LABORATORY FACILITIES FOR RESEARCH AND DEVELOPMENT OF WATER SYSTEMS CONTROL AUTOMATION

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Facilities have been provided in the Hydraulics Branch Laboratory, Division of General Research, Engineering and Research Center to investigate methods and means of automating and remotely controlling irrigation systems for the Bureau of Reclamation. This report describes these laboratory and field facilities for studying, developing, and demonstrating control methods for automatic flow regulation.

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Denver, Colorado

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INTRODUCTION

This report was prepared in accordance with the following: (1) U.S.-U.S.S.R. Agreement on Cooperation in the Field of Science and Technology signed May 24, 1972, (2) the record of the first meeting of the U.S.-U.S.S.R. Joint Working Group on Scientific and Technical Cooperation in the Field of Water Resources signed September 30, 1972, and (3) in accordance with the program developed by the U.S.-U.S.S.R. coordinators in Frunze on September 24, 1974, on Project III 2, "Methods and Means of Automation and Remote Control in Irrigation Systems." Item 3 of the agreement calls for an exchange of information on equipment and laboratory apparatus used to develop automated controls for water systems. This report describes certain laboratory and field facilities used by the U.S. Bureau of Reclamation to study and demonstrate the various control systems available for automatic flow regulation.

LABORATORY FACILITIES

Electronics Shop

Automation and control facilities in use are located in the Division of General Research, Hydraulics Branch laboratory at Denver, Colo., see figure 1. A small electronics shop, run by one technician, is located in a room adjacent to the hydraulics laboratory, see figure 1 (center right). This shop has been equipped with standard electronics test equipment such as analog and digital voltmeters; multimeters measuring voltage, current, and resistance; oscilloscopes, and spare parts. The shop also has a microprocessor development system including microprocessor, two ASCII (American Standard Code for Information Interchange) keyboard and printer terminals, punched tape, and magnetic tape facilities, all maintained in the shop. An electronics engineer supervises the development of electronic components, hardware, and software required for control elements. The shop is in daily use on work associated with the research and development of water conveyance control equipment for which there is no known commercial source of supply.

Canal Model

A canal model was constructed in the Hydraulics Branch laboratory to be used for developing control schemes and equipment, see figure 1 (upper right dashed rectangle). The model has a rectangular flume approximately 335 m (1100 ft) long and is divided into three flow sections of unequal length by four radial gate structures, see figure 2. Bends of 180° direct the flow from channel to channel at each end of the model. The four channels upstream from gate 2 of the model have been in operation for about 3 years. Recently, eight channels and two gates (3 and 4) were added to increase the versatility of the model. The model, as shown on figures 2 and 6, was constructed from the detailed drawings shown on figures 3, 4, and 5. The radial gates were constructed from the drawings shown on figures 7 and 8.

A 3-m (10-ft) crest length spill weir was constructed immediately upstream from each check gate to waste excess water from the channel upstream from the gate to the next downstream section. The weir upstream from the first radial gate bypasses the excess water to the main channel of the laboratory water supply. All water, up to the model capacity of 0.03 m^3/s (1 ft^3/s), is pumped from the main channel into the model by a vertical turbine pump. The inflow to the model is measured by a laboratory constructed Venturi-orifice meter. Orifices ranging in size from 35 to 140 mm (1-3/8 to 5-1/2 in) can be placed in the Venturi throat. The pump is operated at constant discharge during a study and excess water in the forebay of radial gate 1 is bypassed to the main channel. If water becomes excessive in a channel, the side spill weir discharges to the next downstream section. The last weir and radial gate 4 wastes to the main channel. All of the side spill weirs were designed to discharge 0.03 m^3/s for a water surface rise of approximately 30 mm (0.1 ft) in the model water surface.

A fully contracted 254-mm (10-in) crest length rectangular weir was installed downstream from each of the radial gates to provide appropriate submergence on the gate and to measure the discharge. To achieve fully contracted flow, a 203-mm (8-in) drop was provided in the flume invert downstream from each weir. Each of the side spill weirs, rectangular weirs, and radial gates are rated with respect to the discharges through the Venturi-orifice meter.

Operating characteristics.–The three flow sections of the model canal were designed to have different transitory wave travel times by constructing the sections of different lengths. Full sized canals have wave travel times of an order of magnitude larger than the model but control principles can be readily evaluated with the model wave travel time.

Reflections of waves between the gate structures cannot be studied in this model because of the rectangular weirs downstream from each gate. Thus, the laboratory canal does not simulate the irrigation canal with respect to a transitory wave reflecting between gate structures.

Each of the gates can be operated from a gate controller on the operating platform. The control panels (in front of each of the two people in the foreground of figure 2) contain switches and relays for opening and closing the gates. Each panel also contains voltage terminals from test points in the system. A potentiometer attached to the gate hoist shaft has a reference voltage terminal on the panel used for indicating the gate opening and for input to the control equipment under study.

Water levels in the canal are sensed in the model by inductive- or resistive-type transducers connected by plastic tubes to piezometric orifices upstream and downstream of the radial gates. The voltage output of the transducers and signal conditioning circuits becomes the input to the controller under test.

Water levels are also measured in stilling wells large enough to contain 305-mm (12-in) diameter floats. The water level change is transmitted through a float, beaded cable, pulley, and gear reducer to a potentiometer. The stilling well water level may also be sensed by a pressure transducer connected to the well.

Data acquisition.—Analog and digital instruments are used to acquire data for research and development of controllers. Analog signals from test points are recorded on direct-writing recorders. The frequency of control changes usually can be measured on precision recording voltmeters having relatively slow response. Recorders having a response up to 100 Hz may be used to advantage for signal conditioning and for recording the data in laboratory studies. Analog to digital (A/D) conversion of voltages from test points is necessary for adaptation of minicomputer and microprocessor applications. Laboratory experiments are normally designed to employ computers in the research and development of controllers or methods.

GENERAL PURPOSE MEASUREMENT ANALYSIS AND CONTROL COMPUTER SYSTEM

Located within the Division of General Research is a general purpose Measurement Analysis and Control Computer System. This system is a real-time data acquisition, data reduction, and control system; and is maintained and operated by the Division Instrumentation Group. Although used for general-type measurement, analysis, and control work in all areas of the division, the system has also been used for control of the laboratory canal model. The system is controlled by seven minicomputers. A real-time executive program operates the system and offers many featues such as online editing, multiprogramming, FORTRAN, system protection, input-output management, file management, and general coordination of the complete system.

The seven minicomputers are wired together as shown in figure 9a. The main, or central computer, which drives several peripheral devices has 96 thousand words of 16 bit memory, figure 9b. Each branch computer is capable of using the peripheral devices in the central area of the main computer. These devices, used by all branches of the Division of General Research, include a card reader (for punched or marked-sense cards), a line printer, a high-speed paper tape punch, a high-speed paper tape reader, an X-Y plotter, an interface to the telephone lines, two magnetic disks, three 13-mm (1/2-in) nine-channel magnetic tape drives, a graphical A/D input system, and various terminal displays. A keypunch, extra tapes, and other equipment are also maintained.

Branch or remote computers which communicate with the central computer are shown in figure 9c. The branch computers have 24 thousand words of 16 bit memory, and may all be used simultaneously from their location in the various branches. The branch computers are mobile and can be moved from area to area. Output from the branch computers can be sent to central computer peripheral devices, to the teleprinter at the branch computer, or to test equipment in the form of real-time control. Input can be through central computer devices, the teleprinter at the remote, a high-speed paper tape reader at the remote, or through test equipment such as transducers. Signals from test equipment can be analog voltages or digital lines. There are many possibilities for input from test signals and for control output. In general, at each branch computer, many low-level and high-level sensors (such as strain gages or transducers) and many output controls (such as relays) can be connected.

The system is modular and may be expanded or updated at the central system or at any branch computer. As the branch computers are all similar, the various parts may be traded between branches. Thus, for example, if one branch desires more input and another branch is not using their input boards, the additional input may be obtained on loan to increase the capacity of any one system.

General purpose measurement analysis and control systems such as this one have been used frequently in the Division of General Research. An example of a short study conducted with a smaller but similar system was published in report REC-ERC-73-11, "Application of a Mini-Computer to a Channel Control Problem". This report is available from the Bureau of Reclamation.

HYDRAULIC TRANSIENT COMPUTER MODELS

The best engineering tools available for developing controllers and for establishing control methods are computer programs based on hydraulic transients. With an åccurate model of a canal or distribution system, many control algorithms may be tested. A basic model has been developed in the Bureau of Reclamation which undergoes continual study and development for application to a wider scope of distribution problems. Documentation has not been completed.

Control algorithms can be utilized by the computer model to determine the stability of flow of the modeled system. System reaction to changes in flow may be thoroughly tested. Satisfactorily modeled control schemes can then be used in development of equipment or computer control software. Before control equipment is constructed and tested in the laboratory for use in the water system, mathematical model studies are made to predict the hydraulic transient behavior and to adjust the control parameters.

ENVIRONMENTAL TEST FACILITIES

Simple facilities are available for operation, heat, and moisture tests to be performed in the laboratory. Equipment containing mechanical components under test can be cycled in the electronics shop to determine deadband sensitivity, control range capability, and mechanical reliability.

Heat and moisture tests ranging from about 71 °C (160 °F) dry to 21 °C (70 °F) with 100 percent humidity can be performed in the laboratory facility. These tests are particularly important for equipment that is to be installed in stilling well enclosures having high humidity at the controlled structure. Many equipment enclosures exposed to the sun at Bureau projects can reach internal temperatues near the high temperature of the test chamber. Low temperature tests of the equipment are not normally performed because water distribution systems in the colder areas do not operate during the winter season. Tests at low temperatue could be performed as needed in subfreezing rooms available in the Division of General Research laboratories.

RADIAL GATE MODEL

A 762-mm (30-in) wide radial gate model was constructed and installed in the laboratory, see figure 10. The 1:6 scale model is being used to define the flow characteristics of radial gates controlling the flow in Bureau of Reclamation irrigation systems.

Hydraulic transient computer models require definition of the discharge capacity over the range of flow to be controlled by the radial gate. The study in the Hydraulics Branch is planned to define the coefficient of discharge for gates having different trunnion (bearing) heights and radius of curvature. Information is being obtained primarily for flows representing the expected range of submergence of the jet from the gate. Free flow discharge coefficients are being measured concurrently.

The study should produce general information useful to application of radial gates in the design of canals for irrigation.

FIELD DEVELOPMENT (LABORATORY EXTENSION)

Final developing and testing of equipment is performed at a field test site. Installation of the equipment is made by an electronics technician and/or an electronics engineer. In addition, there is usually onsite help from field personnel. By assisting, field personnel learn the characteristics of the equipment and can periodically report on the performance.

The equipment usually remains at the operation site rather than being returned to the laboratory and electronics shop for further development. At this stage of development most of the necessary modifications can be made at the field structure where the equipment was placed in operation. Successful modifications are then incorporated in later equipment designs. A thorough field testing usually concludes the research and development of a particular type of equipment or method of applying control. Operation manuals and reports on the controller or method are written concurrently in the latter stages of research and development of the equipment.

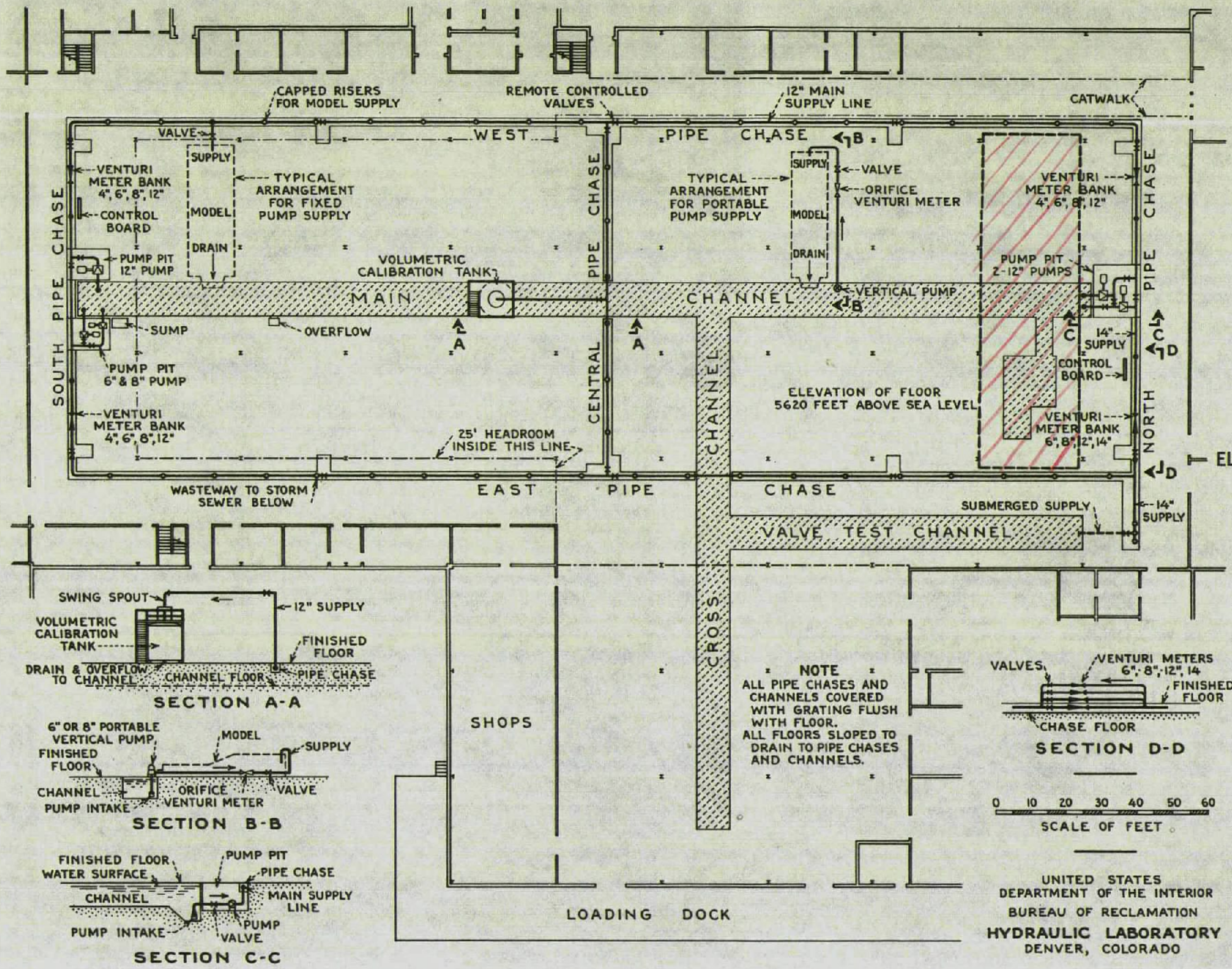

Figure 1.–Plan of hydraulic laboratory.

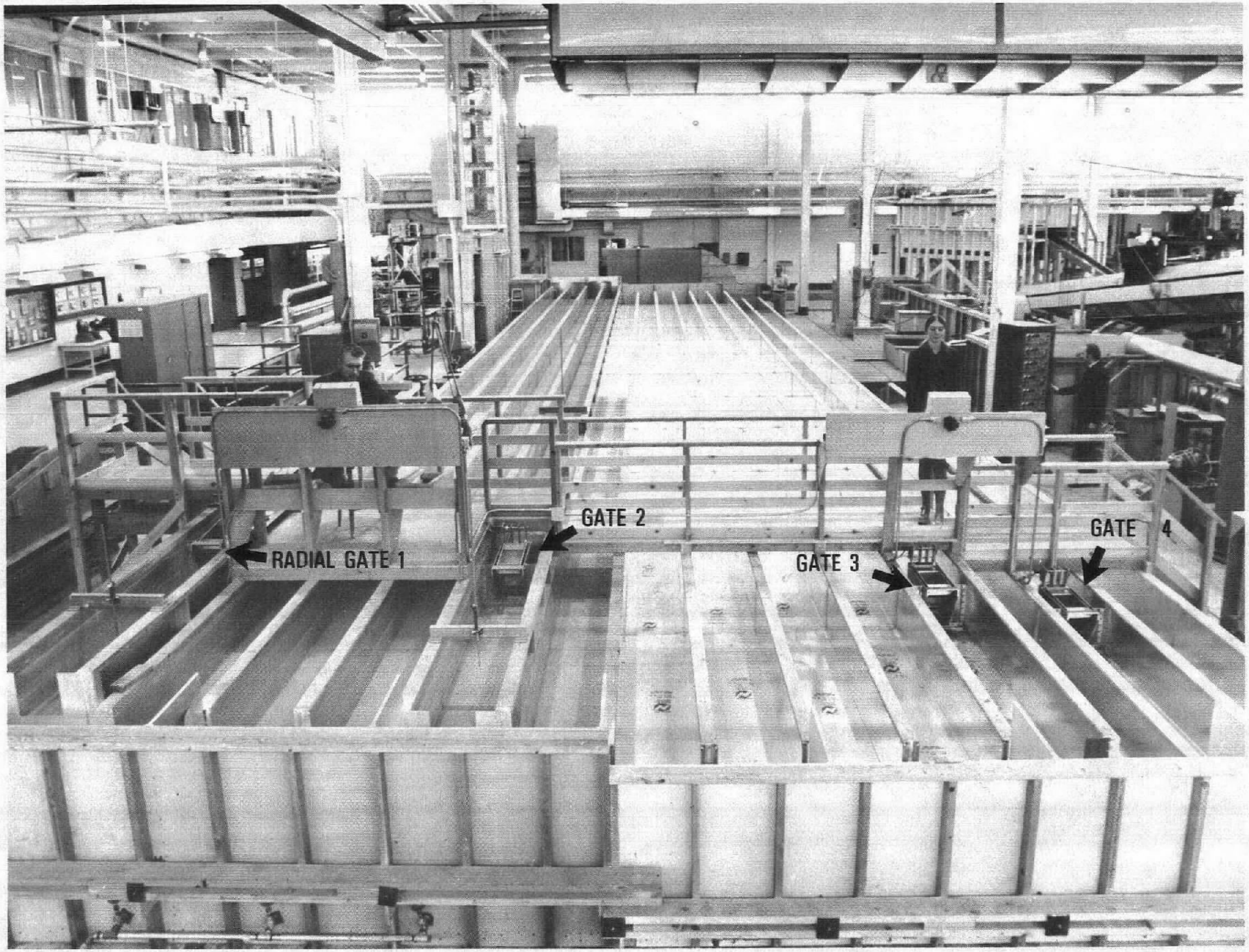

Figure 2.–Canal model. Photo P801-D-77757

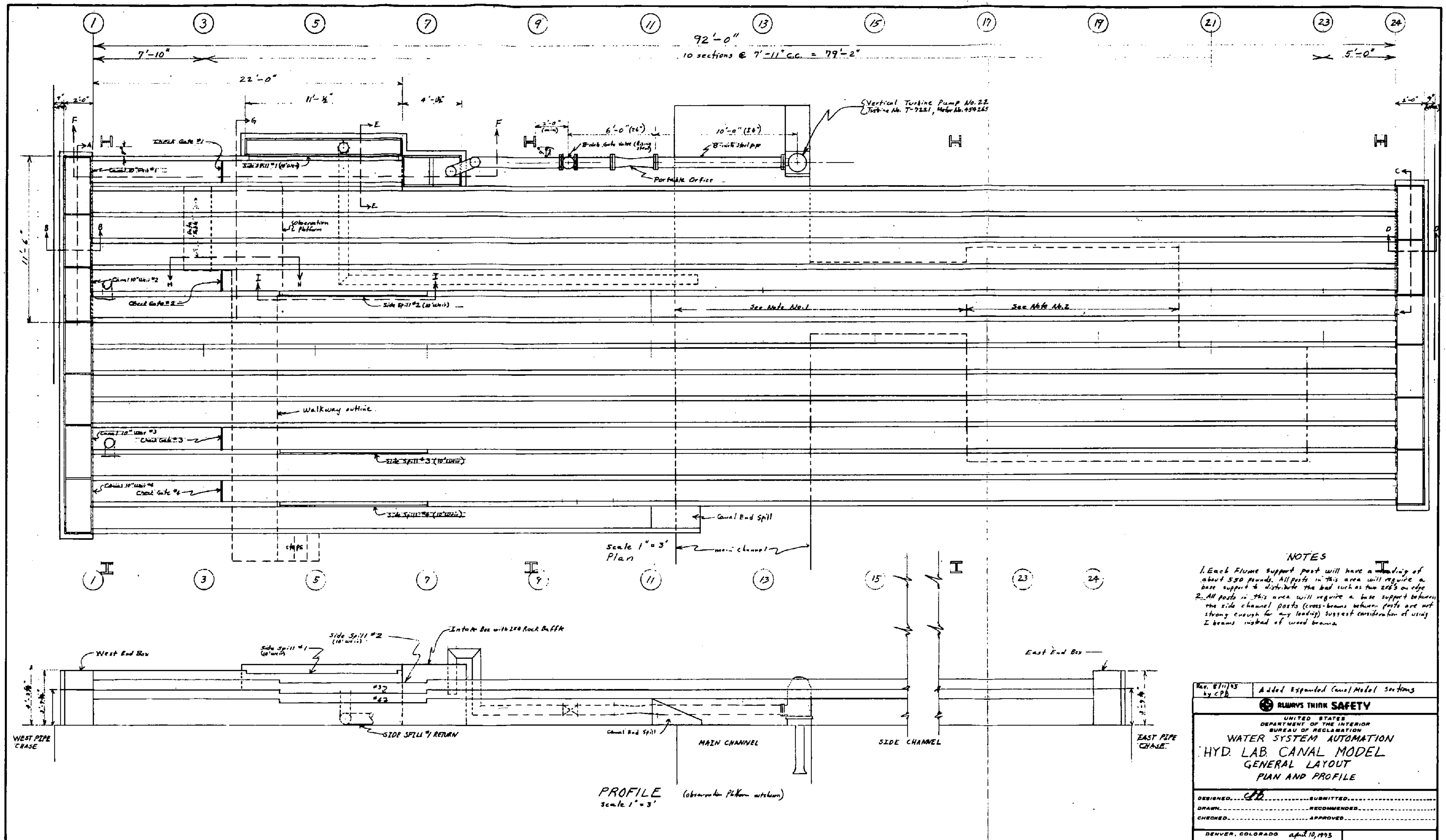

Figure 3.–General layout of canal model.

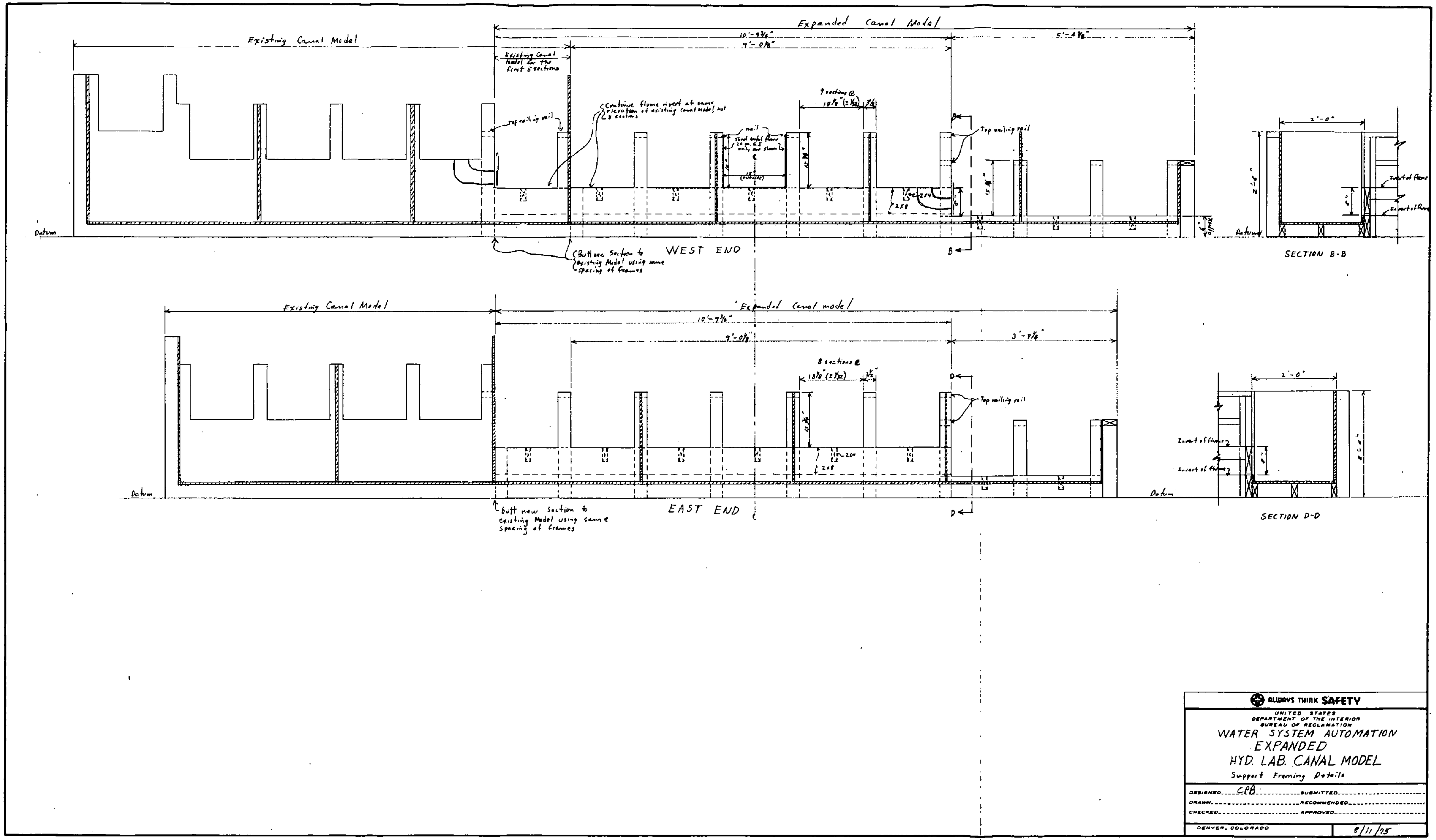

Figure 4.–Support framing details of canal model.

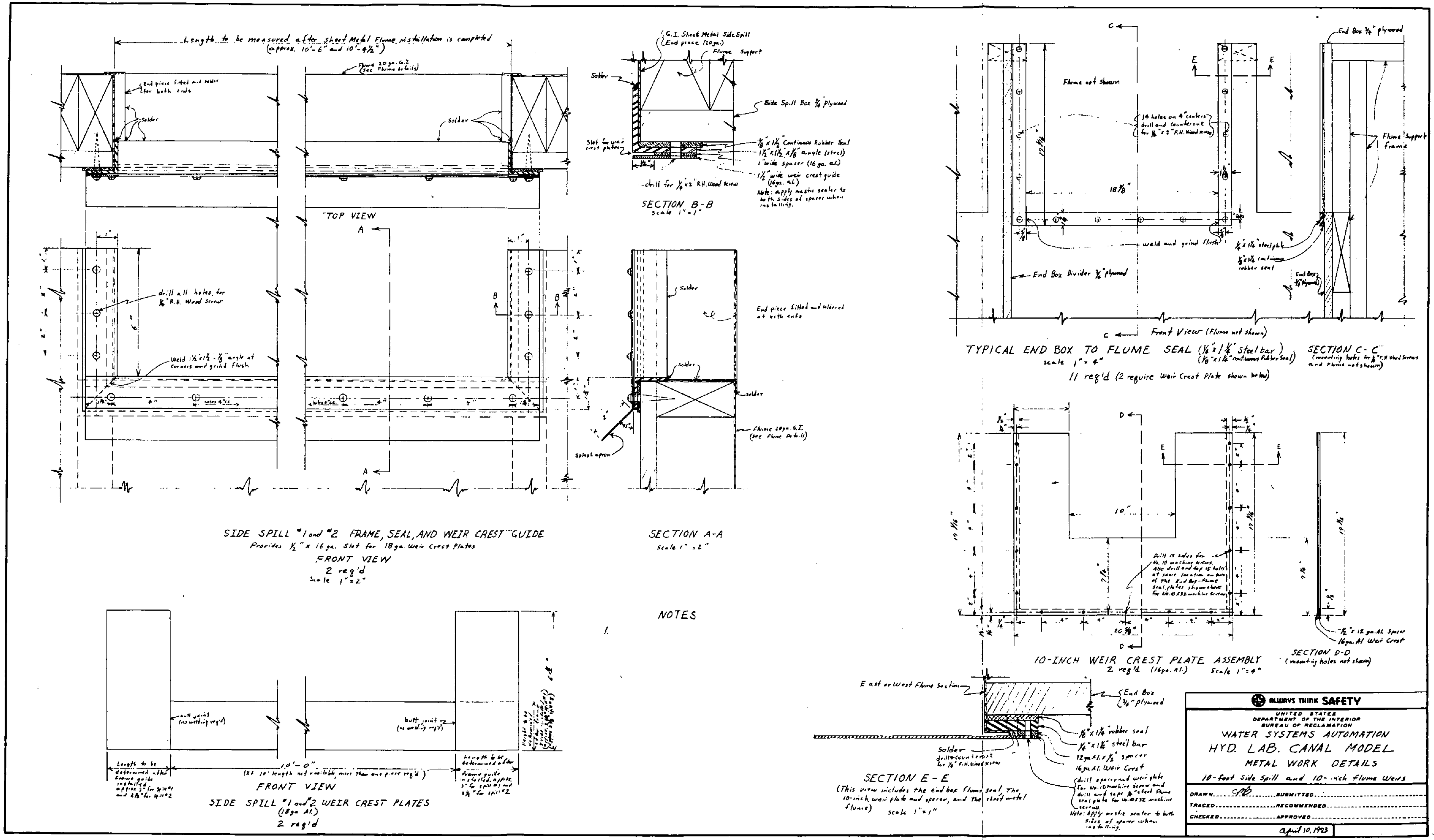

Figure 5.–Metalwork details of canal model.

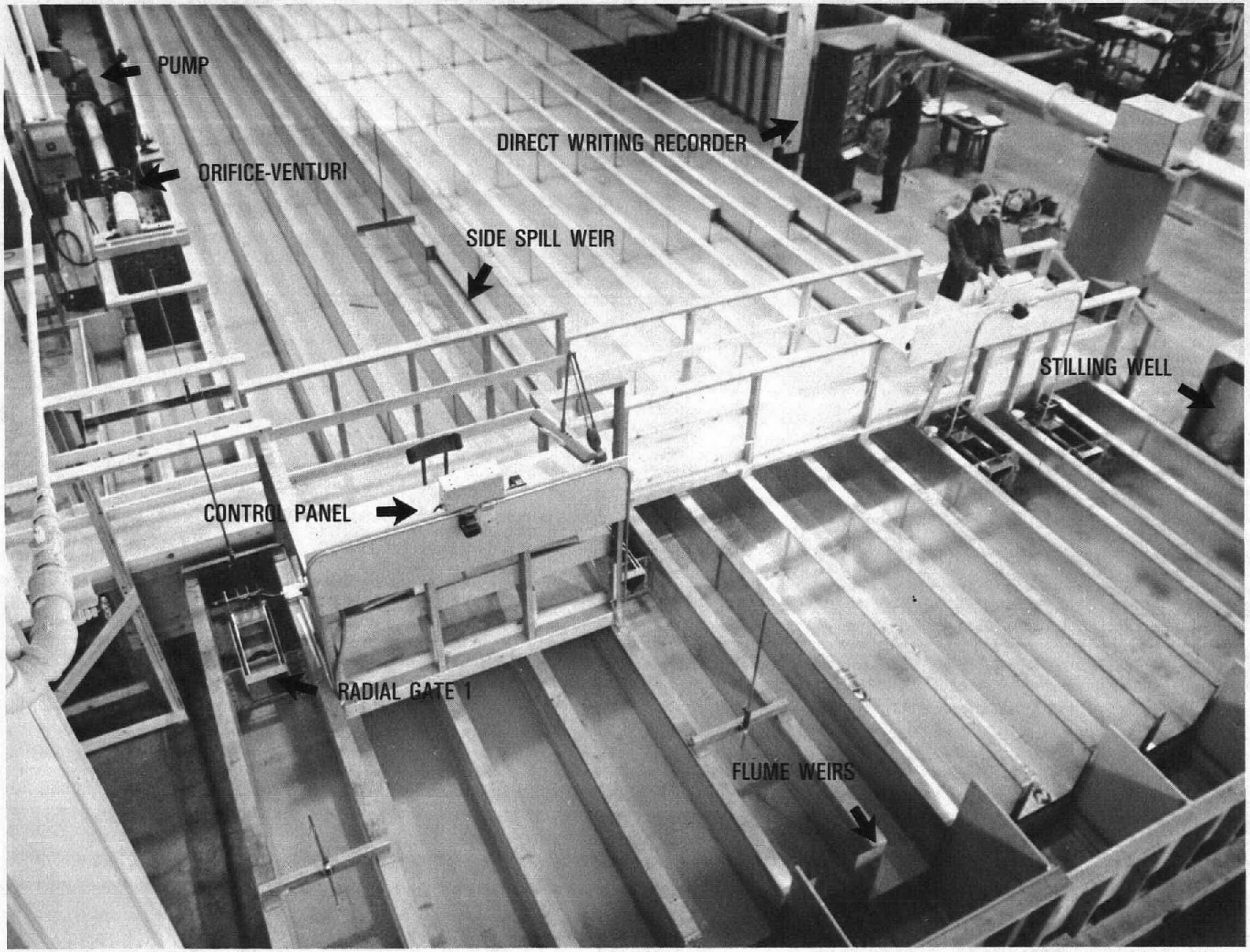

Figure 6.–Control panels, flume, and side spill weirs of canal model. Photo P801-D-77756

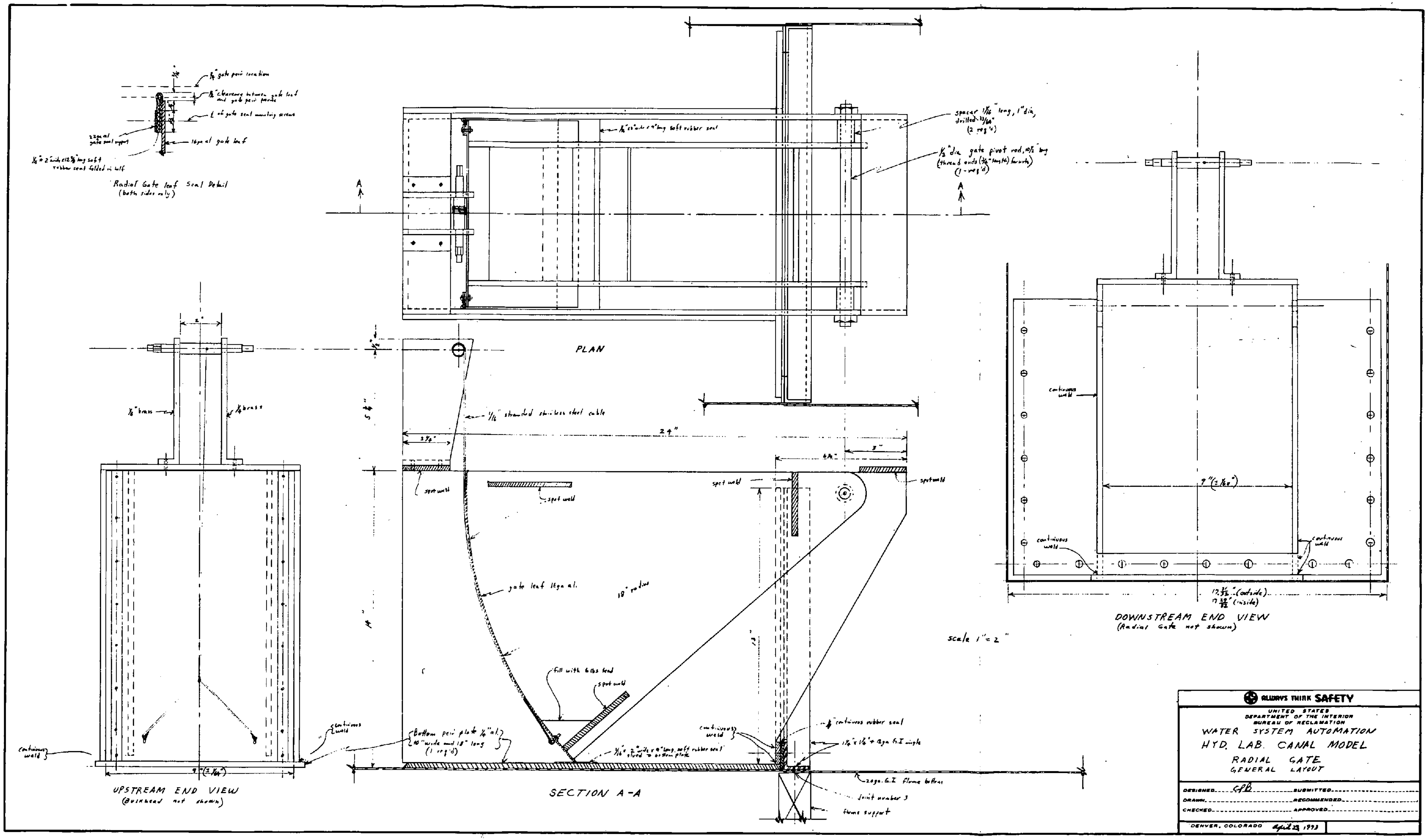

Figure 7.–General layout of radial gate for canal model.

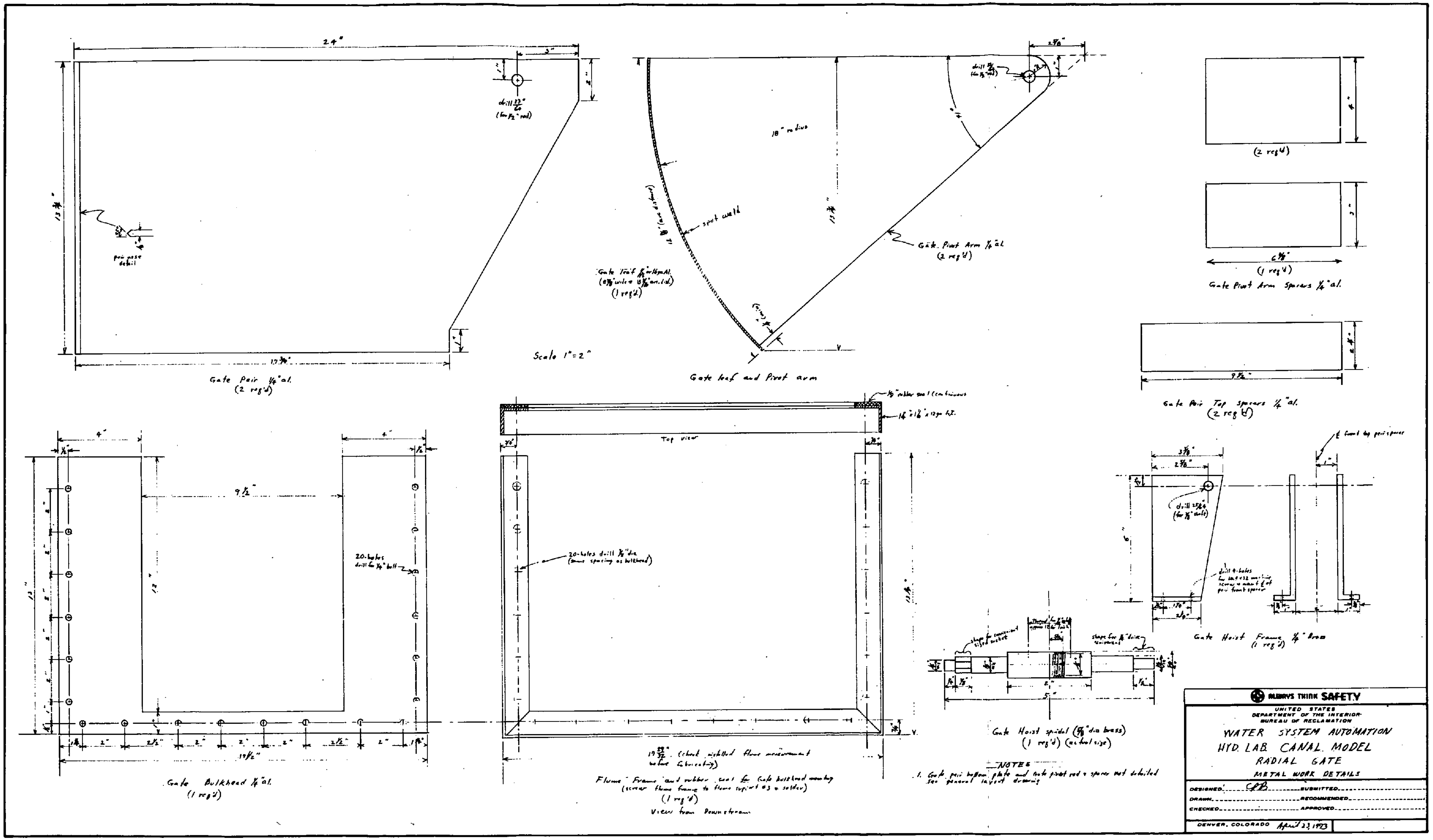

Figure 8.–Metalwork details of radial gate.

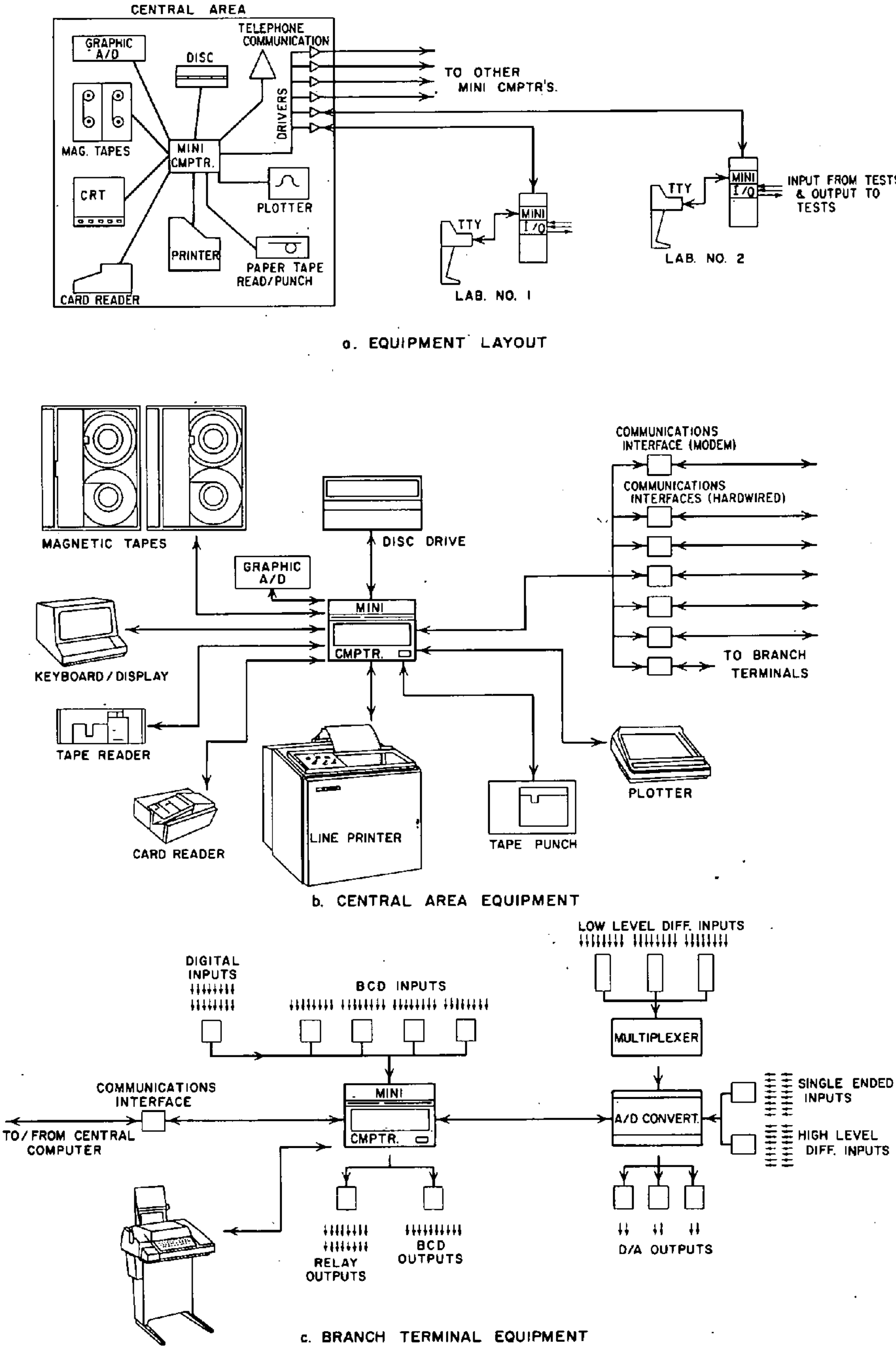

Figure 9.–Measurement analysis and control computer system.

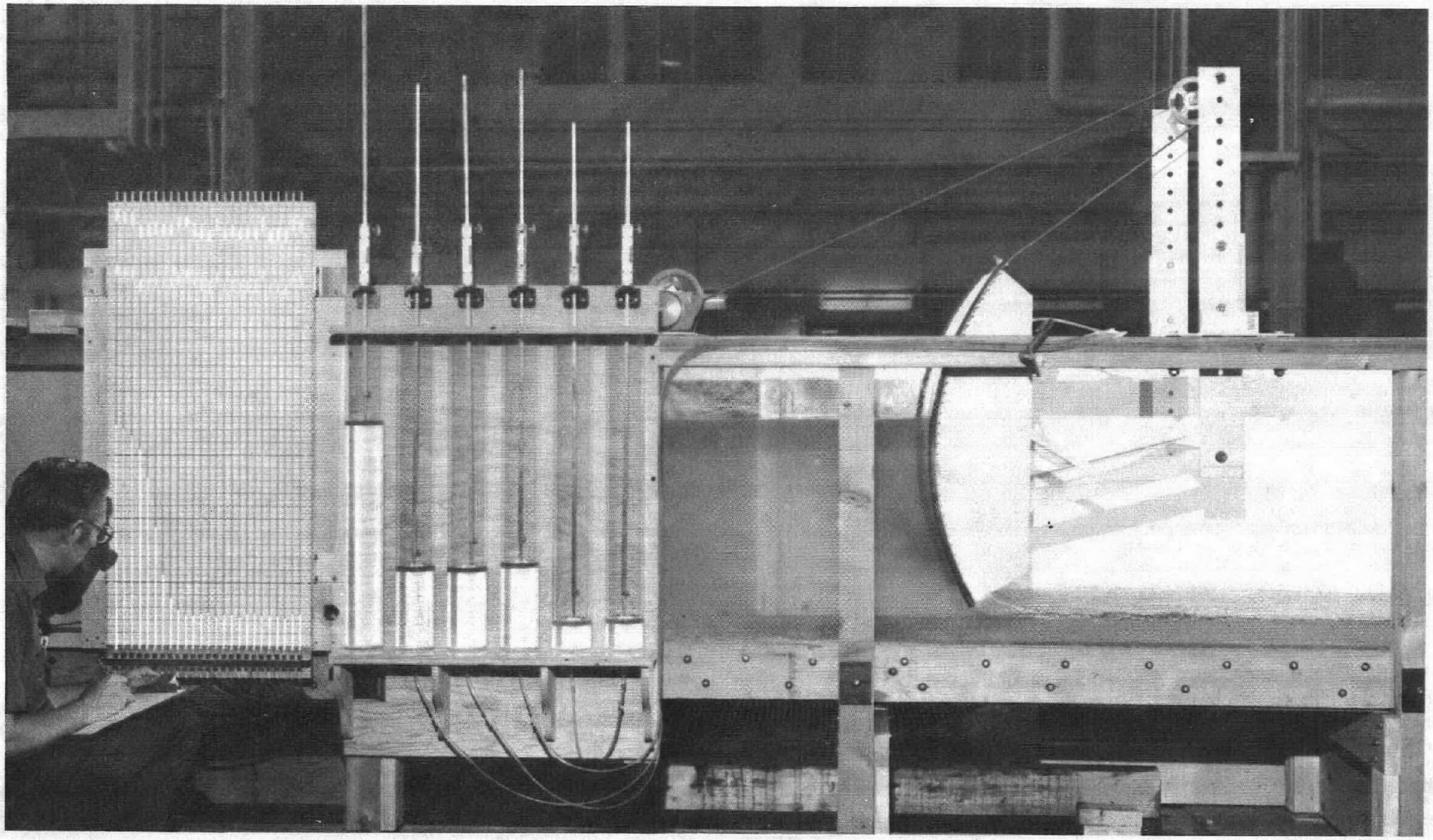

Figure 10.–Radial gate model. Photo P801-D-75701 NA

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