Chapter 6
Hydraulic Model Studies

Section I
Introduction

6-1. General

Laboratory studies have significantly improved the efficiency of lock filling-and-emptying systems. They have reduced lockage times and mitigated many conditions that have been hazardous to both traffic and structures. Prototype studies have verified and added to the data obtained from these model studies.

6-2. Purpose of Model Study

Data for the design of a filling-and-emptying system for a low-lift lock are available. However, if the filling-and-emptying system under consideration varies from conventional types, a thorough study using a hydraulic model may be necessary. A lock with a lift of 40 ft or more generally departs from conventional designs, and normally cannot be confidently patterned after other designs. Even though problems are not apparent, a model study usually brings to light corrections or improvements in design that result in smoother and faster operation and effects savings in construction and maintenance costs. Flow conditions in locks with lifts of 100 ft or more, require model studies and other specialized laboratory studies during early stages of the design process.

6-3. Scales

The most satisfactory scale ratios have been found to range from about 3:100 to 6:100. These scale ratios permit visual observations of turbulence and other flow conditions and permit the use of usual types of laboratory instruments for making measurements of pressures, velocities, discharges, and linear dimensions. A 1:25 scale predominates for recent lock studies.

6-4. Model and Prototype Similarities

Models must be geometrically and, to the extent possible, dynamically similar to the prototype. The common dimensional relationships applied to lock models are listed in Table 6-1.

Table 6-1
Model and Prototype Dimensional Relationships

Quantity	Dimension	Symbol	Scale Relationship
Scale relationship	L_m/L_p	r	____
Length	ft	L	r
Head, lift	ft	h, H	r
Area	ft^2	A	r^2
Volume	ft^3	L^3	r^3
Velocity	ft/sec	V, v	$r^{0.5}$
Time	min or sec	t	$r^{0.5}$
Discharge	cfs	Q	$r^{2.5}$
Force	lb	F	r^3

6-5. Model Construction

Construction materials used for lock models include metal, concrete, plastics, and wood. Transparent plastics are used for sections of conduit where observations of the interior flow conditions are desired and for forming curved surfaces such as entrances, bends, or dividing vanes. Where duplicate parts are required, such as lock chamber ports, lateral entrances, floor laterals, etc., it has been found that accurate reproductions can be made in concrete by the use of wooden forms. Swelling or contraction, which are objectionable features of wood, is not experienced with concrete. Materials for the various parts of the model structure should be selected on the basis of their resistance to dimensional change, particularly those sections and surfaces that are exposed to flow or changing volumes of water. The new Bonneville Lock Model is shown in Figure 6-1.

6-6. Instrumentation

Because of the variable flow conditions in a lock model and because these conditions change quite rapidly, it is essential to have an automatic method for recording most phenomena. Electronic transrecorders, digitizers, etc., have been developed that record and process automatically the following types of data:

a. Elevation of upper pool level (initial value, drawdown, etc.).

b. Elevation of lower pool level (initial value, swell, etc.).

c. Movement of culvert filling (or emptying) valve.

d. Elevation of water surface at required locations in the lock chamber.

e. Pressures at various points in the hydraulic system by means of piezometers, particularly among curved surfaces; at turns, contractions, and expansions; along the culverts; and at the control valves.

f. Longitudinal and transverse forces acting on vessels in the lock chamber (see Figure 6-2).

g. Rate of flow of water into the lock chamber (normally obtained from item *d* above).

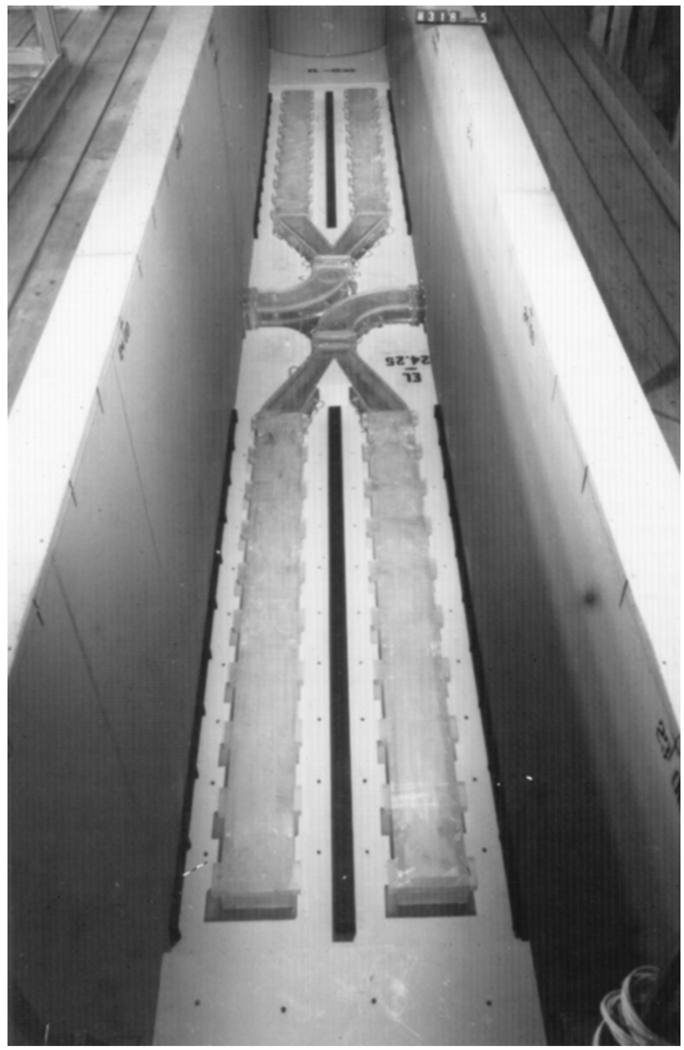

Figure 6-1. Hydraulic model of New Bonneville Lock. The following materials are generally used: chamber, marine grade plywood; culverts, manifolds, valve wells, Plexiglas; valves, bronze plate

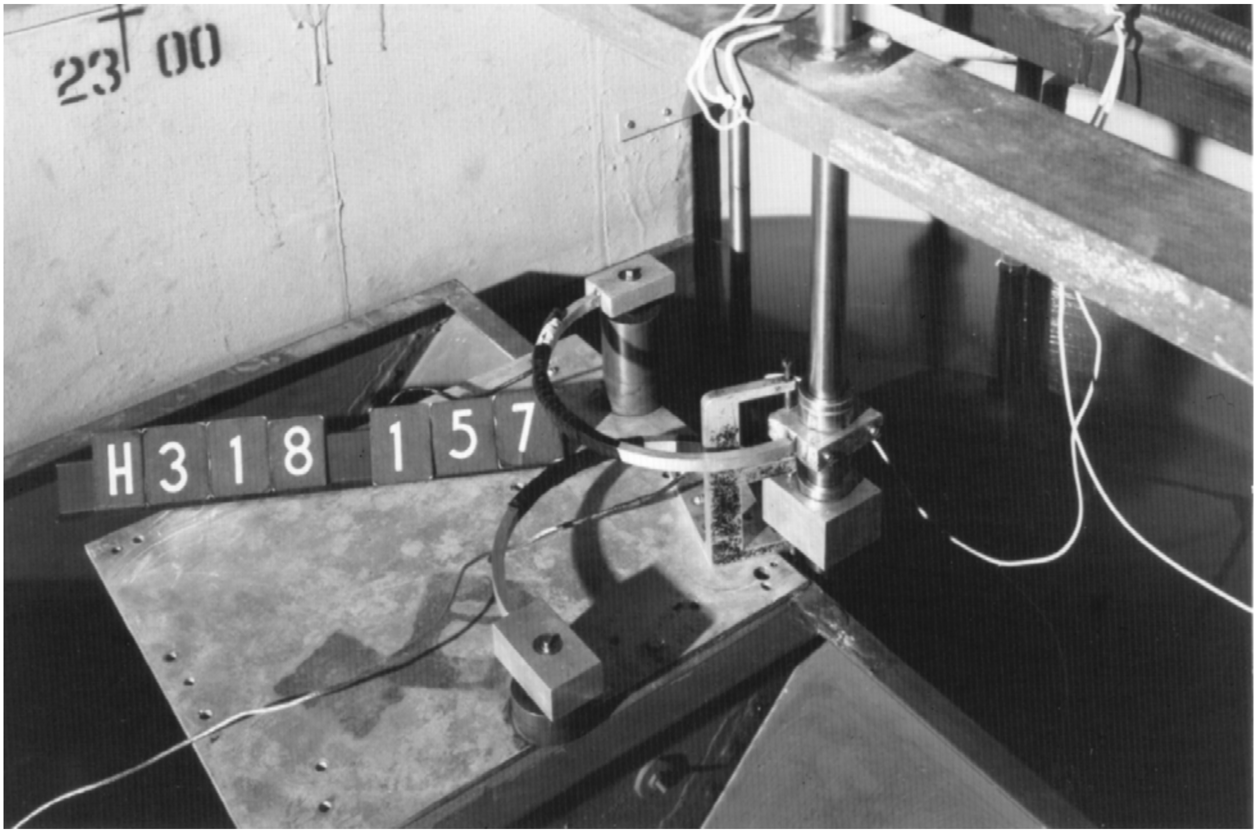

Figure 6-2. Hawser force measuring devices

h. Time synchronization to within about 2 sec (prototype scale); normally to about 0.4 sec, model scale (1:25 model).

i. An event signal that can be operated manually to indicate occurrence of special events such as the taking of photographs during an operation, etc.

6-7. Pressure Measurements

Piezometers recording pressures may be connected by flexible tubing to transparent glass or plastic tubes mounted on a manometer panel board rather than automatically read. These pressures can be read visually on the individual manometers or photographed as a group for later reading and interpretation. Only the latter method is feasible in a regular test where flow conditions are continually changing. Some lag in the readings occurs depending upon the diameter and length of the connecting tubing as well as on the rate of actual pressure change. Steady-flow tests are frequently made to permit more accurate observation of flow and head loss conditions in the system. Flow distribution in manifolds is usually determined using a pitot tube or other small flow-metering device under steady-flow conditions. Where rapid pressure fluctuations occur and cavitation or excessive negative pressures are suspected, the region in question should be investigated by means of surface-mounted electronic pressure cells. Areas of this nature may exist on the downstream face of control valves, culvert surfaces below valves, entrances to inlets, and at gate or bulkhead slots. An example measurement is shown in Figure 6-3.

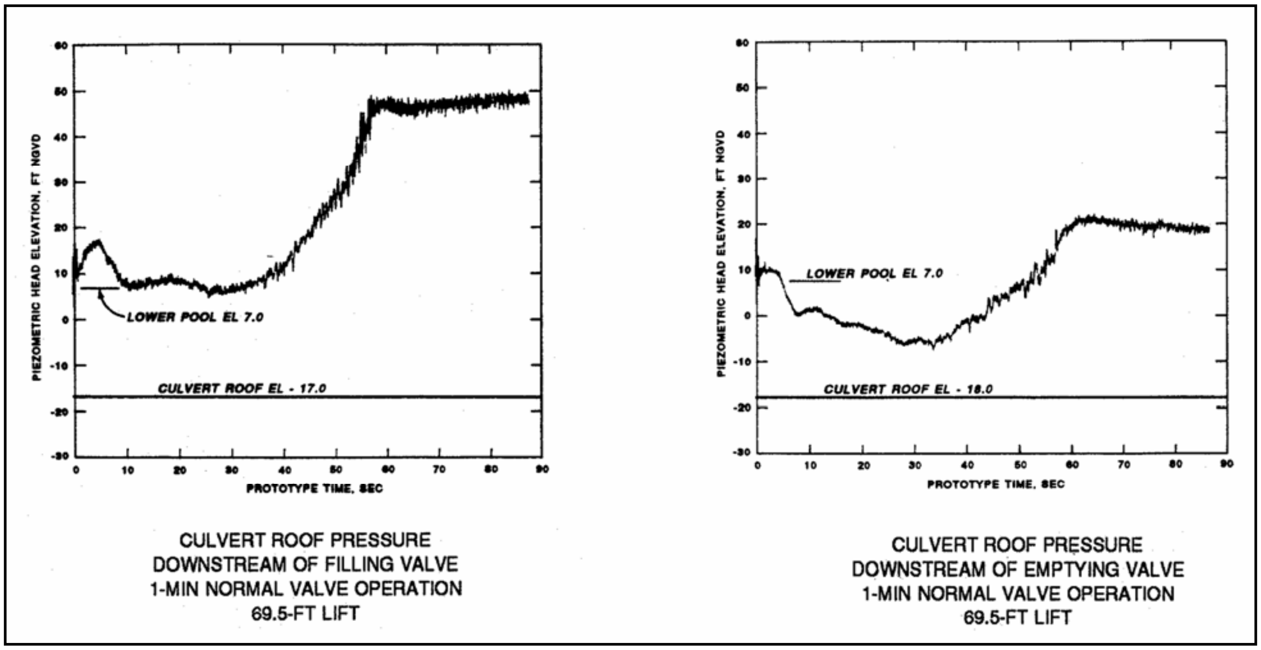

Figure 6-3. Dynamic pressure measurements

Section II
Prototype Expectations

6-8. General

A prototype lock filling-and-emptying system is normally more efficient than predicted by its model (paragraph 6-3). The difference in efficiency is acceptable as far as most of the modeled quantities are concerned (hawser forces, for example) and can be accommodated empirically for others (filling time and overtravel, specifically). However, in circumstances in which knowledge of extreme pressures within the culverts in the prototype is important, additional corrections to the predictions from the model are required. These corrections are particularly important for high-lift locks in which questions regarding cavitation (resulting from extremely low pressures) are of concern. More recent prototype data for locks can be found in items 87, 90, and 97.

6-9. Revisions to Scaled Values

Adjustments to model-based coefficients for prototype application are based on one of the following three general approaches.

a. Filling-and-emptying times. General guidance is that the operation time with rapid valving should be reduced from the model values by about 10 percent for small locks (600 ft or less) with short culverts; about 15 percent for small locks with longer, more complex culvert systems; and about 20 percent for small locks (Lower Granite, for example) or large locks having extremely long culvert systems. Although these values are approximate, the resulting C_L value is a reasonable estimate of discharge coefficient C, which in turn provides a reasonable basis for evaluating a prototype k_t value (see Chapter 5).

b. Similar (model and prototype) locks. A lock as similar as possible to the design lock and for which either operation time or culvert pressure data are available (model and prototype) provides a comparison such as in *a* above, or for pressure values, direct evaluation of prototype loss coefficient values.

c. Reynolds number corrections. Boundary friction differences, assuming smooth boundaries in both model and prototype, explain about one-half of the efficiency change with regard to operation time for certain locks (Lower Granite, for example). The remaining change is due to undeterminable variations in form coefficients or the Reynolds number difference. Sensitivity analysis (systematic variations in individual form coefficients) permits extreme conditions to be accounted for in design.

Section III
CE-Sponsored Hydraulic Model and Prototype Studies

6-10. Database

The database, H5300, contents are summarized in Appendix C. The database is being filled to ultimately include the 86 reports and 251 features studied by WES, Bonneville Hydraulics Laboratory, and the St. Paul District as described in Appendix C.