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THESIS

--FOR THE--

Degree of Bachelor of Science

-IN-

ENGINEERING.

SUBJECT:

"Power Utilization of Meramec Spring."

F. H. WALSH,
For C. E.

LAWRENCE MAY,
For E. M.

MAY, 1902.

POWER UTIDIZATION OF MERAMAC SPRINGS.

Power Utilization of Meramec Spring.

Meramec Spring is situated in the east central part of Phelps County, Missouri, about one quarter of a mile west of the county line. The spring proper is in the center of a small natural amphitheatre from which the water flows through a valley which has a bearing of approximately N. 30 degrees W., about one quarter of a mile from the the spring the course of the stream is changed about sixty degrees to the east, one quarter mile from this bend the stream joins the Meramec River. The spring is situated about six miles S 30 degrees E. from the town of St. James, Missouri and is about thirteen miles due east of Rolla, Missouri. By wagon road the distance from Rolla to the spring is sixteen miles.

The volume of water delivered by the spring is modified to some extent by the amount of rain precipitated in the surrounding district. In the latter part of the summer of 1901, after several months of prolonged drought, the flow from the spring was found by actual measurement to be about 55,000,000 gallons per day (one set of observations gave 47,000,000) of twenty four hours. On March 26th. 1902, after several weeks of ordinary weather, the flow of the spring was found to be about 60,600,000 gallons per day. After a rain of several hours duration the flow was materially increased and probably reaches 100,000,000 gallons at such times.

The improvements contemplated are a dam and sluice to impound and deliver the water from the spring to the turbine in the power house (see Plates I and II). This turbine will be directly connected to Three Phase Alternating Current Dynamo. The energy will be transformed at the power plant and transmitted to St.James and Rolla by Duplicate Three Phase Transmission Lines. The water from the turbine is carried away by an inclined draught tube to the tail race which joins the present valley below the old dam, as shown on Plate I.

The dam is to be of the ordinary rock fill type, built of material taken from the surrounding hill sides. This material is well adapted for the purpose, consisting of boulders from head size down, mixed with gravel, sand and clay. This dam is about ninety-three feet long and three feet wide on the top. The section will not be regular as the material will be dumped and not placed. The westerly end of the dam will terminate in the side of the head sluice. This sluice extends in a straight line to the pen stock which is simply an enlargement of the sluice proper. Gates are provided near the entrance of the sluice and a grating is to be built in the penstock to prevent floating objects from entering the turbine.

The datum of elevations is at the level of that point from which the water of the spring issues, therefore this being zero the present water line is at fourteen feet. As the intention is to use a head of thirty feet the dam is to be thirty-two feet high as about one foot head will be used to obtain the proper slope in the tail race, the gates must be manipulated in order to keep a head of thirty-one feet in the reservoir. The effective head will then be thirty feet. The foot loss in the tail race is occasioned by the fact that the level of the water in the stream and the level of the point where the water issues from the spring is the same, approximately.

The head sluice is of trapezoidal section twenty-three feet wide on top, sixteen feet wide on the bottom and seven and one-half feet deep, the water standing to a height of six feet. The earthwork is part cut, part fill, the two approximately equal.

The forebay or penstock is simply an enlargement of the sluice and is provided with the usual grating and may be covered, it is separated from the power house by a water tight timber partition. The power house partition and the gates are described in description of Plate II.

The turbine as worked out (see notes on pages) is to be a 27" horizontal shaft, inward flow Victor turbine as built by the Stillwell, Pierce and Smith-Vaile Co. of Dayton, Ohio.

The inflow is taken to the turbine through a short sheet iron pipe, In order to get an effective head of thirty feet a draught tube, inclined to the tail race as shown in Plate I, is to be used.

The turbine, which under the given head and running at 286 R.P.M. develops 246 Hp is to be direct connected to a 150 K.W., General Electric, three phase alternator which gives a current of 15.45 ampheres under an E.M.F. of 1000 volts. A masonry pit and foundation for the dynamo is to be provided as shown on Plate II. The current from the dynamo is to be "stepped up", with a three phase stationary transformer, to 10,000 volts and will be transmitted at this tension over a three wire pole line to St. James and Rolla. A switch board and tool room are to be provided, in the power house as shown on Plate II.

The draught tube, which is of sheet iron and slightly enlarging as it goes downward, terminates in a dead water pool which is twenty seven feet long, and twenty four feet wide and six feet deep, the tail race flowing from this pool is eighteen feet wide at the water line, ten feet wide on the bottom, the water flows at a depth of three feet. This sluice is approximately one thousand feet long.

The intention is, that on account of the spring being in a small basin and as there is no opportunity for the storage of water, the reservoir will be nothing more or less than a tank, water entering at one part and being drawn out at another. As before stated, a definite head (of thirty-feet) is to be maintained by manipulation of the sluice gates and any excess of water which can not be used by the turbine is to be wasted over the dam. To effect this, the top of the dam will be slightly lower at the center than at the abutments and an apron of broken stone, laid dry is to be built on the down stream side of the dam to prevent undercutting by the waste water.

Plate No. I.

This plate shows a topographical map of the spring and surroundings, with the improvements contemplated, the contours being shown up to eighty seven feet above the datum. This datum is the plane passing through the exit of the spring and all contours are taken above it.

The topography of the ground above water was determined by the stadia, in the usual manner, from the stations s,s,: the topography of the ground covered by water was determined by soundings from a boat, the position of the boat at time of sounding was taken by an observation on a stadia rod mounted on the boat.

Two sections are shown, one on the lines AB, BC is projected on the line AB, produced, this section shows the relative elevations of the bluff, spring, proposed dam, present dam and the submerged ground.

The present and proposed water lines are also shown. The other section is taken on the line DE and is projected at right angles to the direction of the head bay.

A section of the head bay is shown,giving also the slope of the hill at the line of section. A plan of the gates and frame work is indicated. These gates are two in number. On each gate are two vertical racks meshing in two gear wheels on the same horizontal shaft. This shaft is turned with hand spikes inserted in the orifices of a disk on the center of the shaft as in the ordinary gate for low heads. Each end of the horizontal shafts is supported by a cast iron bracket fastened to horizontal timbers in the framing of the gate. Theframing of the gates and gate supports must be rigid and of necessity is to be braced in a proper manner so that movements or displacements of the gate structure or any of its parts may be impossible. Each gate is entirely separate from the other and may be operated independently.

The scale throughout is fifteen feet to the inch.

Plate No. II.

This plate shows sketches of the power house in plan,side elevation and cross section to a scale of one quarter inch equals one foot. The location of the various devises and a general arrangement of the timber is shown. The roof is to be supported by five timber trusses of extra heavy construction,in order that great weights may be suspended from them without danger to the structure. The building is to be roofed and sided with corrugated iron and windows and a door are to be provided for as shown.

The bulk head between the head bay and power house is to be supported on a well braced framing of timber. This bulkhead consists of two thicknesses of two inch plank with joints at right angles to each other and a layer of water proof roofing material between the layers of plank.

Also on Plate II is shown a cross section of the stream,flowing from the spring,The horizontal scale is,one inch equals five feet, the vertical scale is,one inch equals two-tenths feet.

This profile was obtained by the use of the level, The readings were taken at intervals of five feet on a tape stretched across the stream. These points are indicated by the numbers 65,60,55 etc. At the points marked 65a,65b,60a,60b,etc., readings of the current meter were taken in the usual manner.

Probable Horse Power Developed.

Measurements taken during the summer of 1901 showed that the minimum flow during a severe drought was 84.28 cubic feet per second. March 1902,measurements were again taken,when the flow was supposed to be an average and it was found as shown on Plate No.I to be 93.41 cubic feet per second.

The Horse Power developed theoretically from 84.28 cubic feet per second with 30 feet head is 289.

The water wheel selected was efficient to 79.8 %. This leaves 230.6 Horse Power to be delivered to the dynamo.

During high water the effective head is decreased on account of back water one or more feet but since the volume is increased we can keep the power nearly constant by using a larger wheel. This wheel is as before stated, a Victor Horse Power 246.04.

Losses in Dynamo and Transformer.

The losses generally allowed in dynamo and transformer are 8% and 2% respectively.

This leaves 207.5 Horse Power to be delivered to the line.

Whater Wheel.

Outward Flow.

The equations used are taken from P.387 Merriman's Hydraulics. The angles referred to are the same as those in diagram on page 379. Assume $\alpha = 28^\circ$; $\phi = 90$; $r_1 = 128"$;, $r_2 = 17.3"$ Give $h = 30$ ft.

From Equa.(107)

$$u = \sqrt{\frac{gh \sin(\phi - \alpha)}{\cos\alpha \sin\phi}} \quad 31.04 \text{ ft.sec.}$$

$$v_0 = \sqrt{\frac{gh \sin\phi}{\cos\alpha \sin(\phi - \alpha)}} \quad 35.2 \text{ ft. sec.}$$

From Equa.(105)

$$\frac{u'}{V_0} = \frac{r_1^2 d \sin\alpha}{r_1^2 d \sin\beta} \text{ or } \sin\beta = \frac{r_1^2 V_1 \sin\alpha}{u_1 r_2^2} = .2912$$

$$\text{or } \beta = 16^\circ 56$$

$$r.p.m = \frac{u \times 60 \times 12}{\pi \times 25.6} = 279$$

$$u_2 r = u_1 r_1 \text{ or } u_2 = \frac{u_1 r_2}{r_1} = 42 \text{ ft/sec.}$$

From Equa (104) $V_1 = u_1 = 42$ ft. sec.

" " (103) $d = \frac{Q}{r_1 2 \pi r_1 \sin\alpha} = .82$ ft.

/

From relation in triangles. (p. 379)

$V = \sqrt{u^2 + V_0^2 - 2u V_0 \cos a} = 16.4$ ft/sec

$v_1 = \sqrt{\bar{V}^2 + \bar{u}^2 - 2u_1 V_1 \cos \beta} = 13.3$ ft/sec.

From equations p. 386

$a_0 = 2\pi d \sin \alpha = 2.51$ sq. ft

where $\underline{a_0}$ = area of guide orifices.

$a = 2\pi r d \sin \phi = 5.35$ sq. ft

where $\underline{a}$ = area of entrance in sq. ft.

$a_1 = 2\pi r_1 d_1 \sin \beta = 2.05$ sq ft

where $\underline{a_1}$ = area of exit orifices in sq. ft.

From equation p. 388

$$\text{Efficiency} = 1 - \frac{2u_1^2 \sin^2 \frac{1}{2}\beta}{gh} = 92.1\%$$

$$\text{Theoretic H.P.} = \frac{Q h \lambda}{550} = 308.2$$

where Q = no. cu. ft per. sec

h = height in ft.

λ = 62.5 lbs

308.2 x .921 = 283.8 H.P. This does not include losses by friction, impact, foam, etc.

The wheel selected is a Victor Turbine made by Stilwell - Pierce & Co., Dayton Ohio.

H.P. = 246.04

r.p.m. = 286.

$$\text{Eff} = \frac{\text{Actual H.P.}}{\text{Theoretic H.P.}} = \frac{246.04}{308.2} = 79.8\%$$

Line From Meramec To St. James.

There shall be three No. 8 wires placed 18" apart, the center one being placed on top of pole. These will be transposed every half mile. 10000 volts shall be used for transmission. The voltage at machine shall be 1000 and will be steped up to 10,000 volts by a Three Phase Stataionary Transformer.

The ~~reaction~~ reactance per mile for No.8 conductors spaced 18" apart is .712 ohms
The Resistance per mile for #8 is 3.32 ohms.
The Capacity per mile for #8 spaced 18" is given by Crocker Vol. II p 138. Formula 67 is found to be .00344 micro ~~forced~~ farad. This is so small it may be neglected.

Therefore the empedence per mile where R = Rs

$L\omega$ = Inductance = .71

$= \sqrt{3.32^2 + .712^2} = 3.39$ ohms. $= \sqrt{R^2 + L^2 \omega^2}$

Total resistance = 12 X 3.39 = 40.68 ohms.

Volt drop = C R = 15.45 X 40.68 = 628.5

∴ 10000 − 628.5 = 9371.5 volts delivered at St. James.

Per cent drop in line = $\frac{9371.5}{10000}$ = 6.3%

Cost of Line from Meramec to St.James.

Poles per mile at $1.10	$49.40
Insulators 264 per mile at $1.40 per 1000	39.96
Pins,porcelain base at 25¢	66.00
Cross Frames at 6 ¢ per foot	17.52
Iron braces 5/16 x 1 x 20"(wt.104# per ft) at 6¢	18.20
#8 B & S guage,allowing 10% for losses at 71/2¢ per #	278.84
putting up line wire	20.00
Setting in poles	22.00
Total cost per mile	510.92

Length of line is six miles.

Cost of line from St. James to Rolla.

The same size wire will be used and the same material in constructing the line. Therefore the cost per mile is same as above.

Length of line is ten miles.

Total cost	Meramec to St. James	2065.52
	St. James to Rolla	5109.20
	Total cost of line	8174.72

Loss in Line from St. James to Rolla.

The resistance per mile is the same as before since the same size wire will be used,spaced same distance apart and at the same height from ground.

Length of line 10 miles.

Total resistance equals 3.39 X 10 X 2 = 67.8 ohms.

The probability is that only half the current will be used at Rolla.

Probable volt drop = C R = 7.72 X 67.8 = 523.4

Voltage delivered at Rolla equals 9371 − 523 - 8848

Cost of Dynamo.

of three phase 1000 volt alternator will cost nearly $35 per K.W.

Capacity of Dynamo is 150 K.W.

Cowt of Dynamo will be $5250

Cost of Transformer for Power House.

Voltage must be raised from 1000 to 10000

Cost per K.W. nearly $10

Cost of Transformer $1500

Capacity of Reservoir. Contents of Dam. Amount of Excavation,etc.

The areas within the contour were found by means of the planimeter and knowing the distance between contour the volume can be figured.

The capacity of Reservoir and head race is found to be 109273 cubic feet.

The contents of the dam is approximately 691 cubic yards. The cost per cubic yard,including excavation,hauling,labor,etc. is taken as 75¢

Total cost amounting to $518.

Volume of Excavation for Head Race.

The material **excavated** at upper side will be approximately enough to raise the lower side sufficiently high.

Ifnot excavated equals 891 cubic yards.

Cost per cubic yard.25¢

Total cost $222.

Tail **Race.**

The total length of tail race is approximately 1000 feet.

The amount of excavation equals 41000 cubic yards.

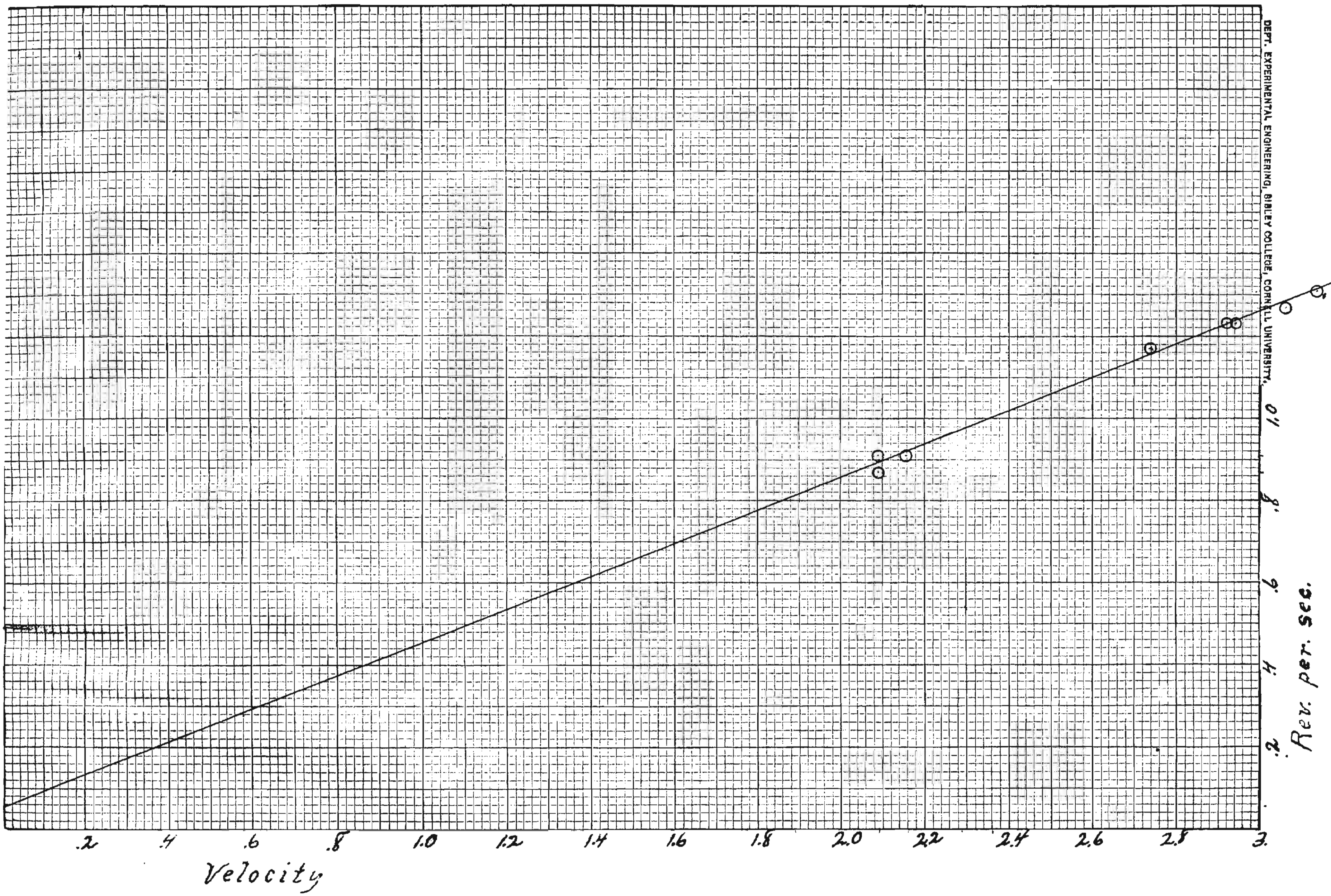
Cost per cubic yard 25¢

Total cost $1020.

Switch Board.

Thisnshall consist of Blue Marble up which will be mounted switches,circuit,breakers,Instruments,etc.

Total cost will approsimate $200.



$y = b + \alpha x$

$y = b = .052$

$Tan.\ \alpha = .175$

Approximate cost of Power House	$1200.00
Turbine and fittings	3000.00
Total line M to St.J and St. James to Rolla	8175.00
Dynamo	5250.00
Trams	1500.00
Dam.	518.00
Ex. Head Sluice	222.00
Tail Race	1000.00
Switch Board and fittings	200.00
Total, including labor but exclusive of superintendence	$21.065.00

Stadia Survey of Meramec Spring. Mar. 25 1902

Station	Dis.	Az	Vert ∠	Red. Dis.	Pfl. Elev.	Elev.	Notes
□ 00							Peg distance 125 ft. Bearing S 45° W from S.W. corner of Barn
	404.	118°57	+0°29'				
□ 0						24.96	Peg on west side of Spring on prominentory near S.E. side of flat rock
	47.0	314°5'	-12°35'	44.8	10.0		
1						14.96	
	20.0	0°0'	-26°40'	15.9	8.02		
2						16.94	
	36.0	138°28'	-11°20'	34.6	6.94		
3						18.02	
	84.0	144°53'	-4°6'	82.6	10.3		
4						14.66	
	108.0	139°29'	-6°31'	106.5	12.2		
5						12.76	
	125.0	127°25'	-4°50'	124.0	10.5		
6						14.46	
	124.0	123°50'	-4°45'	123.0	10.4		
7						14.56	
	115.0	114°21'	-5°20'	114.2	10.6		
8						14.36	
	107.0	100°37'	-5°50'	106.0	10.8		
9						14.16	
	97.0	84°20'	-6°16'	95.8	10.5		
10						14.46	
	98.0	68°24'	-6°12'	97.0	10.5		
11						14.46	
	110.0	40°30'	-5°35'	109.0	10.6		
12						14.36	
	114.0	21°42'	-5°20'	113.0	10.4		
13						14.56	
	135.0	5°23'	-4°28'	134.0	10.5		
14						14.46	
	153.0	257°23'	-4°0°	152.3	10.6		
15						14.36	
	182.0	350°58'	-3°50'	181.5	12.1		
16						12.86	
	176.0	346°48'	-3°30'	175.0	10.7		
17						14.26	
	169.	333°5'	-3°39'	168.2	10.7		
18						14.26	
	165	320°10'	-3°39'	164.0	10.48		
19						14.48	
	180.0	309°47	-3°25'	179.3	10.7		
20						14.26	
	245	305°15'	-2°35'	244.0	11.0		
21						13.96	
	280	308°10'	-2°12'	280.0	10.75		
22						14.21	
	340.	313°20'	-1°46	340.0	10.46		
23						14.50	

Station	Dist.	Az.	Vert L	Red. Dis	Diff. Elev.	Elev.
	375.0	319°24	-1°44	375.0	11.3	
24						13.66
	340.0	300°19	-1°45	340.0	10.4	
25						14.56
	280	296°24	-2°30'	280.0	12.2	
26						12.76
	226.0	292°2	-2°42'	225.7	10.65	
27						14.31
	184.0	289°30'	-3°10'	183.5	10.18	
28						14.78
	160.0	287°12'	-3°55	159.4	10.9	
29						14.06
	150	287°51	-4°51'	149.6	12.62	
30						12.34
	100	290°23'	-6°8'	98.8	10.62	
31						14.34
	70.0	300°13'	-8°45'	68.37	10.52	
32						14.44
	16.0	108°50'	-12°19'	15.3	3.32	
33						11.64
	32.	136°42'	-7°44'	31.4	4.27	
34						20.69
	100.0	149°41	-2°15'	99.8	3.92	
35						21.04
	132	122°53'	-2°5'	132.0	4.8	
36						20.16
	120.	109°42'	-0°49'	120.	1.75	
37						23.21
	108.	96°6'	-2°28'	108.	4.65	
38						20.31
	100.	80°15'	-3°12'	99.7	5.57	
39						19.39
	110	65°00'	-2°41'	109.5	5.33	
40						19.63
	116.	48°2'	-2°15	115.7	5.56	
41						19.40
	121.	30°21	-2°30'	120.5	5.27	
42						19.69
	127.0	21°53'	-2°18'	126.5	5.10	
43						19.86
	135.	11°51'	-2°40'	135.0	6.28	
44						18.68
	150.	3°27'	-2°38'	150.	6.58	
45						17.38
	155	0°15'	-2°25'	154.5	6.53	
46						18.43
	200	354°50'	-1°16'	199.9	4.41	
47						20.55
	~~40~~	298°5'	-6°45'	39.4	4.67	
48						20.29
	175.0	283°7'	-2°21'	174.5	7.16	

Station	Dis.	Az.	Vert L.	Red. Dis	Diff Elev.	Elev.
49						17.80
	234.0	286°53′	−1°40′	234.0	6.8	
50						18.16
	272.0	212°00′	−1°29′	279.6	2.25	
51						22.7[illegible]
	32.0	151°56′	+4°0°	31.5	2.20	
52						27.16
	80.0	152°54′	−5°3′	79.3	7.02	
53						17.64
	140.0	120°49′	+0°38′	140.0	1.55	
54						26.51
	114.0	90°20′	+2°25′	114.0	4.8	
55						29.76
	124.0	51°57′	+0°49′	124.0	1.7	
56						26.66
	140.0	19°23′	+0°10′	140.0	.406	
57						25.36
	160.0	2°47′	+0°38′	160.0	1.77	
58						26.73
	200.0	355°13′	+1°0′	200.0	3.48	
59						28.44
	190.0	0°47′	+4°5′	189.0	9.95	
60						34.91
	160.0	23°4′	+5°57′	158.3	16.5	
61						41.56
	152.0	41°22′	+6°55′	150.0	18.2	
62						43.16
	146.0	56°15′	+7°42′	143.3	19.4	
63						44.36
	135.0	71°3′	+8°50′	131.8	20.5	
64						45.46
	135.0	89°54′	+8°9′	132.2	18.95	
65						43.91
	137.0	100°12′	+7°31	134.8	17.8	
66						42.76
	152.0	117°52′	+6°37′	150.0	17.4	
67						42.36
	100.0	152°47′	+5°51′	98.96	10.4	
68						35.36
	52.0	164°56′	+14°25′	48.8	12.53	
69						37.49
	28.0	235°8′	+28°14′	21.7	11.69	
70						36.65
	60.0	261°0′	+12°1′	57.4	12.21	
71						37.17
	168.0	184°8′	+27°39′	132.0	69.0	
72						95.96
	178.0	157°55′	+24°28′	146.5	67.0	
73						91.96
	200.0	137°20′	+22°46′	170.0	71.4	[illegible]

Sta	Dis	Az.	Vert L	Red. Dis.	Diff Elev.	Elev.
74						96.3
	228.0	125°47'	21°12'	198.4	76.9	
75						101.86
	240.0	104° 35'	+27°47'	257.0	82.8	
76						107.76
	250	89°33'	+23°2'	211.7	90.3	
77						115.26
	270	70°7'	+21°4'	234.9	90.5	
78						115.46
	240	57°41'	+20°40'	225.0	90.2	
79						115.16
	244.	44°20'	+19°22'	217.0	76.4	
80						101.36
	236.	28°39'	+16°37	214.0	64.75	
81						89.71
	240	+18°5'	+13°43'	226.2	55.4	
82						80.36
	240	13° 18'	+12°12'	229.2	49.6	
83						74.56
	252	7°55'	+10°27	243.8	45.0	
84						69.96
	250	126°42'	+21°3'	217.7	84.3	
85						108.26

Soundings taken in Spring Mar. 26. 02

	Dis.	Az.	Depth	Elev	Vert L	Diff Elev	Notes
⊡ 0				24.96			{ See Page I
	114.0	21°84					Holes drilled in rock on ea
⊡ 1				15.61	4°47'	9.35	side of spring + 40 ft. from
	90.	165°31'	8.94				Read.
2				5.54			
	60	154°30'	8.4				
3				6.0			
	17	224°16	7.2				
4				7.2			
	25.	280°16	6.72				
5				7.68			
	45.	296°0°	7.20				
6				7.2			
	65	300°0°	7.92				
7				6.48			
	84.	221°15'	6.72				
8				7.68			
	70.	213°16	8.16				
9				6.24			
	70	205°43	8.76				
10				5.64			
	80	188°52'	8.40				
11				6.00			
	102	179°18'	8.4				
12				6.00			

	Dis.	Az.	Depth.	Elev.
	120	179°57	8.3	
13				6.1
	132.0	180°33'	4.2	
14				10.2
	116.0	175°57'	5.4	
15				9.0
	180	172°18'	4.2	
16				10.2
	184.0	167°57'	4.2	
17				10.2
	172.0	164°37	14.4	
18				0.0
	81.0	167°15'	8.4	1
19				6.0
	57.0	160°47	8.4	
20				6.0
	23.0	204°48'	9.12	
21				5.3
	42.0	257°30'	9.6	
22				4.8
	60.0	279°46	9.6	
23				4.8
	78.0	292°18'	8.4	
24				6.0
	89.0	299°10	8.7	
25				5.7
	104.0	283°46	7.8	
26				6.6
	108.0	270°16'	7.2	
27				7.2
	107.0	255°10'	8.3	
28				6.1
	80.0	249°7'	7.6	
29				6.8
	128.0	263°14	7.1	
30				7.3

Mar. 25. 02 — Stadia Survey of West Side of Spring

Station	Dis	Depth.	Ver. ∠	Red. Dis	Diff Elev.	Elev.	
□ 00						21.69	{See Page I.
	124.0	146°42'	+1°28'	123.0	3.15		
□ 2						24.82	{Reg. drive in center of Δ of maple trees and on top of molehill; about 40 ft. from edge of water
	62.0	130°19'	+1°00'	61.5	1.07		
1						25.89	
	148.0	119°20'	+0°35'	147.6	1.5		
2						26.3	
	260	108°35'	+0°11'	260.0	.75		
3						25.5	
	270.0	118°22'	+5°18'	268.0	24.9		
4						49.1	
	214.0	124°0'	+7°2'	211.0	25.5		
5						50.3	
	146	131°48'	+5°48'	144.0	16.9		
6						41.7	

Station	Dis	Depth	Ver L	Red Dis	Diff Elev	Elev.
	84.0	147°51	+6°40'	83.0	9.6	
7						34.4
	112.0	175°7'	+14° 43'	104.5	25.6	
8						50.4
	166.0	153°40'	+13°51	156.0	36.2	
9						61.0
	192.0	143°8'	+13°30	181.0	41.2	
10						66.0
	235.0	131°9'	+11°52'	225.0	45.7	
11						69.9
	260.0	128°39'	+11°26'	250.	48.7	
12						73.5
	340.	131°18'	+11°45'	326.0	81.5	
13						106.3
	278.	142°56'	+13° 39'	264.0	59.6	
14						84.4
	238.	149°44'	+14°10'	224.0	53.0	
15						77.8
	250.	159°32'	+13°55'	235.0	54.2	
16						79.0
	190.	181°52'	+14°55'	177.5	44.1	
17						69.0
	90.	101°47'	-6° 30'	88.7	10.0	
18						34.9
	152.0	80°14'	-6° 9'	150.0	15.9	
19						40.7
	168.0	78°44'	-6°27	166.0	19.8	
20						44.6
	260.0	71°51'	-2°20	258.0	10.5	
21						35.3
	272.	69°32'	-2°10	270.	10.2	
22						35.0
	282	68°0'	-1°49	281.0	8.7	
23						3[illegible].

Levels run for obtaining difference in elevation between present water level and proposed exit of tail race.

Assumed Datum 40 ft.

H.I.	B.S.	F.S.	Elev.
42.19	2.19		40
33.75	4.08	12.52	29.67
34.995	8.515	7.27	26.48
		9.28	25.715
	Diff of Elevation		14.285

Point of exit is opposite rolling mill in direct line with front of mill.

Rating of Meter.

The following tabulated distance and time are for twenty revolutions of meter.

Dis.in ft.	Time in sec.	Rev.per sec.	Vel.
48	23.1	.87	2.09
46.	22.	.91	2.09
47.5	22	.91	2.16
46.5	17	1.176	2.74
47.5	16.3	1.23	2.92
48.	15.3	1.31	3.14
47.5	16.2	1.23	2.92
48.	15.7	1.27	3.06

These readings were used to plot the following curve which is used to find the velocity having given thenrevoltions per second.

Meter Measurements.

Levels taken for obtaining profile of spring branch. These were taken every five feet and also every two and one-half feet where bed of spring was irregular. The elevations refer to the water surface as a datum. For profile see Plate #.

Sta.	H.I.	F.S.	Elev.
	46.85		
65		4.85	0/17
60		5.22	0.54
55		5.43	0.75
50		5.89	1.21
45		6.15	1.47
42 1/2		6.38	1.70
40		6.11	1.43
37 1/2		5.65	0.79
35		5.87	1.19
32 1/2		6.35	1.67
30		6.40	1.72
27 1/2		6.19	1.51
25		5.85	1.17
22 1/2		5.93	1.25
20		5.80	1.12
15		5.56	0.88
12 1/2		5.31	0.63
10		5.06	0.38

Meter Readings.

Two readings were taken between the five feet station as shown in drawing #

Station	Time of 10 rev.	Time of 10 rev	Av.Time of 10 rev.	Vel in ft. per sec.	Rev/Sec
65a	44.2	43.6	43.9	0.44	.228
65b	28.2	28.0	28.1	0.74	.356
60a	23.4	23.3	23.3	0.94	.429
60b	15.6	15.6	15.6	1.46	.641
55a	15.0	15.2	15.1	1.5	.662
55b	12.8	13.0	12.9	1.79	.776
50a	13.4	13.2	13.3	1.74	.752
50b	15.4	16.0	15.7	1.44	.636
45a	13.0	12.8	12.9	1.79	.775
45b	11.4	11.6	11.5	2.04	.870
40a	12.	11.8	11.9	1.96	.840
40b	12.8	12.6	12.7	1.85	.787
35a	12.4	12.0	12.2	1.92	.820
35b	11.8	12.0	11.9	1.96	.840
30a	12.0	12.0	12.0	1.95	.833
30b	12.6	12.6	12.6	1.80	.793
25a	15.2	15.0	15.1	1.5	.662
25b	16.8	17.0	16.9	1.35	.592
20a	16.4	16.4	16.4	1.39	.610
20b	18.0	18.2	18.1	1.24	.552
15a	30.8	30.6	30.7	0.68	.326