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.. on ..

Hydraulic Mining

.. by ..

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PRACTICAL NOTES

—ON—

HYDRAULIC MINING.

—BY—

GEO. H. EVANS, M. E.

SECOND EDITION

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Practical Notes on Hydraulic Mining.

The following article was written for the MINING AND SCIENTIFIC PRESS by GEORGE H. EVANS, C. E., M. E., General Manager Cons. G. Mines of Cal., Ld., Oroville, Cal.

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Of the various kinds of mining there are none more interesting than hydraulic mining, and in connection with it there are innumerable points on which a mine manager or superintendent should be thoroughly posted, some of the most important being as follows:

First—Water facilities and the different methods of both roughly and accurately measuring the average amount of water available the season through for working the claim or claims.

Second—The nature of country through which the ditches, flumes and pipe lines have to be constructed in order to carry water for mining purposes, and the different grades suitable for such purpose. This is most important. The writer knows instances where ditches have been constructed for long distances with too heavy a grade, and consequently the water when turned in acquired too much velocity and completely washed away the greater portion of the ditch. On the other hand, by the employment of cheap or incompetent men, ditches have been constructed with too little grade, and there are cases where men have constructed ditches with the fall in the wrong direction.

Third—The quantity of water different size pipes will carry or that can be discharged through pipes and nozzles under various heads.

Fourth—The friction caused by using pipes of too small diameter, and the loss of head due to this; also loss of head due to bends of short radius, and angles of all kinds in pipe lines.

Fifth—A full and complete practical knowledge of the different motors used in connection with hydraulic mining, and all particulars relative to the efficiency of the various kinds of water wheels, etc.

Sixth—The strength of materials, and especially of chains, hemp, manilla and wire ropes.

Seventh—The bursting and working strain of iron and steel pipes of different diameters, and the strength of iron and steel plates, single and double-riveted, with punched and drilled holes.

Eighth—Methods of economically treating alluvial deposits in large quantities, when there is not sufficient grade for ground sluices, and yet enough water for piping, or in cases where, owing to the debris law, it is necessary to impound the tailings.

Water Facilities.—This is one of the most important matters in connection with hydraulic mining, and great care should be taken in arriving at the average quantity of water available all the year round, or during the entire season, so that sluicing operations can be carried on continuously. In order to do this it is necessary to correctly measure the creeks, or streams, at different points, to fairly approximate the average supply of water that can safely be relied upon from such source, not forgetting that, according to the location, allowance must be made for loss due to evaporation and leakage, which in some cases reaches as high as 20 per cent.

A very simple method of measuring the quantity of water flowing in a stream is as follows: Measure the depth of water in feet, at from six to twelve points across the stream at equal distances; do this in two or three places along a fairly straight course; add all depths together, and divide the result by the number of measurements taken; this will give the average depth of the stream, and such depth multiplied by the average width in feet will give its cross section, or area in square feet, which, multiplied by the velocity of water in feet per minute, will give the number of cubic feet flowing per minute in the stream.

To find the velocity, a very simple way is to step or measure off 120 feet along the bank, and in order to allow for the surface of the water flowing faster than the bottom or sides, and thus obtain the mean velocity, call the measurement 100 feet, and at the commencement of this 100 feet throw into the middle of the stream several pieces of paper or wood at intervals, and note the time it takes each one of them to reach the end of the measured line; then divide the total time in minutes taken by all the floats by the number of floats, and the result will be the average time taken for each float to make the trip; divide the average time in minutes by the distance in feet, viz, 100, and the result will be the velocity in feet per minute, and this multiplied by the area in square feet will give the number of cubic feet flowing per minute; or, if the answer be required in miners' inches, multiply the cubic feet per minute by 2 and divide by 3.

Another simple method for small streams is to put a small dam across the stream and back up the water sufficiently deep to prevent any considerable velocity, and on top of the dam place a thin board with a notch cut out of it wide enough, by estimation, to carry the whole of the water with a moderate depth of overflow, and the following calculation will give the number of gallons discharged per minute, and this result divided by 11.25 will convert the gallons per minute to miners' inches. For example: A weir with 4 inches overflowing the length of a notch which is 6 feet, or 72 inches, wide, the number of gallons per minute would be found by the following formula:

$$G = d \times \sqrt{d} \times 1 \times 2.67.$$

Where G represents gallons per minute, d = depth of overflow in inches, and 1 = length of notch in inches. In this case G will be found by multiplying 4 by the square root of 4, and by the length of notch or 72 inches, and then by 2.67, making the quantity of water in gallons per minute = 1538, and this divided by 11.25 = 136.71 miners' inches.

There are many other and more correct methods of measuring the flow of water in channels and streams, but I have illustrated the two most simple, in order that any person of ordinary intelligence could easily determine the quantity of water running in open streams without the aid of difficult formulæ.

Nature of Country for Grades, etc.—The nature of the country through which it is intended to carry ditches or flumes must be carefully considered in order to establish the correct grade, upon which, of course, depends the velocity, or, more plainly speaking, the destroying force of the water, and in locating the sites for water races the following points should be carefully considered:

First—Ascertain by careful aneroid readings the lowest point in the stream, creek or other source of water supply that will allow sufficient grade for conveying the water to a point suitable for working the claim or claims, and, if the maximum supply obtainable is less than required for advantageous working, then favorable sites must be located for the construction of storage dams or reservoirs capable of storing sufficient to keep up the required supply.

Second—Should the lowest point in the stream, creek or other source of water supply contain more than enough to meet the requirements of the mine or mines, in driest season, then the locator should select the greatest elevation that the country through which the ditch has to be constructed, and the water supply available at driest season will allow, so that the ditch when completed, will command the largest area of mining ground with the maximum head or pressure. This is an important point, as in many instances ditches of considerable length have been constructed and much money wasted in the endeavor to command large tracts of mining ground, and when such ditches have been completed it was found that they tapped the source of supply at such an elevation that it was impossible, except in the wet season, to get sufficient water to wash with.

Third—All timber work along the line of ditch should be curtailed as much as possible, and when fluming cannot be avoided the use of iron or steel should be carefully considered for ditches of a permanent nature, as in many instances the first cost is not very much greater, but the durability and the great saving in cost of maintaining more than compensates the owner of the ditch.

When timber work is found necessary, care should be taken in securing the most durable kinds, and after flumes and supports are finished they should be thoroughly coated with a hot mixture of asphaltum, or painted with a good mineral paint, while all foundations for trestles, etc., should be placed in such a manner that they can be easily removed and renewed at all times.

Fourth—The line of the ditch should be carefully laid out so that it will be as short as possible, with, of course, due regard to economy, etc., and in coming around long points, or in places where sidelings are very steep and composed of loose rock, tunneling through such spurs should be carefully considered, or when it is proved by boring that such tunnels can be constructed to stand without timbering, they should always be preferred to long ditches around such spurs or points, unless the ground for ditching is exceedingly good and the extra distance quite short.

Fifth—Along the line of ditch all springs or water courses should be connected by means of short flumes or ditches, so that the loss due to leaks and evaporation from the main supply will be entirely or partly made up. It is also absolutely necessary for the safety of the ditch that by-washes or water gates be constructed for the purpose of taking care of any sudden increase of water from heavy rains or melting snow along the line of ditch.

These by-washes must be kept in condition to, at all times, divert any water above the usual height over the gates or through the openings in the sides of the race, and in locating the points for by-washes, or safety outlets, it is necessary to carefully consider what becomes of the surplus water, as in many cases owners of ditches have rendered themselves liable for heavy damages.

Sixth—At the different points along the line of race when fluming has to be resorted to, allowance should be made for an increase of grade, in order that the flume can be constructed of much smaller dimensions than the ditch and yet carry all the water required.

While on this subject, it is necessary to remember that the least amount of friction in ditches and flumes is developed when the least wetted border, or perimeter, is obtained, and to do this the width of the bottom must be from $1\frac{3}{4}$ to $2\frac{1}{4}$ times the depth of the sides. These two points, if carefully studied, will save ditch owners large sums of money in both lumber and construction accounts.

The following is a simple rule for finding the height of the sides of a ditch or flume when area of same is known, and it is desirable to follow the rule just mentioned above:

When width is to be $2\frac{1}{4}$ times the height of the sides, multiply the area in square inches by 4 and divide the result by 9, then take the square root of the product and that will be the height of the sides.

When the width is to be $1\frac{3}{4}$ times the height of the sides, multiply the area in square inches by 4 and divide by 7, then extract the square root of the product and the answer will be the height of the sides.

Seventh—It is agreed by the best authorities that, when constructing tunnels, where they will stand without timbers, the best form of roof is the Gothic arch, as it stands better than the circular or any other kind of roof and is not so liable to flake. In fact, tunnels constructed with circular roof, except in very

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tight ground, have been noticed to flake off until they assume nearly the section of the Gothic arch.

Grades, Capacity, etc.—In connection with the grades and various shapes of water races, the following points require particular attention:

First—As before mentioned, the character of the ground through which the ditch is constructed will have a great bearing on the grade required, but, as a guide, it will be well to remember that practical results have demonstrated that in ordinary ground, the water should travel at the rate of from 180 to 200 feet per minute. Then the grade will be determined by the dimensions of the ditch, and its intended carrying capacity.

Second—Races in which the water flows at too high a velocity through ground of a porous nature will never be free from leakage, owing to the fact that the velocity of the water will not allow any sediment to settle, and in all ditches properly constructed the sediment traveling with the water at a moderate velocity is always relied upon to entirely tighten up all portions of the ditch cut through ground of a porous nature; and, again, if the velocity is too high, it will scour holes in the bottom and sides of the ditch when constructed in sandy or clay soils. By neglecting these points, the cost of maintaining will, unnecessarily, be increased.

Third—To establish the grade of a ditch when the velocity and area of same is known, one of the simplest methods of calculation is as follows: Multiply the velocity in feet per minute by the wetted perimeter, in feet, and divide the result by twice the area in square feet, and the product will be the total fall in feet required to each mile. To reduce this fall to inches, for each 12 feet in length multiply by .027. Example: Suppose we have a ditch to construct for a distance of six miles, to deliver 600 miners' inches, or 900 cubic feet, per minute, or 15 cubic feet per second.

To commence with, we are told that in ordinary ground the velocity should be about 3 feet per second, or 180 feet per minute. Now, knowing the velocity and the distance, the area required is obtained by dividing the discharge in cubic feet per second, viz, 15 by the velocity in feet per second, viz, 3, the result shows that an area of 5 square feet will discharge the quantity of water required, and, in order to have the ditch or flume constructed with least amount of friction, the width of the bottom must be from $1\frac{3}{4}$ to $2\frac{1}{4}$ times the height of the sides, and in this instance the section of the ditch or flume would be 3 feet in bottom, with 1-foot-8-inch sides.

Having now the velocity and area, we next find the wetted border or perimeter—in other words, the length—of so much of the bottom and sides as is wetted by the water; for instance, if a flume or ditch is 30 inches wide and 12 inches deep, its wetted perimeter, when full, is $30+12+12=54$ inches, or 4.5 feet, and the same ditch or flume, if empty, has no wetted perimeter at all. Now, fully understanding the meaning of wetted perimeter, we find that the ditch or flume in our example has a wetted perimeter = to 3 + 1 ft. 8 in. + 1 ft. 8 in. = 6 feet 4 inches, which, for convenience in calculating, we reduce to decimals, and have 6.33. We now have the following results, viz: Velocity, 3 feet per second; discharge, 15 cubic feet per second; wetted perimeter, 6.33 feet.

To find the grade, we first multiply the velocity in feet per second by itself, and in this instance the result is $3\times3=9$, which has to be multiplied by the wetted perimeter in feet, 6.33; therefore, $9\times6.33=56.97$, this total has to be divided by twice the area in square feet, viz, $5\times2=10$; therefore, $56.97\div10=5.69$, the total fall in feet per mile. This result is practically correct for flumes and ditches of short length in good ground, but allowance must be made according to the roughness and the contour of the ditch.

A more difficult, but correct formula, which has been obtained from actual experiments made in connection with ditches constructed in ordinary ground, with the usual winding course and short bends, is as follows: Velocity in feet per second = 6 times the square root of 2×G×R×S. Where G is the acceleration of gravity, or 32.2, R is the hydraulic radius, which is found by dividing the sectional area of the ditch in feet by the wetted perimeter or border in feet, and S, the sine of inclination, or the total fall or grade in feet, divided by the total length in feet.

If the ditch is constructed through rough country and the bottom or sides of same present rough surfaces to the water, then 5 times the square root of 2 g r s will give the mean velocity in feet per second, and the velocity multiplied by the area in square feet will give the discharge in cubic feet per second, which result multiplied by 40 will give the discharge in miners' inches.

Example: To find the velocity and then the discharge in cubic feet per second, and miners' inches from a ditch with a fairly straight course, and constructed through good ground, having the following dimensions and fall, viz, section of ditch, 6×3 feet; fall or gradient, 8 feet to the mile; length of ditch, 15 miles.

We first proceed by working out R, which we are told is the sectional area of ditch in feet divided by the wetted perimeter in feet, and in this instance it is $\frac{6 \times 3}{6+3+3} = \frac{18}{12} = 1.5$.

S, or sine inclination, will be found by dividing the fall by the length, or $\frac{8}{5280} = .001515$.

Since twice G (the acceleration of gravity) is 2× 32.2, or 64.4, we have G, R and S, and our formula stands as follows:

Six times the square root of 64.4×1.5×.001515, and the easiest method of calculation in this case is by logarithms, as follows:

Log's.

$$
\begin{array}{rr}
2g = 2\times32.2 \text{ or } 64.4 = & 1.8089 \\
R = 1.5 = & 0.1761 \\
S = .001515 = & 7.1804 \\
\text{SQUARE ROOT} = 2 \mid & 19.1654 \\
 & 9.5827 \\
\times 6 & 0.7782 \\
 & 10.3609 = 2.29
\end{array}
$$

Answer 2.29 feet per second velocity, and this multiplied by the area, 18 square feet=discharge, or 41.22 cubic feet per second, or 41.22×40=1648.80 miners' inches.

The above formula is also correct for flumes with sawed boards, and battens over the joints inside the boxes, but instead of using 6 or 5 as a co-efficient the formula must read $8\sqrt{2grs}$ for velocity in feet per second, and $8\sqrt{2grs} \times$ area for discharge in cubic feet per second.

I might add here, that these last formulæ have been practically tested by several authorities, and especially by the Government engineers of New Zealand, to whom I believe belongs the credit of arriving at the exact co-efficients shown above.

As before mentioned, it is of great importance that a safe allowance should be made for loss due to leakage and evaporation, more especially when the line of ditch does not pick up any small creeks or springs on its course, and it is agreed by the best authorities that a suitable allowance may be calculated by the following formula:

$$M \times \frac{\text{Sectional area of ditch in feet}}{\text{Mean velocity in feet per second} \times 5280}$$

Equals the loss in cubic feet per second per mile, where M is a co-efficient varying from 3 to 20, according to the climatic conditions of the country through which the ditch is constructed.

In New Zealand, on the west coast, and, in fact, all through the middle island, good results have been obtained by using 3 for a multiplier, but again in the North Island, where the climate more resembles this country and the loss due to evaporation is heavy, it is necessary to often use as high as 20 for M, in order to obtain satisfactory results.

Fourth—When owing to weak banks it is necessary to build walls on the lower side of a ditch, the ground should be removed to obtain a solid foundation, and two walls—an outer and an inner—should be built up, with space enough between to allow a good puddle clay to be rammed in; such a wall, if properly constructed, will never give further trouble.

Fifth—All earth, trees, roots, etc., must be moved quite clear of the lower side of the ditch, with the exception of just sufficient to make a track. Unless all waste materials are moved to such a distance that they will not become a heavy drag on the lower side of the ditch, slides will be frequent and costly.

Sixth—At the entrance of tunnels, commencement of flumes, and at other points where the velocity of the water is considerably retarded, the effect of water changing its form at such places is an important point, and must never be neglected; in fact, all calculations referring to the flow of water in ditches, etc., the mean velocity must be determined as accurately as possible.

Before going further, many readers will appreciate the following simple method of arriving at the areas or cross-sections of the different forms of ditches, sluices and flumes, which may be calculated as follows, viz:

To find the area of a section of a flume or ditch with straight sides, multiply the width of bottom (in inches) by height of sides (in inches), the product will be the area in square inches, and this divided by 144 will give area in square feet.

Example: What is the area of a flume or ditch 28 inches wide and 18 inches deep? Answer: $28 \times 18 =$ 504 sq. in., which, divided by 144, $= 3\frac{1}{2}$ sq. ft.

To find the area of a flume or ditch with sloping sides, add the width at top and bottom (in inches) together and divide the result by 2. This answer will be the area in square inches, which, divided by 144, will give the area in square feet.

Example: What is the area of a cross section of a ditch 48 inches wide at top and 26 inches wide at the bottom, with a depth of 24 inches? Answer: $48 + 26 = 74$, which, $\times$ 24, $= 1776$, and this divided by 2 $= 888$ square inches $\div 144 = 6.16$ square feet.

To find the square feet of the cross section of a ditch or flume with sides sloping to a point at the bottom, multiply the width (in inches) by half the depth (in inches) and the answer will be area in square inches, which, divided by 144, gives area in square feet.

Example: What is the area of a flume or ditch 70 inches wide and sloping to a point at the bottom, with a depth of 36 inches? Answer: 70×18, or half the depth in inches, $= 1260$ inches, or divided by 144 $= 8.75$ square feet.

Carrying Capacity of Pipes, Discharge of Nozzles, etc.—It is hardly possible to point out any portions of a hydraulic plant that are of more importance than pipes and nozzles, and in out of the way places miners have great difficulty in finding out the correct sizes of pipes, and particularly the capacity of same, especially with regard to quantities of water discharged through pipes and nozzles of different diameters, there being innumerable instances at the present day where miners do not know the pressure of water is only as the head, without any regard (neglecting friction and bends) to the size of pipes. For example: A pipe line composed of 6-inch pipe, and another line of 40-inch pipe, with same fall or head, will both give the same pressure. It was only a short time since that I was asked by a miner of some experience if he could not double his pressure by doubling the diameter of his pipe.

As an illustration, this fact is easily demonstrated by attaching the same size and kind of faucet to two tanks, one, say, of 3 feet diameter and 3 feet deep, and the other as large as convenient, say 6 feet in diameter and 3 feet deep. Fill both with water to same depth, then, after placing buckets of equal capacity under each faucet, turn both on at the same time. To the surprise of any person not acquainted with hydraulics it will be seen that, although the larger tank contains four times more water than the smaller one, both buckets will be filled at the same time.

It is well to thoroughly understand the principle of hydrostatics in building storage dams and reservoirs, remembering that there is the same pressure on the bank of a reservoir with water 3 feet deep and extending back for a distance of 10 feet, as there would be if the water dammed back 10 miles, so long as the depth remained the same.

In reference to nozzles, they require great care in construction so as to be of correct form, in order that the water leaving them will be in a solid stream, instead of scattering and thus losing its power, which is the case with nozzles of improper construction. In order to get the best effect it is absolutely necessary that the head of the pipe conveying the water should be at least 3 or 4 feet under water in order to prevent any air getting into the pipe, which also causes the water to scatter when leaving the nozzle.

All pipe lines should be laid as straight as possible, or with curves having as large a radius as can be obtained, and it must be remembered that new pipes well coated will carry more water than old pipes that have been rusted inside; therefore, allowance must be made accordingly. It is good practice to allow one-sixth the diameter of pipes under 6 inches, and 1 inch on all diameters over 6 inches.

The first thing necessary for the miner to do is to ascertain the fall available for the pipe line and its length in feet. Knowing this and the quantity of water he is going to use it is easy to determine the diameter of the pipe, always bearing in mind that in order to secure efficiency and economy in construction water should flow in the pipe at a velocity of not more than 3 feet per second. A few of the simple methods of determining the discharge of pipes are as follows:

First—To obtain the velocity, first multiply the diameter in feet by the effective head in feet and divide the result by the length of the line in feet, then take the square root of the product and multiply by 50; this will give the velocity in feet per second, and the velocity multiplied by the area of the pipe in square feet will give the quantity of water discharged in cubic feet per second, which, multiplied by 40, will give the number of miners' inches.

Second—To find the velocity in feet per minute, multiply the number of cubic feet of water discharged per minute by 144 and divide the product by the area of the pipe in inches. For example: An 11-inch pipe discharging 150 cubic feet of water per minute, the velocity would be $150 \times 144 \div 95.03$ (the area of pipe in inches) or 227.6 feet per minute, or $227.6 \times \frac{2}{3} = 151.7$ miners' inches.

Third—In all cases the pipe will require a funnel or bell-shaped entrance, and an additional head to put the water in train in addition to correct dimensions for overcoming friction, assuming, of course, the total head available be required. To obtain the additional head commonly termed the velocity head, a simple method is to square the velocity in feet per second and divide by 64.4 and then divide that product by 0.70. The answer will be the extra head in feet required.

We are told by some authorities that in cases where the length of the pipe exceeds 1000 diameters the head due to velocity and even bends may be neglected, but in practice I find it better to err on the right side, and in no case neglect working out the heads due to those losses and including them in all estimates.

Another simple and approximate method of finding the velocity is by multiplying the number of miners' inches discharged by 11 and divide the product by three times the square of the diameter of the pipe. For example: A 10-inch pipe discharging 400 miners' inches; the velocity will be $400 \times 11 = 4400$, divided by three times the square of the diameter, or $3 \times 100 = 300$. Answer, 14.6 feet per second. By means of the same formula the number of miners' inches discharged through a pipe of a known diameter and velocity will be found as follows: Multiply the velocity in feet per second by 3 and the product by the square of the diameter, then divide by 11 and the result will be the discharge in miners' inches.

For example: A pipe with a diameter of 20 inches, discharging water at a velocity of 3 feet per second, the number of miners' inches discharged will be as follows: $3 \times 3 \times 400$ (the square of the diameter) or $3600 \div 11 = 327$ miners' inches.

Fourth—A more complicated but accurate formula for determining the velocity per second of water in pipes is: 140 times the square root of $R \times S$ minus 11 times the cube root of $R \times S$—where R is the hydraulic radius, which is found by dividing the diameter of pipe in feet by 4, and S the sine of inclination, which is found by dividing the total fall in feet by length of pipe line in feet.

This formula has been tested in a thoroughly practical manner by Mr. Gordon, the Government Engineer in New Zealand, and he found it could not be relied upon when calculating high velocities, as it gave too great a discharge, but with low velocities and small diameters of pipe, it was deemed fairly accurate.

Fifth—Another set of formulæ given in "Practical Hydraulics," by Thomas Box, are as follows:

Where d = diameter of pipe in inches. L = length in yards. H = head in feet. G = gallons discharged per minute.

$$d = \left(\frac{G^2 \times L}{H}\right)^{1/5} \div 3 \qquad L = \frac{(3d)^5 \times H}{G^2}$$

$$G = \left(\frac{(3d)^5 \times H}{L}\right)^{\frac{1}{2}} \qquad H = \frac{G^2 \times L}{(3d)^5}$$

Example 1. Find the diameter of pipe required to discharge 300 gallons per minute with 80 feet head; length of pipe, 200 yards:

$$d = \left(\frac{300^2 \times 200}{80}\right)^{1/5} \div 3.$$

Log's.

$$\begin{aligned}
300 &= 2.4771 \\
&\quad\ \underline{\quad\quad 2} \\
300^2 &= 4.9542 \\
\times\ 200 &= \underline{2.3010} \\
&\quad\ 7.2552 \\
\div 80 &= \underline{1.9031} \\
5\ |\ &\ \underline{5.3521} \\
\text{Fifth root} &= 1.0704 \\
\div 3 &= \underline{0.4771} \\
.5933 &= 3.92 \text{ inches diameter.}
\end{aligned}$$

Example 2. Find the number of gallons discharged by a pipe 10 inches in diameter, 900 yards in length, with a head of 50 feet:

$$G = \left(\frac{(3 \times 10)^5 \times 50}{900}\right)^{\frac{1}{2}}$$

Log's.

$$\begin{aligned}
3 \times 10 = 30 &= 1.4771 \\
&\quad\ \underline{\quad\quad 5} \\
\text{Fifth power} &= 7.3855 \\
\times\ 50 &= \underline{1.6990} \\
&\quad\ 9.0845 \\
\div\ 900 &= \underline{2.9542} \\
2\ |\ &\ \underline{6.1303}
\end{aligned}$$

Square root = 3.0651 = 1162 gallons per minute.

Example 3. Find the head necessary to discharge 120 gallons per minute through a 6-inch pipe 500 yards long:

$$H = \frac{120^2 \times 500}{(3 \times 6)^5}$$

$$\begin{aligned} & \textit{Log's.} \\ 120 &= 2.0792 \\ & \underline{\quad\quad 2} \\ 120^2 &= 4.1584 \\ \times 500 &= \underline{2.6990} \\ \textit{Log.} \quad & 6.8574 \\ 3 \times 6 = 18 = 1.2553 \times 5 &= \underline{6.2765} \\ & .5809 = 3.81 \text{ feet.} \end{aligned}$$

In all these examples care must be taken, and more especially in short pipe lines, to allow for loss of head due to velocity at entry, also for friction of the water against the sides of the pipe.

Example 4. Given diameter of pipe in inches and velocity in feet per minute to find discharge in cubic feet or gallons per minute. $Q = 0.32725 \times d^2 \times V =$ cubic feet per minute, and cubic feet per minute multiplied by $7.48 =$ gallons per minute.

Sixth—In constructing a pipe line, care must be taken to place air valves at all high places, blow-off valves at all low places in the line, and, when the line is subject to extreme heat and cold, it is absolutely necessary to provide at least one good expansion joint each half mile.

Another excellent precaution is to place near the lower end of the line a safety valve, either the spring or ordinary lever kind, and set it at a pressure slightly above the maximum due to the head, then when gates are closed too quickly by careless attendants the valve will relieve the shock, instead of allowing the whole line to be strained.

All gates should have outside screws, and the threads on them fine, so that it will be impossible to open or shut them too quickly. The careless opening and shutting of gates has wrecked many a good line.

It has always been my rule to place tell-tale gauges in the main lines a few feet behind a main gate, and from such a gauge one can easily see whether the water was turned on or off slowly, and it should be an invariable rule to discharge any man that handles a gate in a careless manner, after once being warned by those in charge of the works.

Seventh—With reference to the numerous devices for joining pipe, I have no hesitation in recommending that all pipes near and around the workings of the claim should be furnished with angle iron flanges. In this country they are certainly the exception to the rule, but, if once used, no other kind of connection will be tolerated.

It is often necessary to find the quantity of water that will be discharged through a sluice gate with side walls, and the number of gallons per minute that will flow through under certain heads may be found by the following easy formula:

In determining the head of water care must be taken to measure from the center of the opening in sluice gate to surface.

$$G = 8.025 \times \sqrt{H} \times .6 \times A \times 6.23 \times 60.$$

$$H = \left\{ \frac{\left(\frac{G}{6.23 \times 60} \div A \right) \div .6}{8.025} \right\}^2$$

Where G = gallons per minute, H = head or depth of water from surface to center of sluice opening, A = area of opening.

Example: How many gallons per minute will be discharged from a reservoir through a sluice gate with side walls, when the depth of water above the center of the opening is 7 feet and the opening is 3 feet wide and 1 foot high?

Answer: $G = 8.025 \times \sqrt{H} \times .6 \times A \times 6.23 \times 60 =$

$8.025 \times \underset{H}{\sqrt{7}} \times .6 \times \underset{A}{3 \text{ ft.}} \times 6.23 \times 60 = 14281.785$ gallons per minute. Which $\div$ 11.25 = 1269.49 miners' inches.

Again, if it is required to find the head or height of water above center of opening in a sluice gate necessary to discharge 14,300 gallons per minute through an opening 3 feet by 1 foot, we proceed as follows:

$$H = \left\{ \frac{\left(\frac{G}{6.23 \times 60} \div A\right)}{8.025} \div .6 \right\}^2 \text{ and in this instance}$$

$$H = \left\{ \frac{\left(\frac{14300}{6.23 \times 60} \div 3\right)}{8.025} \div .6 \right\}^2 =$$

$$\left\{ \frac{\left(\frac{14300}{373.80} \div 3\right)}{8.025} \div .6 \right\}^2 = \left(\frac{38.25 \div 3}{8.025} \div .6\right)^2 =$$

$$\left(\frac{21.25}{8.025}\right)^2 = 2.64^2 \text{ or } 6.96\text{, or nearly 7-inch head.}$$

In many instances a sluice valve is used instead of a gate, and when the pipe attached to the valves is comparatively short, say of a length not exceeding more than three diameters, the following formula may be used:

Where G = gallons per minute, H = head in feet or height of water above the center of the valve opening, d = diameter of valve opening in inches.

Example 1. How many gallons per minute will a sluice valve 10 inches in diameter discharge when the height of water is 3 feet above the center of valve opening?

Answer: $G = \sqrt{H} \times d^2 \times 10 = \sqrt{3} \times 10^2 = 10 =$ 1732 gallons per minute, or 1732 $\div$ 11.25 = 153 miners' inches.

Example 2. With same measurements find the head required to discharge 1732 gallons per minute.

Answer:

$$H = \left(\frac{G}{d^2 \times 10}\right)^2 = \left(\frac{1732}{10^2 \times 10}\right)^2 = 3 \text{ feet.}$$

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Example 3. To find diameter of valve necessary to discharge same quantity of water with same head as in examples 1 and 2.

Answer:

$$d = \sqrt{\left(\frac{G}{\sqrt{H} \times 10}\right)} = \sqrt{\frac{1732}{1.732 \times 10}} = \sqrt{100} = 10$$

inches diameter.

In connection with the last formula it must be borne in mind that if the pipe leading to the sluice valve to reservior is much longer than three diameters, allowance must be made for friction, etc.

Nozzles.—Nozzles require great care in construction so as to be of correct form, and perfectly smooth in bore, in order that the water leaving them will be in a solid stream, instead of scattering and thereby losing power, as is the case with nozzles of improper construction. In order to get the best effect from any kind of nozzle, it is absolutely necessary that the head of the supply pipe should be 3 or 4 feet under water, to avoid air getting into the pipe and causing the water to scatter when leaving the nozzle.

To determine the velocity and discharge in cubic feet per second for well-made nozzles, either of the following simple methods may be followed:

First—Multiply the square root of the hydrostatic or effective head in feet by 8.03. This will give the velocity in feet per second, and that multiplied by the area of the discharge end of the nozzle in square feet will give the discharge in cubic feet per second, which, multiplied by 40, will give the answer in miners' inches. Example: Nozzle 4 inches in diameter, discharging water under an effective head of 400 feet, find velocity and discharge. The square root of the head—or 400 feet—is 20, and 20×8.03 equals the velocity in feet per second, viz, 160.60. Area of 4-inch nozzle in square feet = .087266, and this multiplied by 160.60=14 cubic feet per second, or 14×40=560 miners' inches. The result obtained by this rule is nearly the theoretical discharge, while for ordinary practical results the actual discharge will be from 75 to 85 per cent of the answer obtained by this rule.

Second—To find the discharge in gallons per minute use the following formulæ: $G = \sqrt{h} \times d^2 \times .24$. Where $G =$ gallons discharged per minute, $h =$ hydrostatic or effective head on nozzle in feet, and $d =$ the diameter of nozzle in $\frac{1}{8}$ths of an inch.

Example: Find the discharge from a nozzle 3 inches in diameter with a head of 205 feet. The square root of the head, viz, 205 is 14.317 and the diameter in $\frac{1}{8}$ths of an inch is $3 \times 8 = 24$, which squared is 24×24, or 576. Therefore, $G = 14.317 \times 576 \times .24$ equals 1979 gallons per minute, and this divided by $11.25 = 176$ miners' inches.

For accurate results the following two rules may be followed:

First—Discharge in cubic feet per second $= \sqrt{2 \times gh} \times a \times 0.96$, where g is the acceleration of gravity in feet per second, commonly accepted as 32.2 $h =$ the hydrostatic or effective head in feet, and $a =$ the area of nozzle discharge in square feet.

Second—Discharge in cubic feet per second $= \sqrt{h} \times d_2 \times G$ where $h =$ the effective head in feet, $d =$ diameter of nozzle in $\frac{1}{8}$ths of an inch, and $c =$ a variable co-efficient from .00064 to .00066.

It is a well known fact that water issuing from a nozzle should, theoretically, attain the height of the head. For instance, a nozzle with 300 feet effective head should throw a stream a height of 300 feet, but we all know this efficiency cannot be reached in practice, owing to the resistance of the air, and other causes, but the difference has been found by experiment to vary nearly in inverse ratio to the diameter of the jet, and in "Practical Hydraulics," by Thos. Box, we have a formula for approximately calculating the loss of head for each case, which is as follows: $h' = \frac{H^2}{d} \times .0125$. Where $H =$ the effective head on the nozzle in feet, $h' =$ the difference between the head and the height of discharge column from nozzle, d = the diameter of the jet in $\frac{1}{8}$ths of an inch. Mr. Box goes on to remark that as a result of this rule each size of nozzle attains a maximum height with a certain head, and, when the head is increased beyond that point, the nozzle does not throw the stream so far, but, on the contrary, the efficiency of the nozzle greatly diminishes; a good deal owing to the fact that an excessive head, or, more plainly speaking, a head out of proportion to the diameter of the nozzle tends to scatter the issuing stream and cause it to meet with more resistance from the air than a jet of solid water issuing with a moderate head.

Adopting Mr. Box's formula we will work out the following, and see the result:

First—At what distance will a well-formed nozzle of 2-inch diameter throw a stream of water having an effective head of 200 feet?

Answer: $h' = \frac{200^2}{16} \times .0125 \text{ or } \frac{40000}{16} \times .0125 = 31.25.$

Therefore, the height the nozzle will throw is 200—31.25, or 168.75 feet.

Second—Take the same nozzle, with a head of 450 feet, and the loss will be

$$\frac{450^2}{16} \times .0125 \text{ or } \frac{202500}{16} \times .0125 = 158.20 \text{ feet.}$$

That is to say, the water will be discharged to a height of 450—158.20, or 291.80, feet, instead of 450 feet, the theoretical height minus all friction due to the head.

Friction in Pipes.—This is a most important matter to those who are connected in any way with mining or other enterprises in which water is used under pressure, and very few miners are conversant with the principles relating to friction of water in pipes, etc. Most people connected with water supply have a knowledge of the fact that when large quantities of water are discharged from pipes of small diameter the pressure is greatly reduced, but few know how to arrive at a correct method of finding out the exact loss due to friction. Were it otherwise there would not be in evidence so many palpable blunders in the construction of pipe lines used for hydraulic mining and other purposes, and in many instances success would be the rule in place of failures, many of which are due entirely to errors made in bringing the water supply to the claim, and laying down pipes of too small diameter, thus reducing the effective head or pressure (in instances I have known) to less than one-half that available with pipe lines properly proportioned.

In a previous paragraph I stated that water flowing through pipes should not exceed 3 feet per second, or 180 feet per minute, and if all users of water for hydraulic mining or power purposes had their pipes of the correct diameter to insure a velocity not exceeding that named above there would be very little trouble, as both efficiency of water and economy in construction of pipe line would be attained.

It must be understood that the friction of water in pipes increases as the square of the velocity, and also depends upon the condition of the pipes—whether they are foul and rusty, or are new, or in good condition. Even the rivet heads in a pipe line of considerable length cause a good deal of friction, and, consequently, loss of head.

There are several formulæ for determining the friction in pipes, but most all of them are difficult and too complex for ordinary miners. But Mr. William Cox has simplified Weisbach's formula, and yet gives identical results. Besides it is easy to work out. It is as follows:

$H = \frac{L}{1200d} \times (4 \times V^2 + 5\,V - 2)$ when H = friction head in feet, d = diameter of pipe in inches, L = length of pipe in feet, and v = velocity of water in feet per second.

Example: What is the loss in head of a pipe line discharging 400 miners' inches or 600 cubic feet per minute, diameter of pipe being 12 inches, and length of line 5,000 feet. We must first find the velocity in feet per second, and to do this we use a simple formula, given in remarks on velocity of water through pipes, in a previous paragraph, viz, multiply number of cubic feet of water discharged per minute by 144 and divide the product by the diameter of the pipe in inches. Therefore, in this case, velocity $= 600 \times 144 \div 113.10$ the area in inches, or 763.9 feet per minute or 12.73 feet per second.

Now knowing the velocity, diameter and length, we will find H, or friction head, as follows:

$$H = \frac{L}{1200d}(4V^2 + 5V - 2)$$

$$\frac{L}{1200d} = \frac{5000}{12 \times 1200} \times .3472$$

$4 \times 12.73^2 + 5 \times 12.73 - 2 = 709.86$ and this $\times .3472 = 246.44$ feet or friction head.

That is to say, if we had in this example a fall of 500 feet, and constructed a pipe line with pipes 12 inches in diameter, having a total length of 5,000 feet, our actual head of 500 feet would be reduced to 500—246.44 or 253.56 feet, or, putting it more plainly, we would have a pressure of 110 pounds to the square inch instead of 217 pounds, and this loss is due entirely to using pipes of too small a diameter.

Another formula I use, and which gives clear results, is as follows: $H = \frac{p1cv^2}{2ga}$

H = loss of head by friction in each 100 feet of pipe.

p = the perimeter, or circumference of the pipe in feet.

1 = 100 feet.

c = a variable co-efficient from .00406 to .01338, according to the nature of the pipe, and velocity of water.

v = velocity of water in feet per second.

g = the acceleration of gravity, or 32.2 feet.

a = the sectional area of pipe in feet.

Example: A pipe line 5000 feet in length, of newly-riveted pipe, 20 inches in diameter, with a head of 650 feet between the supply and discharge ends, and delivering 400 miners' inches of water, what is the loss of head?

First determine the velocity, which is 4.58 feet per second, then

$$H = \frac{\overset{p}{5.235} \times \overset{1}{100} \times \overset{c}{.00506} \times \overset{v^2}{20.9}}{2 \times 32.2 \times 2.181} = \frac{55.372}{140.456} =$$

.394 feet, or .394 feet loss for each 100 feet of line, and there being 5000 feet of pipe, the loss will be 5000÷100×.394, 19.70 feet, and the actual pressure head would in this case be 650 feet, less 19.70 feet frictional head, or 630.30 feet.

It is well to remember that it makes no difference whether the water is flowing up hill or down, or whether the pressure is great or small, the total friction will be materially the same, and that in wooden pipes the friction is nearly double that of iron or steel.

Loss of Head Due to Bends and Angles.—This loss is also an important one, and in many instances is great, owing to the number of sharp bends or changes in the direction of a line of pipe, carrying water for mining, or other purposes. In a pipe line there should be no bends having a radius of less than five diameters.

To calculate the loss of head due to the resistance of a right angle bend, the simplest rule is to obtain the velocity of water flowing in feet per second due to the head, and multiply the square of such velocity by .0152. For example: What is the loss of head due to the resistance of a 90-degree elbow, with water flowing at a velocity of 15 feet per second? Answer: $15^2 \times .0152$, or 3.42 feet.

Where the radius of the bend is greater, or more than 5 diameters, the head required to overcome the resistance can be found by multiplying the square of the velocity in feet per second by the number of degrees in the angle, and dividing the product by 88489.

For example: Velocity 10 feet per second, what is the resistance of a bend having an angle of 120°?

$$\text{Answer: } \frac{V^2 \times 120}{88489} = .135 \text{ feet.}$$

When the radius is less than 5 diameters, the resistance would be as per following rule: Mean velocity squared, divided by 64.4, multiplied by the square of half the angle of deflection, multiplied by 2.06 times the 4th power of the same angle.

For fairly accurate results, this formula may be simplified by multiplying the square of the velocity in feet per second by C, C being equal to the following co-efficients for the various angles, viz:

C = .000109 for angle of 10 degrees.
C = .000466 " " " 20 "
C = .001134 " " " 30 "
C = .002158 " " " 40 "
C = .003634 " " " 50 "
C = .005652 " " " 60 "
C = .008276 " " " 70 "
C = .011491 " " " 80 "
C = .015248 " " " 90 "

Hydraulic Motors, Water Wheels, etc.—There is no power easier handled or less complicated than water power, and it would take too much space to give in detail a history of all the various forms of motors, but I will endeavor to describe the particulars and efficiency of the most popular methods.

The power of a fall of water is easily calculated, and is found as follows: Multiply the number of cubic feet per minute by the weight per cubic foot, or $62\frac{1}{2}$ pounds, and the product by the fall in feet, then divide by 33,000. For example: What is the horse-power in a body of water equal to 60 cubic feet per minute, or 40 miners' inches, having a fall of 200 feet?

$$\text{Answer: } \frac{60 \times 62.5 \times 200}{33000} = 22.72 \text{ H. P.,}$$

which is the total power in the water, and from this result allowance must be made for friction, etc.

Another easy method of calculating the power is to remember that one cubic foot of water flowing per minute and falling 1 foot is equal to .0016098 horse-power, and that one miners' inch falling 1 foot is equal to .0024147 horse-power. These multipliers will give result equal to about 85 per cent of the theoretical power.

Example 1. What horse-power can be obtained from 40 cubic feet of water per minute falling 300 feet, using a motor giving about 85 per cent efficiency? Answer: $.0016098 \times 40 \times 300 = 19.31$ H. P.

Example 2. What horse-power can be obtained from 100 miners' inches of water falling 60 feet, using a motor giving about 85 per cent efficiency? Answer: $.0024147 \times 100 \times 60 = 14.48$ H. P.

The most common forms of wheels used by many miners are current or bull wheels, undershot wheels, breast wheels and overshot wheels. The efficiency of these various wheels vary about as follows: Current, or bull wheels, 20 to 50 per cent; undershot wheels, 27 to 35 per cent; breast wheels, 45 to 60 per cent; overshot wheels, 60 to 75 per cent. The next class of motors includes the various forms of turbines, of which there are numerous varieties, many of them giving as high as 85 to 87 per cent.

Approximate and simple rules for finding quantity of water, height of fall and horse-power developed at an efficiency of 75 per cent are as follows:

Quantity of water in cubic feet per minute is found by multiplying the horse-power by 706 and dividing the product by the fall in feet. Example: How much water is required with 200 feet of a fall to develop 10 horse-power, using a motor giving 75 per cent efficiency? Answer: $10 \times 706 \div 200 = 35.3$ cubic feet per minute, or about 24 miners' inches.

To find how much fall is required to generate a required horse-power, with a known quantity of water, multiply the horse-power by 706 and divide by the quantity of cubic feet per minute.

Example: Having a supply of 60 cubic feet per minute, and requiring 20 horse-power from motor giving 75 per cent efficiency, what fall is necessary? Answer: $20 \times 706 \div 60 = 235.3$ feet.

To find the horse-power in a fall of water when the fall and quantity are known, multiply the number of cubic feet per minute by the height of fall and divide by 706.

Example: Having a fall of 100 cubic feet per minute, and a fall of 75 feet, what horse-power can be obtained from a motor giving 75 per cent efficiency? Answer: $100 \times 75 \div 706 = 10.6$ H. P.

Should the motor be of a class that would give only 65 per cent efficiency, such as most overshot wheels, it is necessary to use 815 as a multiplier instead of 706.

Current or Bull Wheels.—To calculate the horse-power of a current or bull wheel, it should be understood that in all such motors the velocity of the periphery of the wheel, or, more plainly speaking, the number of feet per second the rim of the wheel is traveling, should never vary much from half the velocity of the stream, or half the velocity due to the head of water. In this class of wheels the diameter is seldom less than 6 feet, or greater than 16 feet, and the number of floats 7 to 13. The inclination of floats from radial lines should be between 20 and 30 degrees, depth of floats from 10 to 16 inches, and they should be immersed for about one-half their depth.

The horse-power of this class of motors is found by the following formula:

$H = .0028 \times V \times M \times A \times (V - M).$

$M = V \times .55.$

x = cosine of angle between the floats, multiplied by the radius minus the radius, or the distance below a horizontal line produced from under the extremity of the vertical float.

Where H = horse-power.

V = velocity of current in feet per second.

M = the mean velocity of the periphery of the wheel in feet per second.

A = the immersed area of the floats in square feet.

To obtain the angle between the floats, divide 360 (the number of degrees in a circle) by the number of floats on the wheel.

Example: A current or bull wheel, 16 feet in diameter, having 12 floats, each of which are 8 feet long, with a maximum immersion of 15 inches, what is the horse-power of the wheel, when the stream has a velocity of 7 feet per second?

Answer: Angle between floats $= 360 \div 12$ or 30 degrees. $x =$ the cosine of the angle of 30 degrees, or $.86603 \times$ by the radius or 8 feet $= 6.92824$ — the radius, 8 feet $= 1.0717$ or 12.86 inches. This is the distance that the second float will be above the horizontal line produced from under the extreme edge of the vertical float, thus showing that although the maximum immersion of any of the floats is 15 inches the adjoining floats would be 12.86 inches higher, and to get at the area of the immersed floats, the depth of the second float will be $15 - 12.86 = 2.14$ inches, and the area of the three immersed floats$= 15 + 2.14 + 2.14$ inches, or 1.606 feet multiplied by length of floats, or 8 feet$=12.84$ feet area, and the velocity being 7 feet per second, M or the mean velocity of the periphery of the wheel$=7 \times .55$ or 3.85 feet per second.

V M A VM

Now, $H = .0028 \times 8 \times 3.85 \times 12.84 \times (7 - 3.85) = 3.49$ H. P.

Undershot Wheels.—To determine the horse-power of an undershot wheel, with a rim velocity equal to about one-half, or .57 times the velocity due to the head of water, or $.57 \times \sqrt{2gh}$: Where g is the acceleration of gravity, commonly taken as 32.2, and h is the head of water in feet above the bottom of the wheel,

$$H = .00066\, Q\, h \text{ or } \frac{W \times h}{30000} \times 0.35.$$

$$Q = \frac{1511 \times H}{h}$$

Where h = head of water.

Q = quantity of water in cubic feet per minute.

W = weight of water in pounds.

H = effective horse-power.

Example: what horse-power is obtainable from an undershot wheel, with about 35 per cent efficiency, using 1500 cubic feet per minute, with a head of 2 feet? Answer: $H = .00066 \times 1500 \times 2 = 1.98$ H. P., or

$$Q = \frac{1511 \times 1.98}{2} = 1496 \text{ cubic feet per minute.}$$

Breast Wheels.—The following calculations will explain how to arrive at the effective horse-power of breast wheels:

Low breast wheels:

$$H = .00104\ Q \times h.$$

$$Q = \frac{961 \times H}{h} \text{ or, } H = \frac{W \times h}{33000} \times 0.55.$$

High breast wheels:

$$H = .00108\ Q \times h.$$

$$Q = \frac{928 \times H}{h} \text{ or, } H = \frac{W \times h}{33000} \times 0.60.$$

Where Q = quantity of water in cubic feet per minute.

h = head of water in feet.

H = effective horse-power.

W = weight of water in pounds.

Example 1. A breast wheel 16 feet in diameter, using 1500 cubic feet of water per minute, under an 8-foot head, what will be the horse-power of the wheel? Answer: $H = .00104 \times \overset{Q}{1500} \times \overset{h}{8} = 12.48$ H. P.

Example 2. How much water will be required under a 10-foot head to generate 25 horse-power with a breast wheel 21 feet in diameter? Answer:

$$Q = \frac{961 \times H}{h} = \frac{961 - 21}{10} = 2018 \text{ cubic feet per minute.}$$

In either of the above cases if the wheel takes the water above one-half its diameter, of course the power would be increased, and calculations should be made by using the formulæ given for high breast wheels. For example: A wheel 22 feet in diameter, using 500 cubic feet of water per minute, under a head of 16 feet (that is to say, the water goes into the buckets at a point 16 feet from the bottom of the wheel), what horse-power will the wheel give? Answer:

$$H = .00108 \times 500 \times 16 = 8.64 \text{ H. P.; and}$$

$$Q = \frac{928 \times 8.64}{16} = 500 \text{ cubic feet per minute.}$$

Overshot Wheels.—I think I am safe in stating that this class of wheel is more popular than any other class of rough-and-ready water motors. To find the horse-power multiply .00123 by the quantity of water in cubic feet per minute used on the wheel. Then multiply the result by the head of water in feet.

To find the quantity of water required in cubic feet per minute to generate a given horse-power with a known fall, multiply the horse-power by 815 and divide by the fall, or head, of water in feet.

Example 1. What horse-power can be obtained from an overshot wheel 12 feet in diameter, using 200 cubic feet per minute? Answer: $.00123 \times 200 \times 12 = 2.95$ H. P.

Example 2. How many cubic feet of water per minute is required to generate 20 horse-power, using an overshot wheel 22 feet in diameter? Answer: $20 \times 815 \div 22 = 741$ cubic feet.

Strength of Materials.—All those engaged in mining should thoroughly understand this important subject, and especially that branch relating to the breaking and working strain of ropes, bolts, chains, etc.

The number of accidents and fatalities arising from ignorance on this subject should be sufficient to compel all owners of mining property to insist upon superintendents and foremen being able at all times to provide ropes, bolts, chains, etc., of proper dimensions for the work required, and in this manner more work would be accomplished, and with far less risk and expense, than is generally the case.

I will first deal with wooden beams, and as a guide to further calculations the following table compiled from various authorities will be found useful. The columns marked *S*, *N*, *C*, *E* have the following interpretation:

S—Breaking load at center of beam when supported at both ends.

N—Breaking load when placed at one end and the other end fixed.

C—Safe load in center when beam is supported at both ends.

E—Safety load at end of beam when the other end is fixed.

The following table is based on a factor of safety of 7; that is to say, the safe load shown in table is only one-seventh of the calculated breaking load, and even this high factor of safety should be increased when using beams not free from knots and shake. In addition to the factor of safety freedom from knots and shake, it must also be remembered that seasoned timber resists crushing much better than green timber, in many cases twice as well, and the figures given in this table are for good samples of timber; therefore, the factor of safety (7) should be adhered to.

The following figures and results are obtained from experiments with small pieces of timber, and, therefore, considerable allowance must be made for beams that are not of a uniform texture. I have only mentioned the various kinds of American woods that are in general use. Their various breaking strength and safe loads are given in round numbers, so that in working out different problems calculations may be made as simple as possible:

Name of Wood.	*Weight in lbs. per. cu. ft.*	*Breaking load in lbs.* S.	*N.*	*Safe load in lbs.* *C.*	*E.*
Ash	45	590	147.50	84.29	21.07
Beech, white	43	440	110	62.86	15.71
Beech, red	44	570	142.50	81.43	20.36
Birch, black	45	680	170	97.14	24.29
Birch, yellow	44	440	110	62.96	15.74
Cedar, white	35	250	62.50	35.71	8.99
Fir, black	42	340	85	48.57	12.14
Hickory	50	700	175	100	25
Hickory, bt. nut	40	480	120	68.57	17.14
Larch	35	300	75	42.96	10.71
Oak, live	54	621	155.25	88.71	22.18
Oak, red	53	562	140.50	80.28	20.17
Oak, white	49	581	145.25	83	20.75
Pine, red	40	509	127.25	72.71	18.18
Pine, pitch	41	576	144	82.28	20.87
Pine, yellow	33	395	98.70	56.43	14.71
Pine, white	34	410	102.50	58.57	14.64
Pine, Virginian	38	485	121.25	69.28	17.32
Teak	56	673	168.25	96.14	26.03

The above figures represent the number of pounds required to fracture the various kinds of wood having an area or cross section of 1 square inch by 1 foot in length. In finding the strength of beams the following proportions of strength must be observed:

VALUES OF X.

(1.) With a beam fixed at one end and loaded at the other=1.

(2.) With a beam fixed at one end and the load distributed uniformly=2.

(3.) With a beam supported at both ends and loaded at the center=4.

(4.) With a beam firmly fixed at both ends and loaded at the center=6.

(5.) With a beam supported at both ends and uniformly loaded=8.

(6.) With a beam firmly fixed at both ends and uniformly loaded=12.

In calculating the strength of beams, the whole weight of the material must be included when the beam has a uniform load and only half the weight of material when the load is placed at the center.

Let S=tabular number of breaking load in pounds on a beam supported at both ends and loaded at the center.

N=tabular number for breaking load in pounds on a beam loaded at one end, and the other end firmly fixed.

C=Safe load in pounds on center of beam supported at both ends.

E=safe load in pounds on a beam fixed at one end and loaded at the other.

b = breadth of beam in inches.

d = depth of beam in inches.

l = length of beam in feet.

w = breaking load in pounds.

R = w divided by 7=safe load in pounds.

x = proportion of strength due to position of load, and method of fixing the ends of the beam.

Square Beams.—The formula for finding breaking load is as follows:

$$w = \frac{b\, d^2\, N}{l} \times x$$

Example 1. What is the breaking load on a beam of American yellow pine, 12 inches deep, 12 inches broad and 20 feet long, one end of same being firmly fixed and the load at the other end?

Answer:

$$w = \frac{\overset{b}{12} \times \overset{d^2}{12^2} \times \overset{N}{98.7}}{\underset{1}{20}} \times x = \frac{12 \times 144 \times 98.7}{20} \times 1 =$$

85027.68 lbs., or 37.95 tons. And the safe load would be $\frac{37.95}{7}$ or 5.42 tons.

Example 2. With same dimensions, but beam supported at both ends and loaded in the center, the breaking load will be:

$$\frac{\overset{b}{12} \times \overset{d^2}{12^2} \times \overset{N}{98.7}}{\underset{1}{20}} \times \overset{x}{4} = 37.95 \text{ tons} \times 4 = 151.80 \text{ tons.}$$

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And the safe load would be $\frac{151.80}{7}$ or 21.68 tons.

Example 3. If the beam in example 1 was uniformly loaded, the safe load would be the same, viz, 5.42 tons multiplied by x, and by referring to the different proportions of strength tabulated we find in this instance where the beam is fixed at one end and uniformly loaded, x=2. Therefore the safe load would be 5.42×2=10.84 tons, thus showing that a beam will safely stand double the load when uniformly loaded than it will with load in the center.

Example 4. A beam of American pitch pine, 6 inches wide and 10 inches deep by 15 inches long, supported at both ends and uniformly loaded, the breaking and safe loads will be as follows:

$$w = \frac{b\,d^2\,N}{l} \times x \qquad \text{Safe load} = \frac{w}{7}$$

$$w = \frac{\overset{b}{6} \times \overset{d^2}{10^2} \times \overset{N}{144}}{\underset{l}{15}} = 5760 \text{ lbs.} \times \overset{x}{8} = 46080 \text{ lbs., or } 20.57 \text{ tons.}$$

And the safe load would be $\frac{20.57}{7}$ or 2.94 tons.

Example 5. Take the same beam as used in example 4 and lay it flatwise, or, that is, call it 10 inches wide and 6 inches deep, then the breaking strain would be:

$$\frac{\overset{b}{10} \times \overset{d^2}{6^2} \times \overset{N}{144}}{\underset{l}{15}} = 3456 \times \overset{x}{8} = \overset{\text{lbs.}}{27648}, \text{ or } 12.34 \text{ tons.}$$

And the safe load would be $\frac{12.34}{7} = 1.76$ tons,

or a little more than one-half the strength of the same beam laid edgewise.

Round Beams—In order to find the strength of a circular beam it is necessary to first work out the breaking load of a square beam of which each side is equal to the diameter of the circular beam, and multiply this load by .589, so the formula for the breaking load will read:

$$W = \frac{b\,d^2\,N}{1} \times X \times 0.589.$$

Example 1. Having a round beam of American cedar, 40 feet long between supports and uniformly loaded, with a diameter of 10 inches, the breaking load would be:

$$W = \frac{\overset{b}{10} \times \overset{d^2}{10^2} \times \overset{N}{62.5}}{\underset{1}{40}} \times \overset{x}{8} \times 0.589 = 7362 \text{ lbs., or}$$

3.29 tons, and the safe load would be $\frac{7362}{7} = 1052$ lbs.

Oval Beams—In this case first find the load for a rectangular or square beam, with sides equal to the two diameters of the oval beam, and multiply the result by 0.6.

Example. Having an oval beam of American white pine, firmly fixed at both ends and loaded in the center, having 15 feet between supports, the smallest diameter 10 inches, the largest diameter 12 inches, and placed so that it would be 10 inches wide and 12 inches deep, the breaking strain or load would be:

$$\frac{b\,d^2\,N}{1} \times x \times 0.6.$$

Here, on referring to the multiplier given in proportion of strength, we find x=6, and, therefore,

$$W = \frac{\overset{b}{10} \times \overset{d^2}{12^2} \times \overset{N}{102.5}}{\underset{1}{15}} \times \overset{x}{6} \times 0.6 = 35424 \text{ lbs., or}$$

15.8 tons, and the safe load would be $\frac{15.8}{7} = 2.26$ tons.

Triangular Beams—To find the breaking or safe load for this class of beams, first find the strength of a square beam with equal sides and divide the result by 3.

According to experiments made by Barlow and others, it was found that triangular beams were $\frac{1}{6}$ stronger where the base of the triangle was up, and it was found necessary to provide in the support a triangular notch in which to place the sharp edge of the beam.

Strength of Chains.—The strength of chains varies, owing to the nature of the iron from which they are made and their mechanical construction. The strength also varies as the square of the diameter of the iron from which the links are made. Experiments show that a single-link chain from good iron carefully welded, made from 1 inch diameter round bars, has a safe working strain of six tons. Great care must be exercised in using chains on loads that would cause disaster in case of breaking, and each link should be carefully examined, always bearing in mind that the strength of the chain is only equal to the strength of the weakest link. Many serious accidents have been caused by not paying proper attention to this fact.

There are many formulæ for determining the safe load for and breaking strength of chains, all of which are only approximate and depend upon careful examination prior to attaching the load. For crane chains the breaking load can be found by multiplying the square of the circumference of the link in inches by 32.4, and for the safe load divide the result by 6.

Example: What is the breaking load of a chain made with links from a round bar of iron $\frac{3}{4}$ of an inch in diameter? Answer: $75^2 \times 32.4 = 18.225$ tons, and safe load $= \frac{18.225}{6} = 3.04$ tons, nearly.

Another simple and approximate result is to divide the square of the diameter of the iron from which the links are made by 9, and the result is the safe working strain or load.

Example: A chain made from round iron $\frac{1}{2}$ inch in diameter, the safe load would be 4 (the number of eighths of an inch in $\frac{1}{2}$ inch) squared, or 16 divided by $9 = 1.8$ tons, the safe load.

The same result, nearly, is obtained by squaring the diameter of the link iron in inches and multiplying by 7.111. Taking the above example the answer would be: $.5^2$ or $.25 \times 7.111 = 1.77$ tons.

To find the diameter of the iron in eighths of an inch that the links should be made from, to safely support a given load, proceed as follows: Multiply the weight to be hoisted or hauled in tons by 9 and extract the square root of the product, and the answer will be the number of eighths of an inch there should be in the diameter of the links.

Example: What sized iron should the links of a chain be made from to safely support a load of two tons? Answer: $\sqrt{2 \times 9} = \sqrt{18} = 4.24$ eighths of an inch, or a little over ½ inch in diameter.

Some readers will no doubt recall instances to their minds where they have lifted much heavier loads with such chains as shown in the examples given. Although this is often done without any bad results, nevertheless these rules should be followed whenever possible, and especially when chains are used for long pulls and subject to heavy strains, as it is much better to err on the safe side.

While dealing with the strength of chains, it may be of interest and information to readers to have the following table which I have in my pocketbook and often find of great value in making calculations as to strength of iron, bolts, bars, rivets, etc.:

Tensile Strength and Shearing Strain of Iron and Steel.

	Tensile Strength per Sectional In.	*Shearing Strength per Sectional In.*
Cast Iron	7	9
Wrought Iron rolled bars	25	20
Best Lowmoor rivets	29	23
Cast Steel, best quality for tools	52	39
Double Shear Steel	40	30
Cast Steel Boiler Plates	48	36
Puddled Steel Boiler Plates	42	31½
Bessemer Steel Boiler Plates	32	24
Steel Bars	45	31½
Cast Steel Rivets	49	37
Wrought Iron Plates, lengthway	22½	18
Wrought Iron Plates, crosswise	20½	16½

It is as well to explain, for the benefit of some readers that tensile strength of any material is the weight attached to the end of a bar that will tear it asunder, and the shearing strength is the weight or pressure that will cut the material through.

In calculating the strength of screw bolts, of course, a proper allowance must be made for the thread, and an approximate allowance is to deduct $\frac{1}{16}$ from the diameter of small bolts, and from $\frac{1}{8}$ to $\frac{1}{4}$ for large bolts. For instance, a bolt $\frac{1}{2}$ an inch in diameter, deduct $\frac{1}{8}$ of an inch for thread and calculate the strength of said bolt as if it were a $\frac{3}{8}$ bolt, instead of a $\frac{1}{2}$ inch, and with a bolt 2 inches in diameter, deduct $\frac{1}{4}$ and call it $1\frac{3}{4}$, when calculating its working or safe load.

In order to fully explain the use of the above table of tensile strengths and shearing strains, I give an example as follows:

What is the tensile strength of a bar of iron 2 inches in diameter?

Here 2 inches in diameter has an area or cross-section = to 3.141 sectional inches, and $3.141 \times 25 =$ $78\frac{1}{2}$ tons, and the safe load would be $\frac{78.52}{7} = 11.22$ tons.

Strength of Hemp, Manilla, Iron and Steel Rope.— This subject is a most important one, and every superintendent and mine foreman should be thoroughly conversant with the mode of calculating the breaking strain, and, more particularly, the safe load that ropes of different material will stand, as the lives of the men employed, especially in deep mines, are dependent entirely upon the safety of the ropes used in hoisting, etc.; in fact, men working in mines have a right to demand that the employers have a thorough knowledge of this subject.

A simple test for the purity of manilla or sisal ropes is as follows: Take some of the loose fiber and roll it into balls and burn them completely to ashes, and, if the rope is pure manilla, the ash will be a dull grayish black. If the rope be made from sisal, the ash will be a whitish gray, and, if the rope is made from a combination of manilla and sisal, the ash will be of a mixed color.

For calculating the breaking strain of round ropes of different materials, the following table is one of several. Where B = breaking strain in tons, and C = circumference of rope in inches.

$B = C^2 \times 0.277$ for hemp rope.
$B = C^2 \times 0.2$ ordinary fiber rope.
$B = C^2 \times 1.5$ iron wire rope ordinary.
$B = C^2 \times 2.5$ steel wire rope.
$B = C^2 \times 2.09$ flexible galvanized wire rope.
$B = C^2 \times 2.60$ extra flexible galvanized wire rope.
$B = C^2 \times 4.18$ plough steel rope.

The working or safe load should be taken as about $\frac{1}{6}$ or $\frac{1}{7}$ of the breaking load B, or $\frac{B}{6}$.

The weight of ropes can also be approximately calculated from the circumference, as follows: Where W=weight of each 100 feet in pounds, and C=circumference of rope in inches, as follows:

$W = C^2 \times 4.16$ for each 100 feet of hemp or fiber rope.
$W = C^2 \times 14.54$ for each 100 feet of iron or steel rope.

A splice weakens a rope about one-eighth, and it is well to remember that a three-strand rope is about one-fifth stronger than a four-strand one of the same dimensions.

The Bursting and Working Strain of Iron and Steel Pipes, Plates, etc.—Under this head I will deal only with wrought-iron and steel pipes as are generally used in connection with mining work, and in arriving at the safe working strain or pressure it must be understood that the following rules depend upon good workmanship, correct diameters and distance apart in riveting, etc. In making wrought-iron pipe care must be taken to have the plates rolled lengthwise, as it generally affects the strength of the longitudinal seams—that is to say, the plates should be rolled across the grain, and not with it.

The simplest method of calculating the pressure that wrought-iron and steel pipes will stand is as follows:

$$P = \frac{T \times t}{R} \div c \times f.$$

Where P=safe working pressure.

T = tensile strength of plates, taking iron at 48,000 pounds to the square inch and steel at 75,000 pounds.

t = thickness of plates in inches or decimals of an inch.

R = radius of pipe in inches.

f = proportional strength of plates, as follows: when double-riveted=0.7 and single-riveted=.5.

c = a co-efficient or factor of safety usually taken at 3.

p = pressure in pounds per square inch due to head of water.

Example: What is the safe working pressure for a 36-inch pipe, double-riveted along the longitudinal seams, and made from wrought-iron plates rolled across the grain, and $\frac{1}{8}$ of an inch thick?

$$\text{Answer: } P = \frac{\overset{T}{48000} \times \overset{t}{.125}}{18} \div \overset{c}{3} \times \overset{f}{0.7} = 77.7 \text{ lbs.}$$

to square inch or 179 feet pressure head.

By means of the same formula, the thickness of plate is easily found, that will safely stand any given presure; for instance:

$$t = \frac{P \times R \times c}{T \times f}$$

Example: Having a pressure of 179 feet, or 77.7 pounds to the square inch, what thickness must the wrought-iron plates be for making a pipe 36 inches in diameter?

$$\text{Answer: } t = \frac{\overset{P}{77.7} \times \overset{\text{radius}}{18} \times \overset{c}{3}}{\underset{48000}{T} \times \underset{0.7}{f}} = .125 \text{ inch.}$$

With reference to the difference between the strength of drilled and punched holes, it has been determined by experiment that the loss of strength in the metal between the rivet holes when drilled is practically nothing, or, to give the summarized result, the loss when drilled lengthwise was but 1.13 per cent, and when drilled crosswise the loss was only 0.9 per cent, while, on the other hand, experiments made by Mr. Kirkaldy on punched plates showed the mean loss to be 13 per cent with the grain and 17.26 across the grain. Although the result of experiments has conclusively proved that the strength of plates is greater with drilled holes than with punched holes, the extra cost occasioned by drilling would not make up for the extra strength obtained, except in particular cases; and with regard to wrought-iron and steel pipes for mining purposes, the effect of drilling or punching need not be taken into consideration, but at the same time I thought it would be interesting to some readers to learn the difference in strength between the two methods.

Methods of Treating Alluvial Deposits in Large Quantities, Where Sufficient Fall is Not Available, Sluices, Grades, etc.—Under this heading, I will first deal with what is known as the "Hydraulic Elevator," which is the simplest and most economical machine connected with mining alluvial deposits, where, by lack of grade, it is impossible to run bedrock sluices, or when it is impossible to secure a good dump at the end of sluices to keep them running in a proper manner. The elevator also enables large areas of ground to be profitably mined in districts where the debris law is operative, by means of lifting the material into restraining dams, etc.

In this country, with such water facilities, there are thousands of acres that can be profitably worked by means of an elevator; but, owing to the heavy cost, weight and poor efficiency of the elevators used in California, it appears to be regarded by miners that, to work an elevator, it is necessary to have excessive heads and small lifts, or, in other words, one must have a large quantity of water, or it is of no use trying to mine with an elevator.

Now, this is practically correct, when the clumsy and costly machines that have been the custom for years past are considered. It is far from correct when considering the hydraulic elevator now in the market and manufactured in San Francisco, for which patents have been granted to the writer.

I do not in any way wish my readers to think my remarks here are for the purpose of advertising these elevators, for my personal benefit, and, to be frank with all, I may state that in making arrangements for the manufacture of these machines I agreed upon a price to be charged that only carries an ordinary manufacturing profit, and the amount of royalty received on each machine is but $75, my aim being to assist brother miners, and, with that end in view, did not insist on such exorbitant royalties as has been the custom in connection with other elevators. I feel a little diffident about pushing forward the many claims in regard to cost, weight, efficiency, etc., and would much rather any one interested would write for particulars from the manufacturers in San Francisco—the Risdon Iron Works.

What I wish to impress upon readers is that if they have a piece of ground that is too low for ordinary mining and have only a few inches of water under pressure, do not think it is impossible to work it by means of an elevator. I had charge of a large hydraulic claim in New Zealand, where with less than 400 inches of water under a working head of 225 feet I lifted sand and gravel to a height of 52 feet, and each twenty-four hours handled from 2000 to 2400 tons, and for one year elevated at the rate of an acre each month to a depth varying from 30 to 35 feet banks. Of the quantity of water used, only 250 inches was taken by the elevator and the remainder by the giant for piping. The elevator was connected upon the surface, and instead of going to great expense, as is usual in this country, to sink shafts to bedrock before placing the elevator, we let the elevator do its own sinking, and in less than a week the machine had excavated its own shaft to bedrock, a depth of 43 feet through some bad running ground, which is much better than sinking by hand, timbering through running sand, let alone the expense of pumping, etc.

It is well known by those who have gone into the efficiency of the hydraulic elevator that, unless the various parts are well proportioned, it is a most wasteful machine; but, as against this, the enormous amount of work they are capable of doing with a minimum cost for repairs and attendance, make them especially valuable for hydraulic mining, and, when constructed on proper lines, there is no difficulty in obtaining from 40 to 50 per cent efficiency from same.

In this country there are many instances where 10 per cent, and even less, is only obtained, which is partly due to the machine being wrongly constructed and a good deal to the fact that most of those at present using elevators, with few exceptions, do not know how to get the best work from them.

There are cases where superintendents of elevator claims appear to think that, as long as their machines can be made to handle boulders, in some cases 20 and 30 inches in diameter, that is a certain test of their efficiency. Such is not the case, as there is no difficulty in lifting stones double or treble the size, providing plenty of water and pressure be available.

To be successful in elevating auriferous deposits, unless exceedingly rich, one must make up their mind to use the smallest quantity of water, in both elevating jet and giants, so that the proportion of gravel or other auriferous material lifted in comparison with the water required for lifting and piping, will be of a maximum quantity. If this rule was followed by many of the present elevator claims, they would be lifting and treating, in many cases, three and four times the quantity of auriferous material they are now doing.

There are cases, of course, where it may be necessary, for a short time, in opening a claim to elevate the largest stones for the purpose of making room, but to continue such course is a great mistake—far better stack the larger stones in the paddock and use the extra quantity of water required for lifting such stones, in working a second or third elevator, and, in such manner, be treating three and four times more *pay dirt,* than working one heavy and wasteful machine to lift large boulders, etc.

Let any reader of this paper carefully work out the power there is in the water used through their elevator jet, then find out the power required to lift the weight of water used for elevating, plus the weight of the minimum quantity of necessary water for piping, and plus the weight of gravel or material sluiced and lifted by elevator; it will then be seen at a glance whether you are getting the proper work from the machine or not.

I know of an instance where a manager of an elevating claim in this State kicked because he was not getting 75 per cent from his head of water, when using a special form of water wheel, while he was using an elevator not yielding him 12 per cent in the same claim; it never occurred to him to try the efficiency of his elevator, as, from the *appearance* of the huge quantity of water and the large and small rocks coming through the elevator, he was satisfied the efficiency could not be better. In some respects this was true, but the owners of the claim were paying him to lift auriferous material, not water and large stones, *occasionally* mixed with a few tons of pay dirt.

These machines are made in convenient pieces for mule transportation, so that where it is possible to take a mule there will be no difficulty in erecting and working an elevator.

Grades and Sizes of Sluices.—There seems to be a great diversity of opinion, especially among the older miners, as to the size of sluices. Many of them stick to the idea that the best results are obtained from a narrow or deep form of sluice, and will try and make others believe that such a sluice is most easily kept in good running order. Now, this is not correct by any means, the reverse being the case, it having been conclusively proven by practical results that a wide sluice will carry more material, and save more gold, with considerable less grade, than a narrow and deep sluice.

It is a well-known fact in relation to gold saving that one of the first principles is to have as thin a film of water and material in the sluices as is possible, with, of course, due regard to the fact that there must be a sufficient depth of water to just cover the largest stones that are sent down the gold-saving sluices. I have noticed on more than one occasion when using narrow sluices that it takes much less time to cause a block than in wide ones, and when I state that I have worked sluices through ground containing nearly 10 per cent of titaniferous iron, or black sand, a good many miners will realize the difficulty in getting rid of from 2000 to 2400 tons of such a deposit per day, on a grade of 2 inches to 12 feet, and in doing this I soon found out the fallacy of using narrow and deep sluices.

With reference to the grade of sluices, experiments made in river gravel have shown that, with a grade of from 1 in 20 to 1 in 25, 40 miners' inches, or 60 cubic feet, per minute will wash from about 140 to 170 cubic yards per day of 24 hours, and with light grades the depth of water in sluices must be as shallow as possible, just so that it will move the largest stones and prevent the sand from packing. Mr. Gordon says that when there is a large proportion of heavy stones the best results are obtained by having about from 10 to 12 inches of depth of water in the sluice, this, of course, assuming that the large stones do not run over 10 to 12 inches in diameter.

In concluding this paper it is hardly necessary to remind the reader that the different formulæ are not original; but in several instances they have been simplified to meet the result of my own practical experience. The information and data, on the whole, are compiled from figures, formulæ, data and notes accumulated in my private pocketbook, and if what has been written proves of the same assistance to any of my fellow miners or to those interested in mining as myself, I will feel amply repaid for the time taken in preparing this paper.

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