FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
Memorandum No. M-23

FACILITIES FOR INSTRUCTION AND RESEARCH
In
FLUID MECHANICS and HYDRAULICS

Prepared by
John B. Herbich

March 1961
Bethlehem, Pennsylvania

F.L. Report No. 237.16-M-23
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Appendix
A. Instruction - Course Summaries
B. Staff Publications
C. Staff Reports
1. INTRODUCTION

Instruction and research in hydraulics at Lehigh University dates from 1887, when the first American college hydraulics laboratory was erected on the Lehigh campus. It was here that Professor Mansfield Merriman conducted his important pioneer research work.

The Fritz Engineering Laboratory was built in 1909, and was extensively modernized and expanded in recent years. Since 1955, it has served as the headquarters of the Department of Civil Engineering, housing the staffs and laboratories of the various divisions of the Department - including the Hydraulics Division.

The Hydraulics Division provides a comprehensive range of courses of instruction in Fluid Mechanics, Hydraulics, and related topics, at undergraduate and graduate levels. With the present student and staff members, considerable energy can be devoted to research and project investigations for private industry and Governmental bodies. These activities provide the stimulation of industrial practice, essential to staff and students, and assist in the dissemination of recent theoretical developments in fluid mechanics and hydraulics to industry.

The Division is able to draw, where necessary, on the scientific and technical resources of other Divisions of the Department, in particular those specializing in Soil Mechanics and Sanitary Engineering, as well as the Instrumentation Specialists, Machinists and Mechanics of the Department's Laboratory.
Operations Group. In addition, the cooperation of members, and the use of facilities of other Departments of the University are readily available.

The following pages provide details of the facilities and work of the Hydraulics Division.

2. GENERAL LABORATORY DETAILS

The Hydraulics Laboratory occupies an area of more than 6000 square feet, conveniently placed on three levels. Some 4000 square feet of this space are used for research and investigational work. The floor plan is shown in Fig. 1 and 2.

The recirculating water supply system has a capacity of 8 cubic feet per second at 60 feet head, and 4 cubic feet per second at 130 feet head, the power being supplied by two centrifugal pumps - one 8-inch and one 6-inch. Pressure can be controlled by means of either a 300 cubic feet elevated constant-head tank, or a 300 cubic feet constant pressure tank.

Calibration and flow measurement facilities include twin-volumetric tanks, each of 400 cubic feet capacity, together with a wide variety of calibrated Venturi meters, weirs, flow nozzles, and a 4-inch magnetic flow meter.

The main pipe systems are 10 inches and 8 inches in diameter, and, by means of valves and provisions for connections, great flexibility is available for the ready installation of equipment for research and test work.
Electric power is available at 210-volt, 600 amp AC, 3-phase, through bus ducts, and at 240-volt DC up to 60 HP.

3. RESEARCH FACILITIES

(1) Channels and Flumes

(i) Wave Channel (Fig. 3). The main wave channel is 3 feet wide, 2 feet deep, and 67 feet long, excluding the end sections. It is of steel and aluminum frame construction, and is glass-walled over its full length.

The wave generator is of the pendulum type, with provision for variation of wave amplitude and frequency. The upstream wave absorber consists of inclined layers of perforated aluminum plate, while the downstream absorber has perforated plates on a 15° impermeable sloping beach.

Two carriages span the channel, running on rails supported independent of the channel. Each carriage carries capacitive-type wave probes, and a two-channel Sanborn recorder, as well as Brush recorders, are available for recording purposes.

(ii) Glass-Walled Flume (Fig. 4). This flume has a horizontal test section which is 24 feet long, 18 inches wide, and 30 inches deep. The bed, which is above floor level, is of glass and aluminum sections, any of which can be removed or adjusted in height. The entrance sluice gate can maintain a 6 feet head, and the flow rate can be varied up to 4 cubic feet per second. Flow measurement is effected with a calibrated Venturi meter.

(iii) Tilting Flume. The adjustable tilting flume is 40 feet long, 12 inches wide, and 18 inches deep. Its slope can be varied to a maximum of 1 in 20, and flow rates up to 4 cubic feet per second are possible. The depth of flow is regulated by a pressure-type sluice gate, and the flow is measured with a calibrated Venturi meter.

(2) Tanks

(i) Multipurpose Tank (Fig. 5). This tank has a test section 35 feet long, 10 feet wide, and 2 feet deep, excluding entrance and discharge section. The water level
is regulated by means of a screw-driven tail-gate, and the flow is measured by means of a calibrated Venturi meter.

Flow rates up to 6 cubic feet per second are available. This tank can be used for three-dimensional flow studies, sediment transportation research, or wave investigations.

(ii) **Spillway Tank.** The model spillway test tank has a test section 35 feet long, 10 feet wide, and 2 feet deep. The entrance box is 4 feet long, 4 feet deep, and 10 feet wide, and being separate from the main multi-purpose tank, can be removed up to 10 feet from it, and rotated in a horizontal plane up to 90°.

Head differentials up to 10 feet are obtainable, and flow measurement is effected either by Venturi meters or volumetric tanks. The normal capacity of 4 cubic feet per second can be increased, if necessary, to 6 cubic feet per second.

(3) **Sediment Pipe Circuit (Fig. 6 & 7).** The test-circuit for tests on the pumping of sediment-water mixtures consists of a 280 cubic feet tank and a 6-inch pipe line, with a centrifugal dredge pump powered by a calibrated 40 HP direct current motor. The pump speed can be varied between 1100 and 2400 revolutions per minute, and the flow rate, which is measured by a magnetic flow meter, can be varied up to 1200 gallons per minute. Flows with sediment concentrations up to 25 per cent by volume have been tested in this installation with pumps up to 10-1/2-inch impeller diameter in size.

(4) **Wind Tunnel.** The wind tunnel unit has a 12-inch diameter closed test section, and maintains air speeds up to 75 feet per second to within 0.3 feet per second.

(5) **High Pressure Pump Unit.** This pump, driven by a 50 HP A.C. motor, develops pressures up to 5000 lb per sq in. for high pressure test purposes.

(6) **Oil Recirculating Unit (Fig. 8).** Oil flows from 50 to 2000 gallons per minute can be established in this unit, which has six 100-gallon storage tanks which can be used individually or in combination. Flow measurement facilities include two orifice meters and a Venturi meter.
4. **INSTRUCTIONAL FACILITIES.**

The following installations and equipment, although designed primarily for instructional purposes, are in many cases adaptable to research and investigational studies.

1. **Viscosity Measuring Equipment.** These items include Saybolt (Fig. 9) and Ostwald-Fenske viscometers and temperature baths.

2. **Flow-Measuring Equipment** (Fig. 10). A 4-inch pipe and channel circuit contains a series of flow-measuring devices including an orifice, an elbow, a Venturi meter, and a flow nozzle, in the pipe section, and a weir and Parshall flume in the channel section.

3. **Manometry Stand** (Fig. 11). This unit provides facilities for the demonstration of various types of manometers.

4. **Pipe Friction Units** (Fig. 12, 13 & 14). Two pipe friction test units are available for instructional purposes. An oil-recirculation type (Fig. 12) is used primarily for laminar flow studies, and a water-recirculation type (Fig. 13 & 14) for turbulent flow studies.

5. **Smoke Tunnel.** This unit has a test section measuring 20 inches long, 11 inches high, and 1-1/2 inches deep, approximately, the air speed range being from 1-1/2 to 8 feet per second.

6. **Hele-Shaw Unit.** This free surface Hele-Shaw table has a working area 4 feet by 2 feet, for the demonstration of two-dimensional flow patterns past various boundary forms.

7. **Magnus Effect Unit.** Demonstrations of the Magnus effect can be given with this unit, in which fluid flows past a rotating cylinder.

8. **Turbine Test Stand.** The test-loop for turbine testing consists of a constant pressure tank, a pump, water dynamometer, and Venturi meter for flow measurement (Fig. 15).

    A smaller test-loop for an impulse-turbine consists of a pump, a Prony brake, and an orifice meter for flow measurement (Fig. 16).
(9) Force of Jet Apparatus (Fig. 17). The unit provides means for verifying the impulse-momentum equation, as well as determining the coefficients of velocity.

(10) Cavitation Unit (Fig. 18). Demonstration of cavitation in a plexiglas test section can be given.

5. UNDERGRADUATE AND GRADUATE COURSES

The outlines of the undergraduate and graduate courses offered by the Hydraulics Division are given in Appendix A.

6. REPORTS AND STAFF PUBLICATIONS

Staff publications and reports of the Division are listed in Appendices B and C, respectively. Project reports are available on loan, subject to the approval of the organizations which sponsored the investigations.

7. ACKNOWLEDGMENT

The report was written by John B. Herbich, Associate Professor and Chairman of the Hydraulics Division. Mr. R. Kozo prepared the drawings, and Miss E.E. Young typed the manuscript. The writer would like to acknowledge the assistance of H.R. Vallentine, Associate Professor, in preparation of this report, and the encouragement received from Professor W.J. Eney, Head of the Civil Engineering Department and Fritz Engineering Laboratory. Professor L.S. Beedle is the Director of the Laboratory.

* * * * *
Fig. 2
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION

WAVE CHANNEL

DRAWN: jkh  DATE: APRIL 1960
TRACED: jkh  CHECKED: jph
SCALE 1/2"=1'-0

CROSS SECTION

PROBE CARRIAGE

WAVE GENERATOR PADDLE

PERFORATED PLATE LAYERS

WAVE ABSORBER

SIDE ELEVATION

PENDULUM PADDLE

UPSTREAM WAVE ABSORBER
(perforated plate layers)

SIDE VIEW

SCALE 3/4"=1'-0

Fig. 3
FIG. A-I. General View of Test Facility.

Fig. 7
A.) CALIBRATION OF METERS

B.) PERFORMANCE OF PUMPS

FLOW DIAGRAMS OF CIRCULATING SYSTEM

Fig. 8
Fig. 9
Figure 10
Fig. 15

LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION

TURBINE TEST STAND

DRAWN - r/k
TRACED - r/k
DATE - APRIL 1960
CHECKED - jph
SCALE 1/2" = 1'-0"
Fig. 16
PLEXIGLASS TEST SECTION

TO MANOMETERS

PRESSURE TANK

TO MANOMETER

FLOW METER

PUMP & MOTOR

FLOOR

Fig. 18
APPENDIX A

LEHIGH UNIVERSITY
Department of Civil Engineering
Fritz Engineering Laboratory

HYDRAULICS DIVISION

COURSE OUTLINES

The numbers in brackets indicate the number of lectures or meetings per week.

For Undergraduates

C.E.121. MECHANICS OF FLUIDS (3)
The behavior of real fluids and the more important physical laws; potential flow, boundary layer, lift, drag, and waves, with practical applications to flow through pipes, open channels, turbines, and pumps. Dimensional analysis and similitude.

C.E.123. FLUID MECHANICS LABORATORY (1)
Introduction to laboratory techniques, calibration, principles, and fluid measurements. Closed conduit flow of water, oil, and air; open channel flow of water, wind tunnel studies; hydraulic machinery testing.

C.E.123. APPLIED HYDROLOGY (2)

C.E.125. HYDRAULIC ENGINEERING (2)
Flow in pressure conduits in series, parallel and network arrangements; uniform and non-uniform flow in open channels; pumping; design of sanitary and storm sewage systems; consideration of engineering economy as applied to hydraulic projects.
Appendix A - Course Outlines

For Advanced Undergraduates and Graduates

C.E. 320. HYDRAULIC ENGINEERING STRUCTURES (3)

C.E. 321. WATER POWER AND PUMPING (3)
Theory of hydraulic turbines. Study of penstocks, scroll cases, draft tubes, water hammer and cavitation. Theory and design of pumps. Performance and testing of turbines and pumps.

C.E. 322. HYDROMECHANICS (3)
Fundamental principles of fluid motion, with emphasis on hydraulic applications. Euler's, Bernoulli's, and Laplace's equations, gradually varied open channel flow, wave motion, water hammer, sediment transportation, and cavitation.

For Graduates

C.E. 407. THESIS (1-6)

C.E. 420. HYDROLOGY AND OPEN CHANNEL FLOW (3)
Components of the hydrologic cycle. Analysis and prediction of basic quantities required for hydraulic engineering design and storage requirements. Non-uniform flow in open channels and reservoirs, backwater curves in natural and artificial channels, hydraulic jump, surges and waves, standing waves in supercritical flow. Transportation of sediment. Supervised problems.

C.E. 421. HYDRAULIC LABORATORY PRACTICE (2-5)
Study of theory and method of hydraulic experimentation simultaneously with laboratory work.

C.E. 422. HYDRAULIC RESEARCH (2-5)
Individual research problems with reports.

C.E. 423. ADVANCED HYDRAULIC ENGINEERING and HYDROMECHANICS (3)
LEHIGH UNIVERSITY
Department of Civil Engineering
FRITZ ENGINEERING LABORATORY

HYDRAULICS DIVISION

STAFF PUBLICATIONS

McPherson, M.B. DESIGN OF DAM OUTLET TRASH-RACK VERIFIED BY MODEL TESTS
Civil Engineering Aug. 1950

McPherson, M.B. AN INEXPENSIVE DEMONSTRATION FLUID POLARISCOPE
Civil Engineering

White, W.M. Discussion on Paper: DETERMINATION
McPherson, M.B. OF PRESSURE-CONTROLLED PROFILES
ASCE Proceedings, Separate No. 491 1953

Macnaughton, M.F. ACCIDENTAL AIR IN CONCRETE
Herbich, J.B. Jour., ACI, Vol. 26, No. 3
Proc., Vol. 51, Title 51-13 1953

Taylor, D.C. EBOW METER PERFORMANCE
McPherson, M.B. Jour. AWWA, Vol. 46, No. 11
pp. 1087-1095 1954

McPherson, M.B. BUTTERFLY VALVE FLOW CHARACTERISTICS
Paper 1167, HY 1 28 pages 1957

McPherson, M.B. DISCUSSION OF SEVEN EXPLORATORY STUDIES IN HYDRAULICS
Paper 1230 1957

McPherson, M.B. A STUDY OF BUCKET-TYPE Karr, M.H. ENERGY DISSIPATER CHARACTERISTICS
Paper 1266, HY 3 12 pages 1957
Corrections: Paper 1348, HY 4 pp. 57-64

McPherson, M.B. OUTLET PORTAL PRESSURE DISTRIBUTION

Straub, L.G. AN EXPERIMENTAL STUDY OF
Herbich, J.B. HYDRAULIC BREAKWATERS
Bowers, C.E. Coastal Engineering
Chap. 43; pp. 715-728 1958
Straub, L.G. LABORATORY TESTS OF
Bowers, C.E. PERMEABLE WAVE ABSORBERS
Herbich, J.B. Coastal Engineering
                  Chapter 44                                pp. 729-742 1958

Herbich, J.B. Discussion on:
SHIPBOARD HYDRAULIC BREAKWATER
Proc. ASCE, Jour. of Waterways
      and Harbors Div. Paper 1785 1958

Herbich, J.B. Discussion on: WAVE FORCES
ON SUBMERGED STRUCTURES
Paper 2076 1959

Herbich, J.B. Discussion on: TRANSLATIONS OF
FOREIGN LITERATURE ON HYDRAULICS
Paper 2349 1960

Herbich, J.B. THE EFFECT OF SPUR DIKES
ON FLOOD FLOWS THROUGH
BRIDGE CONSTRUCTION
Paper presented at the
ASCE Boston Convention 1960
McPherson, M.B. STUDY OF MISALIGNMENTS IN AN OPEN CHANNEL
Project Report No. 16 12 pages 1950

McPherson, M.B. MODEL STUDY OF HILLS CREEK DAM SPILLWAY
Project Report No. 17 43 pages 1950

Eagleson, P.S. CONTINUATION OF MODEL STUDY OF
HILLS CREEK DAM SPILLWAY
Project Report No. 18 75 pages 1951

McPherson, M.B. MODEL STUDY OF A CORRECTIVE DESIGN
Strausser, H.S. FOR THE LITTLE PINE CREEK
Liebig, J.O. OUTLET STRUCTURE (Sponsored by
Justin and Courtney, Consulting Engineers, Philadelphia, Pa.)
Project Report No. 19 41 pages 1952

Williams, J.C. TESTS OF A SIX-INCH BUTTERFLY VALVE
McPherson, M.B. DISCHARGING UNSUBMERGED (Sponsored
by Fluids Controls Company, Philadelphia, Pennsylvania)
Project Report No. 20 23 pages 1952

McPherson, M.B. MODEL TESTS OF PROPOSED DESIGN OF
ANTITETAM (WAYNESBORO) DAM SHAFT
SPILLWAY STRUCTURE (Sponsored by
Gannett, Fleming, Corddry and Carpenter, Inc., Harrisburg, Pa.)
Project Report No. 21 76 pages 1952

McPherson, M.B. TESTS OF A 1:32 MODEL OF A PROPOSED
OUTLET STRUCTURE FOR FIRST FORK
(SINNEMAHONING) DAM (Sponsored by
Gannett, Fleming, Corddry and Carpenter, Inc., Harrisburg, Pa.)
Project Report No. 22 16 pages 1952

Williams, J.C. REPORT ON TESTS OF BUTTERFLY VALVES
Strausser, H.S. DISCHARGING INTO A MODEL DISCHARGE
CHAMBER AND FLUME (Sponsored by
Project Report No. 23 39 pages 1952
Hydr. Div., FEL - Project Reports

McPherson, M.B.  
Strausser, H.S.  
Additional Stilling Basin Tests with a 1:32 Model for First Fork (Sinnemahoning) Dam  
(Sponsored by Gannett, Fleming, Corddry and Carpenter, Inc., Harrisburg, Pennsylvania)  
Project Report No. 24 46 pages 1952

McPherson, M.B.  
Strausser, H.S.  
Mostert, J.G.  
Colleville, P.J.  
Butterfly Valve Research  
(Sponsored by CDC Control Services, Hatboro, Pennsylvania)  
Project Report No. 25 48 pages 1953

Colleville, P.J.  
6" Butterfly Valve Head Loss Tests  
(Sponsored by W.S. Rockwell Co., Fairfield, Connecticut)  
Project Report No. 26 14 pages 1953

Reid, A.W.  
Model Tests for Shawville Dam  
Project Report No. 1427 (Gilbert Associates, Reading, Pennsylvania)  
1953

Reid, A.W.  
Model Tests for Condensing Water Outlet Structure - Front Street Station, Erie, Pennsylvania  
Project Report No. 1429 (Gilbert Associates, Reading, Pennsylvania)  
1953

McPherson, M.B.  
Strausser, H.S.  
Movable Bed Model Study of Greensboro, North Carolina Dam  
(Sponsored by William C. Olsen and Associates, Raleigh, North Carolina)  
Project Report No. 27 22 pages 1955

McPherson, M.B.  
Strausser, H.S.  
3 to 100 Scale Model Study of Chute Spillway Penn Forest Dam  
(Sponsored by Bethlehem Authority, Bethlehem, Pennsylvania)  
Project Report No. 28 23 pages 1955

Reid, A.W.  
Model Tests - New Diversion Dam  
(Sponsored by Pennsylvania Elec. Co.)  
Project Report No. 29 10 pages 1956

Dittig, R.G.  
Herbich, J.B.  
Tests of a Wire Mesh Filter  
(Sponsored by Purolator Products, Inc., Rahway, New Jersey)  
Project Report No. 30 18 pages 1958

Herbich, J.B.  
Characteristics of a Model Dredge Pump  
(Sponsored by U.S. Army Corps of Engineers, Philadelphia District)  
Project Report No. 31 110 pages 1959
<table>
<thead>
<tr>
<th>Authors</th>
<th>Title</th>
<th>Type</th>
<th>Pages</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delany, A.G.</td>
<td>THE FLUSH VALVE UNDER LOW PRESSURE</td>
<td>Unpublished Thesis</td>
<td>45</td>
<td>1940</td>
</tr>
<tr>
<td>Dawson, J.H.</td>
<td>THE EFFECT OF LATERAL CONTRACTIONS ON SUPER-CRITICAL FLOW IN OPEN CHANNELS</td>
<td>M.S. Thesis</td>
<td>76</td>
<td>1943</td>
</tr>
<tr>
<td>Coles, D.</td>
<td>EXPERIMENTAL RELATION BETWEEN SUDDEN WALL ANGLE CHANGES AND STANDING WAVES IN SUPERCRITICAL FLOW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shintaku, T.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jacobsen, J.T.</td>
<td>HYDRAULIC LABORATORY MANUAL</td>
<td>an Undergraduate Thesis</td>
<td>43</td>
<td>1948</td>
</tr>
<tr>
<td>Becker, H.L.</td>
<td>INVESTIGATION OF PRESSURE MAGNITUDES AT MISALIGNMENTS IN AN OPEN CHANNEL</td>
<td></td>
<td>12</td>
<td>1949</td>
</tr>
<tr>
<td>Becker, H.L.</td>
<td>DESIGN OF LONG-RADIUS, HIGH-RATIO FLOW NOZZLE</td>
<td></td>
<td>6</td>
<td>1949</td>
</tr>
<tr>
<td>Williams, J.C.</td>
<td>A STUDY OF MISALIGNMENT IN A CLOSED CONDUIT</td>
<td>M.S. Thesis</td>
<td>22</td>
<td>1951</td>
</tr>
<tr>
<td>Nece, R.E.</td>
<td>THE CONSTRUCTION AND TESTING OF A SCALE MODEL OF A DAM SPILLWAY AND STILLING BASIN (FALL RIVER DAM, KANSAS)</td>
<td></td>
<td>44</td>
<td>1951</td>
</tr>
<tr>
<td>Brey, G.M.</td>
<td>EXPERIMENTAL DETERMINATION OF CIRCULAR WEIR CHARACTERISTICS</td>
<td></td>
<td>17</td>
<td>1951</td>
</tr>
<tr>
<td>Williams, J.C.</td>
<td>STUDY OF MISALIGNMENT IN AN OPEN CHANNEL AND A CLOSED CONDUIT</td>
<td>M.S. Thesis</td>
<td>61</td>
<td>1952</td>
</tr>
<tr>
<td>McPherson, M.B.</td>
<td>THE DESIGN OF BENDS FOR HYDRAULIC STRUCTURES</td>
<td>C.E. Thesis</td>
<td>46</td>
<td>1952</td>
</tr>
<tr>
<td>VanOommeren, W.</td>
<td>THE CHARACTERISTICS AND ACCURACY OF RECTANGULAR BENDS USED AS FLOW METERS</td>
<td></td>
<td>18</td>
<td>1953</td>
</tr>
<tr>
<td>Name</td>
<td>Title</td>
<td>Report Type</td>
<td>Pages</td>
<td>Year</td>
</tr>
<tr>
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<td>----------------------------------------------------------------------</td>
<td>------------------------------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>Taylor, D.C.</td>
<td>THE CALIBRATION AND ACCURACY OF EIBOW METERS</td>
<td>Undergraduate Study Report</td>
<td></td>
<td>1953</td>
</tr>
<tr>
<td>Karr, M.H.</td>
<td>BUCKET-TYPE ENERGY DISSIPATORS</td>
<td>Graduate Study Report</td>
<td>30</td>
<td>1956</td>
</tr>
<tr>
<td>Murthy, D.S.N.</td>
<td>POTENTIAL FLOW IN 90° BENDS BY ELECTRICAL ANALOGY</td>
<td>Graduate Study Report</td>
<td>23</td>
<td>1956</td>
</tr>
<tr>
<td>Morel, A.R.R.</td>
<td>EXIT PORTAL PRESSURE STUDY. SQUARE CONDUIT</td>
<td>Graduate Study Report</td>
<td>13</td>
<td>1957</td>
</tr>
<tr>
<td>Glomb, J.W.</td>
<td>INVESTIGATION BY ELECTRICAL ANALOGY OF POTENTIAL FLOW IN A 90° EIBOW WITH A DIVIDING VANE</td>
<td>Undergraduate Study Report</td>
<td>17</td>
<td>1957</td>
</tr>
<tr>
<td>Brach, P.</td>
<td>HYDRAULIC MODEL INVESTIGATION ON CHIEF JOSEPH DAM SPILLWAY</td>
<td>Graduate Study Report</td>
<td>41</td>
<td>1959</td>
</tr>
<tr>
<td>Castro, V.A.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kable, J.C.</td>
<td>DESIGN OF A CAVITATION UNIT</td>
<td>Undergraduate Study Report</td>
<td>22</td>
<td>1959</td>
</tr>
<tr>
<td>Carle, R.J.</td>
<td>THE USE OF SPUR DIKES WITH BRIDGE ABUTMENTS</td>
<td>Graduate Study Report</td>
<td>16</td>
<td>1959</td>
</tr>
<tr>
<td>Carle, R.J.</td>
<td>THE EFFECT OF SPUR DIKES ON FLOOD FLOWS THROUGH HIGHWAY BRIDGE ABUTMENTS</td>
<td>Graduate Study Report</td>
<td>135</td>
<td>1959</td>
</tr>
<tr>
<td>Kable, J.C.</td>
<td>THE DETERMINATION OF THE LENGTH OF SPUR DIKES FOR FLOOD FLOWS THROUGH HIGHWAY BRIDGE ABUTMENTS</td>
<td>Graduate Study Report</td>
<td>61</td>
<td>1959</td>
</tr>
<tr>
<td>Weiss, W.L.</td>
<td>SUGGESTED DESIGN CHANGES FOR A CENTRIFUGAL PUMP IMPELLER HANDLING DREDGED MUD</td>
<td>Graduate Study Report</td>
<td>20</td>
<td>1959</td>
</tr>
<tr>
<td>Author</td>
<td>Title</td>
<td>Pages</td>
<td>Year</td>
<td></td>
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<tr>
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<td>------------------------------------------------------------</td>
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<td></td>
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<tr>
<td>Brach, P.L.</td>
<td>SCALE EFFECT ON 270° PIPE BENDS FOR BINGHAM BODY FLUID</td>
<td>50</td>
<td>1960</td>
<td></td>
</tr>
<tr>
<td>Herbich, J.B.</td>
<td>Graduate Study Report</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fritz Lab. Report No. 277-M-10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waddington, W.M.</td>
<td>ANALYSIS OF HIGH-SPEED MOVIES OF A MODEL PUMP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbich, J.B.</td>
<td>Graduate Study Report</td>
<td>36</td>
<td>1960</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fritz Lab. Report No. 277-M-11</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Armanet, L. TURBINE BUTTERFLY VALVES (VANNES - PAPILLON DES TURBINES) Genissiat pp. 199-219 La Houille Blanche Translated by P.J. Colleville Fritz Engineering Laboratory Translation No. T-1 1953