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INDUSTRIAL HYGIENE SURVEY

PB83-102160

OF

The Hanna Nickel Smelting Company
Riddle, Oregon

SURVEY DATE

December 13-17, 1976

SURVEY CONDUCTED BY

Harry Donaldson
Melvin Cassady
Paul Johnson
Terrance Boyle
Rick Culross

REPORT PREPARED BY

Harry M. Donaldson

DATE OF REPORT

March 21, 1977

Industrial Hygiene Section
Division of Surveillance, Hazard Evaluations and Field Studies
National Institute for Occupational Safety and Health
Cincinnati, Ohio

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PLACE VISITED:

The Hanna Nickel Smelting Company
P. O. Box 85
Riddle, Oregon 97469
Telephone: (503) 874-2211

DATE OF VISIT:

December 13-17, 1976

PERSON(S) CONTACTED:

F. J. Coyle, Division Environmental Engineer
M. J. Doyle, Hanna Mining, Cleveland
Robert Elliott, Safety Engineer
R. Robertson, Division Planning Supt., Riddle
Brad Rabern, Environmental Technician
W. G. Fierke, Personnel
Ernest J. Soderberg, Division Safety Supervisor

NIOSH PERSONNEL PRESENT:

Harry Donaldson
Melvin Cassady
Paul Johnson
Terrence Boyle
Rick Culross

UNION:

United Steel Workers
Union Safety Committee
Rhodes, Roark, Woosley

PURPOSE OF VISIT:

To conduct an industrial hygiene survey of the nickel smelting operations which included the collection of personal samples to determine the potential exposure of personnel to nickel and to free silica.

INTRODUCTION AND GENERAL COMMENTS

A literature search for information on the exposure of industrial populations to various forms of airborne nickel revealed that no data on the exposure of those populations in the United States that smelt nickel ore were documented, though two such operations were known to exist. The smelter operated by the Hanna Nickel Smelting Company located in Riddle, Oregon was chosen as a survey candidate because not only is nickel ore smelted at this location to produce ferro nickel alloy, but because the smelter is supplied with nickel ore from an adjacent mine, the only domestic nickel mine in operation.

The mine and smelter are located on about 600 acres in south west Oregon. The terrain is mountainous, wooded and sparsely populated. The mine which covers about 4000 acres, and has about 100 employees, consists of a mountain of ore of approximately 1.5% nickel in the form of oxide, along with small quantities of cobalt and chromium. The population of the smelter is about 450 at the present time. Of this number, 380 are normally in the production area. There are about 168 people on the day shift with smaller numbers on the other shifts.

The company has an environmental engineer and a technician who make periodic measurements for airborne dusts which are analysed both for nickel and for free silica. Gas analyses are run on baghouse effluents also, and dosimeter measurements are taken on a periodic basis.

The smelter unionized by the United Steel Workers has a formal safety program which consists of four management people, including a Division Safety Supervisor and a Safety Engineer, and a union safety committee consisting of three people which meets periodically with management. The company has a formal respiratory protection program which includes provisions for the repair and cleaning of respirators and also a formal hearing conservation program. These programs require the use of respirators or ear plugs in areas which are either dusty, noisy or both. Respirator and ear plug areas are plainly designated.

Though there is neither a full time nor part time physician on the plant site, there is a doctor on call at the Myrtle Creek Clinic about ten miles away. Though there is no nurse on the plant site, there are employees on each shift with formal first aid training who are designated to provide emergency first aid treatment. It appears that most injuries, however minor, are usually taken to the Myrtle Creek Clinic for treatment.

The company has a preemployment physical examination program which includes a chest x-ray, hearing tests, and lung function tests. A periodic physical examination program is to start in 1977.

The plant accident frequency rate of 48 is high. The corresponding severity rate of 1,105 appears to be lower than would be expected with the high frequency rate. The plant furnishes the employees with the following safety items: hard hats, safety glasses, shoes, gloves, ear plugs and respirators, principally disposable masks as permitted in designated areas of the plant. Facilities for showering and for changing clothes are available.

Concerning housekeeping, in general a smelter is a dusty operation with much dust fallout. In spite of this handicap the housekeeping in this smelter is good. In the plant, dust is removed from the floors by sweeping both with large brooms, a practice which is usually not recommended, and with a motor driven mechanical sweeper. The plant also has a vacuum system which is used to pick up the dust in certain areas which is discharged into a dust collector. Besides the collection of dust for housekeeping purposes, the smelter is equipped with considerable process dust collection capacity in the form of seven large cyclones, nine large bag collectors and two electrostatic precipitators. The latter were installed to meet EPA emission requirements to remove dust from the wet plume coming off the calciners.

PLANT PROCESS

The nickel ore which contains about 1.5% nickel and is over 20% water content is transported from the mine to the smelter where it passes through a drying, crushing, and calcining stage after which it is fused and reacted with molten ferro-silicon. This results in the formation of a ferro-nickel alloy of over 50% nickel. The ferro-silicon is produced by the reduction of quartz with coke and iron turnings in an electric furnace. A detailed flow sheet supplied by the Hanna Nickel Smelting Company is appended.

POTENTIAL HAZARDS

Besides exposure to nickel dust and fume there is a potential airborne exposure of the smelter population to free silica and to traces of airborne cobalt and chromium contained in the ore. Noise is definitely a problem, but this appears to be well controlled by the excellent hearing conservation program to which the company adheres.

AIR SAMPLING METHOD, RESULTS AND DISCUSSION

Eighty-one of 380 employees on four shifts were monitored for airborne exposure to nickel, cobalt, copper, lead and chromium by use of personal samplers. Thirty of these employees were also monitored for respirable free silica, also using personal samplers. The samples to be analysed for nickel and other metals were collected on 0.8µm, 37mm Millipore AA filters by pulling air through a personal pump at the rate of 2.0 liter per minute. For the collection of respirable samples for free silica analysis, a sample assembly consisting of a 10mm nylon cyclone followed by a 5µm pore size, 37mm PVC filter were employed, operating at a flow rate of 1.7 liters per minute.

The results of the 81 samples analyzed indicated that the highest exposure to nickel was 0.420 mg/m³ and the lowest exposure was 0.004 mg/m³. Five samples out of the 81 were above 0.100 mg/m³, and 18 samples were above 0.010 mg/m³ with an average exposure of 0.026 mg/m³.

Analyses for cobalt, copper, lead and chromium all fell between 0.001 mg/m³ and 0.010 mg/m³.

The results of the 30 samples analyzed for respirable free silica showed three samples to be above the current OSHA standard. These were all associated with the ferro-silicon furnace. It is interesting that no samples showed exposures above 0.100 mg/m³ to free silica, and that only 3 samples showed values below 0.050 mg/m³, the NIOSH recommended standard for free silica.

Complete details of monitoring and analytical data are shown in Tables I and II attached.

General air samples collected with personal pumps in nine areas of the plant were analyzed for arsenic. All samples showed less than the detectable limit of 0.1 micrograms.

CONCLUSIONS

The results of the December 1976 industrial hygiene survey of the Hanna Nickel Smelting Company at Riddle, Oregon conducted by NIOSH show that the facility meets the current OSHA standards for exposure to airborne nickel and to respirable free silica. And for all practical purposes it also meets the ACGIH-TLV of 0.100 mg/m³ for nickel.

In light of the fact that this plant has operated for over twenty years, handling insoluble nickel, and since there were no other competing exposures found such as arsenic which would complicate the exposure picture, this facility might be satisfactory for the study of the health effects of personnel exposed to low levels of insoluble nickel.

Hanna Nickel Smelting Company
 Riddle, Oregon
 December 1976
 Analyses for Nickel and other Exposures

TABLE I

Operation	Shift	Sample #	Air Vol m ³	Nickel Mg/Sample	Nickel Mg/m ³	Cobalt Mg/m ³	Copper Mg/m ³	Lead Mg/m ³	Chromium Mg/m ³
Loader Operator	2	H17	0.766	0.004	0.005	0.003	0.001	0.006	0.001
"	1	H69	0.690	0.005	0.007	0.003	0.001	0.007	0.001
Crusher Operator	1	H68	0.830	0.120	0.145	0.002	0.001	0.006	0.004
Dryer Operator	1	H9	0.924	0.014	0.015	0.002	0.001	0.005	0.001
"	2	H2	0.782	0.011	0.014	0.003	0.001	0.006	0.003
Dryer Helper	2	H1	0.780	0.009	0.011	0.003	0.001	0.006	0.001
"	1	H64	0.810	0.021	0.026	0.002	0.001	0.006	0.005
Calciner Operator	2	H15	0.822	0.120	0.146	0.002	0.001	0.006	0.004
"	1	H70	0.840	0.096	0.114	0.002	0.001	0.006	0.004
Calciner Helper	2	H18	0.832	0.052	0.063	0.002	0.001	0.006	0.002
"	1	H63	0.840	0.031	0.037	0.002	0.001	0.006	0.001
Skull Driller	2	H82	0.928	0.007	0.007	0.002	0.001	0.005	0.001
"	2	H84	0.896	0.009	0.010	0.002	0.001	0.006	0.001
"	2	H87	0.898	0.022	0.025	0.002	0.001	0.006	0.002
"	2	H90	0.902	0.005	0.006	0.002	0.001	0.006	0.002
"	2	H10	0.726	0.003	0.004	0.003	0.001	0.007	0.001
"	2	H24	0.708	0.005	0.007	0.002	0.001	0.007	0.001
"	2	H25	0.720	0.018	0.024	0.002	0.001	0.007	0.001
"	2	H92	0.898	0.039	0.043	0.002	0.001	0.006	0.002
Stacker Operator Fe-Si	2	H4	0.986	0.017	0.017	0.002	0.001	0.005	0.001
Crusher Operator	2	H26	0.744	0.018	0.024	0.003	0.001	0.007	0.003
"	2	H6	0.754	0.049	0.065	0.003	0.001	0.007	0.003
Loader Operator	2	H5	0.744	0.013	0.017	0.003	0.001	0.007	0.003
Furnace Charger	2	H12	0.738	0.005	0.007	0.003	0.001	0.007	0.001
"	2	H20	0.748	0.020	0.027	0.003	0.001	0.007	0.003
"	2	H78	0.882	0.026	0.029	0.002	0.002	0.006	0.001
Furnace Feeder	1	H51	0.820	0.007	0.009	0.002	0.001	0.006	0.001
"	2	H95	0.796	0.017	0.214	0.002	0.001	0.006	0.001
Furnace Tapper	2	H22	0.746	0.003	0.004	0.003	0.001	0.007	0.001
"	2	H76	0.868	0.017	0.020	0.002	0.001	0.006	0.002
Furnace Tapper (Helper)	2	H83	0.866	0.010	0.016	0.002	0.001	0.006	0.001

TABLE I
(Continued)

Operation	Shift	Sample #	Air Vol m ³	Nickel Mg/Sample	Nickel Mg/m ³	Cobalt Mg/m ³	Copper Mg/m ³	Load Mg/m ³	Chromium Mg/m ³
Furnace Operation Fe-Si	2	H16	0.750	0.005	0.007	0.003	0.001	0.007	0.001
" "	1	H93	0.878	0.017	0.019	0.002	0.001	0.006	0.001
" "	2	H60	0.626	0.005	0.008	0.003	0.002	0.008	0.002
Melter Smelter Helper	2	H42	0.704	0.003	0.004	0.003	0.001	0.007	0.001
" "	1	H7	0.700	0.003	0.004	0.003	0.001	0.007	0.001
" "	2	H99	0.902	0.005	0.005	0.002	0.001	0.006	0.001
Smelter Helper (Belt)	1	H44	0.660	0.003	0.005	0.003	0.001	0.007	0.001
" "	2	H100	0.136	0.003	0.022	0.002	0.007	0.004	0.007
Crane Operator	1	H11	0.790	0.004	0.005	0.002	0.001	0.006	0.002
Crane Chaser	1	H32	0.710	0.003	0.004	0.003	0.001	0.007	0.001
" "	2	H98	0.900	0.006	0.007	0.002	0.001	0.005	0.001
Slag Handler	1	H14	0.680	0.004	0.006	0.003	0.001	0.007	0.003
" "	2	H79	0.902	0.007	0.008	0.002	0.001	0.005	0.003
Mixer Operator	1	H34	0.806	0.003	0.004	0.002	0.001	0.006	0.001
" "	1	H37	0.820	0.003	0.004	0.002	0.001	0.006	0.001
" "	2	H38	0.818	0.003	0.004	0.002	0.001	0.006	0.001
" "	1	H57	0.818	0.003	0.004	0.002	0.001	0.006	0.001
" "	2	H61	0.796	0.003	0.004	0.002	0.001	0.006	0.001
" "	1	H71	0.820	0.003	0.004	0.002	0.001	0.006	0.001
" "	2	H47	0.790	0.003	0.004	0.002	0.001	0.006	0.001
Ladel Mixer Operator	2	H27	0.700	0.006	0.009	0.003	0.001	0.007	0.001
Refinery Furnace Operator	1	H55	0.820	0.005	0.006	0.002	0.001	0.006	0.001
" "	1	H49	0.670	0.023	0.034	0.003	0.001	0.007	0.001
" "	2	H96	0.926	0.010	0.018	0.002	0.001	0.005	0.001
Refinery Furnace Helper	2	H21	0.708	0.006	0.009	0.003	0.001	0.007	0.003
" "	2	H23	0.708	0.003	0.004	0.003	0.001	0.007	0.003
" "	2	H29	0.710	0.002	0.004	0.003	0.001	0.007	0.001
" "	2	H36	0.820	0.003	0.004	0.002	0.001	0.006	0.001
" "	2	H94	0.930	0.004	0.004	0.002	0.001	0.005	0.001
" "	2	H101	0.928	0.009	0.010	0.002	0.001	0.005	0.001
" "	2	H19	0.748	0.006	0.008	0.003	0.001	0.007	0.001
Tapper Helper	1	H31	0.800	0.003	0.004	0.002	0.001	0.006	0.001
Pig Dock Leadman	1	H13	0.766	0.004	0.005	0.003	0.001	0.007	0.001
" " Stacker									

TABLE I

(Continued)

Operation	Shift	Sample #	Air Vol m ³	Nickel Mg/Sample	Nickel Mg/m ³	Cobalt Mg/m ³	Copper Mg/m ³	Lead Mg/m ³	Chromium Mg/m ³
Pig Deck Stacker	1	H66	0.790	0.007	0.009	0.003	0.001	0.006	0.001
Fork Lift Operator Pig Deck	1	H39	0.804	0.003	0.004	0.002	0.001	0.013	0.001
" "	1	H45	0.700	0.003	0.004	0.003	0.001	0.007	0.001
Pig Deck-Laborer	1	H48	0.760	0.006	0.008	0.003	0.001	0.006	0.001
Welder	1	H88	0.710	0.013	0.018	0.003	0.010	0.007	0.008
Can Welder	1	H35	0.664	0.039	0.059	0.003	0.001	0.007	0.003
" "	1	H30	0.648	0.026	0.041	0.003	0.001	0.007	0.003
" "	1	H62							
Millwright Welder	1	H40	0.700	0.013	0.019	0.003	0.014	0.007	0.007
Millwright Oiler	1	H52	0.836	0.006	0.007	0.002	0.001	0.006	0.002
" "	1	H56	0.830	0.006	0.007	0.002	0.001	0.006	0.002
Millwright	1	H46	0.700	0.009	0.013	0.003	0.003	0.007	0.006
Machinist	1	H43	0.700	0.011	0.016	0.003	0.003	0.007	0.006
Utility Man	1	H50	0.790	0.006	0.008	0.002	0.001	0.006	0.001
Plant Clean-up Man	1	H8	0.690	0.290	0.420-	0.007	0.006	0.007	0.011
Sweeper Operator	1	H33	0.800	0.120	0.150-	0.002	0.001	0.006	0.001
OSHA Standard					<u>Mg/m³</u>	<u>Mg/m³</u>	<u>Mg/m³</u>	<u>Mg/m³</u>	<u>Mg/m³</u>
ACGIH-TLV					1.0	0.1	1.0	0.2	1.0
					0.1	0.1	1.0	0.15	0.5

Hanna Nickel Smelting Co.
 Riddle, Oregon
 December 1976
 Analyses for Respirable Free Silica Exposure

TABLE II

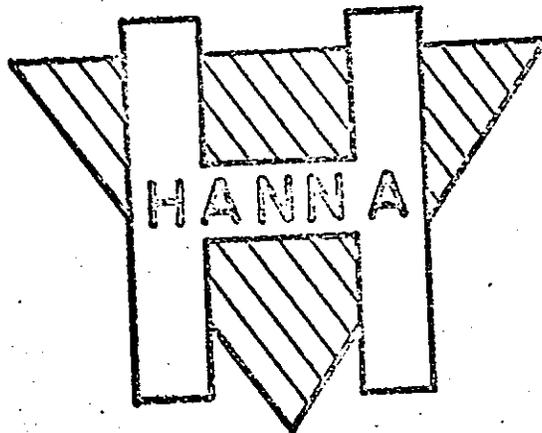
Operation	Shift	Filter #	wt. of Dust Mg	Free Silica		Vol. of Air M ³	Mg Dust M ³	TLV = 10 %SiO ₂ +2	Mg SiO ₂ M ³	% TLV
				%	Mg					
Stacker Operator	1	2194	0.022	-	<40	0.822	-	-	-	-
Dryer Operator	1	2174	0.254	15.7	<40	0.788	0.322	0.565	51	57
Dryer Helper	1	2161	0.265	15.1	<40	0.810	0.326	0.685	49-	48
Calciner Operator	1	2201	0.487	8.2	<40	0.800	0.610	0.980	50	62
Calciner Helper	1	2165	0.773	6.5	50	0.773	1.000	1.170	65	85
Skull Plant Operator	1	2180	0.279	21.6	60	0.876	0.318	0.425	68	75
Skull Plant Helper	1	2185	0.194	21.6	40	0.906	0.214	0.425	44-	50
# 1 Skull Driller	1	2188	0.252	15.8	40	0.760	0.332	0.564	53	59
# 2 Skull Driller	1	2173	0.376	10.6	<40	0.770	0.490	0.795	52	62
Fe-Si Furnace Operator	1	2181	0.679	5.9	<40	0.742	0.915	1.270	54	72
Fe-Si Charger	1	2176	1.402	4.2	60	0.730	19.02	1.610	82	118
Fe-Si Furnace Feeder	2	2179	0.117	34.2	<40	0.792	0.148	0.276	51	54
Fe-Si Furnace Feeder	2	2212	0.172	23.2	40	0.780	0.221	0.397	51	56
Fe-Si Tapper	1	2211	0.482	8.3	40	0.900	0.535	0.970	45-	55
Fe-Si Tapper-Helper	1	2202	0.911	7.7	70	0.744	1.230	1.030	94	120
Fe-Si Crusher	1	2207	0.572	12.2	70	0.750	0.760	0.705	93	108
Crane Operator	1	2177	0.269	14.8	<40	0.790	0.340	0.959	51	57
Crane Operator	2	2166	0.374	10.7	<40	0.808	0.463	0.790	50	59
Crane Chaser	1	2172	0.165	24.2	<40	0.744	0.222	0.380	54	58
Smelting Operator	2	2168	0.096	42.0	<40	0.796	0.113	0.230	50	49
Smelter Helper	2	2175	0.151	26.4	<40	0.724	0.208	0.352	55	59
Mixer Operator	2	2162	0.179	22.4	<40	0.780	0.229	0.410	51	56
Mixer Operator	2	2190	0.129	31.0	<40	0.782	0.165	0.303	51	55
Mixer Operator	2	2208	0.286	14.0	40	0.786	0.364	0.625	51	58
Mixer Operator	2	2210	0.244	16.4	40	0.798	0.305	0.550	50	65
Slag Handler	2	2171	0.245	16.3	<40	0.746	0.329	0.554	54	59
Refining Furnace Oper.	2	2209	0.219	18.2	40	0.754	0.286	0.490	53	58
Refining Furnace 1st Helper	1	2169	0.245	22.0	50	0.844	0.290	0.416	59	70
Refining Furnaces 2nd Helper	1	2189	0.378	13.2	50	0.734	0.513	0.659	68	78
Pig Machine Operator	1	2206	0.231	26.0	60	0.738	0.314	0.358	82	88

Hanna Nickel Smelting Company
Job Dictionary

Stacker Operator	- Operates ore stacker
Loader Operator	- Loads ore onto trucks
Crusher Operator	- Operates crushing and sampling systems to screen, reject, sample, crush, and store ore
Dryer Operator	- Operates rotary dryers
Dryer Helper	- Assists in the operation of rotary dryers
Calciner Operator	- Operates calcining kilns
Calciner Helper	- Assists the calcining operator
Skull Driller	- Operates skull drill to clean ladles
Stacker Operator Fe-Si	- Feeds ferro-silicon furnace
Crusher Operator Fe-Si	- Breaks up ferro-silicon
Furnace Charger Fe-Si	- Charges electric furnace with materials to produce ferro-silicon
Furnace Feeder Fe-Si	- Keeps changing bins full of ferro-silicon materials
Furnace Tapper Fe-Si	- To tap electric furnace in production of ferro-silicon
Tapper Helper	- Assists tappers in his duties in the production of ferro-silicon
Furnace Operator Fe-Si	- Operates ferro-silicon furnace
Melten Smelter Helper	- Tends, inspects and helps to maintain slag belts
Smelter Helper (belt)	- Tends, inspects and helps to maintain slag belts
Crane Operator	- Operates overhead crane
Crane Chaser	- Hooks for overhead crane and directs operator to prepare destination
Slag Handler	- Operates slag granulator
Mixer Operator (ladle Mixer operator)	- Pours melting furnace and operates the ladle mixer
Refinery Furnace Operator	- Operates two refining furnaces in the refining and casting of ferro nickel
Refinery Furnace Helper	- Assists the operator
Pig Dock Leadman	- Directs lift truck operator and pig deck laborers in the handling, shipping or storing of ferro-nickel pigs
Fork Lift Operator Pig Deck	- Operates fork lift truck
Pig Dock Stacker-Laborer	- Stacks ferro-nickel pigs and related duties
Welder	- Does welding

Can Welder	- Welds cans
Millwright Welder	- Does maintenance welding
Millwright Oiler	- Oils machinery
Millwright	- Repairs machinery
Machinist	- Lays out work and operates machine tools
Utility Man	- Does miscellaneous jobs as directed
Plant Clean-up Man	- Sweeps and cleans floors in the plant
Sweeper Operator	- Operates mechanical sweeper

THE HANNA NICKEL OPERATION



THE HANNA MINING COMPANY
HANNA NICKEL SMELTING COMPANY

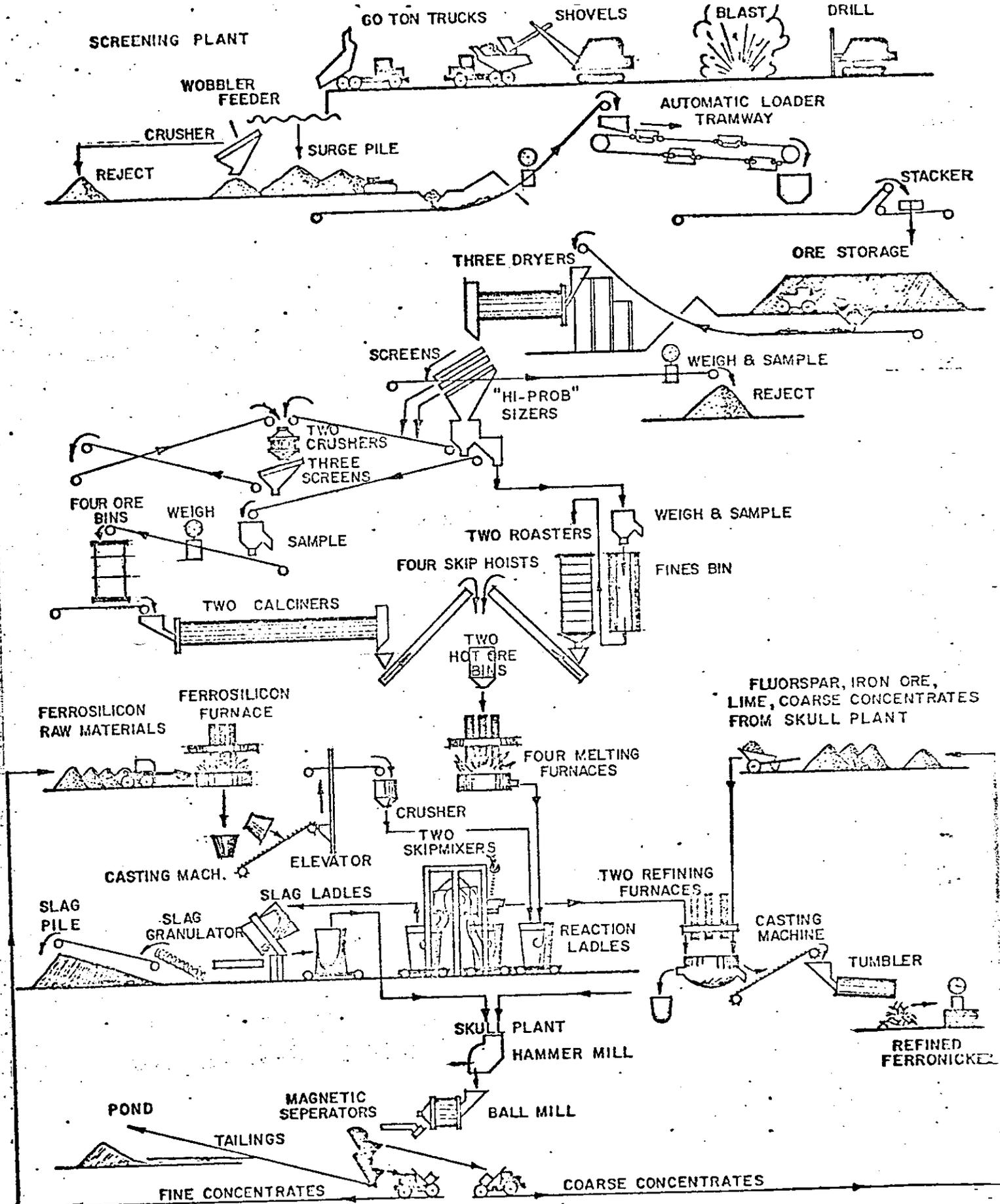
RIDDLE, OREGON

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SEPT. 1, 1974

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FLOW DIAGRAM
11

THE HANNA MINING COMPANY
HANNA NICKEL SMELTING COMPANY

THE HANNA NICKEL OPERATION

Nickel Mountain is located in Southwestern Douglas County, Oregon, four miles West of the town of Riddle. The deposit was discovered in 1864 by local settlers, but it was not until 1881 that the ore was recognized to be nickel silicate rather than copper carbonate as originally assumed. Subsequent to 1881, much prospecting and preliminary development work was done, but no ore was processed for other than metallurgical tests until the present mining operation began.

The Hanna Mining Company and Hanna Nickel Smelting Company began production of ferronickel, the first to be produced in the United States from domestic ores, in July of 1954. The companies have operated on an around-the-clock schedule since that time and provide steady, year around work for approximately 500 employees.

MINE

Geology

The deposit is made up of five major areas covering approximately 600 acres. Mineralization occurs in a sheared and altered peridotite, and, in many cases, consists of finely divided veinlets in a chalcedony boxwork. Several nickel minerals are found with garnierite, a complex magnesium silicate of nickel, being most easily recognized. Chromium, cobalt and aluminum occur in very minor amounts. Iron oxides, magnesia and silica make up the major constituents of the ore. Average nickel grade in the crude ore presently under active development is approximately 1.2%.

Grade Control

Nickel content of ore delivered to the smelter stockpile must be maintained as uniform as possible to produce optimum metallurgical results. This is somewhat difficult due to the wide, inconsistent variations in nickel content throughout the deposit. Twenty foot bench heights, narrow shovel cuts, bank samples, drill hole samples, geologic interpretations, and visual classification, combined with widely spaced daily cuts, make up the grade control pattern.

Development

Open cut mining methods are utilized. The topography is ideal for the development of level mining benches at twenty foot vertical intervals. This interval was chosen for grade control purposes. Benches are a minimum fifty foot width and extend to the limits of the deposit. Main haulage roads, sixty feet wide, traverse the area at a ten percent maximum grade and intersect the mining benches at intervals controlled by the maximum haul on level benches.

Mining and Hauling

Much of the ore can be dug without blasting. When this is necessary, however, a 6-1/2" down-hole drill is used. Ammonium nitrate-fuel oil is the blasting agent.

Loading is accomplished with 3-1/2 and 5-1/2 cubic yard diesel shovels. Large residual boulders, called pit reject, are separated from the ore by the shovel operator and ultimately deposited on waste dumps. The ore is loaded into 60-ton diesel trucks and hauled to the screening plant. Waste and lean ore stripping are deposited on separate dumps.

Screening and Crushing

The ore is deposited directly into the screening plant feed hopper. A separation is made on a wobbler feeder and scalping screens with the minus 5-1/2 inch product going directly to the tramway surge pile and the plus 5-1/2 inch to the crusher. Crushed material is visually classified and directed to the ore product or the reject stockpile. After screening and crushing, the ore product is deposited in a 12,000 ton tramway surge pile.

Tramway

From the surge pile, the ore is fed to the tramway loading terminal where it is loaded automatically into 50 cubic foot tram cars. It is conveyed downhill to the smelter storage stockpile at a maximum rate of 300 short tons per hour.

The tramway runs continuously, carrying ore in the upright tram cars on the upper pair of suspended track cables and returning empty in an inverted position on the lower pair of track cables. Ore is loaded automatically and discharged by inverting the cars at the lower discharge terminal, where it is bedded in the smelter stockpile by an overhead belt conveyor and traveling wing tripper.

A speed of 600 feet per minute is maintained by two 300 horsepower induction generators driven by the loaded tram cars through a gripwheel and gear train in the loading terminal. The braking action of the generators produces approximately 500 horsepower which is used in the operation of the mine facilities.

The tramway is 8,300 feet long and drops a vertical distance of 2,000 feet in its length.

SMELTER

Ore from the stockpile is processed at the smelter to produce ferronickel containing approximately 50% nickel. Steps in the process include reclaiming of ore, drying, fines screening, rejection of lean rock by screening, crushing, sampling, calcining, melting, reducing to ferronickel, refining, casting, and skull metallics recovery.

Ore Preparation

Ore is reclaimed from the stockpile by rubber-tired front end loaders and is conveyed to the dryers where the moisture content is lowered from an average of 21% to 3-5% in three concurrent fired rotary dryers. The dryers are heated by hogged fuel waste wood product from local sawmills. Natural gas or diesel auxiliary burners are installed for use in case sufficient hogged fuel is not available.

After drying, the ore is conveyed to the screening, crushing, and sampling plant, where the coarse, low grade rock is rejected from the top deck of a double-deck screen. The ore remaining on the second deck of the screen, normally -1-1/4" +5/16" is processed in the intermediate screening circuit. The -5/16" ore passes through Hi-Prob crushers where fines are removed and sent to a storage bin. The intermediate circuit consists of two stages of crushing and screening product which is conveyed to storage bins. Both fine and coarse ore is sampled and weighed before going to storage.

From the storage bins, the coarse ore (-5/16" +20 mesh) is fed to two natural gas or Bunker "C" fired rotary calciners, while the fines are fed to two natural gas or diesel fired multiple hearth roasters. To the feed of both calciners and roasters, sawdust is added as a prereductant to convert approximately three-quarters of the trivalent iron contained in the ore to the divalent state.

After calcining to approximately 1300 degrees Fahrenheit, the ore discharged from both the calciners and roasters is transported by automatic skips to hot ore bins above four electric melting furnaces in the smelter building. Skips, transfer chutes and bins are insulated to conserve the heat in the calcined ore.

Melting and Reduction

The ore is charged to the melting furnaces by gravity and heated to a temperature of 2900 to 3000 degrees Fahrenheit. Molten ore is poured from the melting furnaces into ladles for the reduction process.

Reduction of nickel and iron is accomplished by the Uginé Process, which consists of adding a reducing agent containing metallic silicon to an oxide ore in the presence of molten ferrous metals and using vigorous mixing action for good contact of reductant and ore. In Hanna's smelter, crushed ferrosilicon containing 48% silicon is used as the reductant, the ferrosilicon being produced in a separate electric furnace in the smelter. After the vigorous mixing cycle, the ferronickel is allowed to settle to the bottom of the ladle. The slag is skimmed off

and granulated with high pressure water jets.

Refining

As the reducing reactions continue, ferronickel accumulates in the ladle. At regular intervals, a portion of this product is removed, or "thieved", and transported to one of two identical small electric steel furnaces. Here the impurities, predominantly phosphorous, are removed by suitable refining slags, after which the ferronickel is cast into pigs weighing approximately 28 pounds.

Samples from each cast are taken for complete chemical analysis and an accurate record of all casts is available for consumers. The ferro-nickel pigs are packaged on 4,000 pound pallets, with the exact weight and analysis stamped on each pallet. It has proven to be a very desirable product for the major stainless steel manufacturers of the United States.

ENVIRONMENTAL CONTROL

Air

Control of dust emissions from the plant was recognized as a substantial technological problem during the initial design phase prior to 1954 because of the nature of the ore to be handled. In 1957, when the plant was operating at the full capacity envisioned in the original design concept, it was recognized that the air quality control equipment originally installed could not produce a high enough dust collection efficiency to be acceptable. In 1958, cloth type dust filters which were then considered the best possible equipment available, were installed on the melting furnaces, crusher house and storage bins. Electrostatic precipitators were installed on the calciner and wet scrubbers on the dryers and FeSi furnace. This equipment operated at 98.3% efficiency.

In 1970, new State air quality standards again made it necessary to upgrade the system efficiency to 99.8%.

The installation of large cloth dust filters on the crusher house, ore melting furnaces, and ferrosilicon furnace, handling a total of 720,000 actual cubic feet of gas per minute, was required. Improvement to existing equipment on the calciners, roasters, dryers, and storage bins were made. Cloth filter units from the 1958 ore melting furnace installation were adapted to the refining furnaces and skiphoist units. The system was completed in July, 1974, and now meets State air quality standards.

Water

In 1958, a system of large settling ponds was constructed and this system controls the effluent from the smelter and a portion of the mine run-off through the Rail Creek drainage. This system has operated efficiently and the effluent exceeds the State water quality requirements in effect today. The company holds a state water discharge permit.