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The Russell process - laboratory tests and design of plant

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George Vest Bland

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THESIS

FOR THE

Degree of Bachelor of Science

IN

MINE ENGINEERING.

♪ ♪ ♪

SUBJECT:

“The Russell Process—Laboratory Tests and Design of Plant.”

♪ ♪ ♪

GEORGE VEST BLAND.

CHARLES G. WRISBERG,

JUNE 10, 1904.

L O C A L I T Y .

The ore for which the mill is designed was taken from the Bonne Homme mine located at White Cross, Colorado.

The surrounding country is mountainous, the mine itself being reached by a drift in the side of a mountain.

The site selected for plant is in the valley at foot of mountain worked for the ore.

O R E .

The ore is a heavy sulphide with quartz gangue, and contains a large amount of copper and iron in the form of chalcopyrite.

Analysis:

Insoluble constituents - - - - -	51.20
Iron - - - - -	22.81
Copper - - - - -	6.61
Sulphur - - - - -	18.44
Water - - - - -	0.83

Assay:

Silver - - - - -	22.12 oz/ton.
Gold - - - - -	trace.

Process for Extraction.

The Russell process giving a good extraction (92.35%), and better results than other tests made on the ore, was selected as the best method of treating the ore, and the plant designed accordingly.

The ore, which is not suitable for the process in its raw state, is made so by means of a chloridising roast.

The best results obtained were when the ore was crushed to about 25 mesh, ore finer than 30 being very detrimental to the process. For this reason a trommel is used before the last set of rolls, the chalcopyrite giving considerable fines of 30 mesh, when crushed in the rolls set to 18 mesh.

The Russell extra solution is a mixture of copper, sulphate, and sodium ~~thio~~-sulphate in the proportion (by weight) of 4 to 1. The silver chloride is soluble in this solution, and is precipitated as silver sulphide, by means of sodium sulphide.

The refining consists of changing the ~~su~~lphide to sulphate (sulphuric acid), reprecipitating with copper, and working up in cupellation furnace.

The plant is designed to ^{treat} ~~test~~ one hundred tons every twenty-four hours.

System of Treatment.

Ore is brought from mine in cars, and passed over a grizzly to a crusher set to one inch. The undersize from grizzly and product from crusher then go through feeders to two pair of rolls, set to turn out 8 mesh size. The rolled ore then is carried by a bucket conveyor to the bins above the roaster, and there discharged into cars, which in ~~turn~~ turn discharge ~~is~~ into the desired bin. Salt is ~~is~~ mixed with the ore near the end of the roaster, the amount being 9% of the mixture.

When a furnace is ready for new charge, the contents of the bin above is discharged into it. At the end of eight hours when the ~~roast~~ is complete, the mass is discharged into a system of cars. The cars are then pushed out, and allowed to empty slowly onto an automatic cooler. The rakes of the cooler bring the ore to a bucket conveyor, which then takes the ore to the feeders above the second set of rolls.

The product of these rolls (set to 18 mesh size) goes to trommel giving undersize of 25 mesh. The oversize goes to the third set of rolls, the product from this last set being of 25 mesh. This product, and the undersize from trommel, are taken by belt conveyor to the third floor of the leaching building.

The belt conveyor discharges into a system of cars, operated on an elliptical track placed directly above the four leaching vats. When a vat is ready for a new charge, the contents of the whole system of cars is emptied into it, the two capacities being the same. After charging, water is run through until the filtrate gives no precipitate with Na_2S . When the water has sunk to a level below the surface of the ore (vat filled to within 12" of top), the Russell solution is turned in, and allowed to percolate through until Na_2S shows the absence of silver in the filtrate. The tailings are sluiced out through an inclined chute to a position about a hundred feet from the building. The leaching of each charge (including charging, sluicing, etc.) requires about forty-eight hours.

The filtrate from the water treatment runs into one set of tanks, while the filtrate from Russell solution goes to a separate set.

Iron is added to the water solution, precipitating the Cu which has gone into solution; the Cu in turn precipitating the Ag and going again into solution, but being re-precipitated, as there is an excess of iron present.

To the Russell solution filtrate is added just enough ~~and~~ Na_2S to precipitate the Ag, Au and Cu. When the precipitation is complete, the whole is allowed to stand for about four hours; then the supernatant liquor is drawn off through an automatic siphon to a large sump placed a few feet below on the bottom floor.

Below each of the precipitating vats is a storage vat, and in this the precipitates of a week's run are collected.

At the end of the week the precipitates are sent through a pressure tank to a Johnson filter press. The cakes of sulphide are turned out into a wheelbarrow and taken ^{to} the refinery. The filtrate from the press runs into a small sump placed directly below the press, the filtrate in this and in the main sumps being used again.

In the refinery the cakes of sulphide brought from the leaching plant are put in cast iron vessels, and treated with H_2SO_4 . The Cu and Ag go into solution, leaving the small amount of Au behind. The solution is then transferred to more iron vessels, and Cu added. This precipitates the Ag. The Cu SO_4 formed is pumped up to the storage tank in the leaching building, there to be used again in the making up the Russell solution.

The silver is worked up in a cupellation furnace.

The gold residues from the H_2SO_4 treatment are saved up for a month, and then charged into a reverberatory furnace, and finally purified by treatment with nitric acid.

General description of machines, tanks, vats, etc.

(a) Crushing department.

(1) Crusher:

Blake Crusher. Length in clear 5' 4". Breadth 4' 6".
Driving pulley of 3' diam, and 8" face, making 200 R. P. M.

(2) Rolls:

6 Krom rolls.

Diam. of rolls 42". Length of face 6".

Main band wheels - 72" X 12".

Small " " - 36" X 8".

250 R. P. M.

(3) Feeders:

6 Fulloch feeders.

Width at top - 4'. Depth 4'.

(4) Trommel:

Diam. of small end - 42"

" " large " - 60".

Length 108".

R. P. M. 20

(5) Grizzly:

Length - - - - - 10'

Breadth - - - - - 5'

Bars 5/8" X 1 3/4" and set 1" apart.

(6) (Belting, etc. - see page 10)

(b) Roasting Department.

(1) Furnaces:

2 Hoffman furnaces.

Length - - - - - 26 1/2 ft

Diameter - - - - - 8 1/2 "

R. P. M. - - - - - 5

(2) Cooler:

Plows go through ore a distance of 86', and through air 120', making total lengths of 206'. The cooler is of the same principle as Brown's horseshoe furnace, the plows being operated in exactly the same manner.

(3) Conveyors:

2 Jeffrey's bucket conveyors.

No. 1. - - 38 ft long and 12" width.

No. 2. - - 32 " " " 12" "

(4) Cars:

2 cars used above the bins, and 6 below. Have width - 3 1/2 ft, length 5 ft, and depth of 3 1/2 ft. Discharges through hopper shaped bottom. They are operated on 100 ft of track.

(5) Bins.

Two placed above each roaster.

Size - 14" X 10' and 8' deep. 1085 ft of lumber.

(6) Belting, etc: (see page 10)

(c) Leaching Department.

(1) Storage tanks: (fourth floor)

Four in number. One for hyposulphite solution, ~~and~~ ^{one} for Cu SO₄ solution, one for Russell extra solution, and a fourth to be used in case of stoppage for repairs, etc., to one of the other vats.

These tanks are constructed of California white cedar, all joints being covered with white lead. Their dimensions are 17' X 15' and 9 ft deep.

(2, Leaching vats: (third floor)

Four vats, each 15 ft in diameter, and 7 ft in depth. Constructed of California white cedar, all joints covered with white lead.

False bottom and filter constructed as follows:

Wooden slats 1 1/2 inches high, and 1 inch wide, are separated from each other a distance of one inch. A space of 1 1/2 inches is left between ends of slat and the staves of the vat. Around the ends of the slats is placed a wooden hoop one inch wide, leaving an annular space 1/2 inch in width. On this arrangement, but not covering the annular space, is put thick matting. A canvas filter with a diameter of about six inches more than that of the hoop, is put on the matting, the extra width being pressed down into the annular space.

(3) Precipitating tanks: (second floor)

Four tanks of white cedar, etc., of following dimensions: Diameter 10 ft, depth 9 ft.

each has an outlet in center of bottom for discharge of precipitate.

(4) Sodium sulphate tanks: (third floor)

Two tanks of white cedar.

6 ft diam. and 5 ft depth.

(5) Sumps: (first floor)

Four large, and one small sump, all constructed of cedar, with white lead lined joints.

Large sumps 11 1/2 ft diam. 7 1/2 ft depth.

Small sump 6 ft diam. 4 ft depth.

placed just filter press.

(6) Pressure tank:

Johnson pressure tank.

3' diam. Depth of 4 ft to bulge, and total of 6 ft.

(7) Filter press:

Johnson filter press.

Occupy space 8' X 3' and 2 1/2' depth.

(8) Pumps:

Knowles plunger pump.

Space 9' X 2' and 3' depth.

(9) Cars:

Thirty-four cars. 5 ft length, 2 1/2 ft width, and 2 1/2 ft depth. Operated on elliptical track of length 115 ft, and gauge of 18 inches. Discharge of cars is through hopper shaped bottom.

(10) Lift:

Platform four ft square placed at side of building.

Used for hoisting of hyposulphite (crystals), Cu S O_4 (crystals), etc.

(11) Piping:

150 ft of piping of 1 1/4 inches diameter.

(d) Refining department.

(1) Small reverberatory, 12 ft long.

(2) Cupellation furnace.

(3) 8 iron vessels of 4 1/2 ft diam., and 4 ft depth. 4 used for $\text{H}_2\text{S O}_4$ treatment, and 4 used for re-precipitation.

(4) Brick chimney. 100 ft high. First 20 ft of 16 in. thickness. Next 30 ft of 12 in. thickness; next 50 ft of 8 in. thickness. Batter of 1 in 25. Inner shell of one thickness of fire brick. Inside diam. at base 30 inches.

(e) Power plant.

(1) 2 Heine boilers, each requiring a space of 15 1/2 ft length, 7 ft width, and 10 ft height. Each contains 42 tubes. 230 H. P. capac. 80 H. P. required of each of them.

(2) Ideal engine 8 ft long, 4 ft wide, and 5 ft high. Fly-wheel 54 in. diam., and 10 in. face. Piston 11 in. diam., and 12 in. stroke. 300 R. P. M. 150 H. P.

(3) Steel smoke stack. 90 ft high, and 3' diam.

(f) Miscellaneous.

(1) Robins belt conveyor, 12" in width, and 305 ft in length.

COST OF PLANT .

(A) Equipment.

(1) Crushing:

1	Blake Crusher	- - - - -	\$	500.00
6	pair of Krom rolls	- - - - -	"	8,400.00
6	Pullock feeders	- - - - -	"	600.00
1	Trommel	- - - - -	"	440.00
1	Grizzly	- - - - -	"	150.00
2	Bucket conveyors	- - - - -	"	70.00
12	Pulley of 63" diam., 12" face	- - - - -	"	300.00
1	" " 51" " 10" "	- - - - -	"	9.00
1	" " 45" " 10" "	- - - - -	"	8.00
1	" " 39" " 10" "	- - - - -	"	7.00
1	" " 39" " 9" "	- - - - -	"	6.00
1	" " 33" " 8" "	- - - - -	"	3.20
1	" " 33" " 6" "	- - - - -	"	3.00
1	" " 27" " 10" "	- - - - -	"	3.50
1	" " 27" " 8" "	- - - - -	"	3.00
1	" " 18" " 10" "	- - - - -	"	3.50
210	ft of belting of 12" width	- - - - -	"	226.80
44	" " " " 9" "	- - - - -	"	35.20
121	" " " " 8" "	- - - - -	"	84.70
40	" " " " 6" "	- - - - -	"	20.80
59	" " shafting of 4" diam.	- - - - -	"	206.50
6	" " " " 2" "	- - - - -	"	9.80
Total - - - - -				\$ 11,090.00

(II) Roasting.

2	Hoffman furnaces	- - - - -	\$	9,000.00
	cooler (including small engine fans, etc.)	- - - - -	"	2,700.00
8	Cars and 100 ft of track	- - - - -	"	312.00
	Fire boxes, dust chambers, flues, etc.	- - - - -	"	4,000.00
	Bins	- - - - -	"	50.00
3	Pulleys of 72" diam., 10" face	- - - - -	"	45.00
2	" " 27" " 10" "	- - - - -	"	7.00
2	" " 12" " 10" "	- - - - -	"	4.50
102	ft 3 ply belting, 10" width	- - - - -	"	91.80
94	" shafting of 4" diam.	- - - - -	"	329.00
Total - - - - -				" 16,539.30

(111) Leaching.

4	Storage tanks for stock solution - - - - -	\$	400.00
4	Leaching vats - - - - -	"	930.00
4	Precipitating tanks - - - - -	"	560.00
2	Sodium sulphide storage tanks - - - - -	"	480.00
4	Main sumps - - - - -	"	500.00
1	Small sump - - - - -	"	200.00
4	Storage vats for precipitates - - - - -	"	420.00
	Johnson pressure tank - - - - -	"	210.00
	Knowles plunger pump - - - - -	"	450.00
34	Cars and 115 feet of track - - - - -	"	560.00
150	ft of pipings, valves, etc. - - - - -	"	900.00
	Small lift - - - - -	"	50.00
			<hr/>
		"	5,660.00

(1V) Refining.

8	Iron vessels - - - - -	\$	400.00
	Cupellation furnace - - - - -	"	300.00
	Small reverberatory - - - - -	"	350.00
	Knowles plunger pump - - - - -	"	220.00
2	Wheel-barrows - - - - -	"	20.00
	Smoke stack - - - - -	"	2,000.00
			<hr/>
	Total -	\$	3,290.00

(V) Power.

2	Heine boilers - - - - -	\$	4,200.00
	Ideal engine - - - - -	"	2,000.00
	Smoke stack - - - - -	"	500.00
			<hr/>
	Total	\$	6,700.00

(VI) Miscellaneous.

305	ft of belt conveyor - - - - -	\$	1,293.00
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Grand Total --\$39,132.30

(B) Buildings.

(1) Crushing department.

(a) Lumber:

1) Posts:

9 - 4 X 6 - 26'.4 height	- - - - -	- 655.2 sq. ft.
4 - 4 X 4 - 9'.3	" - - - - -	49.6 " "

2) Supports:

of crusher - 6 - 6 X 8 of 13'.9 height	- - - - -	250.2
" 2nd set rolls - 6 - 6 X 8 of 19'.5 height	- - - - -	468.0
" 3 sets feeders - 18 - 3 X 3 of 3'.4 height	- - - - -	45.9
" Trommel - 2 - 4 X 4 of 16'.7 height	- - - - -	44.6
" 1st set rolls - 9 - 3 X 3 of 4'.7 height	- - - - -	31.7
" 2nd " " - 9 - 3 X 3 " 4'.7 "	- - - - -	31.7

3) Rafters:

Four 2 X 4 of 29'.9 length	- - - - -	79.7
Boarding (1" plank)	- - - - -	2512.8
Total lumber		<u>4169.4 sq. ft.</u>

4169.4 sq. ft. at \$20.00 per 1000	- - - - -	\$ 82.39
(b) 334.2 Cu. ft. concrete for flooring @ \$2.00	- - - - -	" 668.40
(c) 1142.5 sq. ft. corrugated iron roofing @ 3 1/2¢	- - - - -	" 396.99
(d) 300 sq. ft. windows (20 windows) @	- - - - -	" 70.00
(e) Cost of labor in constructing, painting, etc.	- - - - -	" 900.00
Total		<u>\$1,765.78</u>

(11) Roasting Department.

(a) Lumber.

(1) Posts:

20 - 4 X 6 of 26'.4 height	- - - - -	- 105600 sq. ft.
10 - 3 X 3 " 10'.3 "	- - - - -	74.3
8 - 4 X 4 " 7'.1 "	- - - - -	75.7

(2) Supports.

Of bins, sixteen 8 X 10 of 6'.9 height	- - - - -	763.4
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(3) Rafters.

10 - 2 X 4 of 43'.6 length	- - - - -	287.3
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(4) Boarding (1" plank)	- - - - -	6947.3
Total lumber		<u>9204.0 sq. ft.</u>

Roasting Department (Con.)

	9204.0 sq. ft. lumber at \$20.00 per 1000 ft - - -	\$ 184.08
(b)	47.6 cu. ft. concrete flooring @ \$2.00 - - - - -	" 95.20
(c)	4005.5 sq. ft. corrugated roofing - - - - -	" 140.19
(d)	760 sq. ft. of windows (60 windows) - - - - -	" 180.00
(e)	Labor in constructing, painting, etc. - - - - -	\$2,000.00
	Total - - - - -	\$2,599.47

(111) Power Department.

(a) Lumber.

(1) Posts:

5 - 4X4 of 19'.2 height - - - - -	128.0 sq ft.
5 - 4X4 of 15'.6 " - - - - -	104.0
5 - 3X4 of 12'.0 " - - - - -	60.0

(2) Boarding (1" plank) - - - - -	741.9
Total lumber - - - - -	1033.9 sq ft.

1033.9 sq ft lumber @ \$20.00 per 1000 ft - - - - - \$20.68

(b)	268.03 cu ft concrete flooring @ \$2.00 - - - - -	\$ 536.07
(c)	910.6 sq ft corrugated iron roofing - - - - -	" 31.87
(d)	150 sq ft of windows (10 windows) - - - - -	" 55.00
(e)	Labor in constructing, painting, etc. - - - - -	" 200.00
	Total - - - - -	\$823.62

(1V) Leaching Department.

(a) Lumber.

(1) Posts:

21 - 10 X 10 of 45'.6 height - - - - -	7980.0 sq ft.
10 - 4 X 6 of 11'.1 " - - - - -	222.0
5 - 4 X 4 of 5'.8 " - - - - -	38.7

(2) Beams:

30 - 10 X 10 of 22'.5 length - - - - - 5625.0

(3) Stringers:

270 - 2 X 12 of 15'.0 length - - - - - 8100.0

(4) Rafters:

6 - 2 X 4 of 17'.4 length - - - - - 69.6

22035.3

Leaching Department (Continued)

		22035.3 sq ft.
(5) Boarding (1" plank)	- - - - -	8550.0 " "
(6) Flooring (1" plank)	- - - - -	6075.0 " "
	Total lumber	<u>36660.3 " "</u>
(b)	36660.3 sq ft of lumber @ \$20.00 per 1000 ft	- - \$ 733.21
(c)	675 cu ft of concrete flooring @ \$2.00	- - " 1350.00
(d)	996 sq ft of windows (72 windows)	- - " 234.00
(e)	2882.8 sq ft of corrugated iron roofing	- - " 100.90
	Labor in constructing, painting, etc.	- - " 8000.00
	Total	<u>\$10418.11</u>

(V) Refining Department.

(a) Lumber.

(1) Posts:

4 - 4 X 6 of 24'.0 height	- - - - -	192.0 sq ft.
4 - 4 X 6 of 19'.75 "	- - - - -	158.00 " "
4 - 4 X 6 of 15'.5 "	- - - - -	124.0 " "
Total lumber	- - - - -	474.0 " "

(2) Supports.

Of vessels, twenty-four 4 X 4 of 8'.8 height	- -	281.6 sq ft.
" " " " 3 X 3 of 3'.0 "	- -	54.0 " "

(3) Boarding (1" plank)	- - - - -	1658.0 " "
(4) Flooring (1" plank)	- - - - -	486.0 " "
	Total lumber	<u>2953.6 " "</u>

(b)	2953.6 sq ft lumber @ \$20.00 per 1000 ft	- - - - - \$ 59.07
(c)	340 cu ft of concrete flooring at \$2.00 a	- - - - " 680.00
(d)	1111.8 sq ft corrugated iron roofing	- - - - " 38.91
(e)	150 sq ft of windows (10 windows)	- - - - " 35.00
	Cost of labor in constructing, painting, etc.	- - - - " 400.00
	Total	<u>-\$1,212.98</u>

(VI) Belt Conveyor Supports, Cover, etc.

(a) Lumber.

(1) Posts:

60 - 6 X 6 of average height of 12'.0	- -	2160.0 sq ft
60 - 8 X 8 " " " " 36'.0	- -	1520.0 " "

(2) Stringers:

60 - 4 X 6 of 4'.0 length	- - - - -	480.0 " "
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(3) Boarding:

Four sides 4' X 305' (1" plank)	- - - - -	4880.0 " "
Total lumber	- - - - -	<u>19040.0 " "</u>

19040.0 sq ft of lumber @ \$20.00 per 1000 ft - - - -	\$	38.08
Cost of labor in constructing - - - - -	"	800.00
	<i>Total</i>	<u>838.08</u>

Grand Total - - - \$17,034.42

Note: Cost of labor in constructing includes placing of machines.

S U M M A R Y .

(A) Cost of machinery, etc. - - - - -	\$	39,132.30
(B) Cost of buildings - - - - -	"	<u>17,034.40</u>
Total cost of plant - -	"	56,166.70

Running Expenses per day.

(a) Chemicals:

175#	Na ₂ S ₂ O ₃	- - - - -	\$	9.00
250#	Cu S O ₄	- - - - -	"	20.00
125#	Sulphur	- - - - -	"	4.00
200#	Caustic Soda	- - - - -	"	10.00
18000#	Salt	- - - - -	"	90.00
50#	H ₂ S O ₄	- - - - -	"	1.50
20#	Copper	- - - - -	"	2.00
	Total	- - - - -	"	<u>137.50</u>

(b)	Fuel	- - - - -	"	60.00
(c)	Allowance for repairs, wear, etc.	- - - - -	"	25.00
(d)	Wages for day shift:			

	Superintendent	- - - - -	"	10.00
	Engineer	- - - - -	"	4.00
	Fireman	- - - - -	"	3.00
	2 Roaster men	- - - - -	"	7.00
	2 Mill men	- - - - -	"	8.00
	4 Refiners, working 2 days during week	- - - - -	"	3.50 per day.
	Lixiviator	- - - - -	"	3.00
	Car system	- - - - -	"	3.00
	Pump, and sluicer-	- - - - -	"	3.00
	Handler of sulphides, etc.	- - - - -	"	3.00
	Assayer	- - - - -	"	4.00
	Ass't Assayer	- - - - -	"	3.00
	Chemist	- - - - -	"	4.00
	Carpenter - Machinist	- - - - -	"	4.00
	Book-keeper	- - - - -	"	3.00
	General help	- - - - -	"	<u>15.00</u>
	Total for one shift	- - - - -	"	83.50
	" " both shifts	- - - - -	"	120.00

Total running expenses:

(a)	Chemicals	- - - - -	\$	137.50
(b)	Fuel	- - - - -	"	60.00
(c)	Repairs	- - - - -	"	25.00
(d)	Wages	- - - - -	"	120.00
	Total	- - - - -	"	<u>342.50</u>

S U M M A R Y .

Cost of plant - - - - - \$ 56,166.70
Expense of running - - - - - " 342.50 per day

Profit.

Extraction of Ag - 22.12 oz. X 92.35% ext. = 2042.78 oz.

2042.78 oz. X .6078 = \$1241.60

Receipts per ton - - - - -	\$ 12.42
Cost of operating per ton - - -	" 3.43
Profit - - - - -	" 8.99 per ton

Exclusive of cost of mining, etc.