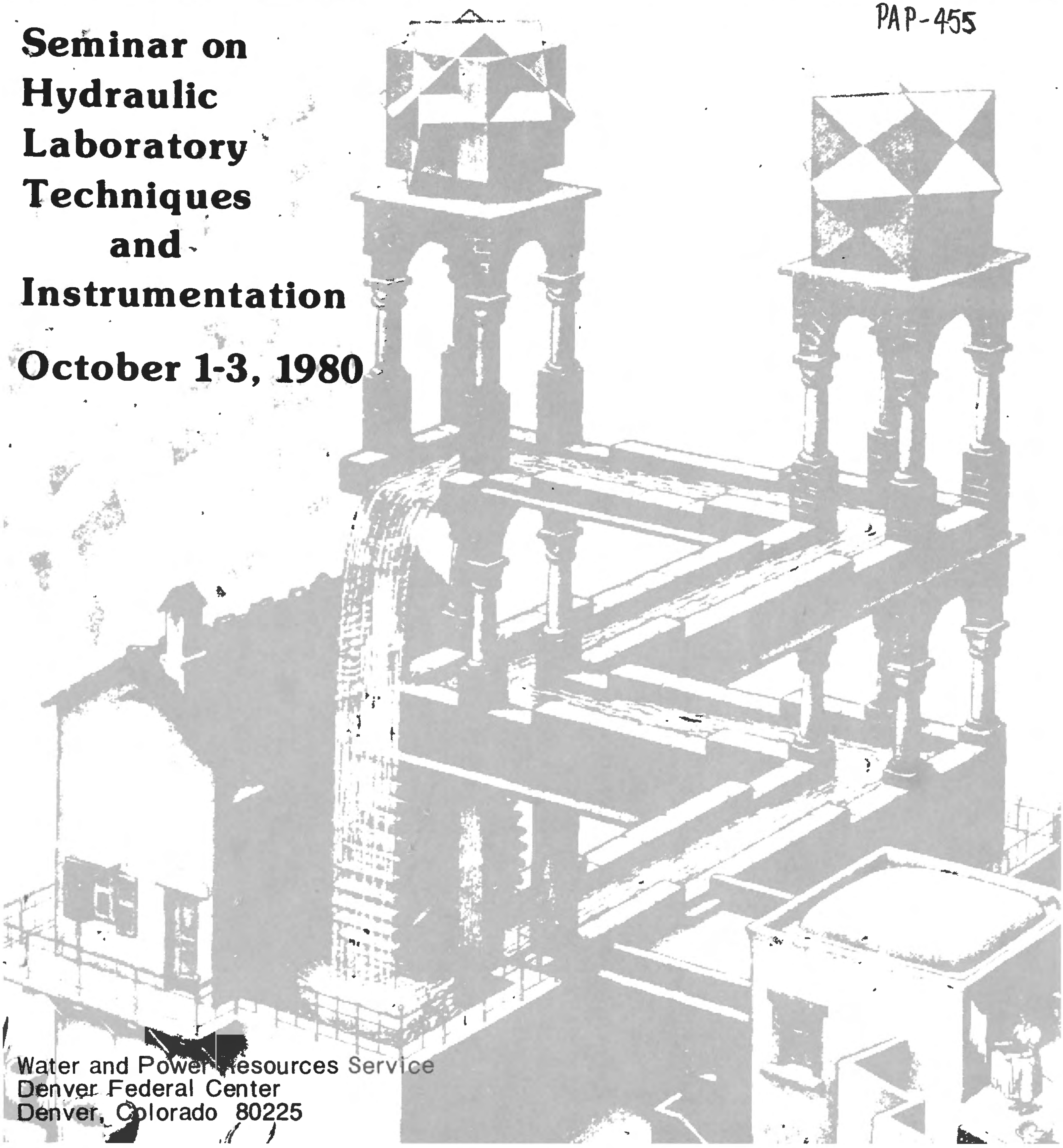
HYDRAULICS LABORATORY 50th ANNIVERSARY

PAP-455

Seminar on Hydraulic Laboratory Techniques and Instrumentation

October 1-3, 1980



Water and Power Resources Service
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Denver, Colorado 80225

INTRODUCTION

Since 1956 Government laboratories have been meeting to exchange ideas on hydraulic laboratory techniques and instrumentation. These meetings have been held at about 2-year intervals. This seminar was the eleventh of the series and represented a radical departure from the traditional participants. For the first time, university and private laboratories were invited to attend. This outside participation added additional spice to the meetings.

To maximize the exchange of information, participation was limited by invitation to the major laboratories in the United States. A strong emphasis was placed upon discussions of what did not work as well as what was successful. In addition to the scheduled talks, an impromptu session was held to discuss "who knows about ____?"

One of the highlights of the seminar was a panel discussion following the banquet concerning the management of research from the Government, private industry, and university viewpoints. Surprisingly, there were far more similarities than differences between the three types of laboratories.

The format of this report is an overall summary of each session, comments on each paper, followed by the papers. It was felt that this format promoted the greatest amount of candid response from the participants.

Seminar Agenda Organizing Committee

Danny L. King
E. J. Carlson
Henry T. Falvey
Thomas J. Rhone

Session I - Recent Developments in Hydraulic Laboratory Instrumentation

Data Acquisition and Analysis

- Laboratory Data Acquisition
- Interactive Data Analysis of Quasi Steady State models
- Computer-based Data Acquisition and Analysis
- Display and Analysis of Prototype Data
- Microprocessor-based Vortex Monitoring System
- Automatic Data Acquisition for Energy Losses in the Bulb Turbine Model
- Calibration and Instrumentation of the Variable Rate Gilsonite Feeder for Gilsonite Bed Model
- Utilization of the Microprocessor-based Computer for Closed Loop Control Both in the Field and Laboratory
- Laboratory Flow Control
- Computer Control and Monitoring of Sacramento River Model

Instrumentation - Special Topics

- Performance of Chamber-mounted Pressure Transducers
- Measurement and Analysis of Velocity Vectors and Pressure Fluctuations in the Model of the Draft Tubes of the Bath County Pumped Storage Project
- Laboratory Instrumentation to Study Fluid-Structure Interactions
- Detection of Cavitation Inception and Damage
- Wire-guided Model Boats
- Remote Sensing of Sediment Density for Prototype Measurements in Inland Waterways
- Precise Radar Positioning System
- Measurement of Velocity Distribution in River Bends

Session II - Similitude and Scale Effect

- Laboratory Modeling of Ice Retention Structures
- Measurement of Floating Ice Forces in Models
- Ground Walnut Shells for River Model Sediment
- Simulation of Free Jet Scour of Rocky River Beds
- Width vs. Depth Curves for Calibration of Sandbed Models
- Fluorometric Sand Tracing
- Investigation of Reaeration Characteristics
- Pump Station Sump Modeling
- Effect of Test Apparatus Geometry on Draft Tube Surge Studies
- Modeling River Hydraulics Under Tidal Influences
- Measuring Air Release During Column Separation

Session III - Model Construction and Simulation Techniques

- Quality Assurance Program
- Erection of Hydraulic Models of Rivers and Reservoirs
- Special Material Used in Hydraulic Model Construction
- Model Construction at the TNSRDC with Numerically Controlled Machine Tools
- Water Tunnel Flow Visualization by the Use of Fluorescent Mini-Tufts
- Simulation of Landslide-Generated Waves
- Friction in Model Gate Investigations
- Dynamic Laboratory Testing of Sea-Going Gravity Separator
- An ECCS Containment Sump Test Facility
- Underwater Camera Remote Operator

Session IV - Joint Utilization of Mathematical and Physical Models

- Laboratory Facilities for Research and Development of Water System Automatic Control
- Utilization of Mathematical and Physical Modeling to Evaluate Surge Reliever
- Using a Mathematical Model to Design a Physical Model for Landslide Simulation
- Stratification and Suspended Sediment Simulation for Shallow Lakes and Reservoirs
- Reservoir Water Quality Modeling
- Joint Use of Computer and Physical Models for the Sacramento River
- Kinematic Wave and Minimization Approach to Modeling of Channels with Sediment

Session V - Lasers

- TVA Laser Velocimetry
- A Two-Dimensional Laser-Doppler Velocimeter for Open Channel Flow Measurements
- Laser-Doppler Anemometer for Velocity Measurements in River Models
- Laser-Doppler Velocimetry Measurements in Rotating Systems
- A Laser-Doppler Velocimeter for Use in Sediment - Laden Flows
- Laser Vibration Sensor for Surface Dynamics Studies

SESSION I

HYDRAULIC LABORATORY INSTRUMENTATION

I. RECENT DEVELOPMENTS IN HYDRAULIC LABORATORY INSTRUMENTATION

Tom Isbester - Chairperson
Brent Mefford - Recorder

Summary Statement

Data Acquisition

Within the representative group there are major differences of opinion in the type of computer equipment needed for data acquisition and computational analysis. Some favor the large central processor with satellite systems. Others prefer the dedicated minicomputer system which is capable of controlling a number of types of peripheral equipment through various types of interfacing. No one system could be recommended over the other without considering the specific needs and requirements of the installation.

Special Topics

There is a widespread need for a commercial system which is capable of dynamically calibrating pressure transducers. There is also an awareness of the need to test the piezometer system as well as the transducer for dynamic measurements. The scanning-type pressure measuring systems are becoming more widely used. Difficulties including temperature stability and nonrepeatability have been encountered by a number of investigators and are not just happenstance. Real problems exist which are often not addressed by the manufacturers and must be solved through innovative engineering.

The information passed during this portion of the seminar will help greatly in keeping us abreast of the latest developments in the rapidly advancing electronics field. It is very rewarding to share information and experiences with others.

Comments on Session I

Laboratory Data Acquisition - George

Examples of two Hewlett Packard data acquisition systems were presented to identify pros and cons of low level versus high level language data acquisition systems.

	Advantages	Disadvantages
Low level language system Example (HP2100)	Speed Control versatility	Level of programming Skill
High level language system Example (HP9825)	Ease of use by nonsystem programmers ACSII Data	Low speed Small buffer Timing speed

Interactive Data Analysis of Quasi Steady State Models - Mefford

No comments.

Computer-based Data Acquisition and Analysis - Durgin

Several problems were brought out concerning timing of interrupts on multiple channel systems and interference problems associated with using telephone lines for data transfer. At Alden, engineers found the normal obstacles of A to D timing overcompounded by requiring different timing intervals between instruments being polled. The problem was referenced to one of minicomputer system saturation.

Support was also presented for hardwiring satellite computers. Previous experience at Alden Laboratory with the use of telephone lines had produced problems with uncontrolled line interference. It was the general viewpoint that the advantages of an independent communication link outweighed the initial cost and limited mobility associated with hardwired systems.

Display and Analysis of Prototype Data - Shingler

No comments.

Microprocessor-based Vortex Monitoring System - March

The prediction method incorporated provided poor repeatability per individual sighting. However, statistical averaging of 20-minute periods showed a better correlation between results. Use of the vortimeter to measure solid body rotation was clarified as it does not measure vorticity as the name can imply.

Automatic Data Acquisition for Energy Losses in a Bulb Turbine Model - Pugh

Questions were raised concerning the settling time and possible leakage of "Scanivalves." Pugh found Scanivalves designed for use with liquids tended to leak extensively when used with gases. It was noted that a Scanivalve built with teflon seals is available for working with gases. The manufacturer also provides data on leakage rate and minimum operating pressure. Alden Laboratory suggested replacing the valve tubing with larger solid tubing to improve both settling time and leakage problems. The address of Scanivalve Corporation is PO Box 20005, 10222 San Diego Mission Road, San Diego, California 92120.

Calibration and Instrumentation of a Variable Rate Gilsonite Feeder for a Gilsonite Bed Model - Tamburi

The main problem cited by the study was the use of Gilsonite as a bed model material. Gilsonite was defined as a hydrocarbon-based material with a specific gravity falling between 1.04 and 1.06. It is hydrophobic and can give off toxic fumes if heated. Problems were also noted as Gilsonite failed to readily sink as it was fed into the model.

Utilization of the Microprocessor-based Computer for Closed Loop Control Both in the Field and Laboratory - Ehler

No comments.

Laboratory Flow Control - George

The laboratory flow control system described was designed to control discharge and head as a function of time. The system enables an inflow hydrograph to be delivered to a model under controller supervision. Questions on the effects of valve hysteresis, response averaging, and stability were raised. It was suggested that going to a system of digital valves would increase valve response time and generally simplify system timing related to the above-mentioned problems. An accompanying high cost was also noted.

Computer Control and Monitoring of Sacramento River Model - DeVries

No comments.

Performance of Chamber-mounted Pressure Transducers - Babb

Is there equipment available for the dynamic calibration of pressure transducers? How do you excite a transducer diaphragm to determine its natural frequency? Both questions were left largely unresolved. During the discussion some criticism was waged of both CEC strain gage type transducers and Entran transducers. Problems with temperature fluctuation were mentioned by several laboratories having used the CEC transducers. Using flush-mounted traducers, temperature variations as well as pressure fluctuations were picked up. The transducers were not found to be totally temperature compensating when a rapid change in temperature occurred on one side of the diaphragm.

Others cited problems with Entran transducer diaphragms when used for extended periods of time in hydraulic tests. Some older models of Entran pressure transducers were constructed with what was thought to be a water-soluble adhesive attaching the diaphragm. Another problem noted with Entran transducers was that there was an apparent shift in output while maintaining the same relative sensitivity.

The paper "Piezometer Investigation," by Charles M. Allen and Leslie J. Hooper contributed by the Hydraulic Division of the American Society of Mechanical Engineers at the Annual Meeting, New York, New York, November 30 to December 4, 1931, was offered as a reference for piezometer tap configuration.

Measurement and Analysis of Velocity Vectors and Pressure Fluctuations in the Model on the Draft Tubes of the Bath County Pumped Storage Project - Tullis

A question was raised surrounding the effect of wall proximity on velocity measurement using the five-hole pitot probe. No one was aware of any boundary influence studies done involving the five-hole probe.

Laboratory Instrumentation to Study Fluid-structure Interactions - Gearhart

Air was used to study the flow-induced vibration on impeller blades. Pressure tranducers were used to determine the pressure distributions. Some kinds of transducers did not work well for this type of measurement. Alden Laboratory mentioned the use of the Pi Tran Transducer made by Sto Laboratory, Hudson, Massachusetts 01749. It is a semiconductor with good frequency response and low range capability. One difficulty can be the isolation of the power supply.

Detection of Cavitation Inception and Damage - Isbester

Several ideas were offered as a means of electronic detection of cavitation damage. Ideas centered on the use of acoustic emission, X-ray refraction, and laser Doppler signal response as possible methods. It was noted that acoustic emission does not provide a clear base level corresponding to the occurrence of incipient damage.

Wire-guided Model Boats - Downing

Questions were raised as to the effective depth of the wire below the surface. WES engineers have used the method at depths up to 4 feet by implementing larger boat-mounted antennas.

Remote Sensing of Sediment Density for Prototype Measurements in Inland Waterways - Downing

Resolution of one-tenth of 1 foot using a 7° beam is expected. The high frequency signal reponds to the top of the sediment, "fluff," and the low frequency signal to the denser lower layers. A relative density of 1.1 is being used to define the bottom of the waterway.

Measurement of Velocity Distribution in River Bends - Hartman

A gray area exists when taking velocity measurements close to a boundary with the electromagnetic flowmeter.

Precise Radar Positioning System - Downing

Corner cube reflectors which reflect parallel to the signal area being used. Reflectors must be set to maintain line of sight between emitter and reflector. Distances up to 5 miles have been used effectively.

LABORATORY DATA AQUISITION

By

R. L. George

Data from laboratory models from transducers is often presented as analog data. Reduction of analog data is often time consuming if strip charts, magnetic tapes or X-Y records are used. Errors are sometimes encountered in the process of data reduction. Often a significant amount of information in the original data is not utilized because mean values are the only items reduced. This ignores the fluctuating components of the signal and the frequency information of the original data. Some of these limitations can be overcome by digitizing the data at a suitable rate and storing the data in a calculator memory as scaled or unscaled readings. These values may be used to compute values that are easily understood by the engineer or they may be plotted directly to be compared with other data.

The calculator systems available today can digitize the analog data, scale the data according to the proper calibrations and store the data in memory for further processing. Programs may be written to correllate the signals, to tabulate the data or to perform statistical analysis of the data.

However, by plotting the scaled data, or analyzed data, the engineer can quickly see the relationships between the variables as the tests are being done. The time required to obtain the data and get it in a usuable form is greatly reduced when compared to analog data aquisition and reduction.

Information about the fluctuations and frequency can be retained as well as mean values with these calculator systems. Also, the user can tailor the analysis to test being done. However, the trade off is from time spent in data reduction and tabulation of analog data for time spent programming the calculator. The programming time depends on the experience of the programmer and the ease of learning the language. After becoming familiar with the calculator, an engineer can program the calculator much easier than doing the analog data reduction and the chance of errors has been minimized.

INTERACTIVE DATA ANALYSIS OF QUASI-STEADY STATE MODELS

By

Brent W. Mefford
Hydraulic Engineer
Water and Power Resources Service
Denver, Colorado

Specialized equipment has long been available to perform limited data reduction and simultaneous display for dynamic and destructive testing. Continuing simplification of intelligent controllers toward application usage now allows the researcher access to a similar opportunity for immediate data analysis in all model testing.

By the use of mini-computers as intelligent data acquisition controllers coupled with peripheral display equipment, a quick feedback path is available between model data analysis and model operation. As such, the intelligent controller-display unit offers a real time savings in data handling, control of errant data, and encourages flexibility in model control.

The time savings in data handling are readily apparent as data does not have to be transferred to a computer by hand, plus data display is variable. Control of errant data is aided by virtual elimination of data reduction after the fact which often leads to relying heavily on recall to analyze questionable data. The fast feedback of data displayed in terms of recognized parameters induces flexibility into a model test program. The researcher has the option to experiment interactively with an operating model and view the results in terms of his own parameters.

COMPUTER BASED DATA ACQUISITION AND ANALYSIS

Professor William W. Durgin
Alden Research Laboratory
Worcester Polytechnic Institute

To avoid the disadvantages of various types of special purpose recorders and analyzers, with their different signal acquisition and processing techniques, a centralized computer system was installed at the ARL. This system consists of a host computer with a multi-user operating system and a number of remote dedicated processors (mini-computers) at the experimental sites. Typical applications of the systems include thermal discharge models as well as velocity, pressure, and other data from hydraulic experiments. The host computer is also used for numerical modeling.

A DEC PDP 11/34A serves as the central laboratory computer system. It is equipped with 128K words of memory and various peripheral devices. Figure 1 shows the system arrangement and indicates the four disk drives, line printer, and nine serial ports. The serial ports are used for local terminals, a plotter, and connection to a laboratory communication network. In the latter case, the transmission rate is 1200 BAUD.

The basic philosophy used in assembling the data acquisition system was one of keeping the amount of hardware at the experimental site to a minimum. This serves to minimize cost and provide portability of equipment. To this end, the satellite systems basically include only a video terminal, mini-computer, and signal conversion equipment. A communication network throughout the Laboratory connects the satellites with the host computer. Programs are written and assembled on the host computer and transferred to a satellite mini-computer. When an experimental run is complete, the satellite processor transfers data to the host computer where data can be permanently stored or further reduced.

The satellite computer systems only execute programs which have been downline loaded from the central computer. To start the load process, a short "bootstrap" program must be entered into the satellite memory either manually or from PROMS. A more extensive communication program is then loaded which enables full access to the central computer from the satellite. In setting up an experiment, a data acquisition program would be loaded at this stage.

The satellite computer systems utilize DEC LSI-11 mini-computers with 32K memory and various compatible devices. There are two basic configurations; one for general data acquisition, Figure 1, and the other specialized for thermocouple measurements in thermal models, Figure 2. Programs usually require only a portion of the memory, so that the remainder is available as a data file. Some data reduction is often done at the satellite location, while more extensive manipulation is performed on the faster host. The terminal at the experimental site is used to set various parameters, such as scan rate and number of channels and to graphically display results such as temperature maps, tables of reduced data, or graphs.

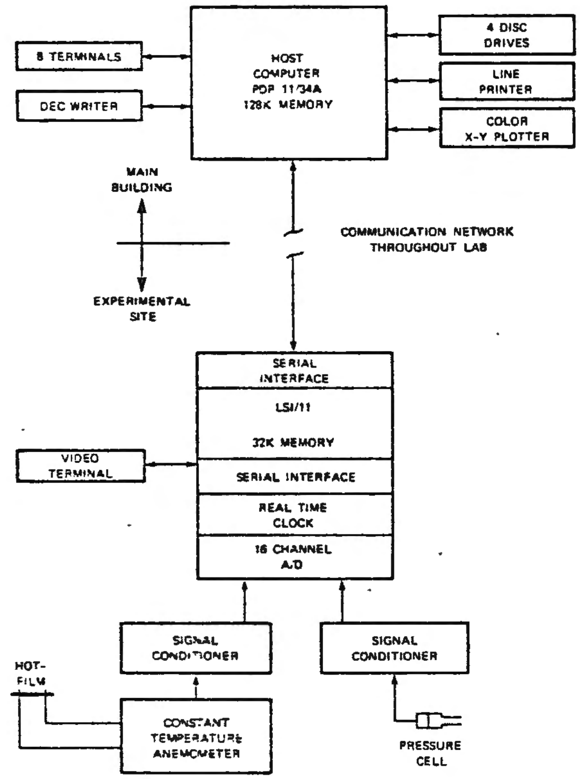

Figure 1 Satellite and Host Computer Systems for General Data Acquisition

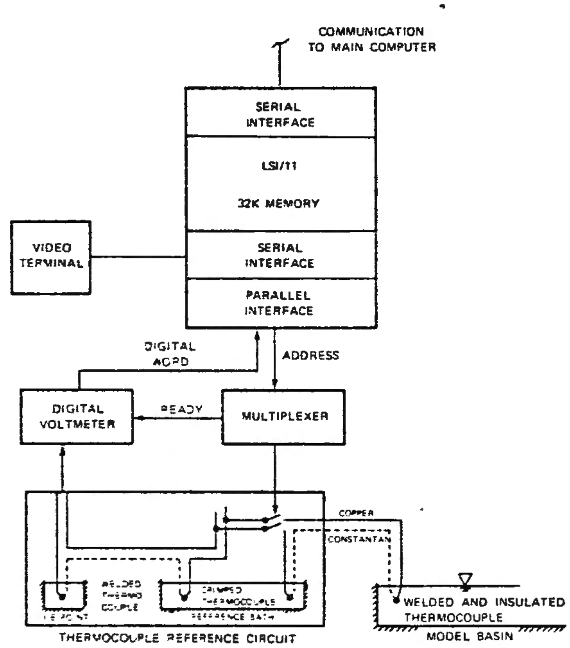

Figure 2 Satellite Computer System for Thermal Data Acquisition

Display and Analysis of Prototype Data - WESHE - Shingler

A minicomputer system for data reduction and display of prototype data has been developed and is currently being used by WES in support of its modeling activities. The minicomputer system includes two subsystems which are used for entering new field data: A reader for digital magnetic tape recordings from tethered current-conductivity-temperature meters and a reader of 16-channel paper-tapes from water surface elevation recorders. Discrete values of various types of time-dependent data - water surface elevation, temperature, conductivity, current speed, and direction - are sensed at precise time intervals by the meters and are digitally recorded on magnetic or paper tape. These data are then processed by the minicomputer system with the aid of the readers. Software has been developed to display, edit, and record data on computer-compatible media. After such data have been edited and filed in computer files, they are readily available for input to various analysis programs and numerical models.

TVA Engineering Lab: Microprocessor-based Vortex Monitoring System - March

Vortex evaluation in hydraulic models usually includes qualitative and quantitative observations of vortex strength and duration. A relatively simple system was developed to facilitate the accumulation and reduction of vortex data. The system utilizes a manually operated vortex indicator and a microprocessor, as shown in figure 1.

An observer watches the water surface under evaluation and ranks each observed vortex on the one-to-six vortex strength scale developed by the Alden Research Laboratory. As long as a vortex of a certain strength persists, the observer presses the correspondingly numbered button on an indicator box. This information on vortex strength and duration is accumulated by a microprocessor which also monitors vortimeter rotation rate and flow rate.

The output from the microprocessor includes a bar graph showing vortex strength as a percent of total test time and a tabulation of vortex strength, percent of total test time, and vortimeter rotation rate (see fig. 2). Present experience indicates that an observation period of 20 minutes is generally adequate to ensure reproducible vortex strength statistics.

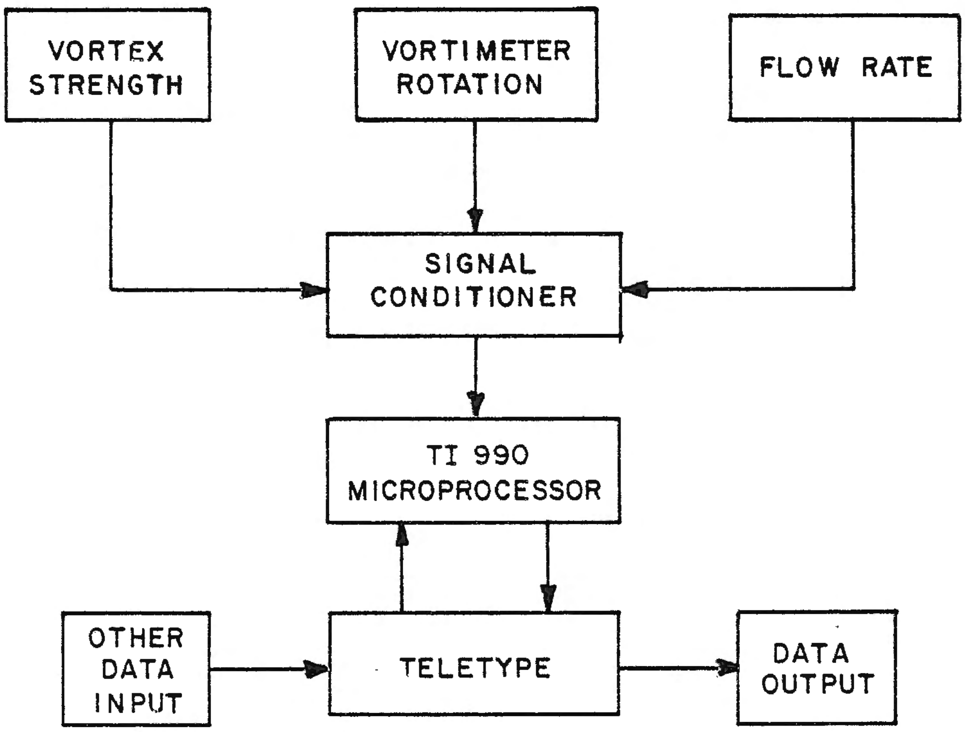

Figure 1:
Microprocessor - Based Vortex
Monitoring System

AUTOMATIC DATA ACQUISITION FOR ENERGY LOSSES IN A BULB TURBINE MODEL

By

Clifford A. Pugh
Hydraulic Engineer
Water and Power Resources Service
Denver, Colorado

A model study is being done by WPRS to investigate energy losses in the flow passages of a bulb turbine. The data are being recorded automatically with a minicomputer and a control processor.

The testing fluid is air and the primary measurements are pressures through the flow passages.

Forty two piezometers are connected to a "scanni valve". Each incoming port in the scanni valve can be opened indivually to the exit port. All the pressures are measured on one 0-17 KPa differential pressure transducer. The other side of the differential transducer is open to the atmosphere. The signal from the transducer is amplified and fed into the control processor. The control processor is an interface between the signal and the minicomputer. A voltmeter in the control processor provides a reading in volts to the minicomputer.

Software in the minicomputer allows a series of readings to be taken for each piezometer. In this application, 10 readings are taken 10 times for each piezometer in a few seconds. The average and fluctuating pressures are then stored in memory.

After the test is complete the measurements and other calculated values are stored in cassette tape, or disc, for future plotting and analysis on the minicomputer. The zero pressure is recorded before and after the test to insure that atmospheric pressure has not changed.

This method of data acquisition has many advantages over manual recordings. The data are more accurate and consistent, the tests can be run in a shorter time period, the data are stored automatically and do not need to be entered manually into a computer for further analysis, and the chance of human error in data recording is greatly reduced.

```
TEST TIME =  22.44 MINUTES

FLOW =  81 GPM

WATER SURFACE ELEVATION =  478.25 FT

DATE   3/ 24/ 80
        JGSIII
TIME  04:47:29
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VORTEX SIZE
V 1.◆◆◆◆
V 2.◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
V 3.◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
V 4.◆◆◆◆◆◆◆
V 5.◆◆◆◆◆◆
V 6.◆◆◆
    ..................................................
        5    10   15   20   25   30   35   40   45   50

          PERCENT OF TOTAL TEST TIME
```

VORTEX SIZE	AVERAGE RPM	PERCENT OF TOTAL TIME
V 1	10	4
V 2	10	47
V 3	9	21
V 4	21	7
V 5	8	6
V 6	25	3

Figure 2 : Example of Data Output

Calabration and Instrumentation of the Variable Rate Gilsonite Feeder for a Gilsonite Bed Model - Tamburi

An ideal velocity scale model with a gilsonite bed was to be run through freshet hydrographs of varying configurations in order to investigate the degradation to be produced by a series of proposed training structures. As the degradation was to proceed in spite of a continued natural sediment supply during the freshet, it was necessary to determine a function relating bedload and discharge for the model and to develop a mechanism which would feed gilsonite according to the function developed.

In order to develop a nonlinear function relating model discharge to gilsonite feed rate, a reach of the model was molded in gilsonite to equilibrium bed contours. The bed was then inundated and a constant discharge was run. For the initial test series the gilsonite feed rate was established theoretically; however, it has been the experience of WCHL that the theoretical feed rates are consistently low. A series of tests was run for the same discharge with a gilsonite feed rate being increased until it was possible to maintain the equilibrium bed contours thus producing the first set of X and Y data to be used for the curve. The procedure was repeated for several discharges and finally the curve defined by the sets of XY points was used to estimate initiation of motion. Initiation of motion was also determined on the model visually with a discrepancy of less than 6 percent. The gilsonite feed function was then programmed on to a programmable chip. The chip used an input analog voltage from an automatic water level recorder situated in the weir box immediately upstream of the V-notch weir which determined the model discharge. This input voltage was then processed by the chip and an output voltage was derived which ran a screw feeder beneath the gilsonite hopper. The output voltage was suitably modified by the chip so that the gilsonite feed function was accurately reproduced for all flow conditions up to discharges where significant scour of the bed began. At this point a short fall was permitted by the function in order to produce scour on the bed of the model.

UTALIZATION OF THE MICRO PROCESSOR BASED COMPUTER FOR CLOSED LOOP CONTROL BOTH IN THE FIELD AND LABORATORY

By

David G. Ehler
Electronics Engineer
Water and Power Reseources Service
Denver, Colorado

The microprocessor, or microcomputer, is being used in many applications for control and monitoring. We are currently involved in studies and applications in which the microcomputer is being used for a closed-loop controller for irrigation canal systems and laboratory facilities. A canal control algorithm called the "Colvin" has been tested in the laboratory on the canal model and used successfully on a gate in the field. Current studies are underway to standardize the hardware systems used and develop other algorithms for canal control. The Intel 8080 microprocessor has been selected for these applications, and a National Starplex development system has recently been purchased for use in these studies.

We are currently developing a second algorithm for the microprocessor called the "EL-FLO". This system is currently being used in Red Bluff, California in an analog control system. This algorithm is a downstream demand system where controllers are installed on consecutive check structures with control of the pumping plant or reservoir gate also operating on downstream control.

The results of these studies, up to this point, have been encouraging, and with the standardization of microcomputer bus systems should improve this situation.

This study has branched into the study of application of the microprocessor to closed-loop control of laboratory facilities. Two applications, the circulating pumps for the north end and the Low Ambient Pressure Chamber, are currently being studied. The Hewlett Packard 9825 is currently used to develop the north end control algorithm. The final algorithm will then be implemented in an 8080 system using the National Development System.

LABORATORY FLOW CONTROL

By

R. L. George

Fixed or variable discharge to the hydraulics laboratory models will provide stable conditions during the tests and will eliminate the need to manually obtain discharge readings during a test.

The differential pressure across the pressure taps of the venturi meters can be sensed by a pressure transducer. The output of the transducer can be calibrated and scaled to indicate the current discharge flowing through the venturi. The difference between the current discharge and the desired discharge indicates the error and can be used to control a valve to obtain the set discharge. If the error is within the dead band, see figure 1, no change in the valve position will be made. If the error is between L (1) and L (2) the algorithm will act as an incremental controller. That is, the flow will be changed toward the set point in small fixed increments. for errors between L (2) and L (3) the algorithm will act as a proportional controller with variable gains as the error becomes larger. For errors that exceed L (3) the algorithm acts as a predictor which computes the error and then changes the position of the control valve so that the discharge is within the dead band. If this correction is not exact then the software will select the appropriate mode to get the discharge within the dead band.

Discharge measurements will be obtained at specified intervals when the desired discharge is being maintained during the test. Variable discharges may be obtained by providing a table of discharge as a function of time that can be compared with the current discharge. The algorithm will then adjust the control valve to attain the variable discharge at each specified time interval.

COMPUTER CONTROL AND MONITORING OF SACRAMENTO RIVER MODEL

J. Amorocho, W. Hartman, and J. DeVries
University of California, Davis

The California Department of Water Resources has planned the construction of the Peripheral Canal which is intended to divert water from the Sacramento River near the town of Hood and to convey it to the Clifton Court forebay at the entrance of the pumping plants of the Federal and State Aqueducts at the Southern boundary of the Sacramento-San Joaquin Delta.

For the selection of the best diversion structure configuration, as well as for the determination of the most appropriate point of diversion on the river, and for a qualitative evaluation of possible sediment problems associated with the diversion operations, a distorted physical model was built with horizontal scale of 1:240 and vertical scale of 1:60.

The main element of the model control and data logging system was a microcomputer located in the laboratory. This system's main function was the control of the upstream water inflow and the downstream stage in the model. It also had the purpose of handling a number of control and data logging tasks.

Figure 1 shows a schematic diagram of the control system. Programming was done in machine language. The system utilized feedback control to actuate various electromechanical devices such as weir positions and water levels for the operation of the model. The control of inflow and stage was effected either by using a table of historical records stored in the computer memory or any specified time dependent function. The system metered the sediment supply rates from storage in proportion to the incoming flow of water in the model. This flow was controlled by moving the upstream weir to calibrated positions on signals from the computer. The position of the weir was monitored by the computer by means of a potentiometer attachment. Downstream water levels were measured by means of a capacitance probe and controlled by the downstream weir.

Target values for inflows and stages in the model were specified at five second intervals (corresponding to about 2.5 minute increments in the river). Tidal gage readings from the river were available at 15 minute intervals. The model settings were interpolated between these readings to provide uniform variation.

Several model data logging and analysis duties were performed by the microcomputer system. All control values (inflow, stage, and control positions) were recorded at one-or two-minute intervals in real time and printed in both model and prototype time scales. All values of flow, stage, and velocities were converted to and recorded at prototype scale.

Water stages were measured using a commercial capacitance-type liquid-level probe (Robertshaw Level-Tel Model No. 158B2A1) and a water level scanning system. The nine stilling wells located along the model and two reference stilling wells, one maintained at a constant low water level and the other at a high water level, were connected to a 12-port fluid water-switch. The switch output was connected to a pressure transducer. The signal from the pressure transducer was sent to the control system, and the fluid switch was advanced from position to positon by a rotary solenoid on command of the control system. A schematic diagram of the logging system is shown in Figure 2.

In addition to the water level scans, a record was made of all control system positions, the model inflow, and the downstream stage. During the verification runs, these recordings were made each minute during the run. A sample output record is shown in Figure 3.

During the testing period, water velocities were taken at selected cross-sections in the vicinity of the diversions. The data logger recorded the point velocities as well as the location of the measurement in the cross-section.

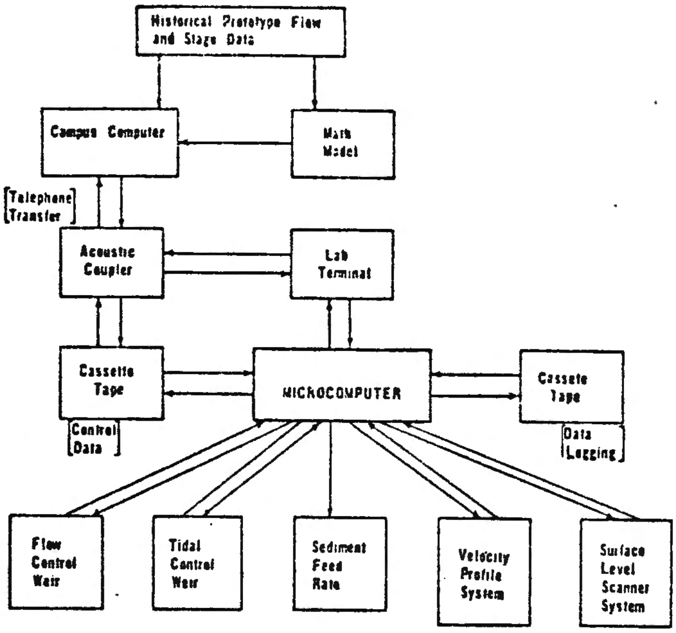

Fig. 1. Diagram of Control System.

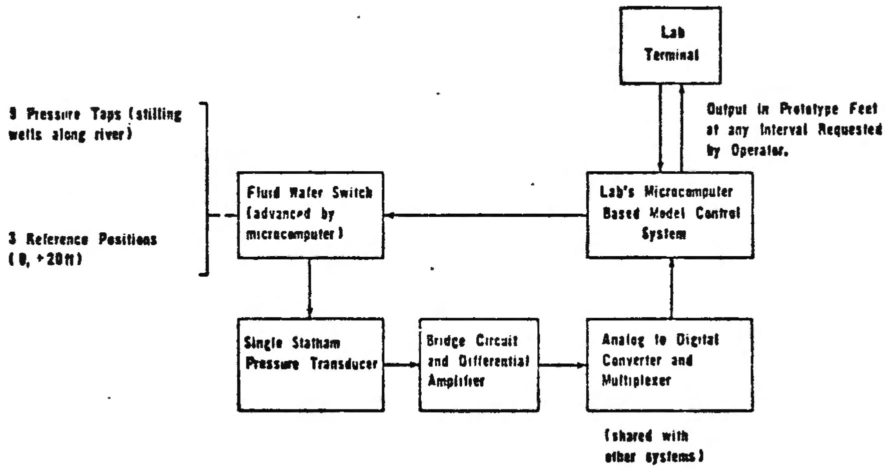

Fig. 2. Diagram of Logging System

Water level scan

1 14.5 2 14.2 3 13.9 4 13.5 5 13.2 6 12.7 7 11.7 8 11.6 9

Date & Time	Control codes				
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0048:05:05:28	A8	A8	B7	BA	6D
0048:05:36:28	A8	A8	B7	BB	71
0048:06:07:27	A8	A7	B9	BB	75
0048:06:38:28	A7	A7	B8	BB	78
0048:07:09:27	A7	A7	BA	BB	7C
0048:07:40:28	A7	A7	BC	BC	7D
0048:08:11:28	A7	A7	BE	BC	7D
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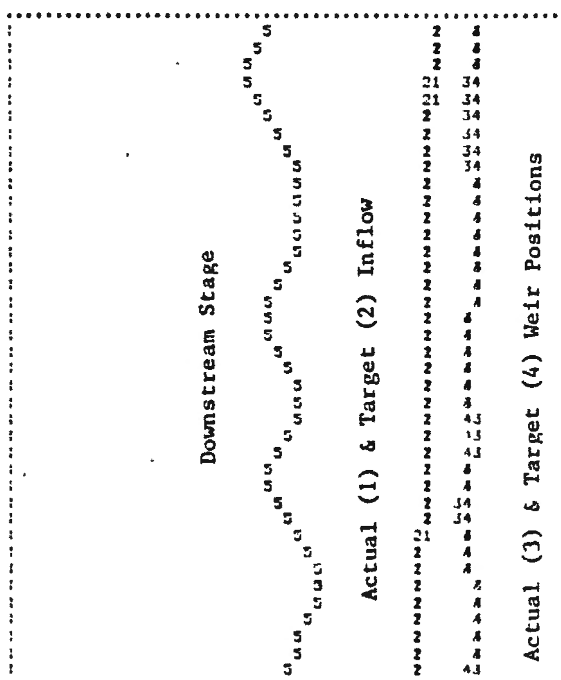

Fig. 3.. Sample Output

PERFORMANCE OF CHAMBER MOUNTED PRESSURE TRANSDUCERS

Alan Babb
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The selection of fluctuating pressure measurement systems is usually based on their ability to respond to rapidly changing pressures. Considerations of frequency response strongly suggest the use of flush-mounted transducers having high natural frequencies. The adoption of flush-mounted transducers is usually not practical, however, because of difficulties in matching curved flow passages with the transducers and the effort required in moving the transducers to other locations. For this reason, selected methods usually involve mounting the transducer so that its sensing diaphragm is remote from the location of pressure measurement. A chamber-type mounting currently in use on a tunnel spillway study is discussed below.

The adopted mounting system is shown in Figure 1. The water in the passage connecting the pressure opening to the diaphragm greatly reduces the natural frequency from that determined for the transducer in air. The frequency of the system can best be analyzed by equating the potential energy of the diaphragm to the kinetic energy of the diaphragm plus the water column. With the use of several simplifying assumptions it can be shown that the system's natural frequency varies as the passage diameter and inversely as the square root of its length. Thus it is preferable to make the connecting passage diameter as large as possible and the length as short as possible. Note in Figure 1 that the passage size (0.32 cm) has been made greater than the pressure opening (0.16 cm) to take advantage of the fact that the natural frequency is greater for the larger passage. The transducer used in this study (CEC Type 4-312-0002) has a natural frequency of about 6000 hz in air. In the system described herein, its natural frequency was about 400 hz. When tested with a passage size of 0.16 cm, the natural frequency was only about 200 hz.

The associated electronic equipment is schematically shown in Figure 2. The spectrum analyzer was particularly useful in determining whether air had been completely evacuated from the system. The evacuation of air required persistence and care and the lower natural frequencies associated with the presence of air were easily detected with the analyzer. Data were recorded by photographing traces stored on the oscilloscope.

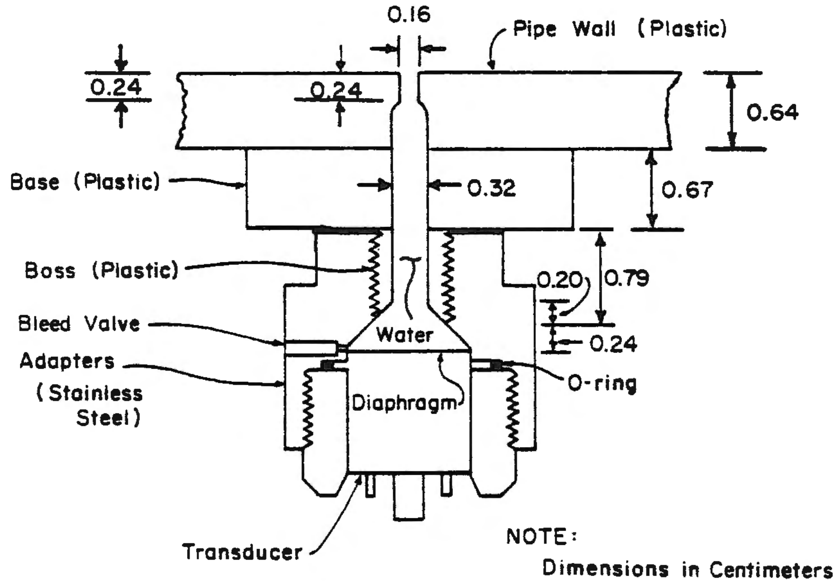


Figure 1. Pressure Transducer Mounting System

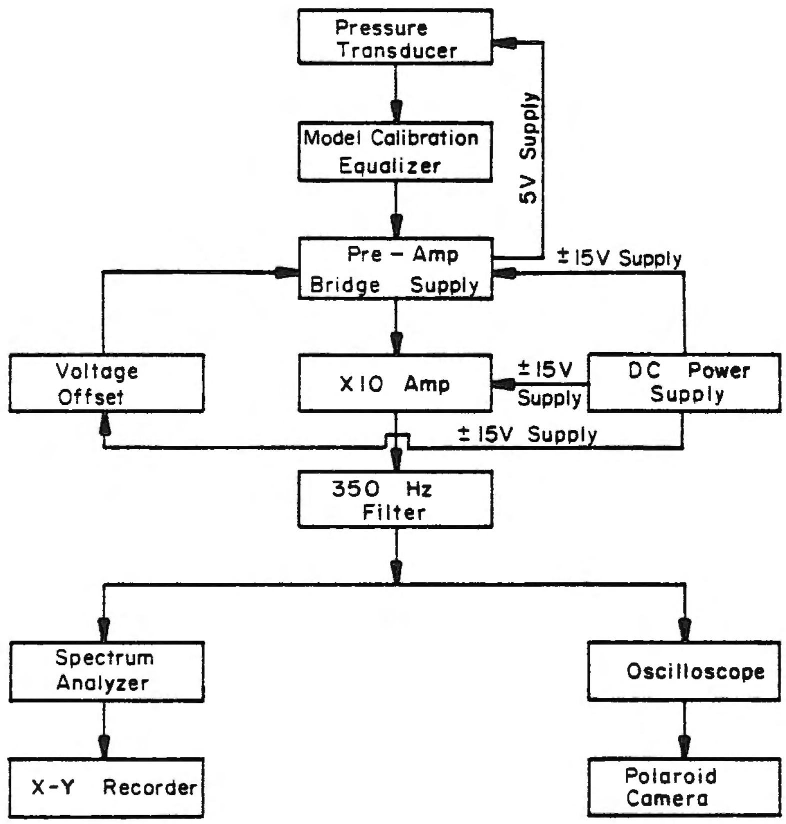


Figure 2. Dynamic Pressure Data Acquisition System

MEASUREMENT AND ANALYSIS OF VELOCITY VECTORS AND PRESSURE FLUCTUATIONS IN A MODEL OF THE DRAFT TUBES OF THE BATH COUNTY PUMPED STORAGE PROJECT

Calvin G. Clyde and J. Paul Tullis

A 1:12.76 scale model of a portion of the Bath County pumped storage project was tested at the Utah Water Research Laboratory of Utah State University. The objective of the study was to measure local velocity vectors and the local pressure fluctuations and pressure fluctuation gradients at the trashrack location in the draft tube in Figure 1 during the generating mode. These data were to be used by Harza Engineering Corporation to estimate the dynamic loading on the trashrack and, if necessary, modify the structural design of the trashrack.

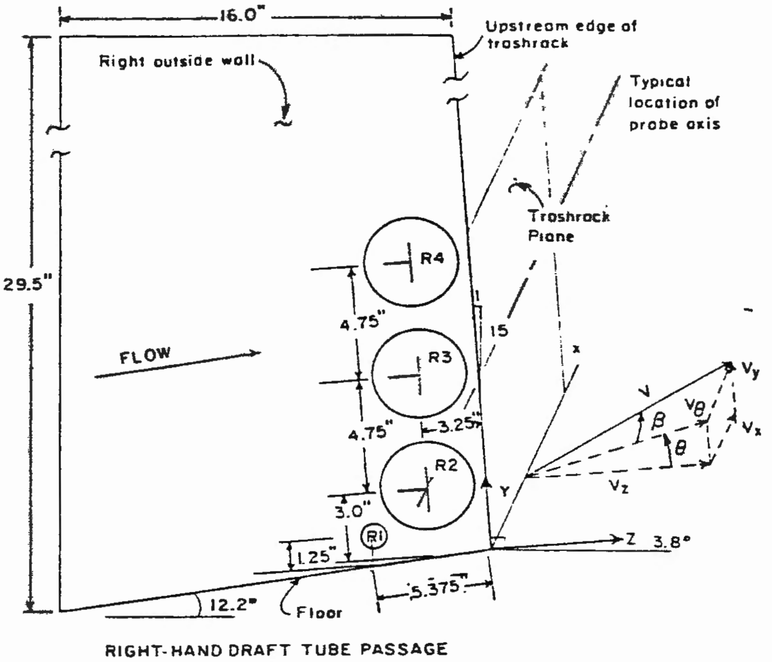
Time averaged velocity profiles just upstream from the trashracks were measured with a United Sensor three dimensional directional five-hole pitot probe which traversed the model passages at four different elevations. Mean velocity components were plotted as shown in Figure 2.

Pressure fluctuations and pressure fluctuation gradients were measured with a streamlined aluminum strut containing three flush-mounted Entran miniature pressure transducers as shown in Figure 3. The strut was 20.5 inches long and 5/8 inch thick and traversed the flow horizontally at the same locations where the velocity measurements were obtained.

In use the pitch angle already had been measured. The strut was oriented with its chord parallel to the V_θ component of velocity shown on Figure 1. Then P_a was the pressure on the leading edge and P_b and P_c were pressures on the top or the bottom of the probe.

The transducers were connected to a Vishay amplifier for voltage excitation, bridge balancing, and signal conditioning. Output from the pressure probe after conditioning was adjusted to equate voltage output in volts to pressure in psi. The output from the runs was recorded on magnetic tape for later processing through the support electronics.

Three major devices were used for processing: 1) Unigon FFT model 4512 spectrum analyzer, 2) Norland model IT-5300 signal analyzer for preparing histograms, and 3) UWRL custom made signal conditioning amplifier units. The UWRL unit provided proper signal polarity and provided sum and difference signals through operational amplifiers. These signals were then fed into the spectrum and histogram analyzers for signal display as shown in Figures 4 and 5.



Note: Left side mirror image
θ = Pitch angle } Positive as shown
β = Yaw angle }

Figure 1. Location of packing glands through which probes were inserted.

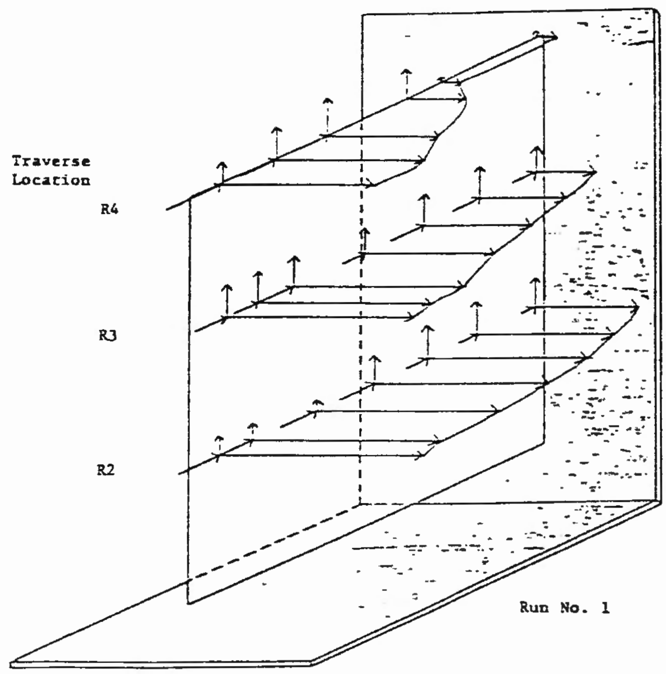
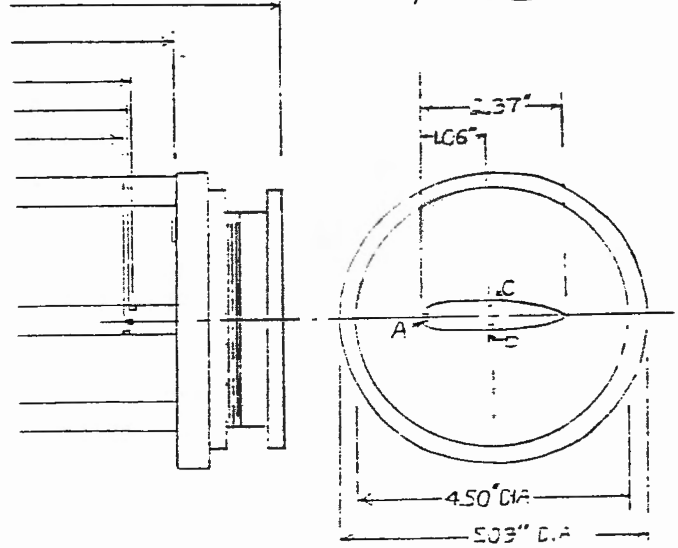


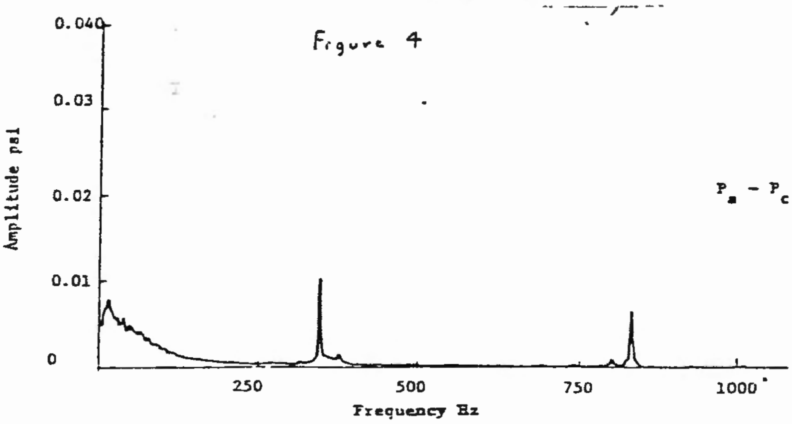
Figure 2. Velocity Profiles

Fig 3 Pressure Fluctuation probe



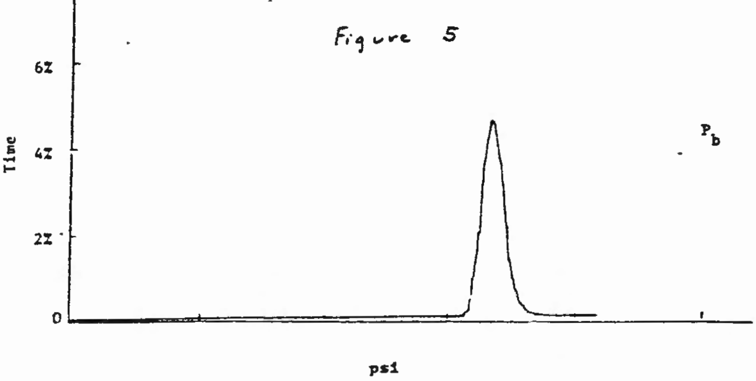
SPECTRUM ANALYSIS OF PRESSURE FLUCTUATIONS

Figure 4



HISTOGRAMS OF FLUCTUATING PRESSURES

Figure 5



LABORATORY INSTRUMENTATION TO STUDY FLUID - STRUCTURE INTERACTIONS

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In any turbomachine - axial-, mixed-, or radial-flow pumps or turbines - the problem of flow induced vibration and performance degradation is significant. To control this problem, a better knowledge is required of the fluid-structure interactions; particularly, the mechanism by which they are generated and the flow parameters which are of significance. This knowledge is best obtained by conducting laboratory studies under controlled conditions in which the time-dependent characteristics of the flow and structure are measured. Described are several methods which have been applied to the study of fluid-structure interactions in axial-flow turbomachines. These methods should be considered for the study of mixed- and radial-flow turbomachines.

The methods which have been employed consider, (1) the time-dependent response of the structure to the flow field and (2) the flow field which generates the time-dependent structural response. Instrumentation and experimental techniques will be discussed which can be used to determine:

(1) the time-dependent forces on a segment of an individual impeller blade and the time-dependent thrust in the impeller shaft,

(2) the time-dependent pressure distribution on stationary vanes,

(3) the wakes and, hence, losses associated with individual impeller blades, and

(4) the means to simulate the specific spatial flow field variations required to conduct laboratory evaluations of fluid-structure interactions.

Examples of these different types of instrumentation and their use in determining fluid-structure interactions will be presented.

DETECTION OF CAVITATION INCEPTION AND DAMAGE

By

T. J. Isbester

The WPRS has very limited experience in the detection of cavitation by electronic means. In the past we have relied heavily on a technique which utilized a combination of visual and aural interpretations coupled with judgement of the investigator to define the point of inception. In addition, we have used erodable paints and foils in suspect areas to detect vapor pocket collapse on boundaries.

Changing output from accelerometers, hydrophones, and sound level meters have been used to evaluate the effectiveness of varying a parameter such as air injection rate or gate opening. This provides relative data and is not used to define inception or degree of damage. Two important factors which are associated with sound intensity and frequency are the number of nuclei and the amount of entrained gas in the water. These are factors which we cannot control in the field, and have difficulty in defining in the laboratory.

Future plans call for the use of hydrophones in the Low Ambient Test Chamber to help determine the point of incipient cavitation. Relating these outputs to damage potential appears further down the road.

Wire-guided Model Boats - WESJD - Downing

The Instrumentation Services Division, WES, has recently developed equipment for guiding model boats along pre-set courses; the path being determined by small current-carrying wires laid on the bottom of the hydraulic model. This technique was developed to replace manual guiding of model boats (via radio control) with the expectation that automatic control would give much more repeatable results. Experience has shown that the automatic wire guided control is not only more repeatable but considerably more accurate as well. Multiple alternate boat paths can be arranged by installing guide wires along as many different paths as desired, and switching the excitation current to the course wanted on a given pass.

Wire guidance requires that low frequency antennas be mounted on the boat to detect (a) lateral distance of the boat from guide wire, (b) angle of boat with respect to guide wire, and (c) signal strength. Frequency used is not critical and WES is using for convenience a frequency of 8 kHz. Signals from the antennas are amplified and processed to drive the runner control motor. Proper ajustment of feedback and gain is necessary to avoid "hunting" problems. All of the necessary amplifiers and feedback control elements can be mounted on one printed circuit card. In the existing wire-guided model boat the same batteries are used to wire guidance circuits as are used for other control and measurement purposes.

Wire guidance conceivably can be used for other moving vehicles such as sounding carriages. As another example WES is building a military target vehicle which will be wire guided along a 7-mile course. Other suggested uses could be guidance of survey boats making sediment studies.

Remote Sensing of Sediment Density for Prototype Measurement in Inland Waterways - WESJD - Downing

The WES is working with a contractor on the development of a dual frequency acoustic depth measuring system which can provide, in addition to depth, data which have significant correlation with the density of the upper layer of the waterway sediment. Use of two simultaneously transmitted acoustic pulses at widely spaced frequencies (240 kHz and 24 kHz) permits the detection of two reflection signatures, which when cross correlated, yield data that give the experimenter or operator a useful tool in classifying bottom sediment conditions. The equipment incorporated a Z-80 microprocessor which performs on-line processing of the data and displays real time results to the operator, Field experiments have been performed in which nuclear density data and dual frequency acoustic data are taken over the same sediment location and closely spaced in time. Results to date are encouraging.

Precise Radar Positioning System - WESJD - Downing

The Instrumentation Services Division, WES, is working with a contractor on the development of a radar boat positioning system using passive microwave reflectors for shore reference. This is expected to be a general purpose tool for navigating or positioning a boat or barge collecting prototype data in rivers, reservoirs, or estuaries. Use of passive reflectors (instead of active responders) makes it possible to have year-round unattended shore references at much lower cost per reference point.

Accuracy of positioning, in experiments to date, show that the passive reflector/radar system equals, or is better than, active responder microwave distance measuring equipment at distances up to 5 miles.

MEASUREMENT OF VELOCITY DISTRIBUTION IN RIVER BENDS

J. Amorocho, J. DeVries, and W. Hartman
University of California, Davis

A study of the hydraulics of the proposed intake to the Peripheral Canal from the Sacramento River at Hood, California, is underway at the University of California at Davis Hydraulics Laboratory. The intake structure will be located on the outside bank of a bend in the river channel. This intake is being studied in a scale model of the river in the laboratory. To evaluate model-to-prototype conformity, measured velocities in the model were compared to field velocity measurements using equivalent flow conditions.

The field measurements were made with a specially constructed velocity meter which indicated both vertical and horizontal velocity directions as well as magnitude of the velocity vector. This meter system, shown in Figure 1, was assembled at the Hydraulics Laboratory using a Price-meter cup and rotor assembly for the velocity magnitude, a remote indicating magnetic compass to indicate horizontal direction, and a vertical-angle indicating potentiometer.

The measurements in the model were made using a Cushing "Velmeter", an electromagnetic-type velocity meter which gives the two components of the velocity vector in a horizontal plane simultaneously. These measurements were made in a 1:50 scale, undistorted model of the Sacramento River at the equivalent positions of measurement as used in the field.

The measurements in the model were at steady-flow conditions. In the field, the flow was changing with time, primarily due to tidal effects. These effects were accounted for by making interpolations in both time and space (across the channel) using velocity measurements at grid of points each taken at a different time. The full set of measurements spanned a complete tidal cycle (about 12 hr).

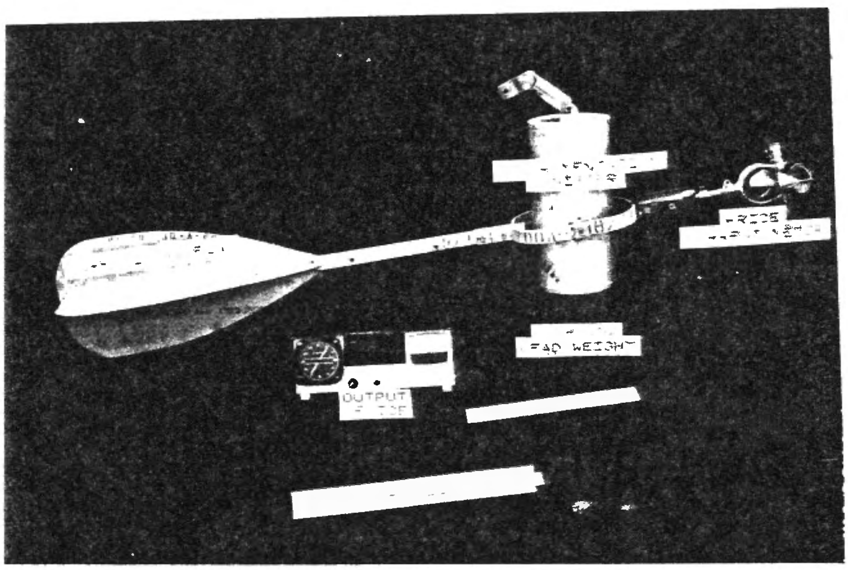

Fig.1. Equipment for River Velocity Measurements

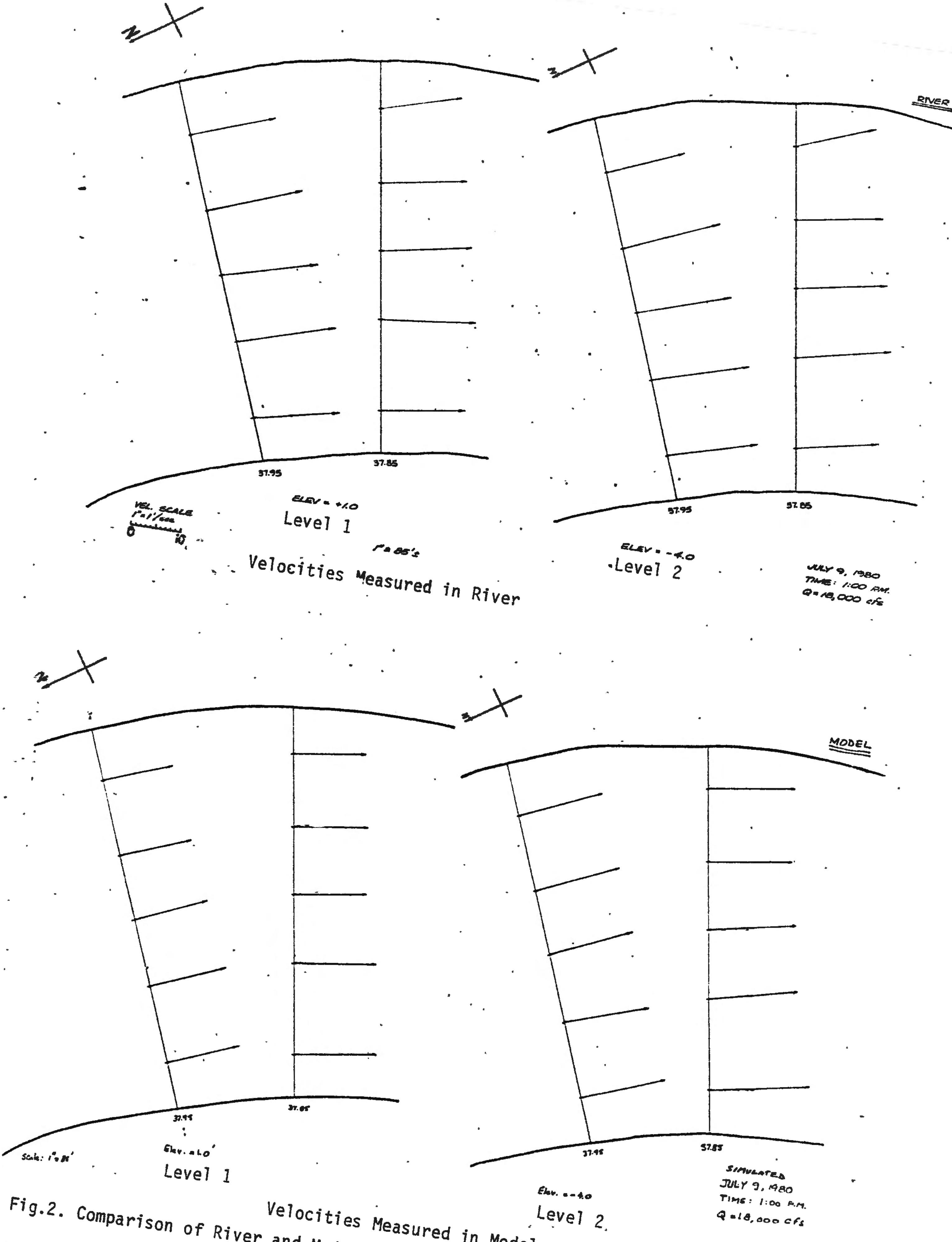

Fig.2. Comparison of River and Model Velocity Data

SESSION II

SIMILITUDE AND SCALE EFFECT

II. SIMILITUDE AND SCALE EFFECTS

Russ Dodge - Chairperson
Kathy Houston - Recorder

Summary Statement

The discussions that were more directly related to the session subject contained some common themes.

Much of the discussion centered around determining how well single force ratio scaling approximates given prototype situations. For example, one discusser noted that we sometimes expect too much of or overdepend upon the Froude number. There were discussions concerning the effects of distorting the Froude number by increasing velocity to study vortices. Some investigators preferred to use pressure fluctuation measurements rather than increasing velocity. However, they still recognized the need to better relate those measurements to the prototype. Discharge augmentation in the model to achieve proper river channel geometry (i.e., width-depth relationship) was another example of a compensation technique for scale effect. Further discussion noted that dimensionless settling velocity ratio and a dimensionless shear ratio could not be scaled simultaneously in the model. It was suggested that consideration should be given to increasing the Froude number in sediment transport models to better represent prototype transport phenomenon.

Another area of discussion dealt with the problem of scaling the physical properties of interacting flow boundaries such as simulating the physical properties related to rock erosion or the cohesion and shear strength of ice. Searching still continues to find an artificial material that better represents all the properties of ice and rock scour. Another interreacting boundary problem mentioned was bed form differences between model and prototype.

Main conclusions of this session's subjects are:

1. We need to quantify the degree of approximation of models to prototypes when scaling using single dimensionless force ratios.

2. We need to develop adequate scale compensation procedures and/or parameters and determine their actual effectiveness.

3. We need ways to more accurately scale physical materials and boundary interactions with the hydraulic properties.

To realize these goals, investigators should be given more opportunity to check their results by field test of prototypes.

Comments on Session II

Ice Modeling - Kennedy; Ashton

The problem of modeling ice and ice jams under laboratory conditions is to find a model ice material that is economical and correctly represents the scaled strength, deformation, and cohesiveness characteristics of ice. When scaling material to be used for ice, random-shaped pieces appeared to be better than uniform blocks. Different types of material for ice modeling included freshwater and saltwater ice, wax or plastic blocks, roughened plastic pellets, adding urea to ice, and styrofoam.

No artificial substance tested to date has had all the characteristics of natural ice.

Sediment and Scour Modeling - DeVries, Sweeny, Tamburi

Discussions of sediment and scour scaling techniques and problems included the use of ground walnut shells to simulate sediment, simulation of free jet scour in a rocky river, a flow augmentation technique using a width-depth criterion and fluorometric tracing of sediment movement.

The discussions of simulating free jet scour in a rocky riverbed were centered around the concept that depth of scour was based upon hydraulic parameters alone or the concept that the bed material was also a factor. When considering the areal extent of the scour, other mechanical properties of the material must be modeled. The model materials used to date are not accurate enough to scale fracture size and ballmilling action, both of which are needed to quantify the amount of scour.

The augmented flow necessary to reproduce the sand bed in a river model may be found by matching flume data to the plot of prototype width versus depth for a given reach. This method does require accurate measurements of the prototype reach but was found to save time during the laboratory testing.

Fluorometric sand tracing may be used to follow the movement of sediment across a bed. You must use dye-coated sand of uniform size so that when the dye is removed from the sample the weight percentage may be calculated.

Investigation of Reaeration Characteristics - McLaren, Fletcher

When studying reaeration techniques krypton 85 is widely accepted by the EPA as a tracer element, rather than dissolved radioactive solids. The tracer was used to study hydraulic structures such as flip buckets in an effort to produce more gas transfer downstream of reservoirs. In a reservoir a line diffuser was more efficient than rectangular arrays of racks. Prototype measurements are needed to correlate the laboratory data.

Pump Station Sump Modeling - Fletcher

When modeling sumps the question arose as to the use of Froude modeling or increasing the velocity to a value higher than indicated by Froude similarity. Pressure fluctuations measured from taps located on the floor of the sump at the centerline of the pump intakes are good indications of vortices. Discussion brought out that for consistent geometry an increase of velocity and decrease in kinematic viscosity have the same effect on the Reynolds number. Increasing the velocity creates the possibility of wiping out the vortex. Prototype measurements are needed to discover what pressures and rotations are harmful and to relate the model to the prototype.

Effects of Test Apparatus Geometry on Draft Tube Surge Studies - Gearhart

The geometry of the draft tube has a significant effect on the results of testing when blowing or sucking air through the tube. It has been found that when swirl is present in the flow a decrease in pressure occurs between the centerline and outer wall of the draft tube. Suction stabilizes the flow which may explain the differences seen between suction and blowing air through the model geometrics.

Modeling River Hydraulics Under Tidal Influence - Babb

A model was built to study the buoyant dispersion of effluents under tidal wave action. General flow distributions were traced with dye and measured by the thermisters. The model was built so that each end contained a water supply and overflow weir to control the flow. The model was operated manually at each end, adjusting the flow rate and weirs as the tidal wave passed. The testing program was relatively short. Thus, computer control was not attempted.

Measuring Air Release During Column Separation - Tullis

A pipeline system was installed to create column separation under controlled conditions of vapor pressure and pressure rise. The amount of air released was determined by the wave speed with the water at vapor pressure measured by transducers.

Laboratory Modelling of Ice-Retention Structures

by

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Institute of Hydraulic Research
The University of Iowa
Iowa City

The precipitous increase in fuel prices in recent years and the fuel efficiency of barge transport have combined to renew the interest in year-round navigation on major waterways, like the St. Lawrence and Mississippi Rivers. Navigation throughout the ice season is practical only if ice jams can be prevented. To this end, ice-control structures would be installed just upstream from jam-prone (usually narrow, high-velocity) reaches of the rivers, to stabilize the ice covers and to prevent their downstream movement and accumulation into jams. Here it should be noted that the integrity of an ice cover against run out and embacle formation is diminished by the ice breaking attendant to ship passage, a factor which heightens the need for stabilization of the ice field by means of structures. The structures most widely used for restraining ice movement are ice booms: steel cables attached to timber floats and anchored to river-bottom foundation blocks by cables tied to the boom cable at intervals of typically 100 ft to 200 ft. Year-round navigation requires inclusion of an open section, typically 200 ft to 300 ft wide, as shown in figure 1, to permit vessel transit through each boom. The key questions of ice-boom forces, volume of ice leakage through boom openings, and stability of the upstream cover have been investigated in laboratory models, four of which have been conducted in the United States. Three of these used wax/plastic floes, while the fourth used ice.

Modelling of ice movement requires use of a model-ice material which correctly reproduces the scaled strength and deformation characteristics of the ice, especially the fracture strength and cohesion bonds between floes. Figure 2 shows formation of an ice bridge behind an idealized channel obstruction, and figures 3 and 4 show the radical effect floe bonding, by cohesion, has on bridge formation in the experiment depicted in figure 2. Figure 5 demonstrates how sensitive the interfloe forces are to rate of ice-field deformation.

The most pressing need in the laboratory modelling of ice-control structures is development of an economical model-ice material which reproduces to scale the crushing and flexural strengths, "elastic modulus", and cohesive strength of ice. The last of these should include the scaled rate of strength formation between floes, which apparently affects cover movement. Until such a material is developed and validated, considerable uncertainty will continue to surround the results of hydraulic/ice model studies.

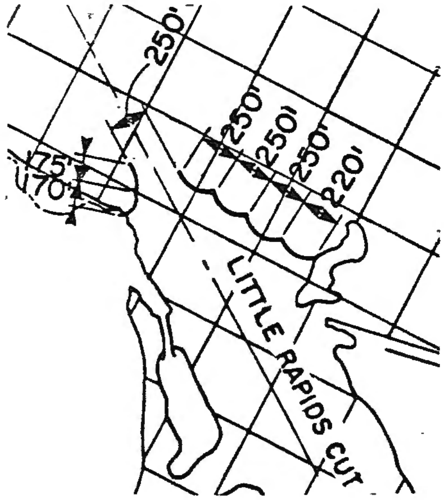


Fig. 1. Little Rapids Cut navigable ice boom, St. Mary's River (Lake Superior), Michigan.

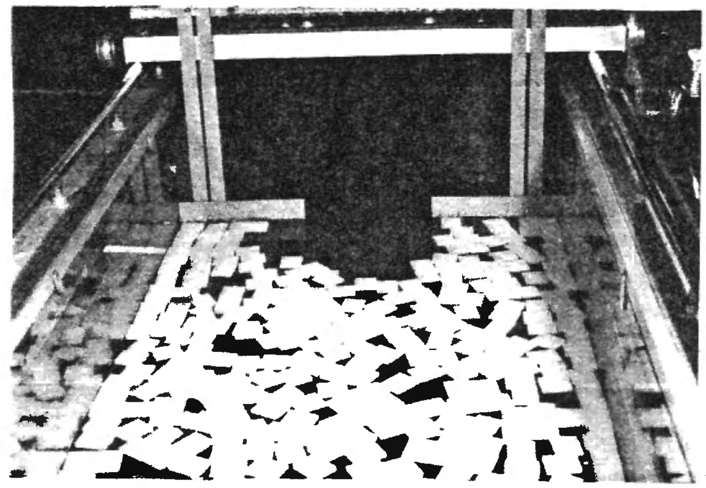


Fig. 2. Formation of an ice bridge behind an obstruction in a flume.

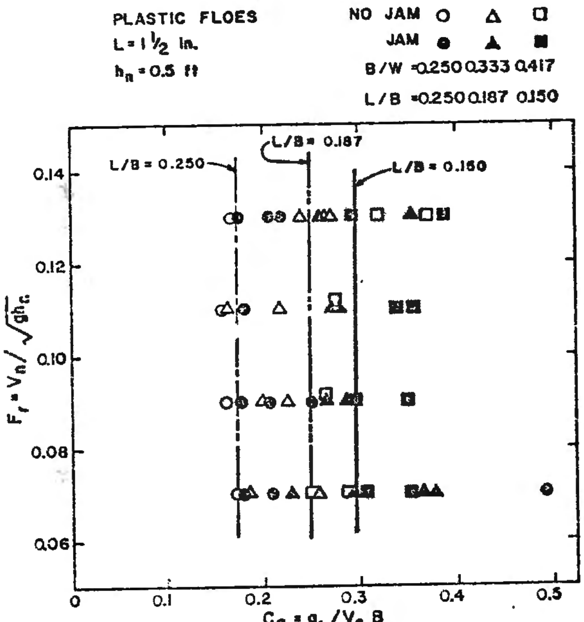


Fig. 3. Critical conditions for ice bridge formation; plastic floes Cg = ice concentration, F_R = Froude no.

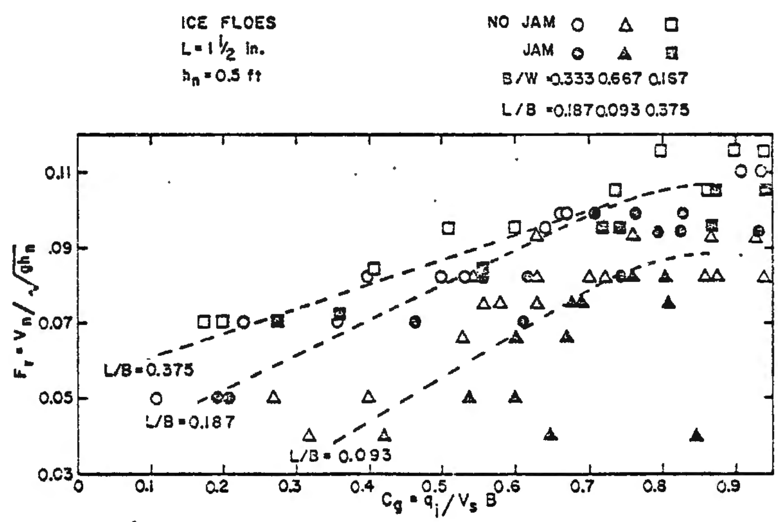


Fig. 4. Critical conditions for ice-bridge formation, ice floes.

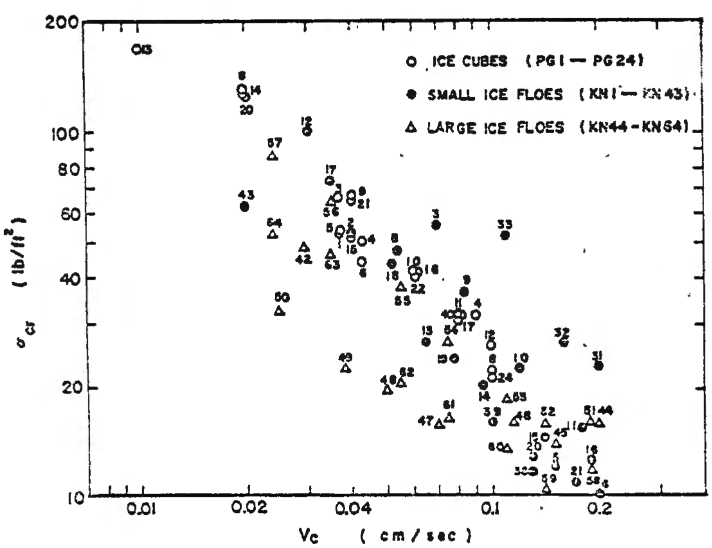


Fig. 5. Dependence of compressive strength of floating fragmented ice on deformation rate.

Measurement of Floating Ice Forces in Models - Ashton

In several model studies involving floating ice it has been necessary to measure the forces exerted by the ice. Example applications include the forces transmitted by intact ice sheets and by broken ice covers of large lakes and of river ice covers. The nature of the problems addressed requires measurement of forces both normal and tangential to elements of shorelines, floating ice booms, and ice control structures.

Our initial attempts to measure these forces used a metal plate element supported by two vertical bars on each end (see fig. 1). Strain gages were attached to the vertical bars and forces determined by monitoring the strain gage output. Considerable difficulty arose because of the statical indeterminacy of the elements and supports that, in turn, resulted in complex signals. Efforts to make the force element and assembly statically determinant, for example by making the connection between the element and vertical bar a "pin" joint, were largely unsuccessful either due to the inability to achieve a true "pin" joint or due to other constraints.

Subsequently the force element assembly was changed to a single vertical support bar attached rigidly to the horizontal plate element with strain gages attached to the sides of the vertical bar (see fig. 2). By appropriate calibration we have been able to measure forces to a resolution of about 0.01 Newton. While the one-bar support does not provide measurement of nonuniform force distribution, its simplicity has been found to be a great advantage for the needs thus far.

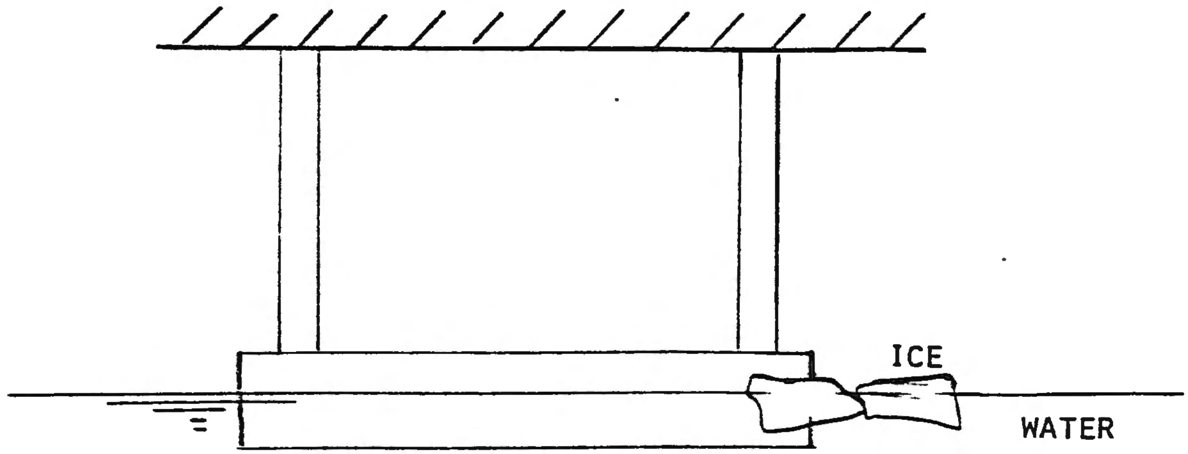


FIGURE 1

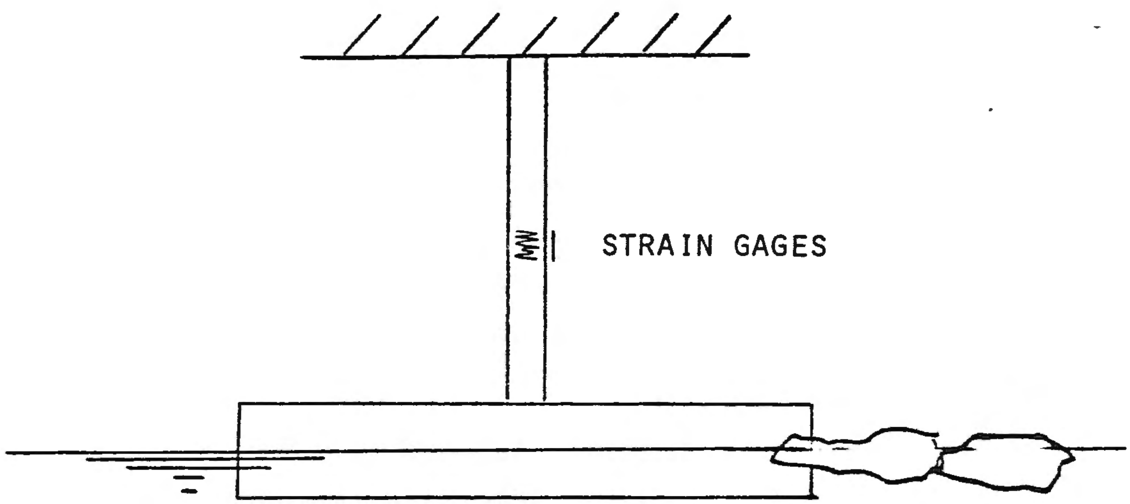


FIGURE 2

GROUND WALNUT SHELLS FOR RIVER MODEL SEDIMENT

J. Amorocho, J. DeVries, and W. Hartman
Univeristy of California, Davis

The similitude criteria used for a movable-bed model of the intake to the Peripheral Canal from the Sacramento River were seleced to represent scour and deposition of bed material, as well as duplication of general hydraulic behavior of the prototype. The Froude criterion was used to ensure dynamic similitude. Additional roughness was added to the model riverbanks to properly scale friction to the prototype.

The criteria dealing with the dimensionless shear on the bed (τ_*) and the ratio of the fall velocity to the shear velocity (w_f/u_*) are considered to be the most important in the determination of the appropriate size of sediment for the model.

The consideration of possible types of sediment for the model indicated stongly that a lightweight material would be required. Ground walnut shells were chosen on the basis of their low specific gravity (γ_s/γ = 1.33), low cost, and availability. Walnut shell "flour" is commercially available in a range of sizes. However, there are a number of disadvantages to using walnut shells. The major problem is that the shells tend to decompose due to their organic nature. In addition, the shell material has to be soaked in water before used to remove very fine material (dust) and oils, both of which can be floated off.

Once the sediment material is chosen, γ_s is fixed, and the values of (w_f/u_*) and τ_* can be computed as a function of particle size d_{50}. A plot of $[w_f/u_*]_p/[w_f/u_*]_m$ and $(\tau_*)_p/(\tau_*)_m$ versus d_{50} is given in figure 1. The plot shows that for a given set of model length scales and sediment material, it is not possible to satisfy both criteria simultaneously.

In addition, bed forms in the model are ripples, while in the river they are likely dunes with superimposed ripples. The lack of complete similitude between model and prototype is such that the relative scour in the model will be less, and there will be less deposition as well

The model was able to reproduce the general riverbed configuration after subjecting the model to a simulated 4-month sequence of flow conditions measured in the river. The model sediment was fed at a rate based on the river flow. This rate was established by experiment in the model. On the basis of this verification, it was expected that bed scour and deposition occurring in the model under various test conditions reflect what will happen in the prototype river under similar conditions.

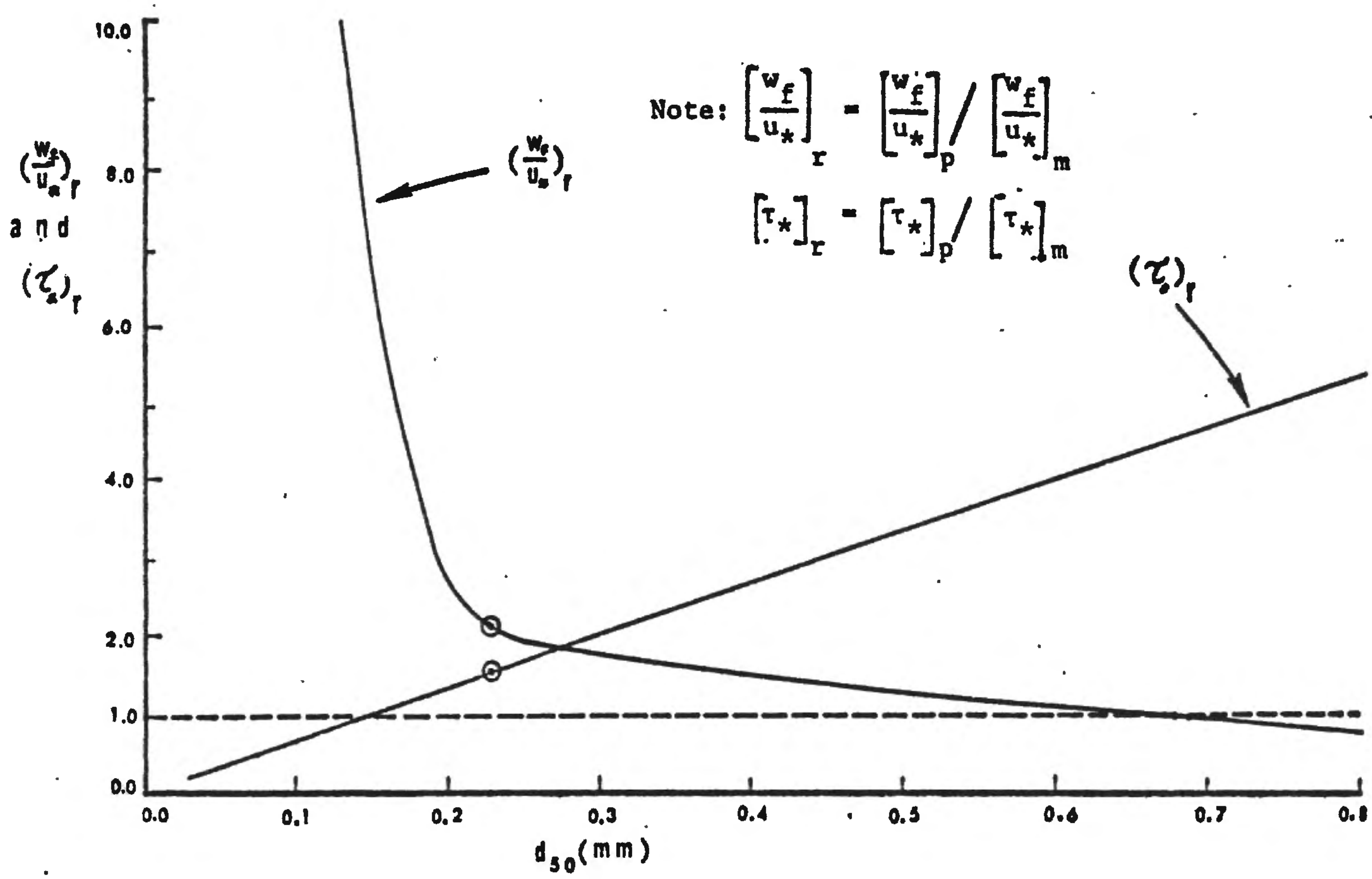


Figure 1. Prototype-to-Model Ratios for w_f/u_* and τ_* for $L_H = 240$, $L_V = 60$, and Walnut Shells with $d_{50} = 0.23$ mm.

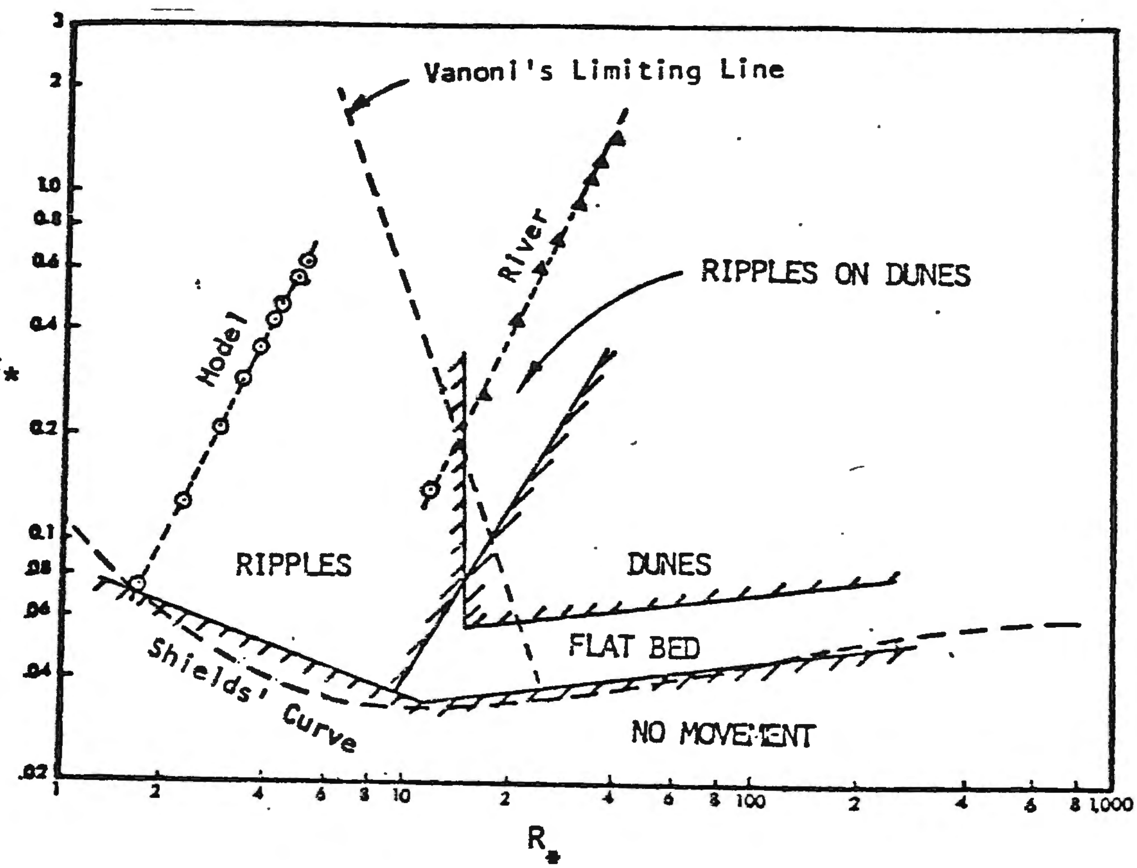


Figure 2. Bed Form Classification by French Investigators (after Bonnefille, 1965).

SIMULATION OF FREE JET SCOUR OF ROCKY RIVER BEDS

By C.E. Sweeney, Senior Engineer/Manager, Engineering Hydraulics, Inc.

Ultimate depth of scour resulting from the impingement of free jets on rocky river beds has been found by Martins (1975) to be dependent only on hydraulic parameters not on bed material properties. If this is the case a physical model may easily be employed to predict scour depth. However prediction of the equally important areal extent of the scour hole is not as simple. Total simulation of the process of scour of rock by a falling jet would require, in addition to scaling of flow phenomena, the correct scaling of the mechanical properties of the rock in question including their spatial variation. Scaling of these parameters is a difficult and ill-defined task and the result of the effort can be no better than the often incomplete geologic information available.

Model scour beds have been traditionally constructed using combinations of sand, crushed rock and gravel to simulate expected fracture sizes of prototype bed materials. However, the scour of cohesionless crushed rock in a model is accompanied by the sloughing of scour hole sides to maintain the angle of repose of the material. The resulting dish-shaped scour hole is not considered to be representative of the configuration expected in the prototype. The interlocking nature of the prototype rock will promote a steep-sided hole which will concentrate flow and possibly result in a migration of scour towards adjacent structures endangering them. It is also likely that the dish-shaped hole may overestimate the extent of the scour hole, resulting in a less economic design.

In some studies a weak cement binder has been utilized to overcome some of the deficiencies in modeling technique by providing the scour bed with cohesive strength. However, use of cement introduces an additional source of experimental error in the form of increase in binder strength with time.

In recent studies a bentonite clay (driller's mud) has been used as a binder. Experiments were performed to determine the minimum bentonite content required to maintain the model bed material on a vertical face. Experiments were also conducted to confirm that the presence of bentonite binder did not affect the ultimate depth of scour. Slight variations in the binder and water content of the mix were also found not to appreciably affect the areal extent of scour.

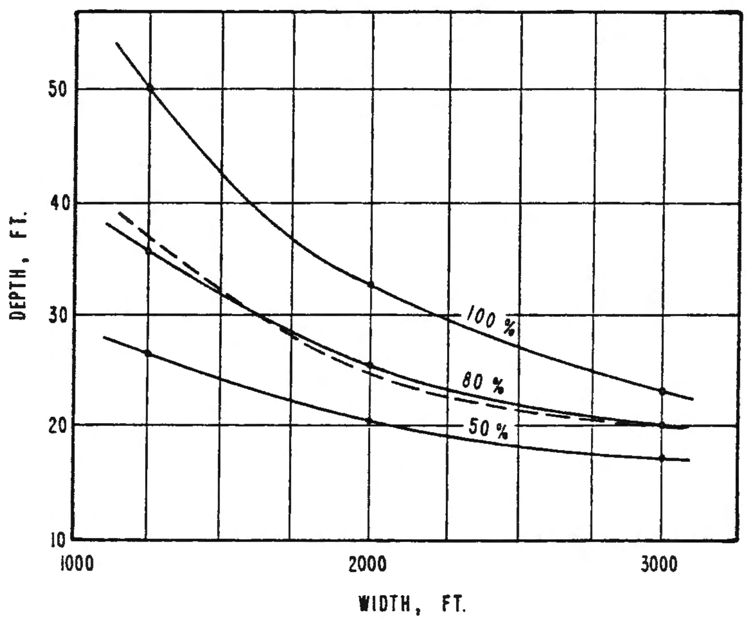
The utilization of bentonite-sand-rock mixtures has proven to be a useful tool in qualitatively assessing scour resulting from the impingement of spillway jets on bedrock. However further research is required before the effects of mechanical properties of both prototype and model bed materials may be quantified.

Martins, Rui B.F., "Scouring of Rocky Riverbeds By Free Jet Spillways," Water Power and Dam Construction, April 1975, pp. 152 & 153.

Width Versus Depth Curves for Calibration of Sand Bed Models - Tamburi

Plots of width versus depth for varying discharges in defined reaches of sand bed rivers may be used to establish flow augmentation required for sand bed models of these reaches. While sand bed models or prototype river problems are a useful engineering tool, the size and specific weight of the sand is not scaled correctly and it is necessary to augment the model flow to generate the correct channel geometry. Previously, augmentation has been established by trial and error with a succession of expensive and time-consuming model test. However, reproduction of the width-depth curve is a simple verification criteria when tested in a flume, figure 1. Three or more channel widths are used to generate the curve for a single augmented flow or discharge using the model sand. If the three or more channel widths tested in the flume for a given percent flow augmentation produce a curve which diverges from the prototype curve, the test may be repeated with a different augmentation until adequate reproduction of the prototype width-depth curve has been achieved.

During a recent series of tests on the Fraser River model at Western Canada Hydraulic Laboratories, Ltd., several months of effort were shaved off the test program using this calibration procedure.



FLUME

PROTOTYPE

% AUGMENTATION

FRASER RIVER MODEL

WIDTH vs. DEPTH CURVES FOR DETERMINATION OF DISCHARGE AUGMENTATION

WESTERN CANADA HYDRAULIC LABORATORIES LTD.

Fluorometric Sand Tracing - McLaren

The use of fluorescent tracer sand for the field measurement of sediment transport is a time-proven technique. However, previous methods of analysis by hand counting of the large number of grains for the samples taken is laborious and expensive. A technique has been developed at Western Canada Hydraulic Laboratories which simplifies the measurement of marked sand grain concentrations in the retrieved samples through use of a standard laboratory or field fluorometer. This technique has been used in a preliminary study to determine sand movement on the Fraser River foreshore.

Tracer sand was prepared by bonding Rhodamine B dye to native sand using urea formaldehyde resin. 18.6 kilograms of urea formadehyde resin were dissolved with 0.4 kilograms of Rhodamine B dye in 25 liters of water. This was mixed into a viscous slurry and the native sand of approximately 0.2-mm diameter added and mixed until a uniform color was achieved. 1.9 kilograms of Ammonium chloride catalyst (NH_4Cl) was then added to set the resin and the mixture spread to dry overnight. The next day, the mixture was broken up, ground in a ballmill, screened, and reground to eliminate all chunks over 0.4-mm diameter.

The tracer sand was placed on the tidal faults with an average thickness equal to the height of the surrounding sand nipples. Background samples of native sand were taken from over the entire collection area prior to the testing to later eliminate spurious results from ambient fluorescence. The fluorometer was calibrated against known concentrations of Rhodamine dye in solution.

Field samples were collected over a 5-kilometer stretch of the tidal flats after periods of 1 day, 3 days, and 13 days. The Rhodamine dye was then eluted from the collected sand grain and the concentration of marked sand in the samples determined.

Previous work in the laboratory had shown that hydrochloric acid would quickly break down the urea formaldehyde resin bonding the dye to the sand and release the Rhodamine B dye. However, the dye was not readily soluble in acid and precipitated out of the acid leaving a clear solution. Addition of ethanol or methanol in which Rhodamine is highly soluble produced a mixture capable of a rapid breakdown of the resin while keeping the dye in solution. The most suitable acid/ethanol proportions for the study purposes were developed by trial and error experimentations.

A mixture of 4 percent by volume of 12 normal hydrochloric acid and 24 percent ethanol with 72 percent water was added to each sample. The total volume of liquid added to each sample was 208 mL. The sample was stirred vigorously, and allowed to sit in the dark for 2 hours. The elute containing the dissolved dye was drained off through Whatman No. 4 filter paper, this type of filter paper also having been determined from experimental tests as best suited for the process, and the concentration of dye in the elute measured by the fluorometer.

Blank samples were also prepared to eliminate ambient background fluorescence by treating undyed native sand samples in the same way as the collected field samples and adjusting the fluorometer reading to zero.

The dye concentration of the sample elute was related back to concentration of marked sand in the field sample through a calibration curve determined from similar elution of hand-counted sand grain samples mixed in known concentration with unmarked native sand (slide 1). The calibration sand was linear up to 10 percent concentration. Concentrations above this level gave nonlinear readouts due to the fluorometer characteristics. The lower limit of the calibration curve was determined by background fluorescence of the acid/alcohol water mixture. Using methanol the technique was limited in accuracy to sand concentration above 70 p/m. Analysis of sand sample by hand counting is considered accurate down to concentrations of 10 p/m.

It is proposed to do further work in improving this measuring technique including examination of the effect of abrasion of the thickness of bonded dye after varying lengths of time in the field and on speeding up the analytical procedure by use of a centrifuge to separate turbidity from the eluted samples in place of paper filters. It is also planned to use alternative dyes with peak emission frequencies different from that of Rhodamine B coat varying sand sizes so that the migration of different sized sediments can be traced in one field survey.

Investigation of Reaeration Characteristics - WESHS - Fletcher

Oxygenation or aeration techniques can be used to enhance the water quality in the reservoir and/or in the release. As demonstrated at Clark Hill, efficient oxygen injection schemes can be used to increase the dissolved oxygen in the hypolimnion without significantly disturbing stratification. Ongoing and completed field results indicate that line injection systems are more effective than rectangular arrays of rack-mounted diffusers. If properly designed, a line injection system will inject diffuse noninteracting bubble columns which results in a high gas transfer efficiency and produces minimum circulation. Pneumatic destratification can also be used to increase the DO in the reservoir; however, some degree of nitrogen supersaturation with respect to the surface is likely to occur. A field study of 11 southern California reservoirs was conducted during the summer of 1979 and peak nitrogen supersaturation levels with respect to the surface ranged from 104 to 135 percent. Although this may pose no environmental problem in the reservoir, it may necessitate the use of outlet works which degas the release. In some cases, pneumatic destratification will not be a viable alternative as a result of the inherent increase in water temperature.

The released water quality can be improved by employing hydraulic structures which aerate the flow and increase the DO without significantly increasing the dissolved nitrogen concentrations. Techniques have been developed by the WES Hydraulics Laboratory to assist in designing environmentally effective hydraulic structures. The approach utilizes a coupling of hydraulic modeling, flow visualization, and radioactive tracer techniques to determine the relative effectiveness of various outlet work designs and/or structural modifications.

Pump Station Sump Modeling - WESHS - Fletcher

Sump performance in models is evaluated by measuring magnitude and direction of currents entering the sumps and pump intakes, by measuring swirl inside pump intakes, and by visual observations of hydraulic flow conditions. Current velocities are measured by current meters and dye displacement. Subsurface and surface current patterns are determined by dye injected into the water and confetti sprinkled on the water surface, respectively. Pressure fluctuations indicative of flow instability at the pump intakes are measured by means of calibrated electronic pressure cells located flush with the floor of the sump and directly below the centerline of the pump column. Swirl in the pump intakes is measured by vortimeters (freewheeling propellers with zero pitch blades) located inside each pump intake at the approximate position of the prototype pump propeller. Visual evaluation includes observation of stages in the development of an air-entraining vortex from a small depression in the water surface to continuous air core extending into the pump intake.

Effects of Test Apparatus Geometry on
Draft Tube Surge Studies

by

Walter S. Gearhart

Applied Research Laboratory
The Pennsylvania State University

Studies relating to draft tube surge have used a test apparatus which consisted of placing swirl in a fluid by the use of a radial vane system. This fluid was then ducted through a draft tube. The ratio of angular momentum to axial momentum could be controlled by adjusting the radial vane system and was found to be the critical parameter causing surge to occur.

Tests of this nature are reported in [1, 2]*. In [2], a short summary was presented on the effects of drawing air from the atmosphere through the radial vane system and draft tube by means of a suction fan. This was contrasted to blowing air through the radial vane system and draft tube which was then dumped to atmosphere. It was found from these tests that the geometry of the test facility had a significant effect on the results obtained.

Efforts to answer questions relative to the differences obtained by either blowing or sucking air through the vanes and draft tube consisted of performing a brief series of tests and obtaining details of the flow field in the draft tube. Flow traverses were performed in the draft tube with each of the test facility geometries. Within the accuracy of the measurements, little difference was recorded in the flow field using either geometry.

When reviewing the results of the flow traverses, it became apparent that with swirl in the flow, a significant decrease in static pressure exists between the outer draft tube wall and the axis of the draft tube. The magnitude of the decrease in static pressure is dependent on the radial distribution of tangential velocity. Should the static pressure of the particles of fluid near the axis of rotation in draft tube become equal to or lower than the static pressure of the medium to which they are being discharged then flow reversal will occur and possibly lead to surge. Suction would tend to stabilize this tendency for flow separation and may explain the difference obtained.

A review of how the test facilities differed and how they effected the results shall be discussed. A brief discussion on the simulation of draft tube surge by these means and their limitations shall be presented.

[1] Palde, V. S., "Model and Prototype Turbine Draft Tube Surge Analysis by the Swirl Momentum," IAHR Symposium 1974.

[2] Gearhart, W. S., A. M. Yocum, and T. A. Seybert, "Studies of a Method to Prevent Draft Tube Surge and the Analysis of Wicket Gate Flow and Forces," Bureau of Reclamation Report REC-ERC-78-12, April 1979.

*Numbers in brackets refer to references.

MODELING RIVER HYDRAULICS UNDER TIDAL INFLUENCES

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A recent hydraulic model study at the Albrook Hydraulics Laboratory of buoyant effluent dispersion in streams required assessment of the effluent plume under tidal influences. Figure 1 shows a portion of one tide that would occur at the study site under a given stream flowrate. Knowing river cross-sections, mean stream velocities and net flowrates were computed at sequential times. Corresponding model values were determined using Froude similitude. Figure 2 shows the resulting values; 571 cfs is the river flowrate prior to tide encroachment and values shown incorporate flows into and out of temporary storage.

The hydraulic model used in the study is illustrated in Figure 3. The water supply could be introduced at either end of the model; an electromagnetic flowmeter with a large dial display was installed in each supply line through which flow was controlled by a sensitive ball valve. A water level control, consisting of an adjustable overflow weir, was placed between the supply lines and outflow tanks. Water level in the model was measured with a piezoelectric pressure transducer output from which was displayed on an oscillograph chart at both ends of the model.

The model tide cycle began after steady-state river conditions were set (571 cfs for Figure 1 tide). River flow entered from upstream, the upstream weir prohibited outflow there and the downstream weir controlled the water level (3.49 ft msl). As flood tide progressed, flowrate from upstream decreased with time and the downstream weir was raised to increase water levels correspondingly. At about 1 hour 20 minutes real time, net upstream velocities began; all model flow from upstream then ceased. Flow from downstream was initiated and model outflow and water level were controlled by the upstream weir. Ebb tide flows found outflows and water levels controlled once again by the downstream weir with inflow being from upstream.

Four persons conducted tidal tests, one at each end of the model to adjust flowrates and the weirs, one to monitor time and one to coordinate tide activity with velocity and temperature measurement. Tides were successfully simulated as shown by Figure 1 (and incidentally, plume dispersion characteristics proved to be quite interesting).

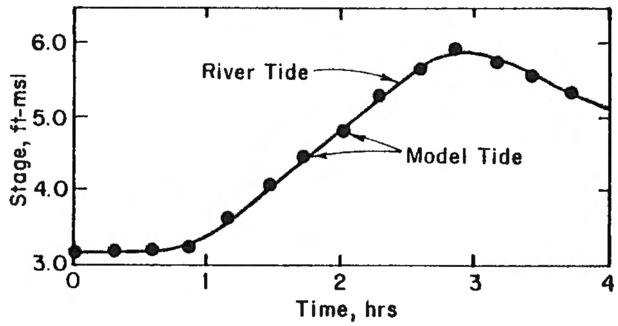

FIGURE 1.

PROTOTYPE			
Real Time (hr-min)	Water Surface Elev. (ft-msl)	Net[a] River Flowrate (cfs)	Net[a] Average Velocity (fps)
0	3.49	571	0.43
1-00	3.65	359	0.26
1-20	4.01	-21	-0.01
1-40	4.36	-15	-0.01
2-00	4.72	-128	-0.08
2-20	5.09	-223	-0.13
2-40	5.39	-142	-0.08
3-00	5.47	444	0.24
3-20	5.34	721	0.40
3-40	5.18	775	0.44

MODEL			
Model Time[c] (min)	Water Surface Elev. (ft-msl)	Flowrate[b] from Upstream (cfs)	Flowrate[b] from Downstream (cfs)
0	3.49	571	0
5	3.50	560	0
10	3.52	534	0
15	3.58	507	0
20	3.80	512	0
22	3.92	407	0
23	3.98	367	0
25	4.12	0	417
30	4.43	0	420
35	4.74	0	469
40	5.05	0	513
45	5.32	0	508
47	5.42	0	334
48	5.45	0	237
50	5.48	164	0
55	5.41	335	0
60	5.28	550	0

[a]Negative values indicate upstream direction. [b]Values shown are actual river quantities; model quantities are 1/499 times values shown.
[c]One-prototype hour = 17.3 model minutes.

FIGURE 2.

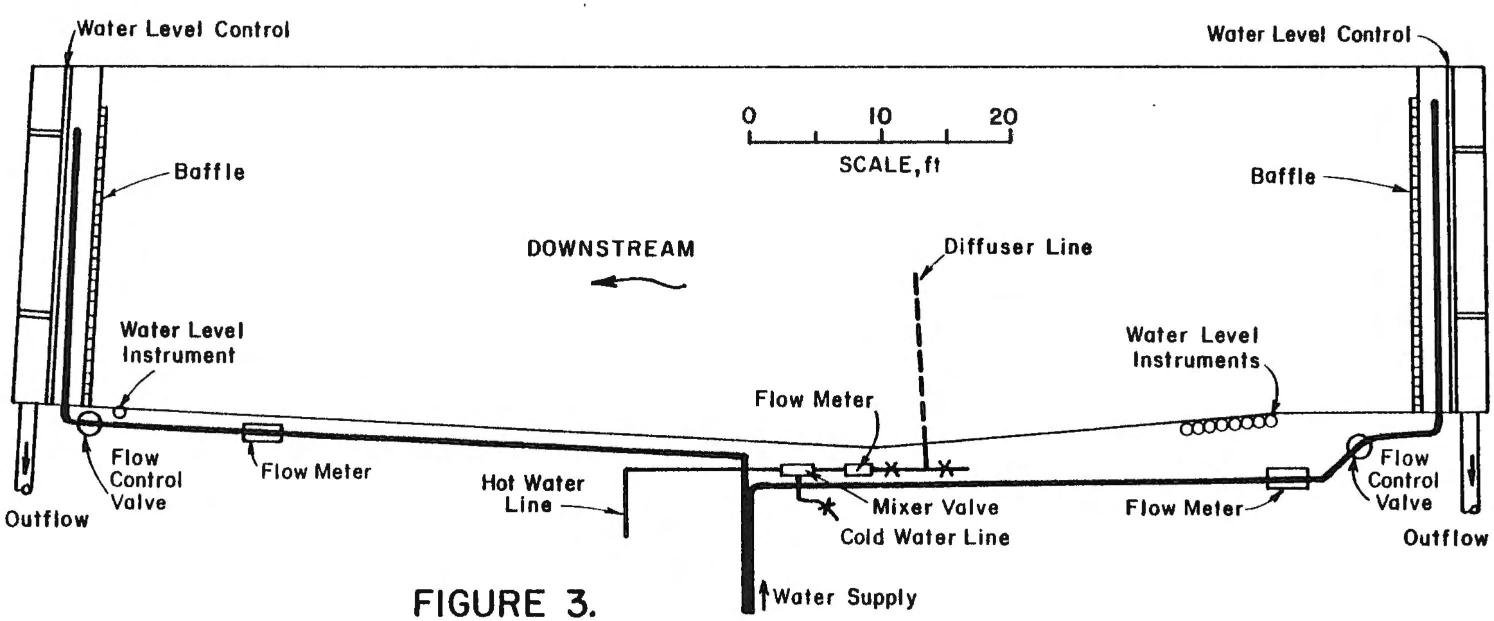

FIGURE 3.

MEASURING AIR RELEASE DURING COLUMN SEPARATION

J. Paul Tullis and Calvin G. Clyde

The objective of this study was to measure the amount of air released during column separation. The procedure was to create column separation in a pipeline in such a way that the time at vapor pressure and the pressure rise at cavity collapse could be carefully controlled. The amount of air released was determined by measuring the wave speed and using the wave speed equation (Equation 9, reference 1).[1]

The test line (Figure 6) was a 1 in. dia. 1089 ft long PVC pipe installed horizontally about 10 ft above the floor. It was connected to pressurized tanks at each end. Pressure transients were monitored by two transducers located 813 ft apart. The output from each transducer was recorded on a light-beam oscillograph (Figure 14).

The pipe was flushed to remove any trapped air and then carefully filled with water which was air saturated at a known temperature and pressure. The pipe was then isolated from the tanks and the pressure in the head tank reduced to vapor pressure. The pipe was then subjected to vapor pressure by rapidly opening the isolation valve. The pipe was once again isolated and the tank pressure returned to a positive value.

After the desired time of column separation, the pressure in the pipe was increased by opening a small bypass line to the head tank. The magnitude of the pressure rise at cavity collapse was controlled by the flow rate through the bypass line.

Since most of the air was released by agitation caused by cavity collapse it was necessary to carefully control the collapse. It was found that opening a solenoid controlled valve at the tail tank just before the positive pressure wave reached the end of the pipe eliminated most of the undesirable pressure reflections and produced a single positive pressure peak.

The wave speed, with the water at vapor pressure, was determined by timing the pressure wave between the two transducers. The final wave speed after the transient was calculated by generating a small transient with the water at a positive pressure and measuring the time between pressure peaks.

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[1]Tullis, J. P., V. L. Streeter, and E. B. Wylie. 1976. Waterhammer analysis with air release. Proceedings of the 2nd International Conference on Pressure Surges, BHRA Fluid Engineering, Cranfield, Bedford MK43 OAJ, England.

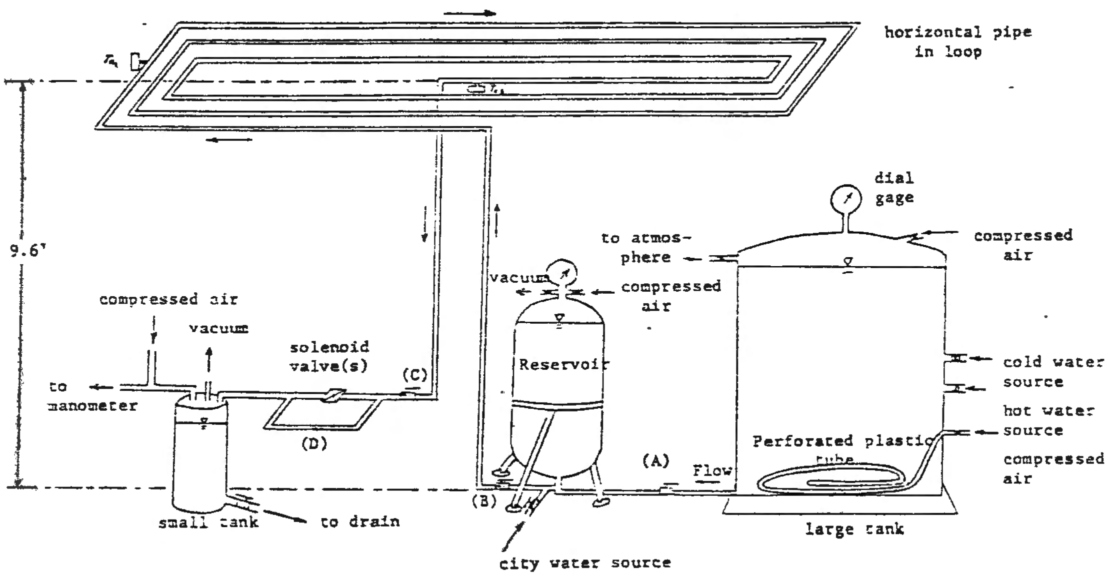

Figure 6. Schematic diagram of the experimental model.

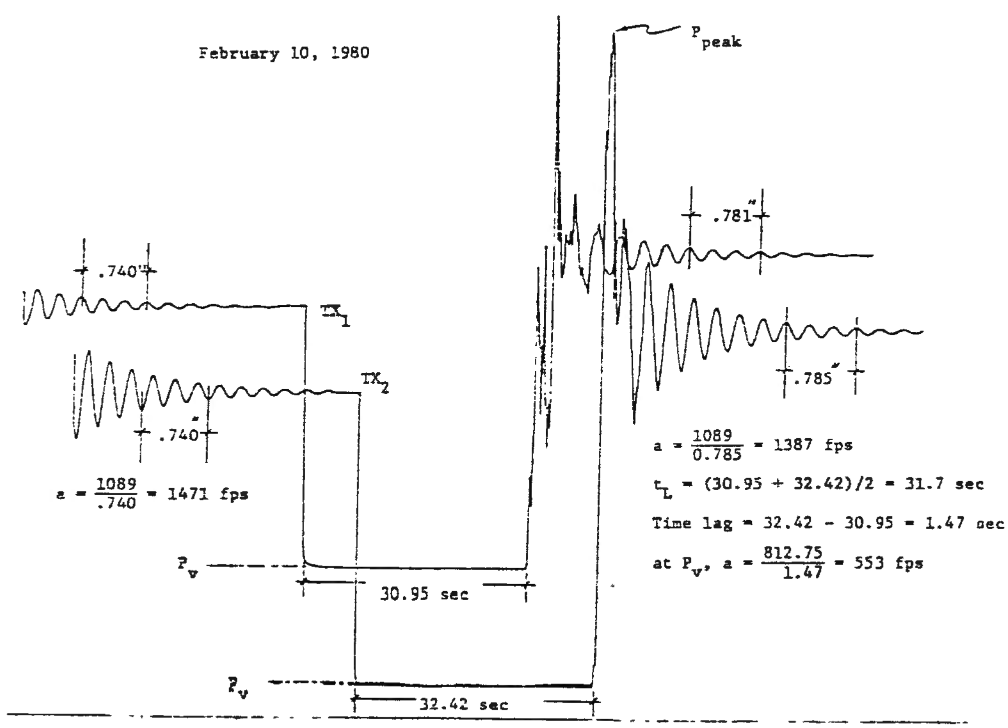

Figure 14. Example record of two transducers, its use for determining average t_L and wave speed at low pressure.

SESSION III

MODEL CONSTRUCTION AND SIMULATION TECHNIQUES

III. Model Construction and Simulation Techniques

Tom Rhone - Chairperson
Warren Frizell - Recorder

Summary Statement

New materials and methods are being used in model construction and simulation. In model construction they consist of everything from usage of a common material in a new and different way, to using the latest in computer-controlled machinery. In simulation techniques, new methods of flow visualization, dynamic force testing, and simulating landslide-generated waves are being used.

An overall feeling of increased quality assurance was noted at this meeting. The need to have a formal quality assurance program was presented and agreed with by many of those attending. It was also agreed that meetings of this type help in spreading and creating new ideas in these fields.

Comments on Session III

Quality Assurance Program - March

March made reference to both Alden Research Laboratory and Burns and Roe QA (Quality Assurance) Department for help in the setup of TVA's QA program. Originally designed to deal with tests involving nuclear facilities, it has now expanded to cover all model studies. Vigander made the comment that the program has a relative lack of burden considering the increase in quality they have achieved. Most agreed some type of QA program is good and actually saves time. One problem area that TVA and other QA programs have run into is dealing with outside communications, such as contractors.

Water Tunnel Flow Visualization by the Use of Fluorescent Minitufts - Stinebring

The discussion stemmed mainly around the application of the minitufts (0.001 in) to a surface, and the systems used for ultraviolet illumination. Stinebring described the application process in a step-by-step method:

1. The nylon rope to be used as the tuft material is first sized according to the size of the object to which they will be applied.

2. The nylon is then dyed with an appropriate ultraviolet sensitive dye, such as Luga-4.

3. An imaginary grid is then set up on the object.

4. The nylon rope is simply wrapped around the object and ends taped in place.

5. Then take a glue, such as Lock-tite adhesive, and with a blunted needle apply a dot of adhesive at each intersection of the grid, attaching the nylon rope to the object at these points. Let dry overnight.

6. Taking a small (20-gage) wire, wrap it around the end of a soldering iron leaving approximately 1/4-inch free.

7. With some experimentation get the wire hot enough to cut through the nylon rope, making sure not to mar the finish of the object of interest. Cut each piece to the desired length.

The tufts can be removed with an acetone solution if changes in spacing or mistakes are made.

The illumination systems can get very complicated when dealing with rotation. A stroboscopic system can be designed with the help of EG&G Massachusetts. Although they no longer provide commercial systems, they are very experienced in their design and operation and will provide all the information needed.

Erection of Hydraulic Models of Rivers and Reservoirs - Babb

This contouring method was discussed as to its speed and ease of construction as well as its accuracy. No one seemed to think it was a particularly fast method. Shooting in the elevations of all the vertical dowels seems cumbersome. This method also presents the problem of sealing the cement-vermiculite mortar watertight. Babb said they had had fairly good luck with using a cement-water slurry. Western Canada Hydraulic Laboratory commented they had used a commercially available mortar seal, Theroseal, with good success. Questions also arose about the ease and accuracy with which contours could be changed if already in place. Babb said if they anticipated any changes, the steel dowels were left out in that area. This factor, along with the softness of the cement-vermiculite mixture made changes fairly easy.

Special Materials Used in Hydraulic Model Construction - Frizell

Most questions concerned the foam products: polyurethane foam and styrofoam insulation. Durability of the polyurethane foam was questioned. Frizell said they had good success using it and that it did not have to be treated that carefully. Callenen said they had used the polyurethane as ship modeling material and found that over long periods of time, problems with dimensional stability and waterlogging occurred. The Service has not had any of these problems as of yet. The cost of the material was also discussed and Frizell said that overall, with the savings in labor, it was a cheaper process. The styrofoam insulation used as a contouring material was questioned as to the accuracy obtainable and shaping methods. The accuracy seems to be equal to any other contouring method. Depending on roughness required, edges can be left straight or can be shaved off with any number of tools; serrated knife, small keyhole saw, hot-wire styrofoam cutter, etc.

Model Construction at the TNSRDC with Numerically Controlled Machine Tools - Callanen

A video tape of the milling process was shown which answered many questions as to size and operation of the multiaxial milling machines. Most discussion centered around cost and the programming of the machine. Callanen said that they purchased the machine because of a lack of outside interest in constructing the models. A machine with a 30-foot bed would cost approximately $100,000. The programs which control the machines are very complicated and have actually taken a couple years to perfect.

Simulation of Landslide-generated Waves - McLaren

The main point brought out by McClaren was to make sure you replicate the appropriate slide material and have similar momentum transfers.

Friction in Model Gate Investigations - Sweeney

No comments.

Dynamic Laboratory Testing of Sea-going Gravity Separator - McClaren

No comments.

An ECCS Containment Sump Test Facility - Gardiner

Points brought up included: why the need for a 1:1 scale facility and what other things can it be used for. Gardiner said that the ECCS was a regulatory commission and they had apprehensions believing the results of a model (scaled down) study involving a nuclear powerplant. Gardiner also said that they could use the facility for any 1:1 study which came along, or for a study which involved heated water.

Underwater Camera, Remote Operator - Fitzwater

No comments.

TVA Engineering Lab: Quality Assurance Program - March

Quality is a primary concern in any conscientiously conducted study. The increased use of physical model studies to investigate structure or systems for nuclear powerplants has made a formal quality assurance (QA) program increasingly important. TVA's Engineering Laboratory adopted a formal QA program in connection with four physical model studies for the Clinch River Breeder Reactor Plant. The QA program is currently being extended to include all major physical model studies and testing programs, regardless of whether or not the studies are related to nuclear power generation.

The quality assurance program is organized around one general procedure, "Quality Assurance Procedure for Conducting Physical Model Studies and Physical Testing Programs," and three implementing procedures: "Special Procedures for Design Drawings," "Special Procedure for Quality Assurance Document and Records," and "Special Procedure for Control of Measuring and Test Equipment." Copies of the procedures are available upon request.

ERECTION OF HYDRAULIC MODELS OF RIVERS AND RESERVOIRS

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Simulation of topographical features of rather wide rivers and reservoirs can occupy a large part of the time and cost of model building. A technique has been developed and used at the Albrook Hydraulics Laboratory that accurately and efficiently reproduces topography in these settings.

Topographic maps and engineering plan drawings of the study area are required here as with any model-building technique. A grid is drawn directly on the maps and drawings which represent a four by eight foot (1.22 x 2.44 m) interval spacing at the selected model scale (see Figure 1). The grid is projected onto a standard plywood sheet on which the contour lines (as well as any instrument positions and horizontal control points) are drawn. All such plywood sheets are then lain on the floor of the model basin to form a "to-scale" map.

Holes are drilled through the plywood along the contours to accept vertical dowels.* These holes are positioned at significant breaks in grade or alignment and otherwise at no greater than about two foot (0.6 m) centers for support of model and fluid weights. After inserting the dowels, their tops are marked at appropriate finished grade with an engineer's level and rod prepared for model scale and each dowel is cut as marked. Horizontal supports* are fastened to each dowel from 4 to 5 inches (0.1-0.13 m) below the dowel tops. A metal lath* then is lain on the horizontal supports and fastened securely thereto.

A cement-vermiculite mixture is packed tightly on the wire mesh and around the vertical dowels to the top of the dowels. Prior to packing, water stops are placed on piping components, instruments, and model structures. Finally, a thin, water-cement slurry is trowled over the entire model surface as a water-tight seal and to provide an attractive photogenic surface. Figure 2 illustrates each of the components in position.

This model building technique has a good deal of flexibility. The cement-vermiculite mixture is relatively soft so that if topographic changes (such as for reorientation of hydraulic structures or for excavation relocation) are necessary, they can be made quite easily. Also, if roughness must be added to the streambed, it can be securely fastened with nails, sheet metal screws or cement slurry. The mixture is inert and is a good insulator, characteristics that may be useful when simulating water quality and thermal dispersion phenomena. The technique also permits elevating the model above floor grade for access to instrumentation and other model apparatus.

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*No. 3 deformed, reinforcing bar has been used successfully; a quick arc welder spot fastens the dowel to the horizontal support. The deformations also act as a water stop to prevent seepage around the dowels. A 3.2 lb/ft^2 expanded metal lath will support the mixture; it must be fastened securely to horizontal supports with wire ties or the mixture may not set firmly to proper grade.

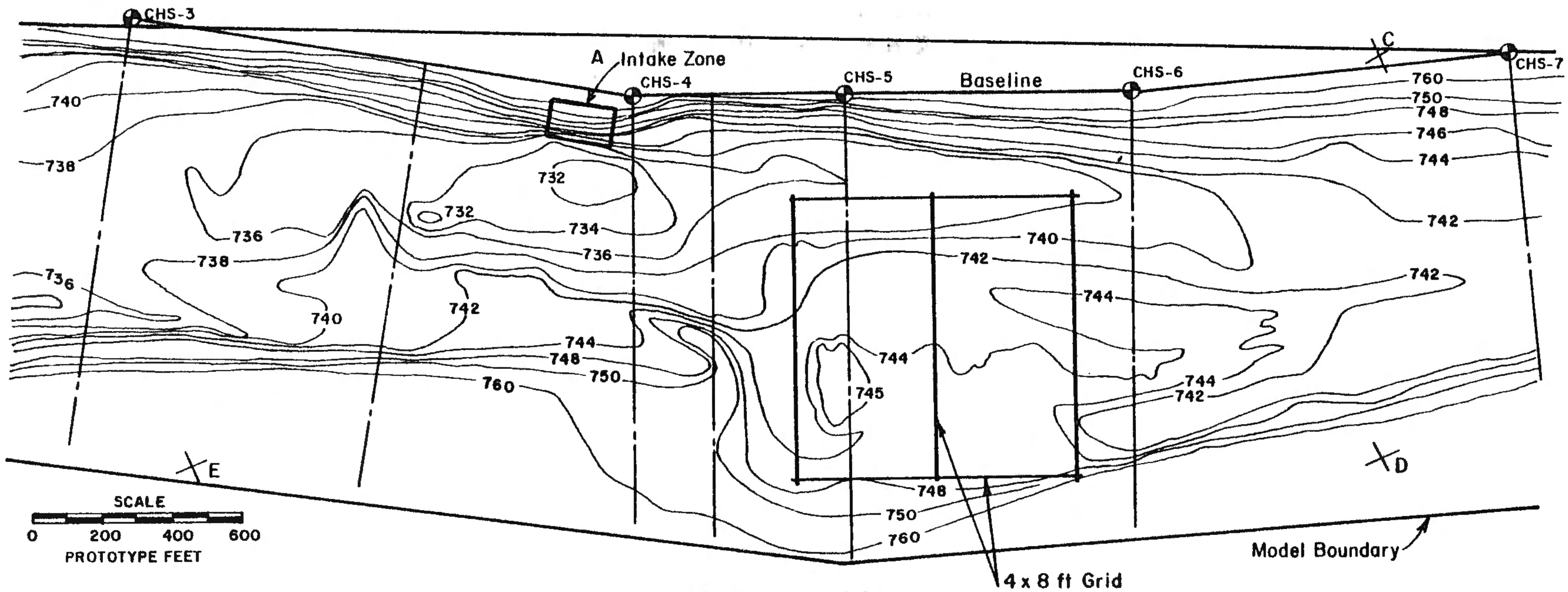

FIGURE 1.—PLAN

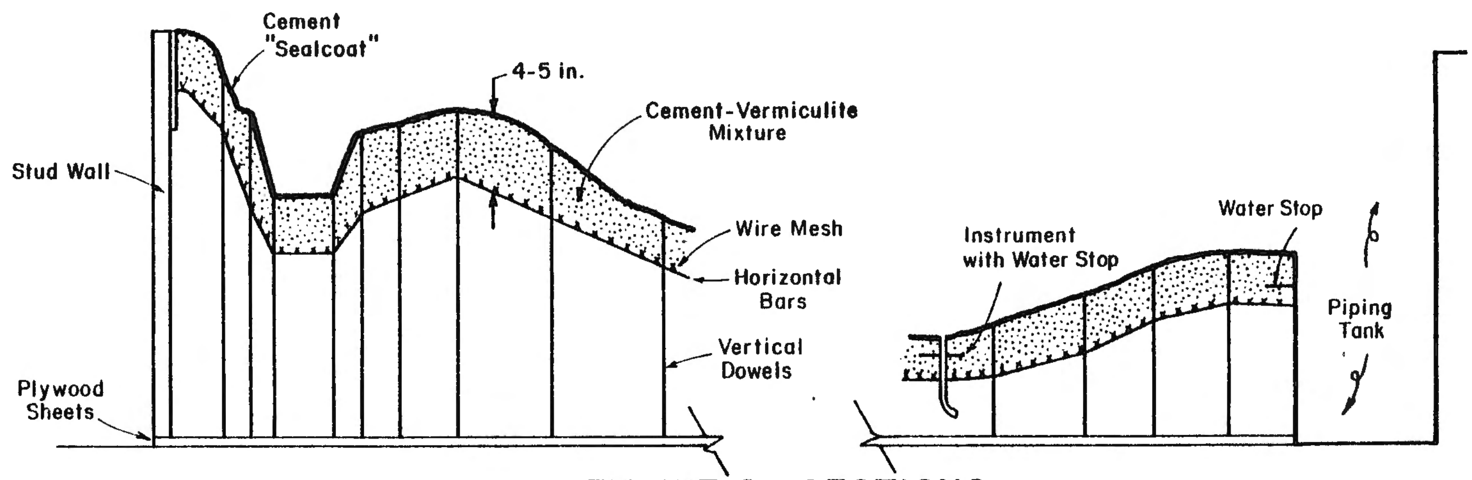

FIGURE 2.—SECTIONS

Special Materials Used in Hydraulic Model Construction - Frizell

Presented below are several special materials used in hydraulic model construction in the Water and Power Resources Service Hydraulic Laboratory.

During the past 15 years, the Water and Power Resources Service Hydraulic Laboratory has been using a resin-fiber-coated plywood for model box construction. The use of this waterproof plywood has shortened construction time and enables the maximum utilization of laboratory space. It is also quite durable, but because of the smooth surface, it is sometimes difficult to seal.

Acrylic plastic is a widely used and durable material. The Service uses this plastic mainly for transitions, tunnels, and piers. The versatility of the material makes it possible to form complicated shapes and allow use either in water or air models.

Polyurethane foam or high-density styrofoam (12 lb/ft^3) is a very versatile and workable material, although it is somewhat expensive. The Service's main use of polyurethane foam has been for fabrication of spillway crests. Polyurethane foam can be shaped on a lathe, sander, saw, etc., so it is easily used for morning-glory as well as more conventional spillway crest types. Waterproofing is done by applying a latex grout and then a plastic paint. Another styrofoam product is used for contours, regular styrofoam insulation, can easily be used as contouring material for complicated topographical areas or especially for areas where changes in the topography are expected. After the contours are transferred from the map to the styrofoam, they are then cut out and cemented together, one on top of another. If further shaping is necessary, it can be done with a knife. Completed contours are then attached to the box by anchor bolts or by an appropriate cement.

The above method of contouring with styrofoam is similar to the normal contouring used by the Hydraulic Laboratory. This process transfers coutours from the map at 5- to 10-foot intervals to plywood templates. These templates are then attached to tiered suports which bring the contours to their proper elevation. Expanded metal lath is stretched over the wood template and finally a coat of concrete to finish off the topography to grade.

Model Construction at the David W. Taylor Naval Ship Research & Development Center with Numerically Controlled Machine Tools

by Stephen E. Callanen

In recent years the David W. Taylor Naval Ship Research and Development Center has successfully adapted modern numerically controlled (NC) milling type machines to the construction of complex scale model ship hull and propeller shapes used in experimental hydrodynamic research programs. These machines have enabled the Navy to fabricate better quality models in less time with less hand finishing than previously required.

Wooden ship hull models are contoured on an ONSRUD[1] 3-axis NC profiler machine with a 6 foot x 34 foot table size. A typical 20 foot surface ship model (figure 1) can be cut to the final finished dimensions in approximately 24 to 32 hours. Hand finishing is necessary only to remove the cutter marks left by the ball type milling tools.

Fixed pitch model propellers with overlapping blades are usually fabricated from either nickel-aluminum-bronze or 7075-T6 aluminum on an OM-3[2] 5-axis NC continuous path milling machine (figure 2). Wooden patterns are also cut on this machine for use in making molds to produce propellers either from bronze castings or from fiberglass.

The combined properties of high strength and good machinability make 7075-T6 aluminum the most commonly used material for model propeller construction. Heat treating is done before the aluminum plates or forgings are machined. Hand filing must be employed to generate the leading and trailing edge radii of the blades and to remove tool marks. Upon completion, the aluminum propellers are black anodized to improve both corrosion resistance and the visibility of cavitation bubbles on the blades during testing.

Model propellers cut on the OM-3 generally have diameters ranging between 6 inches to 24 inches. The number of blades can typically vary up to eleven.

Machining accuracy of finished propellers is checked on a computer controlled Brown and Sharpe "Validator" inspection machine[3] which provides an automatic printout of deviations between the actual blade surface contour and the original input data used to program the OM-3. When necessary, the blade edge radii are checked with a Jones and Lamson optical comparator (Type EPIC-30)[4] which can magnify the edges by a factor of 10, 20, 50, 100, or 200.

Plans are underway for upgrading and expanding propeller manufacturing capabilities by placing in operaton a second OM-3 machine in the spring of 1981. In addition to generating model propellers, these versatile OM-3 machines are extremely valuable for machining a wide variety of components for special fixtures and dynamometers used in experimental work.

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[1] ONSRUD Machine Works, Inc., Div. of Danly Machine Corp., Chicago, Illinois.
[2] Sunstrand Machine Tool Div. of Sunstrand Corp., Belvidere, Illinois.
[3] Brown and Sharpe Manufacturing Co., North Kingstown, Rhode Island.
[4] Jones and Lamson Div. of Waterbury Farrel a Textron Co., Springfield, VT.

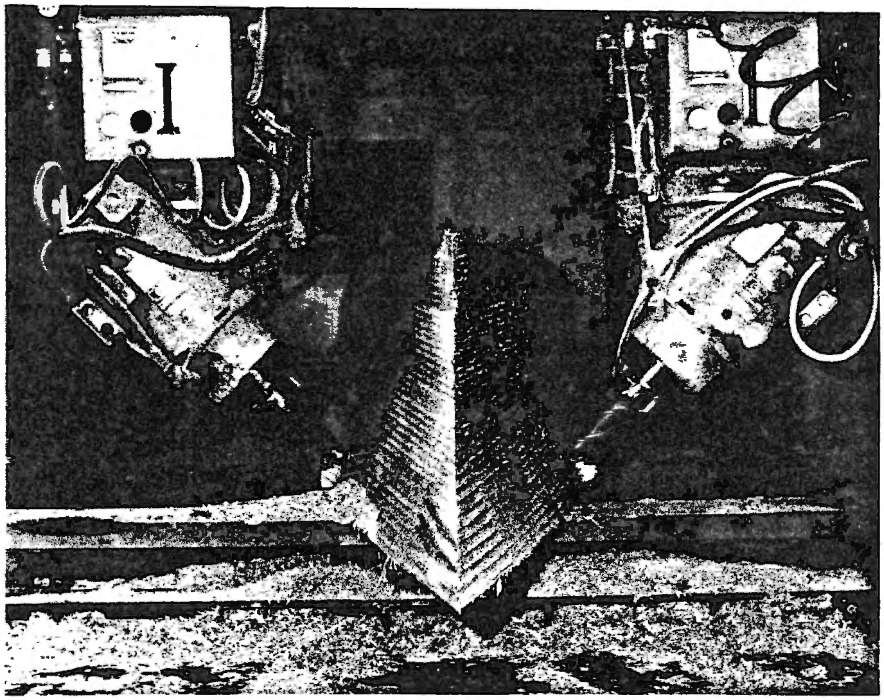


Figure 1 - Typical 20-foot Wooden Surface Ship Model Being Cut on an ONSRUD 3-axis NC Profiler

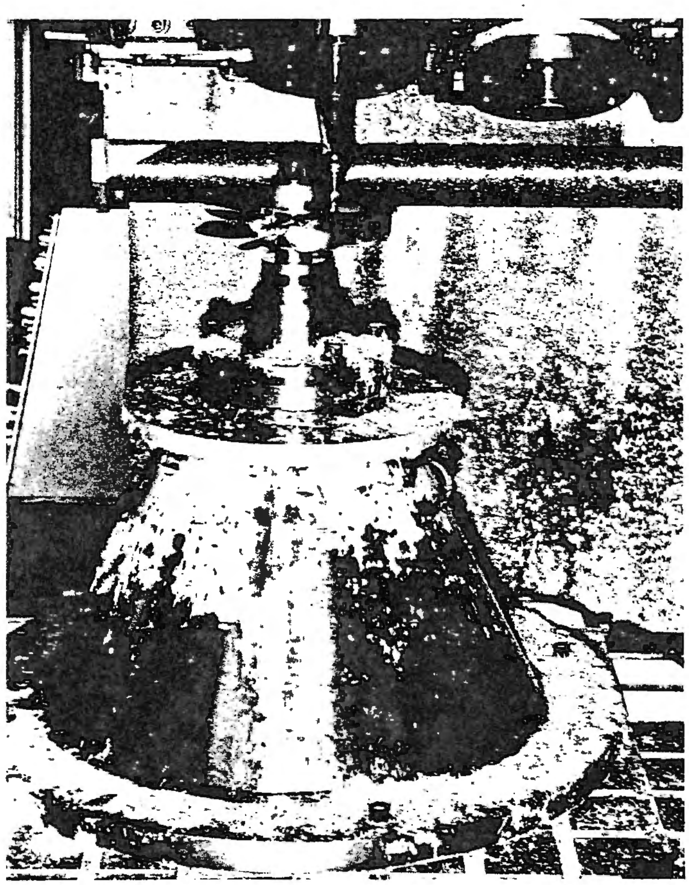


Figure 2 - Typical 9-inch diameter Aluminum Propeller Model Being Cut on an OM-3 5-axis NC Continuous Path Milling Machine

Water Tunnel Flow Visualization by the Use of Fluorescent Mini-Tufts

by

David R. Stinebring and Allen L. Treaster

Applied Research Laboratory
The Pennsylvania State University

The need for improved flow visualization techniques in the Fluids Engineering Department of the Applied Research Laboratory at the Pennsylvania State University (ARL/PSU) has been apparent for some time. The knowledge of surface flow patterns is important to both the designers of hydrodynamic hardware and the test engineers as they correlate and analyze experimental data as a function of differing flow phenomena. Specifically, the identification of regions of separated flow is especially important. Thus, the adaptation of a new air tunnel flow visualization technique developed at the McDonnell Douglas Corporation and discussed at the 1979 Subsonic Aerodynamic Testing Association (SATA) meeting to water tunnel testing at high flow velocities was of definite interest.

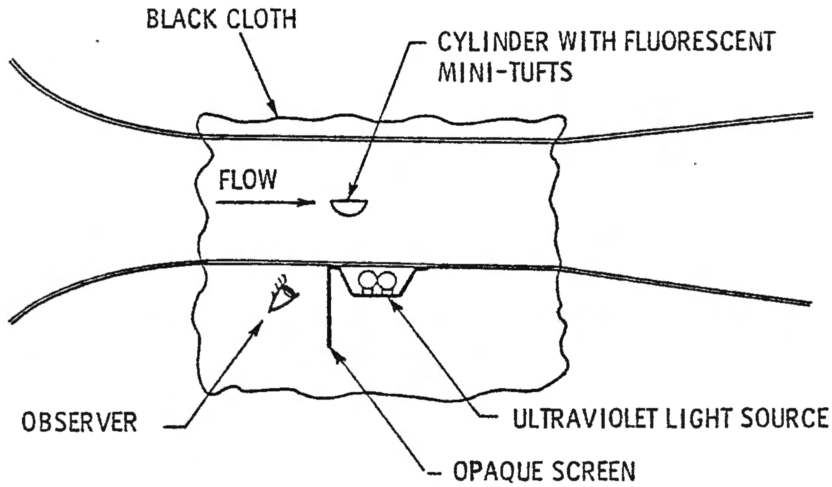
This new technique utilizes what are referred to as "fluorescent mini-tufts." The basis of the method is the use of extremely fine nylon mono-filament fibers, which have been treated with a fluorescent dye, and a process of attaching the tufts to the model surface with small drops of liquid adhesive. The tufts are rendered visible for viewing or photography by ultraviolet light.

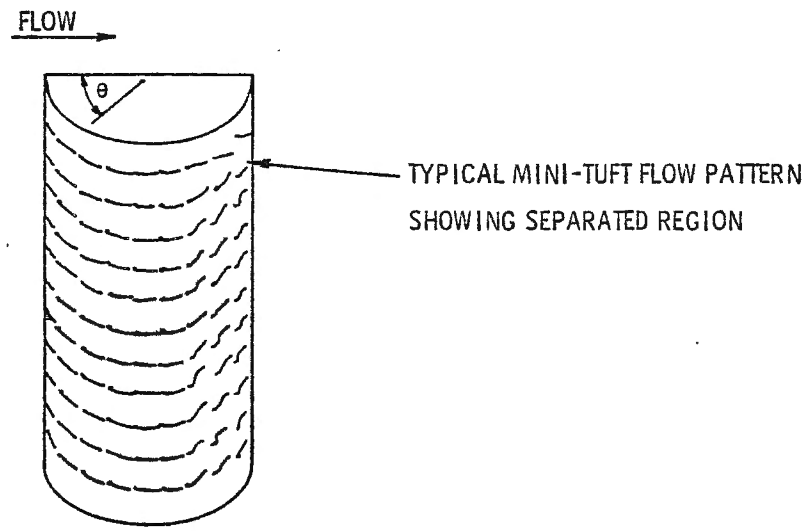
The use of tuft material for flow visualization with visible light is not new except that the tufts had to be made quite large to be visible against a reflective background. In many instances these large tufts could significantly alter the flow pattern.

The important feature of this new technique is that under strong ultraviolet illumination, which is invisible to the unaided eye, the fluorescent tufts stand out in sharp contrast with the nonfluorescent surface to which they were applied. Thus, very small tufts which will not disturb the flow pattern can be applied to the model and still be visible. For the tufts to be photographed, a filter must be used over the camera lens to remove the reflected ultraviolet illumination yet pass the visible light. The filter, termed a barrier filter, is necessary because most photographic emulsions are sensitive in the ultraviolet wavelengths. If the reflected ultraviolet reflection were not removed, glare from the surface would obscure the view of the mini-tufts.

The choice of an ultraviolet light source for illumination of the mini-tufts is dependent upon the particular application. For the observation of flow patterns on a stationary object a continuous source, such as a mercury vapor arc, is suitable. The visible light from the arc is removed with an exciter filter, such as a Corning # 5970, which passes a large percentage of ultraviolet light yet removes the unwanted visible radiation. A typical viewing arrangement is shown in Figure 1. Observation of the tufts on a rotating system is somewhat more complicated; a stroboscopic ultraviolet source is required. Some xenon arcs exhibit an enhanced output in the ultraviolet region, and when used with a suitable exciter filter make good pulsed sources.

To date, fluorescent mini-tufts have been used successfully for observation of the flow patterns on stationary and rotating models in both the 12-inch and 48-inch water tunnels at ARL/PSU.


BLACK CLOTH
CYLINDER WITH FLUORESCENT MINI-TUFTS
FLOW
OBSERVER
ULTRAVIOLET LIGHT SOURCE
OPAQUE SCREEN


FLOW
θ
TYPICAL MINI-TUFT FLOW PATTERN
SHOWING SEPARATED REGION

Simulation of Landslide-generated Waves - McLaren

Water waves generated by three different types of landslides have been investigated by hydraulic models at our laboratory in Vancouver. A different type of slide-generating mechanism was used in each to simulate the entry volume-displacement rate and shape characteristics of the three types of slide.

The first type of slide studied was high velocity rock slides dropping from surrounding moutains into a reservoir behind Mica Dam. The reservoir was modeled to a 1:300 scale with a molded cement cover over packed sand. Following trial and error tests it was determined that the best slide results were obtained by allowing a shaped but flexible mass of 1-foot-square by 4-inch-thick nylon bags filled with loose sand and 1/4-inch gravel to slide under the pull of gravity down an inclined slope to the reservoir. Slide volumes ranged from 50 to 160 million cubic yards in prototype. Steel roller bearings constructed into the concrete model topping both above and below water level allowed the slide to run on into the reservoir. Entry velocities of the slide, up to 200 feet per second in prototype, were controlled by the initial height to which the slide mass was raised on the slope and by the slope angle of inclination. The entry velocity was recorded by the pull rate of a light nylon line passed over recording pulleys and attached to the front of the slide. The volume-displacement rate of the slide is a more important factor influencing wave heights than the entry velocity. This was controlled by appropriate stacking of the gravel bags and attachment in place with wire fencing. Tests were also run using loose sand and gravel to reproduce the slide action but such slides presented more operational difficulties in terms of preparation and cleanup and produced less consistent results than use of the gravel bags. The slide mechanism could be quickly reset for repetitive tests at the same location and was easily transported to other prepared locations. The placement of rollers in the concrete topping during model construction was however fairly time consuming.

Ten slides from three different locations were examined. Waves of over 180 feet from still water level to crest were measured at the damsite following a slide of 50 million cubic yards at the location nearest to the dam.

The second type of slide investigated surface waves developed near the shoreline of fjord-like Kitimat Arm in the area of a proposed supertanker dock following sudden slumping of seabed sediments. A submarine slide of this type had already occurred nearby in 1975, providing some data for calibrating the model. Three possible slide locations were investigated on a 1:600 scale model with slide volumes up to 6 million cubic yards moving at 10 to 17 prototype velocities. The slides were simulated by building up thin rubber layers over flexible 0.4-inch rubber base pad. The slide was pulled from in front by a hydraulic piston pushing against connecting rods. The connecting rods were of sufficent length to prevent the piston from entering the water.

The hydraulic piston was driven by a hydraulic pump and 5-hp motor. Piston rod velocity was controlled by a flow restricting valve on the hydraulic feedline of the pump. The valve setting was in turn controlled by a cam and cam follower which could reproduce an entire varying velocity-time relationship.

Constant velocity slides could also be reproduced through elimination of the cam. Slide distance was controlled by a solenoid valve on the feedline which was actuated either manually or by stroke-limiting microswitches.

The third type of slide-generating mechanism used at the laboratory was for simulation of mud flows composed of melted snow and volcanic ash. Time constraints on this project required that the model be constructed of mass concrete poured and molded between plywood templates. The concrete surface was covered by slurry to give a smooth surface and the waterproof construction joints. It remains to be seen how difficult it will be to break up this solid model.

The slides were simulated by ejecting a viscous slurry down a ramp into the model. The slurry was pushed from a rectangular chamber by a piston with a controlled speed, giving a known volume-displacement rate characteristic. Slide thickness was measured with an electronic profile follower. Experimental tests had been conducted in a small flume to develop a slurry with the relatively low density and approximate viscosity postulated by geologists for the mud flow. A slurry of 28 percent borite and 3 percent bentonite clay, by weight in freshwater, best simulated the desired material. This material did not dispose but retained its cohesion and the shape of the slide front as it flowed into and under the reservoir water. Waves up to 12 feet in height were produced by slides of 30 million cubic yards volume entering the reservoir at velocities up to 60 miles per hour.

It was found in these three studies that the type of slide material used in a model strongly affected the resulting wave heights and that the type of slide generating mechanism must be carefully considered to ensure satisfactory results from such model studies.

FRICTION IN MODEL GATE INVESTIGATIONS

By C.E. Sweeney, Senior Engineer/Manager of Engineering Hydraulics, Inc.

It has been documented in the literature that large gates used to control or shut off flow may be subject to hydraulic uplift of downpull forces and to vibrations induced by flow and fluid-structure interaction. Hydraulic models have been demonstrated to be time and cost effective tools for examining such problems which may be complex enough in nature to defy a rigorous theoretical analysis.

Friction forces in models are often too large due to the difficulties of maintaining wheel or bearing alignments and clearances between the model gate seals and the sealing surfaces. Means have been employed to determine the magnitude of friction forces and to subtract them from model cable tension values to determine the pure hydraulic loading on the model gate:

1) For cases where the downstream side of the gate doesn't become submerged and therefore water levels, normal force and friction force on the gate may be assumed to be equal during an opening or closure sequence at the same gate opening, cable tension (the load on the hoist mechanism) is plotted versus gate opening for both opening and closing sequences. The resulting two curves are separated by a value equal to twice the friction force at that gate opening, Figure 1; and

2) The coefficients of static and dynamic friction of the model gate have been determined from bench tests. Water level data has been used to compute a normal force on the gate assuming a hydro static distribution and the normal force and friction coefficient used to calculate a friction force. Friction values determined by this means have compared favorably with values determined by method 1) for unsubmerged gates.

A conservative analysis of potential vibration problems on a model requires in addition to correct scaling of the natural frequency of oscillation of the gate and suspension system, that the damping of any vibrations, due to model friction, be less than or equal to that expected in the prototype. A system of pulleys and spring balances has been employed to relieve normal loading of the model gate wheels providing an essentially frictionless gate at pre-determined static gate positions, Figure 2.

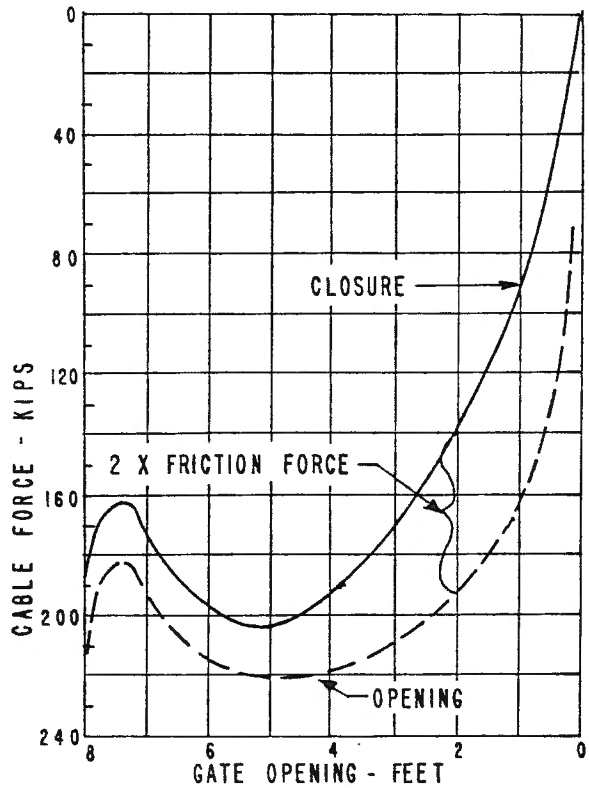


FIGURE I : CABLE FORCES

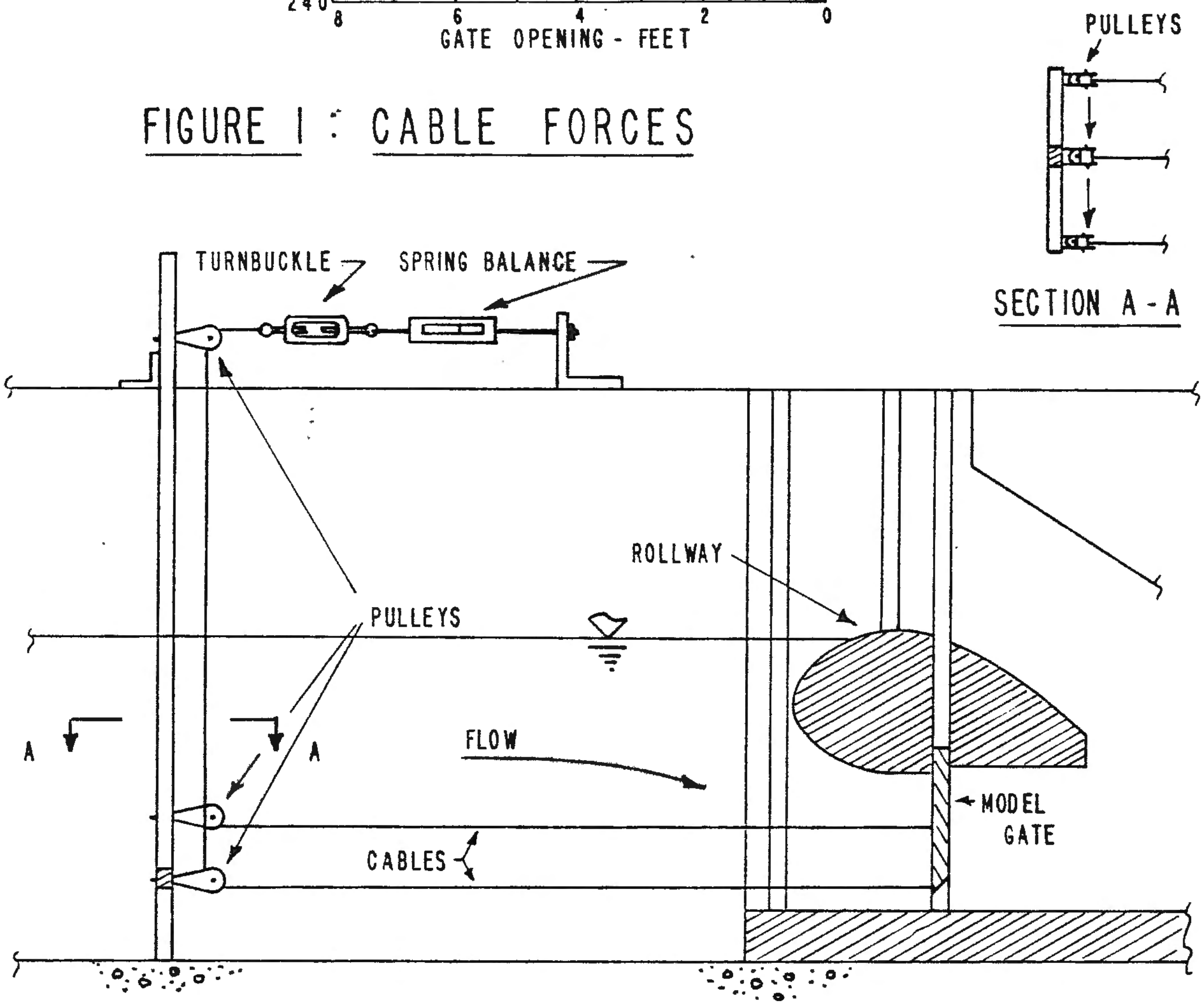


FIGURE 2 : FRICTIONLESS GATE APPARATUS

Dynamic Testing of Sea-Going Separator - McLaren

A gravity oil separator had been constructed and satisfactorily performance tested under below freezing conditions in a cold room to determine its suitability for oil spill cleanup operations along the Arctic coast. Further testing was required to examine the separator's performance while being subjected to ship motions similar to those which would be experienced on a supply barge anchored offshore in waves up to 5-foot height.

The separator was a large volume tank in which oil, being lighter than water, rose to the surface as flow passed through the tank. A deep lateral baffle across the tank dammed the separated surface oil layer from clean water which passed under the baffle and was returned to the ocean. It was anticipated that turbulence generated by rocking of the tank in moderate seas would greatly reduce the separators' output efficiency. Use of a sea-going vessel to test the separator under the desired range of sea states would have been neither expeditious nor economical in the Vancouver area.

A 15-foot-long by 7-foot-wide test frame was fabricated of steel beams and mounted on a centrally located spherical bearing. The test frame and separator were supported on the bearing in three-point fashion by two hydraulic cylinders located at the outer edges of the frame on its longitudinal and transverse axes. The hydraulic cylinders were anchored to concrete pads and were used to generate pitch and roll motions.

A 7-1/2-hp electric motor pumped hydraulic fluid at 1,500 lb/in^2 through control valves to the cylinders (slide 1). A 50-50 percent flow divider isolated the two cylinder systems for pitch and roll motions and prevented the pressure-flow regime in one cylinder from affecting the other. Independent control of the cylinder stroke periods, and thereby the simulated pitch and roll periods of the vessel, were obtained by pressure compensatory flow contol valves on each system. Cylinder stroke length was controlled by microswitches operating solenoid valves to direct flow from one side of the cylinder to the other. Pressure-sensing throttle valves were located immediately before the cylinders to reduce the abrupt shock at each end of the cylinder's stroke and to balance the upward and downward piston stroke periods.

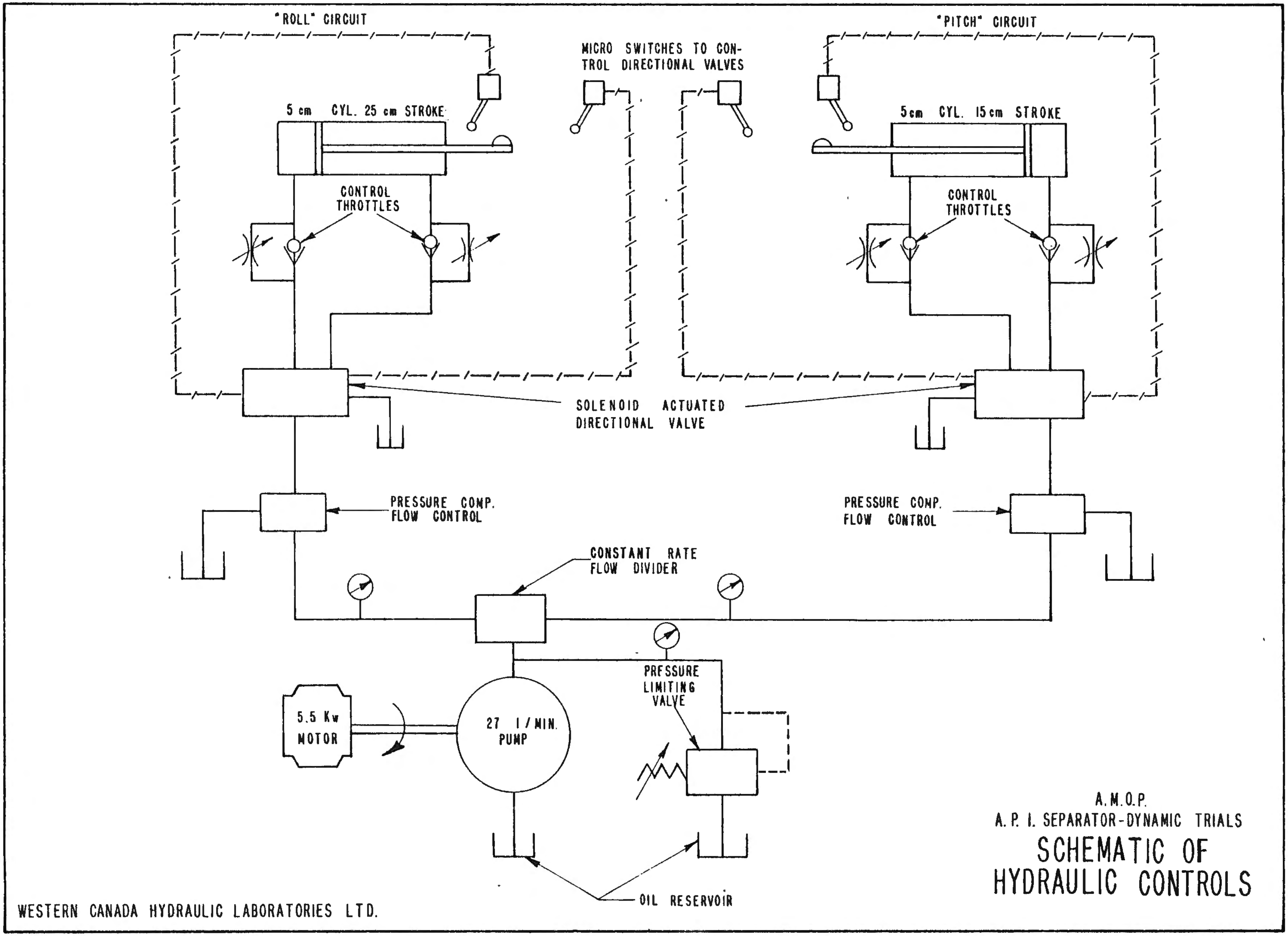
The motions produced by the drive system were of a modified "saw-tooth" wave rather than the preferred sine-wave. The throttle valves were found to reduce but not to eliminate the shock produced by abrupt change of direction at each end of the stroke. The wave term to which the separator was subjected was probably more severe than that which would actually be experienced at sea.

Oil was pumped to the separator on its wobble-bed, using flexible hosing and positive displacement gear pumps to miminize emulsification of any water left in the system from previous tests. Saltwater was mixed with the oil only at the entrance to the separator.

The separator was tested for 50-50 and 75-25 percent oil-water input concentrations. The effect of beam and quartering seas of 1- to 5-foot height with 2- to 5-second significant period were theoretically determined from supply typical barge characteristics. At times the test conditions appeared to be more severe than would actually be considered workable onsite.

One of the project recommendations was to increase separator wall freeboard against overtopping.

It was found that under the most severe design conditions, the clean water output from the separator contained less than 100 p/m of oil and the oil output contained less than 15 percent water. This was considered sufficiently acceptable to warrant further work to optimize the separator design.



A.M.O.P.
A.P.I. SEPARATOR-DYNAMIC TRIALS
SCHEMATIC OF HYDRAULIC CONTROLS

An ECCS Containment Sump Test Facility - Gardiner

A test facility designed to accommodate 1:1 model testing of nuclear power-plant ECCS containment sumps has been constructed at Western Canada Hydraulic Laboratories. The facility includes a 60-foot-long by 25-foot-wide by 14.3-foot-deep concrete tank, pumping capacity of 18,500 gal/min and two 2.5 million Btu/h water heaters.

Containment sump model studies are undertaken to demonstrate vortex free operation under a variety of operating conditions. In addition, the headloss between the water in the containment area to downstream of the intake must be measured to supply information proving sufficient margin on pump NPSH.

Typical containment sump models include the sump, intake pipe, trashrack and screens, coverplate, and a portion of the containment area adjacent to the sumps. Water temperature in the prototype can reach 250 °F or more.

Vortex action in the model is detected visually. A plexiglass section is built into the trashrack coverplate for observation of vortices originating at the coverplate. Plexiglass sections are also built into the sump walls to mate with windows in an observation tunnel constructed under the simulated containment floor. Vortices originating from the floor or sidewalls are viewed from this perspective.

Headlosses are measured at prototype Reynolds number. This is achieved by heating the water to 180 °F and enhancing the discharge to overcome the discrepancy between prototype and model viscosities. Piezometer taps are used to measure the headlosses across trashracks and screens, intake, and, in some tests, elbows, miter bends, valves, and a length of pipe representative of the prototype suction lines.

Underwater Cameral Remote Operator - Fitzwater

The Service has designed and constructed a remote camera operator for a Nikonos 35-mm underwater camera. A Nikonos, having a different type of shutter release and winding mechanism than most Nikon cameras, needed a special-type operator since a commercial one was not available.

The operator was designed for immediate use with the Service's low ambient pressure chamber and the model of the clamshell gate. Many other uses are expected for the future.

SESSION IV

JOINT UTILIZATION OF MATHEMATICAL AND PHYSICAL MODELS

IV. JOINT UTILIZATION OF MATHEMATICAL AND PHYSICAL MODELS

Bob George - Chairperson
Phil Demery - Recorder

Summary Statement

Mathematical models are currently being used to simulate steady and transient open channel flow in rivers and canals. Some applications used physical models to obtain coefficients for the mathematical models, while others used the physical models to verify the mathematical models. One math model used the method of characteristics and interpolated along the time lines of the x-t plane to minimize interpolation errors associated with interpolation errors along the x direction.

Mathematical models were used to develop design parameters or operation limits for physical models. The math models used the basic equations of motion and simulated the physical models. The data obtained were used to design the model or to set limits or constraints on model operation.

Another use of the math models was to use the model to simulate a reach between points where field data were available. Data at interior points were generated by the model and used as boundary conditions of the physical models. The math model was used to provide data about water surface elevation, velocity, and diversions.

Comments on Session IV

Laboratory Facilities for Research and Development of Water System Automatic Control - Buyalski

Physical hydraulic models are used to develop coefficients and initially verify the results of a mathematical model which simulates the transients in an open channel. Stability of the canal control system is being evaluated with the math model. Also, the flow under a radial gate is being studied in a physical model to incorporate its parameters into the math model.

Discussion of the paper: What type of math model? St. Venont equation of motion solved by method of characteristics using a finite difference scheme. A new program has been developed which interpolates along the time line in the distance-time plane instead of along the distance line to minimize the error of interpolation at the boundaries. The goal is to refine the math model so that it will replace physical modeling.

Utilization of Mathematical and Physical Modeling to Evaluate Surge Reliever - Demery

The mathematical model used the method of characteristics to numerically analyze the test system. The model was based on Benjamin Wylie's transient formulation with modifications made as to pump boundary conditions. In order to use the mathematical model to evaluate the surge reliever, the discharge through the reliever as a function of time must be known.

Using a Mathematical Model to Design a Physical Model for Landslide Simulation - Pugh

No comment.

Stratification and Suspended Sediment Simulation in Shallow Lakes and Reservoirs - Stefan

No comment.

Reservoir Water Quality Modeling - Fletcher

A dye was used to distinguish zones of withdrawal for different reservoir stratifications and varying withdrawal rates. By incorporating these results with a numerical heat and water budget model, selective withdrawal structures can be evaluated.

Note: This program is only the selective withdrawal section of a longer program which can simulate the reservoir operation and resulting stratification as well as the releases given a particular stratification.

Joint Use of Computer and Physical Models for the Sacramento River - DeVries

The mathematical model was used to generate an upstream discharge for a physical model as a function of time curve based on historical USGS data downstream and upstream from the section modeled by the physical model. Fishscreens were not placed at the diversion due to the importance of a relatively constant velocity profile in the control section.

Kinematic Wave and Minimization Approach to Modeling of Channels With Sediment - Song

A discussion was presented of sediment transport based on a kinematic or continuity approach and use of the theory of minimum energy which considers the minimization of the sum of kinetics and potential energies of the system. The presentation considered only suspended load and when asked if the method could handle bedload, the response was yes.

Laboratory Facilites for Research and Development of Water System Automatic Control

Two hydraulic laboratory models have been constructed for the Water System Automation on-going research and development program; (1) the Canal model and, (2) the Canal Radial Gate model. (Ref. GR-5-77 dated April 1977)

Canal Model

The Canal model is used to study and demonstrate various automatic check gate control schemes and equipment, including micro and mini computers. The model has a rectangular flume approximately 335 m (1100 ft) long and a capacity of 0.03 m^3/s (1 ft^3/s). The flume is divided into three canal reaches of unequal lengths by four gate structures. The three canal reaches were designed to have different transitory wave travel times so that stability characteristics of control schemes can be evaluated. Bends of 180 degrees direct the flow from channel to channel as the flume traverses back and forth across the laboratory floor. The significant feature of the model is the capability of interfacing prototype control equipment, including micro and mini computers to each check gate control panel.

Studies are in progress to simulate the hydraulic laboratory physical canal model on a mathematical model used to simulate actual operating canal systems. The purpose of the studies is to verify the mathematical model wave transient equations by comparing the mathematical model output to the laboratory data. The reflection of transient waves between canal reaches will be analyzed through the use of simulated siphons between reaches.

Canal Radial Gate Model

The 1:6 scale 762-mm (30-in) wide canal radial gate model is being used to develop discharge algorithms for radial gates controlling flow in irrigation canal systems. The model uses an automatic sequencing scanner valve and one pressure transducerto measure water levels at 35 different points for each test run. The gates pinion height can be adjusted to vary the radius pinion height ratio. Two gate lip seal designs, (1) the hardrubber bar, and, (2) the music note have been accurately scaled and are being studied to determine the difference in the coefficient of discharge.

The Canal Radial Gate model will also be used to verify the mathematical model transient wave reflections and wave propagation through the gate structure, including a simulated inverted siphon downstream.

UTILIZATION OF MATHEMATICAL AND PHYSICAL MODELING TO EVALUATE SURGE RELIEVER

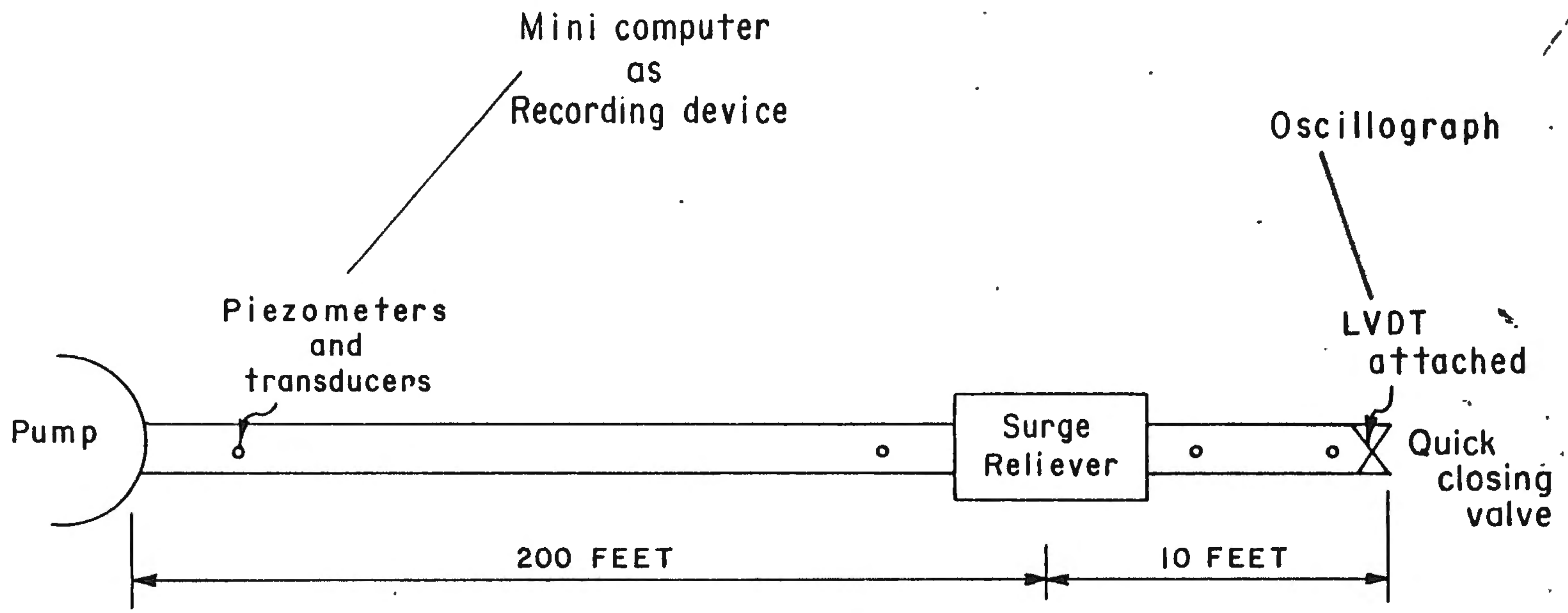
By

Phillip M. Demery and Brent W. Mefford
Hydraulics Engineers
Water and Power Resources Service
Denver, Colorado

In order to test the effectiveness of a surge reliever, both device response time and a system pressure analysis need to be conducted. Due to laboratory limitations such as available water pressure, space, and pipe, it can be advantageous to augment the physical model of the pipe system with a mathematical model. The implementation of a mathematical model enables the researcher to operate the physical test system at lower pressures. This can eleviate possibilities of pump reversal or pipeline rupture.

It is useful to consider the situation in which the surge reliever does not work. This physical situation acts as the control case for the mathematical model calibration. The math model, when calibrated confirms boundary characteristics and establishes the physical limits of the test system. Careful consideration must be maintained as to the mathematical transient analysis at a pump boundary. There are programs available that consider pump failures as the transient initiator; however, these programs need modification if the transient is initiated elsewhere in the system. It is important that the pump operates along a single rating curve during normal operation. Therefore, the rotational speed of the pump must not be allowed to vary.

The following figure represents a schematic drawing of the physical test system. A 10hp pump represents a boundary and a quick closing knife valve represents the transient initiator. Transducers are placed at four locations to pick up pressures within the pipeline. A mini computer set up for data acquisition records the pressures with time and an oscillograph tracks the closing of the knife valve with time.



SCHEMATIC DRAWING OF PHYSICAL MODEL

USING A MATHEMATICAL MODEL TO DESIGN A PHYSICAL MODEL FOR LANDSLIDE SIMULATION

By

Clifford A. Pugh
Hydraulic Engineer
Water and Power Resources Service
Denver, Colorado

Several physical model studies have been done in the last 10 years to simulate landslide generated waves in reservoirs. The hydrodynamics can be correctly simulated in these studies; however, the validity of the landslide simulations is doubtful. The shape of the slide material and the coefficient of friction are only approximated in the model.

A physical model study is being done at Water and Power to simulate landslide generated waves in Morrow Point Reservoir. A computer program was used to develop the design of the landslide in the physical model.

In previous physical models of landslides bags of rocks or sand were pushed, dropped, or slid into the reservoir. In most cases, the precise configuration and velocity of the slide during the event was in question.

The approach being taken in this study is to use a slide with fixed boundaries and measure the position accurately during the slide. If the momentum vs. time relationship of the displaced water is know accurately, in addition to the wave heights in the reservoir, a mathematical model to predict wave height can be developed from the data.

A wedge shape is being used to simulate the slide. The wedge is much thicker proportionately than the prototype slide; therefore, the entire model slide will be submerged before striking the bottom of the reservoir. The slide is mounted on rollers to reduce friction. The computer model computes the location of the slide and forces acting on it for each time interval. In addition, the momentum of the displaced water is computed.

An extension spring is attached to the model slide to slow it as the slide progresses. This simulates the prototype slide striking the bottom of the reservor and slowing.

The momentum vs. time relationship was calculated by hand for the prototype slide using an empirical relationship for slide velocity and accounting for the slide geometry and anticipated mode.

The shape of the wedge, initial position, weight, and spring force were then varied for the model slide in the computer program until the momentum vs. time relationships matched in the model and prototype.

The model landslide can be repositioned easily using this approach, to run additional tests. Repositioning would be a time comsuming and expensive process using bags of sand or rocks.

STRATIFICATION AND SUSPENDED SEDIMENT SIMULATION IN SHALLOW LAKES AND RESERVOIRS

by Heinz Stefan
University of Minnesota, Department of Civil and Mineral Engineering
St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota 55414

A model for the simulation of the one-dimensional, unsteady vertical transport of heat, suspended material and dissolved material in the shallow lake or reservoir has been developed. The stratification dynamics as a result of wind-induced mixing and heat exchange between the surface water and the atmosphere are simulated using integral energy concepts. Daily or diurnal time scales can be used to predict the stratification dynamics realistically. The effects of inflow and outflow on the stratification structure are incorporated. The numerical solution applies an implicit scheme with variable layer thickness. The vertical spatial grid is variable in accordance with inflow, outflow, and water mass balance.

The mass transport equation for suspended sediment incorporating a term for settling and entrapment is solved using an unconditionally stable, hybrid scheme.

The equations for suspended sediment transport, dissolved material transport, surface heat exchange, and wind mixing are solved sequentially and in arbitrary order. It has been verified for several case studies of temperature stratification and for one suspended sediment study that the order is immaterial for the results. The effects of the suspended sediment on the heat budget are considered. The model has been successfully applied to simulate the seasonal and spatial distributions (a) of temperature in several shallow lakes and reservoirs, (b) the distribution of suspended clays in a recreational lake and regulation measures to control turbidity, and (c) the vertical distribution of phytoplankton in a lake, and (d) the requirements for lake dredging to eliminate multiple seasonal overturns resulting in lake quality problems.

Concepts and assumptions used in the model development will be briefly described.

Reservoir Water Quality Modeling - WESHS - Fletcher

Reservoir hydrodynamics and the performance of selective withdrawal structures can be evaluated by coupling experimentally determined withdrawal patterns from physical model studies with a numerical heat and water budget model. Initially, the velocity distributions produced by adding and withdrawing water at various rates from a randomly stratified reservoir through physical models of the reservoir and structure are determined. A mathematical description of the observed characteristics is incorporated into the numerical model WESTEX. WESTEX is a computer code for predicting temperature, dissolved oxygen, and/or turbidity in reservoirs. The WESTEX model can then be used to compare the performance of the reservoir and regulating structures with specific project purposes.

JOINT USE OF COMPUTER AND PHYSICAL MODELS FOR THE SACRAMENTO RIVER

J. Amorocho, J. DeVries, and W. Hartman
University of California, Davis

A set of hydraulic models was developed for a portion of the Sacramento River in California with the objective of studying in detail the behavior of sediments and the patterns of flow in the vicinity of a proposed major diversion structure for the Peripheral Canal of the state water system. One of these models, representing approximately 5.2 miles (8.4 km) of the river, was controlled automatically by a computer system to permit the simulation of unsteady flows, which include tidal action.

The value of reduced scale models for the study of conditions of flow and sediment transport depends on the faithfulness with which the unsteady flows of the river can be simulated in the area of the proposed diversion. Streamflow data originate at a USGS gaging station in Sacramento, approximately 34 kilometers (21 miles) upstream from the prospective diversion site. Continuous stage records are maintained at this station and at two other locations, one designated as Freeport, 12.9 km (8.0 miles) upstream from the town of Hood, and the other at Snodgrass Slough, shortly downstream from the same town.

For calibration of any physical model, as well as to permit the simulation of historical flows, proper discharge and stage data are necessary within the model boundaries. None of the three hydrographic stations mentioned were within these boundaries. Therefore, the data needed had to be obtained by computation. For this purpose, an auxiliary mathematical model capable of calculating stages and discharges in the diversion area, based on the data of the hydrographic stations, was developed.

The mathematical model employs an implicit solution of the St. Venant equations of motion proposed by Preissman reported by Ligget and Cunge (1975), and is in the form of a FORTRAN computer program. As mentioned, data from the recording stations at Sacramento, Freeport, and Snodgrass Slough were used in the calibration which involved determining the proper values of Manning's "n" to give results that corresponded to river stage measurements at the hydrographic stations.

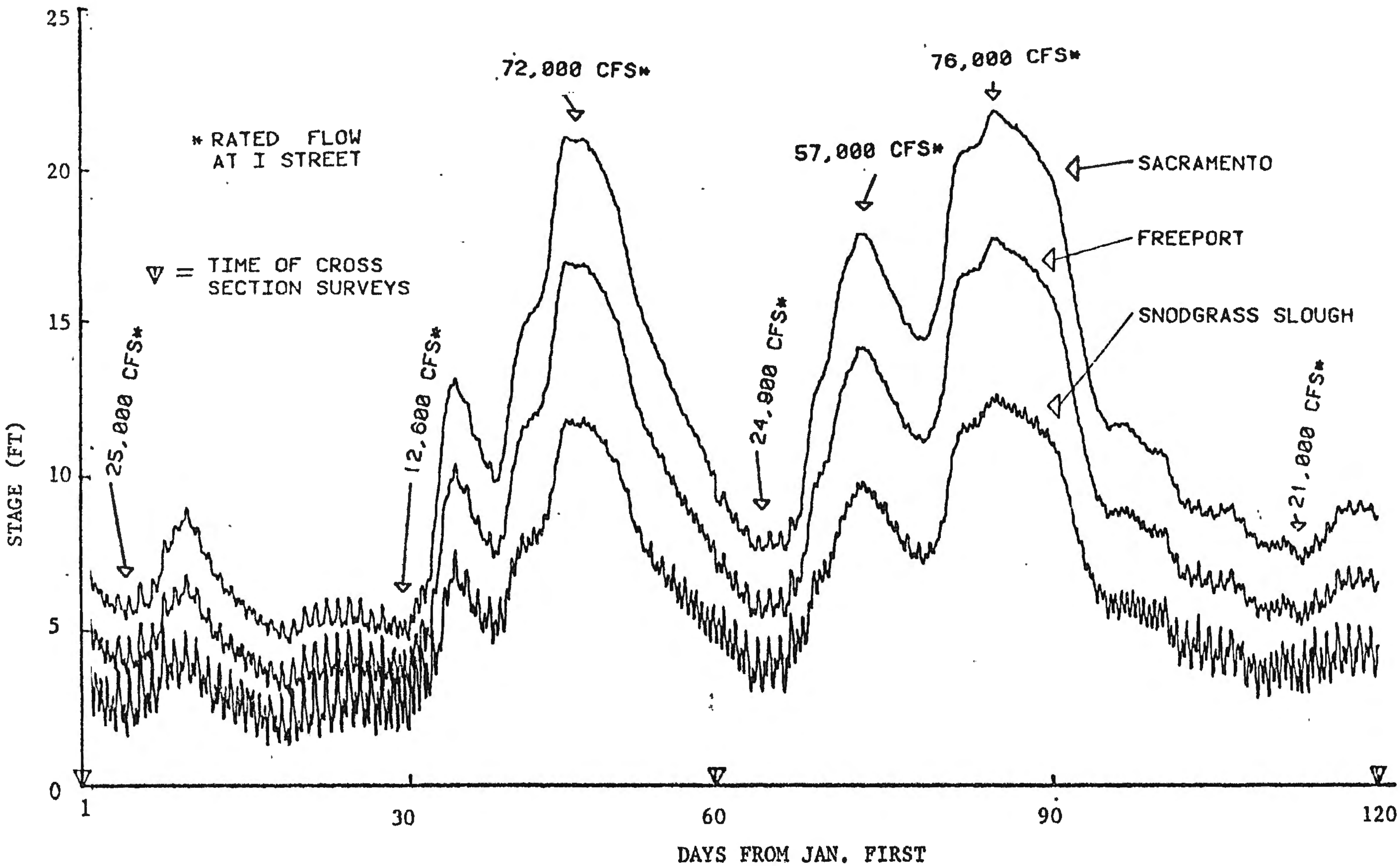
A final simulation of a historical period (December 1974 - April 1975) was made with the computer model to verify its ability to accurately model the river. The data from this period also provided input for the calibration and verification tests of Model II. In general, these data consisted of the flow values required at the upper end of the physical model and the corresponding stages expected along its entire length during many steady and unsteady state conditions.

Simulation of diversions to the Peripheral Canal, both as a point diversion (for an off-river diversion scheme) and as a diversion over a length of river (for an on-river diversion) can be made using options available.

REFERENCES

Hartman, W. J., J. Amorocho and J. J. DeVries, "Peripheral Canal Intake Studies 1. Distorted River Channel Model." Vols. 1 and 2. Department of Land, Air and Water Resources, University of California. Water Science and Engineering Paper 1064. June 1979.

Ligget, J. A. and J. A. Cunge, "Numerical Methods of Solution of the Unsteady Flow Equations," in Unsteady Flow In Open Channels, Water Resources Publications, Fort Collins, CO. (1975).



Sacramento River Stage Hydrographs for Four-Month Verification Period.

Kinematic Wave and Minimization Approach to Modeling of Channels With Sediment - Song

The time rate of change of sediment transport is usually so small that the change in bed form is describable as kinematic waves. An Exner-type equation of continuity for bedload modified to include the influence of suspended load can be transformed into a mass transport equation containing convection, diffusion, and source terms. This equation is capable of simulating the migration, growth, and damping of ripples, dunes, and antidunes as well as general aggradation and degradation phenomena. Some of the coefficients in the kinematic wave equation can be analytically evaluated but some must be obtained by calibration. With this model, it may also be possible to calculate the sediment transport rate from measured bed form.

For the dynamic aspect of the model it is possible to use empirical equations, the equations of motion, or the theory of minimum energy and rate of energy dissipation. As indicated in figure 1, the minimization theory is equivalent to the variational principle of theoretical mechanics specialized for dissipative systems. Since the classical variational principle applies only to nondissipative systems, the minimization theory has been derived on physical grounds. Unlike Navier-Stokes' equations, this minimization theory is independent of the material properties and, for that reason, it is suitable to multicomponent problems such as flow with sediment transport.

Scalar Mechanics and Vector Mechanics

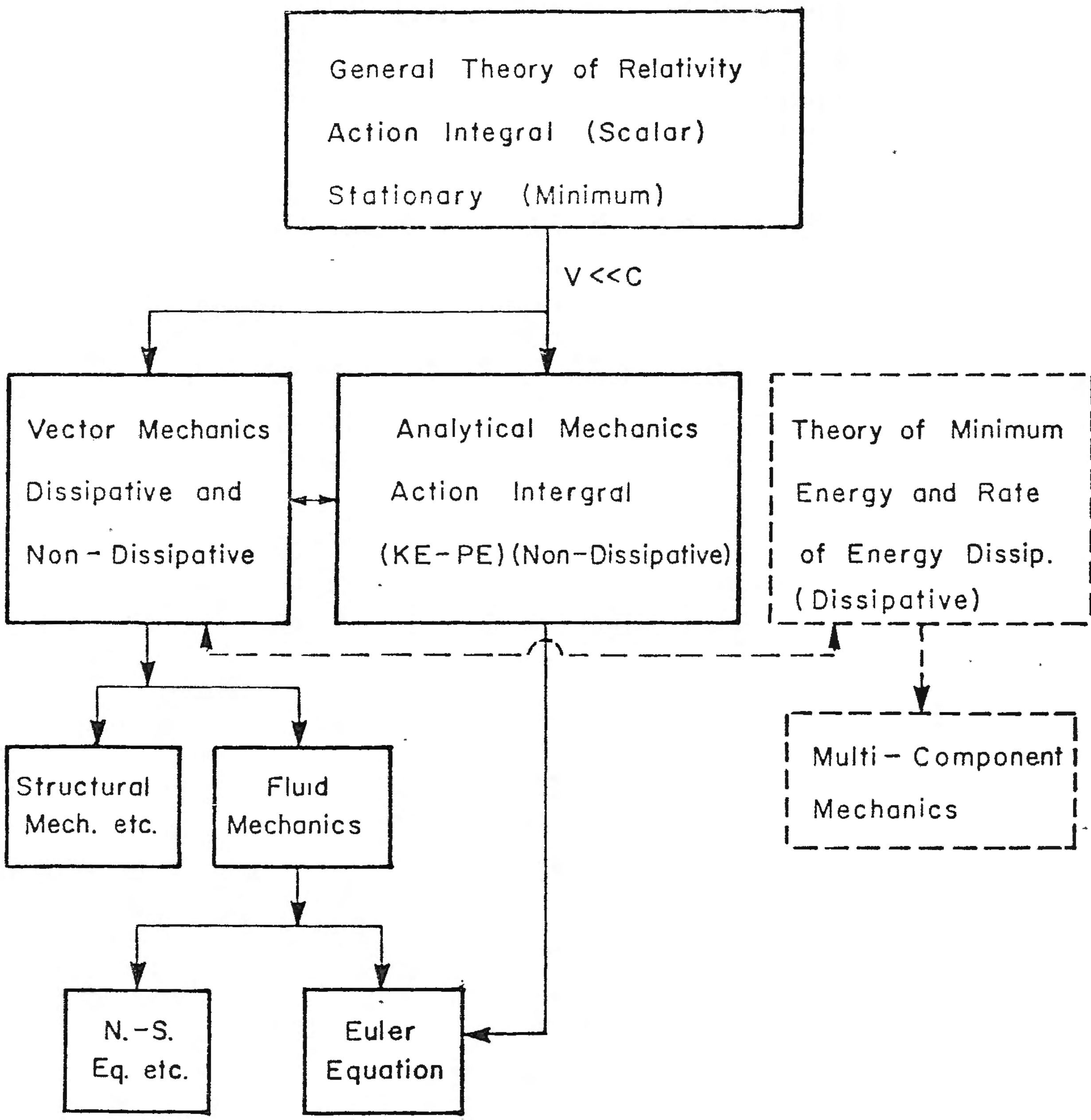


Figure 1

SESSION V

LASERS

V. LASERS

Bob George - Chairperson
Phil Demery - Recorder

Summary Statement

At the last meeting of this group, 4 years ago, all participants indicated that laser velocity systems were too costly and too much a laboratory novelty to be useful. At this conference most participating laboratories have a laser velocity system. This tool will provide both mean and fluctuating velocity components without having a probe in the flow.

The laser systems have been operated in a reference beam mode and an interference beam mode. In the former mode the fringe pattern is created on the photomultiplier tube and in the latter the fringe pattern is created at the intersection of the two beams in space. The collecting optics that receive or mix the scattered light have been set up as forward scatter or backward scatter. With forward scatter the flow boundaries must be transparent to the laser beam; however, the signal to noise ratio is better than for back scatter. Back scatter mode is best for measurements in open channel flow. Problems arise in use of the equipment if the beam penetrates a moving surface such as a wavy surface on the water. Small windows can be used to minimize the problem with waves. Also some plastics adsorb a large amount of the light and are not suitable for measuring through them. If the mount of the laser and optics vibrate with respect to the measuring point, erroneous velocities will be observed.

Commercially available units can be set up quite easily with matching electronics to obtain data. The engineer using the equipment does not have to be familiar with either the optics or the electronics. Shop-built systems cost about one-fifth to one-third the cost of the commercial units but require time to aline the system. The alinement sometimes takes a week to get them working. Also a high level of skill is required in both electronics and laser optics.

So much data are collected by a laser velocity device that a computer is required to scale the data and compute the statistics. Without a computer, the user will have more data than he can handle.

Comments on Session V

TVA Engineering Laboratory: Laser Velocimetry - Vigander

By using a rectangular test section you can cut down the diffusion caused by a curved surface. This rectangular section was placed over the cylindrical pipe with the area between the geometric surfaces filled with water. The TVA has been using LV systems for a variety of applications including calibration of propeller-type flowmeters.

1. Light transmitting plexiglass required for a model that will use laser velocimeter

2. Laser system can be mounted on the bed of old milling machine

A Two-dimensional Laser-Doppler Velocimeter for Open Channel Flow Measurements - Gartrell

This system was built at relatively low cost. However, in using the laser in a reference beam mode, a certain amount of time is needed in alining the optics.

1. Noise and vibration problems caused some erroneous data in laser system.

2. Signal processor was also shop built and reduced the data for both components.

Laser-Doppler Anemometer for Velocity Measurements in River Models - Hartman

The photomultiplier tube was 16 inches long, which made it rather bulky. By using a Cambridge meter, the operator has a digital readout available to him during laser operation. Hartman asked for any information in regard to using prisms instead of lenses. Lenses are expensive items.

1. Two-watt laser used in backscatter mode to measure two components of velocity in plan view.

2. Water waves eliminated by small glass-bottomed box so laser penetrated directly into water surface without effects of waves.

Laser-Doppler Velocimetry Measurements in Rotating Systems - Stinebring

No comments.

Laser-Doppler Velocimeter for Use in Sediment-Laden Flows - van Ingen

In dealing with sediment-laden flows, the measured volume must be kept small so that you can separate the fluid tracers from the sand grains. The fluid tracer used was fine dust or particles in the water and the sand needed to be uniform gradation. A pinhole was needed near the photomultiplier to limit scatter.

1. Alinement of optic was time-consuming task to set system up.

2. Vibration of the flume caused erroneous velocity readings with mean zero and turbulence intensity with a very low frequency. Usually it was eliminated by filtering out low frequency velocity.

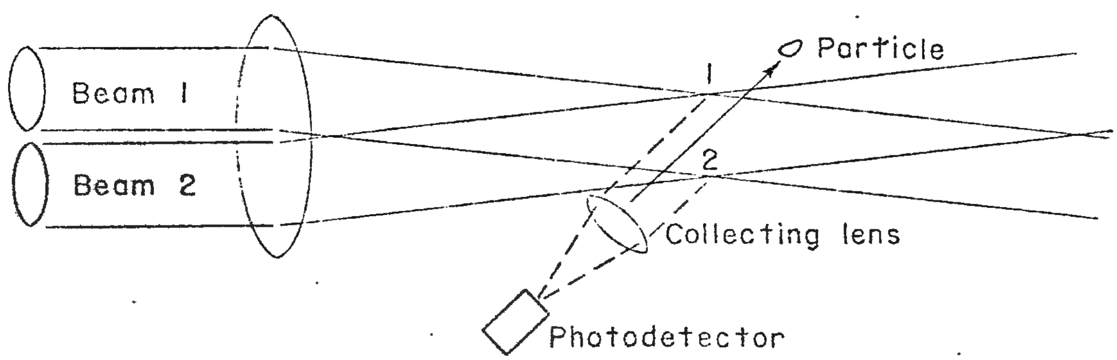
Laser Vibration Sensor for Surface Measurements - Bruce

The laser vibration sensor differs in several respects from the laser Doppler anemometers. This sensor is more sensitive at longer ranges with lower laser output and less detector efficiency than the laser anemometers because of the nature of the subject being sensed: the abrupt interface between air and a surface always relects back a significant amount of light, even with a dark, diffuse surface. Another difference is that the vibration sensor only measures axial motion and the aneometer generally senses orthogonal components. The laser vibration sensor can be used for anemometer studies but has a severe drawback in that its sensing volume is long and thin waisted. Measurements in this volume are distributed throughout a long line and are not closely pinpointed as in the crossed dual-beam or crossed beam-sensing zone probe volume of the laser anemometer. Another difference is that the laser vibration sensor gives a continuous signal of the motion of the surface, whereas the laser anemometer gives signal bursts only when scattering centers are present.

The laser vibration sensor has a severe drawback regarding accuracy if the surface is rough or arbitrarily inclined and has components of motion that are not axial. This sensor then superimposes an apparent component representing a a displacement due to this lateral motion on the true axial displacement. Care should be taken to avoid this in setting up experiments.

Transit Time Approach as Opposed to Doppler Approach

The laser anemometer systems so far discussed are classified as some form of laser Doppler sensing. Another important approach not mentioned was the transit time or two approach. Here two parallel beams are focused close together and are viewed off axis in the following fashion.



A possible implementation of the approach

A particle transmitting both lens gives a double pulse on the photodetector giving data on the flow component on the line normal to the two beams. This approach uses timing or autocorrelation techniques to sort out coincidences of single beam transits and has been shown to be quite sensitive and useful in backscattered situations.

Dr. Joe She of the CSU Physics Department is using such an approach. Personnel at DISA have promised a transit time module for their low power systems.

TVA Engineering Laboratory: Laser Velocimetry - Vigander

A commercial LV (laser velocimeter) system has been in use at TVA's Engineering Laboratory for about 9 months. The following brief descriptions and the accompanying slides illustrate the wide range of studies to which the LV has been applied. In almost all of the studies described below, a 35-mW (15-mW nominal) Helium-Neon laser was used in backscatter in the dual beam mode of a frequency tracker and true rms voltmeter. The transmitting/receiving optics included either a 250-mm or a 660-mm focal length lens.

Axial velocities and turbulence intensities were measured with the LV in a 1:2 model of the suction piping for the main reactor feed pumps at Browns Ferry Nuclear Plant. The LV was mounted on the bed of a milling machine, which provided rapid and accurate positioning of the measuring volume within the test section.

The LV was used with a similar positioning arrangement to measure velocity distributions and turbulence intensities upstream and downstream from tubesheets in a 1:9.6 scale model of a condenser waterbox for the CRBRP (Clinch River Breeder Reactor Project). A problem with spurious data caused by back wall reflections was solved by covering the back wall with black plastic electrical tape which had been roughened with sandpaper on one side.

Velocities approaching a full scale sectional model of the CRBRP river water intake structure were determined with the LV. The entire optics portion of the LV was installed in commercially available rotary mounts, and the optics portion was rotated by 90° to provide measurements of both the vertical and the horizontal components of approach velocity.

Velocities and turbulence intensities at the downstream end of a larval fish return flume were measured with the LV. The flow in the flume was supercritical, and the water depth in the flume was about 4 mm. The velocity measurements were taken through the free surface.

The calibration of the LV depends only on the wave-length of the laser light and the beam intersection angle, both of which are known with a high degree of accuracy. An overall accuracy of 0.5 percent can be obtained. Because the LV does not disturb the flow field, it can be used to determine velocity immediately upstream from a conventional velocity probe to produce or check a calibration curve. The LV has been used to verify calibration curves for a propeller-type velocity meter, a miniature propeller-type velocity meter, and an electromagnetic velocity meter. Forward scatter operation provided a relatively high data rate, even at low velocites. In the near future, the LV will be utilized for the field calibration of the cup-type anemometer used to determine air velocities in cooling tower fan stacks.

A TWO-DIMENSIONAL LASER-DOPPLER VELOCIMETER FOR OPEN CHANNEL FLOW MEASUREMENTS

G. Gartrell, Jr.
W. M. Keck Hydraulics Laboratory
California Institute of Technology, Pasasdena

A simple, yet versatile laser-Doppler velocimeter has been developed and used successfully in measuring two velocity components in an open channel flow. A schematic diagram of the reference beam system is shown in Figure 1. The laser light from a 5 mW Helium-Neon laser first passes through a beam splitter which produces two parallel beams, one of which has an intensity of about 93 percent of the incident beam and the other about 4 percent. The dimmer of these two beam then passes through a radial diffraction grating which can be used to frequency shift the light in the diffracted beams. The intense beam (which becomes the scattering beam) and two of the diffracted beams then pass through rhomboid prisms, which are used to separate the beams, and through 1° wedge prisms, which are used to make fine adjustments on the directions of the beam, thus ensuring that the beams are parallel as they enter the focusing lens.

The receiving optics consist of two photomultiplier tubes, each fitted with optical band-pass filters. The entire system is mounted on a carriage which straddles the flume and allows both the transmitting and receiving optics to be raised and lowered together, so that velocity profiles can be made easily.

This system has been used to make measurements in a density-stratified flow, and is described in detail by Gartrell (1978, 1979). It is presently being used to make measurements under solitary waves.

Gartrell, G. Jr. (1978) "Signal Processor for a Laser-Doppler Velocimeter," Tech. Memo. 78-5, W. M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Pasadena, California.

Gartrell, G. Jr. (1979) "Studies on the Mixing in a Density-Stratified Shear Flow," Report No. KH-R-39, W. M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Pasadena, California.

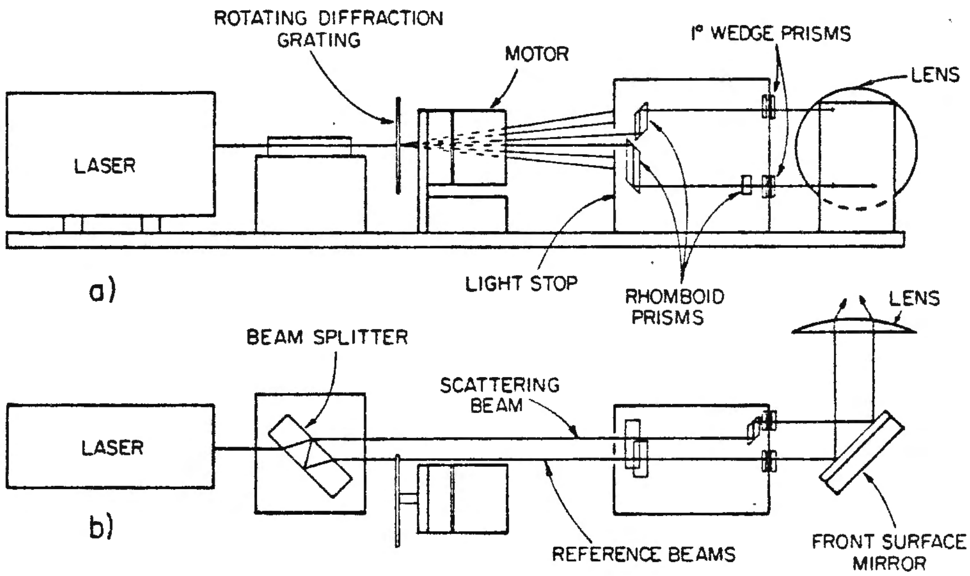


Figure 1

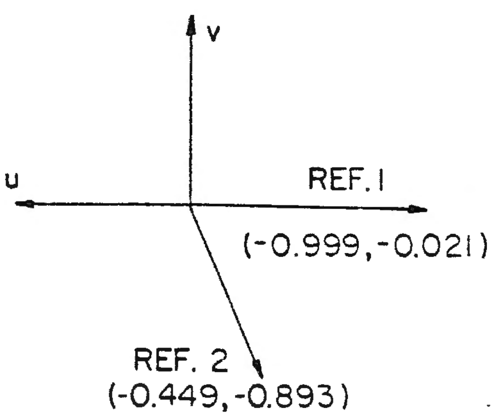


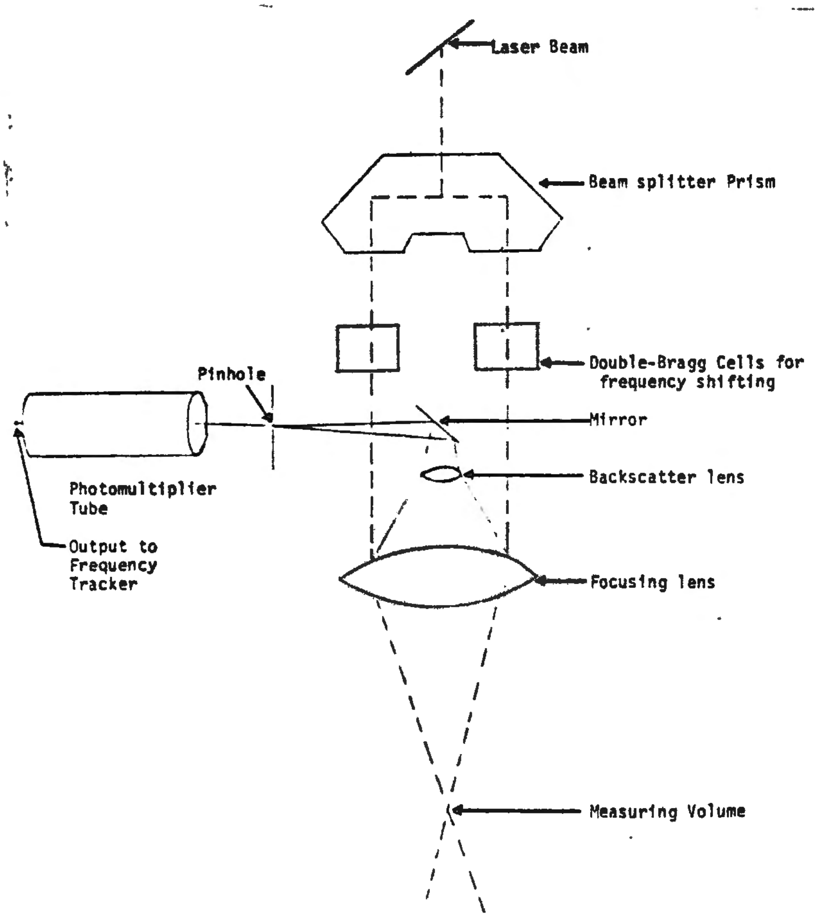
Figure 2

LASER-DOPPLER ANEMOMETER FOR VELOCITY MEASUREMENTS IN RIVER MODELS

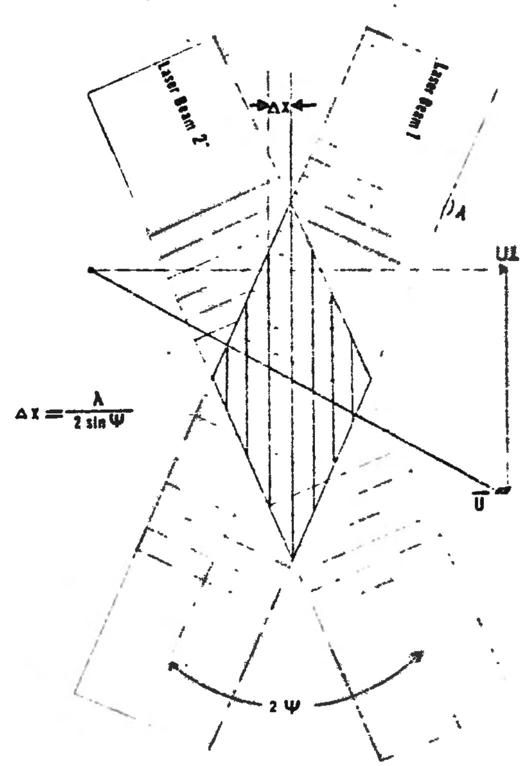
J. Amorocho, W. Hartman, J. DeVries
University of California, Davis

A Laser-Doppler anemometer (LDA) system is under development at the Hydraulics Laboratory of the University of California at Davis for measurement of velocities in scale models of rivers and other shallow open-channel-flow systems. Laser-Doppler anemometry involves the optical measurement of the local, instantaneous velocity of particles suspended in the flow, and thus, the flow is not disturbed by the measuring apparatus. In addition, the UC Davis LDA system is configured to permit the velocities to be measured using "backscattered" light from the flow-suspended particles. All equipment can be placed above the water surface, with the exception of a small glass plate at the air-water interface.

A schematic drawing of the LDA system is shown in Figure 1. The system is set up to permit velocity distributions to be measured by means of mechanical movement of the measurement apparatus. The signals from the LDA and from measurement-location transducers will be processed by a microcomputer, and all data will be recorded in engineering units as it is taken using magnetic disks for storage as well as hardcopy output for immediate reference. The LDA system will be used to provide data in the velocity range from 1 to 10 cm/sec (0.05 to 0.1 ft/sec) where it is not possible to measure velocities with other currently available instruments.

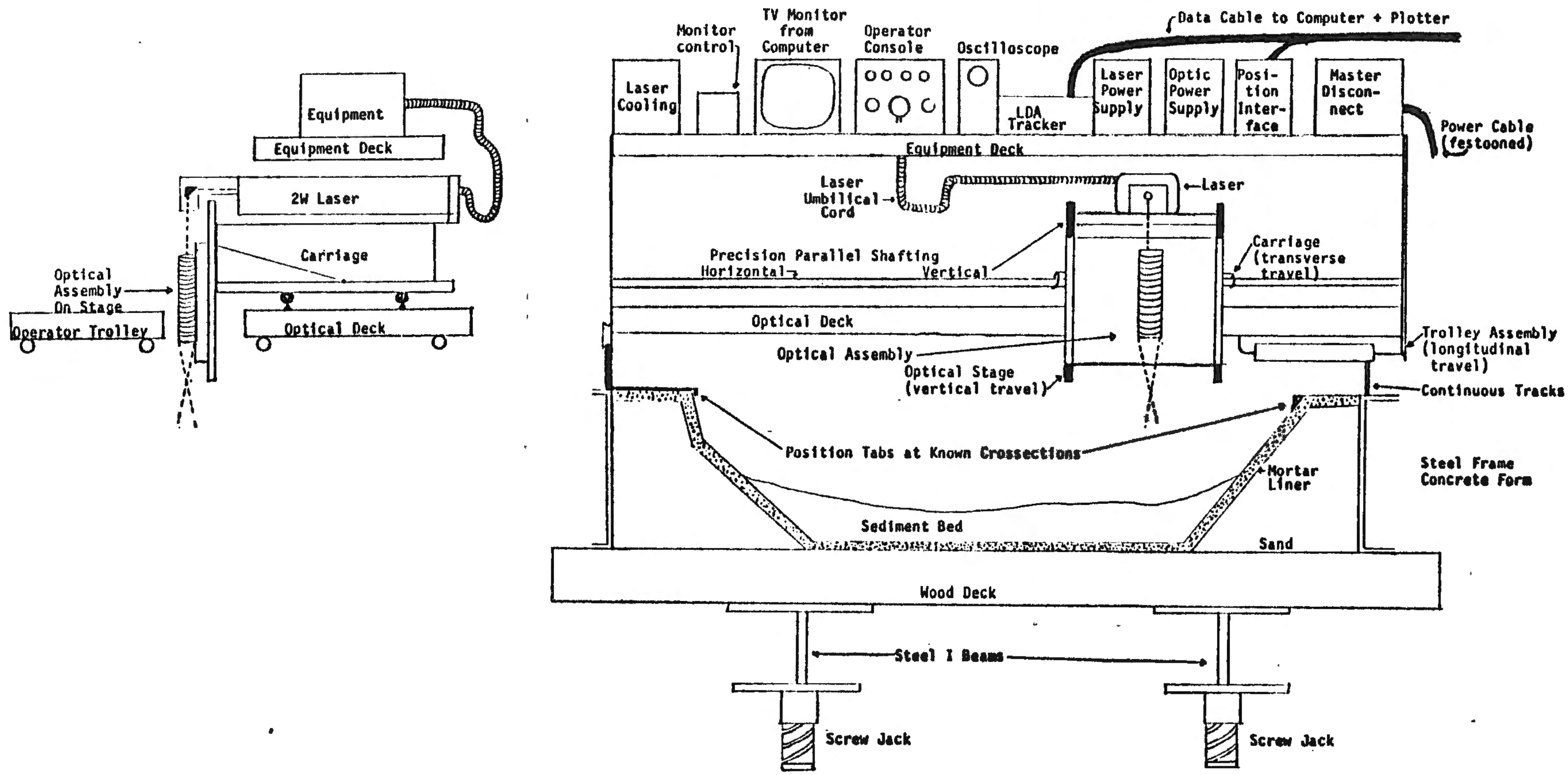


Optical Assembly



Λ= Wave length of laser light

The interference fringe pattern of the measuring volume


Equipment
Equipment Deck
2W Laser
Carriage
Optical Assembly On Stage
Operator Trolley
Optical Deck
Monitor control
TV Monitor from Computer
Operator Console
Oscilloscope
Data Cable to Computer + Plotter
Laser Cooling
LDA Tracker
Laser Power Supply
Optic Power Supply
Position Interface
Master Disconnect
Power Cable (festooned)
Equipment Deck
Laser Umbilical Cord
Laser
Precision Parallel Shafting
Horizontal
Vertical
Carriage (transverse travel)
Optical Deck
Optical Assembly
Optical Stage (vertical travel)
Trolley Assembly (longitudinal travel)
Continuous Tracks
Position Tabs at Known Crossections
Mortar Liner
Steel Frame Concrete Form
Sediment Bed
Sand
Wood Deck
Steel I Beams
Screw Jack
Screw Jack

Laser Doppler Velocimetry Measurements
in Rotating Systems

by

William W. Moyer, Michael L. Billet and David R. Stinebring

Applied Research Laboratory
The Pennsylvania State University

Flow velocity measurements with a Laser Doppler Velocimeter (LDV) system have been made in the water tunnels of the Fluids Engineering Department of ARL/PSU for a number of years. Recently a Data Control System (DCS) has been developed to facilitate the acquisition and processing of LDV data. In past investigations, velocity profile measurements in the vicinity of a propulsor were made upstream and downstream of the rotor system. It was not possible to measure the flow field between the blades until the development of the DCS. For rotational testing, the DCS provides for selection of shaft angles at which data is taken, tags each data word produced by the laser signal processor with a corresponding shaft angle, and executes necessary formatting and handshaking operations in transferring data to a general-purpose digital computer. Initiation of data transfer is done remotely through the DCS.

The TSI Model 1980 Signal Processor (SP) processes signals produced by the photodetector in a laser doppler velocimeter system. Validation of a data point derived from the photodetector output causes a binary word to be placed in the SP output register and issuance of a DATA READY pulse by the SP. The numerical value of the output word corresponds to a doppler frequency from which a detected velocity can be determined. A DATA HOLD signal applied to the SP, when low, does not allow new data to be placed in the SP output register.

The DCS provides a means for the test operator to select the range of shaft angles over which data are taken when the velocimetry system is used with a rotating model. A disk, attached to and rotating with the model, has one deep and 179 shallow slots cut into it. The slots are nominally one degree wide and spaced at angular increments of two degrees, center-to-center. Two stationary light source-sensor pairs span the disk and generate signals as the disk rotates. The HOME signal is high only when the deep slot appears between the inner light source and its sensor. This position is defined as zero degrees shaft angle. The ADVANCE signal is high whenever any slot appears between the outer light source and its corresponding sensor. The rising and falling edges of each ADVANCE pulse cause generation of pulses, one for each edge, within the DCS. One revolution of the disk produces one HOME pulse and 180 ADVANCE pulses. Within the DCS, 360 pulses are produced per revolution, one for each degree of angular motion.

Switches are provided for selection of lower and upper limits on shaft angle. The SP output operation is enabled only when the shaft angle is equal to or greater than the selected lower limit and less than or equal to the selected upper limit. The limits enable rejection of data from undesirable shaft angles.

If the SP output operation is enabled, generation of a DATA READY pulse by the SP causes the available SP data word to be loaded into a set of registers within the DCS. Simultaneously, the shaft angle count is loaded into a second set of registers. Each SP data word is therefore tagged with the shaft angle at which that word is acquired. The tagged data are passed to the IBM System 7 Computer (S7) as two words, transferred in sequence. The DATA HOLD signal to the SP is held low until transfer is complete.

This new DCS is presently in use with the LDV system operating in the backscatter mode, i.e. the focusing optics and photomultiplier detector located on the same side of the tunnel test section. Velocity profiles have been measured between the blades of a propeller operating at approximately 3500 rpm in the test section of the 12-inch diameter water tunnel.

A Laser-Doppler Velocimeter For Use in Sediment-Laden Flows

C. van Ingen
University of California
Berkeley, California 94720

The laser-Doppler technique has been used quite successfully in homogeneous fluid flows. The technique does not distort the local flow field and no calibration is required. Thus, it is particularly attractive for use in sediment-laden flows. There are, however, unique difficulties in the application of the technique to sediment-laden flows. A successful system has been developed and direct measurements of fluid turbulence and instantaneous sediment transport in a laboratory flow are being made.

A schematic diagram of the system is shown in Figure 1. The laser light beam is split into two beams of equal intensity, then made to intersect at a point within the flow field. The angle of beam intersection is large with respect to conventional laser-Doppler systems to allow measurements of both the fluid tracer particles and individual sediment grains.

An example of the photomultiplier output current is shown in Figure 2. The high frequency of the photomultiplier current is proportional to the velocity of the scattering particle. The amplitude of the current is related to the size of the scattering particle. Thus, individual velocity data points may be sorted as to the type of scatterer: fluid tracer particle or sand grain.

The system is presently being used to investigate the basic mechanisms of sediment entrainment and suspension in a high transport, flat bed flow.

van Ingen, C., (1980), "A Signal Processor for Laser-Doppler Velocimetry in Sediment-Laden Flows", Tech. Memo. 80-1, W. M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Pasadena, California.

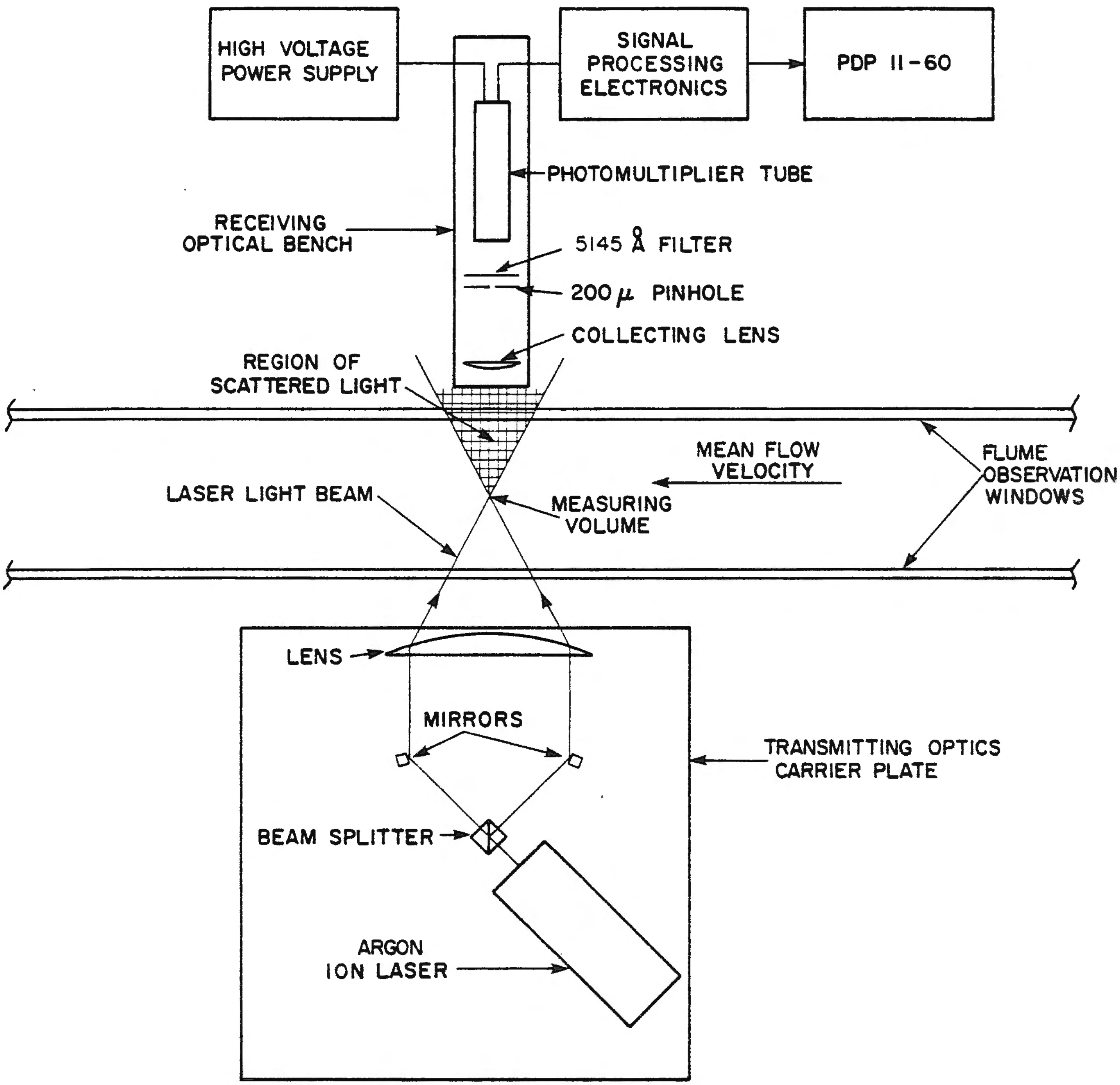
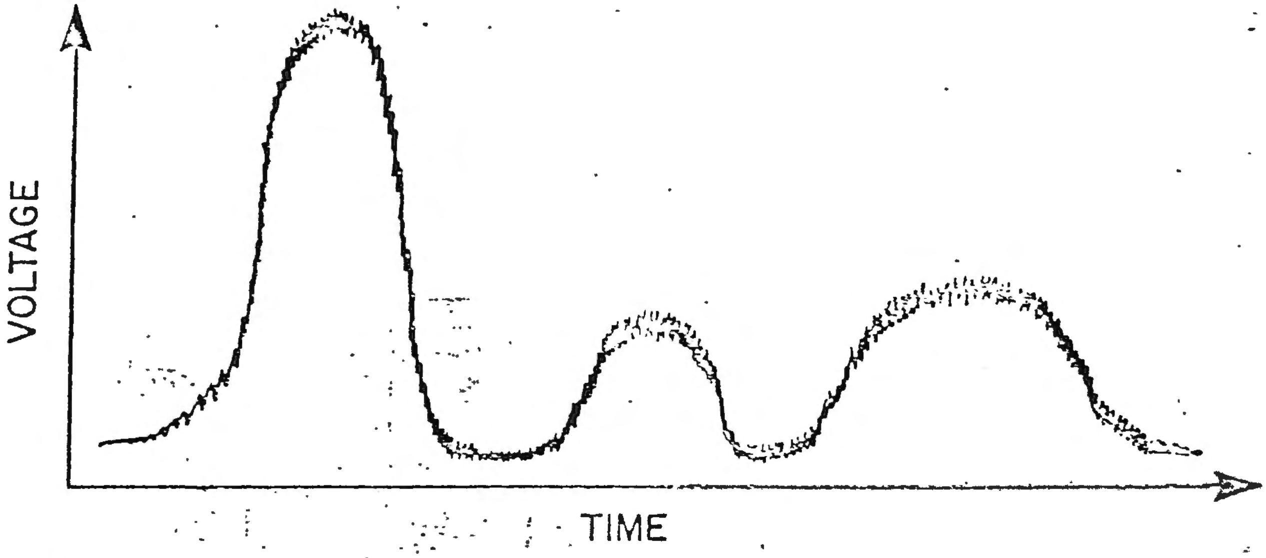
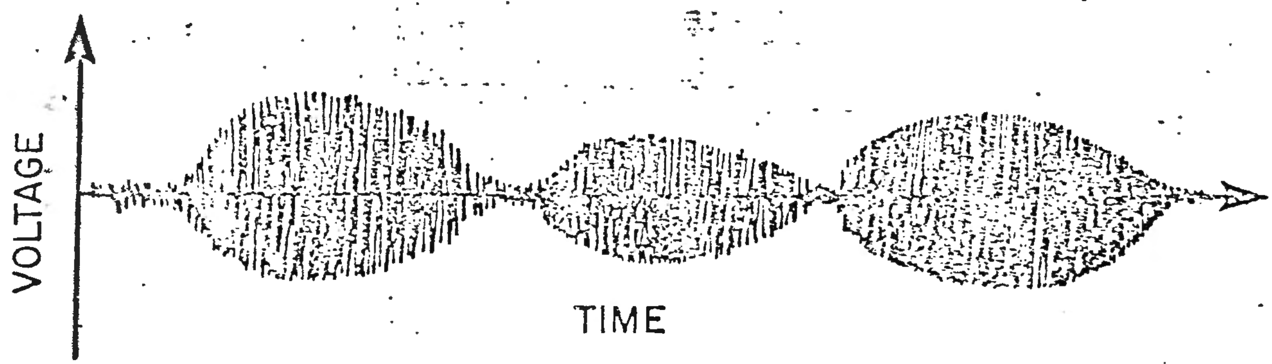


FIGURE 1. One-dimensional laser-Doppler velocimeter schematic.

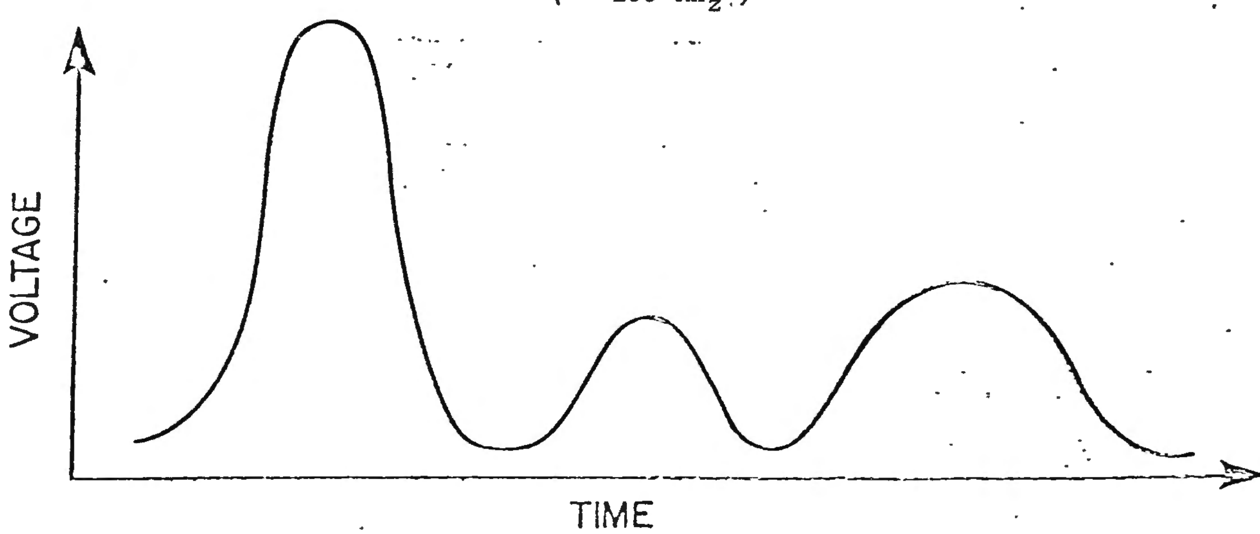
FIGURE 2



a. Raw photomultiplier output current.



b. High frequency photomultiplier output current.
(> 100 KH_z)



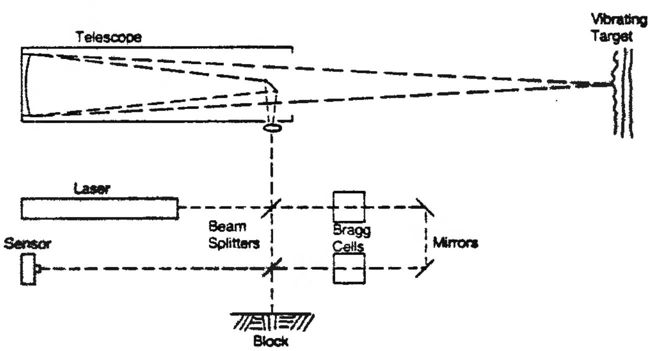
c. Low frequency photomultiplier output current
(< 1 KH_z)

LASER VIBRATION SENSOR FOR SURFACE DYANAMICS STUDIES

by Robert A. Bruce, E&R Center

Motion and vibration of structures can be measured remotely from several meters away by a novel approach using laser light. The technique works well, even on dull, rough surfaces. We anticipate this approach will be utilized on a trashrack from the Mt. Elbert pumped storage facility and the flexible dam model that is being planned for the vibration test laboratory. In both instances, a "roving" sensor concept is applicable because the motion is repetitive and synchronization from a reference point can be used.

A laboratory prototype based on this concept has been evaluated in tests involving an impulsed metal plate. These tests demonstrate important advantages over conventional devices such as accelerometers, particularly in small model studies. These advantages are due to the nearly negligible interaction of the laser sensor to the surface being measured. An accelerometer, for example, affects the surface by the attaching process, by its additional mass, and by frequency resonances of itself or its components. The laser sensor avoids all these problems. Its functional basis is the monitoring of the Doppler frequency shift of the back-scattered light. This frequency is proportional to surface velocity with the detected signal being precisely calibrated in terms of the laser wavelength used. The sensor is designed to sense the diffuse backscattered component so that no surface preparation is required.

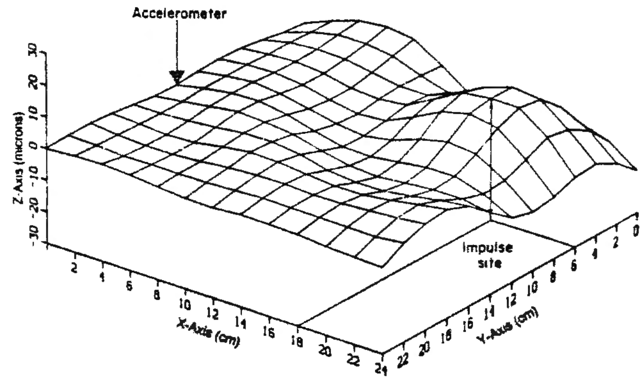


Configuration of the Laser Transducer System

A laboratory prototype of the laser vibration sensor. This instrumentation is capable of making accurate wideband vibration measurements of dull, rough surfaces. The monitoring is completely remote, with simply a laser beam focused upon the point of interest.

In the plate tests, velocity records of 205 separate points were taken in synchronization to a repeatable impulse. These were recorded singly, integrated, and stored sequentially on a large computer file. A movie was produced of the plate motion by plotting successive three-dimensional computer graphics of the points on a frame-by-frame basis. The movie displays deformation exaggerated 2,000 times with a time expansion also of 2,000 times. Edward Strickland, electronics engineer, in the Geotechnical Branch, was responsible for the hardware interfacing, and Pamela Hajny, computer specialist, in the Division of Data Processing, developed the software that converted the digital data to the movie graphics. Their help was indispensible in the successful completion of this work.

Mass loading of the thin plate by an accelerometer was effectively demonstrated by movie segments with and without the accelerometer attached. Motion at the attached accelerometer was shown to be nearly ten times smaller. Neighboring sites 2 centimeters away were affected by 50 percent. The low power 1 milliwatt laser beam does exert a force on the surface, but this force amounts to a negligible 0.3×10^{-6} dynes. Applications with small models or test objects will more appropriately be handled with this sensor because of this lack of interaction.



Elapsed time - 2.56 msec

Surface Dynamics Deformation (Microns)

A frame of the "Surface Dynamics Movie". It represents the exaggerated motion of an impulsed metal plate that was measured by the laser vibration sensor.

Robert Bruce, physicist, Power and Instrumentation Branch, has a B.S. in Physics from Oregon State University and a M.S. in physics from the University of Arizona. He is a specialist in optics, laser systems, and electro-optical instrumentation.

QUESTION AND ANSWER SESSION

QUESTION - ANSWER

Hank Falvey - Chairperson
Bob George - Recorder
Phil Demery - Recorder

1. Tom Isbester (Water and Power Resources Service) - Is there any waterproof sealant available for use with transducers?

a. Steve Callanen (David W. Taylor Model Basin Naval)

- Naval Ship Research and Development Center has used a waterproof sealant in the past.

b. George Downing (WES)

- They have used a 2-part Elastomer produced by BLH Electronics called Gagekote.

2. TVA - What's new in instrumentation for multiphase model?

a. Alden RL - Auburn International - 1 South Side Road, Danvers, MA 01923, telephone (617) 777-2460.

- Problem they have not figured out a method to calibrate the void fraction meter.

3. Water and Power Resources Service - What's new in ultrasonic velocity probes?

a. Svein Vigander (TVA)

- In Norway they have been using a three-axis probe, cost about $5,000

4. Al Tamburi (WCHL) - In their work with freshwater and saltwater, they have found that they need two separate sumps. Sometimes, it would be advantageous to use one sump. Is there any chemical that can be used in scaling stratification that can also be recovered.

a. Dow Chemical has a product; however, it is highly toxic.

5. Cliff Pugh (Water and Power Resources Service) - What methods are being used to calibrate velocity measurement devices.

a. TVA

- Towing tank with variable speed drive, 0 to 15 ft/s.

- Small propeller-type current meter being calibrated with laser velocimeter.

- Anemometers are being calibrated in wind tunnels.

b. U of C at Davis

- Variable speed motor driving a radial arm into still water, with 16-foot-diameter tank.

c. Alden
- Towing tank and radial arm in still water. They calibrate electromagnetic current meters daily before and after each test run.

d. WCHL

- Rotating arm in still water; however, after a few rotations, the water in the tank begins to rotate.

e. Utah State
- Submerged jet discharging into tailwater used for current meters and velocity probes.

f. USGS

- Submerged flow nozzle with $C_L = 1.0$; 24-inch-diameter jet. 8-inch-diameter jet at NOOA in Washington, D.C.

6. Albrook - Has anyone used the three-hole cylindrical pitot tube to pick up swirl components.

a. Perry Johnson (Water and Power Resources Service)

- Accuracy within a degree with some lag time.

b. Paul Tullis (Utah State)

- Transducers can shorten time lag, but questioned if the boundary effect was known.

c. Chic Sweeney (EHL)

- They have experienced boundary effect problems. He referred to German and Japanese reports that discuss the problem.

d. Bill Durgin (Alden)

- They have used a differential pressure cell connection with the pitot.

e. Svein Vigander (TVA)
- They have had success in using pitot tube to measure swirl in pump applications.

7. Steve Callanen (David W. Taylor Naval) - Has anyone had experience with underwater photo lights?

a. Bill Durgin (Alden)

- You might try an auto light connected to the end of a stick.

b. John Replogle (USWC)

- A swimming pool light might work.

c. Water and Power Resources Service

- Suggested that he contact Naval Electronics Laboratory in San Diego, Jerry Stachew in particular.

BANQUET PANEL DISCUSSION ON MANAGEMENT OF RESEARCH - THREE PERSPECTIVES

"Management of Research - Three Perspectives"

Mr. Duncan Hay, President, Western Canada Hydraulic Laboratories, Ltd; Prof. John F. Kennedy, Director, Iowa Institute on Hydraulic Research; Mr. Danny L. King, Chief, Hydraulics Branch, Water and Power Resources Service

The Private Laboratory View - Hay

Mr. Hay explained that their work is divided into three main functions: business/administrative, marketing, and technical. Three types of models are used: (1) the public relations model, (2) the insurance policy model, and (3) the voyage of discovery model. The latter type of model constitutes applied research, includes the potential for surprise, and provides opportunity for accidental discovery.

A good researcher knows when he or she has found sometning of significance, shows serious appreciation for technicians, has a stong theoretical background, and possesses an ability to focus and define. A good researcher "needs to know the difference between a mailbox and a butterfly." That is, if someone is sent to mail a letter you hope they can find a mailbox and not go looking for butterflies.

Mr. Hay is a proponent of the phased approach. He sees the necessity for opportunity to review after each phase. Also, someone is needed to provide an overview (which is the job of management), and someone is needed to look at the details.

Research needs quality control, including checking as designers do. The quality of technical papers reflects the lack of quality control.

The University Laboratory View - Kennedy

Professor Kennedy expressed his view that engineering education is approaching a state of shambles. Japan and Europe require 5 years of technical subjects. Furthermore, our engineering education is not timely, e.g., use of computers, etc.

A laboratory should function such that there is no formal distinction between applied and basic research. That distinction depends on the attitude of the investigator.

A university laboratory exists to train hydraulic engineers, must be self-supporting, and "must allow butterfly hunters."

Major problems concern tenure and academic freedom, and management of personnel is difficult.

In Professor Kennedy's opinion, the laboratory should have access to a large computer, as well as being equipped with minicomputers.

The Federal Laboratory View - King

"A philosopher is a person who gives other people advice about troubles he hasn't had." Mr. King defined research as being nonspecific with respect to design projects; it has broad application, is problem oriented (difficult to identify "basic" research), and receives a nonreimbursable appropriation in the Water and Power Resources Service.

Management of research includes planning, organization, and monitoring. Research needs are identified by designers, the Branch staff, and a formal research review committee. The latter group sets priorities but is not really qualified to do so. Another problem involves employee attitudes about setting objectives (accountability), especially for time required to complete a study. This is due in part to the fact that project-related work has historically taken priority over research. Furthermore, annual funding is often too low to allow significant progress to be made.

Research organization includes principal investigators and informal teams. Formal teams involving other parts of the organization have not worked well, for the most part.

Shop and instrumentation services have not been under branch supervision, which has caused major difficulties at times. Instrumentation services have been largely brought back and the Branch is emphasizing "portable," as opposed to "central" systems.

Contracting is used when in-house capability is exceeded, is very selective, and is intended to enhance, rather than diminish, in-house capability.

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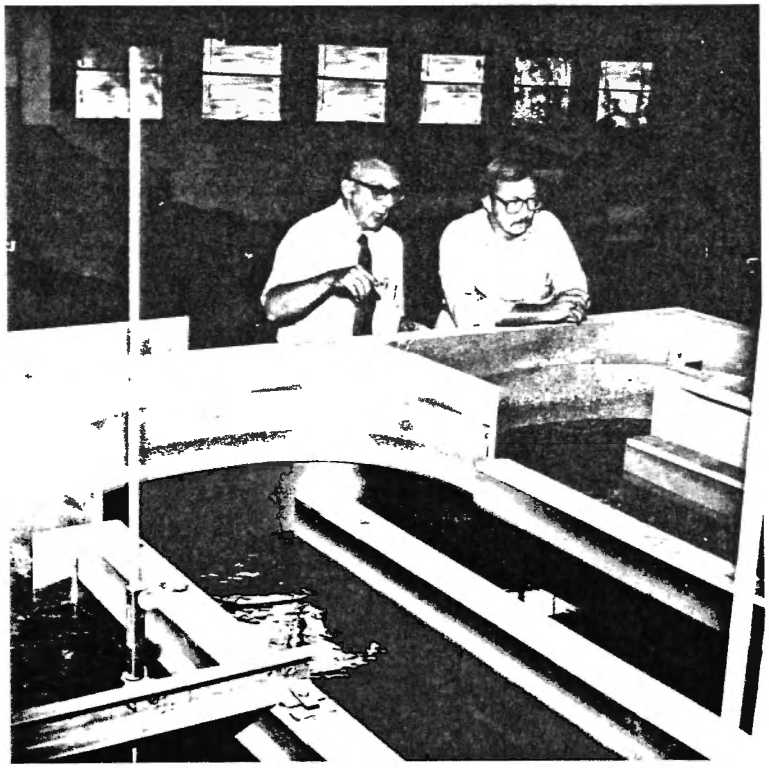
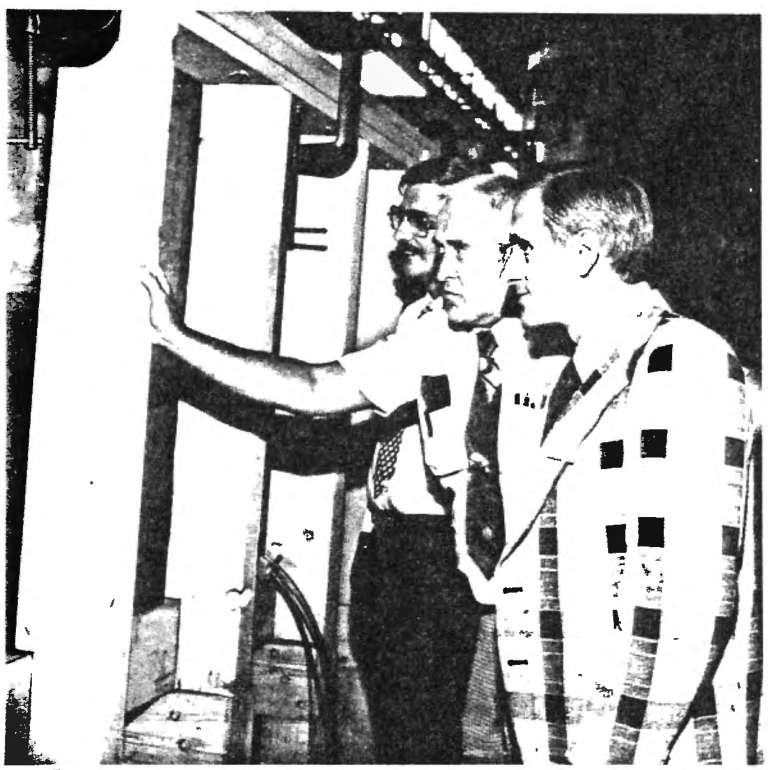
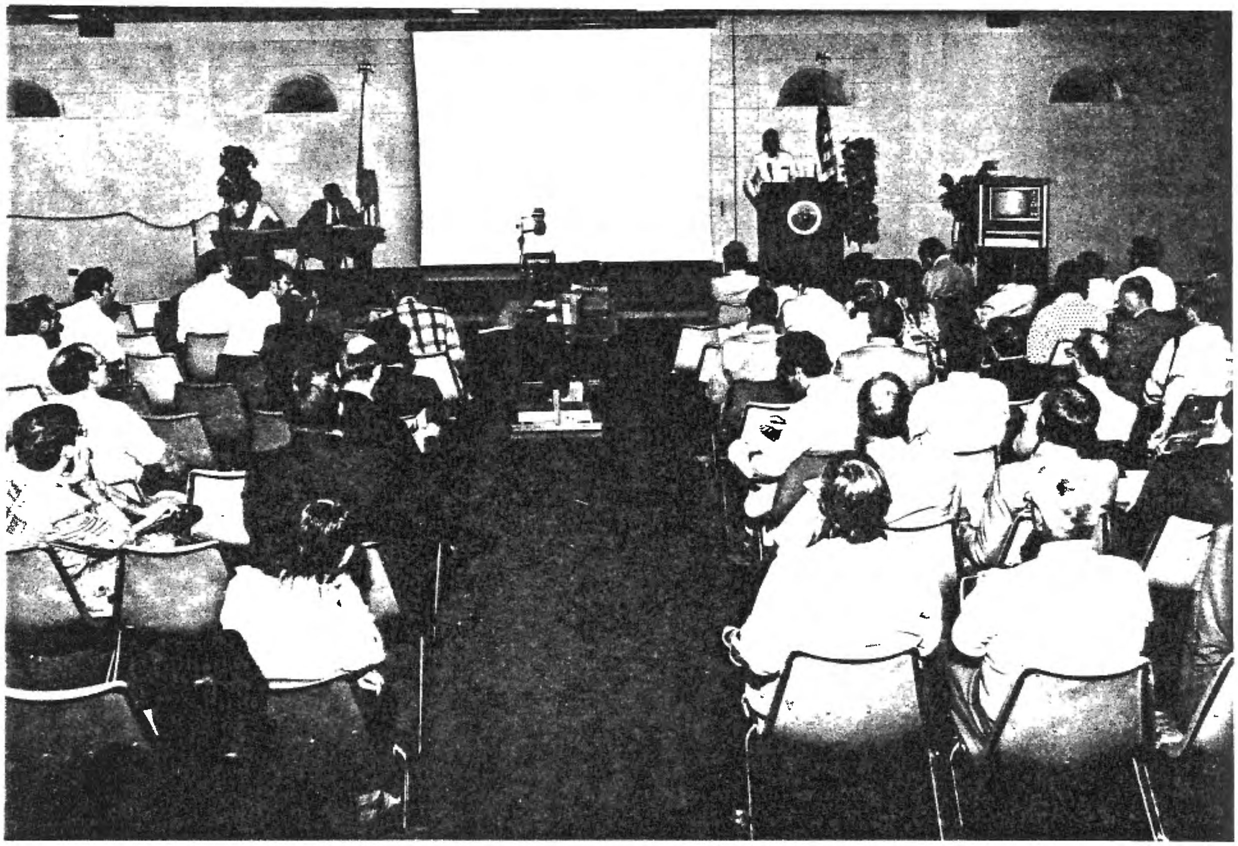


Clark Buyalski and Joe DeVries observing Canal Automation Model



Cliff Pugh, Tom Isbester, and Paul Tullis observing operation of Clamshell Valve



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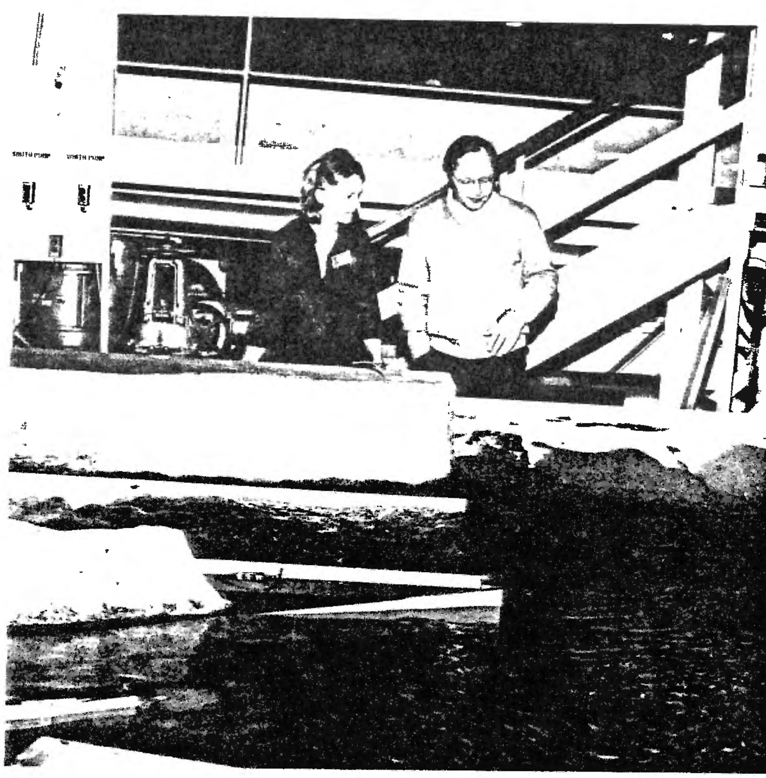

Judy Kinkaid and George Ashton observing Daule Peripa Model