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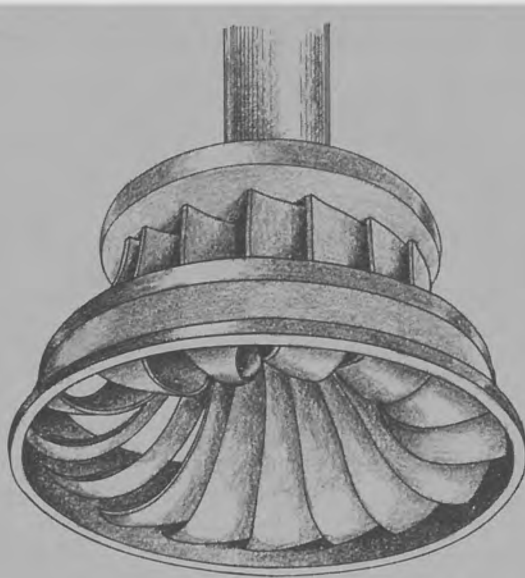

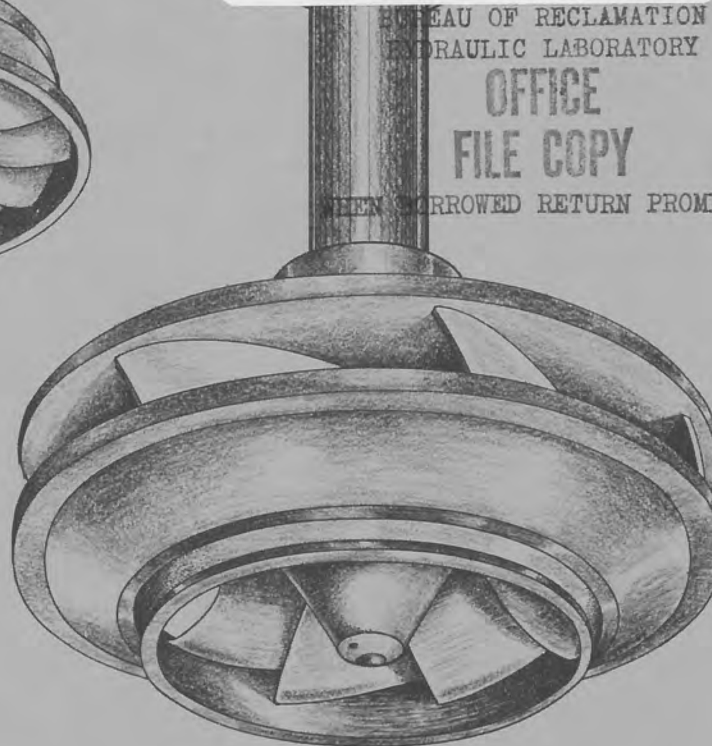

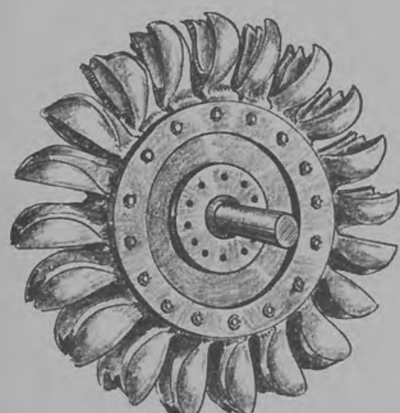

RECONNAISSANCE STUDY AND COST ESTIMATE

PROPOSED HIGH-HEAD TEST FACILITY FOR STUDY OF HYDRAULIC MACHINERY GATES AND VALVES

JULY 1969

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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
OFFICE OF CHIEF ENGINEER
DENVER FEDERAL CENTER

DENVER, COLORADO

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PROPOSED HIGH-HEAD TEST FACILITY FOR STUDY OF HYDRAULIC MACHINERY, GATES AND VALVES

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SUMMARY

There is a recognized and well-documented need for a high-head test facility in the United States. A complete lack of suitable facilities exists in the United States for tests of significant sizes of high-head hydraulic machine models at or near prototype heads. Full-head tests of model machines produce results of superior significance compared to results of tests performed at partial head. Information cannot be found to indicate that any organization or firm has plans to provide a domestic test facility capable of development or research investigations of hydraulic turbines, pumps, or pump-turbines at model test heads in excess of about 150 feet. High-head test facilities, up to about 2,000 feet of head, have been constructed in foreign countries and these facilities have been a major factor in development of foreign-manufactured machines that are advanced beyond comparable machines that can be produced in the United States.

A high-head test facility is needed that would be available to the Bureau of Reclamation and other organizations or firms. Such a facility would enhance development of better high-head machines and permit economic investigations of problems that appear after prototype machines are placed in operation. Minor extension of capabilities of a high-head test facility would also provide for studies of significant sizes of high-head gates and valves.

Considerations of maximum hydraulic capacities indicate that a suitable test facility should provide a water flow rate of 20 cfs at 1,500 feet of head. Proper sizing and arrangement of components of a universal high-head facility would provide a wide range of hydraulic capacities for tests of turbine, pump, and pump-turbine models during any mode of operation. This would require reversible hydraulic circulation capabilities for either a closed loop circuit or with flow circulated through a free-surface reservoir.

A direct-current electrical system involving motor/generator units connected to permanent station pumps and a direct-current motor/generator dynamometer connected to a model machine on the test stand would be desirable to provide unrestricted speed operation of the permanent machines and models under test. An internal direct-current power system would also permit regeneration of direct-current energy during tests of model machines. Use of readily-available solid-state silicon controlled rectifier modules for alternating-current/direct-current energy conversion would provide efficient conversion and provide for a practical internal direct-current electrical circuit.

Relatively large electric machines would be required for a high-head test facility. Three 2,000 hp direct-current electric motors, each connected to a single-stage centrifugal pump with about a 24-inch diameter discharge nozzle, would be needed to provide the anticipated maximum hydraulic capacity of the system. A dynamometer/motor with 3,000-hp absorbing capacity would be needed to absorb the output of model turbines. A dynamometer motoring capacity of 2,000 hp could drive pump models to produce a maximum head of 1,500 feet and a discharge of about 11 cfs. This reversible dynamometer would be essential for tests of pump-turbine models.

Maximum power demand of the entire facility would be about 6,000 kw, and up to 4,000 kw of this demand would be rectified to direct-current energy for operation of the 2,000-hp station pump motors.

A self-contained building would be required to house the machine test hall and to provide office and visitor space. A main building with about 20,000 square feet of floor space (about 200 feet by 100 feet) and 70 feet of headroom would serve as the machine hall. This building size is larger than shown by the enclosed drawing. However, the larger area would be needed to provide access to all parts of the test facility by an overhead crane or by wheeled lift vehicles. A concrete-lined water storage reservoir would occupy a portion of the area under the lower level of the machine hall. A three-level wing attached to one long side of the machine hall would provide office and visitor space. A total of 18,000 square feet of office and visitor space would be needed or about 6,000 square feet per level.

A reconnaissance grade cost estimate has indicated a total cost of $11,880,000 for the needed high-head test facility. This cost should provide an excellent test facility that will provide a wide range of test conditions necessary for development and evaluation of high-head hydraulic machines.

INTRODUCTION

In 1950 the Bureau of Reclamation was installing the last three of nine hydraulic turbines at the Grand Coulee Right Powerplant. At that time, these turbines were considered to be very large machines. Not 20 years later, turbines are being manufactured for the Grand Coulee Third Powerplant which compare with those earlier units as follows:

	Power output	Water flow rate	Turbine inlet diameter
Right Powerplant	165,000 hp	5,000 cfs	15 feet
Third Powerplant	820,000 hp	29,000 cfs	35 feet

This illustrates the very rapid advance taking place now in the design and manufacture of many types of power equipment in use throughout the world. Progress in materials research and manufacturing techniques has extended the upper limits for feasible hydraulic machinery manufacture to much larger physical sizes and higher pressures.

The need for the machinery exists and the need for more thorough model tests of large and high-head machines also exists. The technical literature concerned with up-to-date development and model testing of hydraulic machines repeatedly cites the lack of universal agreement upon procedures for converting model test results to prototype results. Authoritative individuals agree that a major unknown involved in this problem can be eliminated by model tests at prototype heads.

The need for domestic hydraulic test facilities necessary for operation of the Grand Coulee Third Powerplant turbine model at prototype heads (220 to 355 feet) was illustrated recently. A decision of the Secretary of the Interior restricted proposals for furnishing the first three Coulee Third turbines to domestic firms. This restricted model test specifications to capabilities of domestic manufacturers' laboratories and, subsequently, permitted tests of a 10-inch diameter turbine model at a head as low as 50 feet. Potential draft tube surge problems were to be fully explored with the 10-inch model. After the specifications were issued, two reliable foreign manufacturers who had done extensive work in the field of draft tube surges, advised that correlation of model and prototype surges could not be expected with a model head of less than 50 meters or 164 feet. This resulted in a change that required a second model of smaller dimensions to be tested at not less than 140 feet of head. Here again the requirements were decreased to accommodate test facilities available to domestic firms. Several test stands that have the capacity necessary to test the larger Coulee Third turbine model at prototype heads exist in foreign countries, notably in Japan and Switzerland.

The lack of domestic test facilities necessary for investigations of critical characteristics of appropriate size models of high-head (above 150 feet) hydraulic machines is recognized by authoritative persons concerned with the problem. This problem was a major subject at a recent American Society of Civil Engineers' (ASCE) specialty conference concerned with research needs in the civil engineering aspects of power. The result was confirmation, by persons vitally concerned with development and operation of hydraulic machinery, of the need for the test facility under discussion in the United States and the apparent lack of prospects for provision of such a facility by any organization.

The facility that is needed is not one that will compete with low-head test stands now in existence in the United States. Instead, the needed facility is one that goes beyond present domestic capabilities and that can be used to develop new ideas, to compare manufacturers' models, and to determine ways to correct operational deficiencies of prototype machines.

RECOGNIZED NEED FOR A FACILITY IN THE UNITED STATES

The recognized need for a high-head test facility in the United States for thorough tests of turbine, pump, and pump-turbine models is illustrated by the following recommendations and references:

1. Report to the Secretary of the Interior, Second Joint Meeting of the Japanese-American Energy Panel, May 27 - June 11, 1968, submitted by U.S. Chairman, Julian W. Feiss; recommendation 8, page 7:

> "The Japanese capacity for production of heavy electrical equipment through laboratory research has produced higher speed machinery, equipment of more advanced design, and reliable modern water wheel turbines that are more economical than those produced by American manufacturers. The American industry should modernize its laboratories. Our Bureau of Reclamation should implement its plan to establish a turbine test station for conventional and pump-back units in order that it may advance the hydraulic technology in this country."

(A copy of the report was transmitted to the Commissioner, Bureau of Reclamation, by memorandum dated August 23, 1968, from Mr. Morgan D. Dubrow, Assistant and Chief Engineering Research Advisor, Office of Assistant Secretary - Water and

Power Development, Department of the Interior. Mr. Dubrow was a member of the panel that visited Japan and compiled the report.)

2. A specialty conference on research needs in the civil engineering aspects of power was held at Pullman, Washington, by the ASCE Power Division in September 1968. A summary prepared by members of a conference panel concerned with test facilities contained eight recommendations and comments; the first of these was:

> "There is a need for an independent, adequately equipped and staffed testing laboratory with wide capacity in the field of turbines, pumps and valves."

3. Numerous technical articles and papers of international origin contain repeated references to the importance of high-capacity test stands and models for design stage studies and prototype problem investigations of large and/or high-head hydraulic machines and valves. Notable among these articles is "Operation-oriented Research Problems Considered at IAHR Symposium," published in Water Power, May 1969, pp 192-200. This article contains summaries of 28 papers from 22 countries, all concerned with operation oriented research problems in hydraulic machinery. The papers contain numerous references to the use of model studies for research of new design concepts in hydraulic machines, especially pump-turbines for operation in the 700- to 1,300-foot head range. Significant references were also made to the importance of high-head model studies for investigation and correction of prototype operational problems.

4. In early 1968, a board of consultants was retained by the Bureau of Reclamation to assist in research into the phenomenon of pressure surging in hydraulic turbine draft tubes. The board quickly pointed out the need for an independent laboratory in which studies of such difficult problems could be made. The board agreed that laboratory testing as conducted by most United States manufacturers is aimed mainly toward the achievement of high machine operating efficiencies. The consensus of the consultants was that this sort of testing was not adequate for production of power equipment to meet the needs of today, much less tomorrow.

The Department of Water Resources of the State of California recognized the desirability of full-pressure pump model testing early during development of designs for its Tehachapi Pumping Facility. This plant requires fourteen 76,000-horsepower pumps, each pump capable of delivering 315 cubic feet per second against a head of 1,970 feet. It was considered that the value of the reliability of the plant and the pumps was "nearly beyond comprehension," and that the value of the pump efficiency, related to operational costs, was extremely significant. The greatest care was exercised in formulating and conducting a test program for competitive model testing of pump designs, and for the final selection of the pump purchased. The cost of the model testing program eventually proved to be far less than the savings in power cost resulting from the selection of the best competitive pump design. All pump models were required to be tested at practically the full prototype pump operating head. No facility existed in the United States for making these tests, and the State of California found it necessary to contract with the National Engineering Laboratories, East Kilbride, Scotland, to conduct the test program.

Behavior of hydraulic machinery varies with the pressure and quantity of water, and the rotational speed of the machine. For laboratory testing, models are constructed to exact geometric proportions of the prototype machines. The model operating pressure, quantity of water, and speed are selected to suit physical relationships which exist between homologous machines. Prototype machine performance is then predicted from the results of the laboratory model tests. If the laboratory model test pressure and the prototype machine operating pressure are the same, one mathematical adjustment can be eliminated to provide a more direct comparison of the performance of the two machines.

Test facilities that exist in the United States for hydraulic power equipment were designed to operate at the relative low pressures in use in the past. Models are tested at the lower pressures and the results are mathematically adjusted to represent the performance of the machine at the actual higher operating pressure. Growing experience, much of it unhappy, is beginning to indicate that the complete picture is not presented by this means.

Facilities for testing hydraulic power equipment at the higher pressures at which it will be operated do not exist in the United States. Foreign countries are recognizing the need, and excellent testing facilities are becoming available in Europe and in Japan. Articles in Russian scientific and engineering publications describe several advanced hydraulic machinery laboratories operating in the U.S.S.R. Contacts with individuals and organizations throughout the United States have not yielded any indications of plans for the needed high-capacity test facility.

The Federal Power Commissioner's publication, "Hydroelectric Power Resources of the United States, Developed and Undeveloped," contains the information that as of January 1, 1968, the United States had 1,562 hydroelectric plants with installed capacity of 45,800 megawatts and an undeveloped potential of 130,500 megawatts. Therefore, about 26 percent of the total hydroelectric potential of 176,300 megawatts has been developed. According to present indications, much of the future development of hydroelectric potential will be of the pumped storage-type project for peaking power. Pump-turbine units for this type operation are predominately high-head machines suitable for maximum capacity production from minimum water flow.

If this country is to successfully cope with the increasingly complex problems confronting the designer, manufacturer, and user of tomorrow's hydraulic machinery, a good testing facility must be made available. Existing facilities can handle low- and medium-pressure situations. A new, adequately equipped and staffed facility has to be constructed for studies and testing at the higher head range of about 750 to 1,500 feet.

POTENTIAL USE AND BENEFITS

The high-head test stand under discussion should be planned for maximum nation-wide benefit in the field of hydraulic machinery and related equipment development such as large gates and valves. It should be the best universal stand that we can build to provide for tests of high-head hydraulic machinery models in the pump or turbine phases of operation and in the transition phases of pump-to-turbine and turbine-to-pump operation. (These four operational phases are frequently designated as the four quadrants of operation.) To be of maximum value, the facility should be a complete system with a permanent staff that would be available for use by any firm or organization. A plan would be necessary for a user from outside the Bureau of Reclamation to pay for all appropriate costs related to use of the stand. Also, an operational plan would be necessary for safeguarding proprietary information about equipment under test and the related test results. The facility could be beneficial not only to the Bureau of Reclamation, but also to other Federal Government agencies, the hydraulic machinery and equipment industry, state and municipal agencies, private utilities, and consulting firms.

Any of the organizations mentioned above could benefit by use of a high-capacity test stand for investigations in any one or all of the following broad areas of model studies:

1. Efficiency is the measure by which hydraulic turbines, pumps, or pump-turbines are compared or judged. In special cases, before awarding contracts for purchase, a more meaningful comparison of bids can be made by requiring operational test models to be submitted as bid data. Each model can be tested under identical conditions in a common laboratory. Acceptance of a successful bidder's design can be based on model tests, during which operating efficiency and cavitation characteristics are determined, and possible future operating difficulties uncovered. Design modifications leading to higher efficiencies can be developed economically by model testing and the tests would produce results of maximum value when performed at prototype head. The same type test program would be beneficial for development of a machine that had been placed under contract such as the Grand Coulee Third turbine.

2. Operating problems with existing machinery frequently develop as a result of faulty design or manufacture. Many of these problems are very difficult to handle due to physical conditions and difficulties due to water and power scheduling. The laboratory test facility provides an economical alternative to field tests for trial of corrective measures needed to obtain satisfactory performance from a pump, turbine, or valve. Common problems discovered after hydraulic machinery is placed in operation are surging, vibration, bouncing, cavitation damage, and poor efficiency. All of these problems can be reproduced and studied for application of suitable corrective measures using operating models installed in a laboratory test facility.

3. Research opens the door to numerous improvements in design and operation of hydraulic machinery. Serious problems result from the unusual flow characteristics accompanying the flow of large quantites of water at high heads. Machine elements are subject to high and unusual stresses. Behavior of these stressed elements must be studied in detail before acceptable designs can be developed. Frequently, a major maintenance expense is incurred, after a relatively short period of operation, as a result of cavitation damage. Turbine, pump, pump-turbine, or valve models can be constructed and tested under actual high-head conditions to evaluate various metals, alloys, and other materials for resistance to cavitation damage. Turbine draft tube surging is a common problem associated with operation over a wide range of heads. Model test studies can possibly lead to a better understanding of this phenomenon, resulting in better hydraulic design and better operation. Similar advances are possible in solving vibration problems traceable to unsatisfactory hydraulic conditions.

4. Criteria for selecting a pump or turbine to give best performance must be subjected to constant review. A model test stand allows investigations to be carried out with a variety of operating parameters for trial and possible development of new concepts for improvement of machines. The opportunity to stay abreast of foreign developments would also be provided by a suitable high-head test stand. It is, of course, impossible to make development studies using full-size machines.

REQUIRED CAPABILITIES AND MAXIMUM CAPACITIES

An appropriate high-head test facility would provide for full or near-full prototype-head tests of model turbines, pumps, and pump-turbines in the areas of efficiency, cavitation characteristics, and pressure pulsations. Provision would also be made for data acquisition of complete operational range curves and studies of hydraulic transients and machine reactions following shutdown and immediate reversal of rotation. The capability for thorough studies of gates and valves in pressure conduit and free discharge situations should be an integral part of the facility.

Considerations of present and expected future capacities of hydraulic machines indicate that a suitable test facility should be capable of providing a maximum test head of 1,500 feet (650 psi) and a discharge of 20 cfs for tests of turbine models. An appropriate reversible direct-current dynamometer to serve as an energy absorber for a turbine model and as a drive motor for a pump model would have the capacities of 3,000 hp as an absorber and 2,000 hp as a motor. This machine could provide capabilities for pump model tests at a maximum head of 1,500 feet and a discharge of 11 cfs. The speed range for hydraulic machinery models needs to extend from 1,000 to 6,000 rpm.

Use of solid-state silicon controlled rectifier (SCR) equipment to convert incoming alternating-current energy to direct-current energy would provide maximum operational flexibility of a test stand. The conversion to direct-current energy allows the use of an internal regenerative direct-current power loop involving the dynamometer and the direct-current drive motors of the station pumps. The regenerative power loop reduces the electric energy consumption of the test circuit and provides unrestricted intermediate operational speeds of the direct-current machines from their maximum to minimum speeds.

Maximum hydraulic flexibility of the test stand could be achieved with three centrifugal pumps connected hydraulically for single, parallel, or series operation. Each pump would have to be capable of discharging 20 cfs at about 500 feet of total head or 35 cfs at about 420 feet of head. A standard design, single-stage centrifugal pump is manufactured that has the required maximum capacities. Each pump would require a 2,000-hp drive motor. Low capacity operation of the test stand with a flow rate of 17 cfs at about 100 feet of head could be achieved by low speed operation of one station pump. A 2,000-hp direct-current drive motor for each station pump, to permit operation in the 600- to 1,200-rpm speed range, would provide a continuous hydraulic range of discharge-head combinations from minimum to maximum capacities specified above.

The maximum electrical power demand of the entire system would be about 6,000 kw. Rectifier equipment would be required for conversion of 4,000 kw to direct-current energy to drive three 2,000-hp station pump motors under simultaneous load conditions. Other permanent station equipment for alternating-current operation would require about 1,800 kw.

An operation and data acquisition center should be located adjacent to, but isolated from, the test stand. This center would house a combination control and monitor console, a data acquisition visual display panel, and automatic data processing equipment. The control system should provide for automatic sequential-type startup with trouble monitors and manual override capabilities.

A data acquisition system for about 30 channels of information should be automated to the fullest practical extent to allow rapid performance of test sequences. The data system would contain switchable fixed electrical signals for rapid calibration checks of the electronics of the system. A fast method of establishing fixed physical values at transducers and sensors would be necessary for rapid calibration of the entire data acquisition system.

Computer equipment for the facility could serve as both an automatic data processing system and as a test sequence controller. A computer system could be preprogrammed to accept only complete and reasonable data from the acquisition system, perform necessary data processing and printout, and initiate signals to the control system for establishment of the next set of test conditions.

A refrigeration plant and heat exchanger system would constitute significant portions of the physical plant and cost of the facility. A large refrigeration capacity would be needed for temperature control of the test water. Hydraulic energy losses caused by station equipment would be converted to heat in the test water, and certain tests of machine models would convert large quantities of hydraulic energy to heat. Temperature of test water must be controlled within small limits to achieve consistent test results. Limited computations indicate a refrigeration requirement of 1,100 tons. However, this requirement may be reduced by a complete analysis of heat removal possibilities by air forced through the machine building, precooling of test water stored in a recirculation reservoir, and test sequence planning.

Major components that are directly related to needed capabilities and capacities of a test facility have been identified. Many more major and minor items of equipment, systems of hardware, and building facilities would be required for a complete test facility. These components are identified in the following section.

BUILDING AND EQUIPMENT REQUIREMENTS

The enclosed drawing of a test circuit and minimum space needs illustrates the basic hydraulic circulation plan needed for flexible operation of a test stand for hydraulic machines, gates, and valves. The drawing was made to serve as a "starting point" to indicate minimum building requirements to house major components of a high-head test facility. The drawing does not indicate definite space requirements for auxiliary equipment such as electric power supply components, refrigeration plant, or vacuum and compressed air equipment.

The Pumping Plant Structures Section, Structural and Architectural Branch, considered the overall functional requirements of the facility, size and arrangement of equipment, and recommended building and related facilities requirements. The recommendations were based upon very limited studies, and quantities listed below are rough estimates.

Building and reservoir quantities:

Foundation

1. 54-inch-drilled, concrete-filled caissons - 3,000 lineal feet
2. Excavation, common - 15,000 cubic yards
3. Compacted backfill - 5,000 cubic yards

Reservoir

1. Concrete lined, 2,000 square feet by 10-feet deep (under main building)

Pump and machinery spaces (pit under main building)

1. 15,000 square feet with 20 feet of headroom

Main building (heated and ventilated, not air conditioned)

1. Structural steel frame, reinforced masonry walls, 20,000 square feet with 70 feet of headroom

Office and visitor wing, three-story building

1. One level of 6,000 square feet, 15 feet of headroom
2. Two levels of 6,000 square feet each, 10 feet of headroom
3. All three levels air conditioned, acoustical treated, and sanitary facilities where necessary

The Hydraulic Machinery Branch compiled a list of 26 items, many of them multiple quantity items, that would be required as mechanical, hydraulic machinery, and hydraulic circuit components of the test facility. The large and/or critical items are listed below with ancillary equipment grouped into the last listed item.

Mechanical, hydraulic machinery, and hydraulic circuit items:

1. Dynamometer, 3,000/2,000 hp absorbing/motoring, vertical shaft, 750 volt direct current, 500/1,000 rpm

2. Planetary gear box, reversible torque, 3,000-hp rating, 500- to 1,000-rpm input, 1:3 ratio

3. Planetary gear box, reversible torque, 3,000-hp rating, 500- to 1,000-rpm input, 1:6 ratio

4. Torque meter, telemetry output, 8,800 foot pounds and 6,000-rpm capacity with digital readout

5. Flowmeter, magnetic, 24-inch size, 650-psi working pressure (two each)

6. Pump, centrifugal, single stage, rated 35 cfs at 420 feet of head, 500-foot maximum head, 1,200-rpm maximum speed (three each)

7. Receiver tank, steel, 650-psi service, 8-foot diameter by 18 feet long

8. Receiver tank, steel, 50-psi service, 8-foot diameter by 18 feet long

9. Vacuum tank, steel, 8-foot diameter by 40 feet high

10. Weigh tank, steel, 17 feet by 25 feet by 10 feet

11. Bridge crane, 50-ton capacity, for 90-foot span

12. Rotovalve, 24-inch flow passage (three each)

13. Slide valve, 36-inch diameter, for weigh tank

14. Lift truck, portable, 4-ton capacity, air powered

15. Steel pipe and fittings, 12-inch through 24-inch sizes for 650-psi service (222,000 pounds required)

16. Steel gate valves, 12-inch through 24-inch sizes, 650-psi service (161,000 pounds required)

17. Steel pipe supports and miscellaneous metalwork (210,000 pounds required)

18. Vacuum system; compressed air system; sump pump; hydraulic valve operators and accumulator system; and 2-1/2-inch through 10-inch sizes of pipe, valves, and fittings

Sketches necessary to define electrical system functions, equipment requirements, and space needs were prepared in the Electrical Branch. The following sketches are available for future reference:

1. Circuit layout and space needs
2. Alternating-current and direct-current systems - single-line diagram
3. Incoming power facility - plan view
4. Direct-current supply and control equipment
5. Alternating-current control system
6. Dynamometer - two-line diagram
7. 2,000-hp motor or 1,500-kw generator - two-line diagram

A materials list for each major electrical function was prepared. These lists are too extensive to repeat here but each list is identified below according to function along with the number of items that comprise each list.

Electrical materials lists:

1. Alternating-current equipment (6,250 kva maximum demand), 53 items
2. Indication and control devices for direct-current dynamometer, 12 items
3. Indication and control devices for 2,000 hp/1,500 kw direct-current motor/generators, 3 each of 10 items
4. Equipment associated with the direct-current rectifier and regenerative system, 49 items

Data acquisition and computer requirements were estimated in the Hydraulics Branch based upon 28 channels of test data and 22 channels of system control signals. A relatively small computer with 16 k (16 bit) words of core memory could handle the requirements for data and program input, computation, output to storage, and signal output to a system control interface. Computer and satellite software costs have been included in the cost estimate. Software components would provide analog to digital signal conversion, magnetic tape storage, a printer, and a control system interface.

Refrigeration requirements, to control the temperature of test water, have been based upon the maximum possible water cooling load. This load would be the heat equivalent of the maximum electrical input to the three station pump motors. Refrigeration plant and heat exchanger system costs have been based upon a fixed cost per ton of refrigeration. The estimate of refrigeration capacity needed may be excessive. A detailed study of operational possibilities would be required to determine the optimum capacity.

Provision for one-half mile of 15-kv power supply cable in buried steel conduit was included in the materials requirements of the test facility. Length and cost of this item would depend upon the location of the test facility.

COST ESTIMATE

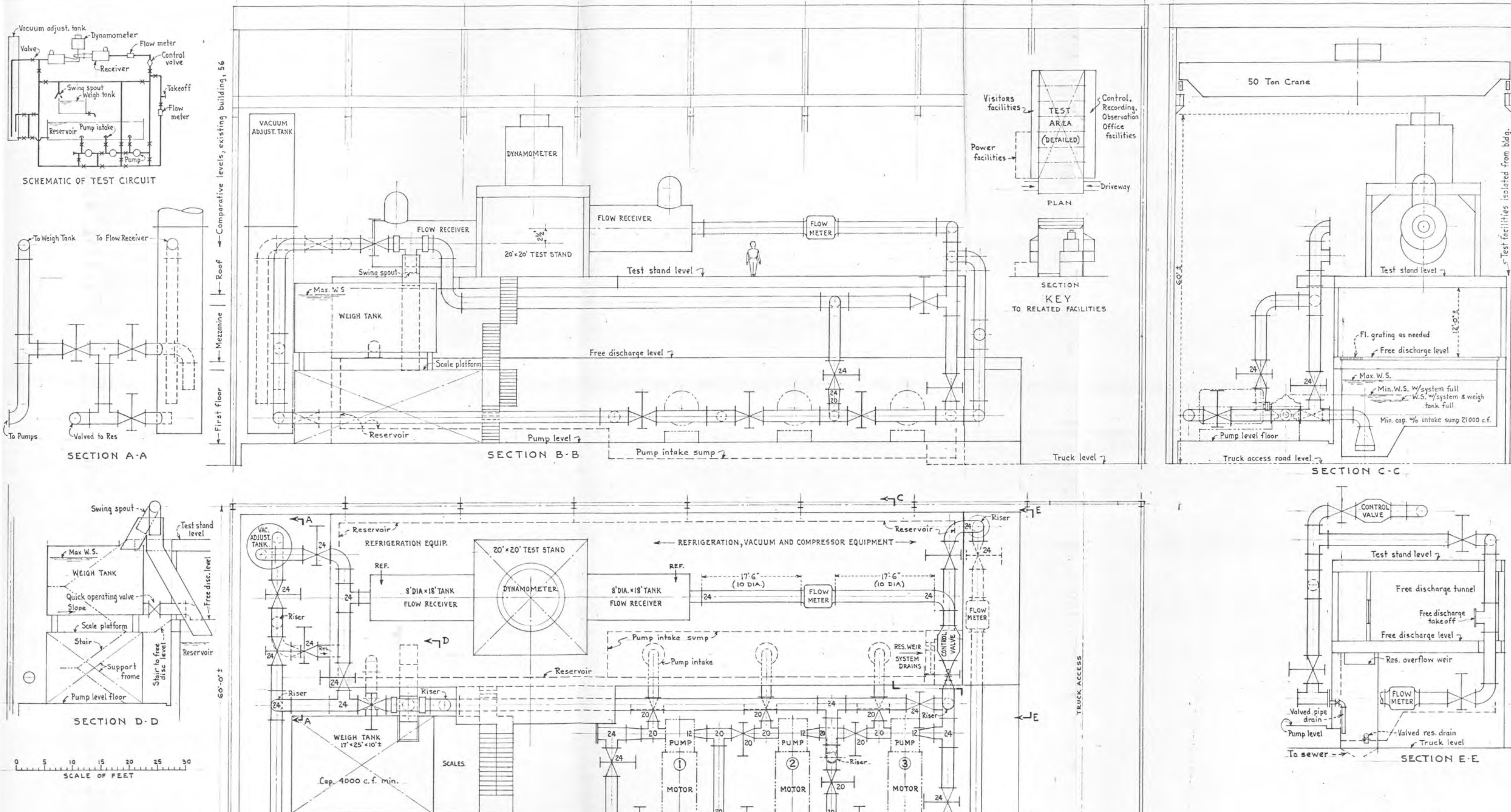
Cost for Proposed High-head Test Facility
for Hydraulic Machinery

(Reconnaissance Estimate)
Revised June 11, 1969

Item		Estimated Cost
Building and Reservoir		$2,160,000
Mechanical Components		1,960,000
Electrical Components		1,440,000
Data Acquisition and Computer		360,000
Refrigeration for test water (1,100 tons)		1,320,000
Buried Cable for Power Supply		80,000
	Major Contracts	7,320,000
	Minor Contracts	1,830,000
	Non-Contract Costs	2,730,000
	Total Construction Costs	$11,880,000

The cost estimate was compiled by the Estimates and Analysis Branch and was based upon materials and building quantities furnished for each category included in the estimate. The materials lists did not include minor items necessary for a refined facility. However, factors were applied to costs of major categories to allow for appropriate costs. Design and internal construction activities costs would be provided by the $2,730,000 non-contract item. It is emphasized that this is a reconnaissance study, and the design plans and cost estimates could be appreciably changed as a result of detailed studies. The cost estimate is considered to be reasonable and adequate for a facility that would provide the most complete and versatile high-head test capabilities than can be anticipated within practical limits.

Building construction unit costs included in the estimate were based upon an arbitrary Denver Federal Center location. Location of the test facility would be important in regard to electric power operational costs. The maximum operational capacities involved would require a power supply with a maximum demand rating of about 6,000 kw. Estimated cost for this demand capacity service furnished by the Public Service Company of Colorado at the Federal Center is $1.50 per kw per month or $9,000 per month for 6,000 kw demand capacity. This fixed cost could be decreased by "off-peak" operation which would probably restrict operating periods to late evening and early morning hours. Another possibility for cost reduction would be an exchange plan between the Bureau's Region 7 Office and the Public Service Company for exchange of demand capacity that would involve Bureau generated capacity available to Public Service Company. This possibility has been suggested but not investigated.



BUREAU OF RECLAMATION
DIVISION OF RESEARCH
PROPOSED HIGH HEAD TEST FACILITY
FOR HYDRAULIC MACHINERY
TEST CIRCUIT LAYOUT AND SPACE NEEDS

MAR. 26, 1969