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# SIXTH INTERAGENCY CONFERENCE ON HYDRAULICS LABORATORY TECHNIQUES AND INSTRUMENTATION

by

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
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SIXTH INTERAGENCY CONFERENCE
ON
HYDRAULIC LABORATORY TECHNIQUES AND INSTRUMENTATION

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13-14 November 1968
Vicksburg, Mississippi

## WEDNESDAY, 13 NOVEMBER 1968

The meeting was convened in the Waterways Experiment Station main conference room in Vicksburg, Mississippi at 8:30 AM with Mr. E. P. Fortson, Jr., Chief of the Hydraulics Division, presiding. Col. Levi A. Brown, Director, WES, welcomed the conferees and expressed the hope that better instrumentation and test techniques might reduce the high labor costs of hydraulic model testing. The increasing use of new mathematical techniques and computers requires greater sophistication in input data and analysis.

Mr. Fortson initiated the introduction of the conferees and gave a brief orientation and history of the conferences. Messrs. Huval and Bastian, WES, served as recorders. A list of attendees is attached as Appendix I. The agenda and discussion topics furnished to the participants are included as Appendices II and III. Agencies participating in the conference were the Tennessee Valley Authority (TVA), the U. S. Bureau of Reclamation (USBR), and the hydraulic laboratories of the U. S. Army Engineers including the North Pacific Division (NPD), the Coastal Engineering Research Center (CERC), and the Waterways Experiment Station (WES). The Naval Ship Research Development Center (formerly David Taylor Model Basin) had been invited to attend, but declined due to previous commitments.

### Record of Discussion Topics

### Waves

1.* A Digital Computer Program for Tsunami Refraction (WES). The main purpose of the tsunami study, as outlined by Captain Harrison, is to provide input data for orientation of tsunami wave fronts in relation to critical harbor locations in the Pacific Ocean. This information can then be used for design of hydraulic models and location of surge generators to simulate tsunamis. A computer program coded to plot tsunami refraction diagrams using a finite difference technique has been developed. The program allows for the distorted representation of the earth's surface as represented by Mercator projection. Several known solution test problems have successfully been tested on the program. No discussion.

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*The order of discussion topics follows that given in Appendix III.

Incl 1

2. Analog Simulation of Wave Action (WES). Mr. Ferguson gave the background and some information on the analog computer of the Chesapeake Bay recently acquired by the WES. The computer was developed for the Defense Support Atomic Agency to study wave damage caused by a possible nuclear explosion in the Chesapeake Bay. The model is quite bulky; did not give the necessary accuracy; and has since been supplanted by digital computer techniques. Mr. Ferguson said this equipment would be demonstrated on the tour scheduled for 14 November. No discussion.

## Laboratory Techniques

3. Techniques for Investigating Stratified Flow (WES). Mr. Bohan explained the laboratory and instrumentation techniques used in this study. Conductivity probes and thermistors with digital thermometers and millivoltmeters are used to sense salinity and water temperatures. A 30-point connection box is used to sequentially scan the thermistors and print out temperatures. Movie cameras are used to record dye traces for determining flow velocities. A computation method for predicting the zone of reservoir withdrawal has been proposed; the investigation is continuing. Mr. Bohan said the test facility would be demonstrated on the tour. No discussion.

4. Stratified Flow and Withdrawal from Reservoirs (USBR). Dr. Falvey explained the study in a wide, 3-dimensional flume using thermal stratification to simulate reservoir stratification. A refrigeration unit and sufficient insulation of flume walls are required for proper water temperature control. Thermistors are used in arrays for measurements, using output equipment similar to the WES study (topic 3, above). A slotted wall inlet is used to simulate various stratifications and a skimmer is used to divide the flume outlet water by temperature. An interesting result of the study was the circular or spiral currents upstream of the withdrawal intake. No discussion.

5. Design of Structures for Control of Thermal Discharge (TVA). Mr. Driver explained the model studies of steam power plant condenser water intake and outlet designs. Studies of the diffusers for the Brown's Ferry steamplant were conducted at MIT in a two-dimensional flume and proved the effectiveness of the diffusers for mixing the outlet flow with channel water. The problem at the Cumberland steam plant involved a skimmer wall at the condenser water intake and excessive mixing at the plant outflow channel. The outlet channel was designed so that the hot water outflow would remain in the upper layers. The problem area was modeled using temperature stratification with a heat exchanger and temperature controlled model water. Temperature stratification was used in the model because salinity stratification is sharper than the prototype thermal interface. Model results did indicate excessive mixing in the outlet channel requiring modifications in the design.

Model instrumentation included 300 thermisters with a cross bar scanner. Each probe had 8 thermisters spaced 0.1 ft apart. A data sample cycling procedure similar to that employed in the WES flume study was used with a print out on a teletype machine. The difficulty with this kind of study is in data analysis and plotting. An on-line computer is on order to help speed up data reduction. Dr. Falvey asked about the problem of changes in the temperature regime right around the thermister due to higher conductivity from the brass support. Mr. Driver replied that the main body of the probe was coated with an epoxy of low thermal conductivity and the thermisters were coated with a high thermal conductive resin.

6. Loads on Stilling Basin Walls (NPD). Mr. Smith presented a brief summary of model tests to measure average and fluctuating pressures on stilling basin walls using 1/2-in.-diam. pressure transducers. Maximum pressure fluctuations of 38 and 26 percent of the spillway inflow velocity head were measured on two high-Froude-number stilling basins (Dworshak and Libby Dams, respectively). Prototype facilities will be installed to obtain similar data at Libby Dam. An Engineer Study program is proposed to study hydraulic loading in the laboratory with provisions for measuring forces and moments on half-monoliths of the stilling basin side wall. The problem is how to measure the moments on the walls. A question was raised by Dr. Falvey as to whether the inertia and stiffness of the wall could be modeled. Mr. Smith said the test planning was in the very preliminary stages, and wondered about the problem of water sealing on both sides of the test monolith. Mr. Huval mentioned that the University of Iowa was doing this type of measurement for vertical vibration of low crest spillways. Mr. Basco suggested contacting the Utah State University which has similarly been involved in measuring fluctuating wind loads.

7. Yellowtail Dam Outlet Works Pressure Tests (USBR). Dr. Falvey gave some information on field test instrumentation to measure pressure fluctuations and acceleration on a hollow jet stilling basin dividing wall. He mentioned the Bhakra Dam (India) splitter wall failure as giving the USBR some concern. The data were recorded on magnetic tape and analyzed by means of an analog wave analyzer. The accelerometer records showed very little wall movement. Several pressure transducers are no longer operable, presumably due to moisture shorting out the electrical circuits. The pressure transducers were flush-mounted CEC cells installed before project flooding. There is a need for waterproofing pressure transducers over long time periods.

Mr. Dale related the TVA experience on navigation locks using 1/2-in.-diameter, CEC cells secured into 8 in. by 8 in. plates, flush-mounted with an adapter and grommet sealing the electrical cable. Reliability has been good over a 4 or 5 year period but some failures must be expected, especially after a year or so. He suggested the source of trouble is probably water leaking in the electrical conduit at inadvertant cable cuts and shorting the electrical cables leading to the cell. Mr. Huval noted that the WES prototype test policy is to install the transducer just prior to testing with removal after test operation. Mr. Fortson

related pressure transducer failure during Mississippi River revetment pressure fluctuations tests some years ago.

8. Techniques for Measuring Drag Forces on Baffle Piers (WES). Mr. Basco explained that the purpose of the study was to determine the hydraulic jump performance under a wide variety of design changes in shape, size, spacing, etc. of baffle piers. For this purpose, the baffle pier drag coefficient will be used for correlation and hopefully the study will result in generalized stilling basin design. Wave rods will be used to measure the depth downstream of the jump as well as wave heights. A light bulb type of point gage will be used in the rough approach flow to obtain average upstream depth. The velocity distribution downstream of the jump will be measured using a differential pressure transducer on a Pitot-static tube. Critical low-pressure zones on baffle piers will be studied using 1/8 in. diameter Sensitech pressure transducers. The drag force will be measured using an instrumented drag box fitted to a sliding floor under the jump. Statham load cells will be used to measure the load on the whole box to give average baffle pier load. Mr. Basco said the flume and some of the equipment would be shown on the tour. Messrs. Elder and Dale mentioned similar tests last spring at TVA; a single stiff support was used with strain gages to measure baffle pier loads. Strain gages are easy to waterproof.

9. A Statistical Definition of Boundary Roughness in Open Channel Flow (WES). Mr. B. J. Brown gave the background of the study. Tests have been conducted on boundary channel roughness of 1 in., 3/4 in., 1/2 in. and 1/8 in. diameter crushed stone. Preliminary results give very good correlation between stone surface standard deviation and the equivalent Nikuradse hydraulic roughness. Suggestions were requested on point gage stone surface measurements which are tedious to do and analyze statistically. Mr. Elder suggested the use of a laser beam as being a promising development for this type of measurement. Brown Engineering, Huntsville, Alabama, is a good contact for laser developments. Mr. Basco suggested commercial concerns might be able to modify standard surface finish measuring equipment. Dr. Falvey said the USBR had made a similar study on sand grain surface using micrometer point gages for statistical correlations. Mr. R. P. Savage pointed out that the cone of an acoustic beam would probably be too wide for the size of rock being studied. He mentioned an optic device developed at Wallingford, England, to measure sand-water interface.

10. Total Head Tubes to Measure Turbulence (USBR). Dr. Falvey said the USBR was interested in turbulence pressure measurements, especially in power penstock studies. A 1 or 2 mm piezoelectric pressure transducer had been purchased. This will be installed in a total head tube. He inquired as to the effect of an angle of attack of flow fluctuations and swirling type flow on the tube response. Information was requested on other experimenters who had done similar work. A typical signal of penstock swirl was shown using a pressure transducer coupled to a piezometer line. The effect of length of piezometer line is also a problem.

Mr. Downing pointed out that piezoelectric crystals respond only to fluctuating total head. Mr. B. J. Brown said that he knew of studies being made at Ling-Temco-Vought using total head apparatus from a recent short course on turbulence at the University of Missouri. Messrs. Basco and Huval noted the extensive work done at MIT on turbulence measurements in water using total head tubes.

11. Digital Recording System for Multigage Location on Hydraulic Models (WES). Mr. Downing reviewed the various methods of measuring water levels on large hydraulic models. The complexity required is a function of the number of needed measurements and increases roughly from (1) manual direct system with point gages, (2) manual remote with central measuring well and point gage, (3) automatic direct with small transmitters as used on the Mississippi River model, (4) automatic remote with manifold and central water level recorder and (5) automatic remote system with rigid piezometer leads connecting to a manifold and central pressure transducers. The last technique is being seriously considered due to the rapid response time and the savings due to elimination of transmitter-receivers. Air bubbles and manifold valve displacement are two problems with this kind of system.

Dr. Falvey inquired about monitoring the valves on the manifold. Mr. Hill, who is involved in the system development, explained the operation of the system including the oscilloscope monitoring for valve positions. The output of the system is in the form of paper tape printout with manual plots of water levels. A general discussion comparing the efficacy of a large central digital computer for data analysis and smaller on-line digital computers for hydraulic model studies was conducted. The USBR is leaning toward digital punch tape and computer data reduction. Mr. Downing pointed out that with large computer systems, setting priorities and time sharing problems become important requiring careful management for effective computer use.

## Instrumentation

12. Instrumentation Development for Field Monitoring (TVA). Mr. Dale explained the hydrological and meteorological monitoring systems required for steam power plant operations. He explained some of the background of the electronic development of a radio telemetry with punch paper tape output system. A study of an alternative computer controlled system has proved that considerable gains can be made in data acquisition and reduction for engineering units. A small 4K memory computer at a cost of less than $10,000 is being considered which compares very favorably with the previously planned system.

In response to a question from Lt. Abel, Mr. Dale said the system reliability is expected to be very good. Mr. Hill asked what type of thermisters were used to measure air temperatures. Mr. Dale

said they were both the resistance and current type purchased from Yellow Springs. These instruments are somewhat expensive but have the considerable advantage of being matched thus not requiring individual calibration factors.

13. Low Velocity Measurements (USBR). Dr. Falvey outlined the problem involved with measuring low velocities for stratified flow tests. Dye tracers and photography present considerable problems due to the 3-dimensional nature of the stratified flow. Mr. Driver suggested the laser technique previously suggested under discussion topic number 9. He mentioned Anwar's work (Wallingford, England) where a light beam was shined through glass walls and scatter technique was used to measure low velocities. The directional aspect could be obtained by rotating the beams. Mr. Elder then described the radioisotope injection rig used by TVA (known as the deep water isotopic tracer counter, DWICA) to measure low velocities. A ring of scintillation detectors senses the time from injection in the center of the ring. The device has been used to measure velocities from 0.01 to 0.1 ft/sec but has very slow response, is very bulky, has considerable anchoring problems and typically requires 8 hours for one vertical velocity traverse.

14. Electronic Instrumentation of the Pitot Tube (WES). Mr. B. J. Brown stated that improved accuracy in low flow velocity measurement was accomplished by using a differential pressure transducer in conjunction with an 1/8-in. Pitot-tube. The flow total head and static pressures are transmitted by 1/8-in. plastic tubes from the Pitot-tube to a variable reluctance differential pressure transducer. The electrical signal from the transducer feeds into a transducer indicator which measures the output signal by means of a digital indicator or a pointer deflection on a meter-scale. Due to pressure fluctuations in the flow the output signal is read by means of the digital indicator (null-balance mode) in conjunction with a digital voltmeter.

The pressure transducer was calibrated statically by means of two cylindrical reservoirs built into the transducer housing. Water elevations in the reservoirs were measured by two hook gages which can be read to 0.001 inch. Dynamic calibration was made in a 14-ft diameter circular rotating tank. The difference between the dynamic and static calibration indicated that the Pitot-tube coefficient had an average value of 0.98. Mr. Brown said that this equipment would be shown during the tour. No discussion.

15. Hot-Film Anemometry (USBR). Dr. Falvey reviewed the USBR experience using Thermal Systems hot-wire and film anemometers. Very successful results have been obtained using hot-film sensors in air. The recent operational improvements to the anemometer system were noted; unfortunately, the probes are still delicate and easily broken by inexperienced personnel. Mr. Downing inquired as to contamination problems in

water and size of the probe. In reply, Dr. Falvey said the parabolic shaped probe showed no detectible change in calibration in spite of algae in the water, and other contaminants. The probe is about 2 or 3 mm in size. In response to Mr. Hill's questions, the probes had not been tried in salt water, the minimum test velocity was in the ft/min. range and the price was in the $5,000-$10,000 range.

Mr. R. P. Savage gave the CERC experience in water wave measurements, mentioning directional velocity response, and a heat "shadow" effect due to the oscillatory flow. At MIT, the latter problem was circumvented by towing the instrument carriage at the wave speed. Wave tank contamination at the University of California led to the use of distilled water. He noted the Australians are beginning to cool their probes rather than heating to eliminate some of the electrolysis and other problems in water.

Mr. Dale gave some of the TVA experience and asked some questions. Cylindrical shapes are poor in water because of contamination but work well in air. Quartz coating tends to crack, oxidizing the wire. Reliable results have been obtained over weeks and months of operation. In response to specific questions Dr. Falvey said that a linearizing system was used, the temperature compensator would not work, and the overheat ratio was kept low. Mr. Boyd mentioned the turbulence work being done at Colorado State by McQuivey. Recently, field tests were conducted in the Mississippi River with apparently encouraging results. Some tests are reported at the recent ASCE meeting at MIT.

16. Remote Control Model Tow Boat (WES). Mr. Glover introduced the model towboats to the conference stating that the system being used is about fifth generation in development. Remote direction and speed control of the boats is done by servo-controlled mechanisms and are continously variable. These model tow boats will be demonstrated during the tour. In response to Mr. Elder's question, the model scale is 1:96 and the actual size boat and tow is 1.75 ft long. Mr. Franco noted that these model tow boats give information on model cross currents not obtainable by velocity measurements and can be used to simulate multi-tow operation at and near navigation locks.

17. Towing Tank Design (WES). Mr. B. J. Brown said that the WES is considering building a towing tank to calibrate midget current meters and other measuring instrumentation for velocities of about 0.01 to 4.0 fps, and would appreciate information on towing tanks used by other organizations. Mr. Elder said TVA's tank was designed for lower velocities than the maximum desired by WES. Mr. Chanda brought out that the NPDL has a 5 X 5.8 X 250 ft towing tank which is described in TR No. 843-1. It was also suggested that inquiry be addressed to the Naval Ship Research and Development Center (formerly DTMB).

18. Prototype Lock Water Level Recording System (WES). Mr. M. J. Savage discussed instrumentation involved in the air-purge system used successfully recently at Demopolis and Barkley Locks to measure lock water slope and differentials. A 1-psid pressure transducer was used to measure the lock water differentials and a water sensing device to indicate minimum bubbling rate to insure complete air purging of piezometer line. Stressed were (a) the importance of equalizing the volume of the two pneumatic lines joining the transducer to the submerged outlets and (b) the regulation of the bubbling rate to avoid differences in the response time of the gas filled line. Mr. Smith noted the response and lag problem with small pressure variations between lock ends.

19. Dynamic Valve Stem Measurements (WES). Mr. M. J. Savage reviewed the recent strain gage tests of the reverse tainter gate valve at Barkley Lock. Three sets of Baldwin-Lima-Hamilton four bridge strain gages were mounted around the valve stem circumference 120 degrees apart. These were employed to yield the lifting strain, bending moment and turbulence effects experienced by the stem during filling and emptying operations. Data will be reduced to give average and fluctuating stresses. No discussion.

20. Hydraulic Telemetry Presentation (WES). Mr. Downing noted that the telemetry work being done at WES is similar to that at TVA (discussion topic No. 12). Generally long range and short range telemetry are involved in different kinds of field testing problems. For long range telemetry in remote locations, butane has been developed as power supply in severe cold and solar cells in more temperate climate. The measurements usually involve weather station, rainfall, water level and other similar data. Short range telemetry involves distances of 1 in. to 200 ft and vary from rotating shafts on trucks to projectile deceleration in ground penetration. In response to questions by Messrs. Elder and Fortson, Mr. Downing said the equipment used for short range telemetry is commercially available, off-the-shelf components.

## Hydraulic Structures

21. Howell-Bunger Valve Containment Structure Studies (TVA). Mr. Elder stated that TVA has become interested in the dissolved oxygen reaeration abilities of Howell-Bunger valves and has worked towards standardizing a containment structure to control spray formation. The study concerns various configurations of containment mountings for heads ranging from 50-350 ft and valves of 3-10 ft in diameter. The first phase of study yielded excellent water reaeration without the containment structure. The second phase demonstrated that with a containment structure reaeration was still good. The third phase involves the valve near the inlet region of a non-pressure tunnel. A report on the first two phases concerning reaeration has been published with more reports due in the near future.

22. Instrumentation Installation in Howell-Bunger Valve (WES). Mr. Downing presented the vibration and strain instrumentation installation for field measurements on a Howell-Bunger valve. The problem here was inability to use telemetry because of the steel conduit and the air-water mixture of the flow. Also the flow around the valve body precluded the use of electrical cables. A solution was found by installing a pipe conduit on the leading edge of one of the valve vanes to a waterproofed hole on the valve periphery. No discussion.

23. Effect of Upward Revision of Spillway Design Discharge (NPD). Mr. Smith reviewed model studies at Chief Joseph and Dworshak Dams designed to check the feasibility of using an existing spillway and one now under construction to pass flows with heads in excess of the maximum design head. Under heads as high as 1.70 $H_d$, it is desired to know what are the minimum pressures for possible cavitation as well as pressure fluctuations. Conventional manometers were used to obtain average pressures and a quick-acting manometer (small piezometer tube, short lead) to measure pressure fluctuations. The tests indicated minimum pressures of -24 ft and -29 ft of water for Chief Joseph and Dworshak, respectively.

24. Revision of Existing Vertical Lift Gate Bottom, Bonneville (NPD). Mr. Smith presented the problem involving the vertical-lift gates of the Bonneville Dam spillway which experience vibration when the gate bottoms are submerged a few feet in the tailwater. The vibration problem will become more acute when greater peak power production is required at Bonneville Dam. Four alternative bottom shapes with distinct extended lips for control and stability of flow on the bottom of the gates are being studied. A problem had been that the suspension of the model gate was more elastic than that in the prototype thus causing resonance which could result in destruction of the model. In response to Mr. Elder, Mr. Smith said that the gates are cable supported and that it is planned to test the gates in dogged positions.

25. Skewed Bellmouth Entrances (NPD). Mr. Smith stated that at the last interagency conference a model study of pressure problems in a skewed bellmouth for high-head sluice intakes was reported; testing of a new bellmouth shape had been proposed. Subsequent tests showed the shape to be satisfactory and was adapted to fit the intakes of the Dworshak and Libby Dam sluices. An ES study is proposed to determine the relative importance of various geometric ratios on entrance pressures. Most of the information and results of these tests have been published.

26. Draft Tube Surge Studies (USBR). Dr. Falvey defined the surging problems for the planned Grand Coulee Dam power plant as an instability from swirling flow in the draft tube which causes pressure fluctuations in the penstock, turbine and generator bounce and power output fluctuations. The investigation involves a library search, mathematical approaches and model tests to study typical draft tubes with swirling flow. A consultant board suggested the USBR start with a simple, basic, air model, designed with capabilities for changing the air discharge and the model configuration. One unique aspect of the air model is that the model runner was fabricated from epoxy resin. With an air model there is no problem from change of state, such as cavitation in water. Studies include the effects of the draft tube length to diameter ratio, the expanding sections and the elbow type draft tube. Measurements are made by pressure transducers and a hot-film anemometer to determine any possible periodic frequencies in the flow. Signals from the hot wire anemometer or pressure transducer are fed into a repetitive type oscilloscope screen to find any periodic frequencies.

Mr. Fortson asked whether this air model investigation would be extended to a water model. Dr. Falvey said that USBR was doing a feasibility study for building a hydraulic test stand capable of handling 1000-2000 hp with full prototype heads up to 1200 ft and to test hydraulic machines in all four quadrants. Testing would include cavitation phenomenon, draft tube surging, turbine efficiency, energy dissipation and other aspects of flow through turbines. No such facility is at present in operation in the country.

27. Grand Coulee Third Power Plant Penstock Entrance Studies (USBR). Dr. Falvey introduced this study as being related to discussion item 26. The effects of unsymmetrical inlet flow conditions and entrance shapes on the turbine and the effect of air entraining vortices on possible turbine instability are being studied. The intake to the penstock was value engineered, balancing the cost of intake construction versus savings in head and power production. In response to Mr. Huval's question Dr. Falvey said pressure fluctuations are being recorded with pressure transducers coupled to long piezometer leads, but it is hoped to measure fluctuating total head with tip mounted transducers.

28. Extension of Central Distribution System Lock Tests (NPD). Mr. Chanda reviewed the model investigation for the Lower Granite Lock. Good results have been obtained with the eight-manifold central distribution system. With the adopted valve opening time of one min., maximum hawser forces for an 11,000-ton tow were less than 2.5 tons. ES funds have been provided for studies to obtain additional design data at other heads and submergences. The study will be extended to a four-manifold system. No discussion.

## Open Channel Flow

29. Radioisotope Studies (USBR). Dr. Falvey presented the problem of developing a simple, rapid and accurate technique for measuring conduit discharge and mixing length. Tests are being made at the Flatiron pump-turbine plant in conjunction with the Atomic Energy Commission. Three methods to compute discharge are by the total count, integrated sample, and peak passage time techniques. It is desired to measure for a range of pipe lengths from 25-100 pipe diameters to insure complete mixing. The calibrated spiral scroll case taps (Winter-Kennedy taps) are used as reference discharges for comparison. Accuracy of the tests was within 10% when sampling 35 diameters downstream and about 1-2% when sampling 300 diameters downstream. Improvement is needed in sampling and injection techniques.

An alternative would be the use of acoustic flowmeters. Specifically suggested by Westinghouse was a configuration with six transducers and the acoustic paths located in three vertical planes in a conduit. The output would be analyzed by Guass quadrature with an estimated accuracy better than 1% irrespective of the velocity distribution. Mr. Hart suggested the review of a recent WES report written by Mr. E. B. Pickett on acoustic flowmeters.

Mr. R. P. Savage reviewed the work done by CERC to develop acoustic flowmeters for wave velocity measurements. Towing tank tests with a leased model from Westinghouse gave very good accuracy and directional response. Present thinking is the use of a 3-sided triangular acoustic path array spaced about 2 or 3 ft apart. Mr. Huval suggested this method for stratified flow density currents. The high ($70,000) cost of such a device could possibly be justified if the rig could be used on several projects. Mr. Hart suggested the use of activation analysis for discharge measurements, that is injecting inactive tracers and then having the resulting samples irradiated and then determine radioactivity in the laboratory. This would avoid the problems of licensing and test timing due to decaying radioactive nuclides.

30. Colorado River Model (USBR). Dr. Falvey spoke about the model study of a reach of the Colorado River in which they are trying to study the mixing of a pollutant injected into the river at the upper end of the reach so that the Mexican and U.S. governments field water sampling techniques can be made consistent. Fluorescent dyes and detectors are used in the model.

The topic of dyes as a tracer for mixing and pollution studies was discussed in some detail. Mr. Herrmann wished to know if there was a replacement for pontacyl pink which has apparently lately become unavailable. He mentioned the WES is using two different fluorescent dyes to

speed up testing operations. Uranine and Prussian blue were mentioned as useful as well as the fact that Colorado State University has run stability and degrading studies (adsorption or staining on model concrete surfaces) of various dyes. Prussian blue had better properties for model testing.

31. Boundary Shear in a Field Canal (USBR). Dr. Falvey presented the method for measuring the field boundary shear in irrigation canals using a Preston tube. The shear strength of the soil is measured using a split shear sampler. The tests are repeated at higher discharges until erosion of the bottom cohesive soil takes place. A report is in preparation. No discussion.

32. Stability of Riprap (USBR). Dr. Falvey's presentation of a graduate research project in which it is desired to ascertain the incipient velocity under a sluice gate necessary to initiate the movement of riprap. Often riprap fails first in the lower turbulence level area well downstream from the gate. The problem here is a criteria for movement and the turbulence level as well as mean velocity at failure. No discussion.

## Data Analysis

33. Spectral Analysis of Data (USBR). Dr. Falvey reviewed the experience of the USBR on the data reduction procedure and use of spectral analysis of fluctuating data. Major problems are whether the data should be reduced in analog or digital form and the interpretation of the spectra in terms of the other hydraulic variables. The USBR has been using a Singer analog filter. He related that MIT has been satisfied with their analog reduction equipment whereas University of Iowa (Mr. Locher) reports superiority of the digital approach.

Mr. R. P. Savage stated that CERC had tried both approaches. It is now their opinion that in spite of formidable mathematics, high data digitizing costs, and quantity of mathematical operations required, the digital approach was better due to flexibility. He mentioned a recent technique called fast Fourier transform which decreases computations by one-tenth. CERC has employed the services of Dr. Harris, Weather Bureau, to help. Programs are available, but usually require extensive modifications to fit the problem and data. Large computer storage is required. Spectrum analysis has been used to describe a confused or random sea more completely than is possible with the simple significant wave height and periods. There is a large problem of education required for use of spectrum data by design engineers.

Mr. Ferguson said the WES is using mostly analog wave techniques. An auto-and-cross-correlator has been purchased to give fluctuating signal correlations in addition to spectrums. Magnetic tapes have to be speeded

up to get accuracy in the low frequency region. Mr. Ferguson also mentioned the probability density analyzer which can be used for statistical descriptions of fluctuating signals. Mr. Basco expressed the view that hydraulic engineers would have to learn about and how to use spectrum analysis in design. For example, the failure of splitter walls requires the knowledge not only of average but fluctuating pressures. The fluctuating pressures from a model study could be presented to a designer in the form of standard deviation and the spectrum of the pressure fluctuations to check whether there is any danger of wall oscillation due to resonance. This kind of information has been provided in other technical fields, especially in aeronautics.

34. Hydro Turbine-Generator Vibration Measurement and Data Reduction (TVA). Mr. Dale presented the field measurements data recording, and analysis techniques on the Wheeler Dam shaft vibration. Strain gages, displacement gages, and pressure transducers were strategically located on the turbine and shaft and recorded on a 14 track magnetic tape. The data were analyzed by a Panoramic analog wave analyzer to give mean-squared values and power spectrum density. TVA is now in the process of obtaining analog to digital converters for digital computer data analysis. It is expected that the development of computer programs to do the analysis will be a major effort.

## Miscellaneous

35. Mortality in Fingerling Fish as they Pass Through Hydraulic Turbines (NPD). Mr. Chanda reviewed the 1:1 scale model study designed to allow safe downstream passage of fingerling fish through hydraulic turbines. Vanes and wicket gates, turbine blades, and hub gaps will be used in the test section to study fingerling mortality and compare with a control group. The problem has become more acute as spillway flows become smaller and power discharges become greater on the Columbia River. With normal mortality of 5 to 10% through hydraulic turbines per dam, the several dams along the river could exact a considerable toll on the salmon migrating to the ocean. Measurements of discharge, static and dynamic pressures and water temperature will be made. High-speed photography will be used to record passage of fingerling salmon through the test section. It is necessary to maintain a velocity of 8 fps to prevent the fish from swimming upstream.

36. Performance of Gravel Packs in Wells (USBR). Dr. Falvey's presentation stated the common problem in water wells is that of small sand particles being sucked through the intakes, leaving a void behind and causing ground settling near water wells. To avoid this problem, gravel packs have been placed around the well intake. In placement of this gravel, vertical segregation often results. A model was used to study and correct this. The gravel pack aggregate used in the model was painted

different colors for different sizes. Motion pictures of gravel pack placement produced rather dramatic confirmation of segregation by sizes. Mr. R. P. Savage mentioned that in England, shoe dye was successfully used to color quartz sand.

37. Groundwater Studies on Sloping Land (USBR). Dr. Falvey presented seepage flow model studies using a glass-walled tilting (up to 30°) flume. Water is applied slowly and allowed to percolate through sand in the flume. The water paths are traced by Prussian blue dye and recorded with time lapse photography. The major model problem was in the application of small amounts of water at a constant, metered rate to the surface. This problem was solved by having water flow into a plugged small diameter tube laying horizontally with small holes drilled on the top. Small vertical cylinders around these holes supported small circular plates. The spray through the small holes shot up against the plates and dropped off the circumferences like condensation.

## Additional Topics

Instrumentation for Scour Measurements Near Bridge Piers (WES). Mr. Hart read a letter from Mr. E. B. Pickett, Vanderbilt University Graduate School, requesting information and suggestions on some means to monitor scour around bridge piers. No discussion.

Pueblo Dam Nappe Instability (USBR). Dr. Falvey presented some model test results of thin nappe instability when both ends of the nappe were fully aerated to the atmosphere. The oscillation could be stopped by breaking the nappe into two halves but was sensitive to the location of the nappe divider. The buttress type dam has a pool type stilling basin and one problem is the dynamic pressure of the falling nappe in the stilling basin. Mr. Grace mentioned a recent German publication which discussed a similar nappe oscillation phenomenon.

Yellowtail Dam Model Air Content (USBR). Dr. Falvey showed a photograph of flow around a model vertical bend with an air collar aeration device to help prevent possible cavitation. The photograph was very misleading due to optical and reflection effects. He asked if there was any way to measure air content and to insure a certain level of air and thus protection against cavitation. Mr. Murphy inquired about similarity of air content in model and prototype. Mr. Cox mentioned the Straub-Anderson studies of air entrainment in high velocity flow at the University of Minnesota.

Critique

Mr. Fortson stated that the past locations of these conferences had been Vicksburg, 1956; Denver, 1960; Washington, 1964; Knoxville, 1966; and again Vicksburg, 1968. The next conference host should therefore be the USBR. All conferees were enthusiastic about the value and need of these conferences and agreed to continue on a two-year interval. The conference was ended with a brief preview by Mr. Cox of the tour of the WES hydraulic model area.

CARL J. HUVAL
RECORDER

DAVID F. BASTIAN
RECORDER

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

SIXTH INTERAGENCY CONFERENCE
ON
HYDRAULIC LABORATORY TECHNIQUES AND INSTRUMENTATION

13-14 November 1968

Vicksburg, Mississippi

CONFERENCE PARTICIPANTS

Tennessee Valley Authority

Mr. R. A. Elder
Mr. J. Dale
Mr. E. Driver

U. S. Bureau of Reclamation

Dr. H. T. Falvey

U. S. Army Engineers

North Pacific Division

Mr. A. J. Chanda
Mr. P. M. Smith

Coastal Engineering Research Center

Mr. R. L. Rector
Mr. R. P. Savage

Waterways Experiment Station

Col. Levi A. Brown, Director
Mr. F. R. Brown
Mr. E. P. Fortson, Jr.
Mr. T. E. Murphy
Mr. J. J. Franco
Mr. R. Y. Hudson
Mr. R. G. Cox
Mr. E. D. Hart
Mr. J. E. Glover
Capt. John Harrison
Mr. J. L. Grace, Jr.
Mr. M. B. Boyd
Mr. F. A. Herrmann, Jr.
Dr. L. L. Daggett
Mr. J. H. Ables, Jr.
Mr. T. C. Hill
Mr. C. D. McKellar, Jr.
1 Lt J. F. Abel
Mr. E. S. Melsheimer, Projectionist
Mr. P. K. Senter, Projectionist
Mr. F. M. Neilson
Mr. E. H. Woodman
Mr. G. C. Downing
Mr. J. L. Ferguson
Mr. M. J. Savage
Mr. C. J. Huval, Recorder
Mr. D. F. Bastian, Recorder
Mr. D. R. Basco
Mr. J. P. Bohan
Mr. D. D. Davidson
Mr. B. J. Brown
Mr. L. J. Shows
Mr. R. A. Sager
Mr. N. R. Oswalt

# AGENDA

Wednesday, 13 November

| | |
|---|---|
| 8:30 AM | Registration (Technical Liaison Office) |
| 8:45 AM | Welcome - Col. Levi A. Brown, CE, Director |
| | Introduction of staff, statement of purpose of meeting, comments on agenda - Mr. E. P. Fortson, Jr., Chief, Hydraulics Division, and Conference Chairman. |
| 9:00 AM | Topic Discussions - No. 1 thru 3 (Main Conference Room) |
| 9:50 AM | Break |
| 10:10 AM | Topic Discussions - No. 4 thru 10 (Main Conference Room) |
| 11:40 AM | Lunch |
| 12:35 PM | Topic Discussions - No. 11 thru 18 (Main Conference Room) |
| 2:25 PM | Break |
| 2:40 PM | Topic Discussions - No. 19 thru 25 (Main Conference Room) |
| 4:00 PM | Recess |

Thursday, 14 November

| | |
|---|---|
| 8:40 AM | Topic Discussions - No. 26 thru 32 (Main Conference Room) |
| 10:00 AM | Break |
| 10:20 AM | Topic Discussions - No. 33 thru 37 (Main Conference Room) |
| 11:20 AM | Critique - suggestions for future conferences |
| 11:45 AM | Lunch |
| 12:45 PM | Tour of Hydraulics Division |
| 12:50 PM | Waterways Branch Navigation Shelter No. 2 - Mr. L. J. Shows |
| 1:20 PM | Hydraulic Analysis Branch Office - Mr. E. D. Hart |
| 1:35 PM | Structures Branch Hangar No. 1 - Messrs. J. P. Bohan and D. R. Basco |
| 2:05 PM | Hydraulic Research Facility - Mr. B. J. Brown |
| 2:20 PM | Analog Simulation of Tidal Action - Mr. J. L. Ferguson (Instrumentation Branch) |
| 2:30 PM | Estuaries Branch Shelter No. 5 - Mr. F. A. Herrmann, Jr. |
| 3:00 PM | Wave Dynamics Branch Shelter No. 1 - Mr. D. D. Davidson |
| 3:30 PM | End Tour and Conference |

## DISCUSSION TOPICS

### Wednesday, 13 November

| Waves | Agency |
|---|---|
| 1. A Digital Computer Program for Tsunami Refraction | WESHV |
| 2. Analog Simulation of Wave Action | WESTI |
| **Laboratory Techniques** | |
| 3. Techniques for Investigating Stratified Flow | WESHS |
| 4. Stratified Flow and Withdrawal from Reservoirs | USBR |
| 5. Design of Structures for Control of Thermal Discharges | TVA |
| a. Brown's Ferry Diffusers | |
| b. Brown's Ferry 3-Dimensional Flow | |
| c. Cumberland Intake | |
| d. Cumberland Outlet | |
| 6. Loads on Stilling Basin Walls | NPD |
| 7. Yellowtail Dam Outlet Works Pressure Tests | USBR |
| 8. Techniques for Measuring Drag Forces on Baffle Piers | WESHS |
| 9. A Statistical Definition of Boundary Roughness in Open Channel Flow | WESHP |
| 10. Total Head Tubes to Measure Turbulence | USBR |
| 11. Digital Recording System for Multigage Location on Hydraulic Models | WESTI |
| **Instrumentation** | |
| 12. Instrumentation Development for Field Monitoring | TVA |
| a. Digital Instruments | |
| b. On line Computers | |
| c. Central Data Collection | |
| 13. Low Velocity Measurements | USBR |
| 14. Electronic Instrumentation of the Pitot Tube | WESHP |
| 15. Hot-Film Anemometry | USBR |
| 16. Remote Control Model Tow Boat | WESHR |
| 17. Towing Tank Design | WESHP |
| 18. Prototype Lock Water Level Recording System | WESTI |
| 19. Dynamic Valve Stem Measurements | WESTI |
| 20. Hydraulic Telemetry Presentation | WESTI |
| **Hydraulic Structures** | |
| 21. Howell-Bunger Valve Containment Structure Studies | TVA |
| 22. Instrumentation Installation in Howell-Bunger Valve | WESTI |
| 23. Effect of Upward Revision of Spillway Design Discharge | NPD |
| 24. Revision of Existing Vertical Lift Gate Bottom, Bonneville | NPD |
| 25. Skewed Bellmouth Entrances | NPD |

## Thursday, 14 November

| Hydraulic Structures (Continued) | Agency |
|---|---|
| 26. Draft Tube Surge Studies | USBR |
| 27. Grand Coulee Third Power Plant Penstock Entrance Studies | USBR |
| 28. Extension of Central Distribution System Lock Tests | NPD |
| **Open Channel Flow** | |
| 29. Radioisotope Studies | USBR |
| 30. Colorado River Model | USBR |
| 31. Boundary Shear in a Field Canal | USBR |
| 32. Stability of Riprap | USBR |
| **Data Analysis** | |
| 33. Spectral Analysis of Data | USBR |
| 34. Hydro Turbine-Generator Vibration Measurement and Data Reduction | TVA |
| **Miscellaneous** | |
| 35. Mortality in Fingerling Fish as they Pass Through Hydraulic Turbines | NPD |
| 36. Performance of Gravel Packs in Wells | USBR |
| 37. Groundwater Studies on Sloping Land | USBR |