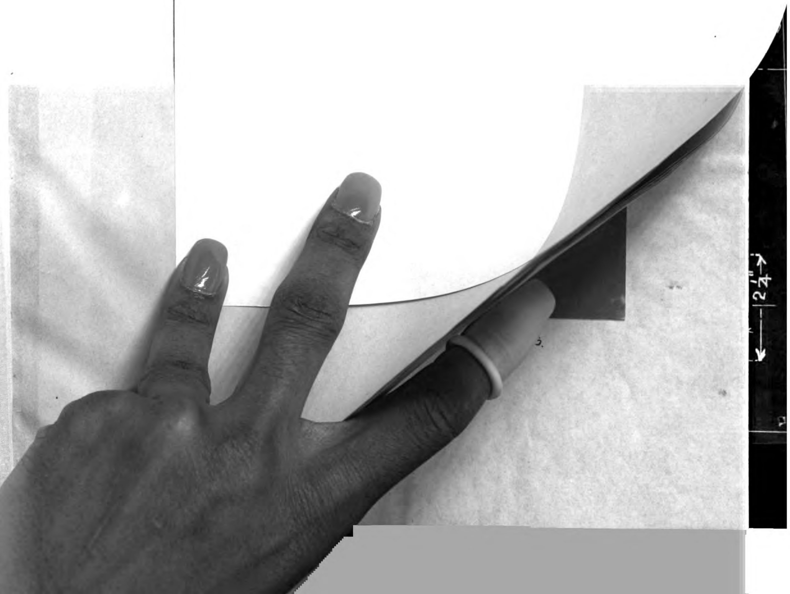
THESIS.

DESIGN, CONSTRUCTION AND TEST

OF HYDRAULIC RAM

Ernest D. Partridge 1896.

THESIS



THESIS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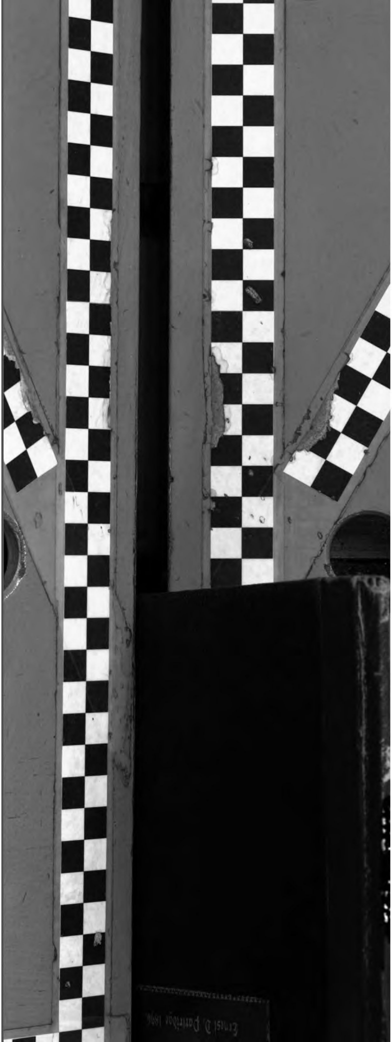
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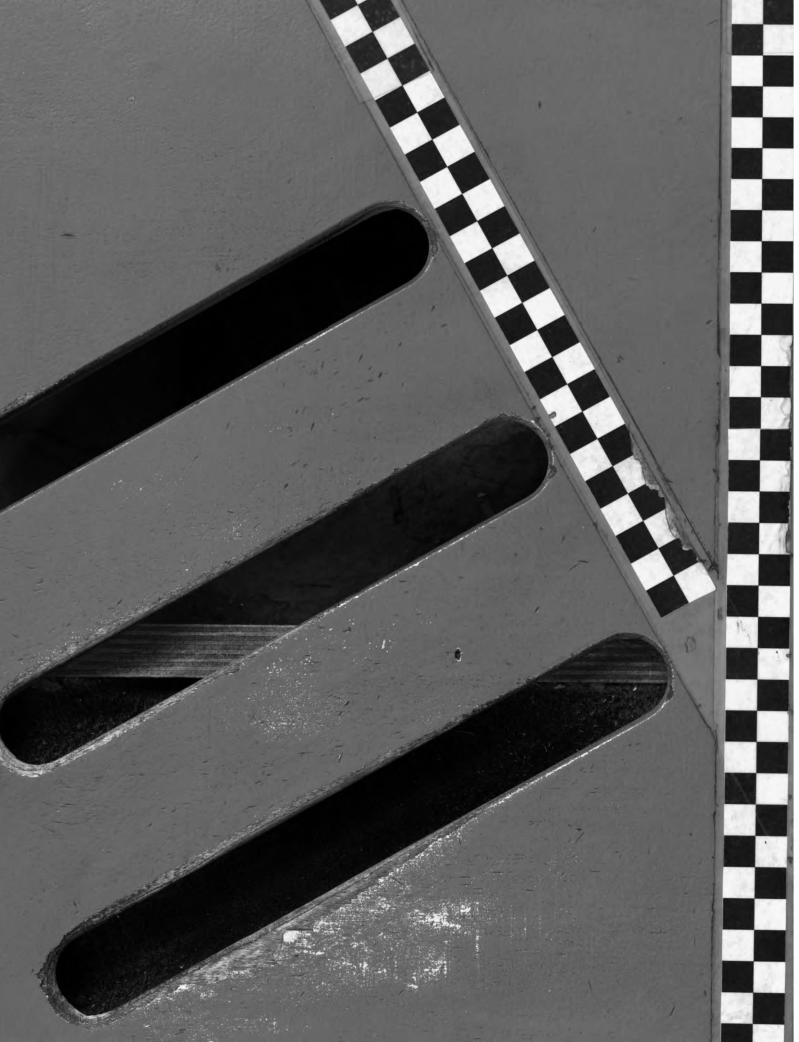

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THESIS

on

DESIGN, CONSTRUCTION, AND TEST

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HYDRAULIC RAM

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Design, Construction, and Test of Hydraulic Ram

by

Ernest D. Partridge.

M. A. C. '96.

Introduction.

Becoming interested in hydraulic rams, and desiring a knowledge of their construction, I decided, with the permission of the professor in charge of mechanical thesis to take the above subject. I also wished to ascertain if formulae given in text books etc., could be used in practice ~~and practiced~~ with satisfactory results.

The last was suggested by the fact that all formulae that I could find were based, by the authors of the books which contained them, on results obtained by one experimenter with hydraulic ram. This man, Mr. Etelwein, carried on a great many experiments for the purpose of finding proper formulae for designing; and the ram which I have built was designed according to his ~~results~~ formulae.

Brief History.

The first approach to a hydraulic ram, often attributed to Montgolphier, was made by a Mr. Whitehurst of England. He had a pipe for supplying water to his house. Instead of ending with a faucet, the pipe continued up to a tank. He

placed a check valve between the faucet and the tank. After drawing water for a few days he found his tank full. Upon lengthening the pipe and raising the tank, he found that he could raise water to higher level than that of his water supply, thereby discovering the principles of the hydraulic ram. From that, designers and experimenters have brought the ram to what it now is. It got its name from the noise it makes while working.

Use of Hydraulic Rams.

The primary use of a hydraulic ram is to raise a little water to a considerable height by means of a great amount of water falling through a small height. Its most valuable function is to raise water from a spring below into a house or barn. Theory says regardless of friction, one-fifth of the water should be raised five times as high. This would be 100 percent efficiency; but of course efficiencies all fall short of this.

Design of this Particular Ram.

D water used, in gallons.

d quantity raised per minute, in gallons.

h height of head from ram.

h' height of delivery.

Etelwein says- $\frac{dh'}{Dh} = 1.42 - .28 \sqrt{\frac{h'}{h}}$

For assuming and calculating parts, he gives the following rules. Length of feed pipe must not be less than three-fourths distance water is to be raised. Its diameter in inches $.58\sqrt{D}$. The diameter of lifting pipe $.3\sqrt{D}$. The volumn of the air chamber should be equal to THAT OF the rising pipe. I assumed $D = 18$ gallons, ~~per minute~~.

h 5 feet.

h' 70 feet.

I then figured for d, and my calculations gave me the dimensions as given on the blue prints within this thesis.

Construction.

Having made my drawings, I proceeded to make paterns for the castings. It took a good deal of time to get this work done; but with help from the department I succeeded. One casting, the lower plate, was a very difficult one; and I was delayed some time with it. The machine work was all done in the shop. Having no formulae by which to design the overflow valve, I made it as near as possible to the one belonging to the department. As designed for strength four tie rods were sufficient; but to make a perfectly air tight joint, eight were used. By the end of the tenth week of the term I had the ram set up and ready to start.

The Test.

It required a good deal of preparation to get ready for the test. One question that came up was, how to get the seventy feet head. I adopted an apparatus similar to that

designed and used by Mr. Dwight Cole of '93, namely a pressure chamber. The scheme is shown in "a general view of apparatus" shown on blue print. The vertical pipe, with pressure gauge and two valves attached is the air chamber. The chamber could be held at any desired pressure by opening and closing the valves, and the pressure read from the gauge; thus giving the height of lift. The small tank under the valves caught the delivered water; and the large tank under the ram caught the over-flow water. Board guides were placed around the overflow valve, to make all the water enter the tank. These were removed that a good view of the working valve could be obtained. The scales at the side were used for weighing the water. I turned on the water and worked a few days trying to get an efficiency as high as possible. I hardly expected the ram to work at all, the first time, without some rearranging; but it pumped against a pressure 24 pounds, (which is equal to 52.8 feet,) without any discharge. I made more opening in the plunger of the over-flow valve, and succeeded in pumping 66 feet without any discharge. I removed the cylinder and cut away some leather on the hinge part of the leather check valve and put a wire stop to prevent the valve from rising too high. I then succeeded in pumping, after some trials, a half a gallon per min. 72 feet. I had taken no account of the water used but felt satisfied that the present conditions would come up to the requirement. I accordingly arranged my tanks, etc., and began a series of experiments, the results of which are given below.

To be more brief, let us use the following symbals.

N =number of experiment.

h= height in feet to which the water is raised.

W =water of overflow valve in gallons.

w= water of delivery if gallons.

t= duration of test.

E =the efficiency of the ram of that particular test.

Each set of trials is made with different throw of valve. The head of feed pipe is held at five feet throughout.

1 st set. Throw.2".

N	h!	W	w'	t	E	
1	74.4	all	0	-	-	pumped against pressure.
2	64.8	6.08	.24	1	.52	
3	40.8	6.4	.48	1	.64	
4	16.8	6.75	2.17	1	81.7	

2nd set. Throw .3"

N	h!	W	w'	t	E	
1	76.8	all	0	-	-	against pressure.
2	64.8	8.3	.48	1	.71	
3	40.8	8.31	.78	1	.70	
4	16.8	7.77	2.95	1	.95	

3rd set. Throw .4"

N	h!	W	w'	t	E	
1	93.6	all	0	-	-	against pressure.
2	76.8	9.3	.36	1	.73	
3	64.8	9.45	.54	1	.73	
4	40.8	9.64	.84	1	.68	
5	28.8	19.3	3.7	2	.67	
6	21.6	19.6	4.74	2	.84	

4th set. Throw .5"

N	h'	W	w'	t	E	
1	88.8	8.67	.3	1	.60	
2	76.8	9.46	.48	1	.75	
3	64.8	11.8	.48	1	.58	
4	40.8	10	.96	1	.71	
5	28.8	10.4	1.72	1	.82	
6	21.6	10.6	2.16	1	.77	

5th set. Throw .7"

1	108.	all	0	-	-	against pressure.
2	88.8	10.2	.24	1	.40	
3	64.8	10.2	.48	1	.58	
4	40.8	10.8	.9	1	.64	
5	15.4	10.4	3	1	.70	

6th set. Throw 1"

1	92.4	all	0	-	-	against pressure.
2	88.8	9.9	.18	1	.32	
3	64.8	11.1	.48	1	.56	
4	40.8	11.6	.6	1	.40	
5	15.4	11	3.13	1	.86	

I hope the result of the experiment is plain. The only trouble I had during the test, was a leaking pipe. I replaced the bad piece by a good one and all went well. It would require an efficiency of 40 % to fulfill the requirements of the formulae. It will be seen that in three cases only did it go as low as this when tested. It will also be noted that the required amount was scarcely pumped the required height. The nearest approach is in 3rd set experiment No. 2 where .36 of a gallon were raised 76.8 feet; but there were only 9.7 gallons that went through the ram, a little more than half the allowable amount. The recorded efficiency shows that the required work would be done easily, if we had a valve that would allow the eighteen gallons to go through, and work properly.

Originally, I expected to make parts enough so that I could vary any one part and note the change. I made two cylinders, both shown in the "general view of apparatus;" prepared two feed pipes one two inches in dimaeter and the other one and a half inches. The volumn of the cylinders differed according to the volumn of the feed pipes as given by Etelwein. I thought the change in valve could be made by varying the length of throw, but I see now that in order to carry this on one must have a variable valve also; Consequently I did not change pipes. The large cylinder and pipe were used, and gave good results. I put in the small cylinder, and could pump but 70.4 feet without any delivery. The highest point for no delivery with large cylinder was 121 feet. I wish to be certain about one more thing. How would

a greater head affect the ram? I gave it seven feet and without any change in parts it pumped 114 feet with a small delivery; and by weighting the over-flow valve this could be increased. This showed that it would do better work according as the head was increased, as we would expect. I did not have time to test for efficiency with this head however.

I have found the work very interesting, and although my figures have not been exact in all cases, yet in my opinion these formulae are at error, but on the safe side. I would suggest as a very interesting subject for a thesis at some future date, that some one begin the work where I have ended; and proceed to produce formulae that will show better the average ram. Make in some way an over-flow valve that can be varied, and proceed to produce formulae that will give the average efficiency. The average efficiency for all my tests was .67. Those above 60 feet delivery averaged .59 against a required efficiency of .40.

The above figures are for the ram including the feed pipe. To be more exact in results it would be necessary to take into consideration the friction of the pipes; also remember that the pressure was taken from the point of delivery and should have been taken at a level with the bottom plate. The latter would make a difference of about one foot. The temperature of the water should also be taken into consideration in using pressures to figure the height of delivery. It would be very interesting to experiment for the purpose of finding the efficiency of each component part,

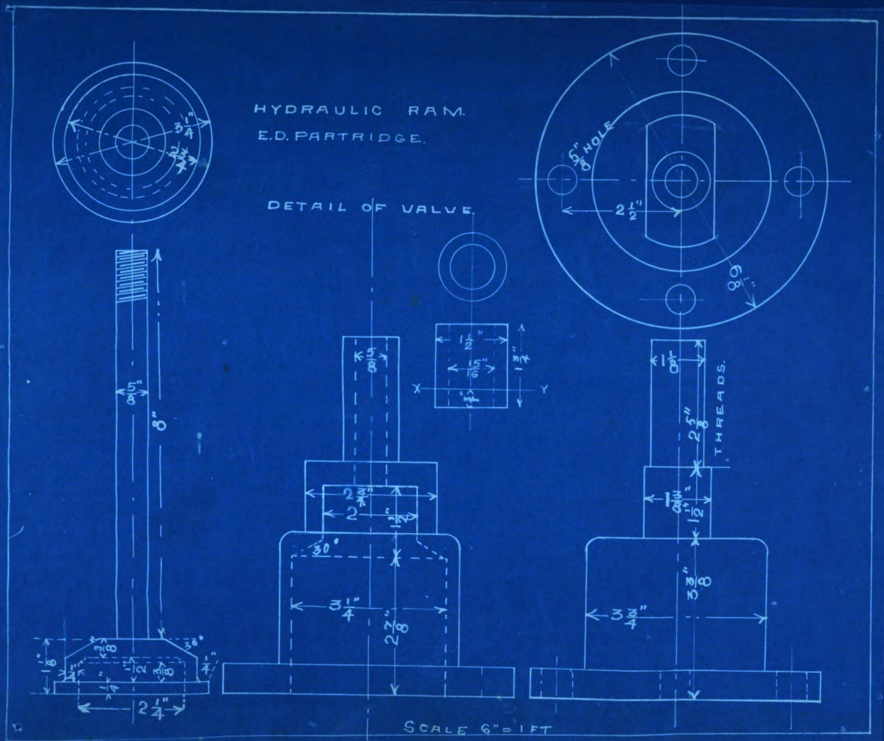
and determine where a change could be made to increase the resultant efficiency most. There must be for a given fall of feed pipe a limit for length and diameter. Judging from my experiments, I do not believe these formulae give the proper limits. In the print entitled "General view of apparatus" the ram is shown at work. The pressure gauge shows 44 pounds (96.8 feet) and a delivery of about half a gallon per minute.

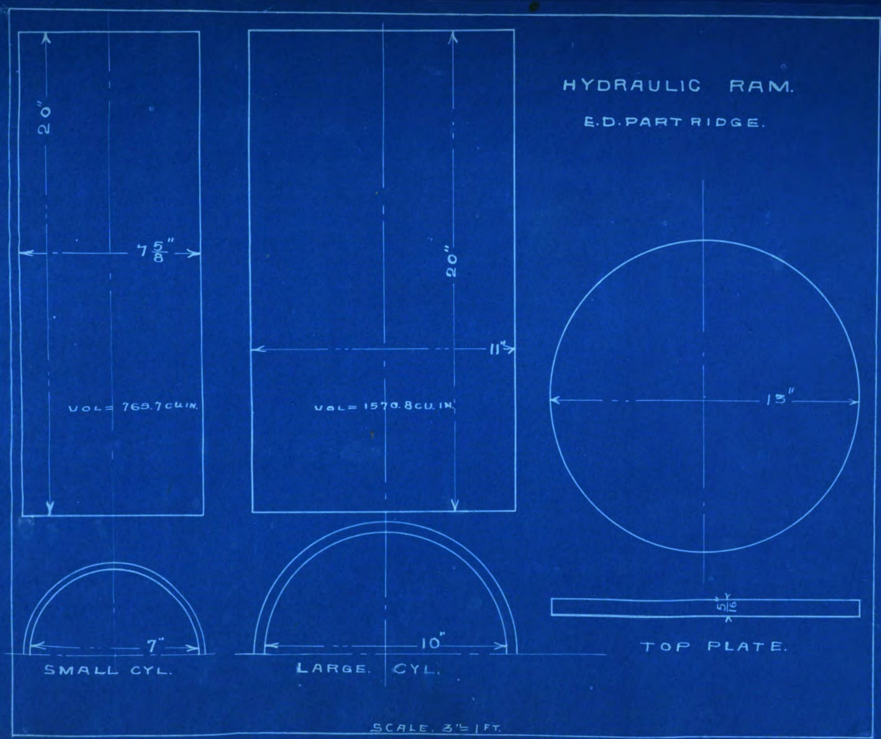
Yours truly,

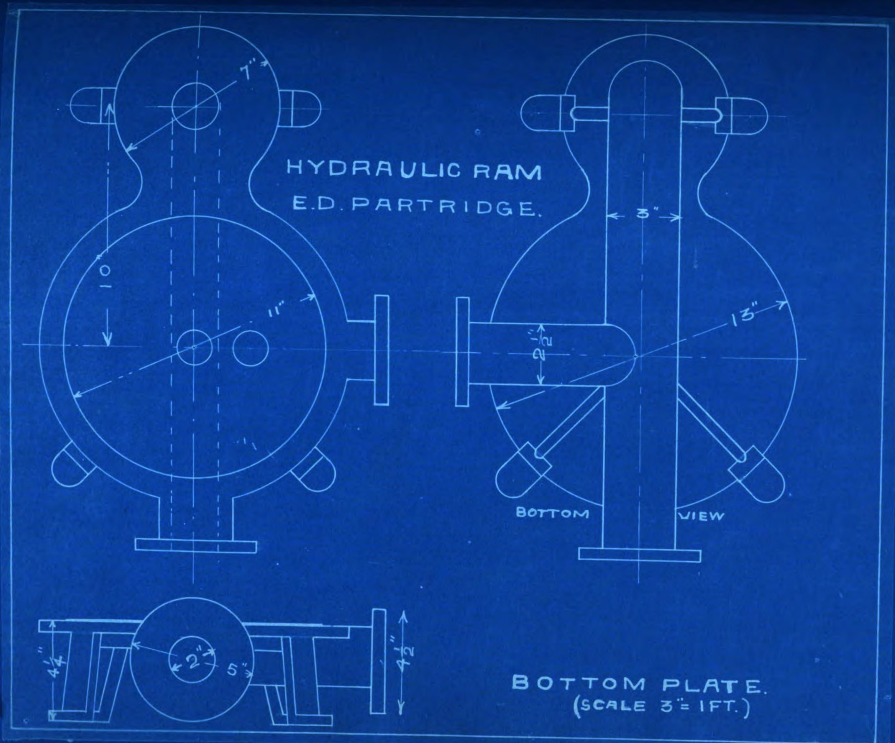
E. D. Partridge.


2 1/4"
SCALE 6" = 1 FT

GEN'L VIEW OF APPARATUS.


HYDRAULIC RAM.
E.D. PARTRIDGE.
DETAIL OF VALVE.
SCALE 6" = 1 FT
THREADS.
5/8" HOLE


HYDRAULIC RAM.
E.D. PARTRIDGE.
20"
7 5/8"
VOL = 769.7 CU. IN.
20"
11"
VOL = 1570.8 CU. IN.
13"
5/16
7"
SMALL CYL.
10"
LARGE. CYL.
TOP PLATE.
SCALE. 3" = 1 FT.



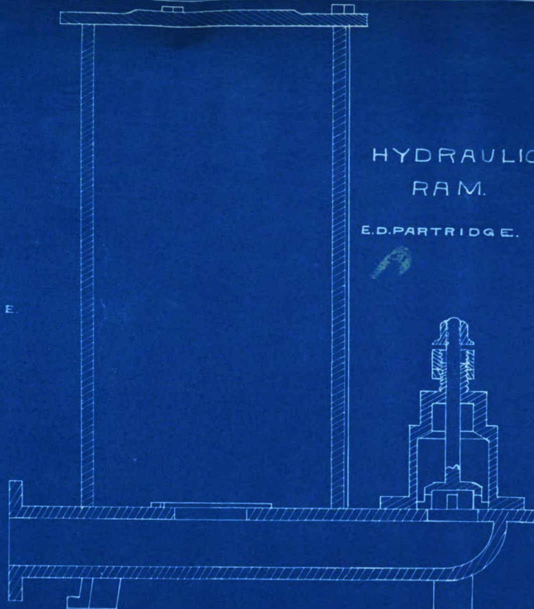
HYDRAULIC RAM
E.D. PARTRIDGE.
7"
10"
11"
3"
13"
2½"
BOTTOM VIEW
2"
5"
4¼"
4½"
BOTTOM PLATE.
(SCALE 3" = 1 FT.)

HYDRAULIC RAM.

E. D. PARTRIDGE.

4 OF THIS ROD.

LEATHER VALVE.

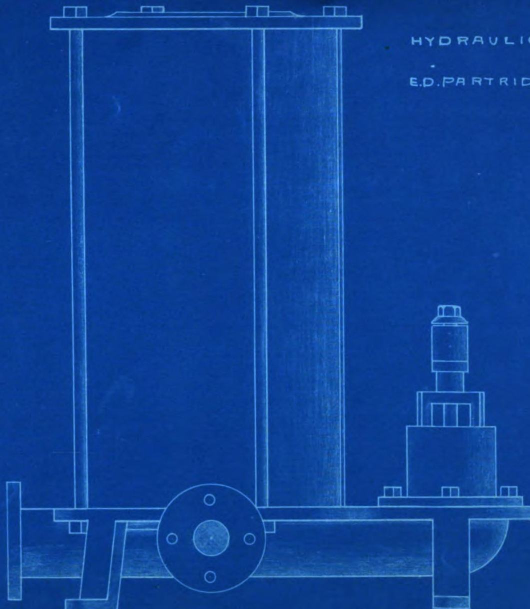


SECTION OF ELEVATION

SCALE. 3" = 1 FT

HYDRAULIC RAM.

E.D. PARTRIDGE.



GENERAL VIEW.