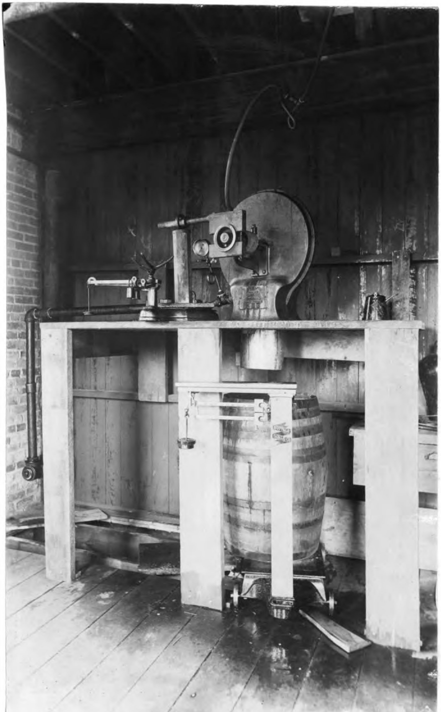


Seymour and Whitlock Motor and apparatus.

THESIS.

SOME EXPERIMENTS

ON

IMPACT WATER MOTORS.

July 20, 1898.

A. C. Burnham.

SOME EXPERIMENTS WITH IMPACT WATER MOTORS.

THE moving water upon the surface of the earth represents immeasurable power, and it was in attempting to find means by which some of this immense power might be utilized that the water motor was evolved. In general these motors are divided into two classes: large water wheels or turbines, and smaller enclosed wheels known as impact motors. A third class, less frequently met with, are the water engines or piston motors.

At present we are concerned with impact motors only. Of these there are many kinds manufactured; but among them all the only significant difference lies in the form of cup and the manner of impact. Among the more important of these motors made in the United States are the Pelton, Backus, Tuerk, Cooper, Benham, Syracuse, Bolkham, Seymoure and Whitlock or Parabolic, and others.

Impact motors are used in many places, under many conditions and for many purposes. They are generally used where water can be had conveniently and where the power needed is small; but recently large ones also have come into use in the West working under immense heads and furnishing very great power.

The object of these experiments was to obtain the comparable efficiencies of the three wheels at hand - a 12" Pelton, a 22" Backus and a 22" Seymoure and Whitlock - and to note as far as possible other characteristics.

Plates 6,7,and 8 show the construction of these motors,the forms and number of cups and the different manners of impact.

The work was done entirely independently and without regard to any work previously done in the same line. In fact,very few results of tests of water motors seem to have been published,and no references,except to a report of tests made by Professor L.P. Breckenridge and published by J.H.Mills in his HEAT FOR THE WARMING AND VENTILATION OF BUILDINGS and to the catalogues of the various motors,can be given. All results are recorded exactly as found,and all irregularities are,as far as possible,accounted for.

The Pelton motor was tested with 1/4 inch,3/8 inch and 1/2 inch cast iron nozzles;the Backus,with 1/4 inch and 3/8 inch nozzles made of brass;and the Seymoure and Whitlock,with 1/4 inch 3/8 inch and 5/16 inch nozzles of cast iron. All nozzles are shown full scale on Plate 5.

The photographs show the manner in which each motor was set up,the power measured and the water weighed. For each nozzle it was assumed that,for the ordinary variations in number of revolutions,the amount of water flowing through motor per minute,for any one head,was constant. Thus,for any one motor and nozzle,the number of revolutions per minute being kept as nearly as possible at the average,the amount of water flowing per minute was determined once for all by noting the time required to run one hundred pounds.

The horse power of the water was determined by the formula: H.P.=34PW ÷(15X33000),where W equals weight in pounds of water flowing through motor per minute,and P equals head of water in pounds pressure. This assumes that a pressure of 15 pounds will hold a water column of 34 feet,but the slight error due to this assumption was thought to be within the limit of error obtainable in the conducting of the experiments themselves.

The brake wheel was 5 inches in diameter with 1 1/2 inch face and with a flange 1/4 inch high on each edge to prevent the brake from slipping off. The brake back was of oak wood 1 1/4 inches square and was continued to form the brake arm 1 1/4 inches in diameter. The rubbing surfaces were of pine wood with face of 1 1/4 inch. The length of brake arm,or the distance from centre of brake wheel to knife-edge over small scales,was one foot. This arrangement gave good results,but it is believed that a 4 inch brake wheel would, for the larger loads,give better results. The pressure upon the small scales used for determining the horse power of the brake,and shown in the photographs,was varied in the course of all the experiments from 1/4 of a pound to 11 pounds,as will appear in the tables of results. The method of varying this pressure was by tightening or loosening the thumb nuts at the lower edge of the brake,and thus increasing or decreasing the friction between the brake and the wheel. In every case,before beginning an experiment, the weight of the overhanging portion of the brake and arm was ballanced on one of the scale beams, so that the weight recorded on the other should be that due to the friction of the brake alone.

The horse power of the motor which was absorbed by the brake was determined by the formula: H.P. of motor equals 2 anw + 33000, where a equals length of brake or one foot, n equals number of revolutions per minute of brake wheel, and W equals pressure in pounds on small scales.

The following tables show the record of observations of all the experiments together with the computed results. The letters at the tops of the columns have the following significance:

P at top of first column - - - - head in pounds pressure.

L " " " second " - - - - load on small scales.

In all other casses,-

R.P.M. - - - - - - revolutions per minute.

p.m. - - - - - - pounds per minute flowing through motor

H.P. Motor. - - - - horse power of motor.

H.P. Water. - - - - horse power of water.

% Eff. - - - - - percentage of efficiency.

P. - - - - - - Pelton motor.

B. - - - - - - Backus motor.

S&W - - - - - - Seymoure and Whitlock motor.

Results for 3/8 inch nozzles.

#	#	R.P.M.			# p.m.			H.P. Moter.			H.P. Water.			% Eff.		
P	L	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W
5	0	303	176	172	54	71	54	0	0	0	.018	.024	.018	0	0	0
10	0	546	282	[illegible]	76	109	79	0	0	0	.053	.075	.054	0	0	0
	¼	426	254	200	"	"	"	.021	.013	.010	"	"	"	39.6	17.4	18.5
	½	326	216	184	"	"	"	.031	.022	.017	"	"	"	55.5	29.4	31.4
	¾		162	176	"	"	"		.024	.026	"	"	"		32.0	48.1
	1			162	"	"	"			.031	"	"	"			57.4
	1¼			150	"	"	"			.036	"	"	"			[illegible]
20	0	857	454		120	148	114	0	0		.162	.201	.155	0	0	
	¼			344						.017						10.8
	½	667	406	330				.064	.041	.031				39.1	20.2	19.9
	¾	597		320				.086	[illegible]	.048				52.5		30.8
	1	529	346	286				.105	.066	.055				64.0	32.7	35.4
	1¼	468		266				.111		.064				68.5		41.1
	1½		292	240					.085	.070					42.3	45.2
	1¾			196						.065						41.7
30	0	1059	542		143	176	138	0	0		.294	.362	.284	0	0	
	¼			434						.022						7.8
	½		528	420					.053	.040					14.7	14.1
	¾	889		406				.147		.061				50.0		21.5
	1	837	488	396				.167	.092	.075				56.8	25.4	26.4
	1½	750	464	370				.214	.134	.111				72.8	37.0	39.1
	2	643	406	330				.245	.154	.127				83.3	42.5	44.7
	2½		356	288					.171	.138					47.2	48.6
	3		306						.174						48.1	
40	0	1241	620		174	222	171	0	0		.478	.609	.469	0	0	
	½			510						.048						10.2
	1	973	568	486				.194	.108	.093				40.6	17.5	19.9
	1½	847	548	468				.242	.159	.140				50.6	26.1	28.9
	2	750	520	442				.286	.178	.168				59.8	32.6	36.9
	2½	654	486	412				.312	.233	.197				65.3	38.5	42.1
	3		454	364					.257	.208					42.5	44.3
	3½		416						.279						45.8	
	4		358						.296						48.5	
	4½		316						.272						48.0	

Results for 3/8 inch nozzles.

#	#	R.P.M.			# p.m.			H.P.Motor.			H.P.Water.			% Eff.		
P	L	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W
50	0	1384	664		193	240	187	0	0		.721	.824	.680	0	0	
	½			566						.054						8.0
	1			542						.103						15.2
	1½	1059		526				.303		.157				42.0		24.1
	2	947	610	504				.361	.232	.192				50.1	28.1	28.3
	2½	837	570	488				.399	.277	.234				56.3	33.9	34.4
	3	735	542	456				.420	.309	.260				58.3	37.1	38.3
	3½	654	500					.438	.335					60.7	40.2	
	4		470						.357						44.8	
	4½		450						.387						46.4	
	5		412						.392						47.1	
	5½		390						.409						49.6	
	6		360						.414						50.3	[illegible]
60	0	1500	716		212	261	207	0	0		.873	1.072	.853	0	0	
	½			620						.059						7.9
	1			592						.118						13.8
	1½	1220		562				350		.168				40.1		19.7
	2	1143		540				436		.205				49.9		24.0
	2½	1059		528				504		.254				57.7		29.8
	3	947	554	498				.541	316	.284				61.9	29.4	33.3
	3½	857	516					.574	346					65.7	32.2	
	4	782	500					.596	380					68.3	35.4	
	4½		466						.401						37.3	
	5		442						.420						39.1	
	5½		436						.458						42.8	
	6		390						.449						41.8	
70	0	1636	776		231	286	222	0	0		1.106	1.375	1.067	0	0	
	½			628						.061						5.7
	1			624						.125						11.7
	1½	1358		620				.390		.186				35.3		17.4
	2	1263		610				.481		.23[illegible]				43.5		21.8
	2½	1220		590				.581		.2[illegible]				52.6		26.[illegible]

Results for 3/8 inch nozzles.

#	#	R.P.M.			# p.m.			H.P. Motor.			H.P. Water.			Eff.		
P	L	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W
70	3	1143		570	231	286	222	.653		.325	1.106	1.375	1.067	59.1		30.5
	3½	1075	526					.720	.352					65.9	25.6	
	4	1000	508					.762	.386					68.9	30.1	
	4½		488						.420						30.6	
	5		470						.447						32.6	
	5½		448						.471						34.3	
	6		440						.506						36.9	
	6½		418						.518						37.7	
80	0	1800	800		250	304	235	0	0		1.373	1.670	1.291	0	0	
	½			720						.068						6.8
	1			692						.138						10.7
	1½	1532		667				.438		.200				32.0		15.4
	2	1440		643				.549		.244				39.3		18.9
	2½	1333		621				.635		.298				46.3		24.0
	3	1286		590				.735		.337				43.5		26.1
	3½	1180						.790						57.5		
	4	1125	542					.857	.412					62.4	24.7	
	4½		520						.447						26.6	
	5		504						.474						28.7	
	5½		496						.521						31.2	
	6		472						.543						32.5	
	6½		454						.563						33.7	
	7		434						.582						34.9	
	7½		426						.609						36.5	
	8		422						.643						38.5	
	8½		410						.664						38.8	
90	0		812		261	333	245	0	0		1.613	2.058	1.514	0	0	
	½			735						.070						4.5
	1			720						.144						9.5
	1½	1714		706				.490		.211				30.4		13.9
	2	1674		692				.639		.263				39.6		15.4
	2½	1600		680				.810		.327				50.2		21.6
	3	1551		667				.808		.380				50.1		25.1

Results for 5/8 inch nozzles.

#	#	R.P.M.			[illegible] P. [illegible]			H.P. Motor.			H.P. Water.			% Eff.		
P.	L.	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W
90	3½	1333			261	333	245	.888			1.613	2.051	1.514	55.1		
	4	1241						.945						58.6		
	4½		510						.508						25.4	
	5 5½		540 520						.513 .546						25.6 27.3	
	6 6½		494 484						.568 .590						28.4 29.5	
	7 7½		468 440						.627 .629						31.3 31.4	
	8		424						.646						32.2	
	8½		416						.673						33.6	
	9		412						.706						34.3	

Results for 1/4 inch nozzles.

5	0	125		142	25		32	0		0	.008		.010	0		0
10	0	419	121		41	35		0	0		.027	.023		0	0	
	¼	246		182			46.1	.012					.031	44.4		29.6
	½			160												51.6
	¾			138						.021						64.5
20	0	750	333		64	61	67.4	0	0		.086	.082	.091	0	0	
	¼	442	302	298				.022	.015					25.6	18.3	16.5
	½	276	246	268				.028	.023					32.6	25.9	28.6
	¾		174	222					.026						31.7	36.2
	1			212						.040						43.9
	1¼			122						.029						31.8
30	0	985	487		80	78	79.1	0	0		.168	.164	.166	0	0	
	¼		454	382					.023						14.0	11.5
	½	574	406	368				.057	.041					33.9	25.0	21.9
	¾	380	306	342				.057	.053					33.9	32.3	31.1
	1	280	304	306				.053	.058					31.6	35.3	53.3
	1¼		246	292					.059						36.0	42.6
	1½		232	260					.067						40.9	45.6
	1¾			240						.082						49.9
	2			[illegible]						.085						51.2

Results for 1/4 inch nozzles.

#	#	R.P.M.			# p.m.			H.P.Motor.			H.P.Water.			% Eff.		
P.	L.	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W
40	0	1161	581		87.5	89	84.5	0	0		.236	.240	.228	0	0	
	½	896	536	470				.090	.054					38.1	22.5	20.6
	1	696	468	430				.132	.089					56.1	37.1	36.0
	1½	524	334	386				.152	.097					64.4	40.4	49.2
	1¾		302						.103						43.9	
	2			330						.125						54.9
	2½			274						.132						57.8
50	0	1286	643		100	101	90.9	0	0		.340	.343	.309	0	0	
	½		616	534					.062						18.0	17.1
	1	888	566	498				.169	.108					49.7	31.4	27.5
	1½	704	468	460				.204	.136					60.0	39.6	42.6
	2	500	386	410				.190	.147					55.9	42.9	51.4
	2½		300	372					.144	.178					41.9	57.5
	3			320						.182						58.9
60	0	1411	708		108	109	98.3	0	0		.442	.447	.403	0	0	
	½			598												14.6
	1	1076	640	558				.204	.122					45.1	27.2	26.3
	1½	830	576	528				.240	.167					54.2	37.2	38.0
	2	732	490	486				.278	.186					62.9	41.5	45.9
	2½	522	408	460				.250	.196	.221				56.5	43.9	54.8
	3		306	420					.175	.239					39.0	57.3
70	0	1583	769		118	113	105.2	0	0		.566	.542	.504	0	0	
	½			678												13.1
	1			640												24.2
	1½	866	720	608				.251	.209					43.8	38.5	35.0
	2	846	610	580				.321	.232					56.1	42.7	44.1
	2½	712	530	550				.341	.254	.264				59.6	46.7	52.1
	2¾	660						.350						61.9		[illegible]
	3		480	514					.274	.293					50.6	58.1
	3½		386						.254						47.7	

Results for 1/4 inch nozzles.

#	#	R.P.M.			#p.m.			H.P. Motor.			H.P. Water.			% Eff.		
P.	L.	P.	B.	S.&W.	P.	B.	S.&W.	P.	B.	S&W	P.	B.	S&W	P.	B.	S&W
80	0	1675	790		128	125	113.2	0	0		.691	.675	.611	0	0	
	½			730												12.0
	1			692												21.5
	1½		762	668					.221						32.7	31.8
	2	1124	712	640				.427	.271					61.8	40.1	39.8
	2½	898	604	608				.431	.290	.292				62.4	42.9	47.8
	3	754	534	590				.429	.304	.336				62.1	45.0	54.9
	3¼	684						.424						61.4		
	3½		494						.282						49.0	
	4		412						.313						46.3	
	4½		375						.323						47.9	
90	0	1756	860		136	130	122.4	0	0		.829	.793	.746	0	0	
	½			770												10.3
	1			734												19.6
	1½			710												27.6
	2	1200	746	694				.456	.283					55.4	35.7	34.6
	2½	1060	696	664				.508	.334	.319				61.4	42.1	42.7
	3	900	628	630				.513	.358	.359				61.8	45.1	48.1
	3½	744	592					.498	.397					60.2	50.0	
	4		546						.415						52.3	
	4½		502						.432						54.6	
	5		414						.393						49.5	

Pelton- Results for 1-2 inch nozzle.

# P.	# L.	R.P.M.	# p.m.	H.P. Motor.	H.P. Water.	% Eff.
5	0	375	105	0	.035	0
10	0	602	175	0	.117	0
	½	554		.056		47.
	¾	300		.075		38.4
	1	274		.052		44.4
20	0	878	216	0	.292	0
	½	774		.077		26.3
	1	744		.147		50.3
	1½	608		.176		60.1
	2	504		.193		66.0
	2½	436		.209		71.5
30	0	1091	286	0	.600	0
	1	936		.177		29.3
	1½	868		.251		41.6
	2	756		.287		47.6
	2½	688		.330		54.7
	3	608		.347		57.9
	3½	496		.332		55.1
40	0	1333	315	0	.850	0
	1½	1072		.310		36.4
	2	1030		.391		45.6
	2½	976		.468		54.8
	3	906		.516		60.3
	3½	766		.513		60.0
	4	656		.499		51.4
	4½	618		.531		62.5
50	0	1440	363	0	1.234	0
	2½	1126		.428		34.6
	3	1082		.616		49.4
	3½	1040		.697		56.4
	4	988		.741		60.2
	4½	930		.800		64.8
	5	878		.834		67.6
	5½	782		.821		66.5
	6	720		.828		67.0

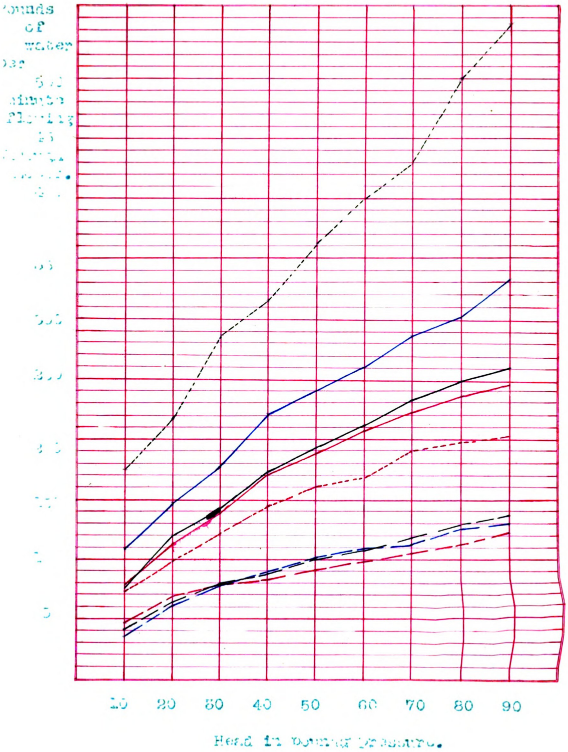
# P.	# L.	R.P.M.	# p.m.	H.P. Motor.	H.P. Water	% Eff.
60	0	1565	400	0	1.640	0
	3	1216		.789		44.2
	3½	1250		.837		50.2
	4	1188		.902		54.1
	4½	1128		.990		58.2
	5	1092		1.035		62.1
	5½	986		1.035		62.1
	6	954		1.097		65.8
	6½	892		1.106		66.4
	7	876		1.174		68.4
	7½	856		1.224		74.6
	8	768		1.175		73.5
70	0	1674	429	0	2.059	0
	4	1464		1.113		53.4
	5	1300		1.235		59.0
	6	1242		1.428		68.5
	7	1150		1.541		73.9
	8	1074		1.643		78.7
	9	1004		1.726		83.8
	10	940		1.406		68.2
80	0	1800	500	0	2.700	0
	5	1408		1.337		50.5
	6	1348		1.560		57.4
	7	1238		1.658		61.0
	8	1158		1.771		65.6
	9	1014		1.745		64.4
	10	908		1.725		63.6
90	0	2000	545	0	3.324	0
	6	1468		1.688		50.6
	7	1426		1.912		57.3
	8	1356		2.075		62.1
	9	1310		2.253		67.5
	10	1202		2.284		68.5
	11	1116		2.343		70.4

Seymour & Whitley - Results for 5/16 inch nozzle.

# P	# L	R.P.M.	# p.m.	H.P. Motor	H.P. Water	% Eff.	# P	# L	R.P.M.	# p.m	H.P. Motor	H.P. Water	% Eff.
5	0	152	46.1	0	.015	0	50	3	425	160	.242	.544	44.5
10	1/4	222	72.3	.011	.048	23.9	60	1/2	592	167	.059	.684	8.6
	1/2	194		.019		39.6		1	578		.115		16.8
	3/4	160		.024		50.0		1 1/2	552		.160		23.4
20	1/4	322	98.3	.016	.133	12.1		2	528		.201		29.3
	1/2	302		.030		22.8		2 1/2	506		.243		36.1
	3/4	280		.042		31.9		3	482		.275		40.2
	1	264		.050		39.5	70	1/2	620	190	.062	.912	12.4
	1 1/4	250		.060		45.6		1	604		.120		24.0
	1 1/2	224		.066		48.9		1 1/2	588		.171		17.2
	1 3/4	194		.066		49.6		2	574		.218		22.0
30	1/4	392	121.2	.019	.254	7.5		2 1/2	552		.265		27.0
	1/2	380		.038		15.1		3	534		.304		33.4
	3/4	364		.054		21.1	80	1/2	678	196	.067	1.068	6.4
	1	350		.070		27.9		1	660		.132		12.5
	1 1/2	324		.094		36.6		1 1/2	640		.186		17.6
	2	218		.113		44.5		2	627		.238		22.6
40	1/2	486	144.5	.048	.390	12.4		2 1/2	618		.297		28.2
	1	464		.092		23.9		3	602		.343		32.4
	1 1/2	448		.130		33.8	90	1/2	706	203	.070	1.238	5.6
	2	414		.157		40.8		1	694		.138		11.0
	2 1/2	398		.191		49.6		1 1/2	672		.195		15.6
	3	372		.212		54.3		2	664		.252		20.1
50	1/2	540	160	.054	.544	9.9		2 1/2	642		.308		24.6
	1	514		.102	[illegible]	18.8		3	624		.356		28.9
	1 1/2	494		.143		26.3							
	2	480		.182		33.5							
	2 1/2	460		.221		40.6							

[illegible] the efficiency [illegible]; [illegible] single curves showing maximum efficiency [illegible] the curves [illegible] power for the different motors, nozzles and heads. The efficiency curves for the 3/8" and 1/4" nozzles for all the motors are shown on Plates 1 and 2 respectively; the characteristic curves are shown on Plate 3, and [illegible] curves, on Plate 4. Instead of attempting to [illegible] curves, these were plotted from the exact results obtained. They should, no doubt in truth, be smooth, regular curves, and the irregularities are probably due to slight variations, in the results obtained, [illegible] the absolute truth. The method of construction of the diagrams is indicated on the Plates and needs no explanation.

The curves on the following page show the amount of water per minute flowing through the different motors for each nozzle for the different heads. The black lines are for the Pelton motor; the blue lines, for the [illegible]; the red lines, for the Seymour and Whitlock. In every case, full lines designate the [illegible]" nozzle; the dash lines, the 1/4" nozzle; and the dotted lines, the 1/2" nozzle for the Pelton, and the 5/16" nozzle for the Seymour and Whitlock. It will be noticed from these curves that the coefficient [illegible] the nozzles of either of the other motors.


of
water
20
30
40
50
60
70
80
90
Head in

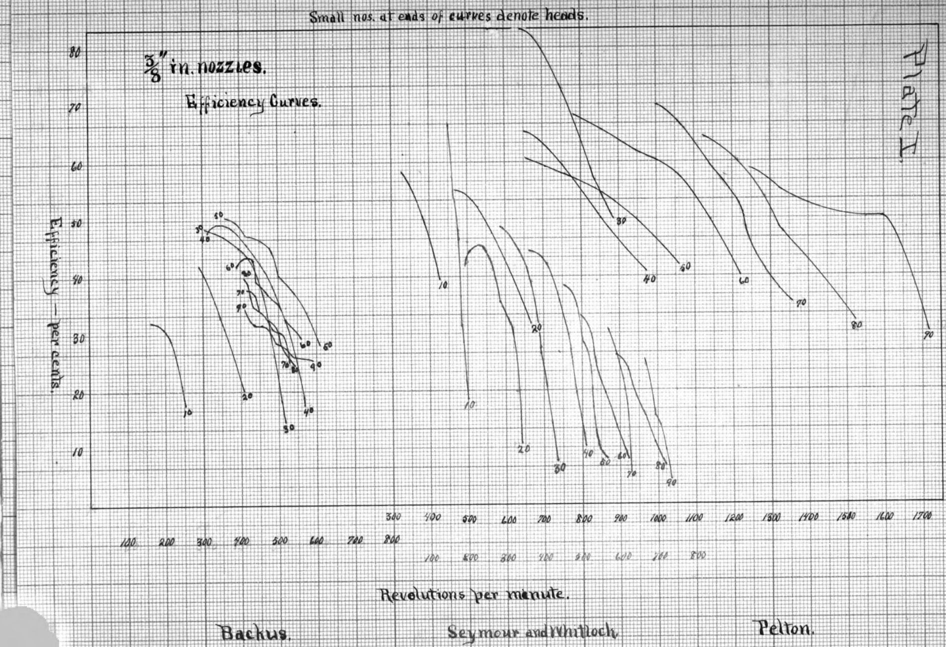


Plate I.
Small nos. at ends of curves denote heads.
3/8" in. nozzles.
Efficiency Curves.
Efficiency — per cents.
Revolutions per minute.
Backus.
Seymour and Whitlock.
Pelton.

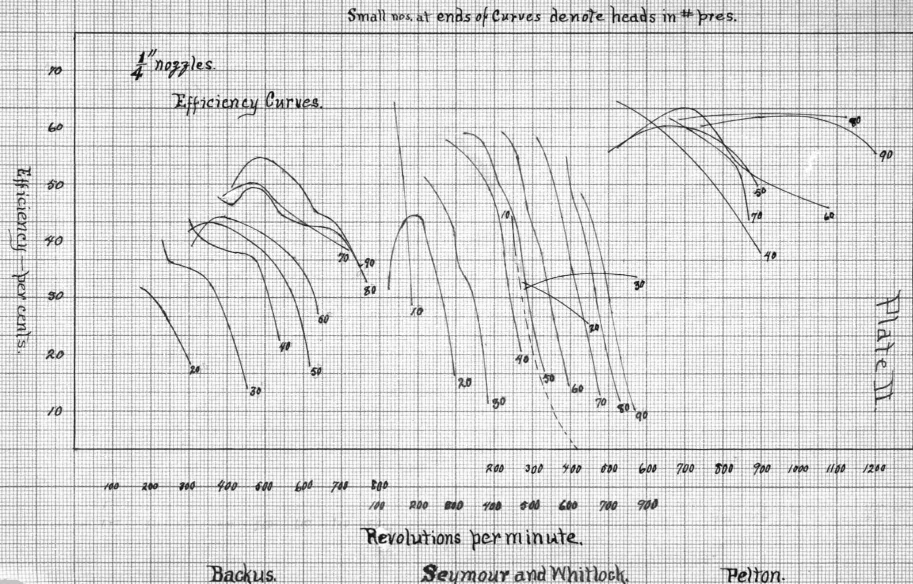
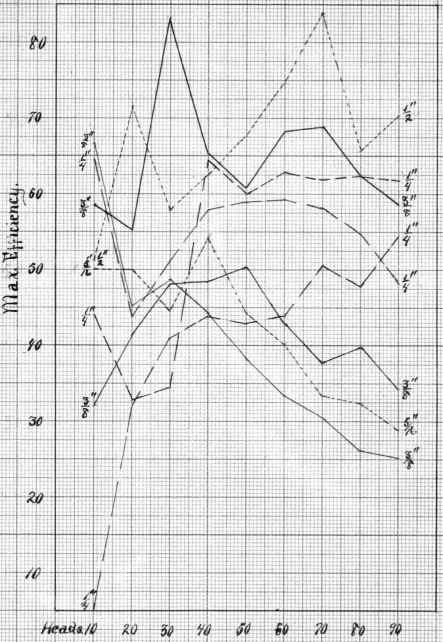


Plate II.
Small nos. at ends of Curves denote heads in # pres.
1/4" nozzles.
Efficiency Curves.
Efficiency — per cents.
70
60
50
40
30
20
10
100 200 300 400 500 600 700 800
100 200 300 400 500 600 700 900
200 300 400 500 600 700 800 900 1000 1100 1200
Revolutions per minute.
Backus.
Seymour and Whitlock.
Pelton.

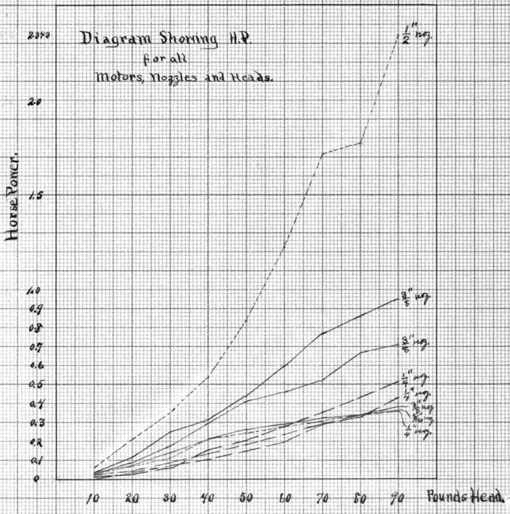


Characteristic Curves.

Plate III.

Ave. Max. Eff. { Pelton — 59.1%
Backus — 43.1%
S. and M. — 46.7%

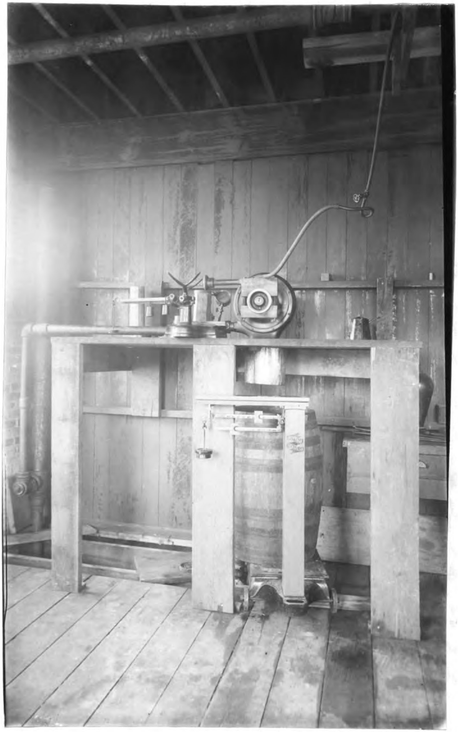
Plate IV.



Black — Pelton.
Blue — Backus.
Red — S. and W.

The determining points of these curves are directly over the heads shown and are connected by straight lines. The true curves would be continuous and would vary from the straight lines at intermediate points.

Pelton Motor and apparatus.



Pelton Motor and apparatus.

It will be seen that not in all cases was the point of best efficiency reached and thus the efficiency curves do not begin to fall off and indicate a smaller efficiency for a slower speed. Where, however, this point was reached in the course of the experiments, it was noticed that the motor gave every evidence of being working at its greatest capacity and ran with much unsteadiness and variation in speed. The experiments thus indicate that, for best efficiency, all motors should be worked to their fullest capacity and at as low a speed as they will [illegible] run steadily.

The most important point to be [illegible] in [illegible] water motors is the proper speed to run them in order to get the best efficiency. For, the horse power any motor is capable of delivering at its best efficiency being known, one can determine upon the size of motor and nozzle to be used to fulfil any conditions as to head, horse power required, etc. It then remains only to know the proper speed at which to run to give the maximum efficiency. For this purpose the following table was arranged to as nearly as it was possible [illegible] the diagrams and results, the number of [illegible] most desireable to run each motor for all nozzles all heads.

Tables Showing Approximately the R.P.M. for Best Efficiency for each Nozzle and Motor under all Heads.

Head.	Revolutions per minute.							
	1/4 inch nozzle			3/8 inch nozzle.			5/16 in. noz.	1/2 in. noz.
	Pelton.	Backus	S&W	Pelton	Backus	S&W	S&W	Pelton
10	200		125	250	160	150	150	300
20	300	150	150	350	250	200	190	400
30	400	200	200	450	285	250	250	500
40	475	275	250	500	320	350	325	600
50	550	315	300	600	325	400	400	700
60	650	325	400	700	350	425	425	800
70	700	350	450	800	365	450	450	900
80	800	375	475	850	375	475	475	950
[illegible]	850	400	500	900	400	500	500	1000

Considerably more loss of power due to friction in the bearings was found in the Backus motor than in either of the others tested. In fact, with a I/4 inch nozzle this motor could not be run unloaded with a five pound head, while very little power was necessary to run either of the others when unloaded.

The following are the average efficiencies for the three motors tested, as found by taking the maximum efficiency for each head for all nozzles used with each motor and averaging them:

Motor	Efficiency
Pelton - - - - - -	5[illegible].1%
R[illegible] - - - - - -	4[illegible].1%
Seymour and Whitlock - - -	46.[illegible]%

By far the greatest source of loss in any of the motors tested was in the Roeding [illegible] in the form and position of the nozzles, especially in the position. By referring to Plate [illegible], it will be seen that the openings in the nozzles for this motor have parallel sides for some distance before the point is reached; the nozzles thus throw a solid round stream. This, in itself, would have no ill effect, if all the water were utilized; but the nozzles are so placed that a large portion of the water, especially from the lower nozzles, does not come in contact with the cups, and thus comes through the motor with its velocity but little decreased. Thus much power is lost. This, no doubt, was the principal factor in reducing the efficiency of this motor below that of [illegible] two. I believe that the [illegible] tested was sufficient, and if [illegible] defect, [illegible] efficiency of this motor by more than ten per cent. This [illegible] is substantiated by the fact that, [illegible] ed, there was [illegible] 1/4 inch [illegible] with a 5/8 inch nozzle; the maximum average efficiency being about three per cent higher for the smaller nozzle.

Very respectfully,

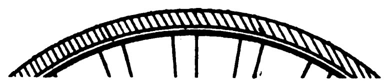
July 20, 1908.

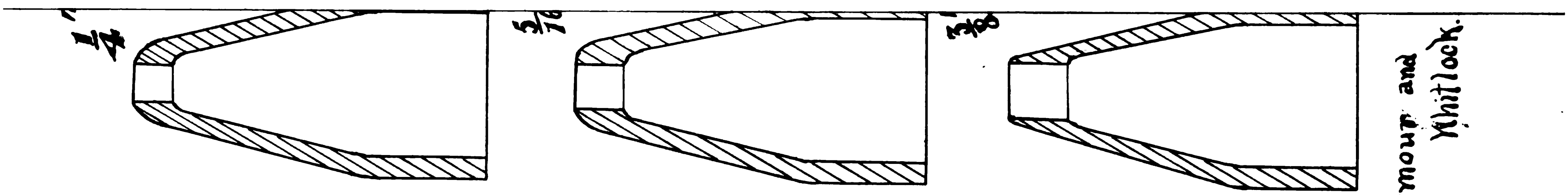
A. C. [illegible].

Seymour and Whitlock

22" Impact motor.

Plate VIII.





Seymour and Whitlock.

Seymour and Whitlock

22″ Impact motor.

Plate VIII

Seymour and Whitlock

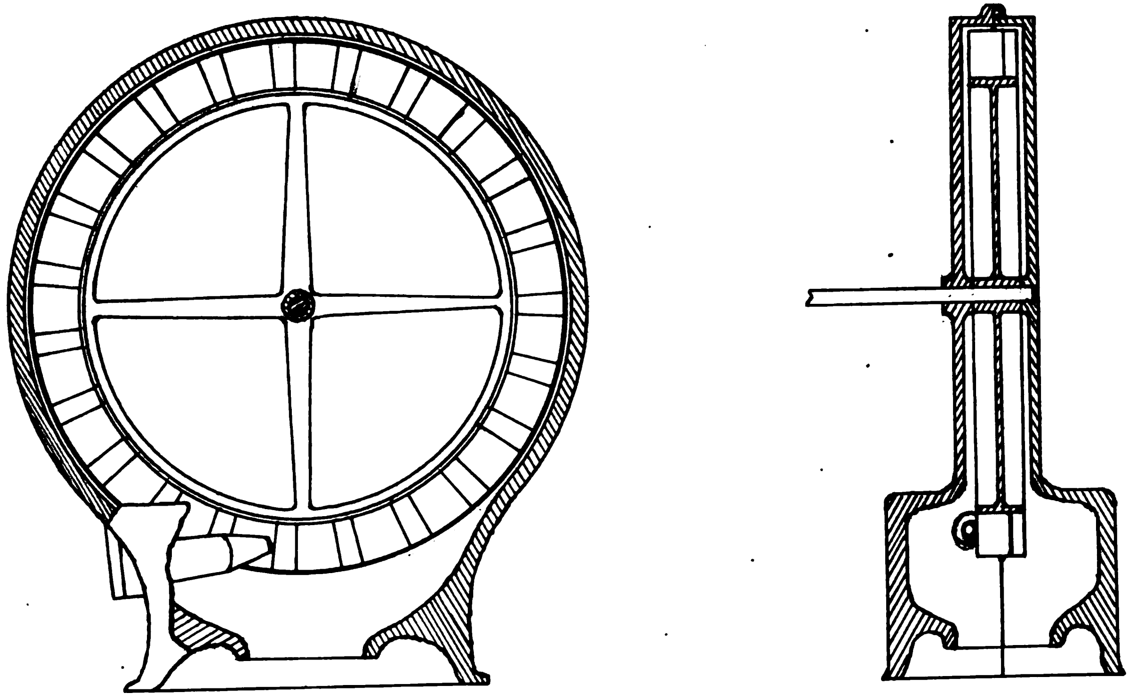
22" Impact motor.

Plate VIIII

Seymour and Whitlock

22" Impact motor.

Plate VIII.

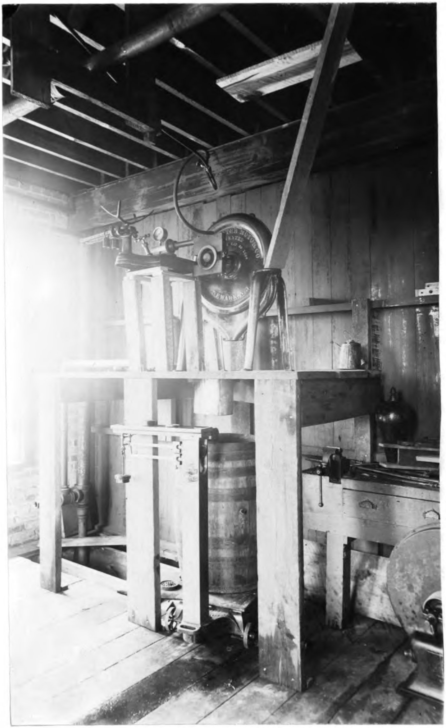


Showing manner of impact.

Scale—1/8

No. of cups – 22.

A.C. Burnham.



Backus Motor and apparatus.