

VISITATION OF
FOREIGN HYDRAULIC LABORATORIES,
SUMMER, 1966
(Revised Spring 1968)

by

Hsieh W. Shen
Freeman Fellow, American Society of Civil Engineers
Professor, Colorado State University

August, 1968

CER67-68HWS31

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I. OBJECTIVES:

A. The main objective of this report is to state briefly the current and future basic hydraulic research programs in many leading foreign laboratories so that researchers working in similar programs may exchange experiences with each other.

B. The second objective is to describe briefly the function and facilities of different laboratories.

C. This report will supplement "Bulletin - Hydraulic Research 1964 and 1965", Volume 19, by International Association for Hydraulic Research, Raam 61, Delft, The Netherlands (Reference 1).

II. LIMITATIONS:

A. Because of the limitations of the author's knowledge and interest, research programs in the general area of river hydraulics are emphasized. This report describes only a portion of the activities in these institutions.

B. Due to the limitations of time and funds, the author was able to spend only a few days in some of the leading hydraulic laboratories and therefore this report does not intend to rate or even compare different laboratories.

C. All references quoted in this report are written in English unless otherwise specified.

III. LABORATORIES VISITED:

- A. Imperial College of Science and Technology, London, England.
- B. Hydraulics Research Station, Wallingford, England.
- C. Royal Institute of Technology, Stockholm, Sweden.
- D. The Geomorphological Laboratory, Uppsala University, Sweden.
- E. Technical University of Denmark, Copenhagen, Denmark.
- F. Waterloopkundig Laboratory, Delft, and de Voorst Hydraulic Laboratory, The Netherlands.
- G. Electricite de France, Centre de Recherche et d'essais de Chatou, France.
- H. Federal Institute of Technology, Zurich, Switzerland.

I. Israel Institute of Technology, Haifa, Israel.

J. Ujigawa Hydraulic Laboratory, Disaster Prevention Institution and University of Kyoto, Kyoto, Japan.

K. University of Tokyo, Tokyo, Japan.

L. The Public Works Research Institute, The Ministry of Construction, Tokyo, Japan.

M. Technical Institute of Tokyo, Tokyo, Japan.

N. Chuo University, Tokyo, Japan.

IV. VISITATION PERIOD:

July - September 1966

V. IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY,
London, England:

A. Persons Visited:

C. M. White, P. O. Wolf, and M. J. Kenn.

B. Facilities:

A large modern hydraulic laboratory has just been completed. Towing tank (9 feet wide and maximum carriage speed 12 fps), large rectangular water tank, circular rotating tank, and flumes of many sizes are available. The potential is very great although the size of the staff is small.

C. Some Active Programs:

1. Cavitating Eddies: (M. J. Kenn). - The main purpose is to study the cavitating eddies behind a 1.25-inch cylinder and their incipient damage to concrete. Approaching mean velocity is on the order of 25 ft/sec.; maximum velocity between the approach tunnel sides and the cylindrical obstruction is as high as 100 ft/sec., the eddy-shedding cycle frequency is about 100 cycles/sec., and the test section is 2 inches wide by 0.25 inch deep and 9 inches long. Stroboscopic light is used to measure the frequency of eddy shedding.

2. Relationship between stress and sediment motion on a rigid sinusoidal boundary: (C. M. White). - Individual particles are placed on top of the rigid sinusoidal boundary of a water flume. The stress due to the fluid is estimated from the velocity distribution of the flow. The main purpose is to find the relationship between the boundary stress due to the flow and the motion of sediment particles.

3. Vibration of a sluice gate: - The time variation of stresses on a sluice gate in an open channel (1/3 foot wide) is investigated under different flow conditions. The stresses are measured

by transducer and strain gages. Strain gages are covered by membrane and sealed by chemical compound. The sealing problem was satisfactorily solved after testing with several chemical compounds.

4. Experiments simulating the effects of mountain building: - (M. J. Kenn). - The experiments, designed to simulate the effects of mountain building by sub-crustal convection currents, stemmed from the work of the late Professor S. W. Wooldridge. Two opposing circulatory motions are induced in glycerol within a Perspex duct, (11-7/8 inches long x 1 inch wide x 7-1/2 inches high) by counter-rotating drums (4-1/4 inches diameter spaced 5-1/2 inches center to center).

References:

Kenn, M.J. (1966). "Cavitating eddies and their incipient damage to concrete." *Civil Engineering and Public Works Review*, 61, 724, pp. 1404-5.

Kenn, Maurice J. (1965). "Experiments simulating the effects of mountain building." *Proc. Geologists' Assoc. London*, 76, 1, pp. 21-28.

Kenn, M.J. (1965). "Further studies concerning the air-control of siphonic water flow." *J. Inst. of Water Engineers*, 19, pp. 231-238.

Kenn, M.J. and Zanker, K.J. (1967). "Aspects of similarity for air-entraining water flows." *Nature*, 213, No. 5071, pp. 59-60.

VI. HYDRAULICS RESEARCH STATION, Wallingford, Berkshire, England, of the Ministry of Technology

A. Persons Visited:

N. P. Radley, G. H. Lean, P. J. Rance, Peter Ackers, F. G. Charlton, and M. Selim Yalin (now with the University of Alberta, Canada).

B. General Function:

This research station is one of more than a score of research establishments administered by the Ministry of Technology. The Station is prepared to offer advice on domestic and overseas hydraulic problems and to undertake model studies, field surveys, calculations and computations. Detailed descriptions of the functions and of the research facilities are given in "Hydraulics Research Station" issued by the Ministry of Technology, Ref. 2.

C. Facilities:

1. Much of the work of the hydraulic research station is carried out in the main hall, which has a floor area of 170,000 square feet interrupted only by eight columns supporting the roof.

2. Four large wave basins with a total area of about 42,000 square feet are equipped with means of producing tides and tidal currents as well as waves.

3. Flumes and channels, the largest having dimensions 350 ft x 12 ft x 2-1/2 ft, are used for research on the discharge characteristics of gauging structures, the transport of sediment, wind waves and the calibration of current meters.

4. A fleet of craft, the largest being a 50 ft launch, is used for the collection of field data on topography, currents, waves, sediment concentrations, salinities and temperatures.

D. Some Active Research Programs:

Most of the research programmes are investigations for central or local governments, consulting engineers or industrial corporations at home or overseas, and most are carried out for the design of particular specific engineering works; however, the research station supports a number of basic research projects which amount in aggregate to one quarter of the station's effort. A complete description of all the active projects is given in Ref. 1. Some of the research programmes in the field of sediment transport, which comprises one third of the basic research programme, are listed below.

1. Meandering of small channels in alluvium: (F. G. Carlton and Peter Ackers). This is a continuation of the studies by Peter Ackers on "Experiments on Small Streams in Alluvium", Journal of Hydraulics Division, ASCE, July 1964 (Reference 3), and by F. G. Carlton and R. W. Benson on "Effects of Discharge and Sediment Charge on the Meandering of Small Channels in Alluvium", Jubilee Symposia of Central Water and Power Research Station, Poona, India, January 1966 (Reference 4). The main purpose is to investigate the effect of discharge and sediment concentration of the geometry of meanders. Up to now, the investigation has been mainly experimental.

2. Effect of channel width on dunes: (G. H. Lean). Three channels 150 feet long and with widths of 1.5, 3.0, and 5.0 feet are used to determine the influence of channel width on bed form characteristics. Variations of sediment bed elevation are analyzed by stochastic process.

3. Determination of sediment transport in oscillatory motion by the dispersion of tracer-sediment: (P. J. Rance). This has been a long-term basic research project in the station. Some papers are: "The Use of Fluorescent Tracers for the Measurements of Littoral Drift" by R. C. H. Russel, published in the Proceedings of the 7th Conference on Coastal Engineering, The Hague, 1960 (Reference 5), "The Investigation of the Transport of Sediment in Uniform Systems by Observations of Tracer Distributions" by A. J. Bowen was published as Hydraulics Research Station Report No. IN 25 (Reference 6), "The Determination of Quantities of Sediment Transport in Oscillatory Motion by Consideration of the Dispersion of Tracer Sediment" by P. J. Rance was published in the 10th International Association of Hydraulic Research Congress, London, 1963 (Reference 7), and "Dilution Methods of Measuring Transport of Sand from a Point Source" , by G. H. Lean and M. J. Grickmore, Journal of Geophysical Research, Vol. 71, No. 24, December 1966 (Reference 8). Current efforts are directed toward theoretical analyses and experimental techniques using fluorescent coatings on coarse material (2.8 mm - 20 mm).

4. Similarity laws in alluvial channels: (M. Selim Yalin). From dimensional analysis and experimental results similarity laws are determined for sediment transport in geometrical properties of sand waves. The two published papers by M. S. Yalin are "Geometric Properties of Sand Waves", Proc. ASCE, HY 5, September 1964 (Reference 9) and "Similarity in Sediment Transport by Currents" Hydraulic Research Paper No. 6, Hydraulic Research Station, Wallingford, England, 1965 (Reference 10). Dr. Yalin is in Canada. His work is being extended by P. J. Rance as a study of bed-forms and their effective resistance in reversing flow.

5. Several research programmes on a full size study of wave forces on obstacles near the sea bed, on shear at a wind-water interface and on the movement of moored ships are under way.

E. Instrumentation:

The instrument and mechanization sections of this station make full use of modern techniques in the design of instruments and servo-control systems. They can thus provide models with a wide range of instruments and efficient automatic devices for control of flow and reproduction of tides. The instrument section in the station is definitely one of the strongest in the world. The following is a list of some of their perfected devices.

1. "Water-Level Surge Recorder" by E. G. Sandels, Electronic Technology, Volume 38, No. 1, pages 2-10, January 1961 (Reference 11).

2. "Pneumatic Tide Generator" by M. J. Wilkie and G. A. J. Young, The Engineer, July 25, 1952 (Reference 12).

3. "Some Automatic Devices for Use on Tidal Models" by M. J. Wilkie, Journal of Scientific Instruments, Volume 30, pages 263-265, August 1953 (Reference 13).
4. "A Recording Water Velocity Meter" by M. J. Wilkie, Journal of Scientific Instruments, Volume 32, pages 350-353, September 1955 (Reference 14).
5. "A Wave Height Analyser" by M. J. Wilkie and R. F. King, Journal of Scientific Instruments, Volume 30, pages 311-314, September 1953 (Reference 15).
6. "An Instrument for the Measurement of Salinity in Estuaries", by E. G. Sandels, Journal of Scientific Instruments, Volume 33, pages 424-428, November 1956 (Reference 16).
7. "Measuring Fluid Velocities Optically" by A. E. Seddon and H. O. Anwar, Engineering, September 1963 (Reference 17).
8. "Miniature Liquid-Flow Meter" by H. R. Dedow and R. E. J. King, Engineering, September 1964 (Reference 18).
9. "The Control of Hydraulic Models" by H. R. A. Dedow, The Engineer, February 1965 (Reference 19). This article describes controlled-weir tide generator on controlled-valve tide generators. Types of tide generators, unidirectional flow control systems, reversible flow control systems, temperature controls of a warm water supply, mobile bed material injectors, wave generating apparatus, salinity controllers and curve readers are compared. Among the items that are being developed are a current-meter direction-sensing device, equipment for the generation and digital recording of irregular waves, thermal survey equipment, a light-weight low-power vibro-corer and an instantaneous rate-meter for use with miniature current meters.

VII. ROYAL INSTITUTE OF TECHNOLOGY, Stockholm, Sweden.

A. Persons Visited:

Erling Reinius and G. Richert.

B. Education System:

Engineering studies on the university level can be pursued at two Institutes of Technology, situated in Gothenburg and in Stockholm. The level of the four years degree is about the M.S. in the United States. Before graduation from the Civil Engineering Department, each student must spend two or three months on thesis work and six months working as a laborer gaining practical experience in the building industry. A higher degree, called "Teknisk licenti or texamen" can be granted to a graduate student after two full years of post graduate studies, satisfactory completion of an examination, and the submission of an acceptable thesis. Having obtained the degree of Tekn. L., one can proceed to obtain the degree of Doctor of Technology (Tekn. D.). For this degree, there are no courses or examinations, but one has to write a doctor's thesis and defend it in a public disputation.

C. Facilities:

The facility is described in "The Hydraulic Laboratory at the Royal Institute of Technology, Stockholm" by Bo Hellström and Erling Reinius, Bulletin No. 63, Division of Hydraulics at the Royal Institute of Technology, Stockholm, Sweden, September 1963 (Reference 20). Total area including offices and workshops is 9902.788 square feet.

D. Some Active Research Programs:

1. Shock pressures on breakwaters: (G. Richert). The experimental set-up is shown by the following sketch:

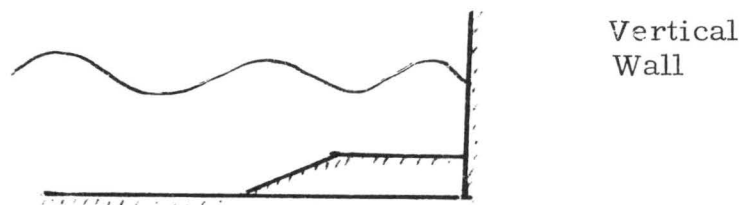


Figure 1. Shock pressures on vertical wall

Pressure cell instruments are mounted on the vertical wall to study shock pressures due to different types of breaking waves. Water depths are about 0.15 meters. Shock pressures are recorded by taking pictures

of the oscilloscope screen. The pressure due to initial impact can be much greater than the pressure of subsequent waves. Certain modifications of the form of the breakwater will be tested.

2. Angles of repose of granular material: - Sand particles are placed on top of sand coated bars. The slope of these bars is varied to study the angle of repose of granular material.

3. Voids in granular materials and filter designs: - Permeameter tests to study the filter criteria and the stability of a filter layer of well graded gravel are being conducted. The largest gravel size is about 64 mm.

4. Guides for launching ships: - Ships may exert large forces on the launching guides due to action of waves and currents. The project is a model test to investigate the magnitude of these forces.

VIII. THE GEOMORPHOLOGICAL LABORATORY; INSTITUTE OF PHYSICAL GEOGRAPHY, Uppsala University, Uppsala, Sweden

A. Persons Visited:

Filip Hjulström and Nils Meland.

B. Facilities:

Laboratory space devoted for hydraulic research is about 2150 square feet. One flume has dimensions of 70 cm wide x 100 cm deep and 12 m long. Half of the space for hydraulic research is devoted for models of river channels, deltas, and shores (e.g., branching and bending channels, 2- and 3-dimensional deltas). A tilting flume and a sedimentation tank has recently been constructed. A complete description of the facility is given in "The Geomorphological Laboratory" by F. Hjulström and Åke Sundborg. Series A, No. 176, Geografiska Institution, Uppsala Universitets (Reference 21).

C. Some Active Projects:

1. Erosion and transport velocities of bed material with varied grain size distribution, shape properties and roughness (Nils Meland and John O. Norrman): Incipient motion: Uniform glass spheres are hand packed and glued on the bottom of channel as artificial roughness. Different sizes of movable particles are placed in the channel to study the correlation between incipient motion of these particles and the velocity distribution of flow under various hydraulic conditions.

2. Revision of erosion curves for uniform bed material under controlled flow conditions (Filip Hjulström). Fluorescent bed material, UV-light, and photo recording techniques are used and developed.

3. River morphology: meandering--flow and channel geometry, sediment behavior (Åke Sundborg); diversion of sediments at branching channels (Valter Axelsson).

4. Studies of elastic bed structures related to varied hydrodynamic conditions in erosional, transport and depositional bed types (Carl Erik Johansson).

Reports of the studies are published as "Meddelanden från Uppsala Universitets Geografiska institution, Ser. A."

IX. COASTAL ENGINEERING LABORATORY AND HYDRAULIC LABORATORY, Technical University of Denmark, Oster Volgade 10 Copenhagen, Denmark.

A. Persons Visited:

H. Lundgren, I. G. Jonsson, I. A. Svendsen and Bo Pedersen.

B. Facilities:

There are two small coastal engineering laboratories (one at the Technical University and the other situated at the outskirts of Copenhagen) and a hydraulic laboratory. A new modern laboratory is planned and should be completed in the near future.

C. Some Active Programs:

The author was rather impressed by the amount of research accomplished by these laboratories with such limited facilities and small staff. Complete details of this research program since 1961 can be found in "Basic Research - Progress Reports" published periodically by the Coastal Engineering Laboratory and the Hydraulic Laboratory of the Technical University of Denmark (Reference 22). The purpose of these Progress Reports is to provide colleagues in other countries with up-to-date information about current research in a less formal way than normal publications which usually deal with completed studies. Many completed studies are published in the Journal "ACTA POLY TECHNICA SCANDINAVICA" Civil Engineering and Building Construction Series. These journals are published (most of them in English) by the four Academies of Technical Sciences in Denmark, Finland, Norway and Sweden. Issues can be purchased from ACTA POLYTECHNICA SCANDINAVICA Publishing Office, Box 5073, Stockholm 5, Sweden.

1. Deformation of wave profiles in shoaling water: (H. Lundgren). This is a continuation of the study as reported in "Analysis of Wave Deformation", the Conf. Coastal Engineering, Tokyo, September 1966 (Reference 23). The main approach is based on the use of two-dimensional potential theory to investigate a wave propagating over an arbitrary bottom topography. A computer program has been worked out by means of which the changing profile, velocities, and pressure may be calculated.

2. Forces on a wave screen: - Measurements are being made of wave forces on a 7.5 m high wave screen on top of a vertical fan prototype breakwater by means of strain gauge pressure cells.

3. Friction factor and other flow characteristics for oscillatory boundary layers: (I. G. Jonsson and J. A. Svendsen). - This has been a large research project in the Coastal Engineering Laboratory. The analysis of friction factors for oscillatory boundary layers is reported in the 9th and 10th Basic Research Progress Report, 1966. A paper on the "Existence of Universal Velocity Distribution in an Oscillatory Turbulent Boundary Layer" was presented in the 12th Basic Research Progress Report, September 1966 (Reference 24). Additional study in this area is being planned. Wave boundary layers and friction factors: (I.G. Jonsson) 1967. Proc. 10th Conf. Coastal Engrg., Tokyo 1966, I, Chapter 10, 127-148. Am. Soc. Civ. Engrs., New York.

4. Measurements of fender deformation: (I.A. Svendsen). Maximum deformations of the fenders on several prototype oil jetties are recorded and analyzed.

5. Sediment transport rate and development of bed form in alluvial channels, and hydraulic resistances of alluvial streams, by F. Engelund, Journal of Hydraulics Division, ASCE, March 1966 (Reference 26). - The experimental part of this study is being conducted in a 6-meter long flume with automatic sand feeder. Theoretical analysis was described in "Investigations of Flow in Alluvial Streams", ACTA POLYTECHNICA SCANDINAVICA, Copenhagen, 1966 (Reference 25).

6. Dispersion of floating particles in an open channel flow over rough boundaries: - Photographs and photo cells are used to study the dispersion of floating particles on the surface of an open channel flow over rough boundaries. Gravels are placed on the bottom of channel.

7. Shear meter: - A shear meter designed to measure shear stress directly was not entirely satisfactory.

8. Hot-wire measurements in a hydraulic rough low-speed wind channel (aspect ratio 1:8) in order to determine the turbulence characteristics.

9. The diffusion of a salt water jet into a large still water tank: Salt concentrations are measured in order to study the diffusion of a salt water jet into a large body of still water.

10. Effect of shape on hydraulic radius: (F. Engelund and Bo Pedersen): - This is an experimental study for the purpose of determining the hydraulic radius for different cross sections following the analysis presented in "Flow Resistance and Hydraulic Radius", by F. Engelund, Acta Polytechnica Scandinavica, Copenhagen 1964.

X. DELFT HYDRAULICS LABORATORY, The Netherlands.

A. Persons Visited:

J. H. Schoemaker, B. Abraham, H. N. C. Breusers,
M. DeVries, F. Koopmans, and L. Bergeron.

B. Facilities:

The main laboratory is located at Delft and a branch laboratory is at de Voorst. It was quite an experience for a foreigner to travel between the two laboratories. One had to transfer three or four times with an average of three to five minutes between trains. It was particularly exciting when part of one train was going to another destination.

The total facility of the two laboratories is the largest the author has visited. Generally, large models are located in the de Voorst laboratory. The total area in de Voorst laboratory is approximately 9,000,000 square feet.

Delft is certainly as good as its reputation and is one of the very best hydraulic research institutions. The author was told that the basic research program is about one-sixth of the total research. The Delft documentation cards (4000 per year) are available at cost to "congenial institutes".

C. Some Active Programs:

1. Salinity intrusion in estuary model: (G. Abraham). - A model with different horizontal and vertical scales will be used to study the stability and the mixing at the interface between two flow layers of different flow characteristics (density and velocity). The immediate problem is to obtain proper mixing at the interface by artificial means. The ultimate goal is to analyze salinity intrusion problems theoretically in the prototype assisted by laboratory measurements.

2. Reproduction of salinity conditions in tidal rivers: (G. Abraham). - In a flume, the following problems are to be studied:
a. reproduction of density currents in models of estuaries under various scale combinations, and b. methods of correcting possible scale effects.

3. River bifurcation: (M. de Vries). - The study concerning river bed changes has been completed and the study on flow pattern is still in progress. The effect of installing artificial guide vanes at the junction on sediment and flow distributions in the two branches is being investigated.

4. Non-steady bed-load transport: (M. de Vries). - The quantitative determination of bed-material transport by means of tracers is being considered. For a stationary-stochastic transport condition, the dispersion of tracers has been described by a diffusion equation of the gradient type. The parameters of the dispersion model are derived from the measured concentrations by a least-squares procedure. The measuring technique has been based on the application of fluorescent tracers. A summary of previous work is given in "Applications of

Luminiferous in Sand Transport Studies¹¹ by M. de Vries. Delft Publications No. 39, June 1966 (Reference 27).

5. Measuring instrument for bed-load transport:

A new type of bed-load transport meter is being designed. A preliminary calibration has been carried out in the laboratory.

6. Computations on water hammer: (L. Bergeron). -

A major portion of a computer program for the calculation of water hammer in a complex system of pipelines has been developed. Future emphasis will be placed upon the effect of cavitation on water hammer problems. Unfortunately, the general solution is extremely sensitive to the effect of cavitation.

7. Fundamental study of scour in two-dimensional flow:

(H. N. C. Breusers). - All the significant factors, such as size and density of sediment, velocity, and depth of flow, etc., were determined at the beginning. A systematic sequence of experiments is carried out in a relatively narrow flume to investigate the effect of each independent variable while keeping all other variables constant. Time variations of scour depth are determined for each condition. Plastic material with a density of slightly greater than one is used to study the effect of density.

8. Fundamental study of scour in three-dimensional flow:

(J. J. Vinje). - A vertical plate (varying in width between 0.6 to 1.5 meters) is placed in a basin 5 meters wide. Comparative tests are made to determine the time-variation of erosion downstream of the vertical plates as a function of length scale, velocity scale, bed material and flow conditions.

9. Velocity distribution of flow above a rigid wavy boundary:

(J. O. Hinze). - The bottom of a wind tunnel is covered by a train of triangular (height of length ratio about 1:15) waves. Velocities normal to the boundary are measured at different locations of the wavy boundary to study the variations of boundary shear stress.

10. Incipient motion of fine silt material:

Incipient motion of very fine silt material is being investigated in a laboratory flume.

D. Development of Instrumentation: (F. Koopmans).

1. Elevation of wave surface:

A probe is moved electronically with very high frequency (50 cycles/second) in and out of the water in such a way that no water would adhere to the probe. This probe can be used to measure waves as small as one centimeter. A servomechanism is set up so that the probe is submerged in the water 50 percent of the time.

2. Miniature propeller current meter: (H. N. C. Breusers). - This is described in "Description of the Propeller Current Meter and Mimosa Apparatus" Delft Publication No. 30, August 1963 (Reference 28). The diameter of the propeller is 15 mm. Prestressed wire (0.15 mm diameter) is used as the rotational axis. The pulse per revolution is 60 and the velocity range is from 0.1 to 4 feet per second. The axis of this meter can deviate up to 30° from the axis of flow without noticeable reduction of rotation. For large scale turbulence (less than 20 cycles per second), this meter will perform satisfactorily.

3. Local velocity and sediment concentration by optical method: - A light beam is emitted toward a small spot in the flow. Two receivers are placed at about ± 50 degrees respectively from the transmitted light axis to receive the reflections. The velocity of the flow at the particular spot is related to the change of frequency of light between the transmitter and receiver. The concentration of sediment within this spot can also be detected by the receiver. This system is still under development.

4. Low temperature resistance: - At low temperatures, the change of resistance for unit variation of temperature is much greater than at high temperatures. Work is being done to take advantage of this phenomenon for high accuracy instrument.

5. Wave height measurement: - An attempt is being made to develop a wave height measuring device which will adjust automatically to the change of conductivity due to variations of temperature.

XI. LABORATOIRE NATIONAL d'HYDRAULIQUE ELECTRICITE
de FRANCE, Centre de Recherches et d'Essais de Chatou, France.

A. Persons Visited:

J. Chabert, M. Remillieux, A. Daubert, P. Cormault, and M. Fabre.

B. General Function:

The National Hydraulic Laboratory is one of the seven departments at this Research and Experimental Center, Chatou, France. There are four divisions, namely, hydrology, marine, fluvial and general hydraulics within the National Hydraulic Laboratory. A description of this research and experimental center is given in "Centre du Recherches et d'Essais de Chatou", published in 1964 (Reference 29 - in French).

Bulletin No. 14, December 1965 (Reference 30 - in French) published by Research and Experimental Center gives a list of nearly all the articles and books published to date by the Research and Experimental Center.

C. Facilities:

This hydraulic laboratory is one of the largest and best research institutions in the world. The department has several laboratories with a surface area of 144,000 square feet. Ten channels of various sizes and three large basins are available for investigation of currents, surges, and tides.

D. Some Active Programs:

1. Degradation study: - Three sediment transport equations developed by Meyer-Peter, J. Chabert and J. Pierre gave approximately the same result. By assuming constant channel width and constant boundary roughness, the continuity of sediment equation can be solved.

2. Velocity in an estuary with constant river inflow: - The attempt is to solve a fourth order differential equation with different boundary conditions.

3. Flood routing: - The main purpose is to investigate the secondary waves following a bore after a dam collapses.

4. Density current with a stable interface: - The friction at the interface is determined by actual prototype measurement.

E. Future Programs - as told by J. Chabert, Chief, Department of National Hydraulics Laboratory.

1. Unsteady flow (two dimensional):

- a) Wave problems in different river cross sections.
- b) Secondary waves following a bore.
- c) Density currents.
- d) With movable bed.

2. Marine:

- a) Action of waves near beach and littoral drift.
- b) Salt intrusion and density current. The one-dimensional phase has been completed. Two-dimensional and three-dimensional studies are planned.
- c) Force due to wave action and added mass.

3. Fluid hydraulics:

- a) Movement of silt and clay in model and prototype.
- b) Difficult bed forms in flumes and rivers -- first phase restricted to subcritical flows.
- c) Degradated studies in laboratory and in the field.

4. Hydrology: - Relationship between rainfall and runoff, etc.

XII. VERSUCHSANSTALT FÜR WASSERBAU UND ERDBAU DER
E. T. H. ZÜRICH, Gloria Strasse 39, Zürich, Switzerland

A. Persons Visited:

G. Schmitter, J. Zeller, Th. Dracos, A. Gunter, and A. Gyr.

B. General Function:

This research institute serves as a training place for students at the Federal Institute of Technology, a basic research station for faculty of the Federal Institute of Technology and a model testing laboratory for domestic and international engineering firms. A large amount of research related to the hydroelectric development on rivers has been conducted here.

C. Facilities:

The "Versuchsanstalt" is divided in 3 sections (hydraulics, hydrology and soil mechanics). The basic facility of the hydraulic section is concentrated on the one side in two large laboratory areas totaling 120 feet x 150 feet and on the other side in a field station with an area of 35,000 sq ft. In the main laboratory a 7-ft wide by 7-ft deep and 300-ft long flume was constructed under the floor. The three other larger flumes are:

- 2 ft wide by 8 ft deep and 30 ft long
- 3 ft wide by 1 ft deep and 130 ft long
- 2 ft wide by 1 ft deep and 40 ft long

and at the field station

- 1 ft wide by 4 ft deep and 100 ft long
- 1 ft wide by 1 ft deep and 120 ft long
for different slopes $J = 0,010 + 0,025$
- 10 ft wide by 2 ft deep and 75 ft long.

In addition there is a 150 ft long concrete pipe of one foot diameter.

The whole laboratory will be moved away on a much larger place (suburb of Zürich).

D. Some Active Programs:

1. Degradation of cohesive channel beds (J. Zeller). This is a long term basic research project at this institute. A lengthy procedure which includes sedimentation and consolidation (desalted water), is established for the preparation of cohesive material before hydraulic testing. This work includes soil mechanical and soil chemical studies.

2. Degradation study with non-uniform coarse cohesionless bed material (A. Günter). Well-graded sediment particles are put in the 150 ft flume. Different water discharges (without feeding sediments) are pushed through the flume to establish final equilibrium bed slopes. For the grain size distribution used, less than five diameter thickness of large particles are sufficient to cause armoring of the bed.
3. Geomorphology of rivers (J. Zeller). Rough study about macroforms of rivers as meandering and braiding including laboratory and field work.
4. Porous media (Th. Dracos). Using sand tank models to investigate flow rates in three-phase flow (air-oil-water). In addition there are studies underway for 2-dimensional non steady flow problems of ground water (Hele-Shaw model and other methods).
5. Turbulence near flow boundary (A. Gyr). A new optical device is being tested to measure turbulent fluctuations near flow boundary. Description of this device is not available at present.
6. Wave height gage: A horizontal plate is inserted above the water surface. The variation of capacitance can be calibrated with the fluctuations of waves. Wave height can be measured with 3×10^{-4} ft accuracy.
7. Generation of unsteady flow in pipes, flumes and models. An electronic system regulates water flow, sediment feeding and water level.
8. Relationship between suspended particles and turbulent flow: (A. Gyr). The first stage of this study is reported in "The Behavior of the Turbulent Flow in a 2-Dimensional Open Channel in The Presence of Suspended Particles," by A. Gyr, Proceedings of the XIIth Congress of the International Association of Hydraulic Research, International Association of Hydraulic Research, International Association of Hydraulic Research, Fort Collins, Colorado 1967 (Reference 31).

E. Future Programs:

1. Model testing: - To assist engineering design (including the cooling system for atomic energy power plant, river diversion, etc.).
2. River engineering:
 - a. Transport of cohesive material with various chemical additives.
 - b. Transport of cohesionless material of different particle size distribution. The armoring of sediment bed during degradation will be investigated.

- c. Aggradation in storage basins
- d. Investigate river morphology.

3. Fluid mechanics: - To investigate the turbulence characteristics near rough boundary.

4. Ground water : - To investigate the flow phenomena in air-oil-water layers.

XIII. HYDRAULIC LABORATORY, ISRAEL INSTITUTE OF TECHNOLOGY, Haifa, Israel.

A. Persons Visited:

M. H. Diskin and M. Poreh.

B. General Function:

The function of this laboratory is similar to a typical hydraulic laboratory of an American university. There are normally 15 to 20 graduate students working on various research projects in the laboratory. The requirements for M.S. and Ph.D. degrees are similar to that of the United States although the number of offered graduate courses is smaller.

C. Facilities:

The facility is described in the article "The Hydraulic Laboratory" - Technion, Israel Institute of Technology (Reference 32). A channel 7-1/2 feet wide by 5 feet deep and 150 feet long is equipped with a towing carriage. This carriage can be moved with a velocity range of 1 inch to 10 feet per second. Several small channels and pipelines (3 to 12 inches diameter) are also available.

D. Some Active Programs:

Some of the active programs are described in "Hydrotechnical Research At The Technion", (Reference 33), at approximately two-year intervals. The last one described the papers presented at its Hydraulic Symposium, May 26, 1965.

1. Flow measuring devices: - The development of various flow measuring devices has been very active here. Different types of obstacles are inserted in pipelines and channels to study their effects on the flow. Investigations have also been carried out in determining the flow rate in a main channel by measuring flow rate through a by-pass section.

2. Pipe network analysis: - Distribution of flow in a pipe network is being studied.
3. Spatially varied flow in an open channel: - Velocity distribution and variation of the depth of flow for both subcritical and supercritical flow are being investigated.
4. Submerged breakwater: - Damping of waves by a submerged breakwater is being investigated.
5. Flow over and under a weir: - A weir with an opening at its bottom is being tested.
6. Localized scour due to impinging turbulent jets: - A preliminary report of this is published as, "Initial Scour and Sediment Motion Due to an Impinging Submerged Jet", by M. Poreh and E. Hefez in the Proceedings of the XIIth Congress of the International Association for Hydraulic Research, Fort Collins, Colorado, 1967 (Reference 34).
7. Reduction of pipe friction by chemical additives: - Velocity distributions in the outer region of a turbulent flow are compared to pipe flow with and without chemical additives.
8. Air pollution problems: - An actual air pollution problem caused by the development of industries in a valley is being investigated.

XIV. UJIGAWA HYDRAULIC LABORATORY, DISASTER PREVENTION INSTITUTE, AND HYDRAULIC LABORATORY, UNIVERSITY OF KYOTO, Kyoto, Japan.

A. Persons Visited:

T. Ishihara, (Director), K. Ashida, Y. Ishihara, Y. Iwasa, C. Nakajima, Y. Tsuchiya, Y. Zshihara, and Y. Iwagaki.

B. General Function:

This laboratory was instituted in 1952 as one branch of the Disaster Prevention Institute of Kyoto University to investigate the means of preventing disasters caused by the water and soil. It is located about ten miles south of the main campus of the Kyoto University beside the levee of the Uji River (Ujigawa) Yoko-oji, Fushimi-ku, Kyoto.

This is by far, the largest hydraulic laboratory in Japan and has the following research sections: (The asterisk denotes the work being done by the full-time staff assigned to the laboratory, and the names in the parentheses are the Heads of the respective sections.)

1. Applied Climatology* (C. Nakajima)
2. Applied Hydrology* (Y. Ishihara)
3. Sedimentation and Debris Control* (K. Yano)
4. River Disaster Prevention* (K. Ashida)
5. Drainage Engineering* (M. Kadoya)
6. Coastal Disaster Prevention* (Y. Iwagaki)
7. Experimental Hydraulics* (H. Nakagawa and S. Yokosi)
8. Soil Mechanics* (S. Murayama)
9. Earthquake Motions
10. Crustal Deformation
11. Instrumentation for Earthquake Predictions
12. Earthquake Resistant Foundation
13. Applied Sedimentology and Dynamic Geomorphology
14. Landslides
15. Wind Resistant Structures.

There are also six attached facilities: Hotaka Sedimentation Observatory*, Shirahama Oceanographic Observatory*, Sakurajima Volcanological Observatory*, Shionomisaki Wind Observatory, Totton Branch of Micro Earthquake Observatory, and Kamitakara Crustal Movement Observatory.

C. Facilities:

The research stations of the hydraulics laboratory are divided into three stations at the Engineering Research Institute, Main Civil Engineering Building and Annexed Building. See also "Ujiganwa Hydraulic Laboratory" Disaster Prevention Research Institute, Kyoto University, June 1966 (Reference 35).

1. Research station at the engineering research institute:
 - a. 18 m steel flume of variable slope: 18.0 x 1.82 x 0.45 m. Constructed in 1921, this flume was used to conduct experimental research on bed scour around bridge piers. The hydraulic behaviors of the free surface flow at sudden expansions and contractions are currently being investigated.
 - b. 24 m wave flume: 24.0 x 1.0-1.2 x 0.5 m of fixed slope. Completed in 1958, this flume is used to study various wave generators and the wave forces acting on the seashore and underwater structures.

c. 15 m lucite flume of variable slope: 15.0 x 0.4 x 0.5 m. Constructed in 1962, the flume can be adjusted to positive or negative slope. The experimental verification of the mathematical theory on the discharge, increasing or decreasing flow, and the hydraulic performance of the side channel spillway to the main flow is in progress.

d. 11 m lucite flume of variable slope: 11.0 x 0.2 x 0.2 m. Constructed in 1953, this flume has a slope which can be adjusted from 30° . The experimental works of the roll wave formation and the boundary layer development in the free surface flow were studied.

e. Connecting flume for curved flow experiment: 15.0-25.0 x 0.35 x 0.25 m of fixed slope. Constructed in 1958, the flume consists of straight channel and curved channel parts. The secondary flow at channel bends were experimentally studied. The present research program is to study the dispersion of solid particles and salt water in connection with the turbulent mean flow characteristics by the use of the straight sections.

f. Steel flume for weir experiment: 4.0 x 1.0-1.5 x 0.5-0.8 m. Constructed in 1958, the flume is used by undergraduate students for weir experiments.

g. Wooden flume for drag force experiment: 8.0 x 0.5 x 1.0 m of fixed slope. The drag forces acting on the cylinder in the free surface flow are in experimental progress.

h. Steel flume for seepage flow: 6.0 x 1.0 x 0.5 m of fixed slope. Constructed in 1958, this flume was used to study the hydraulics of seepage flow in relation to the main flow characteristics in alluvial channels.

i. Wooden flume for underflow hydraulics: 4.0 x 0.30 x 0.30 m of fixed slope. The discharge characteristics of the sluice gate and the hydrodynamic pressure acting on the gate are under experimentation.

j. Wooden flume for bottom intake performance: 9.0 x 0.25 x 0.20 m of fixed slope. The hydraulics of the flow diversion by means of various bottom intake structures was treated experimentally. The flow through a transverse slit is under experimentation.

k. Electronic automatic discharge control device: Constructed in 1958, this device can control the discharge from 0 - 60 l/sec in the main supply pipe and from 0 - 10 l/sec in the branch pipes. Various experimental research programs on unsteady flow will be made by using this device.

2. Research station at the main civil engineering building.

a. Lucite tank for circular jet: 0.60 2.00 in diameter. Constructed in 1966, this tank is currently being used to study the hydraulics of radial flows and circular jets in relation to the water architecture.

b. Experimental tank for stratified flow: 6.0 x 0.6 x 0.5 m. The basic hydrodynamic study of the density and temperature stratified flow will be made in this tank.

c. Experimental tank for settling velocity: 2.0 x 0.6 x 0.6 m. This tank is set for the laboratory work of undergraduate students and basic study in laboratory projects.

d. Wooden flume for channel diversion: 11.6 x 0.3 x 0.4 m of fixed slope. Originally constructed in 1965 and moved into the Main Civil Engineering Building in 1966, this flume will be used for experimental programs on flow diversion.

e. 19 m steel flume of variable slope: 19.1 x 0.8 x 0.7 m of variable slope (1/30). Various basic research programs concerning the free surface shear flow will be conducted in this flume.

f. Wave flume for coastal structure study: 22.0 x 1.0-1.5 x 1.5 m (under planning). The hydrodynamic study of waves to breakers and other coastal structures will be conducted in this flume. The flume will be completed in March 1967.

3. Research station at the annexed building.

a. Fixed flume for hydroelastic programs: 10.0 x 0.4 x 0.3 m. This flume will be used to study vibrations and other elastic problems of hydraulic structures resulting from the hydrodynamic force of fluid flow.

D. Active Research Programs:

A summary of research activities in civil, sanitary, and traffic engineerings at Kyoto University, 1960-1964 is given in Reference 36.

1. Analysis of fluid movement by means of flow visualization: The visualization of fluid movements by means of various tracers like the hydrogen bubble, the smoke, the dye and so on, and the analysis of flow patterns through the flow visualization.

2. Hydrodynamic analysis of Non-Newtonian fluid flow: Basic theoretical and experimental analysis of Non-Newtonian fluid flow.

3. Hydrodynamic study of jet diffusion: Hydrodynamic analysis of the diffusion of jet in the free turbulent zone of flow.

4. Mathematical theory of one-dimensional fluid flow: Mathematical derivation of the one-dimensional fluid flow from the point of view of hydrodynamics and verification of the hydraulic significance to practical applications.

5. Hydraulic significance of control section in open channel hydraulics. Analysis of the mathematical properties of the control section in the basic equation of one-dimensional open channel flow and its application to discharge controlling devices.

6. Use of digital computer to hydraulic problems: Programming and calculation of hydraulic problems by means of digital computers.

7. Hydrodynamic study on surface resistance in open channel flows: Hydrodynamic study of surface resistance at the boundary to turbulent mean flow.

8. Hydraulic analysis of free surface flow at channel discontinuity: Theoretical and experimental study on local behaviors of free surface flow at channel discontinuities like sudden expansion and contraction.

9. Hydrodynamic study of drag forces on hydraulic structures in free surface flow: Hydrodynamic studies on drag force and drag coefficients of various hydraulic structures in free surface shear flow.

10. General theory of analysis for spatially varied flows: Establishment of the mathematical analysis of flow with increasing or decreasing discharge and application to practical hydraulic problems.

11. Hydraulic analysis of radial flows: Theoretical and experimental analysis of the hydraulics of radial flows and its application to practical problems.

12. Basic study on water architecture: Complete visualization of mathematical theory of open channel hydraulics in a basin and its application to recreational life.

13. Dispersion of particles in free surface shear flow: Theoretical and experimental study on the dispersion of solid particles with various densities in free surface turbulent shear flow.

14. Turbulent diffusive process in free surface shear flow: Theoretical and experimental study on the turbulent diffusive process in free surface shear flow by means of salt water.

15. Discharge characteristics of underflow through gates: Basic hydraulic study on the performance of gates to the underflow discharge characteristics.

16. Hydrodynamic forces acting on gates: Theoretical and experimental analysis of hydrodynamic forces acting on hydraulic structures like the gate and its application to structural design.

17. Hydrodynamic application of velocity probes: Basic study on electronic probes and their transducers for velocity measurement of fluid flows and their practical application.

18. Discharge measurement by means of flumes: Theoretical analysis for most desirable channel geometry for discharge measurement and its application to practical usage by means of experimental verification.

19. Application of electronic automatic discharge control device to hydraulic experimentation: Basic applied research for various hydraulic experiments by means of electronic automatic discharge control devices.

20. Basic research on wave generator: Theoretical and experimental research on the wave motion made by various wave generators and its application to basic hydraulic and model experiments.

21. Basic study on development and use of water resources: Basic hydrological, hydraulic and economical studies of water resources in Japan and mathematical analysis of optimization in development and use of these water resources.

22. Hydraulics of ground water flow: Theoretical research on the mechanics of ground water flow and its physical significance in the runoff process.

23. Flow in zone of aeration: Theoretical and experimental research on flow in the zone of aeration to find infiltration procedure in the hydrologic cycle.

24. Hydraulic behaviors of interflow along slopes: Theoretical and field study on the hydraulics of interflows along mountain slopes in relation to the physical characteristics of surfaces and its application to flood predictions.

25. Hydrologic study on conservation of runoff through forest: Field and laboratory study on the hydrologic efficiency of conservation of runoff in the forest in terms of flood protection.

26. Generalization on theory of runoff procedure: Theoretical examination of past procedures of runoff treatment and stochastic study of the runoff procedure to formulate a generalized theory.

27. Runoff procedures in multi-channel systems: Theoretical research on runoff procedures in channels with tributaries and branch rivers by means of the nonlinear theory on unsteady open channel flow.

28. Theoretical study on flood prediction: Theoretical research on long-term and short-term predictions of runoff and on the unified method of prediction in terms of flood protection and water utilization.

29. Analysis of low-stage discharge: Theoretical analysis of discharge characteristics of flow at low stages.

30. Flow diversion by means of side weirs: Theoretical and experimental research on flow diversion by the side weir and on hydraulic performance to the main flow.

31. Hydraulic performance of bottom intake structures: Theoretical and experimental research on the hydraulic performance of flow diversion by means of the bottom intake structure.

32. Basic study on two-dimensional wave motion in wave tank: Hydrodynamic analysis and experimental verification of two-dimensional wave motion generated by various wave generators in the wave tank.

33. Wave forces acting on coastal structures: Theoretical analysis of wave forces acting on various coastal structures and experimental verification of the results.

XV. TOKYO UNIVERSITY, Tokyo, Japan.

A. Person Visited:

K. Horikawa.

B. Facilities:

Tokyo University has two hydraulic research facilities. A flume and a wave basin are located outside of Tokyo. The research facility on the main campus inside Tokyo is small.

C. Some Active Programs:

1. Suspended sediment due to wave action: Several papers have already been published on this subject. The latest one was "A Study on Suspended Sediment Due to Wave Action", Coastal Engineering in Japan, Vol. 8, 1965 (Reference 37).

2. Coastal sediment studies: The main purpose is to investigate the coastal sediment movement in the field. Several papers have been published on this project. (Reference 1).

3. Sediment transport related to river regime: The main purpose is to investigate the sediment transport in rivers and deposition in reservoirs by analyzing field data.

XVI. THE PUBLIC WORKS RESEARCH INSTITUTE, The Ministry of Construction, Tokyo, Japan.

A. Person Visited:

A. Tsuchiya.

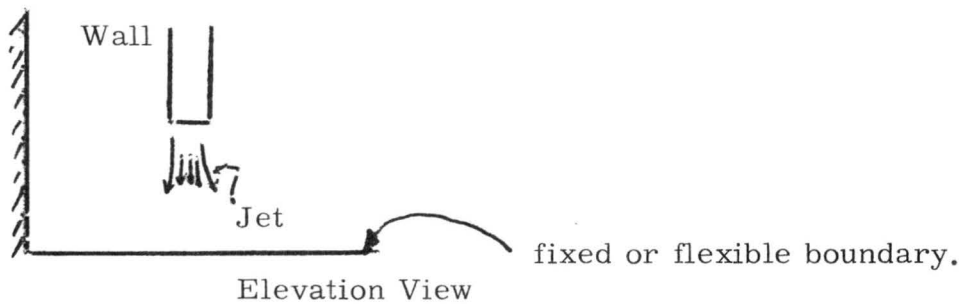
B. Facilities:

Flumes and other facilities are too numerous to be listed here.

C. Some Active Programs:

1. Scour downstream from dam: Three different sizes of sand (5, 10, and 20 mm) are used for bed material. Discharge and shape of bed will be measured to investigate the degradation condition downstream from a dam.

2. Jet, from a two-dimensional slot, shooting downward into a corner.



Sketch 1.

Flow conditions in the corner as shown in Sketch 2 is being measured and analyzed.

3. Depositions upstream from a dam: The shape of sediment deposit and the flow condition upstream from a dam is being investigated.

4. Sediment particle suspension and velocity distribution: The relationship between sediment particle and velocity distribution in an open channel flow is being investigated.

5. Frictional resistance: The variation of frictional resistance with different flow conditions for an open channel is being studied.

6. Reference sediment concentration in open channel flow: Investigation is being made to study the reference sediment concentration to correlate bed load with suspended bed material load.

7. Field studies:

- a. Frictional resistance in river with or without overbank flow.
- b. Sediment load in river.

XVII. TOKYO INSTITUTE OF TECHNOLOGY, Tokyo, JapanA. Person Visited:

H. Kikkawa.

B. Facilities:

1. 1.2 ft wide and 24 ft long glass wall flume tiltable up to 1/20.
2. 3 ft wide and 40 ft long glass wall wave channel.
3. 1.5 ft wide, 1.5 ft deep and 60 ft long glass wall flume tiltable up to 1/30.
4. 1/3 ft wide, 1/2 ft deep and 6 ft long glass wall flume. A hydrogen bubble flow visualization apparatus attached.
5. A low turbulence wind tunnel with 1/3 x 1/3 rectangular plastic measuring cross section. Wind velocity is within a range of 0 to 60 ft per second.
6. 1/3 ft wide, 2 ft deep and 6 ft long glass wall flume. Three artificial turbulence agitators of ultrasonic mechanism are attachable.

C. Some Active Programs:

1. Suspended sediments and bed roughness: To investigate the effect of wash load on the bed shear and the decrease of Kármán constant. A report of this study is presented as "On the Effects of Suspended Sediments to the Bed Roughness," by H. Kikkawa, H. Shi-igai, and S. Fukuoka. Proceedings of the XII Congress of the International Association for Hydraulic Research, Fort Collins, Colorado, 1967.
2. Mixing of salt-and fresh-water by waves: To investigate the rotationality of the waves on the surface of density-gradient water body.
3. Oscillation of submerged oil tanks by waves: To investigate the lateral and transverse vibration of submerged spheres by surface waves. Also to study the characteristics of Kármán vortices caused by wave motion.
4. Run-up and overtopping of waves on inclined shores: A theoretical and experimental study to estimate the amount of overtopping water. A theoretical and precise new formula is proposed.

XVIII. HYDRAULIC LABORATORY, CHUO UNIVERSITY, Tokyo, Japan.A. Person Visited:

T. Hayashi.

B. Function:

This hydraulic laboratory belongs to the Chuo University which is a private university. Contrary to other Japanese National Universities which normally do not perform hydraulic investigations for private industries, this hydraulic laboratory does conduct numerous hydraulic research projects for private industries.

C. Facilities:

This laboratory is very well equipped with modern instruments. Data can be collected from a scanning device of a digital logger and analyzed with an analog.

1. One steel flume, 90 feet long, 3 feet wide and 2.5 feet deep.
2. A wave channel 90 feet long, 2.5 feet wide and 2.8 feet deep, with a flap-type wave generator.
3. A super-critical flow channel (MIT type), 45 feet long, 2.1 feet wide and 0.9 feet deep, tiltable up to 1 on 7 slope.
4. A flume for the study of the gate, 27 feet long, 6 feet wide and 2.5 feet deep.
5. A wave basin 36 feet long, 16 feet wide and 0.9 feet deep.
6. A partially thermally insulated basin for the study of thermally stratified flow, 6 feet long, 6 feet wide, 2.2 feet deep.
7. Pipe-lines for water hammer problems.
8. Pipe-lines for studying surge tanks.

For detailed description of this laboratory, see "The Hydraulic Laboratory of Chuo University" by T. Hayashi, The Seminar on Instrumentation for Hydraulic Research, U. S. - Japan Cooperative Science Program, April 7-15, 1965. (Reference 38).

C. Some Active Programs:

1. Forces on a roller gate: One aim is to determine the range of flow conditions that will cause excessive force and vibration in the roller gate.

2. Intake in a thermally stratified reservoir: The withdrawal of water from a thermally stratified reservoir into an intake is being investigated both theoretically and experimentally. The streamlines of the flow in the reservoir will change greatly if reservoir water is changed from a uniform thermal gradient to a thermally stratified case (Reference 39). "Diffusion of Warm Water Jets Discharged Horizontally at the Water Surface", by T. Hayashi and S. Nabuo. Proceeding the XII Congress of the International Association for Hydraulic Research, September, 1967, Fort Collins, Colorado.

3. Diffusion of cooling water from power stations in the sea basin: The development of a diffusion theory to predict the distribution of cool water into a wave basin with the aid of experimental data.

CONCLUSIONS

1. This report describes only the author's impression of different hydraulic laboratories obtained from brief visits, and thus cannot serve as detailed analysis or even comparison of the institutions during the visits.

2. The author benefited immensely by the discussions held with many leading researchers, and it is his hope to share some of his experiences with others.

3. The warm, kind, and enthusiastic reception accorded the writer at every laboratory is evidence of the increasing, world-wide interest in every phase of hydraulic research.

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