No. 1871

REFINERY AND ROLLING MILL FOR MONEL METAL, HUNTINGTON, W. VA.

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This paper describes in detail the steps taken in selecting the site for the location of a mill for rolling monel metal. The economic problems involved are stated and the facts leading to their solution are given. The remainder of the paper deals with the layout of the plant, emphasizing some features of design that are of particular interest.

Monel metal consists of 67 per cent nickel, 28 per cent copper, and 5 per cent other elements, and is a natural alloy. In appearance it resembles nickel and in tensile strength it is comparable with steel, while its resistance to corrosion is very high. Its resistance to acids together with its physical and working qualities (for it can be cut, rolled, welded, machined, and forged) makes a combination of properties which are not to be found in other common metals.

2 Monel metal is produced at the refinery in shot, pig, and ingot from monel-metal bessemer matte, consisting of approximately 56 per cent nickel, 24 per cent copper, and 20 per cent sulphur, the iron contents being only about 0.4 per cent. The mill product consists of forgings, merchant and sheet bars, wire rod in coils, and sheets.

3 The International Nickel Company, in order to provide facilities for the increased requirements of monel metal, has recently completed a refinery and rolling mill at Huntington, W. Va. The project may be considered as a new industry; active development of markets for monel metal having only been undertaken during the last few years, during which requirements have been met by arrangements with various steel mills for production of the

Presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers.
above-mentioned products from ingots supplied from the Bayonne refinery of The International Nickel Company.

4 The purpose of this paper is to describe the investigation leading to the location of these works together with certain features of their designs and construction and to give information on the products manufactured, all of which is believed to be of general interest to engineers and manufacturers.

5 A general survey of requirements in order to prepare preliminary plans, and estimate the costs and acreage necessary, was first made, and involved the following:

a Analysis of past volume of business — sizes, forms and quality

b Estimate of potential markets
Schedule showing minimum number of furnaces, mills and general equipment necessary to meet present requirements and those of the near future

Flow sheet and general plans, Figs. 1 and 2, utilizing the above information and for the purpose of deciding on the number, size, and relative location of buildings and amount of equipment, in order that an estimate of construction costs may be prepared

Estimate of operating costs which, together with capital requirements, is necessary in order to compare the cost of rolling monel metal by contract with steel mills of large tonnage capacity with that of a specialty mill of relatively small tonnage capacity

Discussion of quality of product to be expected from specialty mill under the company's control, as compared with contract arrangements.

CONCLUSIONS OF SURVEY

6 As a result of the survey outlined the following conclusions were reached:

a That existing and prospective business for monel metal justified the estimated capital expenditure of approximately $3,000,000 for a rolling mill to produce rods and sheets

b That the potential markets for monel metal and other alloys were such that the plant should be laid out with provision for considerable expansion

c That natural gas, being practically free from sulphur, is the ideal fuel for heating purposes. Should it be necessary to utilize producer gas, the estimated capital expenditure for plant and equipment would be increased approximately by $200,000

d That the particular disposition and service of the merchant and sheet mills was such that individual electric drive, with gear reduction where necessary, would be best

e That purchased electric power was preferable, and if not available capital expenditure would be increased by approximately $750,000
That at least twenty, and preferably up to fifty, acres were advisable for a site.

INVESTIGATION REGARDING LOCATION FOR WORKS

With the survey of requirements and the conclusions available, the following districts were given particular study: Bayonne, N. J., Buffalo, N. Y., Baltimore, Md., Pittsburgh, Pa., and Huntington, W. Va.

Although the ores and bessemer matte from which monel metal is produced come from The International Nickel Company's mines and smelter in the Sudbury District of Ontario, Canada, and there had within a few years been constructed by the company a refinery for nickel products at Port Colborne, Ontario, economic factors such as tariff, fuel, markets for finished products, etc., were such as to confine the detailed study of locations for these new works to the eastern half of the United States.

Fig. 3 represents the territory and principal railroads which serve customers and prospective markets for refinery and mill products, including good facilities for export shipment. This territory covers the intensive manufacturing districts of the United States, with Chicago and St. Louis in the West, and New York and Philadelphia in the East, and it will be noted that Huntington, W. Va., occupies a geographic position central to the territory, and is also in close proximity to extensive natural resources, among which coal, oil and natural gas are the most important.

Bayonne, N. J., was considered, as The International Nickel Company's largest refinery had been established there many years, and it was thought the rolling mill might be an addition to the existing works. The investigation resulted, however, in the Bayonne refinery being discontinued and the plant dismantled. Important changes and extensions have therefore been made at the Port Colborne refinery so that nickel in all forms can be refined in Canada, and the refinery with rolling mill has been constructed at Huntington, W. Va., for the production of monel metal, malleable nickel, and other specialties.
Fig. 3 Map Showing Railroad and Major Industrial Portion of the United States

REFINERY AND ROLLING MILL FOR MONEL METAL
The following is a schedule of economic factors investigated:

<table>
<thead>
<tr>
<th>Labor</th>
<th>Skilled</th>
<th>Common</th>
<th>Type</th>
<th>Supply</th>
<th>Rates</th>
<th>Strikes</th>
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<tbody>
<tr>
<td>Fuels</td>
<td>Metallurgical</td>
<td>Power Generation</td>
<td>Cost and Quality</td>
<td>Oil</td>
<td>Producer gas</td>
<td>Natural gas</td>
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<td>Power</td>
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<td>Costs</td>
<td>Service</td>
<td></td>
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<tr>
<td>Living Conditions</td>
<td>Housing</td>
<td>Cost of Living</td>
<td>Sanitation and Health</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Climate</td>
<td>Minimum and Maximum Average Temperatures</td>
<td>Average Snowfall</td>
<td>Average Rainfall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>Railroads</td>
<td>Water</td>
<td>Sources and Costs of Supplies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Matte</td>
<td>Refractories</td>
<td>Rolls, Castings and</td>
<td>Mill Spares</td>
<td>Sheet Bars</td>
<td>Charcoal</td>
</tr>
<tr>
<td></td>
<td>Products, Distribution of</td>
<td></td>
<td></td>
<td>Monel and</td>
<td>Nickel Shot, Pig, Sheet</td>
<td>Domestic</td>
</tr>
<tr>
<td>Water Supply</td>
<td>Service</td>
<td>Costs</td>
<td>Quality</td>
<td>Rod, Wire</td>
<td>Rod, Forging</td>
<td></td>
</tr>
<tr>
<td>Taxes and Laws</td>
<td>State</td>
<td>Local</td>
<td></td>
<td></td>
<td></td>
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The following represent the comparative ratings given to the economic factors:

<table>
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<th>Factor</th>
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<tr>
<td>Power</td>
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<td>Living conditions</td>
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<td>Transportation</td>
<td>50</td>
</tr>
<tr>
<td>Water supply</td>
<td>10</td>
</tr>
<tr>
<td>Climate</td>
<td>50</td>
</tr>
<tr>
<td>Supplies</td>
<td>60</td>
</tr>
<tr>
<td>Taxes and laws</td>
<td>20</td>
</tr>
<tr>
<td>Site (cost and quality)</td>
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<tr>
<td>Construction cost</td>
<td>20</td>
</tr>
</tbody>
</table>

The comparative ratings given economic factors for the principal locations studied are as follows, and were made during the latter portion of 1920:

<table>
<thead>
<tr>
<th>Locations</th>
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<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<td>60</td>
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<tr>
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<td>85</td>
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<tr>
<td>Taxes and laws</td>
<td>100</td>
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<td>80</td>
</tr>
<tr>
<td>Site (cost and quality)</td>
<td>100</td>
<td>75</td>
<td>80</td>
<td>80</td>
<td>70</td>
</tr>
</tbody>
</table>

The following general conditions apply to the district of Huntington, W. Va., which are considered especially suitable for the industry described:

Labor. Labor is made up of 95 per cent English-speaking Americans, both common and skilled, with good records
in the territory in diversified industries; the turnover is light and a
majority of the workers own their homes.

16 **Fuels.** A plentiful supply of natural gas for manufacturing and
domestic purposes, from public-utility companies, is available at a
cost of from 18 to 19 cents per 1000 cu. ft. (1100 B.t.u.
per cu. ft.) Investigation of developed and undeveloped gas fields
indicates supply of gas for 15 to 20 years. A good supply of high-
grade oil of low sulphur content is available from the local oil
refinery at a present price of 5 to 6 cents per gallon delivered at
plant. There is an excellent supply of high-grade bituminous
steam and gas coals from local coal fields costing $2.50 to $3.00
per ton, delivered at the plant.

17 **Power.** Two modern central stations supply power at a
cost to large industries of 11 to 12 mills per kw-hr.

18 **Transportation.** Thirteen important railroads make con-
nections within 175 miles. The Ohio River is navigable all the
year, traffic between Pittsburgh, Huntington, and Cincinnati being
on regular schedule.

19 **Water.** Both river and borehole water of good quality
are available, the latter at an average depth of 60 ft.

20 **Climate.** The climate is equable, with generally cool
nights and little snowfall.

21 **Supplies.** Refractories, charcoal, castings, and steel are
obtainable in the district.

22 **Taxes and Laws.** These compare favorably with those
of other districts. There are no smoke laws in West Virginia.

23 **Site.** A site of 76 acres was procured just outside the
present city boundary of Huntington and directly connected to the
Chesapeake & Ohio Railroad, and will be similarly connected with
the Baltimore & Ohio Railroad when extensions now planned are
completed. The site is also on the Guyan River and within about
a mile of its junction with the Ohio River. The topography of
about ten acres of the seventy-six is ideal for use as a gravity
slag dump. Flood conditions in the Ohio Valley were studied and
records for about forty years analyzed, which showed that only on
two occasions—the last being the 1913 flood—has flood water
been sufficiently high to endanger to a small extent property at the
elevation of the site selected. The ground for foundations is ex-
cellent, being solid clay for a depth of from 12 to 18 ft., under-
neath which is a stratum of coarse, compact sand. The location
was sufficiently close to Huntington, which is a growing city of
about 65,000 inhabitants, to obviate the necessity of the company building homes for officials or workmen. Housing conditions are not at this time very satisfactory, being similar to conditions in other prosperous communities, and rents and costs of houses will undoubtedly be reduced as building catches up with the requirements.

CRUSHING, GRINDING, AND CALCINING DEPARTMENTS

24 The matte, which is received from the company's smelter in Canada in irregular pieces weighing about 50 lb., is unloaded from box cars and put through a 24-in. by 16-in. jaw crusher, being reduced to about 1 1/2-in. product, and is then fed to a No. 8 Krupp-type ball mill to be further reduced by dry grinding to pass a 16-mesh. The crusher and mill capacity is about 45 tons in eight hours, so that with the installation of a large storage bin with seven days' capacity for ground matte, this equipment can be operated intermittently to suit the convenience and arrival of cars of raw material. The crusher, ball mill, and elevators connecting them with each other and with the bin are belt-driven through a lineshaft by a 125-hp. 900-r.p.m. 3-phase high-torque squirrel-cage motor. There are two large flywheels on the crusher, and with regular loading of the ball mill, which is checked by a recording meter, this 125-hp. motor carries the load efficiently.

25 The ground matte is then introduced by mechanical feeders to roasting furnaces, of which there are three, the material being handled between the bins and the furnaces by 2-ton-capacity electric traveling monorail trolley hoists. The telpher has a hook lift of 30 ft., a hoisting speed of 20 ft. to 50 ft. per min., a traveling speed of 300 ft. to 350 ft. per min., and operates on a 12-in. I-beam connected directly to the lower chords of the roof trusses.

26 The roasting furnaces are horizontal, 80 ft. long by 17 ft. wide, and are of a modified Edwards type, the material being moved along the hearth by 32 rabbles operated by mechanical chain and gear transmission and mounted directly over each furnace. These rabbles are of cast iron with monel-metal shoes, and are hollow, being designed especially for efficient water cooling. Natural gas is used as fuel for these furnaces, the capacity of each being about 25,000 lb. per 24 hr., the sulphur in the material being reduced from 20 per cent to 0.005 per cent. The mechanism for each furnace is operated by a 5-hp. 220-volt 900-r.p.m. back-geared motor.
The temperature under which roasting is accomplished varies from 2000 deg. fahr. to 500 deg. fahr. The roasted matte is discharged from the furnace by gravity into large buckets, ground charcoal being mixed with the hot material as it is discharged so that its reduction takes place from the time it leaves the roasting furnace.

27 Large flues with numerous baffles, facilitating the recovery of valuable dust, were given special attention in these furnaces, these connecting with a chimney 200 ft. high and 8 ft. in internal diameter at the top.

28 Large quantities of charcoal are used, so in this department there is provided as an extension a brick building for the storage of charcoal. The charcoal is handled from railroad car to storage bin by a skip hoist driven by a 6-hp. d.c. motor with a Dinkey controller, which provides dynamic breaking. Charcoal is procured locally in irregular sticks and after passing over a conveyor provided with a magnetic pulley to extract any stray metallic substances is delivered to a gyratory crusher, driven by a 10-hp. 220-volt 900-r.p.m. motor, to be pulverized to about $\frac{1}{4}$-in. size. A bin for the storage of crushed charcoal is provided, but the capacity is not large as it is inadvisable, due to the possibility of spontaneous combustion, to store this material in large quantities in ground form. There are also dangers of spontaneous combustion in storage in crude form, and bins of fireproof construction are subdivided to reduce the fire hazard.

29 The cooling of the furnace rabbles takes about 100 gal. of water per min., the temperature being raised to 160 deg. fahr., which heat is utilized by pumping the water to the boiler-feedwater storage system of the auxiliary power plant.

THE REFINERY

30 The refinery department contains two open-hearth furnaces arranged for firing by either natural gas or oil. The capacity of each furnace is approximately 35,000 lb. per day.

31 The electric traveling monorail-trolley hoist system already referred to operates between the calciner and the refinery departments, delivering the roasted monel-metal oxide from the calciner furnaces directly to large feed hoppers mounted over the open-hearth furnaces. The telsphere also delivers to the same feed hoppers ground charcoal from the crushing and grinding department and amounting to approximately 25 per cent of the furnace
charge by weight. High-grade refractories are used in the construction of these furnaces owing to the high temperatures necessary, the tapping temperature being about 2822 deg. fahr. The heat utilized in furnaces of this type does not exceed 15 per cent of the value of the fuel, and a 600-hp. boiler of the waste-heat type, with superheater, is connected as close as practicable to each furnace, Fig. 4. The steam generated is used by the steam hammers and in the auxiliary power house, the latter being an extension of the refinery in which are installed two 750-kw. turbo-alternators.

32 The waste-heat boilers (6-drum type) were reconstructed from boilers of the 4-drum type formerly at the Bayonne Refinery, Fig. 5. The new installations have induced-draft fans of steel-plate construction with shafts of monel metal. Each fan is direct-
connected to a 30-hp. 600-r.p.m. a.c. motor. The auxiliary power generated will cost approximately 4 mills per kw-hr.

33 There are at the side of each open-hearth furnace specially designed tanks used when making monel metal in shot form. This

![Diagram](image)

**Fig. 5 Sectional Elevation of Waste-Heat Boilers Formerly Used at the Bayonne, N. J., Refinery**

is accomplished by using a movable tapping spout and directing the stream of metal into water. There are also two electric furnaces, one known as the Moore, having a normal capacity of three tons per heat, and the other a Heroult, with a normal capacity of
seven tons per heat. These furnaces are installed side by side and operated from a common charge floor 12 ft. above the main floor, the space below being subdivided for transformers, auxiliary electric equipment, storage of electrodes, and general supply bins. The charge floor is 100 ft. by 35 ft., reinforced-concrete construction being decided upon after careful study of comparative designs and costs for structural-steel and concrete construction. The surface of the charge floor, where subject to rough usage, has an additional reinforcement of Irving grating.

34 The furnaces are at present basic-lined, and desulphurization and deoxidization are carried on under basic slag. They are arranged to tilt forward into the ladle and molding bay, which is served by two 15-ton traveling cranes.

35 The refinery department is equipped to produce monel-metal ingots directly from the open-hearth furnaces or from the electric furnaces. In the latter practice the furnace charge consists of pig metal produced in the open-hearth furnaces, together with selected scrap.

36 The operating practice with these electric furnaces has not yet developed sufficiently to afford authentic information, but in the work thus far done the power consumption varies from 642 to 714 kw-hr. per ton of melted monel metal.

37 The casting pit of reinforced-concrete construction is conveniently located to the furnaces, the ingots before being shipped to the chipping department having the heads removed by a cold saw. The floor of the refinery is of cast-iron brick on a concrete base. Equipment for the cleaning of slags is included in this department.

THE CHIPPING DEPARTMENT

38 In order to insure a uniform hammered or rolled product of first-class quality, the outer skin of the monel-metal ingots must first be completely removed. Previous practice has been to remove this outer skin entirely by chipping with pneumatic hammers, a costly and laborious operation.

39 Experiments on a small scale demonstrated the economic possibilities of milling the surface of the ingots, and three high-powered milling machines belt-driven from a 20-hp. motor were installed in the chipping department. During the few months of their use practical experiments have resulted in greatly improved
practice. Three additional milling machines recently ordered will embody certain improvements developed in the practice. One of the main problems encountered in the change from pneumatic chip­ping to milling of the ingots has been the question of economical handling and quick clamping of the ingots square with the table of the machine.

40 The ingot is placed on the table which is fitted with four points of hardened steel: one fixed, one adjustable, and two mounted on a rocker arm so that the ingot can be quickly trued up by the manipulation of the adjustable point. Two set screws are mounted on the bottom clamp casting for squaring the ingot with the table. To turn the ingot a fabricated-steel tower has been erected on one side of each machine supporting two chain slings so that with the table at extreme traverse the chains are placed one around each end of the ingot, the table lowered, and the operator with the aid of a U-bar easily turns the ingot 90 deg. for the new set-up. To overcome the tendency for the tapered ingot to slip longitudinally while being milled, and to eliminate the time wasted by the operator in tightening and loosening the bolts, together with the risk of damage to the milling cutters, a pneu­matic clamp is now being designed which will decrease consider­ably the clamping and reclamping time, besides exerting a constant pressure and making it practically impossible for the ingot to slip.

41 Approximately 250 lb. of metal is milled from the large ingot in actual cutting time of 2 hr. 40 min. The total time to finish the ingot, including resetting of tools, turning and reclamping of ingots is 4 hr., thirteen operations being required. Eight-inch mills are used of special design with extra heavy steel bodies, case-hardened chip breakers, and ten inserted 1½-in. by ¼-in. high-speed-steel blades. The blades are set in the body so that the rake angle which the face of blade makes with a radial line is 15 deg. Cutters of special design are used to mill the corners of the ingots, being mounted on a quick-change extension shank to allow for quick setting without removal of the face mill. The face mill is run at 16 r.p.m., taking ¼-in. depth of cut with feeds of 4½ in. and 4¾ in. per min. Angular cutters are run at 38 r.p.m. with 5½ in. feed per min. The table of the machine with its load is raised and lowered at a proper vertical feed of 19 in. per min., and the hori­zontal adjustments are made at a rate of 150 in. per min. Con­siderable experimentation has been conducted in regard to proper cutter clearance angles and the following practice has been adopted
as the most satisfactory to date: namely, with the blades set in the cutter body at 15 deg. rake angle, to grind them as shown in Fig. 6.

42 In the early experiments an average of $3\frac{1}{2}$ ingots were milled before regrinding of cutter blades was found necessary. This average has gradually been improved and recently a high-speed-steel hardening gas furnace with preheating and final heating chambers was installed, together with lead pot, oil tempering and oil quenching tanks, and all temperature measurements are carefully made by a portable potentiometer using a chromel-alumel thermocouple. High-speed-steel blades hardened and drawn at 1150 deg. fahr. in this equipment have consistently cut on an average of 8 ingots with $5\frac{1}{2}$ in. feed per min. After cutting this number the tool just begins to dull and may be ground in a very short time with only a small loss of edge.
43 A skilled chipper cannot consistently chip out more than 1200 to 1500 sq. in. per eight-hour shift, or approximately two sides of a two-ton monel metal ingot, whereas one milling machine finishes an ingot every four hours. This time will be considerably lessened on the new machines with the improved devices referred to above. An average production from a battery of six machines of 12 ingots or 48,000 lb. per eight-hour shift may be consistently expected.

44 After the ingots have been milled they are taken to the chipping benches and carefully inspected. Any small defects that are not entirely eliminated by milling are chipped out by pneumatic chipping hammers.

THE AIR COMPRESSORS

45 Compressed air for chipping and miscellaneous work is supplied from two direct-connected electrically driven horizontal air compressors located in a corner of the chipping building where most of the air is used. This arrangement is also convenient for the service of one of the two 5-ton traveling cranes in this department. Aftercoolers were installed with the compressors because of the importance of having cool, dry air for pneumatic tools, and tests made have failed to find any moisture in the compressed air within a distance of 300 ft. from the air receivers. With such conditions the lubrication of pneumatic tools is also much improved. Fig. 7 illustrates the general arrangement of this equipment. The space is economically utilized and in practice the arrangement has proved satisfactory. Each compressor will deliver 1030 cu. ft. per min. at 100 lb. gage pressure, and is driven by a 210-b.hp. synchronous motor running at 257 r.p.m. The floor of the chipping department is wood block on concrete base.

THE HAMMER SHOP

46 This department receives the ingots from the chipping shop. The ingots vary in size, depending upon their ultimate use, the major portion being about 13 in. by 13 in. and weighing up to 4 tons.

47 The building is high, being 45 ft. from the floor to the bottom chord of the roof, due to the extreme height of the largest steam hammer, which is 28 ft. The building proportions give excep-
tionally good lighting and ventilation. The equipment consists of one 10-ton crane and four steam hammers of 16,000 lb., 10,000 lb., 3,500 lb. and 1,500 lb. capacity, respectively, together with the necessary handling equipment. There are five heating furnaces of the Stevens regenerative type, four with hearths 7 ft. by 20 ft. and one with a hearth 7 ft. by 14 ft., equipped with manual control and automatic air- and gas-regulating equipment. The re-

![Diagram of Air Compressors with Aftercoolers and Receivers](image)

**Fig. 7 Plan and Elevation of Air Compressors with Aftercoolers and Receivers**

generators are constructed at both ends of the furnace above the floor level.

48 Air for the heating furnaces is supplied at 16 oz. pressure by two steel-plate blowers, each of 7200 cu. ft. per min. capacity. These are driven by 50-hp. d.c. motors with variable-speed control giving a range of 1000 to 1700 r.p.m.

49 The boiler installation in the hammer shop consists of two 350-hp. units of the Stirling type, operating at 160 lb. pressure and located for the convenience of track connections, coal storage and ash-handling facilities, but at present piped for natural gas.
Under normal operating conditions the hammers, however, utilize steam from the waste-heat boilers in the refinery.

50 Owing to the weight and toughness of monel metal the hammers are of a special design and possess some novel features. The 16,000-lb. and 10,000-lb. hammers are used for cogging or breaking down. This is sometimes done on a mill or hydraulic press, but for this class of work a hammer has been found most suitable. These hammers are of a special double-frame type and are built of steel throughout. The main cylinders are bushed and valves of a new design assuring economy of steam and at the same time allowing for full control by the operator, have been embodied in their construction. The weight of one frame of the 16,000-lb. hammer is 44,000 lb., and the total weight, including the anvil, is 370,000 lb. The frames are held together at the bottom by a massive cast-steel base plate, giving a rigid construction. The ratio of the anvil weight to the falling weight is 15 to 1. Cushioned safety cylinder covers are used with these hammers, also special guides and shoes.

51 The two smaller hammers follow the same general lines except they are of the two-leg type and in some parts cast iron replaces steel. Special shapes are forged on these hammers, in addition to the usual forged work.

THE ROLLING MILLS

52 The mills consist of two departments:

a Merchant and wire-rod mills for the production of sheet bars, billets, rods of various sizes and shapes, and wire rod in coils

b A sheet mill for the production of hot- and cold-rolled sheets.

53 On account of the extremely tough character of monel metal and the tendency it has of cooling rapidly, it is necessary to have mills of great strength and rigidity. The type of material rolled is similar to alloy tool steel and it is very necessary to have mills with machine work and general finish the best of its kind and that are equipped with fittings that require a minimum of adjustment.

54 The hammered ingot or bloom after being overhauled to
REFINERY AND ROLLING MILL FOR MONEL METAL

FIG. 8 GENERAL PLAN OF MERCHANT MILL
remove any scale or surface imperfections is delivered to the 24-in.
sheet-bar mill, located in the merchant-mill building. This mill
consists of two stands, the first stand three-high and the bull head,
or finishing stand, two-high.

55 The handling of blooms to the heating furnaces and thence
to the standard mill tables is by means of a Brosius charger, Fig. 9.
The tilting tables, 25 ft. long, the transfer, and other table opera­
tions are controlled from the same pulpit. After being rolled the
bar is carried to an exceptionally heavy shear with a capacity to cut
3\(\frac{1}{2}\)-in. by twelve-in. billets.

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**Fig. 9 Brosius Charger and Stevens Heating Furnaces in Merchant Mill**

**THE SHEET MILLS**

56 The general arrangement of the sheet mills is shown in
Fig. 10. The mills themselves are exceptionally heavy, the roll
diameters being 30 in. and the maximum sheet width 48 in. The
present complement consists of two finishing mills and two rough­
ing mills, each finishing mill having a roughing mill of its own.
The roughing rolls are balanced and are driven by fully enclosed
cut gears, a rather new development in sheet-mill practice, giving
a very smooth movement and reducing the tendency of the pinion
teeth to mark the sheet. A specially designed drag, known as the
"Conklin" drag, is furnished. The roughing rolls are screwed up
and down by a motor drive, a 40-hp. motor being used which is
FIG. 10 GENERAL PLAN OF SHEET MILL
carried on the top of the pinion housing. The main motor to drive this mill is a 1200-hp. motor, which is geared with a double-reduction gear giving a total reduction of 13 to 1 and a mill speed of 26 r.p.m. Two 10-ton flywheels are used, running at the motor speed approximately 10,000 ft. per min.

57 The equipment is that usual for sheet mills, except for some slight changes in the floors. On the side nearest to the furnaces and in front of them the floors are of cast iron as usual, but are air-cooled for the roller and his helper. On the catcher side of the mill, however, wood blocks are used entirely except for a small portion of grating floor, with air circulating below it at the catcher's stand. Doubling machines are furnished, operated by steam or air if necessity demands.

58 The furnaces are of the wide-door type, being double sheet furnaces and four-door pair furnaces. The air at 16 oz. is furnished by three blowers, of 4000 cu. ft. per. min. capacity, which also furnish the air for the six annealing furnaces. Natural gas is used in all furnaces. The annealing furnaces are equipped with Freeman-type charging machines. The crane capacity over this mill is 30 tons with a 25 per cent overload and a 10-ton auxiliary.

59 The 26-in. cold-roll mill at the south end of the building consists of four stands of cold rolls driven by a 300-hp. motor. Construction is standard throughout, except that the housings are very heavy, weighing 12 tons each. The arrangement permits an
addition of four mills on the other end of the motor drive. As there is very little fluctuation in the power required on this type of mill, no flywheel has been furnished, but a motor with large starting torque is provided. All of this machinery, including the gear sets, has given excellent satisfaction, and very little trouble has been experienced in starting up this mill.

THE MERCHANT MILLS

60 It will be noted from Fig. 8 that in the building with the 24-in. merchant mill there are other merchant mills used for furnishing the greatly varied product in tonnages that, from a rolling-mill point of view, are small. This equipment consists of the 24-in. mill referred to previously, which not only makes sheet bar but also the various sizes of billets required, a 20-in. mill, a 14-in. mill, a 10-in. mill, and a 14-in. Belgian rougher; and the wire mill, which consists of two separate mills in line with each other, 9-in. pitch diameter, one being a five-stand roughing mill and the other a four-stand finishing mill. These mills are equipped with gears and direct motor drive and all have a flywheel on the motor-shaft speed except the 9-in. roughing mill, which due to construction difficulties has the flywheel on the mill-shaft speed. The 9-in. finishing mill drives direct without any flywheel or gear reduction.

61 The cast-iron housings with cast-steel fittings and brass liners throughout are equipped with bottom screws arranged to be conveniently operated by the roller. With the exception of the two 9-in. finishing mills, the mills are what might be called slow-speed mills, as in spite of the fact that the material cools quickly, it is not advisable to roll it too fast, and this had to be given special consideration in deciding upon the speeds to employ.

62 All mills are driven by fixed-speed motors except the 10-in. mill, requiring a variation from 120 r.p.m. to about 80 r.p.m. to accommodate the varied size of material, and the 9-in. mill, the intermediate mill between the 14-in. roughing and 9-in. finishing mill, which will have a speed variation of 257 r.p.m. to 384 r.p.m., arranged in 17 intermediate steps, to accommodate the delivery speeds of the 14-in. mill.

63 The whole of the south side of this building is arranged with lifting doors, so that it is easy to adapt the temperature of this end to either summer or winter conditions, the same type of doors being arranged at intervals on the furnace lean-to side, as
will be noticed in the illustrations of the buildings. The lean-tos are arranged with an ascending slope away from the main building, so that the heat will travel away from the mill. This feature of special doors and lean-to has also been carried out in the equipment of the sheet-mill building.

64 Lubrication of mill reduction gears and pinions was given much study and a combined pressure and gravity system was installed in the control houses. Small plunger pumps are considered preferable for this service, as with their use there is not a tendency to form an emulsion as with some pumps of the rotary type.

THE BUILDINGS

65 The dimensions and arrangements of the buildings are shown in Fig. 2. All of the buildings, with the exception of the office, laboratory, oil and grease house and the electric substation, are of steel construction, the average weight per square foot of projected area being specified as 25 lb., although in some cases this is exceeded.

66 Wide monitors one-half the building width were adopted for the main building roof; the sawtooth roof was used for the lean-tos. These features give excellent ventilation and lighting. To assure the best working conditions during the warmer months, the prevailing winds were studied and the buildings were placed accordingly.

67 Steel lifting doors are continuous on the sides of the refinery, hammer shop, merchant-mill and sheet-mill buildings. For truck or railroad entrances to buildings, rolling steel doors are provided.

68 The roofing and sheathing is of corrugated black sheets; the windows have wooden sash, which take up any variation in the steelwork and eliminate warping of frames which otherwise might occur. There is in all about 160,000 sq. ft. of these windows used in the entire plant. The buildings were given two coats of a non-corrosive paint and a finishing coat of battleship gray color, which gives a pleasing appearance and aids the inside lighting.

69 In practically every important department suitable change houses have been provided. The washing facilities, showers and lavatories are arranged to utilize space efficiently, with a minimum of piping, valves, and fittings, and are sanitary and easily kept clean.
OIL AND GREASE HOUSE

70 The problem of the storage of oils and greases, together with a department for the rendering of grease used on the sheet mills, has been met by a small building of fireproof construction. The facilities for handling supplies are most convenient and Fig. 12 shows the general arrangement of this department.

TRANSPORTATION

71 Reference to Fig. 2 will show that every important department is served by track connections to the main line; also that suitable storage facilities for incoming and outgoing cars have been provided. All the standard-gage track is laid with 90-lb. rails, with large-radius curves, so that standard railroad engines may do the switching. The various departments are also served by a 36-in. industrial track, with electric storage-battery locomotives for the handling of materials.

WATER SUPPLY

72 Water was obtained from boreholes during the construction period and until the pumping station on the Guyan River was completed. The water it furnishes is of good quality, but it is chlorinated and tested daily as a precautionary measure, as it is used for drinking in addition to industrial purposes. The present installation (Fig. 13) consists of two 500-gal. DeLaval centrifugal pumps, each driven by a 40-hp. 2200-volt motor, operating against a head of 210 ft. and discharging to a 150,000-gal. tank.

73 In order to reduce the operating load on this station a pond of 10,000,000 gal. capacity, close to the auxiliary power plant, has been provided, and as subsidiary pumping-station connection with this pond supplies certain services of the plant; the water being in a closed circuit, the difference made up from the Guyan station is that due to leakage, which is very small, and the loss from evaporation.

ARRANGEMENTS FOR DESIGN AND CONSTRUCTION

74 No general contractor was engaged in connection with the construction of these works, principally on account of the special character of the work involved. The designs and specifications of
the buildings and mill equipment were prepared by Mr. Frank I. Ellis, consulting engineer, of Pittsburgh, Pa., and the designing of

the refinery, pumping station, and other details by the engineering department of The International Nickel Company at Huntington.
FIG. 13 PLAN AND ELEVATION OF PUMPING STATION (GUYAN RIVER)
Mr. H. M. Brown was engineer in charge of construction, and all the electrical equipment was installed by Mr. F. C. Watson, electrical superintendent.

75 The success of the undertaking is largely due to Dr. John F. Thompson, manager operating and technical department, The International Nickel Company, New York, and Mr. A. S. Shoffstall, manager, Huntington Works. All the engineering work, including the recommendation of the location and site, was under the direction of the author.

76 Construction was commenced in 1921 and the plant was placed in operation in June, 1922.