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HYDRAULIC LABORATORIES IN EUROPE

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Introduction

As a traveling Freeman scholar during 1955, visits were made to as many European laboratories as the time allotted would allow. Laboratories were visited in France, Italy, Switzerland, Germany, Belgium, Netherlands, Denmark, Sweden, Norway, Scotland and England. The total number of university laboratories seen was 56, while 8 of a governmental nature and 16 under private sponsorship were contacted.

The principal interest was on Hydraulic Laboratories but several facilities concerned with research in allied fields were seen when some particular work or interest was indicated.

In all the countries the reaction was most cordial and information was given freely by the staff members. The descriptions of the laboratories are a combination of data supplied by the activities plus notes and excerpts from conversation and it should be pointed out that with short visits and some language difficulty, there may be inaccuracies in the detailed information as presented.

In retrospect the inspection of these laboratories was an unparalleled opportunity for the author who wishes to express his appreciation to the Freeman Fund Committee of the Boston Society of Civil Engineers and the Alden Hydraulic Laboratory of Worcester Polytechnic Institute for making the opportunity possible.

A detailed description of each of the laboratories visited is on

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file with the Boston Society of Civil Engineers. Since the detailed report could not be published in its entirety, an abbreviated summary is herewith presented. In the case of each laboratory a specific piece of equipment or activity has been described. In several cases the item described is not the most important or more representative but because it seemed unique or filled a particular need representing unusual thought and initiative.

Italy

In Italy, university hydraulic laboratories were visited in Pisa, Roma, Naples, Bologna, Padua and Milan as well as the machinery laboratory at the Riva plant in Milan.

Pisa

At Pisa, the laboratory under Professor Ruggiero was devoted to basic research and student instruction. A glass-sided steel framed, tilting flume was used for both basic research and instruction. The flume was ½ meter by ½ meter and 8 meters long and could be tilted from —10° to 10° by a manually operated screw jack. The supply from the laboratory constant head tank was in 20-centimeter diameter pipe with flow measurement by a venturi meter. For a refinement on the alignment and smoothness of the flume floor, the flume was set at 0° and a plastic base was flowed on the floor and allowed to set.

Rome

The hydraulic laboratory at the University of Rome was directed by Professor DiRicco and was concerned mainly with student instruction.

A concrete flume 5 meters wide by 18 meters long and 0.50 meters deep was set up to study the mechanics and origin of meandering flow in natural streams. Flow measurements can be made at either end of the flume by volumetric tank or V-notch weir. Different sizes, weights and mixtures of bed material could be used.

Naples

At the University of Naples, the Hydraulics Department was under the supervision of Professor Ippolito while Professor M. Viparelli handled the work of the Hydraulics Laboratory. The laboratory had a wide range of interest and activity with about equal space

devoted to student or basic work and the sponsored type of research. For use in the basic program, there was a sloping flume extending from one room to a room on the floor below. The flume was constructed of wood and concrete and was 0.2 meters wide with walls 0.1 meters high and inside surfaces of smooth concrete. Located on steel guides was a pitot type sampling device which takes air or water or various mixtures of air and water to be separated and analysed.

Bologna

In Bologna, two laboratories were visited. The laboratory under Professor Evangelisti was concerned with Hydraulic Construction. The principal piece of test equipment was a steel frame tilting flume 0.5 meters wide by 0.8 meters deep and 17 meters long, with glass panelling on both sides for the entire length. It was supported on two sets of jacks interconnected and driven electrically to maintain alignment over the range of angles. The floor of the flume was machined to give a smooth, straight surface and the head box is attached permanently to the flume so that there is no seal difficulty at the joint between head box and flume with the transition maintained at an optimum design.

The Hydraulics Laboratory under Professor Supino, at Bologna, was concerned with the elementary hydraulics as well as some basic research and outside consulting. The flow meter calibration arrangement in the laboratory was set up to accommodate meters from industry as well as the laboratory meters. The three pipe lines (4″, 8″ and 12″ diameter), leading to the volumetric tank were arranged with a single standard manometer setup. The switching arrangement located just downstream of the nozzle consists of a steel vane which was operated by an electric motor and a heavy fly-wheel. A timing device and an automatic time recorder was connected into the switching device. The volumetric tank had a capacity of 10 cubic meters.

Padua

The hydraulic laboratory at the University of Padua was under the direction of Professor Marzolo, but acting director Professor Ghetti conducted the tour of the facilities. The equipment at the laboratory was largely constructed by the staff of the laboratory and the pieces exhibited the ingenuity of the group in the simplicity and effectiveness in operation. A sample was a surge tank study made

up with simple steel pipe, a plexiglass side surge tank and glass tube manometers, all supplied from the laboratory mains.

At the Hydraulic Machinery Laboratory of Professor Medici, the variety of test stands for all the standard types of turbine and pump as well as a number of basic experiments amounted to the largest array of machinery test equipment seen in Italy.

The Maritime Construction Laboratory under Professor Ferro had a large concrete flume with one glass side that was 1 meter wide by 1.2 meters deep and 30 meters long. A vane type wave maker was installed at one end and a rail mounted on the walls for supporting a travelling carriage.

Milan

At Milan, the Institute for Hydraulics and Hydraulic Construction was under the direction of Professor diMarchi. The laboratory has pioneered in many areas over the years. Apparatus was set up at the time of the visit to study the performance of model syphons both to relate the data to a full scale problem and to models of different scale in order to determine the scaling laws for syphons. The models were plastic so that observations and photographs could be made during the tests.

The Industrial Machinery Laboratory of the Riva Company in Milan was outstanding in that the philosophy in arrangement of equipment was to have all the pieces as mobile as possible. This meant that for all the different test equipment, only the heaviest pieces are fixed, thus assuring a maximum of flexibility.

France

In France, University Laboratories were visited in Toulouse, Grenoble and Lille, while other laboratories, both private and government were seen in Grenoble and Paris.

Toulouse

At Toulouse, Professor Escande had developed a laboratory and staff that had many interests in the field of Hydraulics. One model study on transient flow phenomena included a 25 cm. pipe 30 meters long attached to a trapezoidal flume 60 meters long. The transmission of pressure waves from flow changes in the pipe into the open channel was being studied.

Grenoble

At Grenoble, the Hydraulics Laboratory under the direction of Professor Kravchenko had a program of student instruction and basic research. One research project was a study of the mixing process between concentric jets. The apparatus was arranged with the primary flow in the center section of the test area, and the secondary flow discharging around the primary. The test section was approximately 5 centimeters high by 40 centimeters wide and 1 meter long. The primary flow was a jet discharging under a 5-meter head while the secondary jet discharged under a head of about 0.5 meters. Either discharge could be varied and the resulting flow pattern analysed and photographed with the aid of suspended aluminum dust.

Grenoble—S.O.G.R.E.A.T.H.

At Grenoble, the Laboratory of the S.O.G.R.E.A.T.H. under the direction of Professor Danel is the largest laboratory visited. The problems studied by the capable staff cover the hydraulic machinery, hydraulic structures, irrigation, instrumentation and materials transport fields. A feature of the laboratory supplementing all of these sections was the technical library. This fine effort was the most complete collection of works on hydraulics and allied fields known and was arranged in a unique and seeming more workable form than the average technical library.

Paris

The laboratory of the Electricite de France at Chatou was under the direction of M. Gridel. The laboratory was concerned with the hydraulic problems of the Electricite de France and other governmental agencies. A method of studying and recording the motion of the water surface in harbour models was called the "Starry Sky" method. This involved the use of a large grid of small electric light bulbs mounted over the model. The reflection of the grid on the water's surface was photographed as a time exposure. The trace of particles over the entire area was recorded and could be studied in detail.

Under the direction of Dr. Laurent, the Laboratoire Centrale d'Hydraulique at Mason-Alfort was devoted largely to coastal hydraulics. The laboratory in working on a particular problem did not rely on available data for model reproduction or justification but in-

stead specialized in sending groups into the field to obtain the data that would be used in the model studies which resulted in an unusual continuity in the work.

Lille

At Lille, Professor Martinot-LaGarde had a laboratory in which the sponsored research was devoted in large part to the aeronautical industry. However, a wide variety and large number of experiments were demonstrations of fundamental phenomena aimed at undergraduate instruction. These varied from simple parlor tricks to a variable throat supersonic tunnel. One experiment demonstrating the theory of probability was a simple pinball machine.

SWITZERLAND

In Switzerland, laboratories of the university type were visited in Lausanne and Zurich, while commercial laboratories were in Geneva, Zurich and Winterthur.

Lausanne

At the University of Lausanne, the laboratory under the direction of Professor Stucky was visited, accompanied by his two assistants, Professor Bonnard and Mr. Gardel. In addition to a considerable amount of space within the laboratory devoted to student instruction and to sponsored research there was an interesting installation on the roof of the laboratory. A 150 meter length of pipe was set up to represent a penstock and tunnel system in a hydroelectric scheme. This pipe was connected to model surge tanks within the laboratory. Electronic recording equipment was used to study the operation of various types of surge tank design.

The Machinery Laboratory at Lausanne contained the usual test stands for Kaplan, Francis and Pelton models. In addition a small demonstration stand of a Kaplan runner was in operation. A plexiglass window in the side of a flume allowed observation of the 5-centimeter runner operating under a head of about 25 centimeters. The intake structure, pivot gates and vertical draft tube were included. The water was circulated by a small pump located under the bench of the test stand.

Zurich

At the Technical High School in Zurich, the Civil Engineering Hydraulic Laboratory was under the direction of Professor Schnitter. A large amount of space in the laboratory was devoted to development work for design purposes. However, there were a number of student experiments set up, among which was an interesting test on a chute spillway. The students were able to measure flows, velocities and depths over the entire model. After the data was compiled a second model of the same structure but one-quarter the size of the first was studied. The students were able to get a feeling for model work and some of the limits and advantages thereof.

The Hydraulic Machinery Laboratory was under direction of Professor Gerber, and the entire laboratory was devoted to student instruction. Most of the pieces of equipment represented the common pieces of equipment seen in the hydraulic machinery field. A pair of Kaplan test stands were mounted parallel to one another. Each was set up with head tank, runner, elbow draft tube and DC motor drive. The head tanks at either side of the units were interconnected. Thus it was possible to set up a simple turbine test or a pump turbine arrangement by using both units.

Geneva

The visit to the Atelier Charmilles in Geneva came at an unfortunate time since the old laboratory was being dismantled to be moved into a new building under construction. Although some of the old equipment was in place, it was not operative. It was indicated however, that in addition to the test stands using water for complete turbine models; tests of various sections or parts of turbines were made in air and two dimensional flow studies were also used.

Zurich

The Escher-Wyss Company in Zurich included in its machinery laboratory a new cavitation test stand. In this test stand it was possible to include the complete installation including the intake structure and the draft tube in addition to a runner up to 250 to 300 centimeters in diameter. At the operator's console it was possible to view the runner and the area just below the runner by means of a series of prisms and mirrors. The operator controlled the complete operation of the test stand and also could make all the necessary measurements.

Winterthur

At the Sulzer Brothers Laboratory in Winterthur, the emphasis was on pump testing and at the time of the visit the laboratory was devoted to the work requested by the production department. This situation was to be changed in the near future when a new laboratory will be constructed at some distance from the plant and it will be possible to perform research of a long range type. The routine testing will continue in the present laboratory facilities.

GERMANY

In Germany, university laboratories were visited in Munich, Stuttgart, Karlsruhe, Aachen, Darmstadt, Hannover, Braunschweig, Gottingen and Hamburg. Commercial laboratories were visited in Heidenheim, Hannover and Gustavsburg.

Munich

At Munich the Aerodynamics Laboratory of Professor Kaufmann was working on analysis of the boundary layer. Equipment was limited to two wind tunnels while other new facilities and in particular instruments were being developed and produced.

The Hydraulic Machinery Laboratory of Professor Hahn was also rebuilding after the war damage. In the plan for the new laboratory was a cavitation test stand and a Pelton wheel test stand to supplement the Kaplan wheel and Francis test stands already in place.

The Civil Engineering Hydraulic Laboratory which was under the direction of Professor Flierl, was in the process of being moved to another building and therefore not in condition to show equipment and apparatus.

Stuttgart

At Stuttgart, the Hydraulic Machinery Laboratory of Professor Hutarew was in a new building with new equipment. The individual pieces to make a machinery laboratory effective were all present. The six concrete volumetric tanks located below the ground floor had a total capacity of 360 cubic meters. The tanks were all interconnected for regulating or measuring flow. Two of the tanks were set up with a switchway for volumetric tests. All six may be operated singly or in parallel or in series as pairs or all together.

The Gas Dynamics Laboratory of Professor Weise is located about 11 kilometers outside the city of Stuttgart. The theme of this laboratory was to produce results in spite of a minimum of special equipment other than that fabricated within the laboratory. The work was basic with at least six major projects under way.

Karlsruhe

At Karlsruhe, the Theodor Rehbock Laboratory was under the direction of Professor Wittman. A new building to house the river models had been constructed having a clear area of 25 meters by 62 meters. The building had radiant heating to reduce air currents that might influence river model results. The water supply was arranged to give a maximum of flexibility to the system with three independent pumped supplies of 500 liters per second.

The Hydromechanics Laboratory under the direction of Professor Boss had been working in the field of water supply and its allied interests. At the time of the visit a conical separator to remove the bed load material from the normal flow of a mountain stream was under test. The material in the bed of the stream was carried through the rotating separator and discharged into the stream below, thus maintaining the normal bed load conditions.

The Hydraulic Machinery Laboratory at Karlsruhe is under the direction of Professor Dickmann. The principal piece of equipment in this laboratory was the turbine test stand for both the Kaplan and Francis types of runner. The test stand was arranged with a few water surface at the intake and outlet of the model so that no vibrations or disturbances, from the pumps located at either end could be transmitted to the test unit. The stand was capable of performing cavitation test work.

Darmstadt

At Darmstadt, Professor Detig indicated that the laboratory had been completely destroyed and was just being re-constructed. The new laboratory will be located in a new setting with all new equipment.

Aachen

In Aachen, Professor Buntru was also in the process of reconstructing the Hydraulics Laboratory. The building now under construction will be occupied for about five years. At the end of that

time it is expected that the new Mechanical Engineering building will be completed and the laboratory will be installed in the new building thus leaving the other building.

The Aerodynamics Laboratory under Professor Seewald was interested mainly in supersonic flow. Among the studies being carried on was a spectrum analysis of the Karman vortex trails using a Schlerin optical system and color film to show the variation in density in the trails.

Hannover

At Hannover, the Franzius Institute was under the direction of Professor Hensen. An outdoor model of the Elbe River was under test at the time of the visit. The tide cycle was controlled by a rotating drum on which the tide cycle was formed by an angle offset from the drum. A pair of limit switches to follow either side of the angle were attached to a float and electrically connected to the motor-operated gate to follow the tidal variations. In order to protect this model from the elements a tent of translucent plastic had been erected on a steel tube frame to give a light yet inexpensive covering.

Braunschweig

At Braunschweig, Professor Zimmerman was interested mainly in the irrigation aspects of hydraulics. In this connection a cooperative venture with one of the forward looking farmers in the area was underway with an experimental station on the farm. A laboratory building in the city housed the river model and other types of experimental flow equipment.

The Fluid Machinery Laboratory of Professor Petermann was set up near the power station for the Technical University and had only limited space set aside for experimental work. There was a cavitation test stand set up to study axial flow pumps up to 200 millimeters in diameter. The section in which the pump would normally be installed for test was easily removed for alteration and inspection.

The Aerodynamics Laboratory under the direction of Professor Schlicting was being rebuilt in a new university building and would in the future be dealing mainly with problems in the supersonic flow range.

Gottingen

At the Max Planck Institute for Flow Research in Gottingen, the work under Professor Tollmien is being concentrated in the super-

sonic range. Also much attention is being given to the design and study of high speed rotary machinery. At the time of the visit, experimental work was in progress on a compressor operating at 50,000 RPM with a rotor only 6 centimeters in diameter, yet developing over 200 HP.

Hamburg

The Institut for Schiffbau at the University of Hamburg under Professor Weinblum was largely interested in ship design problems. A small wind tunnel was driven by a 30 HP motor and had a slotted test section about 1 meter in diameter and 3 meters long. The slots could be varied in position and shape along the centerline to give different velocity profiles in the throat of the tunnel.

Heidenheim

The Hydraulic Laboratory of the J. M. Voith Company in Heidenheim is under the direction of Dr. Dziallars. The water supply at the laboratory was from a spring close to the laboratory that discharges at a rate of about 0.2 cubic meters per second. The water was pumped into a reservoir located on a hill nearby to give a constant head at the laboratory of approximately 68 meters. This supply was used to operate various tests throughout the laboratory and in addition was used in a unique way to regulate pump speed and flow on a test stand. The pump was driven by a turbine which was in turn driven by the water under the reservoir head. Thus by regulating the turbine operation, the pump was controlled over a wide range of speeds.

Gustavsburg

The Hydraulic Laboratory of the Machinenfabrik Augsburg-Nurnberg (M.A.N.) was set up primarily to test hydraulic control structures. The main piece of equipment was a flume 25 meters long by 4.5 meters wide and 1.4 meters deep with glass side panels at various sections along its length. A maximum discharge of 1 meter was measured by a bank of 4 V-notch weirs that were used to give a wide range of discharges.

NETHERLANDS

Delft

The Hydraulic Laboratory in Delft, Holland, under the direction of Professor Thijsse was concerned mainly with the reclamation

projects of the Netherlands. A flume about 50 meters by 4 meters by 0.4 meters deep was set up to study waves generated by the wind. This was accomplished by surrounding this flume with a wind tunnel set up in a vertical plane with the return circuit of the wind tunnel mounted above the flume test section. Wind velocities over the water surface up to 20 meters per second were possible.

The Mineral Technological Institute under the direction of Mr. Van der Gaag was devoted to research concerned with the operation and improvement of dredging equipment. The laboratory was sponsored by the dredge manufacturers of Holland. Several flumes are set up with glass walls so that data can be taken by direct observation or by photographic means.

Belgium

In Belgium, University Laboratory visits were made in Ghent and Liege while the State Laboratory in Antwerp was also seen.

Ghent

The laboratory at Ghent was under the direction of Professor Tison. The supply system in the laboratory included three pipes about 15 centimeters in diameter which ran the entire length of the laboratory (50 meters). In these pipe lines it was possible to mount various fittings representing pipe connections such as contractions and expansions, which could be placed in the line to allow the students to measure the different types of head loss. A volumetric tank was used to measure the flows.

Liege

The Hydraulic Laboratory at the University of Liege was under the direction of Professor Schlag and was concerned with basic work on flow meter design and with student instruction. Along this line there were a number of two-dimensional flumes in which flow pattern around objects could be developed and studied using dye and floating particles. It was indicated that these studies had been used to guide several design problems.

The Laboratoire d'Hydraulique Fluvial under the direction of Professor Campus was in the process of being completely revamped with about 100% more room than previously but no equipment was in place and no test work underway.

Antwerp

The Hydraulic Laboratory for the Department of Bridges and Roads in Antwerp under the direction of Dr. Lamoen was located in several large buildings in Antwerp. A fine new laboratory hall for river models was being completed at the time of the visit. The hall had an area of 100 meters by 50 meters with a clear span. It will be possible to have a measured flow of 3 cubic meters across a single river model. An elaborate electrical programming system will allow a total of 200 single events to be programmed through the models automatically.

DENMARK

Copenhagen

The only laboratory visited in Denmark was at the University of Copenhagen under the direction of Professor Bretting. In the office area of the laboratory was a small tilting flume 1 meter long by 10 centimeters wide and 25 centimeters deep to be used for demonstrations. The flume is made up with a steel frame and glass sides with a separate sump and supply pump attached.

SWEDEN

In Sweden, university laboratories were visited in Goteborg and Stockholm, as well as the commercial laboratory at Kristinehamn and government laboratory at Alvkarleby.

Goteborg

The Hydraulics Laboratory at the Chalmers Technical High School in Goteborg under the direction of Professor Erling Reinius had a unique flume constructed at the laboratory. The flume was constructed using precast concrete bents at each panel joint. The bents were made in the form of an "H" with the lower arms of the "H" used as legs and the upper loop used to support the sides and floor of the flume. The sides for most of the length were constructed of glass and the floor was of reinforced concrete. The flume is 15 meters long by 60 centimeters wide by 80 centimeters deep. A steel channel was placed at the top to act as a rail and to stiffen the entire flume.

Stockholm

At the Royal Technical High School in Stockholm, the Hydraulics Laboratory was under the direction of Professor Hellstrom. The

laboratory was in the process of being enlarged so that not much was going on at the time of the visit. Professor Hellstrom did have an interesting series of tests under way to determine the effect of various materials, shapes and surfaces on the amount of dew which would be collected in a given time. This would be particularly important to the desert areas of the world.

Alvkarleby

At Alvkarleby, the Swedish State Power Board maintains a Hydraulic Laboratory under the direction of Mr. Angelin. An interesting feature of the work at this laboratory was the preparations for model study in the laboratory. In most cases a river model study was preceded by a small scale model of the area to determine the limits which the larger model should encompass when constructed. This procedure assured the staff that the model will cover the proper reach to provide the necessary design and operating data.

Kristinehamn

The Hydraulic Machinery Laboratory of the WKM Company located at Kristinehamn. In addition to the standard test flumes for turbines and a water tunnel for ships' propellers there was a small flume set aside for exploratory tests. This flume was about 3 meters long and 50 centimeters wide and 50 centimeters deep. In this flume it was possible to test in particular the intake structures of hydraulic turbines. It was indicated that in some cases designs by customers were tested whether or not the tests were requested just to be sure that no improvement in wheel operation was to be gained by changes to the intake.

Norway

Trondheim

In Trondheim three laboratories were visited including the Hydraulic Machinery Laboratory and Civil Engineering Laboratory of the Technical High School and the Ship Model Towing Tank which was connected to the Technical High School.

The Hydraulic Machinery Laboratory under Professor Alming includes the usual machinery test stands, supplied from an excellent system. A "U" shaped channel 1 meter by 1.5 meters in cross section located in the attic and along three walls of the laboratory building, was supplied by a 450 liter pump operating under a head of 15 meters. This channel discharged into a pipe loop 40 centimeters in

diameter located approximately a meter under the channel. In addition for the low head tests a 1.2 cubic meter pump operating under a head of 4.2 meters was available.

At the Ship Model Towing Tank a water tunnel was set up with a test section 20 centimeters in diameter. This tunnel had a maximum velocity of 10 meters per second and was driven by a 10 HP pump. The tunnel while being used as a test facility was also a model of a 1.5 meter diameter tunnel in the design stages at the time of the visit.

The Civil Engineering Hydraulics Laboratory under Professor Vidcum was in the process of being moved into a new building and not much in the way of equipment or tests was available at the time of the visit.

SCOTLAND

In Scotland, university laboratories were visited at Dundee, Aberdeen and Glasgow. While the Mechanical Engineering Research Laboratories at East Kilbride were also visited.

Dundee

At Dundee the Mechanical Engineering Department is under the direction of Professor Dick. A study of velocity distribution in turbulent flow was under way at the laboratory. A small plexiglass flume was arranged with a microscope mounted above the flume and a high intensity light beam directed into the flume at right angles to the line of sight. Because of the critical focus of the microscope only a 1/1000 inch thick layer was in focus. By interrupting the line of sight the particles of dirt in the water reflected as streaks of light and the length of the streaks indicated velocity and the direction of the flow at a particular instant.

Aberdeen

In Professor Allen's laboratory at Aberdeen, a tilting flume was set up for various types of research and demonstration. The flume was arranged with an aluminum frame in which were mounted perspex panels for the sides and floor. The flume was 30 feet long by 1 foot deep by 8 inches wide and was supported at each end and at the center point. The maximum slope was 14 inches difference in elevation between ends. A wave generator was built into the intake box.

Glasgow

The Department of Aeronautics and Fluid Mechanics at the University of Glasgow was under the direction of Professor Duncan while the hydraulics was the immediate concern of Dr. Thom. The laboratory was devoted mainly to student instruction and demonstrations. There were a number of tests including one in a flume 10 feet long by 5 inches by 5 inches, for measurement of rift and drag on an airfoil shape. This device consisted of a simple balance mounted on knife edges in a frame clamped to the top edges of the flume. The test shape was mounted on the end of a simple strut so that it was immersed in the flowing water of the flume. The shape was counterbalanced by a weight on the opposite end of the strut and the drag or lift was measured by adding weight to a calibrated beam.

East Kilbride

At the Mechanical Engineering Research Laboratory in East Kilbride under the overall direction of Dr. Sopwith, the Fluid Mechanics section was headed by Dr. Hutton. There were many impressive pieces of new apparatus in this laboratory. Perhaps the most impressive was the cavitation test stand which would accommodate model runners up to 20 inches in diameter, operating at heads up to 200 feet and up to 250 horsepower. The maximum flow was 48 cubic feet per second from either an axial flow or centrifugal pump. A 60 foot re-absorber is located below ground level to maintain a proper air content in the water. It is possible to include in addition to the model turbine, a model intake and an elbow draft tube under the turbine.

ENGLAND

In England, university laboratories were visited in Durham (Newcastle-on-Tyne), Manchester, Cambridge and Imperial College in London. The Hydraulics Research Station at Wallingford, the English Electric Company Laboratory at Rugby and the British Hydromechanics Research Association at Harlow were also visited.

Durham

The Hydraulic Machinery Laboratory at Newcastle-on-Tyne was under the direction of Professor Burrill, and was primarily interested in ship and propeller design. A towing tank and a water tunnel were the two primary pieces of equipment in the laboratory. A

recent development at the laboratory was the technique of casting clear transparent plastic models of ships. With these models it was possible under correct lighting and photographic treatment to accurately plot the wave formation around the hull of a towed model.

The Hydraulics Laboratory was under the direction of Professor Burstall. The laboratory was devoted to student instruction. A series of test setups were maintained including a model Venturi flume in plexiglass to show the hydraulic gradient for various flows. Pressure taps along the profile allowed the students to analyze the pressure distribution.

Manchester

At Manchester University the Hydraulic Laboratory under the direction of Professor Mathieson was set up for student instruction. A water hammer demonstration in a 2″ pipe with a model surge tank upstream of a quick-acting valve was operated by the students. The size of the opening into the surge tank could be varied to study the effect of the different losses at this point in a hydraulic system. The head measurements were made with a pressure gage mounted on the pipe and the supply was direct from the 110 foot head supply of the laboratory.

Cambridge

At Cambridge, the Fluid Mechanics Laboratory under Mr. Binnie was concerned mainly with student instruction. A total of 14 test setups were available to the undergraduate student. For each test a set of complete instructions was available and the students were allowed to elect an average of 6 of these tests during the course. Certain afternoons are set aside when these tests can be performed during the terms. In addition, there were several basic projects under way at the time of the visit.

At the Cavendish Laboratories in Cambridge, under the direction of Sir Geoffrey Taylor, a number of studies concerning the mixing of liquids of different densities were under way. The apparatus for these tests was all simple yet being used in a most effective manner.

London

At Imperial College in London, the Hawksley Hydraulic Laboratory is under the direction of Professor White. A number of demon-

stration flumes are set up to give the students opportunities to see and study flow phenomena. In addition, there was a tilting flume with a steel frame and glass sides and floor 40 feet long by 1 foot wide and 1 foot deep. The flume was mounted on notched wheels that run on steel wedges set so that the shift in weight as the flume is raised or lowered is automatically taken up and adjusted. The alignment of this flume stays within 0.002 inches over the range of slopes.

Rugby

In the Hydraulic Machinery Laboratory of the English Electric Company at Rugby, there were at least six different test stands for turbines and pump models ranging in size up to 450 HP. In addition, there were three test stands set up to run tests of components of various machines in air. This allowed a more detailed study of a particular vane or strut than would be possible in the water filled test stands.

Wallingford

The Hydraulics Research Station at Wallingford under the direction of Sir Claude Inglis was the Civil Engineering counterpart of the M.E.R.L. at East Kilbride. In addition to a large area devoted to river models and allied open channel work the laboratory had an active instrumentation group. Among the products of this group was a current meter ¾ inch in diameter that depended upon the capacitance principle to indicate velocities under 0.1 feet per second.

Harlow

The Hydraulics Laboratory of the British Hydromechanics Research Association was under the direction of Mr. Prosser. The laboratory was sponsored by industrial members of the association and was available to any group for the study of a wide range of flow problems. At the time of the visit the prime interest was in the transport of solids by fluid flow. In addition to the research work at the station, the staff of the laboratory produces a bulletin every two months carrying reviews of a large number of papers on pertinent fluid flow subjects. In addition, the staff has been responsible for the translation of a number of papers printed in other languages.

SUMMARY

At most of the laboratories the visits lasted only a day or two. In such a short time it was difficult to evaluate reliably the potential of a laboratory. However, after the visits, several overall conclusions were apparent without trying to make comparisons between individual installations.

1. The general caliber of work on basic research in the laboratories visited was at a high level.
2. There was a minimum of electronic equipment in use in the laboratories.
3. The student participation in laboratory experiments for instruction purposes was limited even in laboratories set up solely for student instruction.
4. The classroom instruction load on the teaching staffs at the university laboratories was high.
5. Co-ordination and exchange of ideas from one country to another was good in spite of national and language differences.
6. The approach to problems, as in any laboratory, reflect the attitudes and interest of the director, in particular, and his staff.

The interest and activity on basic research in a majority of the laboratories was at a high level. It would appear also that the caliber of the work going on in this field was good. The variety of detailed projects reflects the varied interests and in many cases needs of the particular area or country.

The equipment in use in the laboratories was of good quality, particularly the apparatus that lent itself to fabrication by the laboratory staff. In general, there seems to be a minimum or even a lack of good electronic test equipment and the necessary personnel to operate and maintain such equipment.

The coordination and exchange of ideas between laboratories on both the national and international level was fair to good. The facility with which most technical personnel handle several languages aided greatly in this interchange.

Undergraduate student participation in laboratory programs either for instruction or research was limited to a small percentage. A majority of the university laboratories have only limited demon-

strations for students with no actual handling of equipment by these students.

The instruction load of most university staffs was heavy. The personnel were carrying a full time teaching load in many cases and had to make extra time available for either the basic or sponsored research.

The industrial and governmental laboratories were well staffed and equipped but in general did not have the desired amount of electronic apparatus and trained personnel. These laboratories were contributing a substantial amount of basic research in addition to work in their own fields of interest.

In the industrial laboratories a change in basic policy seemed to be underway. These laboratories indicated that the routine shop test work should be separated from the forward looking research leading to new design. In many cases this means a complete new building and a separate staff to man the laboratory.