THESIS,

A MILL SITE,

FOR DEGREE OF B. S. SCHOOL OF M. E.

BY

E. Dryer,

1887.
A Mill Site

In the location of a mill, several things are necessary to insure success: the most prominent of which are: - 1", that it must be situated as near as possible to the material, or to the place of production of the article used; - 2", A power, sufficient to operate the mill under all the conditions for which it is designed; - 3", Must be near some common carrier, such as a river, canal, or railroad, in order to have transportation for manufactured article to a market.

In this article I will assume the 1" and 3" conditions fulfilled, and attempt to discuss the 2".
There is nothing more important, in the construction of a mill than its power, as the outlay at first is large, and if water power is used, the expense of repairs on the water ways, is the largest item met with in the yearly account.

The mode of obtaining, and the application of power, is best shown by an example, in this case, one having a capacity of 200 barrels of flour and 1200 bushels of corn, in 24 hours, and the building situated 500 ft. from the stream which supplies water power. Will show the power obtained in three ways; 1" By the construction of a weir, with power transferred by cable to mill; 2", By the construction of a race; 3", By steam power.

The power must next be found to run the mill in full capacity of preparing for market of 980 bu. of wheat and 1200 bu. corn in 24 hr.
The usual amount of power allowed for the various machines in a mill are as follows:—For wheat burn, one H.P. per hour for one bu., of corn burn two-fifths as much, an for burn for regrinding, one-fourth of total amount used the first grinding. Then for this capacity we have a total H.P. of,—

for wheat 21, for shorts 10, for Corn 20, for bottling 3, for corn-sheller 5, smutter 1, for Scalper 2, for elevators 5, for kiln-srier 1, = 88 as the approximate.

In the first case, of the power transferred by cable, from a motor at the dam, the loss in transmission must be accounted for, in order to find power required at wheel, which according to experimental results, there is a loss of about 4%, for each relay, and in this case, about 91.5 H.P. would be required at the wheel.
As the head at the dam is necessarily small, on account of the law, which in many states designate the maximum height, we may assume a fall of 10 feet as the average.

The kind of wheel must next be chosen, and as the turbines are coming into more general use, and are equally efficient, I will use one of the standard makes, of which there are the Swain, Risdon, and Leffel, as standards, which claim an efficiency of from .88 to .88, but it is best to place $ as the amount to use in the calculations, then the amount of water required = \( \frac{945 \times 33000}{62.5 \times 10} \) cu. ft. per minute, or allowing 8 as the efficiency, we must have 5806.7 cu. ft., which power can be obtained from a 50" Risdon wheel with 560" vent, and making 89 revolutions per min., or from a Leffel wheel, 61", vent 606", and revolutions 71.
The penstock must be designed to suit the wheel, also with reference to the manner in which the power is taken off, whether above or below the level of the water in the penstock.

In this case, it would be above, in which a devil gear on the wheel shaft, gears with one on a horizontal shaft, which carries the cable pulley. The usual manner of construction of frame, for supporting the wheel and floor of penstock is shown in Fig. 1, and rests on a foundation, just high enough above the water, to give a free flow from the draft tube of the wheel. The size of the penstock, should be such that, the current is only that caused by the suction of the wheel. In this case for the Biddon, the cross-section would be 6' x 14", and for the Leffel, 5'-8" by 11'-8" or if a Mining Leffel, 5'-5" by 10'-10"
The size of cable must be calculated to transmit the power required at the greatest strain, also the length of cable, the size of wheels to agree to the cable.

In this case of 91.5 H.P., the power transmitted = 3019500 ft. pounds, at a velocity of 62 ft. per second or 3769.92 per minute, can be given by a 10 foot pulley, at 120 revolutions per minute, thus causing a net tension on cable of 801 foot pounds.

The size of cable to transmit this amount, of iron and of 42 wires, and allowing a tensile strength of 8000 pounds, is .8166 inches and diameter of wire, is .0798 inches, having a weight of .9536 pounds per foot of length. The length depends on the ordinate of lower depression and distance between shafts of pulleys, which in this case is 500 ft. Thus the distance between points of contact on pulleys, using the lower side, as the driving side, is
eqn: 500 + 21/5 sine of angle of contact), which is 8° - 43½', from which we obtain the total length of cable equal to the train as 1740.57 ft. and from this the ordinate of depression equal to 19.43 ft., and length of cable between points of contact = 508.28 ft. For driving side which has a tension of 1885 pounds, and stack side of 885 pounds, making an angle of 16° - 7½' and a depression of 38.7 ft. The whole length of rope including that in contact with the pulleys is 1055.78 ft.

The pitch of the devil gears that transmit the power from the wheel shaft to pulley shaft is 2.7 in, and size of pulley shaft 6 3/8 inches and of wheel 5 7/8 in.

At the mill end the power may be taken directly from pulley shaft, by belt, which for the Burr are 12” inches wide, running on 2 4 inch pulleys.
In the second case by means of a race, the power is taken off from the wheel near or under the mill, and by means of a race greater fall and of course less water used, which causes to be determined, 1. The length of the race, 2. The fall per foot in race, 3. The available head of water, 4. The volume of water needed and also the selection of a wheel to utilize the water to best advantage.

Of the 1st much depends on the location, which often restricts the length within a certain limit, which we will assume at 4000 ft, as a limited case, and find the cross-section necessary to deliver the water and the fall. The volume of water must depend on the cross-section and velocity. Then if we assume the relative proportions of the section, such as the depth = 1/4 of the width of bottom and sides to slope at an angle of 45°, we will have, by adding 1/2 of wind surface to wetted
perimeter and dividing by area of section, an hydraulic mean of 3.38, as shown in Fig 2.

The velocity given the current, as stated by some authorities from 60 ft to 100 ft per. min., of which the average of 88 ft or 1 mile per hour will be shown to be much too great, a velocity = 1.4 ft per second, and this used in the formulae, we will have the fall equal to the sum of the two falls due to the falling of the water, plus that due to the friction of the current in the channel, which

\[ H = \left(1 + \frac{2w}{v}ight)^{\frac{a}{2g}} \]

in which \( w \) is that coefficient due to friction. The result of using 1.4 for \( v \) and \( w = 0.0141 \), for sections in earth soon is a fall of .0305' per foot, which would destroy all the fall gained by a race. Let 0.33 foot per second be taken for \( v \), then we get a fall of .00173' per foot as a reasonable amount. The available fall being the difference in fall between the race and river or outlet of race, we must know the fall per foot.
or mile of stream which is found by the usual methods of leveling, but in this case we may assume a fall of 5 inch per 100, or 13 3/8 ft per mile, or 11 ft fall in 4000, which added to that of the dam at the head of the race, = 21 ft, which after deducting the fall of the race 4000 x 0.00173 = 6.92, we have 14.08 ft. Then allowing 8 as the efficiency, we must have water power of 110 H.P., from which the volume of water = \( \frac{110 \times 33000}{62.5 \times 14.08} \) = 4825 cu. ft per minute, or 80 7/8 cu. ft. per second, which divided by the velocity per second, equal area of cross-section = 243.73 sq. ft = 5 \( x^2 \) when \( x \) = the depth and the other dimensions as stated above, or \( x = 6.982 \) feet.

width of follow = 27.928 ft, and wind surface = 41892 ft.

This would be very large and if the length could at all be increased, the expense of construction would be diminished. The wind surface is very seldom over 30 ft. which, keeping the same Hayman, \( x = 5 \) ft with a section of 12.5 ft, which at 33 ft. velocity, delivers 25000 cu. ft. per min.
The volume being given, the case in which the length of the race is to be found which will give fall enough to produce the power, then using the same efficiency as before, to develop 110 H.P. the fall equals \( \frac{110 \times 33000}{62.5 \times 2500} = 23.232 \) ft. As we have the fall per foot of both race and stream, and amount of available fall required, the only thing to find is the level distance of the race from the head gate to fore bay to give this fall.

Let equal the level distance equal \( x \), \( a = \) available fall, \( y = \) \( a \)
\( h = \) fall per foot of stream
\( h_r = \) fall per foot of race, \( y = \) fall of whole length of race, then \( x = \frac{a}{h_r} \) and \( y = \frac{a h}{h_r} \), and from \( x \) we obtain the level distance \( x = \frac{23.232}{0.3123 - 0.00173} = \frac{23.232}{0.2982} = 78.70 \) ft.

The difference in volume of earth to be removed assuming the amount used in banking equal to that excavated, is 1 cu. yd. in favor of the
Case III in which steam is used as power. As when a year of drought, the mill would be useless unless some other power was provided, and to save the expense of both kinds of power, many prefer the use of steam altogether.

In the case of steam power for flouring mills, it has been proven that a very uniform motion is required, to produce a uniform quality of flour. Then we would select a good automatic engine, and if water is plenty with much expense, a condensing engine. As the power required is 88 H.P., we may secure still more uniform motion by using 2 engines of 44 H.P. each with cranks at 90° apart. As the power of any engine depends on the pressure, we must take some pressure most commonly used, say 90 lbs. per sq. in. with a cut-off, say 1/2, with revolutions of 105 per min. which is the common speed of mill engines.
The mean pressure per square inch must be found before the dimensions of the engine can be found, which for 90\(^{\circ}\) per inch boiler or initial pressure \(= 90\left(1 + \frac{\log e}{2}\right)\) = 76.19\(\#\), then deducting for loss of heat and back pressure, about 90\(\#\) is all that can be counted on.

If we take the stroke as \(\frac{3}{4}\) the diameter of cylinder we have for single cylinder \(S = \sqrt[3]{\frac{88 \times 2 \times 33000 \times 12}{70 \times 3 \times 7867 \times 210}}\) = 12.625\(\)\(\)\, and a working area of 121.78 in. by 18\(\frac{1}{2}\)\(\) in.

And for 2, 440 hp engines, with the same ratio of stroke and diameter of cylinder we have \(S = \sqrt[3]{\frac{344 \times 2 \times 33000 \times 12}{70 \times 3 \times 7867 \times 210}}\) = 10.02\(\), this giving a cylinder 10.02\(\) in. by 15.03\(\) in.

The shaft on which the double engines work with the fly wheel between the cranks is 53\(\frac{1}{8}\) in. diameter.

The size of steam pipe for large cylinder, not allowing over 100 ft per sec. for steam from boiler, is 2.96 in. diameter, and for each of the small cylinders a pipe 2.09 in. of free passage for steam.
The water necessary for Steam, with 70° as the effective pressure, will be the volume of the cylinder, into the number of strokes per minute, into the pressure, which gives, using the weight of Steam per cu. ft. at 70° as .1647#, equals 47,472 # of water per minute.

Size of belt to transmit 88 H.P. from fly wheel 10 ft. in diameter, with a rim velocity of 54.97 ft per sec, and thickness of belt 1/4 inch, gives 11 in as the safe size.