Waterwheel rotation speed

From the "Engineers and Mechanics Pocket Book" – A water wheel works best when the outer edge travels no more than 5 feet per second.

Then (ω is rotation speed, v is outer edge speed and d is diameter of the wheel)

$$v = \omega \pi d \; so \; \omega = \frac{v}{\pi d} = \frac{5 \, \frac{ft}{sec}}{\pi \; 23 \; ft} \; x \; 60 \frac{sec}{min} = 4.15 \; \frac{rev}{min}$$

Therefore the rotation speed is set to 4 revolutions per minute and

$$v = \left(\frac{4}{min}\right) \pi (23 \; ft) \left(\frac{1 \; min}{60 \; sec}\right) = 4.817 \; \frac{ft}{sec}$$

Water Flow

Through the batteries

From "The stamp milling of gold ores" – the Hidden Treasure mine (taken as an example of Gilpin County) used 2 gallons of water per stamp per minute.

Then for the Kimber Mill:

$$Water = 2 \frac{gal}{stamp \; x \; minute} \; x \; 32 \; stamps = 64 \; \frac{gal}{minute}$$

Through the wheel

From the "Engineers and Mechanics Pocket Book", o is a coefficient ranging from 3 to 5 depending on the fill of the buckets, s is depth of shrouding (bucket) in feet, v is the velocity of the wheel at the center of the shrouding, V is water discharge speed in cubic ft per second, and w is the width of the wheel:

$$\frac{o \; V}{s \; v} = w$$

This can be rearrange to find the water discharge speed, using the bucket depth of 5mm (or 10/7 scale ft):

$$V = \frac{w \; s \; v}{o} = \frac{(6 \; ft) \; (10/7 \; ft) \; (4.817 \; \frac{ft}{sec})}{5} = \left(8.258 \; \frac{ft^3}{sec}\right) \left(\frac{1 \; gal}{7.4805 \; ft^3}\right) \left(\frac{60 \; sec}{min}\right) = 66.235 \; \frac{gal}{min}$$

Number of Buckets

From the "Engineers and Mechanics Pocket Book", to find the number of buckets, first calculate the distance between the buckets (where s is the shrouding depth in inches – here

$$l = 7(1 + s/10) = 7 * \left(1 + \frac{10(12)}{7(10)}\right) = 19$$

Then the number of buckets is found from (where d is the wheel diameter in feet)

$$\frac{d\pi s}{l} = \frac{23\pi(120/7)}{19} = 65.2$$

Round this up to 72 as this is a divisor of 360 and space every 5 degrees.

Gearing ratios

One Step up: To the Batteries

If ω_w is the rotation speed of the water wheel, d_w is the diameter of the pulley attached to the water wheel ω_b is the rotation sped of the battery camshaft wheel and d_b is the diameter of the battery camshaft wheel then

$$\omega_w d_w = \omega_b d_b \; so \; d_w = \frac{\omega_b d_b}{\omega_w} = \frac{\left(15 \, \frac{rev}{min}\right)(80 \; in)}{4 \, \frac{rev}{min}} \left(\frac{1 \, ft}{12 \, in}\right) = 25 \, ft$$

Two Steps Up: One to the Chilean Mills, One to the Batteries

Instead of a single 15:4 ratio, two ratios of 3:2 and 5:2 would also suffice. In this case, the middle axle would be turning at 6 revolutions per minute (which is consistent with the speed of low speed Chilean Mills quoted in “Stamp Milling and Cyaniding”). However, there is still the issue of driving the camshaft wheel, which would require a pulley diameter of

$$\omega_w d_w = \omega_b d_b \; so \; d_w = \frac{\omega_b d_b}{\omega_w} = \frac{\left(15 \, \frac{rev}{min}\right)(80 \; in)}{6 \, \frac{rev}{min}} \left(\frac{1 \, ft}{12 \, in}\right) = 16\frac{2}{3} \, ft$$

Three Steps: Two Up, One Down

Instead of two steps down, keep the 3:2 ratio for the Chilean Mills and use a 5:1 ratio for a second intermediate axle. Putting a 40” diameter pulley on that wheel would lead to a final 1:2 ratio for the camshaft wheel and the right rotational speed.