HYDRAULICS LABORATORY PROJECT.

Yusuf Nosrat.

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SCHOOL OF ENGINEERING

PROJECT REPORT

AMERICAN UNIVERSITY OF BEIRUT

H Y D R A U L I C S   L A B O R A T O R Y

P R O J E C T

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T H E S I S

By

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May 20th, 1953

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School of Engineering
A.U.B.
Beirut, Lebanon

May 20th, 1953

Prof. Walter Baggaley
School of Engineering
A.U.B.

Dear Sir,

With reference to our conversation of a few months ago, and your recommending to me to design a Hydraulic laboratory for the School of Engineering as a subject for a thesis , I have pleasure in enclosing my report and drawings about it.

I am grateful to you for the help and the valuable information you have given to me on the subject, and hope that my thesis will meet with your approval.

Yours faithfully,

Youseph Nosrat.

Y. Nosrat

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The A.U.B. School of Engineering decided to set up a hydraulic and fluid mechanic laboratory. This was assigned to me as a topic for my thesis. The designing and installation of the hydraulic laboratory equipments were carried out under the supervision of Professor Walter Baggaley.

The north wing of the second floor of the Engineering building, designed previously for that purpose, and part of the first floor, were put at my disposal.

The full plan is shown in drawing No. 3003. In designing a laboratory the first thing to know is the type of experiments to be done. The next is to provide the equipment necessary for that purpose.

Finally and the most important, are the testing methods, the underfounding and the correlation of results.

In designing the hydraulic laboratory consideration was given to isolate the different equipment, in such a way as to allow execution of simultaneous experiments.

Part of the equipment is to be set up permanently and the other part temporary. The reason for that is to provide for the students adequate changes in experiments.

As seen in the enclosed drawings it is designed so that at least five groups of students can test at the same time with the equipment without disturbing each other.

Temporary equipments

The following experiments could be carried out by using the temporary equipments:

a. Friction losses in circular pipes

b. Comparison by orifice for measuring fluid flow

c. Flow in open channels-gauging by means of weirs.

d. Losses in pipe line due to sudden changes in diameters.

e. Calibration of a venturi meter.

f. Determination of comparative pressure losses in bends.

Friction losses in circular pipes

Two 1-inch pipes were chosen for this experiment, one is of galvanized steel, and the other of copper, as these two materials are widely used in hydraulic works.

For reference drawings No 3001, 3002 show a layout of the piping and drawing No. 3004 show the detail.

As for supporting the two pipes timber boards were used as shown in Drawing No. 3001 Detail (C). Water flows down in a 3 inch pipe from a water tank placed on the roof of the Engineering Building. A Tee connection is provided between the main line and the 1 inch pipes.

In order to find friction losses in each of the two 1 inch pipes the pressure difference must be constant between the inlet and the outlet of the pipe. It is of great importance to have static pressure in the pipes for that reason a laminar flow is needed, so as to get a correct reading of the pressure difference between any two points. A piezometric connection was used for that purpose at each point. As shown in Drawing No. 3001 Detail (A), a 9 cm diameter aluminium piezometer was provided and on the top of each there is a brass tap which could be connected to the manometer by a rubber tube. This will show the pressure reading at that particular point.

By knowing the pressure at the inlet and outlet of the pipe the pressure difference through the pipe is readily calculated.

It is wise to explain at this point the theory lying behind this experiment leaving for later the description of how to perform the test and the way of interpreting the results.

Theory

Let h represent the head loss in the pipe length (l). It is customary to express the lost head in the following equation :

$$h = f\left(\frac{l}{D}\right)\cdot\frac{V^2}{2g}$$

V = the velocity flow in pipe

D = diameter of pipe

$2g = 2(32.2)\ ft/sec^2$

This expression is sometimes called the Darcy-Werbach form in honor of two early workers in this field. The ratio l/D is dimensionless. The factor $\frac{V^2}{2g}$ is frequently called a velocity head. It has the same dimensions as h , namely energy per unit weight or the net dimensions of a length.

Thus the friction factor or coefficient "f" is dimensionless.

In one type of practical problem, l, V and D are known or given. The head loss can be computed if the friction can be found. Thus the determination of f is an important feature.

For ordinary velocities a great many experimental data have established the fact that the friction coefficient f depends only on two factors. The Reynolds number of the flow and geometry of conduit surface.

Usually the steady of flow through a circular pipe is only for a new and clean pipe.

The effect of age on pipe roughness is frequently very difficult to predict.

For smooth tubing actual data may show a variation or scatter of ± 5 percent in f. One common and important type of problem is the determination of pressure drop for a given length, diameter, dynamic viscosity, density and average velocity.

Hazen-Parseville law for laminar flow in circular pipes

For fully developed laminar flow in all circular pipe

$$f = 64/N_R \quad (N_R = \text{Reynold's number})$$

For this case the pressure drop in a horizontal pipe becomes

$$\Delta p = p_1 - p_2 = wh = w\,\frac{64}{N_R}\cdot\left(\frac{l}{D}\right)\cdot\frac{V^2}{2g} = \frac{32\mu l V}{D^2}$$

The rate of discharge $Q = \frac{\pi D^2 V}{4}$ then

$$p = 128 \frac{\mu l Q}{\pi D^4}$$

The mathematical analysis of laminar flow checks very accurately with experimental result. If we find Δp which is the difference pressure in two points of a pipe we can find also Q which is the quantity of flow in a pipe in the testing time.

I enclose herewith a copy of an experimental sheet which describes the method of testing, and friction losses in circular pipes and the type of result obtained.

FRICTION LOSSES IN CIRCULAR PIPES

Sequence of Operations

1. Measure distance "L" in meters.
2. Measure inside diameter of pipe sample (average of four measurements, two at each end).
3. Check that connections to manometer are tight.
4. Check balance for compensation of Weighing Tank.
5. Check manometers for freedom from air bubbles.
6. Carefully open valves "S" and "C" and adjust flow of water to give approximately ..-.-.. mm differential on manometers.

7. On signal from Timekeeper start collecting water, meanwhile controlling valve "C" to maintain uniform pressure differential. Length of run to be as indicated in Table II (a).

8. Repeat (7) with (b)___ mm; (c)___ mm differential.
(d)___ mm; (e)___ mm. "

9. Repeat experiment on Copper Pipe.

10. Compute results per Table III (a) and III (b).

Experiment No. 1 (a)

Table I (a)

Description of Pipe : Copper

Length of pipe tested - L : 4.60 meters ; 15.16 feet

Diameter of " " - d : 25 mm. ; 0.985 inches

Area of " " - A : 495 sq.mm. ; 0.00528 sq.ft.

Table II (a)

Test	delta H# mm	delta H# ft.	Flow time in seconds	Weight of water Kgms.	Weight of water Lbs.	Remarks
a	18	0.059	42.5	4.640	10.20	
b	40	0.131	30.0	5.170	11.40	
c	64	0.210	25.0	5.760	12.70	
d	80	0.260	21.3	5.660	12.50	
e	95	0.312	20.0	5.700	12.55	

Table III (a)

Test	Flow Rate lb.ps	Flow Rate cfs	Velocity fps	f*	Remarks
a	0.240	0.00385	0.73	3.88×10^{-2}	
b	0.380	0.00610	1.15	3.48×10^{-2}	
c	0.510	0.00816	1.54	3.10×10^{-2}	
d	0.586	0.00939	1.78	2.98×10^{-2}	
e	0.627	0.0102	1.93	2.92×10^{-2}	

Assume h_f = delta H (Binder, Fluid Mechanics, 1949 ed. page 93)

* Darcy formula - $h_f = f \cdot \frac{LV^2}{2gd}$

Experiment No. 1 (b)

Table I (b)

Description of Pipe : Galvanized steel

Length of Pipe tested - L : 4.70 meters ; 16.5 feet

Diameter of " " - d : 26 mm. ; 1.020 inches

Area of " " - A : 530 sq.mm. ; 0.0057 sq.ft.

Table II (b)

Test	Delta H# mm.	Delta H# ft.	Flow Time in seconds	Weight of Water kgms.	Weight of Water lbs.	Remarks
a	18.0	0.059	40	5.900	11.90	
b	32.0	0.105	30	5.670	12.50	
c	51.5	0.169	25	6.800	14.95	
d	69.0	0.226	23	6.500	14.30	
e	101.0	0.329	20	7.250	15.95	

Assume h_f = delta H (Binder, Fluid Mechanics, 1949 ed. page 93)

Table III (b)

Test	Flow Rate lb.ps	Flow Rate cfs	Velocity fps	f*	Remarks
a	0.298	0.00478	0.839	2.77×10^{-2}	
b	0.417	0.00668	1.172	2.53×10^{-2}	
c	0.598	0.00959	1.680	1.98×10^{-2}	
d	0.622	0.00995	1.745	2.45×10^{-2}	
e	0.795	0.01272	2.250	2.26×10^{-2}	

* Darcy formula - $h_f = f \cdot \frac{LV^2}{2gd}$

Experiment for comparison orifice meters
for measuring fluid flow and friction losses through valves.

For the above experiment, the equipment was designed as shown in Drawing No. 3001, 3002 (c), 3004, 3006.

A globe valve, a gate valve and two flanges were provided on a 1 inch galvanized pipe. The orifice to be tested is placed between the two flanges and fixed by four bolts.

The flanges may be pushed apart by using a jack-screw as shown in Drawing No. 3008.

Four different types of brass orifices are used; namely, Borda mouth piece, sharp edge, thick plate and nozzle. A detail of the flanges and orifices is shown in Drawing No. 3008.

Two aluminium piezometric connections are provided for getting pressure difference through the system. A similar set up is used as for the experiment of friction losses through circular pipe.

Two taps are provided on each flange in order to take the pressure difference through the orifice. All the orifices have 10 mm hole for the flow of water. The orifice is possibly one of the oldest devices for measuring and controlling the flow of fluids.

The thin plate or sharp-edged orifice is frequently employed for metering.

The equation for the orifice to give actual quantity Q :

$$Q = KA_2 \sqrt{2gh}$$

Where A_2 is orifice area and

$$K = C / \sqrt{1 - \frac{A2}{A1}}$$

Where A_1 is the pipe area and C the discharge coefficient and $h = \frac{p_1 - p_2}{w}$ is a differential head (h)

Valve of C and K as functions of Reynolds number for various orifices and orifice installations. In another way we can explain the relation between coefficient of velocity and the coefficient of loss from the energy equation which is

$$\left(\frac{p_1}{w} + z_1 + \frac{V_1^2}{2g}\right) - \left(\frac{p_2}{w} + z_2 + \frac{V_2^2}{2g}\right) = h_f - M$$

h_f = friction of losses of head

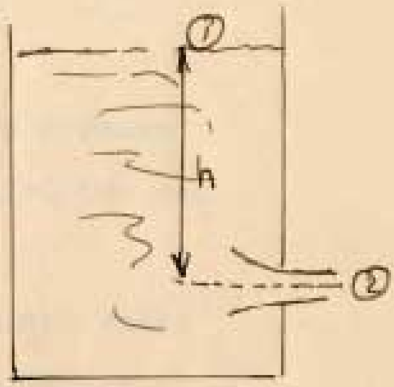
M = input heat

Which is for the energy of point (1) in top of vessel and (2) in the outlet of this vessel assuming that the pressure is atmospheric, or the same at both points, and that the area of the vessel is so large that the velocity at (1) is negligible.

Also assume that the friction be represented as

$$h_f = KV^2/2g$$

since



$$H_1 = 0 + h + 0$$

$$H_2 = 0 + 0 + V^2/2g$$

we have

$$V^2/2g = h - (H_1 + H_2) = h - K\frac{V^2}{2g}$$

from which

$$V = \sqrt{2gh} \Big/ \sqrt{1 + K}$$

The value of K would be zero if there were no frictional resistance to flow. Thus the ideal velocity is

$$v_1 = \sqrt{2gh}$$

Since the true velocity is obtained by multiplying the ideal velocity by the velocity coefficient

$$v = C_v\sqrt{2gh}$$

We know that

$$q = A.V$$

V and A denote the velocity and area of the jet; respectively Ao denotes the area of the orifice; it may be seen that

$$q = A.V = (C_c A_o)(C_v\sqrt{2gh}) = C_d A_o\sqrt{2gh} \quad (a)$$

In case the pressures at (1) and (2) are not in the preceding equations we should have

$$h + \frac{h_1 - h_2}{w}$$

C_d is coefficient of discharge and it is a known if two out of g, h, and Ao are known, the third one can be found in an orifice.

I enclose herewith a copy of an experiments sheet in hydraulic laboratory, which describes the method of testing and the result of tests of orifices.

Pressure losses through valves are obtained in the same way as described for orifices.

Usually the friction losses of valves are given in catalugs in equivalent feet of straight pipe of the same pipe.

For example from Crane catalog No. 53

a 1 inch globe valve is equivalent to 27 ft. of 1 inch pipe.

1 inch gate valve is equivalent to 2.6 feet of 1 inch pipe.

COMPARISON OF ORIFICE METERS FOR MEASURING FLUID FLOW

Sequence of Operations

1. Attach hose to four manometer taps adjacent to Orifice Flanges.

2. Check that all other taps are tightly closed.

3. Check balance for compensation of Weighing Tank.

4. Check manometer for freedom from air bubbles.

5. Carefully open valves "S" and "C" and adjust flow of water to give approximately ___ mm differential on manometers.

6. On signal from Timekeeper start collecting water, meanwhile controlling valve "C" to maintain a uniform pressure differential. Length of run to be determined is indicated in Table II.

7. Repeat (6) with (b) ___ mm; (c) ___ mm
(d) ___ mm; (e) ___ mm

8. Repeat experiment with another orifice plate.

9. Compute results as per Tabulations of sheet No.3

10. Make sketches to illustrate Experiment set-up.

<u>References</u>

Binder : Fluid Mechanics, 2nd Ed., 1949, page 129

Daugherty: Hydraulics ,4th Ed., 1937, page 159

Russel ; Hydraulics ,5th Ed., 1942, page 119

Table I

Description of Orifice Plates - a. sharp-edged orifice plate No. 2

b. Thick-edged orifice plate No. 1

Nominal Pipe Diameter 1 1/32 in. ; 26.8 mm.

	(a)	(b)	(a)	(b)
Diameter of Orifice	9.5	10 mm	3/8	3/8 inches
Area of orifice		______ mm^2	0.000768 ft.^{2}	

Table II

(A) ORIFICE PLATE No. 2

Test	delta H cm	delta H ft	Flow Time in Seconds	Weight of Water Kgms	Weight of Water lbs.	Remarks ΔH 5 diam away cm
a	8.3	0.272	60	4.585	10.10	6.5
b	17.0	0.557	45	4.940	10.86	14.6
c	24.2	0.794	30	4.020	8.85	19.5
d	31.8	1.042	20	2.920	6.43	25.5
e	39.0	1.277	30	4.990	11.00	31.5
f	68.6	2.228	25	5.325	11.76	

Table II

(B) ORIFICE PLATE No 1

Test	delta H		Flow Time in Seconds	Weight of Water		Remarks
	cm	ft		kgms.	lbs.	
a	7.0	0.23	60	4.710	10.40	
b	12.8	0.42	45	4.820	10.60	
c	24.5	0.80	30	4.420	9.75	
d	35.3	1.16	20	3.520	7.75	
e	50.0	1.64	10	2.060	1.55	

Table III

(A) ORIFICE PLATE No. 2

Test	Flow Rate		Velocity	NR#	K*	Remarks
	lbs.per sec.	cfs	fps			
a	0.1684	0.00270	3.52	0.92×10^3	0.843	
b	0.2410	0.00386	5.03	1.27×10^4	0.842	
c	0.2950	0.00473	6.16	1.56×10^4	0.861	
d	0.3217	0.00516	6.72	1.70×10^4	0.820	
e	0.3670	0.00588	7.66	1.94×10^4	0.845	
f	0.4680	0.00752	9.77	2.47×10^4	0.820	

(B) ORIFICE PLATE No. 1

Test	Flow Rate lbs./sec.	Flow Rate cfs	Velocity fps	R#	K*	Remarks
a	0.173	0.0028	3.64	9.2 x 10^3	0.95	
b	0.236	0.0038	4.95	1.25x 10^4	0.95	
c	0.325	0.0052	6.82	1.725x 10^4	0.95	
d	0.388	0.0062	8.15	2.06x 10^4	0.94	
e	0.455	0.0073	9.55	2.42x 10^4	0.93	

\# N_R = Reynolds No. = rhox V2 D2 / mu $\frac{\rho \times V_2 D_2}{\mu}$

*K = Q / A2√2g(deltah)   Δh   (Binder, page 130)

A2 = Orifice area

D2 = " diameter

Check the flow coefficient "K" against Fig. 88 on page 131 (Binder) for the corresponding "N_R"

Flow in open channel gauging by means of weirs

Weirs are used for the measurement and control of the flow of water in open channels. A 46 x 220 cm, 30 cm high steel channel is designed for this experiment, as shown in Drawing No. 3002.

The water flowing through this channel comes from a water tank.

To measure or control the flow of water in open channels it is important to have laminar flow.

In order to accomplish this purpose screens are used in the direction of the flow to change the turbulance flow to laminar flow. The holes of each screen are of different diameters.

Two different shapes of weirs are used in this experiment: triangular or V notch and rectangular.

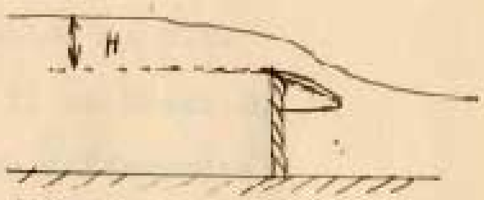
It is also possible to have other types of weirs such as trapezoidal and semi-circular.

With the notation shown in Fig. of a weir in next page height (H) of the undisturbed water level above the crest of the weir is correlated with the volumetric discharge per unit time.

One method of finding (H) is that to have a micrometer screw with a sharp conical point or hook gage. Entirely submerged in the water; this point is screwed up until it touches the surface and the height (H) is observed. Another method involves a height measuring device in which the contact between the water and the movable measuring point completes a simple electrical circuit and lights a small lamp. The quantity of water which is passing through a weir can be computed from the following equation:

(1) $Q = FH^{3/2}$ for rectangular weir

(2) $Q = FH^{5/2}$ for triangular weir



in equation (1)

$F = 2/3\ CL\sqrt{2g}$

C = is a discharge coefficient

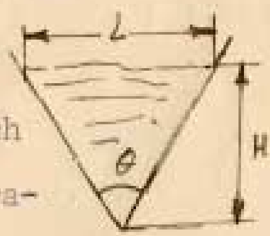
L = is the width of weir

in equation (2)

$F = 8/15\ C\sqrt{2g}\ \ tg\ \frac{\theta}{2}$

(C) is a discharge coefficient)

θ is the angle of weir



I enclose herewith a copy of an experiment which describes the method of testing in a hydraulic laboratory and the result obtained from that experiment.

FLOW IN OPEN CHANNEL, GAUGING BY MEANS OF WEIRS

(a) Triangular V-Notch (b) Rectangular

Sequence of Operations

1. Obtain zero reading on Hook Gage.

2. Measure width and depth (below bottom of Weir) of channel section.

3. Check compensation of Weighing Tank on scales.

4. Open control valve on Water Supply.

5. Set control valve to give an "H" reading on Hook Gage of approximately____ mm.

6. When uniform flow has been established, and on signal from timekeeper, start collecting water in W.T. Length of run to be as indicated in Table II on sheet 21.

7. Repeat operations (5) and (6) with differentials indicated in Table.

8. Repeat Experiment with Rectangular Weir.

9. Sketch and dimension Weirs.

10. Sketch equipment set-up.

11. Answer "Questions" on Sheet 21. ? where are they

Table No. I

Description of Channel and Weirs

Width of Channel 15.7 inches; 1.31 ft.

Depth below bottom of Weir

(a) V-Notch Weir 7.1 inches; 0.59 ft.

(b) Rectangular Weir 8.65 " ; 0.79 ft.

Table II - Experimental Data

3 (a) - V-Notch Weir

Test	Hook Gage Reading mm.	Zero	Net mm	H ft	Time secs.	Q gms.	Q cfs	K#
a	236.0	269	33.0	0.109	50.0	7940	0.0056	1.65
b	209.5	269	59.5	0.195	13.0	9100	0.0246	1.90
c	242.0	269	27.0	0.089	60.0	5600	0.0032	1.85
d	218.0	269	51.0	0.168	16.6	7980	0.0158	1.60
e	226.5	269	42.5	0.140	25.0	7290	0.0104	1.70

Compute "K" from formula $Q = K\sqrt{H^5}$

3 (b) - Rectangular Weir

Test	Hook Gage Reading mm.	Zero	Net mm	H ft	Time secs.	Q gms.	Q cfs	K#
a	205	219	14	0.046	40	7050	0.00625	3.50
b	198	219	21	0.069	21	6200	0.1005	3.52
c	190	219	29	0.095	15	7350	0.0173	3.46
d	184	219	35	0.115	13	8470	0.0228	3.58
e	175	219	44	0.114	9	8120	0.0318	3.63

Compute "K" from formula $Q = KL\sqrt{H^3}$ (Binder page 134)
(Daugherty " 147)

Four conditions should be observed in the use of weirs:

1. The weir plate should be set with its face vertical

2. The crest should be absolutely level, sharp, and normal to the direction of the flow.

3. Admission of air to the space between the sheet of falling water and the downstream face of the weir.

4. The channel upstream from the weir should be straight and level and free of all disturbing influences for a sufficient distance to permit the stream to assume a normal condition of quist flow; a minimum head of approximately 0.2 ft is preferable.

Remarks

Condition 1 and 2 were more or less accurate, while condition 3 was fulfilled except part b of 3 (a)

Condition 4 was perhaps the source of error since the height h was not equal to 0.2 besides having the water disturbed due to movement near by..

Experiment for Calibration of a Venturi Meter

A venturi meter was designed as shown in Drawings 3002, 3006. Water comes from a 1 inch pipe which is connected to a 4 inch main pipe, and flows through the Venturi meter.

The venturi tube which consists of 3 parts A,B and C connected by flanges and 3/8 inch bolts.

Piezometric holes 3 mm in diameter were drilled after the venturi tube was machined and adjusted. Two rings E and D having taps for connections to manometer, were soldered over the holes. The principle of Venturi tube was investigated by Venturi an Italian in 1791.

It was applied to the measurement of water by Clemens Hershel in 1886.

As shown in Drawing No 3006 it consists of a constricted throat, which produces an increased velocity accompanied by a reduction in pressure, followed by a gradually diverging portion in which the velocity is transported back into pressure with but slight friction loss.

Since there is a definite relation between the pressure differential and the rate of flow, the tube may be made to serve as a metering device.

Different venturi tube proportions and different arrangements of pressure gages are found in practice. The diameter of throat is usually between one half and one forth of the inlet diameter.

In my design inlet diameter is 27 mm and throat 14 mm ; the included angle of entrance cone is 20° and the included angle of exit or diffuser cone is 6°, to reduce the diffuser loss. If we don't bring in friction losses for a venturi meter then the energy equation becomes

$$p_1/w + V_1^2/2g = P_2/w + V_2^2/2g \qquad (a)$$

Where :

P_1 = pressure of inlet

V_1 = velocity of inlet

P_2 = pressure of throat

V_2 = velocity of throat

With use of the continuity equation

$$Q = A_1V_1 = A_2V_2 \quad ; \; A_1 = \text{area of inlet}$$

$$A_2 = \text{area of throat}$$

with equation (a) gives

$$P_1/w - P_2/w = V_2^2/2g \left[1 - (A2/A1)^2\right]$$

$$\text{ideal } Q = A_2V_2 = \frac{A2}{\sqrt{1-(A2/A1)^2}} \sqrt{2g\left(\frac{p1-p2}{w}\right)}$$

which Q is the quantity of water in liter per second or cu.ft. per sec.

The specific weight w in above equations is the specific weight of the fluid flowing through the water.

If we bring in the friction losses in our calculation we will have

$$Q = C_r \times C_f \sqrt{2gh} \times a$$

Q = rate of flow in cu.ft. per sec.

C_r= inlet throat ration coefficient

C_f= friction coefficient

$$C_r = \sqrt{\frac{r^2}{r^2 - 1}}$$

where = $\frac{\text{inlet area}}{\text{throat area}} = \left(\frac{D}{d}\right)^2$

D = inlet diameter in feet

d = throat diameter in feet

h = differential head in feet of fluid being metered

a = throat area in sq.ft. = $\frac{\pi d^2}{4}$

C_f allows for the loss of energy of fluid due to friction between the inlet and the throat of the venturi tube commonly called friction coefficient.

Amounts of Cf for different diameters of venturi meters are written usually in builders' catalogs. For measuring the pressure difference between inlet and throat it is designed to have a differential mercury manometer with the venturi tube which we designed.

In order to check the quantity of water through the venturi tube a water-meter is provided in the line. I enclose herewith a copy of an experiment which describes the method of testing, and the results obtained.

CALIBRATION OF A VENTURI METER

Sequence of Operations

1. Transfer hose connections from tape "b" and "d" to "d" and "f".

2. Check that taps a, b, c, and e are plugged.

3. Check balance for compensation of Weighing Tank.

4. Check manometer for freedom from air bubbles.

5. Carefully open valves "S" and "C", and adjust flow of water to give approximately _ _ mm differential on manometer.

6. On signal from Timekeeper start collecting water, meanwhile controlling valve "C" to maintain a

uniform pressure differential. Length of run to be determined from Table II.

7. Repeat (6) with (b) __ mm ; (c) __ __ mm
(d) __ mm ; (e) __ __ mm.

8. Compute results as per Tabulations in Table III.

References:

Binder, Fluid Mechanics. 2nd Ed., 1949, page 124

Daugherty, Hydraulics, 4th Ed., 1937, page 151

Davis, Handbook of Applied Hydraulics, 2nd Ed. 1952, page 1218.

Table I

Inlet Diameter (D_1) = 27 mm   Area = 0.00615 sq.ft.

Throat " (D_2) = 14 15 mm   Area = 0.00166 sq.ft.

Specific Gravity of Manometer Fluid 13.58 55

Table II

Test	delta H in.	delta H ft.	Flow Time in secs.	Weight of Water Kgms.	Weight of Water lbs.	Water Meter End	Water Meter Begining
	0.2	0.0167	40	7.340	16.20	4.177	4.170
a	0.4	0.0334	30	8.710	19.21	4.229	4.221
	0.6	0.0500	25	9.070	20.00	4.282	4.273
b	0.8	0.0667	20	8.110	17.89	4.339	4.331
	1.0	0.0834	20	9.060	19.98	4.377	4.368
c	1.2	0.1000	20	9.740	21.48	4.426	4.418
	1.4	0.1167	20	10.740	23.67	4.489	4.477
d	1.6	0.1333	10	5.530	12.20	4.541	4.530
	1.8	0.1500	10	5.790	12.68	4.585	4.580
e	2.0	0.1670	10	6.340	13.98	4.633	4.629

Table III

Test	Flow Rate - Q lbs.ps.	Flow Rate - Q cfs	Velocity fps	C#	Reynold's Number *	C from Textbook curve
a	0.405	0.0065	3.82	0.99	1.42×10^5	0.98
	0.640	0.0103	5.4	1.11	2.01×10^5	0.98
b	0.800	0.0128	6.59	1.13	2.46×10^5	0.982
	0.897	0.0144	7.63	1.09	2.83×10^5	0.983
c	0.998	0.0160	8.55	1.09	3.18×10^5	0.983
	1.071	0.0172	9.35	1.07	3.40×10^5	0.989
d	1.182	0.0190	10.14	1.09	3.78×10^5	0.984
	1.220	0.0195	10.80	1.05	4.03×10^5	0.984
e	1.268	0.0203	11.44	1.03	4.26×10^5	0.984
	1.395	0.0224	12.08	1.08	4.5×10^5	0.985

$Q = CM\sqrt{2gh}$

$$C = \frac{Q}{M\sqrt{2gh}}$$

$$M = \text{meter constant} = \frac{A1}{\sqrt{r^2 - 1}} = A_2\sqrt{\frac{r^2}{r^2 - 1}}$$

$= 0.00172$

r = ratio of areas of entrance and throat

$= D_1^2 / D_2^2$

* Reynold's Number - compute and compare "C" with curves Fig. 82, page 125 (Binder), 155 (Daugherty) or 1219 (Davis).

Sample of Calculations

a) $\Delta h = \frac{0.2}{12} = 0.01668$ ft.

$w = 7.340 \times 2.2 = 16.2$ #

$Q = \frac{W}{t} = \frac{16.2}{40} = 0.405$ #/sec.

$= \frac{0.405}{62.4} = 0.00648$ cf/sec.

$V = \frac{Q}{A} = \frac{0.00648}{0.00166} = 3.84$ ft/sec

$M = A_1 / \sqrt{r^2 - 1} = 0.00172$

$C = \frac{Q}{M\sqrt{2gh}} = 0.99$

$N_R = \frac{fVD^2}{M} = 1.43 \times 10^5$

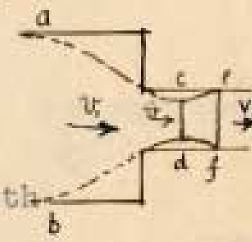
$C' = 0.98$ from the table

Losses in pipe due to sudden changes in diameters.

Drawings Nos. 3001, 3002 and 3004 show the design and the detail of the equipment related to the above named experiment.

The sudden reduction is a one inch pipe to a 1/2 inch pipe and the sudden enlargement is a 1/2 inch to a one inch pipe.

To each side of the reducers part there is one peizometric connection with brass taps connected to a manometer.



Waste of energy at a sudden reduction in a pipe. Referring to figure the water flows in the large pipe with velocity v and will contract as shown at cd on entering into the smaller pipe. the velocity v at cd will be greater than v_1.

Hence up to this section, the water has not overtaken any water moving in front of it, and therefore there has been impact and consequently no waste of energy from this course between ab and cd.

Between cd and ef the velocity of the water is diminishing again. and it will therefore be between these sections that waste of energy will occur.

Hence :

Energy wasted = $(v - v2)^2/ 2g$ ft-lb/pound of water.

If the value for the coefficient of contraction be assumed, it becomes possible to calculate v. Thus let the sectional areas of the stream at ed and ef be A and A_2 square feet respectively and let C_c be the coefficient of contraction then

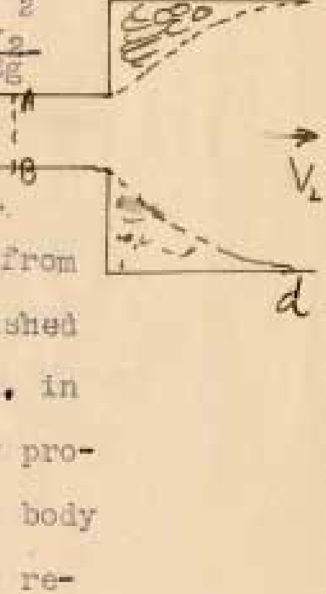
$$A = C_2A_2$$

The quantities of water flowing through Cd and ef per second will be equal Hence

$$v/v_2 = A_2/A = A_2/C_cA_2 = 1/C_c$$

$$\text{or } v = v_2/C_c$$

$$\text{and energy wasted} = \frac{\left(\frac{v_2}{C_c} - v_2\right)^2}{2g} = \left(\frac{1}{C_c} - 1\right)^2 \frac{v_2^2}{2g}$$



Waste of energy at a sudden enlargement in pipe. This case is illustrated in figure . Water flowing from the small into the large pipe has its velocity diminished from v_1 to v_2 and mingles with the water as indicated, in the illustration, and there will be a waste of energy produced in a somewhat similar manner to the case of one body overtaking another which has been discussed above the relative velocity will be ($v_1 - v_2$) and the waste of energy will be given by

$$\text{energy wasted} = \frac{(v_1 - v_2)^2}{2g} \text{ ft lb/ pound of water.}$$

In some calculation the wasted energy is by adding to the above result $1/9\ v_2^2/2g$

If we want to find the lost head in sudden enlargement the lost head (ho) is in the form of

$$ho = \left(\frac{p_1}{w} + \frac{v_1^2}{2g}\right) - \left(\frac{p_2}{w} + \frac{v_2^2}{2g}\right) \qquad (a)$$

p_1 = the pressure just before the enlargement

p_2 = the pressure in section CD

Another equation the dynamic relation, is helpful in eliminating some of the variables and obtaining a convenient form for the loss.

Consider the forces acting the fluid between sections AB and CD

Neglect shear forces along the wall, and assume that p_1 acts directly inside the enlarged area, that is, over the area AB in the fluid. Then the net force in the direction of flow deceleration the fluid is $(p_2 - p_1)\ A_2$

Force equals mass times acceleration

The mass rate of flow is $A_2 v_2 w/g$

Where w is the specific weight of the fluid. Each unit of time the mass $A_2 v_2 w/g$ has its velocity reduced from v_1 to v_2: therefore the dynamic equation shows that

$$(p_2 - p_1)\ A_2 = A_2 V_2 \frac{w}{g} (V_1 - V_2) \qquad (b)$$

Eliminating the pressure difference from equations (a) and (b) gives the final form

$ho = 1/2g\ (V_1-V_2)^2$

This equation is called the Carnot-Borda relation in honor of two pioneers in this field of study. For more information in these equipment and the method of testing, I enclose a copy of an experiment sheet which describes the method of testing of above equipments and result of different tests.

LOSSES IN PIPE LINE DUE TO SUDDEN CHANGES IN DIAMETERS.

(a) Sudden Enlargement (b) Sudden Reduction

Sequence of Operation:

Exp. 2a - Sudden Enlargement

1. Connect manometers No.1 and 2 to taps on each side of the increaser coupling.

2. Measure the inside diameters of the two (2) short samples of pipe that are the same size as the pipes under test. Average four measurements, two at each end at right angles to each other.

3. Check that all hose connections, not being used, are tightly shut off.

4. Check that the pipe line is substantially level.

5. Check balance for compensation of Weighing Tank.

6. Check manometers freedom from air bubbles.

7. Carefully open Valve "B" and "C" and adjust the flow of water to give approximately 50 mms differential on the manometer.

8. On signal from the foreman start collecting water meanwhile controlling valve "C" to maintain a uniform pressure differential. Length of run to be as indicated in Table II on following sheet.

9. Repeat (8) with manometer differentials of

a. mm ; b. mm

c. mm ; d. mm

e. mm

Expe. 2b - Sudden Contraction

1. Transfer hose connections from taps on increaser to taps on the reducer fitting.

2. Check all other taps for tightness.

3. Repeat Operations 4 to 9 inclusive for Exp. b

General

a. Make sketches of Test set-up

b. Compute results for Table III.

Table I

Description of Fittings

Diameter of small pipe	15 mm ; 1/2 inch
" " large "	26.4 mm ; 1 1/8 inch
Area of small pipe	177 sq.mm.; 0.001365 sq.ft.
" " large "	550 sq.mm.; 0.006920 sq.ft.

EXPERIMENTAL DATA

TABLE II

Exp. 2a - Sudden Enlargement.

Test	Time Secs.	H_1 Pressure differential mm.	ft.	Weight of Water Kgs.	lbs.
a	60.0	14	0.046	10.810	23.75
b	41.0	21	0.069	9.180	20.02
c	29.5	25	0.082	7.250	15.90
d	20.4	35	0.115	5.760	12.68
e	15.5	48	0.157	4.970	10.90

Exp. 2b - Sudden Contraction

Test	Time Secs.	Pressure differential mm.	ft.	Weight of Water Kgs.	lbs.
a	44.2	95	0.312	10.080	22.178
b	59.2	58	0.199	10.500	23.100
c	34.5	35	0.115	4.660	10.250
d	22.5	40	0.131	3.320	7.300
e	19.2	75	0.246	3.880	8.540

RESULTS OF EXPERIMENT

TABLE III

Exp. 2a - Sudden Enlargement

Test	Flow Rate lb.ps.	cfs.	Velocities in fps. Small pipe	larege pipe	Total energy Small pipe	large pipe	Energy lost* ft-lbs/lb
a	0.396	0.00635	4.661	0.932	14.78	14.71	0.16
b	0.493	0.00789	5.780	1.158	18.90	18.24	0.33
c	0.578	0.00976	6.790	1.360	21.58	21.31	0.46
d	0.624	0.0100	7.330	1.465	23.23	22.89	0.54
e	0.703	0.0113	8.280	1.667	26.21	25.73	0.68

* Assume energy lost per lb. = $\frac{(V_1 - V_2)^2}{2g}$ ft-lbs.

(See Binder, Fluid Mechanics, 2nd Ed., 1949, page 102)

(Also Daugherty, Hydraulics, 4th Ed., 1937, page 216)

Table III (Cont'd)

Test	Flow Rate LB.PS.	CFS.	Velocities in fps. small pipe	large pipe	Total energy Small Pipe	Large Pipe	Energy lost *
a	0.500	0.0081	5.94	1.19	14.48	18.65	0.35
b	0.390	0.0062	4.54	0.91	14.46	14.54	0.20
c	0.297	0.0048	3.52	0.70	11.04	11.08	0.12
d	0.325	0.0052	3.81	0.76	12.08	12.12	0.14
e	0.445	0.0072	5.27	1.05	16.48	16.60	0.28

* Assume energy lost per lb. = $\frac{(V1 - V2)^2}{2g}$ ft-lbs.

(See Binder, Fluid Mechanics, 2nd Ed., 1949, page 103)
(Also Daugherty, Hydraulics, 4th Ed., 1937, page 216)

Determination of Comparative Pressure Losses in Bends.

(a) Short radius bend (b) Long radius bend.

This experiment is performed by testing a long radius bend, 90° and 45° short radius bends.

The design of these parts is shown in Drawings No. 3001, 3002 and 3004 in detail.

At each side of the bend there is one piezometric connection with brass taps, connected to the manometer by a rubber tube.

All the parts are made of galvanized steel. The velocity profile in a pipe bend is greatly distorted as a result of centrifugal action. This distortion produces disturbances in the flow not only in the bend itself but for a distance of about 100 diameter in the straight pipe immediately following. In fact more than half of the energy loss produced by the curved bend takes place in this section of straight pipe. ~~Because of this the loss is not greatly dependent upon the angle subtended.~~ The friction losses produced by a pipe bend may be expressed as equivalent to an additional length of straight pipe.

A coefficient for the head lost may be found from

$h = K\ V^2/2g$

or $K = 2gh/V^2$

For more information about the above equipment, the method of testing and result of the different tests, I enclose a copy of an experiment which is used in Hydraulic Laboratory.

Sequence of Operations

1. Attach hose to manometer taps on short radius elbow.
2. Check that all other in line taps are tightly closed.
3. Check Balance for compensation of Weighing Tank.
4. Check manometers for freedom from air bubbles.
5. Carefully open valves "B" and "C" and adjust flow of water to give approximately__ mm differential on manometers.
6. On signal from Timekeeper start collecting water, meanwhile controlling valve "C" to maintain a uniform pressure differential. Length of run to be as indicated in Table II.
7. Repeat (6) with (b)___mm; (c)__mm. ; (d)___mm (e)___mm.
8. Repeat Experiment on Long Radius Bend.
9. Compute results as per Tabulations in Table III.
10. Make sketches to illustrate Equipment set-up.

References:

Binder : Fluid Mechanics - 2nd Ed., 1949, page 107

Daugherty; Hydraulics - 4th Ed., 1937, page 226

Russel : Hydraulics - 5th Ed., 1942, page 203

TABLE I - DESCRIPTION OF BENDS.

a. Short Radius Elbow: formed of 3 elbows

1. r = 2 cm., 2. r = 4 cm., 3. r = 2 cm.

b. Long Radius Bend ; formed of one elbow

r = 13 cm.

Nominal Pipe Diameter in inches 1.06 | "

Actual Area 0.882 sq.in., 0.00612 sq.ft.

TABLE II - EXPERIMENTAL DATA

a. Short Radius Elbow

Test	delta H * mm.	delta H * ft.	Flow Time Secs.	Weight of Water kgs.	Weight of Water lbs.	Remarks
a	20	0.0655	29	3.750	8.25	
b	50	0.1640	29.8	7.190	15.85	
c	60	0.1948	34.4	8.280	18.28	
d	72	0.2360	36.4	7.800	17.40	
e	85	0.2785	50	7.470	16.46	

b. Long Radius Bend

Test	delta H * mm.	delta H * ft.	Flow Time Secs.	Weight of Water Kgs.	Weight of Water lbs.	Remarks
a	3	0.0099	49.4	6.580	14.38	
b	7	0.0230	34.7	7.160	15.79	
c	9	0.0296	33.3	7.520	16.58	
d	13	0.0426	22	5.930	13.08	
e	17	0.0557	22.7	7.260	16.00	

TABLE III - CALCULATED RESULTS

a. Short Radius Elbow

Test	Flow Rate lb.ps.	cfs	Velocity fps	K#	Equivalent length of pipe in ft.	Remarks.
a	0.285	0.00456	0.745	7.6	19.4	
b	0.532	0.00854	1.390	5.5	13.8	
c	0.532	0.00854	1.390	6.6	16.6	
d	0.478	0.00767	1.252	9.6	24.6	
e	0.330	0.00529	0.865	2.4	6.05	

b. Long Radius Bend

Test	Flow Rate lb.ps.	cfs.	Velocity fps	K#	Equivalent length of pipe in ft.	Remarks
a	0.291	0.00466	0.762	1.10	2.76	
b	0.455	0.00732	1.197	1.05	2.56	
c	0.498	0.00800	1.309	1.11	2.80	
d	0.594	0.00954	1.560	1.13	2.85	
e	0.705	0.01130	1.848	1.07	2.66	

* Assume h_f = delta H

\# Use formula $h_f = K \frac{V^2}{2g}$

See Binder, Fluid Mechanics, 2nd Ed., 1949, page 107

Also Daugherty, Hydraulics, 4th Ed., 1937, page 226

Also Russel, Hydraulics, 5th Ed., 1942, page 203.

Samplè of Calculations

a. $\Delta h = \frac{2.0}{30.5} = 0.0655'$

$W = 3.75 \times 2.2 = 8.26 \#$

$Q = \frac{8.26}{29} = 0.285 \#/sec.$

$Q = \frac{0.285}{62.4} = 0.00456 \ cf/sec.$

$V = \frac{Q}{A} = \frac{0.00456}{0.00612} = 0.745 \ ft./sec.$

$K = h \frac{2g}{V^2} = 0.0655 \times \frac{64.4}{0.55} = 7.6$

$L = \frac{2Dg}{f} \frac{h}{V^2} = \frac{2 \times 1.06 \times 32.2 \ (0.0655)}{12 \times 0.035 \ (0.55)}$

$= 19.4 \ ft.$

Water Pumping System

The pumping installation was designed to supply water to a concrete tank on the Engineering Building roof for the Hydraulics laboratory use and to permit the students to perform pump tests.

An underground tank receives rain water which will be pumped up to the roof tank.

A 2 x 2 inch centrifugal pump was chosen to deliver 50 Imp Gal/ min. with a head of 132 ft. The discharge pipe is 2 1/2 inch galvanized steel and the suction is a 3 inch rubber hose.

A check valve and a gate valve were provided on the discharge line and a foot valve at the end of suction line. A piece of pipe 1 meter long is provided with a globe valve and a water meter for testing purposes. Pressure gauges are hooked on both, the discharge and the suction lines.

Water is supplied to the Hydraulics Labo. through a 4 inch pipe. An overflow of 2 1/2 in was provided in the system to connect the concrete tank to the underground tank.

The pump is driven by diesel engines and by an electric motor. The installation is so made as to permit any combination of pumps and drives.

One of the engines is a 10 HP with two vertical cylinders and the other is a 10 HP with two horizontal cylinders.

Pulleys were designed to relate together the different speeds.

Flat belts are used between the pump and the engines, and V belt between pump and electric motor.

The complete design of the water piping system is shown in Drawings Nos. 3019, 3021, 3022, and 3023.

It is necessary to say that all the water which is used for experiments in different part of Hydraulic lab. will go back to underground tank to be used again.

The Kerr Canyon Project
for
Hydro-electric plant.

This project is designed by three of the fourth Year students of the Engineering School.

As this project belongs to the Hydraulic laboratory, I shall describe it in brief.

Walking from the Medical gate down to Dr. Kerr's House during summer, one sees a very scanty flow of water, running down to the sea; though during rainy season of the year one is quite surprised at the quantity of flow, especially right after a good rain.

The purpose of this project is to utilize this flow of water to generate electricity, achieving at the same time the following:

1. Making a hydro-electric laboratory for illustrating to engineering students the operation of the different equipments involved.

2. Utilizing the water conduits and channels for hydraulics experiments.

3. Lighting Dr. Kerr"s house during rainy season.

Hence the name of the project "The Kerr Canyon Project".

The starting point was to obtain the head of flow which amounts to 43 ft. of average gross head and 60 cfm as average flow.

Part I

This part was performed by Mr. F. Kandalaft and it included the following:

1. Location of the dam, power house, channels and penstock.

2. Hydraulic study

3. Hydraulogic study.

Part II

This part was performed by Mr. S. Khoury and it included the following:

1. Structural design

2. Foundation study.

Part III

This part was performed by Mr. P. Habash and it included the following:

1. Selection of electrical and mechanical equipment.

2. Layout design of the power house.

The power which could be obtained out of this plan is little. But by this plan the hydraulic laboratory will have a good part for engineering students studies.

PART I

Location, Hydraulogy and Hydraulics.

A special survey was made by a Second Year group and a contour map was drawn with 1 m. intervals on a scale of 1:500.

Location 2-2 was chosen as it yields a capacity of 14500 cf while 1-1 yields only 7500 cf.

A closed penstock was designed with a minimum of horizontal and vertical bends from the dam to the power house.

An 8" size penstock was selected ; the efficiency of which is 97 %. It is designed to have a channel for hydraulics experiments and stream gaging. The normal velocity of stream in the channel will be 2 fps.

Floats, current meter and pitot tube measurements can be checked by 3 weir measurements, which is designed to be in the direction of flow in the channel.

A venturi meter is installed to check all the streams, gaging experiments and to serve as a basis for power house efficiency calculation.

Total flow per year will be 1,500,000 cf.

PART II

This part covers the structural design of the dam, the power house, the penstock and the canals.

The crest elevation of water is 22.40 m. The water stored will be about 14,500 cu.ft. The length of the dam is about 52 ft. The type of dam selected is a solid concrete gravity dam, the width at the top of the dam should be sufficient to provide a walkway for a man to operate the outlet works gate and the sluice gates. It is thus chosen as 3.3 ft.

The width at the foundation was found to be 13.5 ft. Two cantilevers of 0.75 ft. in width project out of the section at each side of foundation. The slope at the up-stream face is 5.05 % and at the downstream face it is 0.51 %. The depth of foundation below ground is assumed as 3.5 ft. Bars in 8, 14 and 12 mm will be used for reinforcement. A 15 x 15 in shear type gate is used at the outlet of the bell-mouthed 8" work pye. The gate is reinforced with plates monolithically fabricated with it.

Canals.

The two sections of the canal, the rectangular and the trapezoidal, are to be constructed of reinforced con-crete.

PART III

The following three hydraulic machinery are to be installed :

1. A 24 in. Pelton wheel, with hand operated needle nozzle, produced by the Pelton water wheel Co., U.S.A.

2. A 4 in Francis turbine laboratory model; pro-duced by the Rodney Hunt Machine Co., U.S.A.

3. A hydraulic Ram, which was not selected, but space was provided for it in the power house.

4. A 3 Kva alternator produced by the Metropolitan Vicbers Electric Co., England.

5. A switch board, valves, a venturi meter, a surge pipe and all necessary piping and fittings.

Power House.

The power house is an ordinary masonry building 7 x 3.5 m. The machinery is spaced quite apart from each other with a minimum clear distance of 3 ft.

The way the plant is functioning is as follows: Water coming from the penstock is directed to any of the three pipes by means of a 3 way cock valve, which directs the flow in one direction only and automatically closes the remaining outlets. In so doing safety of the machinery is secured. The three outlets from the cock valve lead to ;

1. Pelton wheel is, hereby, the runner set in a horizontal position starts rotating and by means of a belt this torque is transmitted to the generator.

2. The second outlet leads to the Francis turbine which duplicates the function of the Pelton wheel.

3. The third outlet leads to the hydraulic ram where water is pumped back to the reservoir by the use of water hammer.

Before the three way cock, there is a by-pass which leads the water to the toibrace (tailrace); thus whenever a wheel is running and is to be stopped there will not be a sudden load on that machine, for the by pass releases this pressure.

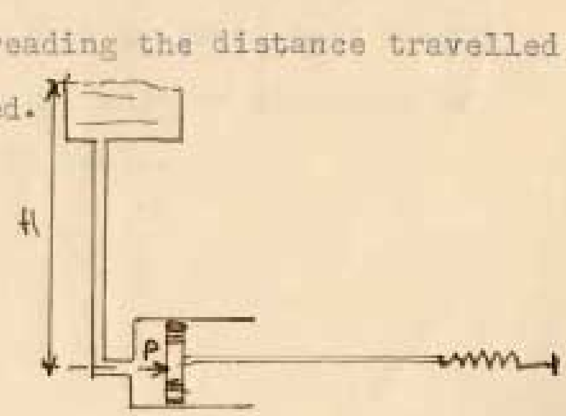
For more detailed information, please refer to the "Kerr Canyon Project" executed by Messers Habash, Khouri and Kandalaft.

RECOMMENDATION

The different experiments that I have set up in the Hydraulic Laboratory were not enough to make of this laboratory a complete one. The time was too short for such an elaborate job. I would like, however, to recommend a few more experiments which will supplement the existing set up and which I believe will help the student to get a wider knowledge in Hydraulic work.

Equipment for Experiment of Energy of flowing water.

(1) A cylinder fitted with a piston is shown in figure 1. and supplied with water from an overhead tank, in which the level is maintained constant. If the piston is allowed to move outwards slowly, work will be done by the water pressure on the piston overcoming the external resistance acting on the water side of the piston or on the piston rod. A spring is attached at the end of the rod to limit the piston travel. A means of reading the distance travelled by the piston should be provided.



Work = P A L ft.lb.

P = fluid stress on piston psi

A = Area of piston in^2

L = The distance the piston moved ft.

The work has been done at the expense of the energy of the water.

(2) Float Control Indicators for Open Channels

This instrument shows the various percentage rates of discharge in open channels.

The mechanical parts of the instrument are shown in figure 2: a float chamber, a float, a translating plate, some rollers, a chart drum and a recording pen. Quite straightforward mechanical translation devices are found suitable. A plate moving up and down with the float is shown in figure 2; its working edge being cut to the requisite profile to impart the correct motion to the roller which is maintained in contact with it.

In order that the flow may be integrated, the variable movements of the float for given increments of discharge should be so modified that the recording pen should have equal increments. This shows the comparative movements of the float and of the pen for various percentage rates of discharge.

(3) Straight channel conditions with different cross - section and different materials such as iron sheet - concrete - asphalt - wood - etc... And also in direction of this channel some bends, in small scale.

(4) A model of two open channel when two streams cross each other.

(5) Experiments for paths of water particles moving in laminary flow around various obstacles, in open channels.

(6) Experiment of siphon by different material such as metals and concrete.

(7) Experiment in the Hydraulic press with two different weights and pistons as shown in figure.

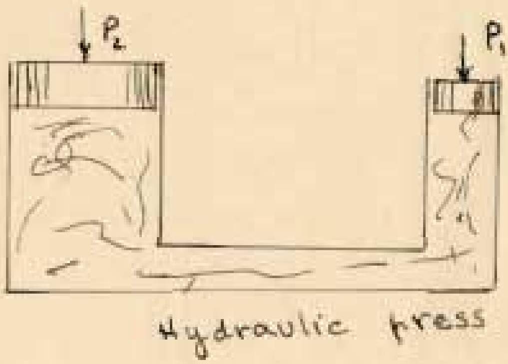
(8) Experiment for a rotation body of liquid by means of container rotating about a vertical axis with constant angular velocity.

(9) Experiment of flow in parallel pipes.

(10) Experiment of velocity in pipes by means of Pitot tube.

(11) Experiment of pumps; such as Vane pump, rotary pump, and some other types of pumps.

(12) Experiment of turbines by different types of laboratory models.



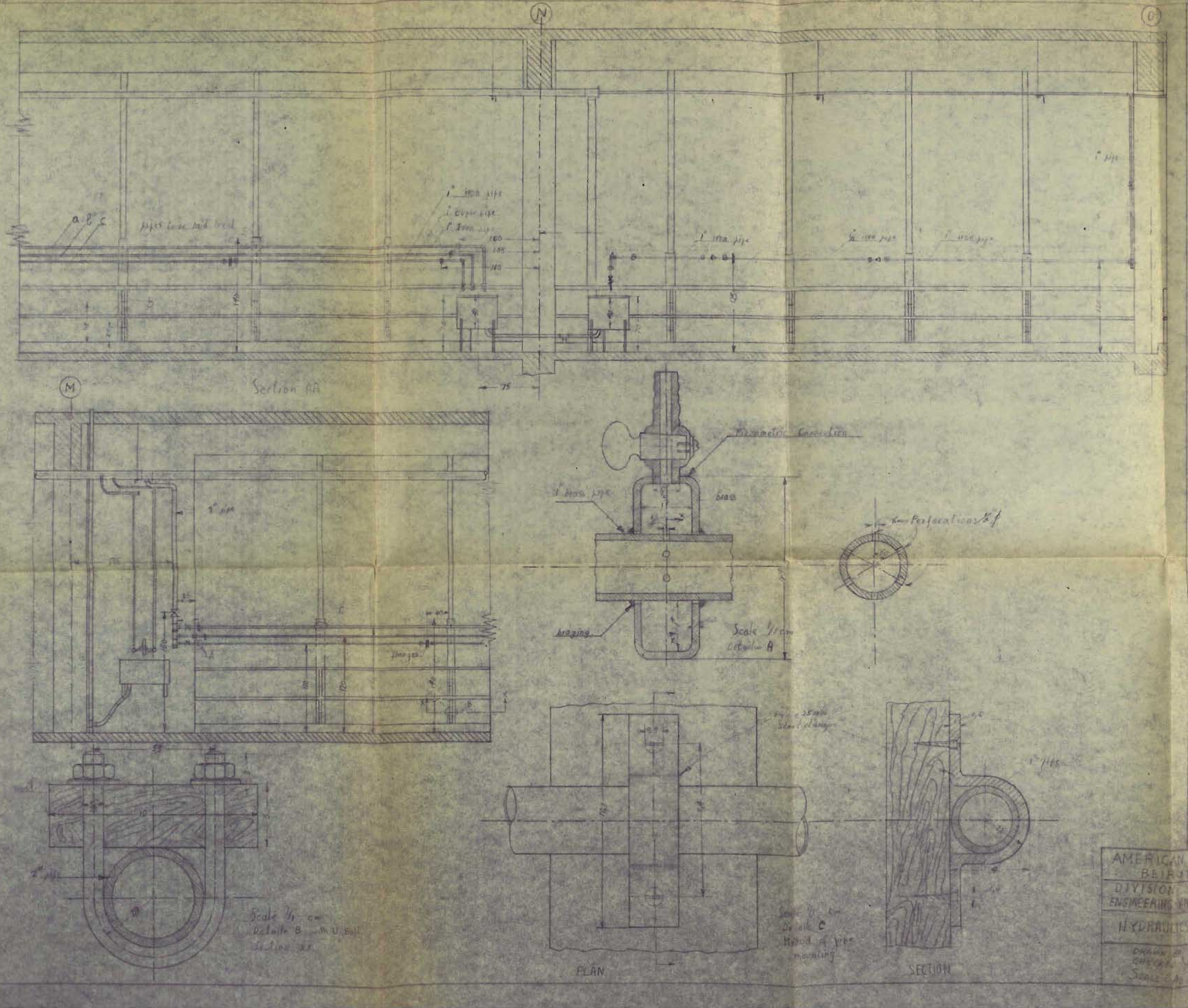
Hydraulic press

AMERICAN UNIVERSITY of BEIRUT
BEIRUT LEBANON

DIVISION of ENGINEERING
ENGINEERING AND PHYSICS BUILDING

HYDRAULICS LABORATORY

DRAWN BY YUSEPH NOSRAT 16-I-53
CHECKED [illegible] 19-I-53
SCALE: AS MARKED. Drg No 3001


Section AA
Piezometric Connection
brass
brazing
PLAN
SECTION
AMERICAN

NOTES

All perforation to be cleaned from the inside and out side of the pipe, with emery paper, all cuts in pipes to be reamed with a pipe reamer

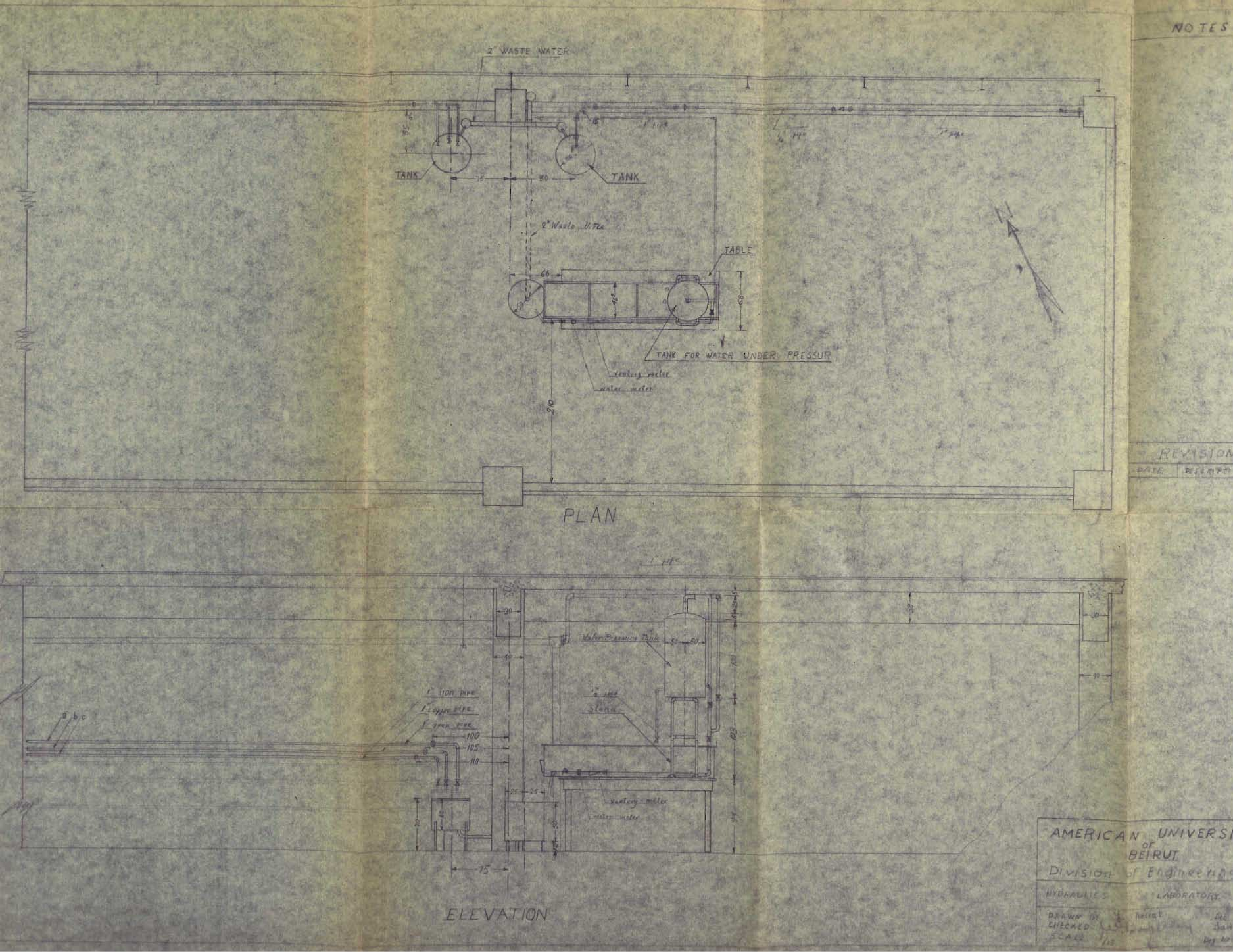
REVISIONS

DATE	DESCRIPTION

AMERICAN UNIVERSITY
OF
BEIRUT

Division of Engineering

HYDRAULICS	LABORATORY
DRAWN BY Y. Nosrat	Dec 18 1952
CHECKED [illegible]	Jan 19-'53
SCALE 1/25	Dwg No 3002



NOTES
2" WASTE WATER
TANK
TANK
2" Waste W. Pipe
TABLE
TANK FOR WATER UNDER PRESSUR
PLAN
1" iron pipe
Water Pressure Tank
Stand
ELEVATION
REVISION
DATE
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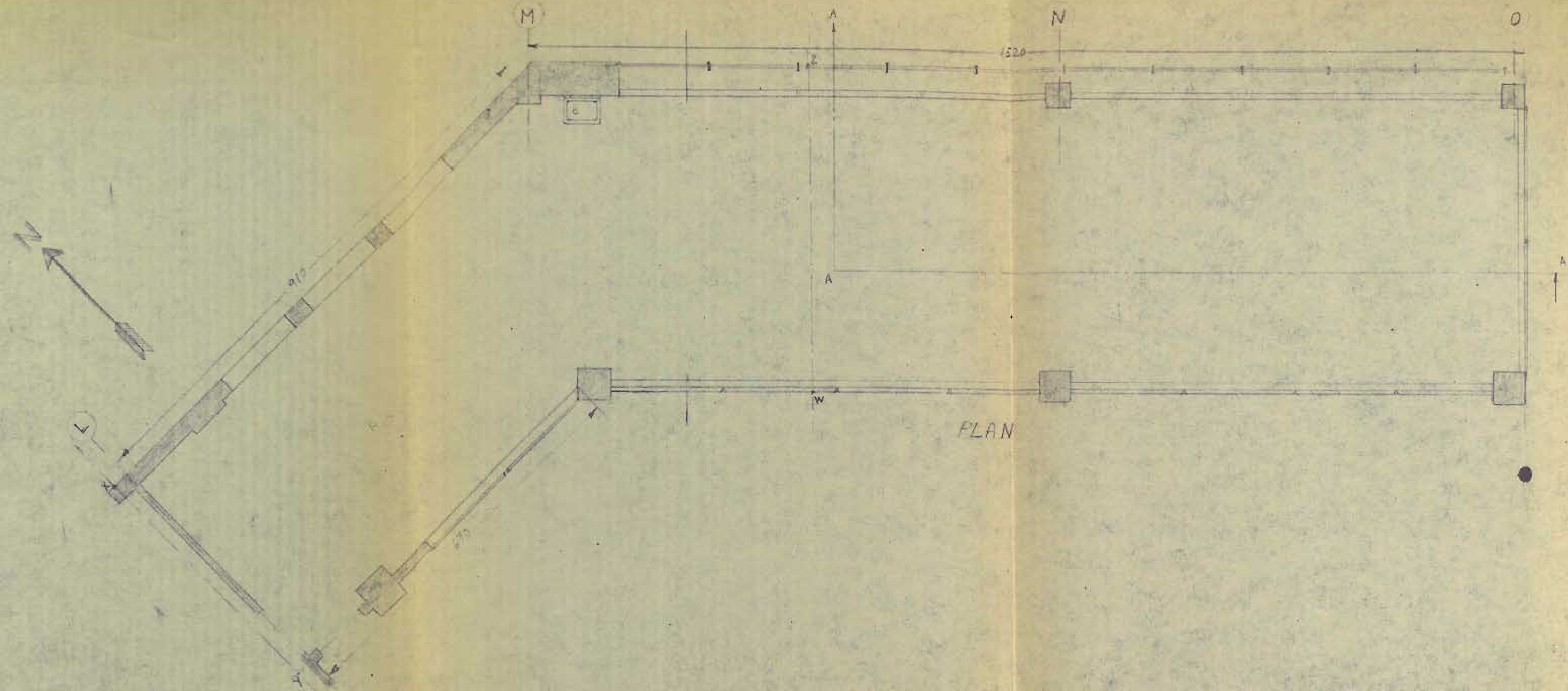
of
BEIRUT
Division of Engineering
HYDRAULICS
LABORATORY
DRAWN BY
CHECKED
SCALE

NOTES

REVISION

DATE	DESCRIPTION



PLAN

NOTES

REVISION

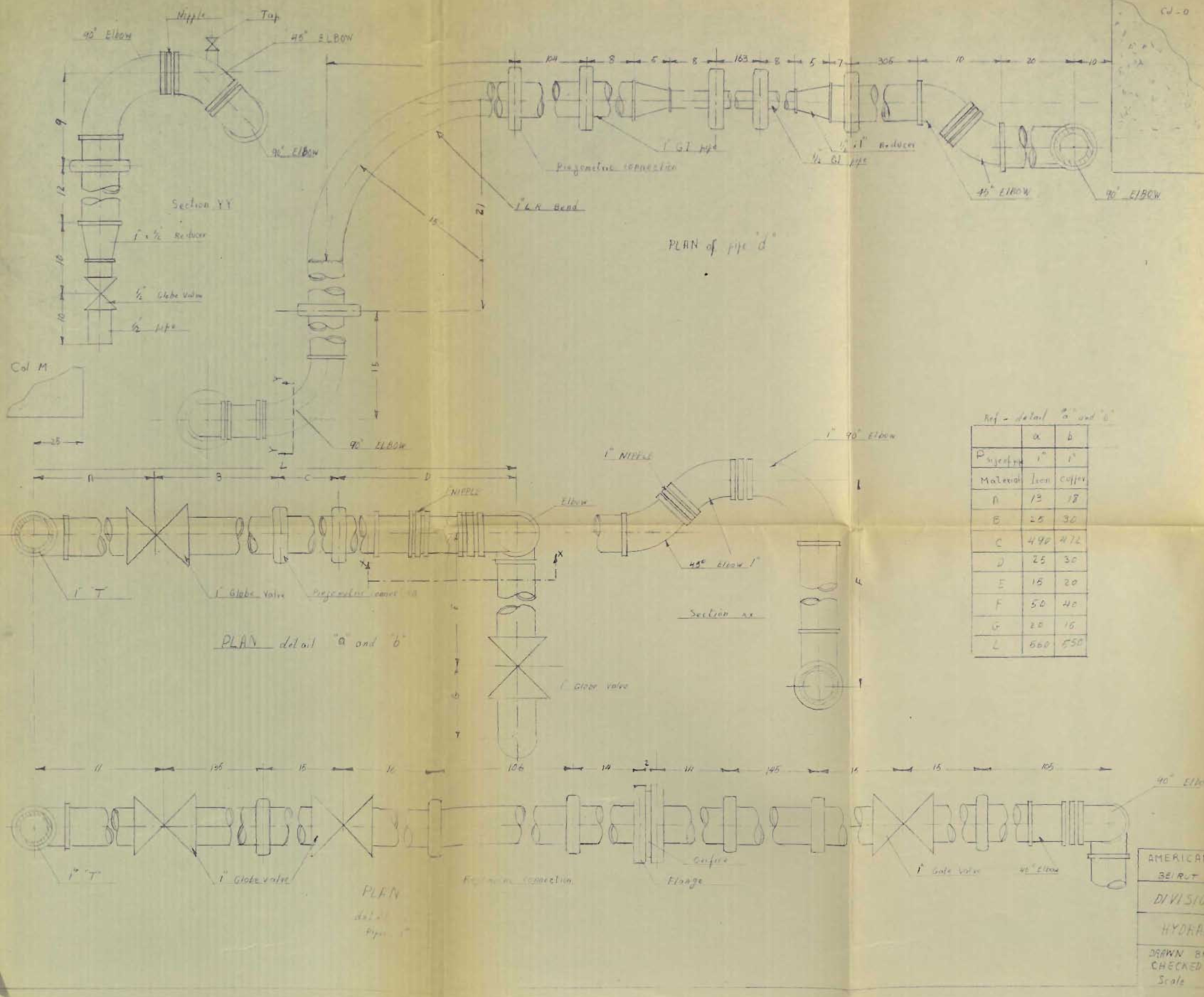
DATE	DESCRIPTION

AMERICAN UNIVERSITY
of
BEIRUT
Division of Engineering

HYDRAULICS LABORATORY

DRAWN BY YUSEPH NUSRAT DEC 2 1956
CHECKED
SCALE 1/50 DRG NO 3003

AMERICAN UNIVERSITY OF BEIRUT BEIRUT LEBANON	
DIVISION OF ENGINEERING	
HYDRAULICS LABORATORY	
DRAWN BY Y. NOSRAT	19-1-53
CHECKED	
Scale	DRAWING Nº 3004



Ref – detail "a" and "b"

	a	b
P	1"	1"
Material	Iron	Copper
A	13	18
B	25	30
C	490	472
D	25	30
E	15	20
F	50	40
G	20	15
L	560	550

NOTES

All perforation to … from the inside … side of the pipe, … emery paper, al… in pipes to be re… with a pipe rea…

REVISIONS

DATE	DESCR…

AMERICAN UNIVERSITY OF …
BEIRUT LEBA…
DIVISION OF ENGINEERI…
HYDRAULICS LABORATOR…
DRAWN BY Y. NOSRAT 19…
CHECKED
Scale DRAWING N…

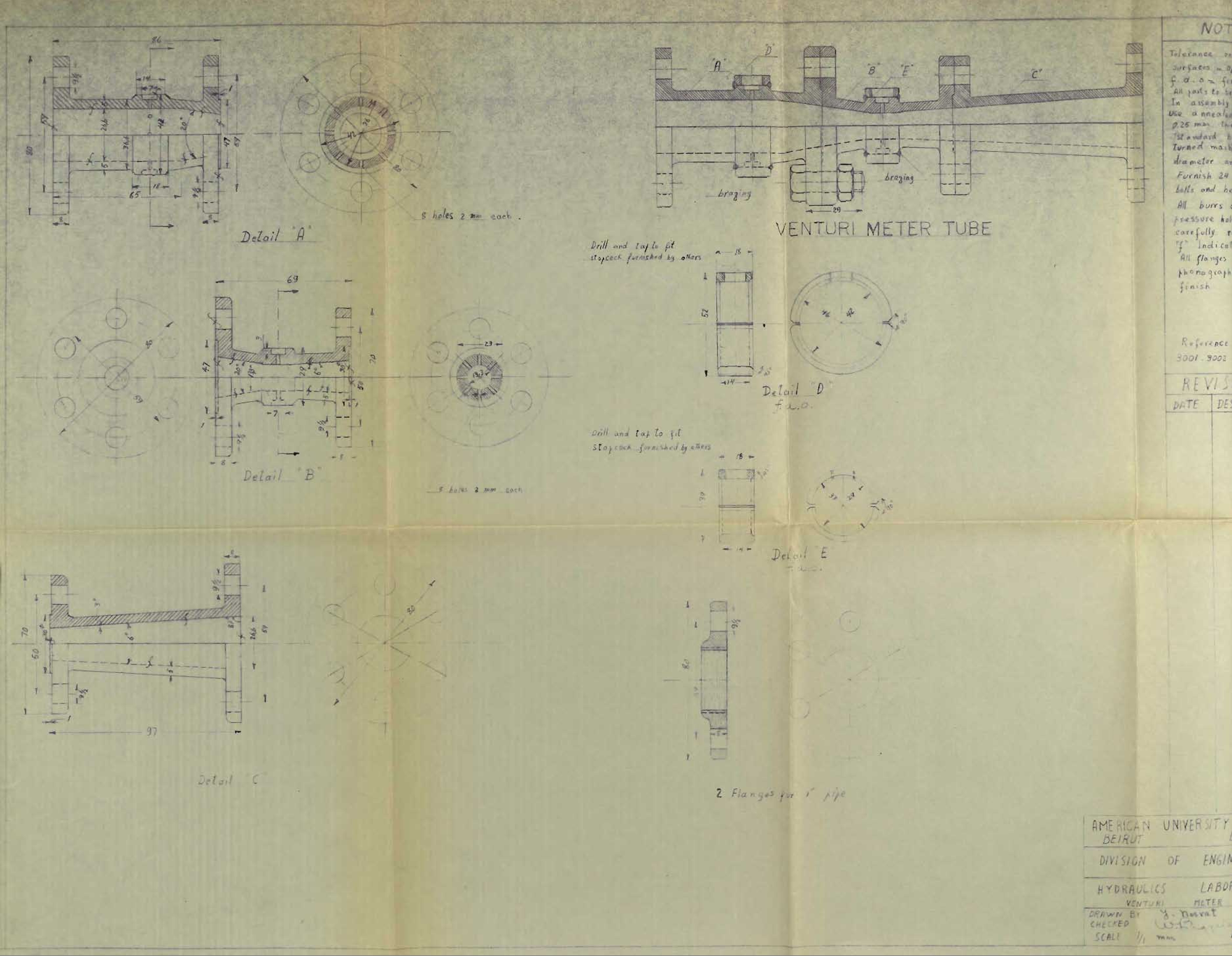
NOTES

All perforation to be cleaned from the inside and out side of the pipe, with emery paper, all cuts in pipes to be reamed with a pipe reamer

REVISIONS

DATE	DESCRIPTION

AMERICAN UNIVERSITY of BEIRUT BEIRUT LEBANON	
DIVISION OF ENGINEERING	
HYDRAULICS LABORATORY VENTURI METER	
DRAWN BY Y. Nasrat	Feb. 2, 1953
CHECKED [illegible signature]	17-II-53
SCALE 1/1 mm	Drg No 3006



VENTURI METER TUBE
"A"
"D"
"B"
"E"
"C"
brazing
brazing
29
Detail "A"
5 holes 2 mm each.
Detail "B"
5 holes 2 mm each
Detail "C"
Drill and tap to fit
stopcock furnished by others
Detail "D"
f.a.o.
Drill and tap to fit
stopcock furnished by others
Detail "E"
2 Flanges for 1" pipe
NOT
Tolerance
surfaces
f.a.o. = f
All parts to be
In assembly
Use annealed
0.25 mm
Standard
Turned mach
diameter
Furnish 24
bolts and he
All burrs
pressure hol
carefully
"f" Indica
All flanges
phonograph
finish
Reference
3001 . 3002
REVIS
DATE
DES
AMERICAN UNIVERSITY
BEIRUT
DIVISION OF ENGIN
HYDRAULICS LABOR
VENTURI METER
DRAWN BY Y. Nusrat
CHECKED
SCALE 1/1 mm

NOTES

Tolerance on all finished surfaces = 0,005"

f. a. o = finished all over

All parts to be made of cast brass

In assembly between flanges use annealed copper gaskets 0,25 mm thick and standard hexagon head turned machine bolts 3/8" diameter and nuts

Furnish 24 3/8" Machine bolts and hexagon nuts

All burrs on manometer pressure holes must be carefully removed

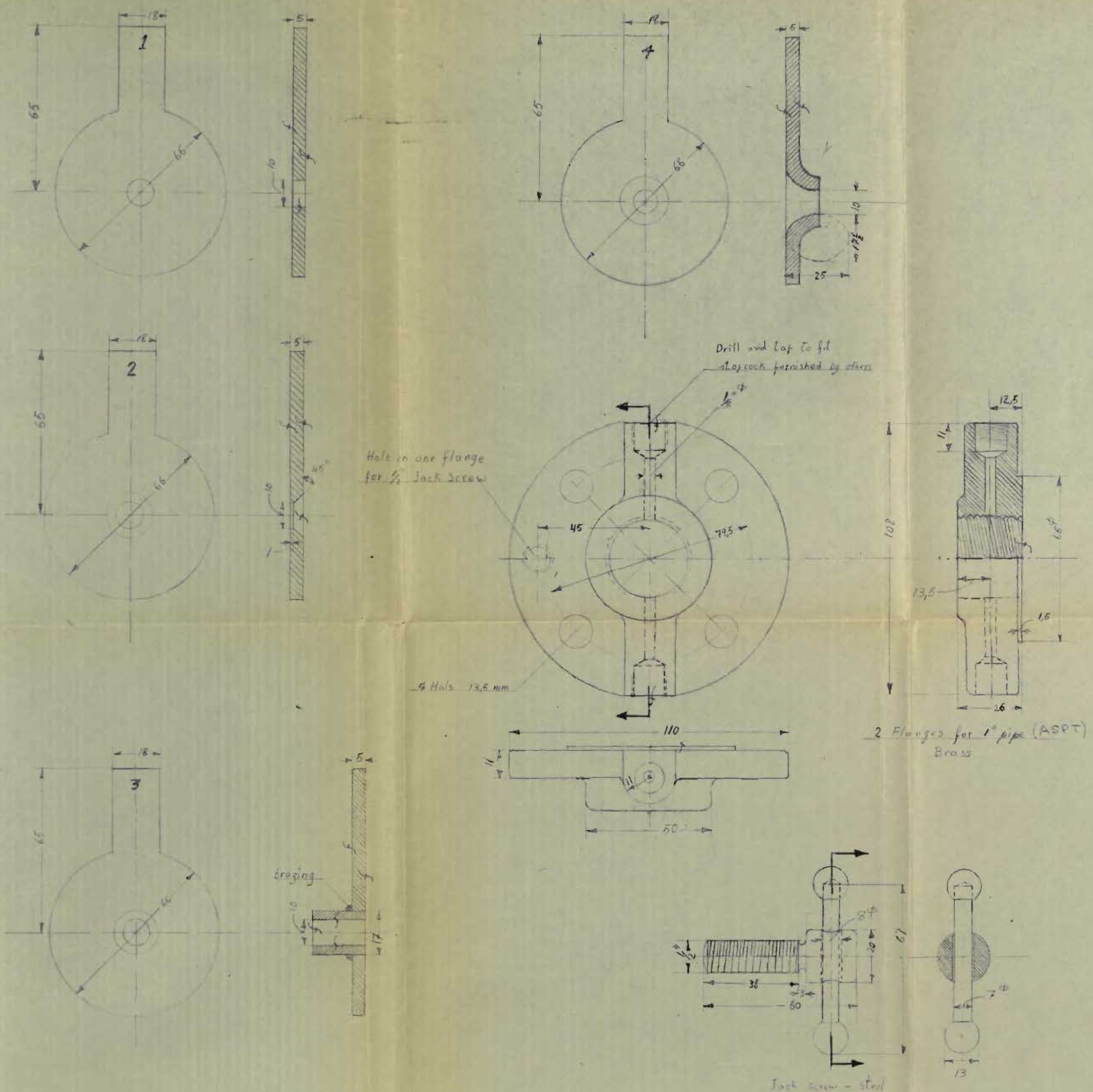
"f" Indicates machine finish

All flanges to have a phonograph (finely serrated) finish

Reference Drawing
3001 . 3002 3003 3004 3005

REVISION

DATE	DESCRIPTION



NOTES

Orifices to be of brass plate dimensions as indicated on drawing
ASPT = American standard pipe thread

Reference Drawing
3001 – 3006

REVISION	
DATE	DESCRIPTION

AMERICAN UNIVERSITY of BEIRUT
BEIRUT LEBANON
DIVISION OF ENGINEERING
HYDRAULICS LABORATORY
Orifices

DRAWN BY	Y. Nosrat	Feb. 24, 1953
CHECKED	W. Bragiano	Feb. 24, 1953
Scale 1/1 mm		Drg No 3008

AMERICAN UNIVERSITY OF BEIRUT

BEIRUT LEBANON

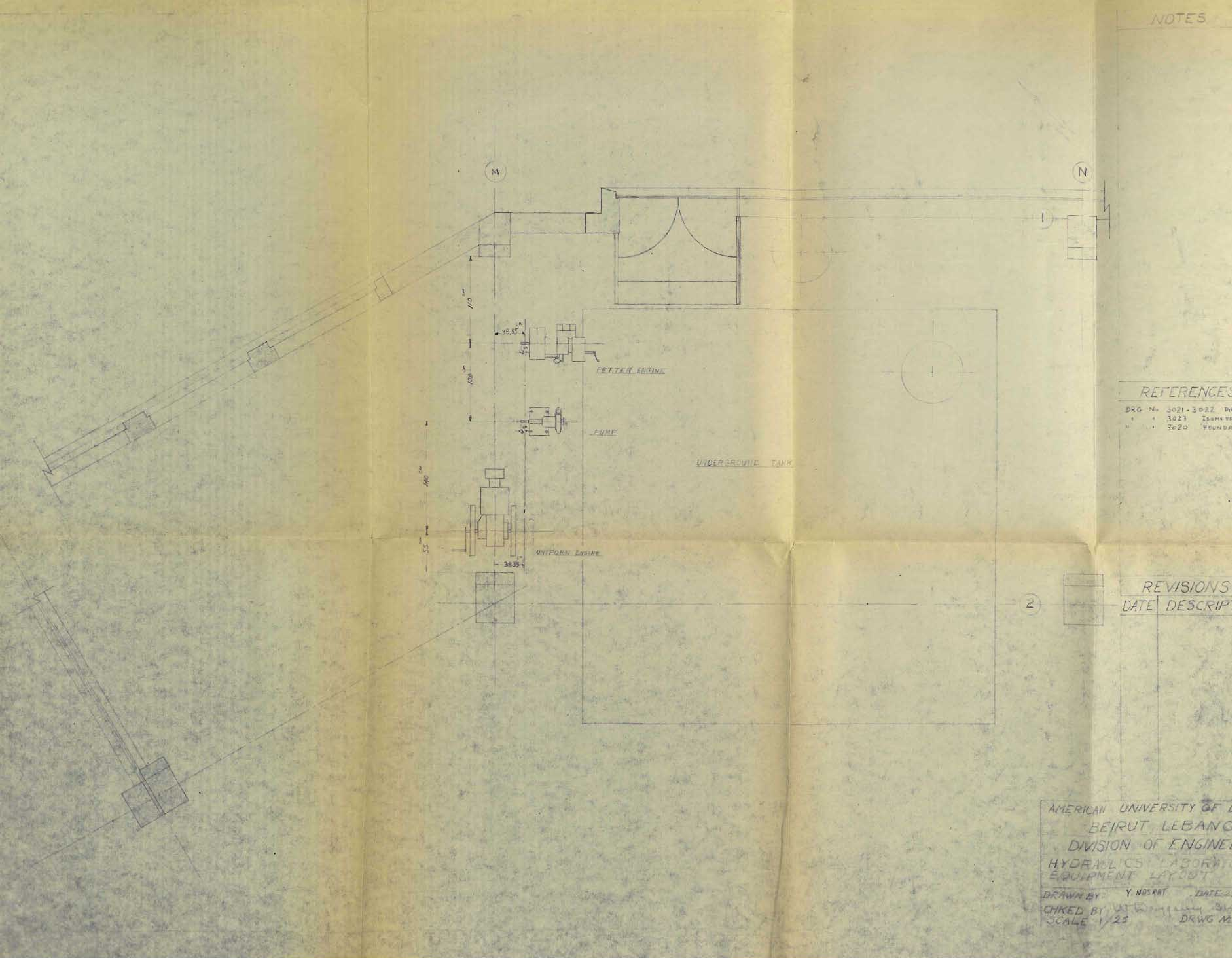
DIVISION OF ENGINEERING

HYDRAULICS LABORATORY
EQUIPMENT LAYOUT

DRAWN BY Y. NOSRAT DATE: 25-III 1953

CHKED BY 31-III-53

SCALE 1/25 DRWG № 3019


NOTES
M
N
1
2
110
100
140
55
38.35
PETTER ENGINE
PUMP
UNDERGROUND TANK
REFERENCES
DRG No 3021-3022
3023
3020
REVISIONS
DATE
AMERICAN UNIVERSITY OF
BEIRUT LEBANO
DIVISION OF ENGINE
HYDRAULICS
EQUIPMENT LAYOUT
DRAWN BY Y. NOSRAT
CHKED BY
SCALE 1/25
DRWG N

NOTES

REFERENCES

DRG No. 3021 - 3022 PIPING LAYOUT
" " 3023 ISOMETRIC OF PIPING
" " 3020 FOUNDATIONS LAYOUT

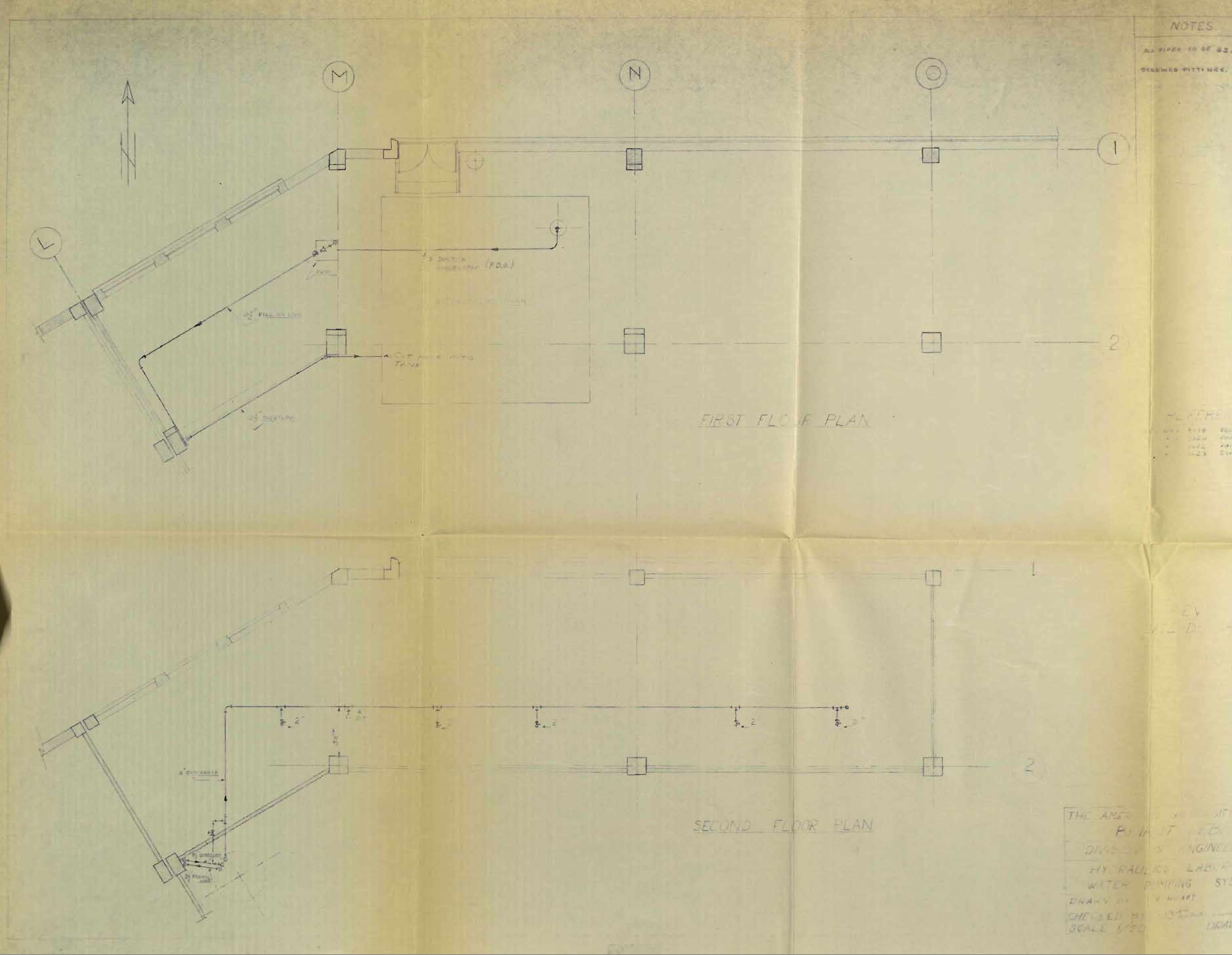
REVISIONS

DATE	DESCRIPTION

THE AMERICAN UNIVERSITY OF BEIRUT
BEIRUT LEBANON
DIVISION OF ENGINEERING

HYDRAULICS LABORATORY
WATER PUMPING SYSTEM

DRAWN BY Y. N. [illegible] DATE [illegible]
CHECKED BY [illegible] 31-III-53
SCALE 1/50 DRAWG Nº 3021



NOTES.
M
N
O
L
1
2
FIRST FLOOR PLAN
SECOND FLOOR PLAN

NOTES

ALL PIPES TO BE G.I. WITH IRON SCREWED FITTINGS.

REFERENCES

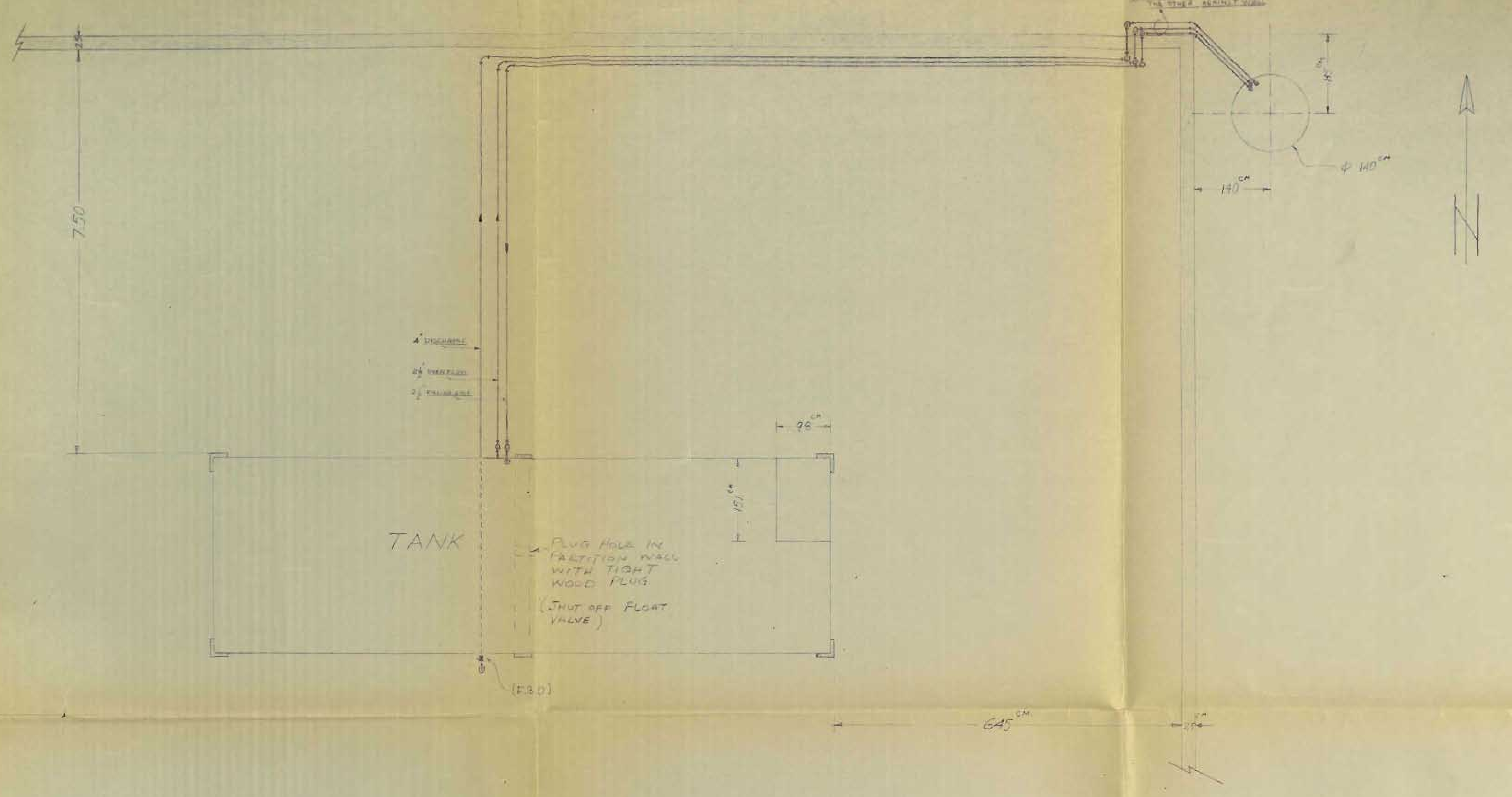
DRG NO.	3019	EQUIPMENT LAYOUT
"	3020	FOUNDATION LAYOUT
"	3022	PIPING LAYOUT
"	3023	ISOMETRIC OF PIPING

THE AMERICAN UNIVERSITY OF BEIRUT
BEIRUT LEBANON

DIVISION OF ENGINEERING

HYDRAULICS LABORATORY
WATER PUMPING SYSTEM

DRAWN BY	Y. NOSAAT	DATE 25.III.53
CHECKED BY	[illegible]	31-III-53
SCALE 1/50		DRWG № 3022



PLAN

PIPING DETAIL ON ROOF

NOTES

REFEREN

DRG	No	3019	
"	"	3020	
"	"	3021	
"	"	3023	

REVISIO

DATE DESC

THE AMERICAN UNIVERSI
BEIRUT LEBA
DIVISION OF ENGINE
HYDRAULICS LAB
WATER PUMPING SY

DRAWN BY Y. NOSRAT
CHECKED BY
SCALE 1/50
DRWS

NOTES

REFERENCES

DRG No 3019 EQUIPMENT LAYOUT
" " 3020 FOUNDATIONS LAYOUT
" " 3021 PIPING LAYOUT
" " 3023 ISOMETRIC OF PIPING

REVISIONS

DATE	DESCRIPTION

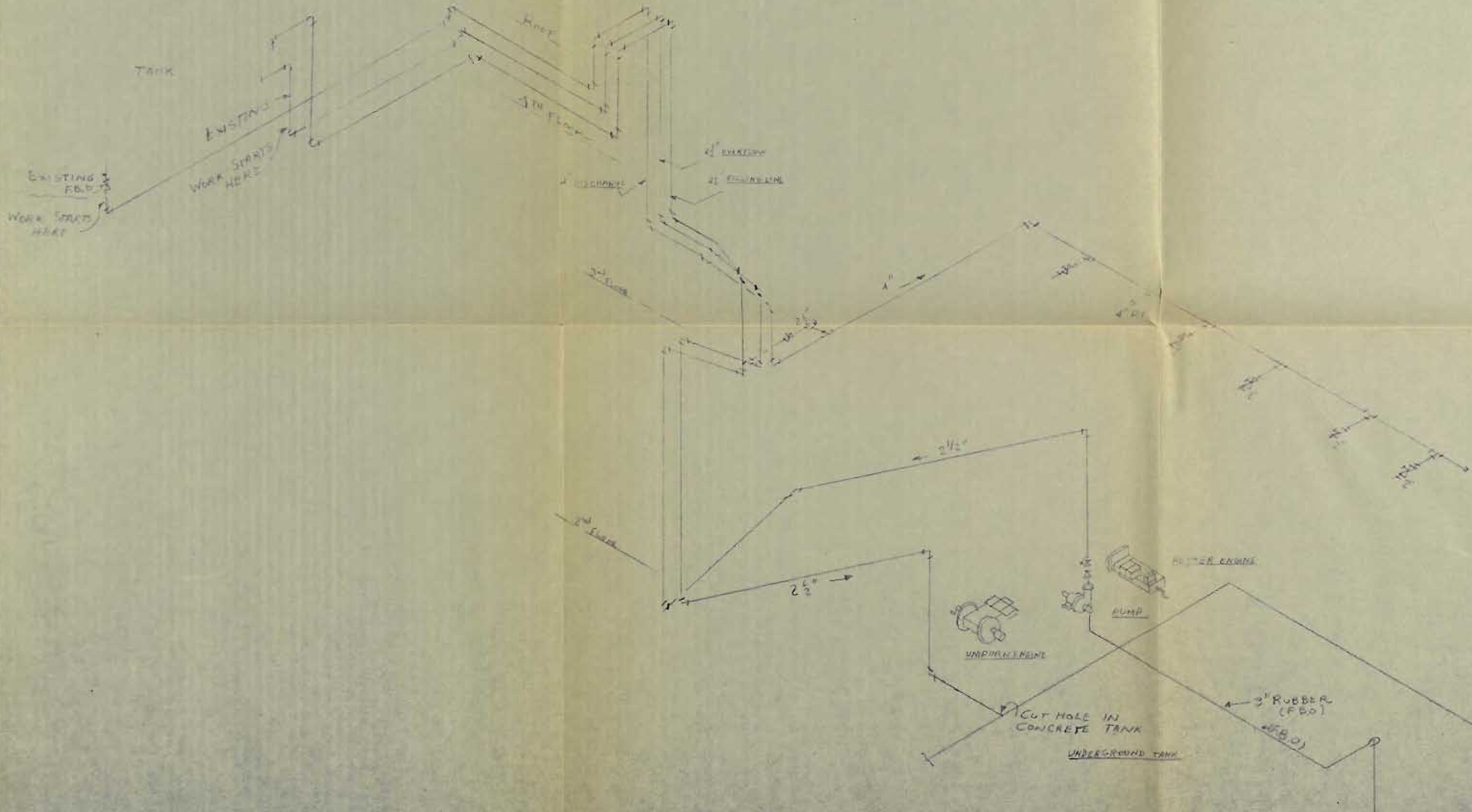
AMERICAN UNIVERSITY OF BEIRUT BEIRUT LEBANON
DIVISION OF ENGINEERING
HYDRAULICS LABORATORY WATER PIPING SYSTEM LAYOUT
DRAWN BY Y. NOSRAT 30 Mar 1953 CHECKED BY SCALE NO SCALE DR'G No 3023

NOTE

LIST OF MATERIALS

DESCRIPTION	SIZES					
	4"	3"	2½"	2"	4"x4"x2½"	4x4x2
45° Elbow	1		2			
Long Radius Elbow	10		28			
Tees	1		1		1	5
Foot Valve (FBO)		1				
Gate Valve			2	5		
Check Valve			1			
G.I. Pipes - [illegible] Run	60		105	150		
Caps	2					

Supply all necessary Hangers & Supports



REFER

DR'G No 3019
3021
3026

REVIS

DATE DES

AMERICAN UNIVERSITY
BEIRUT LEB

DIVISION OF ENGIN

HYDRAULICS LABORA
WATER PIPING SYST

DRAWN BY Y. NOSRAT
CHECKED BY
SCALE NO SCALE DR'G No

NOTES

REFERENCES

DRG NO 3019
" " 3021
" " 3022

REVISIONS

DATE	DESCRIPTION