UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

HYDRAULIC LABORATORY REPORT NO. 80

MEMORANDUM TO CHIEF DESIGNING ENGINEER

LABORATORY INVESTIGATION OF THE LOW-HEAD SIPHON FOR THE SEWAGE-DISPOSAL SYSTEM, ESTES PARK HEADQUARTERS COLORADO-BIG THOMPSON PROJECT, COLORADO

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Hydraulic Laboratory
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Subject: Laboratory investigation of the low-head siphon for the sewage-disposal system, Estes Park headquarters--Colorado-Big Thompson Project, Colorado.

1. Introduction. After the solids in the sewage have been removed, the remaining fluid is to be stored in a concrete vessel until an approximate total of 560 gallons has been accumulated. The proposed design requires that this storage vessel be emptied within 2 to 3 minutes. The fluid in the storage tank is to pass to an adjacent smaller vessel where it will be chlorinated, and then flow on out to the filter beds through vitrified tile pipe.

The conditions of design indicated that a siphon would be the most desirable method to use in emptying the storage tank because its initial cost would be less, the cost of operation and maintenance nil, and its reliability greater than, for example, a pump due to the fact that the siphon has no moving parts and requires no external source of power to actuate it. However, because the maximum available head is only 18 inches, no commercially built siphon suitable for this installation could be found. Furthermore, it was desired to prevent a small flow of long duration at the beginning of the discharging process so that the entire area of the filter beds would be utilized and not just those regions immediately adjoining the tile pipes serving the beds. This latter condition necessitated a siphon which would give a high discharge at the start of the emptying process and which would also prime quickly.

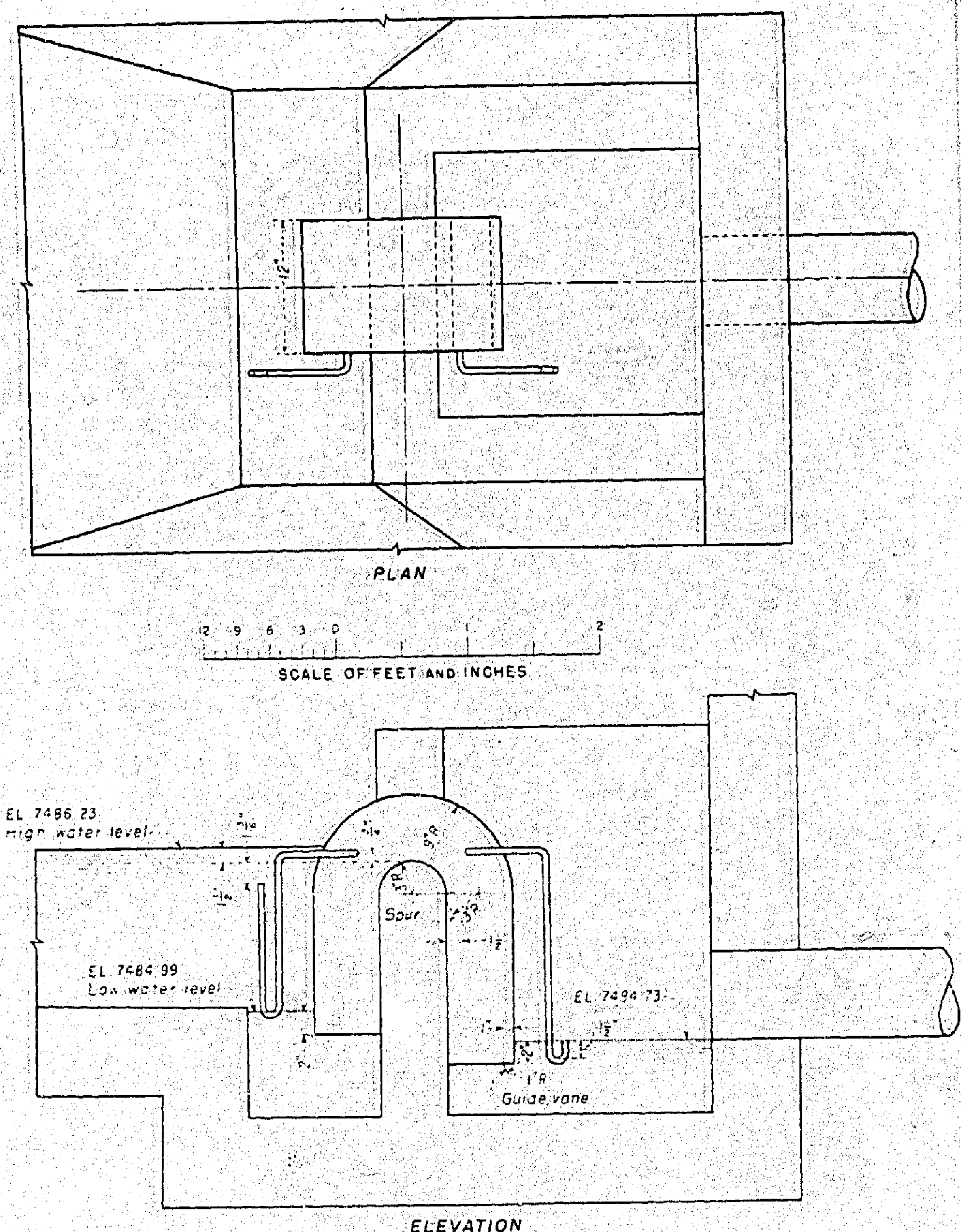
A siphon to adequately meet all these conditions was designed, built, and tested in the hydraulic laboratory.

2. Laboratory installation. The proposed siphon was built full size and installed in an existing channel in the laboratory. By using two bulkheads, the channel was divided into two vessels: the upstream vessel which corresponded to the storage tank; and the downstream vessel which corresponded to the chlorination tank. Field-operation conditions were not duplicated exactly in the laboratory because the available laboratory channel was somewhat too short resulting in the plan area of the upstream vessel (and consequently its volume) being less than that of the proposed storage tank. Furthermore, an 8-inch orifice was used in the wall of the downstream vessel to approximate the 8-inch vitrified tile pipe to be used in the field. It was felt, however, that a sufficiently accurate indication of the operation of the siphon could thus be demonstrated.

3. Description of the siphon and appurtenant devices. The siphon (figure 1) consists of two legs, 6 inches by 12 inches in cross section, with the upstream leg somewhat shorter than the downstream one. To insure that the priming jet will not cling to the crest and to insure that it will spring completely across the downstream leg, a spur is located just below the crest in the downstream leg of the siphon. A guide vane is placed near the lower lip in the downstream leg of the siphon. The purpose of the guide vane is to direct the air-carrying priming jet outward from under the lower lip so that all, not just part, of the air which is released from the priming jet will rise outside of the lower leg, and thus decrease the time required to prime.

It was desired that the siphon prime quickly and also that a long period of small discharge be prevented. These requirements were both met by employing two U-tubes, thus solving the problem with a device which has no moving parts. To explain, the action of this device, one complete cycle of the action of the siphon will be described. As will be seen in the drawing, both the upstream and downstream legs of the siphon are well submerged, thus sealing the interior of the siphon from the atmosphere. Consider the start of the cycle to be the instant that the water level in the storage tank starts to rise. The air inside the siphon will escape through the open upstream U-tube until the water in the forebay rises slightly above the free leg of that U-tube, at which point the air remaining in the siphon will be trapped. As the water level in the forebay continues to rise, the pressure of the air trapped in the siphon will be increased, and due to this increased air pressure the level of the water inside the upstream leg of the siphon will be lower than the free forebay water level. By this device, the free forebay water level will rise to a predetermined elevation above the siphon crest while the water level in the upstream leg of the siphon will be still slightly below the crest level.

The downstream U-tube at the start of the compression process will have water standing in each leg at the elevation of the top of the short leg. As the air pressure in the siphon is raised the water level in the long leg of the downstream U-tube will be lowered. The water level in this leg will continue to drop as the air pressure within the siphon is increased until the water level stands at the low point of the bend of the U-tube. Any further increase of the air pressure within the siphon will precipitate a series of results: all the remaining water in the free leg of the U-tube will be blown out; the air pressure within the siphon will be relieved; the water level in the upstream leg of the siphon will rise instantly to the level of the forebay resulting in an almost instantaneous high priming head on the siphon crest; the siphon will prime quickly thereafter. The first water over the crest will raise the tailwater level above the elevation of the top of the short leg of the downstream U-tube, thus sealing



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DETAILS OF RECOMMENDED DESIGN OF SIPHON FOR USE IN SEWAGE DISPOSAL PLANT

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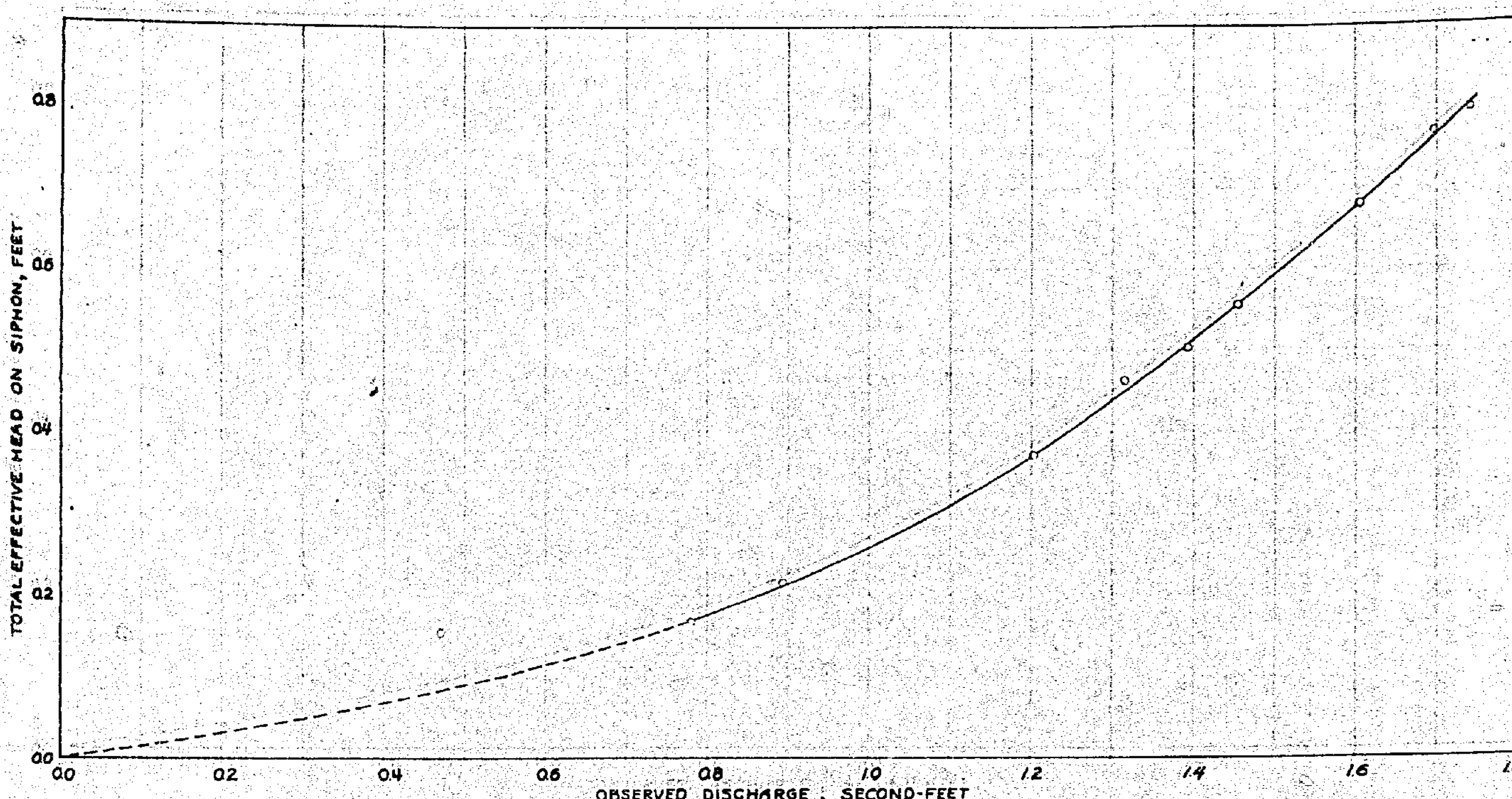

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HEAD-DISCHARGE CURVE
FOR THE LABORATORY-DEVELOPED SIPHON

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FIGURE 2

forebay level and that of the tailwater was observed to be zero. In the laboratory experiments, the crown of the lower bend of the upstream U-tube was so placed that at the time of breaking the siphonic action the tailwater level was 0.042 foot above the invert of the 8-inch orifice. By breaking siphonic action when the tailwater stands at this elevation above the invert of the effluent pipe, a long-sustained flow of a very small quantity of water to the filter beds is prevented.

During testing, a small air leak in the siphon developed. It was impossible to discover the location of the leak without entirely dismantling the siphon, and because time was pressing and because the leak was thought to have a negligible effect on the results, the leak was not repaired.

5. Conclusions. The siphon as developed in the laboratory works very satisfactorily under the required conditions. The spur and guide vane are essential to quick priming. The addition of the two U-tubes both shortens the priming time considerably and prevents a prolonged small initial discharge. By locating the bend of the upstream U-tube well above the invert of the effluent pipe, breaking of the siphonic action is accomplished soon enough to prevent a long-sustained small flow at the end of the cycle. The ends of the upstream and downstream legs of the siphon should be located at elevations somewhat lower than the bends of the respective U-tubes to insure the correct operation.

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the siphon from the atmosphere again and allowing priming of the siphon to be accomplished.

As the forebay level drops, the water level in the short leg of the upstream U-tube also drops. When the forebay vessel is nearly empty, the forebay and tailwater elevations are almost the same because the 8-inch orifice located in one wall of the downstream vessel becomes the control. At this point in the cycle the velocity head corresponding to the velocity of flow through the siphon is small and therefore the water level in the short leg of the upstream U-tube is appreciably the same as the forebay water level. When the water level in the short leg of the upstream U-tube reaches the low point of the bend or slightly below, the seal will be broken, air will rush through the U-tube to relieve the negative pressure within the siphon and carry with it the remaining water in the U-tube. Thus the siphonic action will be broken and also the upstream U-tube will be left water-free, ready for use as an air-escape tube during the first part of the next cycle. The downstream U-tube will be left with water standing in both legs to the elevation of the top of the short leg, being also ready for the next cycle.

The downstream leg of the siphon is extended below the level of the invert of the effluent pipe by an amount somewhat greater than the distance between the top of the short leg of the downstream U-tube and the lowest point of the crown of the bend of that U-tube to insure that air will not escape from the lower leg of the siphon during compression.

The location of the top of the short leg of the upstream U-tube depends upon the point where it is desired to start compression. In the case of the siphon under investigation, it was desired to have compression start at a point such that maximum compression would be developed when the water surface inside the upstream leg of the siphon is one-quarter of an inch below the crest. The maximum desired increase of air pressure inside the siphon over atmospheric pressure, expressed in inches of water, was arbitrarily set at 1½ inches. The final volume of the compressed air could then be computed because the water surface in the upstream leg of the siphon was thus fixed at one-quarter of an inch below the siphon crest; and at 1½ inches pressure, the water surface in the downstream leg of the siphon would stand at 1½ inches below the tailwater level (assumed to be the elevation of invert of the 6-inch tile effluent pipe). The initial volume of the air trapped in the siphon was next computed, assuming constant temperature, by the relation

$$V_I = P_F/P_I \, V_F$$

where subscripts I and F represent initial and final conditions, respectively. Having, then, the initial and final volumes of the trapped air, the amount of rise of the water surface in the upstream leg of the siphon due to compression of the trapped air was computed. Next, computations were made to determine the amount of rise of the water surface in the upstream leg due to forcing down the water surface of the downstream leg by 1½ inches. Thus, the point of start of compression expressed as distance below the crest was found to be 1.74 inches. Knowing that the water of the forebay will stand at some elevation slightly greater than that of the top of the short leg of upstream U-tube before flowing into it, the elevation of the free end of the upstream U-tube was placed at 1-15/16 inches below the siphon crest, or at slightly greater than 3/16 of an inch below the computed point.

If a higher, or lower, priming head on the crest is desired, this may be obtained by varying the length of the short leg of the downstream U-tube and computing a new elevation of the top of the short leg of the upstream U-tube by the method just outlined. If a greater priming head is desired, the downstream leg of the siphon must be further submerged by an amount equal to the increase in head. The point of breaking the siphonic action may be varied by raising or lowering the elevation of the bend of the upstream U-tube, and taking into account the effect of the velocity head on the pressure within the siphon.

4. Description of tests. A 90-degree V-notch weir was used to measure the discharge of the siphon. A constant discharge was supplied to the upstream vessel, and after allowing the system to reach equilibrium the forebay and tailwater elevations corresponding to that particular discharge were measured. The difference between the forebay and tailwater elevations thus found was recorded as the total effective head on the siphon for that discharge. This procedure was repeated for several different discharges and from the results a head-discharge curve for the siphon was plotted (figure 2).

The time required for the siphon to prime was also recorded. Water was supplied to the upstream vessel in such a manner that the forebay water level rose slowly. At the instant when the downstream U-tube allowed the air, which was trapped in the siphon, to escape, the supply of water to the upstream vessel was shut off and a stopwatch was started. The siphon was thus allowed to prime with a falling forebay water level and a rising tailwater level. The time to prime was recorded as the elapsed time between the instant the first air escaped from the downstream U-tube and the instant when all air was exhausted from the siphon. The average value of the time to prime when using the guide vane was found to be 36 seconds, but without the guide vane, the priming interval was many times this value.

At the instant when breaking of the siphonic action was accomplished by the upstream U-tube, the difference between the