Cobalt

By John D. Corrick [1]

Cobalt consumption increased 13% in 1972 compared with that of 1971; this was the first increase in consumption since 1969. Demand for cobalt at the beginning of 1972 was depressed; however, a progressive improvement in demand occurred during the second half of 1972. Consumer stocks, which had reached their lowest level in 5 years during 1971, remained at a low, but relatively stable, level during 1972. Government sales of cobalt from the strategic stockpile were a significant source of supply during 1972 with over 8.6 million pounds sold.

Legislation and Government Programs.—General Services Administration (GSA) continued to offer specification-grade and subspecification-grade (Calera material) cobalt metal in various forms for sale during 1972. Sales were on an unrestricted-bid basis except that total sales of specification-grade material were limited to approximately 1 million pounds per month and 500,000 pounds per bidder per month. Government sales of cobalt for the year totaled 8,629,692 pounds, compared with 901,699 pounds sold in 1971. Of the quantity sold, 5,015,061 pounds was subspecification Calera cobalt, GSA's entire Calera stock.

As of December 13, 1972, total U.S. Government stockpile inventory was 71,499,318 pounds of cobalt. Of this quantity, 67,913,260 pounds was stockpile grade.

Table 1.—Salient cobalt statistics

(Thousand pounds of contained cobalt)

	1968	1969	1970	1971	1972
United States:					
Consumption	12,998	15,608	13,367	12,500	14,130
Imports for consumption	9,068	12,911	12,417	10,912	13,915
Stocks, Dec. 31: Consumer	2,139	2,191	1,890	1,411	1,193
Price: Metal, per pound	$1.85	$1.85–$2.20	$2.20	$2.20–$2.45	$2.45
World: Production, mine	41,968	43,556	52,590	47,908	51,290

DOMESTIC PRODUCTION

Domestic production of cobalt-bearing pyrite concentrates was discontinued at the end of 1971, shutting off the only source of domestically mined cobalt. Professional Oil and Management Co. (POM Corp.) and The Hanna Mining Co. agreed to explore and possibly develop the Iron Creek copper-cobalt prospect located in the Salmon-Blackbird mining district of Idaho. The prospect was owned by POM's subsidiary, Sachem Prospects Corp.[2] At yearend, the company had driven 615 feet of underground openings, built 500 feet of bulldozer roads, and taken approximately 1,000 feet of core samples.

American Metals Climax Inc. (AMAX), through a new division, AMAX Nickel, continued rehabilitation of its Port Nickel, La., refinery. Late in 1972 the company acquired additional acreage which doubled the amount previously owned and increased river frontage from 1,800 to 3,600 feet.[3] Tentatively the refinery will begin processing material from the Botswana Bamangwato Concessions nickel-copper project in 1974. In addition to nickel, the refinery will produce cobalt from other feed materials acquired by AMAX.

[1] Physical scientist, Division of Ferrous Metals.

[2] Mining Journal. Copper-Cobalt Project in the United States. V. 178, No. 7129, Apr. 7, 1972, p. 281.

[3] Skillings' Mining Review. AMAX Buys More Port Nickel, La., Property. V. 61, No. 47, Nov. 11, 1972, p. 10.

CONSUMPTION AND USES

Consumption of cobalt in the United States in 1972 was 13% above that in 1971 and reversed a declining trend that began in 1970. Increased consumption could be related to improved economic activity around the world, particularly the demand for cobalt in superalloys and magnetic alloys. Major uses of cobalt in 1972, as shown in table 4, were in magnetic alloys, superalloys, salts and driers, and cutting and wear-resistant materials. Data reported by consumers showed that of the cobalt consumed in the United States during 1972, 74% was as metal, 19% was as salts and driers, 5% was as oxide, and 1% was as purchased scrap. Total U.S. cobalt consumption was 14.1 million pounds in 1972.

Officials of Varian Associates announced commercial production of samarium-cobalt magnets through the use of powder metallurgy techniques. The magnets were to be produced in the form of rings, rods, bars, rectangles, and sections for use in microwave tubes, electric watches, motors and generators, solid state devices, and instruments. Researchers at Varian investigated other rare-earth cobalt alloys which showed even greater promise than samarium-cobalt. Among those alloys tested were praseodymium-cobalt and misch-metal cobalt.[4]

Numerous new cobalt alloys were introduced in 1972. E. I. du Pont de Nemours & Co., Inc. introduced a novel group of patented, high-temperature cobalt-based alloys with superior wear and friction resistance.[5] These intermetallic materials were designed for high-temperature applications where lubrication was a problem. The alloys were composed of cobalt, molybdenum, and silicon and were available in powder form for plasma spray applications and hard surfacing, and as irregularly shaped powders for powder metallurgy usage. The Huntington Alloy Products Division of the International Nickel Co. (INCO) introduced a new nickel-based heat-resisting alloy containing 12.5% cobalt and designated Inconel 617.[6] The alloy was developed for use in gas turbines exposed to high temperatures and was reported to have excellent resistance to oxidation and carburization at 1,095°C.

[4] American Metal Market. High Energy Magnets Set. V. 79, No. 100, May 26, 1972, p. 9.
[5] American Metal Market. Wear-Resistant Cobalt Alloys for Lubrication on Market. V. 79, No. 233, Dec. 6, 1972, p. 17.
[6] American Metal Market. Variety of Lab Developments Listed for Cobalt Materials. V. 79, No. 138, July 27, 1972, p. 12.

Table 2.—Cobalt materials consumed by refiners or processors in the United States

(Thousand pounds of contained cobalt)

Form [1]	1968	1969	1970	1971	1972
Alloy and concentrate	1,184	516	274	356	333
Metal	1,831	2,819	2,639	2,899	3,063
Hydrate	14	25	32	18	16
Other	11	1	9	9	16

[1] Total consumption is not shown because some metal and hydrate originated from alloy and concentrate, and a total would involve duplication.

Table 3.—Cobalt products [1] produced and shipped by refiners and processors in the United States

(Thousand pounds)

	1971				1972			
	Production		Shipments		Production		Shipments	
	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content
Oxide	713	489	771	519	651	459	824	581
Hydrate	523	322	483	296	830	513	788	487
Salts [2]	6,306	1,681	6,240	1,679	5,354	1,336	5,382	1,361
Driers	8,335	728	8,580	769	9,623	834	9,771	843
Total	15,877	3,220	16,074	3,263	16,458	3,142	16,765	3,272

[1] Figures on metal withheld to avoid disclosing individual company confidential data.
[2] Combined to avoid disclosing individual company confidential data.

Table 4.—Cobalt consumed in the United States, by end use

(Thousand pounds of contained cobalt)

Use	1972
Steel:	
Carbon	3
Stainless and heat-resisting	39
Full alloy	217
High-strength low-alloy	7
Electric	W
Tool	361
Cast irons	W
Superalloys	3,012
Alloys (exclude alloy steels and superalloys):	
Cutting and wear-resistant materials [1]	1,273
Welding and alloy hard-facing rods and materials	199
Magnetic alloys	3,441
Nonferrous alloys	651
Other alloys	676
Mill products made from metal powder	W
Chemical and ceramic uses:	
Pigments	165
Catalysts	702
Ground coat frit	144
Glass decolorizer	61
Other	173
Miscellaneous and unspecified	315
Total	11,439
Salts and driers: Lacquers, varnishes, paints, ink, pigments, enamels, glazes, feed, electroplating, etc.	e 2,691
Grand total	14,130

e Estimate. W Withheld to avoid disclosing individual company confidential data; included in "Miscellaneous and unspecified."

[1] Includes cemented and sintered carbides and cast carbide dies or parts.

Table 5.—Cobalt consumed in the United States, by form

(Thousand pounds of contained cobalt)

Form	1968	1969	1970	1971	1972
Metal	10,456	12,057	10,056	9,006	10,509
Oxide	573	646	626	625	733
Purchased scrap	143	328	69	125	197
Salts and driers	1,826	2,577	2,616	2,744	2,691
Total	12,998	15,608	13,367	12,500	14,130

PRICES

The producer price for cobalt metal in the form of granules (shot) or broken cathodes in 551-pound (250-kilogram) drums remained at $2.45 per pound, f.o.b. New York or Chicago, throughout the year.

Sales of cobalt metal by the Government on a "sealed-bid" basis ranged in price from $2.15 to $2.41 per pound for specification-grade material and from $1.92 to $2.15 per pound for subspecification-grade material. All prices were f.o.b. carrier's conveyance at Government storage locations.

FOREIGN TRADE

Exports of unwrought cobalt metal and alloys and of waste and scrap totaled 2,148,261 pounds, gross weight, having a value of $3,168,899, and went to 17 countries. Japan and West Germany received the greater part, 1,164,710 pounds ($1,358,131) and 550,933 pounds ($1,115,547), respectively. Exports of wrought cobalt metal and alloys, 448,844 pounds, gross weight, having a value of $1,836,158, went to 19 countries. The imports of cobalt salts and compounds given in table 7 came principally from France and the United Kingdom.

Table 6.—U.S. imports for consumption of cobalt metal and oxide, by country

(Thousand pounds and thousand dollars)

Country	Metal				Oxide			
	1971		1972		1971		1972	
	Gross weight	Value	Gross weight	Value	Gross weight	Value	Gross weight	Value
Belgium-Luxembourg	r 2,499	r 5,973	3,344	8,242	726	1,425	878	1,913
Canada	909	1,933	633	1,540	--	--	221	342
Finland	1,208	2,696	1,299	3,189	--	--	--	--
France	126	180	500	1,035	--	--	--	--
Germany, West	2	4	12	25	--	--	(1)	1
Japan	--	--	45	118	--	--	--	--
Netherlands	42	76	49	67	--	--	--	--
Norway	800	1,758	915	2,083	--	--	--	--
United Kingdom	223	212	131	142	(1)	1	(1)	(1)
Zaire	4,572	r 9,545	5,083	11,602	--	--	35	74
Zambia	--	--	1,071	2,607	--	--	--	--
Total	10,381	r 22,377	13,082	30,650	726	1,426	1,134	2,330

r Revised.
1 Less than ½ unit.

Table 7.—U.S. imports for consumption of cobalt, by class

(Thousand pounds and thousand dollars)

Year	Metal		Oxide		Salts and compounds		Total	
	Gross weight	Value	Gross weight	Value	Gross weight	Value	Gross weight	Cobalt content e
1970	11,873	26,020	710	1,394	157	92	12,740	12,417
1971	10,381	r 22,377	726	1,426	40	27	11,147	10,912
1972	13,082	30,650	1,134	2,330	82	44	14,298	13,915

e Estimate. r Revised.

WORLD REVIEW

Cobalt produced in the free world in 1972 was sufficient to meet demand. Zaire led all countries in mine production of cobalt and accounted for 56% of the total world output. Nevertheless, cobalt metal production decreased in Zaire, Zambia, Canada, West Germany, and Finland in 1972 compared with that of 1971. Reasons for decreased production were varied and ranged from Zaire's reducing production in order to bring the supply-demand relationship into better balance to West Germany's difficulties in securing adequate supplies of raw materials.

Australia.—Construction work began in 1972 on the Freeport Minerals Co. Greenvale nickel-cobalt project in Queensland, Australia. The Greenvale project was a 50–50 joint venture between Metals Exploration N.L. and Freeport Minerals Co. Freeport, which held a 22% equity interest in Metals Exploration, holds a total interest of approximately 61% in the project. The Ralph M. Parsons Co. of the United States was contracted to design and construct processing facilities at Townsville, Australia, to treat the Greenvale laterite ore. The plant will treat annually approximately 2.3 million tons of dry ore and produce about 46 million pounds of nickel and 2.75 million pounds of cobalt in the form of nickel-cobalt sulfide. A group of five Japanese companies reportedly will purchase all of the nickel-cobalt sulfide produced for the life of the mine. Production was scheduled for 1974.

Canada.—Mine production of cobalt decreased in 1972 by 4% compared with that of 1971. INCO's deliveries of cobalt were 2,210,000 pounds in 1972, compared with 1,980,000 pounds in 1971 and 1,870,000 pounds in 1970. Cobalt production at the Falconbridge Nickel Mines Ltd. refinery in Kristiansand, Norway, was halted when a fire in May killed three workers and seriously damaged the refinery. Inventories of refined cobalt were exhausted early in 1972. Reportedly, Falconbridge's new refinery in Norway was to begin producing cobalt in March 1973. A newly formed European subsidiary of Falconbridge, Falconbridge Europe S.A., took over the

Table 8.—Cobalt: World production by country
(Short tons)

Country	Mine output, cobalt content [1]			Metal [2]		
	1970	1971	1972 p	1970	1971	1972 p
Australia	517	343	e 815	--	--	--
Canada [3]	2,281	2,162	2,076	1,419	1,204	e 1,030
Cuba e	1,700	1,700	1,700	--	--	--
Finland e	1,400	1,400	1,400	1,111	1,020	885
France [4]	--	--	--	r 335	635	e 660
Germany, West [4]	--	--	--	911	662	504
Morocco	666	1,078	1,261	--	--	--
Norway	NA	NA	NA	[5] 862	[5] 958	[5] e 1,000
U.S.S.R. e	1,700	1,750	1,800	1,700	1,750	1,800
United States	W	W	W	162	154	--
Zaire	15,386	13,228	e 14,330	14,742	16,003	14,377
Zambia [7]	2,645	2,293	2,263	2,262	2,292	e 2,090
Total	r 26,295	23,954	25,645	r 23,504	24,678	22,346

e Estimate. p Preliminary. r Revised. NA Not available. W Withheld to avoid disclosing individual company confidential data.

[1] In addition to the countries listed, Bulgaria, Cyprus, East Germany, New Caledonia, Norway, Poland, Spain and Sweden are known to produce ores (copper, nickel, and/or pyrite) that contain recoverable quantities of cobalt, but available information is inadequate to make reliable estimates of output levels. Other nations may also produce cobalt as a byproduct component of ores and concentrates of other metals.

[2] The United Kingdom recovers cobalt metal from intermediate metallurgical products imported from Canada, but data on output is inseparable from the total reported by Canadian producers. Czechoslovakia presumably recovers cobalt from materials imported from Cuba but data are inadequate to estimate output. Belgium and Japan, which import substantial quantities of crude materials containing cobalt, have not recorded output in recent years, but may be producing metal and/or cobalt compounds. Poland apparently processes cobalt-bearing copper ores but no data on cobalt recovery are available.

[3] Actual mine output not reported. Data presented for mine output are total cobalt content of all products, including nickel oxide sinter shipped to United Kingdom and nickel-copper matte shipped to Norway for further processing. Data presented for metal content are total cobalt content of all products less cobalt output recorded for Norway, thus the metal data include cobalt content of oxides and other compounds that are not reduced to metal as well as total metal actually recovered in Canada and the United Kingdom.

[4] Domestic mine output, if any, is negligible.

[5] Produced entirely from nickel-copper matte imported from Canada; domestic mine output is recovered abroad.

[6] Insufficient data are available to permit separate estimates of mine and metal production.

[7] Metal figures given are content of matte.

sale of cobalt and nickel in Belgium, the Netherlands, and Spain from Brandeis Goldschmidt in 1972. Falconbridge continued to make progress on the construction of the Becancour, Quebec, refinery complex. When completed in 1975, the refinery will produce 500,000 pounds per year of high-purity cobalt salts. Sherritt Gordon Mines Ltd. reportedly had a refinery output of cobalt in 1972 of 809,000 pounds compared with 561,000 pounds in 1971. Sales of cobalt for the 2 years were 713,000 and 679,000 pounds, respectively. Officials of Sherritt Gordon reported the successful completion of tests at its Fort Saskatchewan demonstration plant on laterite ore from Gag Island, Indonesia for P. T. Pacific Nickel Indonesia in 1972. A detailed feasibility study on mining and processing facilities to produce over 100 million pounds of nickel and approximately 4 million pounds of cobalt per year was to be completed in the fourth quarter of 1972. Officials of Dickerson Mines of Canada reported the shutdown of its cobalt refining operation in February 1972. The refinery reportedly had problems obtaining raw materials during its 10 years of operation. The company's inventory of cobalt, silver, gold, and copper at the refinery was liquidated early in 1971.

Finland.—Officials of Outokumpu Oy reported continued progress on the development of the Vuonos mine. Concentration of nickel ore from the Vuonos mine began in late 1971. When in full operation the mine will produce 72,000 tons per year of cobalt-rich iron pyrites. Cobalt metal production was 885 tons in 1972, compared with 1,020 tons in 1971.

India.—Recent discoveries of nickel-cobalt ore bodies in the State of Orissa prompted the National Metallurgical Laboratory at Jamshedpur to develop a suitable process for treating serpentinous and lateritic nickeliferous ores. The process involved a roast-reduction step followed by ammoniacal leaching. Commercial feasibility of the developed process would require a nickel recovery of 60% from an ore containing over 0.41% nickel. The Sukinda

nickel deposit in Orissa was estimated to contain 14 million tons of nickel laterite ore grading 0.8 to 1.4% nickel.

Indonesia.—P. T. Pacific Nickel Indonesia received a favorable report from tests performed at Sherritt Gordon's Fort Saskatchewan plant on laterite ore from Gag Island. Detailed feasibility studies on mining and processing facilities were to be completed in late 1972 by Sherritt Gordon for P. T. Pacific, in which Sherritt had a 10% interest.

Officials of INCO reported signing participation and sales agreements with six Japanese firms covering its nickel project on the Indonesian island of Sulawesi. INCO's subsidiary, P. T. International Nickel Indonesia, was to control 60% with the remaining 40% divided evenly between Japanese firms and Indonesians. Initial production capacity was rated at over 15,000 tons of nickel plus cobalt per year in the form of a 75% nickel matte.

Philippines.—Despite devastating floods which took a heavy toll of life and property in the Philippines in 1972, work progressed satisfactorily on construction of Marinduque Mining and Industrial Corp.'s nickel refinery on Nonoc Island. Bechtel Corp. and Bechtel Overseas Corp. were providing engineering, procurement, and construction management services for the project. When completed in July 1974, the project will produce 3.3 million pounds of cobalt per year in the form of mixed sulfides along with nickel briquets and powder. Overseas Private Investment Corp. pledged to guarantee $17 million in U.S. loans for the $232.5 million project. The value of U.S. equipment and services for the project was estimated at over $60 million. By mid-1972, Marinduque had placed a $1.9 million order with Sumitomo Shipbuilding and Machinery Co. for eight electrostatic precipitators and four dust collectors. Sumitomo was licensed by Joy Manufacturing Co. of the United States to build Joy-designed dust collectors for Asian markets. Delivery of equipment was slated for spring 1973. At yearend, officials of Marinduque announced a $3 million sale of stock, thereby completing its $8 million equity share of the $232.5 million project. Sherritt Gordon was to buy $6.8 million of Marinduque stock, an increase of $1.8 million over the original amount Sherritt agreed to buy.

Sumitomo Metal Mining Co., Ltd., Nippon Mining Co., Ltd., Pacific Metals Co., and Nissho-Iwai Co. of Japan continued negotiating with Soriano Co. of the Philippines for development of nickel-cobalt deposits on Palawan Island. The ore was offered the consortium by Rio Tuba Nickel Mining Corp. of the Philippines. The Japanese were requested to finance 80% of the project's cost. If negotiations succeed, it was estimated that 1 million tons of ore per year would be mined beginning about 1976.

Uganda.—Reduced mine production by Kilembe Copper Cobalt Ltd. in 1972 could be traced to labor unrest resulting from expulsion of technicians by the Government and uncertain copper markets. Kilembe reportedly was "down to the bone" staff-wise. The company requested the Ugandan Government to grant tax reliefs, which if not granted would decrease exploration work and thereby reduce reserves. Probable ore reserves did decrease by about 1.1 million tons in 1971 with little additional probable ore outlined. A cobalt bearing pyrite concentrate was produced and stockpiled at the mine during 1972.

Zaire.—La Générale des Carrières et Mines du Zaïre (GECAMINES), the state holding company for all extractive metallurgy activities in Zaire, through its operating company La Générale Congolaise des Minerais (GÉCOMIN) was again the leading world producer of cobalt, accounting for 56% of the total world mine output. Cobalt production came from the Province of Shaba, formerly known as Kinshasa. Principal producing mines were the western group, comprised of the underground Kamoto and the open pits of Kamoto, Musonoi, and Ruwe; and the central group, comprised of the underground Kambove and the open pits of Sesa and Kakanda. The Luilu refinery treated ore from the western group of mines, while the Shituru plant treated ore from the central group of mines. A new mill at the Musonoi mine began trial operations in mid-July and became operational in October.

As a result of depressed world cobalt markets in 1971, about 3,500 tons of cobalt had been stockpiled by yearend 1971. New ore reserves in Shaba were reported by officials of GECAMINES as 32.4 million tons containing 190,948 tons of recoverable co-

balt and 852,212 tons of recoverable copper.

Japanese interests and the Government of Zaire were negotiating for the construction of approximately 550 miles of rail line to fill gaps in the present rail system and provide an unbroken line from Shaba to the Atlantic Ocean, a distance of 1,240 miles. Ore shipments in Zaire presently must travel a complicated route of jungle river boats and primitive rail lines, taking from 30 to 40 days to reach the Atlantic coast. The new rail lines would cut shipping time to approximately 3 days. Decreased shipping time reportedly would allow the quantity of exported ore to be increased from 500,000 tons per year to about 800,000 tons per year by 1980.

Société Minière de Tenke-Fungurume, in which Standard Oil Co. (Indiana) held a 28% interest, completed 220 test boreholes representing 25,126 meters of diamond drilling in the Tenke-Fungurume district of Zaire. Assays on material from 168 of these holes delineated probable and indicated ore reserves of 20 million tons grading 6.2% copper and 0.4% cobalt. Inferred reserves were estimated at 14.8 million tons.

Zambia.—Nchanga Consolidated Copper Mines Ltd. (NCCM) began installation of commercial-scale carbon columns at its Rokana cobalt plant in 1972. The company was prompted to install the columns after successfully operating pilot-sized columns for 2 years. The pilot columns were capable of removing up to 80% of the contained sulfur with a resulting increase in capacity of 2%.

Roan Consolidated Mines Ltd. (RCM) planned on doubling output of its Chambishi mine by initiating underground operations. RCM awarded a $40 million contract to the British firm of Balfour Bealty and Co. to conduct the necessary civil and mechanical engineering and construction work at Chambishi. The contract will involve extensions to metallurgical buildings, installation of ore crushing and flotation equipment, head frame and hoisting equipment, rail extensions, and construction of permanent living quarters for workers.

Zambia's two mining companies, NCCM and RCM, approved capital expenditures of $663 million during 1972–76 for maintaining and expanding current production of copper and cobalt. These expenditures fall under Zambia's second 5-year national development plan. At yearend, Zambia was successful in lining up loans from foreign countries to cover part of the expenditures. The Government, acting through the state-run Mining and Industrial Development Corp., was setting up a new central committee to supervise the nationalization of the copper-cobalt industry. The stated objectives of centralization were to achieve the optimum rate of nationalization, to rationalize training activities, and to develop industry manpower plans.

TECHNOLOGY

Bureau of Mines scientists reported the use of a cobalt-molybdate catalyst to remove over 90% of the nitrogen and sulfur compounds from shale oil. The catalyst was used in the initial hydrogenation step of a process to convert oil shale to gasoline having an octane rating of 89. The researchers found that a pressure of 200 pounds per square inch and a temperature of 900°F were preferred if optimum amounts of gasoline were to be produced.

Interest was maintained during the year on the development of high-strength magnets formed by alloying cobalt with various rare-earth metals. Scientists from General Electric Co. successfully increased the maximum energy product of the company's rare earth-cobalt permanent magnets by 10% to 25 million gauss-oersteds.[7] Bureau of Mines' scientists continued their investigations into the properties of praseodymium-cobalt magnets during 1972. Researchers at Tohoku University in Japan demonstrated that ductile permanent magnets composed of iron, chromium, cobalt, and molybdenum exhibited a maximum energy product of 5 million gauss-oersteds after appropriate heat treatment. The discovery was significant in that the lower cost ductile alloy's energy product was exceeded only by that of the more expensive cobalt-platinum magnets.[8]

General Magnaplate Corp. of Linden, N.J., announced the development of a

[7] Work cited in footnote 6.
[8] Work cited in footnote 6.

coating process whereby nickel and cobalt metals were electroplated to the surfaces of powdered metal parts. The new technique reportedly gave gears a tough, nonporous surface with permanent lubricity and abrasion and corrosion resistance under severe temperature, atmospheric, and load conditions.[9]

The State University of New York reported development of an antithrombogenic cobalt-chromium alloy. The alloy, in the form of tubes and valves, was tested as cardiovascular implants in dogs. Because of the alloy's resistance to corrosion in biological fluids, it was reported to have great potential in cardiovascular prostheses.[10]

Numerous technological innovations were reported in the formation of cobalt alloys in 1972. General Electric Co. was granted a U.S. patent covering a high-temperature, oxidation- and corrosion-resisting cobalt-based alloy having improved strength and ductility. The new alloy (FSX–430) was claimed to have greater high-temperature ductility, creep-rupture strength, and oxidation resistance while maintaining the high-temperature tensile strength and hot corrosion resistance of its predecessors.[11] INCO developed a cast heat-resistant nickel-base alloy (IN–643) containing 12% cobalt for use over extended periods under high stress and at temperatures up to 1,150°C.

A large number of patents were issued both in the United States and abroad, ranging from extractive metallurgy through smelting technology to the formation of new cobalt alloys. Technical papers were presented on unalloyed and alloyed cobalt systems, heat-resisting alloys, magnetic materials, tool and wear-resisting materials, cast irons and alloy systems, films and coatings, nonmetallic uses of cobalt, and analytical techniques.[12]

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[9] American Metal Market. Nickel-Cobalt Plating Is Key to Improved P/M Components. V. 79, No. 170, Sept. 18, 1972, p. 37.
[10] Work cited in footnote 6.
[11] Work cited in footnote 6.
[12] Cobalt–Quarterly Publication on Cobalt and Its Uses. (Cobalt Information Center, Battelle Mem. Inst., Columbus, Ohio). Nos. 54–57, March–December 1972.