# THESIS

The Design and Test of
a
Model Siphon Spillway.

by

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The Design and Test of a Model Siphon Spillway.

Part I .. Design.



Part II .. Tests.

## Part I .. Design.

### 1 Siphon Spillways.

Siphon spillways date back to at least 1870 when a steel pipe siphon, with a pneumatic ejector, was used at a dam near Mittersheim (Lorraine) to supply water to an irrigation ditch. Perhaps the siphon principle was applied to some similar installation before that but we have no records of anything earlier. In this installation the six inch ejector pipe was brought into action by a definite height of water--this ejector removed the air from the large 2'-6" siphon and brought it into siphonic action. Due to freezing and to becoming filled with debris, this small pipe was not satisfactory.

Siphons without ejectors were erected almost contemporaneously by Mr. J. Heyn, a civil engineer of Stettin, Germany, and by Mr. Gregotti, an Italian engineer, at Mortara in Northern Italy. A typical section and short description of the two types of design is found in Plate I. The action in the case of a siphon without an ejector is this :- As the water rises it seals the upper lip of the air inlet (or perhaps the main water inlet). This compleltely seals the siphon since the lower or discharge lip is also sealed slightly. A further rise starts a stream over the throat of the siphon--this stream entrains air and ejects it under the discharge lip. The air being slightly rarified inside the siphon, the water rises higher, a bigger stream goes over the lip--more air is ejected and in a few seconds the siphon is running full. As soon as the water falls below the air inlet the seal is broken and the siphonic action stops. Siphons on this principle were successful and a number were put in service, some in streams to protect power plants from floods as at La Praz and Largentiere, France, some as spillways for canals or power dams, and others in irrigation projects.

A few years later the first siphon spillways were constructed in America, among the first being a battery of siphons in Arizona on the Salt River Project of the United States Reclamation Service. (See Plate III.) This battery of a thousand second-feet capacity was designed under the direction of Mr. Louis C. Hill, now a consulting engineer in Los Angeles. At about the same time a battery of ~~six~~ five siphons was installed upon the Yuma Project of the U.S.R.S. This battery (see Plate III) had a test capacity of over fifteen hundred second-feet as is shown by Data Sheet I. Probably before both of these, in about 1909, Mr. George F. Stickney, Supervising Engineer on the New York State Barge Canal, installed a number of siphon spillways on the Barge Canal and patented his designs. After the remarks about European practice it might be interesting to quote from the "Barge Canal Bulletin" September 1910. In reference to the Barge Canal spillways, "It is believed that in them the siphon principle is used for the first time to create a spillway of any considerable size. The siphon action will be entirely automatic, in both the starting and the stopping of the flow." Part of the above quotation is evidently based upon a lack of knowledge of Eurppean installations. This prior use would probably invalidate the patents if a test case were made. Whereas the largest battery on the Barge Canal had only seven hundred and ten second-feet capacity, the later development by the Tennessee Power Co. on Ocoee River had a twelve hundred second-feet capacity. These were designed under the Stickney patents and are described in the Engineering Record of May 16th, 1914, page 567. A section of this spillway is shown on Plate II. Besides these, there have been only a few other siphons installed in the United States and there is no information available upon them at present.

2 Advantages of the Siphon Spillways.

The advantages of the siphon spillway were early recognized. The disadvantage of the ejector in a cold climate was eliminated by the automatic siphon. There was fear at first that the automatic siphon would freeze up but this proved groundless since in actual operation the siphon was much less liable to freeze and refuse to operate than any type of automatic or mechanically operated gates or equipment. The danger of becoming clogged by ice or debris was no greater than in the gate type of spillway. This danger is usually eliminated by having a small overflow spillway if any amount of debris must be permitted to pass the dam, by screening the entrance to the siphons, by putting the entrance far enough below the surface to prevent the entrance of debris, or by a combination of all three methods. If this is done the siphon is more reliable than any equipment other than the overflow spillway.

The second and greatest advantage is the greater quantity of water which can be controlled in the same space with the same variation in head. Economy of ground space and also of construction cost results on any siphon installation as compared with the overflow spillway. This is particularily evident where a small variation in head water level is required either by law or by the nature of the installation. The reason for the above statement is seen when the fact is known that the head available to produce velocity at the crest of the overflow spillway is simply the depth of water over the crest, whereas the head available to produce velocity in the throat of the siphon is theoretically the difference in elevation between head water and tail water surfaces (though not exceeding thirty-four feet which corresponds to a vacuum in the siphon tube). From this it is seen that the smaller the allowable variation the larger the advantage is for the siphon spillway. See Plate II for a definite comparison between the overflow and the siphon spillway. For a small depth of water on the crest the overflow spillway will have to be from three to ten times the length of the siphon spillway, which can contain a battery of siphons designed especially for small head water variations. This means a very great saving in construction cost. Also, the siphon spillway is particularly adapted for places where a long spillway is impossible because of topography. Another advantage lies in the quick response of the siphon to large variations in quantity, a necessary thing for power plant installations.

The advantage of the siphon spillway over metal gates, automatic or mechanical, is not so marked. The siphon has a smaller first cost and as ordinarily a dam must be built anyhow--it is much cheaper to build the siphons into the dam than to construct some elaborate steel gates and operating equipment. In addition, the siphon requires less maintenance and attendance, and if properly designed will probably give better service.

## 3 Reasons for Test.

Although siphons have been built for a number of years in both Europe and United States, nothing definite seems to be known as to the exact characteristics governing the design. No very good test data are available in either continent and even what can be found is general and not specific in nature. The formulae used in calculating a siphon are those ordinarily used in hydraulics:-

$$V = c\sqrt{2gh} \qquad Q = AV \qquad Q = Ac\sqrt{2gh}$$

Where V = velocity in ft/sec.

c = a constant.

A = area of smallest cross-section, usually the area of the throat.

Q = quantity in cubic feet per second.

This constant "c" would naturally vary with both the shape and the material of the siphon. It represents the efficiency and varies from .45 to .80 in data available, for which see drawings and test data.

Outside of this general total efficiency no other information is available. All siphons have been designed on the general principles of hydraulics--the one branch of science whose formulae always contain constants which have to be determined by test. Nothing is known of the relative head losses in the various parts of the siphon:- the entrance; the throat; the vertical, overhanging, or sloping (down spout); or the curved discharge end. Nothing, beyond a much expressed opinion, is known of the effect on efficiency of sharp edges on the inlet and discharge lips. The effect of the depth of submersion of the discharge lip upon both speed in priming and on the total efficiency is unknown. Another unknown relation is that between the depth of water running through the throat and the speed in priming, with various tail water elevations. The effect on efficiency of a contracting or an enlarging section is also unknown. Thus these various points seem to have been neglected in the desire to obtain the overall efficiency. This practice seems strange when it is considered that sometimes a very slight change in a part of a hydraulic machine will make a great change in efficiency. Such a practice of design or test is not dangerous since the siphon spillway will work satisfactorily under a great variety of conditions, whereas the overall efficiency is all that need be known to satisfy any guarantee as to performance. This method however, does not help in making the most economical design or in making a design to satisfy some additional specifications as to speed in bringing into operation, or as to a certain allowable variation in head water. All this great lack of valuable data leaves a wide and interesting field for test--a field, which so far as the writer has been able to find, has not been investigated.

4 Design Conditions.

With the decision made as to the desirability of making and testing a model siphon spillway, the first consideration was the plant available. The general design of the hydraulic laboratory and equipment is shown in Plate V.

The quantity available for continuous flow was about a maximum of three second-feet. This could be furnished by the centrifugal pump and the quantity measured direct on the 8" venturi meter. More water (perhaps one second-feet) was available if some other method of determining quantity was used. Abundance of storage capacity was available in the two cisterns, one six by ten by fourteen, the other nine and a half by fourteen by fourteen. The centrifugal could pump from either the large or small cistern whereas both steam and piston pumps must take water from the small cistern. A roof tank two by four by eight was available for a small amount of storage, principally to have water to prime the centrifugal. Extending from the steel pressure tank was a concrete tank two, by two and a half, by thirty feet long, with gates and a pipe leading back to the small cistern.

The conditions imposed by the nature of the tests desired were; --

1 - A number of models, or else a model whose shape

could be easily altered.

2 - Light weight as possible.

3 - A satisfactory method of attaching tubes for water or mercury columns to determine head at the various points on the siphon.

4 - A model with the friction or roughness coefficients the same as for the material used in the construction of a full size siphon.

5 Possible Solutions.

There were at least three possible solutions of the problem.

First method : A small model designed for two and a half foot head, to be built of thin reinforced concrete (wire lath reinforcement). This model to be placed in the concrete trough and water supplied by any or all three pumps.

Second method : A special metal-lined wooden tank to be constructed, fitted with wooden baffles, and set up at any desired elevation above the concrete tank. The water to be sent through the steel tank and a heavy canvas pipe up into the wooden tank. The models to be built of reinforced concrete or if preferred, of heavy galvanized iron reinforced for both internal and external pressure. Any or all pumps to be used.

Third method : A hole to be cut through the concrete wall between the two cisterns with a special dam fitted for connecting the models. The models to be made of either concrete or metal. Only the centrifugal pump available for pumping.

Method I

The advantages of the first method were as follows:- first, small models easily and cheaply constructed of concrete since the whole interior surface could be reached; second, all work out in the open air with consequent ease in reading water columns or gages and in making any necessary adjustments to gages or to the model itself; third, fairly long approach and discharge bed available and consequent close approach to an actual condition.

The disadvantages were:- first, too low a head to get enough velocity to note differences where small changes were made; second, the variations of head and tail water levels would be all out of proportion to the accuracy of the readings of interior points

Method II

Advantages:- first, a higher head than method I would be available, in fact any head desired could be obtained by raising or lowering the water in the concrete tank into which the model discharged; second, all gages, etc. would be at the correct level for easy reading; third, everything would be in the open air with consequent ease in reading gages, making changes in model or set-up etc.; fourth, either concrete or sheet metal could be used with equal ease; fifth, one man operation is possible.

Disadvantages:- first, a comparatively small wooden tank would have to be made, and with the great entrance velocity of a three second-feet quantity it is doubtful how quiet the water could be made by any number or design of baffles; second, the exit pipe from the steel tank is so small as to overload the motor driving the centrifugal pump if three second-feet were forced thru; third, a costly tank and model are necessary; fourth, the tank and model would likely have to be disturbed frequently for class work.

Method III

Advantages:- first, all apparatus set up could be left in place an indefinite time without being disturbed; second, a large body of water at both entrance and discharge ends would aid in keeping the water quiet and consequently give more accurate readings of the total head; third, most of the water could be sent down the turbine draft tube and therefore cause no splash; fourth, concrete tank available for storage and for slow discharge of a small quantity; fifth, cheaper method than method II.

Disadvantages:- first, a hole two foot square would have to be cut in twelve inch concrete and several scaffolds would have to be erected; second, poor light and air due to almost completely closed cistern; third, inconvenient method of getting in and out of the large cistern and of getting the model in and out through the small cistern; fourth, only the centrifugal pump could be used; fifth, two man operation or else a great number of trips in and out of the cistern necessary.

Considering the above advantages and disadvantages along with the fact that time and accuracy were more important than any other considerations, method I was eliminated on account of the probable lack of accuracy of results. Methods II and III were very equal but it was finally decided that the probable greater accuracy and the ability to leave the apparatus set up indefinately in method III outweighed the advantages of method II. It was afterward found that the results obtained would have been almost impossible had either of the other methods been used.

Concrete and sheet metal were both considered as materials for the construction of the model. Concrete had the advantage in that it had the same friction constants as the full size siphons, and also the advantage that it required no special bracing to keep the model from bulging or collapsing. It had the disadvantages that it was heavy and liable to crack and develop air leaks, that it was difficult to make a satisfactory connection for the tubes for the water columns, and that a number of models would have to be made. Another very important disadvantage of concrete was the time which would have been necessary to construct and cure the models. This time was not available.

Sheet metal had the advantage in that a design could be made which might readily be altered in shape in one direction, that it was light, and that very satisfactory water column connections could be made. Its disadvantages were higher cost, and the fact that heavy metal with strong side bracing was required to prevent bulging or collapsing. A great disadvantage for sheet metal was the fact that the friction constants were different from concrete (although relatively the same for any group of medels). The relative losses were the most important however, in the proposed tests.

From the above reasons it is evident that if time were available, a more truly representative test could probably have been made with carefully constructed concrete models. However, since time was a very important consideration, the sheet metal was used for the model.

6 Calculations for Design.

Given quantity available = 3 sec/ft.

Assume a 7' head.

" 60% efficiency.

Formula $Q = Ac\sqrt{2gh}$

$Q = 3$ , $c = .60$

A or area of throat = $\frac{Q}{c\sqrt{2gh}}$ .

$A = \frac{3}{.60 \times 8.025 \times \sqrt{h}}$ .

$= \frac{5}{8.025\sqrt{7}}$

= ~~2.36~~+ .236 ft$^2$ = 34 in$^2$

Q = quantity.

A = area of throat

g = acceleration of gravity, 32.2

h = head

c = efficiency exp. as a decimal.

To allow for a higher efficiency a section $2\frac{1}{2}$" x 12", equal to 30 square inches in cross-section, was chosen for the throat. With this as a basis and seven foot as the approximate head, the design was made as shown on Plate IV.

Some explanation is necessary as to certain features of the design. It was decided that a uniformly enlarging cross-section of the downspout would be used at first, the size being cut down in steps to a uniform and finally to a converging section for different tests. This could best be accomplished by having the section as shown, a form which could be easily soldered or loosened, and which would leave a smooth surface inside (from enlarged to contracted section). The edges of the top and bottom plates were turned out about 5/8" and cut wherever necessary for curves while the side plates extended a minimum of 7/8" beyond the inside line of the siphon, thus leaving at least 1/4" clearance to aid in running the solder under the edge of the plates. The collar around the throat of the siphon is designed to fit against rubber flaps on a wooden block cut to fit the siphon and the iron frame in the concrete wall. This prevents excess leakage when the head water is above the dam. A detail drawing of this connection and the top support of the model is shown on Plate V.

The water column connections, 11 in number, are short 3/8" brass tubes soldered to the side of the siphon on the C.L. of the section. The holes were drilled to the exact inside diameter of the tube and carefully filed, flush with both the inside of the tube and the inside of the siphon. Such an arrangement would give the true reading of the pressure at the point of connection with the siphon.

The joints at the top of the body of the siphon were necessary due to the size of stock and were made as smooth as possible on the inside of the siphon. Those in the side plates were riveted (and soldered) lap joints while those in the upper and lower plates were the ordinary rolled joints.

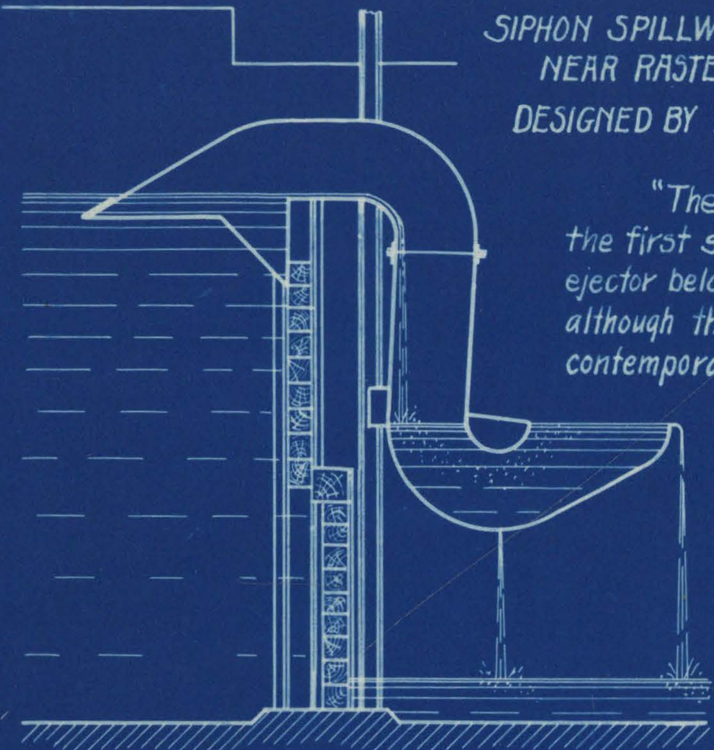
Straight lines were used wherever possible in the design to facilitate the bending of metal and the ease of construction of the model. In the completed model a mistake had been made as to the spacing of some of the water column connections. Just how well these and other dimensions check with those of the design is shown on Plates IV and V and Data Sheet II.

It was expected that braces would have to be placed on the broad faces of the model to resist suction in the upper part of the model and to resist pressure in the lower part. A first test proved that this was necessary so eight braces spaced about six inches apart and composed of bent-up "T's" were soldered upon the upper 2/3 of the model as shown by the photographs. The lower 1/3 was braced on the sides by two boards bolted across the model, one extending to the bottom of the tank as a support to the siphon. With this arrangement the model proved entirely satisfactory.

The total cost of labor and materials upon the metal model was about twenty-two dollars ($22.00).

SIPHON SPILLWAY ON AN IRRIGATION CANAL NEAR RASTENBURG - EAST PRUSSIA

DESIGNED BY MR. J. HEYN, EN'GR, STETTIN.



"The credit for having constructed the first siphon spillway without an ejector belongs to Mr. J. Heyn of Stettin although they were developed almost contemporaneously by Gregotti in N. Italy."
Adolf Ludin - Eng. News 4-20-1911.

This siphon is built of riveted sheet iron and fixed on a floodgate in the irrigation canal. It is of rectangular section $1\frac{1}{2} \times 10\frac{1}{2}$ ft. The head of water available, $4\frac{1}{4}$ ft. gives a discharge of 130 sec. ft. - efficiency 50%.

FIG. I.

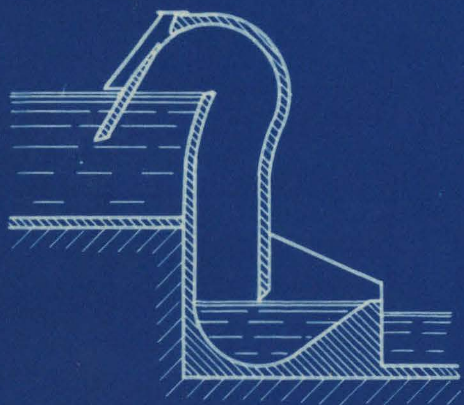


FIG. 2.

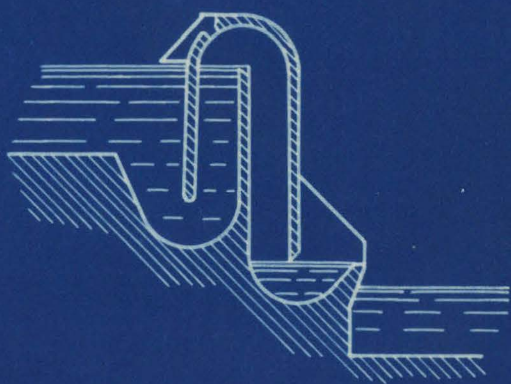


FIG. 3.

TYPES OF SIPHON SPILLWAYS BUILT BY GREGOTTI IN ITALY

Fig.2 shows the section of one of a set of 10 units on the Milan Canal near Verona, Italy. Each siphon has a cross section of 14 sq. ft. With a working head of 20 ft. each siphon discharges 285 sec. ft. This corresponds to an efficiency of 41%.

Reference: Eng. News. April 20 1911 - Page 467.

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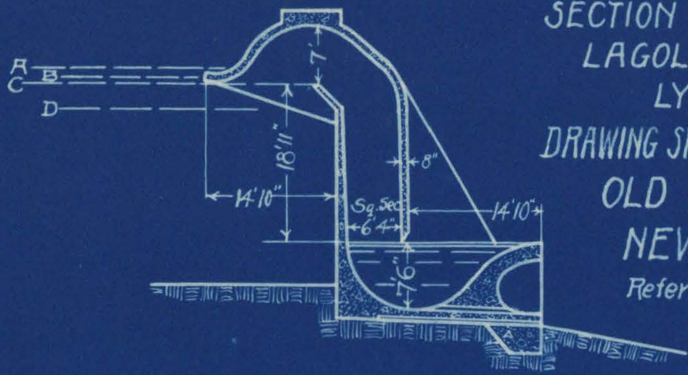


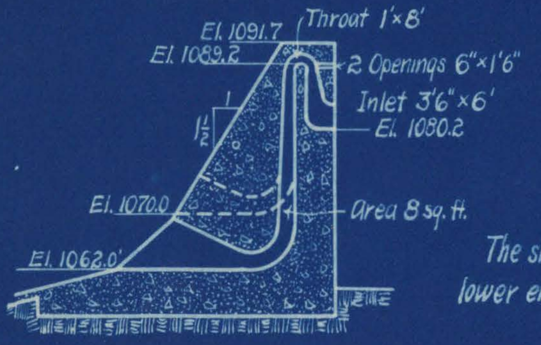

## SECTION OF SIPHON SPILLWAY AT LAGOLUNGO RESERVOIR IN LYBIA (TRIPOLI)

DRAWING SHOWS MAX. & NORMAL SURFACE ELEV. WITH OLD OVERFLOW SPILLWAY AND NEW SIPHON SPILLWAY

Reference:- Transactions of Int. Eng. Cong. 1915 Waterways & Irrigation P. 587.

A = Max. Level With Old Overflow Spillway 717.40 Meters.
B = Max. Level With New Siphon Spillway 717.05 Meters.
C = Normal Level With New Siphon Spillway 716.95 Meters.
D = Normal Level With Old Overflow Spillway 716.00 Meters.

Variation of Level with siphon = .1 M = 4" — with overflow = 1.4 M = 55" Ratio 1:14
Although having 14" lower max. elevation the higher normal elevation causes an increase of 10½ million cu. ft. in the available storage.




## SECTION OF SIPHON SPILLWAY ON OCOEE RIVER - TENNESSEE

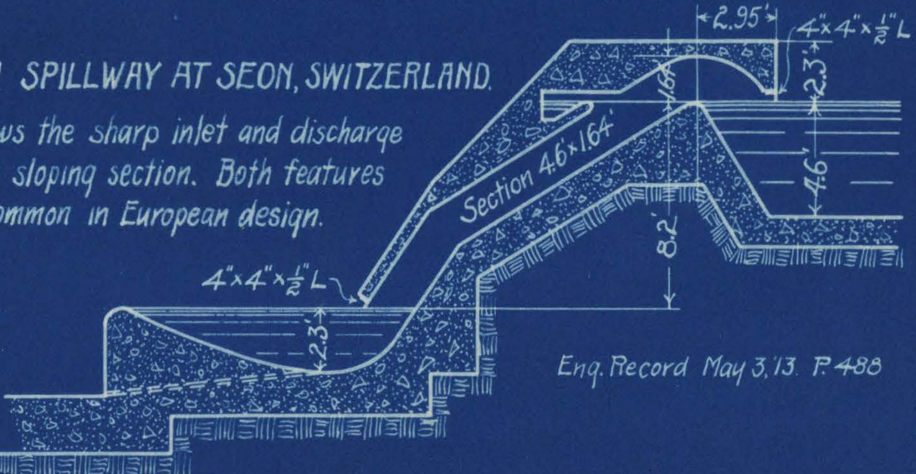
Designed under Stickney & Davis Patents BY J. G. White Eng. Corp. N.Y. City

Reference:- Eng. Record May 16,'14., P. 567

The short siphons (dotted) are never submerged at the lower end. The long siphons gave Efficiency of 62% on test

## SIPHON SPILLWAY AT SEON, SWITZERLAND.

This shows the sharp inlet and discharge lips, and the sloping section. Both features are quite common in European design.




Eng. Record May 3,'13. P. 488

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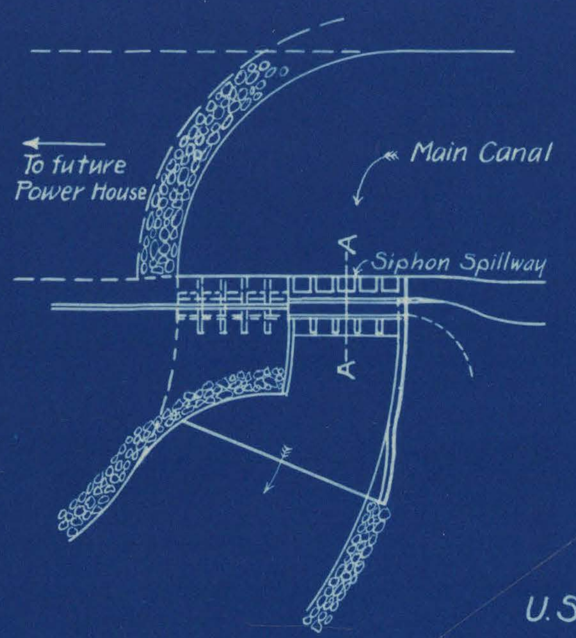
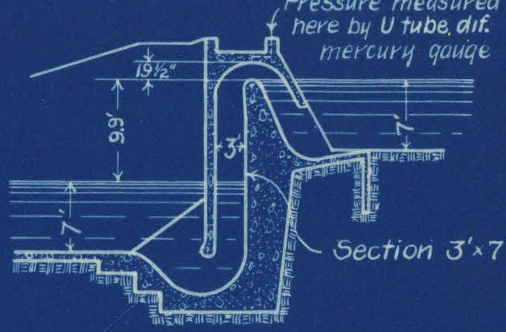
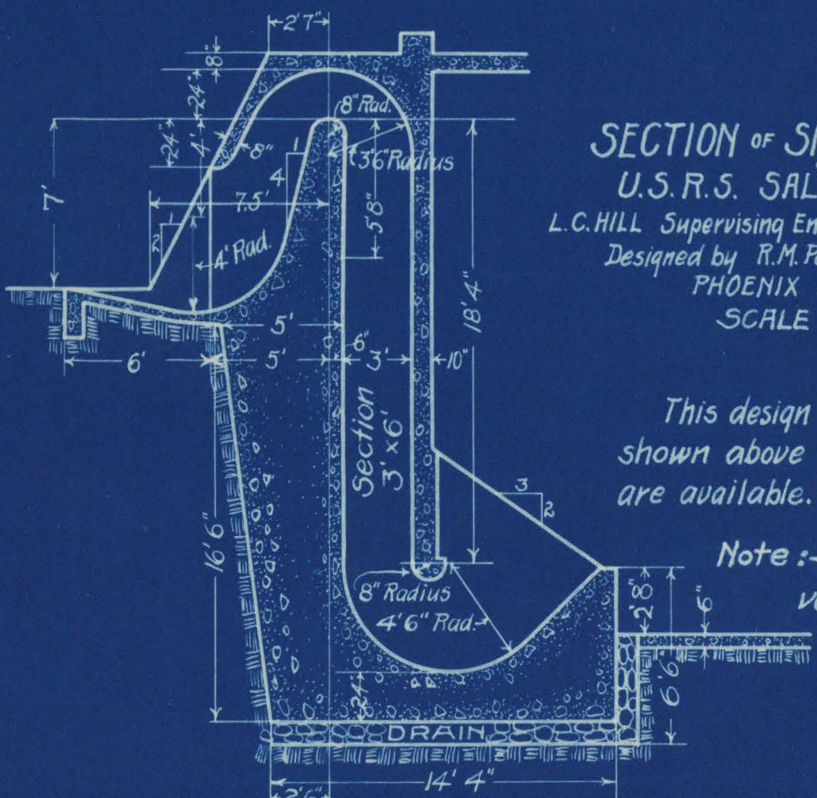



Section A-A

## SIPHON SPILLWAY ON U.S.R.S. YUMA PROJECT

See Data Sheet 1. for record of test.




## SECTION OF SIPHON SPILLWAY ON U.S.R.S. SALT RIVER PROJECT

L.C. HILL Supervising Eng. C.H. FITCH Project Eng.
Designed by R.M. Peabody Dec. 15 1911
PHOENIX ARIZONA
SCALE $\frac{1}{8}$"=1'

This design is very similar to that shown above for which test data are available.

Note :- Special control valve not shown.

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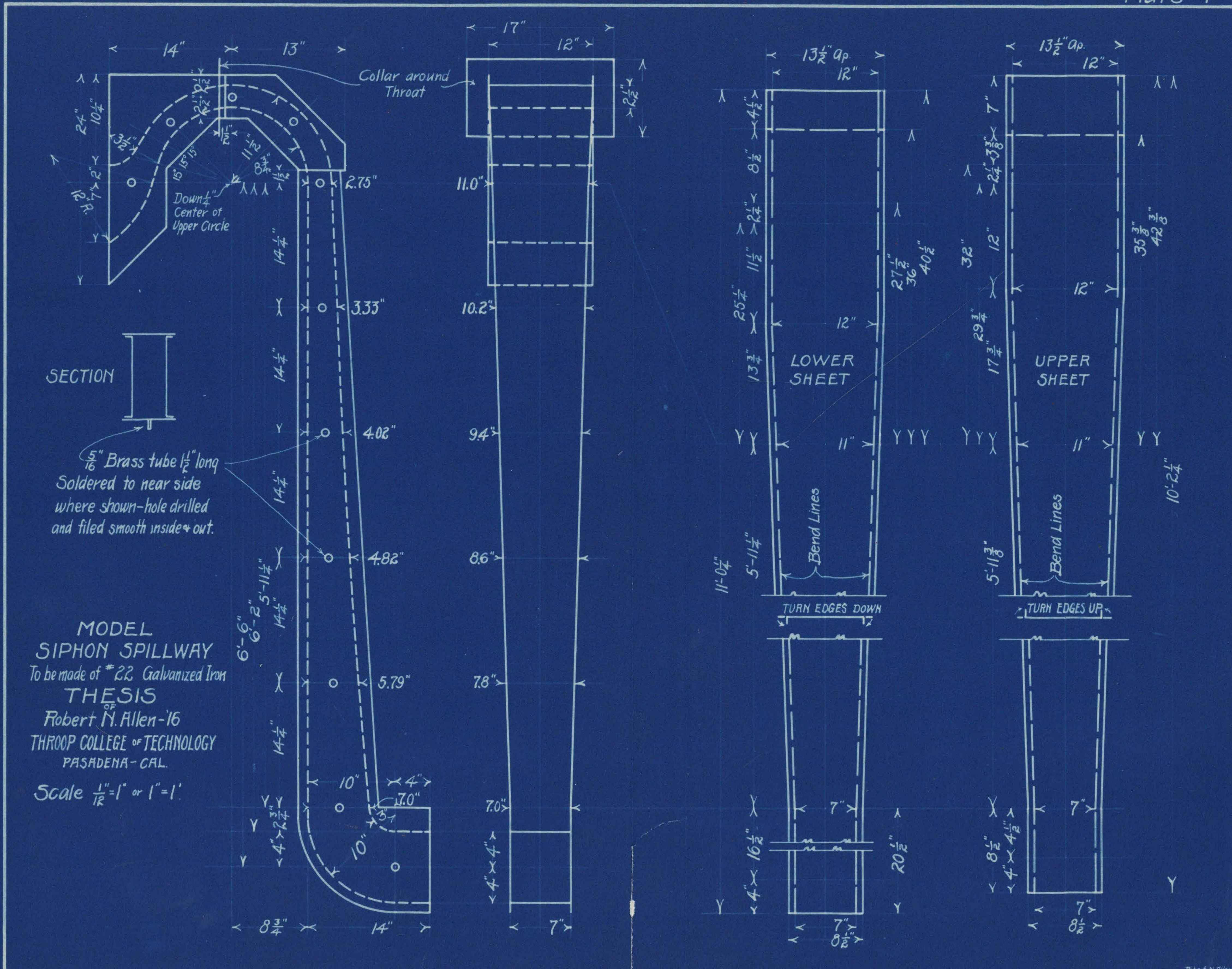
Collar around Throat
Down 1/4" Center of Upper Circle
SECTION
5/16" Brass tube 1 1/2" long Soldered to near side where shown-hole drilled and filed smooth inside & out.
MODEL
SIPHON SPILLWAY
To be made of # 22 Galvanized Iron
THESIS
OF
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PASADENA-CAL.
Scale 1/12"=1" or 1"=1'.
LOWER SHEET
UPPER SHEET
Bend Lines
TURN EDGES DOWN
TURN EDGES UP
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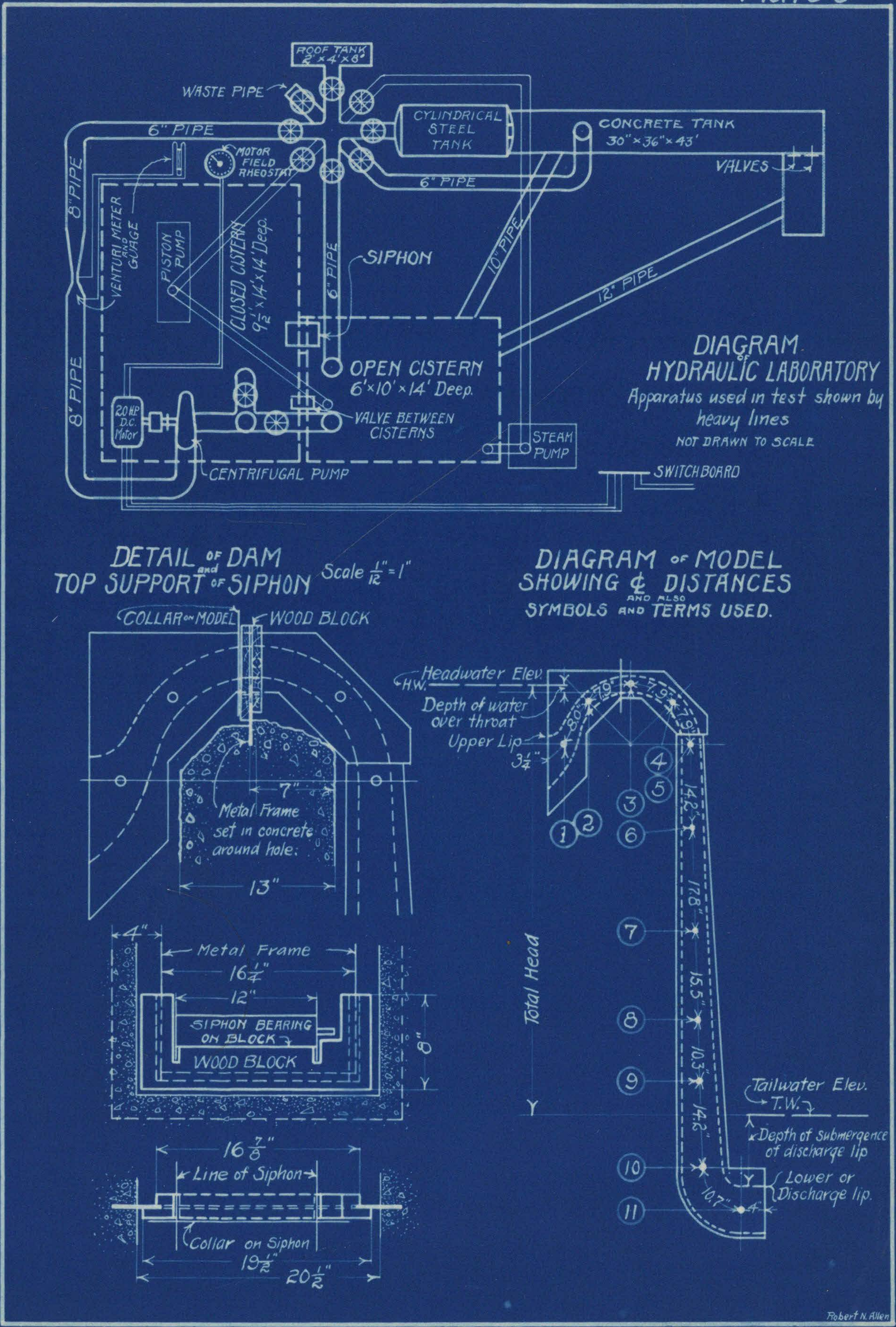
Plate 5


ROOF TANK 2'×4'×8'
WASTE PIPE
6" PIPE
8" PIPE
MOTOR FIELD RHEOSTAT
CYLINDRICAL STEEL TANK
CONCRETE TANK 30"×36"×43'
VALVES
6" PIPE
VENTURI METER AND GUAGE
PISTON PUMP
CLOSED CISTERN 9½'×14'×14' Deep.
6" PIPE
SIPHON
10" PIPE
12" PIPE
OPEN CISTERN 6'×10'×14' Deep.
20 HP D.C. Motor
VALVE BETWEEN CISTERNS
STEAM PUMP
CENTRIFUGAL PUMP
SWITCHBOARD
DIAGRAM OF HYDRAULIC LABORATORY
Apparatus used in test shown by heavy lines
NOT DRAWN TO SCALE
DETAIL OF DAM AND TOP SUPPORT OF SIPHON
Scale 1/12" = 1"
COLLAR ON MODEL
WOOD BLOCK
7"
Metal Frame set in concrete around hole.
13"
4"
Metal Frame
16¼"
12"
SIPHON BEARING ON BLOCK
WOOD BLOCK
8"
16⅞"
Line of Siphon
Collar on Siphon
19½"
20½"
DIAGRAM OF MODEL SHOWING ℄ DISTANCES AND ALSO SYMBOLS AND TERMS USED.
Headwater Elev.
H.W.
Depth of water over throat
Upper Lip
3¼"
Total Head
Tailwater Elev.
T.W.
Depth of submergence of discharge lip
Lower or Discharge lip.
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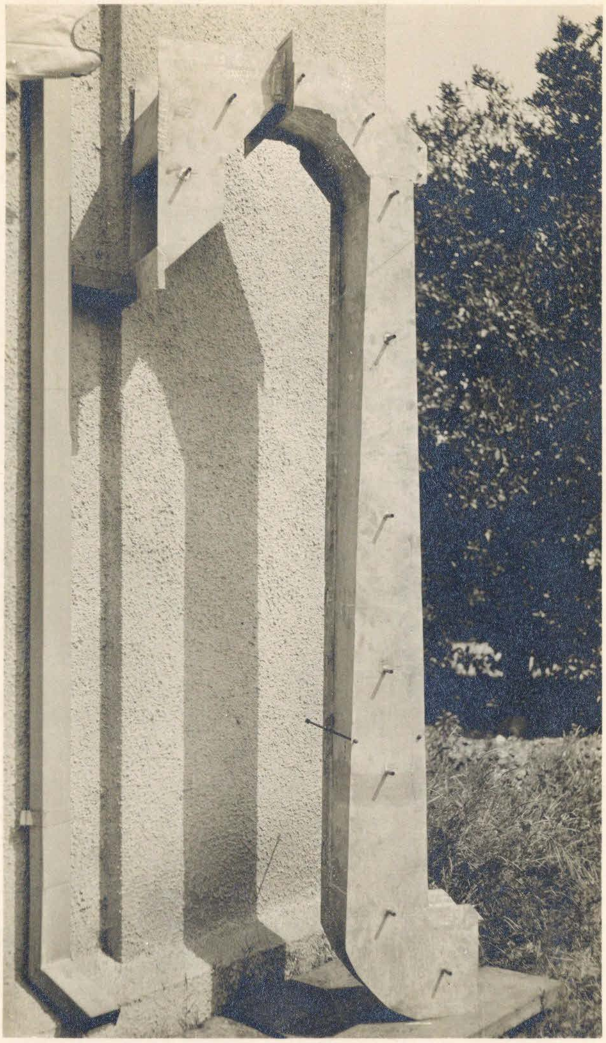
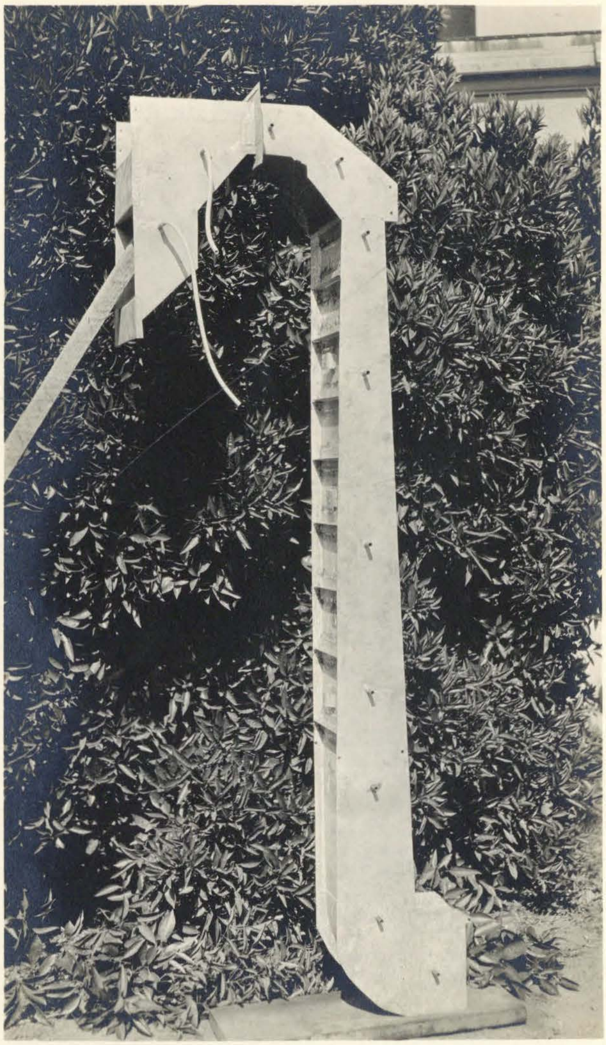


MODEL BEFORE BRACES WERE ADDED

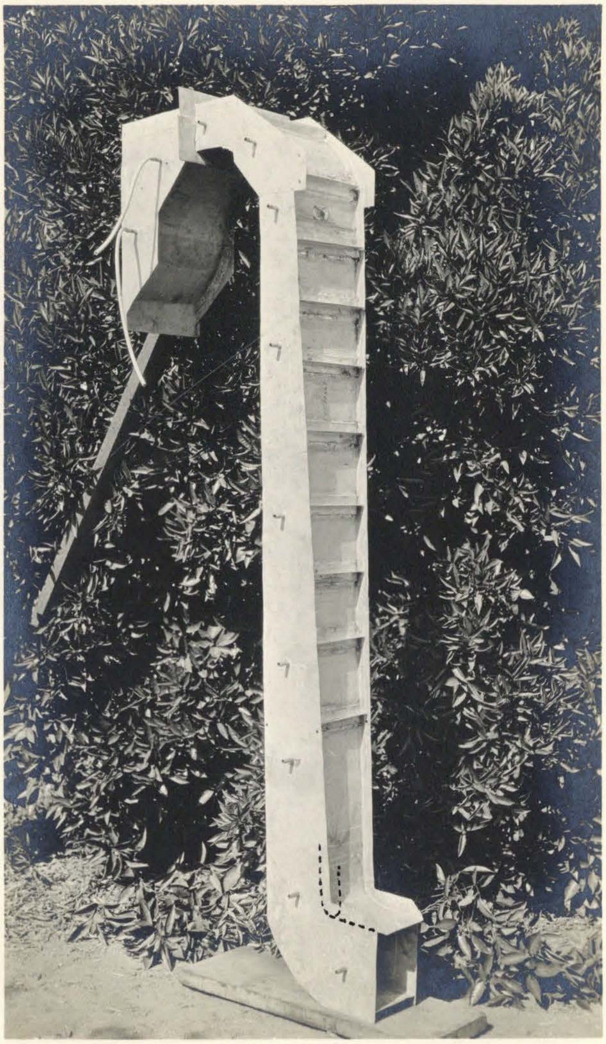
The two small rods shown at about $\frac{1}{4}$ way up the picture were used to clamp boards to the sides of the siphon to prevent bulging (in lower third). One board extended to the bottom of the cistern to help carry the weight of the siphon.



MODEL SIPHON READY FOR INSTALLATION

INLET SIDE

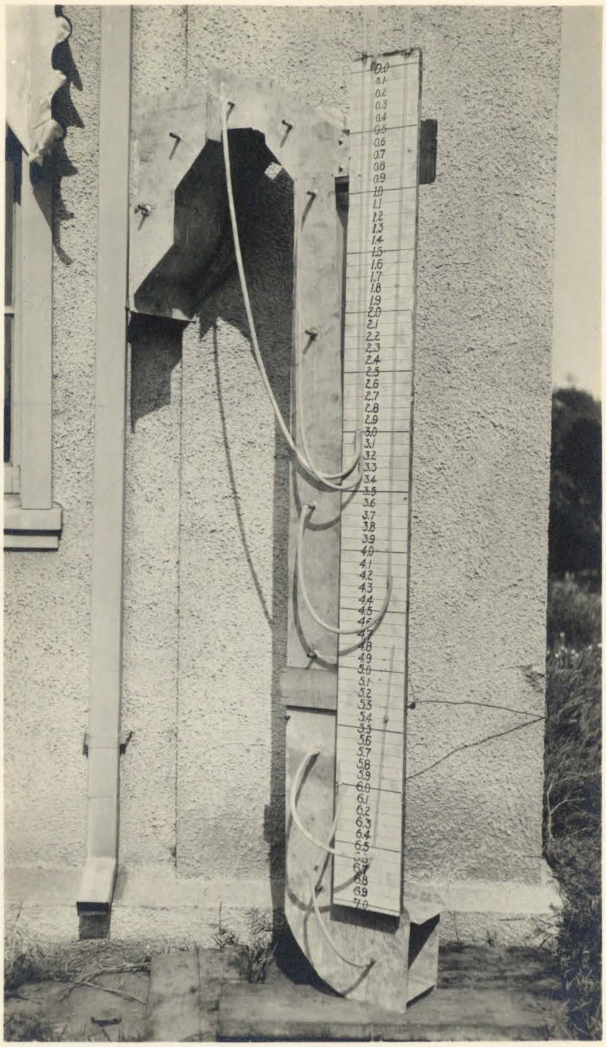
This shows the ⊥ braces which were added to the model to prevent collapsing due to the pressure being below atmospheric inside of the siphon when in action.



MODEL SIPHON READY FOR INSTALLATION

DISCHARGE SIDE

Dotted lines show approximately the shape of the discharge lip for Models I & II. The pictures show Model I.



MODEL SIPHON
WITH
GAUGE BOARD
AND
SEVERAL WATER COLUMNS ATTACHED

## Part II .. Tests.

### 1 - Object of Test.

The definite objects of the tests were to determine the following :-

1 - The relation between the depth of submergence of the discharge lip and the depth of water over throat to bring the siphon into action under various air inlet conditions.

2 - The relation between the depth of submergence of the discharge lip and the speed in priming with various depths of water over the throat and various air inlet conditions.

3 - The relative and actual head lost in various portions of the siphon.

4 - The effect of various shapes of parts of the siphon upon head lost in that part and upon the total efficiency.

5 - The total efficiency of the different shaped models, i.e. the constant "c" in the formula $Q = cA\sqrt{2\ gh}$.

6 - Any other relations which might become apparent during the test.

* * * *

### 2 - Apparatus.

Plate V shows the position of the model during the test. The inlet end of the siphon extended over the dam into the small cistern. A suspended platform was built in this cistern for use in placing and removing the model. The discharge end, all water columns and scale board were in the large covered cistern. Here a platform and bench were built above reach of the water. The photographs show the water column connections and the scale board to which the tubes were attached. The weight of the siphon and contents when running was carried partly by the throat resting upon the dam as shown in Plate V, and partly by a wooden brace bolted to the inside of the siphon and resting on the bottom of the cistern. Water columns were of 5/16" glass tubing connected by 5/16" rubber tubing to the plugs on the siphon. These tubes were suspended by strings from nails on the scale board. The connection was made ajustable by having the strings under a rubber band (short piece of tubing); the strings could be lengthened or shortened by pulling them through the rubber band or the rubber band could itself be moved.

At several points water columns could not be used because of pressure heads lower than atmospheric (i.e. the water column went below the surface in the tail water). At these points "U" tubes of mercury were used on several tests and later these were replaced by inverted water columns which measured the pressure below atmospheric directly in feet of water.

Water for the test was supplied by the centrifugal pump driven by a twenty horse power, direct connected D.C.

motor with adjustable field control and therefor any desired speed within quite a large range. The quantity was measured directly on an 8" Venturi meter in the 8" pump line. As much water as possible was sent through the turbine draft tube, the rest going around through the concrete tank and back into the small cistern. All pumping was directly from the large cistern (tail water) through the Venturi meter, and into the small cistern from which it was drawn by the siphon.

When small quantities were desired the concrete tank was filled and slowly discharged. The amount of flowing (although not desired in any tests made) could be calculated by the known time and the drop in water level. It was at first feared that trouble in making an exact determination of the quantity flowing through the siphon might result through the shifting of storage from one cistern to the other. This fear proved groundless because the very rapid and continuous flow caused the water to quickly assume a level which remained constant.

A later addition to the equipment was a small air valve attached to tube (4) to let out the air entrained in the siphon by the rise of water--shutting off automatically as soon as the suction started. Another addition was a gate over the inlet opening which could be opened at will. This was simply a weighted board with rubber flaps to help make a fairly water tight gate.

Only one slight change was made in model I, but the altered model was called model II. Referring to Plate IV it will be seen that the discharge lip was to extend 4" beyond the last tube (11) on the siphon. Actually, this was about 5". Also, this lip was supposed to be level from point (11) out to the edge. This actually sloped downward about 3/8" in that distance. Thus, due to the shape of the lip, any entrained air in the siphon had to be carried down 1.7" and out about 8" from the edge at tube (10) before it could escape. This was in model I.

In model II this lip was unsoldered back to the bend and bent up on a $1\frac{1}{2}$" radius. It then exactly resembled the discharge lip shown in the lower section on Plate III. Entrained air in this case would only have to be carried down 1-1/8" and over 1-5/8" from the edge at tube (10) to be released. It will be noted in the test data that no reading is given for tube (11) on model II. This is due to the fact that there is no section for which this may be considered a center.

3 Methods of Test and Formulae Used.

There were four air inlet conditions under which tests were desired to show the relations stated in objects 1 and 2. These were:- one tube (No.4) open, one tube open until the water starts over the throat, all tubes closed, and lastly tube (4) fitted with the air valve above-mentioned. The first of these would be the equivalent of any siphon where an air vent was left open continually. The last would be similar to any siphon where this same air vent was fitted with an air valve to prohibit sucking air. The second, with all tubes closed as soon as water starts over the throat, is the equivalent of practically all siphons yet constructed since almost all seal just as soon as, or shortly after, the water starts over the throat. The third, with all tubes closed and the inlet lip extending down into the water is illustrated by the section Figure I, Plate I, and by the sections shown on Plate III. These on Plate III, however, do not work upon this principle since they have an adjustable steel inlet (not shown on drawings) which with a small ejector attachment, enables the siphon to be primed at will regardless of the head water elevation.

Method of Test for Object 1.

The method of test to obtain the relation between the depth of submergence of the discharge lip and the depth of water over throat to bring the siphon into full action was to let the water out slowly from the concrete storage tank, thus causing a gradually increasing depth of water over throat. Then, under one or the other of the conditions named above, readings of head water elevation (H.W.) and tail water elevation (T.W.) were taken for the condition at which the siphon primed. Knowing the gage reading for the edge of the throat and for the discharge lip (see Data Sheet 2) the depth over throat and the depth of submergence of the discharge lip could be found. The results were plotted and as the curves took shape, special points desired could be taken and the curve filled out. Anywhere from one to five or more readings could be taken before the concrete tank needed to be refilled. Data taken by this method and curves obtained are shown on Data Sheets 3, 4, and 5; and on Curve Sheet 1 for model I and upon Data Sheets 8, 9, 10, 11, and Curve Sheet 1a for model II.

### Method of Test for Object II.

The method of test to determine the relation between the depth of submergence of the discharge lip and the speed in priming with various depths of water over the throat was almost the same as for Object I. The only difference was that the inlet gate was closed until the desired depth over throat was reached and then opened, the time in priming being the only additional reading. Readings were only taken under two of the air inlet conditions, that of one tube open and that of all tubes closed as soon as the water started over the throat. A method used to some extent ~~on~~ under the one hole open condition was to blow back into the siphon, this extra air keeping the water from coming over the throat until the desired H.W. elevation was reached and the tube opened. This method proved to be just as satisfactory and gave the same results as that of opening the inlet gate.

For all readings under the closed over throat condition, tube (4) was not closed until the first trickle of water over the throat was heard. This took place at a slightly higher (.005') reading than the gage reading for the edge of the throat.

Data taken by this method and curves obtained are shown on Data Sheets 6 and 7 and on Curve Sheets 2 and 3 for model I, and on Data Sheets 12 and 13 and on Curve Sheets 2a and 3a for model II.

3 Method of test for Objects 3, 4, and 5.

These tests required that the siphon be run at full capacity. This proved to be almost impossible since the actual efficiency of the model (expressed as indicated above in the design) was about 1.4 times as large as the 70% design efficiency. Thus to supply the required quantity of water through the small pipes, the motor driving the centrifugal had to be heavily overloaded. Such a condition made it imperative that the test last no longer than 15 or 20 minutes without great danger of overheating the motor. To balance this, however, it was found that the quantity of flowing water remained constant and that a condition of equilibrium was quickly established.

The operation was as follows;- the pump being started and the siphon running full capacity, the water columns were tested to see that they were full of water or air as the case happened to be. The inverted columns, "sucking" water from the T.W. level, had to be lifted out and allowed to completely fill with air. Then, by pinching the rubber hose, the tubes were gradually allowed to fill with water to the height registering the pressure head (below atmospheric) at the point of attachment to the siphon. With all columns in working order, readings of quantity, H.W. and T.W. levels, and gage heights of all water or mercury columns were taken. All these were checked one or more times and when a small difference resulted, the average of the readings was taken as final.

Readings were taken with both "U" mercury tubes and with inverted water columns on Model I with several different heads and quantities. The data and the calculations therefrom are shown on Data sheets 14, 15 and 16 for Model I and on Data sheet 17 for Model II. Only one test of this type was run on Model II due to lack of time.

The head losses and the total efficiency were calculated from the experimental data in the following manner:-

Let A = the cross-sectional area in square feet of any section as determined by careful measurement. See Data Sheet 2.

V = the velocity in feet per second at any section.

Q = the quantity flowing through the siphon expressed in second feet (cubic feet per second).

G = the gage reading for the point itself--see D.S.2

R = the gage reading for the water column at the point

Z = the height of center of section in question above some assumed elevation, in this case tube (10) whose gage reading was 7.00.

H = the total head to produce velocity (difference in elevation between headwater H.W. and tailwater T.W.)

c = a constant = the efficiency when expressed as a per-cent.

g = the acceleration of gravity = 32.2

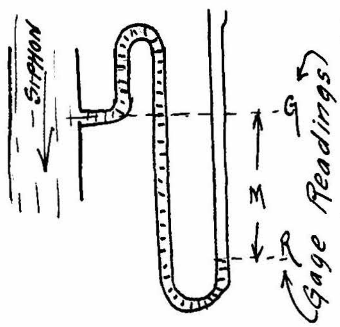
$\frac{P}{w} = \frac{\text{pressure in lbs. per sq. ft.}}{\text{weight of water per cu. ft.}}$ = pressure head in feet at section.

Knowing A and Q, V is found by the equation, Q = A V.

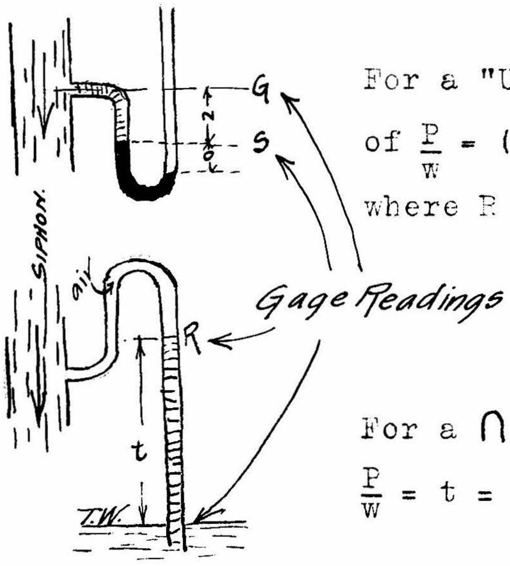
Also from Bernoulli's Equation of the conservation of energy and continuity of flow -

press. $\text{head}_1$+ vel. $\text{head}_1$+ static $\text{head}_1$= press. $\text{head}_2$+ vel. $\text{head}_2$+ static $\text{head}_2$+ lost head

$$\frac{P_1}{w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + Z_2 + \text{Lost head}$$




Now $\frac{P}{w}$ for any section with a "U" water column = M = G ± R, R being the larger since O on the gage is at the top. This means that the value of $\frac{P}{W}$ is negative for the case shown.




For a "U" tube of mercury the value of $\frac{P}{w}$ = (for negative prssures) G - R, where R = Gage reading S + 13.59 x O.

For a ∩ tube , water column (inverted) $\frac{P}{w} = t = R - T.W.$

For any section $Z_x = G_{10} - G_x = 7.0 - G_x$ .

Substituting these values--the value of $\frac{P}{w} + \frac{V^2}{2g} + Z$ was found for each section. The difference between any two values was the true value of the lost head in the section between the two. The total of the lost heads between the successive sections + the velocity head in the discharge must equal H, the total head.

Due to the apparent irregularity of the results, only a rough comparison was made to formulae for head lost at entrance, by bends and by pipe friction.

Common formulae for these are -

Head lost at entrance $= .5 \frac{V^2}{2g}$

Head lost by bends $= c \frac{V^2}{2g}$, c det. by exp. and varying with the ratio--diam of pipe to radius of bend--and with the angle of the bend.

$$\text{Head lost by friction} = f\,\frac{l}{d}\,\frac{V^2}{2g}$$

$$= f\,\frac{l}{4r}\,\frac{V^2}{2g}\text{, where } r = \text{hydraulic radius.}$$

The constant "c" or the efficiency expressed as a decimal can be found as follows :

$Q_{theoretical} = A\sqrt{2gH}$, where A = area of throat or smallest section.

$$\frac{Q_{actual}}{Q_{theoretical}} = c = \frac{Q_{actual}}{A\sqrt{2gH}}$$

Besides the readings with the tubes all closed, the readings of Q, H.W., and T.W. were taken once with tube (4) open to show the decrease in efficiency due to an air leak near the throat of the siphon.

## 4. Conclusions.

Shortly after the tests were started, it was found that it was going to be impossible to make more that a few tests on one or two shapes of the model in the time available. Therefor, knowing that the determinations of the relative head losses in positions of the siphon required a number of different test$ shapes for comparison to obtain definite results, it was decided to spend most of the time on the relations regarding priming conditions. These were therefor worked out carefully as inspection of the Curve Sheets will show.

As stated before, nothing definite was known about the priming relations. Therefor, as the data were obtained and plotted as outlined in "Method of Test for Objects 1 and 2", results were obtained which were both interesting and surprising. The first curves obtained were shown on Curve Sheet 1. The curves on Curve Sheets 1 and 1a are really the lines dividing the region of possible conditions into prime and probable no prime areas. For any point below the curve the chances are that no prime will result for that condition no matter how long it is maintained. For the conditions as shown by any point above the curve a prime will result--the greater the distance above the shorter the interval before a prime starts. As indicated by the points near the curve, there is a doubtful region close to the curve where sometimes there is a prime and sometimes not,

The most surprising feature on Curve Sheet 1 is the close approach of the one hole open curve to a straight line parallel to the base. The ordinary theory of the priming of a siphon has been that of gradually exhausting some air under the discharge lip--a rise in headwater inside, etc. With one hole open there can only be a very slight pressure below atmospheric inside the siphon. Indeed, with the water rising in the throat, it looks as though there would always be a slight compression inside. This is true of course up to a certain time, just when or where it is not known, but at some time, at a very definite height as shown by the curves, this must be changed to a slight suction by the rush of water, and almost instantaneously the siphon starts.

The second surprising feature was the ease with which the siphon primed with the discharge lip out of water .1', .2' and so on as indicated by the negative depths of submergence of the discharge lip. This also seemed to be contrary to the air ejection theory since with few exceptions everybody believed that the discharge lip had to be submerged to produce a seal through which air could be ejected. These tests prove conclusively that a seal is not necessary on a small model, and coupled with this is the fact that the full size siphon on the Ocoee River in Tennessee --see Plate II-- does not require a seal. There might be an objection to the above statement because of the fact that the discharge end of the Ocoee River siphon as well as that of Model I were shaped so as to form a more or less effective seal with a small amount of water. The Model II curves overcome this objection since it is seen that an even smaller depth over throat is required for a discharge lip like that shown on Plate III and on the photograph of the model. Just why a smaller depth is required on Model II is unexplainable--perhaps it is caused by a varying speed of rise in H.W. The fact is that the few points available show Model II curves lower with a very small opening whereas when the discharge lip is .3' out of water the curve is higher. This seems fairly reasonable since it seems that with such a slight chance of the falling water filling the horizontal section at the discharge lip, atmospheric pressure would exist higher up from the discharge than with a longer curved discharge end. The reason why a prime takes place is easily seen. As the water rises there is no air cushion for it to push against, as when the discharge lip is submerged. As soon as water starts over the throat it starts a sort of plunger or friction action or both to push some air out the bottom. This undoubtedly slightly reduces the pressure at the throat, the water rises slightly and the familiar process builds up until the siphon is primed.

The curves for the closed over throat condition are more truly representative of present siphon conditions than the others since practically all of the siphons seal just before, just as, or slightly after the water starts over the throat. These curves show, better than words can describe, the relation between the depth of submergence of the discharge lip and the depth over throat required to prime. The curve with all tubes closed simply represents a very extreme case--i.e. where the air vent is covered long before the water starts over the threat. The variation of both from the curve of one tube open is much greater than would be expected, especially since this closed over throat condition has been so universally adopted. The explanation for the great depth over throat required is that as soon as the water starts to trickle over the throat everything is sealed and any further rise inside the siphon means compression. The success of priming depends upon a large enough stream falling through to entrain air and eject it under the discharge lip. Also, the deeper the submergence of discharge lip the larger size stream required to eject any air. This simply means that the deeper the submergence of the discharge lip the greater the depth over the throat to prime. That the distance which this entrained air must be carried horizontally has also an effect on the depth required is seen by the fact that the curves of Model II are uniformly lower to the right of the O line than those of Model I.

The additional curve on Curve Sheet la was taken with a small air valve. It was thought that perhaps better priming conditions might be obtained with an air valve which would permit the escape of air from the siphon and close as soon as suction began. This was desirable principally because of the fact that the curve with one hole open would be the most satisfactory for starting whereas as shown by Data Sheet 16 it would be the least desirable for efficiency. This air valve was supposed to give the advantages of both. The curve is above the one hole open due almost entirely to the fact that the small surface tension in the water sealing the rubber flap was enough to cause a slight compression inside of the siphon. The idea is worth trying on a large siphon if it will give even as good results as in this test. The one objection to its presence would be that it might freeze or get out of order and that it would be a working part to a piece of construction which owes some of its success to the lack of moving parts.

A better method, one which appears to have been used to a slight extent by Gregotti in Italy (see Plate I, fig. 2 and 3 and Plate II, top drawing) is to have the inlet lip (air or water) raised above the elevation of the throat so that .1' of water is flowing over the throat before a seal results. It is believed that this will give better starting conditions.

The curves on Curve Sheets 2 and 3 are self explanatory after the above discussion. Both sets of curves show the very small range between the no prime and almost instantaneous prime where the discharge lip is just a short distance above or below T.W. surface. Both sets show the lower values on Model II. This is most marked on Curve Sheet 2a. Two seconds is the minimum time shown, this being practically the time which it took the wave of water to pass through the siphon. The surprising point is that the siphon primes in all cases in shorter time and at lower depths of water over the throat when the discharge lip is uncovered than when it is covered a similar distance. Therefor, this leaves no room for doubt that a prime results better and quicker without a seal. This seems contrary to what would be expected, and only actual tests will show whether this fact is equally true with large models. Just an indication that this might not hold good is the fact that with Model II the action at the start occasionally went by jerks for 2 or 3 seconds before a full unbroken discharge resulted when the discharge lip was .2' to .3' above the T.W. It is believed that this resulted from air finding its way under the discharge lip due to the siphon not flowing full. This reduced the suction and caused the column to partly break and then start again. With Model I this did not take place. This action gave reason to suspect that the siphon action would break sooner on Model II than upon #I when the discharge lip was uncovered. It was found that this was not so--the siphon action usually broke shortly before it started sucking air at the inlet. This point was the same for both models. When the tailwater filled up to about .05' from the discharge lip, the siphon action was then very difficult to stop and it usually continued until the inlet was uncovered (even with several tubes open and sucking air). From this irregularity in action coupled with the fact that the siphonic action occasionally broke without sucking air at the inlet, it may be safely said that it is doubtful whether a full size siphon would give satisfaction if the discharge lip were not sealed.

Data Sheets 14, 15, 16, and 17 show the results of the lost head and efficiency tests. As was stated above, these lost head results, due to there being only two models, would have little comparative value. The fact is, in the tests made the total efficiency was exactly the same with Models I and II. This seems to show that the shape of the upper discharge lip has little or no effect on the efficiency. Tests of other shapes are of course needed to verify this.

As to the lost heads in portions of the siphon, it will be seen that the results for any one test are rather irregular, although taken as a whole the four tests are very consistent. It will be noted that tests 14 and 15 give approximately .4' lost head up to the first tube, while in 16 and 17 the average is .06'. Since the friction loss in this large area, short section is negligible, it is seen that an average would indicate that the formula for loss at entrance, head $= (.5 \frac{V^2}{2g})$ holds good.

$$\frac{.40 + .06}{2} = .23', \qquad .5 \frac{V^2}{2g} = .16'$$

The fact is however, that the velocity of approach to the siphon has been neglected and this would indicate that the loss is greater than indicated by the formula.

For friction lost head the formula $\frac{fl}{4r} \frac{V^2}{2g}$ was used where "l" was the length between sections in feet, "r" the hydraulic radius (approximately) in feet, and "f", ± .021, the constant for clean iron pipes of approximately the area of the siphon cross-sections. (Value of "f" taken from table in Russell's Hydraulics,(Table, page 189) This value should represent the friction loss fairly well and since it is greater than the measured loss on the lower half of the siphon and much less than that on the narrow upper section, it is believed that the constant is too small for long, rectangular sections. There was probably some loss due to curvature, but due to long radius, it was not considered as amounting to much. There was undoubtedly quite a bit of eddy loss in this narrow section since there was usually some air going through with the water and this would tend to drag the upper part of the section. The big lost head came between sections 4 and 5 and by looking at Plate IV it will be seen that this section contained the joint in the siphon besides being the smallest section as indicated by the area. This readily explains the big loss.

Just why all tests show the values for the sum, $\frac{P}{w} + \frac{V^2}{2g} + Z$ greater on the last three or four sections than on those directly above may be explained partly by the fact that inverted water columns or "U" mercury tubes were used in the "upper-high suction"-tubes while "U" water columns were used in the lower tubes. Another thing which would help cause this difference is the fact that during the test the sections which were under less than atmospheric pressure would be slightly smaller and those above atmospheric (with internal pressure) would be slightly larger than the actual measured sections. These facts, coupled with the fact that the intermittent sucking of air at the inlet caused a great vibration in some of the water columns, all indicate that the results are as good as could be expected. The conclusions are therfor that the loss at entrance is approximately what is indicated by the standard formula, that the largest part of the head lost is in the small center section, and that there is very little head lost in the diverging downspout.

The total efficiency shown on the Data Sheets is of no great value except as a comparison between the models, which has already been mentioned. That the efficiency is 100% in one case does not indicate anything wrong with the results but shows that such an expression for efficiency is plainly of no value where the cross-section is not constant or nearly so. This value could run up much over 100% due to the Venturi action, which gives a discharge through the small section greater than the actual difference in head would call for.

The figures at the bottom of Data Sheet 16 show how the efficiency is cut down by an air leak, in this case a 3/8" hole.

As a whole, the results of this thesis have been satisfactory. The results have been interpreted in the light of what information was available. There are many points about which suggestions might be made as to future tests or as to future designs. However, due to the fact that everything must be interpreted in the light of the performance of full-size models, and as more information is becoming available from time to time, the writer believes that in any future tests to be made, a comparison of this thesis and the actual performance of constructed siphons might give a clue to even more valuable tests and data.

In closing, the writer wishes to state that he owes many thanks to Mr. Louis C. Hill of Los Angeles and to Professors Ford and Thomas of Throop College for the many valuable drawings and suggestions which have helped to make this thesis very interesting work, so much so in fact, that it required more than double the given amount of thesis time.

Robert N. Allen
Aug 12 1916.

DATA SHEET 1 ....

See Plate III for section of these siphons.

Obtained from Mr. Louis C. Hill, Consulting Engineer of Los Angeles, California.

The Report of Observations by E.V.Baron, Aug. 21st 1912 on the Siphon Spillways of the Yuma Project of the Untied States Reclamation Service.

| Date | Siphons No. | Head | Theo velo | Theo disc | Meas disc | Coeff. |
|---|---|---|---|---|---|---|
| Jul.24 | 4,5 | 11.61 | 27.3 | 620 | 484.9 | 78.3 |
| 24 | 4,5 | 11.80 | 27.5 | 625 | 479.6 | 77.0 |
| 25 | 3,4,5 | 11.77 | 27.4 | 933 | 693.5 | 74.3 |
| 25 | 3,4 | 11.90 | 27.7 | 630 | 443.3 | 70.2 |
| 26 | 3,5 | 11.85 | 27.6 | 627 | 505.1 | 80.5 |
| 26 | 3,4,5 | 11.60 | 27.3 | 930 | 663.0 | 71.5 |
| 29 | All | 10.65 | 26.2 | 1488 | 1043.4 | 70.4 |
| 29 | 1,2,4,5 | 11.00 | 26.6 | 1205 | 853.1 | 71.0 |
| 29 | All | 10.87 | 26.4 | 1498 | 1012.7 | 68.0 |
| Aug. 5 | 3 | 11.90 | 27.7 | 315 | 243.3 | 77.5 |
| 7 | 1,2 | 11.60 | 27.3 | 620 | 405.0 | 65.5 |
| 7 | 1,2 | 11.60 | 27.3 | 620 | 415.0 | 67.1 |
| 8 | 2,3 | 11.48 | 27.2 | 617 | 419.3 | 68.0 |
| 8 | 2 | 11.87 | 27.6 | 314 | 208.0 | 66.5 |
| 19 | 1,2 | 10.98 | 26.7 | 606 | 432.5 | 71.5 |
| 19 | 2 | 11.82 | 27.6 | 314 | 202.0 | 64.4 |

Observed depth of water over Lip to start siphon.

| Tube No. | Outlet Submerged 5.35 feet | Outlet Submerged 6 feet |
|---|---|---|
| 1 | 0.40 | 0.55 |
| 2 | 0.35 | 0.45 |
| 3 | 0.15 | 0.25 |
| 4 | 0.35 | 0.45 |
| 5 | 0.40 | 0.50 |

After a number of leaks were closed up in tubes 1 and 2 they primed at depths about 0.10 less that the above. Seal broke in a few minutes when water surface had dropped about 0.1 foot below air valve.

# DATA SHEET 2 ..

Characteristics of the model.

Table showing area of siphon cross-sections at, center line distances between, and gage readings for, the tubes attached to the siphon.

See Plate V for drawing.

| | C.L. dist betw sec. ins | C.L. dist betw sec. ft. | Desgn Area sq in | Actual Measurements Ave dep ins. | Ave width ins. | Ave area sqin | Ave area sqft | Gage read feet | Z or elev. refer. to El.tube 10 |
|---|---|---|---|---|---|---|---|---|---|
| Up.lip | | | | | | | | 0.82 | 6.18 |
| Inlet | 0 | 0 | 108. | 9.0 | 12.2 | 110. | .765 | | |
| Tube 1 | 3.25 | .271 | 64. | 5.5 | 12.18 | 67.0 | .465 | 0.97 | 6.03 |
| 2 | 8.0 | .667 | 30.12 | 2.67 | 12.25 | 32.7 | .227 | 0.37 | 6.63 |
| Th" 3 | | | | | | | top--- | .00 | |
| Th" 3 | 7.9 | .658 | 30.0 | 2.71 | 12.15 | 32.9 | .229 | Cen. .13 | 6.87 |
| Th" 3 | | | | | | | bottom-- | .22 | |
| 4 | 7.9 | .658 | 30.12 | 2.63 | 11.80 | 31.05 | .2155 | 0.37 | 6.63 |
| 5 | 7.9 | .658 | 30.25 | 2.55 | 11.16 | 28.4 | .1975 | 0.97 | 6.03 |
| 6 | 14.2 | 1.183 | 33.95 | 3.27 | 10.21 | 33.4 | .232 | 2.15 | 4.85 |
| 7 | 17.8 | 1.48 | 38.58 | 3.90 | 9.37 | 36.5 | .254 | 3.63 | 3.37 |
| 8 | 15.5 | 1.29 | 42.61 | 4.83 | 8.65 | 41.8 | .290 | 4.93 | 2.07 |
| 9 | 10.3 | .858 | 45.30 | 5.80 | 7.88 | 45.7 | .318 | 5.78 | 1.22 |
| 10 | 14.2 | 1.183 | 49.0 | 6.91 | 7.24 | 50.1 | .348 | 7.00 | 0 |
| ModI11 | 10.7 | .892 | 56.0 | 8.12 | 7.12 | 57.8 | .401 | 7.55 | -.55 |
| Disc | 4.0 | .33 | 56.0 | | | 57.8 | .401 | Model I only | |

Disc. Lip, Model I see photo or desc. page 21 7.14
" " " II " " " " 21 7.08

DATA SHEET 3 .... Model I.

Gradually increasing depth of water over throat.

Tube (4) open.

Edge of throat gage reading .22
Discharge lip " " 7.14

| Bottom or T.W. ft. | Top or H.W. ft. | Depth over Disc. lip ft. | Reqd. Depth over Thr. to prime | Remarks |
|---|---|---|---|---|
| 6.3 | .10 | .84 | .12 | |
| 5.87 | .095 | 1.27 | .125 | No prime |
| 6.5 | .095 | .64 | .125 | |
| 6.0 | .095 | 1.14 | .125 | Slow Prime |
| 5.6 | .088 | 1.54 | .132 | |
| 5.7 | .11 | 1.44 | .11 | No prime |
| 5.7 | .045 | 1.44 | .175 | Quick prime |
| --- | .07 | open .20 | .15 | |
| 5.8 | .08 | 1.34 | .14 | No prime |
| 5.7 | .06 | 1.44 | .16 | |
| --- | .065 | open .20 | .155 | |
| 6.96 | .095 | .18 | .125 | |
| 6.53 | .09 | .61 | .13 | |
| 6.1 | .07 | 1.04 | .15 | |
| --- | .09 | open .20 | .13 | |
| 6.6 | .095 | .54 | .125 | |
| 6.3 | .11 | .84 | .11 | No prime |
| --- | .08 | open .30 | .14 | |
| 6.9 | .11 | .24 | .11 | Slow prime |
| 5.85 | .14 | 1.29 | .08 | No prime |
| 5.6 | .10 | 1.54 | .12 | No prime |
| 5.65 | .13 | 1.49 | .09 | No prime |
| 5.45 | .07 | 1.69 | .15 | |
| 5.65 | .08 | 1.49 | .14 | |
| 6.5 | .10 | .64 | .12 | No prime |
| --- | .11 | open .10 | .11 | |
| 6.65 | .095 | .49 | .125 | |
| 7.25 | .095 | open .11 | .125 | |

DATA SHEET 4 .... Model I.

Gradually increasing depth of water over throat.

Tube (4) open--closed as soon as water starts over throat-- gage reading - .22

Discharge lip " - 7.14

| Bottom or T.W. | Top or H.W. | Depth over Disc. lip-ft | Reqd depth over Thr. to Prime | Remarks |
|---|---|---|---|---|
| 5.9 | .10 | 1.24 | .12 | No prime |
| --- | .12 | open .10 | .10 | |
| 6.88 | -.05 | .26 | .27 | Slow prime |
| 6.4 | -.17 | .74 | .39 | |
| 5.7 | -.05 | 1.44 | .27 | Jugg.at-.04,no pr. |
| 6.85 | -.06 | .29 | .28 | |
| 6.35 | -.09 | .79 | .31 | Jugg.at-.02 |
| 5.6 | -.13 | 1.54 | .35 | Jugg.at .05,no pr. |
| --- | .10 | .05 | .12 | Quick prime |
| 6.75 | -.10 | .39 | .32 | |
| 6.15 | -.14 | .99 | .36 | Jugg,at-.03 |
| --- | .08 | open .05 | .14 | |
| --- | .08 | open .10 | .14 | |
| 6.9 | -.115 | .24 | .335 | |
| 6.4 | -.14 | .74 | .36 | Jugg.at-.08 |
| 6.1 | -.18 | 1.04 | .40 | " " " ,no pr. |
| 6.8 | -.13 | .34 | .35 | Water ris. fast |
| 6.85 | -.135 | .29 | .355 | " " " |
| 6.9 | -.055 | .24 | .275 | Jugg.at .05 |
| --- | .10 | open .10 | .12 | |
| --- | .095 | open .20 | .125 | |
| --- | .085 | open .30 | .135 | |
| --- | .095 | open .15 | .125 | |
| --- | .095 | open .20 | .125 | |
| 6.2 | -.20 | .94 | .42 | Jugg.at-.06,no pr. |
| 6.05 | -.20 | 1.09 | .42 | No prime |
| 7.02 | .005 | .12 | .215 | |
| 7.0 | -.01 | .14 | .23 | |
| 6.04 | -.20 | 1.10 | .42 | Exp.air -.17,no pr. |
| 6.9 | -.11 | .24 | .32 | H.W. ris. fast |
| 6.1 | -.195 | 1.04 | .415 | Jugg.at-.10 |
| 7.4 | .09 | open .26 | .13 | No prime |
| 7.6 | .09 | open .46 | .13 | No prime |
| 6.8 | -.13 | .34 | .35 | Air out -.10 |
| 6.8 | -.11 | .34 | .33 | Slow prime |
| 7.35 | .08 | open .21 | .14 | |
| 6.88 | -.115 | .26 | .335 | |
| 7.04 | .04 | .10 | .18 | |
| 7.0 | -.02 | .14 | .24 | |
| 7.28 | .085 | open .14 | .135 | Slow prime |
| 7.6 | .09 | open .46 | .13 | |
| 7.0 | -.005 | .14 | .225 | |
| 6.8 | -.115 | .34 | .325 | |
| 6.8 | -.085 | .34 | .305 | |

DATA SHEET 5 .... Model I.

Gradually increasing depth of water over throat.

All tubes closed.

Edge of throat gage reading .22
Discharge lip " " 7.14

| Bottom or T.W. | Top or H.W. | Depth over Disc.lip-ft. | Reqd depth over Thr. to Prime | Remarks. |
|---|---|---|---|---|
| 6.9 | -.03 | .24 | .25 | |
| 6.5 | -.21 | .64 | .43 | No prime |
| 6.3 | -.20 | .84 | .42 | Water over th..02<br>No prime. |
| 6.9 | -.11 | .24 | .33 | Water over th..04 |
| 6.35 | -.20 | .79 | .42 | Water over th..08<br>No prime |
| 6.9 | -.10 | .24 | .32 | Water over th..05 |
| 6.4 | -.21 | .74 | .43 | No prime |
| 6.95 | -.06 | .19 | .28 | Water over th..05 |
| 6.5 | -.21 | .64 | .43 | Water over th..05<br>No prime |
| 5.65 | -.195 | 1.49 | .415 | Jugg.at-.10,no pr. |
| 6.75 | -.195 | .39 | .415 | Air out -.12<br>Slow prime 1½min. |
| 6.90 | -.095 | .24 | .315 | Air out -.07 |
| 6.92 | -.10 | .22 | .30 | Water over th..06<br>Air out -.10 |
| 7.08 | .08 | .06 | .14 | Water over th..14 |
| 7.02 | .02 | .12 | .20 | Water over th..08<br>Air out at .16 |
| 6.98 | -.03 | .16 | .25 | Water over th..075<br>Air out at .02 |

DATA SHEET 6 .. Model I.

Tube (4) opened with a certain depth over throat.

Edge of throat gage reading .22
Discharge lip " " 7.14

| Bottom read. ft | Top read. ft | Time in prim. sec. | Depth over Disch. lip. feet | Depth over Throat feet | Remarks |
|---|---|---|---|---|---|
| 5.8 | .085 | ---- | 1.34 | .135 | No prime |
| 5.7 | .05 | 12 | 1.44 | .17 | |
| 5.8 | .09 | ---- | 1.34 | .13 | No prime |
| 6.3 | -.20 | 6 | .84 | .42 | |
| 6.25 | -.20 | 6 | .89 | .42 | |
| 5.70 | .06 | 13 | 1.44 | .16 | |
| 6.1 | .07 | 12 | 1.04 | .15 | |
| 6.15 | -.20 | 7.5 | .99 | .42 | |
| 5.65 | .03 | 11 | 1.49 | .19 | |
| 6.4 | -.21 | 6 | .74 | .43 | |
| 6.2 | .06 | 12 | .94 | .16 | |
| 6.4 | -.21 | 6 | .74 | .43 | |
| 6.4 | .04 | 10 | .74 | .18 | |
| 6.05 | .01 | 11 | 1.09 | .21 | |
| 6.93 | .11 | 25 | .21 | .11 | |
| 6.52 | .07 | 13 | .62 | .15 | |
| 6.15 | .02 | 12 | .99 | .20 | |
| 5.74 | -.04 | 10 | 1.40 | .26 | |
| 7.0 | .045 | 10 | .14 | .175 | |
| 6.6 | -.06 | 7.5 | .54 | .28 | |
| 6.14 | -.11 | 6 | 1.00 | .33 | |
| 5.7 | -.11 | 8 | 1.44 | .33 | |
| 6.94 | -.01 | 7 | .20 | .23 | |
| 6.52 | -.09 | 8 | .62 | .31 | |
| ---- | .12 | 20 | open .10 | .10 | |
| 6.88 | -.045 | 8 | .26 | .265 | |
| 6.42 | -.14 | 7 | .72 | .36 | |
| 6.7 | -.03 | 8 | .44 | .25 | |
| 6.25 | -.05 | 8 | .89 | .27 | |
| 5.65 | -.195 | 7 | 1.49 | .415 | |
| 6.75 | -.12 | 6-7 | .39 | .34 | |
| 6.3 | -.125 | 7 | .84 | .345 | |
| 5.8 | -.15 | 6-7 | 1.34 | .37 | |
| 6.0 | -.20 | 7 | 1.14 | .42 | |
| 6.8 | .025 | 8-9 | .34 | .195 | |
| 6.4 | .01 | 9 | .74 | .21 | |
| 6.0 | -.03 | 8-9 | 1.14 | .25 | |
| 5.58 | -.01 | 10 | 1.56 | .23 | |
| 6.6 | .055 | 12 | .54 | .165 | |
| 6.24 | .11 | --- | .90 | .11 | No prime 50sec |
| 6.2 | .03 | 10 | .94 | .19 | |
| 5.8 | -.015 | 8-9 | 1.34 | .235 | |
| 6.56 | -.02 | 8 | .58 | .24 | |
| 6.12 | .09 | 20 | 1.02 | .13 | |
| 5.78 | .08 | 25 | 1.36 | .14 | |
| 5.52 | .07 | 15 | 1.62 | .15 | |

Table 6 (cont).. Model I.

| Bottom read. ft | Top read. ft | Time in prim sec. | Depth over Disch. lip feet | Depth over Throat feet | Remarks |
|---|---|---|---|---|---|
| 5.58 | .08 | -- | 1.56 | .14 | No prime 25sec |
| 5.55 | .05 | 15 | 1.59 | .17 | |
| 5.50 | .07 | 18 | 1.64 | .15 | |
| 5.55 | .08 | 20 | 1.59 | .14 | |
| 5.45 | .07 | 20 | 1.69 | .15 | |
| 5.7 | .045 | 11 | 1.44 | .175 | |
| 6.5 | .10 | -- | .64 | .12 | No prime |
| 5.65 | -.18 | 7 | 1.49 | .40 | |
| 5.9 | -.20 | 6-7 | 1.24 | .42 | |
| 6.0 | -.21 | 6 | 1.14 | .43 | |
| 5.6 | -.20 | 7 | 1.54 | .42 | |
| 6.82 | .05 | 11 | .26 | .17 | |
| 6.44 | .11 | -- | .70 | .11 | No prime |
| 7.24 | .10 | 8 | open .10 | .12 | |
| 6.94 | .11 | -- | .20 | .11 | No prime $1\frac{1}{2}$min |
| 6.80 | .06 | 11 | .34 | .16 | |
| 7.42 | .00 | 2.5 | open .28 | .22 | |
| 7.02 | .065 | 9 | .12 | .155 | |
| 6.64 | .11 | -- | .50 | .11 | No prime |
| 6.55 | .08 | 15 | .59 | .14 | |
| 7.5 | .11 | -- | open .36 | .11 | No prime |
| 7.45 | .09 | -- | open .31 | .13 | No prime |
| 7.30 | .09 | -- | open .16 | .13 | No prime |
| 7.24 | .055 | 5 | open .10 | .165 | |
| 6.86 | -.01 | 7 | .26 | .23 | |
| 7.4 | .07 | 7 | open .26 | .15 | |
| 7.25 | .12 | 35 | open .11 | .10 | |
| 6.86 | -.10 | 6 | .26 | .32 | |
| 7.08 | .065 | 9 | .06 | .155 | |
| 7.62 | .11 | -- | open .48 | .11 | No prime |
| 7.45 | .09 | -- | open .31 | .13 | No prime |
| 7.45 | -.065 | 2 | open .31 | .285 | |
| 7.04 | -.03 | 6 | .10 | .25 | |
| 7.24 | .12 | 12 | open .10 | .10 | Prime almost broke at start |
| 7.14 | .135 | -- | .00 | .085 | No prime 30sec |
| 7.13 | .11 | 12 | .01 | .11 | |
| 6.46 | .08 | 15 | .69 | .14 | |
| 7.6 | .06 | 5 | open .46 | .16 | |
| 7.4 | .04 | 4.5 | open .26 | .18 | |
| 7.0 | .105 | 16 | .14 | .115 | |
| 6.64 | .06 | .13 | .48 | .16 | |
| 7.40 | .04 | 4 | open .26 | .18 | |

DATA SHEET 7 .. Model I.

Tube (4) closed as soon as water starts over throat.

Inlet uncovered and time to prime taken for various depths over throat and various tailwater elevations.

| Bottom read. ft | Top read. ft | Time in prim sec | Depth over Disc. lip feet | Depth over Throat feet | Remarks. |
|---|---|---|---|---|---|
| 6.5 | .00 | -- | .64 | .22 | No prime |
| 6.42 | -.145 | 16 | .72 | .365 | |
| 5.9 | -.155 | -- | 1.22 | .37 | No prime 1min |
| 5.75 | -.18 | -- | 1.39 | .40 | No prime 1½ " |
| 6.65 | -.085 | 20 | .49 | .305 | |
| 6.05 | -.185 | 30 | 1.09 | .405 | |
| 6.6 | -.16 | 12 | .54 | .38 | |
| 5.95 | -.20 | 17 | 1.19 | .42 | |
| 6.6 | -.18 | 8 | .54 | .40 | |
| 6.0 | -.20 | 17 | 1.14 | .42 | Not cl. tilov.th. |
| 6.55 | -.085 | 22 | .59 | .305 | |
| 6.04 | -.16 | -- | 1.10 | .38 | No prime 40sec |
| 5.95 | -.20 | -- | 1.19 | .42 | No prime |
| 6.65 | -.075 | 18 | .49 | .295 | |
| 6.55 | -.075 | 25 | .59 | .295 | |
| 6.05 | -.195 | 40 | 1.09 | .415 | |
| 6.7 | -.20 | 9 | .44 | .40 | |
| 6.7 | -.065 | 20 | .44 | .285 | |
| 5.70 | -.20 | -- | 1.44 | .42 | No prime 1min |
| 7.35 | .10 | -- | open .21 | .12 | No prime " |
| 7.25 | .08 | 6 | open .11 | .14 | |
| 7.7 | .05 | 6 | open .56 | .17 | |
| 7.24 | .08 | 5 | open .10 | .14 | |
| 7.55 | .035 | 4 | open .41 | .185 | |
| 7.5 | .005 | 4 | open .36 | .215 | |
| 7.24 | .03 | 4 | open .10 | .19 | |
| 6.84 | -.18 | 8 | .30 | .40 | |
| 7.26 | .06 | 5.5 | open .12 | .16 | |
| 7.14 | .08 | 6 | .00 | .14 | |
| 7.24 | -.05 | 2 | open .18 | .27 | |
| 6.92 | -.08 | 25 | .12 | .30 | |
| 7.40 | -.14 | 2 | open .20 | .36 | |
| 7.24 | .04 | 4 | open .10 | .18 | |
| 7.38 | -.20 | 2 | open .24 | .42 | |
| 7.14 | .145 | 10 | .00 | .075 | |
| 7.14 | .145 | 18 | .00 | .075 | |
| 7.45 | -.07 | 2 | open .31 | .29 | |
| 6.96 | .11 | 35 | .08 | .11 | |
| 7.24 | -.08 | 2 | open .10 | .30 | |
| 7.30 | .09 | -- | open .16 | .13 | No prime |
| 6.84 | -.125 | 11 | .30 | .345 | |
| 7.04 | .02 | 9 | .10 | .20 | |
| 6.62 | -.06 | 30 | .52 | .28 | |
| 6.90 | -.10 | 11 | .22 | .32 | |
| 6.90 | -.18 | 4.5 | .24 | .40 | |
| 6.80 | -.11 | 13 | .24 | .33 | |
| 7.06 | -.01 | 4 | .08 | .25 | |

Data Sheet 7 (cont) .. Model I.

| Bottom read. ft | Top read. ft | Time in prim sec | Depth over Disc lip feet | Depth over Throat feet | Remarks |
|---|---|---|---|---|---|
| 6.96 | -.025 | 10 | .18 | .245 | |
| 7.00 | -.12 | 5 | .14 | .34 | |
| 7.14 | .10 | 6 | .00 | .12 | |
| 7.7 | .00 | 2.5 | open .56 | .22 | |
| 7.24 | .00 | 2 | open .10 | .22 | |
| 7.7 | -.06 | 2 | open .56 | .28 | |
| 7.2 | .12 | 9 | open .06 | .10 | |
| 7.4 | .06 | 5.5 | open .26 | .16 | |
| 7.65 | .11 | -- | open .51 | .11 | No prime |
| 7.6 | .09 | -- | open .46 | .13 | No prime |
| 7.4 | .09 | -- | open .26 | .13 | No prime |
| 7.3 | .085 | 10 | open .16 | .135 | |
| 7.09 | .13 | -- | .05 | .09 | Jugg.at.185 no pr |
| 7.04 | .08 | -- | .10 | .14 | No prime |
| 7.02 | .06 | -- | .12 | .16 | No prime |
| 7.00 | .04 | -- | .14 | .18 | No prime |
| 7.155 | .14 | 10.5 | open .015 | .08 | |
| 7.19 | .13 | -- | open .05 | .09 | No prime |

DATA SHEET 8 .. Model II.

Tube (4) open. Edge of throat gage reading .22
Discharge lip " " 7.08

| Bottom or T.W. feet. | Top or H.W. feet. | Depth over Disch lip | Reqd dep. over throat to prime | Remarks |
|---|---|---|---|---|
| 5.86 | .095 | 1.22 | .125 | |
| 6.46 | .12 | .62 | .10 | No prime |
| 6.5 | .11 | .58 | .11 | |
| 5.55 | .11 | 1.48 | .11 | No prime |
| 5.66 | .11 | 1.42 | .11 | No prime |
| 6.65 | .12 | .43 | .10 | No prime |
| 6.25 | .10 | .83 | .12 | |
| 6.98 | .12 | .10 | .10 | |
| 7.38 | .09 | open .30 | .13 | |
| 7.25 | .105 | open .16 | .115 | |
| 7.14 | .12 | open .06 | .10 | |
| 6.80 | .125 | .28 | .095 | Slow prime |
| 7.06 | .125 | .02 | .095 | |
| 5.9 | .115 | 1.18 | .105 | No prime |
| 6.84 | .12 | .24 | .10 | |
| 5.64 | .105 | 1.44 | .115 | No prime |
| 5.60 | .09 | 1.48 | .13 | |
| 6.46 | .12 | .62 | .10 | No prime |
| 6.18 | .12 | .90 | .10 | No prime |
| 6.0 | .115 | 1.08 | .105 | No prime |
| 7.45 | .08 | open .37 | .14 | |
| 7.38 | .11 | open .30 | .11 | No prime |
| 7.40 | .08 | open .32 | .14 | No prime |

DATA SHEET 9 .. Model II.

Gradually increasing depth of water over throat.

Tube (4) open until water starts over throat and then closed.

Edge of throat gage reading .22
Discharge lip " " 7.08

| Bottom or T.W. ft | Top or H.W. ft | Depth over Disc lip. ft | Req dep over thr to Prime ft. | Remarks |
|---|---|---|---|---|
| 6.54 | -.11 | .54 | .33 | Some air out-.02 |
| 6.52 | -.07 | .56 | .29 | H.W.ris slow "-.01 |
| 7.25 | .105 | open .17 | .115 | |
| 6.26 | -.135 | .82 | .355 | Air -.07, jugg.-.12 |
| 5.75 | -.16 | 1.33 | .38 | No prime |
| 6.25 | -.13 | .83 | .35 | Some air out-.05 |
| 7.18 | .12 | open .10 | .10 | |
| 6.84 | -.06 | .24 | .28 | Some air out .04 |
| 6.30 | -.125 | .78 | .345 | " " -.04 |
| 5.94 | -.18 | 1.18 | .40 | Air -.10, jugg.-10 No prime |
| 5.95 | -.15 | 1.13 | .37 | Air -.09, jugg.-.12 No prime |
| 6.8 | -.08 | .28 | .30 | Some air out-.02 |
| 6.16 | -.14 | .92 | .36 | Air -.06, jugg.-.12 |
| 6.92 | .00 | .16 | .22 | |
| 7.20 | .11 | open .12 | .11 | |
| 6.5 | -.065 | .58 | .285 | Some air out-.01 |
| 6.94 | .005 | .14 | .215 | |
| 7.1 | .13 | open .02 | .09 | |
| 7.0 | .05 | .08 | .17 | |
| 7.08 | .13 | .00 | .09 | |
| 6.88 | -.04 | .20 | .26 | Some air out .03 |
| 7.15 | .10 | open .07 | .12 | |
| 7.08 | .12 | .00 | .10 | |
| 6.65 | -.095 | .43 | .315 | Some air out .0C |
| 6.75 | -.09 | .33 | .31 | |
| 7.30 | .09 | open .22 | .13 | No prime |
| 6.80 | -.085 | .28 | .305 | |
| 7.32 | .08 | open .24 | .14 | No prime |
| 6.88 | .01 | .20 | .21 | |
| 7.20 | .105 | open .12 | .115 | |
| 7.7 | .05 | open .62 | .17 | |
| 6.42 | -.075 | .66 | .295 | Air -.01, slow ris. H.W. |
| 6.05 | -.16 | 1.03 | .38 | Air & jugg. -.11 |

## DATA SHEET 10 .. Model II

Gradually increasing depth of water over throat.

All tubes closed. Edge of throat gage reading .22
Discharge Lip " " 7.08

| Bottom or T.W. ft | Top or H.W. ft | Depth over Disc lip ft | Req dep over thr to prime ft | Remarks |
|---|---|---|---|---|
| 6.50 | -.19 | .48 | .41 | Ov.th.06,air-.12,sl pr |
| 6.8 | -.13 | .28 | .35 | Ov.th.06,air-.08 |
| 6.8 | -.13 | .28 | .35 | Ov.th.08,air-.07 |
| 5.65 | -.205 | 1.43 | .425 | No prime |
| 7.04 | .10 | .04 | .12 | |
| 6.93 | -.02 | .15 | .24 | Ov.th.09,air .05 |
| 6.72 | -.15 | .36 | .37 | Ov.th.10,air-.06 |
| 6.65 | -.16 | .43 | .38 | Ov.th.10,air-.06 |
| 7.0[illegible] | .03 | .08 | .19 | Ov.th.10,air .10 |
| 6.82 | -.10 | .26 | .32 | |

* * * * * * * * * * *

## DATA SHEET 11 .. Model II

Air valve attached to tube (4) permitting the escape of air but closing as soon as suction began.

| Bottom or T.W. ft | Top or H.W. ft | Depth over Disc lip ft | Depth over Throat ft | Remarks |
|---|---|---|---|---|
| 6.05 | .085 | 1.03 | .135 | |
| 7.24 | .115 | open .16 | .105 | |
| 6.06 | -.01 | 1.02 | .23 | Inlet op. pr.17sec |
| 5.86 | .09 | 1.22 | .13 | |
| 7.14 | .115 | open .06 | .105 | |
| 7.08 | .13 | .00 | .09 | |
| 6.82 | .05 | .26 | .17 | |
| 6.78 | .04 | .30 | .18 | |
| 6.35 | .07 | .73 | .15 | |
| 6.12 | .08 | .96 | .14 | |
| 5.45 | .08 | 1.63 | .14 | |
| 7.11 | .125 | open .03 | .095 | |
| 6.48 | .07 | .60 | .15 | |
| 7.16 | .105 | open .08 | .115 | |
| 6.5 | .05 | .58 | .17 | |
| 6.88 | .075 | .20 | .145 | |
| 6.60 | .085 | .48 | .135 | |
| 6.20 | .09 | .88 | .13 | |
| 6.80 | .055 | .28 | .165 | |
| 6.96 | .09 | .12 | .13 | |
| 6.58 | .06 | .50 | .16 | |
| 7.08 | .13 | .00 | .09 | |
| 6.70 | .055 | .38 | .165 | |
| 7.04 | .12 | .04 | .10 | |

DATA SHEET 12 .. Model II

Readings taken with inlet opened with water over the throat as recorded. Tube (4) open at all times.

Edge of throat gage reading .22
Discharge lip " " 7.08

| Bottom read. ft | Top read. ft | Time in prim sec | Depth over Disc lip feet | Depth over Throat feet | Remarks |
|---|---|---|---|---|---|
| 6.68 | -.025 | 7 | .40 | .245 | |
| 6.14 | -.095 | 6 | .94 | .315 | |
| 7.46 | -.18 | 2 | open .38 | .40 | |
| 7.16 | .10 | 12 | open .08 | .12 | |
| 6.86 | .02 | 7 | .22 | .19 | |
| 6.48 | .07 | 9.5 | .60 | .15 | |
| 7.58 | -.05 | 2 | open .50 | .27 | |
| 7.16 | .115 | 9 | open .08 | .105 | Went by jerks until water cov. discharge lip |
| 6.78 | .105 | 13 | .30 | .115 | |
| 6.40 | .11 | -- | .68 | .11 | No prime 30sec |
| 6.36 | .06 | 10.5 | .72 | .16 | |
| 7.62 | .08 | -- | open .54 | .14 | No prime |
| 7.54 | .015 | 3 | open .46 | .205 | |
| 7.34 | .095 | -- | open .26 | .125 | No prime |
| 7.30 | .02 | 4 | open .22 | .20 | Went by jerks |
| 7.14 | .07 | 7 | open .06 | .15 | Jerks 'till cov. |
| 6.76 | .09 | 12 | .32 | .13 | |
| 6.94 | .12 | 19 | .14 | .10 | |
| 6.51 | .10 | 22 | .57 | .12 | |
| 7.36 | .02 | 3 | open .28 | .20 | |
| 7.20 | .135 | -- | open .12 | .085 | No prime |
| 7.16 | .08 | 7 | open .08 | .14 | |
| 6.94 | .13 | -- | .14 | .09 | Np prime 25sec |
| 6.8 | .065 | 7.5 | .28 | .155 | |
| 6.54 | .005 | 7.5 | .54 | .215 | |
| 6.24 | -.165 | 6 | .84 | .385 | |
| 6.80 | -.14 | 5 | .28 | .36 | |
| 7.02 | .04 | 4 | .06 | .18 | |
| 6.84 | -.19 | 5.5 | .24 | .41 | |
| 7.28 | .02 | 3.5 | open .20 | .20 | |
| 5.9 | .115 | -- | 1.18 | .105 | No prime 40sec |
| 5.85 | .09 | 20-25 | 1.23 | .13 | |
| 5.74 | .05 | 11.5 | 1.34 | .17 | |
| 6.94 | .075 | 8 | .14 | .145 | |
| 6.50 | -.13 | 5.5 | .58 | .35 | |

(continued)

Date Sheet 12 (continued) Model II.

| Bottom read. ft | Top read. ft | Time in prim sec | Depth over Disc lip feet | Depth over Throat feet | Remarks |
|---|---|---|---|---|---|
| 6.04 | .08 | 20 | 1.04 | .14 | |
| 5.98 | .07 | 15 | 1.10 | .15 | |
| 5.94 | .035 | 7.5 | 1.14 | .255 | |
| 5.58 | -.03 | 7.5 | 1.50 | .25 | |
| 6.84 | -.05 | 6 | .24 | .27 | |
| 6.48 | -.16 | 5 | .60 | .38 | |
| 5.98 | -.06 | 7 | 1.10 | .28 | |
| 7.34 | .09 | -- | open .26 | .13 | No prime |
| 7.28 | .06 | 7 | open .20 | .16 | Prim.& went by jer |
| 7.4 | .06 | 6 | open .32 | .16 | " " |
| 7.25 | .095 | -- | open .17 | .125 | No pr. wat fal ist |
| 7.21 | .055 | 6 | open .13 | .165 | |
| 7.06 | .095 | 9-10 | .02 | .125 | |
| 6.70 | .10 | 17 | .38 | .12 | |
| 6.36 | -.05 | 7 | .72 | .27 | |
| 6.12 | -.20 | 5.5 | .96 | .42 | |
| 5.66 | .11 | -- | 1.42 | .11 | No prime |
| 5.50 | -.08 | 7 | 1.58 | .30 | |
| 7.32 | .095 | -- | open .24 | .125 | No prime |
| 7.28 | .08 | -- | open .20 | .14 | No prime |
| 7.24 | .055 | 5 | open .16 | .155 | |
| 7.12 | .11 | 8 | open .04 | .11 | |
| 6.65 | .12 | -- | .43 | .10 | No prime |
| 7.40 | .06 | -- | open .32 | .16 | No prime |
| 7.34 | .045 | 5 | open .26 | .175 | Jerks |
| 7.26 | .06 | 6 | open .18 | .16 | " |
| 7.18 | .10 | 15 | open .10 | .12 | |
| 7.11 | .095 | 6 | open .03 | .125 | |
| 6.88 | -.075 | 6 | .18 | .295 | |
| 6.8 | .05 | 7 | .20 | .17 | |
| 6.48 | .10 | 20 | .60 | .12 | |
| 6.25 | .06 | 8 | .83 | .16 | |
| 6.04 | .10 | -- | 1.04 | .12 | No prime |
| 5.9 | .04 | 8 | 1.18 | .18 | |
| 5.64 | .105 | -- | 1.44 | .115 | No prime |
| 5.58 | .04 | 10 | 1.50 | .18 | |
| 5.8 | .065 | 10 | 1.28 | .155 | |
| 5.74 | .03 | 7 | 1.34 | .19 | |
| 5.6 | .09 | -- | 1.48 | .13 | No prime 25sec |
| 5.58 | .03 | 8 | 1.50 | .19 | |

(continued)

Data Sheet 12 (continued) Model II.

| Bottom read. ft | Top read. ft | Time in prim sec | Depth over Disc lip feet | Depth over Throat feet | Remarks |
|---|---|---|---|---|---|
| 7.4 | .00 | 3 | open .32 | .22 | |
| 7.03 | .08 | 8 | .05 | .14 | |
| 6.74 | .08 | 12 | .34 | .14 | |
| 6.38 | -.04 | 7 | .70 | .26 | |
| 6.5 | -.18 | 4.5 | .58 | .40 | |
| 5.90 | -.15 | 6 | 1.18 | .37 | |
| 7.38 | .02 | 2.5 | open .30 | .20 | |
| 6.75 | -.10 | 5.5 | .33 | .32 | |
| 6.3 | .03 | 8 | .78 | .19 | |
| 6.78 | -.18 | 4 | .30 | .40 | |
| 5.72 | -.17 | 6+ | 1.36 | .39 | |
| 7.06 | -.08 | 2 | .02 | .20 | |
| 6.94 | .00 | 6 | .14 | .22 | |
| 6.92 | .02 | 6.5 | .16 | .20 | |
| 6.92 | .06 | 8 | .16 | .16 | |
| 7.64 | .04 | 5-6 | open .56 | .18 | |
| 7.54 | .04 | 5-6 | open .46 | .18 | |
| 7.14 | .11 | 13 | open .06 | .11 | |
| 7.48 | .035 | 5 | open .40 | .185 | |
| 7.34 | .08 | -- | open .26 | .14 | No prime |
| 7.28 | .03 | 5 | open .20 | .19 | Jerks |
| 6.82 | -.14 | 5 | .26 | .36 | |
| 7.6 | .00 | 4 | open .52 | .22 | Jerks |
| 7.34 | .04 | 5.5 | open .26 | .18 | Jerks |
| 7.14 | .095 | 9 | open .06 | .125 | Jerks 'till cov. |
| 6.84 | .10 | 15-16 | .24 | .12 | |

DATA SHEET 13 .. Model II.

Tube (4) closed as soon as water starts over throat.

Inlet uncovered and time to prime taken for various depths over throat.

| Bottom read. ft. | Top read. ft. | Time in prim sec | Depth over Disc lip feet | Depth over Throat feet | Remarks |
|---|---|---|---|---|---|
| 7.18 | .10 | 7 | open .10 | .12 | |
| 7.16 | .06 | 6 | open .08 | .16 | |
| 7.1 | .10 | 8 | open .02 | .12 | |
| 6.86 | .00 | -- | .28 | .22 | No prime |
| 6.86 | -.11 | 5 | .28 | .33 | Two holes open |
| 7.20 | .08 | 12-13 | open .12 | .14 | |
| 7.24 | .10 | 25 | open .16 | .12 | |
| 6.54 | -.21 | 10 | .54 | .43 | |
| 5.88 | -.21 | 11 | 1.20 | .43 | |
| 6.78 | -.09 | 12.5 | .30 | .31 | |
| 6.36 | -.18 | 12 | .72 | .40 | |
| 7.14 | .005 | 2.5 | open .06 | .215 | |
| 6.85 | -.045 | 13 | .23 | .265 | |
| 6.44 | -.11 | 19 | .64 | .33 | |
| 6.08 | -.145 | 25 | 1.00 | .365 | |
| 5.65 | -.205 | -- | 1.43 | .425 | No prime 1min |
| 7.12 | .07 | 5 | open .04 | .15 | |
| 6.84 | -.02 | 15 | .24 | .24 | Closed late |
| 6.54 | -.105 | 20 | .54 | .325 | |
| 6.68 | -.125 | 9-10 | .40 | .345 | |
| 6.18 | -.17 | 15 | .90 | .40 | |
| 6.94 | -.06 | 5.5 | .14 | .28 | |
| 6.18 | -.09 | -- | .90 | .31 | No prime 30sec |
| 7.16 | .08 | 8 | open .08 | .14 | |
| 6.86 | -.18 | 5 | .42 | .40 | |
| 6.4 | -.105 | 30 | .68 | .325 | |
| 6.04 | -.18 | 18 | 1.04 | .40 | |
| 6.20 | -.155 | 20 | .88 | .375 | |
| 5.80 | -.205 | 13 | 1.28 | .425 | |
| 7.32 | .01 | 2.5 | open .24 | .19 | |
| 7.06 | .06 | 5+ | .02 | .16 | |
| 6.81 | -.06 | 13 | .27 | .28 | |
| 6.50 | -.135 | 15 | .58 | .355 | |
| 6.16 | -.125 | 35 | .92 | .345 | |
| 7.18 | .055 | 5 | open .10 | .165 | |
| 7.18 | .08 | 10.5 | open .10 | .14 | |
| 7.14 | .05 | 5.5 | open .06 | .17 | |
| 7.24 | .04 | 4 | open .16 | .18 | |
| 7.35 | .00 | 4.5 | open .27 | .20 | |
| 6.21 | -.20 | 12 | .87 | .42 | |
| 7.24 | .10 | 27 | open .16 | .12 | |
| 7.0 | .07 | 20 | .08 | .15 | |
| 6.64 | -.04 | -- | .44 | .26 | No prime |
| 6.64 | -.07 | 25 | .44 | .29 | |
| 7.44 | .05 | 7 | open .36 | .17 | |

Data Sheet 13 (continued) Model II.

| Bottom read. ft | Top read. ft | Time in prim sec | Depth over Disc lip feet | Depth over Throat feet | Remarks |
|---|---|---|---|---|---|
| 7.34 | .00 | 2.5 | open .26 | .22 | |
| 6.99 | .04 | 20 | .09 | .18 | |
| 7.3 | .06 | 10 | open .22 | .16 | |
| 6.92 | -.015 | 9 | .16 | .235 | |
| 6.92 | .00 | 24 | .16 | .22 | |
| 7.08 | .03 | 9 | .00 | .19 | |
| 7.04 | .06 | 7 | .04 | .16 | |
| 6.96 | -.03 | 5.5 | .12 | .25 | |
| 7.18 | .06 | 8 | open .10 | .16 | |
| 6.40 | -.10 | 34 | .68 | .32 | |
| 7.32 | .08 | -- | open .24 | .14 | No prime |
| 7.18 | .04 | 6 | open .10 | .18 | |
| 6.60 | -.06 | 30 | .48 | .28 | |
| 7.34 | .08 | -- | open .26 | .14 | No prime 35sec |
| 7.28 | .04 | 7 | open .20 | .18 | |
| 6.90 | -.04 | 7.5 | .18 | .26 | |
| 6.60 | -.075 | 16 | .48 | .295 | |
| 6.30 | -.105 | 27 | .78 | .325 | |
| 5.92 | -.15 | 20+ | 1.16 | .37 | |
| 7.08 | .03 | 9 | .00 | .19 | |
| 6.74 | -.035 | 16 | .34 | .255 | |
| 6.42 | -.205 | 9.5 | .66 | .425 | |
| 6.00 | -.13 | -- | 1.08 | .35 | No prime |
| 6.00 | -.14 | slow | 1.08 | .36 | |
| 7.4 | -.11 | 2 | open .32 | .33 | |
| 7.1 | .09 | 6-7 | open .02 | .13 | |
| 6.84 | -.02 | -- | .24 | .24 | No prime |
| 6.44 | -.105 | 15 | .64 | .335 | |
| 7.4 | -.10 | 2 | open .32 | .32 | |
| 7.12 | .04 | 5.5 | open .04 | .18 | |
| 6.54 | -.07 | 20 | .54 | .29 | |
| 7.26 | .06 | 10 | open .18 | .16 | |

DATA SHEET 14 .. Model I.

Siphon drawing some air at times.
Q = 3.5 second feet.
Conditions--three "U" mercury columns, othere "U" water columns. Date--June 19th 1916.

| Pt or Tube no | Sec. area in sqft | Vel. in ft/sec | $\frac{V^2}{2g}$ | Gage read wa.&me. cols ft | $\frac{P}{w}$ | Z refer. tube 10 (DaSh2) | $\frac{P}{w}+\frac{V^2}{2g}+Z$ | Lost Head feet | $\frac{flV^2}{4r2g}$ aprox aver. f=.021 |
|---|---|---|---|---|---|---|---|---|---|
| H.W. | | | .00 | .54 | .00 | 6.46 | 6.46 | | |
| Inl | .765 | 4.57 | .32 | | | | | | .01 |
| 1 | .465 | 7.53 | .88 | 1.9 | - .93 | 6.03 | 5.98 | .48 | .07 |
| 2 | .227 | 15.42 | 3.68 | 4.8 | -4.43 | 6.63 | 5.88 | .10 | .14 |
| 3 | .229 | 15.3 | 3.63 | 5.2 | -5.07 | 6.87 | 5.43 | .45 | .15 |
| 4 | .2155 | 16.25 | 4.10 | M 5.76 | -5.39 | 6.63 | 5.34 | .09 | .18 |
| 5 | .1975 | 17.73 | 4.88 | M 8.02 | -7.05 | 6.03 | 3.86 | 1.48 | .26 |
| 6 | .232 | 15.1 | 3.54 | M 7.39 | -5.24 | 4.85 | 3.15 | .71 | .23 |
| 7 | .254 | 13.78 | 2.94 | | | 3.37 | | | .14 |
| 8 | .290 | 12.07 | 2.26 | | | 2.07 | | .25 | .07 |
| 9 | .318 | 11.0 | 1.88 | 5.48 | .30 | 1.22 | 3.40 | | .07 |
| 10 | .348 | 10.06 | 1.57 | 4.9 | 2.10 | .00 | 3.67 | .02 | .04 |
| 11 | .401 | 8.73 | 1.18 | 4.8 | 2.75 | -.55 | 3.38 | 1.18 | .01 |
| Disc. Vel | | 8.73 | 1.18 | | | | | | 1.35 Total |
| T.W. | | | | 5.61 | | 1.39 | 1.39 | | |

Eff. exp. for discharge through throat 3. =

$$\frac{3.5}{.229 \times 8.025 \times \sqrt{5.61 - .54}} = .845 = 84.5\%$$

Eff. exp. for smallest section 5. =

$$\frac{3.5}{.1975 \times 8.025 \times \sqrt{5.61 - .54}} = .980 = 98.0\%$$

DATA SHEET 15 .. Model I

Q (quantity) - 3.55 second feet.
Siphon drawing some air at times.
Conditions--four mercury "U" tubes, others water columns, also "U".
Date--June 21st 1916.

| Pt or Tube no | Sec. area in sqft | Vel. in ft/sec | $\frac{V^2}{2g}$ | Gage read wa.&me cols ft | $\frac{P}{W}$ | Z refer. tube 10 feet | $Z + \frac{P}{w} + \frac{v^2}{2g}$ | Lost Head ft |
|---|---|---|---|---|---|---|---|---|
| H.W. | | | | .55 | .00 | 6.45 | 6.45 | |
| Inl | .765 | 4.64 | .33 | | | | | .40 |
| 1 | .465 | 7.63 | .905 | 1.85 | -.88 | 6.03 | 6.05 | |
| 2 | .227 | 15.64 | 3.80 | 5.05 | -4.68 | 6.63 | 5.75 | .30 |
| 3 | .229 | 15.5 | 3.73 | 5.37 | -5.24 | 6.87 | 5.35 | .40 |
| 4 | .2155 | 16.47 | 4.22 | M6.40 | -6.03 | 6.63 | 4.82 | .53 |
| 5 | .1975 | 17.97 | 5.01 | M8.36 | -7.39 | 6.03 | 3.65 | 1.17 |
| 6 | .232 | 15.3 | 3.63 | M7.44 | -5.29 | 4.85 | 3.19 | .46 |
| 7 | .254 | 13.96 | 3.03 | M6.92 | -3.29 | 3.37 | 3.11 | .08 |
| 8 | .290 | 12.23 | 2.32 | 6.4 ? | | | | |
| 9 | .318 | 11.15 | 1.93 | 5.25 | .53 | 1.22 | 3.68 | |
| 10 | .348 | 10.2 | 1.61 | 4.95 | 2.05 | 0.00 | 3.66 | |
| 11 | .401 | 8.87 | 1.22 | 4.9 | 2.65 | -.55 | 3.32 | |
| Discharge Velocity Lost Head | | | | | | | | 1.22 |
| T.W. | | | | 5.76 | | 1.24 | 1.24 | |

Eff. exp. for discharge through throat 3 =

$$\frac{3.55}{.229 \times 8.025 \times \sqrt{5.76 - .55}} = .847 = 84.7\%$$

Eff. exp. for smallest section 5 =

$$\frac{3.55}{.1975 \times 8.025 \times \sqrt{5.76 - .55}} = .983 = 98.3\%$$

# DATA SHEET 16 .. Model I.

Q = 3.44

Conditions--~~three~~ four inverted water columns sucking from T.W. and one mercury column (later changed to inverted water).

Sucking some air occasionally---Date, June 22nd 1916.

| Pt or tube no | Sec area in sqft | Vel. in ft/sec | $\frac{V^2}{2g}$ | Gage read wa.&me cols ft | $\frac{P}{W}$ | Z refer. tube 10 feet | Z + $\frac{V^2}{2g}$ + 0.13 | Lost head feet |
|---|---|---|---|---|---|---|---|---|
| H.W. | | | | 0.61 | .00 | 6.39 | 6.39 | |
| Inl | .765 | 4.50 | .31 | | | | | .10 |
| 1 | .465 | 7.55 | .89- | 1.60 | -.63 | 6.03 | 6.29 | |
| 2 | .227 | 15.15 | 3.57 | 4.9 | -4.53 | 6.63 | 5.67 | .62 |
| 3 | .229 | 15.04 | 3.52- | 5.05 | -4.92 | 6.87 | 5.47 | .27 |
| 4 | .2155 | 15.97 | 3.96 | -.43 | -5.76 | 6.63 | 4.83 | .64 |
| 5 | .1975 | 17.44 | 4.72 | -2.24 | -7.57 | 6.03 | 3.18 | 1.13 |
| 6 | .232 | 14.84 | 3.43 | .75 | -4.58 | 4.85 | 3.70 | |
| 7 | .254 | 13.55 | 2.85 | 2.60 | -2.73 | 3.37 | 3.49 | .21 |
| 8 | .290 | 11.87 | 2.18 | 4.20 | -1.13 | 2.07 | 3.12 | |
| 9 | .318 | 10.82 | 1.82 | 5.1 | .68 | 1.22 | 3.72 | .05 |
| 10 | .348 | 9.89 | 1.52 | 4.8 | 2.2 | .00 | 3.72 | |
| 11 | .401 | 8.58 | 1.14 | 4.7 | 2.85 | -.55 | 3.44 | |
| Disc. Veloc ---- | | | 1.14 | | | | | 1.14 |
| T.W. | | | | 5.33 | | 1.67 | 1.67 | |

Eff. exp. for discharge through throat 3. =

$$\frac{3.44}{.229 \times 8.025 \times \sqrt{5.33 - .61}} = .862 = 86.2\%$$

Eff. exp. for discharge through smallest section 5. =

$$\frac{3.44}{.1975 \times 8.025 \times \sqrt{5.33 - .61}} = 1.00 = 100\%$$

---

Test with one tube open --- Q = 3.34 sec.ft.

H.W. = .05

T.W. = 6.30

H = 6.25 feet.

$$\text{Eff. throat} = \frac{3.34}{.229 \times 8.025 \times \sqrt{6.25}} = .727 = 72.7\%$$

$$\text{Eff. smallest area} = \frac{3.34}{.1975 \times 8.025 \times \sqrt{6.25}} = .843 = 84.3\%$$

DATA SHEET .. 17 Model II

Q = 3.5 second feet
Siphon drawing some air.
Conditions--five inverted water columns, others "U" columns.

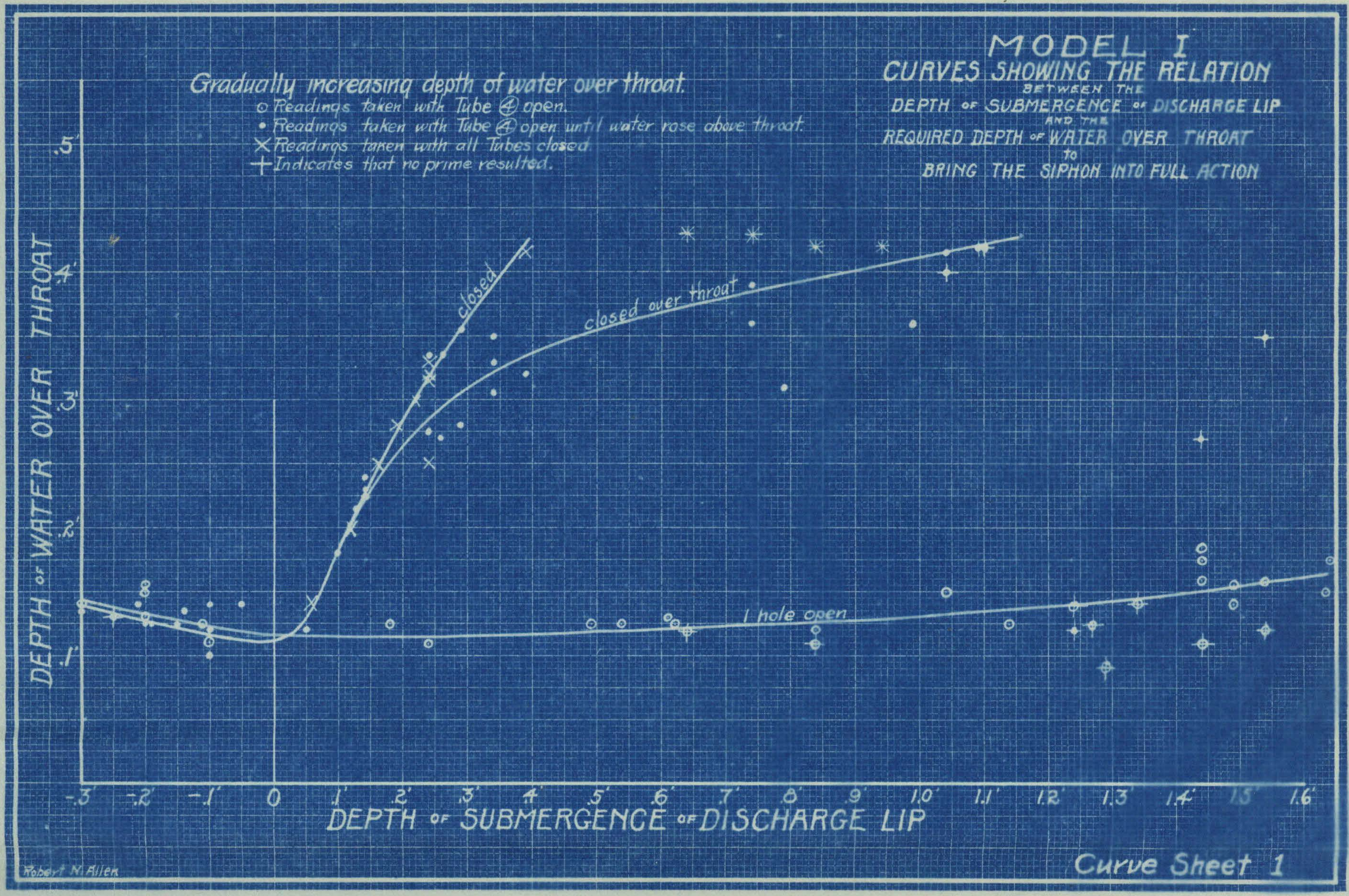
| Pt or tube no | Sec. area in sqft. | Vel. in ft/sec | $\frac{V^2}{2g}$ | Gage read watr cols ft | $\frac{P}{w}$ | Z refer tube 10 feet | $Z + \frac{P}{w} + \frac{V^2}{2g}$ | Lost Head ft | $\frac{flv^2}{4r2g}$ aprox aver. f=.021 |
|---|---|---|---|---|---|---|---|---|---|
| H.W. | | | | 0.56 | .00 | 6.44 | 6.44 | | |
| Inl | .765 | 4.57 | .324 | | | | | .01 | .01 |
| 1 | .465 | 7.53 | .88 | 1.45 | -.48 | 6.03 | 6.43 | | |
| 2 | .227 | 15.41 | 3.69 | 4.80 | -4.43 | 6.63 | 5.89 | .54 | .07 |
| 3 | .229 | 15.28 | 3.63 | 5.0 | -4.87 | 6.87 | 5.63 | .26 | .14 |
| 4 | .2155 | 16.25 | 4.10 | 0.05 | -5.59 | 6.63 | 5.14 | .49 | .15 |
| 5 | .1975 | 17.72 | 4.87 | 1.3 ? | -6.94? | 6.03? | 3.96 | .94 | .18 |
| 6 | .232 | 15.1 | 3.54 | 1.45 | -4.19 | 4.85 | 4.20 | | .26 |
| 7 | .254 | 13.77 | 2.94 | 3.2 | -2.44 | 3.37 | 3.87 | | .23 |
| 8 | .290 | 12.06 | 2.26 | 5.18 | -.46 | 2.07 | 3.87 | .10 | .14 |
| 9 | .318 | 11.0 | 1.88 | 4.7 | 1.08 | 1.22 | 4.10 | | .07 |
| 10 | .348 | 10.05 | 1.57 | 4.4 | 2.60 | .00 | 4.17 | | .07 |
| Discharge Velocity Head Lost (approx) --------- | | | | | | | | 1.50 | .02 |
| T.W. | | | | 5.64 | | 1.36 | 1.36 | | 1.32 Total |

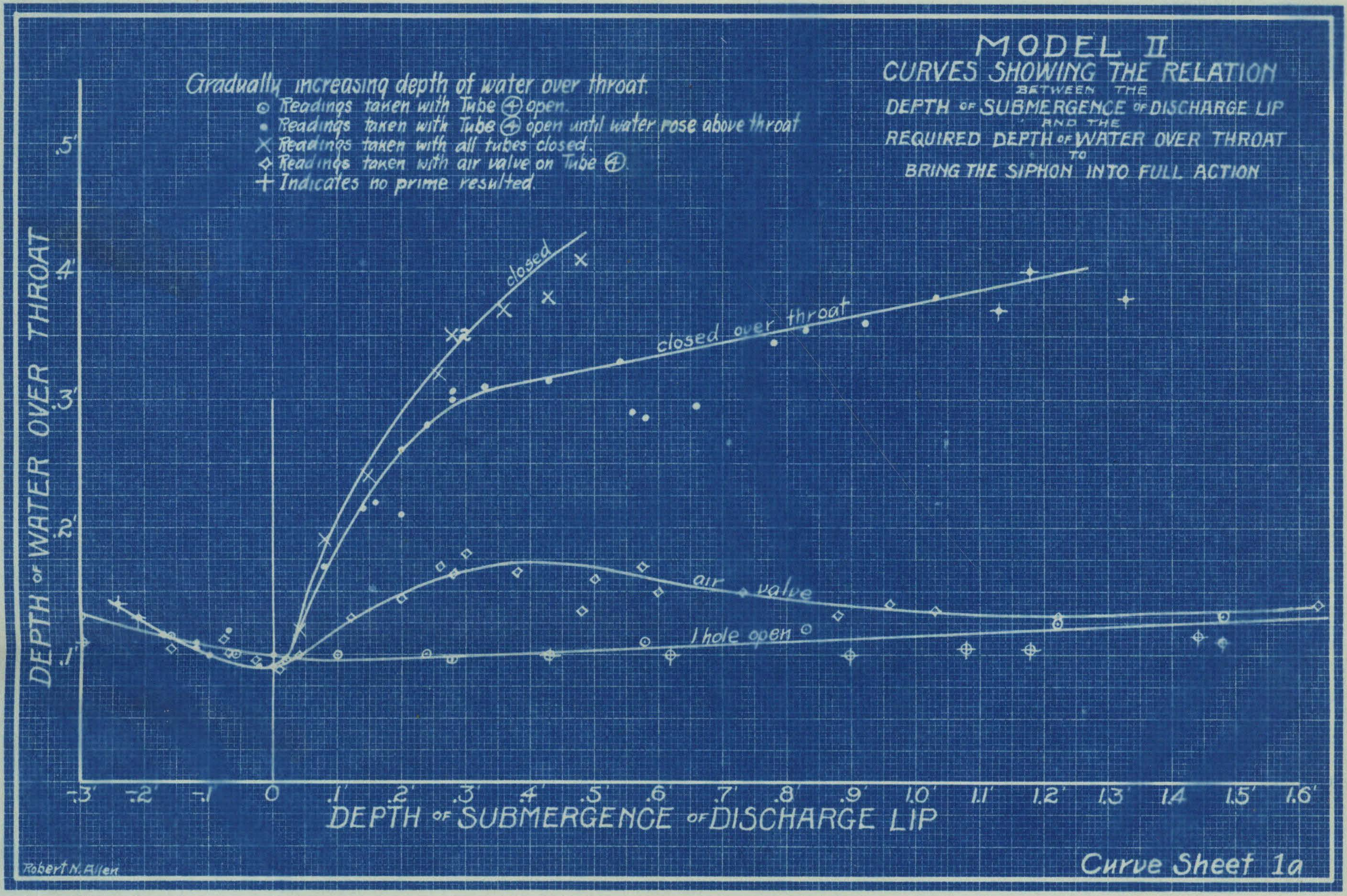
Eff. exp. for discharge through throat 3 =

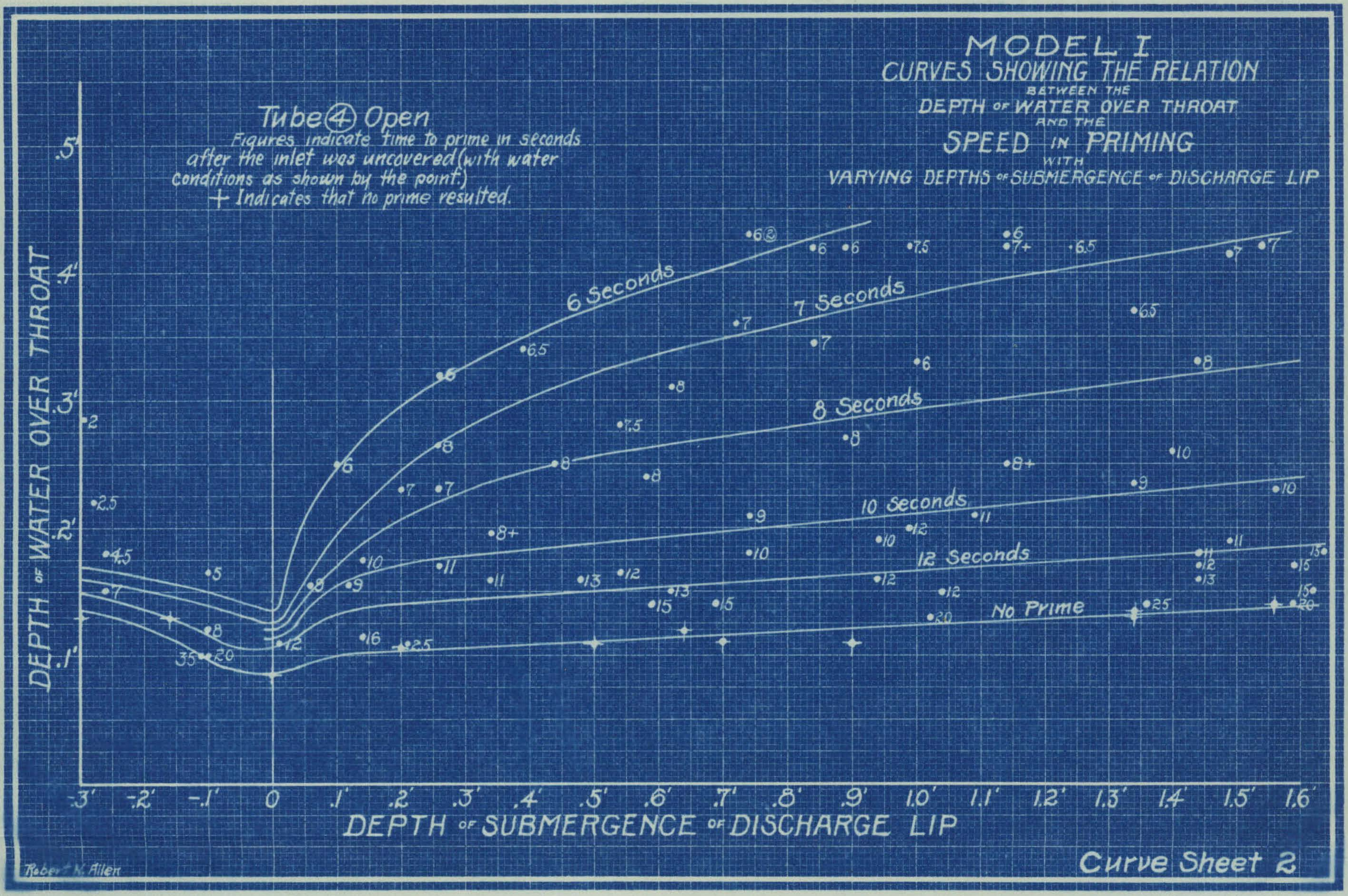
$$\frac{3.5}{.229 \times 8.025 \times \sqrt{5.64 - .56}} = .845 = 84.5\%$$

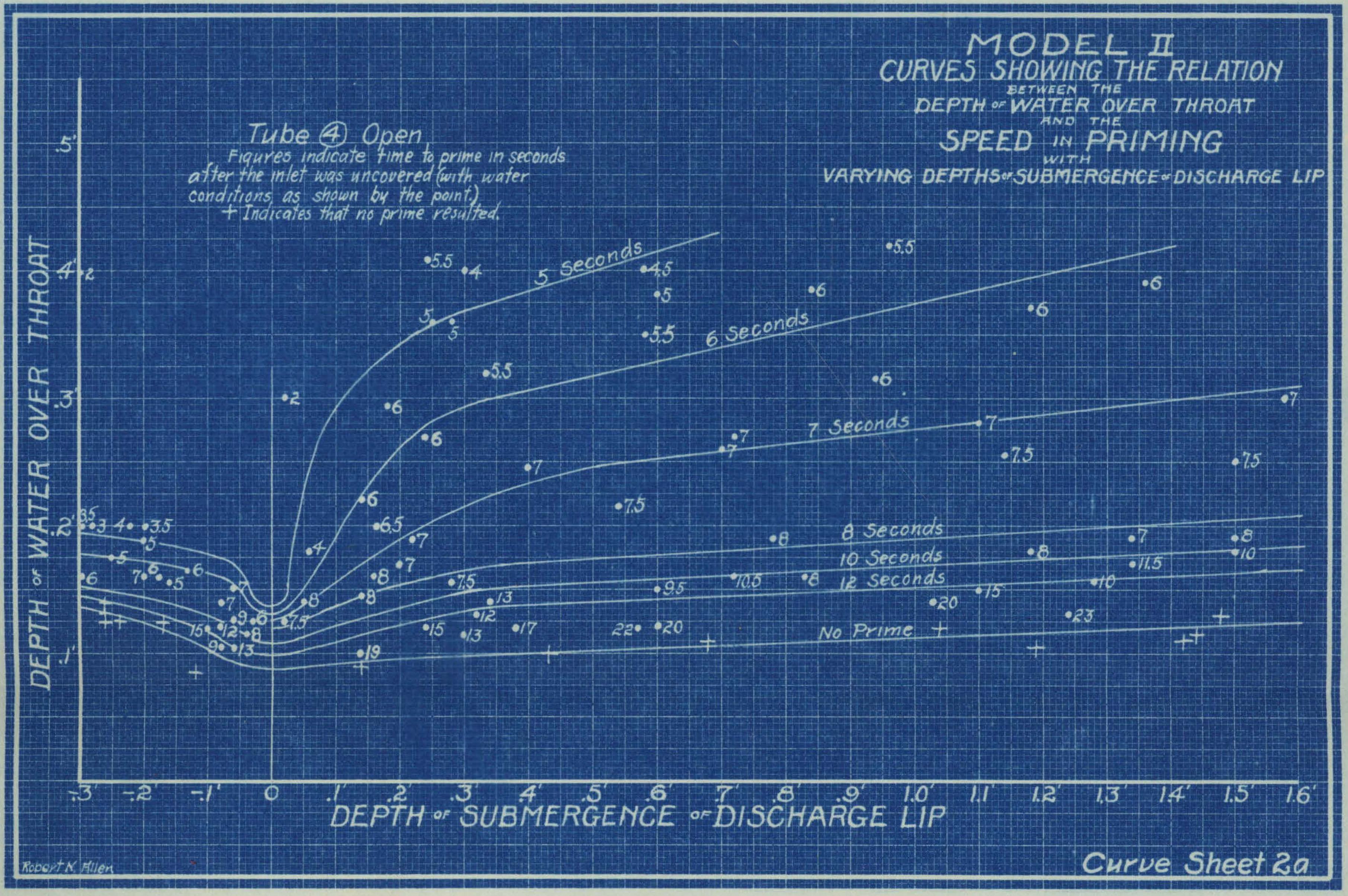
Eff. exp. for discharge through smallest section 5 =

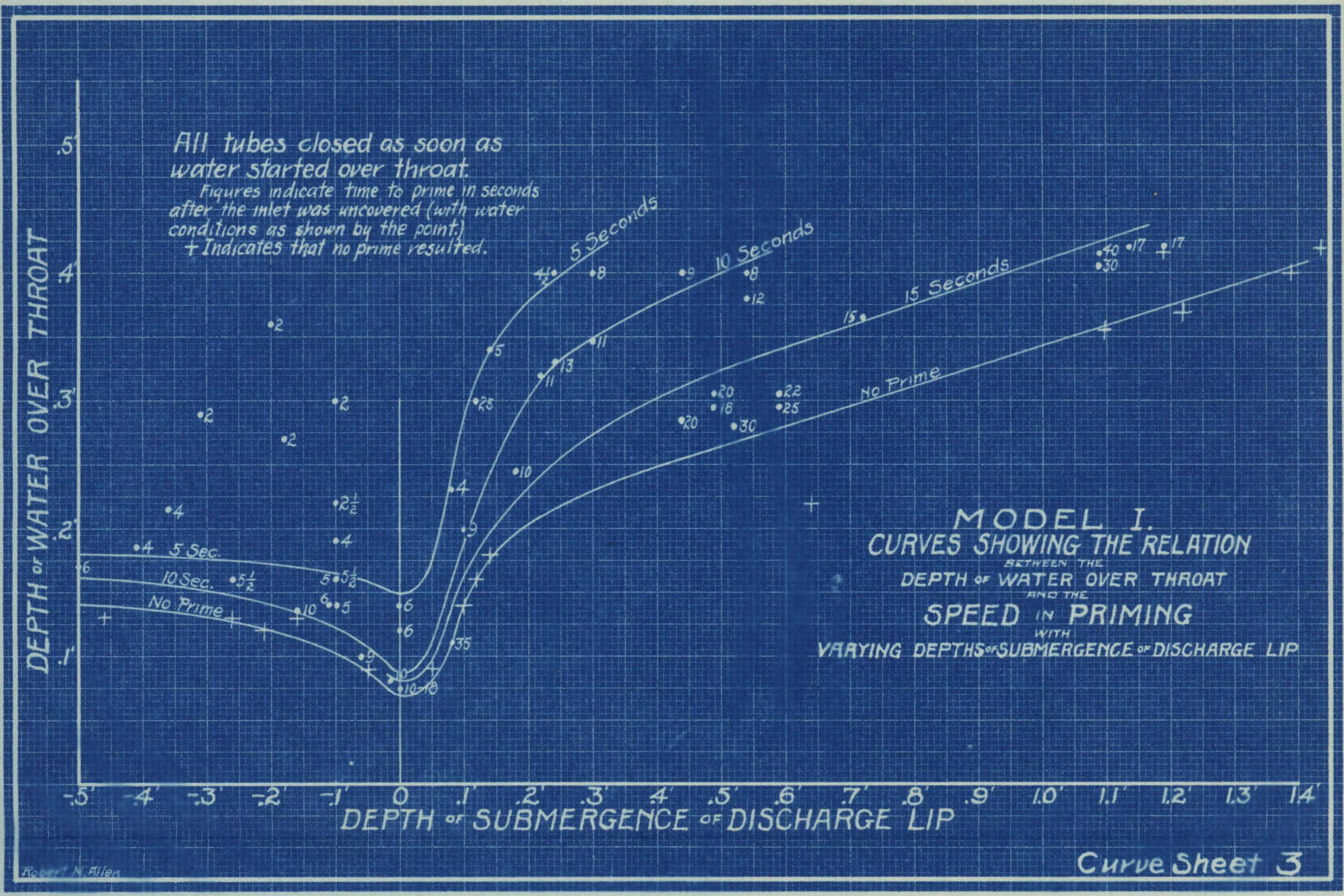
$$\frac{3.5}{.1975 \times 8.025 \times \sqrt{5.64 - .56}} = .980 = 98.0\%$$

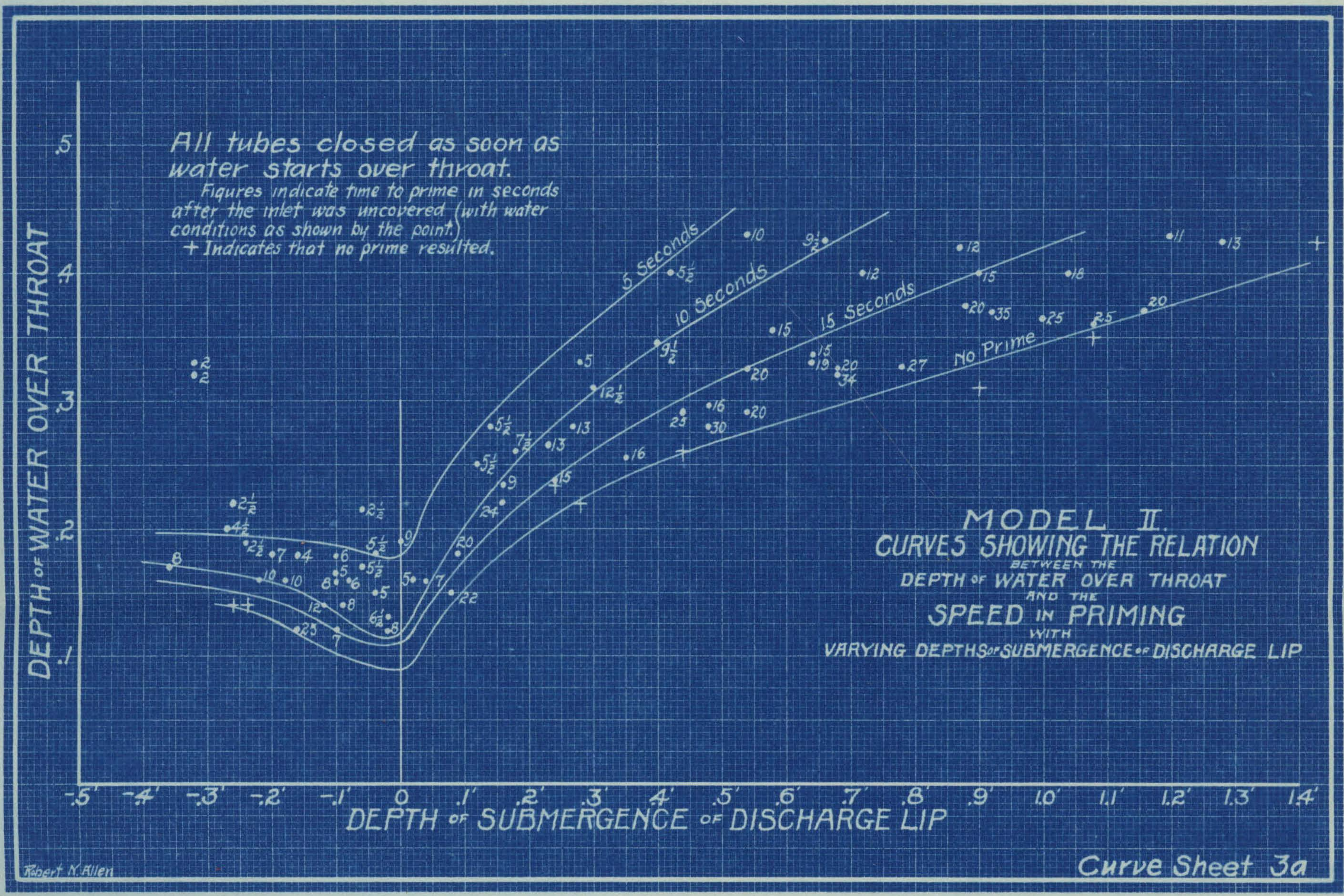

MODEL I
CURVES SHOWING THE RELATION
BETWEEN THE
DEPTH OF SUBMERGENCE OF DISCHARGE LIP
AND THE
REQUIRED DEPTH OF WATER OVER THROAT
TO
BRING THE SIPHON INTO FULL ACTION
Gradually increasing depth of water over throat.
○ Readings taken with Tube 4 open.
• Readings taken with Tube 4 open until water rose above throat.
× Readings taken with all Tubes closed.
+ Indicates that no prime resulted.
closed
closed over throat
1 hole open
DEPTH OF WATER OVER THROAT
DEPTH OF SUBMERGENCE OF DISCHARGE LIP
Robert N. Allen
Curve Sheet 1


MODEL II
CURVES SHOWING THE RELATION
BETWEEN THE
DEPTH OF SUBMERGENCE OF DISCHARGE LIP
AND THE
REQUIRED DEPTH OF WATER OVER THROAT
TO
BRING THE SIPHON INTO FULL ACTION
Gradually increasing depth of water over throat.
○ Readings taken with Tube 4 open.
• Readings taken with Tube 4 open until water rose above throat.
× Readings taken with all tubes closed.
◇ Readings taken with air valve on Tube 4.
+ Indicates no prime resulted.
closed
closed over throat
air valve
1 hole open
DEPTH OF WATER OVER THROAT
DEPTH OF SUBMERGENCE OF DISCHARGE LIP
Robert N. Allen
Curve Sheet 1a


MODEL I
CURVES SHOWING THE RELATION
BETWEEN THE
DEPTH OF WATER OVER THROAT
AND THE
SPEED IN PRIMING
WITH
VARYING DEPTHS OF SUBMERGENCE OF DISCHARGE LIP
Tube 4 Open
Figures indicate time to prime in seconds after the inlet was uncovered (with water conditions as shown by the point.)
+ Indicates that no prime resulted.
6 Seconds
7 Seconds
8 Seconds
10 Seconds
12 Seconds
No Prime
DEPTH OF WATER OVER THROAT
DEPTH OF SUBMERGENCE OF DISCHARGE LIP
Robert N. Allen
Curve Sheet 2


MODEL II
CURVES SHOWING THE RELATION
BETWEEN THE
DEPTH OF WATER OVER THROAT
AND THE
SPEED IN PRIMING
WITH
VARYING DEPTHS OF SUBMERGENCE OF DISCHARGE LIP
Tube 4 Open
Figures indicate time to prime in seconds after the inlet was uncovered (with water conditions as shown by the point.)
+ Indicates that no prime resulted.
5 Seconds
6 Seconds
7 Seconds
8 Seconds
10 Seconds
12 Seconds
No Prime
DEPTH OF WATER OVER THROAT
DEPTH OF SUBMERGENCE OF DISCHARGE LIP
Robert N. Allen
Curve Sheet 2a


All tubes closed as soon as water started over throat.
Figures indicate time to prime in seconds after the inlet was uncovered (with water conditions as shown by the point.)
+ Indicates that no prime resulted.
5 Seconds
10 Seconds
15 Seconds
No Prime
5 Sec.
10 Sec.
MODEL I.
CURVES SHOWING THE RELATION BETWEEN THE DEPTH OF WATER OVER THROAT AND THE SPEED IN PRIMING WITH VARYING DEPTHS OF SUBMERGENCE OF DISCHARGE LIP
DEPTH OF WATER OVER THROAT
DEPTH OF SUBMERGENCE OF DISCHARGE LIP
Robert K. Allen
Curve Sheet 3


All tubes closed as soon as water starts over throat.
Figures indicate time to prime in seconds after the inlet was uncovered (with water conditions as shown by the point.)
+ Indicates that no prime resulted.
5 Seconds
10 Seconds
15 Seconds
No Prime
MODEL II.
CURVES SHOWING THE RELATION BETWEEN THE DEPTH OF WATER OVER THROAT AND THE SPEED IN PRIMING WITH VARYING DEPTHS OF SUBMERGENCE OF DISCHARGE LIP
DEPTH OF WATER OVER THROAT
DEPTH OF SUBMERGENCE OF DISCHARGE LIP
Robert K. Allen
Curve Sheet 3a