The STORY *of* NICKEL

THE INTERNATIONAL NICKEL COMPANY
OF CANADA LIMITED
Copper Cliff, Ontario

ROBERT C. STANLEY

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Foreword

"THE Story of Nickel" has developed in recent years so definitely into a story of Canadian opportunity and enterprise, that it has become an integral chapter in the growth of the Dominion as a world industrial power. Thus it has become a story which all Canadians will want to know.

Here in the Sudbury District of Ontario we have ore deposits which constitute the world's greatest reserve of nickel, a resource adequate to meet world needs for generations to come.

To tap this latent wealth extensive underground developments have been made. One of them, known as the Frood Mine, ranks among the greatest mines of the world.

To convert this ore into marketable products, concentrators, smelters and refineries have been built up, which establish Canada as the home of the world's nickel industry. Although refineries are also operated at Clydach, Wales, and Acton, London. the great bulk of the productive facilities lies within the Province of Ontario.

To find markets for nickel, research and development activities are carried on in every part of the world, where industrialization has created needs for better materials. Supplementing this programme, there has been an equally important extension of sales and distribution; for the impulses which provide work for the men in Ontario and freight for the railroads of Canada depend not only upon stimulating demands for nickel but also upon providing the machinery for satisfying those needs. Consequently, rolling mills are operated in Birmingham, England, and Huntington, West Virginia, to serve the industrial markets of Great Britain and the United States.

The ore deposits under the gossan hillsides of Ontario have existed for ages which only the geologist can number. Yet it was not until the middle of the last century that Man took any cognizance of this natural wealth. The pioneering of the Canadian Pacific Railway in pushing its line westward from Sudbury in 1883 led to the first public interest in mining there; and, even then, the ore, which had been exposed in blasting out a railway cut, was first valued only for its copper content.

One who reads "The Story of Nickel" will appreciate the tribulations suffered by every group which has tried to work copper-nickel ores. It has taken imagination and persistence to develop practical methods for the extraction of the copper and the nickel, and then for their separation into pure metals. These methods require a heavy investment in plant and equipment both below and above ground, the International Nickel Company having spent more than $50,000,000 since 1926 in modernizing and expanding its productive facilities. Such investment and the activity built upon it can be maintained only if the demand for nickel be maintained.

A small area in one Province produces ninety per cent of the world's nickel, but all of Canada consumes less than half of one per cent of that production. The British Empire as a whole uses only 15 per cent of the annual output from Sudbury's ore. Therefore, Canada has a real stake in maintaining and in further developing world markets for nickel. Failure means that modern Sudbury will revert to the gossan hillsides of its antiquity.

The International Nickel Company of Canada, Limited, brings "The Story of Nickel" to the attention of the Canadian public because this Company is the outstanding factor in the world's nickel industry. It and its predecessor companies have played the leading part in the development of the Sudbury ore reserves since mining actually got under way there in 1885, and it has taken the leadership in the post-war development of industrial uses for nickel throughout the world. The Company has ore reserves, plant facilities and marketing organization adequate to maintain its position for generations to come.

A Canadian corporation with share control within the British Empire, International Nickel is an integral part of Canadian enterprise in world commerce. The nature of its ores is such that it is also one of the leading Empire producers of copper, and it is second only to Russia in the production of the platinum metals. Although properly referred to as "by-products" in "The Story of Nickel", these other metals are important factors in the welfare of the Canadian nickel industry.

R. C. STANLEY

Copper Cliff, Ont.,
August 1, 1932.

THE STORY OF NICKEL

PART I

How "Old Nick's" Gnomes Were Outwitted

THE STORY OF NICKEL

HOW "OLD NICK'S" GNOMES WERE OUTWITTED

IT IS A FAR CRY from the "Heaven-sent" blade of the mythological swordsman of Persia or China to the nickel-steel rotor hub which is the very heart of the modern autogiro, but the two are inextricably linked in the story of nickel. Then as now life hung on the dependability of an alloy. Where the fabled warrior had a simple faith in his blade forged from meteoric iron with its high nickel content, the flier today goes up with assurance that science knows exactly the strength of the nickel-steel which has been carefully alloyed for his protection.

Nickel named after "Old Nick"

In the transition from fable to fact, nickel picked up its name at a time when men thought it was sent by the Devil and not by Heaven. In the early part of the eighteenth century fresh lodes of ore were laid open in Saxony where from times immemorial, silver and copper mines had been worked. This new ore was so glittering and full of promise as to cause the greatest excitement, but after innumerable trials and endless labor, all that could be obtained from the ore was not metal but a worthless slag. In disgust the superstitious miners named the ore *kupfer-nickel* (copper-nickel) after "Old Nick" and his mischievous gnomes who were charged with plaguing the miners and bewitching the ore.

What these German miners gave up in disgust the scientists explored with avidity. Gradually the story of nickel began to take shape and direction; but the name coined by the ignorant laborers stuck. Nickel it is in virtually every language. Now it is coming out of the dictionary and into the lives of people wherever modern industrialization is spreading; for nickel in steels is making for sturdier automobiles, nickel in the white metal alloys, by eliminating rust and corrosion, is making for beauty in architecture and for better performance In many industrial and chemical processes, and nickel—both alone and in combination with other metals—is playing its part in the development of communications and power transmission.

But these results were far below the horizon when in 1751, Cronstedt, working with the obstinate Saxon ores, isolated a new element which he named nickel. Then it was not until a quarter-century later that this discovery was confirmed by Bergman. Another thirty years elapsed before Richter produced the first pure nickel and gave a remarkably accurate description of its properties.

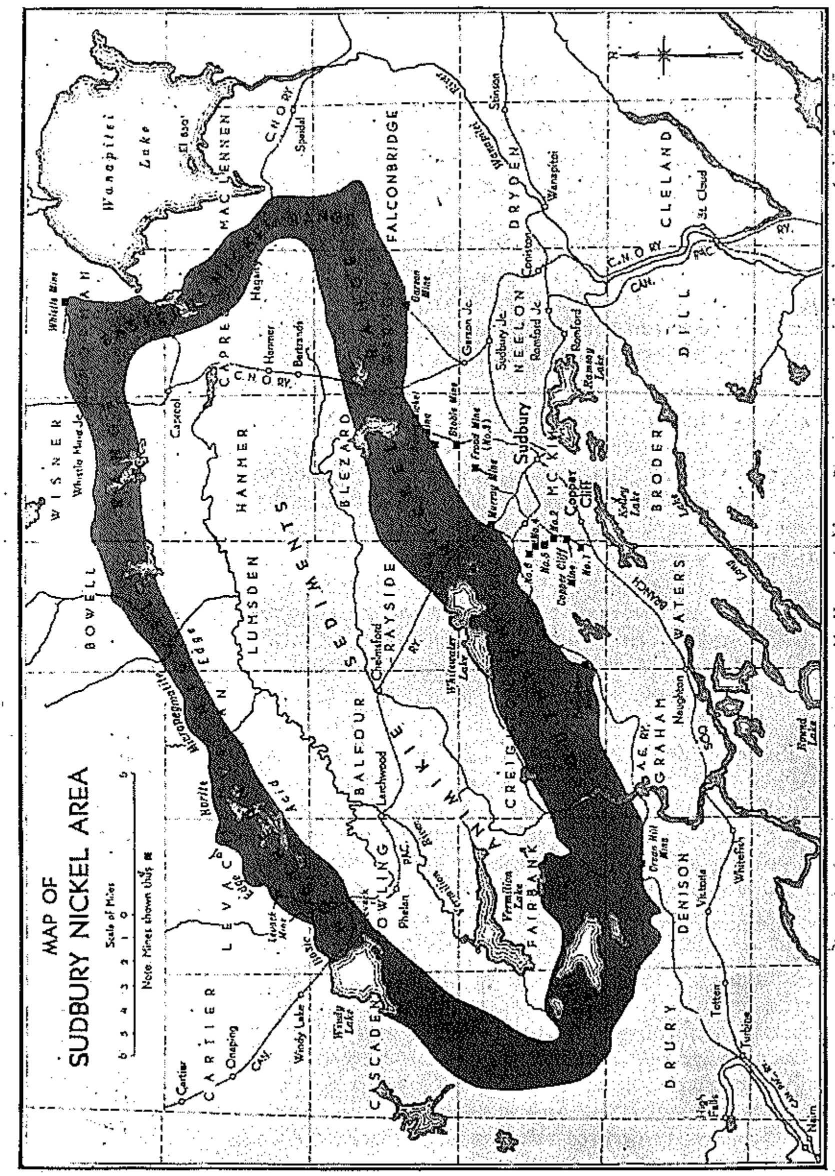
In the meantime von Engeström was studying the famous *paktong*, or "white copper," which was first brought out of China in the caravans to Bactria two centuries before the Christian era. These ancient experimenters with metallurgy had found a copper-nickel ore in Yunnan Province and had learned that the addition of zinc created an alloy which was workable, useful, and attractive in appearance. Before the American Revolutionary War the copper-nickel ores of Litchfield County, Connecticut, were being shipped out to the Far East to supplement the Yunnan ores in the growing paktong industry. This alloy then took a sea voyage to Europe where it enjoyed a growing popularity as a substitute for silver, and where it thus came under the analytical eyes of von Engeström.

In those days there was little or no interchange of scientific information between the Orient and the Occident, and the Swedish scientist, therefore, had to find out by patient research that paktong contained copper, nickel, and zinc. There followed fifty years of struggle with "Old Nick's ores" to learn what any Chinese metallurgist could have told the West: how to make a satisfactory imitation of paktong. But once the secret of zinc's function in the process was discovered, there came a flood of white metal products under such trade names as *argentan* and *metal blanc*, the generic name in English being German silver and remaining such until recent years, when nickel-silver has become the accepted name for these alloys.

It was the development of electroplating as the result of Faraday's researches in electromagnetism that stimulated the use of nickel with two-fold effect, the more important being the introduction of silver plating on a German-silver base, and the other being nickel-plating itself. This development was well under way by the middle of the nineteenth century, when a further impetus was given to nickel consumption by a revolutionary change in policy toward token-money coinage. A Belgian commission on currency reform effectually assailed in 1859 the prevailing theory that the intrinsic value of token money must approximate its nominal value, and the following year Belgium adopted as standard a composition of 75% copper and 25% nickel because of the economy, workability, and appearance of this alloy. The United States followed suit in 1865, Germany in 1873, and Switzerland in 1879.

During this period Joseph Wharton, of Philadelphia, was working with malleable pure nickel; and the showing of his products at the Vienna Exposition in 1873, the Philadelphia Exposition in 1876, and the Paris Exposition of 1878, created widespread interest in this product. The Swiss were the first to adopt it for coinage, and in 1881 they issued the first pure nickel money. Since then some twenty-four countries have stamped three billion pure nickel coins for use in their currencies.

At the same time another field of usefulness was being opened up by Fleitmann who obtained malleability by adding small amounts of magnesium to the melt. He succeeded in rolling nickel so treated into sheets, and then in rolling these sheets upon both iron and



THE FAMOUS SUDBURY BASIN

The dark area indicates the world's greatest concentration of nickel ore.

steel, much as silver was rolled on copper in the manufacture of Sheffield plate. Thus he became the pioneer in the development of what is known today as nickel-clad steel.

Naturally this expanding consumption necessitated increased production of the raw material. For a time the whole world was combed for supplies, and ores containing as little as one per cent of nickel were profitably worked. Practically every country contributed its mite, but the pyrrhotite-chalcopyrite deposits of Norway emerged as the greatest source, reaching their highest production in the years 1870-77.

Then mining in New Caledonia got under way, and a decade later this competition had brought to a standstill all other nickel mining, save that in Norway. Until near the close of the century, that little island in the South Seas was the principal source of nickel in meeting an increasing demand.

Sudbury deposits discovered

For the next and, apparently, the last time the pendulum swung again, and less than 1,000 square miles in the Sudbury district of Ontario became the lodestone of the nickel industry. Although a Government surveyor had reported in 1856 the presence of ores in the district, it was not until the Canadian Pacific Railway was being pushed westward from Sudbury in 1883 that the real discovery was made.

Strangely enough, history repeated itself. As in Saxony more than a century earlier, copper was the magnet which attracted a rush to stake claims. Among the pioneers were Thomas Frood, F. C. Crean, J. H. Metcalf, Rinaldo McConnell, W. B. McAllister and James Stobie, some of whose names survive in the names of famous mines.

There followed nearly half a century of struggle, from which has emerged The International Nickel Company of Canada, Limited, a British-controlled corporation owning more than 200,000,000 tons of proved ore reserves, operating mines, smelters, refineries and rolling mills which normally supply 90 per cent of the world's annual consumption of nickel, and possessing research and marketing facilities which have established the metal throughout the world as an essential factor in modern industry and engineering.

Samuel J. Ritchie became by chance the man who wrote from this Sudbury discovery a new chapter in the story of nickel. Visiting Ontario originally to obtain proper wood for the wheel spokes in his carriage factory, he had interested a group of Ohio capitalists in the organization of the Central Ontario Railway. This brought him in touch with Sir Thomas Tate, then secretary to Sir William Van Horne, president of the Canadian Pacific Railway. Sir Thomas had brought back to his office from a trip to Sudbury a piece of the new ore. Ritchie saw it and learned its history. The Central Ontario Railway having become a bad venture financially, Ritchie conceived

the idea of recouping the losses which he and his group had sustained by buying some of the most promising mines in the Sudbury district and organizing the Canadian Copper Company. This was effected in 1885, the famous Frood Mine being in the group at a purchase price reputed to have been $30,000. The next step was to contract with copper refiners to take over the ore mined.

Here Colonel R. M. Thompson and the Orford Copper Company, of Constable Hook, New Jersey, enter the picture. Thompson was a U.S. Naval Academy graduate with an honorary military title conferred by the State of New Jersey. After a few years at sea he had resigned from the navy to study law at Harvard University and then had started to practice in Boston. Soon he had forgotten law and

PIONEER PROSPECTORS
The man in the background is Thomas Frood.

was on the road to becoming one of the great industrial metallurgists of the New World. Likewise, his company had undergone equally rapid transmutations. It had been started in Boston by W. E. C. Eustis as the Orford Nickel Company to exploit a nickel mine near the village of Orford, Quebec. The ore proved refractory and the company became interested in leasing a copper sulphide mine at Capleton. Thompson, then a lawyer, was retained to handle the negotiations. Upon going to England to treat with the owners of the mine, he decided that it would be more profitable to purchase instead of lease. This he proceeded to do, much to the surprise of the directors of the Orford Nickel Company, who, however, approved the purchase and reorganized as the Orford Copper & Nickel Company with Thompson as general manager.

SAMUEL J. RITCHIE

In due course it was decided to erect a smelter near New York. Thompson went there, bought four acres of sunken meadow, prevailed on New York officials to dump their ashes and rubbish there instead of at sea, and thus developed at small cost a tide-water site for his smelter. Before long, copper ores from the western mines appeared at the seaboard for refining, and soon this business had crowded out the working of the ore from Capleton. With the assistance of a loan from W. A. Clark, Thompson bought out his Boston friends and reorganized as the Orford Copper Company. Thus nickel was completely eliminated from the corporate title; yet almost immediately the company was launched on a development that was to make it one of the world's greatest producers of nickel.

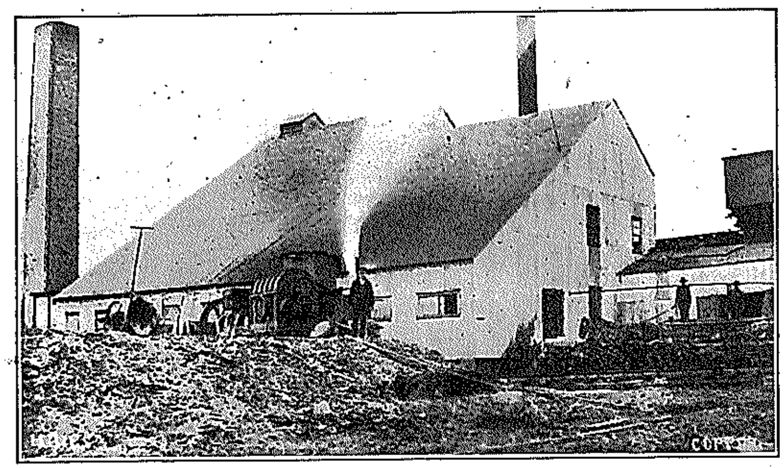
What happened was that Thompson had contracted to buy 100,000 tons of ore from Ritchie. The first shipment was received in the autumn of 1886. Here the experience of the old German miners was repeated; for the smelt produced a pale metal that no copper fabricator would accept. Thompson had an exhaustive analysis of the ore made, and he was advised that it contained 2½ per cent nickel. Ritchie, told the trouble, was greatly depressed until he learned that nickel was then worth $1 a pound. Realizing that his ores would produce many times the world's annual consumption of nickel, Ritchie cast about for some new uses of the metal.

With poetic justice the nickel-iron meteorites which had provided the Heaven-sent blades of the ancient warriors furnished the basis for his answer. Some ten years earlier he had visited the Smithsonian Institution in Washington, D.C., with John Gamgee, an Englishman who had interested the U.S. Government in the construction of a refrigerator ship for the treatment of yellow fever patients in the Gulf ports. Gamgee had found that cast iron tanks would not hold the ammonia gas he required for refrigeration, nor had he been able to discover any alloy that was an acceptable substitute. The attention of these visitors had been attracted by the brightly polished surface of a meteorite. They had discussed the possibility of producing synthetically a similar alloy. Gamgee had obtained some nickel from Joseph Wharton and, after considerable experimentation, had developed a superior alloy containing 8 per cent nickel.

Krupp rejects nickel alloy

All this Ritchie now remembered, and he thereupon made a grand gesture. He wrote Krupp—already a famous gunmaker—and suggested the possibilities of the Gamgee alloy in the manufacture of ordnance. The answer was a more or less amused rejection of the idea on the ground that there was not sufficient nickel in the world to warrant experimentation in this field. To a man as conscious as Ritchie was of the world's surplus of nickel stocks, such an answer must have been exasperating. But he had made his gesture.

However, Krupp—thanks to France—had smiled too soon for two good reasons. First, the French had developed chrome-steel projectiles that raised havoc with the wrought iron and compound armour-plate then standard in the navies. Second, a Frenchman was attracting attention by his production of ferro-nickel and nickel-steel. A British armour-plate manufacturer investigated, and the result was that in 1889 James Riley presented his now famous paper on "Alloys of Nickel and Steel." The U.S. Navy became interested, and, after its own investigation, purchased plain steel plates from British and French manufacturers and a nickel-steel plate from Le Creusot works of Schneider in France. At the trial of these plates



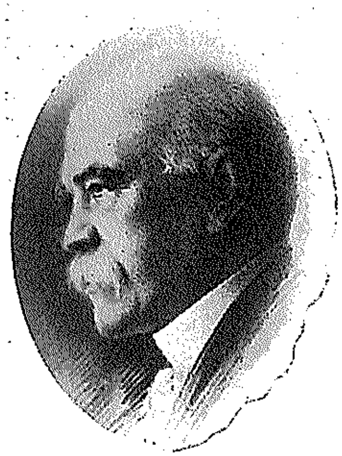
COPPER CLIFF'S FIRST SMELTER

From this humble beginning have grown thirty acres of buildings.

in 1891, the nickel-steel proved decisively superior, world-wide interest resulted, and Congress made a large appropriation for the purchase of nickel to be used in making armour plate.

In the next stage in the history of nickel, Colonel Thompson emerges as an heroic figure. His training at Annapolis had given him an understanding of naval affairs, a deep loyalty to his navy, and a wide circle of friends among the officers and technicians in the Department. Although Wharton was the one great American producer of nickel—his output was 180 tons a year—it was to Thompson and his Orford Copper Company that the U.S. Navy Department turned. He protested, but the department replied that it was in no great hurry and would give him a year in which to begin delivery. The latter part of that year the Orford Copper Company shipped a quantity of red ferro-nickel oxide which was of a most inferior grade, according to modern metallurgical standards, but which was acceptable to the steel makers.

Orford Separation Process discovered



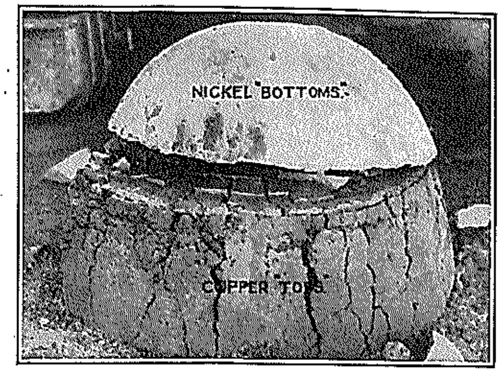
COLONEL M. THOMPSON

But Thompson fully realized that he was beaten unless he could develop something more satisfactory than the wet method which was then the traditional process of copper-nickel separation. One day he was in the refinery when some hundred pots of matte had been dumped on the floor. He tapped one of these cones with a sledge hammer and noticed an unusual fracture. He then tapped cone after cone until he had gone through the whole lot. A score of them had fractured in the same way—the bottom third of the cone had broken away as a bright sulphide from the top two-thirds which showed dark and flaky. Samples were taken and proved that an almost pure nickel sulphide had settled in the bottom third while the top section contained copper, iron, some nickel, and a large amount of sodium.

Thereupon Thompson began to function. Upon inquiry he learned that various residues from the chemical house had been part of the charge that had produced this unusual matte. He detailed a man to melt normal matte in crucibles, each with one of the chemicals used in the plant. One heating after another produced negative results, then at last came a heat which gave a product similar to that which had inspired the experiments. The chemical in that crucible had been nitre cake, a by-product of nitric acid manufacture. Thompson bought a carload, tried it in his cupola and got the expected result. Thereupon was born the Orford Process of nickel separation, one of the two standard processes in use today.

Thompson's next stop was the U.S. Patent Office, and there he came to a full halt, his way blocked by a Connecticut cobbler who

had already departed this earth. Surely, nickel was of the Devil, and "Old Nick's" gnomes were plaguing the refiner as well as the miners of old. Instead of sticking to his last, this shoemaker had been brewing on the back of his kitchen stove, ores from the Litchfield county mines already referred to. He had found that copper was soluble in alkaline sulphide and had filed a patent which, in 1893, was standing in Thompson's way. Investigation proved that the shoemaker had died; that, prior to his death, he had assigned his patent to a company; and that this company was moribund. Diligent search unearthed enough stockholders to revive the company, buy from it the patent rights and then decently inter it.



THE NICKEL-COPPER CONE

This graphically shows the basis of the Orford Process

The red oxides of iron and nickel faded from the picture and the Orford Process became the cornerstone of the nickel industry. Immediately, the need for larger markets became urgent, and Colonel Thompson squared his shoulders to the task. He went to Europe where the Rothschilds, who controlled the New Caledonia output, dominated the market. He asked for a share of the European business, was refused, and cut his price. The next year he followed the same programme. The third year he was conceded a share of the market. On these trips he had letters from his navy friends to officers in the British Navy, and he made a good friend of Lord Beresford of the British Admiralty. He also made a real personal friend of Baron Adolf Rothschild, his keenest business competitor.

Mo dev

At about the time that Thompson was perfecting the refining method upon which he had stumbled, the late Dr. Ludwig Mond, father of Sir Robert Mond and of the late Baron Melchett, developed a chance observation into a wholly different process of nickel extraction. Dr. Mond and Dr. Karl Langer were experimenting with the decomposition of carbon monoxide gas by passing the gas through nickel in a heated combustion tube. The escaping gas was led into a Bunsen flame. One day, when the burners of the combustion furnace had been turned off, the flame showed a greenish-yellow coloration. To determine whether this was due to the presence of arsenic, the gas was passed through another heated glass tube to see if it would produce a mirror of arsenic. The

DR. LUDWIG MOND

metallic mirror which was formed as a result did not surprise these scientists; but an analysis of this coating most certainly did create excitement, for the deposit proved to be not arsenic but metallic nickel. From a purely scientific point of view, this was an important discovery; for at that time no one conceived the possibility of volatilizing a heavy metal at practically ordinary temperature and of later recovering it in solid form without having first reduced the metal to a molten state.

From a commercial viewpoint equally important results followed this discovery. After further experiments it was demonstrated that finely divided metallic nickel would be picked up by carbon monoxide gas at temperatures around 80 deg. C. to form nickel carbonyl gas, and that this gas would decompose and deposit pure nickel when heated to 180 deg. C. From this was developed the Mond, or Carbonyl, Process in which a Bessemer matte is calcined to produce mixed oxides of copper and nickel, then is treated with sulphuric acid to leach out most of the copper. The nickel oxide remaining is then reduced to an impure nickel powder which is volatilized with carbon monoxide at about 50 degrees C. The final step is to heat the carbonyl thus formed to temperatures about 200 degrees C. so that pure nickel is deposited and carbon monoxide is re-formed.

The beauty of this process is its simplicity. However, the mechanical difficulties in handling so dangerous a gas had not been solved when the process first became known on this side of the water. Hence, although the Canadian miners obtained an option on the process and investigated it thoroughly, they finally decided not to exercise their option. Thus the British and American refiners, although using the same matte from the Canadian smelters, separated the nickel and copper by processes which employ equally effective but wholly dissimilar chemical truths.

Whether refined at Clydach, Wales, by the Mond Process, or at Constable Hook, New Jersey, by the Orford Process, production from the Canadian ores remained in British-American hands. Krupp had already regretted his light dismissal of Ritchie's suggestion about the Gamgee alloy. The potentialities of nickel were beginning to be better understood. Hence Krupp tried to buy control of the Canadian Copper Company which was already the great producer

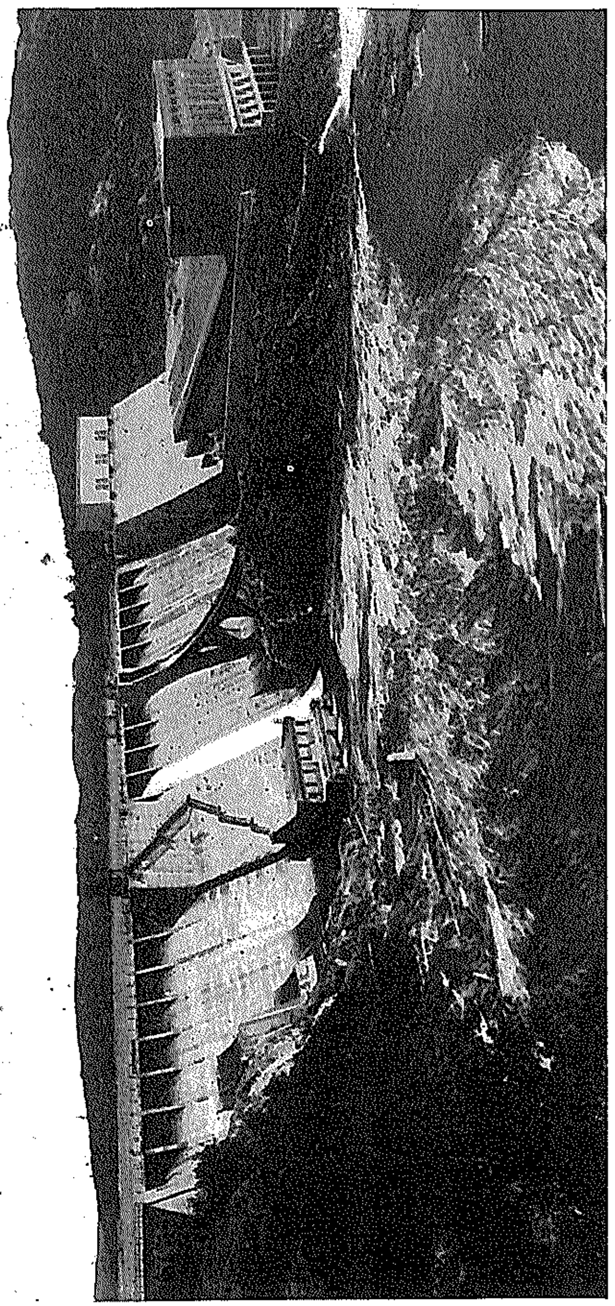
of Canadian ores. Then the Rothschilds, interested through their domination of the New Caledonian production, also started negotiations. At the time the Canadian Copper Company was having a critical time financially, and the temptation to sell out to one or another of these foreign interests was very real.

It is to the credit of Ritchie and his backers that they kept faith and, by pledging their personal fortunes, carried on. In these trying days they had the encouragement and co-operation of the Dominion officials whose goodwill in the Sudbury development had been traditional from the early days when Sir John A. Macdonald, as Prime Minister, Lady Macdonald, Sir Charles Tupper and Canada's two great railroad pioneers, George Stephens and Sir William Van Horne, inspected the Sudbury camp. Hence, when the World War broke in 1914 and nickel became almost a precious metal, not only the properties but also the processes and personnel of Canada's great nickel reserves were British-American.

SIR JOHN A. MACDONALD

Fifteen years after Ritchie was wondering how he could dispose of his metal, nickel was again in world demand. Another scant fifteen years and the outbreak of the World War extended the Canadian mines to their limit to provide the nickel required by the Allies. Germany commandeered nickel cooking utensils and nickel-bearing coinage, reopened its old mines and stimulated Norwegian production. Although nickel-silver, nickel plating, and the coinage of pure nickel and of copper-nickel tokens were consuming larger quantities of the metal than ever, their relative importance had sunk to a small fraction of the total consumption.

The Heaven-sent material from which the blades of the individual warriors of age-old Persia had been fashioned was now being dug from the bowels of Ontario to manufacture the guns and projectiles and armour plating, the tanks and machine-gun "pill boxes," and the airplane engines of a Twentieth Century at war.



The Company's Hydro-Electric Development at Big Eddy, Ontario, on the Spanish River. The ownership of waterpower capable of providing cheap and constant power for present operations and any future developments, is one of the Company's most important natural assets.

THE STORY OF NICKEL

PART II

Nickel Comes of Age

NICKEL COMES OF AGE

WHEN the World War suddenly broke out in August, 1914, the temporary cessation of business caused the nickel refineries to shut down. They remained closed until October when the world began to realize that stronger and tougher steels were a vital element of victory.

Then the insatiable demands of the Allies began to build up until four years later the need became so urgent that ingots as they came glowing from the refinery were doused with cold water and rushed for shipment to the gun and ammunition factories of Canada, England and France. So great was the value put on nickel that no more than 500 tons were allowed on any one vessel traversing the submarine zone, and the day that the United States entered the war a company of soldiers was assigned to the Bayonne refinery. This guard was maintained until the Armistice.

Nickel's war mark wiped ou.

Another four years—the war is ended and the temper of the world is toward progressive reductions in the great naval armaments. Nickel is again a drug upon the market. Practically 90 per cent of the world's consumption had been in the manufacture of armaments and the munitions of war, and this market was almost entirely wiped out.

Then began the slow and persistent work of research, experimentation, and merchandising, which has given nickel as heroic a stature in the many fields of industry as it ever had on the battlefields. Nickel came of age in the laboratories of the great electrical companies, on the proving grounds of the automobile makers, in the test flights of airplane engines, and in countless other places where the search for better materials and better performance is unabated.

Quite naturally the nickel industry itself has been at the forefront of this research, for its very life has been dependent upon finding and developing new markets. At the same time this task has been considerably lightened by the healthy discontent with old standards and practices, with which industry as a whole emerged from the World War.

Behind this discontent has been a fascinating interplay of factors, and thoughtful observers feel that the contribution of the war was in accelerating rather than in actually creating the development. They find the roots of the present situation in the pre-war combination of physics and chemistry and in metallurgy, the child of that union. Metallurgy had developed as an intensive study of the chemistry of metals; then came metallography with a physico-chemical background to delve into the structure of metals and to study the changes which could be effected in these structures by the introduction of various elements in combination, and by variations in heat treatment and in quenching.

At the same time a psychological factor became evident. Our colleges and technological schools were turning out more and more young men eager to use their scientific training. Rule of thumb industrial processes rocked along but were steadily giving place to scientific methods. Imagination was creating needs within industry for special knowledge which previously had been considered as good only for theorizing in the classroom and the college laboratory.

Prior to the war the great electrical companies had established research as a practical function of their activity, and certain of the automobile makers had metallurgists. The steel business is old and rugged, and these young newcomers had to prove their worth to the veteran steel men. They did it by making it possible to produce steel that would meet increasingly more exacting specifications. Those were the early days of the horseless carriage, when something more than the horse was frequently missing. Rear axles were brittle, gears stripped, valves stuck. The driver's head was as often under the hood or under the chassis as it was above the wheel.

Then came the war, and many an industrial plant took its first orders for military supplies. Government inspectors came into the plants and proceeded to reject products right and left as being below specification. The shop foremen and the foundrymen welcomed the metallurgists in working out these new production problems, and the union between the experience of industry and the technique of

NICKEL-CLAD STEEL SHOWS ITS USEFULNESS

This tank car transports caustic soda in bulk with a possible saving of $1,000,000 a year to the rayon industry alone.

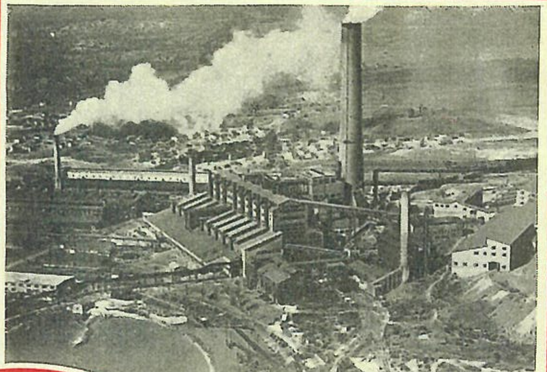
science was thereupon effected. At the same time the governments drafted not only young graduates but also professors and research men from the scientific schools for work in planning boards and as officers of ordnance and in the service of supplies. With the close of the war many of these men turned to industry for their further careers. Thus the stage was set for a modernized attitude toward production and for an enlightened interest in the potentialities of alloys. The old complacency which was content with only three types of special steels—manganese for wear resistance, nickel for toughness, and chrome-nickel where both strength and toughness were required—was shelled at Liége and evacuated long before the Hindenburg Line.

Nickel wins peace-time markets

Nickel did not inherit this new peace-time market free and clear of all strings, however. It had to win the business in its own right, and it had to develop that market into a world-wide demand before it could reach the stature of a world industry. Several important factors have made success hard won. The first is that industry, as a whole, is conservative in its attitude toward new materials and specifications. Another is that nickel must meet on its own merits the competition of other alloying metals, such as chromium, vanadium, magnesium, manganese, aluminum and silicon.

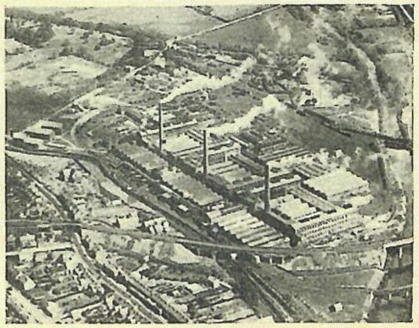
During the first two or three years after the war the situation remained confused. The new production which had been created by the demand for ordnance and armament was in a mad scramble with the older producers for a market which no longer existed. Then, in 1922, Robert C. Stanley was promoted to the presidency of The International Nickel Company. He saw in the fight of modern industry for better materials and improved performance a constructive opportunity for nickel, which was more diversified and lasting than its old market for the destructive uses of war. To this end he inaugurated a policy of active research and aggressive development. A laboratory was constructed at Bayonne, New Jersey, for experimenting with new alloys of nickel and for solving the difficulties experienced by industry with the alloys already developed. A staff was built up of metallurgists who had had practical experience in the key industrial and engineering fields. These men carried the gospel of nickel directly to the foundry bosses and shop foremen, and put the latest scientific knowledge about the metal on the shirt-sleeve basis of helping to work out production problems on the job. Bureaus of nickel information were established in the principal industrial centers of the world (the latest having just been organized in Tokio) to serve as clearing houses for the dissemination of scientific and technical information about nickel.

At the same time the new management of the company put special emphasis on the exploitation of "Monel Metal" both in improving this product and in stimulating new uses for it. "Monel Metal" is a natural alloy made from the ore of The International

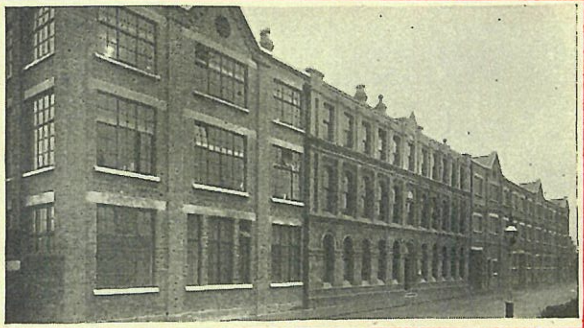


SMELTER
Copper Cliff, Ont.

FROOD MINE *Sudbury District, Ontario*

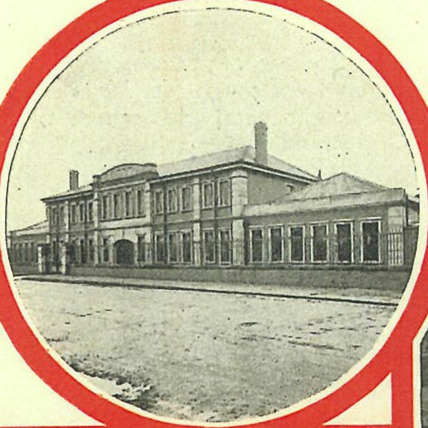


REFINERY *Clydach, Wales*



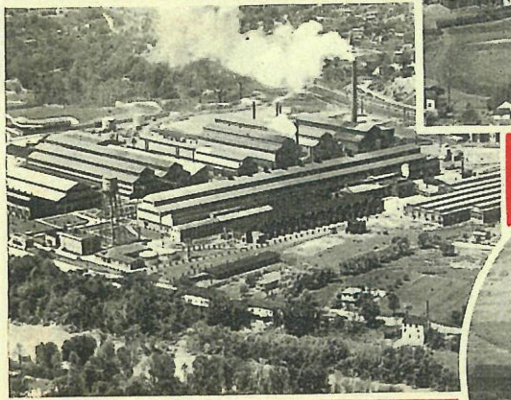
ROLLING MILL
Birmingham, England

MINES AND PLANTS
of The International Nickel Company of Canada Limited.



REFINERY
Acton, England

CREIGHTON MINE
Sudbury District, Ontario



ROLLING MILL *Huntington, West Virginia*

REFINERY
Port Colborne, Ontario

RESEARCH LABORATORY
& FOUNDRY
Bayonne, New Jersey

Over $50,000,000 has been expended since 1926 on additions and betterments to provide the most modern and economical production facilities.

Nickel Company's Creighton Mine near Sudbury. The nickel-copper content of this ore maintains a relation of roughly twice as much nickel as copper, thus making for a bright metal alloy which is rustless and corrosion-resistant. In 1906 an old conception of this natural alloy was revived, and it was demonstrated that it was commercially practical to produce the alloy directly from the Creighton ore. As a product unique with The International Nickel Company, it was named for the late Colonel Ambrose Monell, then president of the company.

COLONEL AMBROSE MONELL

Metal

The outbreak of the World War created special demands for "Monel Metal" in gun manufacture and in the powering of destroyers. Following the Armistice The International Nickel Company constructed at Huntington, West Virginia, a refinery and rolling mill for the production of "Monel Metal" in ingots, sheets, bars, rods and other forms required by the growing industrial uses of the alloy.

Through such leadership the nickel industry was revived on a new basis with The International Nickel Company as the logical beneficiary. By 1929 more nickel was used by world industry than at the peak of war-time consumption. Now, despite the depression, nickel enjoys a wider diversification of industrial and engineering uses than ever before in its history. Where once the munition and armament manufacturers took nearly ninety per cent of the world's nickel production, they now take less than five per cent of a normally larger production. Industry has absorbed the rest.

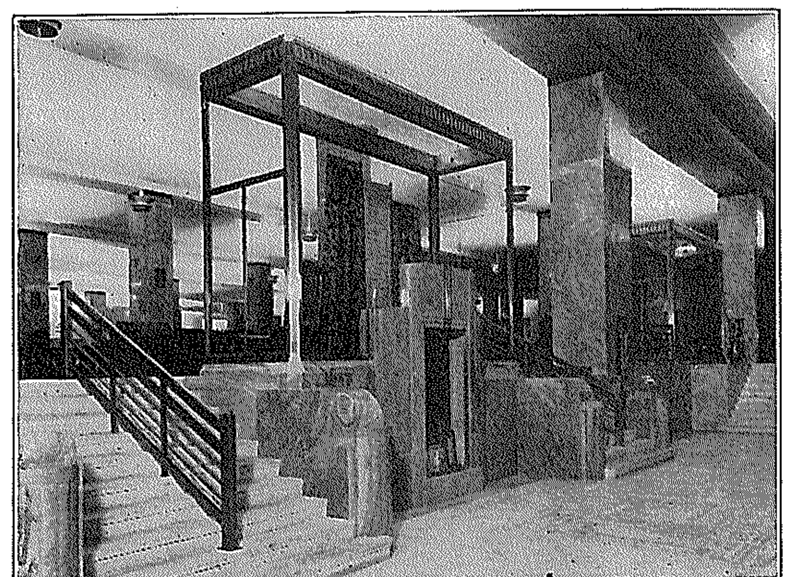
When we start to follow the metal into industry we find that it has gone in surprising directions and to unexpected distances. Take so homely a subject as the kitchen sink. While civilization has been marching on to electric washing machines, mechanical refrigeration and gas and electric ranges, the sink has remained the Cinderella of the kitchen. Since enamel sinks were developed in 1876, nothing had been done to improve this household necessity until, a year ago, "Monel Metal" sinks were brought on the market, embodying in their design improvements which only an age of alloys and machines could produce.

The growing vogue for white metals as decorative trim has spectacular examples in the Empire State Building in New York and the Whitehall Theatre and the Savoy Hotel in London, which

are sheathed with tons of stainless steels with their nickel content of eight per cent by weight. Similarly, the T. Eaton store in Toronto makes wide use of "Monel Metal", there being more than 250,000 pounds of this nickel-copper alloy in this one installation. Nickel-silver plumbing fixtures, silver-bronze grilles and other decorative trim in banks and hotel lobbies all carry their percentages of nickel. Indeed, even chromium plate has as its base a heavy plating of nickel.

Uses of Monel M

But these are picturesque uses as contrasted with the industrial applications where research has selected nickel to perform some essential function. Take the construction of steam turbines in which super-heated steam is driven at high velocity against the turbine blades. Metallurgists have learned that the erosive effect of this steam is an important factor in turbine design, and that "Monel Metal" turbine blades stand up best. Again, take the problem of a dairy where large quantities of milk must be pasteurized, cooled and stored. The lactic acid in the milk, particularly at certain temperatures, creates handling problems which require a special alloy of nickel and chromium for the pipes and tanks. Or if it's a matter of rayon production, nickel enters the picture because the caustic soda used in rayon manufacture is too corrosive to handle in regular containers. Hence tank cars are now being constructed of nickel-



Monel Metal used for beautiful, distinctive and practical decorative effects in the new T. Eaton Co. Store, Toronto clad steel to provide a lining which will not be attacked by the soda while in transit. In hospitals and restaurants "Monel Metal" has become standard for kitchen and pantry installation.

The above examples are indicative of nickel's function in preventing rust and in combatting corrosion. Other important properties have made the metal the subject of intensive study in the electrical field. For example, research in the Bell Telephone Laboratories at Westinghouse and at General Electric has produced a variety of nickel-iron alloys of real significance in cable communications, in the transmission of power and in radio reception. By varying the nickel content, by modifying the heat treatment and by controlling the atmospheric conditions under which the heat is applied, science has produced some nickel-iron alloys which are highly magnetic and others which are non-magnetic; but each has its specific function in electrical engineering.

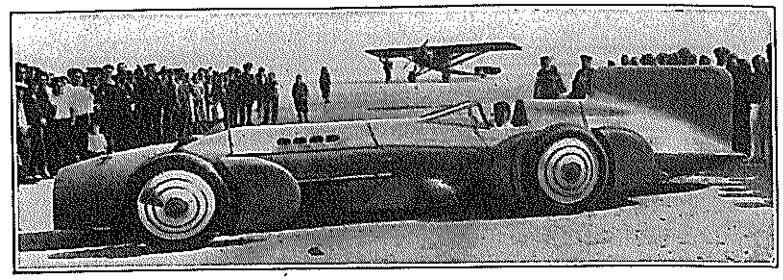
Nickel in one or another of them has helped to make it possible for the notes of the English nightingale to be carried across the Atlantic to radio listeners throughout the United States, for the business man to put in a call from Toronto to Chicago as part of the day's routine, for the diplomat to file an important cable to his home government the other side of the globe, and for the "talkie fan" to listen tonight to her favourite actor who actually spoke months before in Hollywood.

ickel as alloy

There remains a broad field in which nickel plays a very minor role but plays it so often that it aggregates the great bulk of nickel consumption. We have been discussing alloys in which whiteness, rustlessness, corrosion resistance or electrical properties have been the objectives—alloys in which the nickel content has run as high as 80 per cent. Now we are turning to alloys in which nickel is included for its effect upon the grain structure of the metal to obtain greater strength, resistance to fatigue, better reaction to heat, cleaner castings or improved machinability. Here the nickel content ranges from 0.5% to 5%; yet it is the bread and butter end of the nickel industry.

Take, for instance, the automotive field which is paramount in this group. The average amount of nickel per passenger car produced in Canada and the United States was 1.6 lbs. in 1929, 2.01 lbs. in 1930 and 2.08 lbs. in 1931. These figures are for the nickel content of the alloy steels used in the construction of these automobiles; they do not include the nickel used in cast iron parts, in plating or in heat resisting and spark plug wire. Yet in 1931, a year of greatly restricted output in the passenger car field, the nickel in these alloy steels amounted to more than 8,000,000 lbs. This total compares with that of 3,400,000 lbs. for this industry in 1921.

When it is considered that the English racing car "Blue Bird," which recently established a world's speed record of 253 miles per



THE "BLUE BIRD"

Sir Malcolm Campbell's world's record racer is constructed almost entirely of alloy steels.

hour, is constructed almost entirely of alloy steels, the importance of the automotive industry to the nickel industry becomes obvious. Already the trucks and heavy duty omnibuses have been standardized on nickel steels, many of them also containing other alloying elements. Now the passenger cars are fast following suit because the demands for increased speed and better performance require higher factors of safety and more efficient parts

Nickel transp. field

Supplementing this research and development in nickel steels has been a recent experimentation with nickel cast iron. Here is a metal which was the backbone of the Iron Age, which retained an important place in the Age of Steel but which has fast been losing ground in our present Alloy Age. Research and experimentation with the introduction of nickel alone and in combination with other alloying elements, are now producing cast iron alloys which are successfully competing with cast steel and even with steel forgings in many basic industrial and engineering applications. Thus, in seeking through research new outlets for its own product, the nickel industry is reviving an ancient and honorable material that had definitely begun to lag in the march of progress.

Nor are these nickel steels and nickel cast irons identified only with the automotive industry. The vastly heavier power units of modern steam railroads are turning to these alloys for better performance and greater safety. Here it is interesting to note that the Canadian Pacific Railway, whose westward progress in 1883 first brought the nickel ore reserves of Sudbury to public attention, has been the pioneer railroad of North America to standardize on nickel steels for the boiler plates, frames and cross-sections of its great engines. Other railroads have followed suit until now these standards are becoming commonplace in modern locomotive construction. Indeed, the Timken demonstration engine, designed by a committee of experts, contains 100,000 pounds of nickel steels.

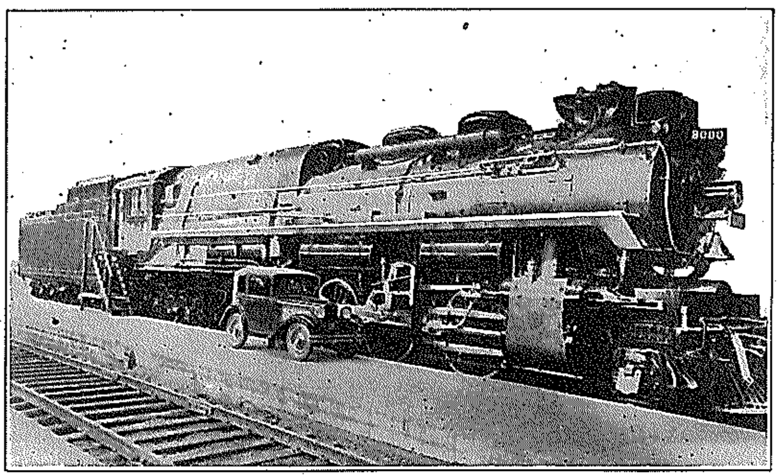
Enough has been said to show how far the nickel industry has spread beyond its popular association with nickel-plating. In fact, the best available statistics indicate that only about 5 per cent of the world's production has been used for this purpose since Faraday first developed electro-plating more than a century ago.

'owth of :kel ɔduction

Since 1850, approximately 1,000,000 tons of nickel have been consumed for all purposes throughout the world. The production data are interesting. Only 14,000 tons were produced from 1850 to 1885. In the next quarter of a century the total rose to 230,000 tons, or an average of 9,200 tons a year. During the next ten years, which included the war period with its vertical rise in consumption, the total jumped to 357,000 tons. Since then—a period which began with the depression of 1921 and which is now in an even more severe and protracted slowing up of industry—the average production has been 32,000 tons a year with a low point of 8,200 tons in 1921 and a peak of 68,000 tons in 1929, greatly exceeding the high-point of wartime production.

Nickel is by no means all things to all men. In many applications where it functions best it has definite rivals, and in many instances it needs the cooperation of other alloying elements to give the desired performance; but it is a friendly element which mixes well with other metals, and there are so many instances where it is a necessary, or at least a highly desirable, factor, that the cumulative effect provides for it a diversified and constantly growing market.

In the post-war development of this composite market the nickel industry has had invaluable help from research scientists who have worked their way to nickel from far beyond the horizon of the industry. At the same time the men within the industry have necessarily carried the main burden and have done much to blaze the trail along which nickel has come of age.



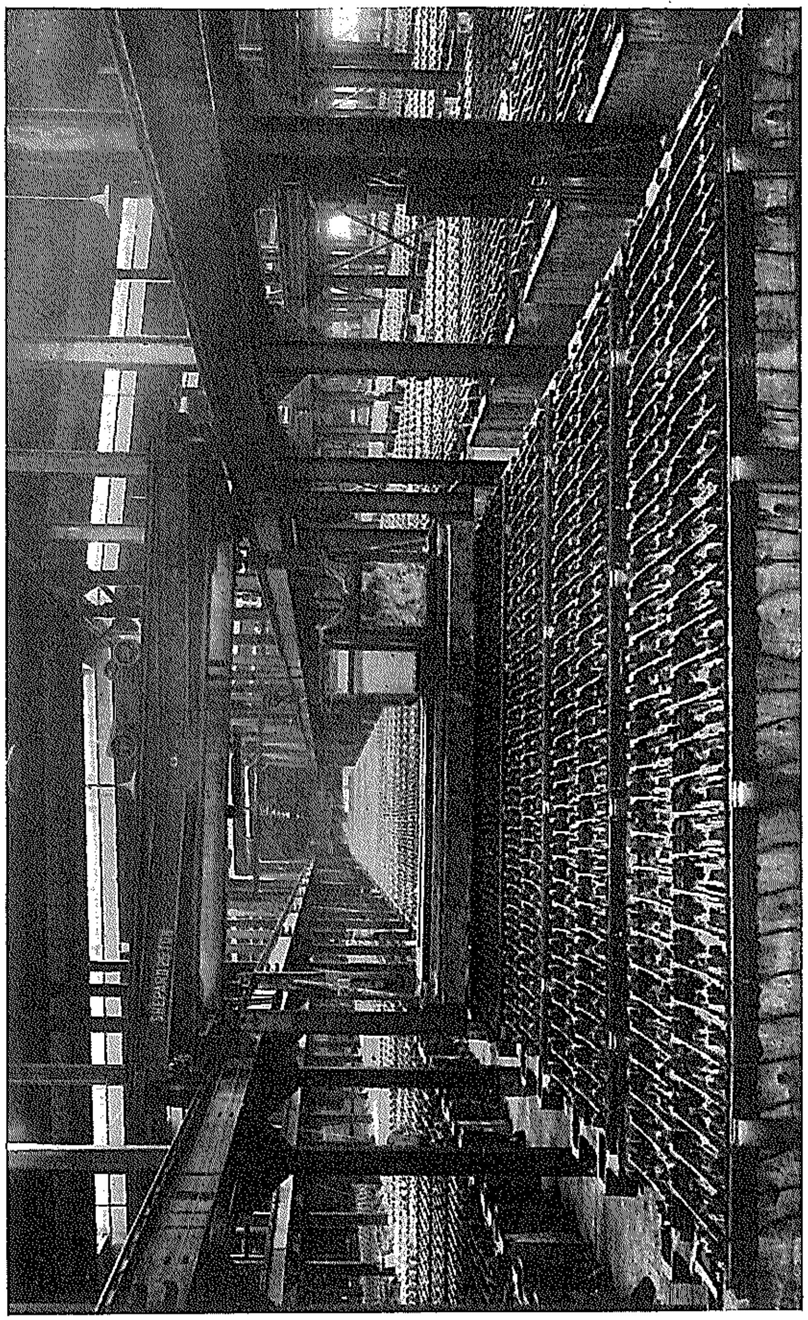
CANADIAN PACIFIC LOCOMOTIVE

The Canadian Pacific Railway pioneered in standardizing on nickel alloys for locomotives.

THE STORY OF NICKEL

PART III

Ore, Matte, and Metal



THE WHISPERING GALLERY

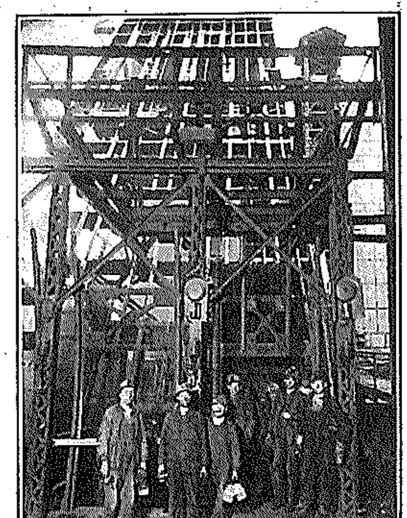
In this six-acre room, where the only sound is a faint whisper from the rows of electrolytic tanks, 96% nickel becomes 99.96% pure nickel.

ORE, MATTE, AND METAL

THE International Nickel Company of Canada, Limited, has become dominate in the world's nickel industry, producing some nine-tenths of the annual consumption and possessing ore reserves that are expected to prove adequate for the world's needs during several generations to come. This fact is stated here because it is essential to an understanding that the nickel of modern commerce is largely mined, smelted, separated from the copper, and refined to 99.96% purity under the *ægis* of a single policy and directive force.

The story of these processes tells itself; there is no need for forcing either the sense of size and power, which pervades the company's activities, or the vast investment in energy, heat and equipment required to extract the nickel from the ore and refine it into pure metal. Within a mile or two of the town of Sudbury, Ontario, is the Frood Mine, with a shaft sunk 3,100 feet alongside an ore body that has already been proved to contain over 135,000,000 tons. Within a few miles, are the Creighton, Garson, and Levack Mines which carry the total proved ore over the 200,000,000 ton mark; but it is Frood which symbolizes the latent power of this great Canadian enterprise.

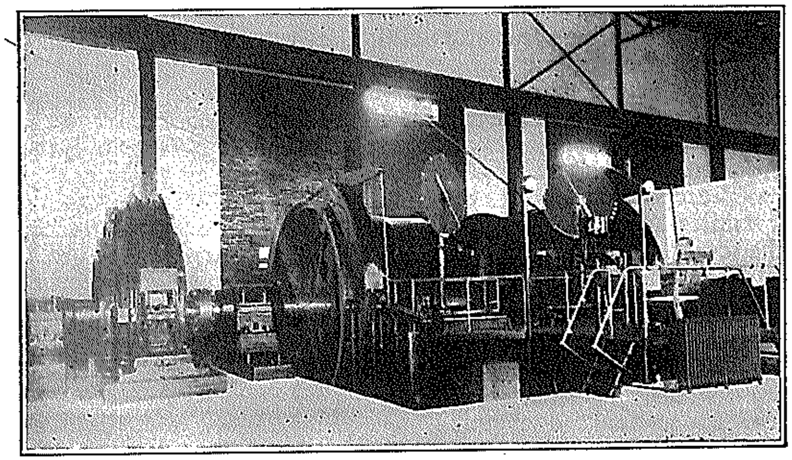
The first impression we gain in approaching Frood is that there must be, indeed, great riches below to justify so large a plant above-ground. The buildings are obviously not built today for use tomorrow and scrapping the day after. Through and around them runs the company's standard gauge railroad with its own ore cars and electric locomotives. Above them towers the main shaft house, 165 feet high, and we are told that at the 2,800-foot level of the mine this shaft is 2,200 feet away from the ore body. One reason is that the vein tilts at an angle of 65 degrees to the northwest as it plunges into the earth from the surface outcroppings. The other reason is that, as the mine will be worked for generations to come, the management can afford to place the



Emerging from Creighton Shaft

above-ground development where it can have the maximum convenience and efficiency.

Our objective is the 2,800-foot level—more than half a mile below. If this is to be our first experience so far underground, a preliminary visit to the hoist house is reassuring. The interior has all the impressive simplicity of a power plant, but in place of dynamos gigantic drums gather in and pay out steel cables which slant upward through the lofty ceiling to the shaft head a hundred yards away, where they bend over wheels and plunge vertically into the main shaft. At the end of each steel cable dangles a cage of about the dimensions of the elevators used in city garages. Back in the hoist house the operator, a mere Lilliputian, sits on a raised platform before a pair of drums. A bell strikes its message; he pulls a lever. The drums turn—swiftly, perhaps, but they by no means whirl. Yet the cages at the ends of the cables race up and down the shaft at the rate of 2,000 feet a minute.



HOIST HOUSE AT FROOD

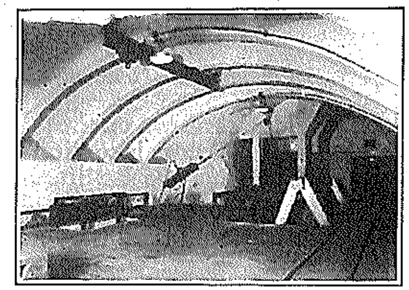
Gigantic drums gather in and pay out steel cables which hold the high-speed cages.

We get into a cage. To a depth greater than the height of the Empire State Building we drop through blackness; then, with the 1,800-foot level, the lights at the openings of the various working levels flash by at intervals of 200 feet. As we come to a stop at 2,800 feet the feeling has become an obsession that we really ought to be suffocated and completely crushed by the myriad tons of rock and earth above us. But the cage door swings up and we walk out into a place that is quite reminiscent of a London underground station. To be sure, there are no tiles, but the walls are painted white and there is more than ample headroom. As far as the eye can see tracks run off through a capacious tunnel frequently lit by overhead

lights. On a nearby siding stands an electric locomotive and its string of six-ton ore cars.

We start our walk along the tracks to the ore body 2,200 feet away. The roadbed is smooth and dry. As we reach the vein the main transverse tunnel goes off at right angles through the ore. Naturally, the ore removed in making this north and south drift has been used; otherwise, for a thousand feet or more along the drift the ore has not been touched. Mining is restricted to operations at the north and south ends, and another generation will be old enough to visit Frood before this 2,800-foot level has been completely stripped of its ore.

Tracks lead off through a side drift which is narrower and dark but still has ample headroom. We follow along until a ladder rises up perpendicularly at the side. We climb to a platform, turn, climb a similar ladder to another platform, turn, and climb again to emerge forty feet above the main floor of the 2,800-foot level. Here we are in a "stope" where the ore is actually being mined. A stout plank floor has been laid and massive timbers—a million feet of lumber are consumed in Frood every month—support the ceiling which, with its seven-foot headroom, seems to lunge down at us between the supporting timbers. The helmets with which we have been equipped as protection against falling rock becomes the personification of an empty gesture.

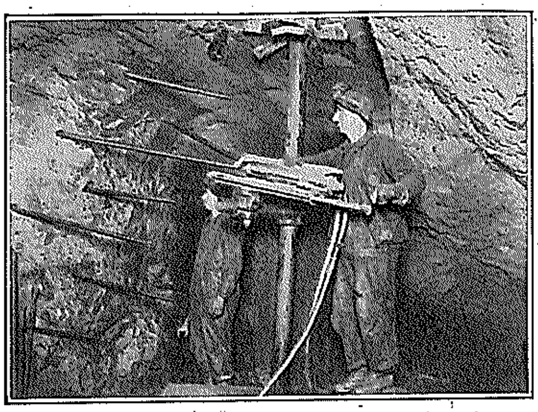


SHAFT STATION

Half a mile down in the earth, it reminds one of a London underground station.

This is the front where the miners drill and blast and start the ore on its way to be refined into the various metals which it contains so abundantly and for which the world has developed so many different uses. Working full time with its modernized processes and equipment on current grade of ore, the company can produce 180,000,000 pounds of pure nickel a year. In so doing it has an indicated by-production of 240,000,000 pounds of copper, 40,000 ounces of gold, 1,500,000 ounces of silver, and 300,000 ounces of the platinum metals. These production figures give this Canadian enterprise a practical world monopoly in nickel, a place second only to Russia in the platinum metals—platinum, palladium, rhodium, ruthenium, and iridium—and an important position in copper. But it is to be remembered in following the ore from mine to markets, that nickel is king; copper and even the precious platinum metals are among the "impurities" which must be eliminated.

Nickel ... by-prod...



A STOPE
Here is where the ore is actually mined.

The first step in elimination is done in the "stopes" where the miners sort out the rock which is broken down along with the ore. This rock has an immediate use as a filler which is packed in behind as the cut into the ore body advances. Were this not done the hanging wall of heavy but structurally weak wall rock would settle down on the miners and their equipment. Indeed, this matter of support is so vital that rock for filling is brought by the trainload from the satellite mines to keep Frood strong.

From the stope floor the ore is dropped down chutes to bins above the tracks on the 2,800-foot level. Here it is dumped into the ore cars which storage-battery locomotives collect from the side drifts and make up into heavy trains which the stronger trolley locomotives haul to the main dump on the level. There a car unloader spills the ore out into a crusher in the pit directly below the tracks. The crusher breaks up the larger lumps and feeds to an ore pocket connecting with the ore skips. These skips are ten-ton affairs which whisk the ore up to the surface at the rate of 3,000 feet a minute.

We follow at the more leisurely pace of 2,000 feet a minute—the express elevators in the most modern office buildings make 1,200 feet a minute—and find upon reaching the rock house in the shaft head that the ore is being fed into a belt conveyor for inspection and rock elimination. It is then dumped into another crusher where the larger chunks are further broken up before loading from overhead bins into the heavy ore cars for shipment to the smelter.

It is to be noted that throughout this first stage of its handling the ore has been lifted only once—its great joy-ride from the depths to the top of the shaft house. The rest of the time it has been either tumbling down chutes and through crushers and bins, or traveling along the level by train or belt conveyor.

From Frood we turn toward a chimney in which even the roundest and jolliest Santa Claus conceivable to childhood would get lost. It is the main stack of the smelter at Copper Cliff a few miles away, a hollow mast of brick 510 feet high and 45 feet in

diameter at the top. This gargantuan wind indicator has been picked up on clear days by aviators more than 80 miles away.

Thirty acres of buildings

At the base of this stack cluster thirty acres of buildings composing the mill, smelter, and Orford separation plant. Even the smelter, which is as high as a sixteen-story office building, seems dwarfed until in due course, we climb to its top. But we start at the mill where the ore comes in from the mines on elevated tracks and is dumped into bins above more crushers. At this point the mill rolls up its sleeves and proceeds to turn the chunks and lumps of ore into something as fine as coral sand. Coarse crushers feed into finer ones, and they in turn into the rod mills. Then a battery of selective flotation tanks make a rough but effective separation of the copper and the nickel sulphides. From then on there are two products; we shall follow the one with the heavier nickel content.

Our first concern now is to get rid of the water which has done its work. A settling tank draws off some; a battery of Dorr Thickeners separates out a lot more. The dewatering machines take the ore in hand and deliver to a belt conveyor a product that has roughly the moisture content of old-fashioned brown sugar. This conveyor climbs out of the mill into the top of the smelter 160 feet high. There cross conveyors distribute the ore to the tops of the multiple-deck roasting furnaces.

A furnace of this type consists of eleven round hearths superimposed upon each other above a reverberatory furnace. Each hearth has a set of revolving arms and a series of holes to the hearth below. These holes are, alternately, near the center of one hearth and around the periphery of the one below, and the arms are so arranged in each hearth that they will pick up the sulphide as it is fed from above and work it across the hearth before dropping it to the next below. Number 1 hearth at the top is the coolest. By the time the sulphide reaches No. 4 it is dry; at No. 7 it is red hot, and it finally drops into a reverberatory furnace in a condition just below the melting point.

The main purpose of the roasting furnaces is to make the first attack on the high sulphur content of the ore. In the old days this was done in a roast yard outdoors, where the ore was piled on great stacks of wood and was fired. Both the wood and the sulphur in the ore would burn for eight months before the roast was completed. Now the nickel sulphide takes only a few hours from its introduction into the first hearth until it drops into the reverberatory. The sulphur elimination is more efficient, the handling is more economical because of the gravity feed from hearth to hearth, and the roasted sulphide drops into the reverberatory without loss of heat.

In the reverberatory furnace, which is fired with powdered coal blown in by air, the sulphide turns to a molten state and the first attack is made on the iron content. Then this molten mass is ladled into a converter which, if one is not familiar with smelting operations, is a spectacular thing. In this great steel cylinder no heat is applied; yet intense heat is generated by the chemical reactions developed through introducing a continuous blast of air. In this process more sulphur is burned off, and the oxygen unites with the iron in the sulphide to form ferrous oxide. This is slagged off, and what remains is ready for the Orford Process of copper-nickel separation.

It will be remembered that this process depends on the chemical action of sodium sulphate on copper-nickel sulphide in the presence of carbon, the sodium turning to a sulphide and the copper sulphide joining with it in a mixable solution similar to sugar in coffee. This solution is lighter than the molten nickel sulphide which has been but slightly affected by the presence of the "soda". Hence, when the melt is tapped off into great pots, the nickel sulphide settles in the bottoms; then when the contents have cooled sufficiently to solidify and to be easily handled, the pots are dumped and there is an easy fracture of the copper-soda tops from the nickel bottoms. However, the separation has been only fractional, some nickel sulphide having dissolved in the copper tops and some copper having settled with the nickel in the bottoms.

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Therefore, the process is divided into two treatments. In the first a blast furnace is charged with the matte, coke, and the copper tops from a previous second treatment, these tops containing both some nickel and sufficient soda to make the melt work. The results of this treatment are a first copper top and a first nickel bottom. The top goes to a basic-lined converter where the soda is removed as refined salt cake, and the copper residuum is transferred to an acid-lined converter where it is again blown, burning off the sulphur. Here any nickel content is oxidized and slagged off, and the copper, blown to blister, is cast in 400-pound slabs. These are the raw material for the copper refinery.

The nickel bottom goes to another blast furnace where it is smelted with coke and nitre cake. This is the second treatment; it yields the second copper top which reverts to the blast furnace carrying on the first treatment, and the second nickel bottom which becomes the raw material for the nickel refinery.

This final matte is still a sulphide, hence sulphur elimination remains a problem. The matte is shipped in box cars to the nickel refinery at Port Colborne on the Welland Canal where it is crushed in ball mills, screened and leached with water to remove the sodium sulphide. After it has been drained to a low moisture content, it is transferred to sintering machines, where most of the remaining sulphur is burned out. The result is a nickel oxide sinter which is mixed with low sulphur soft coal, melted in oil-fired reverberatory furnaces and poured into molds that cast 425-pound anodes.

At this point in the refining of pure nickel all the heat and fireworks of blast furnaces, reverberatories, and converters are left behind. We enter a vast room—six acres under a single roof—where the only persistent noise is a faint whisper from the rows upon rows of electrolytic tanks. Here goes on day and night that final process in which nickel anodes 96% pure are turned into cathodes 99.96% pure nickel. The interesting thing here is, that, whereas the electric current passes directly from anode to cathode, the sulphate bath in which the process takes place travels about 1,000 feet in passing from its contact with the anode to that with the cathode. Yet anode and cathode are suspended in the same tank at a distance of 2½ inches from each other.

Magic "whisp gallery

What happens is this. The electrolytic action releases various ions from the anode and brings them into solution, the minute particles of the platinum metals dropping, however, to the bottom of the tank as the surface of the anode is pulled apart. Among the ions brought into solution are those of copper, iron, etc., which go to make up the 4% impurity of the anode. Hence it is essential to draw off this solution before it reaches the surface of the cathode, and take out by both physical and chemical processes these impurities.

The cathode sheet is therefore suspended in a canvas bag which is sufficiently watertight to maintain a hydrostatic head within the bag, thus maintaining an outward flow of the electrolyte. The foul solution around the anode is piped to a room beyond the tank room, where it is purified and then returned as pure nickel sulphate to the cathode bag. There the transverse current from positive anode to negative cathode—which is not affected by the canvas partition or by the counter flow of the electrolyte—impinges on the surface of the cathode, carrying the nickel ions of the pure sulphate. With an area of 972 square inches the cathode builds up at the rate of eight pounds every twenty-four hours; when it reaches a weight of 125 pounds it is removed and cut up into the sizes required by the various buyers of electrolytic nickel.

This is now the most popular form for using nickel in United States industry which annually consumes some 40% of the world's nickel production. There is still some demand for nickel shot—small, irregular balls of nickel—and this is filled by melting the electrolytic sheets and pouring the molten metal into a stream of water under high pressure. There is a restricted use for nickel oxide of high purity in the ceramic industry. To meet this demand a certain amount of the crushed second nickel bottoms from the blast furnaces is subjected to special roasting processes which convert it to the oxide, practically pure and quite a different product from the red ferrous-nickel oxide which constituted Colonel Thompson's early deliveries to the U.S. Navy a quarter of a century ago.

Overseas at Clydach, Wales, a nickel equally pure is produced by the application of wholly different chemical reactions. This treat-

Mond
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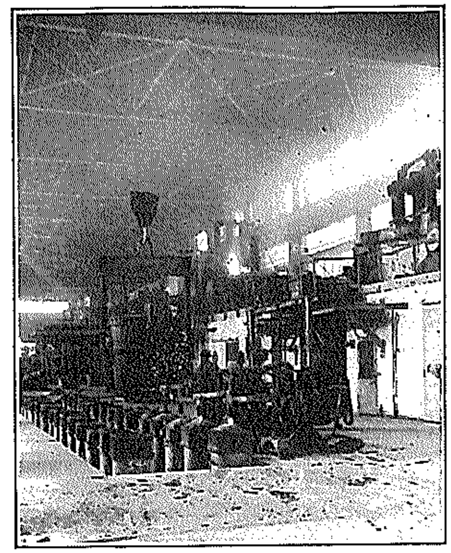
ment, known as the Mond, or Carbonyl, Process, has become the backbone of the British nickel industry. It is based on the fact that when carbon monoxide gas is passed over freshly reduced nickel oxide at temperatures around 80 degrees C., a compound $Ni(CO)_4$ is formed, and this Nickel Carbonyl, when heated to just below 200 degrees C., decomposes, giving nickel and carbon monoxide.

Until quite recently the Clydach refinery received from Canada the old-time, copper-nickel Bessemer matte, thus entailing copper extraction by leaching as copper sulphate. Now, however, Clydach is receiving the nickel bottoms of the Orford process, in which the copper content has been greatly reduced. As the matte is received at the plant, it is ground to pass through 60-mesh sieves and is then fed directly into calcining furnaces where the sulphur content is reduced from 17% to 1.5%. The resulting calcine again goes through a ball sill to break up any lumps formed during calcination, and it is then treated with sulphuric acid solution which extracts most of the copper sulphate, a product for which there is a good market in Europe. The residuum is an impure nickel oxide with low copper content, which is filtered, washed, and dried in preparation for the last three stages of nickel extraction.

The first of these stages is the reduction of this product to fine metallics in water-gas; the second is that of volatilization with carbon monoxide to form the nickel carbonyl. As both these reactions are slow, the oxide passes through both reducers and volatilizers a number of times. Indeed, the total time consumed is six and a half days. Even then a 38% nickel content remains to be reclaimed. As the copper and sulphur contents have not been affected by the volatilization process, their percentages of the mass remaining have become progressively higher until, at this point, it is no longer commercially profitable to treat the concentrate further. Hence, it is smelted and recalcined before being passed through the cycle of reducers and volatilizers for the second time. The result is No. 2 concentrate, which again makes the grand tour from smelter to volatilizer. The end result of this third cycle is then successively oxidized and leached with sulphuric acid to remove the bulk of the base metals still remaining, and this final concentrate is dried and shipped to the precious metals refinery at Acton, London, where the gold, silver, and platinum metals are recovered.

During all this time the carbon monoxide gas is circulating in a sealed circuit between the volatilizers and the decomposers. In the volatilizers the gas—at a temperature of 80 degrees C.—is picking up the finely divided metallic nickel to form nickel carbonyl. The pickup is comparatively slight, as this gaseous nickel is only 2% by volume in the gas passing over to the decomposers where the third stage in this carbonyl process takes place in a temperature maintained around 180 degrees C. What happens when the gas



"MONEL METAL" INGOTS

The ingot molds have "hot tops" formed by electric arcs which control cooling.

hits this higher temperature is that the carbonyl dissociates, the nickel depositing, and the carbon monoxide being liberated to circulate back into the volatilizers for another pickup of nickel carbonyl.

Deposition of the nickel is prepared for by having in the decomposers tiny pellets of pure nickel upon which the nickel from the broken down carbonyl can deposit. To prevent the pellets from cementing together with the freshly deposited nickel, they are kept in circulation by being removed from the decomposer bottom and hoisted to the top in bucket elevators. As nickel is being deposited continuously from the intake of nickel carbonyl, these pellets gradually grow, a cross-section of a pellet having the same type of ring structure as that of an onion. Hence, they are screened at the top of the decomposer, the smaller ones falling back to grow further and the larger ones rolling off into the collecting bins as the "nickel pellets" of commerce.

Because it is the natural alloy of the great copper-nickel deposits of Canada, "Monel Metal" merits at least brief consideration in any account of production methods in the nickel industry. This alloy owed its birth a quarter century ago to the fact that ore in the Creighton Mine near Sudbury contains twice as much nickel as copper and that in this proportion the two metals produced an alloy with properties well adapted to certain important uses in engineering, building, industry, and food-handling equipment.

"Monel Metal" production therefore starts with the selection of ore to assure the proper relation of nickel to copper. As there is no need for the separation of these two metals, the smelting problem is simplified to that of eliminating the sulphur in the ore. The first steps of this elimination are taken in the sintering machines and blast furnaces of the Coniston refinery near Sudbury. The resulting matte is then shipped in box cars to the plant at Huntington, West Virginia, where there is available an abundance of sulphur-free natural gas for use in the final smelting operations. As this matte is received at Huntington, it is crushed in ball mills, and is fed continuously into calcining furnaces. Starting at the cool end of the furnace, this nickel-copper sulphide is slowly worked by mechanical arms toward the great natural gas burners at the other end where the temperature is held at 2,000 degrees F. This slow progress takes some twenty-four hours during which all but a trace of sulphur is burned out, thus producing what is termed a "dead roast."

As the sulphide reaches the end of its trip through the calciners, charcoal is added; then it is dumped from the hot end into tubs. The product at this stage is a reduced copper-nickel oxide. More charcoal and a definite proportion of refinery scrap are added, and it is charged into open-hearth, reverberatory furnaces where it is refined for several hours; after which it is ladled into electric furnaces for another six hours or so of treatment, the total furnace time approximating twenty-four hours. At the end of the electric furnace treatment a small amount of manganese is added and the melt is cast into ingots of a ton and half in weight.

'g

the alloy

Under the old practice these ingots cooled with "heads" of porous metal, which constituted one-fourth of the total weight and which had to be sawed off. Now the ingot molds have "hot tops" formed by electric arcs which control the cooling and thus make for a longer body of solid ingot and for a proportionately smaller head. After stripping from the molds the ingots are overhauled, bloomed under great steam hammers, cropped to the sound metal, cut to size, returned to the chipping room for a second overhauling, run through a blooming mill, and then prepared for the merchant mill or the sheet mill where the "Monel Metal" bars, rods, and sheets of commerce are produced. Some of the melt, however, is cast in pigs—instead of as ingots—for the foundries where "Monel Metal" castings are made.

Such is the story of nickel as it comes from the earth, as it relives in the roast ovens, reverberatories, converters, and calciners its fiery birth eons ago; as it passes into gas at the command of modern chemistry or into ions in electrolysis; as it emerges a white, rustless metal with latent magnetic powers and almost immediately loses itself again in the countless alloys that science is giving to industry. It is a story that may have its roots in mythology and that will always carry in its name the superstitions of the Middle Ages, but that is essentially young and very much still in the making.

Enveloping this story of the metal is one of corporate history that gives a significant interpretation to the rapid strides which nickel has made in establishing itself in modern industry. This history has been affected successively by these major developments:

1. Discovery of the New Caledonian ore deposits and their exploitation by the Rothschilds through the Société Anonyme Le Nickel created the first step toward big business, the industry until then having consisted of widely scattered producers with individual

outputs scarcely above that of experimental work. This phase lasted about a quarter century, New Caledonia continuing as the dominant factor until after the turn of the century and finally losing its place to Canada in 1905.

2. Discovery of the Sudbury nickel basin led to the opening of several mines, thus swinging the focal point of the nickel industry from the Antipodes to Canada, but at the same time substituting for the practical French monopoly almost as many producers as there were mines.

3. Development of the Orford Process here and of the Mond Process overseas as commercially efficient methods for nickel extraction led to a simplification of the industrial structure. By that time nickel had become established as an important alloying metal for armament, and the infant automobile industry was beginning to experiment with it. The Old World was still in the ascendancy in steel production, and there nickel found its greatest market.

4. Then came the World War with its urgent demand for nickel at all costs. Mining and metallurgical operations which had been strangled in the pre-war competition were revived, and they gained a momentum which did not run down until well into the post-war period when the traditional market for nickel in armament production had been reduced to a very small percentage of the production facilities.

Evoluti the nick industr

Against this changing background two companies emerged as the dominant factors in the industry—the Mond Nickel Company and The International Nickel Company of New Jersey. In 1900 Dr. Ludwig Mond formed the Mond Nickel Company to develop the use of the Mond or Carbonyl Process of nickel extraction. The Victoria Mine was purchased in the Sudbury district and a smelter was erected there, while at Clydach, Wales, a refinery was established to carry on the Mond Process. The company prospered, built a new smelter at Coniston (near Sudbury), and acquired the Levack and Garson Mines and what has since become a part of the great Frood Mine. It also developed hydro-electric power for its Canadian operations and purchased a Welsh colliery to serve its Clydach refinery.

Following the war this company bought a rolling mill at clearfield, Penn., and established a precious metals refinery in the Acton district of London. In the meantime it had also acquired the British firm of Henry Wiggin & Company, Limited, with a background of nickel production at Birmingham, England since 1832. Indeed, among the antecedents of the Wiggin firm was Henry Merry who is credited with having been the first producer of an efficient substitute for the Chinese paktong, the forerunner of our modern bright metal alloys containing nickel.

Starting two years later (in 1902) the other great nickel company was created on this side of the water through the incorporation of The International Nickel Company of New Jersey. This was a holding company primarily to bring together the Canadian Copper Company, which had already developed important mines and a smelter in the Sudbury district, and the Orford Copper Company which, through control of the Orford Process, had established itself as the great American refiner of nickel. At the same time there were brought into the group two other Canadian mining properties—the Anglo-American Iron Co. and the Vermilion Mining Co. of Ontario; two relatively unimportant mining properties in New Caledonia—the Nickel Corporation of London and the Société Minière Caledonienne; and the second largest American refiner—Joseph Wharton's American Nickel Works. The next move was to establish strong marketing activities overseas; this was done through agency connections first with Henry Gardner & Company, Ltd., of London, and later also with G. & H. Weir, Ltd., which subsequently developed into Monel-Weir, Limited. In the post-war period these developments were supplemented by the formation of Nickel Information Bureaus in Paris, Brussels, Frankfort, Milan and Tokyo.

During the first twenty-five years of its existence International Nickel Company went through a number of changes in corporate title. On December 16, 1928, The International Nickel Company of Canada, Limited, emerged as the parent company, and, as of January 1, 1929, this company, through an exchange of stock, became also the parent of the Mond Nickel Company, Limited, and of Mond's wholly owned subsidiaries.

Thus there has been brought into a single group the mining, metallurgical, and marketing operations covering ninety per cent of the world's production of nickel and the entire production of "Monel Metal," thereby placing in Canada control over world-wide activities that are based on the Dominion's richest concentration of ore.

Nickel and Nickel Alloys and Their Uses

NICKEL IN NON-FERROUS ALLOYS

ALLOYS WITH CHROMIUM

ELECTRICAL RESISTANCE ALLOYS (Up to 85% Nickel)
Heater and pyrometer wire, rheostat wire (includes household electrical accessories)

HEAT RESISTANT ALLOYS (35% to 85% Nickel)
Electric furnace heating elements, carburizing and annealing boxes for metal treatment, furnace parts, tubes and retorts in chemical industry, ceramic and glass industry equipment

ALLOYS WITH COPPER

COPPER-NICKEL ALLOYS (15% to 50% Nickel)
Bullet jackets, corrosion resistant castings, valves and valve trim, condenser tubes, electric resistance wire

NICKEL BRONZES (½% to 5% Nickel)
Bearings, valve castings, steam packing metal, pressure castings.

NICKEL SILVER (10% to 30% Nickel)
Standard white metal for silver plated ware, flat keys and hardware, plumbing fixtures, base for filled gold, jewelry, coinage

MONEL METAL (68% Nickel)
Power handling and electrical equipment, chemical manufacturing and dye handling, metal pickling equipment, food handling, canning, packing and dispensing, marine shafting, condenser tubes and other salt water uses, architectural, mining, petroleum, pulp and paper, textile and dye handling industries, laundry and hospital equipment, kitchen equipment and household accessories

ALUMINUM AND ZINC ALLOYS

ALUMINUM ALLOYS (2% Nickel)
Pistons and cylinder heads for internal combustion engines, crankcases.

ALUMINUM AND ZINC BASE DIE CASTINGS (½% to 5% Nickel)
Numerous die cast parts for meters and other light machinery

OTHER ALLOYS

NICKEL MANGANESE ALLOYS (96% Nickel)
Spark plug wire

NICKEL MOLYBDENUM IRON ALLOYS (60% Nickel)
For resistance to hydrochloric and other acids.

NICKEL-COBALT-TITANIUM ALLOY (78% Nickel)
Rectifier tubes.

WHITE GOLD (15% Nickel)
Jewelry, eye glass and instrument mountings.

FLESH COLORED GOLDS (5% to 6% Nickel)

GREEN GOLDS (1% to 2% Nickel)
For jewelry

PURE NICKEL

ANODES (99.9% Nickel)
Electro plating of innumerable articles.

COINAGE (99% Nickel)
Canadian 5c piece and similar coins of France, Italy, Switzerland, Belgium and more than fifteen other nations.

MISCELLANEOUS
Nickel elements in storage batteries. Nickel as a catalyzer in hydrogenation of edible oils. Nickel oxide and nickel salts in the chemical, glass and ceramic industries.

NICKEL CLAD STEEL (10% 20% Nickel Coating)
Heavy steel plates with a coating of nickel inseparably bonded by rolling.
Used for heavy equipment to give, at low cost, protection afforded by nickel.

ROLLED MALLEABLE NICKEL (99% Nickel)
Tanks, evaporators, vats, and similar apparatus for handling chemicals, dairy and food handling equipment, radio tube parts, laboratory utensils, photographic film manufacture, radiator shells, heat treating equipment, watch case parts, glass making equipment.

NICKEL IN FERROUS ALLOYS

CAST IRONS

CORROSION RESISTANT CAST. IRONS (12% to 20% Nickel)
Oil refinery equipment, mine equipment, aircraft, automobile and Diesel engine construction, resistance grids, valves, rolls for glass, equipment for handling sugar extracts.

CHILLED CAST IRON (4% to 5% Nickel)
Crusher jaws, ore and coal cariers, pumps handling abrasives, rolls.

NICKEL CAST IRON (½% to 3% Nickel)
Automobile, oil and gas engine and locomotive construction, compressors, pumps, cut gears and cams, resistance grids, machine tool construction, glass molds, forming dies, automobile parts, printing machinery.

(5% Nickel)
Subway and surface car resistance control and car heating grids.

(10% to 15% Nickel)
Electrical machinery castings (non-magnetic, high resistance).

STEELS

HEAT RESISTANT STEELS (7% to 35% Nickel)
Oil refinery construction, ceramic and glass industry construction, furnace and mill parts in the metals industries, power plant construction, equipment for high temperature chemical processes.

CORROSION RESISTANT STEELS (7% to 35% Nickel)
Cooking utensils (household or restaurant trade), marine fittings, building trim, automobile hardware and fittings, power equipment, submarine periscope tubes, turbine blading, chemical apparatus, stranded cables, miscellaneous parts for outdoor equipment.

NICKEL STEEL CASTINGS (1% to 4% Nickel)
Locomotive frames, railway trackwork, ore and rock crushers, high pressure valves, steel mill rolls, tube mill balls, tractor and road machinery parts, general machinery applications.

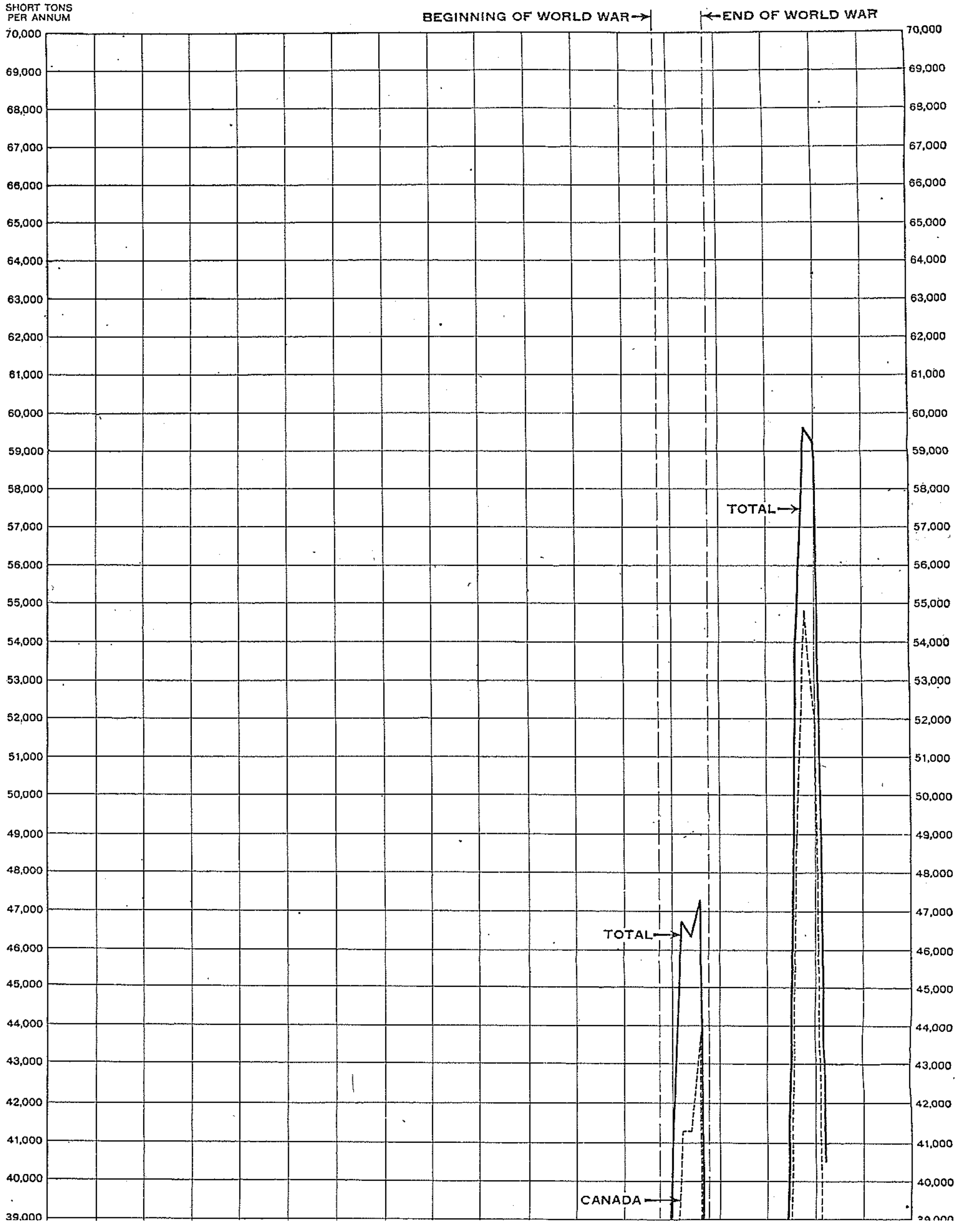
NICKEL STEELS (½% to 7% Nickel)
Automobile, aircraft and motorcycle construction, locomotive and railroad car parts, mining, excavating, milling, lumber mill and power machinery, machine tools, steam and hydraulic turbines, electrical machinery, marine shafting, die blocks, ordnance, oil country tools.

IRON-NICKEL ALLOYS

HIGHLY MAGNETIC ALLOYS (45% to 80% Nickel)
Electrical sheathing of submarine cable, radio transformers, telephone and telegraph relay parts, special type current transformers

NON-MAGNETIC ALLOYS (10% to 25% Nickel)
Transformer, motor and generator parts and miscellaneous uses in electrical equipment.

LOW EXPANSION ALLOYS (35% to 45% Nickel)
Struts in auto engine pistons, thermostatic metals, exact dimension rods, surveyor's tapes, electric light bulb construction, wire glass


SHORT TONS PER ANNUM
BEGINNING OF WORLD WAR
END OF WORLD WAR
70,000
69,000
68,000
67,000
66,000
65,000
64,000
63,000
62,000
61,000
60,000
59,000
58,000
57,000
56,000
55,000
54,000
53,000
52,000
51,000
50,000
49,000
48,000
47,000
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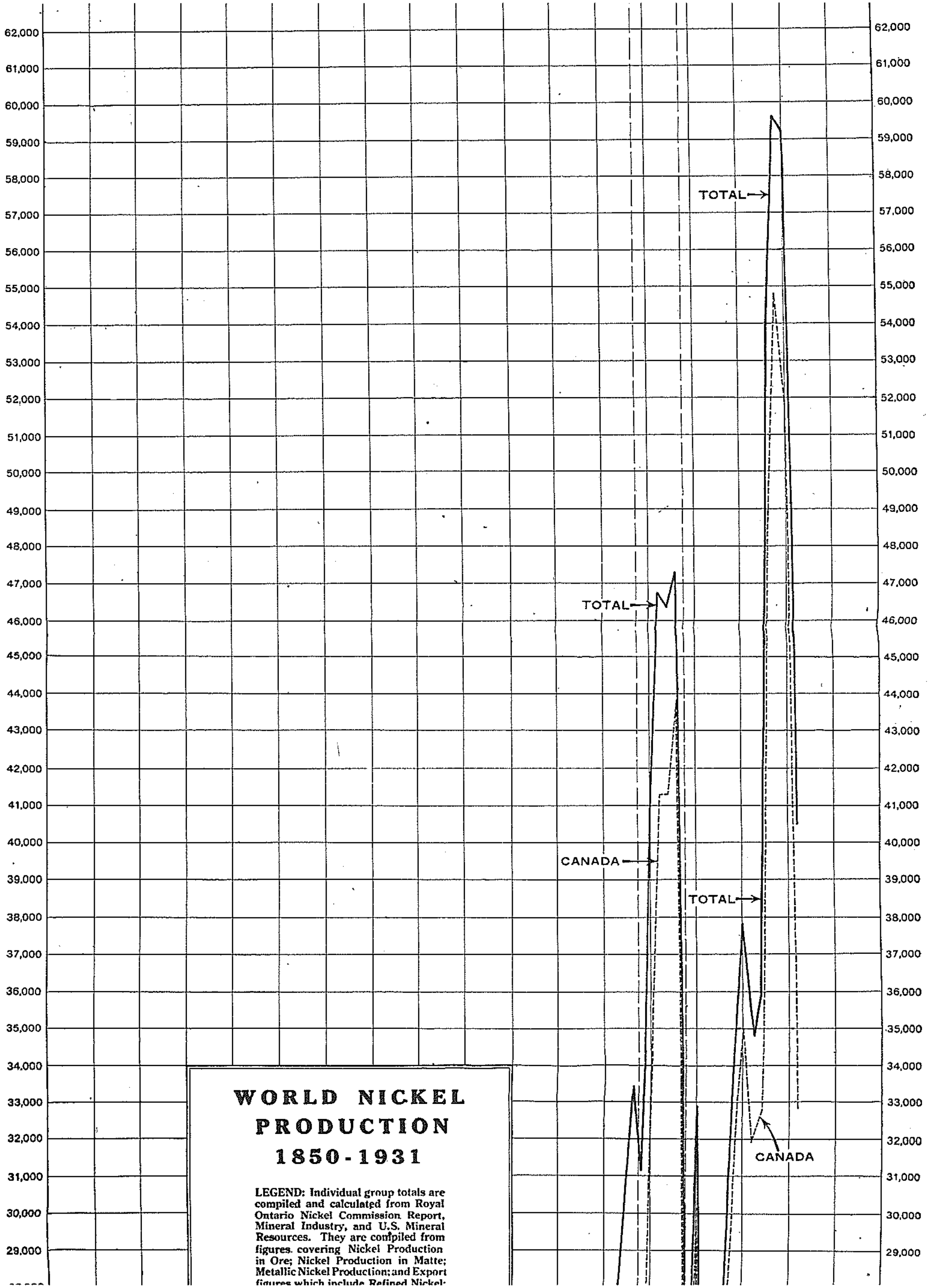
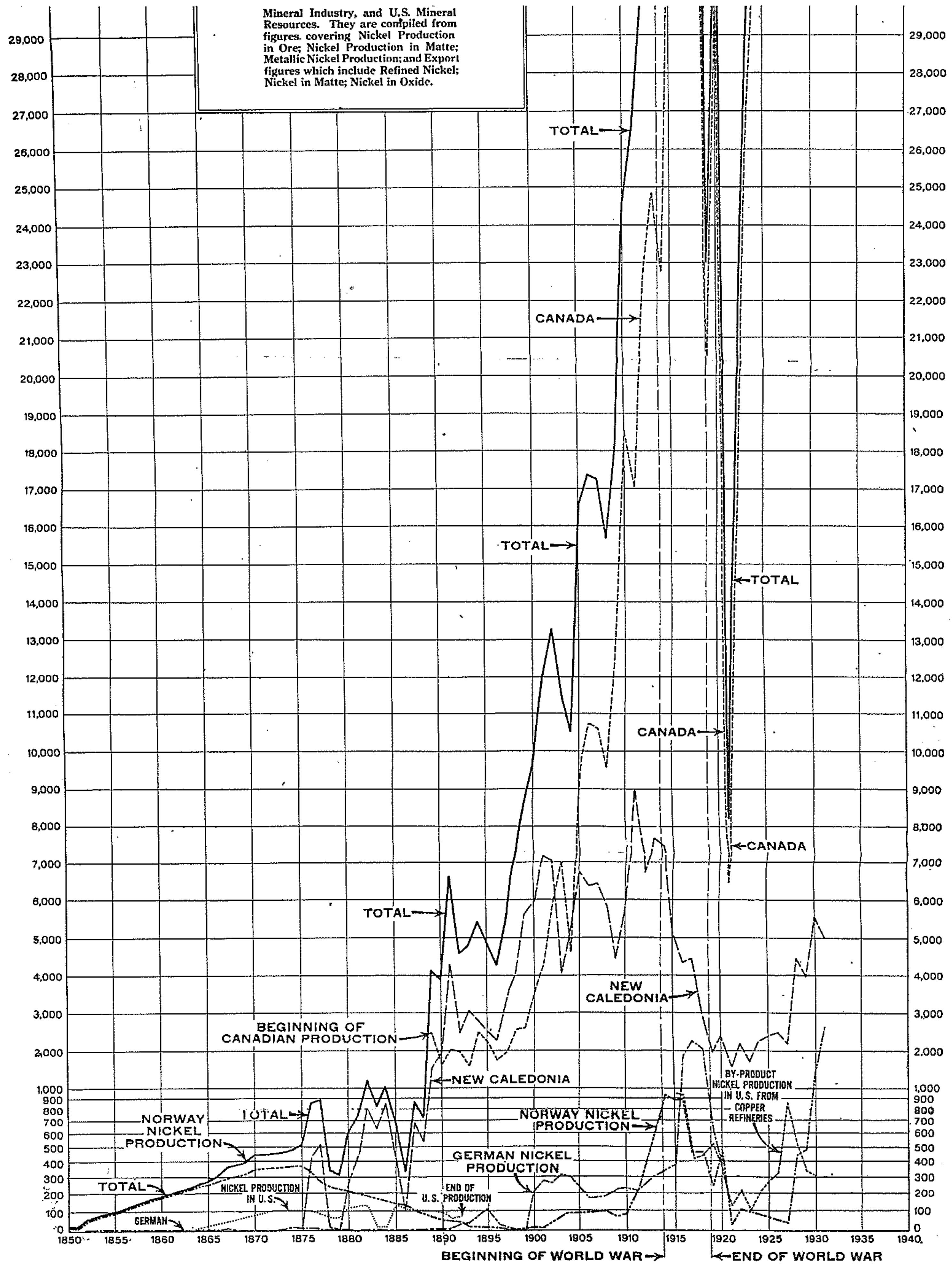
45,000
44,000
43,000
42,000
41,000
40,000
39,000
TOTAL
TOTAL
CANADA



WORLD NICKEL PRODUCTION 1850-1931

LEGEND: Individual group totals are compiled and calculated from Royal Ontario Nickel Commission Report, Mineral Industry, and U.S. Mineral Resources. They are compiled from figures covering Nickel Production in Ore; Nickel Production in Matte; Metallic Nickel Production; and Export figures which include Refined Nickel:


Mineral Industry, and U.S. Mineral Resources. They are compiled from figures covering Nickel Production in Ore; Nickel Production in Matte; Metallic Nickel Production; and Export figures which include Refined Nickel; Nickel in Matte; Nickel in Oxide.
TOTAL
CANADA
TOTAL
TOTAL
CANADA
CANADA
TOTAL
NEW CALEDONIA
BEGINNING OF CANADIAN PRODUCTION
NEW CALEDONIA
NORWAY NICKEL PRODUCTION
TOTAL
NORWAY NICKEL PRODUCTION
BY-PRODUCT NICKEL PRODUCTION IN U.S. FROM COPPER REFINERIES
GERMAN NICKEL PRODUCTION
TOTAL
NICKEL PRODUCTION IN U.S.
END OF U.S. PRODUCTION
GERMAN
29,000
28,000
27,000
26,000
25,000
24,000
23,000
22,000
21,000
20,000
19,000
18,000
17,000
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
900
800
700
600
500
400
300
200
100
0
1850
1855
1860
1865
1870
1875
1880
1885
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
BEGINNING OF WORLD WAR
END OF WORLD WAR