Facilities for instruction and research on fluid mechanics and hydraulics, 1961

Herbich, J. B.
1961

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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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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 for 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. 3

- Cross Section
- Cross Section (wave generator)
- Side Elevation
- Side View (generator + absorber)

Key Components:
- Motor and Hydraulic Transmission
- Wave Generator Paddle
- Probe Carriage
- Perforated Plate Layers
- Wave Absorber
- Pendulum Paddle
- Upstream Wave Absorber (perforated plate layers)

Scale: 1/2'=1'-0
Fig. 6

Fig. 7
A.) CALIBRATION OF METERS

B.) PERFORMANCE OF PUMPS

FLOW DIAGRAMS OF CIRCULATING SYSTEM
Figure 11
Figure 12

LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION

PIPE FRICTION
(REYNOLDS NUMBER BELOW 2000)

DRAWN - rjk  DATE - APRIL 1960
TRACED - rjk  CHECKED - jbh
SCALE 1/2"=1'-0

Figure 12
Figure 13

LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION

PIPE FRICTION
(REYNOLDS NUMBER ABOVE 2000)

DRAWN - rjk DATE - APRIL 1960
TRACED - rjk CHECKED - jbh
SCALE 1/2" = 1'-0"

Figure 13
Figure 14

LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
PIPE FRICTION
(REYNOLDS NUMBER ABOVE 2000)

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

PLAN VIEW
Fig. 16
PLEXIGLASS TEST SECTION

TO MANOMETERS

PRESSURE TANK

TO MANOMETER

FLOW METER

PUMP & MOTOR

FLOOR

TOP VIEW

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 26 pages 1957

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

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

McPherson, M.B. OUTLET PORTAL PRESSURE DISTRIBUTION
at Chicago Feb. 1958

Straub, L.G. AN EXPERIMENTAL STUDY OF
Herbich, J.B. HYDRAULIC BREAKWATERS
Bowers, C.E. Coastal Engineering
Chap. 43; pp. 715-728 1958
Herbich, J.B. Discussion on: WAVE FORCES ON SUBMERGED STRUCTURES

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Herbich, J.B. THE EFFECT OF SPUR DIKES ON FLOOD FLOWS THROUGH BRIDGE CONSTRUCTIONS
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. OUTLET STRUCTURE (Sponsored by
Liebig, J.O. 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
ANTETAM (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.)
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Williams, J.C. REPORT ON TESTS OF BUTTERFLY VALVES
Strausser, H.S. DISCHARGING INTO A MODEL DISCHARGE
CHAMBER AND FLUME (Sponsored by
Fluids Controls Company, Inc.,
Philadelphia, Pennsylvania)
Project Report No. 23 39 pages 1952
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**ADDITIONAL STILLING BASIN TESTS WITH A 1:32 MODEL FOR FIRST FORK (SINNEMAHON-ING) DAM** (Sponsored by Gannett, Fleming, Corddry and Carpenter, Inc., Harrisburg, Pennsylvania)  
Project Report No. 24 46 pages 1952

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**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** (Gilbert Associates, Reading, Pennsylvania)  
Project Report No. 1427 1953

Reid, A.W.  
**MODEL TESTS FOR CONDENSING WATER OUTLET STRUCTURE - FRONT STREET STATION, Erie, Pennsylvania** (Gilbert Associates, Reading, Pennsylvania)  
Project Report No. 1429 1953

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**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

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**3 to 100 SCALE MODEL STUDY OF CHUTE PENN FOREST DAM** (Sponsored by Bethlehem Authority, Bethlehem, Pennsylvania)  
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**MODEL TESTS - NEW DIVERSION DAM** (Sponsored by Pennsylvania Elec. Co.)  
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Project Report No. 30 18 pages 1958

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HYDRAULICS DIVISION

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