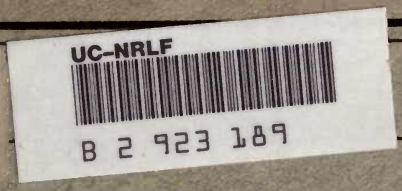


THE ENGINEERING FOUNDATION

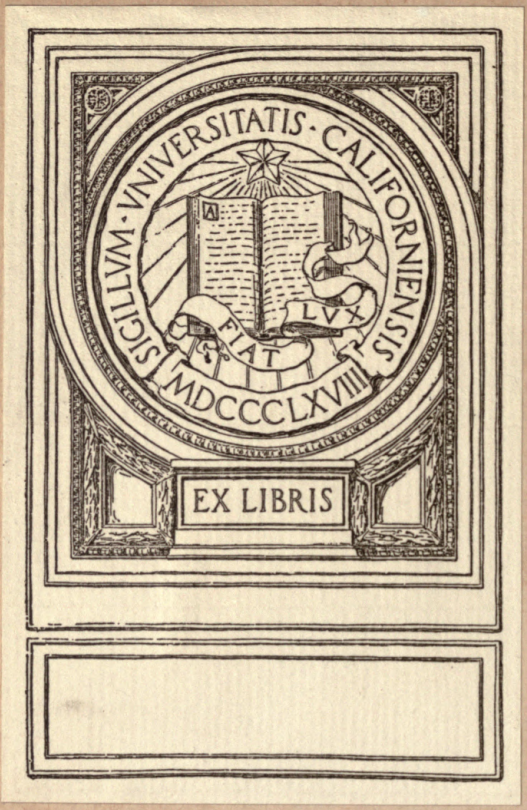
HYDRAULIC LABORATORIES

IN THE

UNITED STATES OF AMERICA

PUBLICATION
NUMBER 5

ENGINEERING SOCIETIES BUILDING
NEW YORK CITY
JUNE, 1922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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

A DESCRIPTIVE DIRECTORY OF
HYDRAULIC LABORATORIES IN U. S. A

COMPILED FOR THE
HYDRAULIC RESEARCH COMMITTEE

J. WALDO SMITH
SILAS H. WOODARD

BY ALFRED D. FLINN, SECRETARY

PUBLICATION
NUMBER 5

ENGINEERING SOCIETIES BUILDING
NEW YORK CITY
JUNE, 1922

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ENGINEERING FOUNDATION—A DEFINITION

Engineering Foundation is an instrumentality for the encouragement and support of research, created for the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers and American Institute of Electrical Engineers by United Engineering Society, incorporated under the laws of the State of New York, May 11, 1904, to hold and administer real estate, endowment funds and other properties for these four Founder Societies. It is a department of United Engineering Society.

The purpose of Engineering Foundation is to exalt the profession of engineering, through increased capacity for service. Its scope is broad, since it was established "for the furtherance of research in science and in engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind." It was founded in 1914 by Ambrose Swasey, whose gifts were intended as the nucleus of a large endowment, to which there would in time be many other contributors.

Engineering Foundation represents in the field of research the four Founder Societies with their 50,000 members. It is a liaison agency between engineers on one hand and scientists and technologists on the other hand, in activities concerned with research in all branches of the mathematical, physical and biological sciences, and their applications. Nor is the Foundation unmindful of the personnel element in engineering and industry and the desirability of studying the problems in this field. Engineering Foundation seeks to serve the Profession and its allied industries, and through them, our country and the world.

HYDRAULIC LABORATORIES IN U. S. A.

FOREWORD

HYDRAULICS, as an art and a science, is of respectable antiquity. Until very modern times, however, the experiments on which the science was based were, in most instances, conducted on a scale that can be characterized only as minute in comparison with quantities and structures in practical use. In recent years, a number of laboratories have been established with much larger equipment—in some cases of full practical size.

There is need for many additions to our experimental knowledge. One step of progress was believed to be the collection and publication of authoritative information concerning hydraulic laboratories in our country. Publication of this information in form for convenient reference, should promote the use of the facilities of the laboratories for research as well as for testing, instruction, and other routine work. Many of the laboratories are in engineering colleges and are intended primarily for instructional purposes, but there is much time when their equipment is not so used and might be employed for experimental research.

In this directory descriptions have been given only of those laboratories from which the information was supplied in response to the request of Engineering Foundation. Names, only, of a few other laboratories have been included in the list. Some organizations believed to have laboratories did not respond to the inquiry. There may also be a few laboratories of which, unfortunately, Engineering Foundation had no knowledge and to which consequently no inquiries were addressed. Therefore, the list probably is not complete.

The letters of inquiry were in the following form:

Hydraulic Laboratories in U. S. A.

Gentlemen:

No descriptive directory of the hydraulic laboratories in the U. S. is known to exist. Such a directory would be useful to many persons in a number of ways. Engineering Foundation's Committee on Hydraulic Research has undertaken to compile the needed information so that it may be generally available. If you have a hydraulic laboratory, please assist by sending informa-

tion about your laboratory in any form most convenient for you. Kindly cover:

1. Name of laboratory;
2. Year established;
3. Kinds of work for which the laboratory is especially fitted;
4. Head and quantity of water available for tests;
   (a) By gravity
   (b) By pumping
5. Principal pieces of equipment, with brief notes on size, capacity, precision or other features of interest;
6. Very unusual equipment or facilities, if any;
7. Possibilities for work, for or by outside persons or companies, and terms therefor;
8. Distance from railroad station or siding;
9. Name and title of person in charge of laboratory;
10. Number of persons on regular staff;
11. Brief general description of laboratory;
12. Research or other work of unusual importance which has been done.

A list of hydraulic laboratories is enclosed; please add to it if you can. Your help will be appreciated. A copy of the Directory will be sent you in due course.

J. Waldo Smith
Silas H. Woodward
Hydraulic Research Committee.

Each description has been written in a style accordant with the information supplied. Departure from the outline of the letter of inquiry has been found desirable in a number of cases.

The descriptive statements about the laboratories are arranged in alphabetical order of the names of the companies, colleges or other institutions with which the laboratories are connected. The directory contains descriptions of 49 laboratories.

ALPHABETICAL LIST AND INDEX

ALLIS-CHALMERS MANUFACTURING COMPANY

1. Allis-Chalmers Manufacturing Company, hydraulic turbine and centrifugal pump testing flume, Milwaukee, Wisconsin.

2. Established, 1914.

3. *Kinds of work for which laboratory is especially fitted:*
   Testing centrifugal pumps and hydraulic turbines and impulse wheels.

4. *Head and quantity of water available for tests:*
   For turbines—
   12 cubic feet per second, 15 feet head.
   20 cubic feet per second, 50 feet head.
   4 cubic feet per second, 200 feet head.
   For pumps—
   2500 gallons per minute, 600 feet head.

5. *Principal pieces of equipment:*
   Concrete weir pits, suction pits, hook gages, turbine tanks, turbine tail race, testing switchboard and accessories, motor-driven pumps; capacities suitable for conditions covered in 4.

6. *Unusual equipment or facilities:*
   50-ton electric cranes to handle material direct from railroad cars to all parts of the testing flume.

7. No outside work has been solicited or taken in.

8. *Railroad station or siding,*
   Siding directly past test flume.

9. *Name and title of person in charge of laboratory:*
   W. M. White, Manager and Chief Engineer, Hydraulic Department.

10. *Number of persons on regular staff:*
    Between two and ten.

Information furnished by W. M. White.

* * *

ARMOUR INSTITUTE OF TECHNOLOGY

1. Armour Institute of Technology Hydraulic and Pneumatic Laboratory. Chicago, Illinois.

2. Established, about 1903.

3. *Kinds of work for which laboratory is especially fitted:*
   Tests of steam- or electric-driven contrifugal or reciprocating pumps of small and medium sizes: calibration of water meters, Venturi meters, Pitot tubes, small weir notches, gages, etc.; tests to deter-

mine coefficients of friction through pipes, elbows, nozzles, orifices, etc.; hydraulic pressure tests of pipes, boilers, radiators, etc., up to 10,000 pounds per square inch.

4. *Head and quantity of water available for tests:*
Water supply from city main through 3-inch pipe. Pressure varies from 18 pounds to 25 pounds per square inch. 4000-gallon reservoir with head of 90 feet. Worthington pump capable of delivering 250 gallons per minute against a 300-foot head.

5. *Principal pieces of equipment:*
12 x 12-inch Marsh steam pump.
Marsh steam pump for pressures up to 10,000 pounds per square inch.
Dayton single-stage centrifugal pump.
Worthington 3-stage pump direct-connected to 40-horse-power steam turbine.
Chicago two-stage centrifugal pump direct-connected to 1½-horse-power variable-speed electric motor, capacity, 40 gallons per minute against 60-foot head.
10-horse-power variable-speed electric motor.
7½-horse-power Sprague dynamometer.
Tank with 14-inch weir.
Weir box to take various notches up to 12 inches in width.
Various notches and hook gages for weir box.
12 weighing tanks of various shapes taking from 150 to 200 gallons each.
Platform balances for each of tank as well as several smaller platform balances, spring scales and Krone scales.
Pitot tubes of different forms.
Venturi meter ⅜ inch x 1 inch.
Two Venturi meters 1 inch x 3 inches.
Venturi meter 1¼ x 3 inches.
Water meters of several makes and sizes.
Hydraulic ram—6 feet supply head and variable discharge head.
18-inch Pelton water wheel with variable opening, Doble nozzle and Woodward governor.
Tachometers, ammeters, voltmeters, etc.

7. Test work for outside persons and firms is carried on regularly and is handled through Professor Gebhardt, head of the Mechanical Department.

8. *Railroad station or siding:*
The Institute is located directly on the Rock Island Railway.

9. *Name and title of person in charge:*
Lynn Eugene Davies, B. S., Instructor of Experimental Engineering.

10. *Number of persons on regular staff:*

Mr. Davies is in direct charge of the hydraulics laboratory, but the entire experimental engineering department has six men besides Professor Gebhardt and several mechanics and helpers. Each of these men is a specialist in some particular phase of the subject, yet each is more or less familiar with the work of the others and each one is ready at all times to lend advice or assistance on any job.

11. *Brief general description:*

Most of the equipment is situated around a sump in the basement of the main building so that waste and discharge water is readily disposed of. This sump has an overflow into the city sewers, but is usually kept filled to a depth of about 5 feet to serve as a convenient source of supply for the various pumps. There is a network of water and steam pipe lines several feet above the floor so that water or steam-driven machines can be connected at almost any point in the laboratory. Most of the water lines are connected with all three sources of supply thus making a large range of pressures available. The Worthington pump is located in the main engine room about 100 feet away, but also in the basement.

Information furnished by Lynn E. Davies, Instructor of Experimental Engineering.

* * *

ASSOCIATED FACTORY MUTUAL FIRE INSURANCE COMPANIES

1. Factory Mutual Laboratories, Boston, Massachusetts

2. Established, 1889.

3. *Kinds of work for which laboratory is especially fitted:*

All matters relating to fire protection engineering,—divided into three main branches:

a. Fire-extinguishing apparatus: detailed laboratory examinations and tests and operating performance of automatic sprinklers, fire pumps, hydrants, valves (gate, check, dry-pipe, etc.), fire hose, chemical extinguishers; calculation of designs of elevated tanks and field inspection of completed structures.

b. Fire hazards: studies of manufacturing processes to reduce fire hazards, development of methods for safely storing, and for controlling fires in hazardous materials.

c. Building construction: tests of building materials and types of construction from the fire standpoint.

4. *Head and quantity of water available for tests:*

By gravity. At the Factory Mutual Laboratories testing station at Lowell, Massachusetts, about 1500 gallons per minute at 50 pounds pressure.

By pump. No large capacity pumps are yet installed, although two 1500-gallon-per-minute centrifugal pumps are proposed. For the present, the pumping facilities at co-operating manufacturing plants are employed.

From pressure tanks. Two 500-gallon pressure tanks are used for testing dry-pipe valves.

5. *Principal pieces of equipment:*

Calibrated meter nozzles: several sets ranging in diameter from ½ inch to 8 inches for accurately measuring the flow of water under pressure at a rate up to 10,000 gallons per minute. This equipment includes the necessary piezometers, mercury columns, U tubes, etc.

Testing stands for operation of valves and hydrants.

Complete apparatus for operating tests of automatic sprinklers, including hot air oven, test rack for subjecting fusible soldered joints to long time tests under various loads, and other specially designed measuring apparatus.

General chemical laboratory with special equipment for testing cotton rubber-lined and unlined linen hose, including physical and chemical tests of the rubber.

6. *Unusual equipment or facilities:*

Certain specially designed pieces of equipment used in tests of automatic sprinklers and an unusually large meter nozzle for measuring water under pressure with a high degree of accuracy.

7. *Possibility for work for or by outside persons, and charges:*

Any manufacturer of fire protective equipment can submit devices for examination and test. The Factory Mutual Laboratories, however, reserve the right to decide what devices are of sufficient interest to warrant conducting the investigation, and for those which are selected no charges are made other than the cost of furnishing the apparatus and setting it up for test.

8. *Railroad station and siding:*

About one-half mile distant.

9. *Name and title of person in charge of laboratory:*

C. W. Mowry, director.

10. *Number of persons on regular staff:*

Eleven.

11. *Brief general description:*

The Factory Mutual Laboratories are located at 184 High Street, Boston, Massachusetts, and a hydraulic testing station is maintained at Lowell, Massachusetts, on the property of The Proprietors of the Locks and Canals on the Merrimack River. Both are a part of the Inspection Department of the Associated Factory Mutual Fire Insurance Companies, which were organized more than eighty-

five years ago by prominent manufacturers in New England for the purpose of lessening their fire losses and providing insurance at actual cost. They confine their business mostly to the larger manufacturing properties and seek to improve the construction of manufacturing buildings, safeguard hazardous processes and constantly to improve the standards of fire protection.

12. *Research or other work of unusual importance which has been done.*
The first conspicuous work of the Factory Mutual Laboratories were the experiments of John R. Freeman relating to the hydraulics of fire streams. The results of the tests made in 1889 are still used as a standard for the friction loss through fire hose and for the discharge and range of fire streams.
Another important work was the development of specifications for hose, valves, hydrants, fire doors, elevated tanks and towers, and other devices used in fire protection work. Important work in recent years has been the design and adaptation of the double fire service check valve for use in safeguarding public water supplies when connected to manufacturing systems, conducting fire tests of building columns in co-operation with the United States Bureau of Standards and the Underwriters Laboratories; and a continual spray system for the protection of large piles of pulp wood as a means of reducing the fire hazard, lessening the amount of rotting, and possibly improving the quality of the pulp.

Information furnished by C. W. Mowry, Director.

* * *

BROOKLYN POLYTECHNIC INSTITUTE

1. Brooklyn Polytechnic Institute, Hydraulic Laboratory, 99 Livingston Street, Brooklyn, New York.

2. First small laboratory installed about 1900. Present laboratory installed 1918-1919. First used January, 1920.

3. *Kinds of work for which laboratory is especially fitted:*
Primarily, for undergraduate laboratory instruction with certain portions of the apparatus so installed as to be used in connection with lectures in the course in "Theoretical Hydraulics"; secondarily, the laboratory may be used for commercial testing or for research investigation.

4. *Head and quantity of water available for tests:*
By pumping,
650 gallons per minute against 60-foot head,
250 gallons per minute against 200-foot head.

5. *Principal pieces of equipment:*
Single-stage, motor-driven, centrifugal pump, rated at 650 gallons

per minute against total dynamic head of 70 feet.
Two-stage, motor-driven turbine pump rated at 250 gallons per minute, against total dynamic head of 250 feet.

6 x 4 x 6-inch duplex steam pump.
8 x 5 x 8-inch duplex steam pump.
12-inch Doble impulse wheel.
2-inch Foster hydraulic ram.
6-inch reaction turbine.
4-inch x 2-inch Venturi meter.
2-inch Worthington meter.
Small water meters.
Two steel weir tanks 4 x 3 x 24 feet with interchangeable weir plates.
Steel pressure tank 5 x 22 feet, equipped with orifice devices for testing nozzles, orifices tubes, etc.

This tank is provided with ten overflow weirs for maintaining constant head on various pieces of apparatus. The overflow weirs are 10 feet in length. They have served their purpose quite well and it is possible to maintain constant head without hand-operation of valves.
Two calibrated steel volumetric measuring tanks of 1600 gallons capacity each, provided with quick acting outlet gates and so arranged as to make possible long continuous runs at the maximum possible rate of pumping. Numerous pipe lines of various sizes for undergraduate experimental work on losses of head in friction, valves, hydraulic gradient, etc. Miscellaneous small equipment such as gages, manometers, Pitot tubes, and current meters.
The principal piping of the laboratory is 6 inches, 4 inches and 8 inches in diameter and is arranged so that the various pumping units and water from the city mains may be applied to different experiments by independent routes. Any portion of the apparatus can be connected to the pressure-regulating tank. Water may be measured either by means of the calibrated measuring tanks or over weirs or by means of Venturi meter.

6. *Unusual equipment or facilities:*—None.

7. Numerous outlets from the piping system have been provided for the attachment of apparatus other than that now installed. Pumps may be tested up to 15-horse-power-motor size, speeds, 825 to 1650 revolutions per minute. No definite schedule of terms, but can be arranged by the professor in charge of the laboratory.

8. *Railroad station or siding:*
The laboratory is situated in the business district of Brooklyn, about one-half mile from Long Island Railroad freight station.

9. *Name and title of person in charge of laboratory:*
H. P. Hammond, Professor of Sanitary and Hydraulic Engineering.

10. *Number of persons on regular staff:*
Two; also competent mechanics available for work in laboratory when needed.

11. *Brief general description of laboratory:*
Water is taken from the city mains through a 2-inch meter. It is stored in concrete reservoir below the laboratory floor level. The reservoir has a capacity of approximately 10,000 gallons and a surface area of approximately 240 square feet. Water is taken from the storage reservoir by any one of the pumps and delivered through the piping system to any desired piece of apparatus. The piping system is arranged in duplicate so that the water may be delivered to any portion of the laboratory from either of the two centrifugal pumps or from the steam pumps. The pressure-regulating tank may be connected into the system or cut out as desired. When connected into the system, it is possible to maintain constant head up to heads of approximately 25 feet. For higher head an air cushion may be formed in the top of the tank and pressure regulation procured, though not quite so satisfactorily as for lower heads. An important feature of the laboratory is the lecture demonstration apparatus located in the class-room on the floor above the laboratory. Here are provided, or to be provided, equipment for illustrating flow from orifices, tubes, nozzles, and pipes; the flow over weirs, the use of the Pitot tube, and other hydraulic phenomena.

12. *Research:* None to date.

Information furnished by H. P. Hammond, Professor of Sanitary and Hydraulic Engineering.

* * *

BROWN UNIVERSITY

1. Brown University, Division of Engineering, Providence, Rhode Island.
2. Established, 1903.
3. *Kinds of work for which laboratory is especially fitted:*
Equipped to do miscellaneous demonstration and testing work.
4. *Head and quantity of water available for tests:*
By gravity, 50 gallons per minute. By means of pumps, up to 1,000 gallons per minute, the head in the latter case being 150 pounds.
5. *Principal pieces of equipment:*
Standard forms of impulse and reaction wheels, weir box, standard nozzles, Venturi meters (6 inches, 3 inches, and 2 inches) and the usual auxiliary measuring apparatus.
6. *Unusual equipment or facilities:*
None.

7. *Possibilities for work, for or by outside persons or companies and terms therefor:*
   It is the practice to aid persons or companies outside the University; to charge for the services of the assistants, but not for the use of apparatus.

8. *Railroad station or siding:*
   About one-half mile from the railroad station.

9. *Name and title of person in charge of laboratory:*
   William H. Kenerson, Professor of Mechanical Engineering.

10. *Number of persons on regular staff:*
    From three to five persons.

11. *Brief general description:*
    Location of equipment is such that apparatus may easily be temporarily installed in our laboratory where ample space is available.

12. *Research or other work of unusual importance which has been done:*
    From time to time we have made commercial tests of various types of pumps, friction of the flow of oil and water through pipes and channels, special investigations for the Providence Water Supply Board to determine discharge of water over special weirs, and similar investigations.

Information furnished by William H. Kenerson, Professor of Mechanical Engineering.

* * *

BUREAU OF STANDARDS

1. Bureau of Standards, Department of Commerce, Washington, District of Columbia.

2. Established, 1915.

3. Facilities for hydraulic work are limited to a laboratory, operated by the Division of Engineering Physics, for the calibration of water current meters by towing tests in still water. This laboratory was installed on the Bureau grounds for this especial purpose.

5 and 11. The laboratory is a housed-in re-inforced concrete flume 400 feet long, 6 feet wide, with a water depth of 6½ feet. The instruments are suspended from an electrically-driven car spanning the flume. The speed range is from about 0.2 foot to 15 feet per second. The speed regulation is within 2 per cent for velocities above three-quarters of a foot per second.

7. Current meter calibrations and such other tests as the facilities of the laboratory permit are regularly made for individuals or companies outside the government service for nominal fees.

Information furnished by Dr. L. J. Briggs, Chief, Engineering Physics Division.

CALIFORNIA INSTITUTE OF TECHNOLOGY

1. California Institute of Technology, Hydraulic Laboratory, Pasadena, California. (Formerly Throop College of Technology)

2. Established, about 1911.

3. *Kinds of work for which laboratory is especially fitted:*
   Undergraduate instruction, though some research is possible in connection with turbines, pumps, and flow through devices of modest size.

4. *Head and quantity of water available for tests:*
   No gravity flow is available, but a small flow at a pressure of about 150 feet can be had with either a steam pump, or a motor-driven reciprocating pump. A flow of about 3 cubic feet per second can be had at a head of about 30 feet from a motor-driven centrifugal pump. 15,000-gallon storage cistern.

5. *Principal pieces of equipment:*
   No. 6 American centrifugal pump.
   Fairbanks-Morse duplex power pump, 5 x 10 inches.
   Marsh steam pump, high pressure, 10 x 8 x 12 inches.
   Scales and weighing tanks.
   6,000-gallon measuring cistern.
   800-gallon roof tank.
   600-gallon steel pressure tank for heads up to 300 feet.
   400-gallon steel nozzle tank.
   Cement channel 50 feet long, for weirs, etc.
   Francis inward-flow turbine.
   Doble impulse wheel, glass casing.
   2-stage centrifugal pump.
   Hydraulic ram.
   8-inch Venturi meter.

6. *Unusual equipment or facilities:*
   None.

7. Glad to co-operate with others in any worth while investigations and would do so at near the actual cost.

8. *Railroad station or siding:*
   About one mile from railroad

9. *Name and title of person in charge of laboratory:*
   R. L. Daugherty, Professor of Mechanical and Hydraulic Engineering.

10. *Number of persons on regular staff:*
    About three.

11. *Brief general description:*
Elaborate and flexible installation of pumps, tanks, piping, channels, gages, meters. Laboratory is crowded for space, but water from any one of the three pumps can be delivered to tanks or piping or open channel so that a number of combinations are possible.

12. Some Research is being done on centrifugal pumps and also upon turbine draft tubes.

Information furnished by R. L. Daugherty, Professor of Mechanical and Hydraulic Engineering.

* * *

UNIVERSITY OF CALIFORNIA

1. California, University of, Hydraulic Laboratory, Berkeley, California.

2. Established, 1902 by Professor J. N. Le Conte.

3. *Kinds of work for which laboratory is best fitted:*
Teaching engineering students the practical applications of the laws of hydraulics;
Testing of small units of hydraulic machinery, such as pumps of all kinds, and small water motors;
Calibration of hydraulic instruments, except current meters.

4. *Head and quantity of water available for tests:*
By gravity,
About 150 gallons per minute at 40-foot head.
By pumping,
Up to 3600 gallons per minute under a 40-foot head.
There are two 5-inch triple-stage centrifugal pumps which may be operated either in series or in parallel, giving a maximum head of 340 feet and delivering 150 gallons per minute.

5. *Principal pieces of equipment:*
Triplex plunger pump 4 x 6 inches, 100 gallons per minute, 500-foot head.
Double-runner Pelton water wheel, pitch diameter 27 inches, head can be made from zero to 300 feet; used to test different styles of runners and buckets, to determine the most efficient nozzle for given buckets and the windage and friction losses.
Two triple-stage pumps, 5-inch discharge, 300 gallons per minute, 300-foot head; used for all high-pressure work.
Centrifugal pump, 5-inch discharge, 1000 gallons per minute, 40-foot head.
Francis turbine, low head, 5-horsepower, 800 revolutions per minute, 3 second-feet, 30-foot head.
4-horsepower Francis turbine equipped with wicket gates and de-

signed to operate under 25-foot head, 1.8 second-feet and 425 revolutions per minute.
4-inch jet pump.
3-inch hydraulic ram.
Collins pitometer.
Two standard pitometers.
Byron Jackson deep well turbine pump.
Six meters of various sizes and types.
Large Pelton water wheel, 30-inch pitch diameter, equipped with needle nozzle; used for efficiency tests.
Two concrete weir boxes, 6 x 16 feet, crest 30 inches long.
Clemens Herschel weir, crest 2 feet, 9 cubic feet per second; used for investigation.
Four concrete tanks, below the floor level:

19 x 20	x 11	feet	4180	cubic	feet
19 x 10½	x 11	"	2200	"	"
11 x 7	x 11	"	850	"	"
7 x 7	x 11	"	540	"	"

Standpipe 4 feet diameter, 40 feet high; so equipped with overflow valves that almost any head under 40 feet can be accurately maintained constantly.
Four low-lift centrifugal pumps; used for weir calibration, meter calibration, etc.
2-stage Pelton centrifugal pump, 5-inch discharge, 500 gallons per minute, 250-foot head, 1650 revolutions per minute; equipped to be tested with and without Kingsbury thrust bearing.
Single-stage DeLaval centrifugal pump, 8-inch discharge, 1800 gallons per minute, 40-foot head, 1720 revolutions per minute; of the most modern design.

6. *Unusual equipment or facilities:*

A Sprague electric dynamometer, which may be used as a generator up to 50 horsepower, and up to 30 horsepower as a motor, over ranges of speed 0 to 2000 revolutions per minute.

7. *Possibilities for work for or by outside persons or companies and terms therefor:*

Normally work by outside companies is not permitted, and commercial testing is done under the supervision of the University instructors only when it cannot be done elsewhere, and then the approval of the President of the University, as well as the Dean of the Department, must be secured. When such work is undertaken the company desiring the test pays for time of the men who are employed to do the testing.

8. *Railroad station or siding:*

About 1½ miles from nearest freight station.

9. *Name and title of person in charge of laboratory:*
Blake R. Vanleer, Assistant Professor in Mechanical Engineering.

10. *Number of persons on regular staff:*
One.

11. *Brief general description:*
The laboratory is situated in the Mechanical Engineering Building, in a court 100 x 63 feet, covered with a glass roof. The west end of the court is excavated over an area of 40 x 20 feet to a depth of 12 feet, and divided by reinforced concrete walls into tanks of various sizes. These tanks are all floored over and a 5-inch centrifugal pump transfers water from any tank to another.
A 12-inch main suction pipe line extends to the extreme eastern end of the laboratory and there supplies the main pressure pumps. One of these is a six-stage centrifugal direct-connected to a 50-horsepower, 4000-volt motor, by which there can be supplied about ¾ second-foot under 350-foot head. This is distributed to a manifold, and feeds three impulse water wheels fitted with Prony brakes, a special nozzle-testing device for calibrating nozzles or orifices of small size, and any other apparatus needing such pressure.
There is also a 6-inch connection to the standpipe. The six-stage pump is so arranged that three stages can be put in parallel with the other three, giving half the head and twice the quantity.
The 4-foot diameter standpipe, 40 feet high, supplies water for low pressures. It is normally supplied by a 5-inch direct-connected centrifugal unit, and overflows at several levels, the excess being by-passed. A mercury column shows the location of the water level and overflow gates so that head can be held constant.
A third manifold is fed by city water pressure. From these are fed various water meters, large and small, a 4-inch Venturi meter, a jet pump or hydraulic elevator, a 6-inch Victor turbine fitted with Prony brake. The discharge from these is measured by tanks, large platform scales, or calibrated weirs.
Two main weir boxes are installed, each with a 30-inch rectangular, fully contracted weir, though any other smaller form can be bolted in place. The 10-inch pipes to these weir boxes are used for Pitot tubes and pitometer traverses.

12. *Research or other work of unusual importance which has been done:*
An investigation of the Herschel Type of Improved weir, by R. H. Morris and A. J. R. Houston.
A study of the Phenomenon of Water Hammer, by Blake R. Vanleer.
Relative comparison of Type E. Pelton Water Wheels, by E. P. Condon, A. H. Gale, T. L. Nudd, and A. J. Swank.
Design, Construction and Calibration of a Proportional Flow Weir, by Howard T. Livingstone.

An Investigation of the Measurement of the Flow of Water by the Cooling Effect on an Electrically Heated Wire, by L. M. K. Boelter and R. E. Meyer.

Rating and Investigation of a Portable Weir, by G. E. Troxell.

Determination of the Coefficients of Discharge for Small Circular Sharp Edged Orifices where the Contraction is not Complete, by K. K. Guha.

Measurement of Water Discharged from a Short Horizontal Pipe, by Ejner Smith and C. A. Pollard.

An Investigation of the Hydraulic Losses through Globe Valves, by L. P. Murray, and L. A. Ashley.

Discharge from Horizontal Pipes, by H. K. Baisley and G. A. Atchison.

An Advanced Study of the Herschel Weir, by L. A. Ashley, C. F. Madsen and L. P. Murray.

Investigation of a Small Francis Turbine, by C. C. Ashley, and L. H. Parker.

Information furnished by Blake R. Vanleer, Assistant Professtor of Mechanical Engineering.

* * *

CARNEGIE INSTITUTE OF TECHNOLOGY

1. Carnegie Institute of Technology, Hydraulic Laboratory, College of Engineering, Pittsburgh, Pennsylvania.

2. Established, 1913.

3. *Kinds of work for which laboratory is especially fitted:*
   No unusual equipment or facilities; equipment designed for standard undergraduate course.

4. *Head and quantity of water available for tests:*
   By gravity,
   City water supply—100 feet head.
   By pumping:
   500 gallons per minute at 200 feet head
   1500 gallons per minute at 40 feet head
   750 gallons per minute at 40 feet head
   500 gallons per minute at 100 feet head

5. *Principal pieces of equipment or facilities:*
   Gould triplex pump, 500 gallons per minute at 100 feet head.
   Wilson-Snyder centrifugal pump, 500 gallons per minute at 200 feet head.
   Jeannesville centrifugal pump, 750 gallons per minute at 40 feet head.
   Allis-Chalmers centrifugal pump, 1500 gallons per minute at 40 feet head.

1-inch Venturi meter, 2-inch line.
1-inch fire nozzle.
12-inch Pelton-Doble water wheel.
6-inch Francis reaction turbine.
Triangular, trapezoidal and rectangular weirs (12-inch width)
Rife hydraulic ram.
15,000-gallon storage tank.
Pressure tank with various types of 1-inch orifices.
1-inch, 2-inch, 3-inch, 4-inch, 6-inch and 8-inch pipe lines, each about 30 feet long, for study of friction losses.
Ells for study of friction losses.
Cole pitotmeter.
Motors to operate pumps.
Weighing tanks, scales, gages and the usual accessory equipment.

6. *Unusual equipment or facilities.*—None.

7. Commercial testing and research for and by outside companies encouraged.
Charges for use of equipment for commercial testing ¼ of one per cent. of valuation per day. Charges for power 3 cents per kilowatt hour. For personal services, terms as arranged.

8. *Railroad station and siding:*
One mile from Shadyside Station, Pennsylvania Railroad and adjoining U. S. Bureau of Mines siding, Baltimore & Ohio Railroad.

9. *Name and title of person in charge:*
F. A. Simmons, Assistant Professor, Department of Civil Engineering.

10. *Number of persons on regular staff:*
Two in laboratory.

11. *Brief general description:*
Main laboratory is 35 feet x 60 feet; shed for storage tank is 20 feet x 20 feet.

12. *Research or other work of unusual importance which has been done:*
None.

Information furnished by William E. Mott, Director, College of Engineering.

CASE SCHOOL OF APPLIED SCIENCE

1. Case School of Applied Science, Hydraulic Laboratory, Cleveland, Ohio.
2. Established, 1892.
3. *Kinds of work for which laboratory is especially fitted:*
   Principally for instruction. Calibration of small meters, automobile radiators, and other apparatus has been conducted.
4. *Head and quantity of water available for tests:*
   By pumping,
   900 gallons per minute against 300 feet head.
5. *Principal pieces of equipment:*
   Usual equipment of calibrated tanks, weirs and orifices.
   Orifices up to 2-inch diameter. Rectangular weirs up to 15 inches wide.
6. *Unusual equipment or facilities.*—None.
7. Work within the capacity of the laboratory will be conducted for outside persons by the staff. No charge is fixed; depends on time required.
8. *Railroad station and siding:*
   Three miles distant.
9. *Name and title of person in charge of laboratory:*
   R. H. Danforth, Professor in Charge of Materials Testing Laboratory.
10. *Number of persons on regular staff:*
    Four.

Information furnished by R. H. Danforth, Professsor in Charge.

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COCHRANE METER TESTING LABORATORY

1. Cochrane Meter Testing Laboratory, Harrison Safety Boiler Works—Cochrane Corporation, 17th St. and Allegheny Ave., Philadelphia, Pennsylvania.
2. Established, 1914.
3. *Kinds of work for which laboratory is especially fitted:*
   Testing any type of flow meter with water, as for example, V-notch weirs, orifices, Venturi meters, Pitot tubes.
4. *Head and quantity of water available for tests:*
   By pumping,

Over 20 feet head, of which about 10 feet can be utilized in a metering device.

5. *Principal pieces of equipment:*
Sump tank, motor-driven centrifugal pump, constant-head tank, standardized V-notch tank and two calibrated measuring tanks mounted just above the sump tank, together with suitable valves, hook-gages, etc. The maximum rate of flow which can be handled is about 120 cubic feet per minute. The precision obtained with the standardized V-notch weir is about 1-3 of 1 per cent plus or minus, that is the rate of flow can be held indefinitely within these limits. Accuracy of calibrated measuring tank is within 1-10 of 1 per cent.

6. *Unusual equipment or facilities:*
The unusual nature of the equipment relates to the facilities offered for carrying out tests rapidly, through the use of the standardized V-notch meter, that is in order to rate a meter under test it is necessary only to establish steady flow conditions and then read the gages.

7. This equipment has not been used by outside parties, but is available for such use provided the purpose of the work is not in competition with the business of the H. S. B. W.-Cochrane Corporation.

8. *Railroad station or siding:*
Close to a railroad siding.

9. *Name and title of person in charge of laboratory:*
Percy S. Lyon.

10. *Number of persons on regular staff:*
Four persons engaged on and off in meter testing and experiments.

Information furnished by George H. Gibson.

* * *

COLORADO COLLEGE

1. Colorado College, Hydraulic Laboratory, Colorado Springs, Colorado.

2. Established, 1915.

3. *Kinds of work for which laboratory is especially fitted:*
Weir calibration, flow through short tubes, calibration of service meters, flow through orifices, determination of coefficient of friction in pipes, (this refers to pipes up to 1½ inches in diameter); experimental work on the Venturimeter, the hydraulic ram, 2-inch centrifugal pump, and 12-inch Doble water wheel.

4. *Head and quantity of water available for tests:*
Supply pipe to laboratory is 3 inches in diameter, static pressure 60 to 65 pounds; no way of boosting the pressure by pumping.

5. *Principal pieces of equipment:*
   Weir tank of about 500 gallons capacity,
   3-inch Venturi meter,
   2-inch centrifugal pump,
   12-inch Doble laboratory impulse wheel,
   Hydraulic ram with a 2-inch lead pipe and a 1-inch discharge,
   Apparatus for testing flow through short tubes and orifices,
   Several types of small service water meters,
   Weighing tanks and scales.

6. *Unusual equipment or facilities.*—None.

7. No work has ever been done for persons or companies.

8. *Railroad station and siding:*
   About a mile and a half distant.

9. *Name and title of person in charge of laboratory:*
   Frank M. Okey, Professor of Civil Engineering.

10. *Number of persons on regular staff:*
    No other individual on the staff.

11. *Brief general description:*
    Equipment is meager and quarters cramped. Floor space is only about 2500 square feet, but arrangement of apparatus makes it possible to carry on a relatively complete set of hydraulic experiments.

12. *Research or other work of unusual importance which has been done:*
    None.

Information supplied by Frank M. Okey, Professor of Civil Engineering.

* * *

COLORADO EXPERIMENT STATION

1. Colorado Experiment Station, Fort Collins, Colorado.

2. Established, 1913.

3. *Kinds of work for which laboratory is especially fitted:*
   Irrigation investigations, calibrations, especially testing practical low head meters, irrigation outlets and similar devices.

4. *Head and quantity of water available for tests:*
   Limited quantity from city mains; storage reservoir on hill of 236,400 gallons capacity. Head available, on weirs 3 feet, on special devices, approximately 10 feet.
   Water is pumped from an auxiliary reservoir receiving waste to supply reservoir and is used repeatedly.

5. *Principal pieces of equipment:*
   Weir box 20 feet long, 10 feet wide, 6 feet deep.
   Two calibration tanks 23.5 x 27 feet and one 27 x 55 feet, all 8.5 feet deep.
   Auxiliary reservoir for waste water, 26 x 26 x 8.5 feet.
   Large and small centrifugal pumps;
   Hook-gages, standard weirs, orifices and other devices.
   Fully equipped current-meter rating station, also circular station.

6. *Unusual equipment or facilities:*
   Channel 3½ x 5 feet, 210 feet long, carrying flow of 15 second-feet at level of station floor.

7. No set policy, as to work for outside persons. Testing and calibration has been done for private individuals. Assistance and encouragement has been given outside persons or companies who wished to develop principles or devices directly appurtenant to irrigation activities. Minor investigations done without charge.

8. *Railroad station or siding:*
   One-quarter mile from College Station on Colorado and Southern Railway.

9. *Name and title of person in charge of laboratory:*
   Ralph L. Parshall, Senior Irrigation Engineer, U. S. Department of Agriculture.

10. *Number of Persons on Regular Staff:*
    Three.

11. *Brief general description:*
    Brick building 40 x 70 feet, one story.

12. *Research or other work of unusual importance which has been done:*
    Detail investigations on weirs and orifices for standard calibration. Various devices of original design have been tested. Original investigations on the Venturi flume.

Information furnished by R. L. Parshall, Irrigation Engineer.

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COLUMBIA UNIVERSITY

1. Columbia University, Worthington Hydraulic Laboratory of the Department of Mechanical Engineering, New York City.

2. Established, 1899.

3. *Kinds of work for which laboratory is especially fitted:*
   Experimental research work on and tests of pumps and small turbines; calibration of nozzle, orifices and various forms of water metering devices.

4. *Head and quantity of water available for tests:*

By pumping,
1 cubic foot per second at head of 25 feet,
500 gallons per minute at head of 300 feet,
1000 gallons per minute at head of 100 feet,
50 gallons per minute at head of 3000 feet.

5. *Principal pieces of equipment:*

Pumps

Worthington triple-expansion duplex pump; 500 gallons per minute, 25 feet head.
Worthington duplex boiler feed pump, 100 gallons per minute, 250 feet head.
Goulds triplex motor-driven pump, 80 gallons per minute, 150 feet head.
Worthington motor-driven centrifugal pump, single-stage, 500 gallons per minute, 100 feet head.
Worthington motor-driven centrifugal pump, 3-stage, 500 gallons per minute, 300 feet head.
Worthington high-pressure duplex pump, 50 gallons per minute, 2000 pounds per square inch head.
Cameron motor-driven, single-stage centrifugal pump, 50 gallons per minute, 100 feet head.

Measuring Devices

Two 20,000-pound steel measuring tanks, arranged with quick opening discharge valves and swing bucket for directing water to other tank so as to take care of continuous flow.

8 x 4 -inch Venturi meter.
3 x 1½-inch Venturi meter.

Calibrated nozzles from ¼ inch to 2 inches in diameter.
Large tank fitted with still well and hook gage and equipped with weirs of various widths.
Numerous small tanks and scales; Pitot tubes and pitometers.

Special Apparatus

For measuring loss in head through straight pipes; for measuring loss in head due to change in pipe sizes; for calibrating orifices and nozzles.

6. *Unusual equipment or facilities:*

Sprague electric dynamometer suitably arranged to act as a brake for turbine tests, or as a driving unit for pump tests, by means of which the input may be accurately measured.
Being situated in close proximity to the steam, air and gas power laboratories, the equipment of these becomes available for use in the hydraulic laboratory. In connection with the former is a fairly complete machine shop.

7. Arrangements may be made for research work to be conducted by the laboratory staff, or use made of the equipment by outside parties. Charges are of two classes: those for use of equipment only and those for personal services, the latter including time spent on opinions rendered. No fixed terms can be given, due to the wide variety of the requirements, the rate depending upon the amount of equipment and time involved.

8. *Railroad station and siding:*

   One and one-half to five miles, depending upon the railroad.

9. *Name and title of person in charge:*

   Edward D. Thurston, Jr., Assistant Professor of Mechanical Engineering.

10. *Number of persons on regular staff:*

    Two men are regularly assigned to the hydraulic laboratory, but the services of the entire mechanical engineering department are available.

11. *Brief general description:*

    The hydraulic laboratory covers a space of 80 x 35 feet and is 20 feet high. Beneath the two large measuring tanks is a pit from which the pumps normally take their suction and into which the water from all is discharged. If necessary, suction can also be taken from a 3-inch city water main running the length of the laboratory, on which the pressure is around 50 pounds. The pumps are located on the main floor and the piping is so arranged that they may discharge independently or into a common header. This latter is connected with an accumulator for steadying the flow. Over a portion of the laboratory is a second floor, on which are placed the weir tanks and most of the special apparatus.

12. *Research or other work of unusual importance which has been done:*

    Investigation on centrifugal and rotary pumps has been done for various individuals and upon hydraulic rams for the Power Specialty Company and the Rife Engine Company.

    Research on "Flow through weir notches with thin edges and full contractions," by V. M. Cone, Irrigation Engineer, Office of Public Roads and Rural Engineering.

Information furnished by Edward D. Thurston, Jr., Assistant Professor of Mechanical Engineering.

CORNELL UNIVERSITY

1. Cornell University, Hydraulic Laboratory of College of Engineering, Ithaca, New York.

2. Established, 1898.

3. *Kinds of work for which laboratory is especially fitted:*
   For determining flow of water in pipes and over all forms of weirs; testing small turbines, water meters, Venturi meters, Pitot tubes, current meters, nozzles and orifices. Also well equipped for general investigations in hydraulics.

4. *Head and quantity of water available for tests:*
   By gravity,
   From Beebe Lake 80 feet head and up to 1000 cubic feet per second during spring and fall flow; 400 cubic feet per second for short periods any time of year; from University reservoir 200 feet head for small quantities.

5. *Principal pieces of equipment:*
   Usual equipment for ordinary laboratory experiments.
   One 9-inch Victor turbine, one 12-inch and one 24-inch Pelton-Doble water wheel, one multi-stage centrifugal pump, several hydraulic rams, and special apparatus for testing water meters.

6. *Unusual equipment or facilities:*
   Laboratory and canals supplied by gravity for all experimental work. Volumes up to 400 cubic feet per second, for short intervals of time, are available any time of year; double this quantity may be had during spring and fall flow.

7. Commercial work falling within our facilities will be undertaken and carried to completion by experienced engineers; terms given upon application.

8. *Railroad station or siding:*
   One-half mile from East Ithaca Station of Lehigh Valley Railroad.

9. *Name and title of person in charge of laboratory:*
   Under the jurisdiction of the Dean of the College.
   Dr. E. W. Schoder, Professor of Theoretical and Experimental Hydraulics, has been in direct charge since September, 1904.

10. *Number of persons on regular staff:*
    Two. Any commercial work requiring more than the regular staff can readily be handled.

11. *Brief general description:*
    The unique location and construction of this laboratory render practicable investigations requiring a steady gravity water supply for long periods using relatively large flows of water. The water

supply is obtained from Fall Creek with a watershed of 126 square miles. Beebe Lake, a pond of about 20 acres, has been formed by the construction of a concrete dam 26 feet high, with a spillway crest length of 130.5 feet. At one end of the dam there is an additional flood spillway 141.5 feet long. A rectangular canal 420 feet long and 16 feet wide is supplied from Beebe Lake through six headgates for controlling the flow. The upper portion of the canal is 17.7 feet deep and the lower portion is 10 feet deep. In this canal are two sharp-crested weirs 16 feet long, over which discharges as large as 400 cubic feet a second may be passed.

The lower portion of the 16-foot canal, 350 feet long between weirs, is used for measurements with floats and current meters. Models of dams may be built in the canal and the flow over them investigated with precision. An electrically-operated car spans this canal and is used for rating current meters and Pitot tubes and for experiments that require means for towing floating or submerged objects through still or running water at various speeds. By means of a gear system the speed of the cable, which moves the car, may be varied through a range from ¼ foot to 12 feet a second.

Out-door work is usually suspended from December 1 to April 1 because of the freezing weather.

The laboratory is built against the south cliff of Fall Creek gorge and extends vertically about 70 feet, from the pool below Triphammer Falls to the top of the gorge. A short branch canal 6 feet wide is housed by the upper portion of the laboratory building and may be supplied directly from Beebe Lake by means of a 48-inch cast iron pipe line with a short 30-inch branch at its lower end. A 30-inch valve controls the flow from the 48-inch pipe into the 6-foot canal. The 6-foot canal discharges either to waste into the pool below Triphammer Falls (a sheer drop of 60 feet), or into the upper end of a steel stand-pipe 6 feet in diameter and 60 feet high. A suitable mechanism causes an instantaneous diversion of discharges as large as 60 cubic feet a second from the waste flume into the standpipe or vice versa. The 6-foot standpipe is provided at the bottom with a 36-inch discharge valve operated by hydraulic pressure. There is a float gage indicating accurately the height of the water surface in the standpipe, when used as a measuring tank. An independent 10-inch pipe line from the 30-inch pipe to the bottom of the laboratory supplies most of the pieces of apparatus used for class work and research. The 6-foot standpipe also may be used as a supply tank, water being supplied to it from either the 6-foot canal or the 10-inch pipe line.

In the laboratory building there is also a concrete flume 2 feet wide, 4 feet deep and 25 feet long. Flows up to 11 cubic feet a second can be passed through this and measured volumetrically. The flume is arranged conveniently for experiments on small weirs, low-head orifices, and other apparatus.

12. *Research, or other work of unusual importance which has been done:*
Among these may be mentioned the results obtained for the Board of Engineers on Deep Waterways, the Michigan-Lake Superior Power Company, the City of New York in connection with its water supply, the U. S. Geological Survey, and the Bureau of Public Roads and Rural Engineering of the U. S. Department of Agriculture.

Information furnished by F. A. Barnes, Director, School of Civil Engineering, Cornell University.

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DARTMOUTH COLLEGE

1. Dartmouth College, Thayer School of Civil Engineering, Hanover, New Hampshire.

The hydraulic laboratory of the Thayer School is used to elucidate the theoretical course and is confined to class work.

Information furnished by Charles A. Holden, Director, Professor of Civil Engineering.

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HARVARD ENGINEERING SCHOOL

1. Harvard Engineering School, Gordon McKay Engineering Laboratory, 50 Oxford Street, Cambridge, Massachusetts.

2. Established, 1919. This was the date of the reestablishment of the Engineering School after the Technology cooperation terminated. There has been a hydraulic laboratory since 1890.

3. *Kinds of work for which laboratory is especially fitted:*
Testing centrifugal pumps, orifices, nozzles, meters and small weirs.

4. *Head and quantity of water available for tests:*
By pumping,
1100 gallons per minute at 230 feet head.

5. *Principal pieces of equipment:*
A weir with channel 21 feet long, 6 feet wide, and 4 feet deep.
A pressure tank 20 feet high and 5 feet in diameter.
Two tanks which will weigh accurately 1200 gallons per minute, each of 5000 pounds capacity.
A storage tank 6 feet deep, 5 feet wide, and 40 feet long, carefully constructed, which can be used for volumetric measurement with a high degree of accuracy.

6. *Unusual equipment or facilities:*
Three Sprague electric dynamometers for driving or absorbing power—0 to 200 horsepower. Apparatus can be delivered by motor truck alongside the hydraulic testing plant.

7. Members of the teaching staff may do work for outside persons or companies to such an amount as will not interfere with their other duties. They make their own terms for services of helpers.

8. *Railroad station and siding:*
   About half a mile distant.

9. *Name and title of person in charge of laboratory:*
   Dean H. J. Hughes.

10. *Number of persons on regular staff:*
    Usually four.

11. *Brief general description:*
    The hydraulic laboratory is a compact group of apparatus placed in the Gordon McKay Laboratory, a building 100 feet wide by 300 feet long, which contains steam, gas, electric, refrigerating and air-reduction machinery, and materials-testing apparatus.

Information furnished by H. J. Hughes, Dean, Harvard Engineering School.

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HOLYOKE WATER POWER COMPANY

1. Holyoke Testing Flume, Holyoke, Massachusetts.

2. Established, 1882.

3. *Kinds of work for which laboratory is especially fitted:*
   Tests of hydraulic turbines.

4. *Head and quantity of water available for tests:*
   Head 11 to 18 feet; capacity 230 cubic feet per second; supplied by gravity only.

5. *Principal pieces of equipment:*
   Standard Francis weir, Prony brakes, electric signal clock, hook gages, etc.

6. *Unusual equipment or facilities:*
   This whole laboratory is unique, as shown by the general description.

7. *Possibilities for work, for or by outside persons or companies and terms therefor:*
   Information about conditions and charges should be obtained from the company.

8. *Railroad station or siding:*
   Siding at the building.

9. *Name and title of person in charge:*
   Hydraulic Engineer of the Holyoke Water Power Company.

10. *Number of persons on regular staff:*

Hydraulic engineer and such assistants as are needed for any test undertaken.

11. *Brief general description:*

Testing flume is equipped for the testing, on a vertical shaft, of hydraulic turbines of any of the usual diameters and of any power up to 300 horsepower; (the pit is twenty feet square). Also for testing wheels of small and medium sizes, singly or in pairs, on horizontal shaft, under certain conditions, details of which with the price will be sent on application. Small wheels on vertical shaft, may be tested under any head up to 18 feet, larger sizes, under a head ranging from 11 to 14 feet.

The Holyoke Water Company controls the flow of the Connecticut River, at Holyoke, Massachusetts, on a fall of nearly 60 feet. Some of the developments are "permanent powers," held by the companies using them under indentures, and subject to annual rental, and the balance are "surplus powers," subject to withdrawal at short notice.

Surplus powers are paid for from day to day, and according to the amount used. In time of drought, if used after prohibition, the parties so using, are liable to a heavy penalty. Observations are taken giving the opening of the speed-gate of each wheel and the head acting upon it, once a day, and once during each night. These are carefully preserved and from them are computed the amounts discharged by each wheel and by each establishment, during the quarter year, and the "surplus power" thus shown to have been used is paid for at the end of the quarter. This system results in economy in the use of water, where otherwise there would be great wastefulness. For the purpose of making the necessary experiments on the wheels of tenants, before they are set in the mills, the Holyoke Water Power Company built a permanent testing flume. Over this testing flume is a substantial brick building containing repair shops, blacksmith shop, and oil room and offices. Wheels are tested here both for power and for quantity of water discharge. They are usually tested at five or six different openings of the speed-gate, ranging from wide open, to the opening at which the discharge is one-half that at full opening, and at six or eight different velocities of revolution at each gate-opening, making some 30 or 40 experiments in all on each wheel. The final result is, that for all practical purposes, the water-wheel has been converted into a water meter, and its discharge may be known under any of the conditions under which it is found in the mill. Besides this, its efficiency, or the value of the wheel as a water-motor, is also known.

The testing flume is suitable moreover to the making of hydraulic experiments, other than the efficiency tests of wheels, and is used

for such, from time to time. The underground portion consists in the main of the trunk, or penstock, bringing the water; a sort of vestibule, an antechamber; the wheel-pit; and the tail-race. The trunk is of boiler iron, about 9 feet in diameter. The vestibule contains the two head-gates, besides which there is a head-gate at the entry of the trunk into the canal whence it takes the water. A small trunk about 3 feet in diameter, takes water from this vestibule, independently of the gates and leads it to a turbine wheel, set in an iron casing, in the chamber, or pit, so that this wheel can run, even when the chamber is empty. This wheel discharges through the floor and is used to operate the repair shops; also to lift and lower the gates. The chamber has stop-planks on two sides for use in regulating the height of the water. At the down-stream end of this tail-race is the measuring weir, the crest being formed of a piece of planed wrought iron. It can be used with or without end contractions. The depth of water on the weir is measured in cylinders set in recesses, fashioned into the sides of the tail-race. These recesses are water-tight, and the observer is thus enabled to stand with the water-level about breast-high, or at convenient hight for accurate observation. The methods of measuring water over this weir are those described in "Lowell Hydraulic Experiments," by James B. Francis. In a well hole is set up a glass tube which measures the head of water upon the wheel. It is connected with the pit or the chamber, by means of pipes running through a cast-iron pipe, built into the masonry dam which forms the down-stream end of the wheelpit. The power is weighed by a Prony brake. To enable the observer at the brake wheel, the one at the head gage, and the one at the measuring weir to take simultaneous observations, an electric clock is set up in the testing flume, which rings three bells simultaneously at intervals of one minute, or of half a minute if desired.

The front of the wall forming the downstream side of the pit is barely damp with 20 feet head of water upon it. The floor of the pit is built so tight that an exact measurement of the leakage of the wheel-gate could be made, if desired. An approximate estimate is readily made by filling the pit before the tail-race is allowed to fill, and apportioning the total measured leakage, between the leakage of the wheel-gate, and that of the flume.

Four waste-pipes from vestibule, ante-chamber, tail-race, and pit help regulate the hight of water in the ante-chamber and pit, during tests under low heads, and enable the tail-race to be emptied to within 3 inches of the bottom.

12. *Research or other work of unusual importance which has been done:*

Experiments for development of the Venturi meter.

The discharge of water through orifices.

Experiments on the trapzoidal weir.

Experiments on a fall increaser.
Tests of motor driven deep well pumps.
Experiments to establish a discharge chart for Holyoke Dam.

Information furnished by A. F. Sickman, Hydraulic Engineer.

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HORTON HYDROLOGICAL LABORATORY

1. Horton Hydrological Laboratory, Voorheesville, New York.

2. Established, 1915.

3. *Kinds of work for which laboratory is especially fitted:*
   Evaporation from water surfaces.
   Evaporation from the soil and crop surfaces.
   Interception losses by vegetation of all kinds.
   Transpiration losses from vegetation, trees, etc.
   Rate of infiltration of rainfall or irrigation water.
   Problems of ground-water flow.
   Fluctuation of ground-water levels.

4. *Head and quantity of water available for tests:*
   There is available a stream draining about 18 square miles area, 4 acres pondage, 72 feet gross fall, concentrated practically in a single drop, with dam, flume, penstock, etc., available for smaller hydraulic experiments.

5. *Principal pieces of equipment:*
   Standard class "A" United States Weather Bureau evaporation outfit, Friez recording hygrothermographs, Friez recording soil and water thermographs, tipping bucket and ordinary rain gages, full equipment of standard test maximum and minimum thermometers and psychrometers; three standard Robinson anemometers, torsion balances, silk scales weighing to 200 pounds by ¼ ounce, numerous special evaporation and infiltration test jars, pans and other apparatus, micrometer hook gages, etc.

6. *Unusual equipment or facilities:*
   Lysimeters, rotating and weighing evaporometers, special rain and snow gages.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*
   Will be arranged for on reasonable terms.

8. *Railroad station and siding:*
   One mile distant.

9. *Name and title of person in charge of laboratory:*
   Robert E. Horton, Consulting Hydraulic Engineer.

10. *Number of persons on regular staff:*
Three.

11. *Brief general description:*
Building, 28 x 60 feet, three stories; with 25 horse-power hydraulic turbine, oil engine and storage battery system for steady power. Complete mechanical tool facilities for ordinary shop and laboratory work. The property includes an area of about 86 acres with an unusual diversity of topography and cultural conditions, with a forest area having a remarkably wide variety of trees,—deciduous and evergreen.

Information furnished by Robert E. Horton.

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UNIVERSITY OF ILLINOIS

1. Illinois, University of, Hydraulic Laboratory, Urbana, Illinois.

2. Established, 1891.

3. *Kinds of work for which laboratory is especially fitted:*
Laboratory is used primarily for student work.

4. *Head and quantity of water available for tests:*
Discharge up to 6000 gallons per minute at heads up to 60 feet are available for testing purposes. A discharge of 275 gallons per minute at a head of 450 feet is available for tests where comparatively high heads are required.

5. *Principal pieces of equipment:*
Pumping equipment consists of two duplex steam pumps of 800 and 2200 gallons per minute;
12-inch single-stage centrifugal pump with capacity of 3000 gallons per minute, connected to 100-horse-power steam engine.
4-inch single-stage centrifugal pump.
4-inch two-stage centrifugal pump.
Two 6-inch single-stage centrifugal pumps
(Centrifugal pumps can be driven with the 100-horse-power steam engine.)
50-kilowatt motor-generator set for supplying direct current to motors for pump tests.
Sump 10 feet in diameter and 12 feet deep, to which water is returned for repeated use after passing through the test apparatus. The water is pumped into a standpipe 4 feet in diameter and 60 feet high, in which a constant water level is maintained by means of automatic steam regulators on the steam pumps.
Seven concrete measuring pits and one steel measuring tank.
Weirs up to 3 feet in length may be used. These are located in a channel 70 feet long and 3 x 3 feet in section through most

of its length, and 3 x 8 feet in section at its upper end. For measuring smaller discharges the equipment consists of orifices ranging in size from 1 inch to 6 inches in diameter, water meters ranging from ⅝ inch to 6 inches, pitometer apparatus, one 4 x 1¼-inch Venturi meter, one 8 x 3½-inch Venturi meter, one set of calibrated Freeman nozzles ranging in size from ½-inch to 6 inches in diameter, and several small tanks on platform scales.
12-inch and 18-inch tangential water wheels.
11½-inch Leffel turbine fitted with Prony brake.
1½-inch two-stage centrifugal pump direct-connected to a calibrated electric motor.
100 feet 2½-inch fire hose, a large set of calibrated nozzles and piezometer couplings, pressure gages of various types.
1200 feet of piping for tests of friction,
Water hammer and loss of head due to expansion and contraction of streams.
Meter testing apparatus.
Intermittently discharging siphons.
Apparatus for determining friction of flow of water through sand.

6. *Unusual equipment or facilities:*
None.

7. *Possibilities for work, for or by outside persons or companies and terms therefor:*
Work for outside parties is not usually undertaken unless the work presents problems of an investigational nature.

8. *Railroad station or siding:*
About 400 feet from nearest railroad siding.

9. *Name and title of person in charge of laboratory:*
Professor Arthur N. Talbot, Professor of Municipal and Sanitary Engineering.

10. *Number of persons on regular staff:*
Twelve men of the Department of Theoretical and Applied Mechanics are available for instructional work in the hydraulic laboratory. Usually the work is handled by four or five of these men.

11. *Brief general description:*
The original laboratory was destroyed by fire in 1900. The laboratory was established in its present quarters in 1902, in the Laboratory of Applied Mechanics, occupying two floors, each 44 x 78 feet.

12. *Research or other work of unusual importance which has been done:*
Bulletin No. 48 of the Engineering Experiment Station of the University of Illinois, "Resistance to Flow through Locomotive Water Columns," by Arthur N. Talbot and Melvin L. Enger;

Bulletin No. 96, "The Effect of Mouthpieces on the Flow of Water Through a Submerged Short Pipe," by Fred B. Seely; Bulletin No. 105, "Hydraulic Experiments with Valves, Orifices, Hose, Nozzles, and Orifice Buckets," by Arthur N. Talbot, Fred B. Seely, Virgil R. Fleming and Melvin L. Enger; Bulletin No. 110, "The Pipe Orifice as a Means of Measuring Flow of Water Through a Pipe."

Information furnished by Professor A. N. Talbot.

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STATE UNIVERSITY OF IOWA

1. Iowa, State University of, Hydraulic Laboratory, Iowa City, Iowa.

2. Established, 1920.

3. *Kinds of work for which laboratory is especially fitted:*
   Testing dam and spillway models; current meter rating; testing water wheels up to 51 inches in diameter; large-scale weir experiments; flow in open channels.

4. *Head and quantity of water available for tests:*
   By gravity,
   Maximum head, 10.3 feet. Minimum flow, 150 cubic feet per second and upward to 1000 cubic feet per second available for half the year.
   By pumping,
   100 feet head; 1 cubic foot per second.

5. *Principal pieces of equipment:*
   Testing flume in which water wheels up to 51 inches in diameter can be mounted.
   Hydraulic canal 130 feet long, 10 feet wide and 10 feet deep, with rails above for mounting car for current-meter rating.
   Measuring chamber of 10,000 cubic feet capacity.
   51-inch McCormick water wheel, installed; 300-gallon-per-minute centrifugal pump; weirs, gages, etc.
   Recording gages on Iowa River, and cable gaging station.
   University water power plant; 51-inch hydro-electric unit installed.

6. *Unusual equipment or facilities:*
   The laboratory is especially adapted to large-scale weir experimentation, and tests on large dam and water wheel models.

7. Work may be undertaken by outside persons in cooperation with the laboratory by special agreement. The terms have been usually a cost settlement for additional equipment involved in the work and ordinary labor.

8. *Railroad station or siding:*
   Siding 400 feet distant.

9. *Name and title of person in charge of laboratory:*
   Professor Floyd A. Nagler.

10. *Number of persons on regular staff:*
    Two research assistants (half time); one mechanic, full time.

11. *Brief general description:*
    The laboratory is situated on the Iowa River, in connection with a power development owned by the University. The laboratory building is 22 feet square inside, with a concrete sub-structure and brick superstructure having stone trimming. Its two floors are of planks made up in sections, supported on steel beams bolted together, so that any section or the whole floor can be removed. The dam across the river is 300 feet long, built in 1906, of gravity spillway section throughout. A concrete canal 130 feet long and 10 feet wide leads from the dam straight to the laboratory; its bottom inside is 5.74 feet below the crest of the dam. During low water, the depth in the canal can be increased two feet by putting flash boards on the dam. A concrete tail-race 22 feet wide prolongs the sub-structure of the laboratory 30 feet down stream; through its terminal wall is an opening, from which a channel, after making a sharp curve, leads to the river. In the center of the laboratory sub-structure is a reinforced concrete column which makes possible the dividing of the sub-structure into four bays. In one compartment a concrete floor 6 feet above the bottom has a circular opening 6 feet 7 inches in diameter. This compartment is intended for water wheel testing. The difference of level of the floors of the sub-structure will permit experiments upon flow increasers.

    The claim for uniqueness of this laboratory rests upon the large quantities of water available. The drainage area of the river above the dam is 3140 square miles. The minimum recorded flow (December 1903) is 150 cubic feet per second. The maximum flow on record is 39,000 cubic feet per second on June 7, 1918. The average low water flow is 300 to 500 cubic feet per second. The plant is especially suitable for problems requiring large quantities at low head, such as those relating to irrigation and drainage engineering and certain water-power problems. There is opportunity also for studying flood protection and river control. The power plant generates current of 2300 volts at 60 cycles.

12. *Research:*
    Research upon an ogee dam model, the hydraulic jump, and flow over weirs.

Information furnished by Professor Floyd A. Nagler, Hydraulic Laboratory.

JOHNS HOPKINS UNIVERSITY

1. Johns Hopkins University, Hydraulic Laboratory, Civil Engineering Department, Baltimore, Maryland.

2. Established, 1917.

4. The laboratory is connected to the city mains by a 2-inch pipe, the pressure varying from 40 to 65 pounds per square inch. There are four interconnected storage wells in the laboratory whose combined dimensions are 18 x 35 x 8 feet deep. The pump ratings are given under the description of equipment.

3, 5, & 6. One single-stage, double-suction, closed-impeller pump directly connected to 2-horse-power, 220-volt, 74-ampere, type S K adjustable-speed motor; rating: 150 gallons per minute against 150 feet head at 1650 revolutions per minute; 375 gallons per minute against 20 feet head at 1150 revolutions per minute. This pump is equipped with pressure and vacuum gages for running test and has switchboard with volt-meter and ammeter.

One single-stage, double-suction, closed-impeller pump directly connected to 65-horse-power, 220-volt, 245-ampere, continuous-current, shunt-wound General Electric motor; rating: 10,000 gallons per minute against 12 feet head at 570 revolutions per minute.

Rectangular, V-notch and proportional weirs with hook gages and weighing tanks.

Venturi meter with several sizes of throat and weighing tanks.

Cole portable test pitometer with traversing attachment.

No. 6 Gould hydraulic ram with gages and weighing tanks.

Twelve-inch Pelton water wheel with gages and Prony brake.

Concrete flume 4 x 5 x 70 feet with track and car for rating current meter.

Standpipe, 58 feet high, with glass gage, connected to standpipe 3 feet in diameter for performing orifice experiments.

Wrought steel pipe 1¼ inches in diameter, with piezometers for determination of friction coefficient and elbow loss.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*

By special arrangement.

8. *Railroad station or siding:*

Convenient access to Pennsylvania Railroad station, 15 minutes by trolley or bus.

9 & 10. John H. Gregory, Professor of Civil and Sanitary Engineering. F. W. Medaugh, Instructor in Civil Engineering.

11. *Brief general description:*

The laboratory is new, well equipped and well lighted. It is in the Civil Engineering Building and is easy of access.

12. *Research:*
Special research work has just been started. Investigation of the loss of head in bends and right-angle turns and in sudden expansion and contradiction have been made.

Information furnished by John H. Gregory, Professor of Civil and Sanitary Engineering.

* * *

LAFAYETTE COLLEGE

1. Lafayette College Hydraulic Laboratory, Easton, Pennsylvania.

2. Established, 1898.

3. *Kinds of work for which laboratory is especially fitted:*
Routine work for students on orifices, weirs, Venturi meters and house meters, also water motors, and a centrifugal pump.

4. *Head and quantity of water available for tests:*
By gravity, 60 feet head.
By pumping, 100 feet head.

5. *Principal pieces of equipment:*
Vertical pressure tank 5 feet diameter, 18 feet high, for heads up to 100 feet for orifices, nozzles, etc.
Standpipe 60 feet high.
Two weir tanks 30 feet long, 4 feet wide.
Weighing tanks, scales, etc.
Impulse wheel.
Centrifugal pump.
Venturi meter, water meters, gages, hydrants, weirs, hook-gage, etc.
Haskell and Price velocity meters.

6. *Unusual equipment or facilities:*
All shapes of small orifices and types of house meters for routine instruction.

7. Outside persons or companies do testing on terms arranged, according to each individual case.

8. *Railroad station and siding:*
About 2000 feet distant.

9. *Name and title of person in charge:*
Lynn Perry, Assistant Professor of Civil Engineering.

10. *Number of persons on regular staff:*
One.

11. *Brief general description:*
The laboratory occupies two floors in the west end of Pardee Hall. It has equipment for rating house meters at various heads,

measuring the flow in streams by velocity meters and two weir tanks the weirs in which can be changed to any type. It also contains every type of small orifice and some motors and a centrifugal pump driven by electric motor.

12. *Research or other work of unusual importance which has been done:* When A. Prescott Folwell was here, some investigations on orifices were made by him and Professor Merriman, but very little original work is now being attempted.

Information furnished by Lynn Perry, Assistant Professor of Civil Engineering.

* * *

LEHIGH UNIVERSITY

1. Lehigh University, Fritz Engineering Laboratory, Bethlehem, Pennsylvania.

2. Established, 1911.

3. *Kinds of work for which laboratory is especially fitted:* Laboratory is equipped to handle all kinds of testing and research work in which large quantities of water are not needed.

4. *Head and quantity of water available for tests:* Water is provided by two centrifugal pumps, one of which delivers 200 gallons per minute against a head of 250 feet and the other 2000 gallons per minute against a head of 60 feet.

5. *Principal pieces of equipment:* A 3-foot-diameter Pelton impulse wheel; a small Trump turbine; Rife hydraulic ram; ultra-violet sterilizer type B, capacity 70 to 120 gallons per hour; four Hershey and Empire water meters; Venturi water meter; pressure tank; calibrating tanks; weirs; current meters; miscellaneous apparatus. Sizes and capacities of equipment here mentioned are those ordinarily used in student hydraulic laboratories.

6. *Unusual equipment or facilities:* None.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:* Excellent opportunity.

8. *Railroad station or siding:* One-quarter mile distant.

9. *Name and title of person in charge of laboratory:* R. J. Fogg, Director, and M. O. Fuller in direct charge.

10. *Number of persons on regular staff:* Three.

11. *Brief general description:*

The hydraulic laboratory occupies one portion of the Fritz Engineering Laboratory and has two levels, each of which covers an area of 40 x 55 feet. The water is pumped into a pressure tank and standpipe, is then delivered to the test points, then to the canal, thence back to the pump pit and used over again. On the upper and lower level are weirs, nozzles, orifices, and other devices, so that a number of student tests can be carried on simultaneously. The meters, test pipe lines, gages, etc. are placed on the upper level. On the lower level are the calibrating and weighing tanks, hydraulic ram, pumps and turbines.

12. *Research:*

Besides regular student experiments, tests have been made on 36-inch vitrified pipe with cement joints. Special weir tests have also been made.

Information furnished by R. J. Fogg, Professor of Civil Engineering.

* * *

LELAND STANFORD UNIVERSITY

1. Stanford University, (a) Hydraulic Laboratory, (b) Hydraulic Machinery Laboratory, Stanford University, California.

2. Established, 1913.

3. *Kinds of work for which laboratory is especially fitted:*

(a) Calibration of instruments; measurement of pressure, velocity, and flow and friction loss of water under various conditions. (b) Testing of hydraulic machinery, including centrifugal, rotary, jet and steam pumps, pulsometers, hydraulic rams, water wheels and hydraulic turbines.

4. *Head and quantity of water available for tests:*

Hydraulic Laboratory:
By pumping,
50-foot head, capacity 2400 gallons per minute,
100-foot head, capacity 1200 gallons per minute.
Hydraulic Machinery Laboratory:
By pumping,
30-foot head, 500 gallons per minute, 1330 revolutions per minute.
60-foot head, 700 gallons per minute, 1890 revolutions per minute.
100-foot head, 900 gallons per minute, 2440 revolutions per minute.

5. *Principal pieces of equipment:*

Two 7-inch, single-suction, class A, Buffalo centrifugal pumps, one direct-connected, 900 revolutions per minute; the other belt-connected to motor, 900 revolutions per minute; pump connected so as to be operated either in series or multiple.
Mueller water meter tester complete with tanks, scales, etc.

Ingersoll-Rand Type XII, 3½ x 4-inch water-cooled, single-cylinder, vertical air-compressor for maintaining constant air pressure in regulating tanks in water supply system.

Nine Venturi meters, with manometers, three different sizes of throats.

25-horsepower 900-revolutions-per-minute General Electric induction motor.

50-horsepower 900-revolutions-per-minute General Electric induction motor.

Four steel measuring tanks, divided into two compartments with tilting valves, etc.

Eight steel weir tanks 5 feet 6 inches x 3 feet 6 inches x 3 feet deep, with interchangeable weir notch plates, orifice plates, blank plates, galvanized iron hoppers, etc.

Eight orifice pressure tanks 24 inches in diameter x 6 feet long for measuring flow through orifices and nozzles of various designs and dimensions.

Nine special 4-inch cast-iron pipe lengths for Pitot tube measurements.

Two riveted steel pressure tanks 36 inches in diameter x 20 feet long for 125 pounds per square inch working pressure.

Two large platform scales with steel tanks.

Irrigation type Venturi meter.

Hammond water meter.

Wilcox water weigher, 125,000 pounds water per hour.

Kennicott water weigher, 150,000 pounds water per hour.

Four 2-inch water meters, Gem, Nash, Crown and Empire.

10-inch Leffel globe case, upright, right-hand turbine.

No. 4 improved-pattern pulsometer steam pump.

8-inch x 5½-inch x 12-inch heavy-pressure Davidson steam pump, suitable for working water pressure of 300 pounds per square inch.

8 x 12 x 7 x 10-inch Worthington duplex compound, outside center-packed, plunger steam pump, designed for 200 pounds per square inch working water pressure.

C. H. Wheeler surface condenser 200 square feet to condense 4000 pounds steam per hour, without vacuum, from the pumps for purposes of measuring steam consumption.

2-inch Brooks centrifugal pump.

3-inch Byron Jackson centrifugal pump.

Two 5-inch Platt double-suction, centrifugal pumps, connected so that they can be operated in series or multiple. Belt drive with three sizes of pulley on pump shaft and coupling of shaft so arranged that they may be driven separately or together.

Westinghouse 3 x 4-inch belt driven air-compressor for maintaining constant air pressure upon pressure-regulating tanks of water supply system.

Two General Electric multi-speed electric motors, 12-horsepower

at constant torque. 1800-1200-900-600-revolutions-per-minute induction motors.
General Electric Type 1, 35-horsepower, 1200-revolutions-per-minute induction motor.
Nine steel weir tanks, 6 feet x 3 feet 6 inches x 3 feet deep with storage compartment.
Steel weir tank 12 feet, 6 inches long x 5 feet wide by 3 feet deep with storage compartment (for Leffel turbine).
Riveted steel pressure tank 60 inches diameter x 22 feet long for 100 pounds per square inch working pressure, with flanges, saddle nozzles, etc.
Riveted steel pressure tank 24 inches diameter x 20 feet long for 250 pounds per square inch working pressure.
12-inch Doble water wheel.
10-inch Pelton water wheel.
4-inch Root rotary pump.
2-inch Schulte & Koerting jet pump.
No. 5 Gould hydraulic ram, 2-inch drive pipe, 1-inch discharge.
Priestman ejector.
Shone sewage ejector (located in hydraulic laboratory).
2-inch Venturi meter.
Concrete sumps and measuring tanks.
Steam hydraulic indicators, pressure gages, manometers and other measuring instruments.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*

Work may be done by outside persons or companies of responsibility by paying all expenses connected with the investigation, provided the work is done at such times as do not interfere with routine class work.

8. *Railroad station or siding:*

Railroad tracks pass by buildings.

9. *Name and title of person in charge of laboratory:*

Hydraulic Laboratory, Professor Charles Moser.
Hydraulic Machinery Laboratory, Professor W. R. Eckart.

10. *Number of persons on regular staff:*

One in each laboratory with student assistants as required.

11. *Brief general description:*

Hydraulic Laboratory. The Hydraulic Laboratory was designed for the instruction of a number of students during the same period and so the equipment was divided into nine main units

of somewhat similar design; provision being made however in each case for considerable flexibility, so that a wide variety of experiments could be performed on any one unit and with some range of capacity. The main pumping unit of 2400 gallons per minute capacity under 50-foot head discharges into the mains, of which a branch passes through two large pressure regulating chambers, thence to a 24-inch manifold running the length of the laboratory. Feed lines from this manifold lead to each of the nine units. Each feed line is provided with a Venturi meter and a pipe section for measuring the flow with Pitot tubes. The water then passes to a weir box where tests can be made with weirs and orifices of various sizes and shapes. The orifice can be placed in either a horizontal or vertical plane. Instead of the water passing to the weir box, it can be delivered under pressure to a pressure chamber, from which it can be discharged through orifices and nozzles under pressure and various coefficients of contraction, velocity and discharge measured. From the orifices or weirs the water passes to calibrated tanks, or tanks on platform scales, or to special weighing equipment, as the Hammond, Kennicott, or Wilcox water weighers. From the measuring boxes it passes into canals, in which measurement of flow can be made by irrigation type Venturi meter, weirs, current meters, or other devices, and thence returns to the pump sump. Other equipment provides for the measurement of friction losses in pipes, and fittings, calibration of water meters, pressure gages, and manometers.

Hydraulic Machinery Laboratory. The equipment provided consists of steam, centrifugal, rotary and jet pumps, ejectors operated by compressed air, impulse water wheels and turbines, hydraulic ram, etc. The piping is arranged so that all the pumps can pump into a common line and the water be delivered to any piece of equipment or weir box in the laboratory, although each piece of apparatus is provided with its own weir box. The water can also be delivered through a connecting line to the hydraulic laboratory and can be returned through suitable channels from that laboratory to the machinery laboratory. The pipe line is made of two sections separated by valves provided for a high-pressure section and a low-pressure section, each with its own pressure-regulating tank. Sumps are provided at both ends of the laboratory connected with a channel near the top. Three large concrete measuring tanks, 17 feet deep with piezometers in an observation pit are provided; one of these is connected by a channel with the Elementary laboratory.

12. *Research:* Surge chamber experiments, Professor W. F. Durand.

Information furnished by Charles D. Marx, Executive Head, Department of Civil Engineering.

LOWELL LOCKS AND CANALS

1. Proprietors of the Locks and Canals on Merrimack River, Lowell, Massachusetts.

2. Established, 1792.

11. *Brief general description:*

No hydraulic laboratory by name. There are, however, several large measuring flumes in the canal system, where measurements of water up to 4000 second-feet and velocities from 1 foot to 6 feet per second may be made with current meters and rod floats. A lock approximately 100 feet long x 12 feet wide x 10 feet deep can be used for bulk measurements of small weirs, Venturi meters, meter nozzles and for rating current meters in still water.

This company from time to time has furnished engineers and manufacturers with experimental data covering the performance of different measuring devices, usually at much less than the cost of doing the work. Without the slightest publicity and covering perhaps fifteen years, the students of Harvard University, the Massachusetts Institute of Technology and Tufts College have used the property of this company for certain of their hydraulic exercises without expense to themselves, and have had the advice of the engineer and his assistants for these exercises. In addition, the Inspection Department of the Associated Factory Mutual Insurance Companies has carried out in one of the buildings and with the water and pressure furnished by the system, a great many experiments on valves, meters, etc., by cooperation with the company.

This company is at the present time (May, 1922) installing a water-wheel testing flume with a maximum capacity of 100 cubic feet per second under a head of about 8 feet. It is believed that wheels up to about 24-inch nominal diameter can be tested with extreme accuracy.

Information furnished by Arthur T. Safford, Engineer.

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

1. Massachusetts Institute of Technology, Hydraulic Laboratory, Cambridge, Massachusetts.

2. Established, 1915.

3. *Kinds of work for which laboratory is especially fitted:*

General hydraulic instruction, tests and research.

4. *Head and quantity of water available for tests:*

Water supply from Charles River nearby. Admitted through 14-inch pipe to 700 feet of canals 5 feet deep in basement. Quantities

up to 50 cubic feet per second can be provided for tests using low heads, and water can be pumped in quantities up to 1500 gallons per minute under pressures up to 250 pounds per square inch.

5. *Principal pieces of equipment:*
90-foot weir box with submerged and open weirs, hook-gages and other appurtenances;
6 by 35-foot pressure tank, up to 200 pounds per square inch; for measuring flow from orifices, nozzles, etc., and furnishing water to tangential wheels.
Two calibrated open tanks 10 by 10 feet for measuring quantities up to 8000 gallons per minute.
Triplex power pumps, steam-driven centrifugals, engine-driven centrifugal, Underwriters' fire pump and duplex pumps;
12-foot diameter steel flume with 135-foot head race, 5 x 5 feet.
Two impulse wheels;
30-inch Venturi meter;
10-ton electric traveling crane.
See general description (No. 11).

6. *Unusual equipment or facilities:*
Larger sizes of many kinds of equipment and greater completeness than in other laboratories and large quantity of water.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*
By special arrangement upon correspondence.

8. *Railroad station and siding:*
Freight station about one mile distant. Siding adjacent to grounds.

9. *Name and title of person in charge:*
George Edmund Russell, Professor of Hydraulics.

10. *Number of persons on regular staff:*
About 8.

11. *Brief general description:*
The hydraulic laboratory has a floor space of about 24,700 square feet on three floors.
Throughout the basement of the steam, hydraulic and refrigerating laboratories canals have been constructed in the sub-basement. These canals which total about 700 feet in length vary in width from 2 to 8 feet and are 5 feet in depth. By means of stop logs different levels may be carried in different parts of the canals. Water from the river is supplied to these canals through two 14-inch valves and a 30-inch discharge pipe leads back to the river on the downstream side of the intake. The normal river level makes a depth of 14 inches of water in these canals. The largest piece of apparatus is a complete plant for testing water wheels.

Wheels using up to 50 cubic feet per second can be tested under heads of 38 feet. A Worthington centrifugal pump, with 36-inch suction, driven by an angle compound engine of 350 horse-power draws water from the canals in the basement and discharges it through a 30-inch Venturi meter into a steel canal 5 feet wide, 5 feet deep and 135 feet long, located on the second floor. This steel canal discharges into a steel penstock 12 feet in diameter supported on I beams spanning a tail-race 10 feet wide and 90 feet long, the bottom of this tail-race being about two feet below the basement floor.

The water wheel to be tested is submerged in the penstock and attached to a casting bolted to the steel plate which forms the bottom of the penstock; this plate resting on the I beam which spans this end of the tail-race. A draft tube is attached to the bottom of this same casting. Present installation consists of an 18-inch type N, S. Morgan Smith wheel.

The back end of the tail-race is built up 16 feet above the floor. A main hydraulic gate 10 feet wide and 10 feet deep, provided with grid openings controlled by a second grid gate sliding on the main gate may be operated from the first floor, so as to hold any level desired in the pit under the draft tube and thus vary the effective length of the draft tube. This gate with grid gate weighs 10 tons; its bearing surface is composition-covered, to prevent corrosion.

Water after passing the main gate flows through baffles and finally over a standard crest 10 feet wide.

In order to test weirs of moderate size and to measure with accuracy quantities of water under 1000 cubic feet per minute a trough 3 feet square and 100 feet long has been constructed to discharge into four large tanks, two 10 feet in diameter and 10 feet tall and two 6 feet in diameter and 10 feet tall, supplied with gage glasses for measuring levels. These tanks are filled and discharged alternately through large valves operated by hydraulic cylinders.

Water under static heads up to 500 feet is obtained in quantities up to 1500 gallons per minute by pumping water into, and compressing the air in, a closed cylinder 5 feet diameter, 30 feet tall, made of 7/8-inch steel plate. This closed cylinder supplies two water wheels of the impulse type and also offers facilities for experiments on the flow through orifices.

Water under pressures up to 250 pounds per square inch is supplied by a steam-driven, outside-packed Warren pot-valve pump of a capacity of 1500 gallons per minute or by a 100-horse-power Terry turbine driving a four-stage Janesville centrifugal, or by a rotary pump of large size. Water under pressures up to 150 pounds is supplied by two 16-inch-10½-inch by 12-inch duplex pumps by a 150-horse-power DeLaval turbine with two-stage centrifugal, by a

Gould or a Davis triplex pump, by a large Emerson pump and by two pulsometers.

In order to test reciprocating pumps with varying suction lifts, two wells each 10 feet long and 5 feet wide extend 26 feet below the basement floor, water being supplied from the canal system to these wells by 16-inch valves operated from the floor; the level being maintained by the amount of opening given these valves, which have been designed in the form of a cone having a very small taper so as to make accurate regulation possible.

A raised platform about 15 by 15 feet has been built up over these deep wells. This platform, which is about 42 feet above the bottom of the well and 16 feet above the basement floor, serves as the operating platform for a Luitweiler deep-well pump, for a 4-inch Pohle Air Lift pump, for a Weber subterranean pump, for an Emerson steam pump and for a pulsometer.

A Rife hydraulic ram with 4-inch drive pipe and a Gould double ram with two 3-inch drive pipes have been installed on the second floor; the water discharged and the overflow being weighed in the basement.

Information furnished by George E. Russell.

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UNIVERSITY OF MICHIGAN

1. Michigan, University of, Hydraulic Experimental Flume, Ann Arbor, Michigan.

2. Established, 1916.

3. *Kinds of work for which laboratory is especially fitted:*
   Salt-solution measurements of water; weir tests.

4. *Head and quantity of water available for tests:*
   By pumping,
   10-foot head, capacity 250 cubic feet per second.

5. *Principal pieces of equipment:*
   Two sets of adjustable baffles (one set being vertical and one set horizontal).
   Five tanks connected to flume by 2-inch pipes, above which hook gages are placed, entire installation enclosed by a gage house; hook gages, piezometers, etc.
   Equipment for measuring water by the salt-solution method.

6. *Unusual equipment or facilities:*
   See Number 11.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*
   Arrangements by correspondence.

8. *Railroad station and siding:*
   Near Michigan Central Railroad; on Huron River.

9. *Name and title of person in charge of laboratory:*
   Horace W. King, Professor of Hydraulic Engineering.

10. *Number of persons on regular staff:*
    Not given.

11. *Brief general description:*
    The total length of the flume is 138 feet, the upstream portion being 8 feet, 6 inches wide and 9 feet deep, while the lower portion, 103 feet long, is exactly 2 meters (6.56 feet) wide and 8 feet deep. Above the flume at its upper end is a small frame building which contains a complete equipment for measuring water by the salt solution method and provides shelter for the men engaged in working up experimental data.
    The flume is so arranged that the models to be experimented upon may be easily erected or removed, and the arrangement within the flume may be modified to conform to the requirements of any particular experiments. The salt-solution equipment provides for the accurate calibration of standard weirs, which in turn may be used for measuring water for other experimental work. The flume is especially adapted to the determination of empirical coefficients such as occur in formulas of discharge for weirs, gates, orifices and pipes under a wide range of conditions. The large supply of water makes it possible, in many cases, to conduct experiments on a larger scale than has hitherto been undertaken.

12. *Research:*
    "Verification of the Bazin Weir Formula by Hydro-Chemical Gagings," Floyd A. Nagler, "Transactions," American Society of Civil Engineers, Vol. LXXXIII, page 105, 1919-1920.

Information furnished by H. W. King, Professor of Hydraulic Engineering.

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UNIVERSITY OF MINNESOTA

1. Minnesota, University of, Experimental Engineering Laboratories, Minneapolis, Minnesota.

2. Established, 1911.

3. *Kinds of work for which laboratory is especially fitted:*
   Laboratory experiments requiring a moderate supply of water.

4. *Head and quantity of water available for tests:*
   By pumping,
   2000 gallons per minute and a head of 30 feet. Heads up to 300 feet may be obtained with smaller quantities of water.

5. *Principal pieces of equipment:*
   Two Worthington centrifugal pumps, class A, each having a capacity of 800 gallons per minute, direct-connected to 50 kilowatt slip-ring type, induction motors with variable speed control.
   Compound Buffalo steam pump, 8 x 12 x 7 x 12 inches.
   12-inch Rumsey centrifugal pump.
   3-cylinder, gear, triplex pump.
   12-inch Pelton-Doble water wheel, 2-inch piping, with glass case for observing the action of the nozzle and propellers.
   Three small Pelton wheels with Prony brakes.
   Apparatus for testing water meters.
   Two hydraulic rams.

6. *Unusual equipment or facilities:*
   A sump 24 x 24 x 10 feet deep is situated under the basement floor. Water may be pumped by two motor-driven Worthington pumps (using the pumps in series or parallel) from this sump into a steel standpipe 5 feet in diameter by 20 feet high, and discharged into two concrete weir channels 4 feet deep and 4 feet wide by 30 feet long. Water may be discharged from the weir channels alternately into either of two large weighing tanks mounted on large platform scales. Each tank has a capacity of 1600 gallons, and is equipped with a quick-opening valve at the center so that it can be drained into the sump in 30 seconds. A complete system of piping and valves permits the supply water to be pumped directly to the weir channels, through suitable Venturi meters, or through the standpipe.

7. Arrangements may be made for outside tests through members of the instructional staff. In such cases the tests are made directly by members of the staff as individuals and not as University tests. The individual obtains a permit for the work from the University comptroller, the terms and price being arranged by the individual doing the work and the outside firm concerned.

8. *Railroad station and siding:*
   About three blocks distant.

9. *Name and title of person in charge:*
   Frank B. Rowley, Director, Experimental Laboratories.

10. *Number of persons on regular staff:*
    Three.

12. *Research:*
    Research is now being undertaken to determine the characteristics of rotary pumps when pumping oil with different viscosities as compared with water.

Information furnished by Frank B. Rowley, Director, Experimental Laboratories.

UNIVERSITY OF NORTH CAROLINA

1. North Carolina, University of, Chapel Hill, North Carolina.

2. Established, 1921.

3. *Kinds of work for which the laboratory is especially fitted:*
   Student instruction.

4. *Head and quantity of water available for tests:*
   By gravity,
   3000 gallons per minute.

5. *Principal pieces of equipment:*
   Small constant-head tank, 1½-inch to 6-inch piping and small weir box, fitted with piezometers, gages, Venturi meter, and rectangular, trapezoidal and triangular weir plates. Fire hose and nozzles, hydraulic ram, orifices, pitometer, house meters.

6. *Unusual equipment or facilities:*
   None.

7. *Possibilities for work, for or by outside persons or companies:*
   Meter testing.

8. *Railroad station and siding:*
   500 feet distant.

9. *Name and title of person in charge of laboratory:*
   Thorndike Saville, Associate Professor of Hydraulics and Sanitary Engineering.

10. *Number of persons on regular staff:*
    One associate professor and one assistant.

12. *Research or other work of unusual importance:*
    Laboratory is two miles from small stream (flow 150 to 5 cubic feet per second) where experiments are to be carried on with U. S. Geological Survey on gaging-station equipment. A specially designed concrete gage house is to be built, and a current meter gaging station installed. They will be used also for studies on silting and silt control.

Information furnished by Professor Thorndike Saville.

OHIO STATE UNIVERSITY

1. Ohio State University, Robinson Laboratory, Columbus, Ohio.
2. Established by the late Professor Stillman W. Robinson, in the Mechanical Engineering Laboratory, probably previous to 1885; removed to present location and enlarged in 1907.
3. *Kinds of work for which laboratory is especially fitted:*
   (1) Flow of liquids through orifices (in pipes up to 20 inches and submerged up to 24 inches diameter), nozzles and pipes;
   (2) Flow of water over weirs, in flumes of different cross-section, and over models of dams;
   (3) Velocity changes and distribution in a flowing stream;
   (4) Determination of loss of head due to friction; and
   (5) Comparative tests of pumps, water wheels, valves, and other hydraulic machinery.
4. *Head and quantity of water available for tests:*
   By pumping,
   The heads of water available are $\left\{\begin{matrix}100\\150\end{matrix}\right\}$ gallons per minute at $\left\{\begin{matrix}200\\100\end{matrix}\right\}$ pounds per square inch;
   2000 gallons per minute at 70 pounds per square inch;
   1000 gallons per minute at 150 pounds per square inch;
   12,000 gallons per minute at 20 pounds per square inch;
   Also a limited supply of city water at 25 to 50 pounds per square inch.
5. *Principal pieces of equipment:*

2	cisterns	3.77	x 15.3	x 10.5	feet—1211	cubic	feet
2	"	8.05	x 7.5	x 10.5	" —1268	"	"
6	"	8.05	x 15.3	x 10.5	" —7758	"	"
1	"	15.3	x 15.3	x 10.5	" —2458	"	"
1	"	15.3	x 26	x 10.5	" —4177	"	"
1	flume	3.0	x 63.2	x 4.6	" — 872	"	"
	Total indoor storage capacity				17,744	"	"

   Equal 132,725 gallons.
   One outdoor reservoir adjacent to laboratory, 400,000 gallons capacity.
   One runway 150 feet long, in this reservoir for gaging current meters.
   One centrally located observation well fitted with water level gages 10 feet high, and hook-gage wells, connected to cisterns by 2-inch pipes.
   Weir plates of various shapes and sizes are placed in dividing walls of cisterns.
   Submerged orifices, up to 24 inches diameter, are placed in some of the partition walls.

Well, 5 feet diameter and 30 feet deep, is located in one cistern for direct pump-suction.
Rectangular concrete flume 3 x 4.6 feet cross-section, 63.2 feet long.
24-inch closed standpipe, 24 feet high, for pressures up to 100 pounds for orifices and nozzles up to 6 inches diameter.
10 and 16 x 12 x 10-inch Worthington horizontal, tandem, compound, duplex, inside-packed plunger pump, capacity 1000 gallons per minute, at 70 and 150 pounds pressure.
12 x 7 x 12-inch Knowles horizontal, outside-packed, plunger pump, capacity 150 gallons per minute, at 100 pounds pressure.
5 x 6-inch Deane, single-acting, triplex power pump, capacity 75 gallons per minute at 100 pounds pressure.
3-inch Goulds single-stage, centrifugal pump, 250 gallons per minute at 50 feet head.
3-inch Buffalo, single-stage, centrifugal pump, 250 gallons per minute at 50 feet head.
5-inch Kerr-Dayton, single-stage, turbo-centrifugal pump, 1000 gallons per minute at 80 pounds pressure.
20-inch Worthington, single-stage, special volute centrifugal pump, 12,000 gallons per minute, 60 feet total head (fitted with special traversing Pitot tubes).
3-inch De Laval two-stage, turbo-centrifugal pump, 100 gallons per minute at 200 pounds pressure.
No. 5 Humphreys hydraulic ram, with 11 feet drive head.
2-inch pulsometer.
3-inch Venturimeter* connected to 100 feet straight run of 3-inch water pipe.
6-inch Venturimeter* connected to circulating pipe of Wheeler condenser.
3-inch Venturimeter* connected to special air pipe line for experimentation.
10-inch standard Leffel reaction water turbine, attached to 24-inch closed standpipe 15 feet high, for 50 feet head.
36-inch Leffel "Cascade" impulse wheel, under 150 feet head.
16-inch American impulse wheel, under 150 feet head.
12-inch Doble-Pelton impulse wheel, under 150 feet head.
Two 2-inch air lifts, 30 feet submergence for 15 feet lift.

6. *Unusual equipment or facilities:* None.

7. During the college year, the laboratory is generally used for the regular student instructional work. The equipment usually stands unused from about June 15 to September 15, and occasionally during other vacations. All arrangements for work for outside persons would have to be made through the Director of the Engineering Experiment Station or the Department of Mechanical Engineering.

*Preference of this laboratory is Venturimeter, as one word, like Wattmeter.

8. *Railroad station or siding:*
There is a university spur track from the Hocking Valley Railroad 200 feet from the rear of the laboratory.

9. *Names and titles of persons in charge of laboratory:*
W. T. Magruder, Professor of Mechanical Engineering, is Head of the Department of Mechanical Engineering, of which the Hydraulic Laboratory is a part. H. Judd, Professor of Hydraulic Engineering, is in direct charge of the Hydraulic Laboratory. Dean E. A. Hitchcock is Director of the Engineering Experiment Station.

10. *Number of persons on regular staff:*
Four professors and several instructors give time to hydraulic work. There is no regular staff devoted solely to hydraulic research.

11. *Brief general description:*
The hydraulic laboratory occupies one 30 x 112-foot bay of the Mechanical Engineering Laboratory and parts of two adjacent bays. This is a mill-construction, brick building, 310 x 115 feet, with saw-tooth roof. Steam and electric power, both alternating current and direct current, are available as needed to drive hydraulic machinery which may be temporarily installed on the test floor.
The sawtooth construction of the building gives ample daylight. Bottoms of trusses are 22 feet above floor, giving plenty of head room for large pieces of machinery and equipment. Adjoining the hydraulic section is a planed cast-iron test-plate 14 x 21.33 feet for the temporary installation of pumps, turbines, and other hydraulic machinery. Adjacent to this test-plate are one 40-horse-power and one 75-horse-power, high-speed steam engines. A 30-horse-power motor and a high-speed line shaft are available, and also additional electric current as needed. A Reeves speed-changing variator, a Flather transmission dynamometer, several surface condensers for creating a vacuum and permitting the weighing of the condensate from pumps, engines, and steam turbines are available. The instrument room is supplied with pressure gages reading from 1 pound to 5000 pounds; manometers reading from 1/1000 inch to 36 inches; sets of Pitot tubes of various makes; a hydraulic caliper graduated to 1/1000 inch for measuring the three coordinates of jets; a dynamometer for determining the impulsive force of a jet; water columns and hook gages; and much other auxiliary equipment.

12. The research work of chief importance has been along the line of the flow of fluids. Professor S. W. Robinson, in 1886, used the Pitot tube for the flow from gas wells and also studied the flow of gas through orifices. (Van Nostrand's Engineering Magazine, Vol. 35, page 89). Since then the Pitot tube has had extensive application in this laboratory to the flow of water. The Pitot tube, as

applied to water flow, was studied by James E. Boyd and Horace Judd in 1903 (Engineering News, Vol. 51, p. 318). A study was made of the frictionless orifice for water flow in 1906 by Horace Judd and R. S. King (Engineering News, Vol. 56, page 326). The orifice as a pipe diaphragm was investigated in 1916 by Horace Judd (Trans. American Society of Mechanical Engineers, 1916, Vol. 38 page 331). At present, experiments are in progress on Pulsating Flow in Pipe Lines for the Flowmeter Committee of the American Society of Mechanical Engineers, of which Professor Judd is a member.

Information furnished by Wm. T. Magruder, Professor, Mechanical Engineering.

* * *

PENNSYLVANIA STATE COLLEGE

1. Pennsylvania State College, Hydraulic Laboratory, State College, Pennsylvania.

2. Established, about 1895.

3. *Kinds of work for which laboratory is especially fitted:*
   Tests of small orifices and weirs.

4. *Head and quantity of water available for tests:*
   By gravity.
   Head about 200 feet; quantity is capacity of piping system.

5. *Principal pieces of equipment:*
   Orifice boxes with standard ½-inch, ¾-inch and 1-inch orifices; 6-inch weirs; V-notch weir. Additional large weirs and tanks in Mechanical Engineering laboratory.

6. *Unusual equipment or facilities:*
   Nothing unusual.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*
   Developmental work and non-commercial tests at cost.

8. *Railroad station and siding:*
   About 100 feet distant.

9. *Name and title of person in charge of laboratory:*
   Professor E. D. Walker.

10. *Number of persons on regular staff:*
    Three instructors in laboratory.

11. *Brief general description of laboratory:*
    Laboratory has weir boxes equipped with stilling devices, standard orifices and weirs; also wide variety of pumping equipment, in-

jectors, ejectors, and other devices for lifting water, large weirs, and weighing tanks for measurement of discharges. In the new engineering building there is to be a hydraulic laboratory 150 by 60 feet, equipped with large motor-driven centrifugal pumps, water turbine, impulse wheel, concrete conduits, large weirs and weighing apparatus. There will be space devoted to research as well as full equipment for class instruction.

12. *Research or other work of unusual importance which has been done:*
No research work of importance has been done, because of limited space and equipment.

Information supplied by R. L. Sackett, Dean, School of Engineering.

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UNIVERSITY OF PENNSYLVANIA

1. Pennsylvania, University of, Civil Engineering Department, Hydraulic Laboratory, Philadelphia, Pennsylvania.

2. Established, 1906.

3. *Kinds of work for which laboratory is especially fitted:*
Student instruction, post graduate research and commercial testing.

4. *Head and quantity of water available for tests:*
2 cubic feet per second against a head of 165 feet,
4 cubic feet per second against a head of 75 feet,
8 cubic feet per second against a head of 40 feet,
all of which is capable of being weighed.

5. *Principal pieces of eqquipment:*
Concrete reservoir of 23,000 gallons capacity, receives discharge from all apparatus, together with necessary makeup water from City mains.
Two electrically-driven, 2-stage turbine pumps of 450 gallons per minute capacity against 165 feet head supply the laboratory from the reservoir.
Low-lift centrifugal pump of 2,000 gallons per minute capacity, 40 feet head, 3-inch double-suction centrifugal pump 300 gallons per minute, 60 feet head. Vertical pressure tank 5½ feet diameter, 37 feet high, with attachments for orifices and other apparatus.
12-inch standpipe 65 feet high, with overflows to regulate static head.
Circuits of 10-inch pipe with numerous openings for attachment of apparatus, connected with the standpipe and the pressure tank.
Two concrete weir tanks, 34 feet long, 5 feet wide; may be used also for measuring tanks; in addition, can be used for investigating flows over dams of various profiles.

Two steel chutes, with hydraulically operated valves, diverting flow alternately into two weighing tanks of 16,000 pounds capacity each, mounted on weighing cars, for weighing continuously the discharge from any part of the laboratory.
9-inch reaction turbine.
12-inch impulse water-wheel.
Meters, gages, etc. of various types.

6. *Unusual equipment or facilities:*
Several forms of special Pitot tubes,
2 and 3-inch hook differential oil gages measuring deflection to 1/100 foot and head to 1/10,000.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*
A great deal of this type of work is done, the outside company paying for the time of the professor, instructor or mechanic, and for power used. If the work is done by outside parties, they pay for the power used and a nominal fee for the use of laboratory.

8. *Railroad station or siding:*
One-quarter mile distant.

9. *Names and titles of persons in charge of laboratory:*
M. S. Ketchum, Director of Civil Engineering,
W. S. Pardoe, Professor of Civil Engineering.

10. *Number of persons on regular staff:*
Usually three of faculty, mechanic and helper.

11. Laboratory occupies three floors, about 35 by 60 feet; is compact, flexible and well lighted.

12. *Research or other work of unusual importance which has been done:*
Investigation of flow in Standard Short Tube; see Engineering News, Sept. 14, 1916, page 520.
The coefficients of Venturi Meters; see Engineering News-Record Sept. 25, 1919 and Sept. 23, 1920.
A long series of tests on Pitot tubes and Pitot meters; not published.
An investigation on Actual Velocity in a 1½-inch Tube; not published.
At present an investigation is being carried on, on the forms of draught tubes and conical mouth pieces.
A series of tests on compound weirs, both rectangular and triangular, in course of preparation for publication.
A number of interesting, but unpublished, student theses.

Information furnished by Milo S. Ketchum, Director, Civil Engineering.

UNIVERSITY OF PITTSBURGH

1. Pittsburgh, University of, Hydraulic Laboratory, Pittsburgh, Pennsylvania.

2. Established, 1918.

3. *Kinds of work for which laboratory is especially fitted:*
   Suppressed and contracted weir calibration and measurements;
   current meter measurements;
   pitometer measurements;
   discharge and losses of pipe lines;
   nozzles and orifice measurements;
   Venturi meter measurements and loss of head determination;
   turbine testing (42-inch mixed flow type);
   channel measurements, and pump tests.

4. *Head and quantity of water available for tests:*
   By gravity,
   15 feet head, volume of water 50 cubic feet per second.

5. *Principal pieces of equipment:*
   Weir channel 8 x 9 x 80 feet.
   Sharp crested weirs 4 feet and 8 feet long.
   Measuring basin, capacity 2560 cubic feet.
   Vertical 42-inch mixed-flow Leffel turbine.
   Horizontal shaft and Prony brake.
   3-inch horizontal Worthington centrifugal pump, belt-connected to pulley on horizontal shaft driven by hydraulic turbine.
   4-inch Venturi meter on discharge line of pump.
   12-inch cast iron pipe for loss-of-head determinations and use of pitometer.
   Current meters, water meter, differential gages, etc.

6. *Unusual equipment or facilities:*
   Channel 2000 feet long takes water from creek having fall of about 100 feet per mile and following higher level creates fall available at laboratory site. Channel has capacity of 100 cubic feet per second.

7. Possibilities for work for outside parties are good. The University will make available equipment for such use at reasonable terms, charging only sufficient to cover expense of making laboratory available.

8. *Railroad station or siding:*
   Three miles distant.

9. *Name and title of person in charge of laboratory:*
   George W. Case, Professor of Sanitary Engineering.

10. *Number of persons on regular staff:*
    Laboratory is not kept open entire year. Operated two weeks at end of Spring term by staff of three.

11. *Brief general description:*
The hydraulic laboratory is at Camp Hamilton, near Windber, Pennsylvania, on the site of an old mill which was driven by hydraulic power, the water being obtained from Shade Creek, which runs through the camp grounds. The water is brought to the laboratory by a canal 2000 feet long, which has sufficient fall and size to be used for steam-gaging experiments. The capacity of the canal is about one hundred cubic feet of water per second.
A flume 8 feet wide, 9 feet deep and 80 feet long carries the water from the fore-bay at the end of the canal to the laboratory. At the end of this flume the water may pass over a 4-foot contracted weir or be deflected through a 42-inch Francis type turbine. The total head on the turbine is 15 feet. In the tail-race of the turbine is a 4-foot suppressed weir. The contracted weir can be calibrated by the use of a 19,000-gallon measuring tank. In addition to the turbine, weirs and measuring tank the laboratory is equipped with a Worthington two-stage pump, a Pelton impulse wheel, Venturi meter, tanks for orifice and nozzle experiments, and pipes for pitometer measurements and loss-of-head determination.

Information furnished by Professor George W. Case.

* * *

PRINCETON UNIVERSITY

1. Princeton University, Civil Engineering Laboratory, Princeton, New Jersey.

2. Established, 1905.

3. *Kinds of work for which laboratory is especially fitted:*
Undergraduate instruction only.

4. *Head and quantity of water available for tests:*
By pumping,
About 125 feet; about 55 gallons per minute.

5. *Principal pieces of equipment:*
Low-head orifices up to one inch diameter; small pipes, 50 feet long; small weirs; small valves and diaphragms; small commercial meters; differential pressure gages; hook and point-gages.

6. *Unusual equipment or facilities:*
None.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*
None.

8. *Railroad station or siding:*
About half a mile distant.

9. *Name and title of person in charge of laboratory:*
H. S. S. Smith, Professor of Civil Engineering, until June, 1922; Arthur M. Greene, Jr., Dean, School of Engineering, after June, 1922.

10. *Number of persons on regular staff:*
About 5 per cent of time of Professor Smith.

11. *Brief general description of laboratory:*
Room about 18 x 60, 10 feet high. Motor-driven turbine pump takes water from measuring and waste tanks and delivers to air-cushion pressure tank. Overhead piping takes water to different apparatus.

12. *Research or other unusual work which has been done:*
None.

Information furnished by H. S. S. Smith, Professor, Civil Engineering.

* * *

PURDUE UNIVERSITY

1. Purdue University, Hydraulic Laboratory, Lafayette, Indiana.

2. Established, 1911.

3. *Kinds of work for which laboratory is especially fitted:*
The laboratory is thoroughly equipped to make tests on any piece of hydraulic apparatus or machinery for a maximum flow of 8,400 gallons per minute at 34 feet or less head, and for a maximum flow of 1,800 gallons per minute with heads up to 231 feet.

4. *Head and quantity of water available for tests:*
Flow is produced by pumping, the head and quantity of water available being dependent upon the particular unit in use.
(See No. 5)

5 & 6. *Principal pieces of equipment are:*
Platt, direct-driven, single-stage centrifugal pump with a capacity of 8,400 gallons per minute against a maximum head of 34 feet.
American two-stage, direct-driven centrifugal pump with a capacity of 1,800 gallons per minute against a maximum head of 231 feet.
Allis-Chalmers direct-driven, single-stage, centrifugal pump with a capacity of 400 gallons per minute against a maximum head of 116 feet. The motor is of the direct-current variable-speed type.
Gould triplex pump with a capacity of 60 gallons per minute.
2-inch rotary pump.
Trump 12-inch reaction turbine.
Fairbanks weighing scale of 20 tons capacity. The balance arm of the scale is equipped with an electric timing device.

Concrete channel 3 feet wide, 3 feet deep, and 80 feet long, supplied with track and carriage for current meter investigations.

Concrete channel, 6 feet deep and 70 feet long composed of two sections, one 8 feet and the other 5 feet in width. Each section is equipped with a rectangular weir. The flow from the channel passes into the large weighing tank.

In additon to the above there are many pieces of small equipment, some of which are noted in Number 11.

7. Always willing to cooperate with outside persons and companies in the furtherance of testing or research work; terms dependent upon the particular test performed; should be arranged with the Director of the Engineering Experiment Station.

8. *Railroad station or siding:*

The laboratory is situated about 200 yards from a railroad siding on the campus.

9. *Name and title of person in charge of laboratory:*

F. W. Greve, Associate Professor of Hydraulic Engineering.

10. *Number of persons on regular staff:*

Two instructors, one of whom gives half of his time to research work.

11. *Brief general description:*

The laboratory is 115 by 50 feet in plan and consists of a main floor and a gallery 16 feet wide that extends around the entire laboratory. A concrete storage reservoir of 82,000 gallons capacity is situated below the level of the main floor. The discharge from all machines and tanks passes back to this reservoir.

The main floor is equipped with the concrete channels and pumps described in No. 5 and in addition there are a number of small tanks and weighing scales.

The gallery is equipped with the Trump reaction turbine, three small impulse wheels, a hydraulic ram, tanks for calibrating small weirs, orifices and tubes and connections for calibrating water meters. The movable equipment consists of a Pitot tube, current meters, differential gages with a maximum range of 5 feet, and other apparatus.

12. *Research work completed:*

Calibration of a moving screen for determining the velocity of flow in open channels.

Flow of water through 1-inch pipe valves and fittings.

Flow of water through 1½-inch valves.

Calibration of sewage sprinkler nozzles.

Calibrating of 1-inch and 1½-inch circular orifices under maximum heads of 231 feet.

Flow of water through 4, 6, 8, and 10-inch spiral riveted galvanized steel pipe.
Calibration and development of parabolic weirs.

Information furnished by A. A. Potter, Dean of Engineering, and W. K. Hatt, Head, School of Civil Engineering, Purdue University.

* * *

RENSSELAER POLYTECHNIC INSTITUTE

1. Rensselaer Polytechnic Institute, Hydraulic Laboratory, Troy, New York.

2. Established, in 1908.

3. *Kinds of work for which laboratory is especially fitted:*
   Testing current meters and small models. Has a tank 80 feet above the laboratory which can be used for tests.

4. *Head and quantity of water available for tests:*
   2000 gallons per minute under a head of 18 feet by pumping.

5. *Principal pieces of equipment:*
   Worthington tandem, duplex, steam pump, 8 x 12 x 7 x 10 inches, can pump against 100 to 300 feet head.
   Fairbanks, Morse & Company low-pressure, duplex pump 10 x 10 x 12 inches.
   Marsh simplex steam pump 12 x 6 x 12 inches.
   Dean triplex power pump, electric-driven.
   Root rotary power pump, electric-driven.
   Lawrence single-stage centrifugal pump, 1000 gallons per minute.
   Platt 2-stage centrifugal pump, 80 feet head.
   Worthington 3-stage centrifugal pump, 250 feet head.
   12-inch Doble water-wheel.
   12-inch Pelton water-wheel.
   Escher, Wyss & Company water-wheel.
   10-inch Leffel turbine.
   Pulsometer injector.
   25,000-gallon tank and 15,000-gallon cistern.
   15,000-gallon tank and a testing flume for current meters 4 x 4 x 90 feet.
   Measuring flumes, Venturi meter, Pitot tubes, nozzles, floats, current meters, etc.
   Orifices in pipe lines for measurement of water.

6. *Unusual equipment or facilities:*
   Testing flume for current meters is unusual.

7. The laboratory will do work for outside persons and under certain conditions outside persons or companies will be allowed to do work in the laboratory. The charge for such work depends on the nature of the work and the expense connected therewith.

8. *Railroad station and siding:*
About 1½ miles from nearest freight yard.

9. *Name and title of person in charge:*
Professor Grant K. Palsgrove.

10. *Number of persons on regular staff:*
There are at least ten persons on the mechanical engineering staff who are competent to do work in the laboratory.

11. *Brief general description:*
The laboratory is located in the sub-basement of the Mechanical Engineering Building covering about 2500 square feet of floor space with a tank of 25,000 gallons on the floor above the laboratory and a cistern of 15,000 gallons beneath the laboratory. A tank of about 15,000 gallons is located in the attic of the Sage Building and connected to the laboratory by an 8-inch pipe. Flumes with weir notches of various forms, Venturi meters, Pitot tubes, nozzles, floats and current meters are found in the laboratory.

12. *Research or other work of unusual importance:*
Accuracy of current meters of various forms, effects of the nearness of current meter to the walls of the flume, the effect of depths of immersion of current meters, the force of water against models of bridge piers and submerged cylindrical forms, the strength of flat plates, and the currents in draft tubes, have been investigated.

Information furnished by Professor Arthur M. Greene, Jr.

* * *

UNIVERSITY OF ROCHESTER

1. Rochester, University of, Rochester, New York.
The hydraulic laboratory is small, designed and used for undergraduate instruction of mechanical engineering and chemical engineering students. For this purpose it is very satisfactory, sufficiently comprehensive, and gives good results; but it is not and cannot conveniently be adapted to research work on any extended scale, and none has ever been attempted, except an investigation of the performance of the Venturi meter under very low discharge heads, made at the request of F. F. Longley, of Hazen, Whipple & Fuller.

Information furnished by M. C. Ernsberger, Department of Mechanical Engineering.

ROSE POLYTECHNIC INSTITUTE

1. Rose Polytechnic Institute, Hydraulic Laboratory, Terre Haute, Indiana.
2. Established, 1878.
3. *Kind of work for which laboratory is especially fitted:*
   Student work, especially calibration of orifices and weirs.
4. *Head and quantity of water available for tests:*
   From tank in attic of main building, head 63 feet, about ½ cubic foot per second.
5. *Principal pieces of equipment:*
   Standpipe and stilling tank for testing orifices, etc., up to 2 inches diameter.
6. *Unusual equipment or facilities:*
   Model channel for studying movements of flood waves.
7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*
   No regular arrangements of this kind.
8. *Railroad station and siding:*
   600 feet distant.
9. *Name and title of person in charge:*
   Harold A. Thomas, Professor of Hydraulics.
10. *Number of persons on regular staff:*
    One.
11. *Brief general description:*
    Small laboratory for student work in general hydraulics. Full equipment for river gaging.
12. *Research or other work of unusual importance:*
    Research and experiments on the movement of flood waves in rivers.
    Special studies on Pitot tubes.

Information furnished by Professor Harold A. Thomas.

S. MORGAN SMITH COMPANY

1. S. Morgan Smith Company, York, Pennsylvania.

2. Established, 1921.

3. *Kinds of work for which laboratory is especially fitted:*
   The laboratory, or, more properly, water-wheel testing flume, is especially fitted for testing model water-wheels, or turbines, and intake and discharge passages for the same.

4. *Head and quantity of water available for tests:*
   Normal head is 10 feet, but can be varied from 3 or 4 feet to 12 feet. The head on the turbine is a gravity head, and the water, after passing through the turbine and over a measuring weir, flows through a return passage and is then pumped into a baffle-chamber and flows thence into the flume proper.

5. *Principal pieces of equipment:*
   The power is absorbed by an Alden absorption dynamometer. A Fairbanks beam scale is used, which is hung on a beam supported from the working deck. An ordinary clock speed-counter is used, such as at the Holyoke flume, and this speed-counter runs continuously with the turbine. The water is measured over a weir without end contractions. An ordinary hook gage is used for obtaining the depth over the weir. The head is measured by float-gages, but these are so arranged that they can be readily checked.

6. *Unusual equipment or facilities:*
   The depth and size of the flume and the tail-pit are arranged so that either horizontal or vertical wheels can be tested. There is ample provision for easily varying the head and the relation of the center line of the turbine with the head and tail-water. There is sufficient space available to test almost any conceivable shape or size of intake or discharge passage.

7. *Possibilities for work, for or by outside persons or companies, and terms therefor:*
   This testing flume is not available for use by outside parties, except that company will cooperate with purchasers of its equipment, to secure the best available turbines and settings.

9. *Name and title of person in charge of laboratory:*
   S. Morgan Smith Company is in charge of the laboratory.

10. *Number of persons on regular staff:*
    Four persons are required to make a test; may possibly be reduced to three.

11. *Brief general description:*
    The water is pumped into a baffle chamber, where it rises to the elevation desired and then passes into the flume proper, through

a baffle. From the flume the water goes through the turbine and out of the draft tube into the tail-pit and thence into the tail-race. There are two baffles in the tail-race, and after passing through these baffles, the water goes over the measuring weir into the return canal. The return canal passes around the flume and carries the water back to the pump intake. For assisting the control of the head, there is an overflow from the baffle chamber, to carry excess water to the return canal. This overflow will permit obtaining a practically constant head on the turbine.

Information furnished by George A. Jessop, Engineering Department.

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STEVENS INSTITUTE OF TECHNOLOGY

1. Stevens Institute of Technology, Hoboken, New Jersey.
2. Established, 1875.
3. *Kinds of work for which laboratory is especially fitted:*
   The laboratory is a part of a general engineering laboratory fitted primarily for student instruction. With that end in view all appliances are small, and are designed to determine the efficiencies and to standardize the appliances.
4. *Head and quantity of water available for tests:*
   The heads are obtained by pumping. The quantities are measured by standardized tanks, by weighing, by Venturi meters, by orifices, Pitot tube, sharp-edge weirs either straight or with end contractions, V-notch weirs, piston and disc meters; also a 36-inch Herschel weir.
5. *Principle pieces of equipment:*
   8½ x 5 x 10-inch Union direct-acting simplex pump.
   5½ x 3¼ x 7-inch Blake direct-acting simplex pump.
   Two 4½ x 2¾ x 4-inch Worthington direct-acting duplex pumps.
   2-inch Worthington single-stage centrifugal, motor-driven pump, capacity 12 cubic feet per minute against 76 feet head.
   2 x 3-inch Worthington triplex pump, motor-driven.
   14-inch Pelton laboratory motor with Prony brake.
   10-inch Pelton impulse water wheel with Prony brake.
   10-inch American impulse water wheel with Prony brake.
   No. 2 pulsometer.
   Rife hydraulic ram.
   8-inch standard sharp-edge weir without end contractions.
   2½-inch Venturi meter with manometer.
   Sixteen weighing tanks on Fairbanks scales.
   Four calibrated displacement tanks.
   Piston and disc meters.
   14-inch Pelton laboratory motor with Prony brake.

10-inch Leffel reaction turbine with vertical viscous dynamometer.
Two 10 x 36 x 36-inch weir boxes set in series for comparison of V-notch and Herschel round edge weirs.
In the delivery pipes curved and flat plate orifices, Pitot tube and Venturi meter.
18 x 10 x 12-inch duplex Underwriters' fire pump having maximum capacity of 134 cubic feet per minute against 600 feet head.
3-inch Goulds single-stage centrifugal pump driven by a 3-horsepower variable-speed motor; capacity 10 cubic feet per minute against 50 feet head.
2-inch Union two-stage centrifugal pump driven by 7½-horsepower motor having variable speed; capacity 13 cubic feet per minute against 200 feet head.
5-inch Union single-stage centrifugal pump driven by 7½-horsepower variable-speed motor, capacity 300 cubic feet per minute against 20 feet head.

6. *Unusual equipment or facilities:*
None.

7. With the present increased size of classes, can take very little outside work.

8. *Railroad station or siding:*
Railway siding is 1000 feet from door.

9. *Name and title of person in charge of laboratory:*
Robert M. Anderson, Professor of Engineering Practice and Mechanical Engineering.

10. *Number of persons on regular staff:*
Six persons.

11. *Brief general description:*
The hydraulic apparatus is among the equipment in the Carnegie Laboratory of Engineering, a three-story brick building of 18,000 square feet total floor space.

12. *Research:*
Doctors J. E. Denton and D. S. Jacobus made a number of investigations on centrifugal pumps and hydraulic motors, the results of which have been accepted as standard.

Information furnished by Robert M. Anderson, Department of Mechanical Engineering.

SYRACUSE UNIVERSITY

1. Syracuse University, Hydraulic Laboratory, Syracuse, New York
(L. C. Smith College of Applied Science)

4. *Head and quantity of water available for tests:*

Water supply contained in an outside reservoir 30 x 120 feet, capacity 20,000 cubic feet, adjoining the building.

5. *Principal pieces of equipment:*

Steel flume along west side of laboratory 6½ feet above floor, 4½ feet wide, 3¼ feet deep, on which are mounted 10-inch Pelton wheel and 14-inch Girard wheel, the latter of 1000 revolutions per minute under 220 feet head.

Near north end of flume is vertical open concrete wheel pit 4½ feet x 5 feet, 10 inches x 10 feet extending through to second floor.
In wheel pit is 10-inch mixed-flow turbine with interchangeable gates of cylinder and wicket types.

Woodward and Lombard governors for water wheels.

Weir in south end of flume.

Large concrete measuring tanks.

Steel orifice tank 5½ feet diameter, 8½ feet high.

Concrete flume 3 feet 5 inches wide, 3 feet deep along east side of laboratory; at its north end is an 8-foot steel overshot wheel; Prony brake on wheel; weir at south end of flume.

10-inch single-stage De Laval centrifugal pump, 300 cubic feet per minute, 25 feet head, driven by 25-horse-power Westinghouse variable-speed motor.

6-inch, 5-stage Morris centrifugal pump, 75 cubic feet per minute, 325 feet head.

Deane (Holyoke) duplex steam pump, 325 feet head or more—16 x 10½ x 12 inches, 150 cubic feet per minute.

Hydraulic ram.

Measuring tanks.

Venturi and other water meters.

Pitometer and current meters.

6. *Unusual equipment or facilities:*

Equipment for testing current meters and models of boats.

11. *Brief general description:*

Hydraulic laboratory occupies 92 x 50 feet on ground floor of Machinery Hall.

Information furnished by Louis Mitchell, Professor of Civil Engineering.

UNIVERSITY OF TEXAS

1. Texas, University of, Hydraulic Laboratory, Austin, Texas.
2. Established, 1904.
3. *Kinds of work for which laboratory is especially fitted:*
   Flow through orifices, short tubes, pipes, hydraulic motors.
4. *Head and quantity of water available for tests:*
   By gravity, 16 feet head.
   By pumping to standpipe, 185 feet head.
5. *Principal pieces of equipment:*
   Weirs, nozzles, pipes, rams, tanks, turbines, meters, current meters.
6. *Unusual equipment or facilities:*
   None.
7. *Possibilities for work, for or by outside persons of companies, and terms therefor:* Stream measurements, power surveys.
8. *Railroad station and siding.*
   One mile distant.
9. *Name and title of person in charge of laboratory:*
   S. P. Finch, Associate Professor of Civil Engineering.
10. *Number of persons on regular staff:*
    Three.
11. *Brief general description:*
    Room 65 by 36 feet.
12. *Research or other work of unusual importance:*
    Friction in pipes.

Information furnished by Prof. S. P. Finch.

* * *

UNITED STATES NAVAL ACADEMY

1. United States Naval Academy, Engineering Experiment Station, Annapolis, Maryland.
2. Established, 1903.
3. *Kinds of work for which laboratory is especially fitted:*
   Test of, and research work in connection with, centrifugal and reciprocating pumps, either motor- or steam-driven, in sizes up to a total power consumption of about 400 horse-power.
4. *Head and quantity of water avaliable for tests:*
   By pumping,
   Unlimited supply of brackish water.

5. *Principal pieces of equipment:*
   Complete power plant for generating and condensing about 10,000 pounds of steam per hour. Electrical generator capacity of about 500 kilowatts. Four electrical dynamometers ranging in size from 25 to 150 horsepower.

6. *Unusual equipment or facilities:*
   None, but this laboratory is unique in many respects.

7. *Possibilities for work for or by outside persons or companies and terms therefor:*
   All tests conducted at the Engineering Experiment Station must be authorized by the Bureau of Engineering, Navy Department, Washington, D. C., but they may originate in the Bureau, at the Station, or from the request of a manufacturer to have his apparatus tested for determining its suitability in the naval service. In the last case, the exhibitor must make a deposit to cover the cost of the test. The amount of this deposit is determined previous to the test. Any unexpended balance remaining at the completion of the test will be returned to the exhibitor. The use of data, obtained during tests, for advertising purposes is prohibited.

8. *Distance from railroad station or siding:*
   Shipments are received on railroad siding about one-half mile away and transferred across the Severn River to the Station by ferry.

9. *Name and title of person in charge of laboratory:*
   Captain John Halligan, Jr., U.S.N.

10. *Number of persons in regular staff:*
    4 naval officers
    3 mechanical engineers
    1 metallurgist
    1 assistant metallurgist
    1 metallographist
    2 chemists
    2 sound aids
    1 sound inspector
    2 technicists
    21 laboratorians
    22 laboratory helpers (technically trained)
    95 mechanics and laborers.

11. *Brief general description of laboratory:*
    The Station consists of one large building and three smaller ones. The larger building is divided into the "main building," extending nearly northeast and southwest, the "boiler room" extending from the middle point of the main building at right angles thereto, and several "leantos" around the boiler house. The main building is 316 feet

long and 66 feet wide and is served throughout its length by a 15-ton crane. In the northeast end of the building are the offices of the officer-in-charge of the Station, the offices of the mechanical and chemical test officers and clerks, the chemical and oil laboratories, the drawing room and library, the blue-print room, tool and store rooms and material-testing machines. In the southwest end of the "main building" are the foreman's office, the metallographic laboratory with offices for the metallographist, the machine shop, miscellaneous experimental apparatus used in the tests of steam turbines, condensers, evaporators, ejectors, and blowers, open and closed tanks, the pump trench, and the testing floor.

In the boiler room are air-compressors, condensers, heaters, pumps, two closed boiler compartments, a generator room, pattern shop, boilermaker's shop and instrument room, a Babcock & Wilcox coal-burning boiler and a Yarrow coal burning boiler. Two oil-burning boilers, one of the Mosher and one of the Colvin type, are in the closed compartments. In the generator room are provided three turbo-driven generators, a Diesel marine type oil engine, a steam-engine-driven generator, a motor-generator, a balancer set and the necessary switchboard equipment. Just outside the generator room is a complete submarine type storage battery.

The first of the three smaller buildings contains special equipment for the construction, development and testing of hydrophones and sound signaling equipment. The second is occupied by the molder, blacksmith and coppersmith, each having a well-equipped shop. The third small building is mainly used for storage purposes and for the testing of internal-combustion engines.

Information furnished by John Halligan, Jr., Captain, U. S. N., Officer-in-Charge.

* * *

WASHINGTON UNIVERSITY

1. Washington University, Hydraulic Laboratory, St. Louis, Missouri.

2. Established, 1909.

3. *Kinds of work for which laboratory is especially fitted:*
   Jet, weir and tube measurements.

4. *Head and quantity of water available for tests:*
   By pumping,
   About 30-foot head, 800 gallons per minute.

5. *Principal pieces of equipment:*
   Centrifugal pump of 800 gallons per minute capacity.
   Vertical pressure tank 10 feet high, 12 inches diameter.
   Horizontal tank, 30 x 5 x 3 feet.

6. *Unusual equipment or facilities, if any:*
   None.
7. *Possibilities for work, for or by outside persons or companies, and terms therefor:* limited.
8. *Railroad station and siding,*
   300 feet distant.
9. *Name and title of person in charge:*
   J. L. Van Ornum, Professor of Civil Engineering.
10. *Number of persons on regular staff:*
    Two.
11. *Brief general description:*
    Floor space about 40 x 10 feet.
12. *Research or other work of unusual importance which has been done:*
    Pitot tube experiments 1909-10 by E. G. Hooper.

Information furnished by Professor J. L. Van Ornum.

NOTE: *May, 1922: This laboratory is not now available for use, due to the imperative need for the space to accommodate other equipment.*

* * *

UNIVERSITY OF WISCONSIN

1. Wisconsin, University of, Hydraulic Laboratory, Madison, Wisconsin.
2. Established, 1905.
3. *Kinds of work for which laboratory is especially fitted:*
   Well equipped for almost any type of problem involving quantities of flow up to 50 or 60 cubic feet per second under heads up to 6 or 8 feet; for heads up to 30 feet with flows up to 10 second-feet; for quantities up to 500 or 600 gallons per minute under heads up to 80 or 90 pounds per square inch.
4. *Head and quantity of water available for tests:*
   By pumping,
   See No. 3.
   The laboratory is situated on the edge of Lake Mendota, which it uses as an immense storage reservoir from which water can be pumped and returned. The laboratory also has a circular concrete reservoir 50 feet in diameter and 15 feet deep which is 60 feet above the laboratory and a short distance from it. A 10-inch supply and 16-inch return pipe lead from the reservoir to the laboratory. The University pumping plant is in a building adjoining the laboratory and has four large pressure tanks which serve as equalizers. The supply and equipment of the pumping plant are available to the laboratory.
5. *Principal pieces of equipment:*
   30-inch diameter, low-head centrifugal pump direct-connected to steam engine, capacity 35,000 gallons per minute.

8-inch low-lift centrifugal pump, speed about 400 revolutions per minute, capacity 4 second-feet, lift 30 feet, direct- connected to steam engine.

8-inch Prescott centrifugal pump, speed 425 revolutions per minute, capacity 1800 gallons per minute, lift 30 feet, 30-inch bronze impeller of the inclosed type, direct-connected to steam engine.

6-inch double-suction Gould centrifugal pump, 1600 to 1800 revolutions per minute, 1100 gallons per minute capacity, lifts up to 120 feet, bronze impeller of the inclosed type; belt-connected to 50-horse-power, variable-speed, direct-current motor.

8½ x 8-inch Deming triplex pump, belt-driven from variable-speed motor.

6 x 10-inch Fairbanks-Morse duplex, double-acting, reciprocating pump, belt-driven from variable-speed motor.

30-inch James Leffel low-head water turbine.

12-inch, inclosed type, medium-head Trump turbine, arranged to be supplied through 16-inch pipe line from concrete reservoir noted above.

14-inch Girard impulse turbine.

12-inch Doble tangential water wheel.

4 x 6-inch triplex pump, belt-connected to 5-horse-power, direct-current motor.

12-inch Victor register-gate water turbine.

12-inch Smith-McCormick water turbine.

10-inch James Leffel water turbine.

Several Venturi meters, numerous weirs, tanks, scales and other weighing devices, and a complete equipment of recording and pressure gages and other small apparatus.

7. *Possibilities for work for or by outside persons or companies and terms therefor:*

Laboratory is ready to assist in the solution of problems that will be of value to the profession or public in general. If the work will not interfere with instructional or research work in progress, arrangements can be made by outside parties to have private tests made. Problems that are suitable for research and thesis study are always welcomed.

8. *Railroad station and siding:*

About one-half mile distant.

9. *Name and title of person in charge:*

Charles I. Corp, Professor of Hydraulic and Sanitary Engineering.

10. *Number of persons on regular staff:*

Five.

Information furnished by Professor Charles I. Corp.

WORCESTER POLYTECHNIC INSTITUTE

1. Worcester Polytechnic Institute, Alden Hydraulic Laboratories, Worcester, Massachusetts.

2. Established, 1895.

3. *Kinds of work for which laboratory is especially fitted:*
   Instruction and thesis work of students and original investigations.

4. *Head and quantity of water available for tests:*
   By gravity, about 30 feet head, up to 40 cubic feet per second. Institute owns entire privilege of 300-acre pond.

5. *Principal pieces of equipment:*
   Two 15-inch Hercules water wheels under 15-foot head.
   18-inch horizontal water wheel with 12-foot draft tube, under 30-foot head, about 80 horse-power.
   Several spare wheels of S. Morgan Smith Co. and Allis-Chalmers Co. design.
   15-inch Platt exciter unit with 12-foot draft tube, under 30-foot head, about 15 horse-power.
   Alden absorption dynamometer on turbine shaft.
   Turbine discharges into weir flume in basement 60 x 16 x 3.5 feet deep below crest of weir.
   Flume has smooth plank bottom, brick walls.
   10-foot standard weir with end contractions; length adjustable from 16 feet (without end contractions) to as small as desired;
   8-foot weir without end contractions, concrete walls, bronze crest, measures discharge from 15-foot head laboratory.
   Two sets hook-gage tanks;
   36-inch Pelton water wheel with small Alden dynamometer, flume and weir.
   4-inch centrifugal pump, single-stage, built by Gould Pump Co.
   4-stage centrifugal pump built by Buffalo Forge Co.
   Four kinds of water-wheel governors: Snow, Improved Holyoke, Replogle, and Lombard Type F.
   Pressure tank supplies artificial head for Pelton wheels.
   Quarter-turn rope and belt drive testing apparatus.
   Clutch and pulley testing machine.
   Set of small flumes 14 x 3 feet x 1 foot deep below weir crests, for calibrating large weir.
   Several small pumps.
   4-inch Gould hydraulic ram.
   2-inch Gould hydraulic ram.
   Cole pitometers.
   12-inch Union water meter;
   12-inch Venturi meter.

Current meters: Price, Fteley, Haskell, Ott and several special types.
50,000-pound weighing tank.

6. *Unusual equipment or facilities:*
Circular current-meter rating station, 84-foot steel boom driven by water wheel, 2-speed gear transmission and rope drive.

7. A limited amount of work can be done for outside persons or companies.

8. *Railroad station or siding.*
One-eighth mile from railroad station.

9. *Name and title of person in charge of laboratory.*
Charles M. Allen, Professor of Hydraulic Engineering.

10. *Number of persons on regular staff:*
Two or three.

11. *Brief general description:*
One-story wooden building, with basement; on 30-foot head privilege, 4000 square feet total floor space. One-story wooden building with basement, 1100 square feet floor space, on 15-foot head privilege.
40-inch riveted steel pipe 400 feet long between supply pond and building.
Piezometer rings 10 feet from either end of pipe;
36-inch Venturi meter just inside building, with recorder.

12. *Research or other work of unusual importance:*
Comparative tests of current meters. Pitometer investigations. Draft tube experiments.

Information furnished by Professor C. M. Allen by courtesy of President Ira N. Hollis.

* * *

YALE UNIVERSITY

A

1. Yale University, Sheffield Scientific School, *Winchester Hall,* New Haven, Connecticut.
(Note: In addition to equipment in Mason Laboratory)

2. Established in 1892.

3. *Kinds of work for which laboratory is especially fitted:*
Undergraduate laboratory work in hydraulics for civil engineering students.

4. *Head and quantity of water available for tests:*
Storage tank and connection to city water supply. Head available about 65 feet.

5. *Principal pieces of equipment:*
   Ordinary equipment for undergraduate work such as weirs, orifices, meters, rams, etc. Also current meters for stream gaging.

6. *Unusual equipment or facilities:*
   None.

7. *Possibilities for work for or by outside persons or companies and terms therefor:*
   Equipped to do stream gaging, and similar work.

8. *Railroad station or siding:*
   Railroad siding located at Hammond Laboratory near by.

9. *Name and title of person in charge of laboratory:*
   R. H. Suttie, Assistant Professor of Civil Engineering.

10. *Number of persons on regular staff:*
    One.

In the future there will probably be built for research work a hydraulics laboratory at the Yale Engineering Camp, East Lyme, Connecticut.

Information furnished by Professor R. H. Suttie.

* * *

YALE UNIVERSITY

B

1. Yale University, Sheffield Scientific School, Mason Laboratory of Mechanical Engineering, New Haven, Connecticut.

2. Established, 1911.

3. *Kinds of work for which laboratory is especially fitted:*
   Mechanical engineering work primarily but provided with facilities for undergraduate experiments and limited research work in hydraulics.

4. *Head and quantity of water available for tests:*
   Concrete sump and storage tanks in basement, small capacity, from which water is pumped to main floor.

5. *Principal pieces of equipment:*
   Several centrifugal and piston pumps; ordinary measuring devices for undergraduate instruction, such as weirs and Venturi meters.

6. *Unusual equipment or facilities:*
   One hydraulic pressure pump, 10,000 pounds per square inch working pressure.

7. *Possibilities for work, for or by oustide persons or companies, and terms therefor:*
   Apparatus available for outside persons or companies as far as ability permits, but no fixed schedule of terms, each case being considered individually.

8. *Railroad station and siding:*
   No railroad facilities.

9. *Name and title of person in charge of laboratory:*
   S. W. Dudley, Professor, Mechanical Engineering, in charge of experimental engineering.

10. *Number of persons on regular staff:*
    Three.

Information furnished by Professor S. W. Dudley.

OFFICERS OF ENGINEERING FOUNDATION FOR 1922

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Second Vice-Chairman	Frank B. Jewett
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J. Vipond Davies

FORMS FOR DEED OF GIFT AND BEQUEST

No. 1—Simple General Form for Deed of Gift

The United Engineering Society, a New York corporation, having established a fund known as the Engineering Foundation,

I hereby give to said United Engineering Society the sum of.....

.....Dollars ($.....),

which shall be invested and reinvested by United Engineering Society and the income thereof used by Engineering Foundation for the furtherance of research in science and engineering or for the advancement in any other manner of the profession of engineering and the good of mankind.

Witness my hand and seal at.....this

..... day of .....19....

.....

(Signature)

In the presence of:

.....

No. 2—Form for Deed of Gift with Preference for Specific Purposes

The United Engineering Society, a New York corporation, having established a fund known as the Engineering Foundation,

I hereby give to said United Engineering Society the sum of.....

.....Dollars ($.....),

which shall be invested and reinvested by United Engineering Society and the income thereof used by Engineering Foundation for the furtherance of research in science and engineering or for the advancement in any other manner of the profession of engineering and the good of mankind. It is, however, my will and desire that so long as may be advisable in the opinion of Engineering Foundation Board, said income or so much thereof as shall by said Board be deemed advisable, shall be used for the following specific purposes: .....

.....

.....

Witness my hand and seal at.....this

..... day of .....19....

.....

(Signature)

In the presence of:

.....

FORM OF BEQUEST

I give to United Engineering Society, a New York corporation, whose principal office is in the City of New York, the sum of.....Dollars ($.....), for the Engineering Foundation maintained by said society.

PUBLICATIONS

1. Report on the Origin, Foundation and Scope of the National Research Council, February, 1917.
2. A Progress Report to United Engineering Society, October, 1919.
3. Annual Report for Year ended February 10, 1921.
4. Annual Report for Year ended February 9, 1922, and Report on Fatigue of Metals.
5. Directory of Hydraulic Laboratories in United States (in preparation).

REPRINTS

1. The Mental Hygiene of Industry, March, 1920; from *Industrial Management*, February, 1920. Out of print.
2. Trade-Unionism and Temperament, April, 1920; from *Industrial Management*, April, 1920. Price, 25 cents.
3. The Modern Specialist in Unrest, June, 1920; from *Industrial Management*, June, 1920. Price, 25 cents.
4. An Improved Form of Weir for Gaging in Open Channels, May, 1920; from American Society of Mechanical Engineers, June, 1920. Price, 35 cents.

RESEARCH NARRATIVES

In January, 1921, the semi-monthly publication was begun of a series of leaflets, each containing the story of some research or discovery or notable achievement in science or engineering, briefly told. There have been printed to date:

Number and Title	*Contributor or Source of Information*
1. Isolated Research: Its Handicaps. The Story of Mendelism.	Prof. A. E. Kennelly, Harvard University and Massachusetts Institute of Technology.
2. Fatigue of Metals: A Story of Co-operation.	Prof. H. F. Moore, Engineering Experiment Station, University of Illinois.
3. Utilizing Low-Grade Ores: An Iron Story.	W. G. Swart, Mining and Metallurgical Engineer, Duluth, Minn.
4. Electric Welding: From Lecture Room to Industry.	Dr. Elihu Thomson, Consulting Engineer, General Electric Co., Lynn, Mass.
5. Early Uses of Nickel: The Accidental Element in Research.	A. J. Wadhams, Assistant General Superintendent, International Nickel Company, Bayonne, N. J.
6. An Ammonia Gas Story: A Simple Solution of a Safety Problem.	Prof. Edward F. Miller, Massachusetts Institute of Technology.
7. Making Explosions Beneficial: Research as a Sociological Factor.	H. W. Jordan, Research Chemist, Semet-Solvay Company, Syracuse, N. Y.
8. The Ruggles Orientator: A Device for Ground Training of Aviators.	Captain Lloyd N. Scott, formerly Liaison Officer to Naval Consulting Board and Secretary, War Committee of Technical Societies.
9. The Centrifugal Creamer: From Laboratory to Factory and Farm.	Dr. Elihu Thomson.
10. Nitrogen: Its Capture and Utilization.	Various sources.

Number and Title	*Contributor or Source of Information*
11. Light in Water: Total Reflection by Animalcules.	Captain Lloyd N. Scott.
12. Thermionics: The Movement of Electricity Under Influence of High Temperature in Vacua.	Dr. D. W. Wilson, Western Electric Company.
13. Radioactivity: New Conceptions of the Constitution of Matter.	Dr. Willis R. Whitney, Director, Research Laboratory, General Electric Company, and Prof. Frederick Soddy on "The Interpretation of Radium and the Structure of the Atom."
14. Wrought Tungsten: A Reward of Many Years Spent in Scientific Research.	Dr. Irving Langmuir, Research Laboratory, General Electric Company.
15. The Gas-Filled Incandescent Lamp: A Product of Continued Search for Higher Efficiency.	Dr. Irving Langmuir.
16. Radium: A Substance so Powerful That One Three-thousand-millionth of a Grain Can Be Identified Easily.	Dr. R. B. Moore, Chief Chemist, United States Bureau of Mines.
17. Helium: One of the Rare Gases of the Atmosphere—Helium, Neon, Argon, Krypton and Xenon.	Dr. R. B. Moore.
18. Direction by Two Ears: Saving Ships by Hearing Magnified Underwater Sounds. Another Example of Results Won by Cooperation.	Dr. Robert A. Millikan, California Institute of Technology.
19. Whittling Iron: Some Irons Are Softened by Saline, Acidulous and Alkaline Waters.	Various sources.
20. Maleic and Fumaric Acids: Discovery of Catalytic Oxidation of Coal Tar Products.	Dr. J. M. Weiss, Manager, Research Department, The Barrett Company.
21. Separating Minerals by Floating: A Metallurgical Process Discovered by a Woman.	Various sources.
22. American Optical Glass: Science Superior to Tradition and Trade Secrets.	Harrison E. Howe, in *The New World of Science,* edited by Dr. Robert M. Yerkes.
23. American Glass for Safety: Achievements of the Collaboration of Science with Industry.	Eugene C. Sullivan, Vice-President, Corning Glass Works.
24. Glassware and Warfare: Industrial Benefits Salvaged from War's Necessities.	Eugene C. Sullivan.
25. Measurement of Illumination: A Defense for Human Eyes.	Dr. Clayton H. Sharp, Technical Director, Electrical Testing Laboratories, New York.
26. Outwitting the Marine Borers: Mighty Destroyers of Wooden Marine Structures.	Prof. C. A. Kofoid, University of California, member of San Francisco Bay Marine Piling Committee.
27. Tight Flexible Joints for Submarine Pipes: A Water Supply Problem.	Alfred D. Flinn, formerly Deputy Chief Engineer, Catskill Aqueduct.

Number and Title	*Contributor or Source of Information*
28. A Serbian Herdsman's Contribution to Telephony: An Example of the Inborn Spirit of Research.	Dr. M. I. Pupin.
29. An Early Rotary Electrical Converter: The Solution of a Welding Problem.	Dr. Hermann Lemp.
30. What Matter is Made of: A Modern Conception.	Dr. W. R. Whitney.
31. Teredos and Tunnels: One of Nature's Engineering Suggestions.	B. H. M. Hewett, of Jacobs & Davies, Consulting Engineers, New York, N. Y.
32. A Farmer's Phenological Records: A Tale of Remarkable Individual Research with a Sad Sequel of Loss Due to Isolation.	Robert E. Horton, Consulting Hydraulic Engineer, Voorheesville, N. Y.
33. The Naval Tortoise Shell: Development of the Defensive Element of Warships.	Dr. Hermann Lemp.
34. Compressed Air for Underwater Construction: A Means for Making Practicable Many Difficult Foundations and Tunnels.	B. H. M. Hewett.
35. The Discovery of Manganese Steel: Its Metallurgical Paradoxes.	Henry D. Hibbard, Consulting Engineer, Plainfield, N. J.
36. A Story of Velox: Overcoming Difficulties by Research and Perseverance.	Dr. Leo H. Baekeland.
37. Pattern-Shop Research: Early Development of Hydraulic Turbines.	Robert E. Horton.
38. Smelting Titaniferous Iron Ore: Prospector and Researcher.	W. M. Goodwin, Editor *Canadian Mining Journal,* Gardenvale, P. Q.
39. The Birth of Bakelite; Its Growth: An Adventure with Synthetic Resins.	Dr. Leo H. Baekeland.
40. Palladium: Danger in Discrediting the Unlikely.	G. Gore, in "The Art of Scientific Discovery."