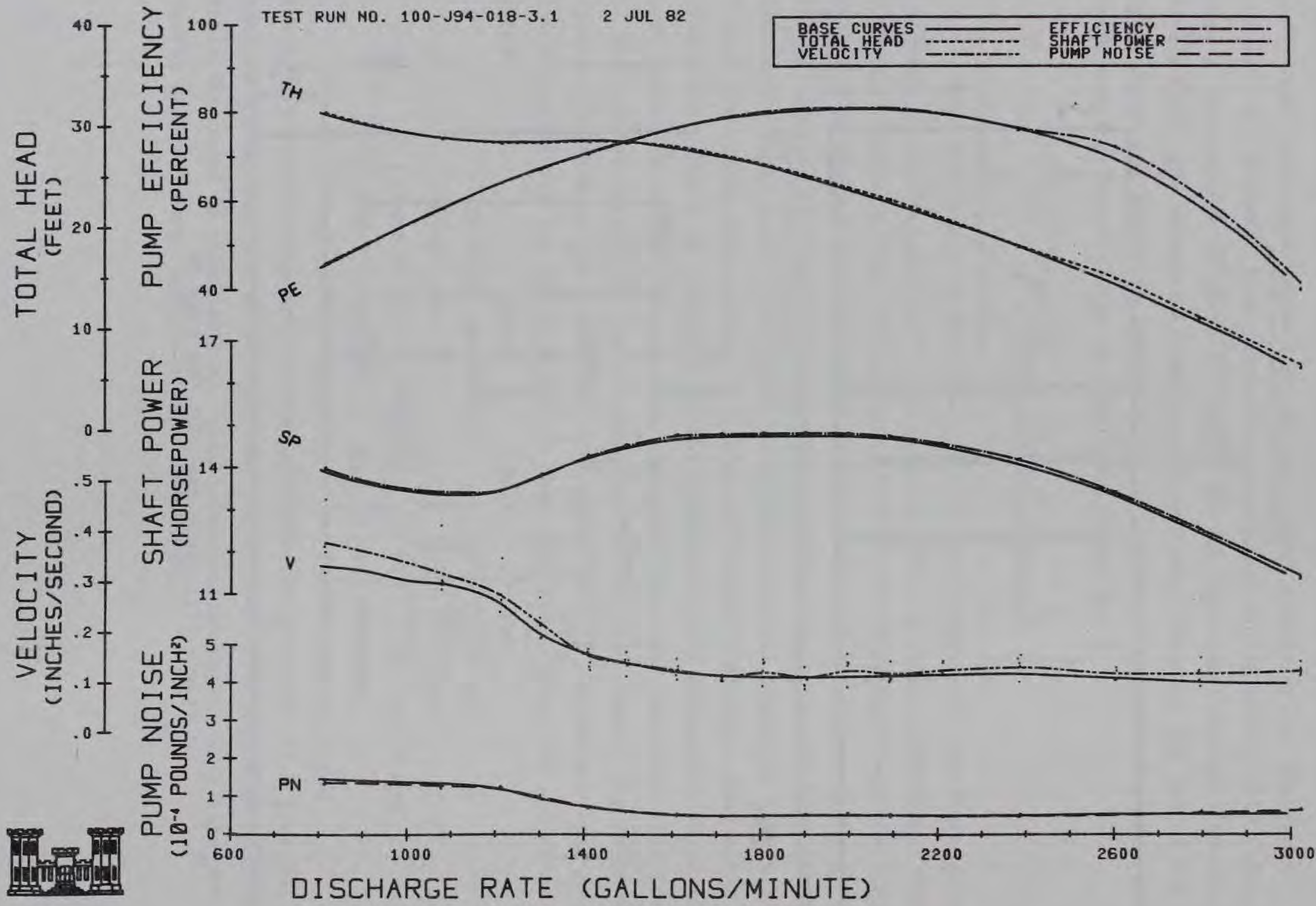


Figure 112. Performance characteristic curves; pump 1, Test J-94, sump 18, submergence 3.1 ft

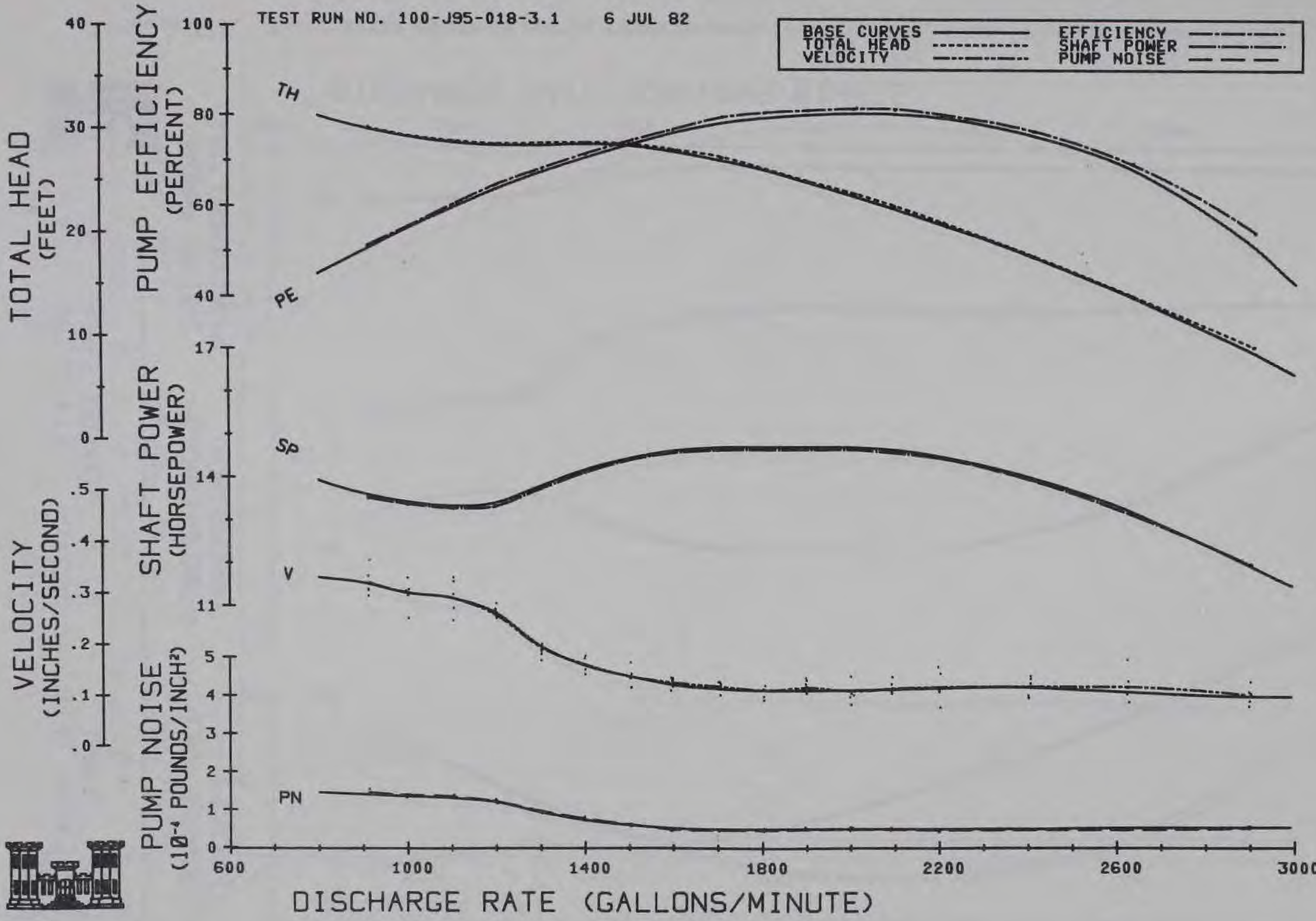


Figure 113. Performance characteristic curves; pump 1, Test J-95, sump 18, submergence 3.1 ft

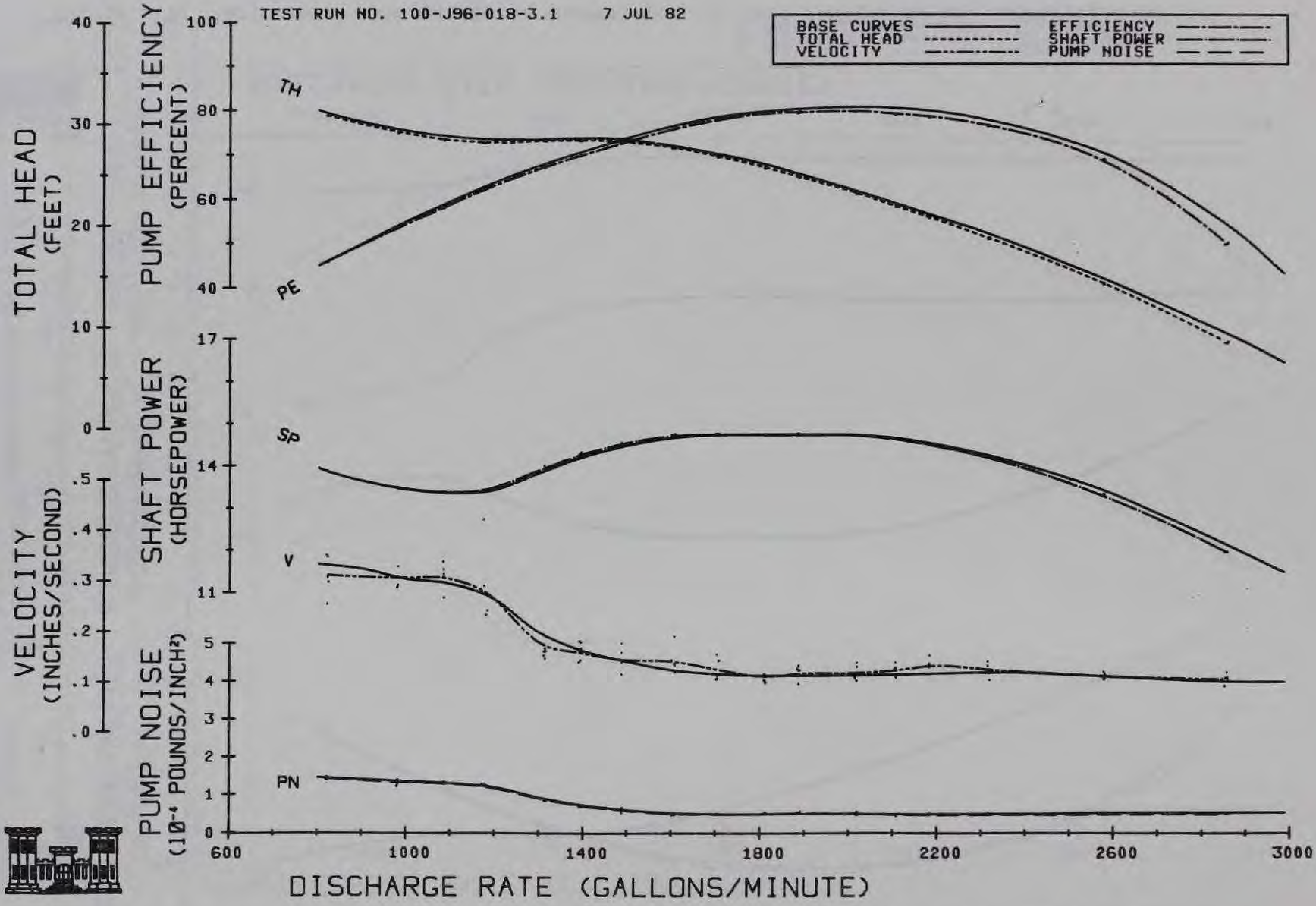


Figure 114. Performance characteristic curves; pump 1, Test J-96, sump 18, submergence 3.1 ft

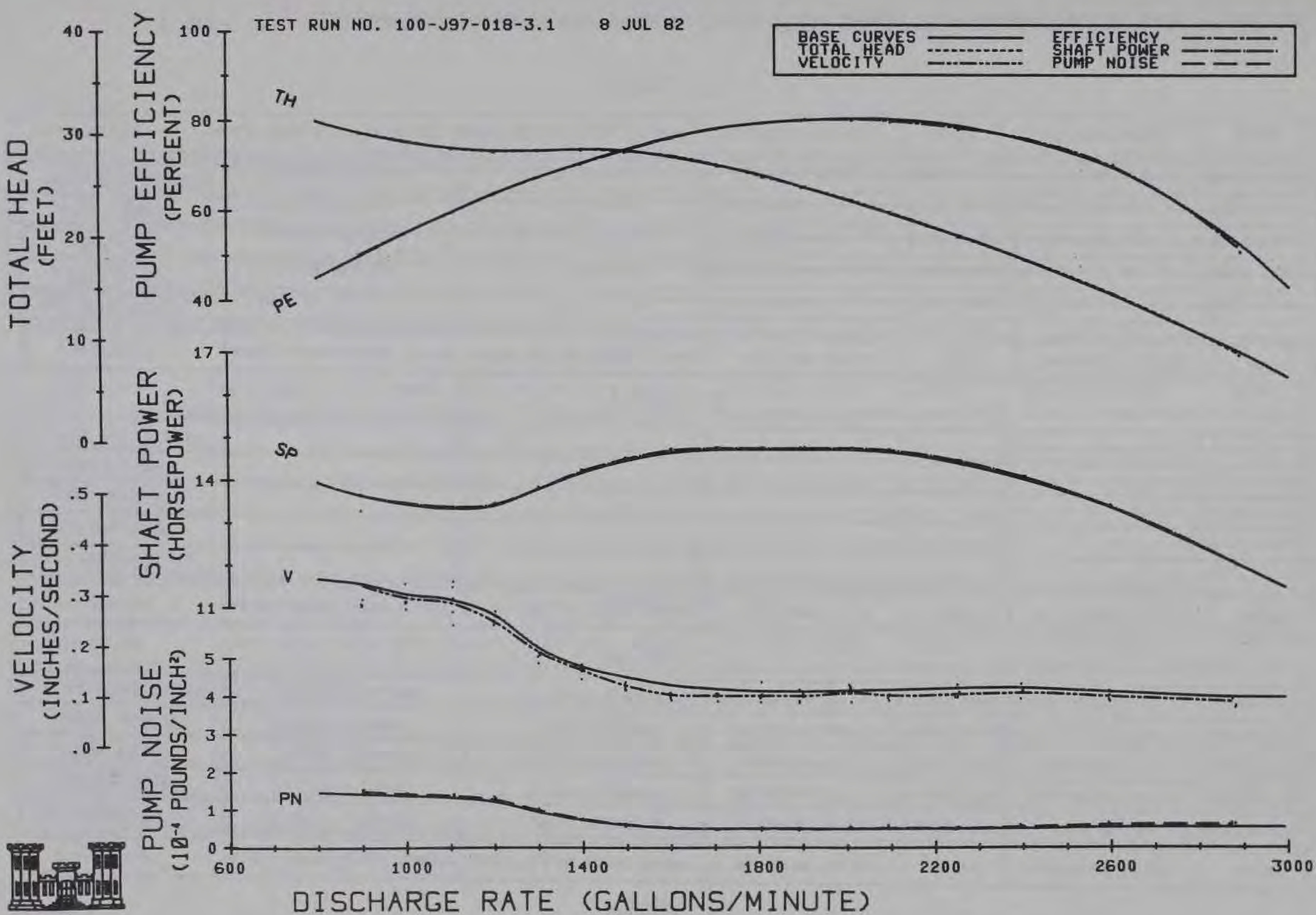


Figure 115. Performance characteristic curves; pump 1, Test J-97, sump 18, submergence 3.1 ft

TEST RUN NO. 100-J94-018-3.1   2 JUL 82   ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	5.2847 IPS*GPM	.2612 IPS*GPM	.134251 IPS	1500 GPM	.106275 IPS	1900 GPM
TOTAL HEAD	101.80 FT*GPM	8.72 FT*GPM	28.11590 FT	1500 GPM	16.18160 FT	2500 GPM
PUMP NOISE	.00000 PSI*GPM	.00263 PSI*GPM	.0000568 PSI	1500 GPM	.0000444 PSI	2250 GPM
SHAFT POWER	53.954 HP*GPM	.000 HP*GPM	14.80910 HP	1880 GPM	13.77360 HP	2500 GPM
PUMP EFFICIENCY	130.97 % * GPM	78.30 % * GPM	80.51590 %	2040 GPM	73.33090 %	1500 GPM

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

Figure 116. Statistical comparison pump 1, Test J-94, sump 18, submergence 3.1 ft

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	1.5193 IPS*GPM	.4039 IPS*GPM	.134414 IPS	1500 GPM	.105775 IPS	2000 GPM
TOTAL HEAD	148.37 FT*GPM	.00 FT*GPM	28.35800 FT	1500 GPM	15.91510 FT	2500 GPM
PUMP NOISE	.00000 PSI*GPM	.00423 PSI*GPM	.0000576 PSI	1500 GPM	.0000432 PSI	2230 GPM
SHAFT POWER	.000 HP*GPM	71.372 HP*GPM	14.68340 HP	1810 GPM	13.61400 HP	2500 GPM
PUMP EFFICIENCY	865.94 % * GPM	.00 % * GPM	81.43860 %	2020 GPM	73.59020 %	2500 GPM

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

Figure 117. Statistical comparison pump 1, Test J-95, sump 18, submergence 3.1 ft

TEST RUN NO. 100-J96-018-3.1 7 JUL 82 ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	5.5059 IPS*GPM	.2022 IPS*GPM	.137146 IPS	1500 GPM	.105060 IPS	1810 GPM
TOTAL HEAD	.00 FT*GPM	375.28 FT*GPM	27.89740 FT	1500 GPM	15.37990 FT	2500 GPM
PUMP NOISE	.00001 PSI*GPM	.00303 PSI*GPM	.0000538 PSI	1500 GPM	.0000440 PSI	2120 GPM
SHAFT POWER	4.150 HP*GPM	45.937 HP*GPM	14.73300 HP	1710 GPM	13.56870 HP	2500 GPM
PUMP EFFICIENCY	.00 % * GPM	1160.54 % * GPM	79.39830 %	1980 GPM	71.20320 %	2500 GPM

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

Figure 118. Statistical comparison pump 1, Test J-96, sump 18, submergence 3.1 ft

TEST RUN NO. 100-J97-018-3.1   8 JUL 82   ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	.0000 IPS*GPM	12.8324 IPS*GPM	.117357 IPS	1500 GPM	.097253 IPS	1660 GPM
TOTAL HEAD	3.34 FT*GPM	44.92 FT*GPM	28.11020 FT	1500 GPM	15.89810 FT	2500 GPM
PUMP NOISE	.00041 PSI*GPM	.00147 PSI*GPM	.0000570 PSI	1500 GPM	.0000448 PSI	1880 GPM
SHAFT POWER	23.943 HP*GPM	.000 HP*GPM	14.77010 HP	1740 GPM	13.71700 HP	2500 GPM
PUMP EFFICIENCY	19.37 % * GPM	297.62 % * GPM	80.17790 %	1970 GPM	72.95080 %	2500 GPM

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

Figure 119. Statistical comparison pump 1, Test J-97, sump 18, submergence 3.1 ft

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	3036	3.10	-1.63	2.39	5.253	33.42	477	15.9	17.66	11.29	4.03	63.93	35.6	1775	.043	.136	.000061	3.48	3.74
1	3036	3.10	-1.68	2.39	5.208	33.54	477	15.9	17.68	11.33	3.99	64.09	35.2	1775	.039	.118	.000060	3.59	3.73
1	3034	3.10	-1.66	2.38	5.222	33.56	477	15.9	17.69	11.34	4.00	64.11	35.3	1775	.039	.112	.000059	3.56	3.73
1	3036	3.10	-1.66	2.39	5.225	33.48	477	15.9	17.66	11.31	4.01	64.07	35.4	1775	.040	.123	.000059	3.46	3.72
1	3037	3.10	-1.68	2.39	5.208	33.41	477	15.9	17.66	11.29	3.99	63.93	35.4	1775	.040	.108	.000059	2.96	3.72
2	2792	3.10	3.62	2.02	10.145	36.97	476	16.3	18.10	12.49	7.16	69.01	57.3	1775	.038	.100	.000052	3.09	3.69
2	2794	3.10	3.65	2.02	10.182	36.94	476	16.3	18.09	12.48	7.19	68.99	57.6	1775	.034	.087	.000053	3.58	3.71
2	2791	3.10	3.62	2.02	10.146	36.97	476	16.3	18.10	12.49	7.16	69.00	57.3	1775	.042	.119	.000052	3.36	3.69
2	2789	3.10	3.68	2.01	10.200	37.08	476	16.3	18.11	12.53	7.19	69.19	57.3	1775	.040	.117	.000052	3.60	3.71
2	2796	3.10	3.59	2.02	10.128	36.98	476	16.3	18.10	12.49	7.16	69.04	57.2	1775	.042	.144	.000057	3.58	3.71
3	2600	3.10	7.72	1.75	13.982	39.56	479	16.6	18.49	13.37	9.19	72.29	68.7	1775	.039	.100	.000044	3.24	3.71
3	2601	3.10	7.75	1.75	14.008	39.55	479	16.6	18,49	13.36	9.21	72.26	68.9	1775	.040	.102	.000045	3.57	3.70
3	2604	3.10	7.72	1.76	13.985	39.61	479	16.6	18.50	13.38	9.20	72.35	68.7	1775	.043	.124	.000048	3.59	3.72
3	2604	3.10	7.74	1.76	14.003	39.58	478	16.6	18.49	13.37	9.22	72.33	68.9	1775	.036	.101	.000048	3.48	3.71
3	2605	3.10	7.75	1.76	14.014	39.62	478	16.6	18.49	13.39	9.23	72.39	68.9	1775	.042	.118	.000047	3.60	3.71
4	2384	3.10	11.22	1.47	17.200	41.93	480	16.9	18.91	14.17	10.36	74.94	73.1	1775	.045	.133	.000046	3.52	3.71
4	2383	3.10	11.23	1.47	17.206	41.91	480	16.9	18.90	14.16	10.37	74.91	73.2	1775	.035	.096	.000041	3.63	3.72
4	2380	3.10	11.19	1.47	17.163	41.88	480	16.9	18.90	14.15	10.33	74.86	72.9	1775	.037	.142	.000042	3.62	3.71
4	2389	3.10	11.22	1.48	17.203	41.95	480	16.9	18.92	14.18	10.39	74.94	73.2	1775	.049	.149	.000045	3.57	3.72
4	2385	3.10	11.23	1.47	17.211	41.86	480	16.9	18.90	14.14	10.38	74.82	73.3	1775	.049	.127	.000048	3.60	3.69
5	2210	3.10	14.22	1.26	19.990	43.00	479	17.1	19.05	14.53	11.17	76.25	76.8	1775	.044	.135	.000041	3.38	3.72
5	2209	3.10	14.25	1.26	20.026	43.07	479	17.1	19.05	14.55	11.18	76.38	76.8	1775	.037	.114	.000044	3.21	3.69
5	2208	3.10	14.25	1.26	20.023	43.04	479	17.1	19.04	14.54	11.17	76.37	76.8	1775	.043	.110	.000045	3.59	3.72
5	2207	3.10	14.22	1.26	19.990	43.02	479	17.1	19.04	14.53	11.15	76.35	76.7	1775	.041	.117	.000042	3.55	3.72
5	2211	3.10	14.25	1.26	20.025	43.07	479	17.1	19.04	14.55	11.19	76.43	76.9	1775	.046	.138	.000046	3.45	3.74
6	2092	3.10	16.17	1.13	21.806	43.56	479	17.1	19.11	14.72	11.53	77.04	78.3	1775	.038	.102	.000045	3.61	3.70
6	2091	3.10	16.16	1.13	21.796	43.58	479	17.1	19.11	14.72	11.52	77.05	78.2	1775	.054	.137	.000048	3.53	3.71
6	2089	3.10	16.16	1.13	21.797	43.54	479	17.1	19.11	14.71	11.51	76.98	78.2	1775	.039	.106	.000047	3.63	3.72
6	2090	3.10	16.16	1.13	21.801	43.52	479	17.1	19.12	14.70	11.52	76.92	78.3	1775	.039	.099	.000040	3.56	3.71
6	2088	3.10	16.22	1.13	21.856	43.62	480	17.1	19.14	14.74	11.53	77.00	78.2	1775	.041	.096	.000046	3.57	3.72

TEST RUN NO. 100-J94-018-3.1   2 JUL 82

Figure 120. Research data; pump 1, Test J-94, sump 18, submergence 3.1 ft (Sheet 1 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
7	1994	3.10	17.47	1.03	23.605	43.76	480	17.2	19.18	14.79	11.90	77.11	80.5	1775	.036	.086	.000049	3.62	3.71
7	1996	3.10	17.46	1.03	23.594	43.73	480	17.2	19.17	14.78	11.90	77.09	80.5	1775	.051	.136	.000052	3.53	3.70
7	1995	3.10	17.45	1.03	23.590	43.78	480	17.2	19.17	14.80	11.90	77.18	80.4	1775	.050	.128	.000051	3.61	3.70
7	1998	3.10	17.47	1.04	23.609	43.78	480	17.2	19.16	14.80	11.93	77.22	80.6	1775	.051	.134	.000046	3.60	3.71
7	1994	3.10	17.48	1.03	23.615	43.75	479	17.2	19.15	14.79	11.90	77.23	80.5	1775	.057	.152	.000046	3.62	3.72
8	1898	3.10	18.76	.93	24.801	43.82	480	17.2	19.20	14.81	11.90	77.15	80.4	1775	.040	.126	.000046	3.63	3.71
8	1904	3.10	18.77	.94	24.813	43.81	480	17.2	19.20	14.81	11.94	77.12	80.7	1775	.037	.101	.000049	3.61	3.72
8	1898	3.10	18.77	.93	24.810	43.82	480	17.2	19.20	14.81	11.90	77.13	80.4	1775	.033	.090	.000048	3.63	3.70
8	1898	3.10	18.82	.93	24.856	43.86	480	17.2	19.20	14.82	11.93	77.19	80.5	1775	.035	.083	.000048	3.60	3.70
8	1897	3.10	18.79	.93	24.832	43.79	480	17.2	19.19	14.80	11.91	77.12	80.5	1775	.034	.091	.000047	3.58	3.71
9	1805	3.10	19.93	.84	25.878	43.75	481	17.2	19.23	14.79	11.81	76.87	79.8	1775	.055	.141	.000043	3.46	3.70
9	1806	3.10	19.95	.85	25.901	43.85	481	17.2	19.25	14.82	11.83	77.01	79.8	1775	.047	.133	.000045	3.60	3.70
9	1804	3.10	19.96	.84	25.906	43.81	481	17.2	19.24	14.81	11.82	76.95	79.8	1775	.049	.119	.000046	3.58	3.70
9	1803	3.10	19.92	.84	25.870	43.78	481	17.2	19.24	14.80	11.79	76.90	79.7	1775	.035	.089	.000047	3.55	3.71
9	1808	3.10	19.94	.85	25.890	43.81	481	17.2	19.25	14.81	11.84	76.90	79.9	1775	.048	.136	.000048	3.32	3.70
10	1710	3.10	20.95	.76	26.813	43.71	481	17.2	19.23	14.77	11.59	76.82	78.5	1775	.041	.100	.000047	3.62	3.72
10	1712	3.10	20.98	.76	26.839	43.77	481	17.2	19.24	14.79	11.61	76.89	78.5	1775	.040	.104	.000045	3.63	3.71
10	1713	3.10	20.98	.76	26.849	43.78	481	17.2	19.23	14.80	11.63	76.93	78.6	1775	.039	.111	.000044	3.63	3.71
10	1709	3.10	20.95	.76	26.810	43.74	481	17.2	19.22	14.78	11.58	76.91	78.3	1775	.033	.099	.000043	3.62	3.72
10	1714	3.10	20.96	.76	26.825	43.73	481	17.2	19.23	14.78	11.62	76.85	78.7	1775	.038	.099	.000045	3.63	3.72
11	1609	3.10	21.92	.67	27.693	43.69	481	17.2	19.19	14.77	11.26	76.95	76.3	1775	.041	.144	.000051	3.62	3.73
11	1612	3.10	21.90	.67	27.676	43.69	481	17.2	19.19	14.77	11.28	76.97	76.4	1775	.048	.122	.000050	3.61	3.75
11	1607	3.10	21.91	.67	27.683	43.69	481	17.2	19.19	14.77	11.24	76.93	76.1	1775	.043	.111	.000045	3.62	3.74
11	1610	3.10	21.89	.67	27.671	43.65	481	17.2	19.18	14.75	11.27	76.90	76.4	1775	.042	.102	.000047	3.60	3.72
11	1613	3.10	21.92	.67	27.700	43.70	481	17.2	19.19	14.77	11.29	76.96	76.5	1775	.046	.128	.000050	3.62	3.73
12	1491	3.10	22.45	.58	28.132	42.98	481	17.1	19.10	14.53	10.60	76.06	73.0	1775	.044	.142	.000055	3.60	3.74
12	1494	3.10	22.44	.58	28.123	42.99	481	17.1	19.09	14.53	10.62	76.10	73.1	1775	.047	.157	.000055	3.58	3.73
12	1493	3.10	22.45	.58	28.131	42.94	481	17.1	19.09	14.51	10.62	76.04	73.2	1775	.045	.109	.000058	3.60	3.76
12	1499	3.10	22.45	.58	28.134	42.97	481	17.1	19.09	14.52	10.66	76.06	73.4	1775	.045	.141	.000058	3.59	3.75
12	1496	3.10	22.45	.58	28.133	42.98	481	17.1	19.09	14.52	10.64	76.08	73.2	1775	.052	.131	.000057	3.59	3.74

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Figure 120. (Sheet 2 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1406	3.10	22.67	.51	28.288	42.19	481	17.0	19.01	14.26	10.05	75.03	70.5	1775	.052	.157	.000070	3.55	3.79
13	1411	3.10	22.68	.52	28.301	42.19	481	17.0	18.99	14.26	10.09	75.07	70.8	1775	.049	.128	.000067	3.55	3.81
13	1412	3.10	22.66	.52	28.283	42.19	481	17.0	18.99	14.26	10.10	75.06	70.8	1775	.049	.137	.000069	3.56	3.79
13	1412	3.10	22.68	.52	28.304	42.21	481	17.0	19.00	14.26	10.10	75.10	70.8	1775	.051	.122	.000069	3.58	3.76
13	1406	3.10	22.70	.51	28.314	42.29	481	17.0	19.00	14.29	10.07	75.21	70.4	1775	.052	.163	.000064	3.54	3.77
14	1298	3.10	22.58	.44	28.124	40.72	482	16.8	18.81	13.76	9.23	73.17	67.1	1775	.071	.265	.000093	3.52	3.82
14	1301	3.10	22.64	.44	28.188	40.81	482	16.8	18.83	13.79	9.27	73.24	67.2	1775	.067	.184	.000091	3.54	3.83
14	1299	3.10	22.59	.44	28.128	40.70	482	16.8	18.81	13.76	9.24	73.13	67.1	1775	.062	.209	.000099	3.53	3.81
14	1298	3.10	22.61	.44	28.154	40.78	482	16.8	18.83	13.78	9.24	73.21	67.0	1775	.069	.225	.000092	3.52	3.83
14	1303	3.10	22.68	.44	28.222	40.94	482	16.8	18.84	13.84	9.30	73.45	67.2	1775	.064	.186	.000087	3.53	3.82
15	1208	3.10	22.63	.38	28.112	39.70	481	16.7	18.63	13.42	8.58	72.04	64.0	1775	.077	.236	.000116	3.48	3.88
15	1212	3.10	22.66	.38	28.141	39.81	481	16.7	18.65	13.45	8.62	72.16	64.1	1775	.081	.260	.000115	3.47	3.88
15	1211	3.10	22.64	.38	28.125	39.76	481	16.7	18.64	13.44	8.61	72.10	64.1	1775	.078	.270	.000121	3.47	3.89
15	1208	3.10	22.63	.38	28.117	39.76	481	16.7	18.63	13.44	8.59	72.12	63.9	1775	.080	.269	.000121	3.53	3.89
15	1214	3.10	22.64	.38	28.129	39.77	481	16.7	18.62	13.44	8.63	72.17	64.2	1775	.083	.342	.000117	3.50	3.86
16	1074	3.10	23.19	.30	28.593	39.57	482	16.7	18.63	13.37	7.77	71.79	58.1	1775	.110	.407	.000116	3.32	4.05
16	1077	3.10	23.22	.30	28.629	39.64	482	16.7	18.64	13.40	7.80	71.88	58.2	1775	.109	.290	.000125	2.83	4.08
16	1077	3.10	23.23	.30	28.638	39.61	482	16.7	18.65	13.39	7.80	71.79	58.2	1775	.106	.298	.000127	3.09	4.07
16	1080	3.10	23.23	.30	28.641	39.64	482	16.7	18.65	13.40	7.82	71.81	58.4	1775	.108	.293	.000127	3.35	4.07
16	1075	3.10	23.16	.30	28.561	39.51	482	16.7	18.64	13.35	7.76	71.64	58.1	1775	.105	.280	.000122	3.27	4.05
17	813	3.10	25.90	.17	31.175	41.44	481	16.9	18.89	14.00	6.40	74.16	45.7	1775	.126	.460	.000138	1.55	4.42
17	811	3.10	25.85	.17	31.126	41.37	481	16.9	18.87	13.98	6.38	74.08	45.6	1775	.123	.372	.000130	-.35	4.49
17	809	3.10	25.83	.17	31.106	41.34	481	16.9	18.87	13.97	6.36	74.02	45.5	1775	.129	.366	.000130	-.80	4.45
17	811	3.10	25.85	.17	31.121	41.35	481	16.9	18.88	13.97	6.38	74.02	45.7	1775	.124	.315	.000128	1.35	4.39
17	813	3.10	25.84	.17	31.116	41.31	481	16.9	18.88	13.96	6.39	73.96	45.8	1775	.115	.356	.000138	.84	4.48

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Figure 120. (Sheet 3 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	2898	3.10	1.52	2.18	8.799	35.31	479	16.1	17.90	11.93	6.45	66.69	54.0	1775	.033	.099	.000047	3.57	3.76
1	2894	3.10	1.56	2.17	8.838	35.36	479	16.1	17.90	11.95	6.47	66.78	54.1	1775	.030	.075	.000049	3.36	3.76
1	2897	3.10	1.56	2.18	8.845	35.30	479	16.1	17.88	11.93	6.48	66.72	54.3	1775	.034	.085	.000046	3.60	3.74
1	2897	3.10	1.53	2.18	8.813	35.24	479	16.1	17.87	11.91	6.46	66.64	54.2	1775	.042	.123	.000052	3.58	3.76
1	2893	3.10	1.59	2.17	8.862	35.31	479	16.1	17.87	11.93	6.48	66.79	54.3	1775	.038	.103	.000051	3.42	3.77
2	2622	3.10	6.86	1.78	13.750	38.92	479	16.6	18.44	13.15	9.12	71.32	69.3	1775	.047	.124	.000044	3.63	3.72
2	2620	3.10	6.89	1.78	13.776	38.90	479	16.6	18.44	13.15	9.12	71.29	69.4	1775	.064	.167	.000043	3.34	3.74
2	2619	3.10	6.87	1.78	13.757	38.91	479	16.6	18.45	13.15	9.11	71.28	69.3	1775	.039	.099	.000042	3.45	3.74
2	2620	3.10	6.93	1.78	13.815	39.01	479	16.6	18.47	13.19	9.15	71.40	69.4	1775	.042	.113	.000047	3.63	3.73
2	2625	3.10	6.90	1.79	13.788	38.93	479	16.6	18.47	13.16	9.15	71.24	69.5	1775	.035	.084	.000045	3.58	3.71
3	2403	3.10	11.01	1.50	17.614	41.30	478	16.9	18.77	13.96	10.70	74.36	76.7	1775	.050	.129	.000045	3.56	3.74
3	2403	3.10	11.01	1.50	17.612	41.31	478	16.9	18.78	13.96	10.70	74.35	76.6	1775	.046	.135	.000046	3.64	3.74
3	2402	3.10	11.00	1.50	17.599	41.28	478	16.9	18.77	13.95	10.69	74.31	76.6	1775	.047	.120	.000044	3.65	3.76
3	2398	3.10	11.00	1.49	17.599	41.30	478	16.9	18.77	13.96	10.67	74.35	76.4	1775	.038	.091	.000044	3.65	3.74
3	2397	3.10	11.05	1.49	17.641	41.34	478	16.9	18.77	13.97	10.69	74.45	76.5	1775	.038	.097	.000047	3.04	3.74
4	2199	3.10	14.49	1.25	20.852	42.79	478	17.1	18.98	14.46	11.59	76.19	80.2	1775	.046	.140	.000040	3.65	3.76
4	2199	3.10	14.46	1.25	20.821	42.80	478	17.1	18.98	14.46	11.58	76.22	80.0	1775	.034	.073	.000045	3.67	3.76
4	2196	3.10	14.49	1.25	20.848	42.79	478	17.1	18.98	14.46	11.58	76.18	80.1	1775	.041	.104	.000039	3.48	3.74
4	2193	3.10	14.50	1.25	20.855	42.82	478	17.1	18.98	14.47	11.56	76.25	79.9	1775	.050	.153	.000044	3.48	3.73
4	2196	3.10	14.50	1.25	20.855	42.87	478	17.1	18.98	14.49	11.58	76.32	79.9	1775	.037	.106	.000045	3.59	3.76
5	2088	3.10	16.17	1.13	22.405	43.15	478	17.1	19.03	14.58	11.83	76.64	81.1	1775	.051	.119	.000042	3.65	3.74
5	2089	3.10	16.24	1.13	22.472	43.21	478	17.2	19.03	14.60	11.87	76.73	81.3	1775	.042	.106	.000046	3.59	3.74
5	2090	3.10	16.20	1.13	22.443	43.15	478	17.1	19.03	14.58	11.86	76.63	81.3	1775	.039	.101	.000048	3.63	3.76
5	2091	3.10	16.23	1.13	22.464	43.17	478	17.1	19.04	14.59	11.88	76.64	81.4	1775	.050	.133	.000045	3.65	3.76
5	2091	3.10	16.24	1.13	22.474	43.20	478	17.2	19.04	14.60	11.88	76.71	81.4	1775	.041	.111	.000044	3.67	3.77
6	1996	3.10	17.51	1.03	23.648	43.42	478	17.2	19.05	14.67	11.93	77.04	81.3	1775	.043	.094	.000045	3.66	3.75
6	2005	3.10	17.51	1.04	23.660	43.42	478	17.2	19.05	14.68	11.99	77.05	81.7	1775	.036	.098	.000049	3.67	3.74
6	1997	3.10	17.52	1.03	23.658	43.43	477	17.2	19.04	14.68	11.94	77.09	81.4	1775	.045	.135	.000042	3.60	3.74
6	1999	3.10	17.52	1.04	23.664	43.46	477	17.2	19.04	14.69	11.96	77.14	81.4	1775	.040	.101	.000046	3.68	3.76
6	1999	3.10	17.51	1.04	23.654	43.40	477	17.2	19.03	14.67	11.95	77.06	81.5	1775	.034	.080	.000051	3.62	3.75

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Figure 121. Research data; pump 1, Test J-95, sump 18, submergence 3.1 ft (Sheet 1 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
7	1896	3.10	18.75	.93	24.787	43.39	478	17.1	19.04	14.66	11.88	76.99	81.0	1775	.043	.131	.000045	3.65	3.76
7	1895	3.10	18.77	.93	24.813	43.47	478	17.1	19.05	14.69	11.89	77.11	80.9	1775	.042	.118	.000050	3.58	3.74
7	1898	3.10	18.75	.93	24.792	43.41	478	17.1	19.04	14.67	11.89	77.02	81.1	1775	.038	.100	.000046	3.65	3.73
7	1898	3.10	18.76	.93	24.805	43.41	478	17.1	19.05	14.67	11.90	76.99	81.1	1775	.043	.113	.000046	3.64	3.74
7	1897	3.10	18.77	.93	24.816	43.45	478	17.1	19.06	14.68	11.90	77.04	81.0	1775	.047	.126	.000043	3.66	3.73
8	1798	3.10	20.00	.83	25.952	43.41	478	17.1	19.05	14.67	11.80	76.99	80.4	1775	.043	.109	.000043	3.65	3.73
8	1801	3.10	20.04	.84	25.989	43.49	478	17.1	19.05	14.70	11.83	77.16	80.5	1775	.037	.095	.000040	3.64	3.73
8	1801	3.10	20.02	.84	25.971	43.45	478	17.1	19.04	14.68	11.83	77.11	80.5	1775	.032	.087	.000043	3.60	3.72
8	1804	3.10	20.01	.84	25.967	43.46	478	17.1	19.04	14.68	11.84	77.14	80.6	1775	.040	.116	.000044	3.65	3.71
8	1801	3.10	20.02	.84	25.969	43.41	478	17.1	19.03	14.67	11.82	77.07	80.6	1775	.042	.108	.000047	3.64	3.72
9	1700	3.10	21.25	.75	27.108	43.41	480	17.1	19.12	14.67	11.65	76.72	79.4	1775	.047	.113	.000041	3.65	3.74
9	1697	3.10	21.26	.74	27.119	43.37	479	17.1	19.11	14.65	11.64	76.66	79.4	1775	.044	.124	.000044	3.65	3.74
9	1702	3.10	21.29	.75	27.151	43.45	479	17.1	19.12	14.68	11.68	76.77	79.5	1775	.043	.124	.000043	3.65	3.74
9	1705	3.10	21.25	.75	27.114	43.42	480	17.1	19.13	14.67	11.68	76.71	79.6	1775	.045	.120	.000043	3.62	3.74
9	1703	3.10	21.27	.75	27.136	43.44	480	17.1	19.13	14.68	11.68	76.71	79.5	1775	.040	.098	.000043	3.65	3.74
10	1592	3.10	22.01	.65	27.778	43.15	479	17.0	19.00	14.58	11.18	76.74	76.6	1775	.042	.107	.000044	3.64	3.75
10	1596	3.10	22.06	.66	27.833	43.22	479	17.0	19.01	14.60	11.23	76.82	76.8	1775	.042	.126	.000041	3.62	3.74
10	1592	3.10	22.10	.65	27.870	43.25	479	17.0	19.01	14.62	11.21	76.86	76.7	1775	.044	.132	.000045	3.64	3.75
10	1597	3.10	22.08	.66	27.847	43.24	479	17.0	19.01	14.61	11.24	76.86	76.9	1775	.046	.130	.000041	3.63	3.73
10	1596	3.10	22.11	.66	27.878	43.26	479	17.0	19.01	14.62	11.25	76.89	76.9	1775	.040	.115	.000044	3.63	3.74
11	1502	3.10	22.64	.58	28.334	42.75	479	17.0	18.90	14.44	10.76	76.43	74.4	1775	.049	.140	.000059	3.62	3.77
11	1501	3.10	22.64	.58	28.335	42.73	479	17.0	18.91	14.44	10.75	76.36	74.4	1775	.043	.112	.000059	3.57	3.77
11	1499	3.10	22.66	.58	28.357	42.74	479	17.0	18.92	14.44	10.75	76.33	74.4	1775	.049	.130	.000057	3.62	3.79
11	1500	3.10	22.67	.58	28.359	42.79	479	17.0	18.92	14.46	10.75	76.40	74.3	1775	.048	.162	.000058	3.64	3.78
11	1503	3.10	22.68	.58	28.374	42.77	479	17.0	18.92	14.45	10.78	76.40	74.5	1775	.042	.113	.000053	3.64	3.78
12	1399	3.10	22.92	.50	28.536	41.78	480	16.8	18.80	14.12	10.09	75.11	71.4	1775	.053	.138	.000069	3.58	3.80
12	1400	3.10	22.90	.50	28.514	41.75	480	16.8	18.79	14.11	10.09	75.08	71.5	1775	.051	.175	.000068	3.60	3.82
12	1399	3.10	22.95	.50	28.570	41.84	480	16.8	18.80	14.14	10.10	75.19	71.4	1775	.056	.147	.000072	3.60	3.80
12	1397	3.10	22.96	.50	28.575	41.88	480	16.8	18.81	14.15	10.09	75.25	71.3	1775	.055	.169	.000077	3.59	3.80
12	1398	3.10	22.93	.50	28.550	41.83	480	16.8	18.80	14.14	10.09	75.18	71.4	1775	.056	.156	.000072	3.60	3.80

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Figure 121. (Sheet 2 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1301	3.10	22.93	.44	28.474	40.60	481	16.7	18.65	13.72	9.36	73.56	68.2	1775	.058	.166	.000092	3.53	3.85
13	1301	3.10	22.97	.44	28.514	40.70	481	16.7	18.66	13.76	9.38	73.72	68.2	1775	.062	.184	.000091	3.56	3.82
13	1302	3.10	22.99	.44	28.535	40.72	480	16.7	18.66	13.76	9.39	73.76	68.2	1775	.062	.178	.000088	3.56	3.80
13	1302	3.10	23.02	.44	28.569	40.77	480	16.7	18.66	13.78	9.40	73.83	68.2	1775	.060	.187	.000094	3.57	3.83
13	1303	3.10	22.99	.44	28.534	40.68	480	16.7	18.65	13.75	9.40	73.74	68.4	1775	.060	.198	.000094	3.52	3.82
14	1200	3.10	22.92	.37	28.393	39.41	480	16.6	18.47	13.32	8.62	72.14	64.7	1775	.078	.249	.000114	3.48	3.91
14	1200	3.10	22.95	.37	28.423	39.45	480	16.6	18.47	13.33	8.62	72.18	64.7	1775	.079	.278	.000122	3.49	3.91
14	1197	3.10	22.92	.37	28.394	39.38	480	16.6	18.47	13.31	8.59	72.06	64.5	1775	.079	.267	.000125	3.52	3.92
14	1193	3.10	22.90	.37	28.372	39.36	480	16.6	18.48	13.30	8.55	72.01	64.3	1775	.080	.257	.000120	3.55	3.89
14	1199	3.10	22.91	.37	28.382	39.43	480	16.6	18.48	13.33	8.60	72.09	64.5	1775	.082	.263	.000122	3.49	3.91
15	1103	3.10	23.25	.32	28.671	39.28	481	16.6	18.48	13.27	8.00	71.83	60.3	1775	.097	.296	.000132	3.40	4.03
15	1104	3.10	23.27	.32	28.687	39.28	481	16.6	18.48	13.28	8.00	71.84	60.3	1775	.092	.328	.000134	3.37	4.14
15	1104	3.10	23.25	.32	28.670	39.28	480	16.6	18.48	13.27	8.00	71.85	60.3	1775	.089	.268	.000135	3.36	3.98
15	1104	3.10	23.21	.32	28.632	39.23	480	16.6	18.47	13.26	7.99	71.79	60.3	1775	.090	.321	.000136	3.33	4.01
15	1102	3.10	23.24	.32	28.662	39.25	480	16.6	18.47	13.27	7.99	71.83	60.2	1775	.084	.244	.000129	3.37	4.08
16	997	3.10	23.78	.26	29.141	39.59	478	16.6	18.40	13.38	7.34	72.71	54.9	1775	.095	.302	.000131	1.79	4.30
16	1002	3.10	23.82	.26	29.183	39.61	478	16.6	18.39	13.39	7.40	72.78	55.3	1775	.101	.294	.000137	2.86	4.22
16	1000	3.10	23.81	.26	29.176	39.52	478	16.6	18.39	13.36	7.38	72.62	55.2	1775	.097	.328	.000137	2.33	4.29
16	1004	3.10	23.86	.26	29.228	39.59	478	16.6	18.41	13.38	7.42	72.66	55.4	1775	.096	.249	.000138	2.70	4.25
16	1004	3.10	23.82	.26	29.182	39.56	478	16.6	18.41	13.37	7.41	72.62	55.4	1775	.101	.305	.000133	2.96	4.25
17	913	3.10	24.72	.22	30.039	40.08	479	16.6	18.49	13.55	6.94	73.28	51.2	1775	.103	.304	.000139	.85	4.33
17	912	3.10	24.60	.22	29.915	39.97	479	16.6	18.47	13.51	6.90	73.13	51.1	1775	.103	.293	.000152	1.98	4.42
17	911	3.10	24.66	.22	29.978	40.01	479	16.6	18.49	13.52	6.91	73.14	51.1	1775	.102	.332	.000141	2.05	4.27
17	916	3.10	24.63	.22	29.954	39.96	479	16.6	18.48	13.51	6.94	73.09	51.4	1775	.105	.361	.000142	2.49	4.45
17	912	3.10	24.70	.22	30.020	40.03	479	16.6	18.49	13.53	6.92	73.16	51.1	1775	.106	.305	.000142	2.91	4.39

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Figure 121. (Sheet 3 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	2860	3.10	.97	2.12	8.194	35.24	477	17.7	19.67	11.91	5.92	60.56	49.7	1775	.038	.096	.000048	3.57	3.73
1	2853	3.10	.94	2.11	8.152	35.23	478	17.7	19.66	11.91	5.88	60.58	49.4	1775	.034	.101	.000045	2.91	3.71
1	2861	3.10	.93	2.12	8.153	35.24	478	17.7	19.62	11.91	5.90	60.69	49.5	1775	.038	.102	.000046	3.10	3.69
1	2857	3.10	.92	2.12	8.140	35.25	478	17.6	19.54	11.91	5.88	60.96	49.4	1775	.039	.112	.000049	3.57	3.69
1	2851	3.10	.96	2.11	8.171	35.33	477	17.8	19.73	11.94	5.89	60.53	49.3	1775	.034	.085	.000046	3.50	3.68
2	2578	3.10	7.14	1.72	13.966	39.34	477	18.4	20.33	13.30	9.10	65.42	68.5	1775	.045	.114	.000048	3.61	3.70
2	2576	3.10	7.12	1.72	13.944	39.25	477	18.4	20.32	13.26	9.08	65.27	68.5	1775	.036	.101	.000047	3.52	3.71
2	2582	3.10	7.12	1.73	13.949	39.30	477	18.4	20.33	13.28	9.10	65.34	68.5	1775	.037	.109	.000043	3.60	3.70
2	2580	3.10	7.09	1.73	13.924	39.28	477	18.4	20.33	13.28	9.08	65.31	68.4	1775	.038	.101	.000047	3.61	3.72
2	2578	3.10	7.08	1.72	13.913	39.21	477	18.3	20.31	13.25	9.07	65.25	68.4	1775	.041	.099	.000046	3.57	3.71
3	2319	3.10	11.92	1.40	18.424	41.96	477	18.8	20.75	14.18	10.80	68.33	76.2	1775	.046	.116	.000045	3.49	3.73
3	2319	3.10	11.89	1.39	18.394	41.93	477	18.7	20.75	14.17	10.78	68.29	76.1	1775	.048	.112	.000045	3.64	3.75
3	2315	3.10	11.91	1.39	18.406	41.96	477	18.8	20.76	14.18	10.77	68.31	76.0	1775	.044	.126	.000048	3.27	3.72
3	2316	3.10	11.92	1.39	18.414	41.98	477	18.8	20.77	14.19	10.78	68.32	76.0	1775	.053	.135	.000044	3.62	3.73
3	2320	3.10	11.92	1.40	18.421	41.95	477	18.8	20.75	14.18	10.80	68.33	76.2	1775	.037	.098	.000043	3.58	3.72
4	2183	3.10	14.14	1.24	20.483	42.85	477	18.9	20.89	14.48	11.30	69.31	78.1	1775	.052	.147	.000048	3.58	3.75
4	2183	3.10	14.14	1.24	20.482	42.86	477	18.9	20.89	14.48	11.30	69.35	78.0	1775	.040	.128	.000044	3.64	3.73
4	2182	3.10	14.16	1.24	20.504	42.91	477	18.9	20.90	14.50	11.31	69.39	78.0	1775	.054	.128	.000044	3.56	3.74
4	2183	3.10	14.16	1.24	20.500	42.82	477	18.9	20.90	14.47	11.31	69.23	78.2	1775	.055	.130	.000047	3.61	3.73
4	2183	3.10	14.15	1.24	20.487	42.86	477	18.9	20.90	14.49	11.30	69.30	78.0	1775	.052	.124	.000043	3.60	3.72
5	2106	3.10	15.31	1.15	21.566	43.25	477	18.9	20.93	14.62	11.48	69.84	78.6	1775	.039	.123	.000043	3.61	3.74
5	2109	3.10	15.37	1.15	21.627	43.28	476	18.9	20.93	14.63	11.53	69.89	78.8	1775	.046	.106	.000040	3.61	3.74
5	2108	3.10	15.32	1.15	21.572	43.26	476	18.9	20.92	14.62	11.50	69.90	78.6	1775	.048	.123	.000044	3.62	3.72
5	2106	3.10	15.34	1.15	21.592	43.25	476	18.9	20.91	14.62	11.50	69.92	78.7	1775	.043	.133	.000043	3.46	3.72
5	2108	3.10	15.32	1.15	21.573	43.23	476	18.9	20.90	14.61	11.50	69.92	78.7	1775	.037	.104	.000045	3.54	3.72
6	2015	3.10	16.72	1.05	22.878	43.52	477	19.0	20.98	14.71	11.66	70.11	79.2	1775	.041	.102	.000047	3.64	3.72
6	2021	3.10	16.72	1.06	22.882	43.53	476	19.0	20.97	14.71	11.69	70.17	79.5	1775	.044	.124	.000050	3.56	3.72
6	2020	3.10	16.72	1.06	22.883	43.54	477	19.0	20.97	14.71	11.68	70.15	79.4	1775	.047	.108	.000049	3.63	3.72
6	2018	3.10	16.70	1.06	22.862	43.49	477	18.9	20.96	14.70	11.66	70.11	79.4	1775	.034	.097	.000042	3.66	3.74
6	2020	3.10	16.72	1.06	22.878	43.52	477	18.9	20.97	14.71	11.68	70.14	79.4	1775	.049	.132	.000051	3.66	3.74

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Figure 122. Research data; pump 1, Test J-96, sump 18, submergence 3.1 ft (Sheet 1 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
7	1885	3.10	18.41	.92	24.436	43.62	477	19.0	20.99	14.74	11.64	70.23	79.0	1775	.038	.120	.000049	3.56	3.73
7	1889	3.10	18.41	.93	24.439	43.57	476	19.0	20.98	14.73	11.67	70.20	79.3	1775	.041	.126	.000047	3.65	3.73
7	1889	3.10	18.40	.93	24.426	43.55	476	19.0	20.97	14.72	11.66	70.19	79.2	1775	.045	.117	.000047	3.66	3.73
7	1887	3.10	18.41	.92	24.443	43.61	477	19.0	20.99	14.74	11.66	70.21	79.1	1775	.042	.090	.000047	3.63	3.74
7	1892	3.10	18.42	.93	24.452	43.59	477	19.0	20.99	14.73	11.70	70.20	79.4	1775	.047	.117	.000053	3.67	3.75
8	1810	3.10	19.43	.85	25.388	43.51	476	18.9	20.95	14.71	11.62	70.20	79.0	1775	.039	.107	.000050	3.66	3.74
8	1813	3.10	19.41	.85	25.362	43.50	476	18.9	20.94	14.70	11.63	70.19	79.1	1775	.037	.092	.000048	3.60	3.74
8	1810	3.10	19.43	.85	25.386	43.56	476	19.0	20.96	14.72	11.62	70.26	78.9	1775	.038	.096	.000047	3.63	3.73
8	1810	3.10	19.44	.85	25.390	43.58	476	19.0	20.97	14.73	11.62	70.25	78.9	1775	.035	.110	.000048	3.63	3.73
8	1809	3.10	19.43	.85	25.385	43.55	476	19.0	20.96	14.72	11.61	70.22	78.9	1775	.037	.097	.000047	3.62	3.72
9	1700	3.10	20.65	.75	26.505	43.61	477	19.0	20.99	14.74	11.39	70.20	77.3	1775	.039	.100	.000044	3.66	3.73
9	1708	3.10	20.65	.76	26.507	43.61	477	19.0	21.00	14.74	11.45	70.20	77.7	1775	.045	.137	.000044	3.66	3.73
9	1702	3.10	20.66	.75	26.511	43.59	477	18.9	20.99	14.73	11.41	70.18	77.4	1775	.056	.149	.000045	3.66	3.75
9	1703	3.10	20.65	.75	26.506	43.56	477	18.9	21.00	14.72	11.41	70.11	77.5	1775	.043	.107	.000047	3.65	3.74
9	1702	3.10	20.71	.75	26.563	43.62	477	19.0	21.01	14.74	11.43	70.15	77.6	1775	.040	.101	.000047	3.66	3.74
10	1608	3.10	21.63	.67	27.401	43.59	478	18.9	21.03	14.73	11.14	70.07	75.6	1775	.039	.127	.000045	3.61	3.75
10	1606	3.10	21.61	.67	27.381	43.52	478	18.9	21.02	14.71	11.12	69.97	75.6	1775	.060	.184	.000047	3.62	3.73
10	1608	3.10	21.63	.67	27.401	43.55	478	18.9	21.03	14.72	11.14	70.00	75.7	1775	.047	.114	.000044	3.59	3.75
10	1605	3.10	21.59	.67	27.361	43.51	478	18.9	21.02	14.70	11.10	69.96	75.5	1775	.044	.130	.000042	3.64	3.75
10	1599	3.10	21.62	.66	27.386	43.53	478	18.9	21.02	14.71	11.07	70.00	75.2	1775	.042	.138	.000041	3.59	3.74
11	1486	3.10	22.24	.57	27.918	42.95	478	18.8	20.90	14.51	10.49	69.47	72.3	1775	.048	.132	.000061	3.63	3.76
11	1486	3.10	22.27	.57	27.947	42.94	478	18.8	20.89	14.51	10.50	69.47	72.3	1775	.058	.170	.000058	3.61	3.78
11	1486	3.10	22.27	.57	27.943	42.95	478	18.8	20.90	14.52	10.50	69.47	72.3	1775	.045	.151	.000056	3.63	3.79
11	1485	3.10	22.29	.57	27.969	42.99	478	18.8	20.90	14.53	10.50	69.53	72.2	1775	.046	.109	.000051	3.61	3.80
11	1485	3.10	22.28	.57	27.956	42.99	478	18.8	20.90	14.53	10.50	69.52	72.3	1775	.042	.109	.000048	3.64	3.77
12	1391	3.10	22.54	.50	28.147	42.16	477	18.7	20.68	14.25	9.90	68.89	69.5	1775	.053	.174	.000067	3.60	3.80
12	1396	3.10	22.59	.51	28.197	42.29	477	18.7	20.70	14.29	9.95	69.05	69.6	1775	.055	.160	.000069	3.37	3.79
12	1394	3.10	22.57	.50	28.181	42.23	477	18.7	20.71	14.27	9.93	68.93	69.6	1775	.052	.171	.000066	3.58	3.81
12	1388	3.10	22.53	.50	28.134	42.08	477	18.7	20.68	14.22	9.88	68.76	69.4	1775	.046	.132	.000066	3.62	3.80
12	1394	3.10	22.53	.50	28.136	42.09	477	18.7	20.67	14.23	9.92	68.81	69.7	1775	.051	.136	.000064	3.62	3.81

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Figure 122. (Sheet 2 of 3)

READ NO.	DISC-HARGE GPM	SUBME-RGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOL-TAGE VOLT	CUR-RENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1313	3.10	22.60	.45	28.154	41.21	478	18.6	20.64	13.93	9.35	67.48	67.1	1775	.058	.160	.000084	3.55	3.80
13	1315	3.10	22.60	.45	28.148	41.23	478	18.6	20.65	13.93	9.36	67.48	67.2	1775	.056	.155	.000084	3.55	3.82
13	1310	3.10	22.57	.45	28.118	41.13	478	18.6	20.62	13.90	9.31	67.41	67.0	1775	.057	.146	.000082	3.56	3.82
13	1311	3.10	22.64	.45	28.187	41.36	478	18.6	20.66	13.98	9.34	67.67	66.8	1775	.057	.154	.000083	3.58	3.82
13	1314	3.10	22.61	.45	28.161	41.20	478	18.6	20.63	13.92	9.35	67.50	67.2	1775	.054	.140	.000081	3.55	3.83
14	1182	3.10	22.47	.36	27.938	39.64	478	18.4	20.38	13.40	8.35	65.73	62.3	1775	.081	.236	.000117	3.46	3.89
14	1179	3.10	22.51	.36	27.977	39.70	478	18.4	20.39	13.42	8.34	65.81	62.2	1775	.078	.227	.000122	3.48	3.92
14	1175	3.10	22.49	.36	27.949	39.68	478	18.4	20.39	13.41	8.30	65.76	61.9	1775	.074	.284	.000126	3.44	3.91
14	1174	3.10	22.52	.36	27.983	39.66	478	18.4	20.40	13.40	8.30	65.72	61.9	1775	.088	.415	.000123	3.43	3.92
14	1169	3.10	22.50	.35	27.962	39.64	478	18.4	20.38	13.40	8.27	65.74	61.7	1775	.086	.273	.000125	3.40	3.92
15	1083	3.10	22.85	.30	28.261	39.56	479	18.3	20.41	13.37	7.74	65.52	57.9	1775	.092	.316	.000127	2.94	4.02
15	1085	3.10	22.83	.31	28.236	39.51	479	18.3	20.38	13.35	7.75	65.51	58.0	1775	.094	.301	.000131	3.18	3.97
15	1083	3.10	22.83	.30	28.240	39.51	479	18.3	20.38	13.35	7.74	65.50	57.9	1775	.096	.307	.000127	3.42	4.00
15	1085	3.10	22.80	.31	28.212	39.48	479	18.3	20.37	13.34	7.74	65.51	58.0	1775	.089	.261	.000126	3.27	3.95
15	1082	3.10	22.84	.30	28.250	39.52	479	18.3	20.37	13.35	7.73	65.57	57.9	1775	.097	.332	.000130	3.28	4.02
16	980	3.10	23.60	.25	28.955	39.80	478	18.4	20.41	13.45	7.17	65.92	53.3	1775	.095	.323	.000137	2.40	4.25
16	980	3.10	23.67	.25	29.020	39.87	478	18.4	20.42	13.47	7.19	65.99	53.4	1775	.093	.301	.000127	3.02	4.20
16	977	3.10	23.67	.25	29.019	39.85	478	18.4	20.42	13.47	7.17	65.95	53.2	1775	.091	.281	.000120	3.05	4.18
16	980	3.10	23.58	.25	28.935	39.79	478	18.4	20.42	13.45	7.17	65.86	53.3	1775	.097	.303	.000133	3.00	4.24
16	980	3.10	23.65	.25	29.001	39.81	478	18.4	20.43	13.45	7.19	65.87	53.4	1775	.094	.286	.000129	2.80	4.25
17	822	3.10	25.30	.18	30.575	40.92	477	18.6	20.54	13.83	6.36	67.34	46.0	1775	.108	.293	.000137	2.10	4.46
17	820	3.10	25.38	.17	30.654	41.01	477	18.6	20.56	13.86	6.35	67.42	45.9	1775	.119	.302	.000144	.99	4.41
17	821	3.10	25.33	.17	30.608	41.00	477	18.6	20.57	13.86	6.35	67.36	45.9	1775	.111	.342	.000145	1.32	4.43
17	820	3.10	25.40	.17	30.681	41.04	477	18.6	20.58	13.87	6.36	67.40	45.9	1775	.106	.249	.000141	2.70	4.53
17	818	3.10	25.39	.17	30.669	41.06	477	18.6	20.58	13.88	6.34	67.42	45.7	1775	.122	.346	.000136	1.84	4.40

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Figure 122. (Sheet 3 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	2871	3.10	1.37	2.14	8.608	35.60	478	18.0	19.98	12.03	6.25	60.21	51.9	1775	.033	.092	.000053	3.41	3.77
1	2871	3.10	1.40	2.14	8.646	35.65	478	18.0	19.99	12.05	6.28	60.28	52.1	1775	.032	.091	.000058	3.27	3.76
1	2870	3.10	1.37	2.14	8.614	35.60	478	18.0	19.98	12.03	6.25	60.23	51.9	1775	.035	.090	.000060	3.56	3.75
1	2878	3.10	1.11	2.15	8.358	35.45	478	18.0	19.96	11.98	6.08	60.03	50.8	1775	.031	.074	.000059	3.64	3.74
1	2880	3.10	1.05	2.15	8.303	35.37	478	18.0	19.94	11.95	6.05	59.94	50.6	1775	.032	.078	.000058	3.64	3.74
2	2593	3.10	7.42	1.74	14.265	39.52	477	18.5	20.54	13.36	9.35	65.02	70.0	1775	.035	.086	.000054	3.50	3.77
2	2589	3.10	7.44	1.74	14.283	39.60	477	18.5	20.55	13.38	9.35	65.14	69.9	1775	.037	.096	.000055	2.69	3.75
2	2592	3.10	7.44	1.74	14.289	39.62	477	18.5	20.53	13.39	9.36	65.20	69.9	1775	.040	.106	.000059	3.63	3.76
2	2591	3.10	7.43	1.74	14.271	39.61	477	18.5	20.54	13.39	9.35	65.18	69.8	1775	.037	.089	.000061	3.68	3.75
2	2593	3.10	7.47	1.74	14.314	39.61	477	18.5	20.54	13.39	9.38	65.18	70.1	1775	.040	.097	.000060	3.62	3.76
3	2393	3.10	11.01	1.49	17.597	41.60	477	18.7	20.72	14.06	10.64	67.84	75.7	1775	.044	.119	.000049	3.47	3.76
3	2401	3.10	11.00	1.50	17.605	41.64	477	18.7	20.73	14.07	10.69	67.89	75.9	1775	.042	.102	.000050	3.67	3.76
3	2391	3.10	11.05	1.48	17.637	41.66	476	18.7	20.72	14.08	10.66	67.96	75.7	1775	.035	.090	.000055	3.68	3.77
3	2397	3.10	11.02	1.49	17.616	41.67	476	18.7	20.71	14.08	10.68	67.99	75.8	1775	.041	.108	.000051	3.56	3.76
3	2394	3.10	11.05	1.49	17.638	41.63	476	18.7	20.71	14.07	10.67	67.95	75.9	1775	.040	.104	.000052	3.69	3.76
4	2248	3.10	13.47	1.31	19.889	42.77	477	18.9	20.93	14.46	11.30	69.06	78.2	1775	.038	.093	.000048	3.12	3.79
4	2246	3.10	13.48	1.31	19.894	42.80	476	18.9	20.92	14.46	11.30	69.14	78.1	1775	.041	.118	.000043	3.53	3.76
4	2241	3.10	13.47	1.30	19.878	42.80	476	18.9	20.92	14.47	11.26	69.14	77.9	1775	.038	.094	.000043	3.65	3.77
4	2252	3.10	13.48	1.32	19.900	42.78	477	18.9	20.93	14.46	11.33	69.08	78.4	1775	.038	.104	.000049	3.68	3.76
4	2246	3.10	13.48	1.31	19.891	42.77	477	18.9	20.93	14.45	11.30	69.05	78.2	1775	.040	.100	.000046	3.56	3.77
5	2090	3.10	15.98	1.13	22.215	43.55	476	19.1	21.05	14.72	11.74	69.93	79.8	1775	.036	.097	.000055	3.69	3.76
5	2089	3.10	15.92	1.13	22.157	43.52	475	19.1	21.03	14.71	11.70	69.92	79.6	1775	.033	.093	.000048	3.67	3.76
5	2092	3.10	15.94	1.14	22.179	43.49	475	19.1	21.03	14.70	11.73	69.89	79.8	1775	.038	.088	.000049	3.67	3.75
5	2089	3.10	15.96	1.13	22.199	43.56	475	19.1	21.04	14.72	11.73	69.98	79.7	1775	.038	.096	.000047	3.68	3.76
5	2093	3.10	15.93	1.14	22.173	43.51	475	19.1	21.03	14.70	11.73	69.93	79.8	1775	.040	.099	.000049	3.64	3.77
6	2005	3.10	17.22	1.04	23.363	43.67	475	19.1	21.00	14.76	11.84	70.29	80.2	1775	.039	.115	.000051	3.49	3.75
6	2005	3.10	17.17	1.04	23.321	43.64	475	19.0	20.98	14.75	11.82	70.31	80.1	1775	.040	.110	.000047	3.66	3.76
6	2008	3.10	17.21	1.05	23.355	43.68	475	19.0	20.97	14.76	11.85	70.38	80.3	1775	.033	.085	.000048	3.69	3.75
6	2001	3.10	17.19	1.04	23.329	43.67	475	19.1	20.99	14.76	11.80	70.30	80.0	1775	.037	.118	.000047	3.64	3.75
6	2005	3.10	17.19	1.04	23.340	43.66	475	19.0	20.98	14.76	11.83	70.32	80.2	1775	.038	.107	.000045	3.60	3.75

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Figure 123. Research data; pump 1, Test J-97, sump 18, submergence 3.1 ft (Sheet 1 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
7	1898	3.10	18.67	.93	24.705	43.73	474	19.1	20.99	14.78	11.86	70.43	80.2	1775	.039	.095	.000044	3.62	3.77
7	1897	3.10	18.67	.93	24.711	43.73	474	19.0	20.98	14.78	11.85	70.46	80.2	1775	.037	.101	.000046	3.67	3.76
7	1888	3.10	18.66	.93	24.687	43.67	474	19.0	20.97	14.76	11.79	70.39	79.9	1775	.040	.109	.000048	3.69	3.77
7	1890	3.10	18.67	.93	24.700	43.73	474	19.0	20.97	14.78	11.80	70.48	79.9	1775	.036	.087	.000042	3.71	3.78
7	1890	3.10	18.69	.93	24.721	43.64	474	19.0	20.95	14.75	11.81	70.40	80.1	1775	.032	.084	.000041	3.68	3.78
8	1802	3.10	19.78	.84	25.732	43.72	476	19.0	21.06	14.77	11.72	70.17	79.4	1775	.038	.085	.000047	3.71	3.76
8	1804	3.10	19.76	.84	25.714	43.69	476	19.0	21.04	14.77	11.73	70.19	79.4	1775	.043	.124	.000048	3.68	3.75
8	1805	3.10	19.76	.85	25.713	43.71	475	19.0	21.00	14.77	11.73	70.35	79.4	1775	.039	.100	.000041	3.68	3.75
8	1805	3.10	19.79	.85	25.737	43.72	476	19.0	21.04	14.77	11.74	70.23	79.5	1775	.038	.096	.000049	3.64	3.76
8	1800	3.10	19.75	.84	25.695	43.64	476	19.1	21.04	14.75	11.69	70.09	79.3	1775	.037	.092	.000046	3.64	3.75
9	1703	3.10	20.93	.75	26.791	43.70	477	19.1	21.17	14.77	11.54	69.77	78.1	1775	.034	.096	.000044	3.68	3.77
9	1707	3.10	20.93	.76	26.789	43.71	477	19.1	21.16	14.77	11.56	69.81	78.2	1775	.035	.101	.000043	3.68	3.77
9	1706	3.10	20.95	.76	26.811	43.69	477	19.1	21.16	14.77	11.56	69.80	78.3	1775	.035	.086	.000046	3.70	3.77
9	1700	3.10	20.94	.75	26.789	43.69	477	19.1	21.15	14.77	11.51	69.81	78.0	1775	.040	.100	.000045	3.68	3.78
9	1703	3.10	20.96	.75	26.821	43.71	477	19.1	21.15	14.77	11.55	69.84	78.2	1775	.036	.101	.000043	3.70	3.78
10	1601	3.10	21.94	.66	27.708	43.63	477	19.0	21.10	14.75	11.21	69.88	76.0	1775	.037	.089	.000050	3.68	3.78
10	1597	3.10	21.89	.66	27.657	43.55	477	19.0	21.09	14.72	11.17	69.80	75.9	1775	.039	.098	.000048	3.67	3.78
10	1599	3.10	21.91	.66	27.675	43.55	477	19.0	21.09	14.72	11.19	69.79	76.0	1775	.040	.103	.000048	3.68	3.79
10	1597	3.10	21.91	.66	27.675	43.57	477	19.0	21.08	14.73	11.18	69.84	75.9	1775	.040	.099	.000051	3.67	3.80
10	1599	3.10	21.91	.66	27.676	43.54	477	19.0	21.08	14.72	11.19	69.79	76.0	1775	.040	.093	.000048	3.68	3.79
11	1496	3.10	22.46	.58	28.144	42.98	477	18.9	20.90	14.52	10.64	69.49	73.3	1775	.040	.110	.000058	3.67	3.80
11	1494	3.10	22.47	.58	28.152	42.99	476	18.9	20.89	14.53	10.63	69.55	73.2	1775	.042	.115	.000053	3.63	3.83
11	1496	3.10	22.44	.58	28.120	42.93	476	18.9	20.89	14.51	10.63	69.46	73.3	1775	.041	.125	.000054	3.66	3.79
11	1493	3.10	22.42	.58	28.099	42.92	476	18.9	20.89	14.50	10.61	69.44	73.1	1775	.042	.122	.000057	3.50	3.79
11	1494	3.10	22.45	.58	28.129	42.96	476	18.9	20.90	14.52	10.62	69.47	73.2	1775	.041	.110	.000060	3.64	3.78
12	1399	3.10	22.78	.51	28.390	42.17	476	18.8	20.78	14.25	10.04	68.59	70.4	1775	.052	.153	.000074	3.65	3.83
12	1395	3.10	22.77	.50	28.379	42.18	476	18.8	20.79	14.25	10.01	68.58	70.2	1775	.048	.131	.000070	3.62	3.82
12	1395	3.10	22.74	.51	28.346	42.08	476	18.8	20.77	14.22	10.00	68.48	70.3	1775	.045	.147	.000070	3.57	3.84
12	1396	3.10	22.70	.51	28.311	42.05	476	18.8	20.76	14.21	9.99	68.45	70.3	1775	.048	.161	.000073	3.58	3.81
12	1397	3.10	22.73	.51	28.345	42.11	476	18.8	20.76	14.23	10.01	68.54	70.4	1775	.048	.156	.000072	3.62	3.82

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Figure 123. (Sheet 2 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1295	3.10	22.73	.43	28.269	40.78	476	18.6	20.51	13.78	9.25	67.20	67.1	1775	.056	.198	.000093	3.59	3.87
13	1303	3.10	22.76	.44	28.310	40.90	476	18.6	20.53	13.82	9.33	67.32	67.5	1775	.058	.180	.000089	3.60	3.86
13	1298	3.10	22.74	.44	28.285	40.80	476	18.6	20.53	13.79	9.28	67.17	67.3	1775	.059	.163	.000100	3.64	3.87
13	1297	3.10	22.74	.44	28.278	40.79	476	18.6	20.53	13.78	9.27	67.16	67.2	1775	.060	.176	.000091	3.60	3.91
13	1300	3.10	22.78	.44	28.324	40.98	476	18.6	20.57	13.85	9.31	67.33	67.2	1775	.059	.183	.000093	3.62	3.86
14	1198	3.10	22.69	.37	28.165	39.72	475	18.4	20.35	13.42	8.53	65.97	63.5	1775	.072	.247	.000122	3.53	3.91
14	1197	3.10	22.70	.37	28.172	39.74	475	18.4	20.35	13.43	8.53	66.00	63.5	1775	.075	.239	.000132	3.56	3.93
14	1202	3.10	22.70	.37	28.178	39.69	475	18.4	20.35	13.41	8.56	65.91	63.8	1775	.079	.256	.000126	3.53	3.98
14	1199	3.10	22.72	.37	28.199	39.76	476	18.4	20.37	13.44	8.55	65.97	63.6	1775	.076	.242	.000127	3.50	3.97
14	1202	3.10	22.77	.38	28.250	39.85	476	18.5	20.38	13.47	8.59	66.07	63.8	1775	.075	.265	.000123	3.55	3.92
15	1105	3.10	23.00	.32	28.418	39.49	476	18.4	20.35	13.35	7.94	65.60	59.5	1775	.087	.264	.000136	3.35	4.04
15	1107	3.10	23.03	.32	28.448	39.52	476	18.4	20.33	13.36	7.96	65.71	59.6	1775	.089	.324	.000134	1.94	4.04
15	1106	3.10	23.05	.32	28.470	39.59	476	18.4	20.36	13.38	7.96	65.72	59.5	1775	.087	.291	.000127	3.44	4.03
15	1106	3.10	23.05	.32	28.474	39.54	476	18.4	20.35	13.36	7.96	65.66	59.6	1775	.088	.238	.000138	3.47	4.07
15	1104	3.10	23.05	.32	28.473	39.54	476	18.4	20.36	13.36	7.95	65.64	59.5	1775	.087	.313	.000130	3.45	4.14
16	999	3.10	23.84	.26	29.199	39.85	477	18.6	20.53	13.47	7.37	65.60	54.7	1775	.093	.281	.000141	2.71	4.35
16	1002	3.10	23.82	.26	29.181	39.79	477	18.6	20.53	13.45	7.39	65.50	55.0	1775	.099	.283	.000141	2.17	4.31
16	999	3.10	23.83	.26	29.190	39.84	477	18.6	20.54	13.46	7.37	65.54	54.8	1775	.095	.269	.000133	3.17	4.28
16	998	3.10	23.82	.26	29.184	39.81	477	18.6	20.54	13.46	7.36	65.51	54.7	1775	.093	.319	.000133	1.25	4.25
16	998	3.10	23.86	.26	29.221	39.86	477	18.6	20.54	13.47	7.37	65.58	54.7	1775	.101	.284	.000137	1.43	4.25
17	898	3.10	24.68	.21	29.993	40.32	477	18.6	20.62	13.63	6.81	66.09	50.0	1775	.098	.279	.000149	2.63	4.43
17	899	3.10	24.66	.21	29.971	40.30	476	18.6	20.59	13.62	6.82	66.14	50.0	1775	.108	.274	.000144	1.24	4.47
17	902	3.10	24.67	.21	29.981	40.30	477	18.6	20.60	13.62	6.84	66.10	50.2	1775	.109	.288	.000151	2.16	4.54
17	900	3.10	24.65	.21	29.962	40.32	477	18.6	20.60	13.63	6.82	66.15	50.0	1775	.104	.276	.000137	.15	4.40
17	899	3.10	24.70	.21	30.015	40.40	477	18.6	20.62	13.65	6.82	66.22	49.9	1775	.104	.462	.000145	2.84	4.48

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Figure 123. (Sheet 3 of 3)

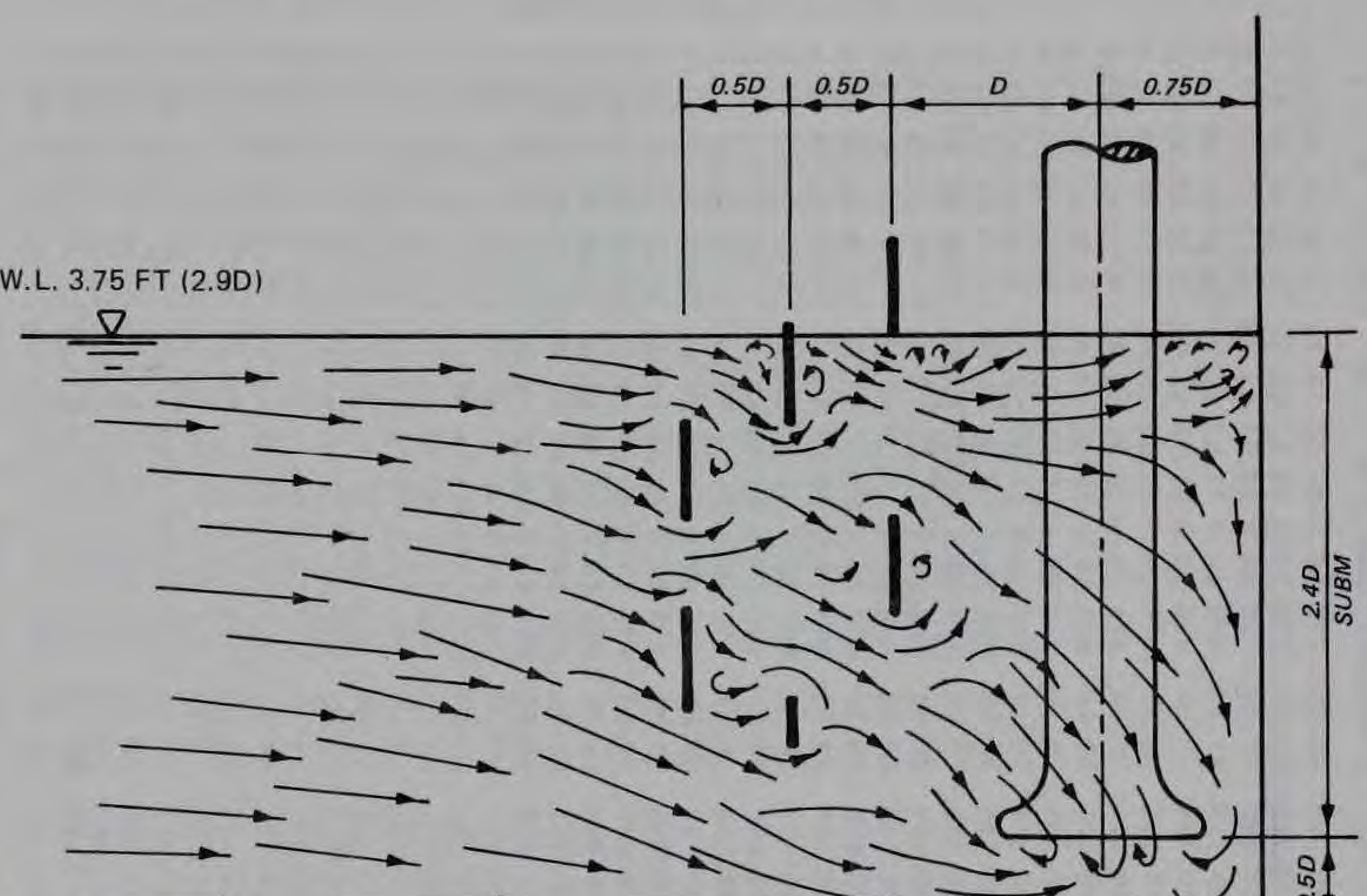

Figure 124. Base sump flow pattern for pump 1 SVS, type 56 pump bell, submergence 3.1 ft (2.4D), discharge 1,900 gpm, $(Q/g^{1/2}D^{5/2}) = 0.40$, base sump type 18

Pumps	Run	Sump	Submergence
100	J95	018	2.5

Date 06 Jul 82, Time 0830, Air Temp 76° F, Water Temp 78° F, Barometric Pressure 29.84 in. Hg.

01 IFV 1/16 in. diam, CW at 8 to 6 o'clock, IBWV, 1/16 in. diam CCW at 6 o'clock. No surface vortices.

02 NSCE (No Significant Change Except) vortices becoming smaller and occurring less frequently.

03 Same as #2, except water surface more calm.

04 NSCE, IBWV gone. IFV is now smaller, approximately 1/32 in. diam.

05 NSC.

06 NSCE IFV getting smaller, occurring less frequently, and mostly at 6 o'clock.

07 NSCE, IFV appearing less frequently (approximately 30-sec intervals).

Date 06 Jul 82, Time 1010, Air Temp 84° F, Water Temp 78° F, Barometric Pressure 29.84 in. Hg.

09 IFV gone. Water surface becoming more calm.

10 NSCE, flashing appearing on tip of blade, possible cavitation.

11 NSC.

12 NSCE flashing on impeller blade becoming larger.

13 Same as #12.

14 Same as #13.

15 NSCE flashing becoming much larger. No vortices.

16 Same as #15.

17 NSCE air spray from bell reaching approximately 4 in. below bell.

Date 06 Jul 82, Time 1110, Air Temp 88° F, Water Temp 79° F, Barometric Pressure 29.86 in. Hg.

Figure 125. Visual observation notes, run J-95

Pumps Run Sump Submergence
100 J97 018

Date 08 Jul 82, Time 0800, Air Temp 75° F, Water Temp 79° F, Barometric Pressure 29.92 in. Hg.

01 IFV CW/CCW, mostly CW, at 3 to 6 o'clock, approximately 1/16 in. diam IBWV CCW at 6 o'clock. Water surface has no vortices but just enough surface. All vortices approximately 1/16 in. diam.

02 NSCE (No Significant Change Except) IFV occurring 7 to 11 o'clock and all vortices becoming smaller.

03 IBWV gone. The IFV now CW, approximately 1/32 in. diam and occurring mostly at 4 to 5 o'clock. Water surface more calm with no vortices or recognizable circular rotational patterns.

04 NSC.

05 NSCE IFV becoming smaller, now approximately 1/64 in. diam.

06 NSC.

07 IFV gone. All vortices gone. Surface relatively still.

Date 08 Jul 82, Time 0900, Air Temp 80° F, Water Temp 79° F, Barometric Pressure 29.92 in. Hg.

08 NSCE flashing appearing on tip of pump impeller blade, possible cavitation.

09-12 NSCE flashing on impeller blade becoming larger.

13-16 Flashing on blade becoming much larger.

17 NSCE spray expulsion from pump bell reaching approximately 4 in. below bell intake.

Date 08 Jul 82, Time 1000, Air Temp 84° F, Water Temp 80° F, Barometric Pressure 29.93 in. Hg.

Figure 126. Visual observation notes, run J-97

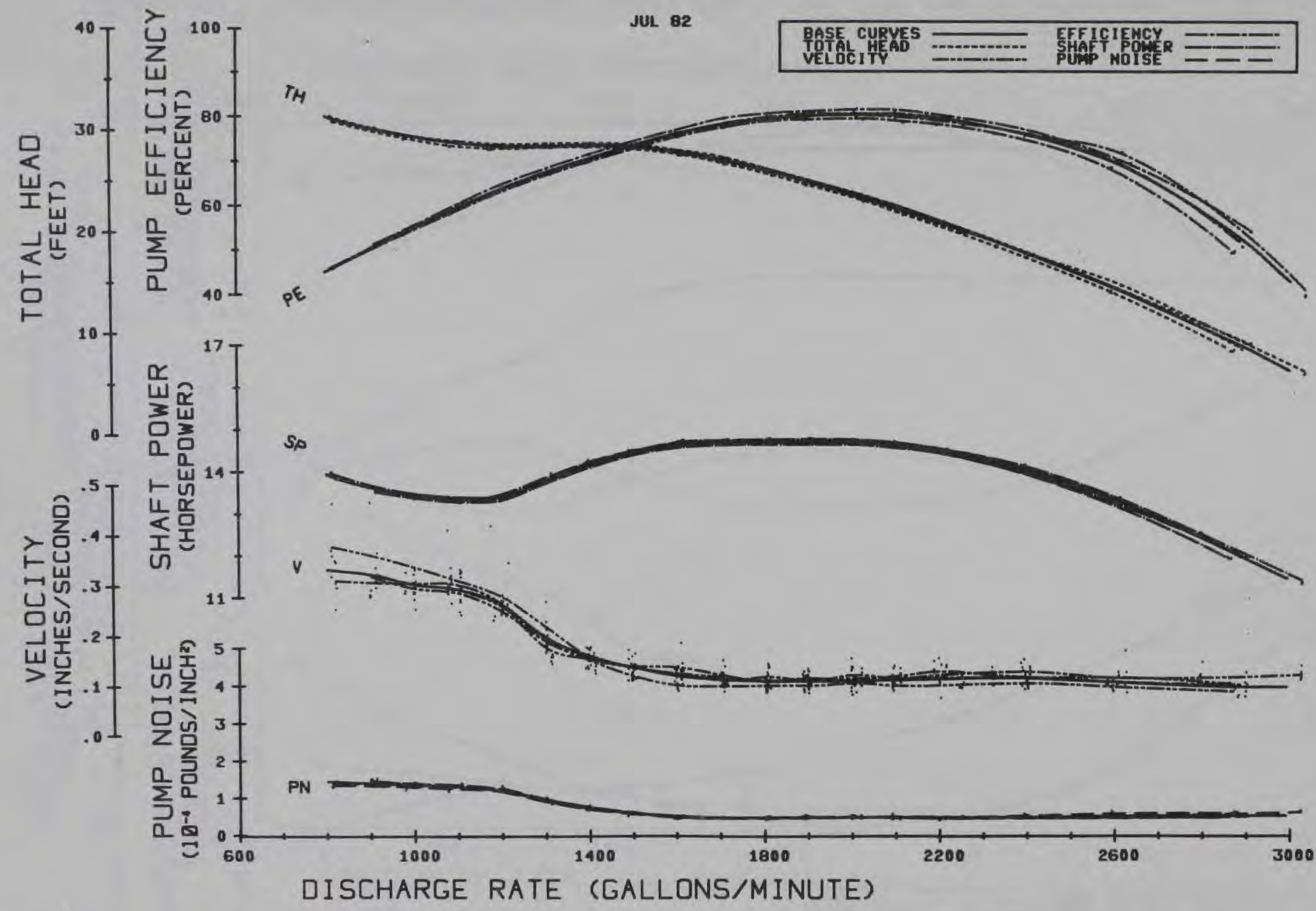

Figure 127. Performance characteristic curves; pump 1, sump 18, submergence 3.1 ft

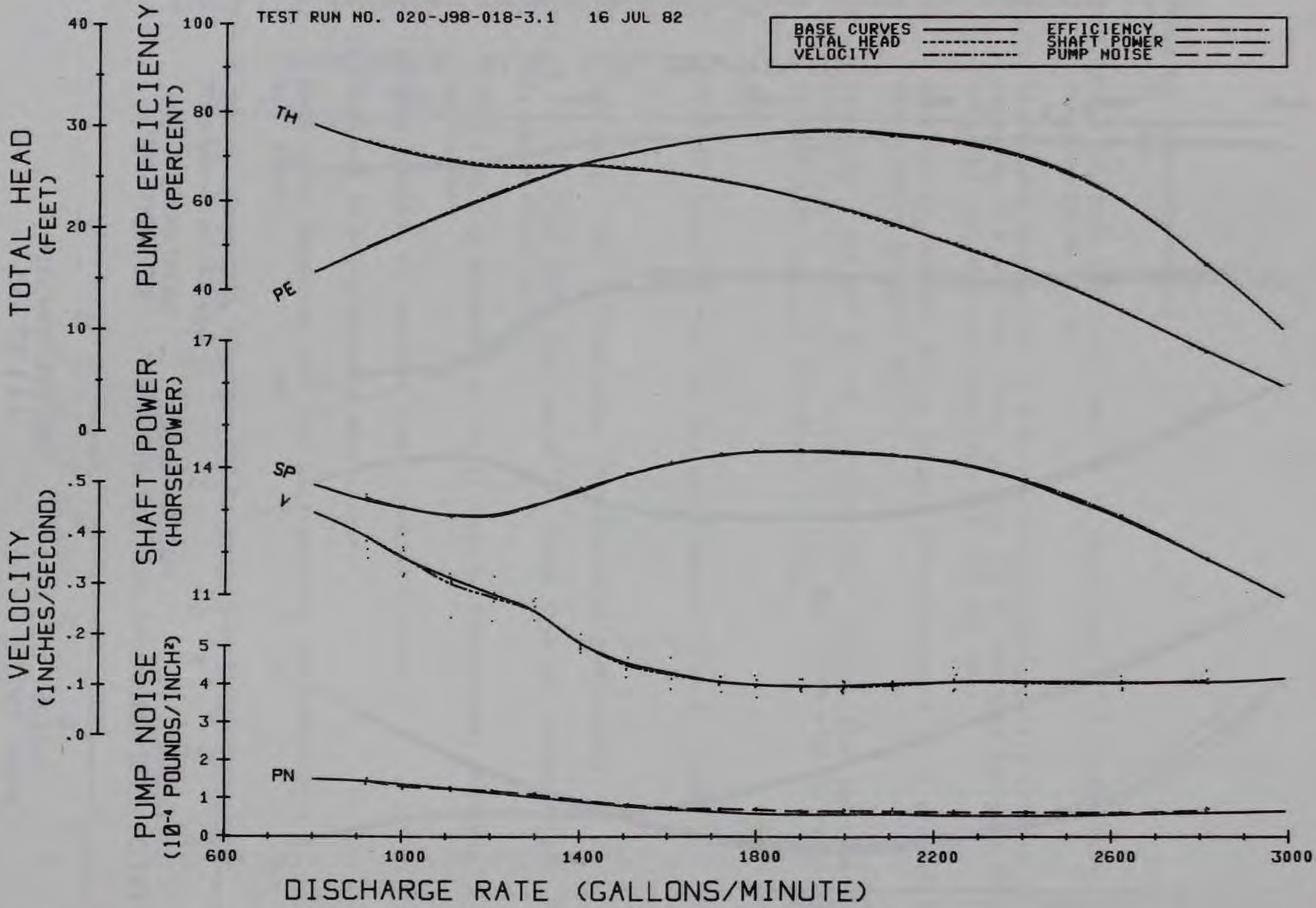

Figure 128. Performance characteristic curves; pump 2, Test J-98, sump 18, submergence 3.1 ft

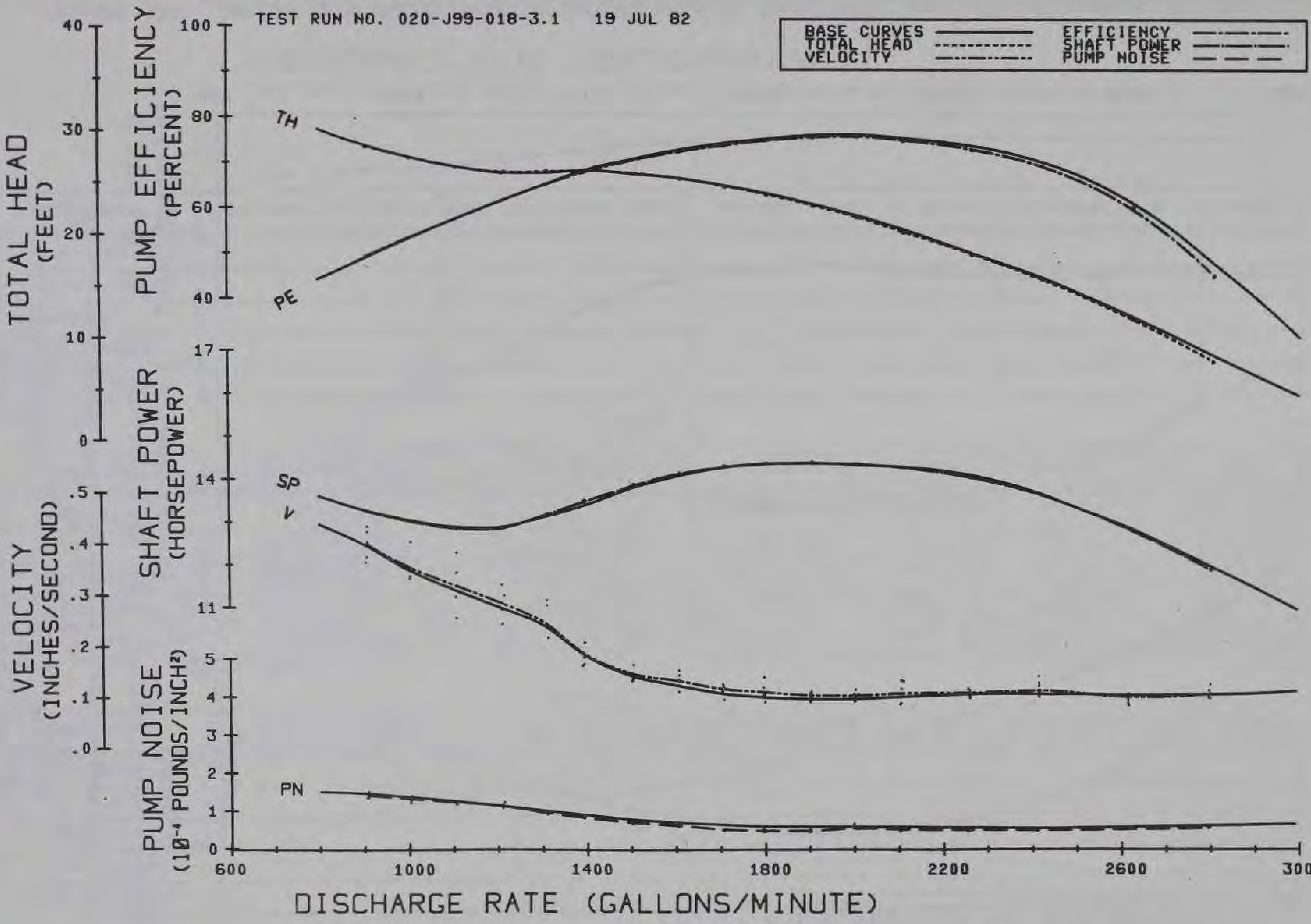

Figure 129. Performance characteristic curves; pump 2, Test J-99, sump 18, submergence 3.1 ft

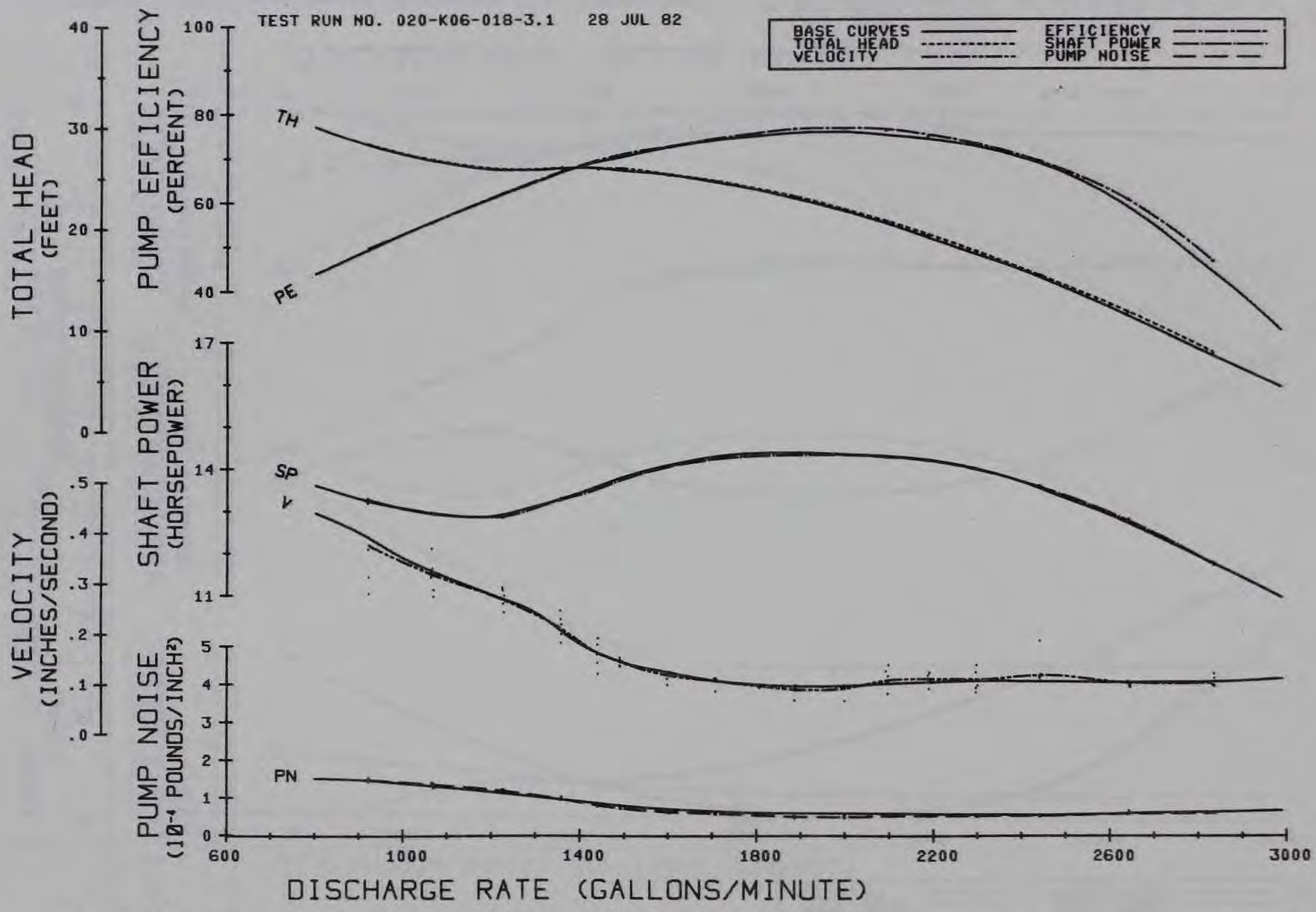

Figure 130. Performance characteristic curves; pump 2, Test K-06, sump 18, submergence 3.1 ft

TEST RUN NO. 020-J98-018-3.1   16 JUL 82   ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	.0000 IPS*GPM	3.1651 IPS*GPM	.135357 IPS	1500 GPM	.091679 IPS	1990 GPM
TOTAL HEAD	20.91 FT*GPM	45.10 FT*GPM	25.69360 FT	1500 GPM	14.01910 FT	2500 GPM
PUMP NOISE	.00584 PSI*GPM	.00000 PSI*GPM	.0000791 PSI	1500 GPM	.0000594 PSI	2500 GPM
SHAFT POWER	13.282 HP*GPM	3.917 HP*GPM	14.41260 HP	1880 GPM	13.36250 HP	2500 GPM
PUMP EFFICIENCY	.00 % * GPM	360.31 % * GPM	75.49070 %	1960 GPM	65.97230 %	2500 GPM

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

Figure 131. Statistical comparison pump 2, Test J-98, sump 18, submergence 3.1 ft

TEST RUN NO. 020-J99-018-3.1   19 JUL 82   ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	5.1307 IPS*GPM	.0000 IPS*GPM	.143749 IPS	1500 GPM	.099636 IPS	1930 GPM
TOTAL HEAD	.00 FT*GPM	190.05 FT*GPM	25.57970 FT	1500 GPM	13.76660 FT	2500 GPM
PUMP NOISE	.00000 PSI*GPM	.00919 PSI*GPM	.0000674 PSI	1500 GPM	.0000440 PSI	1830 GPM
SHAFT POWER	2.567 HP*GPM	29.469 HP*GPM	14.38000 HP	1870 GPM	13.28810 HP	2500 GPM
PUMP EFFICIENCY	.00 % * GPM	789.36 % * GPM	75.27090 %	1970 GPM	65.13370 %	2500 GPM

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

Figure 132. Statistical comparison pump 2, Test J-99, sump 18, submergence 3.1 ft

TEST RUN NO. 020-K06-018-3.1   28 JUL 82   ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	2.4676 IPS*GPM	3.0937 IPS*GPM	.137491 IPS	1500 GPM	.085018 IPS	1920 GPM
TOTAL HEAD	120.18 FT*GPM	1.45 FT*GPM	25.74320 FT	1500 GPM	14.17730 FT	2500 GPM
PUMP NOISE	.00000 PSI*GPM	.00779 PSI*GPM	.0000677 PSI	1500 GPM	.0000452 PSI	1920 GPM
SHAFT POWER	2.067 HP*GPM	48.348 HP*GPM	14.33380 HP	1910 GPM	13.34420 HP	2500 GPM
PUMP EFFICIENCY	505.92 % * GPM	.67 % * GPM	76.61770 %	1960 GPM	66.91520 %	2500 GPM

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

Figure 133. Statistical comparison pump 2, Test K-06, sump 18, submergence 3.1 ft

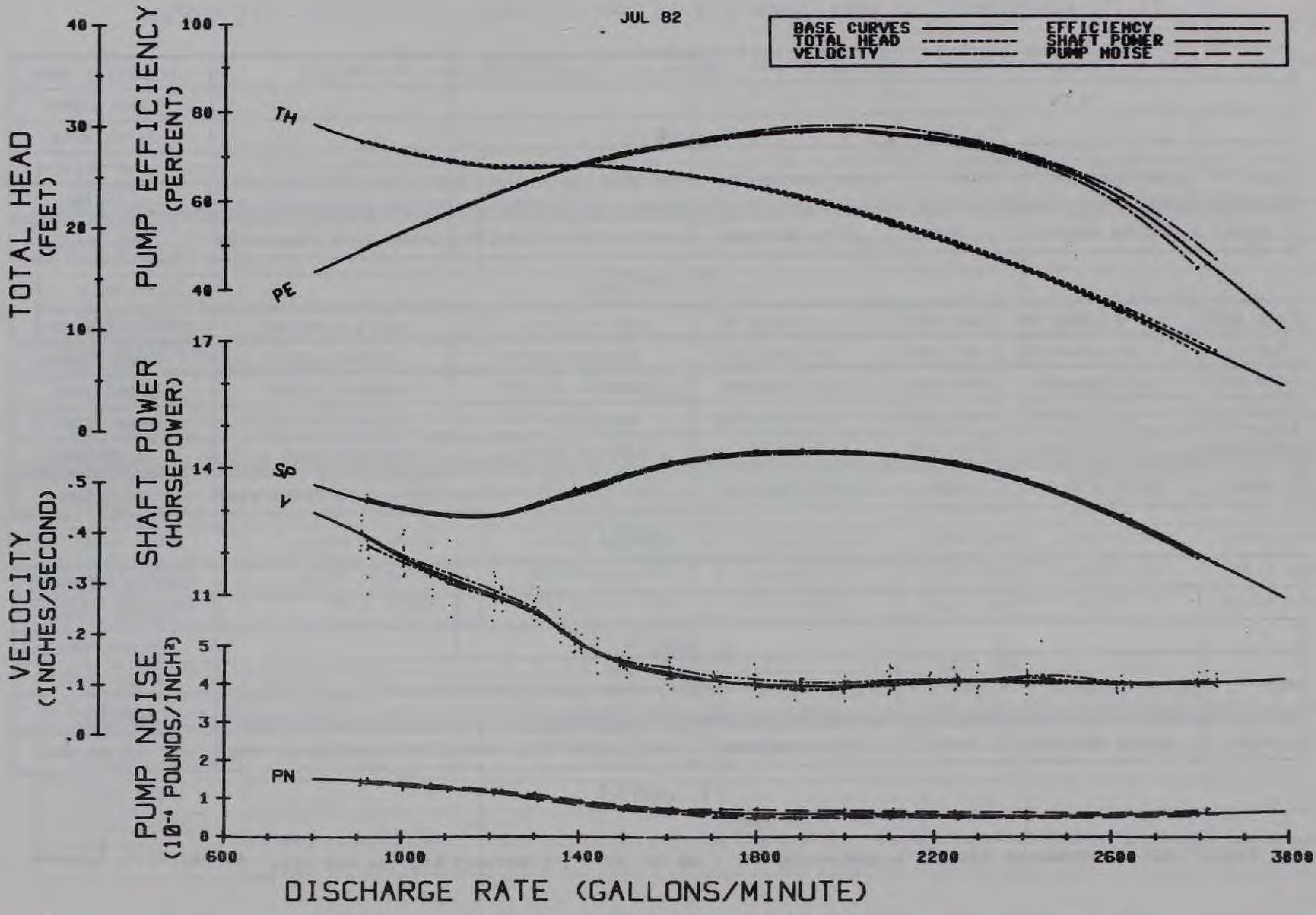

Figure 134. Performance characteristic curves; pump 2, sump 18, submergence 3.1 ft

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	2811	3.10	.45	2.05	7.606	34.99	479	17.4	19.36	11.83	5.41	61.09	45.7	1775	.032	.103	.000066	3.42	3.72
1	2818	3.10	.41	2.06	7.577	34.99	478	17.4	19.35	11.83	5.40	61.13	45.6	1775	.035	.106	.000068	3.01	3.72
1	2815	3.10	.34	2.06	7.501	34.86	479	17.4	19.33	11.78	5.34	60.94	45.3	1775	.031	.098	.000060	3.60	3.75
1	2813	3.10	.39	2.05	7.543	34.92	479	17.4	19.36	11.80	5.36	60.97	45.5	1775	.038	.123	.000072	3.32	3.73
1	2820	3.10	.41	2.06	7.581	34.98	479	17.4	19.37	11.82	5.40	61.05	45.7	1775	.037	.099	.000069	3.60	3.73
2	2625	3.10	4.77	1.79	11.660	38.02	479	17.8	19.79	12.85	7.74	64.93	60.2	1775	.029	.088	.000058	3.45	3.69
2	2621	3.10	4.78	1.78	11.664	37.99	479	17.8	19.78	12.84	7.73	64.92	60.2	1775	.036	.112	.000060	3.29	3.68
2	2625	3.10	4.71	1.79	11.599	37.94	479	17.8	19.75	12.82	7.70	64.91	60.0	1775	.033	.084	.000059	3.51	3.67
2	2623	3.10	4.78	1.79	11.670	37.98	479	17.8	19.78	12.83	7.74	64.89	60.3	1775	.035	.102	.000054	3.45	3.68
2	2622	3.10	4.80	1.78	11.683	38.04	479	17.8	19.78	12.86	7.74	64.98	60.2	1775	.041	.102	.000058	3.61	3.70
3	2408	3.10	9.02	1.50	15.631	40.52	479	18.1	20.18	13.70	9.52	67.88	69.5	1775	.044	.125	.000061	3.28	3.70
3	2412	3.10	9.02	1.51	15.636	40.53	479	18.1	20.16	13.70	9.53	67.96	69.6	1775	.030	.099	.000060	3.40	3.68
3	2411	3.10	9.02	1.51	15.627	40.60	479	18.2	20.18	13.72	9.52	68.00	69.4	1775	.035	.100	.000061	3.61	3.70
3	2406	3.10	9.01	1.50	15.618	40.53	479	18.1	20.17	13.70	9.50	67.92	69.3	1775	.032	.092	.000063	3.60	3.70
3	2407	3.10	9.03	1.50	15.636	40.59	479	18.2	20.19	13.72	9.52	67.96	69.4	1775	.030	.076	.000058	3.54	3.69
4	2250	3.10	11.78	1.31	18.194	41.85	478	18.3	20.32	14.14	10.35	69.62	73.2	1775	.044	.116	.000058	3.33	3.68
4	2244	3.10	11.73	1.31	18.144	41.86	478	18.3	20.34	14.15	10.29	69.58	72.8	1775	.037	.107	.000066	3.60	3.69
4	2247	3.10	11.79	1.31	18.204	41.89	478	18.3	20.33	14.16	10.34	69.63	73.1	1775	.032	.087	.000060	3.36	3.71
4	2243	3.10	11.77	1.31	18.177	41.84	478	18.3	20.33	14.14	10.31	69.56	72.9	1775	.046	.130	.000061	3.49	3.69
4	2243	3.10	11.80	1.31	18.212	41.83	478	18.3	20.31	14.14	10.33	69.59	73.1	1775	.031	.084	.000060	3.60	3.70
5	2107	3.10	13.75	1.15	20.009	42.35	480	18.4	20.45	14.31	10.66	69.99	74.5	1775	.030	.100	.000070	3.49	3.67
5	2107	3.10	13.75	1.15	20.009	42.32	480	18.4	20.45	14.30	10.66	69.94	74.5	1775	.032	.103	.000060	3.58	3.66
5	2108	3.10	13.75	1.15	20.011	42.31	479	18.4	20.42	14.30	10.66	70.03	74.6	1775	.031	.086	.000058	3.50	3.68
5	2106	3.10	13.77	1.15	20.024	42.37	479	18.4	20.44	14.32	10.66	70.07	74.5	1775	.035	.092	.000060	3.41	3.67
5	2101	3.10	13.80	1.15	20.046	42.35	479	18.4	20.42	14.31	10.65	70.08	74.4	1775	.038	.098	.000062	3.50	3.68
6	1993	3.10	15.38	1.03	21.511	42.53	479	18.4	20.41	14.37	10.84	70.41	75.4	1775	.027	.083	.000062	3.44	3.67
6	1998	3.10	15.37	1.04	21.506	42.57	479	18.4	20.42	14.39	10.86	70.44	75.5	1775	.028	.087	.000068	3.45	3.66
6	2001	3.10	15.36	1.04	21.508	42.60	479	18.4	20.44	14.40	10.88	70.43	75.6	1775	.030	.100	.000066	3.49	3.67
6	1995	3.10	15.39	1.03	21.529	42.60	479	18.4	20.44	14.40	10.86	70.44	75.4	1775	.031	.079	.000065	3.55	3.65
6	1996	3.10	15.35	1.03	21.489	42.52	479	18.4	20.42	14.37	10.84	70.38	75.4	1775	.028	.102	.000062	3.55	3.65

TEST RUN NO. 020-J98-018-3.1   16 JUL 82

Figure 135. Research data; pump 2, Test J-98, sump 18, submergence 3.1 ft
(Sheet 1 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
7	1900	3.10	16.59	.94	22.628	42.70	479	18.4	20.44	14.43	10.87	70.61	75.3	1775	.032	.086	.000066	3.54	3.67
7	1903	3.10	16.57	.94	22.615	42.67	480	18.4	20.46	14.42	10.88	70.50	75.4	1775	.031	.090	.000059	3.57	3.68
7	1898	3.10	16.57	.93	22.606	42.63	480	18.4	20.46	14.41	10.85	70.41	75.3	1775	.031	.106	.000[illegible]63	3.56	3.67
7	1905	3.10	16.56	.94	22.603	42.62	479	18.4	20.43	14.40	10.89	70.48	75.6	1775	.029	.106	.000060	3.49	3.65
7	1901	3.10	16.58	.94	22.624	42.63	479	18.4	20.44	14.41	10.87	70.48	75.5	1775	.029	.082	.000064	3.57	3.67
8	1801	3.10	17.75	.84	23.695	42.59	480	18.4	20.48	14.40	10.79	70.28	74.9	1775	.028	.071	.000071	3.58	3.68
8	1803	3.10	17.74	.84	23.689	42.60	481	18.4	20.50	14.40	10.80	70.23	75.0	1775	.033	.094	.000066	3.58	3.68
8	1800	3.10	17.74	.84	23.688	42.59	481	18.4	20.51	14.39	10.78	70.19	74.9	1775	.034	.105	.000066	3.55	3.69
8	1796	3.10	17.70	.84	23.644	42.52	480	18.4	20.46	14.37	10.73	70.24	74.7	1775	.030	.114	.000068	3.55	3.68
8	1798	3.10	17.76	.84	23.702	42.63	480	18.4	20.49	14.41	10.77	70.31	74.8	1775	.033	.091	.000066	3.56	3.68
9	1720	3.10	18.54	.77	24.410	42.41	482	18.3	20.48	14.33	10.62	69.98	74.1	1775	.033	.112	.000068	3.52	3.64
9	1721	3.10	18.51	.77	24.386	42.35	482	18.3	20.49	14.31	10.61	69.85	74.1	1775	.032	.082	.000070	3.56	3.64
9	1718	3.10	18.54	.77	24.409	42.38	481	18.3	20.48	14.32	10.60	69.95	74.0	1775	.034	.112	.000064	3.51	3.64
9	1715	3.10	18.51	.76	24.379	42.26	481	18.3	20.45	14.28	10.57	69.85	74.0	1775	.032	.096	.000069	3.52	3.65
9	1719	3.10	18.52	.77	24.393	42.28	481	18.3	20.42	14.29	10.60	69.98	74.2	1775	.037	.100	.000070	3.43	3.64
10	1609	3.10	19.38	.67	25.155	41.72	481	18.2	20.38	14.10	10.23	69.19	72.6	1775	.038	.107	.000073	3.56	3.66
10	1607	3.10	19.43	.67	25.201	41.80	482	18.2	20.39	14.13	10.24	69.28	72.5	1775	.034	.087	.000070	3.57	3.67
10	1607	3.10	19.40	.67	25.174	41.77	482	18.2	20.39	14.12	10.23	69.24	72.5	1775	.044	.148	.000066	3.57	3.68
10	1608	3.10	19.42	.67	25.190	41.81	482	18.2	20.39	14.13	10.24	69.30	72.4	1775	.045	.119	.000065	3.50	3.67
10	1607	3.10	19.40	.67	25.173	41.78	482	18.2	20.39	14.12	10.23	69.24	72.4	1775	.039	.118	.000068	3.56	3.68
11	1510	3.10	19.95	.59	25.644	40.98	482	18.1	20.29	13.85	9.79	68.26	70.7	1775	.048	.136	.000078	3.54	3.67
11	1506	3.10	19.97	.59	25.667	41.00	482	18.1	20.28	13.86	9.77	68.33	70.5	1775	.045	.126	.000079	3.51	3.67
11	1505	3.10	19.94	.59	25.631	40.93	482	18.1	20.29	13.83	9.75	68.17	70.5	1775	.043	.110	.000079	3.54	3.67
11	1507	3.10	19.99	.59	25.684	40.98	483	18.1	20.30	13.85	9.78	68.22	70.6	1775	.044	.124	.000074	3.55	3.70
11	1511	3.10	20.00	.59	25.698	41.00	482	18.1	20.30	13.86	9.82	68.28	70.8	1775	.045	.148	.000081	3.57	3.69
12	1403	3.10	20.36	.51	25.978	40.00	483	18.0	20.18	13.52	9.21	67.00	68.1	1775	.059	.167	.000088	3.53	3.70
12	1404	3.10	20.35	.51	25.969	39.94	482	18.0	20.16	13.50	9.22	66.98	68.3	1775	.058	.158	.000090	3.53	3.69
12	1402	3.10	20.35	.51	25.966	39.95	483	18.0	20.16	13.50	9.20	66.99	68.2	1775	.059	.173	.000092	3.54	3.68
12	1404	3.10	20.32	.51	25.936	39.86	482	18.0	20.14	13.47	9.21	66.88	68.3	1775	.057	.164	.000088	3.49	3.67
12	1404	3.10	20.35	.51	25.962	39.94	482	18.0	20.13	13.50	9.22	67.07	68.3	1775	.059	.194	.000091	3.51	3.68

TEST RUN NO. 020-J98-018-3.1   16 JUL 82

Figure 135. (Sheet 2 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1302	3.10	20.38	.44	25.920	38.75	482	17.8	19.97	13.10	8.53	65.56	65.1	1775	.078	.265	.000109	3.47	3.73
13	1296	3.10	20.33	.44	25.873	38.69	483	17.8	19.99	13.08	8.48	65.43	64.8	1775	.085	.260	.000109	3.47	3.74
13	1301	3.10	20.36	.44	25.902	38.73	483	17.8	19.98	13.09	8.52	65.50	65.1	1775	.078	.248	.000111	3.49	3.73
13	1299	3.10	20.40	.44	25.942	38.81	483	17.8	20.01	13.12	8.52	65.55	64.9	1775	.081	.240	.000104	3.49	3.73
13	1298	3.10	20.38	.44	25.919	38.79	483	17.8	19.99	13.11	8.51	65.58	64.9	1775	.084	.221	.000105	3.46	3.74
14	1209	3.10	20.45	.38	25.930	38.02	483	17.8	19.92	12.85	7.92	64.51	61.7	1775	.095	.276	.000115	3.36	3.75
14	1209	3.10	20.49	.38	25.970	38.04	483	17.8	19.91	12.86	7.94	64.57	61.7	1775	.096	.308	.000111	3.45	3.79
14	1203	3.10	20.41	.38	25.893	37.97	483	17.7	19.92	12.83	7.88	64.41	61.4	1775	.086	.221	.000119	3.36	3.81
14	1210	3.10	20.44	.38	25.921	38.04	483	17.8	19.91	12.86	7.93	64.57	61.7	1775	.090	.264	.000115	3.43	3.78
14	1206	3.10	20.43	.38	25.910	37.96	483	17.7	19.90	12.83	7.90	64.46	61.6	1775	.098	.259	.000117	3.45	3.76
15	1111	3.10	21.02	.32	26.449	38.06	483	17.8	19.89	12.86	7.43	64.67	57.7	1775	.094	.304	.000117	3.40	3.86
15	1111	3.10	20.98	.32	26.400	37.93	483	17.7	19.88	12.82	7.41	64.49	57.8	1775	.091	.228	.000120	3.31	3.79
15	1111	3.10	21.02	.32	26.447	38.02	482	17.8	19.89	12.85	7.43	64.60	57.8	1775	.103	.298	.000126	3.31	3.79
15	1107	3.10	21.04	.32	26.464	38.03	483	17.7	19.89	12.85	7.41	64.62	57.6	1775	.102	.314	.000124	3.31	3.81
15	1110	3.10	21.01	.32	26.430	38.04	482	17.8	19.89	12.86	7.42	64.65	57.7	1775	.107	.306	.000125	3.35	3.80
16	1003	3.10	22.00	.26	27.365	38.59	484	17.8	20.00	13.04	6.94	65.23	53.2	1775	.114	.360	.000126	3.10	3.96
16	1002	3.10	21.97	.26	27.335	38.60	483	17.8	19.97	13.05	6.92	65.32	53.1	1775	.111	.309	.000124	3.06	4.00
16	1000	3.10	21.99	.26	27.348	38.60	483	17.8	19.98	13.05	6.91	65.30	53.0	1775	.114	.392	.000129	3.00	4.01
16	1003	3.10	22.02	.26	27.386	38.68	483	17.8	19.99	13.07	6.94	65.39	53.1	1775	.118	.366	.000122	3.06	3.91
16	1006	3.10	21.99	.26	27.354	38.64	483	17.8	19.98	13.06	6.95	65.37	53.3	1775	.122	.314	.000133	3.07	4.04
17	919	3.10	22.91	.22	28.235	39.30	484	17.9	20.09	13.28	6.56	66.12	49.4	1775	.122	.471	.000140	2.93	4.15
17	920	3.10	22.94	.22	28.260	39.24	483	17.9	20.07	13.26	6.58	66.09	49.6	1775	.125	.379	.000141	2.92	4.19
17	923	3.10	22.97	.22	28.291	39.29	483	17.9	20.07	13.28	6.60	66.14	49.7	1775	.126	.363	.000150	2.83	4.26
17	924	3.10	22.91	.22	28.240	39.26	483	17.9	20.08	13.27	6.60	66.08	49.7	1775	.124	.345	.000150	2.82	4.27
17	918	3.10	22.98	.22	28.307	39.33	483	17.9	20.07	13.29	6.57	66.21	49.4	1775	.127	.379	.000135	2.90	4.12

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Figure 135. (Sheet 3 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	2793	3.10	.36	2.02	7.485	35.00	472	15.8	17.28	11.83	5.28	68.44	44.7	1775	.034	.107	.000051	3.54	3.74
1	2797	3.10	.35	2.03	7.482	34.96	472	15.8	17.28	11.81	5.29	68.39	44.8	1775	.032	.092	.000052	3.54	3.75
1	2792	3.10	.29	2.02	7.420	35.01	472	15.8	17.26	11.83	5.24	68.55	44.3	1775	.031	.094	.000052	3.48	3.74
1	2798	3.10	.33	2.03	7.466	35.06	471	15.8	17.25	11.85	5.28	68.71	44.6	1775	.034	.120	.000055	3.61	3.74
1	2797	3.10	.33	2.03	7.463	35.00	472	15.7	17.25	11.83	5.28	68.58	44.6	1775	.035	.101	.000054	3.31	3.74
2	2611	3.10	4.66	1.77	11.532	37.90	470	16.1	17.53	12.81	7.61	73.08	59.4	1775	.026	.083	.000049	3.48	3.73
2	2616	3.10	4.67	1.78	11.547	37.90	470	16.1	17.52	12.81	7.64	73.12	59.6	1775	.035	.100	.000049	2.71	3.73
2	2611	3.10	4.64	1.77	11.510	37.84	470	16.1	17.54	12.79	7.60	72.93	59.4	1775	.041	.101	.000050	3.61	3.74
2	2612	3.10	4.67	1.77	11.542	37.83	470	16.1	17.54	12.79	7.62	72.87	59.6	1775	.031	.089	.000048	3.45	3.74
2	2614	3.10	4.65	1.77	11.528	37.84	470	16.1	17.53	12.79	7.62	72.95	59.6	1775	.028	.079	.000049	3.52	3.73
3	2410	3.10	8.77	1.51	15.385	40.35	474	16.4	18.06	13.64	9.37	75.53	68.7	1775	.041	.136	.000047	3.60	3.73
3	2410	3.10	8.76	1.51	15.375	40.36	474	16.4	18.05	13.64	9.37	75.59	68.7	1775	.037	.101	.000043	3.53	3.73
3	2411	3.10	8.78	1.51	15.393	40.35	473	16.4	18.02	13.64	9.38	75.69	68.8	1775	.033	.096	.000048	3.62	3.74
3	2410	3.10	8.77	1.51	15.379	40.29	473	16.4	17.99	13.62	9.37	75.71	68.8	1775	.043	.123	.000046	3.59	3.73
3	2410	3.10	8.76	1.51	15.375	40.37	474	16.4	18.01	13.64	9.37	75.75	68.7	1775	.038	.117	.000047	3.54	3.73
4	2256	3.10	11.40	1.32	17.822	41.51	473	16.6	18.22	14.03	10.16	77.02	72.4	1775	.036	.099	.000048	3.48	3.72
4	2251	3.10	11.40	1.31	17.821	41.52	473	16.6	18.20	14.03	10.14	77.10	72.3	1775	.036	.112	.000045	2.85	3.70
4	2255	3.10	11.35	1.32	17.776	41.47	472	16.6	18.16	14.02	10.14	77.17	72.3	1775	.032	.098	.000042	3.56	3.69
4	2257	3.10	11.39	1.32	17.817	41.58	473	16.6	18.20	14.05	10.17	77.22	72.3	1775	.041	.109	.000049	3.52	3.69
4	2256	3.10	11.40	1.32	17.829	41.58	473	16.6	18.20	14.05	10.17	77.22	72.4	1775	.033	.094	.000051	3.53	3.71
5	2101	3.10	13.69	1.15	19.934	42.20	472	16.6	18.22	14.26	10.59	78.26	74.2	1775	.046	.112	.000042	3.56	3.66
5	2107	3.10	13.72	1.15	19.971	42.24	472	16.7	18.29	14.28	10.64	78.06	74.5	1775	.036	.127	.000046	3.56	3.68
5	2098	3.10	13.74	1.14	19.991	42.25	472	16.7	18.27	14.28	10.60	78.17	74.3	1775	.029	.082	.000052	3.50	3.70
5	2102	3.10	13.72	1.15	19.966	42.20	472	16.7	18.26	14.26	10.61	78.12	74.4	1775	.041	.129	.000052	3.50	3.70
5	2101	3.10	13.69	1.15	19.940	42.19	472	16.7	18.25	14.26	10.59	78.11	74.3	1775	.032	.084	.000044	3.56	3.69
6	1996	3.10	15.22	1.03	21.358	42.45	473	16.5	18.14	14.35	10.78	79.09	75.1	1775	.031	.103	.000057	3.54	3.69
6	2007	3.10	15.20	1.05	21.353	42.41	473	16.5	18.16	14.33	10.84	78.93	75.6	1775	.037	.103	.000049	3.46	3.69
6	1996	3.10	15.24	1.03	21.376	42.50	473	16.6	18.17	14.36	10.79	79.04	75.1	1775	.034	.095	.000054	3.59	3.70
6	2000	3.10	15.25	1.04	21.388	42.49	473	16.5	18.15	14.36	10.82	79.12	75.3	1775	.034	.111	.000055	3.59	3.69
6	1997	3.10	15.24	1.03	21.376	42.47	472	16.5	18.15	14.35	10.79	79.09	75.2	1775	.030	.088	.000063	3.59	3.69

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Figure 136. Research data; pump 2, Test J-99, sump 18, submergence 3.1 ft (Sheet 1 of 3)

READ: NO.	DISC-: HARGE: GPM	SUBME-: RGENCE: FEET	STATIC: HEAD: FEET	VELOC: HEAD: FEET	TOTAL: HEAD: FEET	TORQUE: FT*LB	VOL-: TAGE: VOLT	CUR-: RENT: AMPS	MOTOR: POWER: HP	SHAFT: POWER: HP	WATER: POWER: HP	MOTOR: EFF.: %	PUMP: EFF.: %	SHAFT: SPEED: RPM	VELOCITY: RMS: IPS	VELOCITY: MAX: IPS	NOISE: RMS: PSI	PRESSURE: MIN: FEET	PRESSURE: MAX: FEET
7	1899	3.10	16.46	.94	22.503	42.64	473	16.6	18.22	14.41	10.80	79.08	75.0	1775	.029	.087	.000046	3.54	3.64
7	1902	3.10	16.45	.94	22.488	42.58	473	16.6	18.22	14.39	10.81	78.98	75.1	1775	.031	.094	.000043	3.48	3.64
7	1901	3.10	16.46	.94	22.507	42.58	473	16.6	18.21	14.39	10.82	79.02	75.2	1775	.035	.107	.000043	3.52	3.63
7	1899	3.10	16.45	.94	22.487	42.49	472	16.6	18.18	14.36	10.79	78.99	75.2	1775	.031	.101	.000044	3.48	3.64
7	1898	3.10	16.45	.93	22.485	42.47	473	16.6	18.18	14.35	10.79	78.94	75.2	1775	.032	.104	.000041	3.52	3.66
8	1798	3.10	17.61	.84	23.553	42.51	473	16.2	17.79	14.37	10.71	80.78	74.5	1775	.032	.096	.000043	3.52	3.62
8	1795	3.10	17.59	.84	23.531	42.50	472	16.2	17.79	14.36	10.68	80.71	74.4	1775	.034	.100	.000041	3.52	3.62
8	1794	3.10	17.62	.83	23.561	42.55	472	16.2	17.79	14.38	10.68	80.82	74.3	1775	.037	.115	.000046	3.48	3.62
8	1796	3.10	17.62	.84	23.560	42.54	473	16.2	17.79	14.38	10.70	80.81	74.4	1775	.046	.135	.000048	3.42	3.62
8	1798	3.10	17.59	.84	23.535	42.47	472	16.2	17.79	14.35	10.70	80.66	74.6	1775	.033	.086	.000042	3.52	3.62
9	1706	3.10	18.46	.75	24.323	42.27	473	16.2	17.79	14.29	10.49	80.32	73.4	1775	.035	.091	.000046	3.53	3.63
9	1702	3.10	18.46	.75	24.317	42.30	473	16.2	17.76	14.30	10.46	80.51	73.2	1775	.036	.107	.000047	3.53	3.64
9	1706	3.10	18.47	.75	24.334	42.29	472	16.2	17.76	14.29	10.49	80.46	73.4	1775	.035	.117	.000048	3.52	3.64
9	1709	3.10	18.46	.76	24.321	42.29	473	16.2	17.80	14.29	10.51	80.30	73.5	1775	.039	.112	.000048	3.52	3.64
9	1703	3.10	18.45	.75	24.312	42.34	473	16.2	17.82	14.31	10.47	80.29	73.2	1775	.035	.121	.000047	3.52	3.64
10	1604	3.10	19.30	.67	25.071	41.85	474	16.1	17.75	14.14	10.17	79.68	71.9	1775	.041	.131	.000058	3.53	3.63
10	1605	3.10	19.30	.67	25.075	41.83	473	16.2	17.78	14.14	10.18	79.53	72.0	1775	.042	.127	.000056	3.49	3.63
10	1606	3.10	19.31	.67	25.079	41.81	474	16.2	17.82	14.13	10.18	79.29	72.1	1775	.037	.107	.000063	3.48	3.62
10	1605	3.10	19.31	.67	25.077	41.83	473	16.1	17.74	14.14	10.17	79.67	72.0	1775	.042	.149	.000060	3.41	3.63
10	1606	3.10	19.30	.67	25.075	41.83	474	16.2	17.79	14.14	10.18	79.49	72.0	1775	.039	.139	.000061	3.48	3.63
11	1502	3.10	19.90	.59	25.593	41.07	471	16.1	17.60	13.88	9.72	78.86	70.0	1775	.045	.160	.000070	3.48	3.62
11	1499	3.10	19.87	.58	25.556	40.96	471	16.1	17.59	13.84	9.69	78.69	70.0	1775	.046	.129	.000063	3.49	3.64
11	1502	3.10	19.87	.59	25.557	40.99	471	16.2	17.67	13.85	9.71	78.38	70.1	1775	.046	.133	.000066	3.49	3.66
11	1503	3.10	19.90	.59	25.589	41.03	471	16.2	17.66	13.87	9.72	78.52	70.1	1775	.044	.133	.000067	3.52	3.64
11	1501	3.10	19.89	.58	25.575	40.99	472	16.1	17.62	13.85	9.70	78.64	70.1	1775	.044	.141	.000066	3.52	3.66
12	1388	3.10	20.25	.50	25.849	39.87	471	15.9	17.43	13.48	9.07	77.31	67.3	1775	.063	.159	.000082	3.49	3.68
12	1391	3.10	20.28	.50	25.883	39.91	472	16.0	17.48	13.49	9.10	77.17	67.5	1775	.059	.183	.000080	3.49	3.69
12	1393	3.10	20.23	.50	25.842	39.86	471	16.0	17.49	13.47	9.10	77.04	67.6	1775	.062	.205	.000082	3.51	3.73
12	1390	3.10	20.20	.50	25.808	39.83	471	15.9	17.43	13.46	9.07	77.24	67.4	1775	.062	.175	.000082	3.48	3.67
12	1392	3.10	20.29	.50	25.900	39.99	472	16.0	17.53	13.51	9.11	77.10	67.4	1775	.063	.162	.000079	3.49	3.68

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Figure 136. (Sheet 2 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1308	3.10	20.31	.44	25.857	39.01	474	15.9	17.55	13.18	8.55	75.11	64.9	1775	.077	.233	.000088	3.42	3.68
13	1307	3.10	20.30	.44	25.844	39.02	473	16.0	17.54	13.19	8.54	75.17	64.8	1775	.076	.287	.000093	3.41	3.70
13	1312	3.10	20.30	.45	25.852	39.02	474	15.9	17.52	13.19	8.57	75.26	65.0	1775	.076	.214	.000091	3.42	3.70
13	1308	3.10	20.28	.44	25.828	38.98	474	15.9	17.54	13.18	8.54	75.13	64.8	1775	.081	.277	.000095	3.42	3.68
13	1306	3.10	20.27	.44	25.813	38.95	474	15.9	17.46	13.16	8.52	75.40	64.7	1775	.081	.235	.000090	3.41	3.66
14	1212	3.10	20.31	.38	25.797	38.05	474	15.8	17.37	12.86	7.91	74.03	61.5	1775	.095	.296	.000120	3.38	3.70
14	1208	3.10	20.26	.38	25.741	37.97	474	15.8	17.42	12.83	7.86	73.69	61.3	1775	.094	.281	.000113	3.35	3.73
14	1207	3.10	20.31	.38	25.787	38.02	473	15.8	17.38	12.85	7.87	73.94	61.3	1775	.093	.269	.000113	3.34	3.70
14	1209	3.10	20.26	.38	25.739	38.02	473	15.8	17.35	12.85	7.87	74.06	61.2	1775	.090	.241	.000105	3.32	3.74
14	1208	3.10	20.21	.38	25.693	37.95	473	15.8	17.34	12.83	7.84	73.96	61.2	1775	.091	.317	.000113	3.38	3.74
15	1105	3.10	20.81	.32	26.233	37.96	473	15.8	17.37	12.83	7.33	73.84	57.1	1775	.100	.293	.000114	3.32	3.78
15	1108	3.10	20.81	.32	26.234	37.92	474	15.8	17.38	12.82	7.35	73.75	57.3	1775	.097	.251	.000119	3.29	3.80
15	1107	3.10	20.83	.32	26.252	37.97	473	15.8	17.38	12.83	7.34	73.85	57.2	1775	.109	.340	.000121	3.23	3.80
15	1108	3.10	20.82	.32	26.242	37.97	474	15.8	17.36	12.83	7.35	73.93	57.3	1775	.099	.313	.000122	3.30	3.77
15	1108	3.10	20.82	.32	26.246	37.94	473	15.7	17.27	12.82	7.35	74.27	57.3	1775	.105	.379	.000121	3.19	3.81
16	1002	3.10	21.78	.26	27.146	38.45	472	15.8	17.27	12.99	6.88	75.23	52.9	1775	.110	.328	.000118	3.06	3.96
16	1003	3.10	21.86	.26	27.228	38.52	472	15.7	17.25	13.02	6.90	75.44	53.0	1775	.113	.328	.000125	3.06	3.91
16	1005	3.10	21.83	.26	27.197	38.46	472	15.8	17.27	13.00	6.91	75.26	53.2	1775	.119	.333	.000134	3.06	3.90
16	1005	3.10	21.77	.26	27.138	38.44	471	15.8	17.29	12.99	6.89	75.16	53.0	1775	.108	.350	.000131	3.02	3.87
16	1006	3.10	21.82	.26	27.184	38.48	471	15.8	17.25	13.01	6.92	75.40	53.2	1775	.115	.400	.000136	3.06	4.35
17	908	3.10	22.87	.21	28.188	39.20	474	16.0	17.57	13.25	6.47	75.38	48.9	1775	.125	.420	.000132	2.74	4.10
17	909	3.10	22.89	.21	28.207	39.22	474	16.0	17.58	13.26	6.48	75.39	48.9	1775	.120	.400	.000148	2.71	4.21
17	907	3.10	22.90	.21	28.222	39.21	474	16.0	17.58	13.25	6.47	75.37	48.8	1775	.128	.370	.000139	2.62	4.15
17	909	3.10	22.89	.21	28.211	39.15	475	16.0	17.58	13.23	6.48	75.25	49.0	1775	.126	.430	.000141	2.64	4.14
17	905	3.10	22.91	.21	28.228	39.15	474	16.0	17.59	13.23	6.46	75.24	48.8	1775	.129	.360	.000132	2.80	4.18

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Figure 136. (Sheet 3 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	2832	3.10	.44	2.08	7.624	34.66	470	15.8	17.30	11.71	5.46	67.70	46.6	1775	.030	.093	.000056	3.53	3.66
1	2837	3.10	.38	2.09	7.575	34.61	470	15.8	17.29	11.70	5.43	67.63	46.5	1775	.031	.107	.000055	3.29	3.68
1	2835	3.10	.41	2.09	7.596	34.71	470	15.9	17.30	11.73	5.44	67.83	46.4	1775	.028	.116	.000056	3.56	3.66
1	2838	3.10	.39	2.09	7.582	34.51	470	15.8	17.30	11.66	5.44	67.44	46.6	1775	.031	.091	.000054	3.10	3.66
1	2835	3.10	.38	2.09	7.568	34.54	470	15.8	17.29	11.67	5.42	67.49	46.5	1775	.030	.093	.000059	3.50	3.67
2	2641	3.10	4.63	1.81	11.541	37.71	471	16.2	17.74	12.75	7.71	71.87	60.5	1775	.032	.101	.000051	2.97	3.63
2	2646	3.10	4.65	1.82	11.567	37.74	471	16.2	17.76	12.76	7.74	71.82	60.7	1775	.033	.092	.000055	3.34	3.65
2	2644	3.10	4.65	1.81	11.567	37.71	471	16.2	17.74	12.74	7.73	71.85	60.7	1775	.033	.090	.000055	3.51	3.64
2	2645	3.10	4.64	1.81	11.563	37.78	471	16.2	17.75	12.77	7.73	71.93	60.5	1775	.030	.090	.000059	3.54	3.65
2	2643	3.10	4.64	1.81	11.558	37.70	471	16.2	17.73	12.74	7.72	71.88	60.6	1775	.035	.095	.000061	3.43	3.65
3	2444	3.10	8.53	1.55	15.183	40.19	470	16.5	18.03	13.58	9.38	75.32	69.1	1775	.037	.102	.000048	3.55	3.63
3	2441	3.10	8.53	1.55	15.178	40.12	471	16.5	18.03	13.56	9.37	75.20	69.1	1775	.054	.181	.000046	3.43	3.63
3	2446	3.10	8.54	1.55	15.197	40.14	470	16.5	18.03	13.56	9.40	75.23	69.3	1775	.038	.115	.000050	3.41	3.63
3	2440	3.10	8.52	1.54	15.167	40.10	470	16.5	18.03	13.55	9.35	75.16	69.0	1775	.040	.101	.000052	3.52	3.65
3	2440	3.10	8.51	1.54	15.161	40.07	470	16.5	18.02	13.54	9.35	75.17	69.1	1775	.039	.108	.000049	3.32	3.64
4	2298	3.10	11.07	1.37	17.542	41.35	470	16.7	18.20	13.98	10.19	76.80	72.9	1775	.045	.133	.000051	3.49	3.65
4	2296	3.10	11.09	1.37	17.564	41.36	470	16.7	18.19	13.98	10.20	76.82	72.9	1775	.031	.080	.000050	3.53	3.64
4	2296	3.10	11.11	1.37	17.585	41.40	470	16.7	18.21	13.99	10.21	76.82	72.9	1775	.037	.119	.000046	3.57	3.64
4	2297	3.10	11.08	1.37	17.549	41.31	470	16.7	18.19	13.96	10.19	76.75	73.0	1775	.032	.088	.000052	3.52	3.63
4	2302	3.10	11.13	1.37	17.606	41.38	470	16.7	18.18	13.98	10.25	76.91	73.3	1775	.030	.093	.000046	3.53	3.63
5	2190	3.10	12.83	1.24	19.184	41.91	470	16.7	18.23	14.17	10.62	77.71	75.0	1775	.030	.102	.000047	3.57	3.67
5	2191	3.10	12.84	1.25	19.194	41.97	470	16.7	18.23	14.18	10.63	77.80	74.9	1775	.028	.086	.000050	3.47	3.64
5	2187	3.10	12.83	1.24	19.172	41.93	470	16.7	18.24	14.17	10.60	77.70	74.8	1775	.037	.113	.000047	3.25	3.65
5	2193	3.10	12.86	1.25	19.210	41.98	470	16.7	18.26	14.19	10.65	77.71	75.1	1775	.039	.119	.000048	3.30	3.63
5	2191	3.10	12.88	1.25	19.226	42.02	470	16.7	18.25	14.20	10.65	77.82	75.0	1775	.045	.118	.000053	3.56	3.63
6	2098	3.10	14.26	1.14	20.504	42.21	470	16.7	18.26	14.27	10.87	78.15	76.2	1775	.040	.111	.000049	3.54	3.63
6	2096	3.10	14.26	1.14	20.501	42.16	471	16.7	18.27	14.25	10.86	77.99	76.2	1775	.036	.099	.000050	3.55	3.65
6	2100	3.10	14.25	1.14	20.497	42.19	470	16.7	18.27	14.26	10.88	78.04	76.3	1775	.046	.134	.000050	3.54	3.63
6	2092	3.10	14.26	1.14	20.504	42.20	470	16.7	18.24	14.26	10.84	78.17	76.0	1775	.038	.121	.000050	3.55	3.62
6	2098	3.10	14.29	1.14	20.537	42.26	470	16.7	18.27	14.28	10.89	78.18	76.3	1775	.027	.077	.000051	3.56	3.63

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Figure 137. Research data; pump 2, Test K-06, sump 18, submergence 3.1 ft (Sheet 1 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
7	2000	3.10	15.54	1.04	21.682	42.34	471	16.7	18.29	14.31	10.96	78.25	76.6	1775	.034	.091	.000045	3.47	3.62
7	1998	3.10	15.57	1.04	21.707	42.38	471	16.7	18.28	14.32	10.97	78.35	76.6	1775	.027	.094	.000047	3.51	3.64
7	2000	3.10	15.58	1.04	21.724	42.42	471	16.7	18.30	14.34	10.98	78.35	76.6	1775	.029	.088	.000050	3.56	3.65
7	1999	3.10	15.58	1.04	21.720	42.36	470	16.7	18.28	14.32	10.98	78.34	76.7	1775	.026	.063	.000042	3.51	3.65
7	1997	3.10	15.60	1.03	21.734	42.37	470	16.7	18.27	14.32	10.97	78.36	76.6	1775	.033	.092	.000046	3.55	3.67
8	1889	3.10	16.89	.93	22.923	42.40	470	16.7	18.24	14.33	10.95	78.56	76.4	1775	.030	.086	.000045	3.51	3.62
8	1887	3.10	16.95	.92	22.978	42.45	470	16.7	18.24	14.35	10.96	78.66	76.4	1775	.028	.090	.000043	3.54	3.65
8	1887	3.10	16.94	.92	22.971	42.42	470	16.7	18.24	14.34	10.96	78.60	76.4	1775	.034	.084	.000042	3.55	3.65
8	1885	3.10	16.94	.92	22.963	42.36	470	16.7	18.23	14.32	10.94	78.55	76.4	1775	.029	.064	.000047	3.58	3.65
8	1888	3.10	16.97	.92	22.996	42.43	470	16.7	18.21	14.34	10.98	78.77	76.5	1775	.034	.095	.000045	3.58	3.65
9	1807	3.10	17.70	.85	23.652	42.31	471	16.7	18.20	14.30	10.80	78.58	75.5	1775	.034	.091	.000051	3.47	3.63
9	1807	3.10	17.71	.85	23.658	42.32	471	16.6	18.19	14.30	10.81	78.62	75.6	1775	.031	.096	.000051	3.55	3.64
9	1808	3.10	17.75	.85	23.699	42.40	471	16.7	18.22	14.33	10.83	78.67	75.6	1775	.030	.089	.000048	3.56	3.63
9	1808	3.10	17.72	.85	23.669	42.35	471	16.7	18.20	14.31	10.82	78.64	75.6	1775	.032	.092	.000048	3.55	3.63
9	1806	3.10	17.75	.85	23.699	42.38	471	16.7	18.29	14.32	10.82	78.33	75.6	1775	.033	.095	.000048	3.52	3.63
10	1707	3.10	18.61	.76	24.472	42.10	470	16.7	18.24	14.23	10.56	77.98	74.2	1775	.032	.108	.000053	3.51	3.62
10	1710	3.10	18.60	.76	24.462	42.11	471	16.7	18.27	14.23	10.58	77.91	74.3	1775	.037	.106	.000054	3.51	3.62
10	1710	3.10	18.58	.76	24.442	42.06	471	16.7	18.25	14.22	10.57	77.90	74.3	1775	.036	.107	.000052	3.27	3.62
10	1710	3.10	18.63	.76	24.493	42.17	471	16.7	18.27	14.25	10.59	78.02	74.3	1775	.036	.107	.000054	3.53	3.63
10	1709	3.10	18.60	.76	24.461	42.15	470	16.7	18.26	14.24	10.57	78.03	74.2	1775	.031	.082	.000055	3.45	3.62
11	1606	3.10	19.40	.67	25.171	41.61	473	16.6	18.26	14.06	10.22	77.01	72.7	1775	.036	.120	.000061	3.41	3.64
11	1604	3.10	19.40	.67	25.171	41.57	473	16.6	18.24	14.05	10.21	77.01	72.7	1775	.036	.112	.000057	3.54	3.63
11	1600	3.10	19.37	.66	25.133	41.51	473	16.6	18.22	14.03	10.16	76.99	72.5	1775	.037	.095	.000058	3.53	3.63
11	1600	3.10	19.42	.66	25.188	41.60	473	16.6	18.24	14.06	10.19	77.07	72.5	1775	.048	.119	.000059	3.53	3.62
11	1598	3.10	19.39	.66	25.158	41.59	473	16.6	18.23	14.06	10.17	77.11	72.3	1775	.037	.106	.000059	3.50	3.61
12	1494	3.10	20.11	.58	25.793	40.68	473	16.5	18.15	13.75	9.74	75.76	70.8	1775	.044	.142	.000068	3.49	3.63
12	1490	3.10	20.07	.58	25.748	40.57	474	16.5	18.13	13.71	9.70	75.63	70.8	1775	.043	.131	.000069	3.47	3.62
12	1489	3.10	20.07	.58	25.746	40.60	473	16.5	18.11	13.72	9.69	75.75	70.6	1775	.043	.133	.000069	3.43	3.62
12	1490	3.10	20.09	.58	25.769	40.62	474	16.5	18.14	13.73	9.71	75.67	70.7	1775	.044	.149	.000068	3.48	3.60
12	1491	3.10	20.10	.58	25.783	40.63	473	16.5	18.15	13.73	9.72	75.67	70.8	1775	.044	.144	.000067	3.40	3.60

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Figure 137. (Sheet 2 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1440	3.10	20.19	.54	25.834	39.98	475	16.4	18.08	13.51	9.41	74.74	69.6	1775	.049	.118	.000077	3.49	3.63
13	1439	3.10	20.14	.54	25.780	39.97	475	16.4	18.09	13.51	9.38	74.68	69.4	1775	.049	.139	.000074	3.49	3.63
13	1442	3.10	20.18	.54	25.823	40.04	475	16.4	18.08	13.53	9.41	74.87	69.5	1775	.055	.187	.000076	3.45	3.63
13	1440	3.10	20.15	.54	25.788	39.97	475	16.4	18.07	13.51	9.39	74.76	69.5	1775	.053	.175	.000078	3.36	3.65
13	1439	3.10	20.16	.54	25.805	39.96	475	16.4	18.06	13.50	9.39	74.76	69.5	1775	.052	.156	.000076	3.46	3.65
14	1357	3.10	20.34	.48	25.919	39.34	476	16.3	18.01	13.30	8.89	73.84	66.9	1775	.067	.179	.000093	3.45	3.67
14	1356	3.10	20.30	.48	25.884	39.28	476	16.3	18.01	13.27	8.87	73.71	66.9	1775	.076	.226	.000090	3.42	3.65
14	1359	3.10	20.30	.48	25.887	39.28	476	16.3	18.02	13.28	8.89	73.67	67.0	1775	.073	.215	.000100	3.43	3.67
14	1355	3.10	20.30	.48	25.885	39.24	476	16.3	18.00	13.26	8.87	73.67	66.8	1775	.069	.243	.000093	3.43	3.66
14	1358	3.10	20.25	.48	25.835	39.19	475	16.3	17.97	13.24	8.87	73.69	67.0	1775	.065	.196	.000092	3.42	3.68
15	1229	3.10	20.27	.39	25.769	38.05	476	16.1	17.84	12.86	8.00	72.09	62.2	1775	.086	.272	.000117	3.37	3.75
15	1228	3.10	20.27	.39	25.760	38.03	476	16.1	17.83	12.85	8.00	72.08	62.2	1775	.092	.240	.000109	3.32	3.75
15	1225	3.10	20.28	.39	25.770	38.06	476	16.1	17.84	12.86	7.98	72.08	62.1	1775	.096	.283	.000117	3.40	3.77
15	1224	3.10	20.25	.39	25.742	37.97	477	16.1	17.86	12.83	7.97	71.85	62.1	1775	.091	.288	.000116	3.32	3.74
15	1227	3.10	20.26	.39	25.755	38.01	476	16.1	17.84	12.85	7.99	72.03	62.2	1775	.090	.256	.000118	3.35	3.70
16	1069	3.10	21.28	.30	26.685	38.22	476	16.2	17.86	12.92	7.21	72.32	55.8	1775	.106	.270	.000134	3.24	3.95
16	1070	3.10	21.24	.30	26.638	38.19	476	16.2	17.85	12.91	7.20	72.30	55.8	1775	.098	.283	.000121	3.17	3.97
16	1063	3.10	21.26	.29	26.659	38.26	476	16.2	17.84	12.93	7.16	72.46	55.4	1775	.110	.308	.000133	3.22	3.94
16	1065	3.10	21.31	.29	26.713	38.32	476	16.2	17.88	12.95	7.19	72.42	55.6	1775	.110	.365	.000132	3.14	3.86
16	1066	3.10	21.28	.30	26.680	38.29	476	16.2	17.88	12.94	7.19	72.38	55.6	1775	.110	.326	.000136	3.22	3.84
17	919	3.10	22.92	.22	28.241	39.26	478	16.3	18.07	13.27	6.56	73.41	49.4	1775	.122	.455	.000144	2.69	4.27
17	923	3.10	22.89	.22	28.215	39.13	478	16.3	18.05	13.23	6.58	73.26	49.8	1775	.123	.275	.000151	2.74	4.29
17	921	3.10	22.89	.22	28.216	39.17	478	16.3	18.08	13.24	6.57	73.23	49.6	1775	.128	.308	.000139	2.71	4.23
17	919	3.10	22.95	.22	28.271	39.29	478	16.3	18.09	13.28	6.57	73.42	49.5	1775	.121	.454	.000144	2.78	4.11
17	921	3.10	22.91	.22	28.230	39.23	478	16.3	18.08	13.26	6.57	73.31	49.6	1775	.116	.362	.000140	2.76	4.15

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Figure 137. (Sheet 3 of 3)

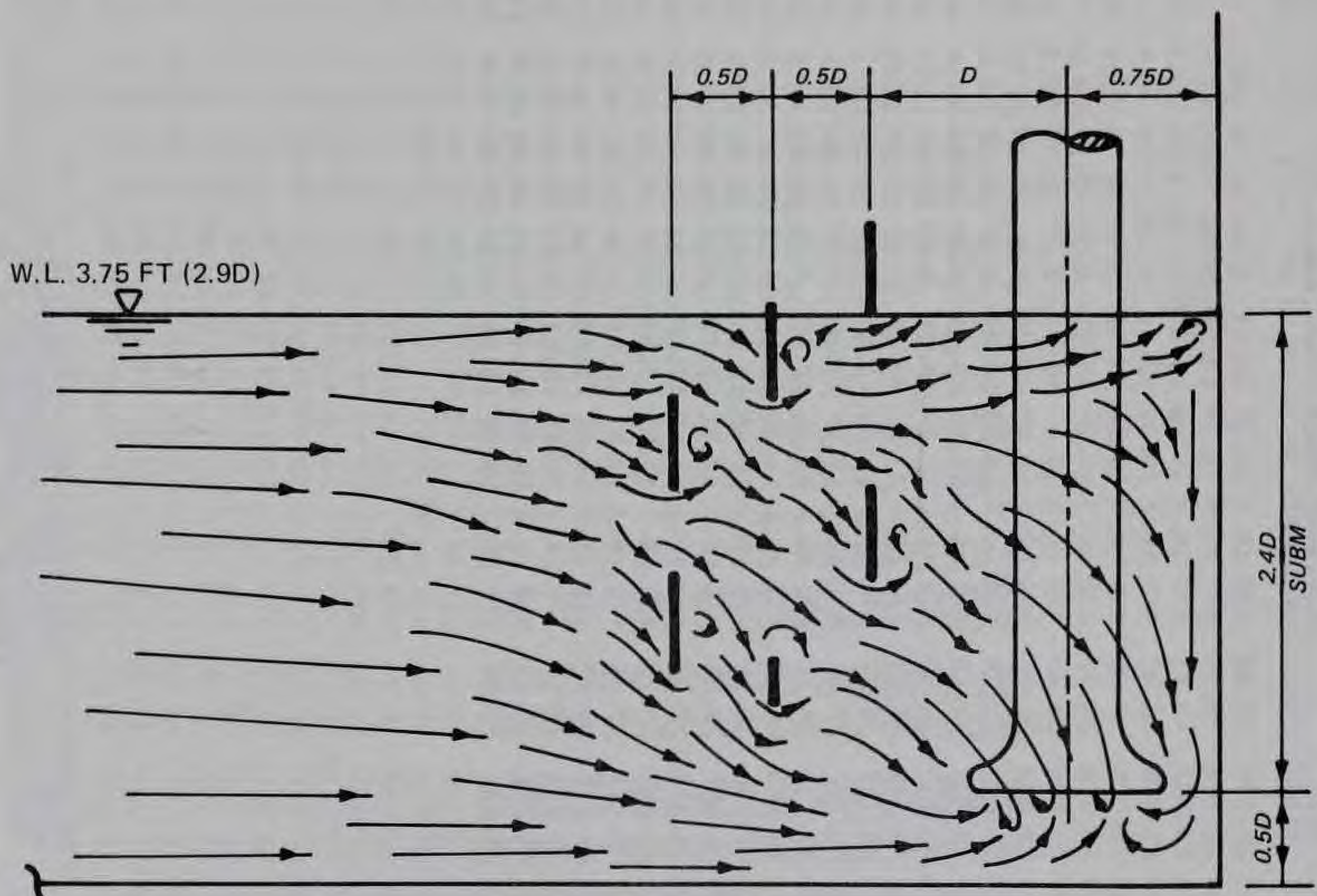

Figure 138. Base sump flow pattern for pump 2, SVS type 56, pump bell submergence 3.1 ft (2.4D), discharge 1,900 gpm, $Q/g^{1/2}D^{5/2} = 0.40$, base sump type 18

Pumps Run Sump Submergence
020 J99 018 2.5

Date 19 Jul 82, Time 0830, Air Temp 80° F, Water Temp 78° F, Barometric Pressure 29.90 in. Hg.

01 ISV, CW, 1/4 in. diam, Stage A at 4 to 6 o'clock. IBWV, CW, 1/16 in. diam at 7 o'clock. IFV, CW, 1/16 in. diam at 5 to 6 o'clock, 3 in. from pump CP (Center Point).

02 NCS (No Significant Change).

03 NSCE (NSC Except) all vortices becoming smaller and occurring less often.

04 FV gone. ISV now only circular motion. CW at 5 o'clock and CCW at 7 o'clock. IBWV at 7 o'clock CW now 1/32 in. diam.

05-08 NSCE IBWV occurring less often and becoming smaller (reading 08 size approximately 1/64 in. diam).

09 NSC.

10 Circular surface motion at 4 o'clock and CCW at 7 o'clock. IFV, CW 1/64 in. diam at 6 o'clock, CW. IBWV, CW, 1/64 in. diam at 7 o'clock.

Date 19 Jul 82, Time 1000, Air Temp 84° F, Water Temp 78° F, Barometric Pressure 29.89 in. Hg.

11 FV and IBWV gone. Surface circular motion CW at 5 o'clock and CCW at 7 o'clock.

12 NSC. No visibility data available for cavitation. Space under pump 2 limited.

13-16 NSC.

17 NSCE spray expulsion of tiny air bubbles from pump bell intakes reaching about 3 in. below pump bell. Surface circulation is still the same except slower.

Figure 139. Visual observation notes, run J-99

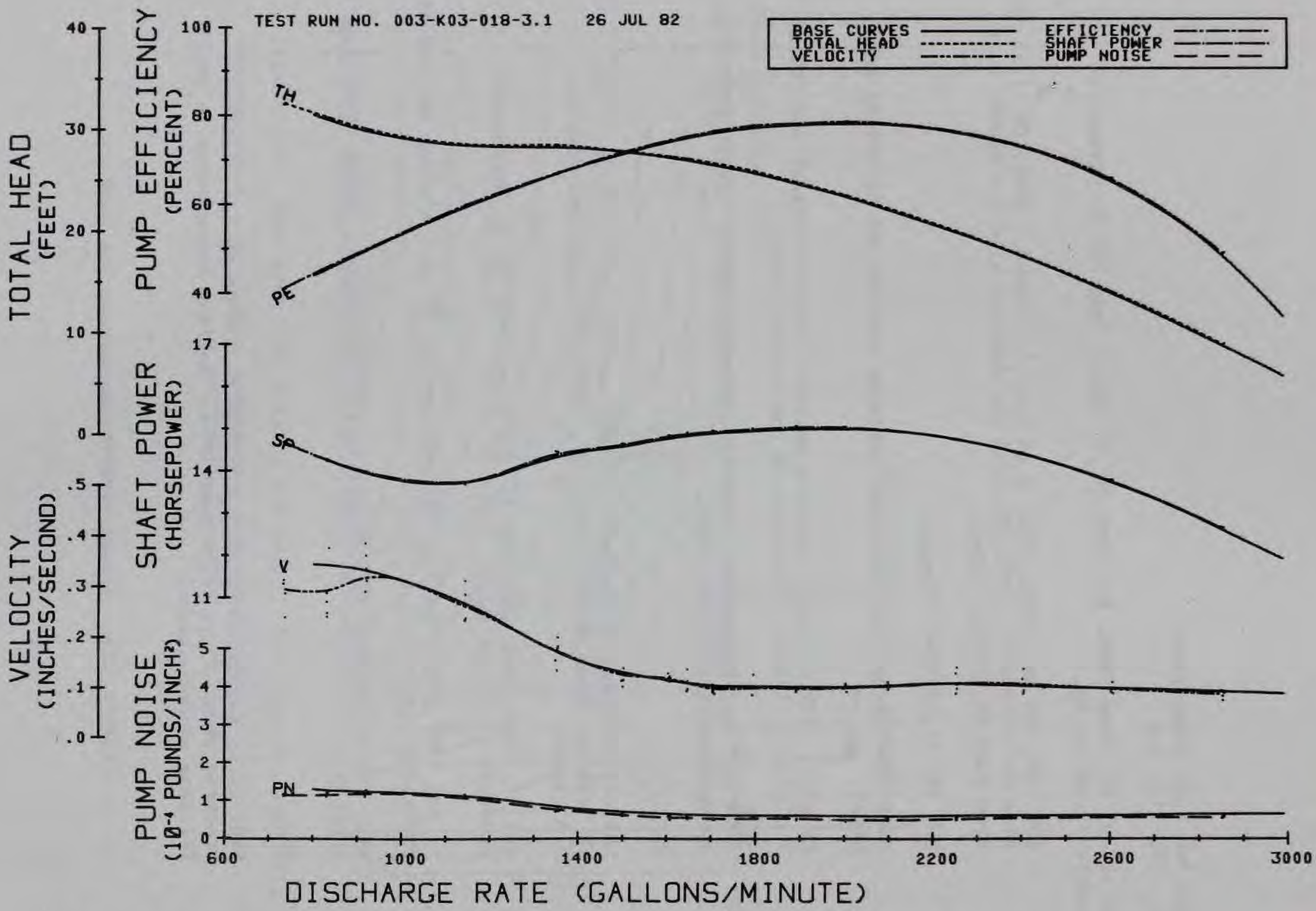

Figure 140. Performance characteristic curves; pump 3, Test K-03, sump 18, submergence 3.1 ft

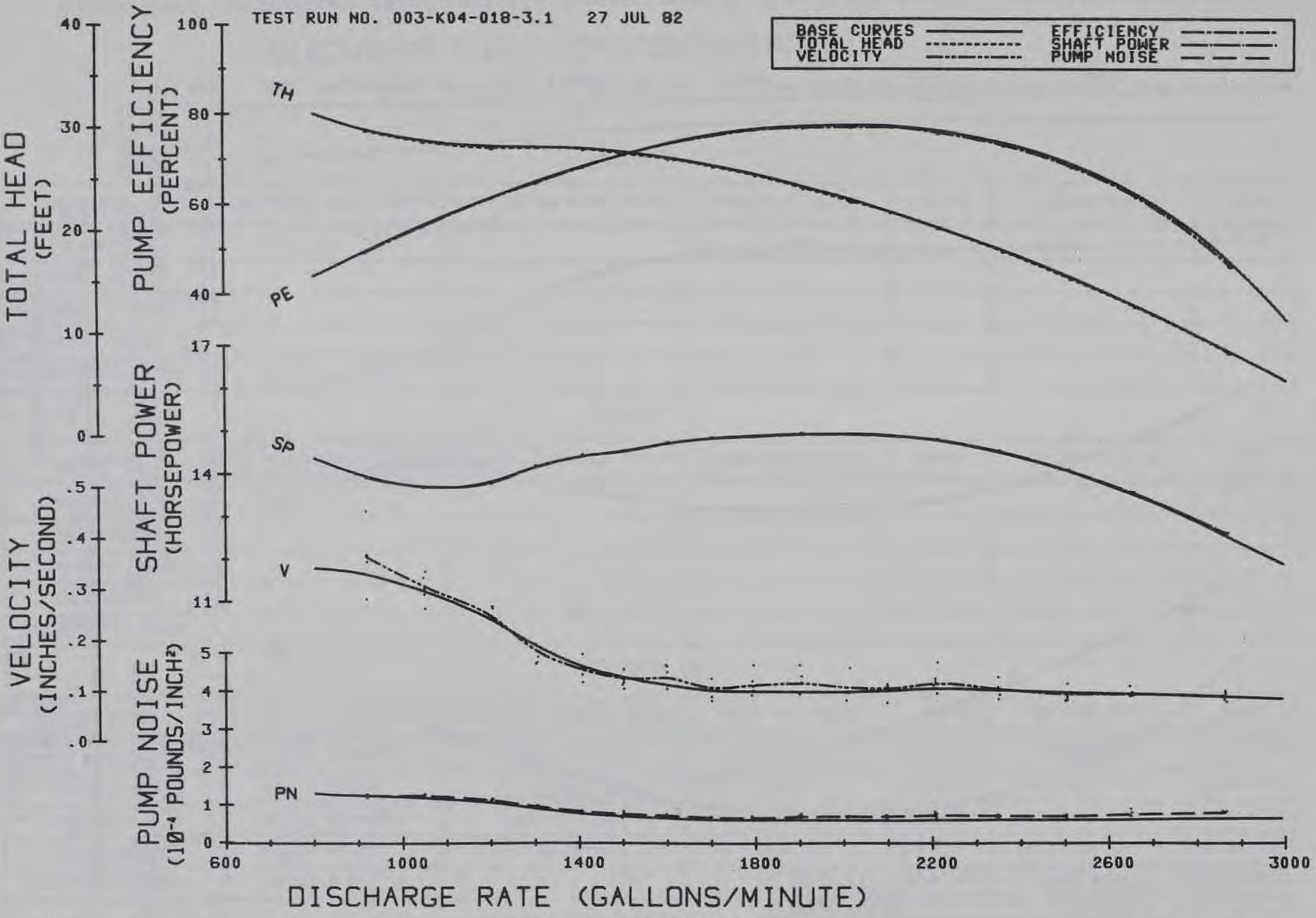

Figure 141. Performance characteristic curves; pump 3, Test K-04, sump 18, submergence 3.1 ft

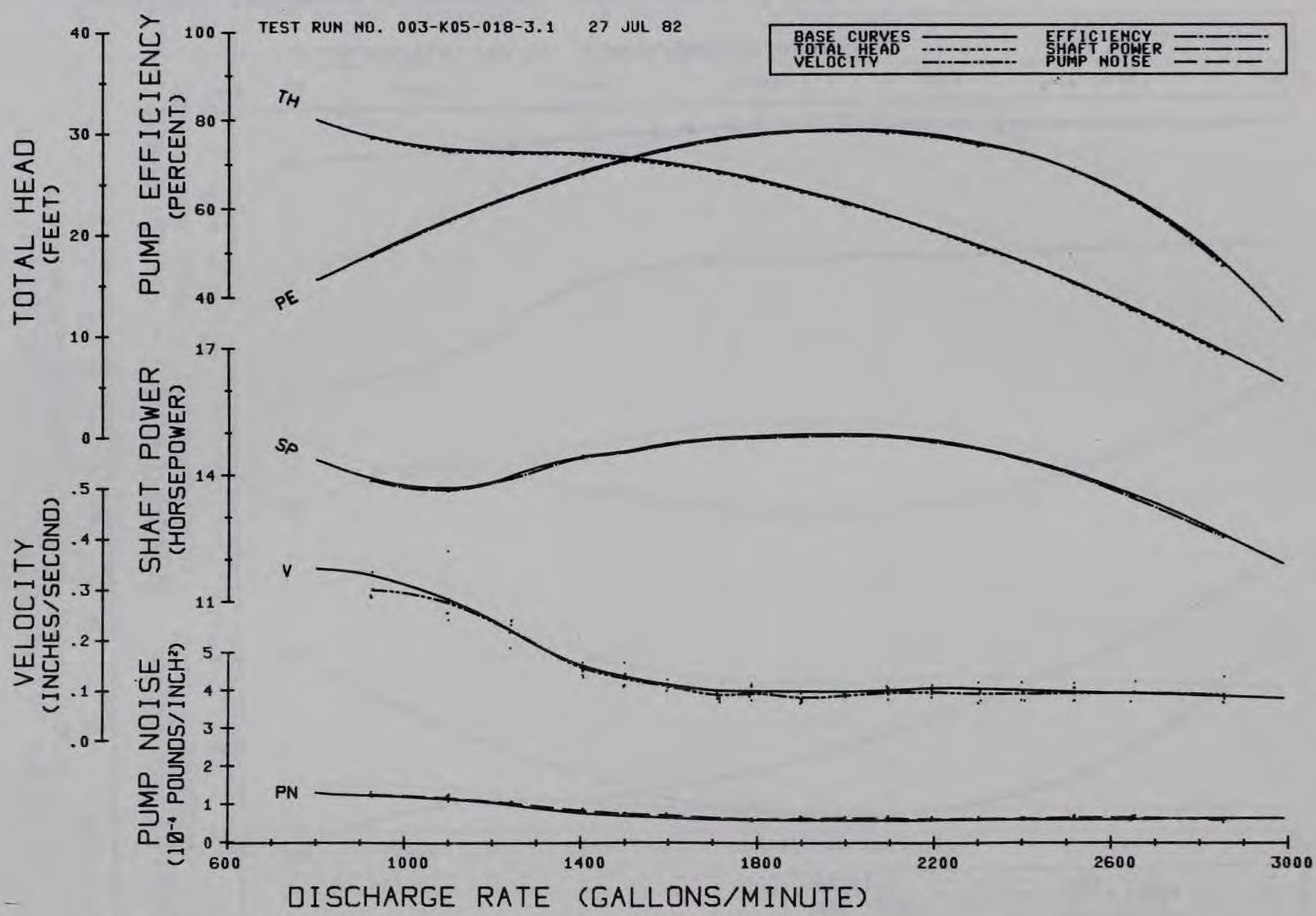

Figure 142. Performance characteristic curves; pump 3, Test K-05, sump 18, submergence 3.1 ft

TEST RUN NO. 003-K03-018-3.1   26 JUL 82   ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	.5264 IPS*GPM	2.4366 IPS*GPM	.120320 IPS	1500 GPM	.091320 IPS	1730 GPM
TOTAL HEAD	89.25 FT*GPM	.00 FT*GPM	27.53380 FT	1500 GPM	15.52510 FT	2500 GPM
PUMP NOISE	.00000 PSI*GPM	.01044 PSI*GPM	.0000573 PSI	1500 GPM	.0000447 PSI	2010 GPM
SHAFT POWER	12.086 HP*GPM	3.704 HP*GPM	15.03240 HP	1910 GPM	14.10130 HP	2500 GPM
PUMP EFFICIENCY	180.89 % * GPM	.00 % * GPM	77.99100 %	1990 GPM	69.31870 %	2500 GPM

Figure 143. Statistical comparison, pump 3, Test K-03, sump 18, submergence 3.1 ft

TEST RUN NO. 003-K04-018-3.1 27 JUL 82 ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	6.3474 IPS*GPM	.4554 IPS*GPM	.124847 IPS	1580 GPM	.091297 IPS	2500 GPM
TOTAL HEAD	.00 FT*GPM	158.89 FT*GPM	27.29270 FT	1500 GPM	15.25860 FT	2500 GPM
PUMP NOISE	.00722 PSI*GPM	.00000 PSI*GPM	.0000724 PSI	1500 GPM	.0000625 PSI	1770 GPM
SHAFT POWER	.123 HP*GPM	21.512 HP*GPM	14.97180 HP	1920 GPM	14.09650 HP	2500 GPM
PUMP EFFICIENCY	.00 % * GPM	493.45 % * GPM	77.16780 %	2050 GPM	68.28180 %	2500 GPM

Figure 144. Statistical comparison, pump 3, Test K-04, sump 18, submergence 3.1 ft

TEST RUN NO. 003-K05-018-3.1 27 JUL 82 ALL MEASUREMENTS BETWEEN DISCHARGE OF 1500 & 2500 GPM

PUMP 1

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 2

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY						
TOTAL HEAD						
PUMP NOISE						
SHAFT POWER						
PUMP EFFICIENCY						

PUMP 3

PARAMETER	AREA ABOVE BASE CURVE	AREA BELOW BASE CURVE	MAXIMUM VALUE	@GPM	MINIMUM VALUE	@GPM
VELOCITY	.0000 IPS*GPM	5.8852 IPS*GPM	.123290 IPS	1500 GPM	.085890 IPS	1900 GPM
TOTAL HEAD	.04 FT*GPM	73.18 FT*GPM	27.32130 FT	1500 GPM	15.39870 FT	2500 GPM
PUMP NOISE	.00503 PSI*GPM	.00000 PSI*GPM	.0000749 PSI	1500 GPM	.0000614 PSI	2220 GPM
SHAFT POWER	.000 HP*GPM	23.690 HP*GPM	14.97220 HP	1980 GPM	14.07280 HP	2500 GPM
PUMP EFFICIENCY	18.45 % * GPM	180.05 % * GPM	77.59650 %	1970 GPM	69.05390 %	2500 GPM

Figure 145. Statistical comparison, pump 3, Test K-05, sump 18, submergence 3.1 ft

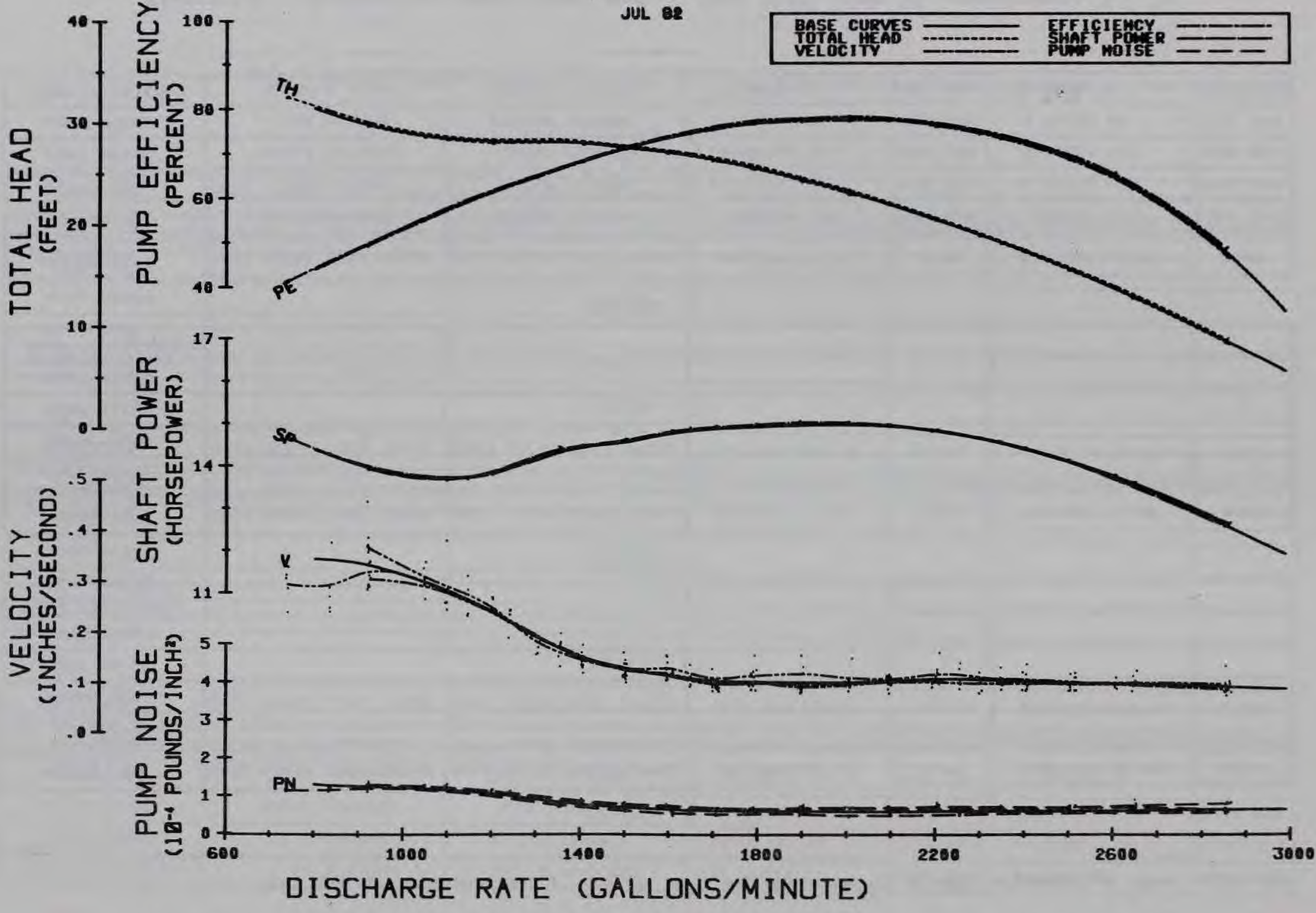

Figure 146. Performance characteristic curves, pump 3, sump 18, submergence 3.1 ft

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	2857	3.10	1.25	2.12	8.475	37.32	480	18.2	20.31	12.61	6.12	62.09	48.5	1775	.031	.083	.000054	3.50	3.66
1	2854	3.10	1.23	2.11	8.449	37.19	480	18.2	20.29	12.57	6.10	61.96	48.5	1775	.027	.087	.000054	3.25	3.68
1	2853	3.10	1.20	2.11	8.416	37.26	480	18.2	20.29	12.59	6.07	62.06	48.2	1775	.028	.077	.000055	3.53	3.66
1	2851	3.10	1.24	2.11	8.449	37.37	480	18.2	20.32	12.63	6.09	62.14	48.2	1775	.031	.087	.000050	3.57	3.67
1	2855	3.10	1.23	2.11	8.453	37.27	480	18.2	20.29	12.60	6.10	62.08	48.4	1775	.027	.068	.000050	3.11	3.68
2	2602	3.10	6.74	1.76	13.598	40.62	480	18.7	20.84	13.73	8.95	65.87	65.2	1775	.036	.090	.000056	3.47	3.68
2	2603	3.10	6.76	1.76	13.624	40.65	480	18.7	20.84	13.74	8.96	65.92	65.2	1775	.030	.093	.000054	3.38	3.68
2	2604	3.10	6.78	1.76	13.638	40.67	480	18.7	20.84	13.75	8.98	65.95	65.3	1775	.029	.085	.000049	3.55	3.68
2	2609	3.10	6.73	1.77	13.598	40.67	480	18.7	20.82	13.75	8.97	66.00	65.2	1775	.032	.082	.000052	3.54	3.68
2	2606	3.10	6.79	1.76	13.654	40.69	480	18.7	20.82	13.75	8.99	66.05	65.4	1775	.036	.104	.000056	3.59	3.68
3	2403	3.10	10.55	1.50	17.147	42.62	481	19.0	21.21	14.40	10.41	67.91	72.3	1775	.034	.097	.000053	3.60	3.69
3	2404	3.10	10.54	1.50	17.146	42.62	482	19.0	21.22	14.41	10.42	67.88	72.3	1775	.035	.110	.000055	3.59	3.68
3	2406	3.10	10.51	1.50	17.118	42.59	481	19.0	21.22	14.39	10.41	67.83	72.3	1775	.030	.082	.000050	3.59	3.69
3	2406	3.10	10.54	1.50	17.147	42.57	481	19.0	21.20	14.39	10.43	67.87	72.5	1775	.035	.130	.000050	3.58	3.67
3	2407	3.10	10.55	1.50	17.159	42.56	481	19.0	21.22	14.38	10.44	67.78	72.6	1775	.031	.088	.000051	3.20	3.68
4	2253	3.10	13.15	1.32	19.575	43.60	482	19.1	21.39	14.74	11.15	68.88	75.7	1775	.042	.122	.000045	3.59	3.70
4	2253	3.10	13.14	1.32	19.564	43.57	482	19.1	21.41	14.72	11.14	68.78	75.7	1775	.030	.082	.000050	3.60	3.69
4	2256	3.10	13.11	1.32	19.533	43.60	482	19.1	21.40	14.74	11.14	68.87	75.6	1775	.036	.133	.000051	3.61	3.69
4	2255	3.10	13.18	1.32	19.605	43.61	483	19.1	21.44	14.74	11.17	68.74	75.8	1775	.039	.100	.000045	3.61	3.68
4	2256	3.10	13.13	1.32	19.550	43.56	482	19.1	21.39	14.72	11.15	68.84	75.7	1775	.035	.091	.000053	3.58	3.67
5	2096	3.10	15.62	1.14	21.860	44.23	481	19.2	21.47	14.95	11.58	69.64	77.5	1775	.036	.098	.000050	3.53	3.68
5	2101	3.10	15.59	1.14	21.835	44.23	482	19.2	21.50	14.95	11.60	69.53	77.6	1775	.031	.090	.000044	3.45	3.68
5	2101	3.10	15.60	1.15	21.846	44.26	481	19.2	21.47	14.96	11.61	69.67	77.6	1775	.032	.100	.000046	3.60	3.68
5	2100	3.10	15.59	1.14	21.834	44.26	481	19.2	21.50	14.96	11.59	69.58	77.5	1775	.034	.094	.000045	3.59	3.68
5	2098	3.10	15.60	1.14	21.845	44.26	481	19.2	21.47	14.96	11.59	69.69	77.5	1775	.043	.105	.000047	3.61	3.69
6	2004	3.10	16.98	1.04	23.128	44.45	483	19.2	21.54	15.02	11.72	69.73	78.0	1775	.032	.102	.000041	3.61	3.69
6	2000	3.10	16.97	1.04	23.112	44.45	483	19.2	21.55	15.02	11.69	69.71	77.8	1775	.035	.092	.000045	3.56	3.68
6	2006	3.10	16.97	1.04	23.119	44.39	483	19.2	21.55	15.00	11.72	69.61	78.1	1775	.031	.098	.000045	3.58	3.69
6	2004	3.10	16.96	1.04	23.101	44.38	483	19.2	21.52	15.00	11.70	69.70	78.0	1775	.029	.100	.000044	3.58	3.68
6	2008	3.10	16.96	1.05	23.111	44.40	483	19.2	21.55	15.01	11.73	69.63	78.2	1775	.029	.085	.000044	3.39	3.68

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Figure 147. Research data; pump 3, Test K-03, sump 18, submergence 3.1 ft (Sheet 1 of 3)

READ NO.	DISC-HARGE GPM	SUBME-RGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOL-TAGE VOLT	CUR-RENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
7	1894	3.10	18.35	.93	24.385	44.48	483	19.2	21.55	15.03	11.68	69.76	77.7	1775	.033	.091	.000058	3.56	3.70
7	1893	3.10	18.33	.93	24.361	44.45	483	19.2	21.57	15.02	11.66	69.64	77.6	1775	.027	.091	.000044	3.49	3.69
7	1893	3.10	18.35	.93	24.380	44.49	483	19.2	21.59	15.04	11.67	69.64	77.6	1775	.027	.085	.000047	3.58	3.69
7	1895	3.10	18.37	.93	24.408	44.52	483	19.2	21.54	15.05	11.70	69.85	77.7	1775	.027	.091	.000048	3.60	3.69
7	1893	3.10	18.35	.93	24.384	44.48	483	19.2	21.57	15.03	11.67	69.70	77.6	1775	.033	.090	.000047	3.60	3.69
8	1797	3.10	19.52	.84	25.464	44.29	483	19.2	21.56	14.97	11.57	69.44	77.3	1775	.027	.096	.000052	3.63	3.71
8	1798	3.10	19.55	.84	25.490	44.33	483	19.2	21.57	14.98	11.59	69.46	77.4	1775	.039	.119	.000049	3.59	3.72
8	1796	3.10	19.55	.84	25.491	44.31	484	19.2	21.58	14.98	11.57	69.40	77.3	1775	.029	.093	.000050	3.65	3.72
8	1796	3.10	19.56	.84	25.500	44.34	484	19.2	21.57	14.98	11.58	69.48	77.3	1775	.031	.094	.000052	3.64	3.71
8	1794	3.10	19.56	.84	25.495	44.34	483	19.2	21.55	14.98	11.57	69.53	77.2	1775	.026	.079	.000052	3.59	3.71
9	1705	3.10	20.40	.75	26.264	44.18	485	19.2	21.61	14.93	11.32	69.10	75.8	1775	.032	.085	.000045	3.57	3.71
9	1705	3.10	20.43	.75	26.284	44.16	485	19.2	21.63	14.93	11.33	69.01	75.9	1775	.030	.088	.000047	3.58	3.69
9	1710	3.10	20.42	.76	26.282	44.15	485	19.2	21.59	14.92	11.36	69.12	76.2	1775	.028	.082	.000046	3.57	3.69
9	1705	3.10	20.44	.75	26.303	44.17	485	19.2	21.59	14.93	11.34	69.14	76.0	1775	.032	.087	.000050	3.61	3.68
9	1705	3.10	20.45	.75	26.305	44.14	485	19.2	21.59	14.92	11.34	69.10	76.0	1775	.031	.100	.000048	3.61	3.68
10	1647	3.10	20.92	.70	26.723	44.00	485	19.2	21.58	14.87	11.13	68.91	74.8	1775	.033	.087	.000057	3.60	3.70
10	1649	3.10	20.93	.71	26.743	44.00	485	19.2	21.57	14.87	11.15	68.93	75.0	1775	.035	.130	.000048	3.60	3.70
10	1649	3.10	20.94	.71	26.745	44.05	485	19.2	21.56	14.89	11.15	69.04	74.9	1775	.036	.091	.000050	3.60	3.70
10	1649	3.10	20.90	.71	26.707	43.98	485	19.1	21.57	14.86	11.13	68.92	74.9	1775	.034	.103	.000054	3.61	3.70
10	1649	3.10	20.96	.71	26.766	44.07	485	19.2	21.59	14.89	11.16	68.97	74.9	1775	.035	.106	.000049	3.61	3.70
11	1609	3.10	21.20	.67	26.977	43.82	485	19.1	21.54	14.81	10.98	68.75	74.1	1775	.038	.113	.000055	3.62	3.70
11	1605	3.10	21.22	.67	26.989	43.85	486	19.1	21.55	14.82	10.95	68.75	73.9	1775	.038	.122	.000054	3.61	3.70
11	1610	3.10	21.23	.67	27.010	43.86	485	19.1	21.56	14.82	10.99	68.76	74.2	1775	.041	.116	.000045	3.61	3.68
11	1607	3.10	21.20	.67	26.970	43.84	486	19.1	21.55	14.82	10.96	68.75	74.0	1775	.036	.112	.000049	3.60	3.69
11	1607	3.10	21.20	.67	26.971	43.84	486	19.1	21.59	14.82	10.96	68.63	74.0	1775	.031	.106	.000050	3.60	3.69
12	1499	3.10	21.82	.58	27.511	43.28	486	19.0	21.46	14.63	10.42	68.16	71.2	1775	.037	.107	.000058	3.57	3.68
12	1502	3.10	21.83	.59	27.520	43.23	486	19.0	21.47	14.61	10.45	68.04	71.5	1775	.036	.096	.000054	3.58	3.69
12	1504	3.10	21.86	.59	27.548	43.30	486	19.0	21.47	14.63	10.47	68.17	71.6	1775	.036	.109	.000057	3.58	3.70
12	1502	3.10	21.83	.59	27.524	43.28	486	19.0	21.48	14.63	10.45	68.12	71.5	1775	.039	.123	.000057	3.59	3.70
12	1504	3.10	21.82	.59	27.510	43.24	486	19.0	21.45	14.61	10.46	68.12	71.6	1775	.040	.132	.000058	3.58	3.69

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Figure 147. (Sheet 2 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1354	3.10	22.55	.48	28.128	42.58	485	18.9	21.33	14.39	9.63	67.45	66.9	1775	.049	.127	.000071	3.59	3.73
13	1357	3.10	22.59	.48	28.169	42.66	485	18.9	21.35	14.42	9.66	67.53	67.0	1775	.052	.175	.000068	3.53	3.71
13	1357	3.10	22.60	.48	28.183	42.71	487	19.0	21.41	14.43	9.67	67.41	67.0	1775	.051	.192	.000067	3.58	3.71
13	1350	3.10	22.62	.47	28.197	42.76	486	19.0	21.40	14.45	9.62	67.52	66.6	1775	.055	.147	.000066	3.54	3.69
13	1356	3.10	22.61	.48	28.187	42.67	486	19.0	21.38	14.42	9.67	67.45	67.0	1775	.054	.171	.000070	3.57	3.72
14	1146	3.10	22.82	.34	28.261	40.53	485	18.6	21.01	13.70	8.18	65.20	59.7	1775	.087	.259	.000106	3.49	3.75
14	1147	3.10	22.82	.34	28.271	40.60	485	18.6	20.99	13.72	8.20	65.38	59.8	1775	.089	.230	.000106	3.53	3.77
14	1146	3.10	22.80	.34	28.241	40.51	485	18.6	20.99	13.69	8.18	65.23	59.7	1775	.088	.305	.000102	3.50	3.78
14	1147	3.10	22.80	.34	28.246	40.56	485	18.6	20.97	13.71	8.19	65.37	59.7	1775	.081	.277	.000104	3.47	3.76
14	1144	3.10	22.78	.34	28.227	40.44	485	18.6	20.97	13.67	8.17	65.19	59.7	1775	.085	.226	.000112	3.54	3.78
15	921	3.10	24.47	.22	29.798	41.31	486	18.7	21.13	13.96	6.94	66.07	49.7	1775	.099	.356	.000121	3.26	3.97
15	919	3.10	24.48	.22	29.800	41.28	486	18.7	21.13	13.95	6.93	66.02	49.6	1775	.110	.380	.000119	3.25	3.88
15	920	3.10	24.51	.22	29.835	41.36	486	18.8	21.18	13.98	6.94	65.98	49.6	1775	.101	.284	.000107	3.19	4.24
15	923	3.10	24.52	.22	29.841	41.35	486	18.7	21.16	13.97	6.96	66.04	49.8	1775	.108	.330	.000125	3.18	4.04
15	923	3.10	24.49	.22	29.819	41.32	487	18.7	21.18	13.96	6.96	65.93	49.8	1775	.104	.306	.000124	3.08	4.14
16	837	3.10	25.63	.18	30.911	42.15	486	18.9	21.29	14.25	6.54	66.91	45.9	1775	.090	.371	.000120	1.84	3.63
16	833	3.10	25.70	.18	30.984	42.24	486	18.9	21.28	14.27	6.52	67.08	45.7	1775	.084	.265	.000110	1.90	3.21
16	834	3.10	25.67	.18	30.957	42.24	486	18.9	21.29	14.27	6.53	67.04	45.7	1775	.088	.235	.000110	1.93	3.09
16	832	3.10	25.70	.18	30.982	42.15	486	18.9	21.27	14.24	6.52	66.98	45.8	1775	.097	.282	.000108	1.81	2.68
16	834	3.10	25.73	.18	31.014	42.26	486	18.9	21.31	14.28	6.54	67.00	45.8	1775	.089	.243	.000119	1.83	3.27
17	740	3.10	27.11	.14	32.355	43.44	486	19.0	21.51	14.68	6.05	68.26	41.2	1775	.092	.324	.000110	1.05	3.20
17	738	3.10	27.10	.14	32.346	43.40	487	19.1	21.52	14.67	6.04	68.14	41.1	1775	.094	.281	.000115	.91	1.95
17	738	3.10	27.16	.14	32.405	43.57	487	19.1	21.55	14.73	6.05	68.32	41.1	1775	.089	.234	.000110	.88	3.52
17	734	3.10	27.10	.14	32.346	43.47	486	19.1	21.53	14.69	6.00	68.23	40.8	1775	.092	.301	.000113	.14	2.17
17	736	3.10	27.08	.14	32.326	43.46	486	19.1	21.53	14.69	6.02	68.21	41.0	1775	.097	.308	.000109	.09	2.83

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Figure 147. (Sheet 3 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	2861	3.10	.80	2.12	8.030	37.25	478	18.2	20.19	12.59	5.81	62.36	46.1	1775	.029	.091	.000076	3.61	3.74
1	2865	3.10	.81	2.13	8.042	37.31	478	18.2	20.22	12.61	5.82	62.35	46.2	1775	.029	.075	.000079	3.53	3.74
1	2857	3.10	.86	2.12	8.079	37.29	479	18.2	20.28	12.60	5.84	62.15	46.3	1775	.026	.079	.000075	3.43	3.74
1	2854	3.10	.87	2.11	8.087	37.32	479	18.3	20.32	12.61	5.83	62.07	46.3	1775	.032	.087	.000080	3.56	3.74
1	2861	3.10	.77	2.12	7.999	37.16	479	18.2	20.26	12.56	5.78	61.98	46.1	1775	.030	.097	.000076	3.56	3.74
2	2649	3.10	5.58	1.82	12.507	40.14	481	18.6	20.81	13.56	8.37	65.18	61.7	1775	.040	.095	.000067	3.56	3.74
2	2643	3.10	5.64	1.81	12.556	40.16	481	18.6	20.81	13.57	8.39	65.24	61.8	1775	.036	.107	.000069	3.59	3.74
2	2644	3.10	5.59	1.81	12.504	40.14	480	18.6	20.76	13.57	8.36	65.36	61.6	1775	.030	.087	.000068	3.57	3.74
2	2651	3.10	5.62	1.82	12.546	40.17	480	18.6	20.79	13.58	8.41	65.32	61.9	1775	.033	.088	.000076	3.62	3.74
2	2648	3.10	5.64	1.82	12.565	40.17	480	18.6	20.75	13.58	8.41	65.42	61.9	1775	.035	.089	.000086	3.51	3.75
3	2502	3.10	8.51	1.62	15.242	41.77	481	18.8	21.04	14.12	9.64	67.11	68.3	1775	.031	.080	.000068	3.63	3.75
3	2502	3.10	8.52	1.62	15.246	41.69	480	18.8	21.03	14.09	9.64	67.01	68.4	1775	.035	.085	.000071	3.19	3.76
3	2502	3.10	8.50	1.62	15.229	41.67	480	18.8	21.00	14.08	9.63	67.05	68.4	1775	.040	.111	.000063	3.62	3.75
3	2500	3.10	8.54	1.62	15.270	41.73	481	18.9	21.06	14.10	9.65	66.96	68.4	1775	.031	.090	.000066	3.54	3.75
3	2497	3.10	8.52	1.62	15.243	41.74	481	18.8	21.03	14.11	9.62	67.06	68.2	1775	.029	.078	.000068	3.56	3.74
4	2345	3.10	11.38	1.43	17.912	43.04	482	19.0	21.28	14.55	10.62	68.36	73.0	1775	.037	.105	.000068	3.65	3.75
4	2346	3.10	11.42	1.43	17.948	43.05	482	19.0	21.27	14.55	10.65	68.41	73.2	1775	.038	.125	.000063	3.65	3.74
4	2347	3.10	11.36	1.43	17.889	42.99	482	19.0	21.28	14.53	10.62	68.27	73.1	1775	.031	.081	.000071	3.66	3.76
4	2350	3.10	11.35	1.43	17.890	43.03	481	19.0	21.27	14.54	10.63	68.39	73.1	1775	.035	.090	.000065	3.66	3.77
4	2344	3.10	11.42	1.43	17.953	43.12	481	19.0	21.26	14.57	10.64	68.56	73.0	1775	.034	.098	.000066	3.67	3.75
5	2206	3.10	13.80	1.26	20.167	43.89	480	19.1	21.33	14.83	11.25	69.54	75.8	1775	.037	.093	.000064	3.58	3.75
5	2208	3.10	13.80	1.26	20.165	43.85	480	19.1	21.30	14.82	11.26	69.57	75.9	1775	.052	.154	.000074	3.53	3.75
5	2202	3.10	13.82	1.26	20.180	43.92	480	19.1	21.35	14.84	11.23	69.53	75.7	1775	.045	.116	.000079	3.66	3.75
5	2202	3.10	13.82	1.26	20.182	43.89	480	19.1	21.32	14.83	11.24	69.57	75.7	1775	.043	.122	.000072	3.65	3.77
5	2198	3.10	13.81	1.25	20.172	43.83	480	19.1	21.31	14.81	11.21	69.51	75.7	1775	.042	.109	.000069	3.67	3.75
6	2095	3.10	15.46	1.14	21.706	44.14	480	19.2	21.34	14.92	11.49	69.91	77.0	1775	.030	.105	.000066	3.66	3.74
6	2096	3.10	15.50	1.14	21.740	44.14	480	19.2	21.34	14.92	11.52	69.91	77.2	1775	.035	.104	.000067	3.66	3.75
6	2094	3.10	15.46	1.14	21.706	44.13	480	19.2	21.35	14.91	11.49	69.85	77.1	1775	.039	.111	.000062	3.67	3.75
6	2092	3.10	15.52	1.14	21.757	44.16	480	19.2	21.36	14.93	11.51	69.87	77.1	1775	.034	.106	.000069	3.67	3.76
6	2095	3.10	15.51	1.14	21.750	44.20	480	19.2	21.37	14.94	11.52	69.90	77.1	1775	.029	.074	.000069	3.67	3.75

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Figure 148. Research data; pump 3, Test K-04, sump 18, submergence 3.1 ft (Sheet 1 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
7	2010	3.10	16.60	1.05	22.754	44.29	480	19.2	21.35	14.97	11.56	70.11	77.3	1775	.053	.143	.000067	3.62	3.76
7	2011	3.10	16.58	1.05	22.732	44.24	481	19.2	21.38	14.95	11.56	69.92	77.3	1775	.037	.095	.000066	3.66	3.79
7	2005	3.10	16.61	1.04	22.753	44.26	480	19.2	21.37	14.96	11.53	70.00	77.1	1775	.038	.104	.000063	3.60	3.73
7	2009	3.10	16.57	1.05	22.721	44.24	480	19.2	21.38	14.95	11.54	69.93	77.2	1775	.036	.094	.000065	3.61	3.72
7	2002	3.10	16.60	1.04	22.744	44.26	481	19.2	21.42	14.96	11.51	69.82	77.0	1775	.031	.078	.000066	3.63	3.70
8	1897	3.10	17.94	.93	23.978	44.31	479	19.2	21.31	14.97	11.50	70.26	76.8	1775	.033	.090	.000069	3.64	3.75
8	1898	3.10	17.92	.93	23.960	44.30	479	19.2	21.31	14.97	11.50	70.27	76.8	1775	.042	.148	.000065	3.66	3.75
8	1898	3.10	17.99	.94	24.027	44.34	479	19.2	21.36	14.99	11.53	70.15	77.0	1775	.037	.095	.000064	3.67	3.75
8	1903	3.10	17.99	.94	24.030	44.26	480	19.2	21.36	14.96	11.56	70.04	77.3	1775	.032	.114	.000067	3.50	3.75
8	1901	3.10	18.01	.94	24.048	44.31	479	19.2	21.36	14.98	11.56	70.12	77.2	1775	.043	.126	.000074	3.64	3.75
9	1789	3.10	19.28	.83	25.210	44.17	481	19.2	21.40	14.93	11.40	69.77	76.4	1775	.032	.117	.000068	3.62	3.72
9	1793	3.10	19.29	.83	25.233	44.14	480	19.1	21.36	14.92	11.44	69.84	76.7	1775	.042	.148	.000058	3.56	3.73
9	1791	3.10	19.28	.83	25.214	44.13	480	19.1	21.35	14.92	11.42	69.87	76.5	1775	.033	.106	.000061	3.62	3.72
9	1792	3.10	19.28	.83	25.213	44.13	480	19.1	21.34	14.91	11.42	69.88	76.6	1775	.033	.097	.000055	3.63	3.72
9	1788	3.10	19.28	.83	25.214	44.13	480	19.1	21.32	14.91	11.40	69.94	76.4	1775	.030	.088	.000065	3.63	3.72
10	1697	3.10	20.24	.75	26.091	44.02	479	19.1	21.30	14.88	11.20	69.84	75.3	1775	.031	.078	.000064	3.66	3.72
10	1696	3.10	20.22	.75	26.069	44.01	480	19.1	21.33	14.87	11.18	69.73	75.2	1775	.039	.098	.000062	3.65	3.73
10	1698	3.10	20.24	.75	26.090	44.02	480	19.1	21.30	14.88	11.20	69.84	75.3	1775	.033	.086	.000066	3.63	3.72
10	1696	3.10	20.22	.75	26.073	44.03	480	19.1	21.30	14.88	11.18	69.88	75.1	1775	.043	.122	.000058	3.63	3.74
10	1694	3.10	20.23	.74	26.076	44.04	479	19.1	21.28	14.88	11.17	69.94	75.0	1775	.033	.100	.000065	3.64	3.72
11	1594	3.10	21.09	.66	26.849	43.67	482	19.1	21.39	14.76	10.82	69.01	73.3	1775	.042	.149	.000071	3.62	3.71
11	1597	3.10	21.08	.66	26.849	43.70	483	19.1	21.42	14.77	10.84	68.95	73.4	1775	.045	.135	.000069	3.62	3.71
11	1598	3.10	21.05	.66	26.819	43.67	483	19.1	21.40	14.76	10.83	68.98	73.4	1775	.031	.102	.000073	3.63	3.72
11	1595	3.10	21.03	.66	26.795	43.64	481	19.1	21.30	14.75	10.81	69.23	73.3	1775	.041	.124	.000069	3.64	3.75
11	1597	3.10	21.06	.66	26.828	43.66	481	19.1	21.31	14.76	10.83	69.23	73.4	1775	.043	.146	.000066	3.57	3.73
12	1499	3.10	21.59	.58	27.273	43.07	480	19.0	21.22	14.56	10.34	68.60	71.0	1775	.043	.121	.000077	3.58	3.73
12	1500	3.10	21.58	.58	27.267	43.07	480	19.0	21.19	14.56	10.34	68.71	71.1	1775	.034	.102	.000068	3.62	3.74
12	1496	3.10	21.61	.58	27.293	43.08	480	19.0	21.22	14.56	10.32	68.62	70.9	1775	.037	.111	.000063	3.57	3.75
12	1500	3.10	21.63	.58	27.321	43.11	480	19.0	21.19	14.57	10.36	68.77	71.1	1775	.038	.115	.000070	3.63	3.75
12	1500	3.10	21.64	.58	27.331	43.12	480	19.0	21.23	14.57	10.36	68.64	71.1	1775	.043	.141	.000081	3.64	3.74

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Figure 148. (Sheet 2 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1405	3.10	22.14	.51	27.761	42.79	482	19.0	21.19	14.46	9.86	68.23	68.2	1775	.047	.130	.000075	3.63	3.76
13	1404	3.10	22.14	.51	27.753	42.81	481	19.0	21.20	14.47	9.85	68.26	68.1	1775	.047	.141	.000081	3.61	3.74
13	1406	3.10	22.19	.51	27.805	42.83	482	19.0	21.22	14.48	9.88	68.21	68.3	1775	.044	.141	.000078	3.62	3.75
13	1406	3.10	22.19	.51	27.802	42.82	481	19.0	21.19	14.47	9.88	68.29	68.3	1775	.046	.115	.000080	3.61	3.74
13	1405	3.10	22.12	.51	27.736	42.69	481	18.9	21.17	14.43	9.85	68.14	68.3	1775	.045	.170	.000076	3.64	3.75
14	1307	3.10	22.41	.44	27.955	42.05	481	18.8	21.02	14.21	9.23	67.62	65.0	1775	.058	.175	.000088	3.58	3.74
14	1304	3.10	22.39	.44	27.936	42.05	481	18.8	21.02	14.21	9.21	67.62	64.8	1775	.060	.165	.000088	3.59	3.75
14	1300	3.10	22.38	.44	27.926	42.02	482	18.8	21.06	14.20	9.17	67.44	64.6	1775	.057	.151	.000090	3.60	3.76
14	1298	3.10	22.39	.44	27.935	42.05	482	18.8	21.05	14.21	9.17	67.50	64.5	1775	.062	.189	.000092	3.59	3.76
14	1304	3.10	22.39	.44	27.933	42.00	481	18.8	21.03	14.20	9.21	67.49	64.9	1775	.059	.153	.000095	3.61	3.77
15	1201	3.10	22.37	.37	27.844	40.80	480	18.7	20.81	13.79	8.45	66.26	61.3	1775	.082	.263	.000113	3.57	3.85
15	1198	3.10	22.37	.37	27.844	40.82	480	18.7	20.80	13.80	8.43	66.34	61.1	1775	.082	.240	.000109	3.61	3.84
15	1198	3.10	22.34	.37	27.814	40.77	481	18.7	20.81	13.78	8.43	66.21	61.2	1775	.088	.243	.000104	3.59	3.83
15	1204	3.10	22.37	.38	27.847	40.84	481	18.7	20.84	13.80	8.47	66.23	61.4	1775	.084	.259	.000113	3.57	3.83
15	1203	3.10	22.40	.38	27.878	40.86	480	18.7	20.83	13.81	8.48	66.28	61.4	1775	.080	.262	.000112	3.58	3.83
16	1047	3.10	23.03	.28	28.417	40.49	480	18.6	20.74	13.68	7.52	65.98	55.0	1775	.098	.299	.000124	3.46	3.85
16	1050	3.10	23.08	.29	28.470	40.55	479	18.6	20.72	13.70	7.56	66.16	55.1	1775	.092	.259	.000126	3.48	3.84
16	1051	3.10	23.02	.29	28.415	40.51	480	18.6	20.73	13.69	7.55	66.05	55.1	1775	.091	.332	.000116	3.49	4.00
16	1045	3.10	23.03	.28	28.416	40.52	480	18.6	20.72	13.70	7.51	66.08	54.8	1775	.096	.320	.000123	3.49	3.88
16	1048	3.10	23.06	.28	28.445	40.57	480	18.6	20.76	13.71	7.53	66.04	54.9	1775	.093	.287	.000124	3.44	3.87
17	918	3.10	24.23	.22	29.550	41.28	481	18.8	20.95	13.95	6.86	66.58	49.1	1775	.101	.278	.000126	3.29	3.92
17	917	3.10	24.21	.22	29.533	41.22	482	18.8	20.98	13.93	6.84	66.40	49.1	1775	.100	.362	.000119	3.26	3.95
17	920	3.10	24.17	.22	29.497	41.22	481	18.8	20.97	13.93	6.86	66.41	49.3	1775	.098	.351	.000125	3.33	4.22
17	918	3.10	24.16	.22	29.487	41.20	481	18.8	20.93	13.92	6.84	66.53	49.1	1775	.100	.365	.000116	3.28	4.83
17	917	3.10	24.20	.22	29.526	41.20	481	18.8	20.94	13.92	6.84	66.48	49.1	1775	.106	.451	.000120	3.28	4.32

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Figure 148. (Sheet 3 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
1	2854	3.10	1.00	2.11	8.217	37.10	482	18.4	20.57	12.54	5.93	60.95	47.3	1775	.031	.126	.000061	3.54	3.68
1	2852	3.10	.95	2.11	8.167	37.04	482	18.4	20.58	12.52	5.89	60.82	47.0	1775	.031	.075	.000053	3.57	3.66
1	2853	3.10	.98	2.11	8.195	37.09	482	18.4	20.57	12.54	5.91	60.94	47.2	1775	.034	.092	.000064	3.57	3.68
1	2855	3.10	.96	2.11	8.174	37.05	482	18.4	20.55	12.52	5.90	60.94	47.1	1775	.030	.083	.000061	3.44	3.67
1	2850	3.10	.97	2.11	8.183	37.09	482	18.4	20.57	12.53	5.90	60.92	47.0	1775	.028	.076	.000057	3.56	3.67
2	2654	3.10	5.52	1.83	12.449	39.77	482	18.8	21.00	13.44	8.35	64.02	62.1	1775	.037	.117	.000070	3.49	3.68
2	2650	3.10	5.54	1.82	12.468	39.91	482	18.8	21.05	13.49	8.35	64.08	61.9	1775	.032	.097	.000067	3.54	3.69
2	2653	3.10	5.52	1.83	12.452	39.81	482	18.8	21.01	13.45	8.35	64.05	62.1	1775	.032	.094	.000065	3.44	3.68
2	2643	3.10	5.57	1.81	12.482	39.88	482	18.8	21.00	13.48	8.34	64.18	61.9	1775	.031	.077	.000057	3.57	3.68
2	2649	3.10	5.56	1.82	12.489	39.87	482	18.8	21.02	13.48	8.36	64.10	62.1	1775	.032	.094	.000069	3.37	3.69
3	2517	3.10	8.36	1.64	15.105	41.50	482	19.0	21.28	14.03	9.61	65.92	68.5	1775	.040	.104	.000071	3.61	3.72
3	2515	3.10	8.35	1.64	15.091	41.48	482	19.0	21.27	14.02	9.60	65.91	68.4	1775	.032	.113	.000067	3.62	3.72
3	2514	3.10	8.36	1.64	15.099	41.55	482	19.0	21.29	14.04	9.60	65.96	68.3	1775	.035	.104	.000066	3.53	3.72
3	2514	3.10	8.37	1.64	15.118	41.48	482	19.0	21.28	14.02	9.61	65.89	68.5	1775	.026	.079	.000067	3.63	3.71
3	2518	3.10	8.37	1.64	15.117	41.48	482	19.0	21.27	14.02	9.62	65.91	68.7	1775	.028	.079	.000068	3.51	3.71
4	2404	3.10	10.59	1.50	17.191	42.55	482	19.1	21.42	14.38	10.45	67.12	72.7	1775	.027	.079	.000064	3.57	3.69
4	2400	3.10	10.60	1.49	17.201	42.56	482	19.2	21.44	14.38	10.44	67.09	72.6	1775	.028	.096	.000062	3.59	3.71
4	2396	3.10	10.60	1.49	17.191	42.54	482	19.2	21.43	14.38	10.41	67.08	72.4	1775	.032	.080	.000061	3.56	3.71
4	2402	3.10	10.59	1.50	17.191	42.57	482	19.2	21.43	14.39	10.44	67.14	72.5	1775	.033	.097	.000058	3.63	3.71
4	2397	3.10	10.65	1.49	17.244	42.59	482	19.2	21.45	14.39	10.45	67.11	72.6	1775	.032	.115	.000064	3.65	3.71
5	2305	3.10	12.19	1.38	18.676	43.32	482	19.2	21.54	14.64	10.88	67.99	74.3	1775	.032	.079	.000061	3.62	3.69
5	2298	3.10	12.18	1.37	18.653	43.33	482	19.2	21.52	14.64	10.84	68.04	74.0	1775	.026	.074	.000058	3.61	3.69
5	2300	3.10	12.23	1.37	18.703	43.31	482	19.2	21.52	14.64	10.87	68.00	74.3	1775	.042	.115	.000067	3.59	3.71
5	2305	3.10	12.17	1.38	18.653	43.26	482	19.2	21.51	14.62	10.87	67.98	74.3	1775	.032	.099	.000062	3.59	3.71
5	2302	3.10	12.21	1.38	18.685	43.30	482	19.2	21.51	14.63	10.88	68.02	74.3	1775	.038	.094	.000062	3.60	3.70
6	2195	3.10	14.03	1.25	20.381	43.83	481	19.3	21.56	14.81	11.31	68.70	76.3	1775	.038	.110	.000061	3.55	3.72
6	2193	3.10	14.00	1.25	20.356	43.86	481	19.3	21.58	14.82	11.28	68.69	76.1	1775	.032	.093	.000062	3.62	3.72
6	2194	3.10	14.02	1.25	20.377	43.88	481	19.3	21.55	14.83	11.30	68.82	76.2	1775	.036	.097	.000067	3.61	3.72
6	2192	3.10	14.04	1.25	20.387	43.86	481	19.3	21.56	14.82	11.30	68.76	76.2	1775	.027	.086	.000058	3.61	3.71
6	2194	3.10	13.98	1.25	20.335	43.77	481	19.3	21.53	14.79	11.28	68.70	76.3	1775	.033	.100	.000057	3.64	3.71

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Figure 149. Research data; pump 3, Test K-05, sump 18, submergence 3.1 ft
(Sheet 1 of 3)

READ NO.	DISC-HARGE GPM	SUBME-RGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOL-TAGE VOLT	CUR-RENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
7	2091	3.10	15.56	1.13	21.802	44.18	481	19.4	21.62	14.93	11.53	69.06	77.2	1775	.039	.108	.000062	3.62	3.72
7	2095	3.10	15.54	1.14	21.780	44.17	481	19.4	21.60	14.93	11.54	69.10	77.3	1775	.025	.082	.000060	3.64	3.73
7	2095	3.10	15.56	1.14	21.798	44.16	480	19.3	21.57	14.92	11.55	69.21	77.4	1775	.040	.092	.000060	3.63	3.72
7	2093	3.10	15.57	1.14	21.813	44.24	481	19.4	21.61	14.95	11.54	69.18	77.2	1775	.035	.105	.000067	3.44	3.72
7	2096	3.10	15.52	1.14	21.762	44.30	481	19.4	21.62	14.97	11.53	69.24	77.0	1775	.039	.104	.000069	3.64	3.71
8	1996	3.10	16.88	1.03	23.017	44.28	482	19.4	21.69	14.97	11.61	69.01	77.6	1775	.029	.090	.000064	3.58	3.72
8	1996	3.10	16.90	1.03	23.034	44.32	482	19.4	21.73	14.98	11.62	68.93	77.6	1775	.035	.092	.000063	3.65	3.72
8	1998	3.10	16.88	1.04	23.024	44.30	482	19.4	21.72	14.97	11.63	68.92	77.7	1775	.030	.097	.000066	3.59	3.72
8	1999	3.10	16.88	1.04	23.025	44.30	482	19.4	21.71	14.97	11.64	68.97	77.7	1775	.033	.087	.000068	3.62	3.72
8	1995	3.10	16.85	1.03	22.991	44.33	481	19.4	21.66	14.98	11.60	69.15	77.4	1775	.030	.092	.000066	3.64	3.72
9	1897	3.10	18.11	.93	24.146	44.29	482	19.4	21.66	14.97	11.58	69.08	77.4	1775	.024	.074	.000069	3.62	3.70
9	1901	3.10	18.12	.94	24.160	44.25	482	19.4	21.67	14.95	11.61	69.01	77.6	1775	.027	.077	.000066	3.61	3.69
9	1898	3.10	18.11	.93	24.150	44.25	482	19.4	21.67	14.96	11.59	69.01	77.5	1775	.034	.095	.000068	3.55	3.69
9	1898	3.10	18.11	.93	24.144	44.27	482	19.4	21.69	14.96	11.58	68.99	77.4	1775	.028	.082	.000062	3.62	3.70
9	1900	3.10	18.11	.94	24.150	44.28	482	19.4	21.68	14.96	11.60	69.01	77.5	1775	.026	.082	.000063	3.60	3.71
10	1786	3.10	19.35	.83	25.285	44.16	482	19.3	21.63	14.93	11.42	69.00	76.5	1775	.039	.107	.000057	3.61	3.71
10	1787	3.10	19.35	.83	25.280	44.18	481	19.3	21.61	14.93	11.42	69.10	76.5	1775	.031	.108	.000062	3.60	3.69
10	1787	3.10	19.39	.83	25.319	44.15	482	19.3	21.63	14.92	11.44	68.98	76.7	1775	.034	.112	.000060	3.47	3.70
10	1787	3.10	19.35	.83	25.286	44.13	481	19.3	21.62	14.91	11.43	68.98	76.6	1775	.032	.081	.000065	3.58	3.69
10	1782	3.10	19.41	.82	25.339	44.16	481	19.3	21.61	14.93	11.41	69.06	76.5	1775	.030	.088	.000063	3.61	3.70
11	1709	3.10	20.18	.76	26.038	44.11	482	19.3	21.66	14.91	11.25	68.84	75.5	1775	.033	.084	.000064	3.62	3.70
11	1716	3.10	20.17	.76	26.037	44.09	482	19.3	21.65	14.90	11.29	68.82	75.8	1775	.028	.078	.000066	3.61	3.71
11	1710	3.10	20.18	.76	26.044	44.10	482	19.3	21.62	14.90	11.26	68.94	75.5	1775	.033	.089	.000063	3.62	3.69
11	1715	3.10	20.19	.76	26.056	44.08	481	19.3	21.60	14.90	11.30	68.97	75.8	1775	.034	.084	.000066	3.60	3.71
11	1708	3.10	20.18	.76	26.038	44.08	481	19.3	21.61	14.90	11.24	68.95	75.5	1775	.031	.098	.000066	3.56	3.69
12	1597	3.10	21.08	.66	26.848	43.68	483	19.3	21.63	14.76	10.84	68.23	73.4	1775	.033	.106	.000071	3.62	3.72
12	1595	3.10	21.08	.66	26.843	43.66	483	19.3	21.64	14.76	10.82	68.20	73.3	1775	.032	.113	.000073	3.63	3.72
12	1595	3.10	21.09	.66	26.856	43.61	483	19.3	21.60	14.74	10.83	68.22	73.5	1775	.034	.100	.000076	3.60	3.72
12	1597	3.10	21.11	.66	26.880	43.69	483	19.3	21.62	14.77	10.86	68.30	73.5	1775	.039	.114	.000070	3.63	3.72
12	1597	3.10	21.11	.66	26.874	43.73	483	19.3	21.62	14.78	10.85	68.37	73.4	1775	.038	.122	.000070	3.61	3.71

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Figure 149. (Sheet 2 of 3)

READ NO.	DISCHARGE GPM	SUBMERGENCE FEET	STATIC HEAD FEET	VELOC. HEAD FEET	TOTAL HEAD FEET	TORQUE FT*LB	VOLTAGE VOLT	CURRENT AMPS	MOTOR POWER HP	SHAFT POWER HP	WATER POWER HP	MOTOR EFF. %	PUMP EFF. %	SHAFT SPEED RPM	VELOCITY RMS IPS	VELOCITY MAX. IPS	NOISE RMS PSI	PRESSURE MIN FEET	PRESSURE MAX FEET
13	1496	3.10	21.65	.58	27.334	43.14	482	19.2	21.52	14.58	10.34	67.76	70.9	1775	.038	.110	.000070	3.60	3.71
13	1500	3.10	21.64	.58	27.332	43.17	482	19.2	21.52	14.59	10.36	67.81	71.0	1775	.039	.111	.000073	3.59	3.70
13	1498	3.10	21.66	.58	27.343	43.14	482	19.2	21.49	14.58	10.35	67.84	71.0	1775	.046	.155	.000074	3.60	3.72
13	1495	3.10	21.65	.58	27.331	43.13	482	19.2	21.51	14.58	10.33	67.75	70.9	1775	.041	.107	.000076	3.61	3.73
13	1501	3.10	21.63	.58	27.315	43.08	482	19.2	21.50	14.56	10.36	67.71	71.2	1775	.042	.133	.000078	3.60	3.71
14	1405	3.10	22.16	.51	27.773	42.81	481	19.1	21.39	14.47	9.86	67.65	68.2	1775	.043	.137	.000079	3.57	3.71
14	1404	3.10	22.18	.51	27.794	42.87	481	19.1	21.40	14.49	9.87	67.71	68.1	1775	.047	.140	.000088	3.60	3.72
14	1407	3.10	22.18	.51	27.797	42.87	482	19.1	21.40	14.49	9.89	67.69	68.2	1775	.046	.125	.000084	3.59	3.72
14	1404	3.10	22.17	.51	27.789	42.79	482	19.1	21.42	14.46	9.86	67.53	68.2	1775	.050	.130	.000080	3.60	3.72
14	1404	3.10	22.14	.51	27.760	42.70	482	19.1	21.39	14.43	9.86	67.49	68.3	1775	.050	.155	.000077	3.59	3.74
15	1240	3.10	22.48	.40	27.984	41.28	481	18.9	21.13	13.95	8.77	66.04	62.9	1775	.076	.213	.000101	3.58	3.77
15	1241	3.10	22.46	.40	27.965	41.29	481	18.9	21.13	13.95	8.77	66.02	62.9	1775	.072	.183	.000106	3.60	3.80
15	1244	3.10	22.44	.40	27.950	41.21	482	18.9	21.13	13.93	8.79	65.93	63.1	1775	.074	.236	.000101	3.59	3.79
15	1243	3.10	22.45	.40	27.958	41.25	482	18.9	21.14	13.94	8.79	65.96	63.0	1775	.070	.228	.000102	3.57	3.77
15	1245	3.10	22.49	.40	27.992	41.28	482	18.9	21.16	13.95	8.81	65.95	63.2	1775	.073	.238	.000108	3.59	3.76
16	1097	3.10	22.79	.31	28.208	40.37	482	18.7	20.94	13.64	7.82	65.15	57.3	1775	.085	.251	.000123	3.51	3.81
16	1102	3.10	22.78	.31	28.200	40.40	482	18.7	20.96	13.65	7.85	65.14	57.5	1775	.090	.238	.000109	3.52	3.80
16	1103	3.10	22.78	.32	28.201	40.38	481	18.7	20.94	13.65	7.87	65.17	57.6	1775	.087	.280	.000128	3.53	3.84
16	1099	3.10	22.77	.31	28.191	40.37	482	18.7	20.97	13.64	7.83	65.08	57.4	1775	.090	.374	.000114	3.51	3.84
16	1100	3.10	22.82	.31	28.237	40.40	481	18.7	20.94	13.65	7.85	65.21	57.5	1775	.085	.252	.000119	3.49	3.86
17	928	3.10	24.29	.22	29.617	41.20	483	18.9	21.16	13.92	6.94	65.80	49.9	1775	.101	.300	.000124	3.25	3.95
17	925	3.10	24.26	.22	29.585	41.20	483	18.8	21.15	13.92	6.92	65.85	49.7	1775	.098	.333	.000121	3.28	4.18
17	923	3.10	24.26	.22	29.582	41.22	483	18.9	21.16	13.93	6.90	65.83	49.5	1775	.104	.283	.000124	3.24	3.98
17	922	3.10	24.20	.22	29.524	41.10	483	18.8	21.14	13.89	6.88	65.72	49.5	1775	.096	.288	.000127	3.31	3.95
17	926	3.10	24.22	.22	29.550	41.20	484	18.9	21.17	13.92	6.92	65.76	49.7	1775	.099	.284	.000134	3.17	4.49

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Figure 149. (Sheet 3 of 3)

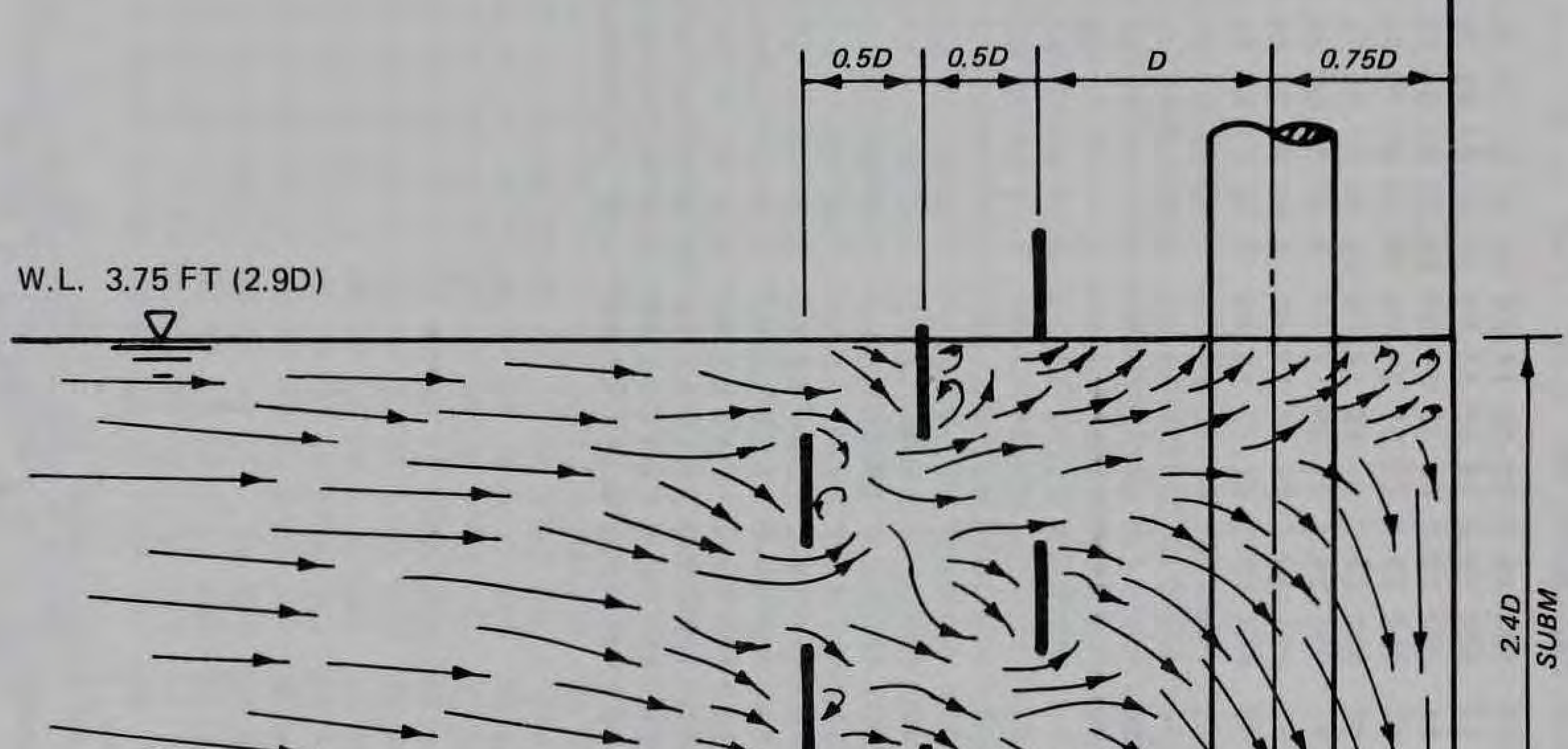


Figure 150. Base sump flow pattern for pump 3, SVS type 56, pump bell submergence 3.1 ft (2.4D), discharge 1,900 gpm, $Q/g^{1/2}D^{5/2} = 0.40$, base sump type 18

Pumps	Run	Sump	Submergence
003	K04	018	2.5

Date 27 Jul 82, Time 0830, Air Temp 78° F, Water Temp 63° F, Barometric Pressure 29.97 in. Hg.

01 ISV, Stage A, CCW at 8 o'clock and CW at 5 o'clock, both approximately 1/4 in. diam. IFV, CW, 1/8 in. diam at 5 to 7 o'clock and about 3 in. from CP (Center Point) of pump bell. IBWV 1/16 in. diam CCW at 7 o'clock.

02-03 NSCE (No Significant Change Except) all vortices becoming smaller and occurring less frequently.

04 NSCE additional ISV's appearing in each BW to SW corner, CCW on right and CW on left (looking downstream) both Stage A.

05 ISV's now only occurring at random positions downstream from pump column, all Stage A. IFV, CW mostly at 5 to 7 o'clock, 1/16 in. diam and approximately 3 to 4 in. from pump CP. IFV gone.

06-08 NSCE all vortices becoming smaller and occurring less frequently.

09-10 NSCE ISV's now occurring as surface dimples at random locations and directions.

11 NSCE surface dimples changing to circular motion at 4 o'clock CW and at 8 o'clock CCW.

Date 27 Jul 82, Time 1030, Air Temp 84° F, Water Temp 80° F, Barometric Pressure 29.96 in. Hg.

12-14 NSCE surface circular rotation becoming slower and more calm. IFV CW now mostly at 6 o'clock and approximately 1/32 in. diam.

15 NSCE IFV gone.

16 Spray expulsion of tiny air bubbles from pump bell intake reaching approximately 3 in. below bell.

Figure 151. Visual observation notes, test K-04

PART XI: VERTICAL DROP APPROACH FLOW

206. The 0.8D vertical drop was tested in a type 4 sump design (Figure 152) for pump 1 only. The sump had straight sidewalls 19D long. The floor of the sump and approach was straight and level (before vertical drop installation), and the sump was 2D wide. The pump bell intake was located 0.34D above the sump floor and 0.04D from the backwall. Comparison curves were developed for the pump 1, type 4 sump by procedures similar to those used to develop the subsequent signature curves for the type 18 sump for all three pumps (see Part X). The comparison curves for the type 4 sump were developed at a pump bell submergence of 2.5D. Curve fit was obtained using the least squares method for simple linear regression analysis. Figure 153 is an overlay of Tests H5, H6, H7, and H8. All four tests were very closely repeated as can be observed in Figure 153 by the thin lines and lack of separations, i.e., each of the four sets of test curves fell almost on top of one another. Figures 154-157 show each of the component tests plotted with the aggregate base curves. Arrows on the curve plots designate the types of vortices and at what operating ranges they were observed. Reading numbers are shown just above the arrows. These may be referenced to the visual observation notes (Figures 158-161). Statistical comparisons of each of the component test curves with the aggregate base curves are shown in Figures 162-165. The statistical comparisons substantiate the good repeatability of the four component base tests. The flow pattern for the base tests for a discharge ratio R of 0.4 is shown in Figure 166. The flow patterns are important for analysis with subsequent vertical step flow patterns and for reference to the visual observation notes. The research data are given in Figures 167-170. Two additional tests (H9 and H10) were conducted with the base sump but at two lower submergences (1.47D and 0.47D). These two arbitrarily selected submergences were tested to provide a basis for comparison of subsequent vertical drop sumps with corresponding submergences. The performance characteristics curves, visual observation notes, statistical comparisons, tabulated data, and flow patterns for Tests H9 and H10 are shown in Figures 171-178 and 166.

Vertical Drop Location 2D

207. Three submergences (2.47D, 1.47D, and 0.47D) were tested with the

0.8D vertical drop located 2D upstream from the pump bell center line (Tests H02-H04). The performance characteristics curves, visual observation notes, statistical comparisons, tabulated data, and flow patterns are shown in Figures 179-191. Instrumentation for noise was not operative during Tests H02 and H03; however, related data were satisfactory for analysis without the noise data. The overall evaluation indicates that this sump (type 7) is adverse by a small degree for most of the varied range of discharges except at the lowest submergence (0.47D). The 0.47D tests (H04) results were much worse than the corresponding submergence with the type 4 sump (Test H10). The cause of the more adverse flow is believed to be due to the formation of a hydraulic jump downstream from the 0.8D drop that entrained a vast amount of air into the flow.

Vertical Drop Location 1D

208. Only two submergences (2.47D and 1.47D) were tested with the vertical drop located 1D upstream from the pump center line (Tests H11 and H12). The lower submergence (0.47D) was omitted due to the severe vibration of the pump and motor. The vibration increased significantly at the low submergence when the 0.8D drop was relocated less than 2D from the pump center line. The data package for the two upper submergences is given in Figures 192-200 consisting of pump performance curves, visual observation notes, statistical comparisons, tabulated data, and flow patterns. A comparison of these results with those of the base curves showed a slight change in H-Q , an increase in P_s , and an increase in vibration.

Vertical Drop Locations 5D, 10D, and 19D

Location 5D

209. The submergences tested and the testing techniques and evaluation used with the 2D drop locations were also used with the 5D located design (sump type 8, Tests H13-H15). The corresponding data package is presented in Figures 201-213 for performance curves, visual observation notes, statistical comparisons, tabulated data, and flow patterns.

Location 10D

210. Data results for the 10D drop location at submergences of 2.47D,

1.47D, and 0.47D are shown by Tests H16-H18 (sump type 9) in Figures 214-226 for pump performance curves, visual observation notes, statistical comparisons, tabulated data, and flow patterns.

Location 19D

211. No tests were conducted with the vertical drop located 19D upstream from the pump center line. The effect of the vertical drop diminishes as its location from the center line of the pump increases. It is assumed that no effect will exist at the 19D location and the base tests can be used as another point for plotting curves of pump location versus discharge ratio (see following section "Discussion of Vertical Drop Testing").

212. Results of testing at a single drop location (5D, 10D, or 19D) produced no clear conclusions when analyzed alone. Consistent patterns or trends were searched for with each additional test. A more complete comparison is made in the following section, "Discussion of Vertical Drop Testing."

Verification of Signature Curve Data

213. Three additional tests (T03, T04, and T05) were conducted at a submergence of 2.47D using the base type 4 sump. These test results were compared with one another and with base test data results (see paragraph 206) previously obtained, to determine the accuracy of repeatability. These test results (T03, T04, and T05) are shown in Figures 227-238 for performance curves, visual observation notes, statistical comparisons, and tabulated data. The latest acquired performance curves were on the same graph as the previously plotted base curves. The spread of these data was used as a guideline for evaluation of the previously tested vertical drop designs. A discussion of this evaluation is presented in the next paragraph.

Discussion of Vertical Drop Testing

Perspective

214. The 0.8D vertical drop was part of the early testing using the generalized pump sump research facility. This testing series was instrumental in providing guidance for testing of pump location, SVS, scale effects, and other appurtenances. It became apparent during vertical drop testing that optimum sump evaluation techniques and accurate, reliable instrumentation are

essential to provide a satisfactory benefit/cost ratio for future testing. It is important that the reader recognize that the signature curves developed for the 0.8D vertical drop testing are different from those discussed in Part X of this report. Those curves presented in Part X are the most recent and include improvements in instrumentation and other development techniques. The 0.8D vertical drop testing part of this report is arranged after the signature curve part in order to avoid repetition of the explanation of the developmental procedure. The procedure was identical except where noted.

Summary and conclusions

215. Single pump (pump 1) operation was used to test for the influence of an 0.8D vertical drop placed across the sump in the approach flow upstream from the pump. A progressive index of this testing is shown in Figure 239. The 0.8D vertical drop causes only minor deviations from the performance standards established by the base sump design; when the drop is located at distances equal to or greater than 2D from the center line of the pump, the flow is uniform in the lateral plane, and submergences are 1.47D or greater. The vortex drop-out evaluation technique as explained in Part V of this report is another means of showing the effects of the vertical drop with respect to location, submergence, and discharge ratio. These patterns are shown in Figures 240-242 with respect to FV, BWV, and SV, respectively. A repeat of the base sump tests revealed some drift in the results of the earlier base sump tests, underscoring the need for more accurate data and an improved base sump. Other testing presented in this report, instrumentation improvements, and improved testing procedures were largely due to these needs recognized during the evaluation of the 0.8D vertical drop tests. Based on test results obtained, the 0.8D drop should be located no closer than 2D from the center line of the pump for uniform flow and submergences greater than 1.47D. For conditions outside these guidelines, a site-specific model study is recommended.

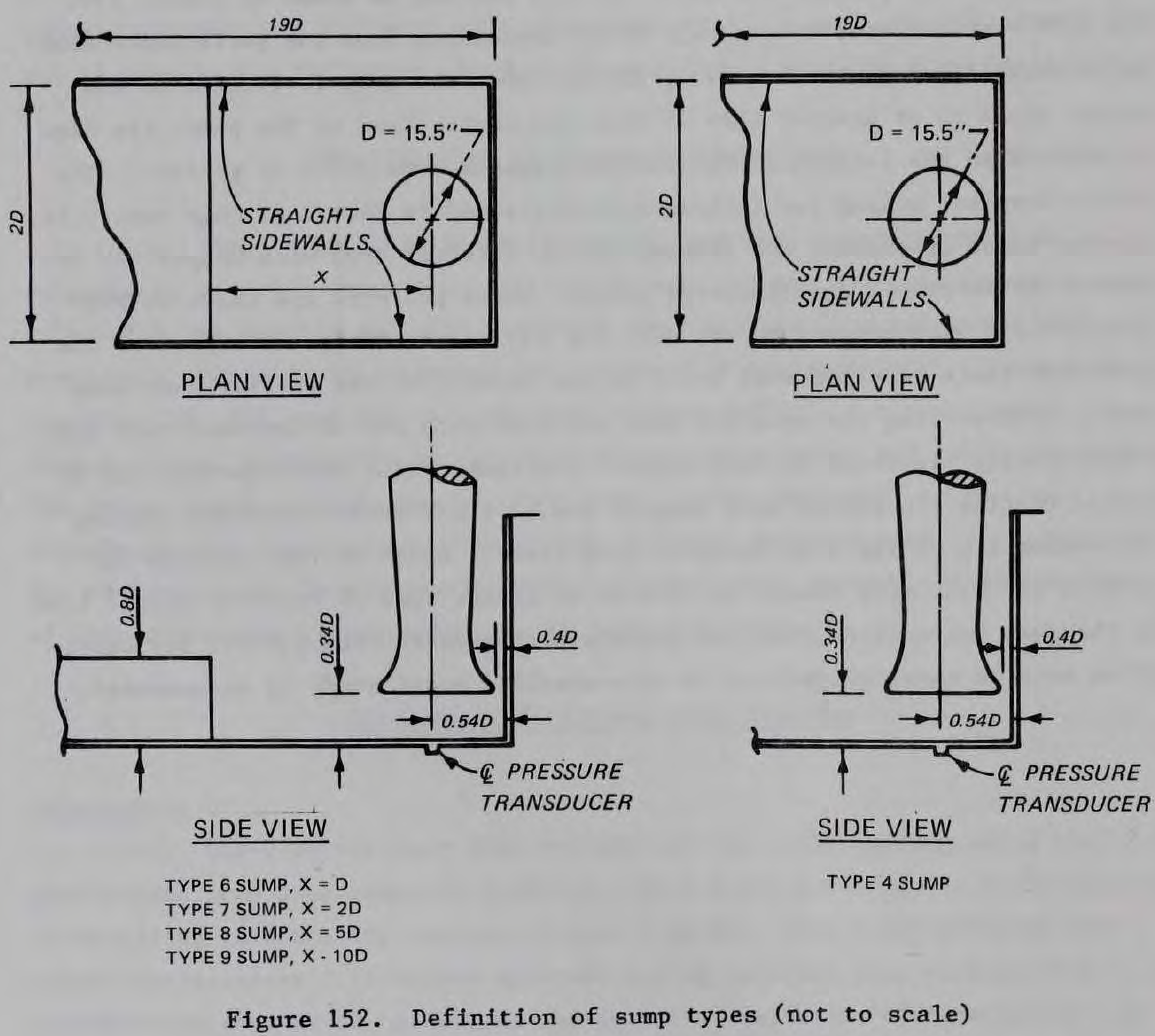


Figure 152. Definition of sump types (not to scale)

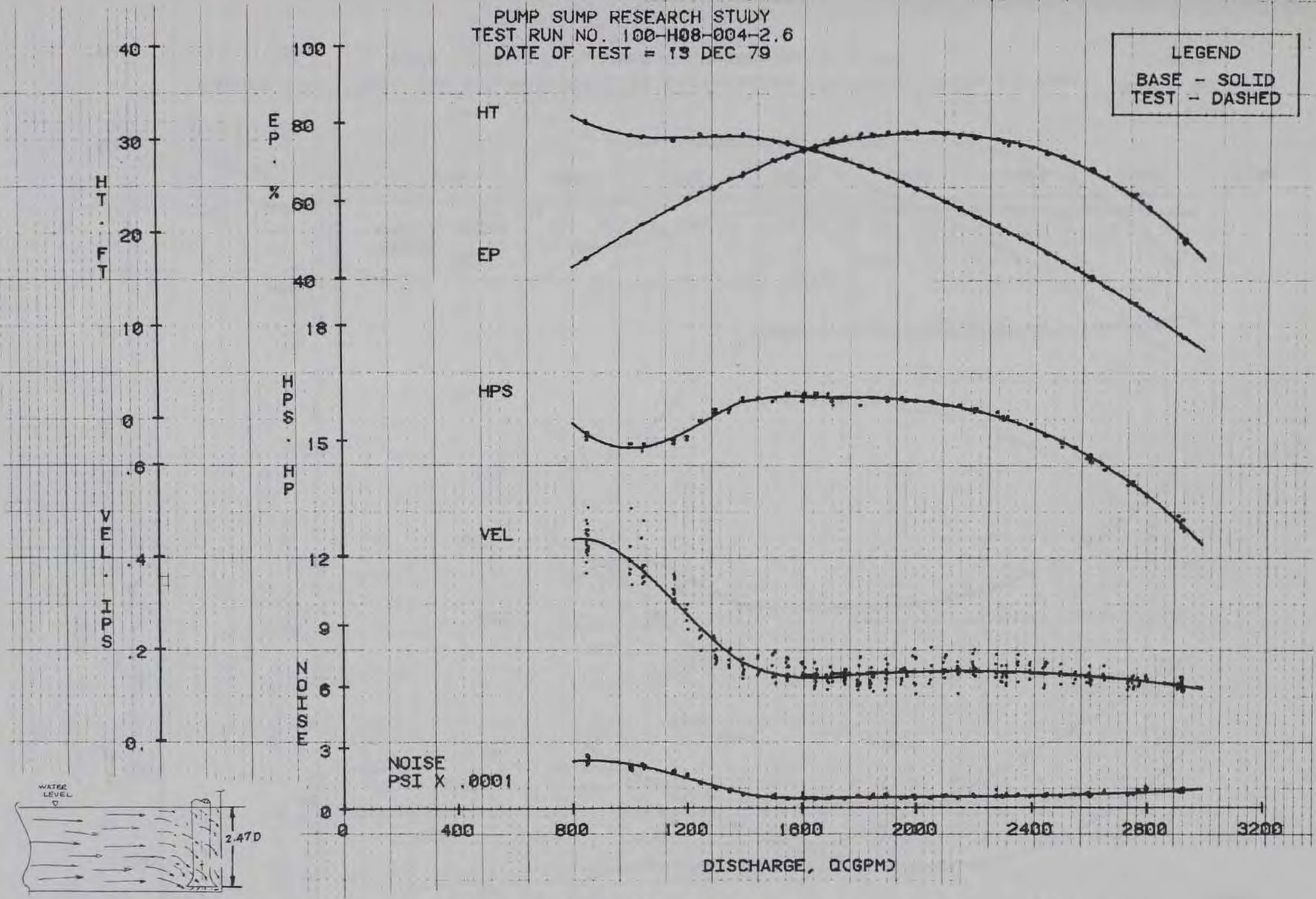


Figure 153. Test run 100-H5678-004-2.6; performance characteristics curves; pump 1, Test H5678, sump 4, submergence 2.47D

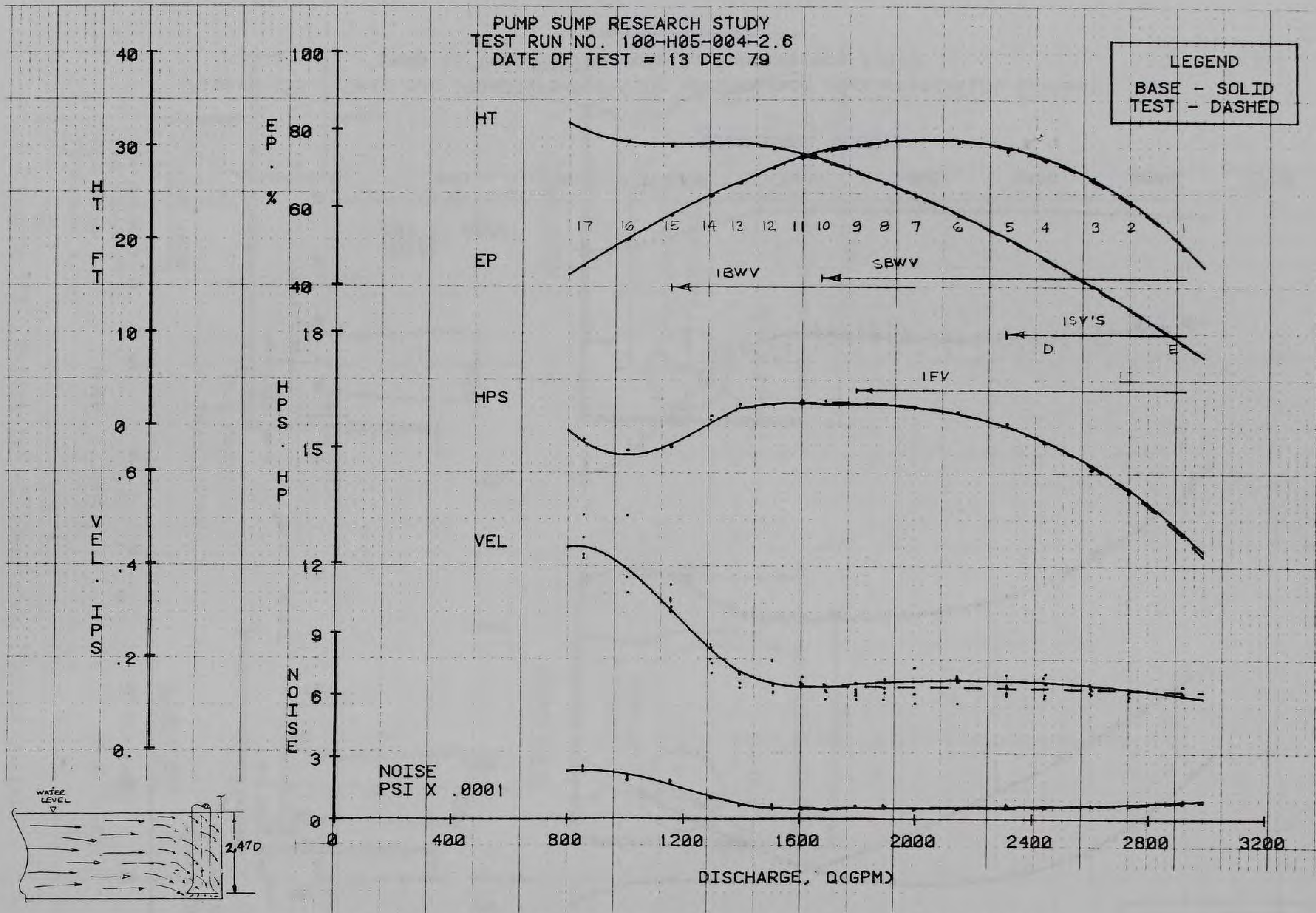


Figure 154. Test run 100-H05-004-2.6; performance characteristics curves; pump 1, Test H05, sump 4, submergence 2.47D

Figure 155. Test run 100-H06-004-2.6; performance characteristics curves; pump 1, Test H06, sump 4, submergence 2.47D

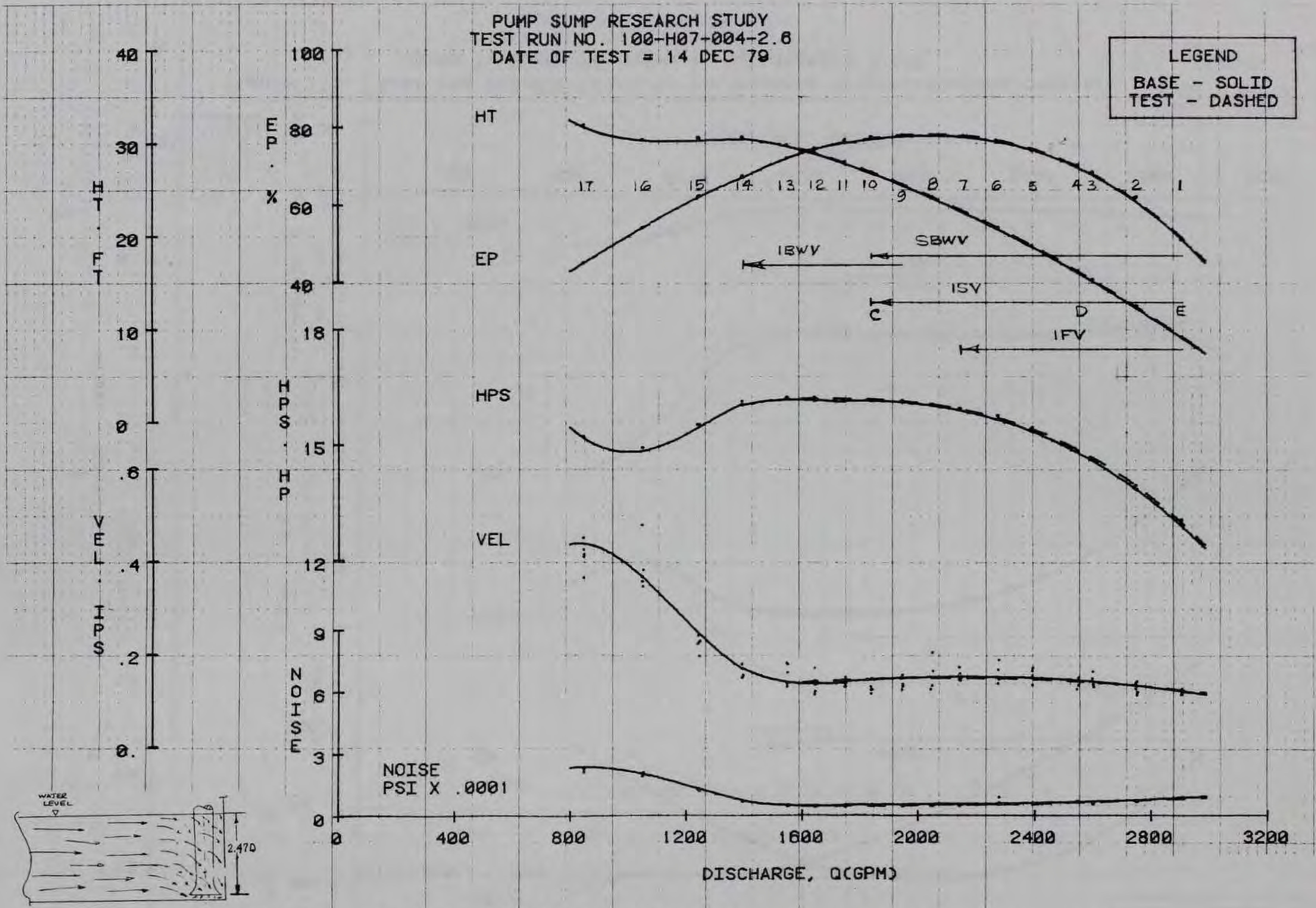


Figure 156. Test run 100-H07-004-2.6; performance characteristics curves; pump 1, Test H07, sump 4, submergence 2.47D

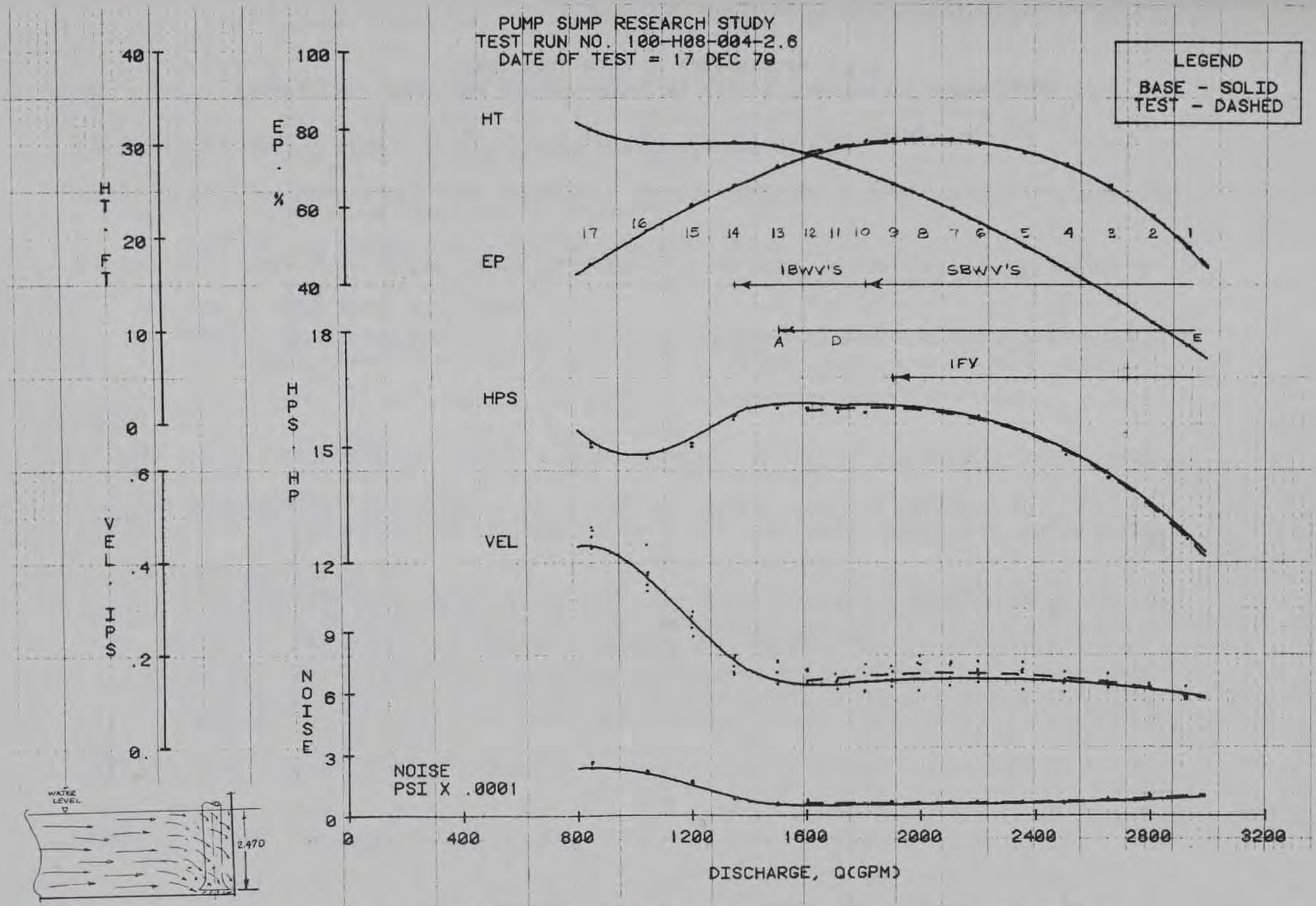


Figure 157. Test run 100-H08-004-2.6; performance characteristics curves; pump 1, Test H08, sump 4, submergence 2.47D

PUMPS RUN SUMP SUBMERGENCE
100 H04 007 0 0

DATE 11 DEC 79 TIME 1200 AIR TEMP 67 F WATER TEMP 54 F BAR PRESS 29.94IN HG

01 EXTREME TURBULENCE WITH HYD JUMP. 1SWV'S 3/4 IN DIA CCW AT 3 TO 5 O'CLOCK & CW AT 7 TO 9 O'CLOCK. SOME OF THE SIDE WALL VORTEXES REACH COMPLETELY ACROSS THE SUMP ABOUT 0.6 FT FROM FLOOR & ABOUT 2-3 IN FROM BACK WALL. TFV CCW LOCATION VARYING ALL AROUND 1/2 IN DIA. SV'S APPEARING TO BE TRYING TO FORM BUT TURBULENCE IS BREAKING THEM UP. THERE IS SO MUCH TRAPPED AIR THAT VALIDITY OF DATA IS QUESTIONABLE. UNABLE TO SEE BLADE FOR AIR BUBBLES.

02-06 NSCE (NO SIGNIFICANT CHANGE EXCEPT) ALL VORTEXES APPRX 1/4 IN SMALLER TURBULENCE ABOUT SAME.

07-08 TURULENCE BECOMING SLIGHTY LESS SEVERE. TFV LESS FREQUENT, SWV'S WEAKER.

09-11 NSC.

12 TFV GONE. TWIN 1BWV'S AT 5:30 CCW & 6:30 CW, BOTH 1/2 IN DIA. STILL UNABLE TO SEE BLADE FOR AIR BUBBLES, TURBULENCE STILL VERY BAD. 1SV CCW 3/4 IN DIA AT 7 O'CLOCK.

13-16 NSCE BWV'S BECOMING SMALLER APRX 1/4 IN DIA, SPRAY EXPULSION ABOUT 4 IN FROM BELL INTAKE.

DATE 11 DEC 79 TIME 1340 AIR TEMP 74 F WATER TEMP 56 F BAR. PRESS. 29.90IN HG

17 NSCE SWV'S GONE. SPRAY EXPULSION REACHING FLOOR.

Figure 158. Test run 100-H05-004-2.6; visual observation notes; pump 1, Test H05, sump 4, submergence 2.47D

PUMPS RUN SUMP SUBMERGENCE
100 H06 004 2.6

DATE 13 DEC 79 TIME 1350 AIR TEMP 48 F WATER TEMP 59 F BAR. PRESS. 30.08IN HG

01 ISV CW 1/2 IN DIA STAGE E AT 4 O'CLOCK. ISV CCW 1/2 IN DIA STAGE E AT 8 O'CLOCK. IFV'S 1/8 IN DIA. CW. LOCATION VARYING ALL AROUND. TWIN SBWV'S AT 6:30 CW & 5:30 CCW, BOTH 1/8 IN DIA.

02 NSCE (NO SIGNIFICANT CHANGE EXCEPT) ALL VORTEXES BECOMING SMALLER & OCCURRING LESS FREQUENT.

03 NSCE ISV NOW 1/4 IN DIA, FV'S NOW 1/16 IN DIA.

04 NSCE IFV AT 8 O'CLOCK HAS DISAPPEARED. ISV AT 4 O'CLOCK NOW STAGE D. SBWV'S NOW 1/16 IN DIA.

05 NSCE IFV NOW 1/32 IN DIA & LOCATION ALMOST ALWAYS AT 8 O'CLOCK, 3 IN FROM BELL CP.

06 NSCE ALL SV'S GONE. IFV ALTERNATING BETWEEN LOCATIONS 4 & 8 O'CLOCK.

07 NSCE BWV'S 1/16 IN DIA, FV'S 1/32 IN DIA.

08 NSCE TINY FLASHING APPEARING ON TIP OF BLADE. POSSIBLE CAVITATION.

09-10 NSCE SBWV AT 6:30 BECOMING IBWV. ALL VORTEXES BECOMING SMALLER & OCCURRING LESS FREQUENT.

11 NSCE FV GONE. SV'S NOW STAGE C. BWV'S 1/32 IN DIA.

DATE 13 DEC 79 TIME 1500 AIR TEMP 48 F WATER TEMP 59 F BAR. PRESS 30.06IN HG

12 NSCE BOTH BWV'S NOW IBWV'S. SURFACE VORTEXES NOW STAGE A.

13 NSCE FLASHING BECOMING MUCH LARGER & VORTEXES BECOMING SMALLER & OCCURRING LESS FREQUENT.

14 NSCE BWV'S GONE.

15 NSCE ALL VORTEXES GONE.

16 NSC

17 NSCE SPRAY EXPULSIONS FROM BELL INTAKE REACHING TO SUMP FLOOR

DATE 13 DEC 79 TIME 1530 AIR TEMP 49 F WATER TEMP 59 F BAR.PRESS. 30.06IN HG

Figure 159. Test run 100-H06-004-2.6; visual observation notes; pump 1, Test H06, sump 4, submergence 2.47D

PUMPS RUN SUMP SUBMERGENCE
100 H02 007 2.6

DATE 06 DEC 79 TIME 1300 AIR TEMP 63 F WATER TEMP 53 F BAR. PRESS. 29.67IN HG

01 ISV 1/2 IN DIA CW AT 5 O'CLOCK STAGE E. ISV 1/2 IN DIA CCW AT 7 O'CLOCK STAGE E, TWIN SBWV'S 1/8 IN DIA AT 5:30 CCW & 6:30 CW, IFV 1/16 IN DIA AT 6:00 O'CLOCK, DIRECTION OF ROTATION UNKNOWN, TOO FAST

02-03 NSCE (NO SIGNIFICANT CHANGE EXCEPT) ISV & IFV BECOMING LESS FREQUENT & SMALLER, ISV'S NOW STAGE D.

04 TWIN SBWV'S NOW 1/16 IN DIA, ISV STAGE C, IFV GONE.

05 NSCE FLASHING APPEARING ON TIP OF BLADES, POSSIBLE CAVITATION.
ISV'S NOW STAGE B & 1/8 IN DIA, SBWV'S NOW 1/16 IN DIA.

05-08 NSCE FLASHING BECOMING LARGER, ISV'S NOW STAGE A.

09 NSCE ISV GONE, CIRCULAR MOTION SAME DIRECTION & LOCATION AS PREVIOUS SV

10-14 NSCE TWIN SBWV'S BECOMING IBWV'S, FLASHING GETTING LARGER

15 ALL VORTEXES GONE

16 NSCE FLASHING ON BLADE GETTING LARGER

17 NSCE SPRAY EXPULSION APPROX 3 IN BELOW BELL INTAKE.

Figure 160. Test run 100-H07-004-2.6; visual observation notes; pump 1, Test H07, sump 4, submergence 2.47D

PUMPS RUN SUMP SUBMERGENCE
100 H08 004 2.6

DATE 17 DEC 79 TIME [illegible] AIR TEMP 36 F WATER TEMP 50 F BAR. PRESS. 30.50IN HG

01 TSV CW 1/2 IN DIA STAGE E AT 6 O'CLOCK. TSV CCW 1/2 IN DIA STAGE E AT 8 O'CLOCK. TFV'S 1/8 IN DIA, CW, LOCATION VARYING ALL AROUND. TWIN SBWV'S AT 4:30 CW & 5:30 CCW, BOTH 1/8 IN DIA

02-03 NSCF (NO SIGNIFICANT CHANGE EXCEPT) ALL TV'S GETTING SMALLER & OCCURRING LESS FREQUENT

04 NSC

05 NSCE ALL TV'S GETTING SMALLER & TFV'S NOW SBWV'S NOW 1/16 IN DIA TSV'S NOW 1/8 IN DIA, STILL STAGE E

06-09 NSCE ALL VORTEXES GETTING SMALLER, WEAKER & OCCURRING LESS OFTEN.

10 NSCE, TV'S [illegible] TINY [illegible] APPEARING ON OUTSIDE TIP OF BLADE, POSSIBLE CAVITATION.

11 NSCE TSV'S NOW STAGE B SBWV'S BECOMING TBWV'S.

12 NSC

DATE 17 DEC 79 TIME 1035 AIR TEMP 37 F WATER TEMP 51 F BAR PRESS. 30.49IN HG

13 NSCE TSV'S NOW STAGE A [illegible] ON BLADE BECOMING MUCH LARGER.

14 [illegible] NOW [illegible] SMALLER & OCCURRING LESS FREQUENT, NOW 1/32 [illegible]

15 NSCE ALL VORTEXES NOW GONE.

16 NSC

17 NSCE [illegible] INTAKE REACHING TO SUMP FLOOR

DATE 17 DEC 79 TIME 1100 AIR TEMP 38 F WATER TEMP 50F BAR. PRESS. 30.49IN HG

Figure 161. Test run 100-H08-004-2.6; visual observation notes; pump 1, Test H08, sump 4, submergence 2.47D

***PUMP EFFICIENCY ***

TOTAL AREA	-512.08	ABSOLUTE AREA	512.08

TEST CURVE

	Y		X
MAX Y =	77.14	, X =	2034.65
MIN Y =	44.35	, X =	2987.62
MEAN Y =	71.38	, X =	2461.38

* * *

SIGNATURE CURVE

	Y		X
MAX Y =	77.31	, X =	2034.65
MIN Y =	44.36	, X =	2987.62
MEAN Y =	71.86	, X =	2460.73

***NOISE LB/IN**2 ***

TOTAL AREA	-25.29	ABSOLUTE AREA	39.62

TEST CURVE

	Y		X
MAX Y =	0.85	, X =	2987.62
MIN Y =	0.53	, X =	1600.00
MEAN Y =	0.57	, X =	2596.49

* * *

SIGNATURE CURVE

	Y		X
MAX Y =	0.93	, X =	2987.62
MIN Y =	0.47	, X =	1631.19
MEAN Y =	0.56	, X =	2571.52

***SHAFT HORSEPOWER ***

TOTAL AREA	-16.51	ABSOLUTE AREA	45.87

TEST CURVE

	Y		X
MAX Y =	16.15	, X =	1723.27
MIN Y =	12.16	, X =	2987.62
MEAN Y =	15.55	, X =	2296.36

* * *

SIGNATURE CURVE

	Y		X
MAX Y =	16.14	, X =	1600.00
MIN Y =	12.27	, X =	2987.62
MEAN Y =	15.54	, X =	2300.66

***TOTAL HEAD ***

TOTAL AREA	-125.97	ABSOLUTE AREA	125.97

TEST CURVE

	Y		X
MAX Y =	28.94	, X =	1600.00
MIN Y =	7.06	, X =	2987.62
MEAN Y =	23.28	, X =	2084.90

* * *

SIGNATURE CURVE

	Y		X
MAX Y =	29.07	, X =	1600.00
MIN Y =	7.10	, X =	2987.62
MEAN Y =	23.39	, X =	2081.24

***ABS VELOCITY,IPS ***

TOTAL AREA	-10.32	ABSOLUTE AREA	13.18

TEST CURVE

	Y		X
MAX Y =	0.13	, X =	1600.00
MIN Y =	0.12	, X =	2987.62
MEAN Y =	0.13	, X =	2181.90

* * *

SIGNATURE CURVE

	Y		X
MAX Y =	0.15	, X =	2158.42
MIN Y =	0.11	, X =	2987.62
MEAN Y =	0.14	, X =	2619.20

Figure 162. Test run 100-H05-004-2.6; statistical comparison; pump 1, Test H05, sump 4, submergence 2.47D

***PUMP EFFICIENCY ***

TOTAL AREA -304.10 ABSOLUTE AREA 304.10

TEST CURVE			
MAX Y =	77.26	, X =	2047.03
MIN Y =	44.19	, X =	2987.62
MEAN Y =	71.50	, X =	2467.70
SIGNATURE CURVE			
MAX Y =	77.31	, X =	2034.65
MIN Y =	44.36	, X =	2987.62
MEAN Y =	71.86	, X =	2460.73

***NOISE LB/IN**2 ***

TOTAL AREA 13.10 ABSOLUTE AREA 20.85

TEST CURVE			
MAX Y =	0.95	, X =	2987.62
MIN Y =	0.47	, X =	1600.00
MEAN Y =	0.57	, X =	2533.30
SIGNATURE CURVE			
MAX Y =	0.93	, X =	2987.62
MIN Y =	0.47	, X =	1631.19
MEAN Y =	0.56	, X =	2571.52

***SHAFT HORSEPOWER ***

TOTAL AREA 19.51 ABSOLUTE AREA 49.74

TEST CURVE			
MAX Y =	16.18	, X =	1634.16
MIN Y =	12.40	, X =	2987.62
MEAN Y =	15.57	, X =	2270.62
SIGNATURE CURVE			
MAX Y =	16.14	, X =	1600.00
MIN Y =	12.27	, X =	2987.62
MEAN Y =	15.54	, X =	2300.66

***TOTAL HEAD ***

TOTAL AREA -52.13 ABSOLUTE AREA 55.76

TEST CURVE			
MAX Y =	29.01	, X =	1600.00
MIN Y =	7.14	, X =	2987.62
MEAN Y =	23.33	, X =	2083.57
SIGNATURE CURVE			
MAX Y =	29.07	, X =	1600.00
MIN Y =	7.10	, X =	2987.62
MEAN Y =	23.39	, X =	2081.24

***ABS VELOCITY,IPS ***

TOTAL AREA 2.13 ABSOLUTE AREA 3.49

TEST CURVE			
MAX Y =	0.15	, X =	2034.65
MIN Y =	0.11	, X =	2987.62
MEAN Y =	0.14	, X =	2467.45
SIGNATURE CURVE			
MAX Y =	0.15	, X =	2158.42
MIN Y =	0.11	, X =	2987.62
MEAN Y =	0.14	, X =	2619.20

Figure 163. Test run 100-H06-004-2.6; statistical comparison; pump 1, Test H06, sump 4, submergence 2.47D

◆◆◆PUMP EFFICIENCY ◆◆◆

TOTAL AREA 420.80 ABSOLUTE AREA 436.24

TEST CURVE

MAX Y = 77.68 , X = 2047.03
MIN Y = 44.90 , X = 2987.62
MEAN Y = 72.04 , X = 2466.43

◆ ◆ ◆

SIGNATURE CURVE

MAX Y = 77.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 71.86 , X = 2460.73

◆◆◆NOISE LB/IN◆◆2 ◆◆◆

TOTAL AREA -53.29 ABSOLUTE AREA 53.29

TEST CURVE

MAX Y = 0.86 , X = 2987.62
MIN Y = 0.47 , X = 1600.00
MEAN Y = 0.54 , X = 2491.90

◆ ◆ ◆

SIGNATURE CURVE

MAX Y = 0.93 , X = 2987.62
MIN Y = 0.47 , X = 1631.19
MEAN Y = 0.56 , X = 2571.52

◆◆◆SHAFT HORSEPOWER ◆◆◆

TOTAL AREA 85.32 ABSOLUTE AREA 85.32

TEST CURVE

MAX Y = 16.17 , X = 1660.89
MIN Y = 12.36 , X = 2987.62
MEAN Y = 15.60 , X = 2297.42

◆ ◆ ◆

SIGNATURE CURVE

MAX Y = 16.14 , X = 1600.00
MIN Y = 12.27 , X = 2987.62
MEAN Y = 15.54 , X = 2300.66

◆◆◆TOTAL HEAD ◆◆◆

TOTAL AREA 203.75 ABSOLUTE AREA 203.75

TEST CURVE

MAX Y = 29.21 , X = 1600.00
MIN Y = 7.20 , X = 2987.62
MEAN Y = 23.51 , X = 2083.98

◆ ◆ ◆

SIGNATURE CURVE

MAX Y = 29.07 , X = 1600.00
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.39 , X = 2081.24

◆◆◆ABS VELOCITY,IPS ◆◆◆

TOTAL AREA -0.51 ABSOLUTE AREA 3.06

TEST CURVE

MAX Y = 0.15 , X = 2084.16
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2523.99

◆ ◆ ◆

SIGNATURE CURVE

MAX Y = 0.15 , X = 2158.42
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2619.20

Figure 164. Test run 100-H07-004-2.6; statistical comparison; pump 1, Test H07, sump 4, submergence 2.47D

***PUMP EFFICIENCY ***

TOTAL AREA 313.57 ABSOLUTE AREA 344.66

TEST CURVE

MAX Y =	77.63	, X =	2022.28
MIN Y =	45.01	, X =	2987.62
MEAN Y =	72.25	, X =	2444.36

* * *

SIGNATURE CURVE

MAX Y =	77.31	, X =	2034.65
MIN Y =	44.36	, X =	2987.62
MEAN Y =	71.86	, X =	2460.73

***NOISE LB/IN**2 ***

TOTAL AREA 83.80 ABSOLUTE AREA 83.80

TEST CURVE

MAX Y =	1.01	, X =	2987.62
MIN Y =	0.59	, X =	1600.00
MEAN Y =	0.65	, X =	2620.00

* * *

SIGNATURE CURVE

MAX Y =	0.93	, X =	2987.62
MIN Y =	0.47	, X =	1631.19
MEAN Y =	0.56	, X =	2571.52

***SHAFT HORSEPOWER ***

TOTAL AREA -93.30 ABSOLUTE AREA 93.30

TEST CURVE

MAX Y =	16.02	, X =	1824.26
MIN Y =	12.15	, X =	2987.62
MEAN Y =	15.44	, X =	2326.44

* * *

SIGNATURE CURVE

MAX Y =	16.14	, X =	1600.00
MIN Y =	12.27	, X =	2987.62
MEAN Y =	15.54	, X =	2300.66

***TOTAL HEAD ***

TOTAL AREA -50.49 ABSOLUTE AREA 52.03

TEST CURVE

MAX Y =	29.05	, X =	1600.00
MIN Y =	7.12	, X =	2987.62
MEAN Y =	23.34	, X =	2082.53

* * *

SIGNATURE CURVE

MAX Y =	29.07	, X =	1600.00
MIN Y =	7.10	, X =	2987.62
MEAN Y =	23.39	, X =	2081.24

***ABS VELOCITY,IPS ***

TOTAL AREA 11.96 ABSOLUTE AREA 12.25

TEST CURVE

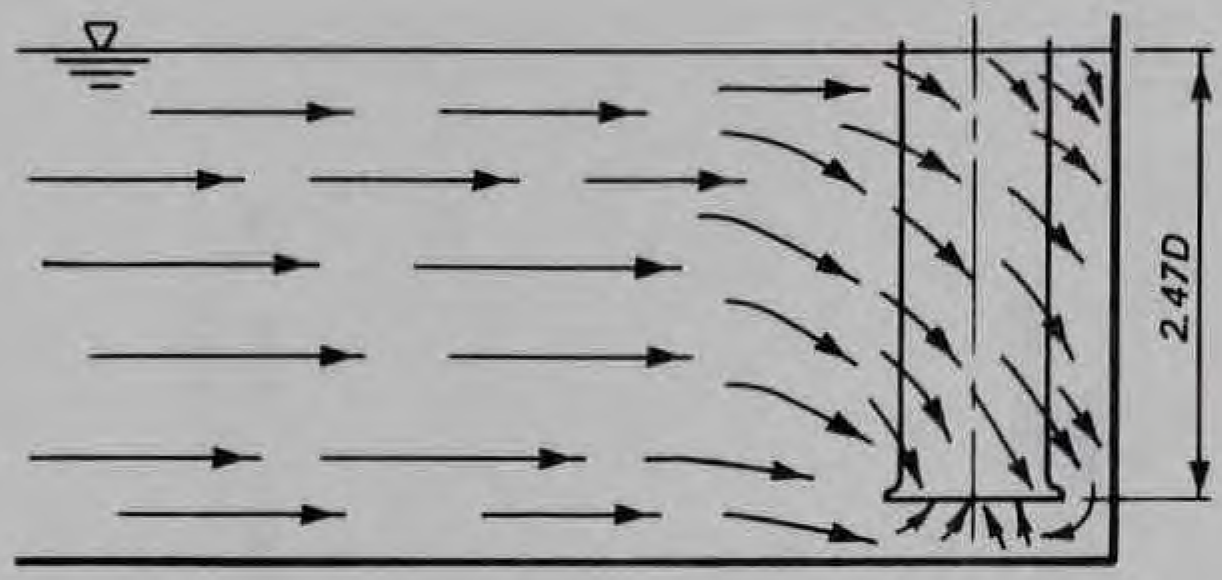
MAX Y =	0.16	, X =	2108.91
MIN Y =	0.11	, X =	2987.62
MEAN Y =	0.15	, X =	2543.55

* * *

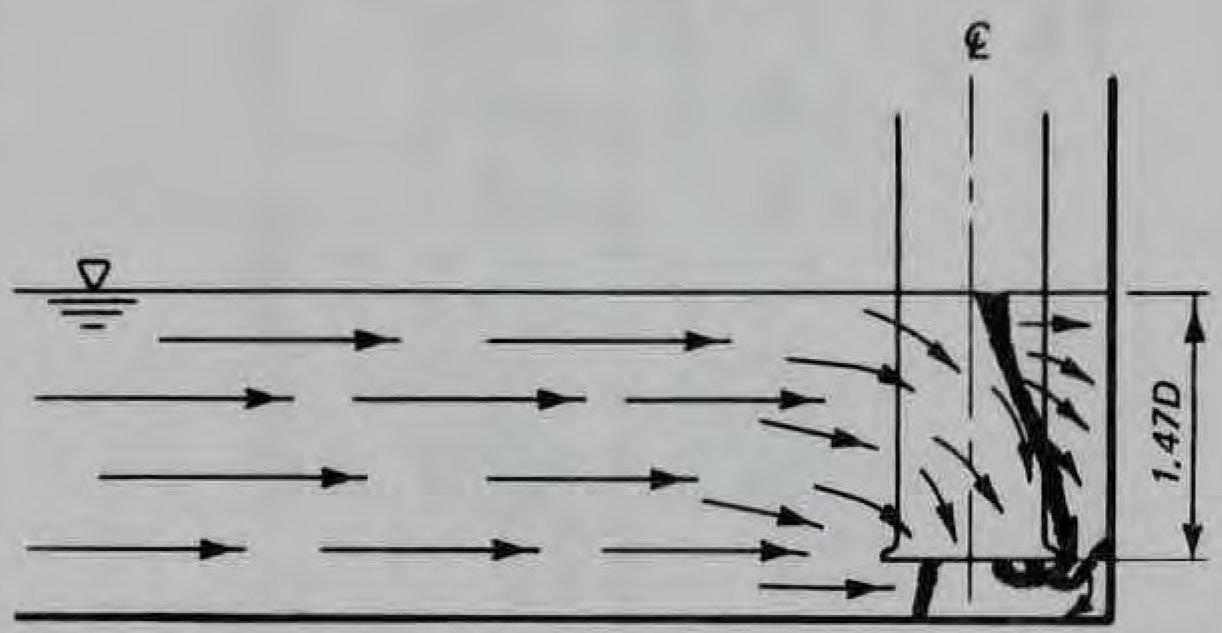
SIGNATURE CURVE

MAX Y =	0.15	, X =	2158.42
MIN Y =	0.11	, X =	2987.62
MEAN Y =	0.14	, X =	2619.20

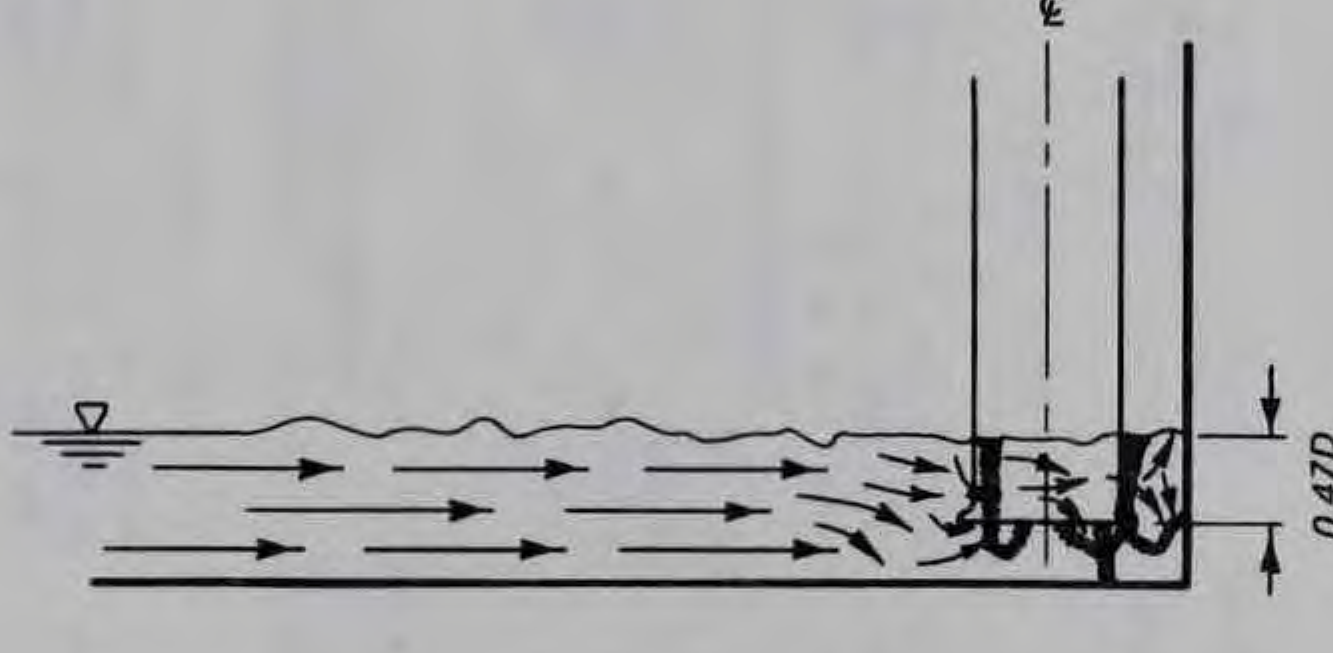
Figure 165. Test run 100-H08-004-2.6; statistical comparison, pump 1, Test H08, sump 4, submergence 2.47D



TESTS H05-H08, T03-T05, SUBMERGENCE = 2.47D



TEST H09, SUBMERGENCE = 1.47D



TEST H10, SUBMERGENCE = 0.47D

Figure 166. Flow pattern for sump type 4; discharge 1,930 gpm (4.3 cfs); bell diam D - 1.3 ft, $Q/g^{1/2}D^{5/2} = 0.4$

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2917.	2.6	1.2	2.2	8.454	37.7	483.	18.2	20.4	12.7	6.2	62.5	48.9	1775.	0.041	0.114	0.92	2.37	3.80
1	2915.	2.6	1.3	2.2	8.482	37.8	483.	18.2	20.4	12.8	6.3	62.6	48.9	1775.	0.043	0.119	0.85	3.10	3.74
1	2917.	2.6	1.3	2.2	8.483	37.7	483.	18.2	20.4	12.7	6.3	62.5	49.1	1775.	0.043	0.135	0.80	2.78	3.78
1	2917.	2.6	1.3	2.2	8.470	37.7	483.	18.2	20.4	12.7	6.2	62.5	49.1	1775.	0.041	0.119	0.81	2.14	3.80
1	2914.	2.6	1.3	2.2	8.513	37.7	483.	18.2	20.4	12.7	6.3	62.5	49.2	1775.	0.046	0.134	0.77	2.09	3.77
2	2733.	2.6	5.3	1.9	12.281	40.9	484.	18.7	21.0	13.8	8.5	66.0	61.3	1775.	0.042	0.129	0.64	3.60	3.80
2	2731.	2.6	5.3	1.9	12.254	41.0	485.	18.7	21.0	13.8	8.5	65.9	61.1	1775.	0.037	0.106	0.64	3.49	3.81
2	2731.	2.6	5.3	1.9	12.282	41.0	485.	18.7	21.0	13.8	8.5	65.9	61.3	1775.	0.040	0.120	0.66	1.11	3.79
2	2734.	2.6	5.4	1.9	12.308	41.0	485.	18.7	21.0	13.9	8.5	66.0	61.4	1775.	0.044	0.123	0.68	3.57	3.80
2	2736.	2.6	5.3	1.9	12.268	41.0	485.	18.7	21.0	13.9	8.5	66.0	61.2	1775.	0.042	0.113	0.65	3.49	3.78
3	2601.	2.6	8.0	1.8	14.732	42.8	483.	18.9	21.2	14.5	9.7	68.2	67.0	1775.	0.045	0.131	0.67	3.63	3.79
3	2599.	2.6	8.0	1.8	14.747	42.8	484.	18.9	21.2	14.5	9.7	68.1	67.0	1775.	0.043	0.121	0.69	3.60	3.81
3	2600.	2.6	8.0	1.8	14.743	42.7	483.	18.9	21.2	14.4	9.7	68.1	67.1	1775.	0.048	0.140	0.66	3.46	3.80
3	2608.	2.6	8.0	1.8	14.776	42.7	484.	18.9	21.2	14.4	9.7	68.1	67.4	1775.	0.048	0.127	0.62	3.64	3.80
3	2605.	2.6	8.0	1.8	14.723	42.7	484.	18.9	21.2	14.4	9.7	68.1	67.1	1775.	0.045	0.117	0.69	3.51	3.81
4	2448.	2.6	11.0	1.6	17.553	44.8	484.	19.1	21.4	15.1	10.9	70.6	71.8	1775.	0.049	0.140	0.62	3.61	3.80
4	2445.	2.6	11.0	1.6	17.551	44.8	484.	19.1	21.5	15.1	10.9	70.6	71.7	1775.	0.045	0.117	0.64	3.27	3.79
4	2443.	2.6	11.0	1.5	17.564	44.7	485.	19.1	21.5	15.1	10.8	70.4	71.7	1775.	0.040	0.110	0.62	2.76	3.80
4	2439.	2.6	11.1	1.5	17.607	44.8	484.	19.1	21.5	15.1	10.9	70.5	71.7	1775.	0.055	0.154	0.57	2.73	3.78
4	2447.	2.6	11.1	1.6	17.608	44.8	484.	19.1	21.4	15.1	10.9	70.6	72.0	1775.	0.067	0.161	0.56	3.49	3.80
5	2312.	2.6	13.4	1.4	19.741	46.1	482.	19.2	21.5	15.6	11.5	72.5	74.1	1775.	0.041	0.121	0.72	3.52	3.81
5	2311.	2.6	13.4	1.4	19.748	46.1	482.	19.2	21.5	15.6	11.5	72.5	74.1	1775.	0.047	0.137	0.67	3.46	3.82
5	2311.	2.6	13.4	1.4	19.761	46.1	482.	19.2	21.5	15.6	11.5	72.4	74.1	1775.	0.058	0.160	0.63	2.49	3.82
5	2311.	2.6	13.3	1.4	19.731	46.1	483.	19.2	21.5	15.6	11.5	72.4	74.0	1775.	0.045	0.116	0.62	3.49	3.82
5	2314.	2.6	13.4	1.4	19.786	46.1	483.	19.2	21.5	15.6	11.6	72.4	74.3	1775.	0.048	0.134	0.66	3.32	3.83
6	2143.	2.6	16.1	1.2	22.331	47.0	482.	19.4	21.7	15.9	12.1	73.3	76.2	1775.	0.058	0.158	0.50	3.60	3.80
6	2144.	2.6	16.2	1.2	22.359	47.0	482.	19.4	21.7	15.9	12.1	73.3	76.2	1775.	0.058	0.155	0.49	3.65	3.81
6	2145.	2.6	16.2	1.2	22.355	47.0	482.	19.4	21.7	15.9	12.1	73.2	76.3	1775.	0.046	0.143	0.54	3.65	3.80
6	2143.	2.6	16.2	1.2	22.370	47.0	483.	19.4	21.7	15.9	12.1	73.1	76.2	1775.	0.049	0.152	0.48	3.68	3.83
6	2145.	2.6	16.2	1.2	22.353	47.1	483.	19.4	21.8	15.9	12.1	73.1	76.2	1775.	0.038	0.098	0.48	3.68	3.82
7	1999.	2.6	18.4	1.0	24.460	47.4	484.	19.4	21.8	16.0	12.4	73.5	77.1	1775.	0.038	0.098	0.48	3.65	3.81
7	1995.	2.6	18.4	1.0	24.460	47.4	484.	19.4	21.8	16.0	12.3	73.4	77.1	1775.	0.047	0.146	0.43	3.51	3.80
7	1997.	2.6	18.4	1.0	24.446	47.5	484	19.4	21.8	16.0	12.3	73.6	77.0	1775.	0.057	0.175	0.48	3.42	3.78
7	1996	2.6	18.4	1.0	24.457	47.5	483.	19.4	21.8	16.0	12.3	73.6	76.9	1775.	0.045	0.118	0.48	3.45	3.79
7	1997.	2.6	18.4	1.0	24.435	47.5	483.	19.4	21.8	16.0	12.3	73.7	76.9	1775.	0.045	0.118	0.49	2.94	3.79
8	1894.	2.6	19.9	0.9	25.842	47.6	483.	19.5	21.8	16.1	12.4	73.7	76.9	1775.	0.046	0.121	0.54	3.67	3.83
8	1894.	2.6	19.9	0.9	25.841	47.6	483.	19.5	21.8	16.1	12.4	73.6	77.0	1775.	0.054	0.150	0.61	3.67	3.83
8	1897.	2.6	19.9	0.9	25.831	47.6	483.	19.5	21.8	16.1	12.4	73.7	77.0	1775.	0.051	0.142	0.59	3.65	3.83
8	1892.	2.6	19.9	0.9	25.828	47.6	483.	19.5	21.8	16.1	12.4	73.7	76.8	1775.	0.044	0.131	0.58	3.70	3.84

Figure 167. Test run 100-H05-004-2.6; research data; pump, 1 Test H05, sump 4, submergence 2.47D (Continued)

8	1889.	2.6	19.9	0.9	25.848	47.6	483.	19.5	21.8	16.1	12.3	73.7	76.7	1775.	0.039	0.106	0.67	3.68	3.83
9	1792.	2.6	21.2	0.8	27.044	47.8	483.	19.4	21.8	16.1	12.3	74.2	75.9	1775.	0.046	0.128	0.63	3.43	3.82
9	1795.	2.6	21.2	0.8	27.052	47.7	483.	19.4	21.8	16.1	12.3	74.1	76.1	1775.	0.039	0.106	0.63	3.68	3.84
9	1792.	2.6	21.2	0.8	27.041	47.7	483.	19.4	21.8	16.1	12.2	74.1	76.0	1775.	0.046	0.142	0.61	3.68	3.83
9	1793.	2.6	21.2	0.8	27.057	47.7	482.	19.4	21.7	16.1	12.3	74.2	76.1	1775.	0.042	0.121	0.57	3.69	3.83
9	1792.	2.6	21.2	0.8	27.022	47.6	482.	19.4	21.7	16.1	12.2	74.1	76.1	1775.	0.042	0.115	0.57	3.67	3.84
10	1693.	2.6	22.4	0.7	28.159	47.7	483.	19.5	21.8	16.1	12.1	74.0	74.7	1775.	0.047	0.122	0.46	3.48	3.85
10	1684.	2.6	22.4	0.7	28.151	47.7	483.	19.5	21.8	16.1	12.0	74.0	74.3	1775.	0.045	0.139	0.46	3.59	3.83
10	1691.	2.6	22.4	0.7	28.180	47.7	483.	19.5	21.8	16.1	12.0	74.0	74.7	1775.	0.049	0.135	0.47	3.68	3.85
10	1689.	2.6	22.4	0.7	28.161	47.8	483.	19.5	21.8	16.2	12.0	74.0	74.5	1775.	0.044	0.107	0.50	3.65	3.84
10	1688.	2.6	22.4	0.7	28.180	47.8	483.	19.5	21.8	16.2	12.0	74.1	74.4	1775.	0.044	0.126	0.51	3.68	3.87
11	1606.	2.6	23.2	0.7	28.909	47.8	483.	19.4	21.8	16.1	11.7	74.0	72.7	1775.	0.044	0.141	0.51	3.41	3.86
11	1610.	2.6	23.2	0.7	28.914	47.8	483.	19.5	21.8	16.2	11.8	74.0	72.9	1775.	0.048	0.155	0.45	3.65	3.83
11	1610.	2.6	23.2	0.7	28.910	47.8	483.	19.5	21.8	16.2	11.8	74.1	72.8	1775.	0.045	0.139	0.50	3.64	3.84
11	1603.	2.6	23.2	0.7	28.909	47.9	483.	19.5	21.8	16.2	11.7	74.2	72.4	1775.	0.041	0.143	0.52	3.65	3.83
11	1606.	2.6	23.3	0.7	28.920	47.8	483.	19.5	21.8	16.2	11.7	74.1	72.6	1775.	0.048	0.133	0.55	3.65	3.82
12	1509.	2.6	24.0	0.6	29.638	47.7	483.	19.5	21.8	16.1	11.3	73.8	70.1	1775.	0.050	0.136	0.53	3.65	3.88
12	1510.	2.6	24.1	0.6	29.663	47.6	484.	19.5	21.8	16.1	11.3	73.7	70.3	1775.	0.045	0.122	0.51	3.64	3.87
12	1506.	2.6	24.0	0.6	29.634	47.7	483.	19.5	21.8	16.1	11.3	73.9	70.0	1775.	0.057	0.189	0.68	3.30	3.90
12	1509.	2.6	24.0	0.6	29.637	47.8	483.	19.5	21.8	16.1	11.3	74.0	70.0	1775.	0.046	0.136	0.50	3.65	3.88
12	1509.	2.6	24.1	0.6	29.677	47.8	483.	19.5	21.8	16.1	11.3	74.1	70.1	1775.	0.044	0.120	0.52	3.66	3.89
13	1396.	2.6	24.7	0.5	30.177	47.6	483.	19.4	21.8	16.1	10.7	73.8	66.2	1775.	0.048	0.141	0.68	3.57	3.95
13	1395.	2.6	24.7	0.5	30.196	47.7	484.	19.5	21.8	16.1	10.6	73.8	66.1	1775.	0.047	0.131	0.74	3.55	3.97
13	1393.	2.6	24.7	0.5	30.186	47.6	484.	19.4	21.8	16.1	10.6	73.7	66.1	1775.	0.049	0.161	0.64	3.64	3.97
13	1394.	2.6	24.7	0.5	30.189	47.6	484.	19.4	21.8	16.1	10.6	73.6	66.2	1775.	0.050	0.141	0.65	3.57	3.93
13	1394.	2.6	24.7	0.5	30.168	47.6	484.	19.4	21.8	16.1	10.6	73.6	66.1	1775.	0.049	0.159	0.68	3.59	3.92
14	1293.	2.6	24.9	0.4	30.316	46.6	484.	19.3	21.7	15.8	9.9	72.7	62.9	1775.	0.063	0.225	1.04	3.43	4.12
14	1292.	2.6	24.9	0.4	30.292	46.6	484.	19.3	21.7	15.7	9.9	72.6	62.8	1775.	0.060	0.193	1.08	3.49	4.07
14	1295.	2.6	24.9	0.4	30.299	46.7	484.	19.3	21.7	15.8	9.9	72.8	62.9	1775.	0.065	0.218	1.04	3.47	4.12
14	1298.	2.6	24.9	0.4	30.328	46.7	484.	19.3	21.7	15.8	9.9	72.9	63.0	1775.	0.056	0.184	1.03	3.39	4.06
14	1298.	2.6	24.9	0.4	30.292	46.8	484.	19.3	21.7	15.8	9.9	72.9	62.9	1775.	0.059	0.163	1.01	3.34	4.07
15	1156.	2.6	24.4	0.3	29.778	44.4	485.	19.0	21.4	15.0	8.7	70.1	58.0	1775.	0.104	0.353	1.87	2.69	4.69
15	1154.	2.6	24.5	0.3	29.797	44.4	485.	19.0	21.4	15.0	8.7	70.1	57.9	1775.	0.098	0.318	1.87	2.68	5.01
15	1154.	2.6	24.5	0.3	29.798	44.4	485.	19.0	21.4	15.0	8.7	70.2	57.9	1775.	0.095	0.295	1.82	2.75	4.69
15	1157.	2.6	24.4	0.3	29.756	44.4	485.	19.0	21.4	15.0	8.7	70.1	58.0	1775.	0.097	0.305	1.80	2.74	4.76
15	1154.	2.6	24.4	0.3	29.780	44.4	485.	19.0	21.4	15.0	8.7	70.2	57.9	1775.	0.094	0.323	1.75	2.50	4.70
16	1007.	2.6	25.1	0.3	30.354	44.2	485.	19.0	21.4	14.9	7.7	69.8	51.8	1775.	0.105	0.336	1.83	2.25	4.89
16	1003.	2.6	25.1	0.3	30.329	44.2	485.	19.0	21.3	14.9	7.7	69.9	51.5	1775.	0.109	0.370	1.88	2.72	4.91
16	1006.	2.6	25.0	0.3	30.295	44.1	485.	19.0	21.4	14.9	7.7	69.8	51.7	1775.	0.112	0.502	2.16	2.25	4.79
16	1007.	2.6	25.0	0.3	30.311	44.1	485.	19.0	21.4	14.9	7.7	69.8	51.8	1775.	0.111	0.387	2.07	2.22	4.85
16	1008.	2.6	25.1	0.3	30.351	44.1	485.	19.0	21.4	14.9	7.7	69.9	51.9	1775.	0.106	0.336	1.92	2.37	4.79
17	854.	2.6	26.4	0.2	31.588	45.1	485.	19.1	21.5	15.2	6.8	70.9	44.8	1775.	0.133	0.504	2.39	2.60	4.98
17	854.	2.6	26.4	0.2	31.558	45.0	485.	19.1	21.5	15.2	6.8	70.9	44.8	1775.	0.129	0.410	2.51	2.33	5.01
17	854.	2.6	26.4	0.2	31.597	45.0	485.	19.1	21.5	15.2	6.8	70.9	44.9	1775.	0.133	0.456	2.57	2.54	4.82
17	854.	2.6	26.4	0.2	31.567	45.0	485	19.1	21.5	15.2	6.8	70.9	44.8	1775.	0.131	0.418	2.60	2.46	5.01
17	854.	2.6	26.4	0.2	31.587	45.0	485.	19.1	21.5	15.2	6.8	70.8	44.9	1775.	0.121	0.420	2.28	2.41	4.92

Figure 167. (Concluded)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER HPM INPUT MOTOR HP	HPS SHAFT HP	HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2921.	2.6	1.3	2.2	8.483	38.1	488.	18.1	20.5	12.9	6.3	62.7	48.7	1775.	0.041	0.113	0.86	3.19	3.76
1	2920.	2.6	1.3	2.2	8.515	38.1	488.	18.1	20.5	12.9	6.3	62.8	48.8	1775.	0.041	0.103	0.85	2.44	3.78
1	2918.	2.6	1.2	2.2	8.459	38.1	488.	18.1	20.5	12.9	6.2	62.7	48.4	1775.	0.043	0.125	0.93	3.56	3.80
1	2926.	2.6	1.3	2.2	8.525	38.1	488.	18.1	20.5	12.9	6.3	62.7	49.0	1775.	0.041	0.106	0.79	3.58	3.78
1	2919.	2.6	1.3	2.2	8.511	38.1	488.	18.1	20.5	12.9	6.3	62.7	48.8	1775.	0.044	0.128	0.96	3.51	3.78
2	2769.	2.6	4.6	2.0	11.603	40.6	487.	18.5	20.9	13.7	8.1	65.7	59.2	1775.	0.040	0.114	0.88	3.45	3.78
2	2773.	2.6	4.6	2.0	11.607	40.5	487.	18.5	20.9	13.7	8.1	65.6	59.4	1775.	0.042	0.120	0.81	3.50	3.79
2	2766.	2.6	4.6	2.0	11.622	40.6	487.	18.5	20.9	13.7	8.1	65.7	59.3	1775.	0.046	0.132	0.82	1.86	3.77
2	2771.	2.6	4.6	2.0	11.598	40.6	487.	18.5	20.9	13.7	8.1	65.6	59.3	1775.	0.047	0.115	0.82	3.42	3.77
2	2773.	2.6	4.6	2.0	11.645	40.6	487.	18.5	20.9	13.7	8.2	65.6	59.6	1775.	0.044	0.122	0.80	3.53	3.78
3	2592.	2.6	8.3	1.7	15.003	43.0	487.	18.8	21.3	14.5	9.8	68.4	67.6	1775.	0.053	0.138	0.72	1.77	3.78
3	2589.	2.6	8.2	1.7	14.980	43.0	487.	18.8	21.2	14.5	9.8	68.5	67.5	1775.	0.049	0.122	0.67	2.57	3.78
3	2587.	2.6	8.3	1.7	15.014	43.0	486.	18.8	21.2	14.5	9.8	68.7	67.5	1775.	0.049	0.134	0.72	3.50	3.77
3	2593.	2.6	8.3	1.7	15.063	43.0	486.	18.8	21.2	14.5	9.9	68.6	68.0	1775.	0.049	0.137	0.71	2.54	3.76
3	2595.	2.6	8.2	1.7	14.995	43.0	486.	18.8	21.2	14.5	9.8	68.6	67.7	1775.	0.051	0.139	0.78	3.54	3.80
4	2453.	2.6	10.9	1.6	17.484	44.6	486.	19.0	21.4	15.1	10.8	70.5	71.9	1775.	0.052	0.165	0.70	3.47	3.85
4	2455.	2.6	10.9	1.6	17.506	44.7	486.	19.0	21.4	15.1	10.9	70.5	72.0	1775.	0.055	0.165	0.73	3.19	3.82
4	2451.	2.6	10.9	1.6	17.501	44.6	486.	19.0	21.4	15.1	10.8	70.5	71.9	1775.	0.051	0.142	0.60	3.49	3.83
4	2448.	2.6	11.0	1.6	17.520	44.7	486.	19.0	21.4	15.1	10.8	70.6	71.7	1775.	0.051	0.158	0.68	3.55	3.81
4	2450.	2.6	11.0	1.6	17.526	44.8	486.	19.0	21.4	15.1	10.9	70.6	71.8	1775.	0.057	0.167	0.62	3.46	3.83
5	2296.	2.6	13.7	1.4	20.043	46.1	486.	19.2	21.6	15.6	11.6	72.0	74.7	1775.	0.065	0.159	0.63	3.00	3.82
5	2293.	2.6	13.7	1.4	20.095	46.1	486.	19.2	21.6	15.6	11.7	72.0	74.8	1775.	0.048	0.125	0.56	3.53	3.80
5	2301.	2.6	13.7	1.4	20.075	46.0	486.	19.2	21.6	15.5	11.7	71.9	75.1	1775.	0.051	0.142	0.53	3.50	3.81
5	2297.	2.6	13.7	1.4	20.110	46.0	486.	19.2	21.6	15.6	11.7	71.9	75.1	1775.	0.044	0.123	0.53	3.26	3.82
5	2298.	2.6	13.7	1.4	20.104	46.0	486.	19.2	21.6	15.5	11.7	71.9	75.1	1775.	0.048	0.134	0.54	3.61	3.82
6	2203.	2.6	15.3	1.3	21.516	46.7	487.	19.3	21.8	15.8	12.0	72.3	76.0	1775.	0.057	0.194	0.60	3.57	3.82
6	2207.	2.6	15.2	1.3	21.504	46.7	486.	19.3	21.8	15.8	12.0	72.4	76.1	1775.	0.051	0.151	0.56	3.68	3.82
6	2203.	2.6	15.3	1.3	21.532	46.7	487.	19.3	21.8	15.8	12.0	72.3	76.0	1775.	0.047	0.147	0.53	3.69	3.85
6	2205.	2.6	15.3	1.3	21.531	46.6	487.	19.3	21.8	15.8	12.0	72.2	76.1	1775.	0.053	0.136	0.56	3.68	3.82
6	2203.	2.6	15.3	1.3	21.528	46.6	488.	19.3	21.8	15.8	12.0	72.2	76.1	1775.	0.065	0.153	0.55	3.59	3.82
7	2091.	2.6	17.0	1.1	23.184	47.2	488.	19.4	21.9	15.9	12.3	72.7	76.9	1775.	0.045	0.148	0.63	3.64	3.81
7	2093.	2.6	17.0	1.1	23.178	47.1	487.	19.4	21.9	15.9	12.3	72.7	77.0	1775.	0.057	0.166	0.59	3.54	3.79
7	2094.	2.6	17.0	1.1	23.170	47.2	487.	19.4	21.9	15.9	12.3	72.7	77.0	1775.	0.053	0.145	0.58	3.67	3.82
7	2095.	2.6	17.0	1.1	23.165	47.1	487.	19.4	21.9	15.9	12.3	72.7	77.0	1775.	0.048	0.146	0.59	3.68	3.82
7	2095.	2.6	17.0	1.1	23.173	47.1	488.	19.4	21.9	15.9	12.3	72.6	77.1	1775.	0.051	0.142	0.54	3.40	3.82
8	1968.	2.6	18.9	1.0	24.865	47.5	488.	19.4	22.0	16.0	12.4	73.0	77.1	1775.	0.043	0.136	0.51	3.64	3.80
8	1961.	2.6	18.9	1.0	24.904	47.4	488.	19.4	22.0	16.0	12.3	72.9	77.0	1775.	0.052	0.149	0.51	3.60	3.82
8	1966.	2.6	18.9	1.0	24.926	47.4	488.	19.4	22.0	16.0	12.4	72.9	77.3	1775.	0.057	0.143	0.48	3.33	3.80
8	1960.	2.6	19.0	1.0	24.951	47.4	488.	19.4	21.9	16.0	12.4	73.0	77.1	1775.	0.048	0.148	0.53	3.58	3.79

Figure 168. Test run 100-H06-004-2.6; research data; pump 1, Test H06, sump 4, submergence 2.47D (Continued)

8	1958.	2.6	19.0	1.0	25.011	47.4	488.	19.4	22.0	16.0	12.4	73.0	77.3	1775.	0.054	0.154	0.52	3.54	3.82
9	1849.	2.6	20.5	0.9	26.388	47.7	488.	19.4	22.0	16.1	12.3	73.3	76.6	1775.	0.047	0.135	0.64	3.64	3.80
9	1845.	2.6	20.5	0.9	26.374	47.7	489.	19.4	22.0	16.1	12.3	73.3	76.3	1775.	0.050	0.136	0.61	3.66	3.80
9	1848.	2.6	20.5	0.9	26.385	47.6	488.	19.4	21.9	16.1	12.3	73.4	76.5	1775.	0.049	0.137	0.67	3.53	3.81
9	1842.	2.6	20.5	0.9	26.400	47.6	488.	19.4	21.9	16.1	12.3	73.4	76.4	1775.	0.052	0.155	0.53	3.66	3.82
9	1849.	2.6	20.5	0.9	26.429	47.6	488.	19.4	21.9	16.1	12.4	73.3	76.8	1775.	0.043	0.103	0.55	3.66	3.83
10	1750.	2.6	21.7	0.8	27.536	47.8	488.	19.4	22.0	16.1	12.2	73.3	75.5	1775.	0.047	0.130	0.48	3.61	3.83
10	1750.	2.6	21.8	0.8	27.558	47.8	489.	19.4	22.0	16.1	12.2	73.3	75.5	1775.	0.044	0.119	0.49	3.66	3.82
10	1751.	2.6	21.8	0.8	27.551	47.8	489.	19.4	22.0	16.1	12.2	73.3	75.5	1775.	0.055	0.150	0.49	3.45	3.83
10	1751.	2.6	21.8	0.8	27.547	47.8	489.	19.4	22.0	16.1	12.2	73.2	75.5	1775.	0.056	0.152	0.51	3.67	3.82
10	1754.	2.6	21.8	0.8	27.558	47.8	489.	19.4	22.0	16.1	12.2	73.3	75.6	1775.	0.048	0.150	0.53	3.68	3.82
11	1652.	2.6	22.9	0.7	28.640	47.9	488.	19.4	22.0	16.2	12.0	73.5	73.9	1775.	0.046	0.151	0.45	3.67	3.84
11	1649.	2.6	22.9	0.7	28.624	47.9	489.	19.4	22.1	16.2	11.9	73.4	73.7	1775.	0.047	0.124	0.44	3.67	3.84
11	1649.	2.6	22.9	0.7	28.603	47.9	489.	19.4	22.1	16.2	11.9	73.4	73.7	1775.	0.051	0.142	0.44	3.62	3.83
11	1649.	2.6	22.9	0.7	28.620	47.9	489.	19.4	22.0	16.2	11.9	73.5	73.7	1775.	0.046	0.135	0.44	3.65	3.84
11	1650.	2.6	22.9	0.7	28.619	47.9	488.	19.4	22.0	16.2	11.9	73.5	73.8	1775.	0.048	0.137	0.48	3.66	3.83
12	1554.	2.6	23.7	0.6	29.371	47.9	489.	19.4	22.1	16.2	11.5	73.4	71.3	1775.	0.057	0.157	0.44	3.66	3.87
12	1552.	2.6	23.7	0.6	29.344	47.9	488.	19.4	22.0	16.2	11.5	73.4	71.1	1775.	0.049	0.159	0.47	3.64	3.86
12	1553.	2.6	23.7	0.6	29.368	47.8	488.	19.4	22.0	16.2	11.5	73.4	71.3	1775.	0.044	0.138	0.47	3.60	3.87
12	1545.	2.6	23.7	0.6	29.365	47.9	488.	19.4	22.0	16.2	11.5	73.5	70.8	1775.	0.049	0.166	0.49	3.61	3.85
12	1551.	2.6	23.7	0.6	29.354	47.8	488.	19.4	22.0	16.2	11.5	73.4	71.3	1775.	0.053	0.141	0.49	3.64	3.89
13	1446.	2.6	24.4	0.5	29.985	47.7	489.	19.4	22.0	16.1	11.0	73.4	67.9	1775.	0.058	0.178	0.58	3.37	3.93
13	1450.	2.6	24.5	0.5	30.003	47.7	489.	19.4	22.0	16.1	11.0	73.3	68.2	1775.	0.054	0.145	0.59	3.63	3.95
13	1446.	2.6	24.4	0.5	29.978	47.7	490.	19.4	22.0	16.1	11.0	73.2	68.0	1775.	0.055	0.175	0.54	3.64	3.91
13	1448.	2.6	24.4	0.5	29.981	47.7	490.	19.4	22.0	16.1	11.0	73.2	68.1	1775.	0.057	0.181	0.56	3.62	3.93
13	1445.	2.6	24.5	0.5	29.995	47.7	490.	19.4	22.0	16.1	11.0	73.2	68.0	1775.	0.055	0.139	0.59	3.61	3.90
14	1303.	2.6	24.9	0.4	30.293	46.6	490.	19.3	22.0	15.7	10.0	71.6	63.3	1775.	0.060	0.170	0.98	3.41	4.07
14	1300.	2.6	24.8	0.4	30.280	46.6	490.	19.3	22.0	15.8	10.0	71.8	63.2	1775.	0.063	0.165	0.92	3.52	4.09
14	1302.	2.6	24.9	0.4	30.306	46.7	490.	19.3	22.0	15.8	10.0	71.8	63.3	1775.	0.066	0.196	0.99	3.45	4.08
14	1298.	2.6	24.8	0.4	30.257	46.6	490.	19.3	21.9	15.7	9.9	71.7	63.1	1775.	0.056	0.176	1.05	3.42	4.04
14	1303.	2.6	24.8	0.4	30.259	46.5	490.	19.3	21.9	15.7	10.0	71.7	63.4	1775.	0.062	0.178	0.99	3.42	3.99
15	1150.	2.6	24.4	0.3	29.735	44.2	492.	19.0	21.7	14.9	8.6	68.8	57.9	1775.	0.101	0.327	1.77	2.52	4.81
15	1153.	2.6	24.4	0.3	29.742	44.2	492.	19.0	21.7	14.9	8.7	68.8	58.1	1775.	0.097	0.359	1.86	2.73	4.82
15	1152.	2.6	24.4	0.3	29.752	44.2	492.	19.0	21.7	14.9	8.7	68.8	58.0	1775.	0.096	0.315	1.79	2.61	4.59
15	1156.	2.6	24.4	0.3	29.748	44.2	491.	19.0	21.7	14.9	8.7	69.0	58.2	1775.	0.101	0.348	1.77	2.48	4.92
15	1148.	2.6	24.4	0.3	29.760	44.3	491.	19.0	21.7	15.0	8.6	69.0	57.8	1775.	0.104	0.299	1.83	2.62	4.89
16	999.	2.6	25.1	0.3	30.327	44.0	492.	19.0	21.7	14.9	7.7	68.6	51.5	1775.	0.123	0.361	1.93	2.19	4.81
16	1001.	2.6	25.1	0.3	30.338	44.0	491.	19.0	21.6	14.9	7.7	68.7	51.6	1775.	0.113	0.359	2.05	2.18	4.87
16	1002.	2.6	25.1	0.3	30.323	44.0	491.	19.0	21.6	14.9	7.7	68.7	51.7	1775.	0.118	0.420	1.99	2.38	4.73
16	1001.	2.6	25.1	0.3	30.321	44.0	492.	19.0	21.6	14.9	7.7	68.7	51.6	1775.	0.104	0.388	2.04	2.46	4.75
16	998.	2.6	25.1	0.3	30.328	43.9	492.	19.0	21.6	14.8	7.7	68.6	51.6	1775.	0.108	0.392	2.04	2.46	4.84
17	847.	2.6	26.4	0.2	31.615	44.8	491.	19.1	21.7	15.1	6.8	69.7	44.7	1775.	0.131	0.385	2.35	2.31	4.76
17	852.	2.6	26.4	0.2	31.633	44.8	491.	19.1	21.7	15.1	6.8	69.7	45.0	1775.	0.134	0.443	2.36	2.57	5.42
17	851.	2.6	26.4	0.2	31.594	44.7	491.	19.1	21.7	15.1	6.8	69.6	45.0	1775.	0.128	0.401	2.24	2.69	4.76
17	853.	2.6	26.4	0.2	31.588	44.8	491.	19.1	21.7	15.1	6.8	69.7	45.0	1775.	0.129	0.415	2.21	2.31	4.92
17	852.	2.6	26.4	0.2	31.627	44.8	491.	19.0	21.7	15.1	6.8	69.7	45.0	1775.	0.108	0.445	2.21	2.14	4.95

Figure 168. (Concluded)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2905.	2.6	1.7	2.2	8.934	38.5	486.	18.2	20.5	13.0	6.6	63.3	50.5	1775.	0.040	0.110	0.81	2.07	3.72
1	2908.	2.6	1.7	2.2	8.889	38.4	486.	18.2	20.5	13.0	6.5	63.3	50.3	1775.	0.045	0.114	0.83	3.34	3.73
1	2906.	2.6	1.7	2.2	8.888	38.4	486.	18.2	20.5	13.0	6.5	63.3	50.3	1775.	0.042	0.121	0.81	3.03	3.74
1	2903.	2.6	1.7	2.2	8.891	38.5	486.	18.2	20.5	13.0	6.5	63.4	50.1	1775.	0.042	0.108	0.82	2.79	3.72
1	2909.	2.6	1.7	2.2	8.921	38.5	485.	18.2	20.5	13.0	6.6	63.6	50.4	1775.	0.040	0.118	0.89	3.41	3.79
2	2751.	2.6	5.2	2.0	12.210	41.0	485.	18.5	20.9	13.9	8.5	66.4	61.3	1775.	0.040	0.108	0.74	3.51	3.76
2	2748.	2.6	5.3	2.0	12.216	41.0	485.	18.5	20.9	13.9	8.5	66.4	61.2	1775.	0.043	0.121	0.71	3.48	3.76
2	2747.	2.6	5.3	2.0	12.211	41.0	485.	18.5	20.9	13.8	8.5	66.3	61.3	1775.	0.047	0.134	0.71	3.54	3.78
2	2752.	2.6	5.2	2.0	12.174	41.0	485.	18.5	20.9	13.8	8.5	66.3	61.2	1775.	0.044	0.137	0.66	3.53	3.76
2	2754.	2.6	5.2	2.0	12.205	41.0	485.	18.5	20.9	13.8	8.5	66.3	61.4	1775.	0.041	0.114	0.67	3.44	3.76
3	2601.	2.6	8.2	1.8	14.994	43.1	485.	18.8	21.2	14.6	9.9	68.8	67.7	1775.	0.047	0.158	0.68	2.87	3.74
3	2600.	2.6	8.3	1.8	15.012	43.1	485.	18.8	21.2	14.6	9.9	68.8	67.7	1775.	0.052	0.143	0.61	3.43	3.72
3	2602.	2.6	8.3	1.8	15.051	43.1	485.	18.8	21.2	14.6	9.9	68.8	68.0	1775.	0.049	0.130	0.55	3.34	3.74
3	2600.	2.6	8.2	1.8	14.973	43.1	486.	18.8	21.2	14.6	9.8	68.7	67.6	1775.	0.043	0.137	0.58	3.22	3.74
3	2604.	2.6	8.2	1.8	14.982	43.1	486.	18.8	21.2	14.6	9.9	68.8	67.7	1775.	0.044	0.125	0.62	3.56	3.75
4	2552.	2.6	9.3	1.7	15.959	43.8	485.	18.8	21.2	14.8	10.3	69.9	69.6	1775.	0.049	0.145	0.68	3.20	3.76
4	2552.	2.6	9.3	1.7	15.986	43.8	485.	18.8	21.2	14.8	10.3	69.9	69.6	1775.	0.048	0.142	0.63	2.91	3.75
4	2551.	2.6	9.3	1.7	15.993	43.8	485.	18.8	21.2	14.8	10.3	69.9	69.6	1775.	0.057	0.143	0.63	3.57	3.76
4	2546.	2.6	9.3	1.7	15.948	43.8	485.	18.8	21.2	14.8	10.3	69.9	69.4	1775.	0.044	0.120	0.71	3.54	3.74
4	2552.	2.6	9.3	1.7	15.987	43.8	485.	18.8	21.2	14.8	10.3	69.8	69.7	1775.	0.046	0.128	0.67	2.94	3.75
5	2394.	2.6	12.2	1.5	18.657	45.5	485.	19.1	21.5	15.4	11.3	71.4	73.4	1775.	0.055	0.148	0.61	3.58	3.76
5	2395.	2.6	12.2	1.5	18.650	45.5	485.	19.1	21.5	15.4	11.3	71.4	73.5	1775.	0.056	0.143	0.63	3.60	3.76
5	2395.	2.6	12.1	1.5	18.629	45.5	486.	19.1	21.5	15.4	11.3	71.3	73.4	1775.	0.056	0.166	0.59	3.43	3.79
5	2394.	2.6	12.1	1.5	18.634	45.5	486.	19.1	21.5	15.4	11.3	71.4	73.3	1775.	0.052	0.160	0.53	3.63	3.80
5	2393.	2.6	12.2	1.5	18.669	45.5	486.	19.1	21.6	15.4	11.3	71.4	73.4	1775.	0.042	0.129	0.54	3.63	3.78
6	2274.	2.6	14.3	1.3	20.645	46.4	486.	19.2	21.7	15.7	11.9	72.3	75.6	1775.	0.046	0.133	0.55	3.49	3.76
6	2275.	2.6	14.3	1.3	20.665	46.4	486.	19.2	21.7	15.7	11.9	72.3	75.8	1775.	0.055	0.163	0.54	3.60	3.77
6	2274.	2.6	14.3	1.3	20.688	46.5	486.	19.2	21.7	15.7	11.9	72.4	75.7	1775.	0.049	0.145	0.59	3.28	3.76
6	2277.	2.6	14.3	1.3	20.627	46.4	486.	19.2	21.7	15.7	11.9	72.4	75.7	1775.	0.048	0.142	0.88	3.61	3.76
6	2278.	2.6	14.3	1.3	20.657	46.4	486.	19.2	21.7	15.7	11.9	72.4	75.8	1775.	0.053	0.184	0.63	3.59	3.76
7	2145.	2.6	16.4	1.2	22.613	47.1	486.	19.3	21.8	15.9	12.3	73.0	77.0	1775.	0.054	0.154	0.50	3.39	3.74
7	2148.	2.6	16.4	1.2	22.602	47.1	486.	19.3	21.8	15.9	12.3	73.1	77.1	1775.	0.049	0.145	0.51	2.91	3.75
7	2146.	2.6	16.4	1.2	22.579	47.1	485.	19.3	21.8	15.9	12.2	73.1	77.0	1775.	0.052	0.139	0.50	3.42	3.74
7	2144.	2.6	16.4	1.2	22.595	47.1	485.	19.3	21.8	15.9	12.2	73.2	77.0	1775.	0.062	0.168	0.51	3.59	3.76
7	2144.	2.6	16.4	1.2	22.619	47.1	486.	19.3	21.8	15.9	12.3	73.1	77.0	1775.	0.059	0.141	0.46	3.61	3.76
8	2049.	2.6	17.9	1.1	23.989	47.5	486.	19.4	21.9	16.0	12.4	73.4	77.5	1775.	0.051	0.128	0.54	3.62	3.74
8	2049.	2.6	17.9	1.1	23.987	47.4	485.	19.4	21.8	16.0	12.4	73.5	77.5	1775.	0.050	0.145	0.52	3.50	3.74
8	2052.	2.6	17.9	1.1	24.010	47.5	486.	19.4	21.8	16.0	12.5	73.5	77.6	1775.	0.054	0.159	0.51	3.61	3.76
8	2050.	2.6	17.9	1.1	24.008	47.5	486.	19.4	21.9	16.0	12.4	73.4	77.6	1775.	0.066	0.199	0.46	3.60	3.74

Figure 169. Test run 100-H07-004-2.6; research data; pump 1, Test H07, sump 4, submergence 2.47D (Continued)

8	2044.	2.6	17.9	1.1	24.008	47.5	486.	19.4	21.9	16.0	12.4	73.4	77.3	1775.	0.052	0.120	0.47	3.62	3.77
9	1945.	2.6	19.3	1.0	25.285	47.6	486.	19.4	21.9	16.1	12.4	73.5	77.3	1775.	0.056	0.148	0.45	3.54	3.74
9	1948.	2.6	19.3	1.0	25.308	47.6	486.	19.4	21.9	16.1	12.5	73.5	77.5	1775.	0.046	0.131	0.46	3.59	3.74
9	1947.	2.6	19.3	1.0	25.313	47.6	486.	19.4	21.9	16.1	12.5	73.5	77.4	1775.	0.056	0.151	0.49	3.46	3.75
9	1945.	2.6	19.3	1.0	25.311	47.6	486.	19.4	21.9	16.1	12.4	73.5	77.4	1775.	0.045	0.119	0.44	3.58	3.76
9	1948.	2.6	19.3	1.0	25.309	47.6	486.	19.4	21.9	16.1	12.5	73.5	77.4	1775.	0.047	0.126	0.47	3.59	3.75
10	1838.	2.6	20.8	0.9	26.695	47.7	486.	19.4	21.9	16.1	12.4	73.8	76.9	1775.	0.044	0.111	0.52	3.58	3.76
10	1840.	2.6	20.8	0.9	26.696	47.7	486.	19.4	21.8	16.1	12.4	73.8	77.0	1775.	0.044	0.120	0.52	3.62	3.78
10	1837.	2.6	20.8	0.9	26.701	47.7	486.	19.3	21.8	16.1	12.4	73.9	76.9	1775.	0.044	0.127	0.46	3.63	3.75
10	1839.	2.6	20.8	0.9	26.706	47.7	486.	19.3	21.8	16.1	12.4	73.9	77.1	1775.	0.051	0.144	0.53	3.62	3.78
10	1837.	2.6	20.8	0.9	26.706	47.6	486.	19.3	21.8	16.1	12.4	73.8	77.1	1775.	0.039	0.119	0.52	3.60	3.76
11	1750.	2.6	22.0	0.8	27.763	47.6	487.	19.4	21.9	16.1	12.3	73.5	76.3	1775.	0.048	0.127	0.43	3.61	3.78
11	1750.	2.6	22.0	0.8	27.786	47.7	487.	19.4	21.9	16.1	12.3	73.6	76.3	1775.	0.043	0.134	0.49	3.59	3.78
11	1746.	2.6	22.0	0.8	27.785	47.7	487.	19.4	21.9	16.1	12.3	73.5	76.2	1775.	0.045	0.126	0.46	3.60	3.78
11	1750.	2.6	22.0	0.8	27.795	47.7	487.	19.4	21.9	16.1	12.3	73.6	76.4	1775.	0.053	0.147	0.50	3.58	3.77
11	1750.	2.6	22.0	0.8	27.766	47.6	487.	19.4	21.9	16.1	12.3	73.6	76.3	1775.	0.049	0.133	0.47	3.35	3.78
12	1646.	2.6	23.1	0.7	28.802	47.8	487.	19.4	21.9	16.1	12.0	73.6	74.3	1775.	0.046	0.131	0.43	3.58	3.78
12	1646.	2.6	23.1	0.7	28.814	47.8	487.	19.4	21.9	16.2	12.0	73.7	74.2	1775.	0.044	0.116	0.43	3.46	3.78
12	1643.	2.6	23.1	0.7	28.826	47.8	487.	19.4	21.9	16.2	12.0	73.7	74.1	1775.	0.042	0.109	0.46	3.03	3.77
12	1645.	2.6	23.1	0.7	28.816	47.8	487.	19.4	21.9	16.2	12.0	73.7	74.2	1775.	0.046	0.139	0.46	3.61	3.78
12	1644.	2.6	23.1	0.7	28.823	47.8	487.	19.4	21.9	16.2	12.0	73.8	74.1	1775.	0.057	0.166	0.48	3.54	3.79
13	1552.	2.6	24.0	0.6	29.612	47.9	487.	19.4	21.9	16.2	11.6	73.9	71.7	1775.	0.055	0.174	0.47	3.58	3.80
13	1551.	2.6	24.0	0.6	29.620	47.9	487.	19.4	21.9	16.2	11.6	73.9	71.7	1775.	0.056	0.157	0.49	3.61	3.81
13	1548.	2.6	24.0	0.6	29.599	47.9	487.	19.4	21.9	16.2	11.6	73.8	71.6	1775.	0.051	0.177	0.50	3.58	3.80
13	1550.	2.6	24.0	0.6	29.631	47.9	487.	19.4	21.9	16.2	11.6	73.9	71.7	1775.	0.043	0.133	0.52	3.58	3.80
13	1550.	2.6	24.0	0.6	29.620	47.8	487.	19.4	21.9	16.2	11.6	73.8	71.8	1775.	0.044	0.126	0.47	3.58	3.81
14	1396.	2.6	24.9	0.5	30.453	47.6	490.	19.4	22.0	16.1	10.7	73.1	66.8	1775.	0.058	0.165	0.74	3.51	3.86
14	1398.	2.6	24.9	0.5	30.423	47.5	490.	19.3	22.0	16.0	10.8	73.0	67.0	1775.	0.057	0.149	0.67	3.54	3.86
14	1395.	2.6	24.9	0.5	30.444	47.4	490.	19.3	22.0	16.0	10.7	72.9	67.0	1775.	0.058	0.175	0.67	3.54	3.93
14	1398.	2.6	25.0	0.5	30.464	47.4	490.	19.4	22.0	16.0	10.8	72.9	67.2	1775.	0.050	0.151	0.72	3.04	3.89
14	1395.	2.6	25.0	0.5	30.461	47.4	490.	19.4	22.0	16.0	10.7	72.8	67.1	1775.	0.051	0.145	0.72	3.47	3.88
15	1245.	2.6	25.0	0.4	30.452	45.8	489.	19.2	21.8	15.5	9.6	71.2	61.9	1775.	0.074	0.222	1.31	3.23	4.26
15	1244.	2.6	25.1	0.4	30.485	45.8	489.	19.2	21.8	15.5	9.6	71.1	62.0	1775.	0.073	0.238	1.29	3.26	4.30
15	1247.	2.6	25.1	0.4	30.512	45.9	489.	19.2	21.8	15.5	9.6	71.2	62.0	1775.	0.067	0.193	1.18	3.27	4.14
15	1241.	2.6	25.1	0.4	30.460	45.8	490.	19.2	21.8	15.5	9.6	71.0	61.8	1775.	0.074	0.219	1.26	2.97	4.25
15	1249.	2.6	25.0	0.4	30.447	45.7	490.	19.2	21.8	15.5	9.6	71.0	62.2	1775.	0.073	0.226	1.27	3.10	4.32
16	1050.	2.6	25.0	0.3	30.284	44.1	489.	18.9	21.5	14.9	8.0	69.3	53.9	1775.	0.116	0.343	2.01	2.57	4.67
16	1052.	2.6	25.0	0.3	30.314	44.1	489.	18.9	21.5	14.9	8.1	69.4	54.0	1775.	0.115	0.379	2.09	2.56	4.74
16	1049.	2.6	25.0	0.3	30.296	44.1	489.	18.9	21.5	14.9	8.0	69.3	54.0	1775.	0.118	0.364	2.00	2.19	4.97
16	1049.	2.6	25.0	0.3	30.323	44.1	489.	18.9	21.5	14.9	8.0	69.4	53.9	1775.	0.109	0.475	1.95	2.69	4.75
16	1049.	2.6	25.0	0.3	30.269	44.0	489.	18.9	21.5	14.9	8.0	69.2	54.0	1775.	0.113	0.354	1.89	2.28	4.81
17	848.	2.6	26.7	0.2	31.903	45.1	490.	19.1	21.7	15.2	6.8	70.3	44.9	1775.	0.117	0.362	2.12	2.74	4.72
17	848.	2.6	26.7	0.2	31.876	45.0	489.	19.1	21.6	15.2	6.8	70.3	44.9	1775.	0.129	0.407	2.11	2.52	4.96
17	848.	2.6	26.7	0.2	31.841	45.0	489.	19.1	21.6	15.2	6.8	70.2	44.9	1775.	0.127	0.423	2.29	2.16	4.89
17	845.	2.6	26.7	0.2	31.856	45.0	489.	19.1	21.7	15.2	6.8	70.2	44.8	1775.	0.130	0.448	2.33	2.27	4.89
17	849.	2.6	26.7	0.2	31.921	45.1	489.	19.1	21.6	15.2	6.9	70.4	45.0	1775.	0.135	0.412	2.27	2.48	4.82

Figure 169. (Concluded)

READ NO.	Q DISCHARGE GPM	HW SUBMERGENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HPM INPUT MOTOR HP	HPS SHAFT HP	HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2926.	2.6	1.3	2.2	8.476	37.3	485.	18.5	20.8	12.6	6.3	60.7	49.7	1775.	0.040	0.107	0.88	3.38	3.78
1	2920.	2.6	1.3	2.2	8.538	37.4	485.	18.5	20.8	12.7	6.3	60.7	49.8	1775.	0.042	0.104	0.86	3.20	3.78
1	2926.	2.6	1.2	2.2	8.458	37.4	485.	18.5	20.8	12.6	6.3	60.7	49.5	1775.	0.039	0.103	0.96	3.05	3.78
1	2921.	2.6	1.3	2.2	8.478	37.5	485.	18.5	20.8	12.7	6.3	60.8	49.4	1775.	0.044	0.131	0.92	3.32	3.77
1	2916.	2.6	1.3	2.2	8.498	37.6	485.	18.5	20.8	12.7	6.3	61.1	49.2	1775.	0.041	0.110	0.90	2.25	3.78
2	2801.	2.6	4.0	2.0	10.994	39.8	485.	18.7	21.1	13.5	7.8	63.9	57.8	1775.	0.046	0.124	0.95	2.90	3.74
2	2795.	2.6	4.0	2.0	11.006	39.9	485.	18.7	21.1	13.5	7.8	63.9	57.7	1775.	0.048	0.135	0.84	1.29	3.74
2	2799.	2.6	4.0	2.0	10.994	39.9	485.	18.7	21.1	13.5	7.8	63.9	57.7	1775.	0.045	0.129	0.98	2.37	3.76
2	2794.	2.6	4.0	2.0	11.022	39.9	485.	18.7	21.1	13.5	7.8	63.9	57.8	1775.	0.053	0.137	0.88	3.39	3.73
2	2795.	2.6	4.0	2.0	11.004	39.8	485.	18.7	21.1	13.5	7.8	63.8	57.7	1775.	0.049	0.129	1.08	2.57	3.74
3	2650.	2.6	7.1	1.8	13.873	41.9	487.	19.0	21.5	14.2	9.3	65.8	65.6	1775.	0.075	0.158	0.79	3.53	3.76
3	2654.	2.6	7.1	1.8	13.913	42.0	487.	19.0	21.5	14.2	9.3	66.0	65.8	1775.	0.050	0.132	0.74	3.16	3.76
3	2653.	2.6	7.0	1.8	13.857	42.0	487.	19.0	21.5	14.2	9.3	66.0	65.5	1775.	0.049	0.127	0.85	3.58	3.74
3	2648.	2.6	7.1	1.8	13.923	42.1	487.	19.0	21.5	14.2	9.3	66.2	65.6	1775.	0.048	0.141	0.75	2.96	3.75
3	2652.	2.6	7.1	1.8	13.877	42.1	487.	19.0	21.5	14.2	9.3	66.3	65.3	1775.	0.051	0.135	0.77	3.19	3.73
4	2500.	2.6	10.1	1.6	16.740	44.0	488.	19.3	21.8	14.9	10.6	68.1	71.2	1775.	0.048	0.146	0.60	3.59	3.75
4	2500.	2.6	10.1	1.6	16.686	43.9	488.	19.3	21.8	14.9	10.5	68.1	71.0	1775.	0.044	0.118	0.60	3.16	3.74
4	2500.	2.6	10.1	1.6	16.717	43.9	488.	19.3	21.8	14.8	10.6	68.1	71.2	1775.	0.061	0.162	0.56	3.56	3.77
4	2498.	2.6	10.1	1.6	16.685	44.1	488.	19.3	21.8	14.9	10.5	68.3	70.7	1775.	0.060	0.143	0.66	3.59	3.76
4	2497.	2.6	10.0	1.6	16.648	44.0	488.	19.3	21.8	14.9	10.5	68.2	70.6	1775.	0.051	0.137	0.62	3.38	3.73
5	2351	2.6	12.7	1.4	19.150	45.6	488.	19.5	22.0	15.4	11.4	69.9	73.9	1775.	0.055	0.160	0.60	3.25	3.75
5	2352.	2.6	12.7	1.4	19.132	45.5	488.	19.5	22.0	15.4	11.4	69.8	74.0	1775.	0.055	0.167	0.63	3.58	3.76
5	2349.	2.6	12.7	1.4	19.162	45.6	488.	19.5	22.0	15.4	11.4	69.9	73.9	1775.	0.045	0.164	0.66	2.71	3.76
5	2353.	2.6	12.7	1.4	19.150	45.6	487.	19.5	22.0	15.4	11.4	70.1	74.0	1775.	0.045	0.123	0.68	3.61	3.76
5	2353.	2.6	12.7	1.4	19.117	45.5	487.	19.5	22.0	15.4	11.4	70.0	73.9	1775.	0.068	0.183	0.63	3.54	3.73
6	2198.	2.6	15.3	1.3	21.593	46.6	487.	19.6	22.1	15.7	12.0	71.2	76.3	1775.	0.055	0.156	0.62	3.26	3.77
6	2198.	2.6	15.3	1.3	21.595	46.6	487.	19.5	22.1	15.7	12.0	71.3	76.2	1775.	0.056	0.139	0.60	3.60	3.78
6	2195.	2.6	15.3	1.2	21.587	46.6	487.	19.6	22.1	15.8	12.0	71.3	76.0	1775.	0.068	0.163	0.64	3.15	3.75
6	2196.	2.6	15.3	1.3	21.594	46.6	487.	19.6	22.1	15.8	12.0	71.3	76.0	1775.	0.056	0.168	0.63	3.56	3.75
6	2197.	2.6	15.4	1.3	21.605	46.6	487.	19.6	22.1	15.8	12.0	71.3	76.1	1775.	0.062	0.185	0.68	3.54	3.75
7	2098.	2.6	17.0	1.1	23.133	46.9	486.	19.5	22.0	15.9	12.3	72.0	77.4	1775.	0.046	0.132	0.64	3.22	3.77
7	2100.	2.6	17.0	1.1	23.128	47.0	486.	19.5	22.0	15.9	12.3	72.0	77.4	1775.	0.046	0.149	0.65	2.90	3.77
7	2103.	2.6	17.0	1.1	23.144	46.9	486.	19.5	22.0	15.9	12.3	72.0	77.6	1775.	0.058	0.182	0.63	3.59	3.75
7	2103.	2.6	17.1	1.1	23.201	47.0	486.	19.5	22.0	15.9	12.3	72.1	77.6	1775.	0.069	0.184	0.65	3.59	3.77
7	2099.	2.6	17.1	1.1	23.195	47.0	486.	19.5	22.0	15.9	12.3	72.1	77.4	1775.	0.062	0.177	0.63	3.61	3.75
8	1996.	2.6	18.5	1.0	24.570	47.2	487.	19.6	22.2	16.0	12.4	71.9	77.7	1775.	0.060	0.177	0.55	3.56	3.75
8	1992.	2.6	18.5	1.0	24.554	47.2	487.	19.6	22.2	16.0	12.4	71.8	77.5	1775.	0.048	0.121	0.61	3.04	3.75
8	1993.	2.6	18.6	1.0	24.591	47.2	487.	19.7	22.2	16.0	12.4	71.9	77.6	1775.	0.056	0.196	0.61	2.74	3.76
8	1986.	2.6	18.6	1.0	24.598	47.2	487.	19.7	22.2	16.0	12.4	71.9	77.4	1775.	0.051	0.146	0.58	3.60	3.76

Figure 170. Test run 100-H08-004-2.6; research data; pump 1, Test H08, sump 4, submergence 2.47D (Continued)

8	1986.	2.6	18.6	1.0	24.625	47.2	487.	19.6	22.2	16.0	12.4	71.9	77.5	1775.	0.063	0.181	0.63	3.48	3.76
9	1898.	2.6	19.9	0.9	25.820	47.3	486.	19.6	22.2	16.0	12.4	72.1	77.6	1775.	0.045	0.146	0.68	3.63	3.78
9	1895.	2.6	19.9	0.9	25.817	47.3	487.	19.6	22.2	16.0	12.4	72.0	77.4	1775.	0.043	0.130	0.66	3.49	3.77
9	1899.	2.6	19.9	0.9	25.822	47.3	487.	19.6	22.2	16.0	12.4	72.0	77.6	1775.	0.058	0.163	0.62	3.63	3.77
9	1893.	2.6	19.9	0.9	25.844	47.2	487.	19.6	22.2	16.0	12.4	72.0	77.5	1775.	0.065	0.174	0.68	3.61	3.77
9	1895.	2.6	19.9	0.9	25.880	47.2	486.	19.6	22.2	16.0	12.4	72.0	77.6	1775.	0.048	0.141	0.63	3.61	3.77
10	1803.	2.6	21.1	0.8	26.929	47.2	486.	19.6	22.1	15.9	12.3	72.0	77.0	1775.	0.044	0.121	0.56	3.50	3.77
10	1801.	2.6	21.1	0.8	26.928	47.2	486.	19.6	22.1	15.9	12.3	72.0	76.9	1775.	0.044	0.118	0.58	3.65	3.79
10	1803.	2.6	21.1	0.8	26.938	47.2	486.	19.6	22.1	15.9	12.3	72.1	77.0	1775.	0.051	0.140	0.56	3.59	3.77
10	1804.	2.6	21.1	0.8	26.955	47.1	486.	19.6	22.1	15.9	12.3	72.0	77.2	1775.	0.065	0.178	0.57	3.63	3.77
10	1799.	2.6	21.1	0.8	26.951	47.2	486.	19.6	22.1	15.9	12.3	72.0	76.8	1775.	0.059	0.160	0.55	3.35	3.79
11	1707.	2.6	22.3	0.8	28.098	47.2	486.	19.6	22.1	15.9	12.1	72.1	76.0	1775.	0.043	0.124	0.53	3.59	3.78
11	1705.	2.6	22.3	0.8	28.095	47.2	486.	19.6	22.1	16.0	12.1	72.1	75.8	1775.	0.048	0.144	0.58	3.59	3.79
11	1705.	2.6	22.4	0.8	28.118	47.3	486.	19.6	22.1	16.0	12.1	72.1	75.9	1775.	0.050	0.144	0.54	3.60	3.79
11	1698.	2.6	22.4	0.7	28.126	47.3	486.	19.6	22.1	16.0	12.1	72.2	75.6	1775.	0.060	0.157	0.53	3.63	3.80
11	1702.	2.6	22.4	0.8	28.111	47.2	486.	19.6	22.1	16.0	12.1	72.1	75.7	1775.	0.050	0.140	0.53	3.61	3.79
12	1601.	2.6	23.4	0.7	29.034	47.3	486.	19.6	22.1	16.0	11.7	72.4	73.5	1775.	0.046	0.135	0.55	3.57	3.77
12	1604.	2.6	23.4	0.7	29.047	47.3	486.	19.6	22.1	16.0	11.8	72.4	73.6	1775.	0.048	0.168	0.72	3.58	3.77
12	1602.	2.6	23.4	0.7	29.041	47.3	486.	19.6	22.1	16.0	11.8	72.3	73.5	1775.	0.065	0.163	0.56	3.53	3.77
12	1603.	2.6	23.4	0.7	29.040	47.3	486.	19.6	22.1	16.0	11.8	72.3	73.5	1775.	0.047	0.133	0.77	3.59	3.79
12	1598.	2.6	23.4	0.7	29.038	47.3	486.	19.6	22.1	16.0	11.7	72.2	73.3	1775.	0.055	0.166	0.53	3.61	3.77
13	1499.	2.6	24.2	0.6	29.770	47.3	486.	19.6	22.1	16.0	11.3	72.2	70.6	1775.	0.056	0.143	0.53	3.61	3.82
13	1498.	2.6	24.2	0.6	29.794	47.3	486.	19.6	22.1	16.0	11.3	72.3	70.5	1775.	0.047	0.134	0.53	3.59	3.83
13	1498.	2.6	24.2	0.6	29.777	47.3	486.	19.6	22.1	16.0	11.3	72.3	70.5	1775.	0.058	0.182	0.55	3.61	3.84
13	1497.	2.6	24.2	0.6	29.804	47.4	486.	19.6	22.2	16.0	11.3	72.3	70.4	1775.	0.056	0.160	0.52	3.61	3.85
13	1498.	2.6	24.2	0.6	29.787	47.4	487.	19.6	22.2	16.0	11.3	72.3	70.4	1775.	0.049	0.185	0.63	3.58	3.84
14	1344.	2.6	24.8	0.5	30.304	46.6	487.	19.6	22.1	15.8	10.3	71.2	65.3	1775.	0.063	0.173	0.83	3.39	3.98
14	1352.	2.6	24.9	0.5	30.343	46.7	487.	19.6	22.1	15.8	10.4	71.3	65.7	1775.	0.061	0.198	0.82	3.43	3.91
14	1347.	2.6	24.8	0.5	30.318	46.7	487.	19.6	22.1	15.8	10.3	71.3	65.4	1775.	0.054	0.155	0.79	3.53	3.92
14	1347.	2.6	24.8	0.5	30.318	46.6	485.	19.6	22.0	15.8	10.3	71.6	65.5	1775.	0.055	0.191	0.80	3.47	3.89
14	1345.	2.6	24.8	0.5	30.285	46.6	486.	19.5	22.0	15.7	10.3	71.4	65.4	1775.	0.052	0.161	0.85	3.39	3.92
15	1203.	2.6	24.7	0.4	30.103	44.6	487.	19.3	21.8	15.1	9.2	69.3	60.7	1775.	0.086	0.239	1.61	3.01	4.44
15	1197.	2.6	24.7	0.4	30.076	44.6	487.	19.3	21.8	15.1	9.1	69.2	60.4	1775.	0.082	0.282	1.69	2.97	4.48
15	1200.	2.6	24.7	0.4	30.055	44.6	487.	19.3	21.8	15.1	9.1	69.3	60.5	1775.	0.087	0.293	1.69	2.86	4.33
15	1201.	2.6	24.7	0.4	30.061	44.5	487.	19.3	21.7	15.0	9.1	69.1	60.7	1775.	0.091	0.268	1.59	2.88	4.50
15	1198.	2.6	24.7	0.4	30.076	44.5	487.	19.3	21.8	15.0	9.1	69.1	60.5	1775.	0.084	0.258	1.62	2.83	4.34
16	1044.	2.6	24.8	0.3	30.118	43.7	487.	19.2	21.7	14.8	7.9	68.1	53.8	1775.	0.112	0.338	2.18	2.57	4.70
16	1046.	2.6	24.8	0.3	30.125	43.7	487.	19.2	21.7	14.8	8.0	68.2	53.9	1775.	0.117	0.378	2.14	2.29	4.90
16	1041.	2.6	24.8	0.3	30.108	43.7	487.	19.2	21.7	14.8	7.9	68.1	53.7	1775.	0.118	0.437	2.20	2.52	4.78
16	1044.	2.6	24.8	0.3	30.096	43.6	486.	19.2	21.6	14.7	7.9	68.2	53.9	1775.	0.118	0.372	2.17	2.33	4.78
16	1044.	2.6	24.9	0.3	30.138	43.7	486.	19.2	21.6	14.8	8.0	68.3	53.9	1775.	0.115	0.352	2.16	2.19	4.80
17	847.	2.6	26.5	0.2	31.650	44.5	487.	19.3	21.8	15.0	6.8	68.9	45.1	1775.	0.132	0.456	2.56	2.47	5.02
17	847.	2.6	26.5	0.2	31.673	44.5	487.	19.3	21.8	15.1	6.8	68.9	45.1	1775.	0.130	0.476	2.66	2.20	4.93
17	848.	2.6	26.5	0.2	31.698	44.5	487.	19.3	21.8	15.0	6.8	68.9	45.2	1775.	0.126	0.456	2.34	2.60	4.76
17	851.	2.6	26.5	0.2	31.638	44.5	487.	19.3	21.8	15.0	6.8	69.0	45.2	1775.	0.133	0.469	2.67	2.43	4.74
17	848.	2.6	26.5	0.2	31.715	44.6	487.	19.3	21.8	15.1	6.8	69.0	45.1	1775.	0.125	0.430	2.61	2.32	4.76

Figure 170. (Concluded)

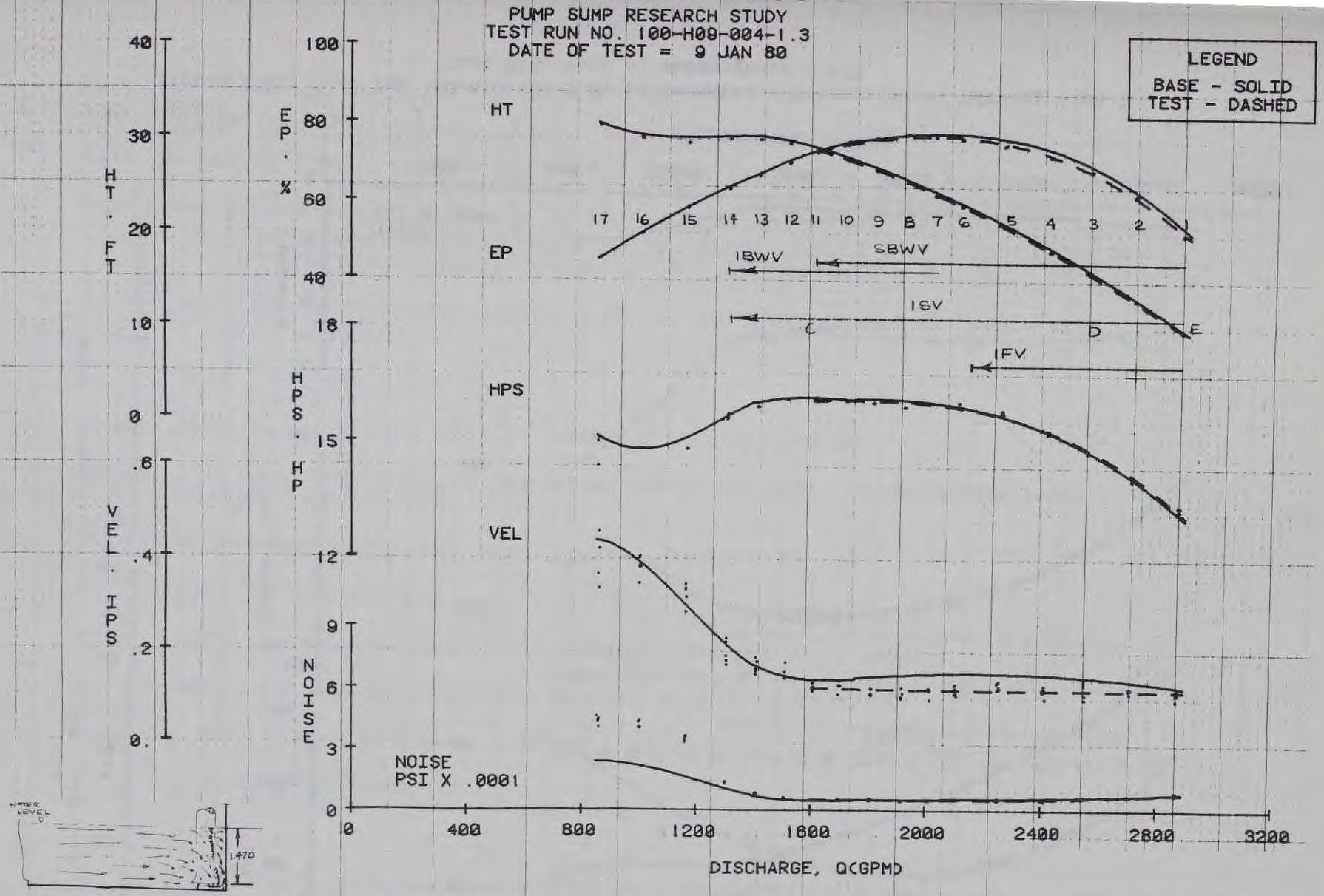


Figure 171. Test run 100-H09-004-1.3; performance characteristics curves; pump 1, Test H09, sump 4, submergence 1.47D

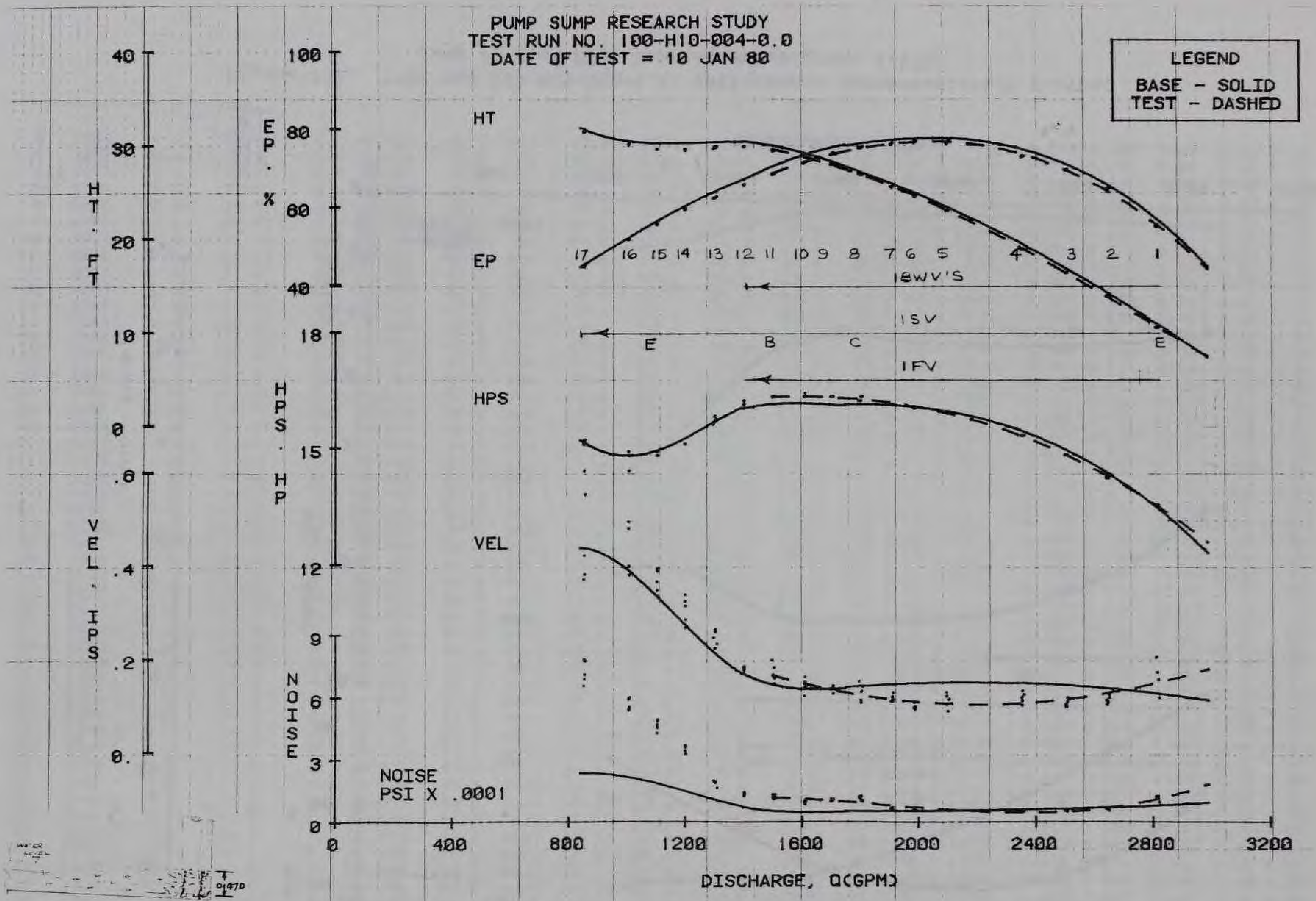


Figure 172. Test run 100-H10-004-0.0; performance characteristics curves; pump 1, Test H10, sump 4, submergence 0.47D

PUMPS RUN SUMP SUBMERGENCE
100 H09 004 1 3

DATE 09 JAN 80 TIME 1430 AIR TEMP 54 F WATER TEMP 49 F BAR. PRESS. 30.09IN HG

01 TWIN SBWV'S 1/8 IN DIA AT 5:30 CCW & 6:30 CW. TFV 1/16 IN DIA CW, LOCATION CHANGING BUT MOSTLY AT 11:00 O'CLOCK. ISV 1/4 IN DIA AT 5 O'CLOCK CW & ISV 1/4 IN DIA AT 7 O'CLOCK CCW BOTH STAGE E.

02 NSCE (NO SIGNIFICANT CHANGE EXCEPT) TV'S BECOMING SMALLER & LESS FREQUENT

03 NSCE SV'S NOW STAGE D.

04-06 NSCE ALL VORTEXES GETTING SMALLER & LESS FREQUENT.

07-08 IFV GONE SBWV AT 6:30 BECOMING IBWV. IFV GONE, FLASHING ON BLADE-POSSIBLY CAVITATION.

09-10 NSCE BWV NOW 1/16 IN DIA, ISV'S ALSO 1/16 IN DIA.

11 NSCE SV NOW STAGE C.

12 NSCE BWV'S BOTH IBWV'S & FLASHING BECOMING MUCH LARGER.

13-14 NSCE ALL VORTEXES GETTING SMALLER & LESS FREQUENT.

DATE 09 JAN 80 TIME 1550 AIR TEMP 54 F WATER TEMP 49 F BAR. PRESS. 30.09IN HG

15 ALL VORTEXES GONE

16 NSC

17 NSCE SPRAY EXPULSION FROM PUMP BELL REACHING TO SUMP FLOOR.

Figure 173. Test run 100-H09-004-1.3; visual observation notes; pump 1, Test H09, sump 4, submergence 1.47D

PUMPS RUN SUMP SUBMERGENCE
100 H10 004 0.0

DATE 10 JAN 80 TIME 1440 AIR TEMP 62 F WATER TEMP 53 F BAR PRESS. 29.87IN HG

01 ISV CCW 1 IN DIA AT 7 O'CLOCK STAGE E. TWIN IBWV'S AT 5:30 CCW & 6:30 CW BOTH 1/8 IN DIA. IFV 1/8 IN DIA CW OCCURING MOSTLY AT 11 & 2 O'CLOCK. ISV CW 1 IN DIA AT 5 O'CLOCK STAGE E.

02 NSC (NO SIGNIFICANT CHANGE).

03 NSCE (NO EXCEPT) THAT THE ISV AT 5 O'CLOCK IS MORE PREDOMINENT THAN THE ISV AT 7 O'CLOCK. ISV'S AT 4 O'CLOCK CCW & 8 O'CLOCK CW BOTH IN SUMP CORNER, STAGE D & 1/2 IN DIA.

04-06 NSCE ALL VORTEXES GETTING SMALLER & LESS FREQUENT.

07 ISV AT 7 O'CLOCK GONE. ISV AT 5 O'CLOCK NOW 1/2 IN DIA. IFV NOW 1/16 IN DIA. BOTH CORNER VORTEXES NOW 1/4 IN DIA & STAGE D.

08-09 NSCE IFV NOW 1/32 IN DIA & APPEARING MOSTLY AT 9 O'CLOCK. CORNER ISV'S NOW STAGE C.

10 NSCE ALL VORTEXES GETTING SMALL & OCCURRING LESS FREQUENT.

DATE 10 JAN 80 TIME 1540 AIR TEMP 62 F WATER TEMP 53 F BAR. PRESS. 29.86IN HG

11 NSCE IBWV AT 6:30 NOW GONE. CORNER ISV'S NOW STAGE B.

12 NSCE FLASHING BECOMING MUCH LARGER ON BLADE.

13 NSCE BWV'S GONE. IFV GONE. OTHERS LESS FREQUENT.

14 NSCE FLASHING ON BLADE BECOMING LARGER.

15 ALL VORTEXES GONE EXCEPT ISV AT 5 O'CLOCK CW 1/4 IN DIA STAGE E.

16 NSC.

17 NSCE THE ISV AT 5 O'CLOCK NOW 1/8 IN DIA. SPRAY EXPULSIONS FROM BELL REACHING TO SUMP FLOOR.

DATE 10 JAN 80 TIME 1600 AIR TEMP 62 F WATER TEMP 53 F BAR. PRESS. 29.85IN HG

Figure 174. Test run 100-H10-004-0.0; visual observation notes; pump 1, Test H10, sump 4, submergence 0.47D

```
            ***PUMP EFFICIENCY          ***
TOTAL AREA -1507.56   ABSOLUTE AREA  1507.56

              TEST CURVE
MAX Y =     76.76  , X =   1997.52
MIN Y =     44.14  , X =   2987.62
MEAN Y =    70.92  , X =   2434.38
                * * *
            SIGNATURE CURVE
MAX Y =     77.31  , X =   2034.65
MIN Y =     44.36  , X =   2987.62
MEAN Y =    71.86  , X =   2460.73


            ***SHAFT HORSEPOWER         ***
TOTAL AREA    13.19   ABSOLUTE AREA   63.97

              TEST CURVE
MAX Y =     16.08  , X =   1600.00
MIN Y =     12.32  , X =   2987.62
MEAN Y =    15.53  , X =   2307.08
                * * *
            SIGNATURE CURVE
MAX Y =     16.14  , X =   1600.00
MIN Y =     12.27  , X =   2987.62
MEAN Y =    15.54  , X =   2300.66


            ***ABS VELOCITY,IPS         ***
TOTAL AREA   -35.44   ABSOLUTE AREA   36.02

              TEST CURVE
MAX Y =      0.13  , X =   1600.00
MIN Y =      0.11  , X =   2405.94
MEAN Y =     0.12  , X =   2981.07
                * * *
            SIGNATURE CURVE
MAX Y =      0.15  , X =   2158.42
MIN Y =      0.11  , X =   2987.62
MEAN Y =     0.14  , X =   2619.20


            ***NOISE LB/IN**2           ***
TOTAL AREA   -33.29   ABSOLUTE AREA   48.90

              TEST CURVE
MAX Y =      0.93  , X =   2987.62
MIN Y =      0.51  , X =   1997.52
MEAN Y =     0.57  , X =   2614.83
                * * *
            SIGNATURE CURVE
MAX Y =      0.93  , X =   2987.62
MIN Y =      0.47  , X =   1631.19
MEAN Y =     0.56  , X =   2571.52


            ***TOTAL HEAD               ***
TOTAL AREA  -389.51   ABSOLUTE AREA  389.51

              TEST CURVE
MAX Y =     28.72  , X =   1600.00
MIN Y =      7.07  , X =   2987.62
MEAN Y =    23.08  , X =   2084.05
                * * *
            SIGNATURE CURVE
MAX Y =     29.07  , X =   1600.00
MIN Y =      7.10  , X =   2987.62
MEAN Y =    23.39  , X =   2081.24
```

Figure 175. Test run 100-H09-004-1.3; statistical comparison; pump 1, Test H09, sump 4, submergence 1.47D

***PUMP EFFICIENCY ***
TOTAL AREA -2259.68 ABSOLUTE AREA 2259.68

TEST CURVE

MAX Y = 76.37 , X = 2047.03
MIN Y = 43.08 , X = 2987.62
MEAN Y = 68.35 , X = 2529.89

* * *

SIGNATURE CURVE

MAX Y = 77.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 69.74 , X = 2529.77

***SHAFT HORSEPOWER ***
TOTAL AREA 47.79 ABSOLUTE AREA 261.66

TEST CURVE

MAX Y = 16.34 , X = 1718.81
MIN Y = 12.94 , X = 2987.62
MEAN Y = 15.56 , X = 2234.73

* * *

SIGNATURE CURVE

MAX Y = 16.14 , X = 1571.78
MIN Y = 12.27 , X = 2987.62
MEAN Y = 15.51 , X = 2311.99

***ABS VELOCITY,FPS ***
TOTAL AREA -17.10 ABSOLUTE AREA 62.90

TEST CURVE

MAX Y = 0.24 , X = 1300.00
MIN Y = [illegible] , X = [illegible]
MEAN Y = 0.15 , X = 2002.39

* * *

SIGNATURE CURVE

MAX Y = 0.21 , X = 1300.00
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2419.83

***NOISE LB/IN**2 ***
TOTAL AREA 431.97 ABSOLUTE AREA 447.31

TEST CURVE

MAX Y = 2.31 , X = 1300.00
MIN Y = 0.52 , X = 2096.53
MEAN Y = 1.06 , X = 1620.66

* * *

SIGNATURE CURVE

MAX Y = 1.02 , X = 1300.00
MIN Y = 0.47 , X = 1629.70
MEAN Y = 0.62 , X = 2638.57

***TOTAL HEAD ***
TOTAL AREA -636.37 ABSOLUTE AREA 683.46

TEST CURVE

MAX Y = 29.67 , X = 1313.37
MIN Y = 7.56 , X = 2987.62
MEAN Y = 23.49 , X = 2055.27

* * *

SIGNATURE CURVE

MAX Y = 30.36 , X = 1317.82
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.91 , X = 2043.45

Figure 176. Test run 100-H10-004-0.0; statistical comparison; pump 1, Test H10, sump 4, submergence 0.47D

READ NO.	Q DISCHARGE GPM	HW SUBMERGENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2864.	1.3	1.0	2.1	9.409	39.2	481.	18.2	20.3	13.3	6.8	65.4	51.4	1775.	0.038	0.102	0.80	0.39	2.38
1	2871.	1.3	0.9	2.1	9.379	39.2	481.	18.2	20.3	13.2	6.8	65.3	51.4	1775.	0.040	0.114	0.82	1.79	2.39
1	2865.	1.3	1.0	2.1	9.397	39.2	480.	18.2	20.2	13.2	6.8	65.4	51.4	1775.	0.037	0.089	0.83	2.13	2.38
1	2865.	1.3	1.0	2.1	9.390	39.2	480.	18.2	20.2	13.2	6.8	65.5	51.3	1775.	0.037	0.110	0.80	2.17	2.38
1	2872.	1.3	1.0	2.1	9.412	39.2	480.	18.2	20.2	13.3	6.8	65.6	51.5	1775.	0.038	0.103	0.85	2.19	2.38
2	2701.	1.3	4.5	1.9	12.683	41.7	480.	18.5	20.6	14.1	8.7	68.3	61.5	1775.	0.040	0.113	0.77	1.83	2.42
2	2699.	1.3	4.5	1.9	12.689	41.6	480.	18.5	20.6	14.0	8.7	68.1	61.6	1775.	0.038	0.116	0.68	2.19	2.39
2	2702.	1.3	4.5	1.9	12.722	41.5	480.	18.5	20.6	14.0	8.7	68.1	61.9	1775.	0.037	0.111	0.71	2.06	2.40
2	2705.	1.3	4.5	1.9	12.673	41.6	480.	18.5	20.6	14.1	8.7	68.2	61.7	1775.	0.042	0.105	0.73	2.07	2.41
2	2708.	1.3	4.5	1.9	12.694	41.6	480.	18.5	20.6	14.1	8.7	68.2	61.8	1775.	0.041	0.114	0.70	2.19	2.42
3	2546.	1.3	7.6	1.7	15.565	43.7	481.	18.8	21.0	14.8	10.0	70.5	67.8	1775.	0.045	0.133	0.66	1.98	2.41
3	2550.	1.3	7.5	1.7	15.517	43.6	481.	18.8	20.9	14.8	10.0	70.4	67.8	1775.	0.039	0.101	0.62	1.82	2.41
3	2550.	1.3	7.6	1.7	15.546	43.7	481.	18.8	21.0	14.8	10.0	70.4	67.9	1775.	0.037	0.091	0.69	2.02	2.39
3	2546.	1.3	7.5	1.7	15.500	43.7	481.	18.8	21.0	14.8	10.0	70.4	67.5	1775.	0.044	0.122	0.64	1.97	2.41
3	2546.	1.3	7.5	1.7	15.527	43.6	481.	18.8	20.9	14.7	10.0	70.4	67.8	1775.	0.041	0.128	0.65	1.97	2.41
4	2410.	1.3	10.2	1.5	17.957	45.2	482.	19.0	21.2	15.3	10.9	72.0	71.6	1775.	0.039	0.092	0.48	2.12	2.41
4	2407.	1.3	10.2	1.5	17.958	45.1	482.	19.0	21.2	15.2	10.9	71.9	71.7	1775.	0.040	0.115	0.52	1.77	2.39
4	2403.	1.3	10.2	1.5	17.964	45.2	482.	19.0	21.2	15.3	10.9	72.0	71.4	1775.	0.038	0.107	0.54	2.09	2.39
4	2402.	1.3	10.2	1.5	17.981	45.2	482.	19.0	21.2	15.3	10.9	72.0	71.4	1775.	0.041	0.114	0.54	2.09	2.39
4	2406.	1.3	10.1	1.5	17.939	45.2	481.	19.0	21.2	15.3	10.9	72.1	71.4	1775.	0.042	0.121	0.54	1.68	2.38
5	2249.	1.3	13.0	1.3	20.581	46.6	482.	19.2	21.5	15.8	11.7	73.4	74.3	1775.	0.043	0.130	0.59	2.17	2.42
5	2246.	1.3	13.0	1.3	20.588	46.6	482.	19.2	21.5	15.8	11.7	73.5	74.2	1775.	0.042	0.112	0.56	2.17	2.42
5	2251.	1.3	13.0	1.3	20.573	46.5	482.	19.2	21.4	15.7	11.7	73.4	74.4	1775.	0.043	0.119	0.47	2.27	2.42
5	2243.	1.3	13.0	1.3	20.567	46.5	482.	19.2	21.4	15.7	11.7	73.4	74.1	1775.	0.042	0.126	0.52	2.20	2.41
5	2253.	1.3	13.0	1.3	20.583	46.6	482.	19.2	21.4	15.7	11.7	73.4	74.5	1775.	0.040	0.115	0.51	2.23	2.42
6	2099.	1.3	15.3	1.1	22.773	47.2	481.	19.3	21.5	16.0	12.1	74.2	75.8	1775.	0.038	0.103	0.54	2.26	2.41
6	2099.	1.3	15.4	1.1	22.811	47.2	481.	19.3	21.5	15.9	12.1	74.2	75.9	1775.	0.040	0.115	0.51	2.30	2.42
6	2104.	1.3	15.3	1.1	22.783	47.2	481.	19.3	21.5	15.9	12.1	74.1	76.0	1775.	0.040	0.100	0.57	2.07	2.42
6	2101.	1.3	15.3	1.1	22.794	47.1	481.	19.3	21.5	15.9	12.1	74.0	76.0	1775.	0.041	0.123	0.57	2.29	2.42
6	2102.	1.3	15.4	1.1	22.825	47.3	481.	19.3	21.5	16.0	12.1	74.1	75.9	1775.	0.040	0.104	0.53	2.28	2.43
7	2012.	1.3	16.7	1.0	24.042	47.3	482.	19.3	21.6	16.0	12.2	74.0	76.5	1775.	0.037	0.111	0.49	2.26	2.40
7	2009.	1.3	16.7	1.0	24.043	47.3	482.	19.3	21.6	16.0	12.2	74.1	76.4	1775.	0.041	0.110	0.49	2.25	2.41
7	2007.	1.3	16.7	1.0	24.033	47.3	482.	19.3	21.6	16.0	12.2	74.1	76.4	1775.	0.037	0.116	0.50	2.26	2.40
7	2011	1.3	16.7	1.0	24.058	47.3	482.	19.3	21.6	16.0	12.2	74.1	76.5	1775.	0.041	0.112	0.53	2.23	2.41
7	2012.	1.3	16.7	1.1	24.058	47.4	482.	19.3	21.6	16.0	12.2	74.2	76.4	1775.	0.037	0.090	0.55	2.19	2.41
8	1915.	1.3	18.1	1.0	25.363	47.1	483.	19.3	21.6	15.9	12.3	73.6	77.2	1775.	0.037	0.105	0.48	2.29	2.45
8	1912.	1.3	18.1	0.9	25.358	47.1	483.	19.3	21.6	15.9	12.3	73.6	77.1	1775.	0.036	0.094	0.48	1.84	2.44
8	1911.	1.3	18.1	0.9	25.373	47.1	483.	19.3	21.6	15.9	12.3	73.7	77.0	1775.	0.036	0.097	0.49	2.22	2.43
8	1910.	1.3	18.1	0.9	25.338	47.1	483.	19.3	21.6	15.9	12.2	73.6	76.9	1775.	0.037	0.097	0.51	2.24	2.44

Figure 177. Test run 100-H09-004-1.3; research data; pump 1, Test H09, sump 4, submergence 1.47D (Continued)

8	1913.	1.3	18.1	0.9	25.382	47.1	483.	19.3	21.6	15.9	12.3	73.5	77.2	1775.	0.040	0.117	0.52	2.33	2.46
9	1803.	1.3	19.5	0.8	26.676	47.3	486.	19.3	21.8	16.0	12.2	73.5	76.0	1775.	0.037	0.102	0.48	2.24	2.43
9	1805.	1.3	19.5	0.8	26.696	47.3	486.	19.3	21.8	16.0	12.2	73.5	76.2	1775.	0.037	0.104	0.47	2.29	2.44
9	1805.	1.3	19.5	0.8	26.643	47.4	486.	19.3	21.7	16.0	12.2	73.6	76.0	1775.	0.039	0.116	0.59	2.28	2.44
9	1807.	1.3	19.5	0.8	26.660	47.4	485.	19.3	21.8	16.0	12.2	73.7	76.0	1775.	0.037	0.101	0.60	2.18	2.43
9	1808.	1.3	19.5	0.8	26.666	47.4	485.	19.3	21.7	16.0	12.2	73.7	76.1	1775.	0.037	0.115	0.53	2.27	2.44
10	1699.	1.3	20.9	0.7	27.958	47.6	485.	19.4	21.8	16.1	12.0	73.9	74.6	1775.	0.043	0.121	0.51	2.29	2.44
10	1699.	1.3	20.9	0.7	27.952	47.6	485.	19.4	21.8	16.1	12.0	73.8	74.6	1775.	0.040	0.132	0.54	2.28	2.44
10	1696.	1.3	20.9	0.7	27.941	47.7	485.	19.4	21.8	16.1	12.0	74.0	74.4	1775.	0.046	0.132	0.56	2.22	2.47
10	1691.	1.3	20.9	0.7	27.939	47.7	485.	19.4	21.8	16.1	11.9	73.9	74.2	1775.	0.040	0.102	0.53	2.29	2.44
10	1693.	1.3	20.9	0.7	27.954	47.6	485.	19.4	21.8	16.1	12.0	73.8	74.4	1775.	0.041	0.122	0.52	2.23	2.46
11	1603.	1.3	21.8	0.7	28.723	47.5	485.	19.3	21.8	16.1	11.6	73.8	72.4	1775.	0.041	0.109	0.51	2.27	2.44
11	1604.	1.3	21.8	0.7	28.735	47.6	485.	19.3	21.8	16.1	11.7	73.9	72.4	1775.	0.045	0.127	0.51	2.27	2.46
11	1606.	1.3	21.8	0.7	28.729	47.6	485.	19.3	21.8	16.1	11.7	73.8	72.6	1775.	0.044	0.118	0.52	2.25	2.47
11	1603.	1.3	21.8	0.7	28.727	47.6	485.	19.3	21.8	16.1	11.6	73.9	72.4	1775.	0.044	0.126	0.53	2.10	2.46
11	1602.	1.3	21.8	0.7	28.736	47.6	485.	19.3	21.8	16.1	11.6	73.9	72.4	1775.	0.042	0.116	0.52	2.28	2.45
12	1506.	1.3	22.5	0.6	29.412	47.7	486.	19.4	21.8	16.1	11.2	73.8	69.5	1775.	0.048	0.150	0.59	2.28	2.52
12	1506.	1.3	22.5	0.6	29.373	47.6	486.	19.4	21.8	16.1	11.2	73.7	69.6	1775.	0.045	0.137	0.62	2.26	2.51
12	1510.	1.3	22.5	0.6	29.396	47.7	486.	19.4	21.8	16.1	11.2	73.8	69.7	1775.	0.053	0.141	0.61	2.29	2.50
12	1506.	1.3	22.5	0.6	29.421	47.7	486.	19.4	21.8	16.1	11.2	73.8	69.5	1775.	0.051	0.141	0.57	2.29	2.51
12	1508.	1.3	22.5	0.6	29.409	47.7	486.	19.4	21.8	16.1	11.2	73.8	69.6	1775.	0.053	0.171	0.56	2.26	2.50
13	1410.	1.3	23.0	0.5	29.824	47.0	486.	19.3	21.8	15.9	10.6	73.0	66.9	1775.	0.057	0.172	0.84	2.17	2.55
13	1406.	1.3	23.0	0.5	29.837	46.9	486.	19.3	21.8	15.9	10.6	72.8	66.9	1775.	0.051	0.144	0.79	2.23	2.65
13	1405.	1.3	23.0	0.5	29.831	47.2	486.	19.3	21.8	16.0	10.6	73.1	66.4	1775.	0.052	0.151	0.80	2.12	2.56
13	1405.	1.3	23.0	0.5	29.822	47.2	487.	19.3	21.8	16.0	10.6	73.1	66.4	1775.	0.051	0.181	0.86	2.23	2.57
13	1405.	1.3	23.0	0.5	29.831	47.1	486.	19.3	21.8	15.9	10.6	73.0	66.5	1775.	0.055	0.156	0.83	2.20	2.54
14	1304.	1.3	23.2	0.4	29.959	46.4	486.	19.2	21.7	15.7	9.9	72.2	63.0	1775.	0.060	0.174	1.31	2.07	2.77
14	1303.	1.3	23.2	0.4	29.932	46.3	486.	19.2	21.7	15.7	9.9	72.2	63.0	1775.	0.064	0.223	1.41	2.11	2.77
14	1301.	1.3	23.2	0.4	29.933	46.3	486.	19.2	21.7	15.6	9.8	72.2	62.9	1775.	0.061	0.184	1.29	2.09	2.71
14	1304.	1.3	23.2	0.4	29.922	46.3	486.	19.2	21.7	15.6	9.9	72.2	63.1	1775.	0.059	0.165	1.39	2.04	2.71
14	1301.	1.3	23.2	0.4	29.925	46.3	485.	19.2	21.6	15.6	9.8	72.3	63.0	1775.	0.065	0.214	1.39	2.00	2.74
15	1161.	1.3	22.8	0.3	29.460	43.7	486.	18.9	21.3	14.8	8.6	69.2	58.6	1775	0.096	0.340	3.38	1.21	3.23
15	1162.	1.3	22.8	0.4	29.485	43.8	486.	18.9	21.3	14.8	8.7	69.5	58.5	1775.	0.105	0.330	3.54	1.35	3.29
15	1162.	1.3	22.8	0.3	29.468	43.8	485.	18.9	21.2	14.8	8.7	69.7	58.5	1775.	0.098	0.280	3.52	1.31	3.43
15	1164.	1.3	22.8	0.4	29.470	43.8	485.	18.9	21.3	14.8	8.7	69.6	58.6	1775.	0.096	0.312	3.61	1.37	3.30
15	1160.	1.3	22.8	0.3	29.456	43.9	486.	18.9	21.3	14.8	8.6	69.7	58.2	1775.	0.098	0.328	3.47	1.34	3.23
16	1004.	1.3	23.6	0.3	30.160	43.8	487.	18.9	21.3	14.8	7.7	69.3	51.7	1775.	0.131	0.377	4.02	1.25	3.62
16	1005.	1.3	23.6	0.3	30.126	43.8	487.	18.9	21.3	14.8	7.7	69.4	51.7	1775.	0.113	0.381	4.41	1.09	3.60
16	1001.	1.3	23.5	0.3	30.092	43.7	487.	18.9	21.3	14.8	7.6	69.3	51.5	1775.	0.118	0.342	4.32	0.98	3.47
16	1006.	1.3	23.5	0.3	30.100	43.8	487.	18.9	21.3	14.8	7.7	69.3	51.7	1775.	0.108	0.377	4.03	0.93	3.69
16	1002.	1.3	23.5	0.3	30.073	43.7	487.	18.9	21.3	14.8	7.6	69.3	51.6	1775.	0.122	0.400	4.04	1.00	3.53
17	860.	1.3	24.9	0.2	31.439	44.7	486.	19.0	21.4	15.1	6.8	70.5	45.2	1775.	0.114	0.331	4.05	1.13	3.47
17	857.	1.3	24.9	0.2	31.384	44.6	486.	19.0	21.4	15.1	6.8	70.4	45.1	1775.	0.127	0.362	4.32	1.08	3.98
17	860.	1.3	24.9	0.2	31.392	44.5	486.	19.0	21.4	15.1	6.8	70.4	45.4	1775.	0.137	0.417	4.43	0.67	3.72
17	858.	1.3	24.9	0.2	31.398	44.6	486.	19.0	21.4	15.1	6.8	70.4	45.2	1775.	0.124	0.454	4.38	0.98	3.52
17	853.	1.3	24.9	0.2	31.391	44.4	486.	19.0	21.4	15.0	6.8	70.2	45.1	1775.	0.139	0.597	4.59	0.96	4.00

Figure 177. (Concluded)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HPM INPUT MOTOR HP (HORSEPOWER)	HPS SHAFT HP (HORSEPOWER)	HPW WATER HP (HORSEPOWER)	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2811.	0.	0.7	2.0	10.343	39.8	482.	18.3	20.5	13.5	7.3	65.7	54.6	1775.	0.053	0.200	1.24	0.03	1.16
1	2818.	0.	0.7	2.1	10.362	40.0	482.	18.3	20.5	13.5	7.4	65.9	54.7	1775.	0.053	0.152	1.24	0.27	1.19
1	2821.	0.	0.6	2.1	10.313	39.9	482.	18.3	20.5	13.5	7.4	65.8	54.6	1775.	0.048	0.114	0.94	0.63	1.11
1	2814.	0.	0.6	2.1	10.300	39.9	482.	18.3	20.5	13.5	7.3	65.8	54.4	1775.	0.051	0.168	1.15	0.68	1.15
1	2818.	0.	0.7	2.1	10.334	40.0	482.	18.3	20.5	13.5	7.4	66.0	54.5	1775.	0.055	0.153	1.14	0.54	1.13
2	2651.	0.	4.2	1.8	13.658	42.1	483.	18.6	20.8	14.2	9.2	68.3	64.4	1775.	0.043	0.114	0.54	0.39	1.11
2	2651.	0.	4.2	1.8	13.633	42.0	483.	18.6	20.8	14.2	9.1	68.3	64.4	1775.	0.044	0.120	0.58	0.36	1.11
2	2644.	0.	4.2	1.8	13.653	42.0	483.	18.6	20.8	14.2	9.1	68.3	64.3	1775.	0.044	0.099	0.63	0.71	1.10
2	2643.	0.	4.2	1.8	13.626	42.0	483.	18.6	20.8	14.2	9.1	68.3	64.1	1775.	0.045	0.108	0.67	0.49	1.10
2	2648.	0.	4.2	1.8	13.618	41.9	483.	18.6	20.8	14.2	9.1	68.2	64.3	1775.	0.044	0.105	0.64	0.24	1.10
3	2509.	0.	6.9	1.6	16.118	43.7	483.	18.8	21.1	14.8	10.2	70.1	69.2	1775.	0.044	0.114	0.52	0.75	1.09
3	2504.	0.	6.9	1.6	16.125	43.7	483.	18.8	21.1	14.8	10.2	70.1	69.1	1775.	0.043	0.099	0.55	0.20	1.10
3	2508.	0.	6.9	1.6	16.131	43.8	483.	18.8	21.1	14.8	10.2	70.2	69.1	1775.	0.044	0.106	0.53	0.37	1.07
3	2509.	0.	6.9	1.6	16.159	43.8	483.	18.8	21.1	14.8	10.2	70.3	69.2	1775.	0.044	0.105	0.50	0.67	1.05
3	2505.	0.	6.9	1.6	16.121	43.7	483.	18.8	21.0	14.8	10.2	70.2	69.1	1775.	0.043	0.095	0.56	0.17	1.10
4	2351.	0.	9.6	1.4	18.618	45.2	483.	19.0	21.3	15.3	11.1	71.9	72.4	1775.	0.045	0.115	0.52	0.56	1.08
4	2359.	0.	9.6	1.4	18.644	45.3	483.	19.0	21.3	15.3	11.1	71.9	72.6	1775.	0.044	0.121	0.53	0.83	1.08
4	2352.	0.	9.6	1.4	18.614	45.3	483.	19.0	21.3	15.3	11.1	71.9	72.4	1775.	0.044	0.107	0.52	0.90	1.09
4	2353.	0.	9.7	1.4	18.688	45.3	483.	19.0	21.3	15.3	11.1	72.0	72.5	1775.	0.044	0.129	0.52	0.74	1.05
4	2353.	0.	9.6	1.4	18.675	45.2	483.	19.0	21.3	15.3	11.1	71.8	72.7	1775.	0.043	0.098	0.51	0.25	1.09
5	2095.	0.	14.1	1.1	22.836	47.0	483.	19.3	21.6	15.9	12.1	73.6	76.1	1775.	0.045	0.126	0.58	0.64	1.11
5	2096.	0.	14.1	1.1	22.843	47.2	483.	19.3	21.6	15.9	12.1	73.8	75.9	1775.	0.045	0.118	0.60	0.87	1.16
5	2096.	0.	14.1	1.1	22.814	47.0	483.	19.2	21.6	15.9	12.1	73.7	76.1	1775.	0.043	0.100	0.59	0.84	1.26
5	2099.	0.	14.1	1.1	22.809	47.0	483.	19.2	21.5	15.9	12.1	73.7	76.2	1775.	0.041	0.086	0.55	1.00	1.14
5	2103.	0.	14.1	1.1	22.850	47.0	483.	19.2	21.6	15.9	12.1	73.7	76.4	1775.	0.043	0.111	0.56	0.87	1.11
6	1988.	0.	15.7	1.0	24.329	47.3	484.	19.2	21.6	16.0	12.2	73.9	76.5	1775.	0.041	0.095	0.61	0.73	1.11
6	1987.	0.	15.7	1.0	24.369	47.4	484.	19.2	21.6	16.0	12.2	74.1	76.4	1775.	0.040	0.091	0.60	0.64	1.07
6	1984.	0.	15.7	1.0	24.355	47.4	484.	19.2	21.6	16.0	12.2	74.1	76.3	1775.	0.041	0.105	0.60	0.80	1.09
6	1983.	0.	15.7	1.0	24.339	47.4	484.	19.2	21.6	16.0	12.2	74.1	76.2	1775.	0.040	0.094	0.64	0.06	1.10
6	1986.	0.	15.7	1.0	24.357	47.4	484.	19.2	21.6	16.0	12.2	74.1	76.4	1775.	0.041	0.092	0.66	0.80	1.09
7	1911.	0.	16.8	0.9	25.370	47.6	485.	19.2	21.6	16.1	12.3	74.4	76.2	1775.	0.042	0.126	0.68	0.80	1.07
7	1903.	0.	16.8	0.9	25.356	47.6	485.	19.2	21.6	16.1	12.2	74.4	75.8	1775.	0.042	0.107	0.67	0.87	1.12
7	1908.	0.	16.8	0.9	25.315	47.6	485.	19.2	21.6	16.1	12.2	74.4	76.0	1775.	0.042	0.117	0.71	0.54	1.08
7	1909.	0.	16.8	0.9	25.367	47.6	485.	19.2	21.6	16.1	12.2	74.4	76.1	1775.	0.041	0.111	0.70	0.66	1.09
7	1910.	0.	16.8	0.9	25.366	47.6	485.	19.2	21.6	16.1	12.2	74.4	76.1	1775.	0.042	0.107	0.61	0.58	1.08
8	1803.	0.	18.3	0.8	26.742	48.2	485.	19.3	21.7	16.3	12.2	75.1	74.9	1775.	0.046	0.128	1.25	0.87	1.14
8	1800.	0.	18.3	0.8	26.759	48.1	485.	19.3	21.7	16.3	12.2	75.1	74.8	1775.	0.043	0.105	1.06	0.92	1.13
8	1807.	0.	18.3	0.8	26.741	48.1	485.	19.3	21.7	16.3	12.2	75.0	75.1	1775.	0.045	0.139	1.03	0.90	1.16
8	1800.	0.	18.3	0.8	26.734	48.0	485.	19.3	21.7	16.2	12.2	74.9	75.0	1775.	0.045	0.110	1.26	0.10	1.15

Figure 178. Test run 100-H10-004-0.0; research data; pump 1, Test H10, sump 4, submergence 0.47D (Continued)

8	1795.	0.	18.3	0.8	26.771	48.1	485.	19.3	21.7	16.2	12.2	75.0	74.8	1775.	0.049	0.150	1.20	0.41	1.15
9	1700.	0.	19.5	0.7	27.803	48.4	486.	19.3	21.8	16.3	11.9	75.0	73.1	1775.	0.048	0.133	1.00	0.88	1.13
9	1707.	0.	19.4	0.8	27.802	48.2	486.	19.3	21.8	16.3	12.0	74.9	73.6	1775.	0.048	0.141	1.06	0.82	1.12
9	1709.	0.	19.4	0.8	27.769	48.2	485.	19.3	21.7	16.3	12.0	74.9	73.2	1775.	0.047	0.134	1.10	0.90	1.14
9	1707.	0.	19.4	0.8	27.805	48.3	486.	19.3	21.8	16.3	12.0	75.0	73.5	1775.	0.046	0.124	1.08	0.86	1.14
9	1700.	0.	19.4	0.7	27.790	48.2	485.	19.3	21.8	16.3	11.9	75.0	73.2	1775.	0.046	0.134	1.12	0.78	1.11
10	1613.	0.	20.3	0.7	28.596	48.4	485.	19.3	21.8	16.4	11.7	75.1	71.3	1775.	0.049	0.137	0.99	0.90	1.18
10	1608.	0.	20.3	0.7	28.554	48.3	486.	19.3	21.8	16.3	11.6	75.0	71.1	1775.	0.049	0.118	0.99	0.86	1.15
10	1610.	0.	20.3	0.7	28.603	48.4	486.	19.3	21.8	16.3	11.6	75.1	71.2	1775.	0.053	0.159	0.85	0.79	1.13
10	1610.	0.	20.3	0.7	28.555	48.3	486.	19.3	21.8	16.3	11.6	75.0	71.2	1775.	0.052	0.136	0.95	0.74	1.13
10	1610.	0.	20.3	0.7	28.563	48.3	486.	19.3	21.8	16.3	11.6	75.0	71.1	1775.	0.050	0.149	0.94	0.60	1.10
11	1507.	0.	21.1	0.6	29.263	48.3	485.	19.3	21.8	16.3	11.1	75.0	68.2	1775.	0.055	0.156	1.31	0.82	1.20
11	1506.	0.	21.1	0.6	29.273	48.3	485.	19.3	21.8	16.3	11.1	75.0	68.2	1775.	0.058	0.179	1.27	0.75	1.17
11	1506	0.	21.1	0.6	29.261	48.3	485.	19.3	21.8	16.3	11.1	75.0	68.2	1775.	0.053	0.144	1.11	0.85	1.21
11	1499	0	21.1	0.6	29.273	48.2	485.	19.3	21.7	16.3	11.1	75.0	68.1	1775.	0.056	0.195	1.32	0.45	1.23
11	1502	0	21.0	0.6	29.234	48.2	485.	19.3	21.7	16.3	11.1	74.9	68.2	1775.	0.053	0.162	1.30	0.90	1.25
12	1404	0	21.6	0.5	29.666	47.6	486.	19.3	21.7	16.1	10.5	73.9	65.5	1775.	0.060	0.175	1.36	0.82	1.27
12	1402.	0	21.6	0.5	29.705	47.7	486	19.3	21.8	16.1	10.5	74.2	65.3	1775	0.058	0.179	1.27	0.80	1.31
12	1403.	0.	21.6	0.5	29.694	47.7	486.	19.3	21.8	16.1	10.5	74.1	65.3	1775	0.059	0.172	1.41	0.84	1.33
12	1403	0	21.6	0.5	29.744	47.8	486	19.3	21.7	16.2	10.6	74.3	65.3	1775	0.061	0.180	1.45	0.50	1.35
12	1404.	0	21.6	0.5	29.737	47.8	486.	19.3	21.7	16.2	10.6	74.3	65.3	1775	0.065	0.180	1.36	0.57	1.27
13	1305.	0.	21.6	0.4	29.656	46.5	487	19.1	21.6	15.7	9.8	72.9	62.2	1775.	0.072	0.256	1.89	0.60	1.40
13	1303.	0.	21.6	0.4	29.677	46.6	487.	19.1	21.6	15.8	9.8	73.0	62.1	1775.	0.072	0.220	1.89	0.69	1.41
13	1305.	0.	21.6	0.4	29.671	46.5	487	19.1	21.6	15.7	9.8	72.8	62.2	1775.	0.068	0.260	1.88	0.56	1.49
13	1299.	0	21.5	0.4	29.516	46.2	486.	19.1	21.5	15.6	9.7	72.6	62.0	1775	0.071	0.242	1.96	0.51	1.43
13	1310	0.	21.6	0.4	29.652	46.6	486.	19.1	21.6	15.7	9.8	72.9	62.4	1775	0.070	0.229	1.62	0.58	1.41
14	1201.	0.	21.3	0.4	29.309	44.6	487	18.9	21.4	15.1	8.9	70.6	59.0	1775.	0.089	0.264	3.57	0.25	2.14
14	1203.	0.	21.4	0.4	29.379	44.7	487	18.9	21.4	15.1	8.9	70.7	59.1	1775.	0.095	0.281	3.24	0.19	2.08
14	1202.	0.	21.4	0.4	29.354	44.5	487	18.9	21.4	15.1	8.9	70.4	59.5	1775.	0.099	0.335	3.69	0.33	2.41
14	1203	0	21.4	0.4	29.395	44.6	487	18.9	21.4	15.1	8.9	70.4	59.4	1775.	0.097	0.310	3.62	0.43	2.20
14	1200.	0.	21.4	0.4	29.390	44.6	487.	18.9	21.4	15.1	8.9	70.4	59.2	1775.	0.097	0.320	3.40	0.12	2.18
15	1105.	0.	21.5	0.3	29.401	43.9	488	18.8	21.3	14.8	8.2	69.7	55.3	1775.	0.103	0.344	4.54	0.31	2.26
15	1104.	0	21.4	0.3	29.362	43.9	488.	18.8	21.3	14.8	8.2	69.6	55.3	1775.	0.118	0.390	4.67	0.28	2.34
15	1104	0	21.5	0.3	29.416	44.0	488.	18.8	21.3	14.9	8.2	69.7	55.3	1775	0.112	0.362	4.27	0.33	2.20
15	1105	0.	21.5	0.3	29.439	43.9	488	18.8	21.3	14.8	8.2	69.7	55.4	1775	0.105	0.332	4.85	0.56	2.38
15	1106.	0.	21.5	0.3	29.414	43.9	488	18.8	21.3	14.8	8.2	69.7	55.4	1775	0.119	0.385	4.92	0.43	2.40
16	1006.	0.	22.1	0.3	29.989	43.9	488	18.8	21.3	14.9	7.6	69.7	51.4	1775.	0.125	0.396	5.42	0.60	2.54
16	1006.	0.	22.2	0.3	30.017	44.0	488	18.8	21.3	14.9	7.6	69.7	51.4	1775.	0.124	0.491	5.38	0.71	2.38
16	1007.	0	22.1	0.3	29.963	43.9	488	18.8	21.3	14.8	7.6	69.5	51.5	1775	0.126	0.377	5.55	0.69	2.63
16	1007.	0.	22.1	0.3	29.977	43.8	488	18.9	21.3	14.8	7.6	69.5	51.5	1775.	0.128	0.673	6.01	0.61	2.53
16	1006.	0.	22.1	0.3	29.998	43.9	488	18.8	21.3	14.8	7.6	69.5	51.5	1775	0.113	0.476	5.90	1.10	2.70
17	851.	0.	23.6	0.2	31.340	44.8	488.	18.9	21.5	15.1	6.7	70.5	44.5	1775	0.132	0.368	6.57	1.00	2.64
17	855.	0	23.6	0.2	31.384	44.9	488.	19.0	21.5	15.2	6.8	70.7	44.7	1775	0.138	0.419	6.85	0.71	2.57
17	853.	0.	23.6	0.2	31.430	45.0	488.	19.0	21.5	15.2	6.8	70.7	44.6	1775.	0.140	0.613	7.85	0.56	2.63
17	856.	0.	23.6	0.2	31.412	44.9	488.	19.0	21.5	15.2	6.8	70.6	44.8	1775	0.129	0.379	7.10	0.41	2.93
17	858	0	23.6	0.2	31.422	45.0	488	19.0	21.5	15.2	6.8	70.7	44.9	1775	0.135	0.550	7.76	0.55	2.74

Figure 178. (Concluded)

Figure 179. Test run 100-H02-007-2.6; performance characteristics curves; pump 1, Test H02, sump 7, submergence 2.47D

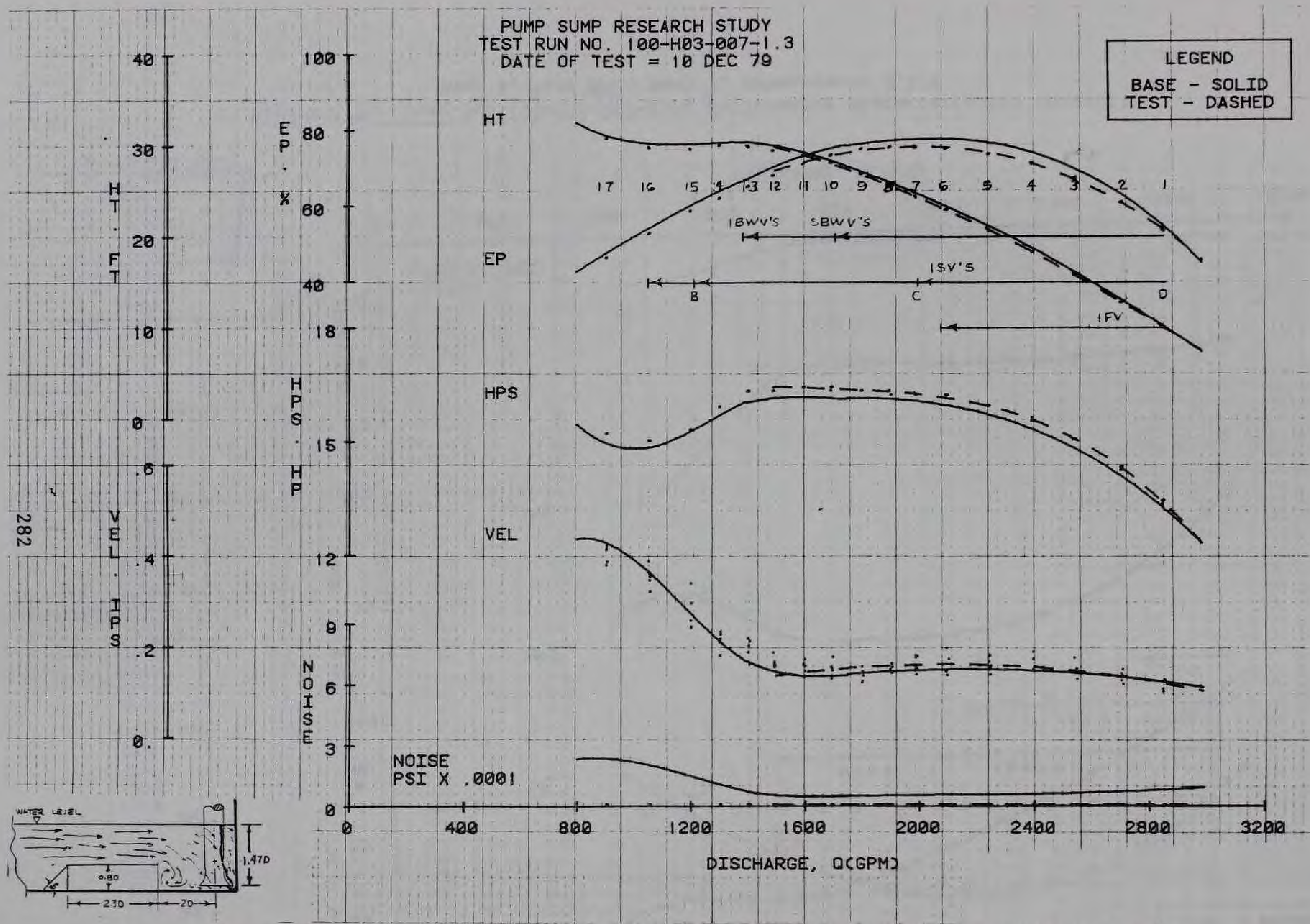


Figure 180. Test run 100-H03-007-1.3; performance characteristics curves; pump 1, Test H03, sump 7, submergence 1.47D

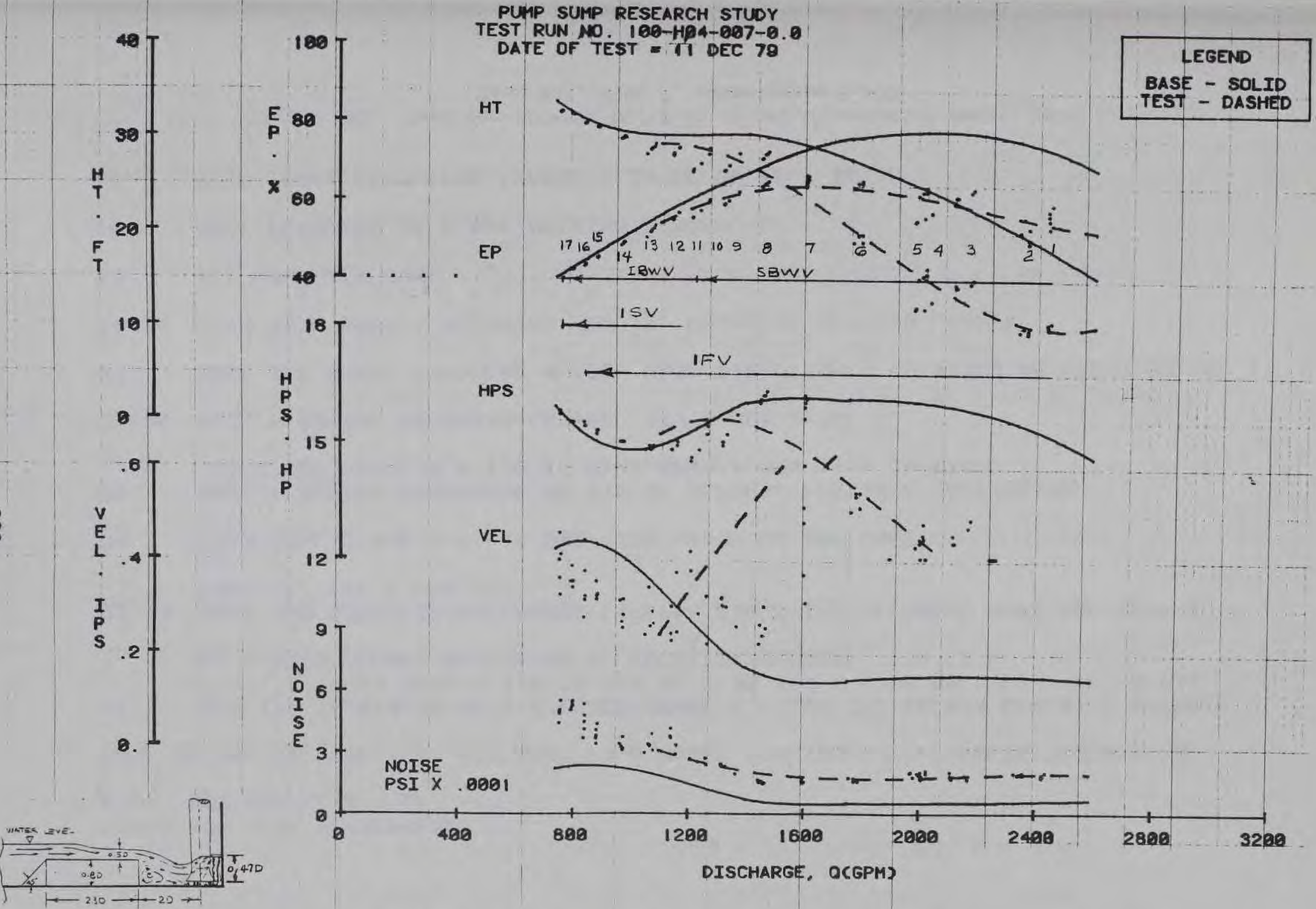


Figure 181. Test run 100-H04-007-0.0; performance characteristics curves; pump 1, Test H04, sump 7, submergence 0.47D

PUMPS RUN SUMP SUBMERGENCE
100 H02 007 2 6

DATE 06 DEC 79 TIME 1300 AIR TEMP 63 F WATER TEMP 53 F BAR PRESS. 29.67IN HG

01	ISV 1/2 IN DIA CW AT 5 O'CLOCK STAGE E. ISV 1/2 IN DIA CCW AT 7 O'CLOCK STAGE E, TWIN SBWV'S 1/8 IN DIA AT 5:30 CCW & 6:30 CW, IFV 1/16 IN DIA AT 6:00 O'CLOCK, DIRECTION OF ROTATION UNKNOWN, TOO FAST.
02-03	NSCE (NO SIGNIFICANT CHANGE EXCEPT) ISV & IFV BECOMING LESS FREQUENT & SMALLER, ISV'S NOW STAGE D.
04	TWIN SBWV'S NOW 1/16 IN DIA, ISV STAGE C, IFV GONE.
05	NSCE FLASHING APPEARING ON TIP OF BLADES, POSSIBLE CAVITATION. ISV'S NOW STAGE B & 1/8 IN DIA, SBWV'S NOW 1/16 IN DIA.
05-08	NSCE FLASHING BECOMING LARGER, ISV'S NOW STAGE A.
09	NSCE ISV GONE, CIRCULAR MOTION SAME DIRECTION & LOCATION AS PREVIOUS SV.
10-14	NSCE TWIN SBWV'S BECOMING IBWV'S, FLASHING GETTING LARGER.
15	ALL VORTEXES GONE.
16	NSCE FLASHING ON BLADE GETTING LARGER.
17	NSCE SPRAY EXPULSION APPROX 3 IN BELOW BELL INTAKE.

Figure 182. Test run 100-H02-007-2.6; visual observation notes; pump 1, Test H02, sump 7, submergence 2.47D

PLAPS RUN SUMP SUBMERGENCE
100 H03 007 1.3

DATE 10 DEC 79 TIME 1100 AIR TEMP 57 F WATER TEMP 45 F BAR. PRESS. 29.96IN HG

01 ISV 1/2 IN DIA CW, LOCATION CHANGING FROM 5 TO 7 O'CLOCK, STAGE D
ISV 1/2 IN DIA CW, STAGE D, LOCATION CHANGING FROM 3 TO 6 O'CLOCK IFV
1/8 IN DIA CCW LOCATON CHANGING FROM 10 TO 12 O'CLOCK. TWIN SBWV'S 1/8
IN DIA AT 5:30 CCW & 6:30 CW

02 NO SIGNIFICANT CHANGE EXCEPT (NSCE) IFV NOW 1/16 IN DIA.

03-04 NSCE ISV'S STAGE C & OCCURRING LESS FREQUENT, SBWV AT 6:30 BECOMING
IBWV.

05-06 NSCE ISV'S BECOMING STAGE C & SMALLER (1/4 IN), IFV SMALLER (1/32 IN) &
BWV'S BECOMING SMALLER (1/16 IN).

07 NSCE IFV NOW GONE, SV'S NOW STAGE C. FLASHING ON BLADE, POSSIBLE
CAVITATION

08-10 NSCE BOTH BWV'S BECOMING IBWV'S, SV'S BECOMING STAGE B & APPRX 1/8 IN DIA.

11-12 NSCE IBWV'S BECOMING SMALLER (APPRX 1/32).

13 NSCE ISV CW 1/4 IN DIA AT 5 O'CLOCK, FLASHING BECOMING LARGER ON BLADE

DATE 10 DEC 79 TIME 1230 AIR TEMP 65 F WATER TEMP 48 F BAR.PRESS. 30.06IN HG

14 NSCE IBWV'S GONE

15-16 NSCE ISV AT 5 O'CLOCK BECOMING STAGE B, ALL OTHER VOTEXES GONE.

17 ALL VORTEXES GONE. SPRAY EXPULSION APPRX 3 IN FROM BELL INTAKE.

Figure 183. Test run 100-H03-007-1.3; visual observation notes; pump 1, Test H03, sump 7, submergence 1.47D

PUMPS RUN SUMP SUBMERGENCE
05N
100 H04 007 0.0

DATE 11 DEC 79 TIME 1200 AIR TEMP 67 F WATER TEMP 54 F BAR PRESS.29.94IN HG

01 EXTREME TURBULENCE WITH HYD JUMP. 1SWV'S 3/4 IN DIA CCW AT 3 TO 5 O'CLOCK & CW AT 7 TO 9 O'CLOCK. SOME OF THE SIDE WALL VORTEXES REACH COMPLETELY ACROSS THE SUMP ABOUT 0.6 FT FROM FLOOR & ABOUT 2-3 IN FROM BACK WALL, IFV CCW LOCATION VARYING ALL AROUND 1/2 IN DIA. SV'S APPEARING TO BE TRYING TO FORM BUT TURBULENCE IS BREAKING THEM UP. THERE IS SO MUCH TRAPPED AIR THAT VALIDITY OF DATA IS QUESTIONABLE. UNABLE TO SEE BLADE FOR AIR BUBBLES.

02-06 NSCE (NO SIGNIFICANT CHANGE EXCEPT) ALL VORTEXES APPRX 1/4 IN SMALLER. TURBULENCE ABOUT SAME.

07-08 TUBULENCE BECOMING SLIGHTY LESS SEVERE. IFV LESS FREQUENT, SWV'S WEAKER.

09-11 NSC.

12 IFV GONE. TWIN IBWV'S AT 5:30 CCW & 6:30 CW, BOTH 1/2 IN DIA. STILL UNABLE TO SEE BLADE FOR AIR BUBBLES, TURBULENCE STILL VERY BAD. ISV CCW 3/4 IN DIA AT 7 O'CLOCK.

13-16 NSCE BWV'S BECOMING SMALLER APRX 1/4 IN DIA, SPRAY EXPULSION ABOUT 4 IN FROM BELL INTAKE.

DATE 11 DEC 79 TIME 1340 AIR TEMP 74 F WATER TEMP 56 F BAR. PRESS. 29.90IN HG

17 NSCE SWV'S GONE, SPRAY EXPULSION REACHING FLOOR.

Figure 184. Test run 100-H04-007-0.0; visual observation notes; pump 1, Test H04, sump 7, submergence 0.47D

```
          ***PUMP EFFICIENCY        ***
TOTAL AREA -2242.38    ABSOLUTE AREA  2242.38

               TEST CURVE
MAX Y =      75.80   , X =    2022.28
MIN Y =      43.59   , X =    2987.62
MEAN Y =      70.18   , X =    2455.67
                 * * *
              SIGNATURE CURVE
MAX Y =      77.31   , X =    2034.65
MIN Y =      44.36   , X =    2987.62
MEAN Y =      71.86   , X =    2460.73
```

```
               ***NOISE LB/IN**2        ***
TOTAL AREA  -762.43    ABSOLUTE AREA   762.43

               TEST CURVE
MAX Y =      0.08   , X =    2195.54
MIN Y =      0.07   , X =    2987.62
MEAN Y =      0.08   , X =    2544.86
                 * * *
              SIGNATURE CURVE
MAX Y =      0.93   , X =    2987.62
MIN Y =      0.47   , X =    1631.19
MEAN Y =      0.56   , X =    2571.52
```

```
          ***SHAFT HORSEPOWER       ***
TOTAL AREA   112.25    ABSOLUTE AREA   112.35

               TEST CURVE
MAX Y =      16.21   , X =    1675.74
MIN Y =      12.30   , X =    2987.62
MEAN Y =      15.63   , X =    2294.66
                 * * *
              SIGNATURE CURVE
MAX Y =      16.14   , X =    1600.00
MIN Y =      12.27   , X =    2987.62
MEAN Y =      15.54   , X =    2300.66
```

```
               ***TOTAL HEAD            ***
TOTAL AREA  -483.88    ABSOLUTE AREA   483.88

               TEST CURVE
MAX Y =      28.56   , X =    1600.00
MIN Y =      6.98   , X =    2987.62
MEAN Y =      22.96   , X =    2084.23
                 * * *
              SIGNATURE CURVE
MAX Y =      29.07   , X =    1630.00
MIN Y =      7.10   , X =    2987.62
MEAN Y =      23.39   , X =    2081.24
```

```
          ***AIR VELOCITY,IPS       ***
TOTAL AREA    -0.51    ABSOLUTE AREA     8.79

               TEST CURVE
MAX Y =      0.15   , X =    1600.00
MIN Y =      0.12   , X =    [illegible]
MEAN Y =      0.14   [illegible]
                 * * *
              SIGNATURE CURVE
MAX Y =      0.15   , X =    2158.42
MIN Y =      0.11   , X =    2987.62
MEAN Y =      0.14   , X =    2619.20
```

Figure 185. Test run 100-H02-007-2.6; statistical comparison; pump 1, Test H02, sump 7, submergence 2.47D

```
             ***PUMP EFFICIENCY     ***
TOTAL AREA -2911.89    ABSOLUTE AREA  2946.08

               TEST CURVE
MAX Y =     75.70  , X =   1997.52
MIN Y =     45.09  , X =   2987.62
MEAN Y =     69.83  , X =   2427.17
                * * *
              SIGNATURE CURVE
MAX Y =     77.31  , X =   2034.65
MIN Y =     44.36  , X =   2987.62
MEAN Y =     71.86  , X =   2460.73


             ***SHAFT HORSEPOWER    ***
TOTAL AREA   283.61    ABSOLUTE AREA   283.61

               TEST CURVE
MAX Y =     16.38  , X =   1600.00
MIN Y =     12.28  , X =   2987.62
MEAN Y =     15.76  , X =   2304.93
                * * *
              SIGNATURE CURVE
MAX Y =     16.14  , X =   1600.00
MIN Y =     12.27  , X =   2987.62
MEAN Y =     15.54  , X =   2300.66


             ***ABS VELOCITY IPS    ***
TOTAL AREA     9.28    ABSOLUTE AREA    11.38

               TEST CURVE
MAX Y =      0.16  , X =   2084.16
MIN Y =      0.10  , X =   [illegible]
MEAN Y =     0.15  , X =   2522.22
                * * *
              SIGNATURE CURVE
MAX Y =      0.15  , X =   2158.42
MIN Y =      0.11  , X =   2987.62
MEAN Y =     0.14  , X =   2619.20


             ***NOISE LB/IN**2      ***
TOTAL AREA  -767.32    ABSOLUTE AREA   767.32

               TEST CURVE
MAX Y =      0.08  , X =   2987.62

MIN Y =      0.07  , X =   2566.83
MEAN Y =     0.07  , X =   2856.75
                * * *
              SIGNATURE CURVE
MAX Y =      0.93  , X =   2987.62
MIN Y =      0.47  , X =   1631.19
MEAN Y =     0.56  , X =   2571.52


             ***TOTAL HEAD          ***
TOTAL AREA  -457.79    ABSOLUTE AREA   461.94

               TEST CURVE
MAX Y =     28.76  , X =   1600.00
MIN Y =      7.18  , X =   2987.62
MEAN Y =    23.05  , X =   2076.67
                * * *
              SIGNATURE CURVE
MAX Y =     29.07  , X =   1600.00
MIN Y =      7.10  , X =   2987.62
MEAN Y =    23.39  , X =   2081.24
```

Figure 186. Test run 100-H03-007-1.3; statistical comparison; pump 1, Test H03, sump 7, submergence 2.47D

```
***PUMP EFFICIENCY     ***
TOTAL AREA ********    ABSOLUTE AREA 16972.69

TEST CURVE
MAX Y =     64.38  , X =   1584.16
MIN Y =     53.94  , X =   2490.59
MEAN Y =    60.88  , X =   1957.41
* * *
SIGNATURE CURVE
MAX Y =     77.31  , X =   2036.14
MIN Y =     67.51  , X =   2591.58
MEAN Y =    74.14  , X =   2365.55
```

```
***NOISE LB/IN**2      ***
TOTAL AREA  1350.17    ABSOLUTE AREA  1350.17

TEST CURVE
MAX Y =     1.95   , X =   2229.70
MIN Y =     1.55   , X =   1500.00
MEAN Y =    1.73   , X =   2536.18
* * *
SIGNATURE CURVE
MAX Y =     0.68   , X =   2591.58
MIN Y =     0.47   , X =   1631.19
MEAN Y =    0.53   , X =   2245.26
```

```
***SHAFT HORSEPOWER    ***
TOTAL AREA -3504.21    ABSOLUTE AREA  3504.21

TEST CURVE
MAX Y =     16.07  , X =   1500.00
MIN Y =     10.97  , X =   2414.85
MEAN Y =    13.42  , X =   1820.93
* * *
SIGNATURE CURVE
MAX Y =     16.14  , X =   1574.26
MIN Y =     14.58  , X =   2591.58
MEAN Y =    15.89  , X =   2115.88
```

```
***TOTAL HEAD          ***
TOTAL AREA -8811.88    ABSOLUTE AREA  8811.88

TEST CURVE
MAX Y =     27.11  , X =   1500.00
MIN Y =     9.74   , X =   2465.35
MEAN Y =    18.27  , X =   1827.55
* * *
SIGNATURE CURVE
MAX Y =     29.79  , X =   1500.00
MIN Y =     15.04  , X =   2591.58
MEAN Y =    25.31  , X =   1938.78
```

```
***ABS VELOCITY,FPS    ***
TOTAL AREA   859.43    ABSOLUTE AREA   859.43

TEST CURVE
MAX Y =     1.16   , X =   2120.36
MIN Y =     0.52   , X =   1500.00
MEAN Y =    0.82   , X =   2516.63
* * *
SIGNATURE CURVE
MAX Y =     0.15   , X =   2153.76
MIN Y =     0.13   , X =   1643.56
MEAN Y =    0.14   , X =   2536.23
```

Figure 187. Test run 100-H04-007-0.0; statistical comparison; pump 1, Test H04, sump 7, submergence 0.47D

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2912.	2.6	1.2	2.2	8.449	38.2	490.	18.4	20.9	12.9	6.2	61.8	48.2	1775.	0.039	0.106	0.08	2.42	3.71
1	2909.	2.6	1.3	2.2	8.472	38.2	490.	18.4	20.9	12.9	6.2	61.8	48.3	1775.	0.038	0.105	0.07	3.13	3.69
1	2912.	2.6	1.3	2.2	8.476	38.2	490.	18.4	20.9	12.9	6.2	61.9	48.3	1775.	0.040	0.096	0.08	3.21	3.71
1	2909.	2.6	1.3	2.2	8.454	38.2	490.	18.4	20.9	12.9	6.2	61.8	48.1	1775.	0.044	0.162	0.08	3.23	3.71
1	2912.	2.6	1.3	2.2	8.485	38.2	490.	18.4	20.9	12.9	6.2	61.8	48.4	1775.	0.037	0.099	0.08	3.44	3.72
2	2749.	2.6	5.0	2.0	11.937	41.1	490.	18.7	21.3	13.9	8.3	65.2	59.8	1775.	0.051	0.154	0.08	2.57	3.68
2	2746.	2.6	5.0	2.0	11.979	41.1	490.	18.7	21.3	13.9	8.3	65.3	59.9	1775.	0.050	0.129	0.08	2.79	3.68
2	2744.	2.6	5.1	2.0	12.040	41.2	490.	18.7	21.3	13.9	8.4	65.3	60.0	1775.	0.052	0.150	0.09	2.75	3.67
2	2743.	2.6	5.0	2.0	11.938	41.1	490.	18.7	21.3	13.9	8.3	65.3	59.5	1775.	0.053	0.140	0.09	1.52	3.69
2	2743.	2.6	5.1	2.0	12.048	41.1	490.	18.7	21.3	13.9	8.4	65.3	60.1	1775.	0.046	0.122	0.08	2.44	3.70
3	2606.	2.6	7.8	1.8	14.570	43.1	491.	19.0	21.6	14.6	9.6	67.5	65.8	1775.	0.048	0.144	0.09	3.17	3.75
3	2607.	2.6	7.8	1.8	14.515	43.1	491.	19.0	21.6	14.6	9.6	67.5	65.7	1775.	0.039	0.093	0.09	3.07	3.71
3	2606.	2.6	7.7	1.8	14.471	43.1	491.	19.0	21.6	14.6	9.5	67.4	65.4	1775.	0.044	0.131	0.09	2.98	3.73
3	2611.	2.6	7.7	1.8	14.476	43.2	492.	19.0	21.7	14.6	9.6	67.4	65.5	1775.	0.059	0.153	0.07	3.20	3.71
3	2606.	2.6	7.8	1.8	14.557	43.1	491.	19.0	21.6	14.6	9.6	67.3	65.8	1775.	0.058	0.171	0.08	2.92	3.71
4	2446.	2.6	10.8	1.6	17.313	45.1	491.	19.2	21.9	15.2	10.7	69.6	70.3	1775.	0.048	0.115	0.09	3.47	3.76
4	2439.	2.6	10.9	1.5	17.398	45.0	491.	19.2	21.9	15.2	10.7	69.4	70.5	1775.	0.066	0.170	0.08	3.38	3.75
4	2437.	2.6	10.8	1.5	17.309	45.0	491.	19.2	21.9	15.2	10.7	69.5	70.1	1775.	0.050	0.136	0.08	3.56	3.73
4	2439.	2.6	10.8	1.5	17.312	45.0	490.	19.2	21.8	15.2	10.7	69.7	70.1	1775.	0.061	0.152	0.08	3.36	3.75
4	2445.	2.6	10.8	1.6	17.316	45.0	491.	19.2	21.9	15.2	10.7	69.6	70.3	1775.	0.049	0.126	0.08	3.43	3.74
5	2292.	2.6	13.4	1.4	19.797	46.5	492.	19.3	22.0	15.7	11.5	71.3	73.0	1775.	0.056	0.146	0.09	3.46	3.74
5	2292.	2.6	13.4	1.4	19.787	46.5	492.	19.3	22.1	15.7	11.5	71.2	73.0	1775.	0.055	0.142	0.09	3.46	3.74
5	2291.	2.6	13.4	1.4	19.808	46.4	492.	19.3	22.1	15.7	11.5	71.1	73.2	1775.	0.052	0.143	0.09	3.58	3.74
5	2293.	2.6	13.4	1.4	19.802	46.4	492.	19.4	22.1	15.7	11.5	71.0	73.2	1775.	0.050	0.157	0.09	3.19	3.72
5	2290.	2.6	13.4	1.4	19.777	46.4	492.	19.3	22.1	15.7	11.4	71.1	72.9	1775.	0.045	0.122	0.09	3.23	3.73
6	2198.	2.6	15.0	1.3	21.232	46.9	492.	19.4	22.2	15.8	11.8	71.5	74.5	1775.	0.052	0.138	0.09	3.41	3.76
6	2203.	2.6	15.0	1.3	21.274	46.9	492.	19.4	22.2	15.9	11.8	71.5	74.7	1775.	0.054	0.151	0.09	3.50	3.75
6	2199.	2.6	15.0	1.3	21.220	46.8	492.	19.4	22.2	15.8	11.8	71.5	74.5	1775.	0.049	0.149	0.09	3.50	3.76
6	2202.	2.6	15.0	1.3	21.232	46.8	491.	19.4	22.2	15.8	11.8	71.5	74.6	1775.	0.048	0.135	0.09	3.60	3.76
6	2204.	2.6	15.0	1.3	21.246	46.9	491.	19.4	22.2	15.9	11.8	71.6	74.6	1775.	0.042	0.117	0.08	3.57	3.77
7	2107.	2.6	16.4	1.2	22.566	47.3	492.	19.5	22.2	16.0	12.0	72.0	75.2	1775.	0.045	0.128	0.09	3.40	3.74
7	2105.	2.6	16.4	1.1	22.589	47.4	492.	19.5	22.2	16.0	12.0	72.1	75.1	1775.	0.050	0.128	0.09	3.60	3.73
7	2108.	2.6	16.4	1.2	22.561	47.3	491.	19.5	22.2	16.0	12.0	72.1	75.2	1775.	0.044	0.125	0.09	3.32	3.74
7	2111.	2.6	16.4	1.2	22.576	47.3	491.	19.5	22.2	16.0	12.0	72.1	75.4	1775.	0.050	0.176	0.09	3.58	3.75
7	2110.	2.6	16.4	1.2	22.558	47.3	491.	19.5	22.2	16.0	12.0	72.1	75.3	1775.	0.050	0.145	0.09	3.46	3.73
8	1999.	2.6	18.1	1.0	24.103	47.5	490.	19.5	22.2	16.1	12.2	72.5	75.8	1775.	0.050	0.136	0.09	3.07	3.75
8	2001.	2.6	18.1	1.0	24.101	47.5	490.	19.5	22.2	16.1	12.2	72.4	76.0	1775.	0.057	0.160	0.08	3.61	3.75
8	2004.	2.6	18.1	1.0	24.106	47.5	490.	19.5	22.2	16.1	12.2	72.5	76.0	1775.	0.050	0.140	0.08	3.23	3.76
8	2000.	2.6	18.1	1.0	24.096	47.5	490.	19.5	22.2	16.1	12.2	72.4	75.9	1775.	0.045	0.145	0.08	3.57	3.75

Figure 188. Test run 100-H02-007-2.6; research data; pump 1, Test H02, sump 7, submergence 2.47D (Continued)

8	1999.	2.6	18.1	1.0	24.110	47.5	490.	19.5	22.2	16.1	12.2	72.5	75.8	1775.	0.046	0.126	0.09	3.58	3.74
9	1902.	2.6	19.4	0.9	25.337	47.7	491.	19.5	22.2	16.1	12.2	72.6	75.6	1775.	0.047	0.128	0.09	2.82	3.75
9	1906.	2.6	19.4	0.9	25.350	47.7	491.	19.5	22.2	16.1	12.2	72.7	75.7	1775.	0.038	0.102	0.09	3.47	3.74
9	1909	2.6	19.4	0.9	25.314	47.7	491.	19.5	22.2	16.1	12.2	72.6	75.8	1775.	0.052	0.134	0.08	3.58	3.75
9	1907.	2.6	19.4	0.9	25.321	47.7	491.	19.5	22.2	16.1	12.2	72.5	75.8	1775.	0.051	0.151	0.09	3.56	3.75
9	1902.	2.6	19.4	0.9	25.328	47.7	491.	19.5	22.2	16.1	12.2	72.6	75.6	1775.	0.047	0.117	0.09	3.43	3.73
10	1798.	2.6	20.7	0.8	26.585	47.8	491.	19.5	22.2	16.1	12.1	72.8	74.9	1775.	0.054	0.168	0.09	3.54	3.77
10	1799.	2.6	20.8	0.8	26.615	47.8	491.	19.5	22.2	16.2	12.1	72.7	74.9	1775.	0.043	0.124	0.09	3.61	3.76
10	1799.	2.6	20.8	0.8	26.598	47.8	491.	19.5	22.2	16.2	12.1	72.8	74.9	1775.	0.044	0.130	0.09	3.60	3.76
10	1801.	2.6	20.8	0.8	26.605	47.8	491.	19.5	22.2	16.2	12.1	72.9	75.0	1775.	0.044	0.133	0.08	3.61	3.75
10	1801.	2.6	20.8	0.8	26.597	47.8	491.	19.5	22.2	16.2	12.1	72.9	75.0	1775.	0.051	0.144	0.08	3.48	3.75
11	1699.	2.6	22.0	0.7	27.743	47.9	491.	19.5	22.2	16.2	11.9	72.9	73.5	1775.	0.049	0.149	0.09	3.38	3.76
11	1698.	2.6	22.0	0.7	27.724	47.9	492.	19.5	22.3	16.2	11.9	72.7	73.5	1775.	0.057	0.158	0.09	3.59	3.77
11	1700.	2.6	22.0	0.7	27.736	47.9	492.	19.5	22.3	16.2	11.9	72.7	73.6	1775.	0.063	0.185	0.08	3.51	3.77
11	1698.	2.6	22.0	0.7	27.723	47.9	492.	19.5	22.2	16.2	11.9	72.8	73.5	1775.	0.055	0.140	0.08	3.57	3.76
11	1701.	2.6	22.0	0.8	27.717	47.9	492.	19.5	22.2	16.2	11.9	72.8	73.6	1775.	0.050	0.158	0.08	3.60	3.76
12	1606.	2.6	22.8	0.7	28.508	48.0	491.	19.5	22.2	16.2	11.6	73.0	71.4	1775.	0.044	0.126	0.09	3.48	3.76
12	1599.	2.6	22.9	0.7	28.521	48.0	491.	19.5	22.2	16.2	11.5	72.9	71.1	1775.	0.051	0.161	0.09	3.42	3.77
12	1604.	2.6	22.9	0.7	28.526	48.0	491.	19.5	22.2	16.2	11.6	72.9	71.3	1775.	0.045	0.132	0.09	3.54	3.76
12	1604.	2.6	22.8	0.7	28.517	48.0	491.	19.5	22.2	16.2	11.6	73.0	71.3	1775.	0.044	0.125	0.09	3.60	3.78
12	1607.	2.6	22.9	0.7	28.548	48.0	491.	19.5	22.2	16.2	11.6	73.0	71.5	1775.	0.058	0.156	0.09	3.46	3.76
13	1503.	2.6	23.7	0.6	29.246	48.1	492.	19.5	22.3	16.3	11.1	73.0	68.4	1775.	0.051	0.167	0.09	3.57	3.83
13	1500.	2.6	23.7	0.6	29.258	48.0	491.	19.5	22.2	16.2	11.1	72.9	68.4	1775.	0.058	0.158	0.09	3.56	3.80
13	1496.	2.6	23.7	0.6	29.250	48.1	491.	19.5	22.2	16.2	11.1	73.0	68.1	1775.	0.048	0.141	0.09	3.59	3.83
13	1499.	2.6	23.7	0.6	29.287	48.1	492.	19.5	22.3	16.3	11.1	73.0	68.3	1775.	0.066	0.216	0.09	3.35	3.79
13	1498.	2.6	23.7	0.6	29.259	48.0	492.	19.5	22.3	16.2	11.1	72.8	68.3	1775.	0.051	0.149	0.08	3.57	3.80
14	1345.	2.6	24.3	0.5	29.801	47.3	494.	19.4	22.2	16.0	10.1	71.8	63.4	1775.	0.060	0.167	0.09	3.51	3.95
14	1348.	2.6	24.3	0.5	29.821	47.3	493.	19.4	22.2	16.0	10.2	71.9	63.6	1775.	0.054	0.143	0.09	3.45	3.93
14	1348.	2.6	24.3	0.5	29.802	47.3	494.	19.4	22.2	16.0	10.2	71.9	63.5	1775.	0.055	0.164	0.09	3.53	3.95
14	1347.	2.6	24.3	0.5	29.791	47.3	494.	19.4	22.2	16.0	10.1	71.9	63.5	1775.	0.053	0.140	0.09	3.47	3.96
14	1345.	2.6	24.4	0.5	29.826	47.3	493.	19.4	22.2	16.0	10.1	71.9	63.4	1775.	0.059	0.164	0.09	3.41	3.90
15	1204.	2.6	24.2	0.4	29.536	45.1	492.	19.2	21.9	15.3	9.0	69.7	59.0	1775.	0.085	0.229	0.09	2.88	4.54
15	1203.	2.6	24.2	0.4	29.574	45.2	492.	19.2	21.9	15.3	9.0	69.7	58.9	1775.	0.082	0.249	0.09	2.77	4.69
15	1206.	2.6	24.2	0.4	29.577	45.2	492.	19.2	21.9	15.3	9.0	69.7	59.1	1775.	0.076	0.236	0.09	2.91	4.63
15	1202.	2.6	24.2	0.4	29.572	45.1	493.	19.2	21.9	15.2	9.0	69.4	59.0	1775.	0.084	0.303	0.09	2.90	4.57
15	1201.	2.6	24.2	0.4	29.562	45.1	493.	19.2	21.9	15.3	9.0	69.5	58.8	1775.	0.083	0.241	0.09	2.57	4.62
16	1052.	2.6	24.3	0.3	29.618	44.1	494.	19.1	21.8	14.9	7.9	68.3	52.8	1775.	0.111	0.296	0.09	2.29	4.76
16	1051.	2.6	24.3	0.3	29.612	44.2	493.	19.1	21.8	14.9	7.9	68.5	52.7	1775.	0.104	0.308	0.09	2.43	4.65
16	1049	2.6	24.3	0.3	29.589	44.2	493.	19.1	21.8	14.9	7.8	68.6	52.5	1775.	0.110	0.308	0.09	2.46	4.83
16	1050.	2.6	24.3	0.3	29.626	44.2	493.	19.1	21.8	14.9	7.9	68.5	52.7	1775.	0.112	0.353	0.09	2.51	4.88
16	1052.	2.6	24.3	0.3	29.602	44.2	493.	19.1	21.8	14.9	7.9	68.5	52.7	1775.	0.098	0.350	0.09	2.53	4.69
17	898.	2.6	25.4	0.2	30.657	44.7	493.	19.1	21.9	15.1	7.0	69.1	46.1	1775.	0.116	0.385	0.09	2.31	4.97
17	897.	2.6	25.4	0.2	30.636	44.7	493.	19.1	21.8	15.1	6.9	69.1	46.0	1775.	0.115	0.353	0.09	2.53	4.86
17	897.	2.6	25.4	0.2	30.654	44.7	493.	19.1	21.8	15.1	7.0	69.1	46.0	1775.	0.118	0.410	0.09	2.45	4.96
17	900.	2.6	25.5	0.2	30.671	44.7	493.	19.1	21.8	15.1	7.0	69.2	46.2	1775.	0.120	0.405	0.09	2.13	4.78
17	897.	2.6	25.4	0.2	30.654	44.7	493.	19.1	21.8	15.1	7.0	69.2	46.0	1775.	0.119	0.430	0.09	2.38	4.79

Figure 188. (Concluded)

8	1905.	1.3	18.1	0.9	25.383	48.1	486.	19.4	21.9	16.2	12.2	74.1	75.2	1775.	0.048	0.161	0.08	0.58	2.32
9	1799.	1.3	19.5	0.8	26.689	48.2	487.	19.5	22.0	16.3	12.1	74.0	74.6	1775.	0.043	0.119	0.08	2.21	2.40
9	1804.	1.3	19.6	0.8	26.731	48.2	487.	19.5	22.0	16.3	12.2	74.0	74.8	1775.	0.049	0.134	0.08	2.24	2.37
9	1801.	1.3	19.6	0.8	26.742	48.2	487.	19.5	22.0	16.3	12.2	74.0	74.7	1775.	0.053	0.144	0.08	2.25	2.37
9	1799.	1.3	19.6	0.8	26.701	48.2	487.	19.5	22.0	16.3	12.1	74.0	74.6	1775.	0.049	0.154	0.08	2.22	2.39
9	1800.	1.3	19.6	0.8	26.714	48.2	487.	19.5	22.0	16.3	12.2	73.9	74.7	1775.	0.042	0.123	0.08	2.23	2.38
10	1698.	1.3	20.9	0.7	27.932	48.5	489.	19.5	22.1	16.4	12.0	74.0	73.2	1775.	0.053	0.175	0.08	2.18	2.39
10	1696.	1.3	20.8	0.7	27.888	48.5	489.	19.5	22.1	16.4	12.0	74.1	73.0	1775.	0.048	0.146	0.08	1.97	2.35
10	1693.	1.3	20.8	0.7	27.889	48.4	488.	19.5	22.1	16.4	11.9	74.1	73.0	1775.	0.050	0.128	0.08	2.08	2.35
10	1694.	1.3	20.8	0.7	27.882	48.4	488.	19.5	22.1	16.3	11.9	74.1	73.1	1775.	0.054	0.152	0.08	2.07	2.36
10	1691.	1.3	20.9	0.7	27.895	48.4	489.	19.5	22.1	16.3	11.9	74.0	72.9	1775.	0.052	0.153	0.08	2.20	2.35
11	1598.	1.3	21.8	0.7	28.734	48.6	489.	19.5	22.1	16.4	11.6	74.2	70.7	1775.	0.048	0.131	0.08	2.14	2.35
11	1601.	1.3	21.8	0.7	28.726	48.5	489.	19.5	22.1	16.4	11.6	74.2	70.9	1775.	0.051	0.155	0.08	2.03	2.36
11	1600.	1.3	21.8	0.7	28.727	48.5	489.	19.5	22.1	16.4	11.6	74.1	70.9	1775.	0.047	0.144	0.08	2.18	2.35
11	1596.	1.3	21.7	0.7	28.706	48.5	489.	19.5	22.1	16.4	11.6	74.1	70.7	1775.	0.045	0.159	0.08	2.18	2.38
11	1600.	1.3	21.8	0.7	28.721	48.5	489.	19.5	22.1	16.4	11.6	74.2	70.8	1775.	0.057	0.170	0.08	2.09	2.38
12	1491.	1.3	22.5	0.6	29.336	48.4	489.	19.5	22.1	16.3	11.1	74.0	67.7	1775.	0.056	0.184	0.08	2.15	2.41
12	1495.	1.3	22.4	0.6	29.327	48.4	489.	19.5	22.1	16.3	11.1	74.0	67.8	1775.	0.054	0.153	0.08	2.14	2.41
12	1493.	1.3	22.5	0.6	29.334	48.4	489.	19.5	22.1	16.4	11.1	74.1	67.6	1775.	0.055	0.162	0.08	2.15	2.41
12	1494.	1.3	22.4	0.6	29.307	48.4	489.	19.5	22.1	16.3	11.1	74.1	67.7	1775.	0.053	0.157	0.08	2.13	2.41
12	1495.	1.3	22.4	0.6	29.317	48.3	489.	19.5	22.1	16.3	11.1	74.1	67.8	1775.	0.056	0.165	0.08	2.13	2.41
13	1407.	1.3	22.9	0.5	29.715	48.1	489.	19.4	22.1	16.3	10.6	73.7	65.0	1775.	0.053	0.159	0.08	2.00	2.51
13	1401.	1.3	22.9	0.5	29.758	48.2	490.	19.4	22.1	16.3	10.5	73.7	64.8	1775.	0.061	0.215	0.08	2.13	2.52
13	1408.	1.3	22.9	0.5	29.747	48.2	490.	19.4	22.1	16.3	10.6	73.7	65.0	1775.	0.062	0.210	0.08	2.08	2.46
13	1405.	1.3	22.9	0.5	29.748	48.2	490.	19.4	22.1	16.3	10.6	73.8	64.9	1775.	0.060	0.200	0.08	2.10	2.48
13	1402.	1.3	23.0	0.5	29.764	48.1	490.	19.4	22.1	16.3	10.5	73.7	64.8	1775.	0.062	0.185	0.08	2.09	2.46
14	1304.	1.3	23.1	0.4	29.878	47.1	490.	19.3	21.9	15.9	9.9	72.5	61.9	1775.	0.063	0.179	0.08	1.92	2.63
14	1302.	1.3	23.1	0.4	29.867	47.0	490.	19.3	21.9	15.9	9.8	72.5	61.8	1775.	0.065	0.207	0.08	1.99	2.67
14	1306.	1.3	23.1	0.4	29.878	47.1	490.	19.3	22.0	15.9	9.9	72.5	62.0	1775.	0.071	0.231	0.08	1.98	2.59
14	1305.	1.3	23.2	0.4	29.916	47.2	490.	19.3	22.0	15.9	9.9	72.6	61.9	1775.	0.070	0.215	0.08	1.98	2.65
14	1306.	1.3	23.2	0.4	29.895	47.2	490.	19.3	22.0	15.9	9.9	72.5	61.9	1775.	0.067	0.225	0.08	1.90	2.64
15	1202.	1.3	22.9	0.4	29.552	45.4	490.	19.1	21.7	15.3	9.0	70.7	58.6	1775.	0.098	0.337	0.08	1.36	3.13
15	1201.	1.3	22.9	0.4	29.562	45.4	490.	19.1	21.7	15.3	9.0	70.6	58.6	1775.	0.090	0.293	0.08	1.44	3.11
15	1200.	1.3	22.9	0.4	29.572	45.4	490.	19.1	21.7	15.3	9.0	70.6	58.5	1775.	0.085	0.255	0.08	1.40	3.11
15	1202.	1.3	22.9	0.4	29.563	45.3	490.	19.1	21.7	15.3	9.0	70.5	58.7	1775.	0.085	0.242	0.08	1.48	2.94
15	1201.	1.3	22.9	0.4	29.539	45.3	490.	19.1	21.7	15.3	9.0	70.5	58.6	1775.	0.088	0.239	0.08	1.45	2.91
16	1056.	1.3	23.1	0.3	29.691	44.4	490.	19.0	21.6	15.0	7.9	69.5	52.8	1775.	0.105	0.353	0.08	1.14	3.26
16	1056.	1.3	23.1	0.3	29.698	44.5	490.	19.0	21.6	15.0	7.9	69.5	52.8	1775.	0.104	0.320	0.08	1.12	3.18
16	1053.	1.3	23.1	0.3	29.660	44.4	490.	19.0	21.6	15.0	7.9	69.5	52.6	1775.	0.109	0.362	0.08	0.90	3.40
16	1055.	1.3	23.1	0.3	29.675	44.4	491.	19.0	21.6	15.0	7.9	69.3	52.8	1775.	0.106	0.344	0.08	1.06	3.32
16	1051.	1.3	23.1	0.3	29.710	44.4	491.	19.0	21.7	15.0	7.9	69.4	52.6	1775.	0.120	0.386	0.08	1.28	3.25
17	904.	1.3	24.2	0.2	30.740	44.9	490.	19.0	21.7	15.2	7.0	70.1	46.3	1775.	0.113	0.420	0.08	0.97	3.30
17	904.	1.3	24.2	0.2	30.737	45.0	490.	19.0	21.7	15.2	7.0	70.2	46.2	1775.	0.128	0.413	0.08	0.86	3.44
17	903.	1.3	24.2	0.2	30.717	44.9	490.	19.1	21.7	15.2	7.0	70.1	46.2	1775.	0.115	0.378	0.08	0.73	3.36
17	907.	1.3	24.2	0.2	30.746	45.0	490.	19.1	21.7	15.2	7.1	70.2	46.3	1775.	0.115	0.385	0.08	0.97	3.34
17	903.	1.3	24.2	0.2	30.711	44.9	490.	19.0	21.7	15.2	7.0	70.1	46.2	1775.	0.119	0.410	0.08	0.82	3.63

Figure 189. Test run 100-H03-007-1.3; research data; pump 1, Test H03, sump 7, submergence 1.47D (Continued)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2856.	1.3	1.3	2.1	9.758	39.7	487.	18.5	20.9	13.4	7.0	64.1	52.6	1775.	0.044	0.123	0.08	1.97	2.38
1	2849.	1.3	1.4	2.1	9.771	39.5	487.	18.5	20.9	13.3	7.0	63.8	52.8	1775.	0.039	0.105	0.08	2.18	2.38
1	2851.	1.3	1.4	2.1	9.785	39.5	487.	18.5	20.9	13.3	7.1	63.9	52.8	1775.	0.039	0.099	0.08	2.15	2.38
1	2850.	1.3	1.5	2.1	9.859	39.5	487.	18.5	20.9	13.4	7.1	64.0	53.2	1775.	0.042	0.105	0.08	2.02	2.37
1	2854.	1.3	1.4	2.1	9.845	39.6	487.	18.5	20.9	13.4	7.1	64.0	53.1	1775.	0.044	0.125	0.08	2.09	2.37
2	2705.	1.3	4.3	1.9	12.525	42.1	487.	18.7	21.2	14.2	8.6	67.3	60.1	1775.	0.052	0.138	0.08	2.07	2.36
2	2711.	1.3	4.3	1.9	12.509	42.2	487.	18.7	21.2	14.3	8.6	67.4	60.1	1775.	0.048	0.115	0.08	2.08	2.39
2	2710.	1.3	4.3	1.9	12.553	42.2	487.	18.7	21.2	14.3	8.6	67.3	60.3	1775.	0.050	0.147	0.08	1.57	2.41
2	2705.	1.3	4.3	1.9	12.509	42.1	487.	18.7	21.2	14.2	8.6	67.2	60.1	1775.	0.043	0.123	0.08	1.74	2.37
2	2711.	1.3	4.3	1.9	12.524	42.1	487.	18.7	21.2	14.2	8.6	67.2	60.3	1775.	0.046	0.132	0.08	2.17	2.36
3	2551.	1.3	7.5	1.7	15.530	44.3	486.	19.0	21.5	15.0	10.0	69.8	66.9	1775.	0.051	0.143	0.08	2.09	2.37
3	2547.	1.3	7.5	1.7	15.518	44.3	486.	19.0	21.5	15.0	10.0	69.8	66.7	1775.	0.050	0.146	0.08	2.15	2.38
3	2541.	1.3	7.5	1.7	15.519	44.3	487.	19.0	21.5	15.0	10.0	69.7	66.6	1775.	0.060	0.173	0.08	2.19	2.37
3	2551.	1.3	7.6	1.7	15.542	44.3	487.	19.0	21.5	15.0	10.0	69.7	66.9	1775.	0.045	0.126	0.08	2.19	2.35
3	2550.	1.3	7.5	1.7	15.518	44.4	487.	19.0	21.5	15.0	10.0	69.7	66.7	1775.	0.049	0.149	0.08	2.11	2.37
4	2402.	1.3	10.3	1.5	18.062	45.9	488.	19.2	21.7	15.5	11.0	71.5	70.7	1775.	0.059	0.153	0.08	2.21	2.33
4	2398.	1.3	10.3	1.5	18.047	46.0	488.	19.2	21.7	15.5	10.9	71.4	70.5	1775.	0.053	0.186	0.08	2.13	2.34
4	2396.	1.3	10.3	1.5	18.105	45.9	487.	19.2	21.7	15.5	11.0	71.5	70.6	1775.	0.051	0.147	0.08	2.16	2.33
4	2397.	1.3	10.3	1.5	18.092	46.0	487.	19.2	21.7	15.6	11.0	71.6	70.5	1775.	0.061	0.170	0.08	2.14	2.35
4	2396.	1.3	10.2	1.5	18.009	45.9	487.	19.2	21.7	15.5	10.9	71.5	70.3	1775.	0.053	0.144	0.08	2.19	2.35
5	2247.	1.3	12.9	1.3	20.481	47.2	487.	19.3	21.8	15.9	11.6	73.0	73.0	1775.	0.053	0.178	0.08	2.17	2.34
5	2248.	1.3	12.8	1.3	20.430	47.1	487.	19.3	21.8	15.9	11.6	73.0	72.9	1775.	0.047	0.136	0.08	2.20	2.34
5	2247.	1.3	12.8	1.3	20.445	47.1	487.	19.3	21.8	15.9	11.6	72.9	72.9	1775.	0.053	0.152	0.08	2.17	2.37
5	2250.	1.3	12.9	1.3	20.469	47.1	487.	19.3	21.9	15.9	11.6	72.9	73.1	1775.	0.054	0.156	0.08	2.17	2.36
5	2245.	1.3	12.9	1.3	20.463	47.1	487.	19.3	21.9	15.9	11.6	72.8	73.0	1775.	0.057	0.164	0.08	2.14	2.36
6	2104.	1.3	15.3	1.1	22.709	47.8	487.	19.4	21.9	16.2	12.1	73.7	74.8	1775.	0.056	0.170	0.08	2.20	2.34
6	2097.	1.3	15.3	1.1	22.723	47.9	487.	19.4	21.9	16.2	12.0	73.8	74.5	1775.	0.056	0.194	0.08	2.09	2.34
6	2098.	1.3	15.3	1.1	22.741	47.8	487.	19.4	21.9	16.1	12.1	73.6	74.7	1775.	0.053	0.135	0.08	2.21	2.34
6	2095.	1.3	15.3	1.1	22.719	47.8	487.	19.4	21.9	16.2	12.0	73.6	74.5	1775.	0.054	0.142	0.08	2.21	2.33
6	2099.	1.3	15.3	1.1	22.764	47.8	487.	19.4	21.9	16.1	12.1	73.6	74.8	1775.	0.043	0.135	0.08	2.23	2.35
7	1994.	1.3	16.8	1.0	24.133	48.0	486.	19.4	21.9	16.2	12.2	73.9	75.0	1775.	0.059	0.177	0.08	2.18	2.33
7	1989.	1.3	16.8	1.0	24.174	48.0	487.	19.4	21.9	16.2	12.2	74.0	74.9	1775.	0.062	0.174	0.08	2.21	2.35
7	1990	1.3	16.9	1.0	24.182	48.0	486.	19.4	21.9	16.2	12.2	73.9	75.0	1775.	0.050	0.137	0.08	2.22	2.33
7	1989.	1.3	16.8	1.0	24.166	48.0	486.	19.4	21.9	16.2	12.2	73.9	75.0	1775.	0.055	0.178	0.08	2.17	2.33
7	1990.	1.3	16.9	1.0	24.198	48.0	486.	19.5	21.9	16.2	12.2	73.9	75.0	1775.	0.047	0.150	0.08	2.20	2.35
8	1902.	1.3	18.2	0.9	25.400	48.1	487.	19.5	22.0	16.2	12.2	73.9	75.2	1775.	0.060	0.161	0.08	2.19	2.34
8	1903.	1.3	18.2	0.9	25.407	48.0	487.	19.5	22.0	16.2	12.2	73.9	75.3	1775.	0.053	0.140	0.08	2.20	2.37
8	1898.	1.3	18.2	0.9	25.411	48.1	487.	19.4	22.0	16.3	12.2	74.0	75.0	1775.	0.048	0.148	0.08	2.21	2.33
8	1905.	1.3	18.2	0.9	25.409	48.1	487.	19.4	22.0	16.2	12.2	74.0	75.3	1775.	0.050	0.153	0.08	2.21	2.33

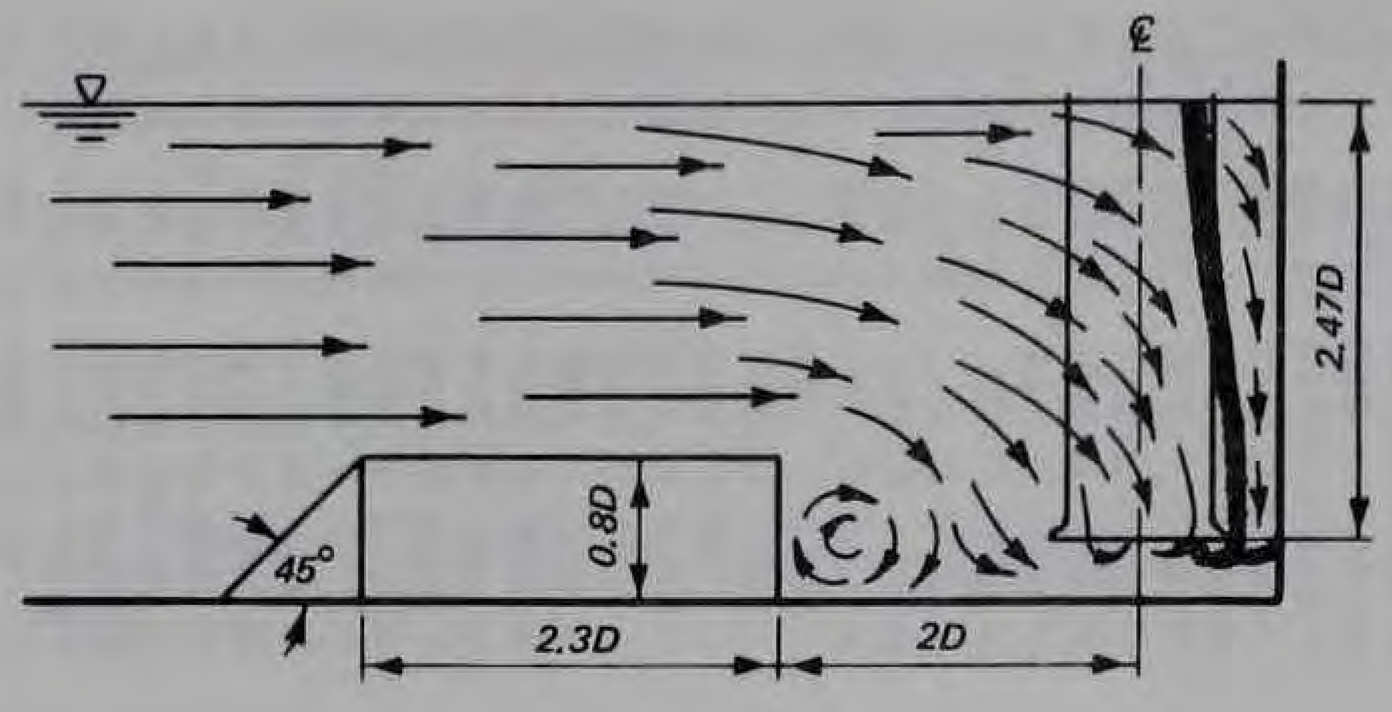
Figure 189. (Concluded)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2425.	0.	0.9	1.5	10.071	32.0	491.	17.5	19.9	10.8	6.2	54.4	57.0	1775.	0.323	1.019	1.77	0.29	1.61
1	2429.	0.	0.4	1.5	9.563	33.1	491.	17.6	20.0	11.2	5.9	55.9	52.5	1775.	0.250	0.864	1.84	0.49	1.75
1	2426.	0.	0.7	1.5	9.842	32.8	491.	17.6	20.0	11.1	6.0	55.4	54.5	1775.	0.345	1.027	1.89	0.50	1.74
1	2425.	0.	0.9	1.5	10.000	32.5	491.	17.5	19.9	11.0	6.1	55.1	55.8	1775.	0.274	0.794	1.87	0.26	1.76
1	2437.	0.	1.1	1.5	10.254	31.9	491.	17.4	19.9	10.8	6.3	54.4	58.5	1775.	0.298	0.970	2.02	0.34	1.87
2	2329.	0.	0.3	1.4	9.285	31.4	491.	17.4	19.8	10.6	5.5	53.5	51.6	1775.	0.428	1.275	1.99	0.19	1.78
2	2342.	0.	0.6	1.4	9.668	30.7	491.	17.3	19.7	10.4	5.7	52.7	55.2	1775.	0.297	0.975	1.89	0.25	1.63
2	2356.	0.	0.1	1.4	9.117	32.3	491.	17.5	19.9	10.9	5.4	54.9	49.7	1775.	0.277	1.066	1.90	0.40	1.62
2	2356.	0.	0.0	1.4	9.072	32.8	491.	17.5	20.0	11.1	5.4	55.5	48.7	1775.	0.348	1.061	1.95	0.24	1.60
2	2358.	0.	0.3	1.4	9.390	31.5	491.	17.4	19.8	10.6	5.6	53.7	52.6	1775.	0.323	1.053	1.99	0.24	1.72
3	2168.	0.	6.0	1.2	14.801	38.4	491.	18.2	20.7	13.0	8.1	62.6	62.4	1775.	0.291	1.046	1.70	0.22	1.74
3	2161.	0.	5.6	1.2	14.440	37.8	491.	18.1	20.6	12.8	7.9	61.9	61.7	1775.	0.304	1.138	1.86	0.20	1.55
3	2115.	0.	5.3	1.2	14.027	36.7	491.	18.0	20.5	12.4	7.5	60.5	60.4	1775.	0.281	0.942	1.72	0.14	2.07
3	2110.	0.	5.2	1.2	13.984	36.6	491.	18.0	20.5	12.4	7.5	60.5	60.3	1775.	0.296	0.792	1.83	0.40	1.64
3	2108.	0.	5.6	1.2	14.304	37.3	491.	18.1	20.6	12.6	7.6	61.3	60.4	1775.	0.353	0.979	2.03	0.23	1.64
4	1972.	0.	3.3	1.0	11.914	32.3	491.	17.5	19.9	10.9	5.9	54.8	54.4	1775.	0.358	1.092	2.06	0.09	1.94
4	2001.	0.	3.1	1.0	11.704	31.8	490.	17.4	19.8	10.7	5.9	54.2	55.1	1775.	0.396	1.338	1.91	0.02	1.55
4	1969.	0.	3.0	1.0	11.608	31.6	491.	17.4	19.8	10.7	5.8	53.9	54.1	1775.	0.497	1.360	2.01	0.15	1.72
4	2026.	0.	3.9	1.1	12.534	33.6	491.	17.6	20.1	11.4	6.4	56.6	56.5	1775.	0.340	1.512	2.12	0.16	1.90
4	2026.	0.	3.7	1.1	12.385	33.3	491.	17.6	20.0	11.3	6.3	56.2	56.3	1775.	0.401	1.418	1.97	0.05	1.81
5	1980.	0.	6.3	1.0	14.901	36.3	490.	17.9	20.4	12.3	7.5	60.1	60.9	1775.	0.406	1.411	1.81	0.27	1.55
5	2008.	0.	6.7	1.0	15.302	37.1	489.	18.0	20.4	12.5	7.8	61.4	61.9	1775.	0.322	1.052	1.85	0.25	1.78
5	2006.	0.	6.7	1.0	15.364	37.3	489.	18.0	20.5	12.6	7.8	61.7	61.8	1775.	0.323	0.908	2.05	0.33	1.57
5	1995.	0.	6.6	1.0	15.229	36.8	490.	18.0	20.4	12.4	7.7	60.9	61.7	1775.	0.361	1.243	1.97	0.30	1.61
5	2007.	0.	7.4	1.0	16.008	38.2	490.	18.1	20.6	12.9	8.1	62.5	62.9	1775.	0.297	1.019	1.69	0.21	1.80
6	1758.	0.	10.3	0.8	18.681	39.1	489.	18.2	20.7	13.2	8.3	64.0	62.8	1775.	0.299	1.010	1.78	0.20	1.89
6	1787.	0.	10.3	0.8	18.768	39.2	489.	18.2	20.7	13.3	8.5	64.1	64.0	1775.	0.243	0.786	1.59	0.28	1.55
6	1774.	0.	11.2	0.8	19.606	40.7	489.	18.4	20.9	13.7	8.8	65.8	64.0	1775.	0.306	0.945	1.60	0.34	1.61
6	1773.	0.	11.0	0.8	19.456	40.3	489.	18.4	20.8	13.6	8.7	65.4	64.0	1775.	0.219	0.663	1.74	0.18	1.54
6	1788.	0.	11.2	0.8	19.584	40.5	489.	18.4	20.9	13.7	8.9	65.6	64.6	1775.	0.260	0.910	1.63	0.09	1.82
7	1595.	0.	16.4	0.7	24.646	46.1	487.	19.1	21.6	15.6	9.9	72.3	63.7	1775.	0.150	0.510	1.70	0.16	1.61
7	1598.	0.	17.2	0.7	25.459	47.4	487.	19.2	21.7	16.0	10.3	73.7	64.2	1775.	0.134	0.713	1.52	0.38	1.41
7	1596.	0.	16.9	0.7	25.200	47.0	488.	19.2	21.7	15.9	10.2	73.1	64.1	1775.	0.133	0.478	1.58	0.58	1.59
7	1597.	0.	17.7	0.7	25.944	47.9	487.	19.3	21.8	16.2	10.5	74.3	64.6	1775.	0.114	0.364	1.53	0.42	1.41
7	1602.	0.	17.5	0.7	25.779	47.6	487.	19.3	21.8	16.1	10.4	73.9	64.9	1775.	0.100	0.304	1.56	0.44	1.39
8	1444.	0.	19.5	0.5	27.615	47.3	488.	19.2	21.8	16.0	10.1	73.4	63.1	1775.	0.082	0.216	1.65	0.28	1.49
8	1447.	0.	19.6	0.5	27.748	47.5	487.	19.2	21.7	16.1	10.2	73.9	63.2	1775.	0.086	0.258	1.53	0.35	1.54
8	1456.	0.	20.0	0.5	28.117	48.0	488.	19.3	21.9	16.2	10.3	74.2	63.8	1775.	0.078	0.233	1.61	0.50	1.35
8	1466.	0.	20.3	0.6	28.410	48.4	488.	19.4	21.9	16.3	10.5	74.5	64.4	1775.	0.075	0.249	1.51	0.55	1.34

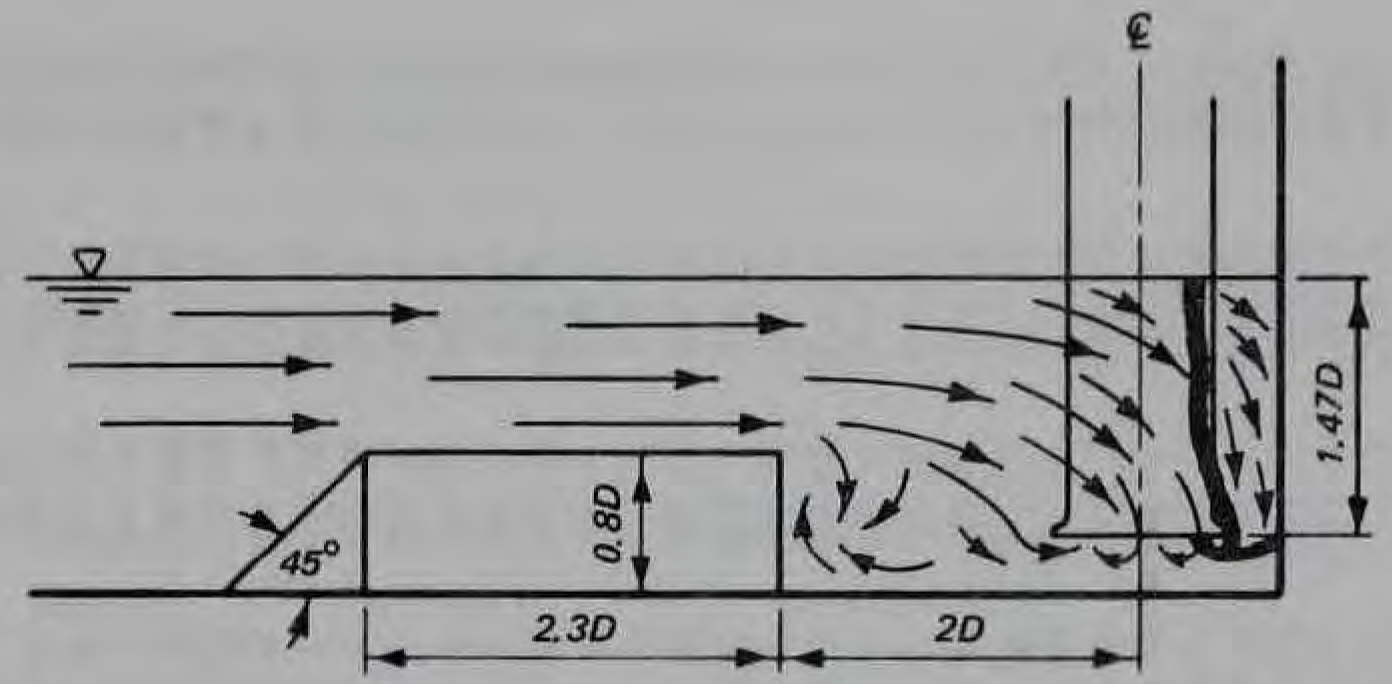
Figure 190. Test run 100-H04-007-010; research data; pump 1, Test H04, sump 7, submergence 0.47D (Continued)

8	1460.	0.	20.0	0.6	28.183	48.1	488.	19.3	21.9	16.2	10.4	74.3	64.0	1775.	0.097	0.297	1.50	0.50	1.37
9	1365.	0.	20.1	0.5	28.193	46.5	486.	19.1	21.6	15.7	9.7	72.9	61.8	1775.	0.083	0.253	1.94	0.42	1.49
9	1330.	0.	18.9	0.5	26.925	45.0	486.	18.9	21.3	15.2	9.1	71.3	59.5	1775.	0.093	0.295	2.31	0.04	1.58
9	1314.	0.	18.3	0.4	26.327	44.3	486.	18.8	21.2	15.0	8.7	70.5	58.4	1775.	0.102	0.313	2.37	0.09	1.55
9	1316.	0.	18.2	0.4	26.279	44.2	486.	18.8	21.2	14.9	8.7	70.4	58.5	1775.	0.093	0.316	2.41	0.01	1.54
9	1318.	0.	18.4	0.5	26.443	44.4	486.	18.9	21.3	15.0	8.8	70.5	58.8	1775.	0.094	0.298	2.29	0.13	1.39
10	1265.	0.	20.6	0.4	28.661	45.4	486.	19.0	21.4	15.4	9.2	71.8	59.7	1775.	0.070	0.215	2.37	0.17	1.68
10	1261.	0.	20.1	0.4	28.085	44.9	485.	18.9	21.3	15.2	9.0	71.2	59.1	1775.	0.081	0.318	2.69	0.34	1.63
10	1234.	0.	19.1	0.4	27.097	43.9	486.	18.8	21.2	14.8	8.5	70.1	57.0	1775.	0.101	0.280	2.50	0.48	1.78
10	1206.	0.	18.2	0.4	26.152	42.9	486.	18.7	21.0	14.5	8.0	68.9	55.0	1775.	0.129	0.414	2.62	0.28	1.71
10	1208.	0.	18.5	0.4	26.453	43.2	486.	18.7	21.1	14.6	8.1	69.3	55.3	1775.	0.096	0.372	2.66	0.45	1.53
11	1142.	0.	20.1	0.3	28.033	43.8	487.	18.8	21.2	14.8	8.1	69.9	54.7	1775.	0.088	0.297	4.16	0.19	2.21
11	1141.	0	20.1	0.3	28.019	43.7	487.	18.7	21.2	14.8	8.1	69.8	54.7	1775.	0.090	0.238	3.78	0.01	1.93
11	1142	0	20.2	0.3	28.166	43.9	487.	18.8	21.2	14.8	8.1	70.0	54.8	1775.	0.078	0.223	3.67	0.24	2.12
11	1160.	0.	20.9	0.3	28.843	44.4	486.	18.8	21.2	15.0	8.5	70.6	56.4	1775.	0.079	0.241	3.34	0.25	1.94
11	1159.	0.	20.8	0.3	28.741	44.1	486.	18.8	21.2	14.9	8.4	70.3	56.5	1775.	0.083	0.369	2.87	0.09	1.76
12	1075.	0.	21.0	0.3	28.913	44.1	487.	18.8	21.2	14.9	7.9	70.2	52.7	1775.	0.094	0.286	3.89	0.24	2.08
12	1078.	0.	21.3	0.3	29.191	44.2	486.	18.8	21.2	14.9	8.0	70.4	53.3	1775.	0.088	0.260	3.06	0.57	2.06
12	1067.	0.	20.8	0.3	28.683	43.9	485.	18.8	21.1	14.8	7.7	70.3	52.1	1775.	0.094	0.254	3.32	0.46	2.32
12	1062.	0.	20.7	0.3	28.593	44.0	485.	18.8	21.1	14.9	7.7	70.4	51.6	1775.	0.088	0.338	3.38	0.59	2.27
12	1046.	0.	20.2	0.3	28.110	43.9	485.	18.8	21.1	14.8	7.5	70.3	50.2	1775.	0.094	0.236	2.95	0.49	2.03
13	974.	0.	22.1	0.2	29.903	44.4	485.	18.8	21.2	15.0	7.4	70.9	49.0	1775.	0.103	0.313	3.77	0.33	2.07
13	972.	0.	22.2	0.2	29.999	44.4	485.	18.8	21.2	15.0	7.4	70.9	49.1	1775.	0.087	0.251	3.12	0.73	2.74
13	973.	0.	22.0	0.2	29.894	44.4	484.	18.8	21.1	15.0	7.4	71.1	48.9	1775.	0.093	0.279	3.19	0.24	1.90
13	968.	0.	21.9	0.2	29.763	44.5	484.	18.8	21.2	15.0	7.3	71.1	48.5	1775.	0.086	0.264	3.27	0.47	2.16
13	962.	0.	21.9	0.2	29.735	44.4	484.	18.8	21.1	15.0	7.2	71.0	48.2	1775.	0.092	0.309	3.43	1.06	2.26
14	882.	0.	23.1	0.2	30.878	45.2	486.	18.9	21.3	15.3	6.9	71.7	45.1	1775.	0.114	0.312	4.07	0.27	2.15
14	885.	0	23.1	0.2	30.944	45.2	486.	18.9	21.3	15.3	6.9	71.7	45.3	1775.	0.108	0.324	4.38	0.60	2.47
14	881.	0.	23.1	0.2	30.904	45.1	485.	18.9	21.3	15.3	6.9	71.7	45.1	1775.	0.102	0.319	3.80	1.00	2.97
14	880	0.	23.1	0.2	30.879	45.1	485.	18.9	21.3	15.2	6.9	71.7	45.1	1775.	0.106	0.351	3.69	1.05	2.20
14	881.	0.	23.1	0.2	30.945	45.3	486.	18.9	21.3	15.3	6.9	71.8	45.0	1775.	0.112	0.431	3.41	0.20	2.07
15	840.	0.	23.6	0.2	31.430	45.5	487.	18.9	21.4	15.4	6.7	71.9	43.4	1775.	0.106	0.311	5.34	1.11	2.96
15	842.	0.	23.6	0.2	31.407	45.6	486.	18.9	21.3	15.4	6.7	72.2	43.4	1775.	0.112	0.319	4.78	0.78	2.34
15	841.	0	23.6	0.2	31.351	45.6	486.	18.9	21.3	15.4	6.7	72.2	43.3	1775.	0.123	0.439	4.48	1.32	2.65
15	841.	0.	23.6	0.2	31.352	45.6	485.	18.9	21.3	15.4	6.7	72.4	43.2	1775.	0.117	0.373	4.12	0.86	2.48
15	838.	0.	23.5	0.2	31.283	45.7	485.	18.9	21.3	15.5	6.6	72.5	42.9	1775.	0.102	0.273	3.67	0.36	1.89
16	801.	0.	24.5	0.2	32.306	46.0	488.	19.0	21.5	15.5	6.5	72.2	42.1	1775.	0.107	0.352	5.49	0.57	2.85
16	799	0.	24.5	0.2	32.308	45.9	488.	19.0	21.5	15.5	6.5	72.1	42.1	1775.	0.105	0.338	5.38	0.45	2.72
16	797.	0.	24.6	0.2	32.349	45.9	488.	19.0	21.5	15.5	6.5	72.2	42.0	1775.	0.108	0.384	5.20	0.67	3.00
16	795.	0.	24.6	0.2	32.348	45.9	488.	19.0	21.5	15.5	6.5	72.2	41.9	1775.	0.115	0.350	5.04	0.70	2.79
16	801.	0.	24.5	0.2	32.309	45.9	488.	19.0	21.5	15.5	6.5	72.1	42.1	1775.	0.108	0.351	5.24	0.55	3.11
17	758.	0.	24.9	0.1	32.611	46.6	487.	19.1	21.6	15.7	6.2	72.9	39.7	1775.	0.131	0.409	5.49	0.81	3.15
17	756.	0.	24.9	0.1	32.637	46.7	487.	19.1	21.6	15.8	6.2	73.1	39.6	1775.	0.120	0.322	5.02	1.21	2.83
17	754.	0	24.8	0.1	32.501	46.5	486.	19.1	21.5	15.7	6.2	73.1	39.4	1775.	0.122	0.454	4.85	1.22	2.65
17	754.	0	24.8	0.1	32.549	46.6	486.	19.1	21.5	15.7	6.2	73.2	39.4	1775.	0.119	0.358	4.94	1.62	2.61
17	752.	0	24.7	0.1	32.459	46.8	486.	19.1	21.6	15.8	6.2	73.4	39.0	1775.	0.146	0.397	4.40	0.97	2.59

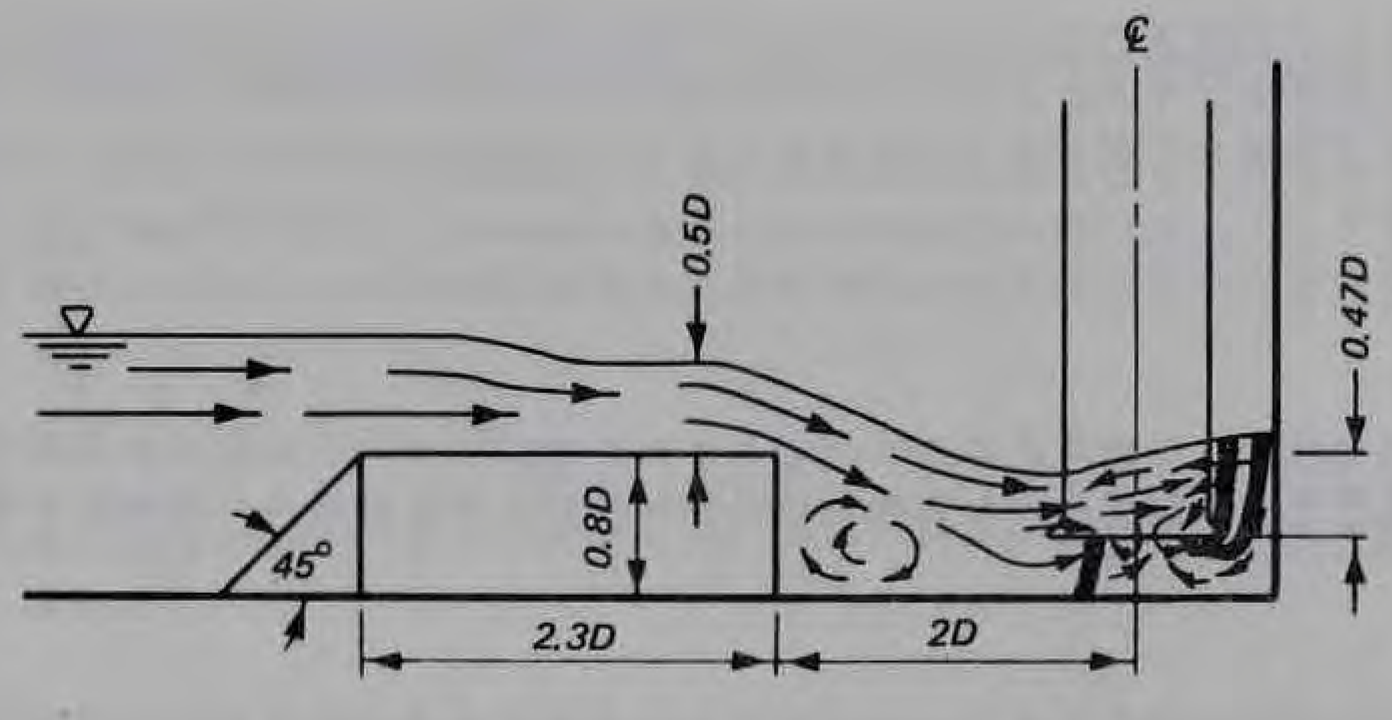
Figure 190. (Concluded)



TEST H02, SUBMERGENCE = 2.47D



TEST H03, SUBMERGENCE = 1.47D



TEST H04, SUBMERGENCE = 0.47D

Figure 191. Flow pattern for sump type 7, discharge 1,930 gpm (4.3 cfs), bell diam D = 1.3 ft, $Q/g^{1/2}D^{5/2} = 0.4$

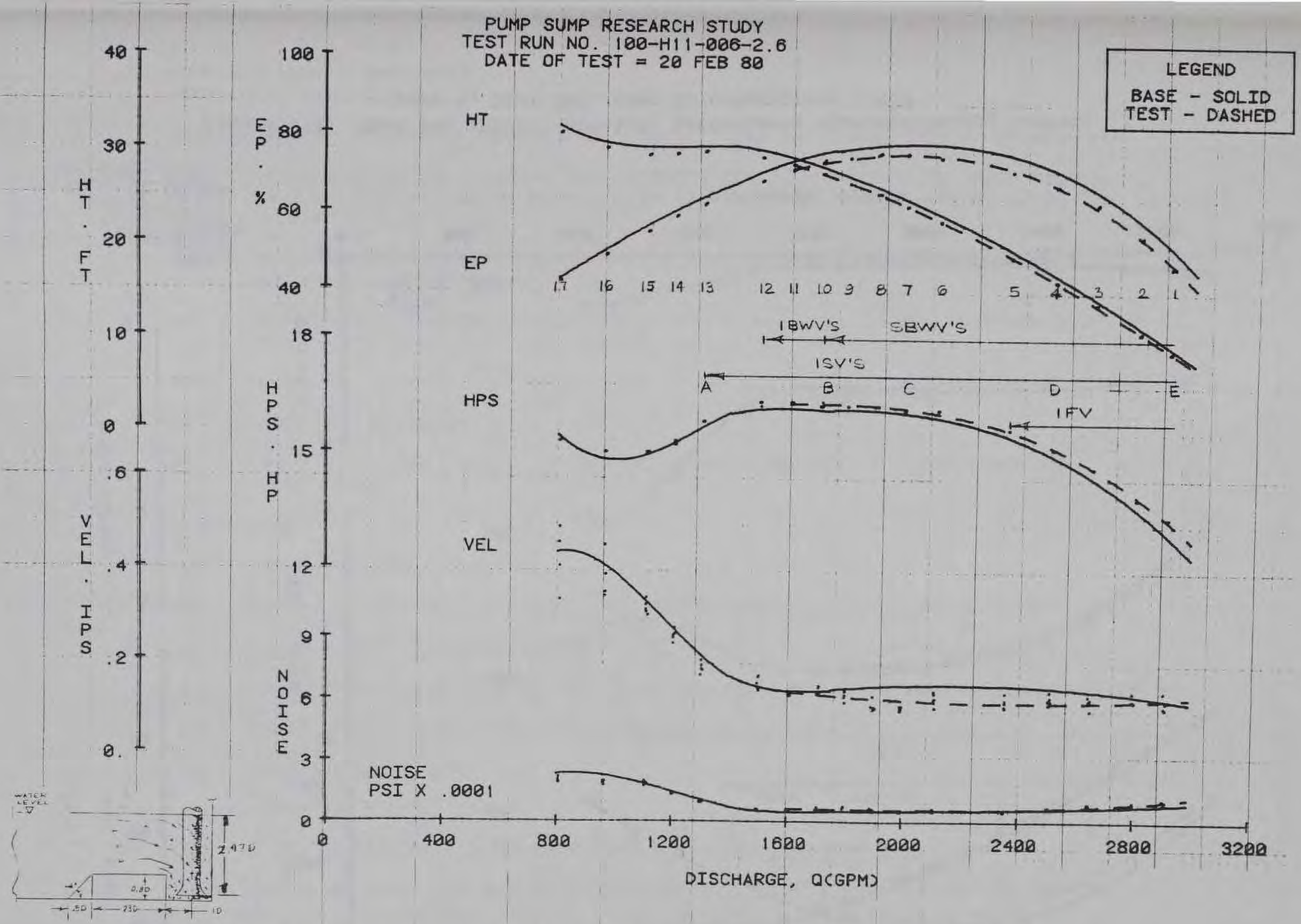


Figure 192. Test run 100-H11-006-2.6; performance characteristics curves; pump 1, Test H11, sump 6, submergence 2.47D

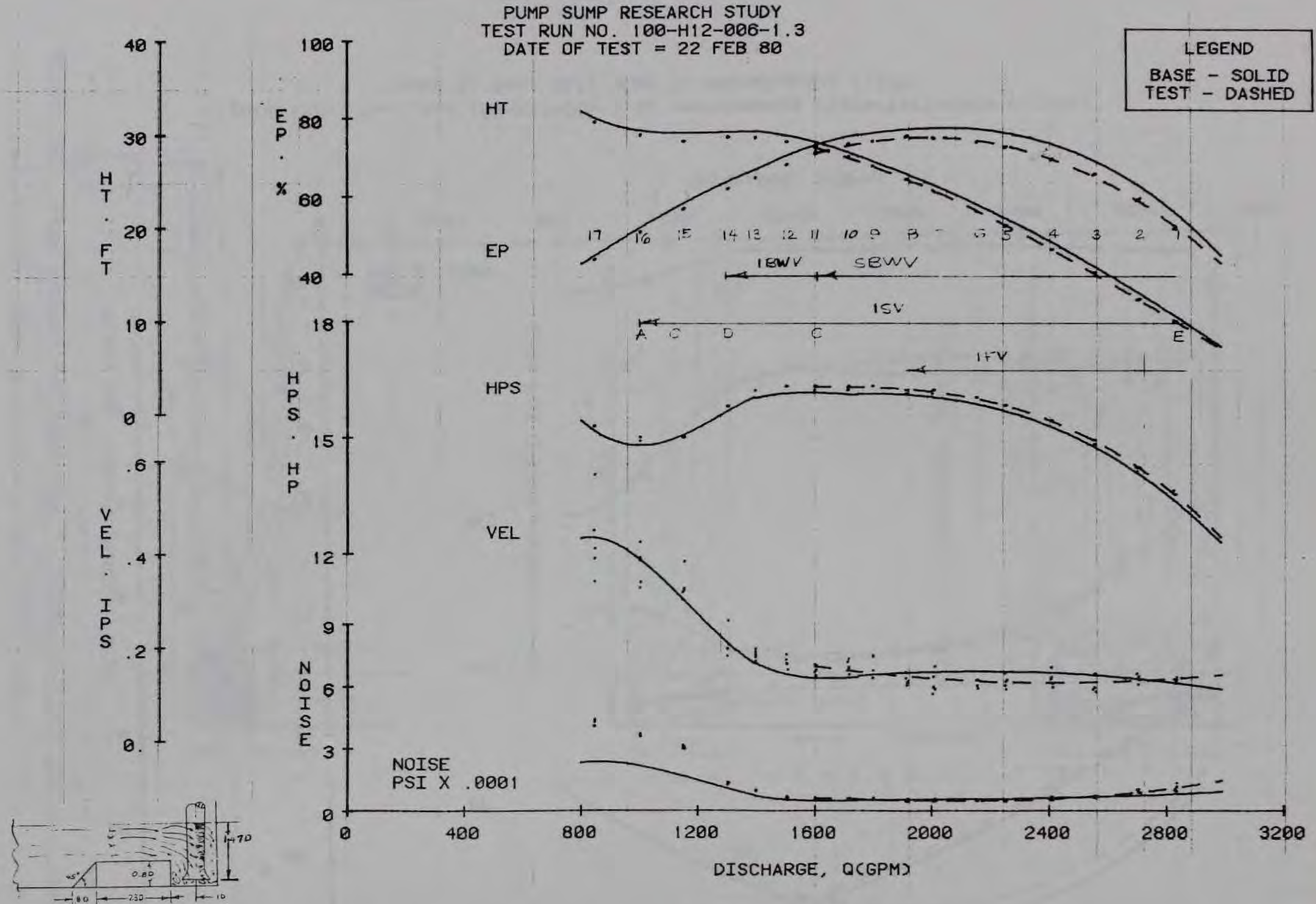


Figure 193. Test run 100-H12-006-1.3; performance characteristics curves; pump 1, Test H12, sump 6, submergence 1.47D

PUMP RUN SUMP SUBMERGENCE
100 H11 006 2.6

DATE 20 FEB 80 TIME 1400 AIR TEMP 78 F WATER TEMP 52 F BAR. PRESS 29.66IN HG

01 ISV'S 1/2 IN DIA STAGE E AT 5 O'CLOCK CCW & 7 O'CLOCK CW, TWIN SBWV'S AT 5:30 CCW & 6:30 CW BOTH 1/8 IN DIA IFV CW 1/8 IN DIA AT 12:00 O'CLOCK

02-03 NSCE (NO SIGNIFICANT CHANGE EXCEPT) ALL VORTEXES GETTINNG SMALLER & IV'S OCCURRING LESS FREQUENT

04 NSCE IV'S OCCURRING LESS OFTEN & IBWV'S NOW 1/16 IN DIA, IFV NOW 1/32 IN DIA. ISV'S NOW 1/8 IN DIA & STAGE D

05 NSC.

06 NSCE IFV NOW GONE.

07 NSCE ISV'S NOW STAGE C, FLASHING APEARING ON TIP OF BLADE POSSIBLE CAVITATION

08-09 NSC.

10 NSCE ISV'S NOW STAGE B

DATE 20 FEB 80 TIME 1515 AIR TEMP 78 F WATER TEMP 52 F BAR. PRESS 29.64IN GHG

11 NSCE SBWV'S BECOMING IBWV'S

12 NSCE IBWV'S NOW 1/32 IN DIA, FLASHING ON BLADE BECOMING MUCH LARGER

13 NSCE IBWV'S GONE. ISV'S NOW STAGE A

14 ALL VORTEXES GONE

15-16 NSCE VERY STILL

17 NSCE SPRAY EXPLOSIONS FROM PUMP BELL REACHING TO FLOOR.

DATE 20 FEB 80 TIME 1540 AIR TEMP 78 F WATER TEMP 52 F BAR. PRESS. 29.64IN HG

Figure 194. Test run 100-H11-006-2.6; visual observation notes; pump 1, Test H11, sump 6, submergence 2.47D

PUMPS RUN SUMP SUBMERGENCE
100 H12 006 1.3

DATE 22 FEB 80 TIME 0950 AIR TEMP 67 F WATER TEMP 54 F BAR PRESS 29.76IN HG

01 ISV CCW 3/4 IN DIA STAGE [illegible] AT 5 O'CLOCK, ISV CW 1 IN DIA STAGE [illegible] AT 7 O'CLOCK. IFWV CCW 1/8 IN DIA AT 12 O'CLOCK, IFV CCW AT 12 O'CLOCK 1/8 IN DIA, TWIN SBWV'S 1/8 IN DIA AT 5:30 CCW & 6:30 CW.

02 NSC (NO SIGNIFICANT CHANGE).

03 NSC

04 NSCE (NSC EXCEPT) IFWV GONE, SBWV'S SLIGHTLY SMALLER & WEAKER.

05 NSCE ALL VORTEXES BECOMING SMALLER & WEAKER.

06 NSCE ISV'S NOW 1/2 IN DIA STAGE D. SBWV'S & IFV'S 1/16 IN DIA.

07 NSC

08 NSCE TINY FLASHING APPEARING ON PUMP BLADE, POSSIBLE CAVITATION.

09 NSCE IV'S OCCURRING LESS FREQUENT, ARE SMALLER & WEAKER.

DATE 22 FEB 80 TIME 1040 AIR TEMP 76 F WATER TEMP 54 F BAR. PRESS 29.76IN HG

10 NSCE IFV GONE. ISV AT 5 O'CLOCK NOW 1/4 IN DIA & STAGE C.

11 NSCE ALL SV'S NOW STAGE C.

12 NSCE MULTIPLE ISV'S STAGE C CCW OCCURRING 1-4 O'CLOCK, SBWV'S BECOMING IBWV'S

13 NSCE FLASHING ON BLADE BECOMING MUCH LARGER.

14 NSCE THE ISV AT 5 O'CLOCK NOW 1/8 IN DIA STAGE D CCW.

15 NSCE IBWV'S GONE, ALL SV'S NOW STAGE A EXCEPT THE ISV AT 5 O'CLOCK NOW STAGE C

16 NSCE, ALL SV'S STAGE A.

17 NSCE SPRAY EXPULSION FROM PUMP BELL EXTENDING ABOUT 3 IN BELOW BELL.

DATE 22 FEB 80 TIME 1130 AIR TEMP 76 F WATER TEMP 54 F BAR PRESS 29.76IN HG

Figure 195. Test run 100-H12-006-1.3; visual observation notes; pump 1, Test H12, sump 6, submergence 1.47D

***PUMP EFFICIENCY ***
TOTAL AREA -4681.85 ABSOLUTE AREA 4681.85

TEST CURVE
MAX Y = 74.58 , X = 1997.52
MIN Y = 40.52 , X = 2987.62
MEAN Y = 68.85 , X = 2431.89
* * *
SIGNATURE CURVE
MAX Y = 77.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 71.86 , X = 2460.73

***SHAFT HORSEPOWER ***
TOTAL AREA 277.20 ABSOLUTE AREA 277.20

TEST CURVE
MAX Y = 16.26 , X = 1641.58
MIN Y = 12.71 , X = 2987.62
MEAN Y = 15.72 , X = 2287.23
* * *
SIGNATURE CURVE
MAX Y = 16.14 , X = 1600.00
MIN Y = 12.77 , X = 2987.62
MEAN Y = 15.54 , X = 2300.66

***ABS VELOCITY, IPS ***
TOTAL AREA -32.60 ABSOLUTE AREA 33.53

TEST CURVE
MAX Y = 0.13 , X = 1600.00
MIN Y = 0.11 , X = 2418.32
MEAN Y = 0.12 , X = 1830.64
* * *
SIGNATURE CURVE
MAX Y = 0.15 , X = 2118.42
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2619.20

***NOISE LB/IN**2 ***
TOTAL AREA 103.02 ABSOLUTE AREA 103.02

TEST CURVE
MAX Y = 1.19 , X = 2987.62

MIN Y = 0.59 , X = 2108.91
MEAN Y = 0.67 , X = 2682.55
* * *
SIGNATURE CURVE
MAX Y = 0.93 , X = 2987.62
MIN Y = 0.47 , X = 1631.19
MEAN Y = 0.56 , X = 2571.52

***TOTAL HEAD ***
TOTAL AREA -923.78 ABSOLUTE AREA 923.78

TEST CURVE
MAX Y = 28.34 , X = 1600.00
MIN Y = 6.73 , X = 2987.62
MEAN Y = 22.69 , X = 2081.45
* * *
SIGNATURE CURVE
MAX Y = 29.07 , X = 1600.00
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.39 , X = 2081.24

Figure 196. Test run 100-H11-006-2.6; statistical comparison; pump 1, Test H11, sump 6, submergence 2.47D

◆◆◆PUMP EFFICIENCY ◆◆◆

TOTAL AREA -4357.00 ABSOLUTE AREA 4357.00

TEST CURVE

MAX Y = 74.88 , X = 1985.15
MIN Y = 42.36 , X = 2987.62
MEAN Y = 69.04 , X = 2418.16

◆ ◆ ◆

SIGNATURE CURVE

MAX Y = 77.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 71.86 , X = 2460.73

◆◆◆ SHAFT HORSEPOWER ◆◆◆

TOTAL AREA 211.84 ABSOLUTE AREA 211.84

TEST CURVE

MAX Y = 16.29 , X = 1641.58
MIN Y = 12.42 , X = 2987.62
MEAN Y = 15.70 , X = 2292.34

* * *

SIGNATURE CURVE

MAX Y = 16.14 , X = 1600.00
MIN Y = 12.27 , X = 2987.62
MEAN Y = 15.54 , X = 2300.66

***ABS VELOCITY, FPS ***

TOTAL AREA -7.20 ABSOLUTE AREA 20.76

TEST CURVE

MAX Y = 0.16 , X = 1600.00
MIN Y = 0.12 , X = 2418.32
MEAN Y = 0.14 , X = 1832.47

* * *

SIGNATURE CURVE

MAX Y = 0.15 , X = 2158.42
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2619.20

◆◆◆NOISE LB/IN◆◆2 ◆◆◆

TOTAL AREA 84.59 ABSOLUTE AREA 160.44

TEST CURVE

MAX Y = 1.47 , X = 2987.62
MIN Y = 0.48 , X = 2096.53
MEAN Y = 0.64 , X = 2673.02

◆ ◆ ◆

SIGNATURE CURVE

MAX Y = 0.93 , X = 2987.62
MIN Y = 0.47 , X = 1631.19
MEAN Y = 0.56 , X = 2571.52

***TOTAL HEAD ***

TOTAL AREA -892.22 ABSOLUTE AREA 892.22

TEST CURVE

MAX Y = 28.45 , X = 1600.00
MIN Y = 6.86 , X = 2987.62
MEAN Y = 22.76 , X = 2081.18

* * *

SIGNATURE CURVE

MAX Y = 29.07 , X = 1600.00
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.39 , X = 2081.24

Figure 197. Test run 100-H12-006-1.3; statistical comparison; pump 1, Test H12, sump 6, submergence 1.47D

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT PRESSURE FLUCTUATIL MIN	P(FT PRESSURE FLUCTUATIL MAX
1	2906.	2.6	1.2	2.2	8.373	39.3	483.	18.1	20.3	13.3	6.2	65.6	46.3	1775.	0.040	0.097	1.12	3.33	3.60
1	2908.	2.6	1.2	2.2	8.393	39.4	483.	18.1	20.3	13.3	6.2	65.6	46.3	1775.	0.040	0.097	0.99	3.36	3.57
1	2903.	2.6	1.1	2.2	8.323	39.4	483.	18.1	20.3	13.3	6.1	65.6	45.9	1775.	0.042	0.100	1.10	3.32	3.58
1	2909.	2.6	1.1	2.2	8.328	39.4	483.	18.1	20.3	13.3	6.1	65.6	46.0	1775.	0.040	0.111	0.91	3.32	3.61
1	2902.	2.6	1.1	2.2	8.281	39.5	483.	18.1	20.3	13.3	6.1	65.7	45.6	1775.	0.043	0.132	1.10	3.18	3.56
2	2796.	2.6	3.4	2.0	10.405	41.0	483.	18.3	20.5	13.8	7.4	67.6	53.1	1775.	0.040	0.132	0.87	3.06	3.61
2	2802.	2.6	3.4	2.0	10.466	41.0	483.	18.3	20.5	13.8	7.4	67.6	53.6	1775.	0.039	0.111	0.87	3.36	3.63
2	2796.	2.6	3.4	2.0	10.449	40.9	483.	18.3	20.5	13.8	7.4	67.6	53.4	1775.	0.042	0.114	0.79	3.44	3.60
2	2802.	2.6	3.4	2.0	10.447	41.0	483.	18.3	20.5	13.8	7.4	67.7	53.5	1775.	0.040	0.111	0.92	3.39	3.64
2	2802.	2.6	3.4	2.0	10.395	40.8	483.	18.2	20.5	13.8	7.4	67.5	53.3	1775.	0.039	0.113	1.01	3.39	3.61
3	2644.	2.6	6.7	1.8	13.515	43.2	483.	18.6	20.8	14.6	9.0	70.2	61.8	1775.	0.044	0.114	0.91	3.38	3.62
3	2649.	2.6	6.7	1.8	13.484	43.1	483.	18.6	20.8	14.6	9.0	70.1	61.9	1775.	0.040	0.117	0.84	3.36	3.62
3	2649.	2.6	6.7	1.8	13.540	43.2	483.	18.6	20.8	14.6	9.1	70.2	62.2	1775.	0.039	0.092	0.74	3.34	3.64
3	2647.	2.6	6.7	1.8	13.477	43.2	483.	18.6	20.8	14.6	9.0	70.3	61.7	1775.	0.039	0.113	0.91	3.41	3.63
3	2642.	2.6	6.6	1.8	13.448	43.2	483.	18.6	20.8	14.6	9.0	70.3	61.5	1775.	0.042	0.124	0.83	3.39	3.62
4	2511.	2.6	9.2	1.6	15.867	44.8	483.	18.8	21.0	15.1	10.1	72.0	66.6	1775.	0.041	0.113	0.73	3.40	3.61
4	2506.	2.6	9.3	1.6	15.890	44.8	483.	18.8	21.0	15.1	10.1	72.0	66.5	1775.	0.041	0.105	0.72	3.43	3.62
4	2510.	2.6	9.2	1.6	15.845	44.7	483.	18.8	21.0	15.1	10.1	71.9	66.5	1775.	0.041	0.120	0.68	3.42	3.62
4	2509.	2.6	9.3	1.6	15.892	44.8	483.	18.8	21.0	15.1	10.1	71.9	66.6	1775.	0.041	0.133	0.68	3.42	3.63
4	2504.	2.6	9.2	1.6	15.858	44.7	483.	18.8	21.0	15.1	10.0	71.9	66.5	1775.	0.042	0.115	0.72	3.39	3.61
5	2352.	2.6	12.0	1.4	18.399	46.0	483.	18.9	21.2	15.6	10.9	73.4	70.3	1775.	0.037	0.098	0.50	3.48	3.61
5	2351.	2.6	12.0	1.4	18.390	46.1	483.	18.9	21.2	15.6	10.9	73.3	70.2	1775.	0.038	0.101	0.54	3.46	3.61
5	2352.	2.6	12.0	1.4	18.435	46.1	483.	18.9	21.2	15.6	11.0	73.4	70.3	1775.	0.038	0.130	0.61	3.45	3.60
5	2352.	2.6	12.0	1.4	18.441	46.1	483.	18.9	21.2	15.6	11.0	73.4	70.3	1775.	0.039	0.110	0.57	3.46	3.61
5	2353.	2.6	12.0	1.4	18.403	46.1	483.	18.9	21.2	15.6	10.9	73.4	70.2	1775.	0.040	0.114	0.57	3.45	3.60
6	2110.	2.6	16.1	1.2	22.265	47.6	483.	19.1	21.4	16.1	11.9	75.2	73.8	1775.	0.039	0.098	0.54	3.51	3.63
6	2110.	2.6	16.1	1.2	22.257	47.7	483.	19.1	21.4	16.1	11.9	75.2	73.7	1775.	0.042	0.118	0.59	3.35	3.65
6	2108.	2.6	16.1	1.2	22.243	47.6	483.	19.1	21.4	16.1	11.9	75.1	73.7	1775.	0.043	0.129	0.67	3.17	3.62
6	2106.	2.6	16.1	1.2	22.282	47.7	483.	19.1	21.4	16.1	11.9	75.2	73.6	1775.	0.039	0.116	0.54	3.43	3.62
6	2106.	2.6	16.1	1.2	22.283	47.6	484.	19.1	21.4	16.1	11.9	75.1	73.7	1775.	0.042	0.134	0.52	3.49	3.64
7	1996.	2.6	17.9	1.0	23.895	47.8	485.	19.2	21.5	16.1	12.1	75.0	74.7	1775.	0.037	0.101	0.51	3.48	3.61
7	1991.	2.6	17.8	1.0	23.864	47.8	484.	19.2	21.5	16.1	12.0	75.0	74.4	1775.	0.038	0.102	0.55	3.49	3.62
7	1992.	2.6	17.8	1.0	23.874	47.7	484.	19.1	21.5	16.1	12.0	74.9	74.5	1775.	0.039	0.099	0.51	3.49	3.60
7	1991.	2.6	17.8	1.0	23.874	47.7	484.	19.1	21.5	16.1	12.0	75.0	74.5	1775.	0.038	0.092	0.50	3.49	3.59
7	1993.	2.6	17.9	1.0	23.912	47.7	484.	19.2	21.5	16.1	12.0	74.9	74.8	1775.	0.040	0.095	0.51	3.01	3.60
8	1899.	2.6	19.2	0.9	25.176	47.8	485.	19.2	21.5	16.2	12.1	75.0	74.8	1775.	0.039	0.099	0.52	3.50	3.63
8	1895.	2.6	19.3	0.9	25.193	47.9	485.	19.2	21.5	16.2	12.1	75.1	74.6	1775.	0.040	0.123	0.62	3.50	3.64
8	1902.	2.6	19.3	0.9	25.209	47.9	485.	19.2	21.6	16.2	12.1	75.1	74.9	1775.	0.039	0.097	0.61	3.50	3.64
8	1897.	2.6	19.2	0.9	25.152	47.9	485.	19.2	21.5	16.2	12.1	75.1	74.6	1775.	0.039	0.095	0.63	3.49	3.64

Figure 198. Test run 100-H11-006-2.6; research data; pump 1, Test H11, sump 6, submergence 2.47D (Continued)

8	1890.	2.6	19.3	0.9	25.190	47.8	485.	19.2	21.5	16.2	12.0	75.0	74.4	1775.	0.039	0.101	0.68	3.48	3.65
9	1797.	2.6	20.5	0.8	26.331	48.0	485.	19.2	21.5	16.2	12.0	75.3	73.7	1775.	0.046	0.134	0.77	3.49	3.65
9	1797.	2.6	20.5	0.8	26.311	47.9	485.	19.1	21.5	16.2	12.0	75.2	73.8	1775.	0.043	0.126	0.75	3.49	3.64
9	1797.	2.6	20.5	0.8	26.324	47.9	484.	19.2	21.5	16.2	12.0	75.3	73.8	1775.	0.042	0.110	0.78	3.49	3.65
9	1797.	2.6	20.5	0.8	26.332	48.0	484.	19.1	21.5	16.2	12.0	75.3	73.8	1775.	0.043	0.136	0.76	3.49	3.65
9	1794.	2.6	20.5	0.8	26.318	48.0	484	19.1	21.5	16.2	11.9	75.4	73.6	1775.	0.044	0.122	0.68	3.49	3.65
10	1708.	2.6	21.6	0.8	27.375	48.1	486.	19.1	21.6	16.3	11.8	75.4	72.6	1775	0.047	0.146	0.64	3.48	3.62
10	1705.	2.6	21.6	0.8	27.390	48.1	486.	19.1	21.6	16.2	11.8	75.3	72.7	1775	0.047	0.142	0.73	3.37	3.63
10	1710.	2.6	21.7	0.8	27.412	47.9	486.	19.1	21.6	16.2	11.9	75.0	73.2	1775.	0.043	0.131	0.59	3.47	3.63
10	1706.	2.6	21.6	0.8	27.387	48.0	486.	19.2	21.6	16.2	11.8	75.1	72.8	1775.	0.048	0.126	0.62	3.47	3.63
10	1701.	2.6	21.6	0.8	27.381	48.1	486.	19.1	21.6	16.2	11.8	75.3	72.5	1775.	0.047	0.128	0.61	3.47	3.64
11	1603.	2.6	22.6	0.7	28.314	48.2	486.	19.2	21.6	16.3	11.5	75.4	70.5	1775.	0.046	0.126	0.55	3.49	3.66
11	1601.	2.6	22.7	0.7	28.338	48.2	486.	19.2	21.6	16.3	11.5	75.5	70.4	1775.	0.047	0.132	0.56	3.49	3.69
11	1602.	2.6	22.7	0.7	28.321	48.1	486.	19.2	21.6	16.3	11.5	75.3	70.5	1775.	0.045	0.127	0.56	3.49	3.69
11	1609.	2.6	22.7	0.7	28.322	48.2	486	19.2	21.6	16.3	11.5	75.4	70.8	1775	0.045	0.124	0.56	3.49	3.66
11	1606.	2.6	22.7	0.7	28.340	48.2	486.	19.2	21.6	16.3	11.5	75.5	70.6	1775.	0.046	0.124	0.60	3.49	3.69
12	1500.	2.6	23.5	0.6	29.043	48.1	487.	19.2	21.6	16.3	11.0	75.1	67.8	1775.	0.050	0.166	0.61	3.42	3.67
12	1498.	2.6	23.5	0.6	29.057	48.1	487.	19.2	21.6	16.3	11.0	75.2	67.7	1775.	0.049	0.164	0.56	3.42	3.66
12	1496.	2.6	23.4	0.6	29.018	48.1	487.	19.1	21.6	16.3	11.0	75.2	67.5	1775.	0.049	0.150	0.64	3.42	3.67
12	1499.	2.6	23.4	0.6	29.031	48.1	486.	19.1	21.6	16.2	11.0	75.2	67.7	1775.	0.048	0.135	0.59	3.42	3.66
12	1498.	2.6	23.4	0.6	29.013	48.1	487.	19.1	21.6	16.3	11.0	75.2	67.6	1775.	0.047	0.139	0.57	3.41	3.65
13	1299.	2.6	24.2	0.4	29.648	46.8	486.	19.0	21.4	15.8	9.7	74.0	61.5	1775.	0.057	0.168	0.93	3.29	4.02
13	1301.	2.6	24.2	0.4	29.642	46.8	486.	19.0	21.4	15.8	9.8	74.0	61.6	1775.	0.062	0.188	0.95	3.20	3.90
13	1301.	2.6	24.2	0.4	29.633	46.8	486.	19.0	21.4	15.8	9.7	74.0	61.6	1775.	0.062	0.181	0.96	3.27	4.07
13	1305.	2.6	24.2	0.4	29.687	46.9	486.	19.0	21.4	15.8	9.8	74.0	61.9	1775.	0.058	0.179	0.93	3.23	3.94
13	1300.	2.6	24.2	0.4	29.661	46.8	486.	19.0	21.4	15.8	9.7	73.9	61.7	1775.	0.059	0.200	1.05	3.31	3.93
14	1207.	2.6	24.0	0.4	29.366	45.1	486.	18.8	21.2	15.2	9.0	71.9	58.8	1775.	0.087	0.258	1.39	2.65	4.20
14	1202.	2.6	24.0	0.4	29.329	45.1	486.	18.8	21.2	15.2	8.9	71.9	58.5	1775.	0.083	0.254	1.34	2.73	4.53
14	1202.	2.6	24.0	0.4	29.370	45.1	486.	18.8	21.2	15.3	8.9	72.0	58.5	1775.	0.084	0.237	1.32	2.67	4.47
14	1202.	2.6	24.0	0.4	29.381	45.2	486.	18.8	21.2	15.3	8.9	72.0	58.5	1775.	0.080	0.249	1.35	2.61	4.47
14	1205.	2.6	24.0	0.4	29.388	45.1	486.	18.8	21.2	15.3	9.0	72.0	58.7	1775.	0.084	0.271	1.34	2.63	4.52
15	1108.	2.6	23.9	0.3	29.188	44.3	487.	18.7	21.1	15.0	8.2	70.9	54.6	1775.	0.106	0.305	1.82	2.65	4.60
15	1107.	2.6	23.9	0.3	29.206	44.3	487.	18.7	21.1	15.0	8.2	71.0	54.6	1775.	0.104	0.321	1.96	2.20	4.79
15	1107.	2.6	23.9	0.3	29.217	44.3	487.	18.7	21.1	15.0	8.2	70.9	54.6	1775.	0.099	0.310	1.72	2.63	4.53
15	1108.	2.6	23.9	0.3	29.234	44.4	487.	18.7	21.1	15.0	8.2	71.0	54.6	1775.	0.103	0.336	1.80	2.46	4.50
15	1112.	2.6	23.9	0.3	29.266	44.4	487.	18.7	21.1	15.0	8.2	71.1	54.8	1775.	0.099	0.298	1.86	2.53	4.66
16	962.	2.6	24.8	0.2	30.010	44.4	487.	18.7	21.1	15.0	7.3	71.0	48.6	1775.	0.112	0.339	1.90	2.40	4.70
16	960.	2.6	24.8	0.2	30.003	44.4	487.	18.7	21.1	15.0	7.3	70.9	48.6	1775.	0.110	0.339	1.93	2.17	4.87
16	966.	2.6	24.7	0.2	29.960	44.3	487.	18.7	21.1	15.0	7.3	70.9	48.9	1775.	0.113	0.386	1.99	1.84	4.61
16	963.	2.6	24.8	0.2	29.996	44.4	487.	18.7	21.1	15.0	7.3	71.0	48.7	1775.	0.114	0.348	1.77	2.36	4.67
16	962	2.6	24.8	0.2	30.001	44.4	487.	18.7	21.1	15.0	7.3	70.9	48.7	1775.	0.116	0.449	1.95	2.16	4.72
17	805.	2.6	26.5	0.2	31.644	45.4	487.	18.8	21.3	15.3	6.4	72.0	42.0	1775	0.128	0.456	2.02	2.05	4.82
17	807.	2.6	26.4	0.2	31.617	45.4	487.	18.8	21.3	15.3	6.5	72.0	42.1	1775.	0.127	0.404	2.19	1.93	4.70
17	807.	2.6	26.5	0.2	31.639	45.4	487.	18.9	21.3	15.3	6.5	72.0	42.1	1775	0.127	0.489	1.93	2.02	4.78
17	805.	2.6	26.5	0.2	31.631	45.3	487.	18.8	21.3	15.3	6.4	72.0	42.0	1775.	0.125	0.456	1.91	2.26	4.85
17	806.	2.6	26.5	0.2	31.681	45.4	487.	18.8	21.3	15.4	6.5	72.0	42.1	1775.	0.113	0.332	1.91	2.42	4.57

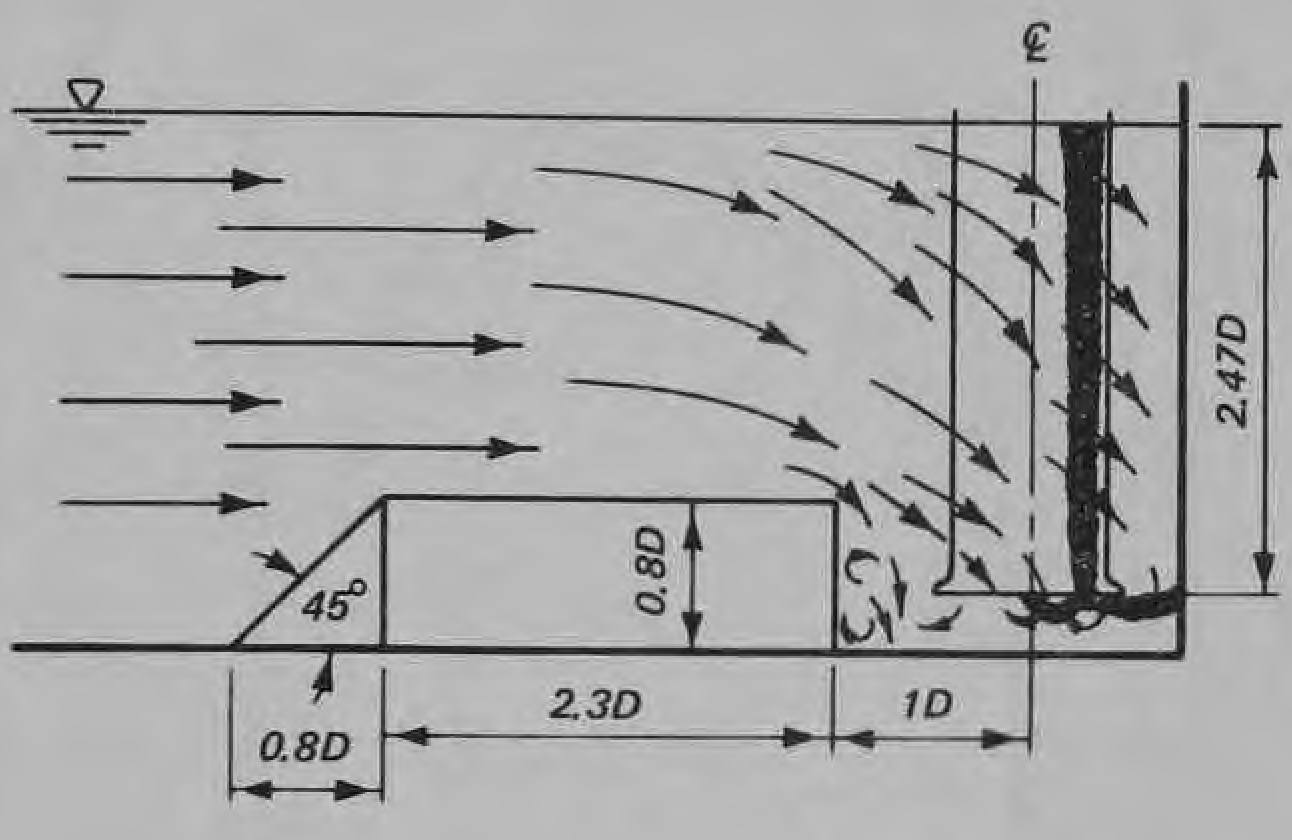
Figure 198. (Concluded)

READ: NO.	Q DIS-CHARGE: GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE: FT/LB	E VOLTS	I AMPS	HORSEPOWER HPM INPUT MOTOR HP	HORSEPOWER HPS SHAFT HP	HORSEPOWER HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY FT/SEC**2 RMS	VELOCITY FT/SEC**2 IMAXI	PUMP NOISE: PSI *10-4: RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2831.	1.3	1.4	2.1	9.792	40.0	481.	18.2	20.4	13.5	7.0	66.4	51.9	1775.	0.046	0.121	1.06	2.10	2.39
1	2835.	1.3	1.4	2.1	9.794	40.1	482.	18.2	20.4	13.5	7.0	66.5	51.8	1775.	0.045	0.135	1.16	2.04	2.38
1	2835.	1.3	1.3	2.1	9.653	40.0	482.	18.2	20.4	13.5	6.9	66.4	51.1	1775.	0.047	0.129	1.33	2.04	2.38
1	2828.	1.3	1.3	2.1	9.722	40.1	482.	18.2	20.4	13.6	7.0	66.5	51.3	1775.	0.045	0.130	1.01	2.07	2.43
1	2834.	1.3	1.3	2.1	9.674	39.9	482.	18.2	20.4	13.5	6.9	66.3	51.3	1775.	0.045	0.127	0.93	2.10	2.40
2	2704.	1.3	3.9	1.9	12.115	41.8	481.	18.4	20.5	14.1	8.3	68.9	58.6	1775.	0.044	0.119	0.91	2.08	2.37
2	2707.	1.3	3.9	1.9	12.129	41.9	481.	18.4	20.5	14.2	8.3	68.9	58.6	1775.	0.045	0.129	0.86	2.09	2.33
2	2714.	1.3	4.0	1.9	12.164	41.9	481.	18.4	20.5	14.2	8.3	68.9	59.0	1775.	0.043	0.129	0.87	2.12	2.35
2	2701.	1.3	3.9	1.9	12.124	41.9	481.	18.4	20.5	14.2	8.3	69.0	58.4	1775.	0.046	0.142	1.03	2.08	2.34
2	2706.	1.3	4.0	1.9	12.171	42.0	481.	18.4	20.6	14.2	8.3	69.0	58.7	1775.	0.047	0.136	1.03	2.08	2.40
3	2560.	1.3	7.0	1.7	14.992	43.9	481.	18.6	20.8	14.8	9.7	71.3	65.4	1775.	0.044	0.140	0.65	2.13	2.34
3	2551.	1.3	7.0	1.7	14.973	43.9	481.	18.6	20.8	14.9	9.7	71.4	65.0	1775.	0.044	0.108	0.63	1.96	2.34
3	2560.	1.3	7.0	1.7	15.012	43.9	481.	18.7	20.8	14.9	9.7	71.3	65.4	1775.	0.041	0.103	0.61	2.14	2.31
3	2556.	1.3	7.0	1.7	15.015	44.0	481.	18.7	20.8	14.9	9.7	71.4	65.2	1775.	0.043	0.142	0.71	2.10	2.33
3	2557.	1.3	7.0	1.7	15.002	43.9	481.	18.6	20.8	14.8	9.7	71.3	65.4	1775.	0.043	0.113	0.66	2.12	2.30
4	2413.	1.3	9.7	1.5	17.516	45.6	480.	18.9	21.0	15.4	10.7	73.4	69.3	1775.	0.042	0.121	0.65	2.17	2.36
4	2413.	1.3	9.7	1.5	17.481	45.5	480.	18.8	21.0	15.4	10.7	73.2	69.3	1775.	0.042	0.113	0.51	2.20	2.35
4	2410.	1.3	9.7	1.5	17.502	45.6	481.	18.9	21.1	15.4	10.7	73.3	69.1	1775.	0.047	0.135	0.66	2.15	2.38
4	2408.	1.3	9.7	1.5	17.484	45.6	481.	18.9	21.1	15.4	10.6	73.2	69.0	1775.	0.043	0.131	0.54	2.20	2.36
4	2409.	1.3	9.7	1.5	17.461	45.6	481.	18.9	21.1	15.4	10.6	73.1	69.0	1775.	0.045	0.156	0.66	2.16	2.40
5	2253.	1.3	12.4	1.3	20.047	46.7	481.	19.0	21.2	15.8	11.4	74.4	72.4	1775.	0.042	0.109	0.45	2.22	2.35
5	2252.	1.3	12.5	1.3	20.066	46.9	481.	19.0	21.2	15.8	11.4	74.5	72.1	1775.	0.043	0.126	0.51	2.19	2.38
5	2250.	1.3	12.4	1.3	20.043	46.7	481.	19.0	21.2	15.8	11.4	74.4	72.2	1775.	0.044	0.144	0.45	2.20	2.36
5	2251.	1.3	12.4	1.3	20.045	46.7	481.	19.0	21.2	15.8	11.4	74.4	72.3	1775.	0.043	0.117	0.46	2.20	2.36
5	2256.	1.3	12.4	1.3	20.050	46.8	481.	19.0	21.2	15.8	11.4	74.5	72.4	1775.	0.044	0.130	0.52	2.18	2.38
6	2153.	1.3	14.1	1.2	21.623	47.4	481.	19.1	21.3	16.0	11.8	75.1	73.5	1775.	0.043	0.129	0.48	2.21	2.38
6	2154.	1.3	14.1	1.2	21.584	47.3	481.	19.1	21.3	16.0	11.8	75.0	73.5	1775.	0.042	0.129	0.47	2.22	2.37
6	2157.	1.3	14.1	1.2	21.607	47.4	481.	19.1	21.3	16.0	11.8	75.1	73.6	1775.	0.043	0.111	0.48	2.24	2.40
6	2154.	1.3	14.1	1.2	21.564	47.4	481.	19.1	21.3	16.0	11.7	75.1	73.4	1775.	0.042	0.117	0.51	2.22	2.36
6	2156.	1.3	14.1	1.2	21.606	47.3	481.	19.1	21.3	16.0	11.8	75.1	73.7	1775.	0.045	0.130	0.51	2.18	2.36
7	2011.	1.3	16.3	1.0	23.699	47.8	481.	19.2	21.4	16.2	12.0	75.5	74.6	1775.	0.043	0.109	0.45	2.20	2.38
7	2010.	1.3	16.4	1.0	23.738	47.9	481.	19.2	21.4	16.2	12.1	75.6	74.5	1775.	0.046	0.158	0.57	2.20	2.39
7	2005.	1.3	16.4	1.0	23.783	47.9	481.	19.2	21.4	16.2	12.1	75.6	74.5	1775.	0.047	0.136	0.52	2.22	2.40
7	2005.	1.3	16.5	1.0	23.833	47.8	481.	19.2	21.4	16.2	12.1	75.5	74.7	1775.	0.045	0.114	0.51	2.17	2.38
7	2003.	1.3	16.5	1.0	23.861	47.8	481.	19.2	21.4	16.1	12.1	75.5	74.8	1775.	0.041	0.099	0.45	2.24	2.36
8	1917.	1.3	17.8	1.0	25.063	47.6	481.	19.2	21.4	16.1	12.1	75.3	75.4	1775.	0.042	0.123	0.58	2.25	2.41
8	1912.	1.3	17.8	0.9	25.038	47.7	481.	19.2	21.4	16.1	12.1	75.3	75.1	1775.	0.045	0.132	0.46	2.25	2.41
8	1914.	1.3	17.8	1.0	25.030	47.8	481.	19.2	21.4	16.1	12.1	75.5	75.0	1775.	0.043	0.117	0.46	2.28	2.41
8	1911.	1.3	17.8	0.9	25.027	47.8	481.	19.2	21.4	16.2	12.1	75.4	74.8	1775.	0.048	0.145	0.53	2.22	2.41

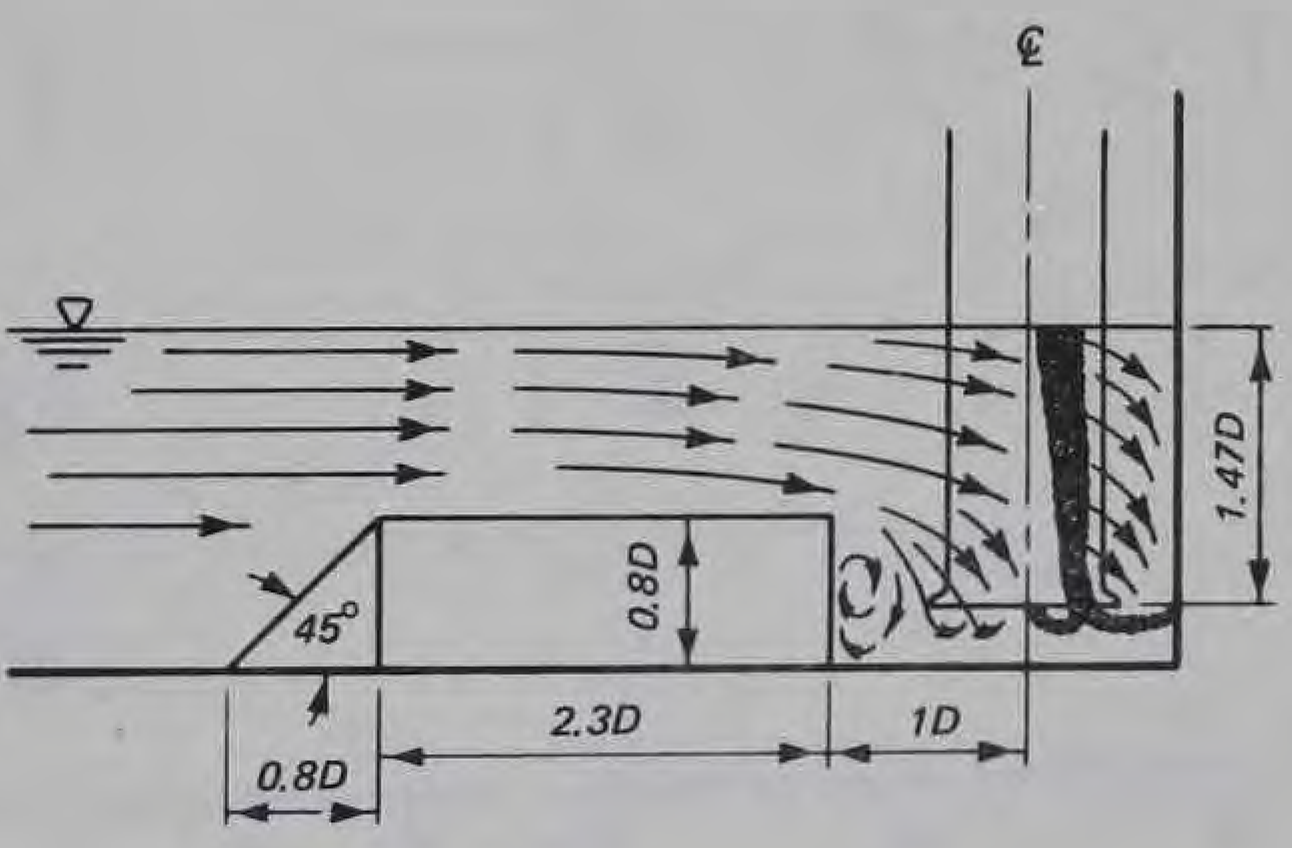
Figure 199. Test run 100-H12-006-1.3; research data; pump 1, Test H12, sump 6, submergence 1.47D (Continued)

8	1919.	1.3	17.8	1.0	25.025	47.8	481.	19.2	21.4	16.2	12.1	75.5	75.1	1775.	0.044	0.126	0.46	2.23	2.40
9	1799.	1.3	19.3	0.8	26.480	48.3	481.	19.2	21.5	16.3	12.0	76.0	73.8	1775.	0.058	0.182	0.58	2.22	2.44
9	1798.	1.3	19.4	0.8	26.499	48.2	481.	19.2	21.5	16.3	12.0	75.9	73.9	1775.	0.051	0.133	0.55	2.22	2.41
9	1798.	1.3	19.3	0.8	26.479	48.1	481.	19.2	21.4	16.3	12.0	75.9	74.0	1775.	0.050	0.133	0.52	2.21	2.43
9	1799.	1.3	19.3	0.8	26.460	48.2	481.	19.2	21.4	16.3	12.0	75.9	73.9	1775.	0.054	0.149	0.59	2.18	2.43
9	1799.	1.3	19.3	0.8	26.470	48.2	481.	19.2	21.5	16.3	12.0	75.9	74.0	1775.	0.052	0.179	0.61	2.20	2.42
10	1716.	1.3	20.4	0.8	27.454	48.1	481.	19.2	21.5	16.3	11.9	75.8	73.2	1775.	0.051	0.174	0.57	2.24	2.47
10	1717.	1.3	20.4	0.8	27.455	48.1	481.	19.2	21.5	16.3	11.9	75.7	73.3	1775.	0.050	0.140	0.61	2.23	2.47
10	1716.	1.3	20.4	0.8	27.424	48.2	481.	19.2	21.5	16.3	11.9	75.8	73.1	1775.	0.054	0.157	0.55	2.23	2.45
10	1716.	1.3	20.4	0.8	27.424	48.1	481.	19.2	21.5	16.2	11.9	75.6	73.2	1775.	0.055	0.152	0.56	2.21	2.47
10	1713.	1.3	20.4	0.8	27.421	48.0	482.	19.2	21.5	16.2	11.9	75.5	73.2	1775.	0.053	0.167	0.61	2.21	2.46
11	1606.	1.3	21.5	0.7	28.459	48.3	481.	19.2	21.5	16.3	11.6	76.0	70.8	1775.	0.052	0.150	0.52	2.26	2.48
11	1605.	1.3	21.5	0.7	28.498	48.1	481.	19.2	21.4	16.3	11.6	75.9	71.1	1775.	0.050	0.138	0.54	2.26	2.48
11	1601.	1.3	21.5	0.7	28.475	48.1	481.	19.2	21.4	16.2	11.5	75.8	70.9	1775.	0.051	0.163	0.55	2.27	2.49
11	1600.	1.3	21.5	0.7	28.464	48.2	481.	19.2	21.4	16.3	11.5	75.9	70.7	1775.	0.053	0.146	0.62	2.25	2.50
11	1607.	1.3	21.5	0.7	28.470	48.3	481.	19.2	21.5	16.3	11.6	76.1	70.9	1775.	0.055	0.160	0.51	2.27	2.51
12	1506.	1.3	22.2	0.6	29.058	48.2	481.	19.2	21.4	16.3	11.1	76.0	67.9	1775.	0.056	0.163	0.66	2.25	2.50
12	1504.	1.3	22.2	0.6	29.057	48.1	481.	19.2	21.4	16.3	11.0	75.9	67.9	1775.	0.056	0.165	0.69	2.21	2.53
12	1504.	1.3	22.2	0.6	29.057	48.2	481.	19.2	21.4	16.3	11.0	76.0	67.8	1775.	0.055	0.184	0.68	2.22	2.54
12	1503.	1.3	22.2	0.6	29.066	48.2	481.	19.2	21.4	16.3	11.0	75.9	67.8	1775.	0.055	0.172	0.64	2.24	2.52
12	1508.	1.3	22.2	0.6	29.110	48.3	481.	19.2	21.5	16.3	11.1	76.1	68.0	1775.	0.051	0.151	0.66	2.25	2.52
13	1398.	1.3	22.8	0.5	29.557	47.9	481.	19.1	21.4	16.2	10.4	75.8	64.5	1775.	0.061	0.189	0.98	2.21	2.62
13	1399.	1.3	22.7	0.5	29.548	47.9	481.	19.1	21.4	16.2	10.5	75.7	64.6	1775.	0.060	0.183	0.95	2.16	2.64
13	1400.	1.3	22.8	0.5	29.578	48.0	481.	19.2	21.4	16.2	10.5	75.9	64.6	1775.	0.061	0.196	0.94	2.17	2.66
13	1399.	1.3	22.7	0.5	29.528	47.8	481.	19.1	21.4	16.2	10.4	75.7	64.6	1775.	0.057	0.169	1.02	2.15	2.63
13	1399.	1.3	22.7	0.5	29.508	47.8	481.	19.1	21.3	16.2	10.4	75.7	64.6	1775.	0.059	0.178	0.99	2.14	2.61
14	1302.	1.3	22.9	0.4	29.600	46.7	481.	19.0	21.2	15.8	9.7	74.6	61.7	1775.	0.071	0.198	1.37	2.06	2.84
14	1308.	1.3	22.9	0.4	29.634	46.9	481.	19.0	21.2	15.8	9.8	74.7	61.9	1775.	0.066	0.205	1.34	2.04	2.89
14	1303.	1.3	22.9	0.4	29.670	46.9	481.	19.0	21.2	15.8	9.8	74.8	61.7	1775.	0.070	0.196	1.26	2.03	2.81
14	1306.	1.3	22.9	0.4	29.642	46.8	481.	19.0	21.2	15.8	9.8	74.6	61.9	1775.	0.064	0.257	1.34	2.02	2.78
14	1302.	1.3	22.9	0.4	29.640	46.9	481.	19.0	21.2	15.8	9.8	74.7	61.6	1775.	0.067	0.181	1.27	2.09	2.77
15	1150.	1.3	22.6	0.3	29.203	44.5	482.	18.7	20.9	15.0	8.5	71.9	56.5	1775.	0.099	0.317	3.17	1.13	3.44
15	1153.	1.3	22.6	0.3	29.225	44.5	482.	18.7	20.9	15.0	8.5	71.9	56.7	1775.	0.096	0.321	3.03	1.24	3.45
15	1150.	1.3	22.6	0.3	29.203	44.4	482.	18.7	20.9	15.0	8.5	71.8	56.6	1775.	0.095	0.301	3.00	1.30	3.40
15	1156.	1.3	22.5	0.3	29.197	44.4	482.	18.7	20.9	15.0	8.5	71.8	56.8	1775.	0.107	0.383	2.99	1.16	3.36
15	1155.	1.3	22.6	0.3	29.236	44.4	482.	18.7	20.9	15.0	8.5	71.8	56.9	1775.	0.100	0.325	3.08	1.14	3.52
16	1006.	1.3	23.3	0.3	29.893	44.3	482.	18.7	20.9	15.0	7.6	71.8	50.8	1775.	0.111	0.339	3.58	0.90	3.87
16	1003.	1.3	23.3	0.3	29.891	44.3	482.	18.7	20.9	15.0	7.6	71.7	50.7	1775.	0.117	0.327	3.58	0.81	3.84
16	1005.	1.3	23.3	0.3	29.872	44.2	482.	18.7	20.8	14.9	7.6	71.7	50.8	1775.	0.125	0.391	3.71	1.08	3.45
16	1004.	1.3	23.3	0.3	29.882	44.2	482.	18.6	20.8	15.0	7.6	71.8	50.7	1775.	0.125	0.425	3.62	1.11	3.63
16	1004.	1.3	23.3	0.3	29.882	44.3	482.	18.7	20.8	15.0	7.6	71.9	50.6	1775.	0.117	0.386	3.72	1.25	3.56
17	844.	1.3	24.8	0.2	31.295	45.3	481.	18.8	21.0	15.3	6.7	72.9	43.6	1775.	0.128	0.451	4.10	1.08	3.64
17	848.	1.3	24.8	0.2	31.297	45.3	482.	18.8	21.0	15.3	6.7	72.9	43.9	1775.	0.128	0.412	4.05	1.12	3.69
17	848.	1.3	24.8	0.2	31.297	45.3	481.	18.8	21.0	15.3	6.7	73.0	43.8	1775.	0.138	0.571	4.26	1.01	3.80
17	846.	1.3	24.8	0.2	31.235	45.2	482.	18.8	21.0	15.3	6.7	72.8	43.7	1775.	0.120	0.341	4.32	1.10	3.66
17	848.	1.3	24.8	0.2	31.296	45.3	482.	18.8	21.0	15.3	6.7	73.0	43.8	1775.	0.120	0.391	4.40	0.99	3.76

Figure 199. (Concluded)



TEST H11, SUBMERGENCE = 2.47D



TEST H12, SUBMERGENCE = 1.47D

SUBMERGENCE 0.47 NOT TESTED
DUE TO EXTREME ADVERSE
HYDRAULIC FLOW CONDITIONS

Figure 200. Flow pattern for sump type 6, discharge 1,930 gpm (4.3 cfs); bell diam D = 1.3 ft, $Q/g^{1/2}D^{5/2}$

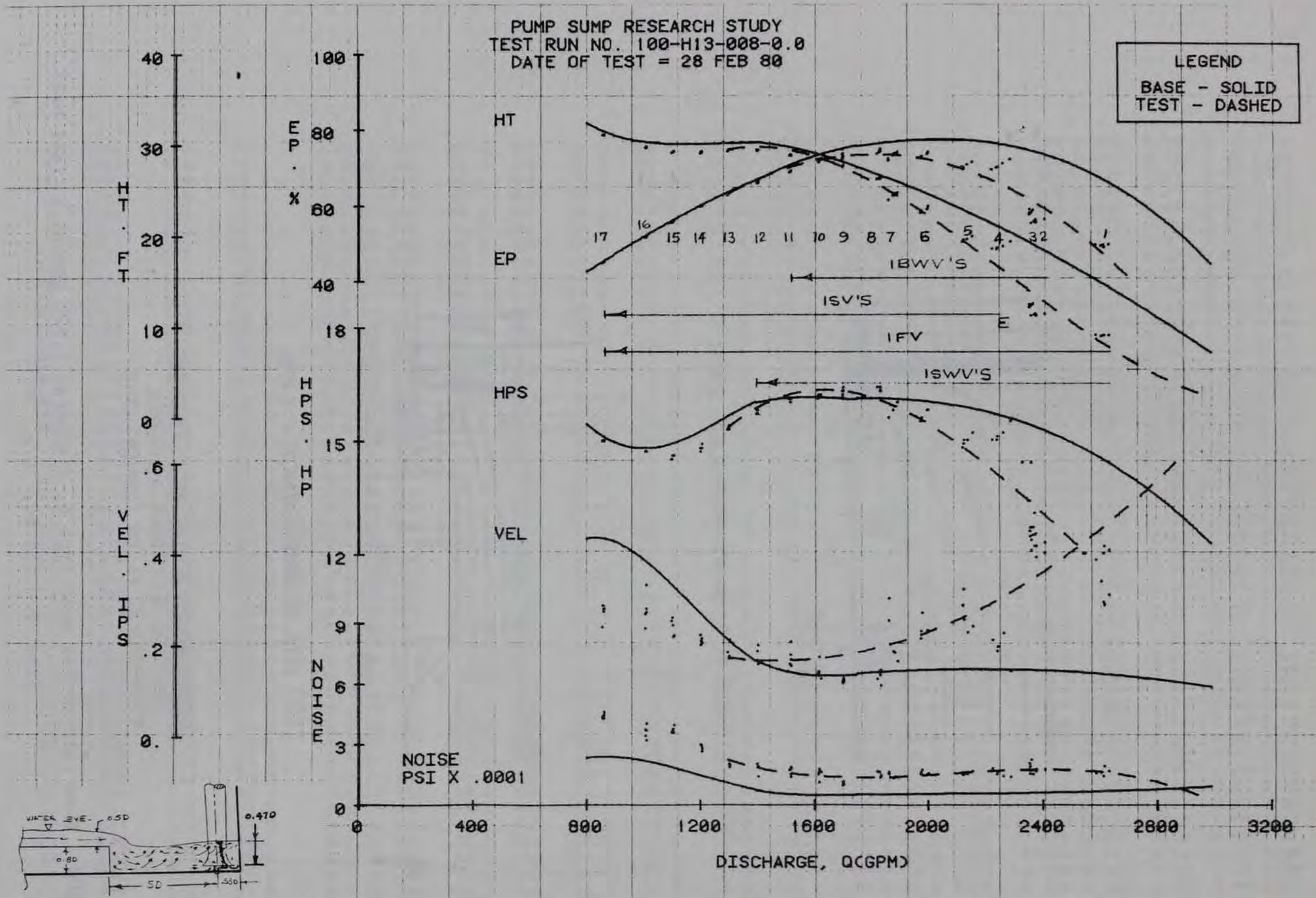


Figure 201. Test run 100-H13-008-0.0; performance characteristics curves; pump 1, Test H13, sump 8, submergence 0.47D

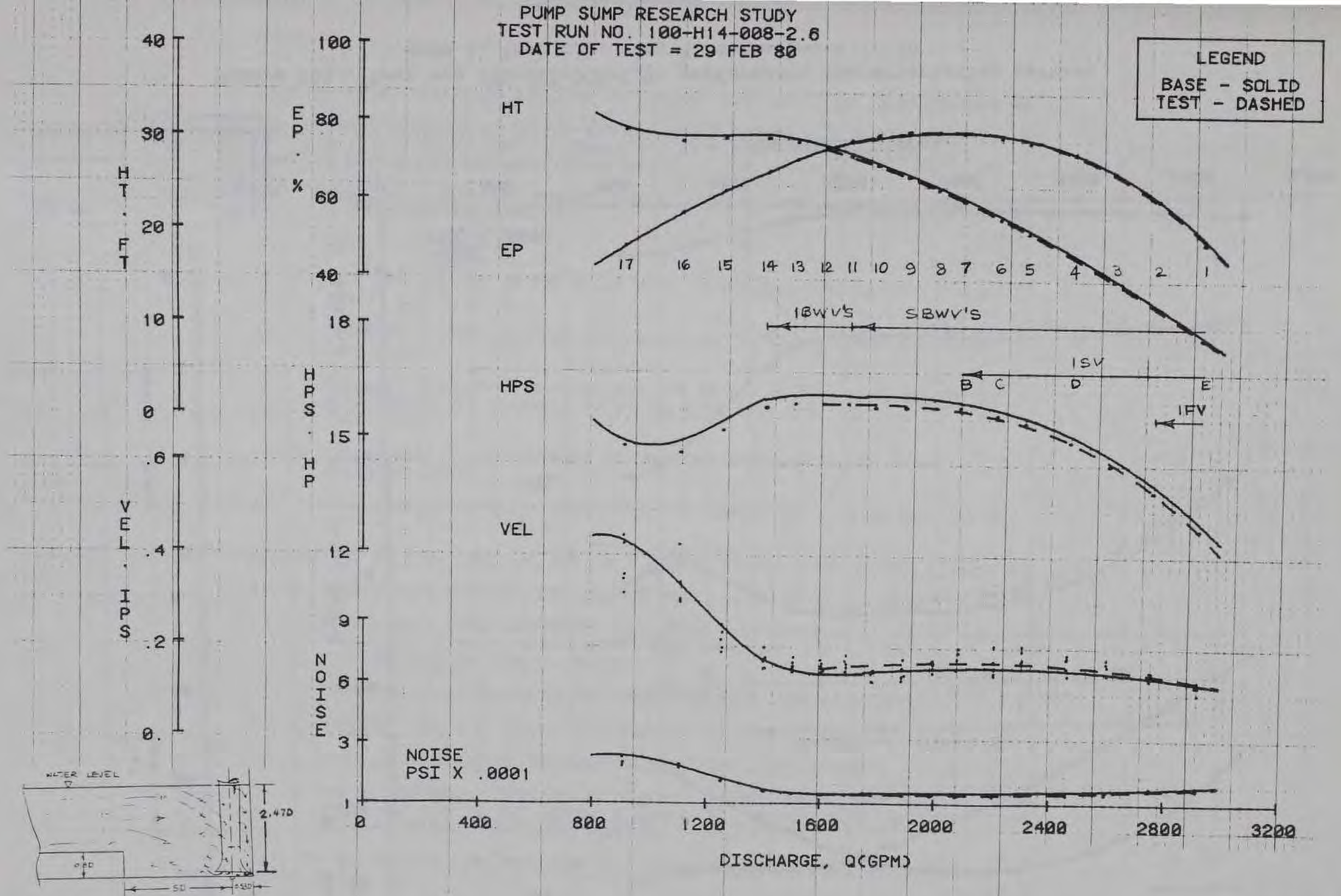


Figure 202. Test run 100-H14-008-2.6; performance characteristics curves; pump 1, Test H14, sump 8, submergence 2.47D

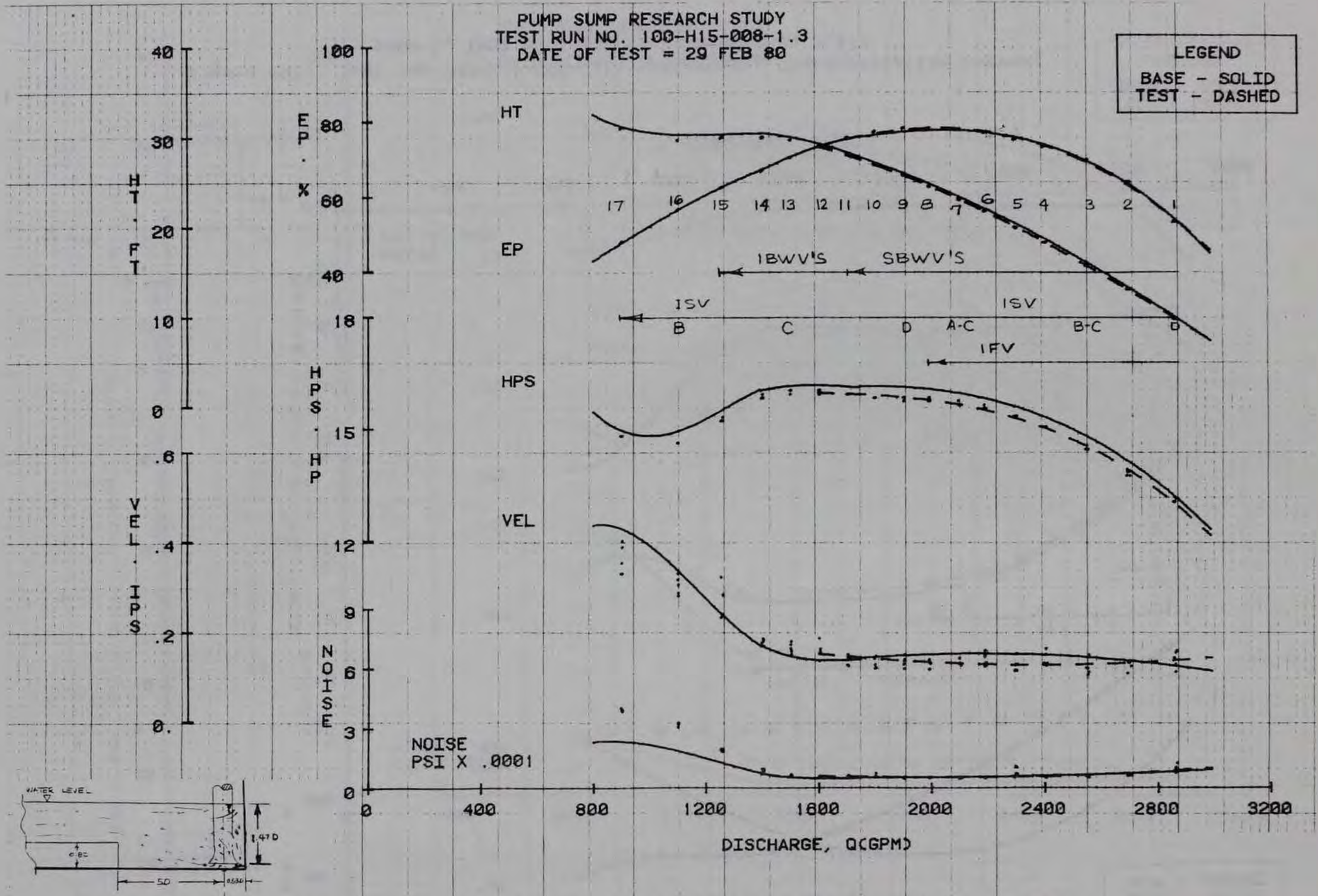


Figure 203. Test run 100-H15-008-1.3; performance characteristics curves; pump 1, Test H15, sump 8, submergence 1.47D

LIST

PUMPS RUN SUMP SUBMERGENCE
100 H13 008 0.47 .

DATE 28 FEB 80 TIME 1000 AIR TEMP 61 F WATER TEMP 55 F BAR PRESS 29.90IN HG

01 TREMENDOUS AMOUNT OF AIR BUBBLES IFV'S 1/8 TO 1/2 IN DIA CCW FROM 1 TO 8 O'CLOCK MOSTLY, ISWV'S 1/2 IN DIA AT 4 O'CLOCK CCW AND 8 O'CLOCK CW HYD JUMP OCCURRING

02 NSCE (NO SIGNFICANT CHANGE EXCEPT) NOW HAS TWIN IBWV'S AT 5:30 O'CLOCK CCW AND 6:30 CW

03 NSC

04 NSCE ISV CCW 3/4 IN DIA STAGE E AT 10 O'CLOCK, ISV CW AT 2 O'CLOCK 1/2 IN DIA STAGE E

05 NSCE TINY FLASHING APPEARING ON TIP OF PROPELLER BLADE, POSSIBLE CAVITATION.

06 NSCE IFV'S BECOMING SMALLER NOW 1/8 TO 1/4 IN DIA. THE AMOUNT OF AIR BUBBLES HAS REMAINED ABOUT THE SAME FROM START OF TEST TO THIS POINT.

07-09 NSCE AMOUNT OF AIR BUBBLES DIMINISHING AND FLASHING ON BLADE BECOMING LARGER.

10 NSCE ISWV'S OCCURRING LESS OFTEN AND IBWV'S NOW 1/16 IN DIA, IFV'S NOW 1/16 TO 1/8 IN DIA.

DATE 28 FEB 80 TIME 1155 AIR TEMP 71 F WATER TEMP 57 F BAR PRESS. 29.85IN HG

11-12 NSCE IBWV'S GONE ON TEST READING #12.

13 NSCE ISWV'S GONE, ALL ISV'S GONE EXCEPT ISV CCW 3/4 IN DIA AT 7 O'CLOCK, STAGE E 8 IN FROM CL PUMP SHAFT AND ISV 3/4 IN DIA AT 7 O'CLOCK 12 IN FROM CL SHAFT.

14 NSCE THE IFV'S OCCURRING ALL AROUND BELL CP (ONE AT A TIME).

15 NSCE ISV CCW 1/2 IN DIA AT 4 O'CLOCK 12 IN FROM PUMP CL.

16 NSCE ISV'S BECOMING SMALLER AND OCCURRING LESS FREQUENT.

17 THE SUBMERGENCE LEVEL HAS BEEN VERY DIFFICULT TO MAINTAIN DURING THIS TEST DUE TO THE HYDRAULIC JUMP. NSC ON #17 EXCEPT SPRAY EXPULSIONS FROM PUMP BELL REACHING TO FLOOR.

DATE 28 FEB 80 TIME 1250 AIR TEMP 73 F WATER TEMP 59 F BAR. PRESS. 29.80 IN HG

Figure 204. Test run 100-H13-008-0.0; visual observation notes; pump 1, Test H13, sump 8, submergence 0.47D

PUMPS RUN SUMP SUBMERGENCE
100 H14 008 2.6

DATE 29 FEB 80 TIME 1030 AIR TEMP 61 F WATER TEMP 59 F BAR. PRESS. 29.91IN HG

01 ISV CW 1/2 IN DIA STAGE E AT 4 O'CLOCK, ISV CCW 1/2 IN DIA STAGE E AT 8 O'CLOCK. TWIN SBWV'S AT 5:30 CCW & 6:30 CW BOTH 1/8 IN DIA. IFV 1/8 IN DIA, LOCATION CHANGING BUT MOSTLY 4 TO 8 O'CLOCK CW

02 NSC (NO SIGNIFICANT CHANGE).

03 NSCE (NSC EXCEPT) IFV GONE.

04 NSCE ISV'S NOW 1/4 IN DIA STAGE D.

05 NSCE ALL VORTEXES BECOMING SMALLER & WEAKER.

06 NSCE SBWV'S NOW 1/16 IN DIA. SV'S NOW STAGE C.

07 NSCE SV'S NOW STAGE B

08 NSCE TINY FLASH APPEARING ON TIP OF BLADE, POSSIBLE CAVITATION.

09-11 NSC.

DATE 29 FEB 80 TIME 1120 AIR TEMP 64 F WATER TEMP 59 F BAR. PRESS. 29.90IN HG

12 NSCE SBWV'S BECOMING IBWV'S. FLASHING ON BLADE BECOMING MUCH LARGER.

13-14 NSC

15 ALL VORTEXES GONE. FLASHING ON BLADE GETTING LARGER

16 NSC

17 NSCE SPRAY EXPULSIONS REACHING FROM BELL TO 3 IN BELOW.

DATE 29 FEB 80 TIME 1145 AIR TEMP 67 F WATER TEMP 59 F BAR. PRESS 29.89IN HG

Figure 205. Test run 100-H14-008-2.6; visual observation notes; pump 1, Test H14, sump 8, submergence 2.47D

PUMPS RUN SUMP SUBMERGENCE
100 H15 008 1.3

DATE 29 FEB 80 TIME 1345 AIR TEMP 70 F WATER TEMP 59 F BAR. PRESS. 29.82IN HG

01 ISV CW AT 5 O'CLOCK & CCW AT 7 O'CLOCK, BOTH 1/2 IN DIA STAGE D. TWIN SBWV'S CCW AT 5:30 & CW AT 6:30 BOTH 1/8 IN DIA. IFV 1/8 IN CCW AT 11 TO 1 O'CLOCK.

02-03 NSCE (NO SIGNIFICANT CHANGE EXCEPT) MULTIPLE SMALL SV'S APPEARING AT 1-4 O'CLOCK & 9 TO 11 O'CLOCK, DIRECTIONS CHANGING, MOST STAGE B TO C.

04-06 NSCE ALL VORTEXES BECOMING SMALLER & WEAKER.

07 NSCE ALL SV'S NOW STAGE A TO C NOT AS MANY.

08 NSCE FLASHING APPEARING ON TIP OF PROPELLER BLADE, POSSIBLE CAVITATION

09 NSCE IFV GONE. ALL SV'S GONE EXCEPT ISV CW 1/4 IN DIA AT 4 O'CLOCK & ISV 1/4 IN DIA CCW AT 8 O'CLOCK, BOTH STAGE D.

10-11 NSCE FLASHING ON BLADE GETTING LARGER.

12 NSCE SBWV'S BECOMING IBWV'S.

13 NSCE ISV'S NOW STAGE C

DATE 29 FEB 80 TIME 1455 AIR TEMP 69 F WATER TEMP 60 F BAR. PRESS. 29.82IN HG

14 NSCE BWV'S NOW 1/16 IN DIA. ISV 1/4 IN DIA CCW AT 8 O'CLOCK

15 NSCE FLASHING BECOMING MUCH LARGER ON BLADE.

16 ALL VORTEXES GONE EXCEPT ISV CW STAGE B AT 5 O'CLOCK.

17 ALL VORTEXES GONE SPRAY EXPLUSION FROM PUMP BELL EXTENDING ABOUT 3 INCHES FROM BELL.

SPECIAL NOTES: DURING THIS TEST 3 SMALL PUMPS WERE OPERATING ADJACENT TO THIS MODEL BUT CALIBRATION WAS MADE TO ZERO IT OUT. THE NOISE LEVEL OF THE 3 PUMPS WAS CONSTANT THOUGHOUT THIS TEST. VOLTAGE DURING THIS TEST WAS ABOUT 3 VOLTS HIGHER THAN USUAL-CAUSE IS BELIEVED TO BE DUE TO UNRELATED SOURCE.

DATE 29 FEB 80 TIME 1515 AIR TEMP 68 F WATER TEMP 60 BAR. PRESS.29.82IN HG

Figure 206. Test run 100-H15-008-1.3; visual observation notes; pump 1, Test H15, sump 8, submergence 1.47D

PUMP EFFICIENCY

TOTAL AREA ABSOLUTE AREA 17727.50

TEST CURVE

MAX Y = 73.39 , X = 1811.88
MIN Y = 16.20 , X = 2987.62
MEAN Y = 62.38 , X = 2331.57

SIGNATURE CURVE

MAX Y = 77.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 69.74 , X = 2529.77

SHAFT HORSEPOWER

TOTAL AREA -2291.91 ABSOLUTE AREA 2388.20

TEST CURVE

MAX Y = 16.34 , X = 1634.16
MIN Y = 9.33 , X = 2987.62
MEAN Y = 14.60 , X = 2159.90

SIGNATURE CURVE

MAX Y = 16.14 , X = 1571.78
MIN Y = 12.27 , X = 2987.62
MEAN Y = 15.51 , X = 2311.99

ABS VELOCITY, IPS

TOTAL AREA 304.03 ABSOLUTE AREA 306.92

TEST CURVE

MAX Y = 0.68 , X = 2987.62
MIN Y = 0.17 , X = 1460.40
MEAN Y = 0.27 , X = 2381.96

SIGNATURE CURVE

MAX Y = 0.21 , X = 1300.00
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2419.83

NOISE LB/SQ IN

TOTAL AREA 1432.10 ABSOLUTE AREA 1511.68

TEST CURVE

MAX Y = 2.22 , X = 1300.00
MIN Y = 0.20 , X = 2987.62
MEAN Y = 1.52 , X = 2660.35

SIGNATURE CURVE

MAX Y = 1.02 , X = 1300.00
MIN Y = 0.47 , X = 1629.70
MEAN Y = 0.62 , X = 2638.57

TOTAL HEAD

TOTAL AREA -5835.64 ABSOLUTE AREA 5835.64

TEST CURVE

MAX Y = 29.74 , X = 1393.56
MIN Y = 2.16 , X = 2987.62
MEAN Y = 21.41 , X = 2034.05

SIGNATURE CURVE

MAX Y = 30.36 , X = 1317.82
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.91 , X = 2043.45

Figure 207. Test run 100-H13-008-0.0; statistical comparison; pump 1, Test H13, sump 8, submergence 0.47D

PUMP EFFICIENCY

TOTAL AREA -292.18 ABSOLUTE AREA 497.53

TEST CURVE

MAX Y = 77.60 , X = 2022.28
MIN Y = 43.93 , X = 2987.62
MEAN Y = 71.68 , X = 2453.02

SIGNATURE CURVE

MAX Y = 77.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 44.36 , X = 2460.73

SHAFT HORSEPOWER

TOTAL AREA -285.92 ABSOLUTE AREA 285.92

TEST CURVE

MAX Y = 15.90 , X = 1692.08
MIN Y = 12.00 , X = 2987.62
MEAN Y = 15.33 , X = 2309.39

SIGNATURE CURVE

MAX Y = 16.14 , X = 1600.00
MIN Y = 12.27 , X = 2987.62
MEAN Y = 15.51 , X = 2300.66

TEST CURVE

MAX Y = 0.16 , X = 2084.16
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.15 , X = 2526.95

SIGNATURE CURVE

MAX Y = 0.15 , X = 2158.42
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2619.20

NOISE LB/SQ IN

TOTAL AREA -116.04 ABSOLUTE AREA 116.04

TEST CURVE

MAX Y = 0.87 , X = 2987.62
MIN Y = 0.44 , X = 1935.64
MEAN Y = 0.51 , X = 2576.77

SIGNATURE CURVE

MAX Y = 0.93 , X = 2987.62
MIN Y = 0.47 , X = 1631.19
MEAN Y = 0.56 , X = 2571.52

TOTAL HEAD

TOTAL AREA -411.29 ABSOLUTE AREA 411.29

TEST CURVE

MAX Y = 28.69 , X = 1600.00
MIN Y = 6.89 , X = 2987.62
MEAN Y = 23.06 , X = 2085.75

SIGNATURE CURVE

MAX Y = 29.07 , X = 1600.00
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.39 , X = 2081.24

Figure 208. Test run 100-H14-008-2.6; statistical comparison; pump 1, Test H14, sump 8, submergence 2.47D

PUMP EFFICIENCY

TOTAL AREA 68.62 ABSOLUTE AREA 451.51

TEST CURVE

MAX Y = 77.85 , X = 2022.28
MIN Y = 45.15 , X = 2987.62
MEAN Y = 71.86 , X = 2449.10

SIGNATURE CURVE

MAX Y = 77.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 71.86 , X = 2460.73

SHAFT HORSEPOWER

TOTAL AREA -352.75 ABSOLUTE AREA 352.75

TEST CURVE

MAX Y = 15.94 , X = 1600.00
MIN Y = 12.11 , X = 2987.62
MEAN Y = 15.31 , X = 2266.11

SIGNATURE CURVE

MAX Y = 16.14 , X = 1600.00
MIN Y = 12.27 , X = 2987.62
MEAN Y = 15.54 , X = 2300.66

ABS VELOCITY, IPS

TOTAL AREA -11.20 ABSOLUTE AREA 20.84

TEST CURVE

MAX Y = 0.15 , X = 1600.00
MIN Y = 0.12 , X = 2381.19
MEAN Y = 0.14 , X = 2938.31

SIGNATURE CURVE

MAX Y = 0.15 , X = 2158.42
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2619.20

NOISE LB/SQ IN

TOTAL AREA 18.96 ABSOLUTE AREA 43.40

TEST CURVE

MAX Y = 1.01 , X = 2987.62
MIN Y = 0.54 , X = 2047.03
MEAN Y = 0.61 , X = 2647.61

SIGNATURE CURVE

MAX Y = 0.93 , X = 2987.62
MIN Y = 0.47 , X = 1631.19
MEAN Y = 0.56 , X = 2571.52

TOTAL HEAD

TOTAL AREA -399.02 ABSOLUTE AREA 400.39

TEST CURVE

MAX Y = 28.72 , X = 1600.00
MIN Y = 7.15 , X = 2987.62
MEAN Y = 23.08 , X = 2083.31

SIGNATURE CURVE

MAX Y = 29.07 , X = 1600.00
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.39 , X = 2081.24

Figure 209. Test run 100-H15-008-2.6; statistical comparison; pump 1, Test H15, sump 8, submergence 2.47D

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HPM INPUT MOTOR HP (HORSEPOWER)	HPS SHAFT HP (HORSEPOWER)	HPW WATER HP (HORSEPOWER)	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2586.	0.	-0.3	1.7	8.986	35.2	487.	17.0	19.2	11.9	5.9	62.2	49.3	1775.	0.104	0.387	1.56	-1.21	1.26
1	2615.	0.	-0.4	1.8	8.963	36.1	487.	17.0	19.3	12.2	5.9	63.3	48.6	1775.	0.090	0.289	1.92	-2.12	1.33
1	2632.	0.	-0.4	1.8	8.954	35.7	487.	17.0	19.2	12.1	6.0	62.8	49.4	1775.	0.092	0.310	1.66	-1.50	1.39
1	2605.	0.	-0.5	1.8	8.883	35.2	487.	16.9	19.1	11.9	5.8	62.3	49.1	1775.	0.112	0.339	1.62	-1.17	1.35
1	2613.	0.	-0.4	1.8	8.967	35.6	487.	17.0	19.2	12.0	5.9	62.8	49.3	1775.	0.089	0.294	1.42	-2.95	1.25
2	2407.	0.	2.3	1.5	11.402	36.5	488.	17.1	19.3	12.3	6.9	63.9	56.2	1775.	0.140	0.402	1.78	-1.05	1.31
2	2377.	0.	2.2	1.5	11.244	36.1	487.	17.0	19.3	12.2	6.8	63.4	55.3	1775.	0.129	0.393	1.74	-3.39	1.41
2	2360.	0.	2.1	1.4	11.163	35.8	487.	17.0	19.2	12.1	6.7	63.0	55.0	1775.	0.168	0.614	2.22	-2.38	1.57
2	2370.	0.	2.3	1.5	11.327	36.1	487.	17.0	19.3	12.2	6.8	63.3	55.6	1775.	0.160	0.490	1.73	-2.81	1.45
2	2375.	0.	2.4	1.5	11.421	36.2	487.	17.0	19.3	12.2	6.9	63.5	56.0	1775.	0.138	0.445	1.68	-1.84	1.26
3	2355.	0.	3.3	1.4	12.296	37.5	487.	17.2	19.4	12.7	7.3	65.4	57.8	1775.	0.120	0.438	1.90	-2.42	1.28
3	2353.	0.	3.1	1.4	12.105	37.2	487.	17.1	19.3	12.6	7.2	65.0	57.3	1775.	0.153	0.861	2.05	-0.00	1.40
3	2359.	0.	3.3	1.4	12.335	37.6	487.	17.2	19.4	12.7	7.4	65.5	57.9	1775.	0.135	0.430	1.71	-4.62	1.19
3	2366.	0.	3.4	1.5	12.464	37.7	487.	17.2	19.4	12.7	7.5	65.5	58.6	1775.	0.127	0.441	1.52	0.04	1.18
3	2354.	0.	3.4	1.4	12.417	37.3	487.	17.2	19.4	12.6	7.4	64.9	58.7	1775.	0.131	0.516	1.54	-0.82	1.36
4	2287.	0.	10.4	1.4	19.327	45.9	487.	18.1	20.5	15.5	11.2	75.7	72.0	1775.	0.050	0.143	1.36	-0.78	1.19
4	2261.	0.	9.9	1.3	18.815	44.9	487.	18.0	20.3	15.2	10.8	74.6	70.9	1775.	0.066	0.227	1.43	0.66	1.25
4	2241.	0.	9.7	1.3	18.587	44.5	487.	18.0	20.3	15.1	10.5	74.2	69.9	1775.	0.072	0.197	1.66	0.45	1.26
4	2239.	0.	9.6	1.3	18.488	44.4	486.	17.9	20.2	15.0	10.5	74.1	69.8	1775.	0.063	0.187	1.53	-0.34	1.22
4	2224.	0.	9.6	1.3	18.451	44.4	487.	17.9	20.2	15.0	10.4	74.1	69.2	1775.	0.062	0.211	1.82	-0.29	1.39
5	2154	0.	11.1	1.2	19.884	44.9	487.	18.0	20.3	15.2	10.8	74.6	71.3	1775.	0.074	0.242	1.68	0.38	1.24
5	2137.	0.	10.8	1.2	19.585	44.4	487.	18.0	20.3	15.0	10.6	73.9	70.6	1775.	0.074	0.228	1.55	-1.65	1.17
5	2123.	0.	10.6	1.2	19.389	44.1	487.	17.9	20.2	14.9	10.4	73.7	69.8	1775.	0.092	0.323	1.50	-0.24	1.28
5	2119.	0.	10.5	1.2	19.275	43.7	487.	17.9	20.2	14.8	10.3	73.1	70.0	1775.	0.099	0.289	1.49	-1.97	1.21
5	2124.	0.	10.8	1.2	19.530	44.4	487.	18.0	20.3	15.0	10.5	74.0	69.8	1775.	0.090	0.256	1.55	-0.44	1.17
6	1972.	0	13.9	1.0	22.519	46.0	487.	18.2	20.5	15.5	11.2	75.7	72.3	1775.	0.076	0.215	1.54	-1.87	1.09
6	1973.	0.	13.9	1.0	22.520	45.9	487.	18.2	20.5	15.5	11.2	75.6	72.4	1775.	0.081	0.231	1.64	0.44	1.18
6	1978.	0.	14.0	1.0	22.645	46.0	487.	18.2	20.5	15.6	11.3	75.7	72.8	1775.	0.077	0.271	1.74	-0.34	1.22
6	1996.	0.	14.3	1.0	22.944	46.7	487.	18.2	20.6	15.8	11.6	76.5	73.4	1775.	0.081	0.232	1.49	0.53	1.16
6	2000.	0.	14.5	1.0	23.158	46.8	486.	18.3	20.6	15.8	11.7	76.8	74.0	1775.	0.082	0.231	1.56	0.06	1.22
7	1860.	0.	15.4	0.9	23.858	46.2	488.	18.2	20.6	15.6	11.2	76.0	71.8	1775.	0.091	0.303	1.62	0.05	1.12
7	1859.	0.	15.5	0.9	23.947	46.1	488.	18.2	20.5	15.6	11.3	75.9	72.2	1775.	0.079	0.254	1.56	-0.25	1.18
7	1875.	0.	15.9	0.9	24.412	46.9	488.	18.2	20.6	15.8	11.6	76.7	73.1	1775.	0.062	0.186	1.34	0.10	1.14
7	1881.	0.	16.1	0.9	24.578	47.0	488.	18.3	20.7	15.9	11.7	76.9	73.6	1775.	0.063	0.184	1.40	-0.02	1.15
7	1891.	0.	16.2	0.9	24.728	47.3	488.	18.3	20.7	16.0	11.8	77.2	74.0	1775.	0.057	0.165	1.38	-0.54	1.04
8	1819.	0.	17.7	0.9	26.178	48.5	488.	18.4	20.8	16.4	12.0	78.8	73.5	1775.	0.049	0.127	1.67	0.41	1.11
8	1827.	0.	17.8	0.9	26.256	48.6	488.	18.4	20.8	16.4	12.1	78.8	73.9	1775.	0.049	0.143	1.64	-0.10	1.13
8	1832.	0.	17.8	0.9	26.301	48.7	487.	18.4	20.8	16.4	12.2	79.1	74.1	1775.	0.049	0.146	1.47	0.30	1.14
8	1830.	0.	17.8	0.9	26.309	48.3	487.	18.4	20.8	16.3	12.2	78.6	74.5	1775.	0.047	0.135	1.36	0.41	1.10

Figure 210. Test run 100-H13-008-0.0; research data; pump I, Test H13, sump 8, submergence 0.47D (Continued)

8	1832.	0.	17.9	0.9	26.351	48.2	487.	18.4	20.8	16.3	12.2	78.6	74.8	1775.	0.045	0.112	1.43	-0.64	1.14
9	1699.	0.	19.2	0.7	27.559	48.4	488.	18.3	20.8	16.3	11.8	78.7	72.4	1775.	0.047	0.117	0.97	-0.15	1.03
9	1702.	0.	19.3	0.8	27.662	48.5	488.	18.4	20.8	16.4	11.9	78.9	72.6	1775.	0.048	0.120	1.01	0.43	1.05
9	1702.	0.	19.3	0.8	27.702	48.4	488.	18.3	20.8	16.3	11.9	78.7	72.9	1775.	0.048	0.127	1.14	0.45	1.09
9	1700.	0.	19.3	0.7	27.680	47.9	488.	18.3	20.7	16.2	11.9	78.1	73.5	1775.	0.047	0.122	1.08	0.74	1.09
9	1698.	0.	19.3	0.7	27.598	47.7	488.	18.3	20.7	16.1	11.8	77.9	73.4	1775.	0.047	0.120	1.11	-1.60	1.21
10	1616.	0.	20.1	0.7	28.337	48.0	488.	18.3	20.8	16.2	11.6	78.2	71.3	1775.	0.048	0.133	1.11	0.71	1.08
10	1616.	0.	20.1	0.7	28.347	47.9	488.	18.3	20.7	16.2	11.6	78.1	71.5	1775.	0.048	0.174	1.78	-0.03	1.22
10	1615.	0.	20.1	0.7	28.367	47.8	488.	18.3	20.7	16.2	11.6	78.1	71.6	1775.	0.048	0.142	1.59	-1.34	1.20
10	1614.	0.	20.1	0.7	28.356	47.6	489.	18.3	20.7	16.1	11.6	77.7	72.0	1775.	0.048	0.138	1.50	0.21	1.23
10	1623.	0.	20.2	0.7	28.443	47.8	488.	18.3	20.7	16.2	11.7	78.1	72.2	1775.	0.050	0.126	1.62	0.37	1.23
11	1518.	0.	20.5	0.6	28.748	47.5	489.	18.3	20.7	16.0	11.0	77.4	68.8	1775.	0.051	0.207	1.36	-0.72	1.09
11	1517.	0.	20.6	0.6	28.807	47.5	490.	18.3	20.7	16.1	11.0	77.5	68.8	1775.	0.055	0.179	1.53	0.62	1.10
11	1514.	0.	20.6	0.6	28.785	47.5	489.	18.3	20.7	16.1	11.0	77.6	68.6	1775.	0.056	0.158	1.73	-0.27	1.10
11	1518.	0.	20.7	0.6	28.888	47.6	489.	18.3	20.7	16.1	11.1	77.7	68.9	1775.	0.055	0.168	1.87	0.64	1.18
11	1519.	0.	20.6	0.6	28.839	47.5	489.	18.3	20.7	16.1	11.1	77.5	69.0	1775.	0.051	0.154	1.83	-1.78	1.15
12	1403.	0.	21.3	0.5	29.381	46.8	490.	18.2	20.6	15.8	10.4	76.6	65.9	1775.	0.057	0.158	1.41	-0.27	1.18
12	1401.	0.	21.2	0.5	29.349	46.8	490.	18.2	20.6	15.8	10.4	76.6	65.8	1775.	0.062	0.187	1.84	-2.74	1.23
12	1403.	0.	21.2	0.5	29.351	46.5	491.	18.1	20.6	15.7	10.4	76.1	66.2	1775.	0.058	0.200	1.89	0.68	1.32
12	1403.	0.	21.3	0.5	29.421	46.6	490.	18.1	20.6	15.8	10.4	76.3	66.2	1775.	0.058	0.166	1.86	0.56	1.38
12	1400.	0.	21.3	0.5	29.378	46.4	490.	18.1	20.6	15.7	10.4	76.2	66.3	1775.	0.055	0.166	2.03	0.56	1.36
13	1296.	0.	21.3	0.4	29.316	45.2	491.	18.0	20.5	15.3	9.6	74.7	62.8	1775.	0.064	0.184	2.23	0.11	1.45
13	1302.	0.	21.4	0.4	29.420	45.3	491.	18.0	20.5	15.3	9.7	74.8	63.2	1775.	0.058	0.176	1.92	0.29	1.55
13	1301.	0.	21.4	0.4	29.439	45.4	491.	18.0	20.5	15.3	9.7	74.9	63.1	1775.	0.060	0.170	2.02	0.25	1.46
13	1303.	0.	21.5	0.4	29.540	45.5	491.	18.0	20.5	15.4	9.7	75.1	63.2	1775.	0.056	0.211	1.97	-0.43	1.42
13	1302.	0.	21.5	0.4	29.550	45.5	491.	18.0	20.5	15.4	9.7	75.0	63.3	1775.	0.058	0.171	1.87	0.49	1.61
14	1200.	0.	21.0	0.4	29.014	43.7	491.	17.8	20.2	14.8	8.8	72.9	59.7	1775.	0.070	0.222	2.97	-0.53	2.40
14	1204.	0.	21.1	0.4	29.056	43.7	491.	17.8	20.2	14.8	8.8	73.0	59.9	1775.	0.065	0.209	2.94	-0.66	2.26
14	1206.	0.	21.3	0.4	29.247	44.1	491.	17.8	20.3	14.9	8.9	73.4	59.9	1775.	0.064	0.204	2.81	-0.33	2.21
14	1205.	0.	21.3	0.4	29.267	43.9	491.	17.8	20.3	14.8	8.9	73.2	60.1	1775.	0.067	0.215	2.64	-0.22	1.97
14	1201.	0.	21.2	0.4	29.194	43.6	491.	17.8	20.3	14.7	8.9	72.8	60.1	1775.	0.068	0.200	2.97	-0.31	2.30
15	1104.	0.	21.3	0.3	29.206	43.3	491.	17.7	20.2	14.6	8.2	72.5	55.7	1775.	0.079	0.243	3.74	-0.71	2.06
15	1100.	0.	21.2	0.3	29.084	43.0	491.	17.7	20.1	14.5	8.1	72.1	55.7	1775.	0.076	0.252	3.58	-0.70	2.09
15	1103.	0.	21.3	0.3	29.246	43.2	491.	17.7	20.2	14.6	8.2	72.4	55.9	1775.	0.076	0.260	3.55	-0.33	2.16
15	1109.	0.	21.4	0.3	29.299	43.3	491.	17.7	20.2	14.6	8.2	72.5	56.2	1775.	0.079	0.221	3.92	-0.35	2.02
15	1105.	0.	21.4	0.3	29.277	43.2	491.	17.7	20.2	14.6	8.2	72.4	56.0	1775.	0.074	0.217	3.56	-0.51	2.03
16	1012.	0.	21.9	0.3	29.786	43.5	490.	17.7	20.2	14.7	7.6	73.0	51.8	1775.	0.083	0.272	4.00	-0.54	2.40
16	1012.	0.	21.8	0.3	29.676	43.4	490.	17.7	20.1	14.7	7.6	72.9	51.8	1775.	0.089	0.279	3.67	-0.49	2.25
16	1008.	0.	21.8	0.3	29.714	43.4	490.	17.7	20.1	14.7	7.6	72.9	51.6	1775.	0.082	0.269	3.71	-0.79	2.46
16	1011.	0.	21.9	0.3	29.725	43.5	490.	17.7	20.1	14.7	7.6	73.0	51.7	1775.	0.086	0.332	3.17	-1.10	2.15
16	1008.	0.	21.8	0.3	29.654	43.4	490.	17.7	20.1	14.7	7.6	72.8	51.6	1775.	0.077	0.236	3.39	-0.81	2.25
17	856.	0.	23.3	0.2	31.070	44.3	490.	17.8	20.2	15.0	6.7	74.1	44.8	1775.	0.090	0.239	4.34	-0.50	2.31
17	862.	0.	23.3	0.2	31.133	44.4	490.	17.8	20.3	15.0	6.8	74.0	45.2	1775.	0.084	0.279	4.56	-0.70	2.48
17	859.	0.	23.3	0.2	31.102	44.4	490.	17.8	20.3	15.0	6.8	74.0	45.1	1775.	0.088	0.279	4.25	-0.33	2.22
17	860.	0.	23.3	0.2	31.142	44.4	490.	17.8	20.3	15.0	6.8	74.1	45.1	1775.	0.087	0.273	4.43	-0.62	2.46
17	857.	0.	23.3	0.2	31.131	44.4	490.	17.8	20.3	15.0	6.7	74.2	44.9	1775.	0.086	0.287	4.27	-0.76	2.34

Figure 210. (Concluded)

READ NO	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HPM INPUT MOTOR HP (HORSEPOWER)	HPS SHAFT HP (HORSEPOWER)	HPW WATER HP (HORSEPOWER)	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2914	2.6	1.2	2.2	8.556	37.4	481	17.7	19.7	12.6	6.2	64.1	48.7	1775.	0.043	0.120	0.88	3.06	3.74
1	2914	2.6	1.2	2.2	8.396	37.4	481	17.7	19.7	12.6	6.2	64.1	48.9	1775.	0.039	0.092	0.71	2.57	3.71
1	2912	2.6	1.1	2.2	8.345	37.3	481	17.7	19.7	12.6	6.1	63.9	48.7	1775.	0.043	0.117	0.80	3.14	3.71
1	2916	2.6	1.2	2.2	8.390	37.3	481	17.7	19.8	12.6	6.2	63.9	49.0	1775.	0.043	0.109	0.79	3.06	3.69
1	2907	2.6	1.2	2.2	8.384	37.4	481	17.7	19.8	12.6	6.2	63.9	48.8	1775.	0.042	0.109	0.76	3.31	3.68
2	2754	2.6	4.7	2.0	11.712	40.3	482	18.1	20.2	13.6	8.2	67.3	59.9	1775.	0.046	0.133	0.80	3.51	3.75
2	2754	2.6	4.8	2.0	11.719	40.2	482	18.1	20.2	13.6	8.2	67.3	60.0	1775.	0.049	0.139	0.76	3.08	3.71
2	2748	2.6	4.8	2.0	11.756	40.2	482	18.1	20.2	13.6	8.2	67.4	60.1	1775.	0.050	0.141	0.72	3.01	3.71
2	2755	2.6	4.8	2.0	11.724	40.2	482	18.1	20.2	13.6	8.2	67.4	60.1	1775.	0.045	0.131	0.71	3.19	3.69
2	2749	2.6	4.7	2.0	11.707	40.2	481	18.1	20.2	13.6	8.1	67.4	59.8	1775.	0.049	0.122	0.75	3.24	3.75
3	2601	2.6	7.9	1.8	14.626	42.4	482	18.3	20.5	14.3	9.6	70.0	67.1	1775.	0.056	0.152	0.59	2.78	3.71
3	2602	2.6	7.9	1.8	14.606	42.4	482	18.3	20.5	14.3	9.6	69.9	67.1	1775.	0.054	0.135	0.59	2.22	3.71
3	2601	2.6	7.9	1.8	14.650	42.4	482	18.3	20.5	14.3	9.6	70.0	67.2	1775.	0.050	0.133	0.62	3.35	3.72
3	2598	2.6	7.9	1.8	14.630	42.3	482	18.3	20.5	14.3	9.6	69.8	67.1	1775.	0.055	0.158	0.48	2.93	3.71
3	2598	2.6	7.9	1.8	14.627	42.4	482	18.3	20.5	14.3	9.6	69.9	67.0	1775.	0.066	0.167	0.58	3.50	3.71
4	2457	2.6	10.6	1.6	17.126	44.0	481	18.5	20.7	14.9	10.6	72.0	71.6	1775.	0.059	0.168	0.51	3.16	3.68
4	2457	2.6	10.6	1.6	17.186	44.0	481	18.5	20.6	14.9	10.7	72.0	71.8	1775.	0.045	0.147	0.52	3.50	3.72
4	2461	2.6	10.6	1.6	17.201	44.0	480	18.5	20.6	14.9	10.7	72.0	72.0	1775.	0.054	0.131	0.46	3.42	3.71
4	2460	2.6	10.6	1.6	17.150	44.0	481	18.5	20.6	14.9	10.7	72.0	71.7	1775.	0.067	0.171	0.55	3.06	3.71
4	2460	2.6	10.6	1.6	17.210	44.0	481	18.5	20.6	14.9	10.7	72.1	71.9	1775.	0.057	0.177	0.48	3.48	3.72
5	2300	2.6	13.4	1.4	19.722	45.5	481	18.7	20.9	15.4	11.5	73.8	74.5	1775.	0.056	0.158	0.49	3.52	3.70
5	2302	2.6	13.3	1.4	19.705	45.5	481	18.7	20.9	15.4	11.5	73.7	74.5	1775.	0.064	0.196	0.58	2.52	3.71
5	2302	2.6	13.3	1.4	19.715	45.5	481	18.7	20.9	15.4	11.5	73.7	74.6	1775.	0.064	0.185	0.54	3.38	3.73
5	2303	2.6	13.4	1.4	19.756	45.5	481	18.7	20.9	15.4	11.5	73.7	74.8	1775.	0.060	0.166	0.53	3.24	3.71
5	2300	2.6	13.4	1.4	19.722	45.5	481	18.7	20.9	15.4	11.5	73.8	74.5	1775.	0.054	0.163	0.58	3.20	3.72
6	2204	2.6	15.0	1.3	21.250	46.1	481	18.8	21.0	15.6	11.8	74.4	76.0	1775.	0.049	0.132	0.40	3.42	3.71
6	2205	2.6	15.0	1.3	21.241	46.1	481	18.8	21.0	15.6	11.8	74.4	75.9	1775.	0.051	0.146	0.44	2.87	3.70
6	2205	2.6	15.0	1.3	21.231	46.2	481	18.8	21.0	15.6	11.8	74.4	75.9	1775.	0.077	0.196	0.47	3.42	3.71
6	2205	2.6	15.0	1.3	21.231	46.1	481	18.8	21.0	15.6	11.8	74.4	75.9	1775.	0.050	0.136	0.48	3.20	3.71
6	2203	2.6	15.0	1.3	21.239	46.1	481	18.8	21.0	15.6	11.8	74.4	75.9	1775.	0.056	0.162	0.48	3.30	3.69
7	2080	2.6	17.0	1.1	23.112	46.6	481	18.8	21.0	15.7	12.2	75.0	77.2	1775.	0.072	0.191	0.42	3.48	3.67
7	2078	2.6	17.0	1.1	23.100	46.6	481	18.8	21.0	15.7	12.1	75.1	77.1	1775.	0.067	0.180	0.43	3.45	3.67
7	2081	2.6	17.0	1.1	23.143	46.6	481	18.8	21.0	15.[illegible]	12.[illegible]	75.0	77.3	1775.	0.067	0.181	0.42	3.49	3.67
7	2072	2.6	17.0	1.1	23.144	46.7	481	18.8	21.0	15.8	12.1	75.1	76.9	1775.	0.057	0.144	0.41	3.49	3.68
7	2076	2.6	17.0	1.1	23.148	46.6	481	18.8	21.0	15.8	12.1	75.1	77.1	1775.	0.055	0.167	0.42	3.42	3.65
8	1989	2.6	18.3	1.0	24.356	46.8	481	18.8	21.0	15.8	12.2	75.3	77.5	1775.	0.048	0.137	0.44	2.98	3.66
8	1989	2.6	18.3	1.0	24.376	46.8	481	18.8	21.0	15.8	12.3	75.4	77.5	1775.	0.053	0.147	0.42	3.32	3.68
8	1991	2.6	18.3	1.0	24.358	46.8	481	18.8	21.0	15.8	12.3	75.3	77.6	1775.	0.053	0.156	0.42	3.07	3.65
8	1989	2.6	18.3	1.0	24.356	46.8	481	18.8	21.0	15.8	12.2	75.3	77.5	1775.	0.057	0.165	0.41	3.51	3.69

Figure 211. Test run 100-H14-008-2.6; research data; pump 1, Test H14, sump 8, submergence 2.47D (Continued)

8	1987.	2.6	18.3	1.0	24.344	46.8	481.	18.8	21.0	15.8	12.2	75.3	77.3	1775.	0.064	0.163	0.41	3.55	3.69
9	1891.	2.6	19.8	0.9	25.718	46.9	482.	18.8	21.1	15.8	12.3	75.2	77.6	1775.	0.055	0.132	0.43	3.25	3.65
9	1886.	2.6	19.8	0.9	25.743	46.9	482.	18.8	21.1	15.8	12.3	75.2	77.5	1775.	0.059	0.167	0.48	3.48	3.68
9	1881.	2.6	19.8	0.9	25.738	46.9	482.	18.8	21.1	15.8	12.2	75.3	77.2	1775.	0.052	0.128	0.52	3.37	3.69
9	1883.	2.6	19.8	0.9	25.750	46.8	482.	18.8	21.1	15.8	12.3	75.1	77.5	1775.	0.057	0.147	0.50	3.44	3.70
9	1881.	2.6	19.8	0.9	25.758	46.8	482.	18.8	21.1	15.8	12.2	75.2	77.4	1775.	0.047	0.120	0.46	3.53	3.68
10	1782.	2.6	21.2	0.8	26.984	46.9	481.	18.8	21.0	15.8	12.2	75.3	76.7	1775.	0.046	0.142	0.44	3.18	3.69
10	1777.	2.6	21.2	0.8	26.989	46.9	481	18.8	21.0	15.8	12.1	75.3	76.5	1775.	0.044	0.118	0.44	3.13	3.69
10	1779.	2.6	21.2	0.8	26.971	46.9	481	18.8	21.1	15.9	12.1	75.4	76.5	1775.	0.046	0.138	0.53	3.46	3.70
10	1775.	2.6	21.2	0.8	26.977	47.0	481.	18.8	21.0	15.9	12.1	75.4	76.3	1775.	0.046	0.135	0.50	3.51	3.70
10	1779.	2.6	21.2	0.8	26.971	47.0	481.	18.8	21.0	·15.9	12.1	75.4	76.4	1775.	0.042	0.117	0.49	3.55	3.71
11	1683.	2.6	22.2	0.7	27.955	47.0	481.	18.8	21.0	15.9	11.9	75.6	74.9	1775.	0.057	0.163	0.44	3.19	3.71
11	1688.	2.6	22.2	0.7	27.969	47.0	481	18.8	21.0	15.9	11.9	75.6	75.1	1775.	0.058	0.148	0.48	3.57	3.71
11	1688.	2.6	22.2	0.7	27.949	47.0	481.	18.8	21.0	15.9	11.9	75.5	75.1	1775.	0.052	0.156	0.47	3.56	3.72
11	1685.	2.6	22.3	0.7	27.987	47.0	481.	18.8	21.0	15.9	11.9	75.6	75.0	1775.	0.052	0.139	0.46	3.57	3.72
11	1688.	2.6	22.3	0.7	27.999	47.0	481.	18.8	21.0	15.9	11.9	75.6	75.2	1775.	0.059	0.175	0.44	3.56	3.71
12	1599.	2.6	23.1	0.7	28.733	47.1	481.	18.8	21.0	15.9	11.6	75.8	72.9	1775.	0.062	0.164	0.44	3.45	3.72
12	1604.	2.6	23.0	0.7	28.697	47.1	481.	18.8	21.0	15.9	11.6	75.7	73.1	1775.	0.048	0.157	0.46	3.53	3.71
12	1601.	2.6	23.0	0.7	28.715	47.1	481	18.8	21.0	15.9	11.6	75.7	73.0	1775.	0.049	0.151	0.43	3.54	3.71
12	1608.	2.6	23.0	0.7	28.701	47.1	481.	18.8	21.0	15.9	11.7	75.7	73.3	1775.	0.056	0.141	0.44	3.49	3.71
12	1600.	2.6	23.0	0.7	28.704	47.1	481.	18.8	21.0	15.9	11.6	75.8	72.9	1775.	0.046	0.137	0.46	3.55	3.73
13	1505.	2.6	23.8	0.6	29.408	47.1	480	18.9	21.0	15.9	11.2	75.8	70.3	1775.	0.059	0.170	0.50	3.44	3.70
13	1502.	2.6	23.8	0.6	29.395	47.2	480.	18.8	21.0	15.9	11.2	75.9	70.0	1775.	0.048	0.138	0.51	3.50	3.73
13	1503.	2.6	23.8	0.6	29.386	47.1	480.	18.8	21.0	15.9	11.2	75.8	70.2	1775.	0.051	0.150	0.53	3.51	3.73
13	1501.	2.6	23.8	0.6	29.394	47.0	480	18.8	21.0	15.9	11.2	75.7	70.2	1775.	0.049	0.146	0.51	3.53	3.74
13	1503.	2.6	23.8	0.6	29.396	47.1	480	18.9	21.0	15.9	11.2	75.8	70.1	1775.	0.049	0.158	0.50	3.52	3.78
14	1407.	2.6	24.3	0.5	29.834	46.8	481.	18.8	21.0	15.8	10.6	75.4	67.1	1775.	0.058	0.169	0.63	3.45	3.81
14	1400.	2.6	24.3	0.5	29.838	46.8	481	18.8	21.0	15.8	10.6	75.4	66.7	1775.	0.051	0.161	0.63	3.45	3.80
14	1405.	2.6	24.3	0.5	29.832	46.8	481	18.8	21.0	15.8	10.6	75.3	67.0	1775.	0.047	0.146	0.61	3.47	3.84
14	1402.	2.6	24.3	0.5	29.820	46.8	481	18.8	21.0	15.8	10.6	75.3	66.8	1775.	0.055	0.191	0.65	3.44	3.80
14	1400.	2.6	24.3	0.5	29.808	46.8	481.	18.8	21.0	15.8	10.6	75.3	66.7	1775.	0.050	0.144	0.64	3.42	3.81
15	1255.	2.6	24.4	0.4	29.849	45.1	482	18.6	20.8	15.2	9.5	73.4	62.2	1775.	0.070	0.224	1.20	3.07	4.23
15	1254.	2.6	24.5	0.4	29.868	45.1	482	18.6	20.8	15.2	9.5	73.4	62.1	1775.	0.066	0.190	1.10	3.14	4.25
15	1251.	2.6	24.4	0.4	29.836	45.0	482	18.6	20.8	15.2	9.4	73.3	62.0	1775.	0.066	0.207	1.11	3.16	4.25
15	1252.	2.6	24.4	0.4	29.827	45.0	482	18.6	20.8	15.2	9.4	73.2	62.1	1775.	0.066	0.180	1.11	2.97	4.16
15	1252.	2.6	24.4	0.4	29.847	45.0	482	18.6	20.8	15.2	9.4	73.2	62.1	1775.	0.072	0.241	1.12	3.10	4.16
16	1107.	2.6	24.2	0.3	29.478	43.2	483.	18.4	20.6	14.6	8.2	71.1	56.5	1775.	0.107	0.334	1.94	2.66	4.59
16	1107.	2.6	24.2	0.3	29.488	43.3	483.	18.4	20.6	14.6	8.3	71.2	56.4	1775.	0.099	0.297	1.90	2.59	4.66
16	1109.	2.6	24.2	0.3	29.499	43.3	483	18.4	20.6	14.6	8.3	71.1	56.5	1775.	0.106	0.329	1.93	2.67	4.66
16	1107.	2.6	24.2	0.3	29.488	43.3	482	18.4	20.6	14.6	[illegible]	71.1	56.4	1775.	0.099	0.291	1.73	2.71	4.50
16	1103.	2.6	24.2	0.3	29.506	43.3	483	18.4	20.6	14.6	8.2	71.1	56.3	1775.	0.105	0.417	1.86	2.40	4.50
17	910.	2.6	25.5	0.2	30.755	43.7	483.	18.4	20.6	14.8	7.1	71.6	47.9	1775.	0.115	0.352	2.01	2.16	5.03
17	906.	2.6	25.5	0.2	30.743	43.7	482	18.4	20.6	14.8	7.0	71.7	47.6	1775.	0.130	0.436	2.25	2.41	4.76
17	906.	2.6	25.5	0.2	30.743	43.7	482	18.4	20.6	14.8	7.0	71.7	47.7	1775.	0.109	0.341	1.83	2.45	4.79
17	907	2.6	25.6	0.2	30.773	43.7	483.	18.4	20.6	14.8	7.1	71.7	47.7	1775.	0.108	0.310	1.96	1.85	4.83
17	907.	2.6	25.6	0.2	30.773	43.7	482	18.4	20.6	14.8	7.1	71.8	47.8	1775.	0.115	0.418	2.01	2.34	4.64

Figure 211. (Concluded)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2857.	1.3	1.1	2.1	9.472	38.5	483.	16.5	18.5	13.0	6.8	70.2	52.6	1775.	0.044	0.138	0.85	2.16	2.41
1	2863.	1.3	1.0	2.1	9.469	38.4	483.	16.5	18.5	13.0	6.9	70.2	52.8	1775.	0.045	0.149	1.03	2.06	2.40
1	2863.	1.3	1.1	2.1	9.501	38.5	483.	16.5	18.5	13.0	6.9	70.2	52.9	1775.	0.044	0.123	0.80	1.98	2.40
1	2862.	1.3	1.1	2.1	9.510	38.4	483.	16.5	18.5	13.0	6.9	70.1	53.0	1775.	0.042	0.106	0.74	2.18	2.41
1	2866.	1.3	1.1	2.1	9.499	38.6	483.	16.5	18.5	13.1	6.9	70.4	52.7	1775.	0.049	0.153	1.26	2.08	2.44
2	2693.	1.3	4.6	1.9	12.800	40.7	483.	16.8	18.8	13.7	8.7	72.9	63.4	1775.	0.042	0.103	0.62	2.22	2.40
2	2695.	1.3	4.6	1.9	12.785	40.8	483.	16.8	18.9	13.8	8.7	73.1	63.2	1775.	0.047	0.127	0.73	2.06	2.43
2	2704.	1.3	4.6	1.9	12.751	40.7	483.	16.8	18.8	13.7	8.7	73.0	63.4	1775.	0.041	0.119	0.63	2.23	2.41
2	2698.	1.3	4.6	1.9	12.795	40.8	483.	16.8	18.9	13.8	8.7	73.1	63.3	1775.	0.044	0.127	0.64	2.22	2.44
2	2700.	1.3	4.6	1.9	12.809	40.8	483.	16.8	18.9	13.8	8.7	73.2	63.4	1775.	0.044	0.131	0.67	2.23	2.42
3	2552.	1.3	7.5	1.7	15.497	42.8	483.	17.0	19.1	14.5	10.0	75.8	69.1	1775.	0.041	0.114	0.63	2.28	2.43
3	2552.	1.3	7.5	1.7	15.468	42.7	483.	17.0	19.1	14.4	10.0	75.6	69.2	1775.	0.041	0.099	0.64	2.20	2.47
3	2555.	1.3	7.4	1.7	15.416	42.6	483.	17.0	19.1	14.4	10.0	75.6	69.1	1775.	0.047	0.144	0.66	2.16	2.41
3	2546	1.3	7.4	1.7	15.411	42.6	483.	17.0	19.1	14.4	9.9	75.5	68.9	1775.	0.042	0.115	0.61	2.09	2.42
3	2555.	1.3	7.5	1.7	15.500	42.7	483.	17.0	19.1	14.4	10.0	75.7	69.3	1775.	0.039	0.106	0.53	2.25	2.40
4	2403.	1.3	10.2	1.5	17.988	44.3	483.	17.2	19.3	15.0	10.9	77.6	73.0	1775.	0.051	0.145	0.52	1.89	2.41
4	2405.	1.3	10.2	1.5	17.971	44.3	483.	17.2	19.3	15.0	10.9	77.5	73.0	1775.	0.043	0.120	0.51	2.21	2.44
4	2397.	1.3	10.2	1.5	18.001	44.4	483.	17.2	19.3	15.0	10.9	77.7	72.6	1775.	0.045	0.126	0.57	2.19	2.41
4	2408.	1.3	10.2	1.5	17.984	44.4	483.	17.2	19.3	15.0	10.9	77.7	72.9	1775.	0.046	0.125	0.59	2.12	2.44
4	2404.	1.3	10.2	1.5	18.009	44.4	483.	17.2	19.3	15.0	10.9	77.6	72.9	1775.	0.051	0.158	0.58	2.22	2.44
5	2294.	1.3	12.0	1.4	19.665	45.2	483.	17.3	19.4	15.3	11.4	78.7	74.6	1775.	0.043	0.109	0.51	2.28	2.43
5	2302.	1.3	12.0	1.4	19.635	45.2	483.	17.3	19.4	15.3	11.4	78.7	74.8	1775.	0.047	0.123	0.67	2.28	2.44
5	2301.	1.3	12.0	1.4	19.664	45.2	483.	17.3	19.4	15.3	11.4	78.7	74.8	1775.	0.039	0.109	1.02	2.27	2.43
5	2296.	1.3	12.0	1.4	19.678	45.2	483.	17.3	19.4	15.3	11.4	78.7	74.7	1775.	0.044	0.123	1.07	2.16	2.42
5	2300.	1.3	12.0	1.4	19.642	45.2	483.	17.3	19.4	15.3	11.4	78.7	74.8	1775.	0.055	0.147	0.70	2.06	2.44
6	2189.	1.3	13.9	1.2	21.473	46.0	483.	17.4	19.5	15.5	11.9	79.6	76.5	1775.	0.053	0.154	0.49	2.32	2.42
6	2187.	1.3	13.9	1.2	21.481	45.9	483.	17.4	19.5	15.5	11.9	79.6	76.5	1775.	0.048	0.140	0.49	2.32	2.41
6	2192.	1.3	13.9	1.2	21.457	45.9	483.	17.4	19.5	15.5	11.9	79.5	76.6	1775.	0.044	0.127	0.52	2.20	2.41
6	2188.	1.3	14.0	1.2	21.492	46.0	483.	17.4	19.5	15.5	11.9	79.6	76.5	1775.	0.047	0.119	0.51	2.27	2.41
6	2189.	1.3	14.0	1.2	21.513	46.1	483.	17.4	19.5	15.6	11.9	79.7	76.4	1775.	0.050	0.143	0.52	2.26	2.42
7	2097.	1.3	15.4	1.1	22.851	46.4	484.	17.5	19.6	15.7	12.1	79.8	77.3	1775.	0.047	0.125	0.49	1.83	2.43
7	2104.	1.3	15.4	1.1	22.808	46.3	484.	17.5	19.6	15.6	12.1	79.7	77.6	1775.	0.046	0.121	0.50	2.16	2.44
7	2100.	1.3	15.4	1.1	22.804	46.3	484.	17.5	19.6	15.6	12.1	79.7	77.4	1775.	0.043	0.125	0.52	2.23	2.44
7	2098.	1.3	15.4	1.1	22.822	46.3	484.	17.5	19.6	15.6	12.1	79.8	77.4	1775.	0.051	0.137	0.54	2.30	2.46
7	2098.	1.3	15.4	1.1	22.822	46.3	484.	17.5	19.6	15.6	12.1	79.6	77.4	1775.	0.044	0.125	0.50	2.28	2.44
8	1996.	1.3	16.9	1.0	24.234	46.6	483.	17.5	19.7	15.7	12.2	80.1	77.7	1775.	0.045	0.125	0.53	2.30	2.41
8	1992.	1.3	16.9	1.0	24.229	46.5	483.	17.5	19.6	15.7	12.2	80.1	77.6	1775.	0.041	0.134	0.54	2.22	2.42
8	1990.	1.3	16.9	1.0	24.257	46.5	484.	17.5	19.7	15.7	12.2	80.0	77.6	1775.	0.041	0.112	0.51	2.05	2.41
8	1993.	1.3	17.0	1.0	24.280	46.6	484.	17.5	19.7	15.7	12.2	80.1	77.7	1775.	0.043	0.127	0.51	2.28	2.40

Figure 212. Test run 100-H15-008-1.3; research data; pump 1, Test H15, sump 8, submergence 1.47D (Continued)

8	1993.	1.3	16.9	1.0	24.270	46.6	484.	17.5	19.7	15.8	12.2	80.1	77.6	1775.	0.043	0.113	0.55	2.19	2.41
9	1901.	1.3	18.3	0.9	25.548	46.7	484.	17.5	19.7	15.8	12.3	80.2	77.7	1775.	0.043	0.145	0.53	2.28	2.41
9	1904.	1.3	18.3	0.9	25.530	46.7	484.	17.5	19.7	15.8	12.3	80.1	77.9	1775.	0.039	0.135	0.56	2.18	2.44
9	1900.	1.3	18.3	0.9	25.557	46.7	484.	17.5	19.7	15.8	12.3	80.2	77.7	1775.	0.041	0.124	0.47	2.28	2.44
9	1901.	1.3	18.3	0.9	25.528	46.6	484.	17.5	19.7	15.7	12.3	80.0	77.9	1775.	0.039	0.114	0.49	2.30	2.42
9	1901.	1.3	18.3	0.9	25.538	46.7	484.	17.5	19.7	15.8	12.3	80.1	77.8	1775.	0.046	0.131	0.53	2.28	2.43
10	1802.	1.3	19.6	0.8	26.752	46.9	484.	17.5	19.7	15.8	12.2	80.3	77.0	1775.	0.042	0.142	0.73	2.26	2.44
10	1799.	1.3	19.6	0.8	26.760	46.9	484.	17.5	19.7	15.8	12.2	80.4	76.8	1775.	0.044	0.123	0.57	2.26	2.45
10	1803.	1.3	19.6	0.8	26.753	46.8	484.	17.5	19.7	15.8	12.2	80.4	77.0	1775.	0.044	0.116	0.54	2.22	2.46
10	1799.	1.3	19.6	0.8	26.750	46.9	484.	17.5	19.7	15.8	12.2	80.4	76.8	1775.	0.042	0.114	0.53	2.29	2.42
10	1797.	1.3	19.6	0.8	26.778	46.9	485.	17.5	19.7	15.8	12.2	80.3	76.8	1775.	0.043	0.137	0.53	2.10	2.44
11	1702.	1.3	20.9	0.8	27.922	47.1	484.	17.6	19.7	15.9	12.0	80.6	75.4	1775.	0.045	0.122	0.60	2.22	2.47
11	1706.	1.3	20.8	0.8	27.855	47.2	484.	17.6	19.8	15.9	12.0	80.7	75.4	1775.	0.047	0.120	0.63	2.26	2.47
11	1703.	1.3	20.9	0.8	27.912	47.1	484.	17.6	19.8	15.9	12.0	80.6	75.4	1775.	0.045	0.146	0.54	2.26	2.45
11	1704.	1.3	20.8	0.8	27.893	47.2	485.	17.6	19.8	15.9	12.0	80.7	75.4	1775.	0.046	0.138	0.53	2.29	2.51
11	1703.	1.3	20.8	0.8	27.892	47.1	485.	17.6	19.8	15.9	12.0	80.6	75.4	1775.	0.046	0.141	0.52	2.29	2.50
12	1606.	1.3	21.8	0.7	28.729	47.3	485.	17.6	19.8	16.0	11.7	80.7	73.0	1775.	0.047	0.151	0.54	2.25	2.47
12	1606.	1.3	21.7	0.7	28.699	47.2	485.	17.6	19.8	15.9	11.7	80.7	73.1	1775.	0.047	0.158	0.59	2.18	2.50
12	1602.	1.3	21.7	0.7	28.686	47.2	485.	17.6	19.8	16.0	11.6	80.7	72.8	1775.	0.054	0.182	0.60	2.18	2.49
12	1606.	1.3	21.7	0.7	28.699	47.2	485.	17.6	19.8	16.0	11.7	80.7	73.0	1775.	0.053	0.147	0.54	2.27	2.53
12	1603.	1.3	21.7	0.7	28.657	47.2	485.	17.6	19.8	15.9	11.6	80.7	72.8	1775.	0.049	0.131	0.55	2.20	2.47
13	1503.	1.3	22.5	0.6	29.366	47.3	485.	17.6	19.8	16.0	11.2	80.8	69.9	1775.	0.051	0.175	0.65	2.26	2.49
13	1502.	1.3	22.5	0.6	29.355	47.1	485.	17.6	19.8	15.9	11.1	80.6	70.0	1775.	0.050	0.168	0.68	2.25	2.49
13	1504.	1.3	22.5	0.6	29.377	47.2	485.	17.6	19.8	16.0	11.2	80.7	70.0	1775.	0.053	0.153	0.66	2.26	2.51
13	1501.	1.3	22.5	0.6	29.384	47.2	485.	17.6	19.8	16.0	11.2	80.7	69.9	1775.	0.052	0.159	0.62	2.26	2.53
13	1504.	1.3	22.5	0.6	29.407	47.3	485.	17.6	19.8	16.0	11.2	80.7	70.0	1775.	0.052	0.146	0.61	2.26	2.54
14	1401.	1.3	22.9	0.5	29.749	46.9	486.	17.6	19.8	15.8	10.5	80.1	66.5	1775.	0.058	0.172	0.95	2.18	2.67
14	1405.	1.3	22.9	0.5	29.732	46.8	486.	17.5	19.8	15.8	10.6	80.0	66.8	1775.	0.057	0.164	0.95	2.14	2.55
14	1406.	1.3	23.0	0.5	29.783	46.8	486.	17.5	19.8	15.8	10.6	80.1	66.9	1775.	0.058	0.178	0.88	2.22	2.59
14	1403.	1.3	23.0	0.5	29.791	46.9	486.	17.6	19.8	15.8	10.6	80.0	66.7	1775.	0.059	0.181	0.86	2.22	2.59
14	1404.	1.3	23.0	0.5	29.811	47.0	486.	17.6	19.8	15.9	10.6	80.3	66.6	1775.	0.054	0.175	0.82	2.20	2.55
15	1260.	1.3	23.1	0.4	29.772	45.0	486.	17.3	19.5	15.2	9.5	78.0	62.3	1775.	0.076	0.234	1.92	1.94	2.87
15	1255.	1.3	23.0	0.4	29.729	45.0	486.	17.3	19.5	15.2	9.4	77.9	62.0	1775.	0.080	0.319	1.84	1.92	2.93
15	1258.	1.3	23.1	0.4	29.821	45.1	486.	17.3	19.5	15.2	9.5	78.0	62.2	1775	0.073	0.235	1.92	1.93	2.91
15	1261.	1.3	23.1	0.4	29.823	45.1	486.	17.3	19.6	15.3	9.5	78.0	62.3	1775.	0.079	0.279	1.81	1.73	3.12
15	1255.	1.3	23.0	0.4	29.719	44.9	486.	17.3	19.5	15.2	9.4	77.7	62.1	1775.	0.081	0.228	1.95	1.80	2.92
16	1103.	1.3	22.9	0.3	29.496	43.3	485.	17.1	19.3	14.6	8.2	75.7	56.3	1775.	0.104	0.283	3.21	1.31	3.43
16	1102.	1.3	22.8	0.3	29.455	43.2	485.	17.1	19.3	14.6	8.2	75.8	56.2	1775.	0.103	0.326	3.04	1.38	3.41
16	1102.	1.3	22.9	0.3	29.475	43.3	485	17.1	19.3	14.6	8.2	75.8	56.2	1775.	0.108	0.312	3.21	1.39	3.48
16	1103.	1.3	22.8	0.3	29.456	43.2	485.	17.1	19.3	14.6	8.2	75.7	56.3	1775.	0.111	0.301	3.29	1.22	3.26
16	1103.	1.3	22.8	0.3	29.416	43.2	485.	17.1	19.3	14.6	8.2	75.7	56.2	1775.	0.104	0.276	3.19	1.07	3.45
17	905.	1.3	24.4	0.2	30.882	43.8	487.	17.2	19.4	14.8	7.1	76.2	47.8	1775.	0.117	0.326	3.86	0.95	3.53
17	905.	1.3	24.3	0.2	30.862	43.7	487.	17.2	19.4	14.8	7.1	76.1	47.8	1775.	0.116	0.399	3.82	1.11	3.72
17	905.	1.3	24.4	0.2	30.872	43.7	486.	17.2	19.4	14.8	7.1	76.1	47.7	1775.	0.117	0.385	3.94	1.20	3.66
17	900.	1.3	24.3	0.2	30.830	43.8	486.	17.2	19.4	14.8	7.0	76.2	47.4	1775.	0.121	0.326	4.02	1.09	3.65
17	902.	1.3	24.4	0.2	30.881	43.8	486.	17.2	19.4	14.8	7.0	76.2	47.6	1775.	0.134	0.350	3.87	0.80	3.43

Figure 212. (Concluded)

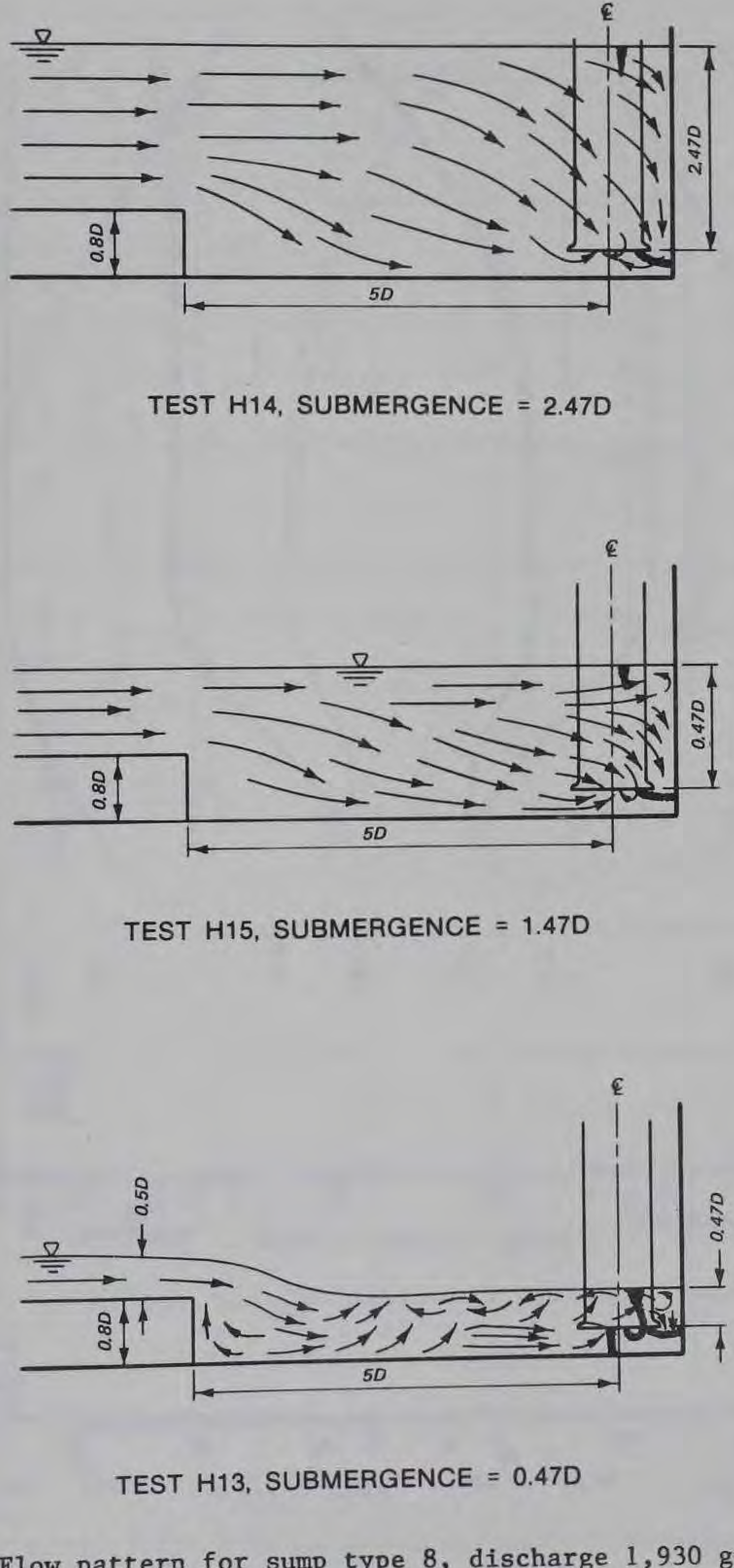


Figure 213. Flow pattern for sump type 8, discharge 1,930 gpm (4.3 cfs), bell diam D = 1.3 ft, $Q/g^{1/2}D^{5/2} = 0.4$

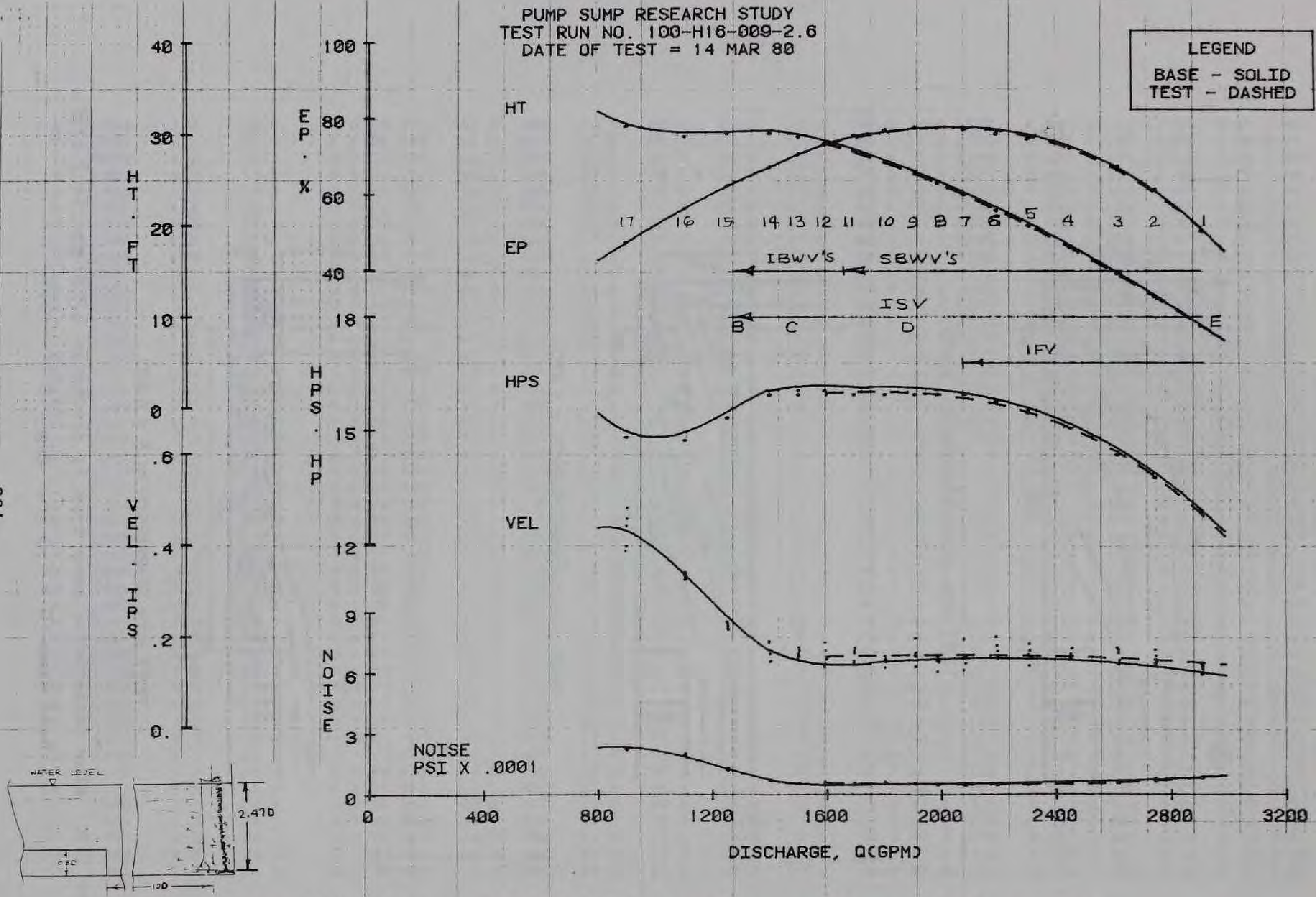


Figure 214. Test run 100-H16-009-2.6; performance characteristics curves; pump 1, Test H16, sump 9, submergence 2.47D

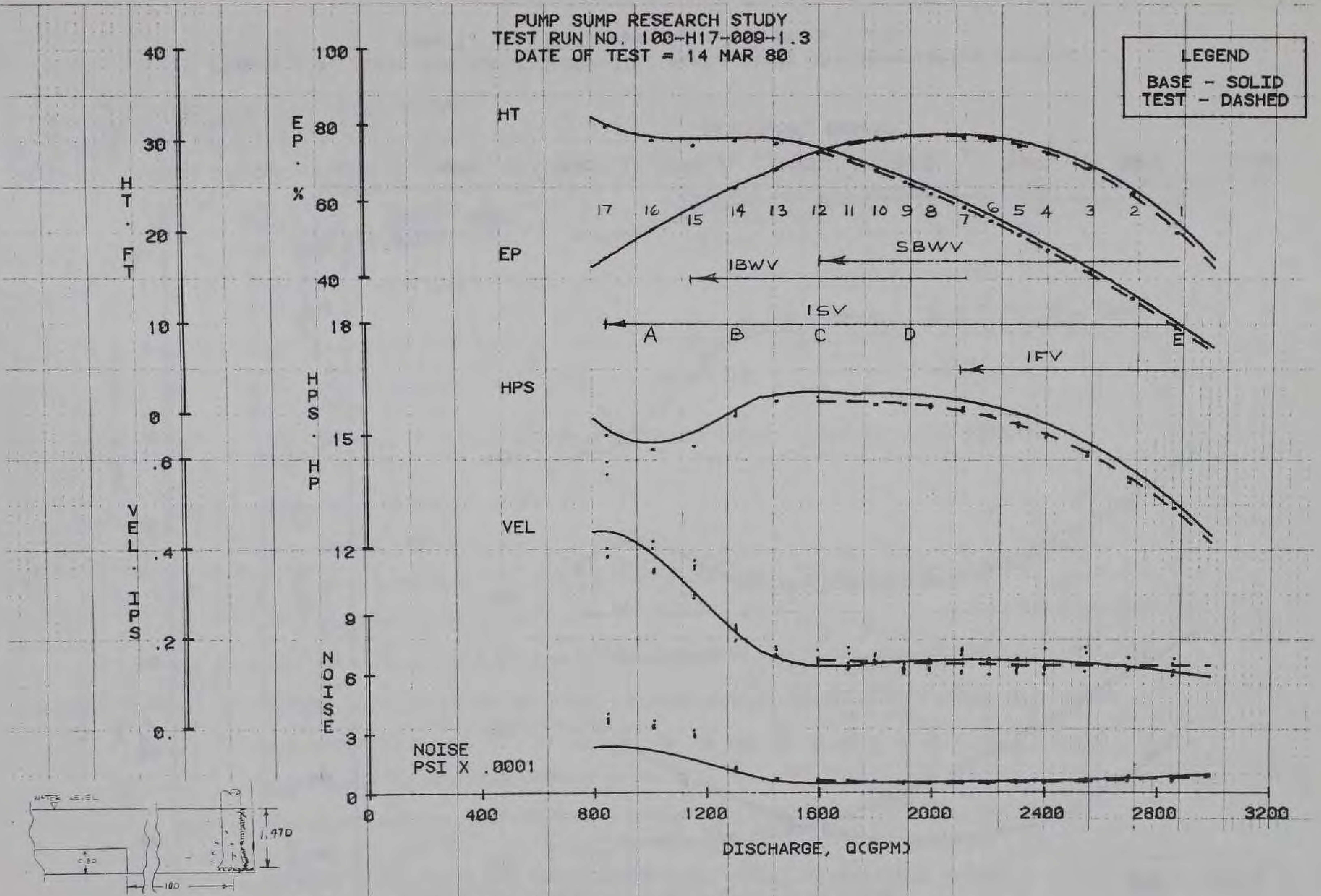


Figure 215. Test run 100-H17-009-1.3; performance characteristics curves; pump 1, Test H17, sump 9, submergence 1.47D

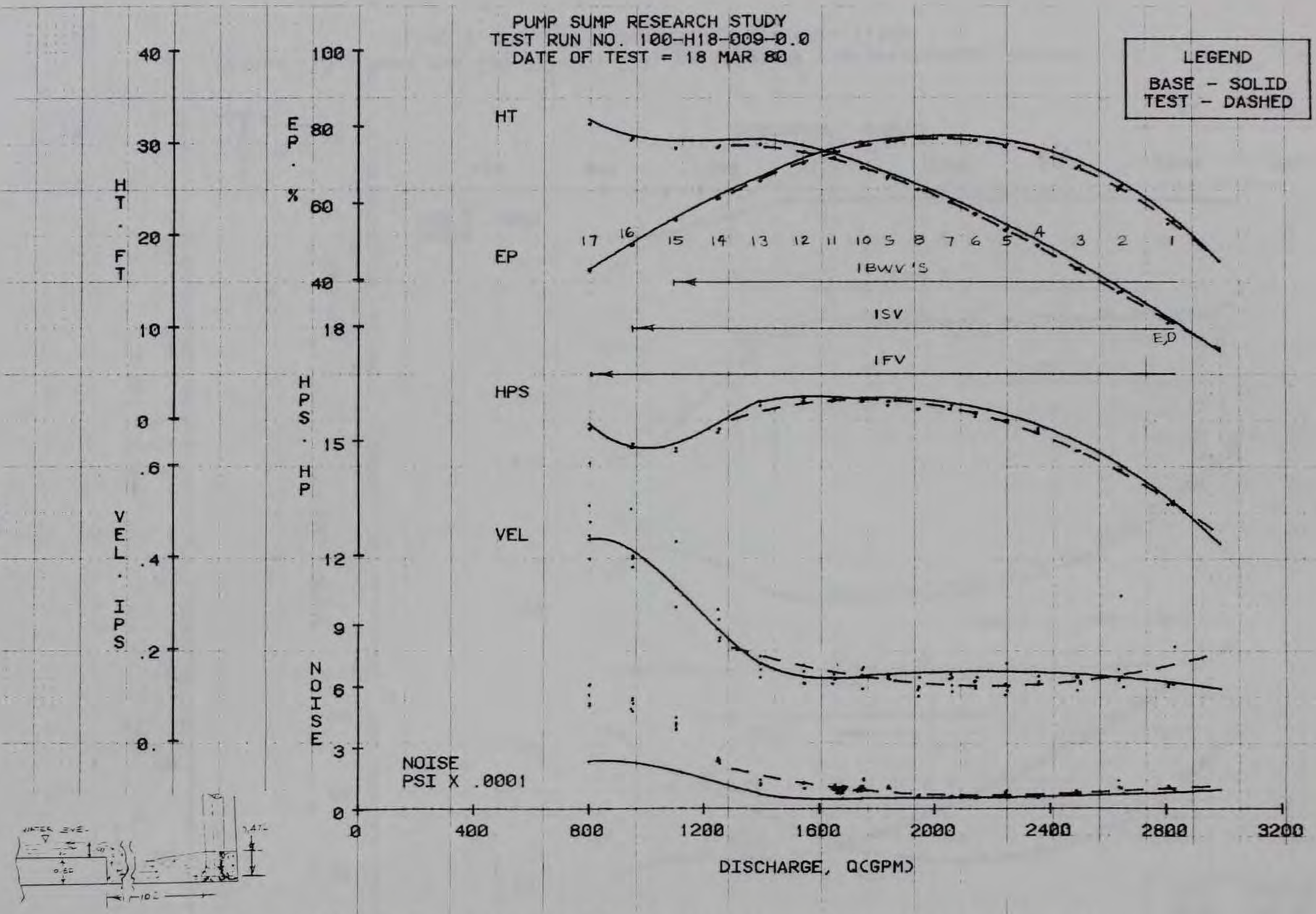


Figure 216. Test run 100-H18-009-0.0; performance characteristics curves; pump 1, Test H18, sump 9, submergence 0.47D

PUMPS RUN SUMP SUBMERGENCE
100 H16 009 2.6

DATE 14 MAR 80 TIME 1010 AIR TEMP 60 F WATER TEMP 60 F BAR. PRESS. 30.24IN HG

01 ISV CW AT 4 O'CLOCK & ISV CCW AT 8 O'CLOCK BOTH 1/2 IN DIA & STAGE E. TWIN SBWV'S AT 5:30 CCW & 6:30 CW BOTH 1/8 IN DIA. IFV, CW, LOCATION VARYING BUT MOSTLY 5 TO 12 O'CLOCK & WITHIN 3 IN OF BELL CP.

02-05 NSCE (NO SIGNIFICANT CHANGE EXCEPT) ALL VORTEXES BECOMING WEAKER & SMALLER.

06 NSCE ISV'S NOW 1/4 IN DIA, SBWV'S 1/16 IN DIA & IFV 1/16 IN DIA.

07 NSCE TINY FLASH NOW APPEARING ON TIP OF PROPELLER BLADE, POSSIBLE CAVITATION

08 NSCE IFV GONE & OTHER VORTEXES GETTING SMALLER, WEAKER & OCCURRING LESS FREQUENT

09-11 NSCE ISV'S BECOMING STAGE D.

12 NSCE SBWV'S BECOMING IBWV'S.

13 NSCE SV'S BECOMING STAGE C. FLASHING ON BLADE BECOMING MUCH LARGER.

14 NSCE IBWV'S NOW 1/32 IN DIA

DATE 14 MAR 80 TIME 1125 AIR TEMP 63 F WATER TEMP 60 F BAR. PRESS. 30.24IN HG

15 NSCE ISV AT 8:00 O'CLOCK GONE. ISV AT 4 O'CLOCK BECOMING STAGE B.

16 ALL VORTEXES GONE.

17 NSCE SPRAY EXPULSIONS APPROX 4 IN FROM BELL INTAKE.

DATE 14 MAR 80 TIME 1140 AIR TEMP 65 F WATER TEMP 60 F BAR. PRESS. 30.22IN HG

Figure 217. Test run 100-H16-009-2.6; visual observation notes; pump 1, Test H16, sump 9, submergence 2.47D

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*OLD H17N
*LIST

PUMPS RUN SUMP SUBMERGENCE
100   H17 009   1.3

DATE 14 MAR 80 TIME 1325 AIR TEMP 69 F WATER TEMP 60 F BAR. PRESS. 30.18IN HG

01      IFV CCW 1/8 IN DIA, LOCATION VARYING BUT MOSTLY AT 11 O'CLOCK & WITHIN
        3 IN. OF PUMP CP. SBWV'S AT 5:30 CCW & 6:30 CW BOTH 1/8 IN DIA. ISV CW
        1 IN DIA AT 3 TO 5 O'CLOCK STAGE E, ISV CCW AT 8 O'CLOCK STAGE E.  MANY
        OTHER SV'S TRYING TO FROM ON EACH SIDE 1 TO 5 & 7 TO 11 O'CLOCK BUT
        SURFACE TURBULENCE IS SEVERE ENOUGH TO BREAK THEM UP BEFORE THEY HAVE
        TIME TO FULLY DEVELOP.

02-04   NSCE (NO SIGNIFICANT CHANGE EXCEPT)ALL VORTEXES GETTING SMALLER & WEAKER.

05      NSCE ISV'S NOW 1/4 IN DIA. IFV NOW 1/16 IN DIA.

06-07   NSCE SBWV AT 6:30 O'CLOCK BECOMING IBWV'S. TINY FLASHING APPEARING ON
        TIP OF PROPELLER BLADE, POSSIBLE CAVITATION.

08      NSCE IFV GONE.

09      NSCE SV'S NOW 1/4 IN DIA & BECOMING STAGE D. SBWV'S NOW 1/16 IN DIA.

10-11   NSCE SURFACE TURBULENCE BECOMING LESS SEVERE. FLASHING ON BLADE BECOMING
        MUCH LARGER.

DATE 14 MAR 80 TIME 1425 AIR TEMP 68 F WATER TEMP 60 F BAR. PRESS. 30.16 IN HG

12-13   NSCE SBWV'S BECOMING IBWV'S, SMALLER & WEAKER. ISV'S BECOMING STAGE C,
        WEAKER, & OCCURRING LESS FREQUENT.

14      NSCE IBWV'S NOW 1/32 IN DIA. WATER SURFACE RELATIVELY CALM. SV'S BECOMING
        STAGE B.

15      NSC.

16      NSCE ISV'S NOW STAGE A & IBWV'S GONE.

17      NSCE SPRAY EXPULSIONS FROM BELL REACHING TO SUMP FLOOR.

DATE 14 MAR 80 TIME 1450 AIR TEMP 68 F WATER TEMP 60 F BAR. PRESS. 30.16IN HG
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Figure 218. Test run 100-H17-009-1.3; visual observation notes; pump 1, Test H17, sump 9, submergence 1.47D

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PUMPS RUN SUMP SUBMERGENCE
100   H18 009  0.0

DATE 18 MAR 80 TIME 1330 AIR TEMP 67 F WATER TEMP 60 F BAR. PRESS. 30.16IN HG

01      IFV CCW 1/4 IN DIA MOSTLY AT 9 O'CLOCK. TWIN IBWV'S AT 5:30 CCW
        & 6:30 CW. BOTH 1/4 IN DIA. ISV CW 2 IN DIA AT 4 O'CLOCK STAGE E, 3 IN
        FROM PUMP COLUMN. ISV CW AT 7 O'CLOCK, 1/2 IN DIA, STAGE D, 8 IN FROM
        COLUMN. ISV 1/2 IN DIA CCW AT 4 O'CLOCK, STAGE D, 8 IN FROM PUMP COLUMN.
        ISV CCW AT 7 O'CLOCK, 1/2 IN DIA STAGE D, 3 IN FROM PUMP COLUMN.
        MUCH SURFACE TURBULENCE & A SIGNIFICANT AMOUNT OF AIR BUBBLES.

02-05   NSCE (NO SIGNIFICANT CHANGE EXCEPT) ALL VORTEXES BECOMING SMALLER, WEAKER,
        & OCCURRING LESS FREQUENT. TURBULENCE LESS SEVERE & FEWER AIR BUBBLES.

06      NSCE IFV'S & ISV'S NOW 1/8 IN DIA. ISV AT 4 O'CLOCK NEAR SHAFT NOW 1 IN
        DIA.

07      NSCE ALL ISV'S DISAPPEARING EXCEPT THE ONE AT 4 O'CLOCK NEAR PUMP COLUMN
        TINY FLASHING APPEARING ON TIP OF PUMP PROPELLER BLADE, POSSIBLE
        CAVITATION.

08-10   NSCE IFV'S & IBWV'S BECOMING SMALLER.

11      NSCE SUBMERGED VORTEXES NOW 1/16 IN DIA. SURFACE TURBULENCE & AIR BUBBLES
        DIMINISHING

DATE 18 MAR 80 TIME 1440 AIR TEMP 67 F WATER TEMP 60 F BAR. PRESS. 30.12IN HG

12-13   NSCE FLASHING ON BLADE BECOMING MUCH LARGER.

14-15   NSCE IBWV'S DISAPPEARING.

16      NSCE IBWV'S GONE. IFV NOW 1/32 IN DIA & APPEARING MOSTLY AT 9-11 O'CLOCK.

17      NSCE ALL VORTEXES GONE EXCEPT IFV CCW 1/32 IN DIA AT 12 O'CLOCK. SPRAY
        EXPULSION FROM BELL REACHING TO SUMP FLOOR.
```

Figure 219. Test run 100-H18-009-0.0; visual observation notes; pump 1, Test H18, sump 9, submergence 0.47D

```
***PUMP EFFICIENCY          ***
TOTAL AREA  -503.87    ABSOLUTE AREA   519.35

              TEST CURVE
MAX Y =     77.12  , X =   2022.28
MIN Y =     44.64  , X =   2987.62
MEAN Y =     71.53  , X =   2449.61
               * * *
              SIGNATURE CURVE
MAX Y =     77.31  , X =   2034.65
MIN Y =     44.36  , X =   2987.62
MEAN Y =     71.86  , X =   2460.73
```

```
***NOISE LB/IN**2          ***
TOTAL AREA  -64.79    ABSOLUTE AREA   85.27

              TEST CURVE
MAX Y =     0.95  , X =   2987.62
MIN Y =     0.49  , X =   2183.17
MEAN Y =     0.57  , X =   2709.78
               * * *
              SIGNATURE CURVE
MAX Y =     0.93  , X =   2987.62
MIN Y =     0.47  , X =   1631.19
MEAN Y =     0.56  , X =   2571.52
```

```
***SHAFT HORSEPOWER          ***
TOTAL AREA  -164.70    ABSOLUTE AREA   164.70

              TEST CURVE
MAX Y =     15.98  , X =   1762.38
MIN Y =     12.16  , X =   2987.62
MEAN Y =     15.41  , X =   2307.93
               * * *
              SIGNATURE CURVE
MAX Y =     16.14  , X =   1600.00
MIN Y =     12.27  , X =   2987.62
MEAN Y =     15.54  , X =   2300.66
```

```
***TOTAL HEAD          ***
TOTAL AREA  -344.62    ABSOLUTE AREA   344.62

              TEST CURVE
MAX Y =     28.74  , X =   1600.00
MIN Y =      7.07  , X =   2987.62
MEAN Y =     23.10  , X =   2082.49
               * * *
              SIGNATURE CURVE
MAX Y =     29.07  , X =   1600.00
MIN Y =      7.10  , X =   2987.62
MEAN Y =     23.39  , X =   2081.24
```

```
***ABS VELOCITY,IPS          ***
TOTAL AREA    16.33    ABSOLUTE AREA   16.33

              TEST CURVE
MAX Y =     0.15  , X =   1997.52
MIN Y =     0.13  , X =   2987.62
MEAN Y =     0.15  , X =   2432.39
               * * *
              SIGNATURE CURVE
MAX Y =     0.15  , X =   2158.42
MIN Y =     0.11  , X =   2987.62
MEAN Y =     0.14  , X =   2619.20
```

Figure 220. Test run 100-H16-009-2.6; statistical comparison; pump 1, Test H16, sump 9, submergence 2.47D

```
***PUMP EFFICIENCY     ***
TOTAL AREA -1445.57    ABSOLUTE AREA  1447.11

              TEST CURVE
MAX Y =    76.89   , X =   2009.90
MIN Y =    42.14   , X =   2987.62
MEAN Y =    71.14   , X =   2442.28
              * * *
              SIGNATURE CURVE
MAX Y =    77.31   , X =   2034.65
MIN Y =    44.36   , X =   2987.62
MEAN Y =    71.86   , X =   2460.73
```

```
***NOISE LB/IN**2      ***
TOTAL AREA   -71.37    ABSOLUTE AREA   102.40

              TEST CURVE
MAX Y =     0.80   , X =   2987.62
MIN Y =     0.48   , X =   2059.41
MEAN Y =     0.58   , X =   2545.90
              * * *
              SIGNATURE CURVE
MAX Y =     0.93   , X =   2987.62
MIN Y =     0.47   , X =   1631.19
MEAN Y =     0.56   , X =   2571.52
```

```
***SHAFT HORSEPOWER    ***
TOTAL AREA  -356.64    ABSOLUTE AREA   356.64

              TEST CURVE
MAX Y =    15.89   , X =   1686.14
MIN Y =    12.09   , X =   2987.62
MEAN Y =    15.30   , X =   2280.47
              * * *
              SIGNATURE CURVE
MAX Y =    16.14   , X =   1600.00
MIN Y =    12.27   , X =   2987.62
MEAN Y =    15.54   , X =   2300.66
```

```
***TOTAL HEAD          ***
TOTAL AREA  -793.79    ABSOLUTE AREA   793.79

              TEST CURVE
MAX Y =    28.63   , X =   1600.00
MIN Y =     6.54   , X =   2987.62
MEAN Y =    22.85   , X =   2079.52
              * * *
              SIGNATURE CURVE
MAX Y =    29.07   , X =   1600.00
MIN Y =     7.10   , X =   2987.62
MEAN Y =    23.39   , X =   2081.24
```

```
***ABS VELOCITY,IPS    ***
TOTAL AREA     0.27    ABSOLUTE AREA    11.78

              TEST CURVE
MAX Y =     0.15   , X =   1600.00
MIN Y =     0.13   , X =   2789.60
MEAN Y =     0.14   , X =   1907.51
              * * *
              SIGNATURE CURVE
MAX Y =     0.15   , X =   2158.42
MIN Y =     0.11   , X =   2987.62
MEAN Y =     0.14   , X =   2619.20
```

Figure 221. Test run 100-H17-009-1.3; statistical comparison; pump 1, Test H17, sump 9, submergence 1.47D

```
        ***PUMP EFFICIENCY        ***
TOTAL AREA -1893.30   ABSOLUTE AREA  1894.43

             TEST CURVE
MAX Y =    76.59  , X =   2009.90
MIN Y =    44.30  , X =   2987.62
MEAN Y =    68.72  , X =   2504.69
               * * *
           SIGNATURE CURVE
MAX Y =    77.31  , X =   2034.65
MIN Y =    44.36  , X =   2987.62
MEAN Y =    69.74  , X =   2529.77
```

```
        ***NOISE LB/IN**2        **
TOTAL AREA   544.04   ABSOLUTE AREA   544.04

             TEST CURVE
MAX Y =     1.95  , X =   1300.00
MIN Y =     0.66  , X =   2158.42
MEAN Y =     1.08  , X =   2931.72
               * * *
           SIGNATURE CURVE
MAX Y =     1.02  , X =   1300.00
MIN Y =     0.47  , X =   1629.70
MEAN Y =     0.62  , X =   2638.57
```

```
        ***SHAFT HORSEPOWER       ***
TOTAL AREA  -226.32   ABSOLUTE AREA   260.97

             TEST CURVE
MAX Y =    16.06  , X =   1745.54
MIN Y =    12.53  , X =   2987.62
MEAN Y =    15.37  , X =   2282.33
               * * *
           SIGNATURE CURVE
MAX Y =    16.14  , X =   1571.78
MIN Y =    12.27  , X =   2987.62
MEAN Y =    15.51  , X =   2311.99
```

```
        ***TOTAL HEAD             ***
TOTAL AREA  -890.13   ABSOLUTE AREA   909.58

             TEST CURVE
MAX Y =    29.55  , X =   1300.00
MIN Y =     7.39  , X =   2987.62
MEAN Y =    23.33  , X =   2054.73
               * * *
           SIGNATURE CURVE
MAX Y =    30.36  , X =   1317.82
MIN Y =     7.10  , X =   2987.62
MEAN Y =    23.91  , X =   2043.45
```

```
        ***ABS VELOCITY,IPS       ***
TOTAL AREA     1.61   ABSOLUTE AREA    38.40

             TEST CURVE
MAX Y =     0.20  , X =   1300.00
MIN Y =     0.12  , X =   2183.17
MEAN Y =     0.15  , X =   2770.25
               * * *
           SIGNATURE CURVE
MAX Y =     0.21  , X =   1300.00
MIN Y =     0.11  , X =   2987.62
MEAN Y =     0.14  , X =   2419.83
```

Figure 222. Test run 100-H18-009-0.0; statistical comparison; pump 1, Test H18, sump 9, submergence 0.47D

READ NO.	Q DIS- CHARGE GPM	HW SUBMERGENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2905.	2.6	1.5	2.2	8.649	37.9	485.	16.6	18.6	12.8	6.4	68.6	49.7	1775.	0.045	0.111	0.82	3.25	3.74
1	2906.	2.6	1.5	2.2	8.700	38.0	485.	16.6	18.7	12.8	6.4	68.8	49.8	1775.	0.046	0.136	0.81	2.85	3.71
1	2909.	2.6	1.5	2.2	8.661	38.0	485.	16.6	18.7	12.8	6.4	68.8	49.6	1775.	0.043	0.123	0.83	3.07	3.74
1	2904.	2.6	1.5	2.2	8.654	37.9	485.	16.6	18.6	12.8	6.4	68.7	49.6	1775.	0.056	0.135	0.82	2.13	3.70
1	2908.	2.6	1.5	2.2	8.663	37.9	485.	16.6	18.6	12.8	6.4	68.7	49.7	1775.	0.046	0.128	0.89	2.79	3.71
2	2750.	2.6	5.0	2.0	11.936	40.5	486.	16.9	19.0	13.7	8.3	71.8	60.7	1775.	0.049	0.137	0.71	3.10	3.71
2	2748.	2.6	5.0	2.0	11.976	40.5	486.	16.9	19.1	13.7	8.3	71.9	60.7	1775.	0.052	0.151	0.71	2.74	3.73
2	2743.	2.6	5.0	2.0	11.950	40.6	486.	16.9	19.1	13.7	8.3	71.9	60.5	1775.	0.045	0.134	0.67	2.79	3.73
2	2743.	2.6	5.0	2.0	11.919	40.4	486.	16.9	19.0	13.7	8.3	71.7	60.5	1775.	0.054	0.143	0.66	2.35	3.73
2	2744.	2.6	5.0	2.0	11.939	40.5	487.	16.9	19.1	13.7	8.3	71.8	60.5	1775.	0.062	0.165	0.80	3.11	3.73
3	2613.	2.6	7.7	1.8	14.431	42.3	486.	17.0	19.2	14.3	9.5	74.5	66.6	1775.	0.058	0.169	0.58	3.39	3.73
3	2620.	2.6	7.7	1.8	14.455	42.4	486.	17.1	19.2	14.3	9.6	74.5	66.8	1775.	0.055	0.141	0.58	3.23	3.74
3	2616.	2.6	7.7	1.8	14.432	42.4	486.	17.1	19.2	14.3	9.5	74.6	66.6	1775.	0.054	0.133	0.63	3.47	3.73
3	2616.	2.6	7.7	1.8	14.485	42.4	486.	17.1	19.2	14.3	9.6	74.5	66.8	1775.	0.059	0.158	0.63	3.07	3.74
3	2618.	2.6	7.6	1.8	14.404	42.4	486.	17.1	19.2	14.3	9.5	74.5	66.5	1775.	0.064	0.165	0.64	3.36	3.73
4	2449.	2.6	10.8	1.6	17.306	44.3	486.	17.3	19.5	15.0	10.7	76.8	71.5	1775.	0.053	0.146	0.51	3.43	3.72
4	2450.	2.6	10.8	1.6	17.317	44.3	486.	17.3	19.5	15.0	10.7	76.8	71.6	1775.	0.060	0.157	0.50	3.08	3.72
4	2451.	2.6	10.8	1.6	17.338	44.4	486.	17.3	19.5	15.0	10.7	76.9	71.7	1775.	0.053	0.154	0.54	3.14	3.70
4	2453.	2.6	10.8	1.6	17.331	44.4	486.	17.3	19.5	15.0	10.7	76.9	71.6	1775.	0.062	0.169	0.58	3.25	3.71
4	2450.	2.6	10.8	1.6	17.317	44.4	486.	17.3	19.5	15.0	10.7	76.8	71.5	1775.	0.050	0.144	0.50	3.49	3.70
5	2300.	2.6	13.3	1.4	19.652	45.7	486.	17.4	19.7	15.4	11.4	78.5	74.0	1775.	0.055	0.155	0.48	3.36	3.70
5	2307.	2.6	13.3	1.4	19.661	45.7	486.	17.4	19.7	15.4	11.5	78.6	74.3	1775.	0.060	0.164	0.53	3.46	3.73
5	2309.	2.6	13.3	1.4	19.643	45.7	486.	17.4	19.6	15.5	11.5	78.7	74.2	1775.	0.055	0.151	0.51	3.57	3.73
5	2305.	2.6	13.3	1.4	19.658	45.7	486.	17.4	19.6	15.4	11.5	78.6	74.2	1775.	0.071	0.179	0.50	3.43	3.73
5	2305.	2.6	13.3	1.4	19.668	45.7	486.	17.4	19.6	15.5	11.5	78.7	74.2	1775.	0.054	0.131	0.48	3.11	3.70
6	2194.	2.6	15.1	1.2	21.339	46.5	485.	17.5	19.7	15.7	11.8	79.6	75.3	1775.	0.056	0.148	0.48	3.25	3.70
6	2193.	2.6	15.1	1.2	21.358	46.5	485.	17.5	19.8	15.7	11.8	79.5	75.4	1775.	0.062	0.175	0.46	3.18	3.71
6	2195.	2.6	15.1	1.2	21.380	46.5	486.	17.5	19.8	15.7	11.9	79.6	75.5	1775.	0.048	0.146	0.51	3.39	3.72
6	2195.	2.6	15.1	1.2	21.380	46.5	485.	17.5	19.8	15.7	11.9	79.5	75.5	1775.	0.062	0.163	0.48	3.28	3.70
6	2190.	2.6	15.1	1.2	21.374	46.5	486.	17.5	19.8	15.7	11.8	79.5	75.4	1775.	0.072	0.194	0.49	3.49	3.71
7	2084.	2.6	17.0	1.1	23.107	47.0	485.	17.5	19.8	15.9	12.2	80.3	76.7	1775.	0.052	0.136	0.46	2.71	3.72
7	2086.	2.6	17.0	1.1	23.099	47.0	485.	17.6	19.8	15.9	12.2	80.3	76.7	1775.	0.059	0.153	0.50	3.42	3.72
7	2081.	2.6	17.0	1.1	23.123	47.0	486.	17.6	19.8	15.9	12.2	80.2	76.6	1775.	0.061	0.150	0.45	3.58	3.72
7	2077.	2.6	17.0	1.1	23.089	47.0	485.	17.6	19.8	15.9	12.1	80.3	76.4	1775.	0.050	0.121	0.49	3.60	3.72
7	2078.	2.6	17.0	1.1	23.120	46.9	485.	17.6	19.8	15.9	12.1	80.2	76.6	1775.	0.059	0.188	0.50	3.57	3.71
8	1986.	2.6	18.3	1.0	24.373	47.1	485.	17.6	19.8	15.9	12.2	80.5	76.9	1775.	0.054	0.141	0.50	3.09	3.72
8	1988.	2.6	18.4	1.0	24.395	47.1	485.	17.6	19.8	15.9	12.3	80.5	77.0	1775.	0.052	0.146	0.48	3.42	3.71
8	1984.	2.6	18.4	1.0	24.371	47.1	485.	17.5	19.8	15.9	12.2	80.5	76.9	1775.	0.057	0.153	0.47	3.57	3.72
8	1989.	2.6	18.4	1.0	24.396	47.1	485.	17.6	19.8	15.9	12.3	80.5	77.0	1775.	0.057	0.139	0.48	3.56	3.73

Figure 223. Test run 100-H16-009-2.6; research data; pump 1, Test H16, sump 9, submergence 2.47D (Continued)

8	1984.	2.6	18.4	1.0	24.401	47.1	485.	17.6	19.8	15.9	12.2	80.5	76.9	1775.	0.047	0.118	0.48	3.29	3.73
9	1908.	2.6	19.5	0.9	25.414	47.0	488.	17.5	19.8	15.9	12.3	80.1	77.2	1775.	0.054	0.159	0.55	3.58	3.74
9	1906.	2.6	19.5	0.9	25.452	47.0	488.	17.5	19.8	15.9	12.3	80.0	77.2	1775.	0.057	0.154	0.55	3.56	3.73
9	1908.	2.6	19.5	0.9	25.444	47.0	488.	17.5	19.8	15.9	12.3	80.0	77.3	1775.	0.056	0.152	0.54	3.48	3.71
9	1908.	2.6	19.5	0.9	25.454	47.0	488.	17.5	19.9	15.9	12.3	80.0	77.3	1775.	0.051	0.129	0.54	3.60	3.72
9	1907.	2.6	19.5	0.9	25.423	47.0	488.	17.5	19.9	15.9	12.3	79.9	77.2	1775.	0.057	0.191	0.57	3.52	3.73
10	1802.	2.6	20.8	0.8	26.662	47.0	488.	17.6	19.9	15.9	12.1	80.0	76.4	1775.	0.045	0.127	0.59	3.12	3.76
10	1805.	2.6	20.9	0.8	26.705	47.0	488.	17.6	19.9	15.9	12.2	80.0	76.6	1775.	0.051	0.140	0.55	3.60	3.74
10	1804.	2.6	20.9	0.8	26.724	47.0	488.	17.6	19.9	15.9	12.2	80.0	76.7	1775.	0.062	0.146	0.57	3.60	3.74
10	1802.	2.6	20.8	0.8	26.692	47.1	488.	17.6	19.9	15.9	12.2	80.0	76.5	1775.	0.052	0.144	0.64	3.57	3.74
10	1801.	2.6	20.9	0.8	26.711	47.0	488.	17.6	19.9	15.9	12.2	80.0	76.5	1775.	0.055	0.152	0.54	3.58	3.76
11	1696.	2.6	22.2	0.7	27.946	47.2	486.	17.6	19.8	15.9	12.0	80.4	75.1	1775.	0.059	0.158	0.53	3.06	3.75
11	1697.	2.6	22.2	0.7	27.947	47.2	486.	17.6	19.8	15.9	12.0	80.3	75.2	1775.	0.056	0.171	0.56	3.59	3.77
11	1693.	2.6	22.2	0.7	27.954	47.2	486.	17.6	19.8	15.9	12.0	80.4	75.0	1775.	0.055	0.141	0.53	3.60	3.75
11	1695.	2.6	22.2	0.7	27.945	47.2	486.	17.6	19.8	15.9	12.0	80.4	75.1	1775.	0.051	0.164	0.52	3.62	3.77
11	1694.	2.6	22.2	0.7	27.944	47.2	486.	17.6	19.8	15.9	12.0	80.3	75.1	1775.	0.055	0.135	0.53	3.62	3.78
12	1595.	2.6	23.2	0.7	28.820	47.2	486.	17.6	19.9	16.0	11.6	80.4	72.8	1775.	0.056	0.165	0.56	3.51	3.77
12	1593.	2.6	23.2	0.7	28.818	47.2	486.	17.6	19.9	16.0	11.6	80.4	72.7	1775.	0.049	0.134	0.56	3.59	3.78
12	1592.	2.6	23.2	0.7	28.828	47.2	486.	17.6	19.8	16.0	11.6	80.4	72.7	1775.	0.052	0.128	0.53	3.56	3.79
12	1599.	2.6	23.2	0.7	28.823	47.2	486.	17.6	19.8	15.9	11.7	80.4	73.1	1775.	0.055	0.145	0.50	3.61	3.77
12	1593.	2.6	23.2	0.7	28.828	47.3	486.	17.6	19.8	16.0	11.6	80.5	72.7	1775.	0.063	0.182	0.62	3.55	3.78
13	1499.	2.6	23.9	0.6	29.493	47.2	486.	17.6	19.8	15.9	11.2	80.4	70.1	1775.	0.051	0.147	0.54	3.58	3.80
13	1501.	2.6	23.9	0.6	29.484	47.3	486.	17.6	19.8	16.0	11.2	80.5	70.1	1775.	0.052	0.171	0.55	3.56	3.79
13	1501.	2.6	23.9	0.6	29.474	47.2	486.	17.6	19.9	16.0	11.2	80.4	70.1	1775.	0.056	0.152	0.56	3.51	3.78
13	1502.	2.6	23.9	0.6	29.465	47.2	486.	17.6	19.8	15.9	11.2	80.3	70.2	1775.	0.054	0.157	0.56	3.46	3.81
13	1504.	2.6	23.9	0.6	29.497	47.2	486.	17.6	19.8	15.9	11.2	80.3	70.4	1775.	0.064	0.164	0.56	3.57	3.81
14	1400.	2.6	24.4	0.5	29.938	46.9	487.	17.6	19.8	15.9	10.6	79.9	66.8	1775.	0.062	0.181	0.69	3.55	3.84
14	1402.	2.6	24.4	0.5	29.930	47.0	487.	17.6	19.9	15.9	10.6	80.0	66.8	1775.	0.051	0.139	0.72	3.56	3.88
14	1405.	2.6	24.4	0.5	29.922	46.9	487.	17.6	19.9	15.9	10.6	79.9	67.0	1775.	0.052	0.140	0.71	3.49	3.88
14	1400.	2.6	24.4	0.5	29.928	47.0	487.	17.6	19.9	15.9	10.6	80.0	66.7	1775.	0.055	0.184	0.72	3.53	3.84
14	1403.	2.6	24.4	0.5	29.931	47.0	487.	17.6	19.9	15.9	10.6	80.0	66.8	1775.	0.056	0.157	0.76	3.53	3.86
15	1253.	2.6	24.6	0.4	29.967	45.3	487.	17.4	19.6	15.3	9.5	78.0	62.0	1775.	0.070	0.224	1.21	3.25	4.16
15	1254.	2.6	24.6	0.4	29.968	45.3	487.	17.4	19.6	15.3	9.5	78.0	62.1	1775.	0.071	0.212	1.18	3.20	4.27
15	1255.	2.6	24.5	0.4	29.959	45.2	487.	17.4	19.6	15.3	9.5	77.9	62.2	1775.	0.075	0.218	1.19	3.10	4.32
15	1256.	2.6	24.6	0.4	29.989	45.3	487.	17.4	19.6	15.3	9.5	78.0	62.2	1775.	0.071	0.210	1.29	3.19	4.21
15	1251.	2.6	24.6	0.4	29.976	45.3	487.	17.4	19.6	15.3	9.5	78.0	61.9	1775.	0.071	0.227	1.23	3.28	4.07
16	1103.	2.6	24.3	0.3	29.596	43.5	487.	17.2	19.4	14.7	8.3	75.7	56.1	1775.	0.113	0.329	1.93	2.58	4.70
16	1104.	2.6	24.3	0.3	29.586	43.5	487.	17.2	19.4	14.7	8.3	75.7	56.2	1775.	0.106	0.321	1.93	2.35	4.66
16	1102.	2.6	24.2	0.3	29.555	43.4	487.	17.2	19.4	14.7	8.2	75.7	56.1	1775.	0.101	0.336	1.93	2.41	4.69
16	1105.	2.6	24.3	0.3	29.597	43.5	487.	17.2	19.4	14.7	8.3	75.8	56.3	1775.	0.100	0.336	2.01	2.64	4.80
16	1105.	2.6	24.3	0.3	29.567	43.5	487.	17.2	19.4	14.7	8.3	75.8	56.2	1775.	0.110	0.323	1.90	2.40	4.68
17	898.	2.6	25.6	0.2	30.809	43.9	487.	17.2	19.4	14.8	7.0	76.4	47.1	1775.	0.125	0.394	2.30	2.37	4.71
17	901.	2.6	25.6	0.2	30.840	43.9	487.	17.2	19.4	14.8	7.0	76.4	47.3	1775.	0.128	0.478	2.23	2.27	4.82
17	896.	2.6	25.6	0.2	30.798	43.8	487.	17.2	19.4	14.8	7.0	76.2	47.1	1775.	0.128	0.384	2.25	2.42	4.78
17	899.	2.6	25.6	0.2	30.820	43.8	487.	17.2	19.4	14.8	7.0	76.2	47.3	1775.	0.128	0.439	2.20	2.40	4.73
17	901.	2.6	25.6	0.2	30.830	43.9	487.	17.2	19.4	14.8	7.0	76.3	47.3	1775.	0.116	0.454	2.29	2.62	4.95

Figure 223. (Concluded)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2854.	1.3	0.8	2.1	9.204	38.4	487.	16.5	18.6	13.0	6.6	69.7	51.2	1775.	0.043	0.111	0.83	1.45	2.43
1	2861.	1.3	0.8	2.1	9.206	38.5	487	16.5	18.6	13.0	6.7	69.8	51.2	1775.	0.046	0.149	0.69	1.92	2.40
1	2855	1.3	0.8	2.1	9.205	38.5	487	16.5	18.6	13.0	6.6	69.8	51.1	1775.	0.044	0.138	0.69	1.14	2.40
1	2855.	1.3	0.8	2.1	9.234	38.5	487.	16.5	18.6	13.0	6.7	69.8	51.3	1775.	0.040	0.112	0.59	2.17	2.38
1	2859.	1.3	0.8	2.1	9.243	38.6	487.	16.5	18.6	13.0	6.7	69.9	51.2	1775.	0.045	0.123	0.70	1.89	2.41
2	2698.	1.3	4.3	1.9	12.469	40.8	487.	16.7	18.9	13.8	8.5	73.0	61.7	1775.	0.044	0.130	0.83	2.17	2.44
2	2704.	1.3	4.2	1.9	12.397	40.7	487.	16.7	18.9	13.8	8.5	72.8	61.6	1775.	0.047	0.129	0.82	2.03	2.45
2	2697.	1.3	4.2	1.9	12.425	40.6	487.	16.7	18.9	13.7	8.5	72.7	61.8	1775.	0.044	0.123	0.57	1.44	2.38
2	2698.	1.3	4.2	1.9	12.425	40.6	487.	16.7	18.9	13.7	8.5	72.7	61.7	1775.	0.049	0.152	0.76	1.27	2.44
2	2701.	1.3	4.3	1.9	12.461	40.7	487.	16.7	18.9	13.8	8.5	72.8	61.9	1775.	0.042	0.150	0.74	1.86	2.42
3	2548.	1.3	7.3	1.7	15.269	42.6	487	17.0	19.2	14.4	9.8	75.1	68.3	1775.	0.046	0.135	0.54	2.09	2.41
3	2544.	1.3	7.3	1.7	15.321	42.8	487.	17.0	19.2	14.4	9.9	75.3	68.2	1775.	0.045	0.120	0.52	1.52	2.41
3	2546.	1.3	7.3	1.7	15.302	42.8	487.	17.0	19.2	14.5	9.8	75.4	68.0	1775.	0.053	0.174	0.63	1.89	2.45
3	2550.	1.3	7.4	1.7	15.358	42.9	487.	17.0	19.2	14.5	9.9	75.4	68.3	1775.	0.044	0.139	0.55	1.87	2.42
3	2549.	1.3	7.4	1.7	15.350	42.9	487.	17.0	19.2	14.5	9.9	75.4	68.3	1775.	0.050	0.162	0.70	2.03	2.42
4	2400.	1.3	10.0	1.5	17.804	44.4	487.	17.2	19.4	.15.0	10.8	77.2	72.0	1775.	0.045	0.124	0.52	2.10	2.41
4	2398.	1.3	10.0	1.5	17.746	44.3	487.	17.2	19.4	15.0	10.8	77.1	71.9	1775.	0.044	0.114	0.54	2.21	2.40
4	2400.	1.3	10.0	1.5	17.788	44.3	487.	17.2	19.4	15.0	10.8	77.2	72.1	1775.	0.046	0.125	0.47	1.76	2.40
4	2398.	1.3	10.0	1.5	17.752	44.2	487.	17.2	19.4	14.9	10.8	77.1	72.0	1775.	0.045	0.130	0.50	1.76	2.40
4	2403.	1.3	10.0	1.5	17.788	44.3	487.	17.2	19.4	15.0	10.8	77.2	72.2	1775.	0.056	0.173	0.48	1.99	2.41
5	2300.	1.3	11.7	1.4	19.402	45.1	487.	17.2	19.5	15.2	11.3	78.3	74.1	1775.	0.047	0.123	0.47	2.04	2.41
5	2303.	1.3	11.8	1.4	19.436	45.2	487.	17.3	19.5	15.3	11.3	78.4	74.0	1775.	0.050	0.150	0.51	1.74	2.39
5	2303.	1.3	11.8	1.4	19.466	45.3	487.	17.3	19.5	15.3	11.3	78.5	74.0	1775.	0.047	0.130	0.47	2.00	2.42
5	2298.	1.3	11.8	1.4	19.430	45.3	487.	17.3	19.5	15.3	11.3	78.4	73.8	1775.	0.053	0.147	0.62	1.68	2.45
5	2301.	1.3	11.8	1.4	19.474	45.3	487.	17.3	19.5	15.3	11.3	78.5	74.0	1775.	0.046	0.117	0.49	2.03	2.41
6	2203.	1.3	13.5	1.3	21.019	45.8	487.	17.3	19.6	15.5	11.7	79.1	75.6	1775.	0.042	0.114	0.45	1.86	2.43
6	2197.	1.3	13.5	1.3	21.032	45.8	487.	17.3	19.6	15.5	11.7	79.1	75.4	1775.	0.047	0.141	0.44	1.87	2.40
6	2203.	1.3	13.5	1.3	21.049	45.9	487.	17.3	19.6	15.5	11.7	79.2	75.6	1775.	0.047	0.138	0.45	1.80	2.36
6	2198.	1.3	13.5	1.3	21.033	45.9	487.	17.3	19.6	15.5	11.7	79.3	75.3	1775.	0.054	0.139	0.48	2.02	2.37
6	2202.	1.3	13.5	1.3	21.028	45.8	487.	17.3	19.6	15.5	11.7	79.1	75.6	1775.	0.051	0.150	0.43	2.15	2.39
7	2108.	1.3	15.0	1.2	22.453	46.4	487.	17.4	19.6	15.7	12.0	79.8	76.4	1775.	0.049	0.172	0.49	2.27	2.41
7	2106.	1.3	15.0	1.2	22.411	46.3	487.	17.4	19.7	15.7	11.9	79.7	76.2	1775.	0.043	0.121	0.54	1.69	2.39
7	2105.	1.3	15.0	1.1	22.460	46.4	487.	17.4	19.7	15.7	12.0	79.7	76.3	1775.	0.041	0.117	0.51	2.16	2.38
7	2107.	1.3	15.0	1.2	22.412	46.4	487.	17.4	19.7	15.7	11.9	79.7	76.2	1775.	0.049	0.166	0.52	2.01	2.38
7	2105.	1.3	15.0	1.1	22.400	46.3	487.	17.4	19.7	15.6	11.9	79.6	76.2	1775.	0.050	0.158	0.52	2.08	2.40
8	1992.	1.3	16.7	1.0	24.049	46.7	488.	17.4	19.7	15.8	12.1	80.0	76.8	1775.	0.048	0.124	0.53	2.08	2.45
8	1990.	1.3	16.7	1.0	24.047	46.6	487.	17.4	19.7	15.7	12.1	79.9	76.8	1775.	0.049	0.148	0.49	2.25	2.41
8	1990.	1.3	16.7	1.0	24.067	46.7	487.	17.4	19.7	15.8	12.1	80.1	76.8	1775.	0.047	0.139	0.51	2.15	2.40
8	1991	1.3	16.7	1.0	24.048	46.6	487.	17.4	19.7	15.7	12.1	80.0	76.9	1775.	0.048	0.123	0.46	2.19	2.41

Figure 224. Test run 100-H17-009-1.3; research data; pump 1, Test H17, sump 9, submergence 1.47D (Continued)

8	1991.	1.3	16.7	1.0	24.038	46.6	487.	17.4	19.7	15.7	12.1	79.9	76.9	1775.	0.046	0.129	0.46	2.24	2.41
9	1900.	1.3	18.0	0.9	25.267	46.6	487.	17.4	19.6	15.8	12.1	80.3	77.0	1775.	0.039	0.118	0.44	2.12	2.38
9	1897.	1.3	18.0	0.9	25.274	46.8	487.	17.4	19.6	15.8	12.1	80.5	76.7	1775.	0.046	0.130	0.48	1.87	2.37
9	1901.	1.3	18.0	0.9	25.258	46.7	487.	17.4	19.6	15.8	12.1	80.5	76.9	1775.	0.043	0.125	0.51	2.17	2.41
9	1897.	1.3	18.0	0.9	25.264	46.7	487.	17.4	19.6	15.8	12.1	80.4	76.7	1775.	0.044	0.124	0.52	2.02	2.39
9	1901.	1.3	18.0	0.9	25.258	46.7	486.	17.4	19.6	15.8	12.1	80.5	77.0	1775.	0.048	0.138	0.54	1.86	2.41
10	1795.	1.3	19.4	0.8	26.576	46.8	487.	17.4	19.7	15.8	12.1	80.5	76.2	1775.	0.052	0.147	0.57	2.16	2.43
10	1798.	1.3	19.4	0.8	26.559	46.9	487.	17.4	19.7	15.8	12.1	80.6	76.2	1775.	0.054	0.156	0.56	2.19	2.43
10	1799.	1.3	19.4	0.8	26.570	46.8	487.	17.4	19.6	15.8	12.1	80.5	76.4	1775.	0.042	0.138	0.56	2.08	2.42
10	1800.	1.3	19.4	0.8	26.551	46.8	487.	17.4	19.7	15.8	12.1	80.6	76.3	1775.	0.048	0.143	0.57	1.98	2.46
10	1799.	1.3	19.4	0.8	26.550	46.7	487.	17.4	19.6	15.8	12.1	80.5	76.5	1775.	0.046	0.161	0.54	2.19	2.45
11	1707.	1.3	20.6	0.8	27.686	47.0	486.	17.4	19.7	15.9	11.9	80.9	75.2	1775.	0.051	0.161	0.55	2.10	2.46
11	1703.	1.3	20.6	0.8	27.682	47.1	486.	17.4	19.7	15.9	11.9	80.9	75.0	1775.	0.048	0.175	0.55	2.24	2.45
11	1701.	1.3	20.7	0.8	27.701	47.0	486.	17.4	19.6	15.9	11.9	81.0	75.0	1775.	0.045	0.125	0.58	1.83	2.43
11	1705.	1.3	20.7	0.8	27.704	47.1	486.	17.4	19.6	15.9	11.9	81.0	75.1	1775.	0.046	0.130	0.53	2.05	2.44
11	1702.	1.3	20.6	0.8	27.682	47.1	486.	17.4	19.6	15.9	11.9	81.1	74.8	1775.	0.052	0.141	0.65	2.14	2.48
12	1595.	1.3	21.6	0.7	28.560	47.1	486.	17.5	19.7	15.9	11.5	80.8	72.4	1775.	0.054	0.169	0.55	1.82	2.41
12	1598.	1.3	21.6	0.7	28.572	47.2	486.	17.5	19.7	15.9	11.5	81.0	72.4	1775.	0.056	0.146	0.64	1.95	2.45
12	1594.	1.3	21.6	0.7	28.569	47.2	486.	17.5	19.7	16.0	11.5	81.0	72.1	1775.	0.049	0.151	0.58	2.09	2.43
12	1597.	1.3	21.6	0.7	28.522	47.2	486.	17.5	19.7	15.9	11.5	80.9	72.3	1775.	0.049	0.147	0.65	2.21	2.45
12	1595.	1.3	21.6	0.7	28.540	47.2	486.	17.5	19.7	15.9	11.5	80.9	72.2	1775.	0.051	0.141	0.69	2.01	2.48
13	1446.	1.3	22.7	0.5	29.512	47.0	487.	17.5	19.7	15.9	10.8	80.6	67.9	1775.	0.053	0.155	0.67	2.19	2.49
13	1452.	1.3	22.6	0.5	29.487	47.0	487.	17.5	19.7	15.9	10.8	80.6	68.1	1775.	0.053	0.154	0.73	2.21	2.53
13	1447.	1.3	22.7	0.5	29.503	47.1	487.	17.5	19.7	15.9	10.8	80.7	67.8	1775.	0.058	0.177	0.73	2.21	2.56
13	1446.	1.3	22.7	0.5	29.542	47.1	487.	17.5	19.7	15.9	10.8	80.7	67.9	1775.	0.054	0.160	0.71	2.20	2.53
13	1449.	1.3	22.7	0.5	29.525	47.2	487.	17.5	19.7	15.9	10.8	80.8	67.9	1775.	0.052	0.169	0.68	2.21	2.49
14	1303.	1.3	23.0	0.4	29.790	45.9	489.	17.3	19.7	15.5	9.8	78.8	63.2	1775.	0.065	0.226	1.27	1.84	2.76
14	1305.	1.3	23.0	0.4	29.782	45.9	489.	17.3	19.7	15.5	9.8	78.8	63.4	1775.	0.066	0.212	1.32	1.94	2.76
14	1303.	1.3	23.1	0.4	29.800	45.9	489.	17.3	19.7	15.5	9.8	78.8	63.3	1775.	0.065	0.220	1.21	1.83	2.74
14	1301.	1.3	23.0	0.4	29.779	45.9	489.	17.3	19.7	15.5	9.8	78.8	63.2	1775.	0.061	0.189	1.21	2.01	2.73
14	1306.	1.3	23.1	0.4	29.862	46.0	489.	17.3	19.7	15.6	9.9	79.0	63.4	1775.	0.068	0.217	1.20	2.05	2.76
15	1158.	1.3	22.6	0.3	29.278	43.6	489.	17.1	19.4	14.7	8.6	76.0	58.2	1775.	0.103	0.358	2.87	1.28	3.34
15	1157.	1.3	22.7	0.3	29.307	43.5	489.	17.1	19.3	14.7	8.6	76.0	58.3	1775.	0.097	0.293	2.95	1.27	3.32
15	1158.	1.3	22.8	0.3	29.398	43.6	489.	17.1	19.4	14.7	8.6	76.1	58.4	1775.	0.102	0.370	2.79	1.15	3.30
15	1157.	1.3	22.7	0.3	29.297	43.5	489.	17.1	19.4	14.7	8.6	75.9	58.3	1775.	0.107	0.352	2.84	1.45	3.25
15	1154.	1.3	22.7	0.3	29.315	43.4	489.	17.1	19.4	14.7	8.6	75.8	58.2	1775.	0.098	0.285	3.14	1.02	3.31
16	1010.	1.3	23.3	0.3	29.905	43.3	490.	17.1	19.4	14.6	7.6	75.3	52.2	1775.	0.109	0.413	3.39	0.76	3.54
16	1014.	1.3	23.4	0.3	29.927	43.3	490.	17.1	19.4	14.6	7.7	75.3	52.4	1775.	0.113	0.352	3.66	0.94	3.56
16	1012.	1.3	23.3	0.3	29.906	43.3	490.	17.1	19.4	14.6	7.7	75.3	52.3	1775.	0.110	0.346	3.46	1.09	3.46
16	1012.	1.3	23.3	0.3	29.906	43.3	490.	17.1	19.4	14.6	7.7	75.3	52.3	1775.	0.107	0.343	3.26	1.08	3.51
16	1008.	1.3	23.3	0.3	29.854	43.2	490.	17.1	19.4	14.6	7.6	75.2	52.1	1775.	0.118	0.397	3.37	0.97	3.61
17	848.	1.3	24.9	0.2	31.347	44.3	491.	17.2	19.6	15.0	6.7	76.5	44.9	1775.	0.143	0.590	3.51	1.11	3.50
17	845.	1.3	24.9	0.2	31.385	44.3	491.	17.2	19.6	15.0	6.7	76.5	44.8	1775.	0.122	0.398	3.76	1.06	3.55
17	847.	1.3	24.9	0.2	31.356	44.3	491.	17.2	19.6	15.0	6.7	76.5	44.8	1775.	0.119	0.378	3.78	0.69	3.65
17	847.	1.3	24.9	0.2	31.376	44.3	491.	17.2	19.6	15.0	6.7	76.5	44.9	1775.	0.121	0.380	3.64	0.87	3.72
17	848.	1.3	24.8	0.2	31.336	44.3	491.	17.2	19.6	15.0	6.7	76.4	44.9	1775.	0.128	0.563	4.01	0.92	3.50

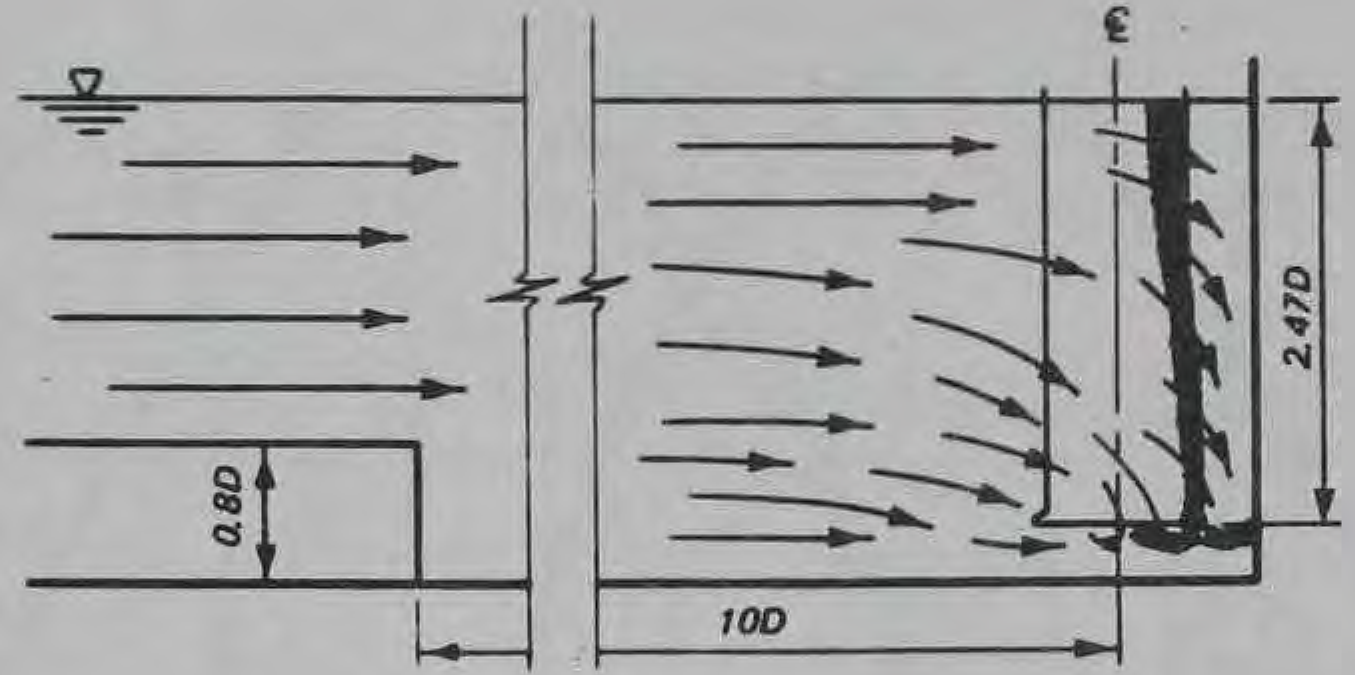
Figure 224. (Concluded)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2831.	0.	0.6	2.1	10.293	39.7	484.	17.8	20.0	13.4	7.4	67.1	54.9	1775.	0.041	0.120	0.80	0.25	1.07
1	2831.	0.	0.6	2.1	10.233	39.5	484.	17.8	20.0	13.3	7.3	66.9	54.9	1775.	0.042	0.200	0.84	0.73	1.20
1	2825.	0.	0.6	2.1	10.222	39.5	484.	17.8	20.0	13.3	7.3	66.8	54.7	1775.	0.041	0.118	0.96	0.62	1.25
1	2808.	0.	0.5	2.0	10.136	39.3	484.	17.8	19.9	13.3	7.2	66.7	54.1	1775.	0.041	0.113	1.11	0.26	1.05
1	2811.	0.	0.5	2.0	10.146	39.4	484.	17.8	19.9	13.3	7.2	66.7	54.2	1775.	0.039	0.119	1.07	-0.26	1.06
2	2654.	0.	4.3	1.8	13.741	42.3	483.	18.1	20.3	14.3	9.2	70.3	64.5	1775.	0.038	0.113	0.73	-0.18	1.05
2	2646.	0.	4.2	1.8	13.632	42.1	483.	18.1	20.3	14.2	9.1	70.1	64.1	1775.	0.047	0.310	1.01	-0.80	1.27
2	2648.	0.	4.1	1.8	13.530	41.9	483.	18.1	20.3	14.2	9.1	69.9	63.9	1775.	0.042	0.135	1.00	-0.59	1.05
2	2639.	0.	4.1	1.8	13.463	41.9	483.	18.1	20.3	14.2	9.0	69.8	63.5	1775.	0.045	0.127	1.04	0.50	1.01
2	2637.	0.	4.0	1.8	13.369	41.9	483.	18.1	20.3	14.2	8.9	69.9	62.9	1775.	0.045	0.152	1.38	0.03	0.95
3	2505.	0.	6.9	1.6	16.085	43.5	484.	18.3	20.5	14.7	10.2	71.7	69.2	1775.	0.040	0.120	0.77	0.69	1.02
3	2495.	0	6.8	1.6	16.055	43.6	484.	18.3	20.5	14.7	10.1	71.8	68.8	1775.	0.044	0.134	0.74	0.39	1.02
3	2502.	0	6.9	1.6	16.128	43.6	484.	18.3	20.5	14.7	10.2	71.8	69.3	1775.	0.042	0.126	0.78	0.63	1.13
3	2493.	0.	6.8	1.6	16.022	43.5	484.	18.3	20.5	14.7	10.1	71.7	68.7	1775.	0.040	0.106	0.81	0.29	1.05
3	2491.	0.	6.8	1.6	16.031	43.6	484.	18.3	20.5	14.7	10.1	71.7	68.6	1775.	0.045	0.135	0.86	0.32	1.04
4	2356.	0.	9.6	1.4	18.607	45.1	484.	18.5	20.8	15.2	11.1	73.5	72.7	1775.	0.042	0.119	0.59	0.78	1.02
4	2357.	0.	9.5	1.4	18.505	45.0	484.	18.5	20.8	15.2	11.0	73.3	72.5	1775.	0.039	0.119	0.54	0.77	1.03
4	2359.	0.	9.5	1.4	18.519	45.0	484.	18.5	20.8	15.2	11.0	73.4	72.5	1775.	0.043	0.137	0.55	0.69	0.95
4	2360.	0.	9.6	1.4	18.626	45.2	484.	18.5	20.8	15.3	11.1	73.6	72.7	1775.	0.042	0.136	0.59	0.28	0.97
4	2359.	0.	9.5	1.4	18.581	45.1	484.	18.5	20.8	15.3	11.1	73.4	72.7	1775.	0.041	0.125	0.65	0.75	1.00
5	2249.	0.	11.3	1.3	20.192	45.8	483.	18.6	20.8	15.5	11.5	74.3	74.1	1775.	0.045	0.165	0.88	0.57	1.09
5	2244.	0.	11.3	1.3	20.206	45.7	483.	18.6	20.8	15.5	11.5	74.2	74.2	1775.	0.039	0.096	0.71	0.65	1.06
5	2245.	0.	11.4	1.3	20.278	45.9	483.	18.6	20.9	15.5	11.5	74.4	74.2	1775.	0.042	0.120	0.80	0.75	1.09
5	2250.	0.	11.5	1.3	20.403	46.0	483.	18.6	20.9	15.5	11.6	74.5	74.7	1775.	0.040	0.105	0.61	0.73	1.09
5	2254.	0.	11.5	1.3	20.408	45.9	483.	18.6	20.8	15.5	11.6	74.4	74.9	1775.	0.039	0.115	0.59	0.61	1.14
6	2141.	0.	13.3	1.2	22.069	46.5	484.	18.6	20.9	15.7	11.9	75.1	76.0	1775.	0.041	0.110	0.52	0.81	1.09
6	2138.	0.	13.2	1.2	22.016	46.3	484.	18.6	20.9	15.7	11.9	74.9	76.0	1775.	0.042	0.124	0.54	0.85	1.06
6	2137.	0.	13.2	1.2	22.025	46.4	484.	18.6	20.9	15.7	11.9	75.0	75.8	1775.	0.040	0.126	0.53	0.87	1.03
6	2146.	0.	13.2	1.2	22.005	46.5	484.	18.6	20.9	15.7	11.9	75.0	76.0	1775.	0.045	0.135	0.54	0.85	1.00
6	2142.	0.	13.1	1.2	21.940	46.3	484.	18.6	20.9	15.6	11.9	74.8	75.9	1775.	0.045	0.127	0.53	0.80	1.01
7	2059.	0.	14.7	1.1	23.420	47.0	484.	18.7	21.0	15.9	12.2	75.6	76.7	1775.	0.041	0.117	0.57	-0.48	0.95
7	2061.	0.	14.8	1.1	23.472	47.2	484.	18.7	21.0	15.9	12.2	75.7	76.7	1775.	0.038	0.103	0.59	-0.57	0.92
7	2061.	0.	14.7	1.1	23.402	47.1	484.	18.7	21.0	15.9	12.2	75.7	76.7	1775.	0.042	0.134	0.64	-0.64	1.01
7	2056	0.	14.6	1.1	23.317	46.9	484.	18.7	21.0	15.8	12.1	75.5	76.5	1775.	0.046	0.141	0.59	0.80	0.99
7	2050.	0.	14.6	1.1	23.270	46.7	484.	18.7	20.9	15.8	12.1	75.3	76.5	1775.	0.039	0.131	0.58	0.79	1.00
8	1943.	0.	16.1	1.0	24.679	46.8	484.	18.7	21.0	15.8	12.1	75.6	76.6	1775.	0.039	0.115	0.61	0.85	1.06
8	1940.	0.	16.1	1.0	24.686	46.8	484.	18.7	20.9	15.8	12.1	75.6	76.5	1775.	0.038	0.107	0.64	0.85	1.01
8	1946.	0.	16.1	1.0	24.682	46.9	484.	18.7	21.0	15.8	12.1	75.6	76.7	1775.	0.042	0.113	0.69	0.79	0.99
8	1947.	0	16.1	1.0	24.683	46.8	484.	18.7	21.0	15.8	12.1	75.5	76.8	1775.	0.042	0.135	0.67	0.79	1.00

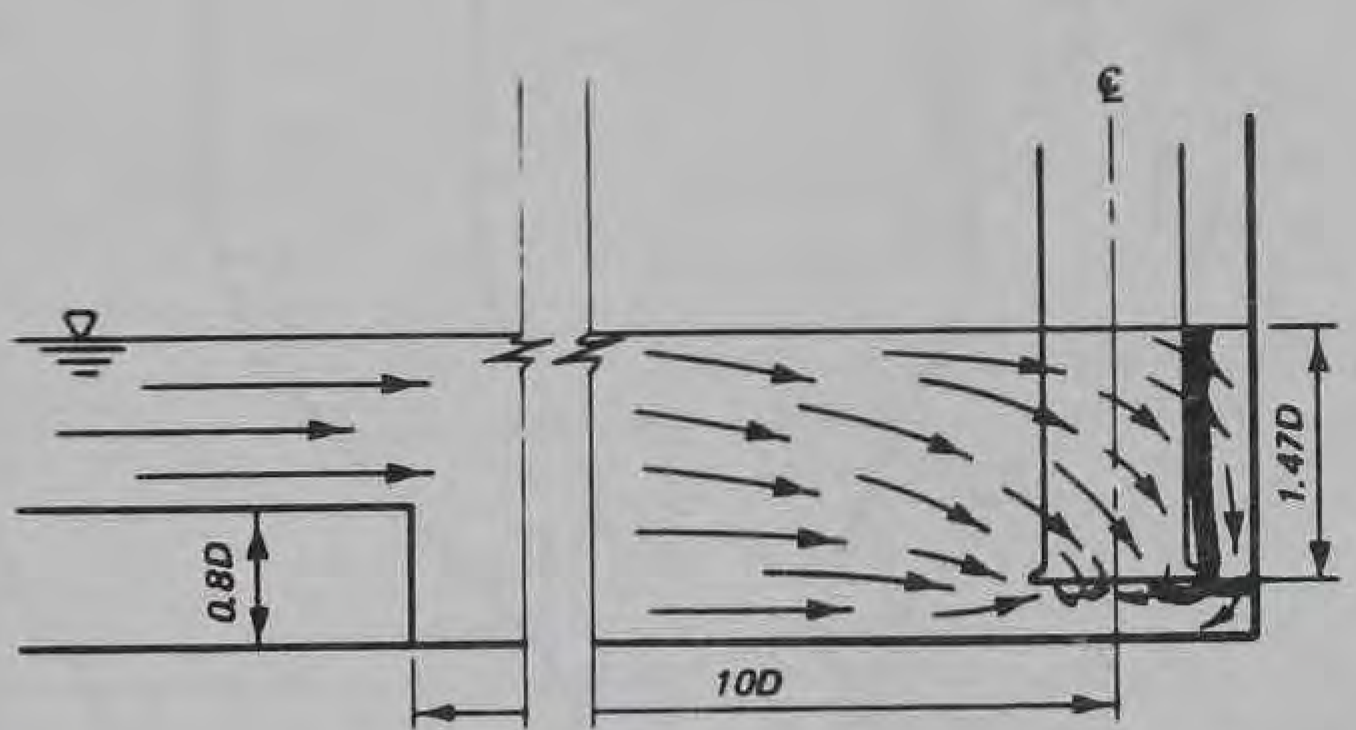
Figure 225. Test run 100-H18-009-0.0; research data; pump 1, Test H18, sump 9, submergence 0.47D (Continued)

8	1943.	0.	16.1	1.0	24.669	46.8	484.	18.7	21.0	15.8	12.1	75.6	76.5	1775.	0.038	0.094	0.66	0.47	0.96
9	1839.	0.	17.6	0.9	26.057	47.1	485.	18.7	21.1	15.9	12.1	75.5	76.2	1775.	0.043	0.139	1.08	0.39	1.01
9	1838.	0.	17.5	0.9	25.946	47.0	485.	18.7	21.0	15.9	12.1	75.5	75.9	1775.	0.046	0.132	1.08	0.71	0.95
9	1839.	0.	17.5	0.9	26.027	47.1	485.	18.7	21.0	15.9	12.1	75.6	76.0	1775.	0.044	0.136	1.11	0.72	0.97
9	1838.	0.	17.6	0.9	26.056	47.2	485.	18.7	21.1	16.0	12.1	75.8	75.9	1775.	0.048	0.132	1.03	0.72	0.94
9	1844.	0.	17.7	0.9	26.152	47.3	485.	18.7	21.1	16.0	12.2	75.9	76.2	1775.	0.041	0.130	1.00	0.64	0.90
10	1753.	0.	18.7	0.8	27.087	47.3	485.	18.7	21.1	16.0	12.0	75.8	75.1	1775.	0.042	0.135	1.38	0.26	1.04
10	1748.	0.	18.7	0.8	27.043	47.2	485.	18.7	21.1	16.0	12.0	75.7	74.9	1775.	0.040	0.150	1.08	0.62	1.00
10	1746.	0.	18.7	0.8	27.061	47.3	485.	18.7	21.1	16.0	11.9	75.8	74.7	1775.	0.043	0.139	0.98	0.78	0.97
10	1752.	0.	18.7	0.8	27.086	47.4	485.	18.7	21.1	16.0	12.0	76.0	74.8	1775.	0.043	0.156	1.47	0.70	1.00
10	1750.	0.	18.6	0.8	26.995	47.3	485.	18.7	21.1	16.0	11.9	75.8	74.7	1775.	0.043	0.109	1.07	0.66	0.94
11	1651.	0.	19.8	0.7	28.077	47.6	486.	18.8	21.1	16.1	11.7	76.1	72.9	1775.	0.046	0.141	1.11	0.73	1.04
11	1651.	0.	19.8	0.7	28.137	47.5	486.	18.8	21.1	16.1	11.7	76.0	73.1	1775.	0.045	0.131	0.91	0.86	1.07
11	1655.	0.	19.8	0.7	28.131	47.6	485.	18.8	21.1	16.1	11.8	76.2	73.2	1775.	0.045	0.130	1.19	0.81	1.08
11	1647.	0.	19.8	0.7	28.054	47.5	485.	18.7	21.1	16.0	11.7	76.0	72.8	1775.	0.040	0.120	0.94	0.76	1.13
11	1654.	0.	19.9	0.7	28.200	47.6	485.	18.8	21.1	16.1	11.8	76.2	73.2	1775.	0.046	0.130	1.00	0.68	1.11
12	1548.	0.	20.6	0.6	28.832	47.6	486.	18.8	21.1	16.1	11.3	76.1	70.1	1775.	0.045	0.122	1.01	0.82	1.07
12	1551.	0.	20.6	0.6	28.814	47.6	485.	18.8	21.1	16.1	11.3	76.2	70.2	1775.	0.043	0.120	1.02	0.78	1.05
12	1548.	0.	20.5	0.6	28.702	47.4	485.	18.7	21.1	16.0	11.2	76.0	70.1	1775.	0.048	0.147	1.27	0.77	1.05
12	1546.	0.	20.5	0.6	28.710	47.5	485.	18.7	21.1	16.1	11.2	76.1	69.9	1775.	0.048	0.161	1.30	0.74	1.04
12	1545.	0.	20.5	0.6	28.699	47.5	486.	18.7	21.1	16.0	11.2	76.0	69.9	1775.	0.049	0.160	1.26	0.75	1.01
13	1397.	0.	21.5	0.5	29.616	47.2	485.	18.7	21.1	15.9	10.5	75.8	65.6	1775.	0.052	0.134	1.42	0.81	1.28
13	1397.	0.	21.6	0.5	29.696	47.4	485.	18.7	21.1	16.0	10.5	76.0	65.5	1775.	0.051	0.163	1.14	0.58	1.24
13	1399.	0.	21.5	0.5	29.628	47.3	485.	18.7	21.1	16.0	10.5	75.9	65.5	1775.	0.053	0.151	1.24	0.78	1.26
13	1397.	0.	21.5	0.5	29.586	47.2	485.	18.7	21.0	15.9	10.4	75.9	65.5	1775.	0.052	0.180	1.42	0.44	1.15
13	1400.	0.	21.5	0.5	29.588	47.3	485.	18.7	21.0	16.0	10.5	75.9	65.5	1775.	0.054	0.164	1.21	0.71	1.14
14	1257.	0.	21.5	0.4	29.480	45.4	486.	18.5	20.8	15.3	9.4	73.6	61.1	1775.	0.072	0.221	2.19	0.29	1.48
14	1248.	0.	21.3	0.4	29.324	44.9	486.	18.4	20.8	15.2	9.3	73.1	60.9	1775.	0.081	0.239	2.31	0.19	1.64
14	1255.	0.	21.4	0.4	29.429	45.2	486.	18.5	20.8	15.3	9.3	73.4	61.2	1775.	0.076	0.213	2.34	0.44	1.56
14	1253.	0.	21.4	0.4	29.417	45.2	486.	18.5	20.8	15.3	9.3	73.4	61.0	1775.	0.081	0.260	2.37	0.37	1.54
14	1251.	0.	21.3	0.4	29.346	45.0	486.	18.4	20.8	15.2	9.3	73.2	61.1	1775.	0.080	0.282	2.45	0.28	1.73
15	1104.	0.	21.3	0.3	29.236	43.7	487.	18.3	20.6	14.8	8.2	71.5	55.3	1775.	0.103	0.429	3.86	-0.61	2.04
15	1104.	0.	21.4	0.3	29.276	43.6	487.	18.3	20.6	14.8	8.2	71.5	55.4	1775.	0.105	0.289	4.21	-0.33	2.17
15	1104.	0.	21.4	0.3	29.296	43.6	487.	18.3	20.6	14.7	8.2	71.5	55.4	1775.	0.101	0.287	4.09	-0.22	2.23
15	1104.	0.	21.4	0.3	29.276	43.6	487.	18.2	20.6	14.7	8.2	71.5	55.5	1775.	0.101	0.329	3.91	-0.05	2.09
15	1104.	0.	21.4	0.3	29.336	43.6	488.	18.2	20.6	14.7	8.2	71.4	55.6	1775.	0.118	0.328	4.46	-0.12	2.16
16	953.	0.	22.5	0.2	30.365	44.1	487.	18.3	20.7	14.9	7.3	72.1	49.1	1775.	0.121	0.399	5.41	-0.57	2.37
16	952.	0.	22.5	0.2	30.285	44.0	487.	18.3	20.6	14.9	7.3	72.0	49.0	1775.	0.114	0.392	5.30	-0.50	2.37
16	954.	0.	22.4	0.2	30.276	44.0	487.	18.3	20.6	14.9	7.3	72.0	49.1	1775.	0.127	0.395	5.15	-0.73	2.37
16	953.	0.	22.4	0.2	30.255	43.9	486.	18.3	20.6	14.8	7.3	72.0	49.1	1775.	0.118	0.374	4.74	-0.54	2.28
16	947.	0.	22.3	0.2	30.123	43.8	486.	18.3	20.6	14.8	7.2	71.9	48.8	1775.	0.123	0.500	4.89	-0.61	2.12
17	805.	0.	24.2	0.2	31.948	45.2	486.	18.4	20.8	15.3	6.5	73.6	42.5	1775.	0.127	0.472	6.07	-0.52	2.32
17	802.	0.	24.1	0.2	31.907	45.2	486.	18.4	20.8	15.3	6.5	73.6	42.3	1775.	0.138	0.508	6.04	-0.57	2.54
17	802.	0.	24.1	0.2	31.877	45.3	486.	18.4	20.8	15.3	6.5	73.6	42.2	1775.	0.144	0.442	5.56	-0.80	2.39
17	804.	0.	24.2	0.2	31.918	45.4	486.	18.4	20.8	15.3	6.5	73.7	42.3	1775.	0.142	0.650	5.03	-1.11	2.54
17	804.	0.	24.1	0.2	31.908	45.3	486.	18.4	20.8	15.3	6.5	73.7	42.4	1775.	0.136	0.392	5.16	-0.70	2.29

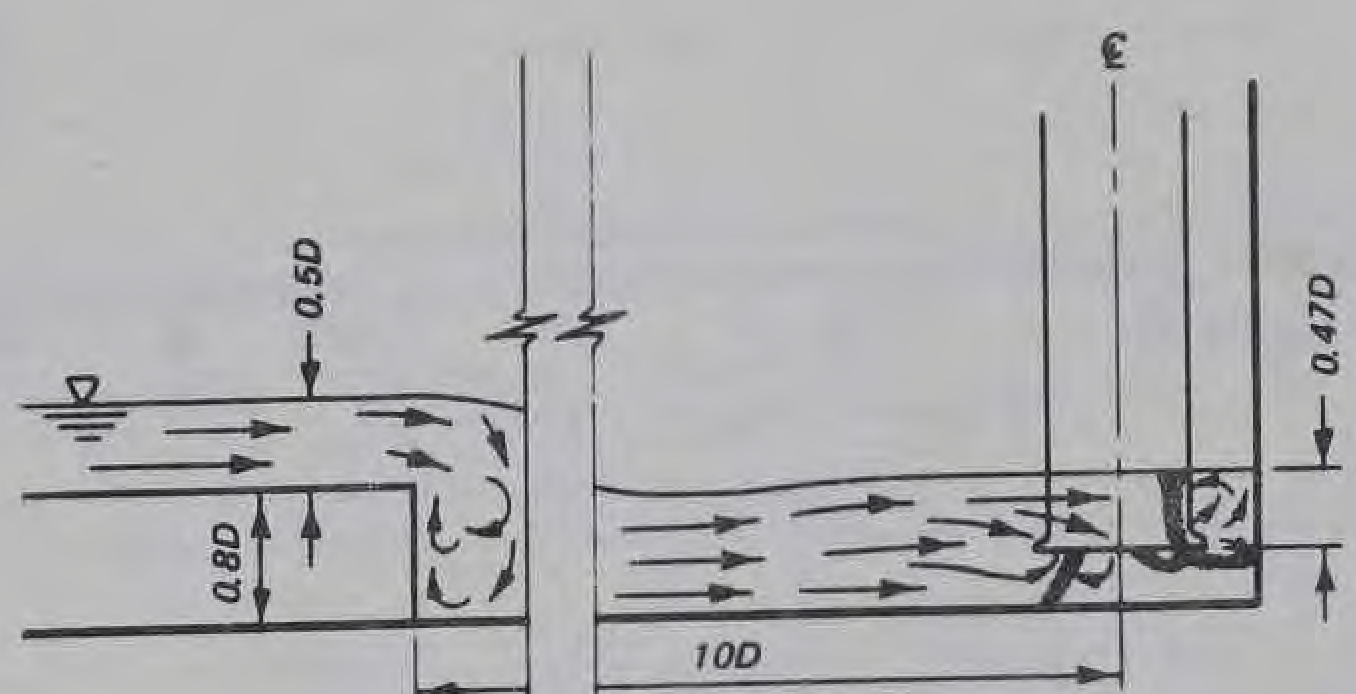
Figure 225. (Concluded)



TEST H16, SUBMERGENCE = 2.47D



TEST H17, SUBMERGENCE = 1.47D



TEST H18, SUBMERGENCE = 0.47D

Figure 226. Flow pattern for sump type 9, discharge 1,930 gpm (4.3 cfs), bell diam $D = 1.3$ ft, $Q/g^{1/2}D^{5/2} = 0.4$

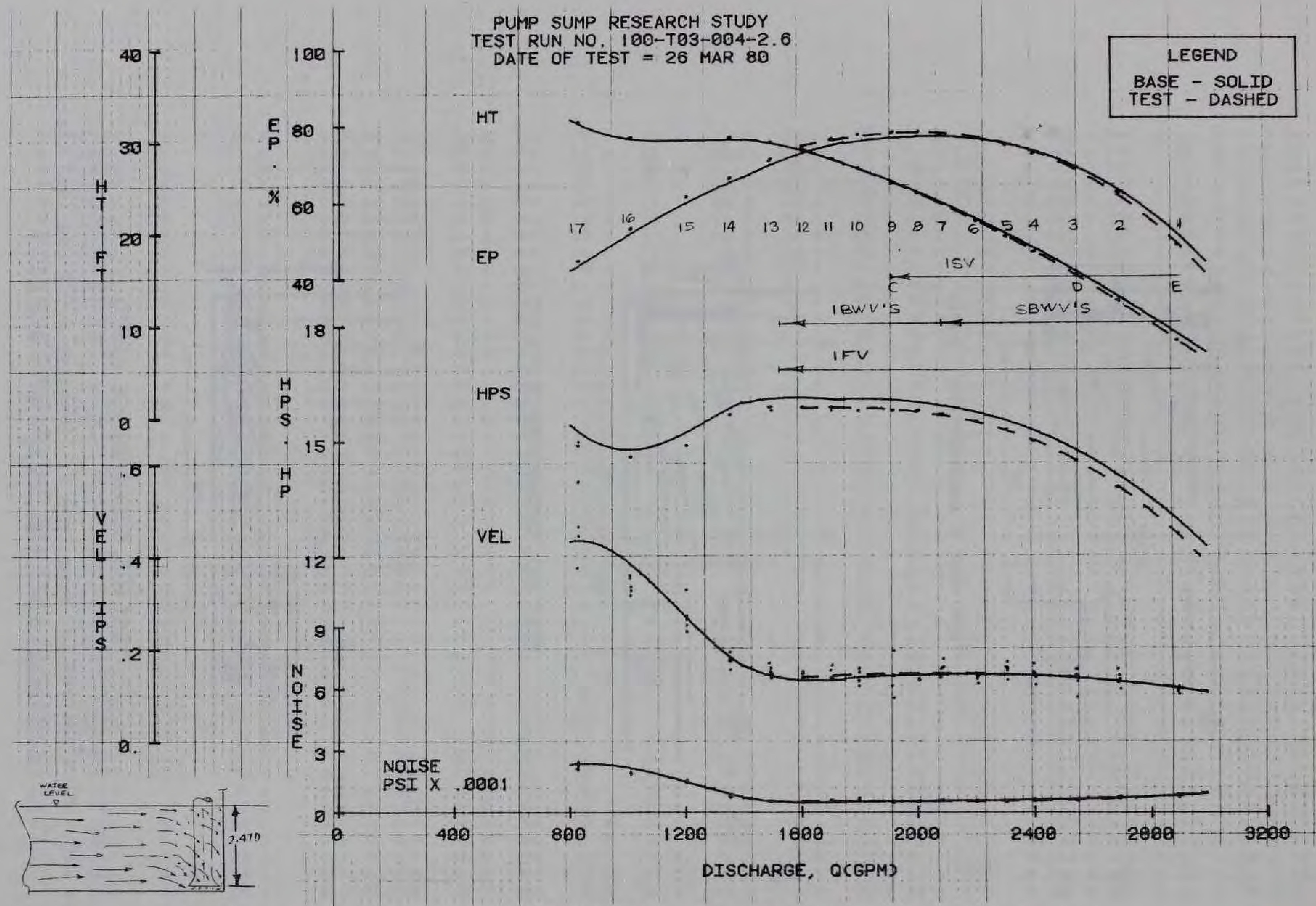


Figure 227. Test run 100-T03-004-2.6; performance characteristics curves; pump 1, Test T03, sump 4, submergence 2.47D

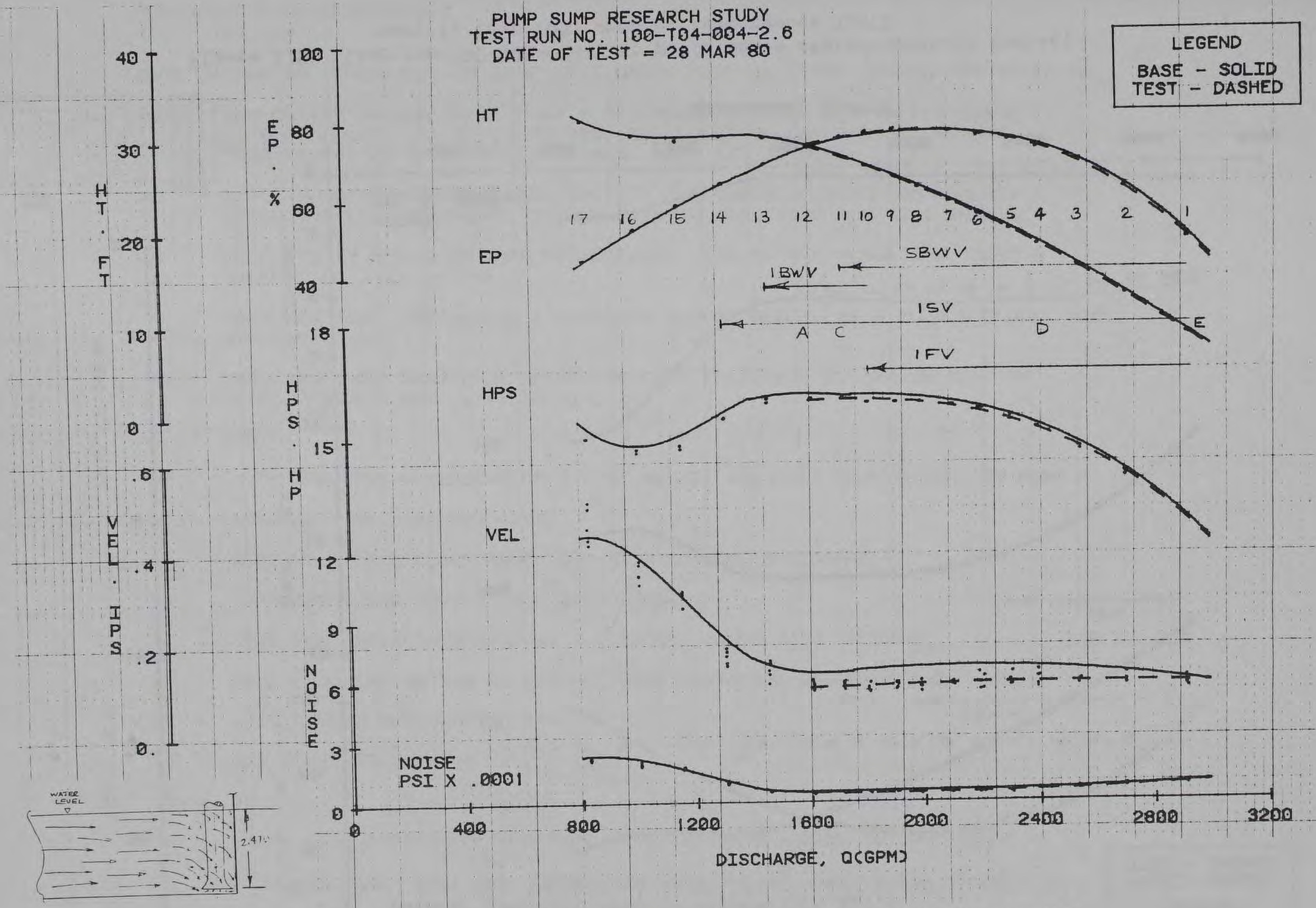


Figure 228. Test run 100-T04-004-2.6; performance characteristics curves; pump 1, Test T04, sump 4, submergence 2.47D

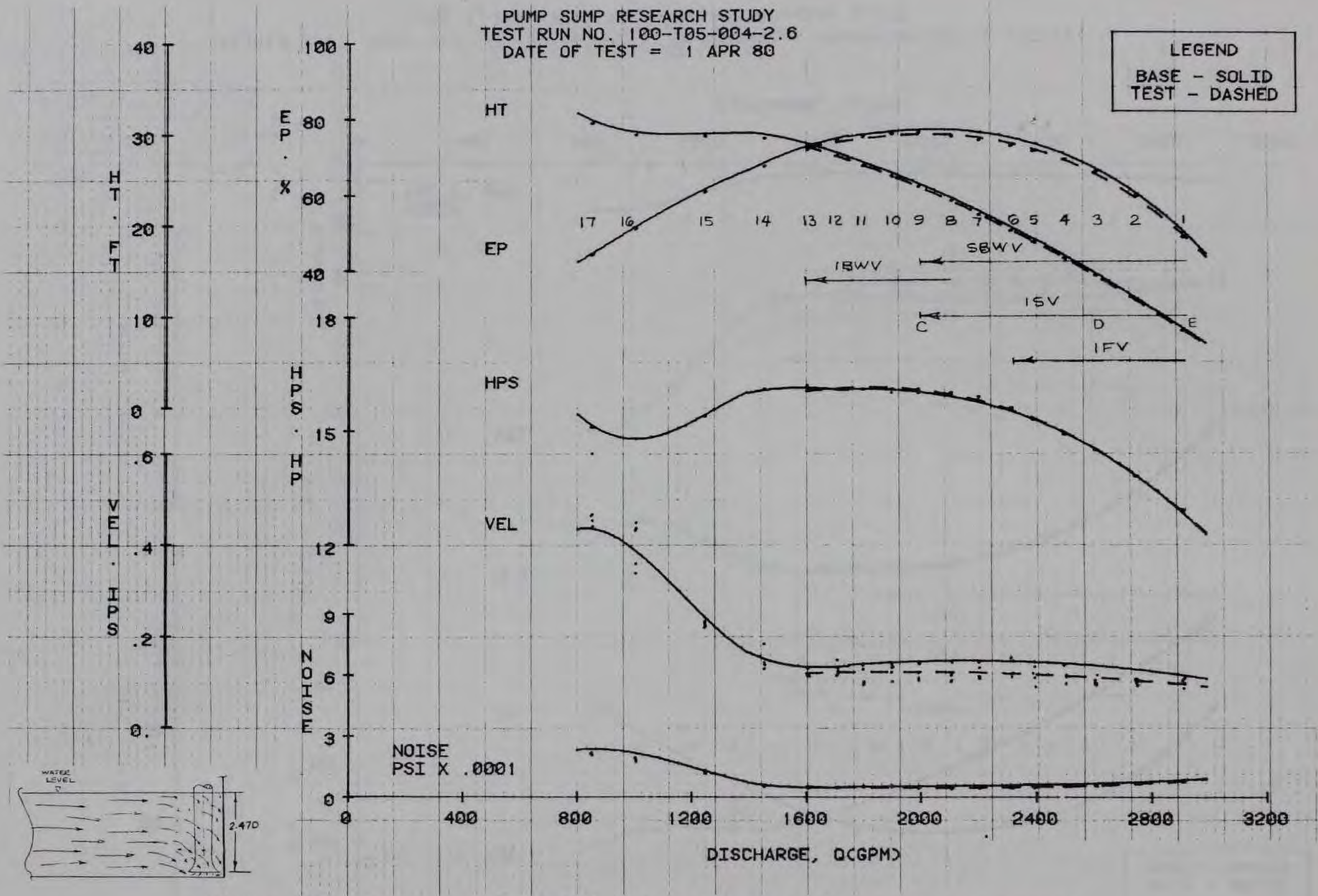


Figure 229. Test run 100-T05-004-2.6; performance characteristics curves; pump 1, Test T05, sump 4, submergence 2.47D

PUMPS RUN SUMP SUBMERGENCE
100 T03 004 2.6

DATE 26 MAR 80 TIME 1350 AIR TEMP 57 F WATER TEMP 61 F BAR. PRESS. 29.98 IN HG

01 ISV CW 1/2 IN DIA STAGE E AT 4 O'CLOCK. ISV CCW 1/2 IN DIA STAGE E AT 8 O'CLOCK. IFV'S 1/8 IN DIA, CW, LOCATION VARYING ALL AROUND. TWIN SBWV'S AT 6:30 CW & 5:30 CCW, BOTH 1/8 IN DIA

02 NSCE (NO SIGNIFICANT CHANGE EXCEPT) ALL VORTEXES BECOMING SMALLER & OCCURRING LESS FREQUENT. ISV NOW 1/4 IN DIA, FV'S NOW 1/16 IN DIA.

03 NSCE ISV AT 8 O'CLOCK HAS DISAPPEARED. ISV AT 4 O'CLOCK NOW STAGE D. SBWV'S NOW 1/16 IN DIA

04 NSCE IFV NOW 1/32 IN DIA & LOCATION ALMOST ALWAYS AT 8 TO 9 O'CLOCK, 3 IN FROM BELL CP.

05 NSCE VORTEXES SMALLER & OCCURRING LESS FREQUENT; SV 1/4 IN DIA, FV 1/32 IN DIA & BWV' 1/16 IN DIA

06 NSC.

07 NSCE FLASHING APPEARING ON TIP OF BLADE, POSSIBLE CAVITATION. FV GONE.

08 NSCE SBWV AT 6:30 NOW IBWV

09 NSCE SV AT 8 O'CLOCK GONE, ISV AT 4 O'CLOCK NOW STAGE C.

10 BOTH BWV'S NOW IBWV'S, ALL SV'S GONE.

11 NSCE CCW CIRCULAR MOTION AT 7 O'CLOCK, BWV'S 1/32 IN DIA.

12 NSCE CIRCULAR MOTION ON SURFACE GONE, FLASHING BECOMING MUCH LARGER.

13 NSCE IBWV'S NOW 1/32 IN DIA.

14 ALL VORTEXES GONE.

15-16 NSC.

17 NSCE SPRAY EXPULSION FROM PUMP BELL INTAKE REACHING TO SUMP FLOOR.

Figure 230. Test run 100-T03-004-2.6; visual observation notes; pump 1, Test T03, sump 4, submergence 2.47D

PUMPS RUN SUMP SUBMERGENCE
100 T04 004 2.6

DATE 28 MAR 80 TIME 1315 AIR TEMP 66 F WATER TEMP 61 F BAR. PRESS. 29.74IN HG

01 ISV CW 1/2 IN DIA STAGE E AT 4 O'CLOCK. ISV CCW 1/2 IN DIA STAGE E AT 8 O'CLOCK. IFV'S 1/8 IN DIA, CW, LOCATION VARYING ALL AROUND. TWIN SBWV'S AT 6:30 CW & 5:30 CCW, BOTH 1/8 IN DIA.

02 NSCE (NO SIGNIFICANT CHANGE EXCEPT) ALL VORTEXES BECOMING SMALLER & OCCURRING LESS FREQUENT

03 NSCE ISV NOW 1/4 IN DIA, FV'S NOW 1/16 IN DIA.

04 NSCE ISV AT 8 O'CLOCK HAS DISAPPEARED. ISV AT 4 O'CLOCK NOW STAGE D. SBWV'S NOW 1/16 IN DIA.

05 NSCE IFV NOW 1/32 IN DIA & LOCATION ALMOST ALWAYS AT 8 O'CLOCK, 3 IN FROM BELL CP

06 NSCE ALL SV'S GONE. IFV ALTERNATING BETWEEN LOCATIONS 4 & 8 O'CLOCK.

07 NSCE BWV'S 1/16 IN DIA.

08 NSCE TINY FLASHING APPEARING ON TIP OF BLADE, POSSIBLE CAVITATION.

09-10 NSCE SBWV AT 6:30 BECOMING IBWV. ALL VORTEXES BECOMING SMALLER & OCCURRING LESS FREQUENT.

11 NSCE FV GONE. SV'S NOW STAGE C. BWV'S 1/32 IN DIA.

12 NSCE BOTH BWV'S NOW IBWV'S. SURFACE VORTEXES NOW STAGE A.

13 NSCE FLASHING BECOMING MUCH LARGER & VORTEXES BECOMING SMALLER & OCCURRING LESS FREQUENT.

14 NSCE BWV'S GONE.

15 NSCE ALL VORTEXES GONE.

16 NSC.

17 NSCE SPRAY EXPULSIONS FROM BELL INTAKE REACHING TO SUMP FLOOR.

Figure 231. Test run 100-T04-004-2.6; visual observation notes; pump 1, Test T04, sump 4, submergence 2.47D

PUMPS RUN SUMP SUBMERGENCE
100 T05 004 2.6

DATE 26 MAR 80 TIME 1350 AIR TEMP 57 F WATER TEMP 61 F BAR. PRESS. 29.98 IN HG

01 ISV CW 1/2 IN DIA STAGE E AT 4 O'CLOCK. ISV CCW 1/2 IN DIA STAGE E AT 8 O'CLOCK. IFV'S 1/8 IN DIA, CW, LOCATION VARYING ALL AROUND. TWIN SBWV'S AT 6:30 CW & 5:30 CCW, BOTH 1/8 IN DIA.

02 NSCE (NO SIGNIFICANT CHANGE EXCEPT) ALL VORTEXES BECOMING SMALLER & OCCURRING LESS FREQUENT. ISV NOW 1/4 IN DIA, FV'S NOW 1/16 IN DIA.

03 NSCE ISV AT 8 O'CLOCK HAS DISAPPEARED. ISV AT 4 O'CLOCK NOW STAGE D. SBWV'S NOW 1/16 IN DIA.

04 NSCE IFV NOW 1/32 IN DIA & LOCATION ALMOST ALWAYS AT 8 TO 9 O'CLOCK, 3 IN FROM BELL CP.

05 NSCE VORTEXES SMALLER & OCCURRING LESS FREQUENT, SV 1/4 IN DIA, FV 1/32 IN DIA & BWV'S 1/16 IN DIA.

06 NSC

07 NSCE FLASHING APPEARING ON TIP OF BLADE, POSSIBLE CAVITATION. FV GONE.

08 NSCE SBWV AT 6:30 NOW IBWV

09 NSCE SV AT 8 O'CLOCK GONE, ISV AT 4 O'CLOCK NOW STAGE C.

10 BOTH BWV'S NOW IBWV'S. ALL SV'S GONE.

11 NSCE CCW CIRCULAR MOTION AT 7 O'CLOCK, BWV'S 1/32 IN DIA.

12 NSCE CIRCULAR MOTION ON SURFACE GONE, FLASHING BECOMING MUCH LARGER.

13 NSCE IBWV'S NOW 1/32 IN DIA.

14 ALL VORTEXES GONE

15-16 NSC.

17 NSCE SPRAY EXPULSION FROM PUMP BELL INTAKE REACHING TO SUMP FLOOR.

Figure 232. Test run 100-T05-004-2.6; visual observation notes; pump 1, Test T05, sump 4, submergence 2.47D

PUMP EFFICIENCY

TOTAL AREA -238.43 ABSOLUTE AREA 1590.92

TEST CURVE

MAX Y = 78.23 , X = 1997.52
MIN Y = 41.40 , X = 2987.62
MEAN Y = 72.40 , X = 2426.71

SIGNATURE CURVE

MAX Y = 71.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 71.86 , X = 2460.73

SHAFT HORSEPOWER

TOTAL AREA -384.24 ABSOLUTE AREA 384.24

TEST CURVE

MAX Y = 15.88 , X = 1699.50
MIN Y = 11.84 , X = 2987.62
MEAN Y = 15.28 , X = 2303.97

SIGNATURE CURVE

MAX Y = 16.14 , X = 1600.00
MIN Y = 12.27 , X = 2987.62
MEAN Y = 15.54 , X = 2300.66

ABS VELOCITY, IPS

TOTAL AREA 3.34 ABSOLUTE AREA 3.41

TEST CURVE

MAX Y = 0.15 , X = 2059.41
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2494.65

SIGNATURE CURVE

MAX Y = 0.15 , X = 2158.42
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2619.20

NOISE LB/SQ IN

TOTAL AREA -7.06 ABSOLUTE AREA 37.75

TEST CURVE

MAX Y = 0.97 , X = 2987.62
MIN Y = 0.54 , X = 1600.00
MEAN Y = 0.59 , X = 2682.22

SIGNATURE CURVE

MAX Y = 0.93 , X = 2987.62
MIN Y = 0.47 , X = 1631.19
MEAN Y = 0.56 , X = 2571.52

TOTAL HEAD

TOTAL AREA -415.24 ABSOLUTE AREA 431.17

TEST CURVE

MAX Y = 29.19 , X = 1600.00
MIN Y = 6.31 , X = 2987.62
MEAN Y = 23.24 , X = 2082.16

SIGNATURE CURVE

MAX Y = 29.07 , X = 1600.00
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.39 , X = 2081.24

Figure 233. Test run 100-T03-004-2.6; statistical comparison; pump 1, Test T03, sump 4, submergence 2.47D

PUMP EFFICIENCY

TOTAL AREA -462.48 ABSOLUTE AREA 727.24

TEST CURVE

MAX Y = 77.47 , X = 2009.90
MIN Y = 43.46 , X = 2987.62
MEAN Y = 71.83 , X = 2439.44

SIGNATURE CURVE

MAX Y = 77.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 71.86 , X = 2460.73

SHAFT HORSEPOWER

TOTAL AREA -158.59 ABSOLUTE AREA 158.59

TEST CURVE

MAX Y = 15.98 , X = 1739.60
MIN Y = 12.21 , X = 2987.62
MEAN Y = 15.42 , X = 2300.98

SIGNATURE CURVE

MAX Y = 16.14 , X = 1600.00
MIN Y = 12.27 , X = 2987.62
MEAN Y = 15.54 , X = 2300.66

ABS VELOCITY, IPS

TOTAL AREA -40.37 ABSOLUTE AREA 40.37

TEST CURVE

MAX Y = 0.11 , X = 2492.57
MIN Y = 0.10 , X = 1600.00
MEAN Y = 0.11 , X = 3164.45

SIGNATURE CURVE

MAX Y = 0.15 , X = 2158.42
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2619.20

NOISE LB/SQ IN

TOTAL AREA -99.42 ABSOLUTE AREA 99.42

TEST CURVE

MAX Y = 0.90 , X = 2987.62
MIN Y = 0.43 , X = 1824.26
MEAN Y = 0.50 , X = 2529.07

SIGNATURE CURVE

MAX Y = 0.93 , X = 2987.62
MIN Y = 0.47 , X = 1631.19
MEAN Y = 0.56 , X = 2571.52

TOTAL HEAD

TOTAL AREA -299.50 ABSOLUTE AREA 299.50

TEST CURVE

MAX Y = 28.95 , X = 1600.00
MIN Y = 6.89 , X = 2987.62
MEAN Y = 23.20 , X = 2082.33

SIGNATURE CURVE

MAX Y = 29.07 , X = 1600.00
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.39 , X = 2081.24

Figure 234. Test run 100-T04-004-2.6; statistical comparison; pump 1, Test T04, sump 4, submergence 2.47D

PUMP EFFICIENCY

TOTAL AREA -1773.62 ABSOLUTE AREA 1773.62

TEST CURVE

MAX Y = 76.00 , X = 2009.90
MIN Y = 43.53 , X = 2987.62
MEAN Y = 70.78 , X = 2443.52

SIGNATURE CURVE

MAX Y = 77.31 , X = 2034.65
MIN Y = 44.36 , X = 2987.62
MEAN Y = 71.86 , X = 2460.73

SHAFT HORSEPOWER

TOTAL AREA 40.13 ABSOLUTE AREA 47.24

TEST CURVE

MAX Y = 16.15 , X = 1811.88
MIN Y = 12.32 , X = 2987.62
MEAN Y = 15.55 , X = 2311.08

SIGNATURE CURVE

MAX Y = 16.14 , X = 1600.00
MIN Y = 12.27 , X = 2987.62
MEAN Y = 15.54 , X = 2300.66

ABS VELOCITY, IPS

TOTAL AREA -31.24 ABSOLUTE AREA 31.24

TEST CURVE

MAX Y = 0.12 , X = 1948.02
MIN Y = 0.09 , X = 2987.62
MEAN Y = 0.12 , X = 2386.85

SIGNATURE CURVE

MAX Y = 0.15 , X = 2158.42
MIN Y = 0.11 , X = 2987.62
MEAN Y = 0.14 , X = 2619.20

NOISE LB/SQ IN

TOTAL AREA -104.68 ABSOLUTE AREA 109.85

TEST CURVE

MAX Y = 0.90 , X = 2987.62
MIN Y = 0.47 , X = 2108.91
MEAN Y = 0.53 , X = 2682.40

SIGNATURE CURVE

MAX Y = 0.93 , X = 2987.62
MIN Y = 0.47 , X = 1631.19
MEAN Y = 0.56 , X = 2571.52

TOTAL HEAD

TOTAL AREA -441.26 ABSOLUTE AREA 441.26

TEST CURVE

MAX Y = 28.73 , X = 1600.00
MIN Y = 6.91 , X = 2987.62
MEAN Y = 23.04 , X = 2081.25

SIGNATURE CURVE

MAX Y = 29.07 , X = 1600.00
MIN Y = 7.10 , X = 2987.62
MEAN Y = 23.39 , X = 2081.24

Figure 235. Test run 100-T05-004-2.6; statistical comparison; pump 1, Test T05, sump 4, submergence 2.47D

READ: NO.	Q DIS- CHARGE: GPM	HW SUBMER- GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL: HEAD FT	T TORQUE: FT/LB	E VOLTS	I AMPS	HPM INPUT MOTOR HP	HPS SHAFT HP	HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2888.	2.6	1.2	2.2	8.393	37.3	482.	17.1	19.1	12.6	6.1	65.9	48.7	1775.	0.041	0.111	8.50	3.11	3.69
1	2892.	2.6	1.2	2.2	8.389	37.3	482.	17.1	19.1	12.6	6.1	66.0	48.7	1775.	0.041	0.117	8.51	3.17	3.72
1	2888.	2.6	1.2	2.2	8.413	37.4	481.	17.1	19.1	12.6	6.1	66.2	48.6	1775.	0.040	0.112	8.91	3.42	3.70
1	2892.	2.6	1.2	2.2	8.398	37.3	482.	17.1	19.1	12.6	6.1	66.1	48.7	1775.	0.039	0.120	8.63	2.14	3.68
1	2893.	2.6	1.2	2.2	8.415	37.3	482.	17.1	19.1	12.6	6.2	66.1	48.8	1775.	0.038	0.104	7.35	3.29	3.68
2	2693.	2.6	5.8	1.9	12.701	40.8	481.	17.5	19.5	13.8	8.6	70.8	62.7	1775.	0.049	0.136	6.71	3.47	3.74
2	2690.	2.6	5.8	1.9	12.670	40.8	481.	17.5	19.5	13.8	8.6	70.8	62.4	1775.	0.059	0.145	7.75	2.22	3.70
2	2695.	2.6	5.7	1.9	12.626	40.8	481.	17.5	19.5	13.8	8.6	70.8	62.3	1775.	0.042	0.115	7.93	3.44	3.69
2	2687.	2.6	5.8	1.9	12.712	40.9	481.	17.5	19.5	13.8	8.6	70.9	62.5	1775.	0.053	0.129	7.14	3.03	3.68
2	2685.	2.6	5.8	1.9	12.692	40.8	481.	17.5	19.5	13.8	8.6	70.9	62.4	1775.	0.045	0.158	7.76	3.28	3.70
3	2547.	2.6	8.8	1.7	15.518	42.8	480.	17.7	19.7	14.5	10.0	73.4	69.1	1775.	0.038	0.097	6.18	3.49	3.70
3	2546.	2.6	8.8	1.7	15.466	42.8	481.	17.7	19.7	14.5	10.0	73.3	68.8	1775.	0.052	0.158	6.31	3.13	3.70
3	2542.	2.6	8.8	1.7	15.472	42.8	481.	17.7	19.7	14.5	9.9	73.4	68.7	1775.	0.048	0.158	6.16	3.49	3.69
3	2543.	2.6	8.8	1.7	15.451	42.8	481.	17.7	19.7	14.5	9.9	73.4	68.7	1775.	0.054	0.145	6.06	2.34	3.70
3	2548.	2.6	8.8	1.7	15.468	42.8	481.	17.7	19.7	14.5	10.0	73.4	68.9	1775.	0.051	0.132	5.67	2.58	3.68
4	2404.	2.6	11.5	1.5	18.037	44.5	481.	17.9	19.9	15.0	11.0	75.4	72.9	1775.	0.043	0.124	5.87	3.12	3.70
4	2404.	2.6	11.5	1.5	18.006	44.5	481.	17.9	19.9	15.0	10.9	75.3	72.8	1775.	0.051	0.141	5.72	2.85	3.72
4	2396.	2.6	11.5	1.5	17.976	44.5	481.	17.9	19.9	15.0	10.9	75.3	72.5	1775.	0.046	0.152	5.83	2.65	3.68
4	2397.	2.6	11.5	1.5	17.997	44.5	481.	17.9	19.9	15.0	10.9	75.4	72.5	1775.	0.058	0.170	6.26	3.49	3.71
4	2399.	2.6	11.5	1.5	17.990	44.5	481.	17.9	19.9	15.0	10.9	75.4	72.6	1775.	0.046	0.148	6.49	2.88	3.70
5	2307.	2.6	13.3	1.4	19.674	45.3	482.	18.0	20.1	15.3	11.5	75.9	75.0	1775.	0.049	0.135	5.60	3.37	3.70
5	2304.	2.6	13.3	1.4	19.681	45.3	482.	18.0	20.1	15.3	11.5	76.0	74.9	1775.	0.055	0.155	5.26	2.86	3.70
5	2302.	2.6	13.3	1.4	19.668	45.3	482.	18.0	20.1	15.3	11.4	76.0	74.8	1775.	0.054	0.163	5.01	2.96	3.69
5	2304.	2.6	13.3	1.4	19.681	45.2	482.	18.0	20.1	15.3	11.5	76.0	75.0	1775.	0.066	0.174	5.39	3.34	3.70
5	2306.	2.6	13.3	1.4	19.653	45.2	482.	18.0	20.1	15.3	11.5	75.9	75.0	1775.	0.064	0.160	4.97	3.39	3.68
6	2200.	2.6	15.1	1.3	21.387	45.9	481.	18.1	20.2	15.5	11.9	76.8	76.6	1775.	0.053	0.148	5.37	2.09	3.69
6	2203.	2.6	15.1	1.3	21.349	45.9	481.	18.1	20.2	15.5	11.9	76.8	76.6	1775.	0.049	0.137	5.31	3.53	3.69
6	2206.	2.6	15.1	1.3	21.373	45.9	481.	18.1	20.2	15.5	11.9	76.8	76.8	1775.	0.043	0.127	5.51	3.56	3.71
6	2204.	2.6	15.1	1.3	21.381	45.9	481.	18.1	20.2	15.5	11.9	76.8	76.7	1775.	0.056	0.146	5.21	3.52	3.70
6	2206.	2.6	15.1	1.3	21.373	45.9	481.	18.1	20.2	15.5	11.9	76.8	76.8	1775.	0.056	0.143	5.62	3.54	3.69
7	2088.	2.6	17.1	1.1	23.192	46.5	482.	18.2	20.3	15.7	12.2	77.4	77.8	1775.	0.059	0.163	5.52	3.37	3.71
7	2087.	2.6	17.1	1.1	23.211	46.5	482.	18.2	20.3	15.7	12.2	77.4	77.9	1775.	0.048	0.162	6.08	3.43	3.69
7	2088.	2.6	17.1	1.1	23.233	46.5	482.	18.2	20.3	15.7	12.3	77.4	78.0	1775.	0.074	0.180	5.54	3.37	3.71
7	2079.	2.6	17.2	1.1	23.284	46.5	482.	18.2	20.3	15.7	12.2	77.4	77.8	1775.	0.055	0.159	5.81	3.57	3.70
7	2078.	2.6	17.2	1.1	23.345	46.5	482.	18.2	20.3	15.7	12.3	77.4	78.0	1775.	0.054	0.140	5.81	3.57	3.71
8	1999.	2.6	18.4	1.0	24.425	46.7	482.	18.2	20.3	15.8	12.3	77.6	78.2	1775.	0.055	0.149	5.13	3.51	3.69
8	2002.	2.6	18.4	1.0	24.408	46.7	482.	18.2	20.3	15.8	12.4	77.6	78.3	1775.	0.053	0.137	5.38	3.57	3.69
8	2002.	2.6	18.4	1.0	24.428	46.7	482.	18.2	20.3	15.8	12.4	77.6	78.3	1775.	0.044	0.134	5.24	3.57	3.70
8	1997.	2.6	18.4	1.0	24.423	46.7	482.	18.2	20.3	15.8	12.3	77.5	78.2	1775.	0.057	0.147	5.15	3.58	3.70

Figure 236. Test run 100-T03-004-2.6; research data; pump 1, Test T03, sump 4, submergence 2.47D (Continued)

8	2005.	2.6	18.4	1.0	24.441	46.7	482.	18.2	20.3	15.8	12.4	77.6	78.5	1775.	0.053	0.134	5.56	3.57	3.70
9	1916.	2.6	19.6	1.0	25.566	46.7	482.	18.2	20.3	15.8	12.4	77.7	78.4	1775.	0.051	0.143	5.10	3.07	3.69
9	1910.	2.6	19.6	0.9	25.550	46.7	482.	18.2	20.3	15.8	12.3	77.7	78.1	1775.	0.048	0.122	5.02	3.53	3.68
9	1913.	2.6	19.6	0.9	25.563	46.7	482.	18.2	20.3	15.8	12.4	77.7	78.3	1775.	0.055	0.145	5.46	3.48	3.68
9	1916.	2.6	19.6	1.0	25.525	46.8	482.	18.2	20.3	15.8	12.4	77.7	78.2	1775.	0.062	0.198	4.68	3.12	3.69
9	1916.	2.6	19.6	1.0	25.535	46.7	482.	18.2	20.3	15.8	12.4	77.6	78.4	1775.	0.039	0.096	4.96	3.40	3.69
10	1796.	2.6	21.2	0.8	27.074	46.8	482.	18.2	20.4	15.8	12.3	77.7	77.7	1775.	0.048	0.132	6.73	3.57	3.70
10	1796.	2.6	21.3	0.8	27.104	46.8	482.	18.2	20.4	15.8	12.3	77.8	77.8	1775.	0.052	0.151	6.46	3.57	3.70
10	1796.	2.6	21.3	0.8	27.094	46.8	482.	18.2	20.3	15.8	12.3	77.7	77.8	1775.	0.046	0.121	6.23	3.56	3.74
10	1796.	2.6	21.3	0.8	27.104	46.8	482.	18.2	20.3	15.8	12.3	77.7	77.8	1775.	0.055	0.159	6.30	3.58	3.73
10	1794.	2.6	21.3	0.8	27.092	46.8	482.	18.2	20.3	15.8	12.3	77.7	77.7	1775.	0.054	0.133	6.15	3.57	3.73
11	1705.	2.6	22.5	0.8	28.237	46.9	482.	18.2	20.4	15.9	12.2	77.9	76.8	1775.	0.049	0.135	5.91	3.54	3.72
11	1698.	2.6	22.5	0.7	28.220	46.9	482.	18.2	20.4	15.9	12.1	77.9	76.4	1775.	0.052	0.155	6.06	3.57	3.74
11	1703.	2.6	22.5	0.8	28.214	46.9	482.	18.2	20.4	15.8	12.1	77.8	76.7	1775.	0.051	0.166	5.57	3.57	3.73
11	1699.	2.6	22.5	0.7	28.231	46.9	482.	18.2	20.4	15.9	12.1	77.9	76.5	1775.	0.055	0.139	5.66	3.58	3.72
11	1703.	2.6	22.5	0.8	28.225	46.9	482.	18.2	20.4	15.9	12.2	77.9	76.6	1775.	0.049	0.137	5.46	3.56	3.73
12	1601.	2.6	23.5	0.7	29.128	47.0	482.	18.2	20.4	15.9	11.8	77.9	74.3	1775.	0.055	0.148	5.00	3.06	3.74
12	1603.	2.6	23.5	0.7	29.129	46.9	482.	18.2	20.4	15.9	11.8	77.9	74.4	1775.	0.051	0.138	5.29	3.56	3.71
12	1603.	2.6	23.5	0.7	29.119	46.9	482.	18.2	20.4	15.9	11.8	77.9	74.4	1775.	0.047	0.151	4.86	3.54	3.72
12	1603.	2.6	23.4	0.7	29.109	46.9	482.	18.2	20.4	15.9	11.8	77.8	74.4	1775.	0.053	0.153	5.19	3.52	3.73
12	1605.	2.6	23.4	0.7	29.110	46.9	482.	18.2	20.4	15.9	11.8	77.9	74.5	1775.	0.051	0.148	5.08	3.49	3.73
13	1496.	2.6	24.4	0.6	29.952	47.0	482.	18.2	20.4	15.9	11.3	77.8	71.4	1775.	0.050	0.138	5.35	3.54	3.75
13	1492.	2.6	24.4	0.6	29.928	46.9	482.	18.3	20.4	15.9	11.3	77.7	71.1	1775.	0.051	0.152	5.56	3.52	3.77
13	1488.	2.6	24.3	0.6	29.915	46.9	482.	18.3	20.4	15.9	11.3	77.6	71.0	1775.	0.056	0.170	5.29	3.53	3.77
13	1497.	2.6	24.3	0.6	29.922	46.9	482.	18.2	20.4	15.8	11.3	77.6	71.5	1775.	0.051	0.147	5.59	3.54	3.79
13	1494.	2.6	24.3	0.6	29.920	46.9	482.	18.2	20.4	15.9	11.3	77.7	71.3	1775.	0.055	0.160	5.62	3.55	3.77
14	1355.	2.6	25.0	0.5	30.470	46.3	483.	18.2	20.4	15.7	10.4	76.8	66.7	1775.	0.060	0.175	7.52	3.47	3.92
14	1354.	2.6	25.0	0.5	30.500	46.4	483.	18.2	20.4	15.7	10.4	76.9	66.6	1775.	0.053	0.156	7.29	3.38	3.84
14	1353.	2.6	25.0	0.5	30.459	46.4	483.	18.2	20.4	15.7	10.4	76.9	66.5	1775.	0.054	0.178	7.83	3.45	3.89
14	1351.	2.6	25.0	0.5	30.488	46.4	483.	18.2	20.4	15.7	10.4	76.9	66.4	1775.	0.058	0.175	7.75	3.44	3.90
14	1353.	2.6	25.0	0.5	30.489	46.3	483.	18.2	20.4	15.7	10.4	76.8	66.6	1775.	0.062	0.195	7.48	3.47	3.89
15	1204.	2.6	24.9	0.4	30.248	44.2	484.	17.9	20.1	14.9	9.2	74.2	61.7	1775.	0.083	0.239	14.27	2.91	4.37
15	1203.	2.6	24.9	0.4	30.237	44.2	484.	17.9	20.1	14.9	9.2	74.2	61.6	1775.	0.083	0.329	14.23	2.91	4.33
15	1204.	2.6	24.9	0.4	30.248	44.2	484.	17.9	20.1	14.9	9.2	74.2	61.7	1775.	0.083	0.253	15.05	2.92	4.40
15	1204.	2.6	24.9	0.4	30.227	44.2	484.	17.9	20.1	14.9	9.2	74.3	61.6	1775.	0.083	0.265	15.37	2.89	4.28
15	1204.	2.6	24.8	0.4	30.217	44.2	484.	17.9	20.1	14.9	9.2	74.3	61.6	1775.	0.090	0.273	15.08	2.96	4.41
16	1008.	2.6	25.2	0.3	30.513	43.1	484.	17.8	19.9	14.6	7.8	73.1	53.4	1775.	0.111	0.355	19.57	2.49	4.71
16	1013.	2.6	25.2	0.3	30.495	43.1	484.	17.7	19.9	14.6	7.8	73.0	53.7	1775.	0.109	0.328	18.83	2.38	4.70
16	1010.	2.6	25.3	0.3	30.524	43.1	484.	17.8	20.0	14.6	7.8	73.0	53.5	1775.	0.105	0.317	19.14	2.31	4.73
16	1008.	2.6	25.2	0.3	30.503	43.1	484.	17.8	19.9	14.6	7.8	73.1	53.3	1775.	0.108	0.361	19.03	2.42	4.93
16	1011.	2.6	25.2	0.3	30.504	43.1	484.	17.8	19.9	14.6	7.8	73.0	53.5	1775.	0.109	0.337	18.39	2.25	4.75
17	829.	2.6	27.1	0.2	32.235	44.2	484.	17.9	20.1	15.0	6.8	74.5	45.2	1775.	0.129	0.466	20.44	2.42	4.87
17	829.	2.6	27.0	0.2	32.224	44.1	483.	17.9	20.1	14.9	6.8	74.4	45.2	1775.	0.137	0.446	24.47	2.06	4.76
17	826.	2.6	27.0	0.2	32.223	44.2	484.	17.9	20.1	14.9	6.7	74.4	45.1	1775.	0.124	0.562	21.26	2.51	4.61
17	829.	2.6	27.0	0.2	32.214	44.2	484.	17.9	20.1	14.9	6.7	74.4	45.2	1775.	0.140	0.564	22.57	2.34	4.97
17	825.	2.6	27.1	0.2	32.233	44.2	484.	17.9	20.1	14.9	6.7	74.4	45.1	1775.	0.128	0.377	21.22	2.32	5.43

Figure 236. (Concluded)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2907.	2.6	1.3	2.2	8.531	37.8	485.	17.0	19.1	12.8	6.3	66.9	49.1	1775.	0.041	0.102	0.83	2.33	3.73
1	2913.	2.6	1.3	2.2	8.501	37.8	485.	17.0	19.1	12.8	6.3	66.8	49.1	1775.	0.040	0.097	0.86	1.89	3.70
1	2909.	2.6	1.3	2.2	8.489	37.7	485.	17.0	19.1	12.8	6.2	66.7	48.9	1775.	0.039	0.104	0.75	3.38	3.76
1	2907.	2.6	1.3	2.2	8.479	37.8	485.	17.0	19.1	12.8	6.2	66.7	48.8	1775.	0.041	0.120	0.81	3.36	3.76
1	2907.	2.6	1.3	2.2	8.487	37.8	486.	17.0	19.1	12.8	6.2	66.8	48.9	1775.	0.038	0.106	0.83	3.54	3.73
2	2700.	2.6	5.9	1.9	12.816	41.3	485.	17.4	19.6	14.0	8.7	71.3	62.7	1775.	0.041	0.128	0.73	2.33	3.71
2	2696.	2.6	5.9	1.9	12.792	41.3	484.	17.4	19.6	13.9	8.7	71.3	62.5	1775.	0.044	0.109	0.73	3.50	3.68
2	2698.	2.6	5.9	1.9	12.779	41.3	484.	17.4	19.6	13.9	8.7	71.3	62.5	1775.	0.041	0.113	0.77	3.46	3.70
2	2697.	2.6	5.9	1.9	12.785	41.3	484.	17.4	19.6	14.0	8.7	71.4	62.4	1775.	0.039	0.109	0.73	3.46	3.71
2	2698.	2.6	5.9	1.9	12.769	41.3	484.	17.4	19.6	13.9	8.7	71.3	62.5	1775.	0.040	0.104	0.66	3.50	3.71
3	2535.	2.6	9.2	1.7	15.842	43.4	485.	17.6	19.8	14.7	10.2	73.9	69.3	1775.	0.040	0.111	0.56	2.97	3.70
3	2543.	2.6	9.1	1.7	15.818	43.3	485.	17.6	19.8	14.6	10.2	73.8	69.5	1775.	0.038	0.115	0.56	3.34	3.72
3	2535.	2.6	9.1	1.7	15.791	43.4	485.	17.7	19.9	14.7	10.1	73.8	69.0	1775.	0.040	0.111	0.60	3.10	3.71
3	2534.	2.6	9.1	1.7	15.793	43.4	485.	17.7	19.9	14.7	10.1	73.9	69.0	1775.	0.040	0.105	0.58	2.87	3.70
3	2533.	2.6	9.1	1.7	15.815	43.4	485.	17.7	19.9	14.7	10.1	73.9	69.0	1775.	0.039	0.109	0.66	1.97	3.72
4	2391.	2.6	11.7	1.5	18.203	44.9	485.	17.8	20.1	15.2	11.0	75.6	72.5	1775.	0.044	0.121	0.57	1.93	3.71
4	2392.	2.6	11.8	1.5	18.234	45.0	485.	17.8	20.1	15.2	11.0	75.8	72.6	1775.	0.038	0.104	0.61	3.21	3.68
4	2392.	2.6	11.7	1.5	18.224	44.9	485.	17.8	20.0	15.2	11.0	75.7	72.6	1775.	0.039	0.098	0.59	3.48	3.69
4	2396.	2.6	11.7	1.5	18.219	44.9	485.	17.8	20.0	15.2	11.0	75.7	72.7	1775.	0.046	0.122	0.57	3.26	3.70
4	2394.	2.6	11.7	1.5	18.197	44.9	485.	17.8	20.1	15.2	11.0	75.7	72.6	1775.	0.043	0.136	0.59	3.44	3.73
5	2295.	2.6	13.5	1.4	19.856	45.7	485.	18.0	20.2	15.4	11.5	76.5	74.6	1775.	0.039	0.115	0.44	2.71	3.71
5	2302.	2.6	13.5	1.4	19.865	45.7	485.	18.0	20.2	15.4	11.6	76.5	74.9	1775.	0.045	0.133	0.41	3.36	3.70
5	2298.	2.6	13.5	1.4	19.880	45.7	485.	18.0	20.2	15.4	11.5	76.5	74.8	1775.	0.040	0.103	0.47	3.35	3.70
5	2297.	2.6	13.5	1.4	19.859	45.7	485.	17.9	20.2	15.4	11.5	76.5	74.7	1775.	0.041	0.103	0.48	2.81	3.69
5	2301.	2.6	13.5	1.4	19.884	45.7	485.	17.9	20.2	15.5	11.6	76.6	74.8	1775.	0.039	0.105	0.48	3.18	3.70
6	2205.	2.6	15.1	1.3	21.371	46.3	485.	18.0	20.3	15.7	11.9	77.3	76.1	1775.	0.044	0.123	0.44	1.99	3.72
6	2203.	2.6	15.2	1.3	21.439	46.4	485.	18.0	20.3	15.7	11.9	77.3	76.2	1775.	0.039	0.096	0.45	3.31	3.72
6	2192.	2.6	15.2	1.2	21.467	46.3	485.	18.0	20.3	15.7	11.9	77.3	75.9	1775.	0.036	0.094	0.43	2.90	3.70
6	2192.	2.6	15.3	1.2	21.527	46.3	485.	18.0	20.3	15.7	11.9	77.3	76.2	1775.	0.039	0.109	0.45	3.48	3.70
6	2188.	2.6	15.3	1.2	21.562	46.3	485.	18.0	20.3	15.7	11.9	77.2	76.2	1775.	0.042	0.132	0.42	3.54	3.71
7	2102.	2.6	16.8	1.1	22.966	46.8	485.	18.1	20.3	15.8	12.2	77.8	77.2	1775.	0.040	0.104	0.48	3.36	3.72
7	2096.	2.6	16.8	1.1	22.980	46.8	485.	18.1	20.3	15.8	12.2	77.8	77.1	1775.	0.039	0.110	0.46	3.57	3.71
7	2097.	2.6	16.8	1.1	22.981	46.8	484.	18.1	20.3	15.8	12.2	77.9	77.0	1775.	0.041	0.112	0.47	3.35	3.70
7	2094.	2.6	16.8	1.1	22.968	46.7	484.	18.0	20.3	15.8	12.2	77.9	77.0	1775.	0.040	0.106	0.42	2.42	3.70
7	2091.	2.6	16.9	1.1	23.004	46.7	484.	18.0	20.3	15.8	12.2	77.9	77.0	1775.	0.041	0.109	0.42	3.47	3.70
8	1988.	2.6	18.5	1.0	24.515	47.0	485.	18.1	20.4	15.9	12.3	78.0	77.5	1775.	0.038	0.101	0.44	3.60	3.71
8	1983.	2.6	18.5	1.0	24.480	47.0	485.	18.1	20.4	15.9	12.3	78.0	77.3	1775.	0.037	0.102	0.42	3.57	3.71
8	1984.	2.6	18.5	1.0	24.501	47.0	485.	18.1	20.4	15.9	12.3	78.0	77.4	1775.	0.035	0.107	0.39	2.71	3.70
8	1987.	2.6	18.5	1.0	24.514	47.0	485.	18.1	20.4	15.9	12.3	78.0	77.5	1775.	0.038	0.091	0.42	3.57	3.70

Figure 237. Test run 100-T04-004-2.6; research data; pump 1, Test T04, sump 4, submergence 2.47D (Continued)

8	1985.	2.6	18.5	1.0	24.532	47.0	485.	18.1	20.4	15.9	12.3	77.9	77.5	1775.	0.037	0.115	0.44	3.35	3.71
9	1904.	2.6	19.7	0.9	25.650	47.1	485.	18.1	20.4	15.9	12.3	78.1	77.6	1775.	0.043	0.111	0.49	3.57	3.72
9	1906.	2.6	19.7	0.9	25.672	47.1	485.	18.1	20.4	15.9	12.4	78.2	77.7	1775.	0.038	0.107	0.47	3.57	3.72
9	1903.	2.6	19.7	0.9	25.639	47.1	485.	18.1	20.4	15.9	12.3	78.1	77.5	1775.	0.034	0.100	0.49	3.35	3.72
9	1898.	2.6	19.7	0.9	25.665	47.1	485.	18.1	20.4	15.9	12.3	78.2	77.4	1775.	0.043	0.110	0.49	3.57	3.73
9	1899.	2.6	19.8	0.9	25.686	47.1	485.	18.1	20.4	15.9	12.3	78.1	77.5	1775.	0.038	0.096	0.44	3.55	3.71
10	1807.	2.6	21.0	0.8	26.827	47.1	485.	18.1	20.4	15.9	12.3	78.1	76.9	1775.	0.036	0.092	0.47	3.59	3.73
10	1802.	2.6	21.0	0.8	26.832	47.1	486.	18.1	20.4	15.9	12.2	78.1	76.7	1775.	0.038	0.101	0.48	3.54	3.74
10	1808.	2.6	21.0	0.8	26.828	47.1	485.	18.1	20.4	15.9	12.3	78.0	77.0	1775.	0.038	0.111	0.42	3.56	3.73
10	1800.	2.6	21.0	0.8	26.811	47.1	485.	18.1	20.4	15.9	12.2	78.0	76.7	1775.	0.038	0.095	0.48	3.60	3.74
10	1806.	2.6	21.0	0.8	26.846	47.1	485.	18.1	20.4	15.9	12.3	78.1	77.0	1775.	0.036	0.090	0.46	3.60	3.73
11	1720.	2.6	22.1	0.8	27.857	47.2	485.	18.1	20.4	16.0	12.1	78.2	75.9	1775.	0.039	0.114	0.48	3.59	3.76
11	1718.	2.6	22.1	0.8	27.856	47.3	485.	18.1	20.4	16.0	12.1	78.3	75.8	1775.	0.038	0.096	0.44	3.59	3.74
11	1716.	2.6	22.1	0.8	27.844	47.3	485.	18.1	20.4	16.0	12.1	78.3	75.6	1775.	0.039	0.107	0.41	3.39	3.74
11	1715.	2.6	22.1	0.8	27.853	47.3	485.	18.1	20.4	16.0	12.1	78.3	75.6	1775.	0.043	0.111	0.46	3.60	3.75
11	1715.	2.6	22.1	0.8	27.863	47.3	485.	18.1	20.4	16.0	12.1	78.3	75.6	1775.	0.039	0.102	0.44	3.59	3.74
12	1608.	2.6	23.1	0.7	28.791	47.3	485.	18.1	20.4	16.0	11.7	78.3	73.2	1775.	0.041	0.112	0.41	3.53	3.73
12	1611.	2.6	23.1	0.7	28.793	47.3	485.	18.1	20.4	16.0	11.7	78.3	73.4	1775.	0.039	0.093	0.41	3.57	3.74
12	1610.	2.6	23.1	0.7	28.792	47.3	485.	18.1	20.4	16.0	11.7	78.2	73.3	1775.	0.039	0.097	0.40	3.57	3.73
12	1606.	2.6	23.1	0.7	28.779	47.3	485.	18.1	20.4	16.0	11.7	78.3	73.2	1775.	0.043	0.117	0.46	3.52,	3.76
12	1610.	2.6	23.1	0.7	28.802	47.3	485.	18.1	20.4	16.0	11.7	78.3	73.4	1775.	0.041	0.106	0.41	3.56	3.74
13	1458.	2.6	24.3	0.6	29.841	47.2	485.	18.1	20.4	16.0	11.0	78.2	68.9	1775.	0.043	0.153	0.52.	3.54	3.78
13	1455.	2.6	24.3	0.5	29.799	47.2	485.	18.1	20.4	16.0	11.0	78.2	68.7	1775.	0.045	0.138	0.54	3.54	3.83
13	1457.	2.6	24.3	0.6	29.801	47.2	485.	18.1	20.4	15.9	11.0	78.1	68.8	1775.	0.045	0.130	0.59	3.57	3.82
13	1458.	2.6	24.3	0.6	29.801	47.1	485.	18.1	20.4	15.9	11.0	78.0	69.0	1775.	0.046	0.160	0.54	3.55	3.83
13	1456.	2.6	24.2	0.5	29.790	47.1	486.	18.1	20.4	15.9	11.0	78.0	68.8	1775.	0.045	0.109	0.52	3.53	3.82
14	1305.	2.6	24.7	0.4	30.112	45.9	486.	18.0	20.3	15.5	9.9	76.4	64.0	1775.	0.055	0.170	0.88	3.38	4.01
14	1307.	2.6	24.7	0.4	30.103	45.9	486.	18.0	20.3	15.5	9.9	76.4	64.1	1775.	0.054	0.180	0.89	3.36	4.07
14	1307.	2.6	24.7	0.4	30.143	46.0	486.	18.0	20.3	15.5	10.0	76.5	64.1	1775.	0.057	0.155	0.98	3.38	4.06
14	1305.	2.6	24.7	0.4	30.092	45.9	486.	18.0	20.3	15.5	9.9	76.3	64.1	1775.	0.056	0.188	0.92	3.38	3.94
14	1308.	2.6	24.7	0.4	30.114	45.9	486.	18.0	20.3	15.5	10.0	76.3	64.2	1775.	0.053	0.149	0.91	3.39	3.96
15	1155.	2.6	24.3	0.3	29.636	43.6	486.	17.7	20.0	14.7	8.7	73.7	58.7	1775.	0.101	0.277	1.77	2.63	4.84
15	1154.	2.6	24.3	0.3	29.615	43.6	486.	17.7	20.0	14.7	8.6	73.8	58.6	1775.	0.090	0.276	1.72	2.67	4.63
15	1151.	2.6	24.3	0.3	29.684	43.6	486.	17.7	20.0	14.8	8.6	73.8	58.6	1775.	0.098	0.311	1.64	2.31	4.69
15	1152.	2.6	24.3	0.3	29.674	43.7	486.	17.7	20.0	14.8	8.6	73.8	58.6	1775.	0.098	0.306	1.70	2.71	4.75
15	1152.	2.6	24.3	0.3	29.634	43.6	486.	17.7	20.0	14.7	8.6	73.7	58.6	1775.	0.099	0.312	1.71	2.06	4.95
16	1003.	2.6	25.0	0.3	30.211	43.4	487.	17.7	19.9	14.7	7.7	73.6	52.2	1775.	0.110	0.381	1.93	2.55	4.68
16	1005.	2.6	24.9	0.3	30.202	43.4	487.	17.7	19.9	14.7	7.7	73.5	52.4	1775.	0.104	0.329	1.84	2.36	4.94
16	1002.	2.6	24.9	0.3	30.180	43.4	487.	17.7	19.9	14.7	7.6	73.5	52.2	1775.	0.116	0.373	1.82	2.12	4.76
16	1002.	2.6	24.9	0.3	30.190	43.4	487.	17.7	19.9	14.7	7.6	73.6	52.1	1775.	0.113	0.347	1.89	2.38	4.98
16	1002.	2.6	24.9	0.3	30.170	43.3	487.	17.7	19.9	14.6	7.6	73.4	52.2	1775.	0.119	0.349	2.03	2.40	4.75
17	828.	2.6	26.7	0.2	31.828	44.5	487.	17.8	20.1	15.0	6.7	74.9	44.3	1775.	0.132	0.427	2.11	2.22	4.88
17	828.	2.6	26.6	0.2	31.818	44.5	487.	17.8	20.1	15.0	6.7	74.9	44.3	1775.	0.146	0.510	2.27	2.43	5.41
17	830.	2.6	26.7	0.2	31.839	44.5	486.	17.8	20.1	15.0	6.7	74.9	44.4	1775.	0.124	0.416	2.21	2.23	4.79
17	828.	2.6	26.7	0.2	31.828	44.5	487.	17.8	20.1	15.0	6.7	74.8	44.3	1775.	0.125	0.496	2.10	2.22	4.95
17	825.	2.6	26.6	0.2	31.807	44.5	487.	17.8	20.1	15.0	6.6	74.7	44.2	1775.	0.137	0.453	2.20	2.48	4.90

Figure 237. (Concluded)

READ NO.	Q DIS-CHARGE GPM	HW SUBMER-GENCE FT	HS STATIC HEAD FT	HV VELOCITY HEAD FT	HT TOTAL HEAD FT	T TORQUE FT/LB	E VOLTS	I AMPS	HORSEPOWER: HPM INPUT MOTOR HP	HORSEPOWER: HPS SHAFT HP	HORSEPOWER: HPW WATER HP	EM MOTOR EFF %	EP PUMP EFF %	W SHAFT SPEED RPM	VELOCITY IPS RMS	VELOCITY IPS IMAXI	PUMP NOISE PSI *10-4 RMS	P(FT) PRESSURE FLUCTUATION MIN	P(FT) PRESSURE FLUCTUATION MAX
1	2909.	2.6	1.3	2.2	8.497	38.2	486.	16.9	19.1	12.9	6.2	67.5	48.5	1775.	0.037	0.087	0.84	3.41	3.70
1	2913.	2.6	1.3	2.2	8.526	38.2	486.	16.9	19.1	12.9	6.3	67.6	48.7	1775.	0.039	0.110	0.78	1.49	3.67
1	2913.	2.6	1.3	2.2	8.521	38.2	486.	16.9	19.1	12.9	6.3	67.6	48.7	1775.	0.038	0.097	0.77	3.45	3.66
1	2905.	2.6	1.4	2.2	8.544	38.1	486.	16.9	19.1	12.9	6.3	67.6	48.7	1775.	0.039	0.104	0.78	3.37	3.67
1	2908.	2.6	1.3	2.2	8.504	38.1	486.	16.9	19.1	12.9	6.3	67.5	48.6	1775.	0.041	0.107	0.80	2.97	3.69
2	2749.	2.6	4.9	2.0	11.824	40.8	485.	17.3	19.4	13.8	8.2	71.0	59.6	1775.	0.039	0.107	0.69	2.63	3.69
2	2750.	2.6	4.8	2.0	11.786	40.8	485.	17.2	19.4	13.8	8.2	71.1	59.4	1775.	0.038	0.092	0.69	2.33	3.66
2	2751.	2.6	4.9	2.0	11.847	40.8	485.	17.3	19.4	13.8	8.2	71.0	59.8	1775.	0.038	0.094	0.69	3.38	3.65
2	2743.	2.6	4.9	2.0	11.857	40.8	485.	17.3	19.4	13.8	8.2	71.1	59.6	1775.	0.039	0.107	0.69	3.50	3.67
2	2748.	2.6	4.9	2.0	11.841	40.8	485.	17.3	19.4	13.8	8.2	71.0	59.6	1775.	0.039	0.098	0.71	2.51	3.68
3	2609.	2.6	7.7	1.8	14.489	42.8	485.	17.5	19.7	14.5	9.6	73.6	66.1	1775.	0.037	0.093	0.56	3.38	3.71
3	2604.	2.6	7.7	1.8	14.463	42.8	485.	17.5	19.7	14.5	9.5	73.6	65.8	1775.	0.041	0.105	0.61	3.20	3.69
3	2609.	2.6	7.7	1.8	14.455	42.8	485.	17.5	19.7	14.5	9.5	73.6	65.9	1775.	0.038	0.096	0.62	3.53	3.69
3	2604.	2.6	7.7	1.8	14.502	42.8	485.	17.5	19.7	14.5	9.5	73.6	66.0	1775.	0.038	0.096	0.60	3.46	3.69
3	2611.	2.6	7.8	1.8	14.521	42.8	485.	17.5	19.7	14.5	9.6	73.6	66.2	1775.	0.042	0.116	0.55	3.07	3.66
4	2504.	2.6	9.7	1.6	16.366	44.1	485.	17.6	19.8	14.9	10.4	75.3	69.4	1775.	0.040	0.096	0.52	3.45	3.66
4	2502.	2.6	9.8	1.6	16.383	44.2	485.	17.6	19.8	14.9	10.4	75.3	69.4	1775.	0.041	0.114	0.53	3.43	3.67
4	2496.	2.6	9.8	1.6	16.391	44.2	485.	17.6	19.8	14.9	10.3	75.4	69.3	1775.	0.046	0.137	0.55	3.51	3.69
4	2504.	2.6	9.7	1.6	16.349	44.2	485.	17.6	19.8	14.9	10.3	75.4	69.3	1775.	0.041	0.112	0.56	3.44	3.68
4	2504.	2.6	9.7	1.6	16.329	44.2	485.	17.6	19.8	14.9	10.3	75.4	69.2	1775.	0.043	0.115	0.58	3.47	3.68
5	2394.	2.6	11.7	1.5	18.177	45.4	485.	17.8	20.0	15.3	11.0	76.7	71.7	1775.	0.040	0.110	0.46	3.48	3.66
5	2397.	2.6	11.6	1.5	18.141	45.3	483.	17.8	19.9	15.3	11.0	77.0	71.8	1775.	0.037	0.090	0.49	2.71	3.66
5	2393.	2.6	11.7	1.5	18.186	45.4	484.	17.8	19.9	15.3	11.0	76.9	71.8	1775.	0.047	0.134	0.50	2.91	3.65
5	2388.	2.6	11.7	1.5	18.169	45.4	485.	17.8	20.0	15.3	11.0	76.8	71.5	1775.	0.042	0.120	0.52	3.24	3.65
5	2392.	2.6	11.7	1.5	18.154	45.4	485.	17.8	20.0	15.3	11.0	76.8	71.6	1775.	0.049	0.146	0.57	3.36	3.67
6	2311.	2.6	13.1	1.4	19.446	46.2	485.	17.8	20.1	15.6	11.4	77.8	72.8	1775.	0.050	0.154	0.49	3.36	3.67
6	2317.	2.6	13.1	1.4	19.473	46.2	485.	17.8	20.1	15.6	11.4	77.9	73.1	1775.	0.043	0.120	0.48	3.11	3.66
6	2314.	2.6	13.1	1.4	19.469	46.2	485.	17.8	20.0	15.6	11.4	77.9	73.0	1775.	0.044	0.112	0.47	3.40	3.67
6	2316.	2.6	13.1	1.4	19.462	46.2	485.	17.8	20.1	15.6	11.4	77.8	73.1	1775.	0.043	0.120	0.45	3.27	3.66
6	2319.	2.6	13.1	1.4	19.495	46.2	485.	17.8	20.1	15.6	11.4	77.9	73.2	1775.	0.051	0.147	0.46	2.56	3.65
7	2203.	2.6	15.0	1.3	21.229	46.9	485.	17.9	20.2	15.9	11.8	78.6	74.5	1775.	0.044	0.132	0.44	2.44	3.68
7	2201.	2.6	15.0	1.3	21.217	47.0	485.	17.9	20.2	15.9	11.8	78.7	74.4	1775.	0.039	0.113	0.47	2.56	3.66
7	2202.	2.6	15.0	1.3	21.208	46.9	485.	17.9	20.2	15.9	11.8	78.6	74.5	1775.	0.040	0.108	0.45	3.51	3.65
7	2201.	2.6	15.0	1.3	21.227	47.0	485.	17.9	20.2	15.9	11.8	78.7	74.4	1775.	0.047	0.144	0.45	2.39	3.65
7	2204.	2.6	15.0	1.3	21.230	47.0	485.	17.9	20.2	15.9	11.8	78.8	74.5	1775.	0.040	0.113	0.44	3.28	3.66
8	2109.	2.6	16.5	1.2	22.674	47.4	485.	18.0	20.2	16.0	12.1	79.3	75.4	1775.	0.044	0.144	0.44	3.33	3.67
8	2106.	2.6	16.5	1.2	22.691	47.4	485.	18.0	20.2	16.0	12.1	79.3	75.4	1775.	0.039	0.104	0.41	3.41	3.65
8	2105.	2.6	16.5	1.1	22.690	47.4	485.	18.0	20.2	16.0	12.1	79.1	75.4	1775.	0.040	0.101	0.45	3.03	3.67
8	2105.	2.6	16.6	1.1	22.710	47.4	485.	18.0	20.2	16.0	12.1	79.2	75.5	1775.	0.045	0.115	0.43	3.30	3.66

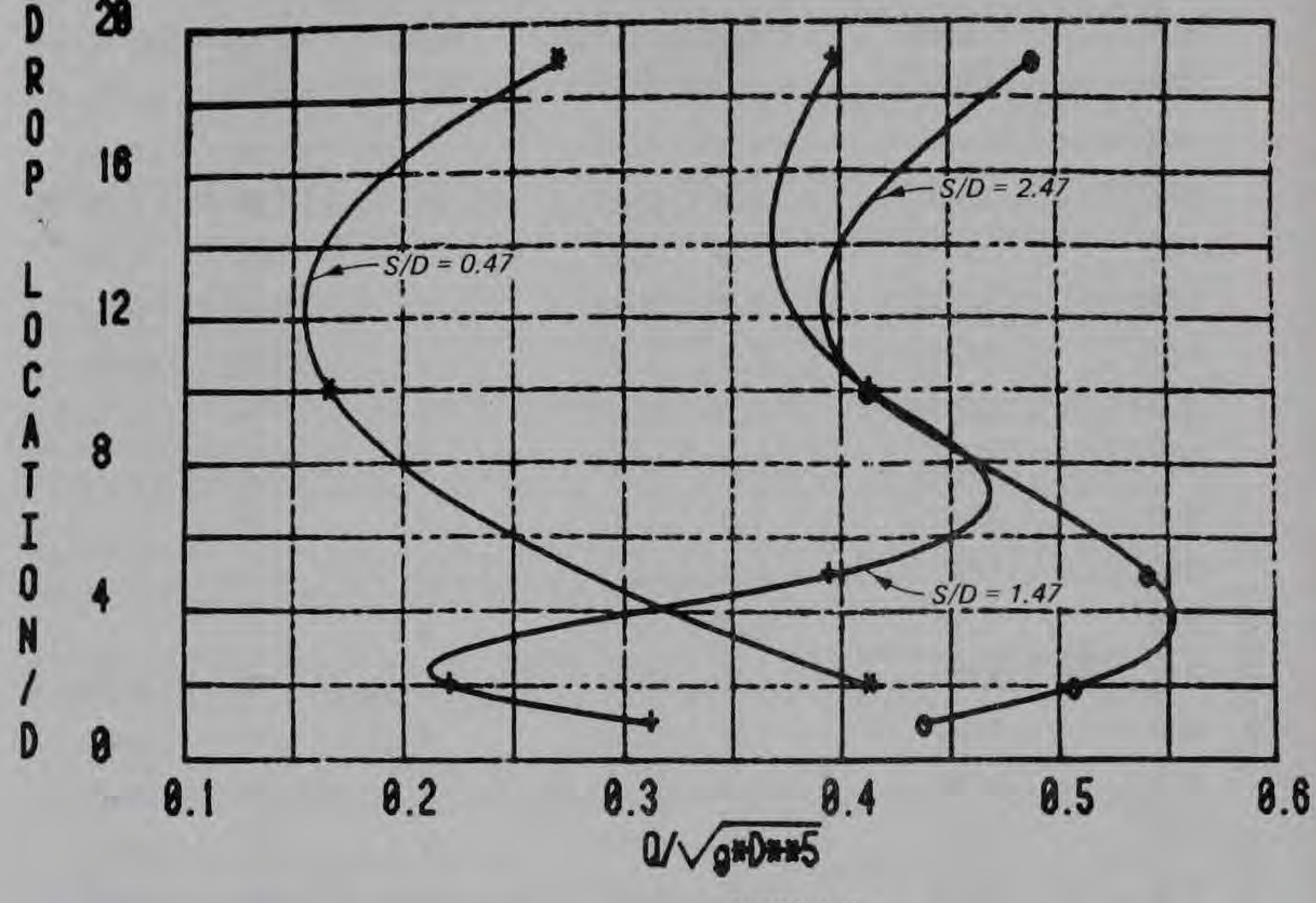
Figure 238. Test run 100-T05-004-2.6; research data; pump 1, Test T05, sump 4, submergence 2.47D (Continued)

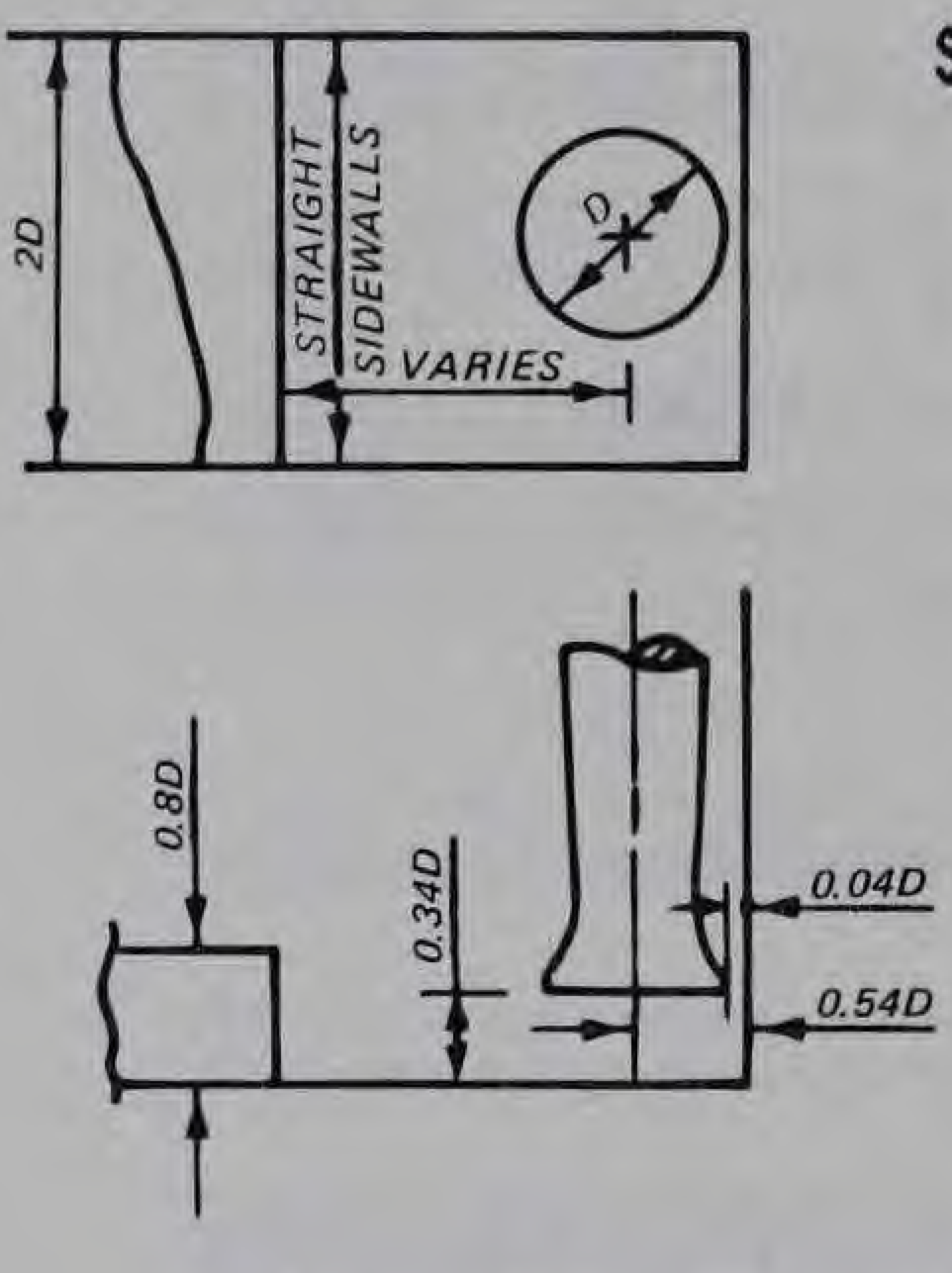
8	2107.	2.6	16.5	1.2	22.702	47.4	485.	18.0	20.2	16.0	12.1	79.2	75.5	1775.	0.045	0.120	0.41	3.50	3.65
9	1991.	2.6	18.3	1.0	24.308	47.5	484.	18.0	20.2	16.0	12.2	79.3	76.3	1775.	0.046	0.144	0.44	3.53	3.66
9	1990.	2.6	18.2	1.0	24.267	47.5	484.	18.0	20.2	16.0	12.2	79.3	76.1	1775.	0.039	0.121	0.49	3.52	3.67
9	1995.	2.6	18.3	1.0	24.293	47.5	484.	18.0	20.2	16.0	12.3	79.3	76.4	1775.	0.043	0.141	0.49	3.48	3.67
9	1991.	2.6	18.3	1.0	24.318	47.5	484.	18.0	20.2	16.1	12.2	79.3	76.3	1775.	0.041	0.109	0.46	3.54	3.68
9	1992.	2.6	18.3	1.0	24.329	47.5	485.	18.0	20.3	16.1	12.3	79.3	76.3	1775.	0.039	0.105	0.47	3.55	3.66
10	1902.	2.6	19.5	0.9	25.439	47.5	485.	18.0	20.3	16.1	12.2	79.2	76.2	1775.	0.044	0.134	0.53	3.52	3.70
10	1899.	2.6	19.5	0.9	25.456	47.5	485.	18.0	20.3	16.1	12.2	79.2	76.1	1775.	0.046	0.132	0.53	3.36	3.70
10	1900.	2.6	19.5	0.9	25.437	47.5	485.	18.0	20.3	16.1	12.2	79.1	76.1	1775.	0.039	0.102	0.57	3.49	3.70
10	1898.	2.6	19.5	0.9	25.465	47.5	485.	18.0	20.3	16.0	12.2	79.0	76.2	1775.	0.046	0.140	0.50	3.53	3.72
10	1897.	2.6	19.6	0.9	25.524	47.5	485.	18.0	20.3	16.1	12.2	79.1	76.2	1775.	0.045	0.122	0.55	3.14	3.71
11	1798.	2.6	20.8	0.8	26.649	47.5	484.	18.0	20.3	16.1	12.1	79.2	75.4	1775.	0.044	0.128	0.53	3.54	3.70
11	1802.	2.6	20.8	0.8	26.682	47.5	485.	18.0	20.3	16.1	12.2	79.1	75.7	1775.	0.040	0.101	0.55	3.44	3.69
11	1798.	2.6	20.8	0.8	26.639	47.5	485.	18.0	20.3	16.1	12.1	79.2	75.4	1775.	0.039	0.094	0.56	3.49	3.69
11	1800.	2.6	20.8	0.8	26.661	47.5	485.	18.0	20.3	16.1	12.1	79.2	75.6	1775.	0.040	0.097	0.52	3.45	3.68
11	1797.	2.6	20.8	0.8	26.648	47.5	485.	18.0	20.3	16.1	12.1	79.2	75.4	1775.	0.047	0.137	0.50	3.47	3.68
12	1710.	2.6	22.0	0.8	27.729	47.7	485.	18.1	20.3	16.1	12.0	79.2	74.4	1775.	0.047	0.118	0.48	3.49	3.69
12	1708.	2.6	22.0	0.8	27.727	47.6	485.	18.1	20.3	16.1	12.0	79.2	74.4	1775.	0.050	0.149	0.48	3.52	3.70
12	1710.	2.6	22.0	0.8	27.729	47.6	485.	18.1	20.3	16.1	12.0	79.2	74.5	1775.	0.042	0.124	0.48	3.52	3.71
12	1707.	2.6	22.0	0.8	27.746	47.7	485.	18.1	20.3	16.1	12.0	79.2	74.3	1775.	0.044	0.114	0.48	3.50	3.70
12	1709.	2.6	22.0	0.8	27.738	47.6	485.	18.1	20.3	16.1	12.0	79.2	74.4	1775.	0.047	0.131	0.49	3.54	3.70
13	1606.	2.6	23.0	0.7	28.629	47.8	485.	18.1	20.4	16.1	11.6	79.3	72.0	1775.	0.044	0.130	0.53	3.03	3.72
13	1603.	2.6	23.0	0.7	28.637	47.8	485.	18.1	20.4	16.1	11.6	79.3	71.9	1775.	0.043	0.114	0.50	3.51	3.70
13	1607.	2.6	23.0	0.7	28.640	47.8	486.	18.1	20.4	16.1	11.6	79.3	72.1	1775.	0.045	0.114	0.50	3.55	3.70
13	1605.	2.6	23.0	0.7	28.648	47.8	486.	18.1	20.4	16.2	11.6	79.3	72.0	1775.	0.048	0.131	0.48	3.36	3.72
13	1610.	2.6	23.0	0.7	28.672	47.8	486.	18.1	20.4	16.1	11.7	79.3	72.3	1775.	0.043	0.113	0.46	3.54	3.70
14	1453.	2.6	24.1	0.5	29.638	47.7	486.	18.1	20.4	16.1	10.9	79.2	67.6	1775.	0.050	0.183	0.54	3.48	3.79
14	1453.	2.6	24.1	0.5	29.648	47.7	486.	18.1	20.3	16.1	10.9	79.3	67.5	1775.	0.044	0.129	0.51	3.22	3.76
14	1457.	2.6	24.1	0.6	29.621	47.7	486.	18.0	20.3	16.1	10.9	79.2	67.7	1775.	0.046	0.138	0.56	3.44	3.76
14	1456.	2.6	24.1	0.5	29.620	47.6	486.	18.1	20.3	16.1	10.9	79.1	67.7	1775.	0.049	0.129	0.56	3.47	3.78
14	1455.	2.6	24.1	0.5	29.609	47.7	486.	18.0	20.3	16.1	10.9	79.2	67.6	1775.	0.045	0.143	0.58	3.47	3.76
15	1250.	2.6	24.4	0.4	29.805	45.7	485.	17.8	20.0	15.4	9.4	77.0	61.0	1775.	0.068	0.223	1.15	3.05	4.05
15	1247.	2.6	24.4	0.4	29.783	45.6	486.	17.8	20.1	15.4	9.4	76.9	60.9	1775.	0.069	0.230	1.16	2.82	4.12
15	1247.	2.6	24.4	0.4	29.783	45.6	486.	17.8	20.1	15.4	9.4	76.9	60.9	1775.	0.069	0.226	1.31	3.17	4.11
15	1247.	2.6	24.4	0.4	29.773	45.6	486.	17.8	20.1	15.4	9.4	76.8	60.9	1775.	0.076	0.233	1.16	2.91	4.37
15	1245.	2.6	24.4	0.4	29.782	45.6	486.	17.8	20.0	15.4	9.4	77.0	60.8	1775.	0.073	0.219	1.27	3.09	4.11
16	1007.	2.6	24.7	0.3	29.963	43.9	486.	17.6	19.8	14.8	7.6	75.0	51.4	1775.	0.120	0.435	1.72	2.38	4.87
16	1005.	2.6	24.7	0.3	29.952	43.9	486.	17.6	19.8	14.8	7.6	74.9	51.3	1775.	0.105	0.431	1.92	2.42	4.73
16	1006.	2.6	24.7	0.3	29.983	43.9	486.	17.6	19.8	14.8	7.6	75.0	51.4	1775.	0.111	0.338	1.90	2.30	4.79
16	1006.	2.6	24.7	0.3	29.973	43.9	486.	17.6	19.8	14.8	7.6	74.9	51.4	1775.	0.112	0.359	1.89	2.32	4.86
16	1007.	2.6	24.7	0.3	29.983	43.9	486.	17.6	19.8	14.8	7.6	74.9	51.5	1775.	0.114	0.448	1.79	2.46	4.66
17	847.	2.6	26.1	0.2	31.286	44.7	487.	17.7	20.0	15.1	6.7	75.6	44.4	1775.	0.129	0.464	2.16	2.19	4.75
17	852.	2.6	26.1	0.2	31.328	44.8	487.	17.7	20.0	15.1	6.7	75.7	44.6	1775.	0.127	0.453	2.08	2.16	5.10
17	853.	2.6	26.1	0.2	31.319	44.7	487.	17.7	20.0	15.1	6.8	75.7	44.7	1775.	0.131	0.440	2.07	2.03	4.77
17	852.	2.6	26.1	0.2	31.298	44.7	487.	17.7	20.0	15.1	6.7	75.6	44.7	1775.	0.134	0.467	2.10	2.12	4.87
17	851.	2.6	26.1	0.2	31.288	44.7	487	17.7	20.0	15.1	6.7	75.7	44.5	1775.	0.135	0.644	2.20	2.15	4.87

Figure 238. (Concluded)

TEST NO.	DATE '79-'80	SUBMERGENCE FT	S/D	TYPE SUMP	STEP DIST U/S DIA	FT
H01		1.4		7	2D	2.58
H02	12/6	3.2	2.47	7	2D	2.58
H03	12/10	1.9	1.47	7	2D	2.58
H04	12/11	0.6	0.47	7	2D	2.58
H05	12/13	3.2	2.47	4	NONE	(BASE)
H06	12/13	3.2	2.47	4	"	
H07	12/14	3.2	2.47	4	"	
H08	12/17	3.2	2.47	4	"	
H09	1/9	1.9	1.47	4	"	
H10	1/10	0.6	0.47	4	"	
H11	2/20	3.2	2.47	6	1D	1.29
H12	2/22	1.9	1.47	6	1D	1.29
H13	2/28	0.6	0.47	8	5D	6.45
H14	2/29	3.2	2.47	8	5D	6.45
H15	2/29	1.9	1.47	8	5D	6.45
H16	3/14	3.2	2.47	9	10D	12.90
H17	3/14	1.9	1.47	9	10D	12.90
H18	3/18	0.6	0.47	9	10D	12.90
T02	3/24	3.2	2.47	9	10D	12.90
T03	3/26	3.2	2.47	4	NONE	
T04	3/28	3.2	2.47	4	"	
T05	4/1	3.2	2.47	4	"	

Figure 239. Testing log for vertical drop

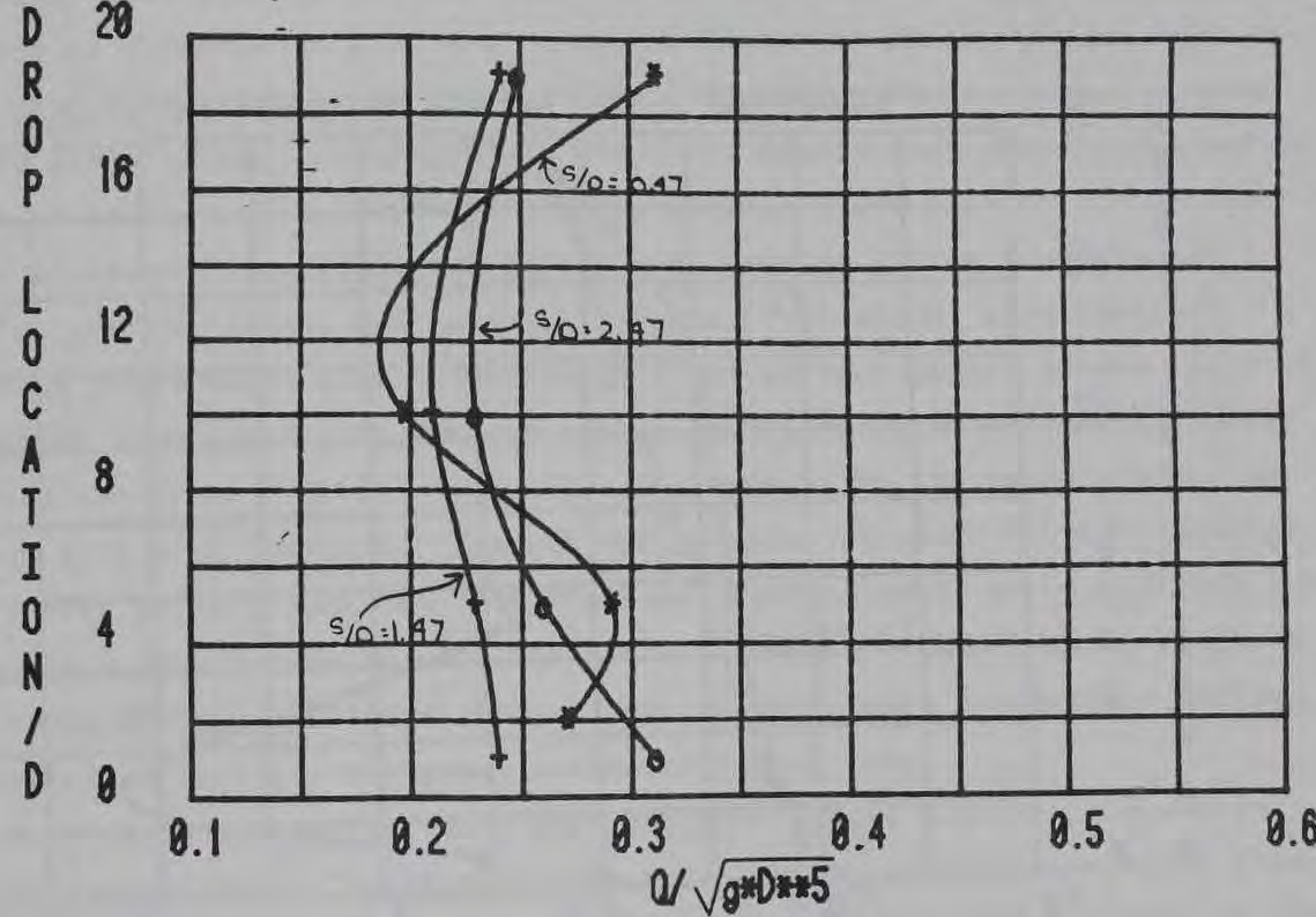


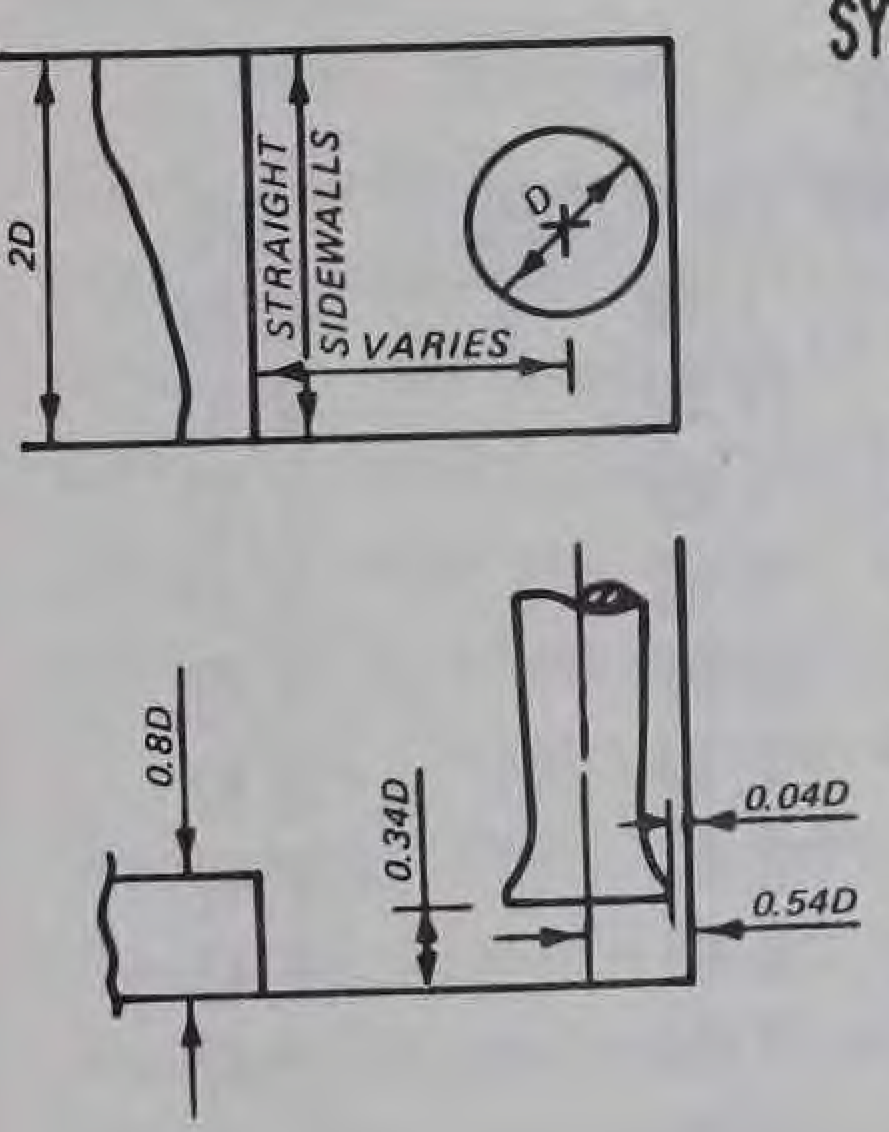


BASIC DATA

SYMBOL	$Q/\sqrt{g*D**5}$	DROP LOCATION/D	S/D
*	0.41	2.00	0.47
*	0.17	10.00	0.47
*	0.27	19.00	0.47
+	0.31	1.00	1.47
+	0.22	2.00	1.47
+	0.39	5.00	1.47
+	0.41	10.00	1.47
+	0.40	19.00	1.47
o	0.44	1.00	2.47
o	0.51	2.00	2.47
o	0.54	5.00	2.47
o	0.41	10.00	2.47
o	0.49	19.00	2.47

Figure 240. FV, vertical drop; vertical drop height = 0.8D ; F/D = 0.34 ; B/D = 0.04 ; W/D = 2.0

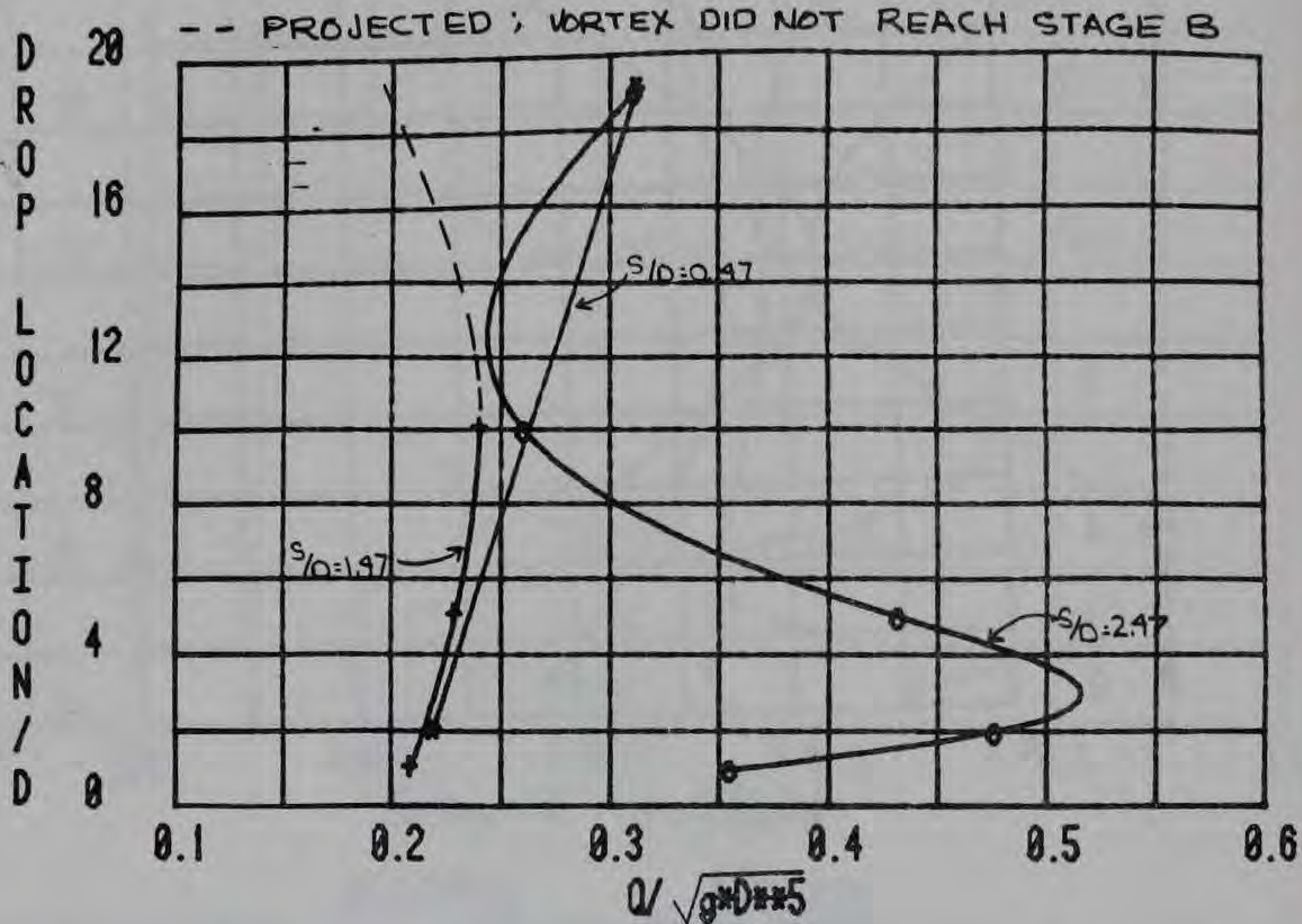


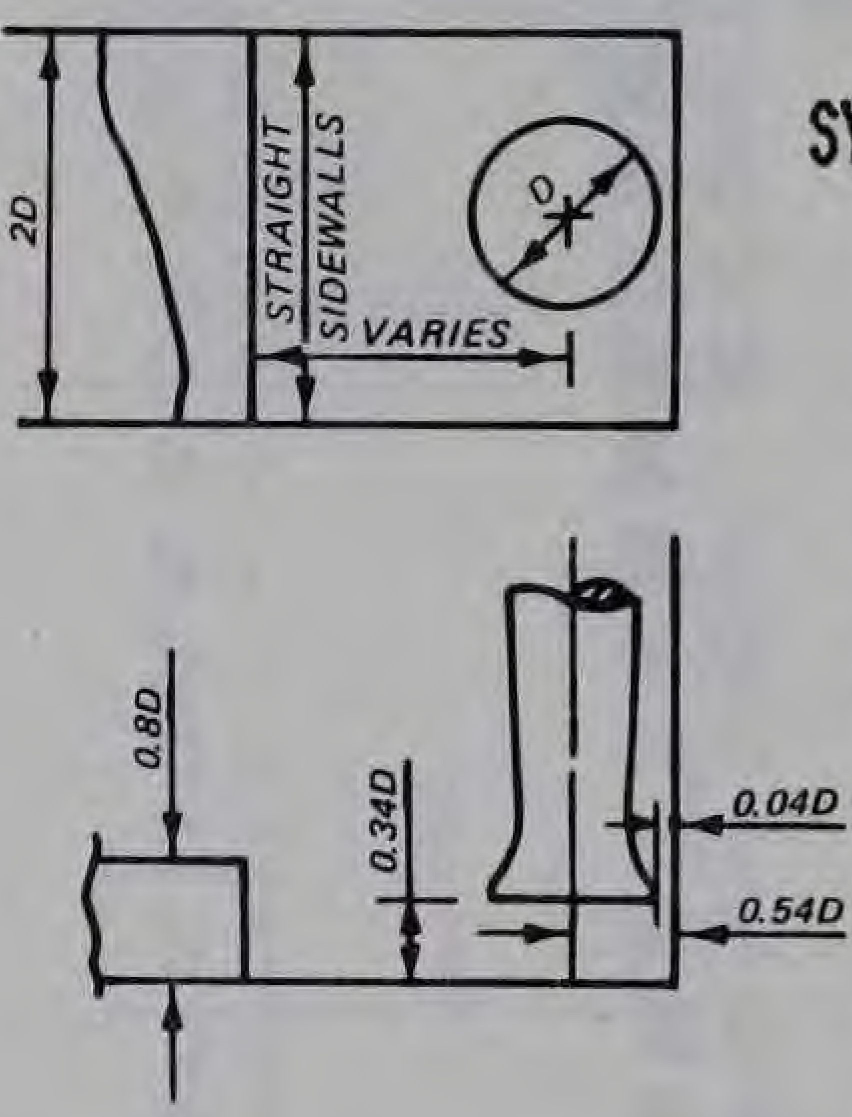


BASIC DATA

SYMBOL	$Q/\sqrt{g*D**5}$	DROP LOCATION/D	S/D
*	0.27	2.00	0.47
*	0.29	5.00	0.47
*	0.20	10.00	0.47
*	0.31	19.00	0.47
+	0.24	1.00	1.47
+	0.23	5.00	1.47
+	0.21	10.00	1.47
+	0.24	19.00	1.47
o	0.31	1.00	2.47
o	0.26	5.00	2.47
o	0.23	10.00	2.47
o	0.25	19.00	2.47

Figure 241. BWV, vertical drop; vertical drop height = 0.8D ; F/D = 0.34 ; B/D = 0.04 ; W/D = 2.0





BASIC DATA

SYMBOL	Q/ √g*D**5	DROP LOCATION/D	S/D
*	0.22	2.00	0.47
*	0.31	19.00	0.47
+	0.21	1.00	1.47
+	0.23	5.00	1.47
+	0.24	10.00	1.47
o	0.35	1.00	2.47
o	0.48	2.00	2.47
o	0.43	5.00	2.47
o	0.26	10.00	2.47
o	0.31	19.00	2.47

Figure 242. SV, vertical drop; vertical drop height = 0.8D ; F/D = 0.34 ; B/D = 0.04 ; W/D = 2.0

PART XII: SUMMARY AND CONCLUSIONS

216. This pumping station inflow-discharge hydraulic research study was initiated as a result of a US Army Corps of Engineers investigation which revealed that approximately 50 percent of all sumps for flood-control pumping stations designed and constructed by the Corps needed postconstruction modifications to improve flow conditions to the pumps. The experimental test facility was constructed sufficiently flexible to provide inflow from simulated channels, ponding areas, and conduits. Three 10-in.-diam, single-stage, mixed-flow pumps were installed along with one suction pump. A rear reservoir with return flow pumps was provided rather than recirculating water directly back into the flume. This design allowed pumping from the primary pumps to approach zero head pressure. Control valves were installed in the discharge lines of the primary pumps so that the head pressure could be varied from near zero up to approximately 33 ft. The other parameters could then be compared relative to the head pressure change. An automatic data acquisition system facilitated collection, analyses, and recording of data.

217. Sump evaluation techniques included visual observations and quantitative comparisons. Signature curves were developed for a base sump; then test results from subsequent geometrically altered sumps were compared to the base sump.

218. The pump intake location was tested with respect to the sump floor, backwall, and sidewalls. The degree of optimum location is a trade-off with the economics of excavation with respect to submergence and sump width. Generally the pump should be located 0.50D from the floor, 0.25D from the backwall, and 0.50D from the sidewalls. The suction pump was operated and compared with the actual pump at these various locations with very small differences in visual observations.

219. Various sump appurtenances were studied including surface vortex suppressor (SVS), fillets, converging sidewalls, converging floor, and umbrellas. The appurtenances, other than the SVS, were unsatisfactory for various reasons and are not recommended for sumps with evenly distributed approach flow. Many configurations of SVS beams were studied in a range from single beam/single stage to multibeam/multistage. The SVS beams create turbulence which breaks up SV's. Single beams are effective for a limited change of surface elevations or submergences. For larger changes in submergence, larger

numbers of SVS beams and stages are necessary. No satisfactory SVS configuration was found for very low submergence (0.75D or less), but a small improvement was recognized when the width of the sump was increased from 2D to 2.5D.

220. The approach flow was made to drop 0.8D over a vertical step across the sump. This 0.8D vertical drop was positioned at various distances upstream from the center line of the pump. For best results, it was concluded that the 0.8D drop should not be nearer than 2D from the pump bell center line for uniform flow and submergences greater than 1.47D.

221. Similarity of pump station models was studied in two parts: research of existing literature, and testing of submerged vortices. Similarity of the model can be affected if consideration is not given to the proper model size and method of operation. Submerged vortices are affected when the fluid has minute air bubbles or when a significant variation exists in model size.

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APPENDIX A: NOTATION

A	Inside area of discharge conduit, square feet
ADC	Analog-to-digital converter
A/D	Analog to digital
ASCII	American Standard Code of Information Interchange, a 7-bit representation of alphabetic, symbolic, and numeric characters
ASCBIN	ASCII to binary conversion routine
ASCFLT	ASCII to floating-point conversion routine
B	Distance from backwall
b	y-intercept value in linear equation of a line
Baud	Signaling elements (bits) per second
BCD	Binary Coded Decimal, a 4-bit representation of a decimal digit
BINASC	Binary to ASCII conversion routine
Bit	A binary digit
BWV	Backwall vortex
Byte	A group of bits (8)
C	A constant dependent on other factors
Cal ref	Calibration reference
Cal step	Calibration step
CMOS	Complementary Metal Oxide Semiconductor, a low power digital technology
CPU	Central Processing Unit
Cal	Calibration
CRT	Cathode Ray Tube, a display device
CTC	Counter Time Chip, a Z80 peripheral integrated circuit containing four counters

CCW	Counterclockwise
CW	Clockwise
d	Pump column intake diameter (not bell diameter)
D	Pump bell diameter
DAC or D/A	Digital-to-Analog Converter
DMA	Direct Memory Access
E	Voltage
EIA	Electronic Industries Association
EOF	End of file
EPROM	Erasable Programmable-Read-Only Memory
f	Friction factor
F	Floating, Distance from floor, or Froude number
FBA	Flow blockage allowable
F_m	Model Froude Criteria
F_p	Prototype Froude Criteria
F_{max}	Maximum pump column vibration
F_{rms}	Root mean square of pump column vibration
FV	Floor vortex
g	Acceleration due to gravity, ft/sec^2
H	Total pump head, ft
H_d	Discharge head, ft
H_{p_d}	Static head in discharge conduit, ft
H_s	Suction head, ft
H_v	Velocity head, ft
H_{v_d}	Velocity head in discharge conduit, ft
H_{z_d}	Vertical distance from datum to water surface, ft

H_{z_s} Elevation head, ft

I Current

IBWV Intermittent backwall vortex

ID Identification

IF Intermediate frequency

IFV Intermittent floor vortex

INBUF Routine for terminal keyboard handler

INBCD Input to BCD routine

INCAS Routine that disables the keyboard, enables the cassette playback, and reads in a block of characters

I/O Input/Output

ISV Intermittent surface vortex

K Factor used to correct the submergence predicted by a model operated according to Froude Criteria

Ka Total rotor weight

Ks Setting constant

Kt Thrust factor

LF Local oscillator frequency

LCD Liquid crystal diode

MI First memory cycle

m Ratio of engineering to analog-to-digital converter reading units

n Shaft speed, rpm

N Noise, psi

OFl Intermediate lower frequency that can be processed by a band-limited tuner

PC Printed circuit

P_i Power input, hp; power delivered to driver, hp

P_{MAX} Maximum pressure

P_{MIN}	Minimum pressure
P_s	Power delivered to pump (shaft power), hp
P_w	Pump power output (water power), hp
PVC	Polyvinyl chloride
PCB	Printed circuit board
$PRETEST_{A/D}$	Known engineering value
$PRETEST_{ENG}$	Acquired gage output
Q	Discharge, ft^3/sec, gpm
R	Discharge ratio, dimensionless or Reynolds number
$Q/g^{1/2}D^{5/2}$	Dimensionless parameter describing pump discharge
R'	Reynolds number at which surface vortex formation becomes independent of viscous effects
r	Orifice radius
R_r	Radial Reynolds number
RATIO	Ratio of engineering values to A/D readings
RAM	Random Access Memory
ref	Reference
RF	Radio frequency signal
rms	Root mean square
S	submergence, ft
SBWV	Sustained backwall vortex
SD	Standard deviation
S/D	Dimensionless parameter describing submergence
SUM	Sum of N data points
SUMSQ	Sum of the squares of N data points
SV	Surface vortex
SVS	Surface vortex suppressor

SWV	Sidewall vortex
T	Shaft torque, ft-lb
TTL	Transistor/Transistor Logic, a commonly used logic technology
UART	Universal Asynchronous Receiver/Transmitter, a serial communication peripheral integrated circuit
UARTIN	Routine that initiatizes UART
VAC	Volts alternating current
V	Velocity, fps; average velocity; average velocity in discharge conduit, ft/sec
W	Pump bay width
WK	Moment, $lb\text{-}ft^2$
x	Acquired analog-to-digital reading value representing a data point
x_i	Corresponding subsequent A/D data value
x_o	Acquired gage output corresponding to a known engineering value, usually zero
XADD	Address of the location in which X is stored
XBUFF	Base address of the X buffer
XCACL	Subroutine that calculates address of X
XDEPTH	Index value from the order buffer
XFRST	Buffer index of the first X point
XMUX, YMUX	Number of channels multiplexed
y	Unknown engineering variable
y_i	Engineering units of the subsequent data value
y_o	Known engineering value corresponding to an acquired gage output x_o, usually zero
YADD	Address of the location in which Y is stored
YBUFF	Base address of the Y buffer
YCALC	Subroutine that calculates address of Y

YFRST	Buffer index of the first Y point
Z80	An 8-bit microprocessor designed by Zilog
γ	Specific weight of water, lb/ft^3
η	Efficiency, %
η_d	Driver (motor) efficiency
η_p	Pump efficiency
ν	Kinematic viscosity of water
ω	Angular rotation, rad/sec