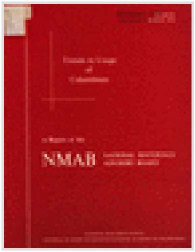

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TRENDS IN USAGE OF COLUMBIUM

REPORT OF
THE PANEL ON COLUMBIUM
of the
COMMITTEE ON THE TECHNICAL ASPECTS OF
CRITICAL AND STRATEGIC MATERIALS

NATIONAL MATERIALS ADVISORY BOARD
Division of Engineering - National Research Council

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Columbium consumption in ferrous alloys will continue to increase, along with their generally increasing usage. Increased consumption is estimated to range from 6% to 10% annually; on this basis, columbium consumption for ferrous alloys will reach 3,250,000 to 4,000,000 pounds by 1975. The projected usage of superalloys is expected to increase at a rate of 20% per year and columbium consumption for these alloys is expected to follow the same trend. Contained columbium in superalloys is expected to reach 4,000,000 pounds by 1975. Consumption of columbium-base alloys is strongly dependent on the levels of spending for nuclear energy and aerospace vehicles. An increase in consumption to about 175,000 pounds per year is anticipated before 1975. After that, aerospace vehicles may require an additional 60,000 pounds per year. Compared to the requirements for ferrous alloys and superalloys, this is small. Minor applications for columbium may utilize about 25,000 pounds by 1975.

Substitutes for columbium in most of the applications reviewed are not likely unless the material would become in short supply. Considering known availability, this is not anticipated.

National Stockpile Purchase Specifications for columbium-bearing raw materials were reviewed and found to be generally satisfactory. It is recommended that specifications P-15-R3 and P-113-R1 be combined into one specification and that it clearly cover the major raw material sources. Because of the need for higher purity alloy additions for superalloys, a revision in the specification, P-104-R1, Grade A is suggested. Increasing superalloy production will also require a tightening of the columbium oxide specification. If demands for superconducting alloys increase, the columbium oxide specification and specification P-103-R1 would have to be upgraded.

The shift in columbium usage from steels to superalloys makes it necessary to upgrade the purity of the columbium source material. Present plant capacity for the production of Cb_2O_5 (as contrasted to ferrocolumbium) may be inadequate to supply the future needs for high purity Cb_2O_5. It is also recommended that some consideration be given to stockpiling Cb_2O_5 of sufficient purity. In light of the possible shortage of suitable columbite for processing into Cb_2O_5, using current Cb-Ta plants, present plans for the disposal of excess columbite from the stockpile should be re-evaluated. Possibly, an alloy of nickel-columbium should be stockpiled. The present disposal of pyrochlore concentrates should be continued.

II. INTRODUCTION

Columbium was discovered in the analysis of a heavy black mineral from Connecticut in 1801 by the English chemist, Charles Hatchett, who named it after its country of origin, "Columbia." Niobium, a supposedly new element, was discovered in 1844, but was proved in 1866 to be identical with columbium. Niobium (Nb) is the preferred name in chemistry and most other sciences and was officially adopted by the International Union of Pure and Applied Chemistry in 1950. Columbium is generally restricted to use in metallurgy and in the mineral trades.

Commercial usage of columbium did not become significant until after 1930, when it began to be used as ferrocolumbium in steel. Today, this application continues to be the largest consumer of columbium. Columbium additions are also widely used in superalloys which represent the most rapidly growing area. A superalloy is an alloy developed for very high temperature service where relatively high stresses (tensile, thermal, vibratory, and shock) are encountered and where oxidation and other high temperature corrosion resistance are frequently required. These high temperature alloys are designed for structural service (strength, resistance to creep, and resistance to scaling) at temperatures from 700°F up to 1800°F, e.g., for the hot sections of aircraft gas turbine engines. They are principally alloys of nickel or cobalt with chromium added for oxidation resistance. Other elements are added for solid solution strengthening and for strengthening by precipitation hardening from solid solution. Some high temperature applications utilize columbium-base alloys. Columbium is also used in superconductor materials and as a component in nuclear reactors.

Prior to 1956, imports of columbium accounted for 98% of the domestic supply. From 1956 to 1959, columbium production from a placer deposit in Idaho supplied about 20% of domestic consumption. Since 1959, all columbium has come from imports and releases from the government stockpile.

This report describes both the applications and reserves of columbium and discusses trends that may be inferred from the relationships between these two factors.

III. APPLICATIONS

A. Ferrous Alloys

1. Carbon and alloy steel. This classification of columbium-containing alloys represents at least 60% of the ferro-columbium and ferro-tantalum-columbium consumed in the United States. A breakdown of the yearly ferro-columbium usage is given in Table 1. In most cases, the amount of columbium used is very small, but the benefits that it imparts to the alloys in question are large in proportion to the amount added. Table 2 gives the composition of high-strength steels which contain columbium.

In the low carbon, low alloy steels, columbium is added to lower the ductile-to-brittle transition temperature by refining the grain size which not only lowers the transition temperature, but also improves the level of toughness or impact resistance. Additionally, columbium will increase the yield, creep, and fatigue strengths of these materials. Low carbon, low alloy steels represent a growth area for columbium consumption.

As strength requirements of steels increase, demands for columbium increase proportionately. Properties that are important in the high-strength alloys include high strength, cryogenic properties, weldability, and, in many cases, weathering capabilities. Many of the high-strength steels originally contained nickel, chromium, vanadium, and copper. However, some recent work has indicated that alloys containing columbium and molybdenum in combination may replace some of these earlier grades and impart improved properties, including better stress corrosion properties. In addition, the nickel content of these steels can be minimized or eliminated.

TABLE 1. Consumption by Alloy Types of Ferrocolumbium in the United States
(Pounds of Contained Columbium)

PRODUCT	1965	1966	1967	1968	1969 (5)
Stainless steels	601,247	567,307	437,116	421,313	e 475,000
Other alloy steels	974,999	1,181,467	1,400,805	1,096,983	e 1,111,000
Carbon steels	265,545	362,114	491,460	507,598	e 791,000
Tool steels[1]	1,268	6,013	6,053	3,639	——
Welding rods[2]	11,492	10,813	12,654	10,933	——
Gray and malleable castings	158	857	300	——	——
High-temperature nonferrous alloys	313,043	537,370	536,572	627,304	e 589,000
Permanent-Magnet alloys	5,222	4,512	e 1,700	1,794	——
Nickel-base alloys	11,468	16,684	12,965	9,068	(4)
Miscellaneous[3]	14,302	9,666	13,662	4,882	e 3,340
Unspecified	——	——	278,424	12,399	e 29,660
TOTAL	2,198,744[6]	2,696,803[6]	3,191,711[6]	2,695,908[6]	2,999,000[6]

NOTES: e – Estimate

1 – Includes high-speed steel

2 – Includes hard facing alloys and cutting and wear resistant alloys

3 – Includes electrical resistance alloys, premixed powders, cemented carbides, capacitors, flame plating high-nickel chromium alloy coatings, metal-to-glass seal materials, and unspecified alloy powders

4 – Included under high-temperature nonferrous alloys

5 – Extrapolated from the first seven months of 1969 from data supplied by R. F. Stevens, Jr.

6 – Ferrotantalum-columbium comprises about 1% of these totals

SOURCE: Table 6 (modified) from R. F. Stevens, Jr., "Columbium and Tantalum," Bureau of Mines Minerals Yearbook, 1968, U.S. Bureau of Mines, U.S. Department of the Interior.

TABLE 2. Composition of High-Strength Steels Which Contain Columbium

I. COLUMBIUM OR VANADIUM GROUP(1)

Name	Producer Code *	Nominal Composition, Weight Percent, Max. (unless noted)(2) C	Mn	P	S	Si	Cu (Min)	Cb (Min) or	V (Min)	ASTM or SAE Specification No.
AWX-42	AW	(0.12)	(0.45)	(0.02)	(0.03)	(0.04)	-	(0.02)	-	A572
45	AW	(0.12)	(0.45)	(0.02)	(0.03)	(0.04)	-	(0.02)	-	A572
50	AW	(0.14)	(0.50)	(0.02)	(0.03)	(0.04)	-	(0.02)	-	A572
55	AW	(0.16)	(0.55)	(0.02)	(0.03)	(0.04)	-	(0.02)	-	A572
AW-Ten	AW	(0.18)	(0.75)	(0.02)	(0.03)	(0.04)	(0.25)	(0.02)	-	A572
Armco High-Strength										
C-42	ARM	0.21	1.35	0.04	0.05	0.30	Opt.	0.005-0.05(a)		A572
C-45	ARM	0.22	1.35	0.04	0.05	0.30	Opt.	0.005-0.05(a)		A572
C-50	ARM	0.23	1.35	0.04	0.05	0.30	Opt.	0.005-0.05(a)		A572
C-55	ARM	0.25	1.35	0.04	0.05	0.30	Opt.	0.005-0.05(a)		A572
C-60	ARM	0.26	1.35	0.04	0.05	0.30	Opt.	0.005-0.05(a)		A572
C-65	ARM	0.26	1.35	0.04	0.05	0.30	Opt.	0.005-0.05(a)		A572
C-70	ARM	0.26	1.35	0.04	0.05	0.30	Opt.	0.005-0.05(a)		-
Hi-Yield C-42	GC	0.21	0.90	0.04	0.05	-	-	0.01	-	A572
C-45	GC	0.22	1.25	0.04	0.05	-	-	0.01	-	A572
C-50	GC	0.22	1.25	0.04	0.05	-	-	0.01	-	A572
C-55	GC	0.25	1.35	0.04	0.05	-	-	0.01	-	A572
(Sheet)										
INX-45	IN	0.20	1.00	0.04	0.05	0.30	Opt.	0.01	0.01	A572, J410B
50	IN	0.20	1.00	0.04	0.05	0.30	Opt.	0.01	0.01	
55	IN	0.21	1.25	0.04	0.05	0.30	Opt.	0.01	0.01	
60	IN	0.22	1.25	0.04	0.05	0.30	Opt.	0.01	0.01	
65	IN	0.24	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	
70	IN	0.26	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	J410B
(Plates, shapes, bars)										
INX-42	IN	0.21	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	A572
45	IN	0.22	1.25	0.04	0.05	0.30	Opt.	0.01	0.01	
50	IN	0.23	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	
55	IN	0.25	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	J410B

* See Page 11

(a) and/or 0.01-0.10 V, or 0.01-0.10 V + 0.015 max N

TABLE 2 (CONT'D)

I. COLUMBIUM OR VANADIUM GROUP (1) (CONT'D)

Name	Producer Code*	Nominal Composition, Weight Percent, Max. (unless noted)(2)								ASTM or SAE Specification No.
		C	Mn	P	S	Si	Cu (Min)	Cb (Min) or	V (Min)	
INX-60	IN	0.26	1.45	0.04	0.05	0.30	Opt.	0.01	0.01	A572,
65	IN	0.26	1.45	0.04	0.05	0.30	Opt.	0.01	0.01	J410B
70	IN	0.26	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	J410b
Ansco1 45	IA	0.16	0.70	0.04	0.05	-	-	0.015	-	
50	IA	0.18	0.70	0.04	0.05	0.04	-	0.015	-	
IH 50	IH	0.22	1.50	0.04	0.05	0.70	0.20	-	-	
65	IH	0.22	1.65	0.04	0.05	0.70	0.20	0.01	0.01	
IHX-42	IH	0.21	1.35	0.04	0.05	-	Opt.	0.01	0.01	A572
45	IH	0.20	1.00	0.04	0.05	0.10	Opt.	0.01	0.01	A572
50	IH	0.22	1.10	0.04	0.05	0.10	Opt.	0.01	0.01	A572
55	IH	0.24	1.40	0.04	0.05	0.30	Opt.	0.01	0.01	A572
60	IH	0.26	1.55	0.04	0.05	0.30	Opt.	0.01	0.01	A572
65	IH	0.26	1.60	0.04	0.05	0.30	Opt.	0.01	0.01	A572
70	IH	0.26	1.65	0.04	0.05	0.30	Opt.	0.01	0.01	-
JLX-42	JL	0.20	1.00	0.04	0.05	0.30	Opt.	0.01	0.01	
45	JL	0.20	1.10	0.04	0.05	0.30	Opt.	0.01	0.01	A572,
50	JL	0.22	1.20	0.04	0.05	0.30	Opt.	0.01	0.01	J410B
55	JL	0.24	1.20	0.04	0.05	0.30	Opt.	0.01	0.01	
60	JL	0.25	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	
65	JL	0.26	1.50	0.04	0.05	0.30	Opt.	0.01	0.01	J410b
70	JL	0.26	1.65	0.04	0.05	0.30	Opt.	0.01	0.01	J410b
JLX-50 CC(d)	JL	0.12	0.90	0.04	0.05	0.10	Opt.	0.01	-	
JLX-55 CC	JL	0.13	0.95	0.04	0.05	0.10	Opt.	0.01	-	A572,
JLX-60 CC	JL	0.14	1.00	0.04	0.05	0.10	Opt.	0.01	-	J410b
JLX-65 CC	JL	0.16	1.10	0.04	0.05	0.10	Opt.	0.01	-	J410b
JLX-70 CC	JL	0.18	1.20	0.04	0.05	0.10	Opt.	0.01	-	J410b
Kaisaloy										
42-CV	K	0.21	1.35	0.04	0.05	0.30	-	0.005-0.050	0.01-0.10	A572
45-CV	K	0.22	1.35	0.04	0.05	0.30	-	0.005-0.050	0.01-0.10	A572
50-CV	K	0.23	1.35	0.04	0.05	0.30	-	0.005-0.050	0.01-0.10	A572
55-CV	K	0.25	1.35	0.04	0.05	0.30	-	0.005-0.050	0.01-0.10	A572
60-CV	K	0.26	1.35	0.04	0.05	0.30	-	0.005-0.050	0.01-0.10	A572

*See Page 11

TABLE 2 (CONT'D)

I. COLUMBIUM OR VANADIUM GROUP[1] (CONT'D)

Name	Producer Code*	Nominal Composition, Weight Percent, Max. (unless noted)[2]								ASTM or SAE Specification No.
		C	Mn	P	S	Si	Cu (Min)	Cb (Min) or	V (Min)	
MLX-45	McL	0.15	1.00	0.04	0.05	0.10	-	0.005	0.02	A572
50	McL	0.20	1.00	0.04	0.05	0.10	-	0.005	0.02	A572
55	McL	0.24	1.20	0.04	0.05	0.30	-	0.005	0.02	A572
60	McL	0.26	1.50	0.04	0.05	0.30	-	0.005	0.02	A572
GLX-45W	N	0.20	1.25	0.04	0.05	-	Opt.	0.01	-	A572
50W	N	0.22	1.25	0.04	0.05	-	Opt.	0.01	-	A572
55W	N	0.22	1.35	0.04	0.05	-	Opt.	0.01	-	A572
60W	N	0.22	1.35	0.04	0.05	-	Opt.	0.01	-	A572
65W	N	0.24	1.35	0.04	0.05	-	Opt.	0.01	-	A572
70W	N	0.26	1.35	0.04	0.05	-	Opt.	0.01	-	-
X42W	R	0.21	1.25	0.04	0.05	0.30	Opt.	0.01	0.01	
X45W	R	0.22	1.25	0.04	0.05	0.30	Opt.	0.01	0.01	
X50W	R	0.22	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	A572, J410b
X55W	R	0.25	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	
X60W	R	0.26	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	
X65W	R	0.26	1.35	0.04	0.05	0.30	Opt.	0.01	0.01	
X70W	R	0.26	1.65	0.04	0.05	0.30	Opt.	0.01	0.01	J410b
Sharalloy 45	SH	0.16	0.40	0.04	0.05	-	-	0.03	-	-
50	SH	0.16	0.40	0.04	0.05	-	-	0.03	-	-
55	SH	0.16	0.40	0.04	0.05	-	-	0.03	-	-
60	SH	0.16	0.40	0.04	0.05	-	-	0.03	-	-
(Sheet)										
Ex-Ten 45	US	0.20	1.00	0.04	0.05	0.30	Opt.			J410b
50	US	0.20	1.00	0.04	0.05	0.30	Opt.			J410b
55	US	0.20	1.25	0.04	0.05	0.30	Opt.			J410b
60	US	0.22	1.25	0.04	0.05	0.30	Opt.			J410b
65	US	0.22	1.35	0.04	0.05	0.30	Opt.	All Ex-Ten grades have 0.01 min Cb or 0.02 min V (singly or together); or 0.02 min V + 0.015 max N		J410b
70	US	0.26	1.35	0.04	0.05	0.30	Opt.			J410b
(Plate)										
Ex-Ten 42	US	0.21	1.35	0.04	0.05	0.30	Opt.			
45	US	0.22	1.35	0.04	0.05	0.30	Opt.			A572, J410b
50	US	0.23	1.35	0.04	0.05	0.30	Opt.			
55	US	0.25	1.35	0.04	0.05	0.30	Opt.			
60	US	0.26	1.35	0.04	0.05	0.30	Opt.			
65	US	0.26	1.35	0.04	0.05	0.30	Opt.			
70	US	0.26	1.35	0.04	0.05	0.30	Opt.			J410b

TABLE 2 (CONT'D)

I. COLUMBIUM OR VANADIUM GROUP[(1)] (CONT'D)

Name	Producer Code*	Nominal Composition, Weight Percent, Max. (unless noted)[(2)] C	Mn	P	S	Si	Cu (Min)	Cb (Min) or	V (Min)	ASTM or SAE Specification No.
Pitt-Ten										
X45W	WP	0.20	1.00	0.04	0.05	0.10	-	0.01	-	J410b
X50W	WP	0.20	1.00	0.04	0.05	0.10	-	0.01	-	J410b
X55W	WP	0.20	1.00	0.04	0.05	0.10	-	0.01	-	J410b
X60W	WP	0.20	1.00	0.04	0.05	0.10	-	0.01	-	J410b
YSW-42	Y	0.20	1.10	0.04	0.05	-	Opt.	0.01	0.01	A572
45	Y	0.20	1.25	0.04	0.05	-	Opt.	0.01	0.01	A572
50	Y	0.22	1.25	0.04	0.05	-	Opt.	0.01	0.01	A572
55	Y	0.25	1.35	0.04	0.05	-	Opt.	0.01	0.01	A572
60	Y	0.26	1.35	0.04	0.05	-	Opt.	0.01	0.01	A572
65	Y	0.26	1.35	-	-	-	Opt.	0.01	0.01	A572
70	Y	0.26	1.50	-	-	-	Opt.	0.01	0.01	-
CB/V45	ALG	0.22	1.35	0.04	0.05	-	-	0.01	0.01	A572
V50	ALG	0.23	1.35	0.04	0.05	-	-	0.01	0.01	A572
V55	ALG	0.25	1.35	0.04	0.05	-	-	0.01	0.01	A572
V60	ALG	0.26	1.35	0.04	0.05	-	-	0.01	0.01	A572
Dofascoloy										
42W	DF	0.21	1.35	0.04	0.05	0.30	Opt.	0.005-0.05	-	A572
45W	DF	0.22	1.35	0.04	0.05	0.10	-	0.01	-	A572
50W	DF	0.23	1.35	0.04	0.05	0.10	-	0.01	-	A572
55W	DF	0.25	1.35	0.04	0.05	0.10	-	0.01	-	A572
60W	DF	0.26	1.35	0.04	0.05	0.10	-	0.01	-	A572
CB-42	SC	0.21	1.35	0.04	0.05	0.30	-	0.005	-	A572
45	SC	0.22	1.35	0.04	0.05	0.30	-	0.005	-	A572
50	SC	0.23	1.35	0.04	0.05	0.30	-	0.005	-	A572
55	SC	0.25	1.35	0.04	0.05	0.30	-	0.005	-	A572
60	SC	0.26	1.35	0.04	0.05	0.30	-	0.005	-	A572
65	SC	0.26	1.35	0.04	0.05	0.30	-	0.005	-	A572

*See Page 11

TABLE 2 (CONT'D)

II. LOW MANGANESE-VANADIUM GROUP (copper is usually omitted for better formability)

Name	Producer Code *	Nominal Composition, Weight Percent, Max. (Unless Noted) (2)							ASTM or SAE Specification No.
		C	Mn	P	S	Si	Cu	Other (a)	
Republic 35	R	0.12	0.75	0.04	0.05	0.10	-	0.005 Cb or V	-
Par-Ten	US	0.12	0.75	0.04	0.05	0.10	-	0.04 Cb or 0.07 V max	-

(a) Minimum unless otherwise specified.

III. MULTIPLE ALLOY AND COPPER GROUP

Name	Producer Code*	Nominal Composition, Weight Percent, Max. (Unless Noted)(2)										ASTM or SAE Specification No.
		C	Mn	P	S	Si	Cu	Mo	Cr	Ni	Other (Min)	
ML-50	McL	0.13	0.48	0.010	0.015	0.17	0.22	0.01	0.40	0.61	0.014 Cb	A242, J410a
ML-60	McL	0.13	0.90	0.010	0.016	0.20	0.29	0.01	0.51	0.68	0.014 Cb	-
ML-70	McL	0.16	0.95	0.010	0.021	0.17	0.30	0.01	0.55	0.73	0.029 Cb	-
Republic 60	R	0.15	0.50-1.00	0.04	0.05	-	0.30-1.00	0.10 min.	0.30	0.40 1.10	0.01 Cb, a/o 0.02	J410b, A242, A588
Stelcoloy 70	SC	0.22	1.50	0.03	0.04	0.15-0.30	0.20-0.50	-	0.30-0.50	0.25-0.50	0.02-0.10 V, 0.05 Cb	-

*See Page 11

TABLE 2 (CONT'D)

IV. PRECIPITATION-HARDENING ALLOYS

Name	Producer Code *	Nominal Composition, Weight Percent, Max. (Unless Noted)(2)								ASTM or SAE Specification No.
		C	Mn	P	S	Si	Cu	Mo	Other	
80	R	0.20	1.00	0.04	0.04	0.15	1.00-1.50	0.20-0.30	1.20-1.75 Ni, 0.01 Cb, a/o 0.02 V	-
Ni-Cu-Cb	US	0.06	0.40-0.65	0.025	0.025	0.20-0.35	1.00-1.30	-	1.20-1.50 Ni, 0.02 Cb	-

SOURCE: METAL PROGRESS, August 1969.

(1) Steels in Group I do not contain more than residual copper; therefore, the atmospheric corrosion resistance is usually equal to that of plain carbon steel. If 0.20% minimum Cu is added, then corrosion resistance is up to twice that of plain carbon steel. Usually these are semikilled steels, but may be killed, particularly at higher strength levels.

(2) Maximum values for composition are listed except where ranges, minimum or typical values are indicated. Typical values are enclosed in parentheses. Many producers list steels with differing strengths as having the same maximum or typical chemistry. Exact chemical compositions would show differences in carbon and alloy content. Differences in composition are also introduced in order to maintain the required mechanical properties in different section sizes.

*Producer Code:

AW = Alan Wood Steel Co.
ALG = Algoma Steel Corp.
ARM = Armco Steel Corp.
DF = Dominion Foundries & Steel, Ltd.
GC = Granite City Steel Co.
IN = Inland Steel Co.
IA = Interlake (Acme) Steel Co.
IH = International Harvester, (Wisconsin Steel Div.)
JL = Jones & Laughlin Steel Corp.
K = Kaiser Steel Corp.
McL = McLouth Steel Corp.
N = National Steel Corp.
R = Republic Steel Corp.
SH = Sharon Steel Corp.
SC = Steel Co. of Canada, Ltd.
US = United States Steel Corp.
WP = Wheeling-Pittsburgh Steel Corp.
Y = Youngstown Sheet & Tube Co.

Applications for these higher strength steels include water towers, buildings, bridges, box cars, military vehicles, dump trucks, cargo containers, etc. In such uses, columbium-containing steels offer advantages. When the weathering criterion is of importance, these steels will also contain copper, up to .25%. In cases where strength is the major criterion for use (such as in some painted transportation vehicles and other painted structures), columbium-containing grades without copper are utilized.

In alloy steels, such as $2\frac{1}{4}$ Cr, 1 Mo being used for elevated temperature applications, additions of .01 to .10 percent columbium improve strength, creep resistance, and toughness. This columbium addition should result in increased use of these steels at elevated temperatures.

2. Stainless steels. A tabulation of the columbium-containing stainless steels is shown in Table 3. Of the alloys listed, those in greatest production are AISI Types 347, 348, 436, and Alloy 20. Currently, Types 435, 410Cb, and 304Cb have not found widespread use.

In the case of the austenitic Cr-Ni grades (particularly Types 318, 347, and 348), columbium is added to tie up the carbon and stabilize the alloy by preventing the formation of Cr carbides that deplete the Cr in solid solution and thus lower corrosion resistance. Also, in the Cr-Ni series, the tying up of the carbon allows solution treatment at a relatively low temperature (1650°F), with a resultant advantageous fine grain size. In AISI 304Cb, the columbium is added more for this grain refining and strengthening purpose rather than for stabilization.

The 435 and 436 grades are used in the automotive industry predominantly to eliminate roping (striations due to yield point straining). For some reason, possibly related to carbon, the addition of columbium minimizes the roping characteristics of these grades when they are stretch formed. In the 410Cb

TABLE 3. Composition (Weight Percent) of Stainless Steels Containing Columbium

AISI Type	C	Mn	Si	Cr	Ni	Cb	Mo	Fe	Other
Type 318	0.08 max. 0.06	2.0 max. 1.75	1.0 max. 0.75	17/19 18	13/15 14	10xC min. 0.80	2.0/3.0 2.5	Bal.	
Type 347	0.08 max. 0.06	2.0 max. 1.75	1.0 max. 0.75	17/19 17.5	9/13 10.5	10xC min. 0.80		Bal.	
Type 348	0.08 max. 0.06	2.0 max. 1.75	1.0 max. 0.75	17/19 17.5	9/13 10.5	10xC min. 0.80	(.10 max Ta)	Bal.	(.10 max Ta)
Type 435	0.12 max. 0.06	1.0 max. 0.50	1.0 max. 0.40	14/18 17.0	—	0.4/0.6 0.50		Bal.	
Type 436	0.12 max. 0.06	1.0 max. 0.50	1.0 max. 0.40	14/18 17.0	—	0.4/0.6 0.50	0.75/1.25 1.0	Bal.	
Alloy 410Cb	0.08	0.75	0.40	12.5	—	0.10		Bal.	
Alloy 304Cb	0.06	1.75	0.75	17.5	9.0	0.10		Bal.	
Alloy 20	0.07 max. 0.05	2.0 max. 0.75	1.0 max. 0.60	19/21 20	32.5/36 33.5	8xC min. 0.75	2/3 2.3	Bal.	
15-5 PH	0.04	0.30	0.40	15	4.6	0.25	--	Bal.	3.30 Cu
17-4 PH	0.04	0.30	0.60	16	4.25	0.25	--	Bal.	3.30 Cu

grade, the columbium is added mainly as a grain refiner. Also, when columbium is added as a grain refiner, it has a tendency to improve weldability.

Alloy 20 is used mainly in applications requiring enhanced corrosion resistance, specifically, its exceptionally good corrosion resistance in sulfuric acid. Also, columbium can be added to other stainless steels when a balanced critical chemistry is required. In these instances, the columbium addition is as a ferrite former.

3. Tool steels. The use of columbium in tool steels has been very minimal. Being a strong carbide former, it has been used in development programs aimed at replacing vanadium and molybdenum. Apparently, such work has occurred because the price of columbium is trending down, relative to that of vanadium. Whether this trend will continue is uncertain at the present time. There does not seem to be any inherent advantage in using columbium to replace other carbide formers in the high speed tool steels. In the water-hardening, high-carbon tool steels, very little activity with columbium has been seen.

B. Superalloys

Columbium has been a common alloying addition to nickel-, iron-, or cobalt-base superalloys. Currently, it is used as an alloying addition primarily in nickel-base superalloys. Two nickel-base compositions, Alloy 718 and Inconel Alloy X-750, account for most of the columbium-bearing superalloy production. Columbium generally is added to gamma prime forming alloys in order to improve the high temperature strength by modifying the existing $Ni_3(Al, Ti)$ antiphase boundary energy and by formation of the monocarbide CbC. In some alloys, the Ni_3Cb phase forms and degrades mechanical properties.

Approximately 80% of the columbium-bearing superalloys currently produced are used in aircraft gas turbines (discs, blades, stator vanes, combustors, flame holders, exhaust liners, etc.). An additional 10% to 15% are used in industrial gas turbines, with the remaining 5% to 10% divided between space power systems and vehicles, airframes, hot tooling, hot shear blades, and automotive turbines. A survey has shown a total of 93 nickel-, cobalt- and iron-base superalloys that contain from .4% to 6.5% columbium (Table 4).

Nickel-base alloys, such as Alloys MAR-M-432, MAR-M-200, MAR-M-421, SEL-15, Inco Alloy 713, and TRW VI-A were developed for use in jet engine blades. A relatively new high strength alloy, René 95, will be applied in engine compressor and turbine discs and shafts, while many bar, sheet, and tubing structural components are fabricated from Inco Alloys 718 and 625. As engine cycle temperatures increase, more and more components such as compressor discs and shafts, bearing housings, ducting, and structural members will be fabricated from these nickel-base alloys.

Inconel Alloy X-750, containing 0.9% columbium, is used extensively in industrial gas turbines. A recent survey* indicated a continuing market, on the order of 2,500,000 - 4,000,000 hp of capacity per year, for industrial gas turbines divided about 60/40 between electrical utility and industrial applications. The utilization of Inconel Alloy X-750 is expected to continue at approximately the same, or at a slightly higher, level as is the current production. The utilization of columbium-bearing, nickel-base superalloys is expected to increase along with the overall increase in requirements for nickel-base superalloys.

Most of the cobalt-base alloys, including WI-52 (HS-152), also are used in the high temperature regions of aircraft and industrial gas turbines such as vanes, blades, or liners. However, the majority of the cobalt-base alloys lack the potent strengthening mechanism such as that of the gamma prime phase $Ni_3(Ti, Al)$ that is utilized in the high strength nickel-base alloys. For this reason,

*Materials Advisory Board Publication MAB 248, "Applications of Nickel," December 1968.

TABLE 4. Columbium-Bearing Superalloys

No.	Alloy	C	Cb	Cr	Ni	Fe	Mo	W	Co	Ti	Al	Mn	Si	B	N	Other
		Nominal Composition, Weight Percent														
		NICKEL-BASE SUPERALLOYS														
Ni- 1	IN 102	0.06	2.9	15	Bal	7	2.9	3	-	0.5	0.5	-	-	0.005	-	0.03 Zr, 0.02 Mg
2	Inconel Alloy 550	0.05	1	15	Bal	7	-	-	-	2.3	1.2	-	-	-	-	-
3	Inconel Alloy 600	0.04	2.5	16	Bal	7	-	-	-	-	-	-	-	-	-	0.1 Cu
4	Inconel Alloy 604	0.1X	2.5	16	Bal	7	-	-	-	-	-	1X	0.75X	-	-	0.1 Cu
5	Inconel Alloy 625	0.05	4	22	Bal	3	9	-	-	0.2	0.2	0.15	0.3	-	-	0.1 Cu
6	Alloy 706	0.04	2.8	15.5	Bal	38	-	-	-	1.8	0.3	0.03	0.1	0.005	-	-
7	Alloy 713C	0.12	2	12.5	Bal	-	4.2	-	-	0.8	6.1	-	-	0.012	-	0.1 Zr
8	Alloy 713LC	0.05	2	12	Bal	-	4.5	-	-	0.6	5.9	-	-	0.01	-	0.1 Zr
9	Inconel Alloy 718**	0.04	5	18.6	Bal	18.5	3.1	-	-	0.9	0.4	0.2	0.3	-	-	0.1 Cu
10	Alloy 738	0.17	0.9	16	Bal	-	1.75	2.6	8.5	3.4	3.4	-	-	0.01	-	1.75 Ta, 0.1 Zr
11	Inconel Alloy X-750	0.04	0.9	15	Bal	6.8	-	-	-	2.5	0.8	0.7	0.3	-	-	0.05 Cu
12	Inconel Alloy 751	0.04	1	15	Bal	6.8	-	-	-	2.5	1.2	0.7	0.3	-	-	0.05 Cu
13	Mar-M-200	0.15	1	9	Bal	-	-	12.5	10	2	5	-	-	0.015	-	0.05 Zr
14	Mar-M-211	0.15	2.7	9	Bal	-	2.5	5.5	10	2	5	-	-	0.015	-	0.05 Zr
15	Mar-M-421	0.15	1.75	15.5	Bal	-	1.75	3.5	10	1.75	4.25	-	-	0.015	-	0.05 Zr
16	Mar-M-432	0.15	2	15.5	Bal	0.5X	-	3	20	4.3	2.8	0.1X	0.1X	0.015	-	2 Ta, 0.05 Zr
17	TRW-1800	0.09	1.5	13	Bal	-	-	9	-	0.6	6	-	-	0.07	-	0.07 Zr
18	TRW-1900	0.11	1.5	10.3	Bal	-	-	9	10	1.0	6.3	-	-	0.03	-	0.1 Zr
19	TRW-VI-A	0.13	0.5	6.1	Bal	-	2	5.8	7.5	1	5.4	-	-	0.02	-	9 Ta, 0.5 Re, 0.4 Hf, 0.
20	René 62	0.05	2.25	15	Bal	22	9	-	-	2.5	1.25	-	-	-	-	-
21	René 95	0.15	3.5	14	Bal	-	3.5	-	8	2.5	3.5	-	-	-	-	-

X - Maximum
** - Also Allvac 718, Firth FS 718, Lescalloy 718

TABLE 4. Columbium-Bearing Superalloys (Cont'd)

No.	Alloy	C	Cb	Cr	Ni	Fe	Mo	W	Co	Ti	Al	Mn	Si	B	N	Other
		Nominal Composition, Weight Percent														
		NICKEL-BASE SUPERALLOYS (Cont'd)														
Ni-22	Hastelloy F	0.05	2*	22	Bal	24	6	-	-	-	-	1.5	-	-	-	-
23	Hastelloy G	0.03	2.1*	22	Bal	19.5	6.5	0.5	-	-	-	1.3	0.35	-	-	2 Cu
24	PDRL 162	0.12	1	10	Bal	-	4	2	-	1	6.5	-	-	0.02	-	2 Ta, 0.1 Zr
25	PDRL 163	0.05	1	17	Bal	-	1.5	2	-	-	6.2	-	-	0.02	-	2 Ta, 0.1 Zr
26	SEL-15	0.07	0.5	11	Bal	-	6.5	1.5	14.5	2.5	5.4	-	-	0.015	-	-
27	TAZ-8A	0.12	2.5	6	Bal	-	4	4	-	-	6	-	-	0.004	-	8 Ta, 1 Zr
28	SM-200	0.15	1	9	Bal	-	-	12.5	10	2	5	-	-	0.015	-	0.05 Zr
29	GE-B-129	0.06	2	5	Bal	4	15	-	-	-	6	0.4	0.4	0.5	-	-
30	Udimet 630	0.03	6	17	Bal	17.5	3.1	3	-	1.1	0.6	-	-	0.005	-	-
31	Jessop G.39	0.5	1.5	19	Bal	-	3	3	-	-	-	-	1	-	-	1.5 Ta
32	Jessop G.54	0.52	1.5	19.5	Bal	-	3	3	-	-	-	1	1	-	-	1.5 Ta
33	Jessop G.64	0.12	2	11	Bal	-	3	3.5	-	-	6	0.4	0.5	0.25	-	-
34	Jessop G.94	0.08	4	9.5	Bal	-	4	4	10	-	6.2	-	-	-	-	-
35	Circle Lin	0.1X	1.5	16	Bal	8	-	-	-	-	-	1X	1.5X	-	-	0.5X Cu
36	Nickel Vac Super X	0.6	1*	16	Bal	6.7	-	-	-	2.5	0.8	0.25X	0.35X	-	-	1X Cu
37	GUY Alloy	0.1	2	13.5	Bal	4.5	5.5	-	-	-	6.2	-	-	0.5	-	-
38	D-H No. 242	0.03	1.1	19.5	Bal	-	-	-	-	-	-	-	1.2	-	-	-
39	GE-J-1360	0.1	2	10	Bal	4.5	5	-	-	-	6	-	-	-	-	0.3 Zr
40	Nimocast PE 10	0.02	6.5	20	Bal	0.25	6	2.5	1	-	-	0.25	0.15	-	-	-
41	Nimonic PK 31	0.05	5	20	Bal	0.05	4.5	-	14	2.3	0.5	0.1	0.15	0.03	-	-

* - Cb+Ta
X - Maximum

TABLE 4. Columbium-Bearing Superalloys (Cont'd)

No.	Alloy	C	Cb	Cr	Ni	Fe	Mo	W	Co	Ti	Al	Mn	Si	B	N	Other
		Nominal Composition, Weight Percent														
		IRON-BASE SUPERALLOYS														
Fe- 1	S-590	0.43	4	20.5	20	Bal	4	4	20	-	-	1.25	0.4	-	-	-
2	N-155, HS-95	0.15	1	21	20	Bal	3	2.5	20	-	-	1.5	0.5	-	0.15	-
3	Uniloy 19-9 DL	0.32	0.4*	18.5	9	Bal	1.4	1.4	-	0.25	-	1.15	0.55	-	-	-
4	Uniloy 19-9 W Mo	0.1	0.4*	19	9	Bal	0.4	1.25	-	3.5	-	-	-	-	-	-
5	Uniloy 19-9 WX	0.11	1.3*	20.5	8.5	Bal	0.5	1.6	-	0.2	-	-	-	-	-	-
6	CRM-60	1.05	1	22	5	Bal	1	1	-	-	-	5	0.5	0.003	-	-
7	CRM-15D	1	2	20	5	Bal	2	2	-	-	-	5	0.5	0.003	0.2	-
8	CRM-17D	0.7	2	20	5	Bal	1	1	-	-	-	5	0.5	0.003	0.2	-
9	CRM-18D	0.75	2	23	5	Bal	1	1	5	-	-	5	0.5	0.003	0.25	-
10	CG-27	0.05	0.6	13	38	Bal	5.5	-	-	2.5	1.5	0.1	0.1	0.01	-	-
11	Haynes Alloy 56	0.27	0.75	21	13	Bal	4.5	1.5	11.5	-	-	1.5	-	-	0.1	-
12	Unitemp 212	0.08	0.5	16	25	Bal	-	-	-	4	0.15	0.05	0.15	0.06	-	0.05 Zr
13	15-15N	0.1	1.1	15.5	15	Bal	1.5	1.5	-	-	-	-	-	-	0.1	-
14	G-18B	0.4	3	13	13	Bal	1.75	2.5	10	-	-	-	-	-	-	-
15	Gamma Cb	0.4	2.2	15.2	24.6	Bal	4.1	-	-	-	-	0.54	0.62	-	-	-
16	Thermalloy 40AZ	0.5	1	26	15	Bal	-	-	-	-	-	1	1	-	0.13	-
17	Thermalloy 50CQ	0.5	1	15	35	Bal	-	-	-	-	-	1	1.7	-	-	-
18	CSA	0.35	0.6	18.5	4.5	Bal	1.35	1.35	-	-	-	4	-	-	-	-
19	REX-326D	0.43	2.8	14.3	14.6	Bal	2	2.2	9.5	-	-	-	-	-	-	-

* - Cb+Ta

TABLE 4. Columbium-Bearing Superalloys (Cont'd)

No.	Alloy	C	Cb	Cr	Ni	Fe	Mo	W	Co	Ti	Al	Mn	Si	B	N	Other
		Nominal Composition, Weight Percent														
								IRON-BASE SUPERALLOYS (Cont'd)								
Fe- 20	326	0.25	1.8	17	17	Bal	2.5	-	7	-	-	3	-	-	-	-
21	EME	0.1	1.25	19	12	Bal	-	3.25	-	-	-	-	-	-	0.15	-
22	GT-45+	0.12	0.45	16.3	14	Bal	2.5	-	-	0.25	-	-	-	-	-	3 Cu
23	Hastelloy F	0.05X	2	22	45.5	Bal	6.5	1X	2.5X	-	-	1.5	1X	-	-	-
24	448	0.12	0.45	10.5	-	Bal	0.75	-	-	-	-	-	-	-	-	0.15V
25	F.C.B.	0.12	1.2	17.5	11	Bal	-	-	-	-	-	1.5	0.6	-	-	-
26	Hecla EM35	0.35	1	17	15	Bal	2.9	2.5	12	-	-	1.5	0.4	-	0.09	-
27	Hecla MM35	0.35	1	21	20	Bal	2.9	2.5	20	-	-	1.5	0.5	-	0.12	-
28	Hecla EM20	0.18	1	17	15	Bal	2.9	2.5	12	-	-	1.5	0.4	-	0.09	-
29	Hecla MM20	0.18	1	21	20	Bal	2.9	2.5	20	-	-	1.5	0.5	-	0.12	-
30	Jessop R. 20	0.12	1.25	19	12	Bal	-	-	-	-	-	1.3	0.5	-	-	-
31	Jessop G. 18B	0.4	3	13	13	Bal	1.8	2.5	10	-	-	0.8	1	-	-	-
32	Jessop G. 19	0.4	3	19	13	Bal	1.8	2.5	10	-	-	0.8	1	-	-	-
33	Jessop G. 21	0.4	1	13	13.5	Bal	-	2.5	-	-	-	0.7	1.4	-	-	-
34	Multi-Alloy	0.25	2.9	20.5	46.5	Bal	2.7	3.5	3	1.2	-	1.6	1	-	-	-
35	ATS	0.1X	1.2	16	13	Bal	-	-	-	-	-	1	0.5	-	-	-
36	ATS-15	0.1X	1.2	16.5	16.5	Bal	1.8	-	-	-	-	1	0.5	-	-	-

\+ - Also 17-14 Cu Mo
X - Maximum

TABLE 4. Columbium-Bearing Superalloys (Cont'd)

No.	Alloy	Nominal Composition, Weight Percent														
		C	Cb	Cr	Ni	Fe	Mo	W	Co	Ti	Al	Mn	Si	B	N	Other
		COBALT-BASE SUPERALLOYS														
Co- 1	S-816	0.38	4	20	20	4	4	4	Bal	-	-	1.2	0.4	-	-	-
2	V-36	0.27	2	25	20	3	4	2	Bal	-	-	1	0.4	-	-	-
3	J-1650	0.2	2	19	26	-	-	12	Bal	4	-	-	-	0.02	-	-
4	W1-52, HS-152	0.45	2	21	-	2	-	11	Bal	-	-	-	-	-	-	-
5	UMCo-51	0.3	2.1	28	-	19	-	-	Bal	-	-	0.7	0.7	-	-	0.02X P, 0.02X S
6	25Ni	0.17	1.5	19	24.5	1	-	10	Bal	-	-	-	-	-	-	-
7	Jessop G.32	0.3	1.3	19	13	16	2	-	Bal	-	-	0.8	0.5	-	-	2.8V
8	Jessop G.34	0.1	1.2	19	13	18	2	-	Bal	-	-	0.8	0.5	-	-	2.8V
9	I-336	0.19	0.9	19.2	15.5	1.3	-	12	Bal	-	-	-	-	-	-	-
10	AiResist 13	0.45	2	21	-	-	-	11	Bal	-	3.5	-	-	-	-	0.1Y
11	M-203	0.07	1.5	19.5	24.5	1.6	-	12	Bal	2.15	0.75	-	-	-	-	-
12	M-204	0.07	1.2	18.5	24.5	1.6	-	12	Bal	-	-	-	-	0.22	-	-
13	M-205	0.07	1.2	18.5	24.5	1.6	-	12	Bal	-	2.75	-	-	0.22	-	-

X - Maximum

the majority of the cobalt alloys are used in the lower stressed and higher temperature applications than the high strength nickel-base alloys. The newer cobalt-base alloys such as the MAR-M Alloys 302, 322, and 509 (not included in Table 4) are more competitive with the nickel-base alloys in the high stressed applications. Substantial strengthening is achieved in these alloys through the addition of tantalum (rather than columbium) which forms an MC carbide. In general, cobalt-base alloys, because of their high chromium content, offer some advantages over nickel-base alloys with respect to hot gas corrosion. However, the utilization of columbium-bearing cobalt-base superalloys is not expected to increase substantially over the next five years.

Relatively little effort has gone into the development of new iron-base (iron-nickel-chromium) superalloys. They do not have the strength or temperature capabilities of the nickel- and cobalt-base alloys and are used primarily in low stressed and/or low temperature applications where cost is a factor. Columbium-containing iron-base alloys such as N-155 are being applied to aircraft gas turbine afterburner liners and flame holders; and those such as 19-9DL for high temperature bolting applications.

The use of superalloys in airframe construction is relatively small in comparison to their utilization in gas turbines, and is limited to hot gas ducting and structural components in and around engines or engine exhausts. Future usage of superalloys in airframe construction may increase considerably, depending upon the technical successes and level of funding allocated to the F-14 and F-15 fighter aircraft, the B-1 bomber (Advanced Manned Strategic Aircraft), SST and future advanced supersonic and hypersonic transport aircraft. Advanced thinking for the 1980's shows hypersonic aircraft with Mach 12 to 20 capabilities. The space shuttle to be developed by NASA-Manned Space Flight Center (MSFC) for use in the later 1970's is expected to utilize a radiative design that may require considerable quantities of superalloy mill products per vehicle. Although the total number of vehicles to be required in any one year probably will be small, the requirements for replaceable heat shield panels and other components may be sizable. Currently, superalloys (Alloy 718, René 41, Alloy 188) or columbium-base alloys are being considered as suitable materials. Since substantial usage of superalloys in advanced aircraft is unlikely before 1975, an estimate of the total columbium requirements in this area would be highly speculative at this time.

Use of superalloys in automotive components is limited to heat resisting castings such as diesel turbocharger rotors. Alloy 713C, containing 2% columbium, has been used for this application. Future requirements for superalloys in the automotive industry will increase when gas turbines become more of a factor in power plant design—primarily in truck and passenger bus applications. Superalloys may also find applications in automotive exhaust reactors used to reduce carbon monoxide and hydrocarbon emissions.

Rapid fire automatic and semi-automatic small bore weapons currently used in tactical aircraft and by combat infantry personnel, necessitate frequent replacement of barrels because of severe operating conditions. A columbium-containing superalloy currently is being investigated for this application with the objective of increasing barrel life. However, even if this superalloy is successful and is employed in one or more weapons systems, projected lessening of combat activities in Vietnam and Elsewhere over the next five years should result in relatively small requirements for columbium for this application.

C. Commercially Pure Columbium and Columbium-Base Alloys

Columbium and its alloys are being used, chiefly in mill product forms, in nuclear applications, rocket engines, and superconductors. Possible future applications may develop in gas turbine engines, aerospace vehicles, space power systems and chemical equipment. Stevens* states that the consumption of high-purity columbium totaled 92,384 pounds in 1968, a 7% decrease from the 1967 total of 111,000 pounds. In 1969, the consumption trend is increasing again for commercially pure columbium and columbium-base alloys.

Currently, nuclear applications consume the largest quantities of columbium and its alloys. About 100,000 pounds of unalloyed columbium, mainly in mill product form, were used during 1969 for classified nuclear applications. This requirement for columbium is expected to grow steadily during the next three to four years to a total of about 140,000 pounds per year.

A much smaller amount of columbium is utilized for rocket engines and attitude control engines. Cb-1%Zr, Cb-10W-10Ta, Cb-10Hf-1Ti, Cb-10W-10Hf-.1Y and Cb-10W-2.5Zr have been utilized in various missile and spacecraft programs. In 1969, the total columbium consumption for these various programs was approximately 17,000 pounds. During the period 1969 through 1971, total consumption should be about 70,000 pounds.

Another application that utilizes only a relatively small amount of columbium is the fabrication of superconductor components. Superconducting high field strength magnets have been developed for bubble chambers and electron microscopes. Cb-48% by weight Ti has been used in the construction of a 20,000 gauss, 16-foot magnet at Argonne National Laboratory. The amount of columbium contained in the magnet was 2,000 pounds.

Superconducting power transmission cables are also being developed, but the actual usage of columbium is small because it is used as a thin coating. Such cables would utilize 1000 to 2000 pounds of Cb per cable mile. In the next ten years, four one-half mile lengths could be developed. By the end of the century, 500 miles of cable may be developed in a ten-year period.

*R. F. Stevens, Jr., "Columbium and Tantalum," Bureau of Mines Minerals Yearbook, 1968, U.S. Bureau of Mines, U.S. Department of the Interior.

Total consumption of columbium in superconductor applications is estimated at about 10,000 pounds during 1969. Consumption is expected to remain at this level for the next five to ten years.

The remaining areas of application for columbium are technically very complex or economically uncertain. An example of one area is the effort devoted to utilizing columbium alloys in gas turbine engines. Up to now, the severe service requirements for long times at high temperatures in an oxidizing environment have been beyond the capabilities of the coating system on the columbium alloy. If the oxidation problem is solved, columbium would be very attractive for high performance engines operating up to 2500°F. In comparison with the currently used superalloys, the columbium alloys offer three to four times the thermal conductivity and only one third to one half of the thermal expansion.

An economically uncertain area of columbium applications is in the realm of space related hardware. Current designs for reusable space shuttles incorporate about 60,000 pounds of columbium per vehicle for about five to ten vehicles. These vehicles would be in service in the late 1970's, if Federally funded. Other vehicles which may utilize columbium alloys, are maneuverable re-entry missiles and hypersonic vehicles. The amount of columbium required for these vehicles has not been determined.

Space power systems are another area of possible applications for columbium alloys at temperatures under 1400°F. This is a result of their good creep strength, excellent fabricability, good liquid metal corrosion resistance, and nuclear fuel compatibility. Molybdenum and tungsten alloys are superior to columbium or tantalum for applications where contamination is possible from impurities in the fuel. Within the space nuclear power system, applications for columbium alloys could include pressure vessels (with molybdenum liners) for isotope fuel capsules, containment and structural components for solar thermal energy storage materials such as lithium fluoride, containment and turbine components in closed, inert gas (helium-xenon) and metal vapor (potassium) turbomachinery, and liquid metal containment components for thermionic direct energy conversion systems. Unalloyed columbium and several columbium-base alloys, such as Cb-1% Zr, have demonstrated excellent resistance to molten potassium, sodium, and lithium. During the next four to five years, there are planned, government-sponsored programs to design, procure materials, construct and conduct operational evaluation of advanced power systems of the (probably) closed cycle Brayton, thermionic, and radioisotope capsule types. Projected columbium alloy requirements for these prototype units are respectively about 6000, 2000, and 5000 pounds. Further requirements will depend on the success of these programs and the funding levels.

Columbium's sister metal, tantalum, is gaining wide acceptance for chemical processing equipment because of its greater resistance to many chemicals and its reduced fabrication costs.

D. Minor Applications

1. Permanent magnet alloys. Columbium is added as an alloy addition to the Alnico grades of cast permanent magnets to control the grain orientation. The Alnico-V grade (8Al-14Ni-24Co-3Cu-Fe) has been used in approximately 90% of the Alnico applications because of its high magnetic properties (~ 5 million energy product, B_dH_d). However, Alnico-V is highly anisotropic and its excellent magnetic properties are achieved only in one direction, that is, parallel to the direction of the magnetic field. Alnico-VII, which contains 0.8% columbium, was developed so as to achieve a columnar grain structure in the casting, thereby permitting (control over the direction of magnetization.) Up to 25% improvement in magnetic properties also can be achieved by the addition of columbium to the Alnicos.

2. Miscellaneous applications. One commercial titanium alloy, Ti-6Al-2Cb-1Ta-1Mo, utilizes columbium as a solid solution strengthener. The addition is made through an Al-Cb-Ta master alloy added to the melt. This alloy possesses high strength and fracture toughness, along with good resistance to stress corrosion cracking, and good weldability in thick sections. It is experiencing some usage in deep submergence vessels such as the Navy's Alvin. During 1969, approximately 85,000 pounds of the alloy were supplied.

Small quantities (330 lbs/year) of columbium carbide are presently used in the NERVA nuclear space reactors. Additional material, perhaps 1000 lbs/year, is consumed for various research programs.

IV. TRENDS AND CHANGING REQUIREMENTS

A. Ferrous Alloys

1. Carbon and alloy steel. The specific amount of columbium used in carbon steels should not change appreciably. However, columbium will see an ever-increasing use as the consumption of these steels increases—probably as a reflection of the growth in Gross National Product (GNP). However, there are no breakthroughs foreseen which would indicate that increased uses of columbium would be forthcoming.

In the case of alloy steels, the situation could be significantly different. The long range trend in the utilization of columbium in these materials will be upward. However, there could be some immediate short term depressions in the cycle because of the delay in building. If the building of bridges and buildings and all other construction are reduced, then the use of columbium in high strength steels will also see this decrease. However, the anticipated long range trend is for increasing amounts of these materials to be used especially in the transportation field. Thus, the prediction is approximately a 10% yearly increase in the utilization of these materials.

2. Stainless steels. The present trend in stainless steels is to work to lower carbon contents in the melting furnaces. This is accomplished by electron beam melting or by vacuum induction melting. If the accomplishments of .01% maximum carbon can be attained on a consistent basis, the requirements for columbium may be significantly reduced. On the other hand, the utilization of stainless steels should significantly increase because of ever-increasing corrosion requirements. However, this anticipated increase in use of stainless steels is expected to occur in the 400 series stainless alloys rather than in the 300 series. Accordingly, anticipated future requirements might see columbium used in the lower Cr 400 series alloys. There is one other possibility with respect to trends and requirements and this could be the substitution of titanium for columbium. The cost of titanium is less and, in many cases, the job performed by titanium is just as effective as that performed by columbium. Just exactly where these prognostications will lead us is very difficult to ascertain at the present time.

If no widespread substitution of the 400 series stainless takes place, the total amount of columbium expected to be used in the 300 and 400 types would increase at the rate of 4% per year—or to a level of 258 tons by 1973. If, however, there is a widespread substitution of straight chromium steels for the 300 series, then significant replacement of 347 and 348 types could occur, which would reduce this rate of growth in columbium consumption.

3. Tool steels. There are no impending changing requirements related to tool steels. The only possible change is a drastic change in the price of vanadium (or such other presently used material) which would necessitate a switch to columbium. At present, this is not foreseen. Therefore, unless some new breakthrough occurs, the amount of columbium used in tool steels should not appreciably change.

B. Superalloys

A survey of total superalloy production (iron-, nickel-, and cobalt-base) made several years ago showed 90 million pounds of mill products shipped in 1966. Another survey showed a little over 100 million pounds shipped in 1967 and a projected increase in mill product shipments to approximately 600 million pounds in 1977 (approximately 465 million pounds in 1975). (See Figure 1.) This represents a growth rate in mill product shipments of approximately 20% per year. Imports of superalloy products have a negligible influence on this total.

The estimated total production of five of the most widely used columbium-bearing superalloys in 1966 is shown in Table 5. Assuming the five alloys listed represent 80% of the total columbium-containing alloys shipped, the total contained columbium in superalloys shipped in 1966 is estimated to be approximately 725,000 pounds.

The anticipated increase in production of columbium-containing superalloys is expected to be slightly less than the growth rate for the total production of superalloys. This estimate is based on the assumption that (1) the production of columbium-containing iron-base superalloys will decrease, (2) the production of columbium-containing cobalt-base superalloys will remain about the same, and (3) the production of columbium-containing nickel-base alloys may increase substantially. New nickel-base alloys such as René 95 and Inconel Alloy 625 contain substantial amounts of columbium (3.5% and 4%, respectively) due to its importance as a gamma prime former and, thus, may result in increased overall consumption of columbium. Utilization of other new columbium-containing nickel-base alloys such as Alloy 706, Alloy 738, MAR-M-421, and MAR-M-432 also will increase the consumption of columbium. Production of established columbium-containing nickel-base superalloys such as Alloy 718 is expected to increase at a rate of 10% to 15% per year.

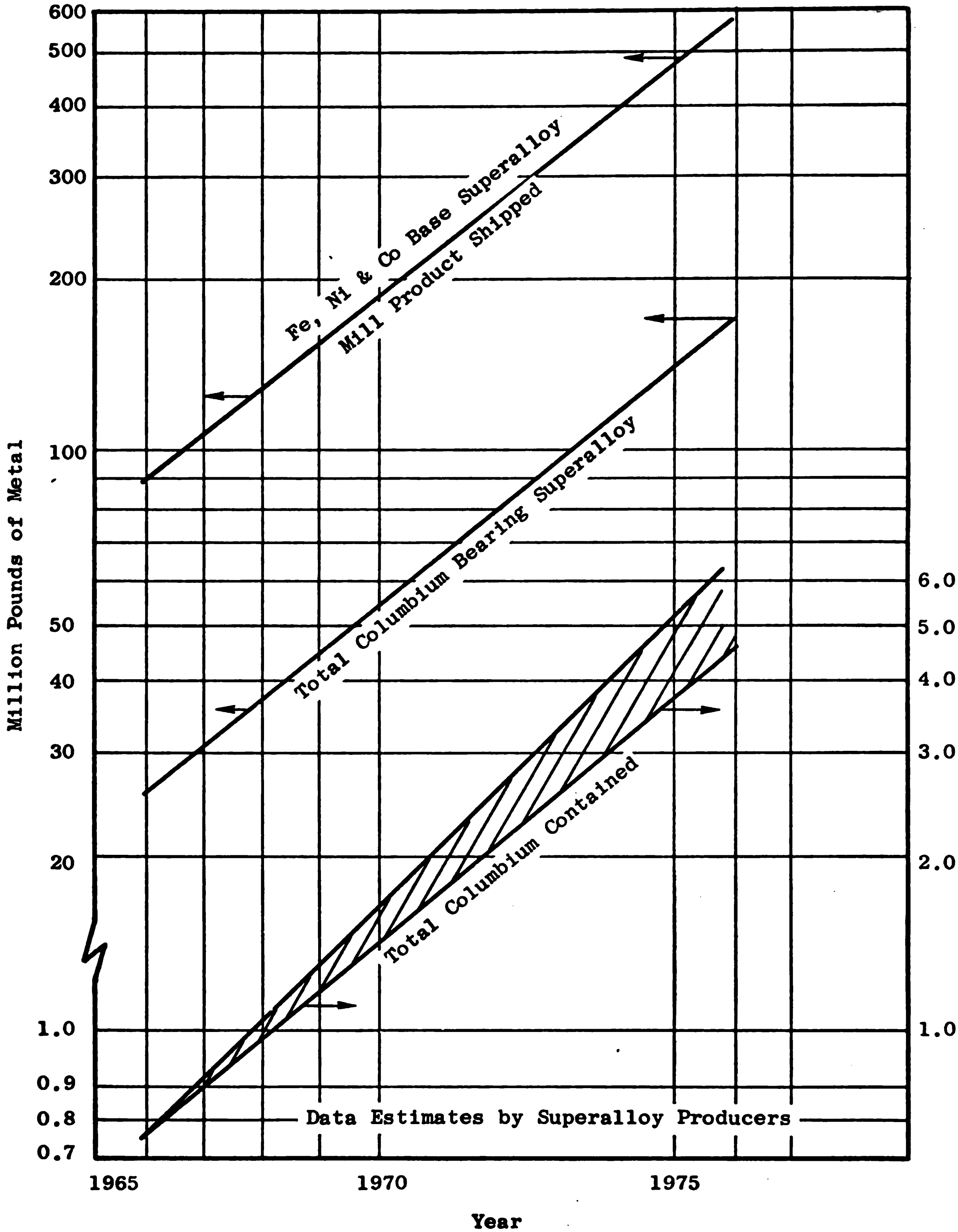

Figure 1. Trends in Consumption of Columbium in Superalloys.

TABLE 5 1966 Consumption of Columbium in Five Major Superalloys

Alloy	Nominal Columbium Content Weight %	Estimated Alloy Production (Pounds)	Estimated Total Columbium Contained (Pounds)
Inconel Alloy 718	5	9,000,000	450,000
Inconel Alloy X-750	0.9	7,000,000	63,000
N-155	1	2,000,000	20,000
Alloy 713C	2	1,400,000	28,000
WI-52	2	1,000,000	20,000
		20,400,000	581,000

The growth in production of superalloys is commensurate with the rapid growth of aircraft and land gas turbine production. For example, General Electric has forecast a growth rate for passenger and cargo aircraft engines and for the number of aircraft as shown in Figures 2 and 3. Columbium-bearing superalloys can be expected to keep pace with this expansion. This same engine manufacturer's projected raw material requirements for Alloy 718, N-155, and René 95 are presented in Table 6. The data indicate a significant increase in the use of Alloy 718 and René 95 for the next several years while the use of N-155 will be declining.

As vacuum melting technology improves and raw material quality assumes added importance in the production of complex superalloys, ferro-columbium and nickel-columbium specifications will have to be upgraded. Most ferrocolumbium and nickel-columbium vendors presently supply a Grade A or vacuum quality grade, along with a lower grade ferrocolumbium usually used in stainless steel. Table 7 indicates the chemical composition of VQ grade ferro-columbium and nickel-columbium supplied by a major vendor. These nominal limits meet or exceed the requirements of 15 of the largest superalloy melters. Several melters indicate that they can tolerate significantly higher levels of tantalum and silicon in ferro-columbium, and tantalum, silicon, and iron in nickel-columbium than the VQ specification. Because of the deleterious effect of trace amounts of tin on the properties of superalloys, columbium raw materials, containing tin oxide, must be processed into high purity columbium oxide for use in ferro or nickel alloy additions to superalloys.

Table 8 indicates the ferrocolumbium consumption for use in super-alloys during the past four years. In 1968, ferrocolumbium for superalloys accounted for approximately 25% of the total consumption in the United States (USA). Trends indicate this percentage will increase in the future.

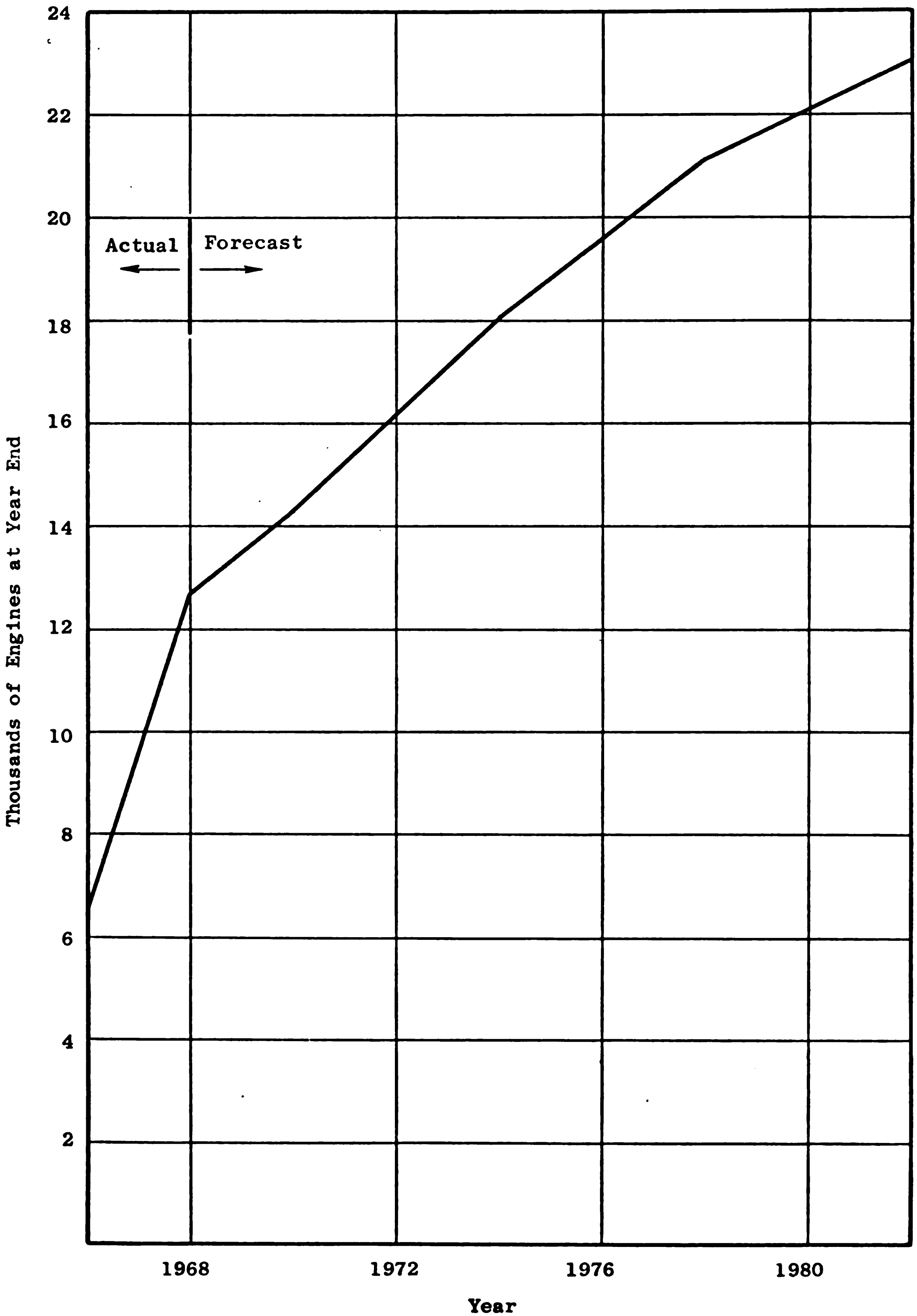

Figure 2. Free World Passenger and Cargo Aircraft, Engine Forecast.

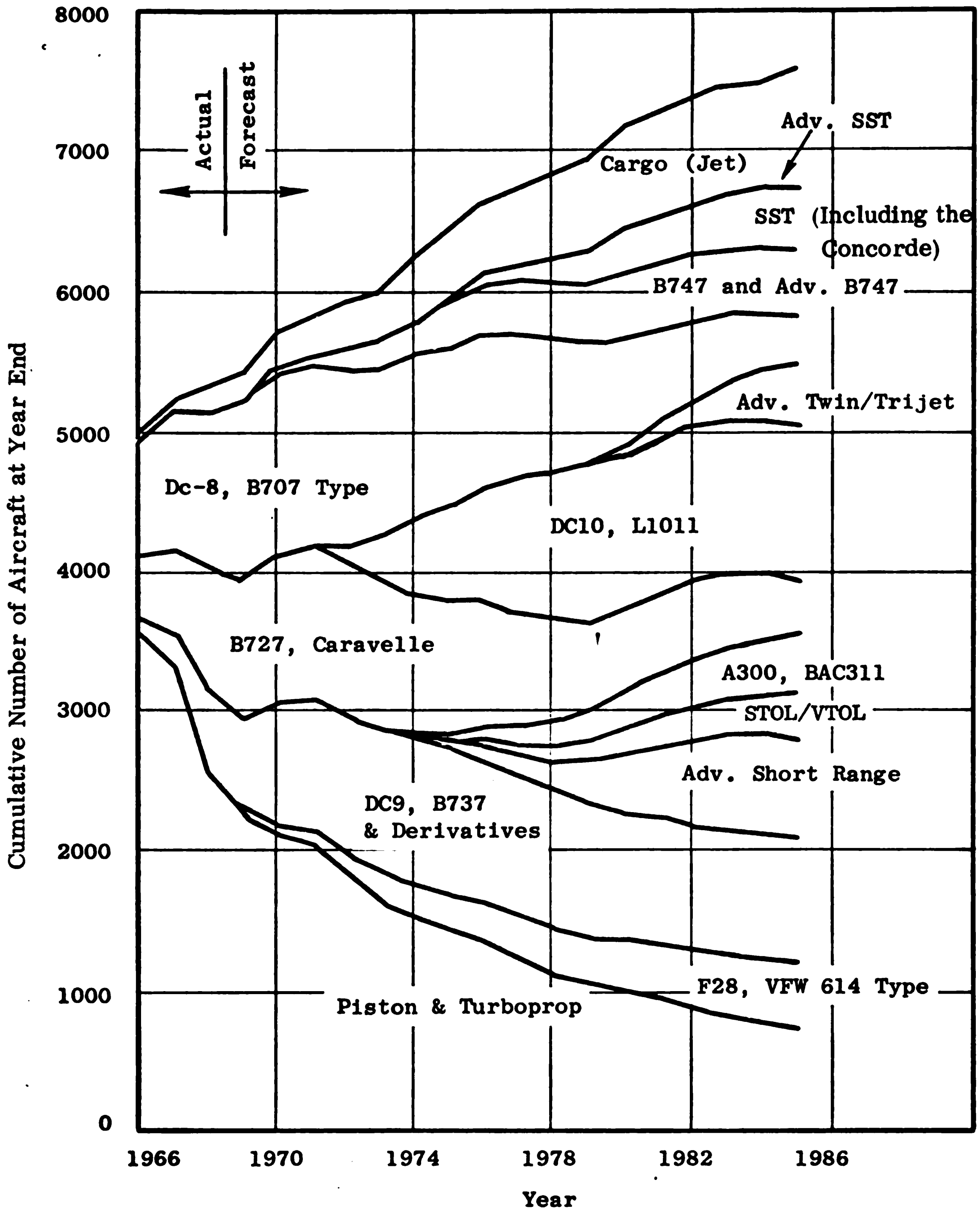

Figure 3. Airline Active Fleet Forecast, Free World Passenger and Cargo Aircraft.

TABLE 6 Major Aircraft Gas Turbine Manufacturers' Columbium-Bearing Superalloy Raw Material Consumption Forecast in Pounds Gross Weight of Alloy

Material	1969	1970	1971	1972	1973
Alloy 718[a]	1,345,610	4,764,570	7,598,680	9,322,410	9,171,180
N-155[b]	100,875	78,000	52,800	42,800	30,700
René 95[c]	27,600	87,400	230,000	230,000	230,000

[a]Total for sheet, strip, coil, forging billets, minor forgings, and rolled and welded ring bars.

[b]Total for sheet, strip, and coil stock.

[c]Total for minor forgings and rolled and welded ring bar.

TABLE 7 Chemical Composition VQ Grade Ferrocolumbium and Nickel-Columbium Supplied By One Major Producer in Weight Percent

	Cb (min)	Ta (max)	C (max)	N (max)	O (max)	H (max)	Fe (max)	Si (max)	Zr (max)
Ferro-Columbium	60	0.5	0.10	0.020	0.08	0.005	Bal	0.25	< 0.01
Nickel-Columbium	55	0.5	0.10	0.020	0.08	0.005	< 1	0.15	< 0.01

	Ti (max)	W (max)	Sn (max)	Ni (max)	Mo (max)	Cr (max)	V (max)	P (max)	S (max)
Ferro-Columbium	0.10	0.03	< 0.01	0.05	< 0.01	0.05	< 0.01	0.02	0.01
Nickel-Columbium	0.10	0.03	< 0.01	Bal	< 0.01	0.05	< 0.01	0.02	0.01

TABLE 8 Ferrocolumbium[a] Consumed for Superalloy Production

Thousands of Pounds[b], Gross Weight of Alloy			
1965	1966	1967	1968
522	895	894	1045

[a]Includes ferrocolumbium and ferrotantalum-columbium, but does not include nickel-columbium.

[b]Based on approximately 60% columbium content.

A major ferrocolumbium and nickel-columbium vendor reports that, although they currently supply more ferrocolumbium than nickel-columbium, the ratio does not exceed 2:1. These data suggest nickel-columbium, which is not presently stockpiled, should be included in future emergency reserves.

C. Commercially Pure Columbium and Columbium-Base Alloys

Consumption of columbium in applications involving pure columbium and columbium-base alloys during 1969 is estimated at about 125,000 pounds. This consumption is expected to increase at a rate of about 10% per year for the next three to four years. Beyond 1973, consumption will depend on the success and on future funding for scale-up of programs now in progress on superconductors, gas turbine engines, aerospace vehicles, and space power systems.

D. Minor Applications

1. Permanent magnet alloys. The current cast Alnico production (1968, 1969) in this country is approximately 16 million pounds. Of this total, 5% or 800,000 pounds is represented by the columnar Alnico-VII grade containing 0.8% columbium. The total columbium consumed in shipped products is about 6,400 pounds.

The estimated annual growth in the cast permanent magnet business is about 10%. Assuming the Alnico-VII grade maintains its 5% share of the market, the production of Alnico-VII in 1975 should be approximately 1,300,000 pounds, consuming approximately 10,300 pounds of columbium. A new cast magnet alloy is being developed that contains 1% - 2% columbium and it is expected that this alloy will capture about 2% of the market by 1975, which, if true, will consume another 10,300 pounds of columbium. The total columbium in shipped product is estimated to be about 20,600 pounds annually by 1975.

The columbium-containing raw material used by one leading permanent magnet manufacturer is the vacuum grade nickel-columbium. Major impurities that appear to be critical are sulfur and carbon which should be kept less than 100 ppm in the raw material.

2. Miscellaneous applications. Annual usage of CbC in the NERVA nuclear reactor program may eventually reach 1500 pounds. Columbium consumption in the Ti-6Al-2Cb-1Ta-1Mo alloy is expected to be below 800 pounds annually.

V. SUBSTITUTES

A. Ferrous Alloys

1. Carbon and alloy steel. In many cases, vanadium may be substituted for columbium in carbon steels. Also, vanadium may be used as a substitute for columbium in many of the high strength steels. However, where weldability is a requirement, columbium seems to impart superior properties. No widespread substitution of columbium is expected unless the material becomes extremely short in supply.

2. Stainless steels. Substitutes for columbium in the stainless steels could be accomplished by using titanium or tantalum, in some cases, and in others, vanadium. The most widespread substitution would be by titanium. However, at the present time, this substitution is not believed likely to occur and columbium will continue to be used.

3. Tool steels. Currently, the substitution of columbium for other alloying elements in tool steels does not seem probable, since columbium imparts no specific property to tool steels that cannot be obtained more economically by alloying elements now in these alloys. Technically, columbium could be substituted for any of the alpha-forming elements (those which tend to close the gamma loop in

the Fe-C diagram): Cr, Mo, V, W, Ti, Zr, Ta, Si. A further restriction would limit substitution to those elements which form MC type carbides: V, Ti, Zr, and Ta.

B. Superalloys

Columbium is employed in most superalloys because of its beneficial effect on high temperature strength through the modification of the gamma prime precipitate and the formation of the carbide CbC. The addition of columbium effects an increase in mechanical properties which cannot be achieved by simply increasing the amount of nickel-aluminum-titanium gamma prime [Ni_3(Al, Ti)].

Probable substitutes for columbium in nickel-base superalloys are tantalum and possibly vanadium. Similar physical properties and position in the periodic table make tantalum a logical substitute for columbium. However, an atom for atom substitution would double the weight percent alloy added. In any case, new alloy development programs would have to be initiated in order to develop columbium-free superalloys with mechanical properties comparable to the strongest columbium-bearing alloys available. Also, the fact that tantalum is generally considered to be a more strategic material than columbium makes the value of this substitution unlikely.

Several of the most common columbium-bearing superalloys, their columbium content and possible substitutes drawn from existing alloys,* are listed in Table 9. In most cases, the substitute is inferior to the columbium-bearing alloy in one or more respects depending on the application. The most common deficiency is in the area of mechanical properties, where columbium makes a significant contribution.

*W. F. Simmons and M. C. Metzger, "Compilation of Chemical Compositions and Rupture Strengths of Super-Strength Alloys," ASTM Data Series Publication No. DS 9d.

TABLE 9 Substitutes for Columbium-Bearing Superalloys

Alloy	Cb Content Weight %	Possible Substitute Alloy
Nickel Base		
Inconel Alloy 625	4	Hastelloy-X
Alloy 713C, LC	2	GMR - 235D
Inconel Alloy 718	5	Alloy 722
Inconel Alloy X-750	0.9	Alloy 722
René 95	3.5	Astroloy
MAR-M-421	2	Udimet 700
MAR-M-432	2	Udimet 700
Alloy 738	0.9	GMR-235D
Alloy 706	2.8	Incoloy Alloy 901
Cobalt Base		
WI-52 (HS-152)	2	HS-151, MAR-M-509
S-816	4	MAR-M-918, HS-188
Iron Base		
N-155 (HS-95)	1	Refractaloy 70

C. Commercially Pure Columbium and Columbium-Base Alloys

Columbium or columbium-base alloys compete with superalloys and dispersion modified materials for potential applications in some hardware in rocket engines, gas turbine engines, and aerospace vehicles. The columbium materials also compete with tantalum-base alloys in potential space power systems, and with tantalum in chemical applications. Materials with which columbium may be competing in the classified nuclear applications, which constitute the largest consumption of commercially pure columbium, have not been disclosed.

Selection of materials in the above applications will be the major factor influencing future consumption of columbium in the forms of pure columbium and columbium-base alloys.

D. Minor Applications

1. Permanent magnet alloys. Titanium can be used in place of columbium in order to achieve magnetic properties similar to Alnico-VII.

2. Miscellaneous applications. Vanadium carbide may be a suitable substitute for the columbium carbide used in the NERVA nuclear space reactor.

A suitable substitute is not believed to exist for columbium in the Ti-6Al-2Cb-1Ta-1Mo alloy. Other non-columbium-containing alloys may be suitable substitutes for this alloy.

VI. RESOURCES

Although columbium is relatively more abundant in the earth's crust than some ferroalloy elements such as tungsten and molybdenum, concentrations of economically minable deposits are rare. Various estimates of the average crustal abundance of columbium are in the range 20 to 24 parts per million (0.04 to 0.048 lbs/ton). If this amount were present in a commercially recoverable form as Cb_2O_5 concentrate, it would be worth around five cents a ton. For the most part, however, columbium is present in nonrecoverable form, occurring in minor amounts in many oxide, tungstate, phosphate, and silicate minerals. In these minerals, columbium is nearly always accompanied by tantalum and the two are associated with titanium, tungsten, tin, zirconium, and hafnium for which they may substitute isomorphously. Other elements such as uranium, thorium, the rare earths, iron, manganese, and bismuth commonly occur in the same minerals or in coexisting minerals in the same rocks.

Minable concentrations of the two principal columbium ore minerals, columbite $(Fe, Mn)(Cb, Ta)_2O_6$ and pyrochlore $(Na, Ca)_2Cb_2O_6(O, OH, F)$ are restricted to relatively few geologic formations. Both minerals form in the final states of cooling and consolidation of intrusive igneous rocks.

Pyrochlore contains little or no tantalum and is generally associated with felsic and mafic alkalic igneous complexes and especially with late stage differentiates of the composing rocks including pegmatites, and adjacent hydrothermally altered metasomatic bodies. Especially notable is the association of pyrochlore with carbonatites that are part of the intrusive sequences of these alkalic complexes. Such carbonatite deposits may contain many million tons of ore, some containing 1% to 2% or more columbium, but more generally in the range 0.17% to 0.42% columbium (about $4.50 to $11.00 per ton). Exploitation of these lower grade, large deposits has only recently become feasible. With expansion of demand, other large lower grade bodies will no doubt become producers.

Columbite deposits, generally containing tantalum, normally are found with biotite granites, alkalic granites, and especially with intrusive pegmatites. Some columbite-tantalite production has come from pegmatites, but erratic distribution and the generally small content of columbium minerals in individual deposits commonly exclude them from consideration as large sources of supply. By-product recovery from placers in association with the production of other minerals such as cassiterite, and various uranium, thorium, and rare earth minerals has constituted most of past production, and remains the principal source of supply of columbite-tantalite.

Columbium tends to be concentrated in hydrolyzates such as bauxite, especially in bauxites that have been developed from nepheline syenite. Some bauxites, such as those mined in Arkansas, may contain as much as a pound of columbium per ton of bauxite and eventually may serve as a low grade source for by-product recovery.

World reserves (exclusive of USSR) of such a grade that they were considered to be exploitable at the time each deposit or district was evaluated, are estimated to contain 9,800,000 short tons of Cb_2O_5, equivalent to 13,700 million pounds of Cb metal content. World resources of additional materials that might become available with some expectable changes in technology or more favorable prices, and also including known deposits that have not yet been adequately evaluated and geologically predictable discoveries of materials similar to present reserves, are estimated at 8,600,000 tons. By far, the largest part of these reserves and resources are in Brazil, with Canada and Africa accounting for much of the remainder.

Domestic deposits of columbium-bearing materials contain only a small reserve that can be economically recovered at current prices, chiefly in pegmatite from which columbite is recovered as a byproduct. The largest known potential columbium resource in the United States is an alkalic complex at Powderhorn, Gunnison County, Colorado, where columbium occurs principally as pyrochlore in a large carbonatite intrusive plug composed mainly of dolomitic marble. This resource has been estimated at 40 million tons averaging at least 0.25% Cb_2O_5 or about 140 million pounds of contained columbium. Known placer deposits in Idaho contain an estimated 20 million pounds of columbium. These types of resources would probably become economic before the 140 million pounds of inferred columbium resources contained in Arkansas bauxite, titanium deposits, and alumina plant wastes, or 20 million pounds present in a large low-grade placer deposit in Oklahoma.

An approximate idea of the geographic distribution of the indicated and measured reserves of columbium, as estimated in 1960, is given in Table 10.

Columbium reserves of the USSR, most of which is probably too low grade for economical recovery at free world prices, have been estimated at 7,000 million pounds of contained columbium.

VII. STOCKPILE REVIEW

A. Specifications Review

A review has been made of the National Stockpile Purchase Specifications, Appendix A, for columbium-bearing raw materials, ferrocolumbium, columbium oxide, carbide, and metal. The specifications were discussed with major producers and raw material suppliers, and questionnaires were sent to the principal users in the most critical application field, that of the superalloys.

Columbium-bearing raw materials are presently defined in two specifications, P-15-R3, dated November 7, 1962, and P-113-R1, dated May 6, 1968. The former covers the range of columbites and the low grade tantalite, or tantalo-columbite, and the latter covers pyrochlore, columbite, and tantalite. It is recommended that a new, single specification be drafted, to cover columbium and tantalum minerals, since the two metals are so interrelated. This specification should cover clearly the major raw material sources, i.e., tantalite, columbite, pyrochlore, and tin slags. A suggested breakdown for the specification's chemical requirements is given in Table 11.

TABLE 10 Estimated Geographic Distribution and Measured World Reserves of Columbium as of 1960

Country	Columbium Content (million pounds)	Type
BRAZIL	9,000	Pyrochlore in weathered alkalic rocks and carbonatite, major. Columbite in pegmatites and placers, minor.
CANADA	2,000	Pyrochlore in alkalic rocks and carbonatite, major. Columbite, pyrochlore, and euxenite in placers, minor.
NIGERIA	650	Tin mining byproducts, placer and eluvial, major. Pegmatite, minor.
UGANDA	550	Pyrochlore-bearing carbonatites, major. Columbite pegmatites, minor.
TANZANIA	350	Pyrochlore-bearing carbonatites, eluvial and bedrock, major.
KENYA	250	Pyrochlore in weathered carbonatite, eluvial.
CONGO (KINSHASA)	100	Pyrochlore in carbonatite (open pit mining) major. Columbite in pegmatites and tin mining byproduct, major.
NORWAY	50	Pyrochlore-bearing carbonatites dikes.
OTHER*	50	Placer and eluvial, largely byproduct, carbonatite and pegmatites.
Total	13,000	

*Rwanda and other African countries, Malaysia, Thailand, and Guyana.

TABLE 11 Chemical Requirements for Raw Materials (Weight Percent)

	Pyrochlore	Columbite A	Columbite B	Tantalite	Tin Slags A	Tin Slags B
$Cb_2O_5 + Ta_2O_5$ Min	50.0	65.0	60.0	50.0	20.0	12.0
Min. Ratio Cb_2O_5/Ta_2O_5	50:1	10:1	8.5:1	--	--	--
Ta_2O_5 Min	--	--	--	25.0	10.0	4.0
TiO_2 Max	6.0	6.0	6.0	6.0	--	--
SnO_2 Max	0.2	6.0	6.0	10.0	--	--
$TiO_2 + SnO_2$ Max	--	12.0	12.0	12.0	--	--
S Max	0.1	0.1	0.1	--	--	--
P Max	0.2	0.2	0.2	0.2	--	--
ThO_2 and U_3O_8	..... To be Reported					

This would clearly identify the major sources available for any future purchasing, including Canadian and Brazilian pyrochlore; Nigerian, Brazilian and Malaysian columbite; Canadian, Brazilian, Congolese and Mozambique tantalite; and Nigerian, Congolese and Thai tin slags.

Ferrocolumbium specifications (P-104-R1, dated October 3, 1966) for Grades B and C appear to be still generally satisfactory, but the increasing demand for higher purity in the additions for high temperature alloys makes a revision in the Grade A desirable. Alternatively, a specification for a vacuum melting grade might be added.

The suggested chemical specification is as follows:

	Percent By Weight			Percent By Weight	
Cb	60.0	min	Sn	0.01	max
Ta	0.50	max	Ni	0.10	max
Al	0.75	max	Mo	0.01	max
C	0.10	max	Cr	0.30	max
N	0.02	max	V	0.10	max
O	0.06	max	Pb	0.003	max
H	0.003	max	As	0.002	max
Mn	0.05	max	Sb	0.002	max
Si	0.25	max	Bi	0.003	max
Zr	0.01	max	Ag	0.001	max
Ti	0.10	max	S	0.01	max
W	0.05	max	P	0.02	max

The Columbium Oxide Specification (Special GSA-DMS Specification for Columbium Oxide Powder, dated June 10, 1965) appears to require tightening up for high purity ferro-columbium and nickel-columbium alloys, as follows:

	Percent of Weight	
Loss on Ignition	1.0	max
Cb_2O_5	99.7	min
Ta_2O_5	0.1	max
Fe_2O_3	0.05	max
SiO_2	0.02	max
ZrO_2	0.01	max
TiO_2	0.02	max
WO_3	0.05	max
SnO_2	0.01	max
MoO_3	0.02	max
MnO	0.03	max
S	0.01	max
P	0.02	max

The current specification is not adequate if an optical grade (very low Fe, Ni) is needed, or if the oxide is to be used as a source for columbium metal for the superconducting transmission line application (very low Ta required).

Columbium Carbide Powder Specification (P-105-R1, dated September 3, 1963) appears to be currently acceptable.

Columbium Metal Specification (P-103-R1, dated July 12, 1963) is applicable to melting stock for high temperature columbium-base alloys, but not for all superconducting alloys. If metal were to be stockpiled for the latter, it is recommended that the tantalum should be 0.05% maximum, and the maxima for C, N, and O should be 0.010%, 0.010%, and 0.015%, respectively, and the metal should be specified to be in consolidated form, not as powder.

B. Quantity Review

The Stockpile status, as of March 31, 1970, was as follows (weight in pounds Cb content):

	Objective	Inventory	Excess
Columbium Concentrates	---	8,078,786	8,078,786
Columbium Carbide	20,000	21,372	1,372
Ferro-columbium	930,000	1,107,417	177,417
Columbium Metal	45,000	44,851	---
Columbium Oxide	---	85,826	85,826

At that time, 279,000 pounds of columbium contained in Grade A ferrocolumbium were on order in an upgrading program, and a portion of the ferrocolumbium in the inventory was Grade A.

The General Services Administration has been offering the excess columbium concentrates for sale periodically. Materials having a low Cb_2O_5 to Ta_2O_5 ratio (5 to 7:1) have been purchased for processing in Cb-Ta separation plants, while columbite with high ratios (over 7:1) and pyrochlore have gone into ferroalloy manufacture.

Industry inventories have been reported by the U.S. Bureau of Mines in the Columbium and Tantalum chapter of the Minerals Yearbook as follows (for year end):

RAW MATERIALS	(in short tons) 1967	1968
Columbite	1,298	1,020
Tantalite	1,819	1,972
Pyrochlore	433	464
Tin Slags	32,852	31,981

PRODUCTS	(in pounds of contained Cb) 1967	1968
Ferroalloys, (producers)	950,000	1,194,300
Columbium Metal	109,562	85,319
Columbium Oxide	597,436	679,604

Domestic consumption is analysed annually by end use for ferroalloys, in the Minerals Yearbook, and since 1967, the Tantalum Producers' Association has gathered data on shipments of the principal tantalum and columbium products. Putting all the available data together results in the following rough breakdown of domestic consumption (in thousands of pounds contained columbium):

Form	1967	1968	1969 (Estimated)	1975 (Forecast)
Std. and Low Grade Ferroalloys	2,348	2,040	2,100	2,500
High Purity Grade Ferroalloys	537	628	750	2,500
Nickel Alloys, Oxide	363	372	450	1,500
Columbium Metal	92	47	120	175
Total	3,340	3,087	3,420	6,675
Oxide Equivalent (at 95% yield)	5,030	4,650	5,150	10,000

The 1975 figures are estimates based on the forecasts in this study. The large growth in the demand for the forms used in the production of high temperature alloys, both iron and nickel base, requires an examination of the raw material needs which would be a consequence of such growth.

In 1968, the total oxide required was about 4,590,000 pounds plus another 436,000 pounds for producers' increases in inventories of ferroalloys and other columbium products, to make a total of about 5,000,000 pounds.

Analysis of raw material imports and inventory changes indicates the rough breakdown of raw materials sources to be, in pounds of contained or equivalent oxide:

	Pounds
Ferroalloy imports	1,060,000
Pyrochlore	995,000
Columbite	1,032,000
Tantalite	255,000
Tin slags	650,000
GSA stockpile	1,008,000
Total	5,000,000

This cannot be an exact analysis because of system errors such as the effect of in-process inventories, but it is at least an indication of the principal factors and their magnitudes. Evidently, there would have been a shortage of oxide if the GSA material, accounting for about 20% of the total, had not been available, or if ferroalloy, accounting for about another 20%, had not been imported.

In view of the forecast shift in growth, from ferroalloys for steels to high purity ferroalloys and nickel-columbium for high temperature alloys, the primary question is whether the available mix in raw materials can accommodate such a shift.

Primary sources for the standard and low grade ferroalloys have been the pyrochlore and columbite with a high Cb_2O_5 ratio, which go directly into the ferroalloy process. The sources for the high purity ferroalloy and nickel-columbium master alloy have been columbite with a low Cb_2O_5 ratio, tantalite, and tin slags, all of which have been processed in the Cb-Ta separation plants to yield a high purity oxide. Tin slags require different initial processing, but the final processing stages are the same as for the tantalite-columbite concentrates. The economics of processing the columbium and tantalum products, produced in these plants, are inter-related, and their overall economics are dependent upon the markets for both tantalum metal and columbium oxide. Therefore, the mix that is fed to the plants is determined extensively by the relative demand for, and pricing of, the two product lines, and the economics of processing as affected by the Cb-Ta ratio.

In 1968, the requirements for oxide for the high purity products were readily met by the Cb-Ta plants, using a considerable amount of GSA material with relatively high Cb_2O_5 content. In 1969, the growth in demand could still be met, with only a modest increase in tantalum throughput, and a good ratio of Cb_2O_5 to Ta_2O_5. If the demand for this high purity oxide grows to meet the 1975 forecast requirement of 4,000,000 pounds of Cb in the high temperature alloys, then about 6,000,000 pounds of oxide in raw materials suitable for such processing must be available. If the Cb-Ta plant is the only route for getting the required quality product, then two major problems must be recognized.

The first problem is that the plants will have to be run on a different basis, because the demand for tantalum is not forecast to increase at the same rate as that for Cb_2O_5, and a much higher ratio of Cb to Ta will have to be maintained in the plant feed. This will be further complicated by the shift in tantalite composition to lower columbium content with the high Ta_2O_5 Canadian source coming in, in addition to the high grade Brazilian and Mozambique concentrates.

The second problem arises because a sustained demand for this much columbite probably cannot be satisfied, and because of the present unsuitability of pyrochlore as a feed in these plants.

An in-depth study should be made to determine: (1) the probable maximum capacity of present plants in the U.S. to make an oxide suitable for additives for high temperature alloys, (2) the ability to meet the demand of these plants for raw materials which they can process, and (3) the possibility of getting a plant in operation in the early 1970's, capable of converting pyrochlore into the necessary high purity oxide.

Consideration should be given to stockpiling Cb_2O_5 of sufficient purity to make the high purity additive alloys, both ferro and nickel, until such time as pyrochlore becomes a suitable feed material for a high purity product. The possibility of a shortage of columbite suitable for processing in the Cb-Ta plants into Cb_2O_5, also places in question the wisdom of continuing to dispose of that part of the stockpile excess which can be so used.

In view of the large Canadian pyrochlore production, and the extensive North American reserves, there seems no justification for stockpiling pyrochlore concentrates, and disposal of those in the stockpile excess should be continued. However, pyrochlore represents only 4% of the columbium being stockpiled and is difficult to sell because of its high phosphorus content.

Current stockpile quantities of metal and carbide are of the magnitude of a year's demand, and appear to be adequate. If a critical superconductor application for a sizeable quantity of metal develops, the metal in the stockpile may not be of sufficient purity to be used.

APPENDIX A

NATIONAL STOCKPILE SPECIFICATIONS

NATIONAL STOCKPILE PURCHASE SPECIFICATION — P-15-R3

COLUMBIUM MINERALS — November 7, 1962 (Supersedes issue of July 27, 1959)

1. DESCRIPTION

This specification covers three grades of columbium ores and concentrates suitable for use in the production of ferrocolumbium, ferrotantalum-columbium, columbium oxide, columbium carbide, and columbium metal.

2. CHEMICAL AND PHYSICAL REQUIREMENTS

Each lot of columbium minerals purchased under this specification shall conform to the following applicable chemical and physical requirements:

a. Chemical Requirements:

The columbium pentoxide (Cb_2O_5) content shall exceed the tantalum pentoxide (Ta_2O_5) content.

			Percent by Weight (Dry Basis)		
			Grade A	Grade I	Grade II
Columbium Pentoxide plus Tantalum Pentoxide	(Cb_2O_5 + Ta_2O_5)	Min.	65.00 1/	60.00 2/	55.00 3/
Ferrous Oxide	(FeO)	Max.	25.00	25.00	25.00
Manganese Oxide	(MnO)	Max.	8.00	8.00	8.00
Titanium Dioxide	(TiO_2)	Max.	8.00	8.00	8.00
Stannous Dioxide	(SnO_2)	Max.	8.00	8.00	8.00
Titanium Dioxide plus Stannous Dioxide	(TiO_2 + SnO_2)	Max.	12.00	12.00	12.00
Phosphorus	(P)	Max.	0.20	0.20	0.30

1/ The minimum ratio of Cb_2O_5 to Ta_2O_5 shall be 10 to 1.
2/ The minimum ratio of Cb_2O_5 to Ta_2O_5 shall be 8.5 to 1.
3/ The minimum ratio of Cb_2O_5 to Ta_2O_5 shall be 1 to 1.

b. Physical Requirements:

Columbium ores and concentrates may be any size.

3. PACKAGING, MARKING, IDENTIFICATION, AND SHIPPING

a. Packaging:

Columbium minerals shall be packed in new 55-gallon, 16-gauge, steel drums, hot-dipped galvanized after fabrication, conforming to the requirements of National Stockpile Container Specification, C-1-R (Latest Revision), Drums: Steel, Hot-Dip, Galvanized.

FOR OFFICIAL USE ONLY

b. Marking:

All markings shall be in English. Each drum shall have attached to the clamp ring bolt, by a 12-gauge aluminum wire, a 28-gauge three-inch by five-inch aluminum tag on which shall be embossed the following:

Name of Product
Name of Producer
Country of Origin
Gross and Net Weights
Government Contract Number
Lot Number and Drum Serial Number (e.g., 1/20, 2/20, etc.)
Cb_2O_5 %
Ta_2O_5 %
The Notice "DUPLICATE TAG INSIDE DRUM"

A duplicate aluminum tag shall be placed inside of each drum except the reference to duplicate tag may be omitted from the tags placed inside the drums. The duplicate tag shall be attached to a nonferrous wire which shall not exceed 18-gauge. The end of the wire shall be hooked over the edge of the drum so that it will be held in place by the cover and clamp ring when the drum is closed.

The marking shall not include a security classification or anything indicating National Stockpile ownership other than the contract number.

c. Identification:

Appropriate identifying documents shall accompany each shipment.

d. Shipping:

All columbium minerals shall be loaded, braced, and blocked in the carrier's conveyance in compliance with applicable rules and regulations set forth in the carrier's classifications and other tariffs. For rail shipments, the applicable rules and regulations published by the Association of American Railroads (AAR) in such as Pamphlets Nos. 4 and 14 and Circular No. 42-B (Latest Revisions) shall be followed.

4. SAMPLING, INSPECTION, AND TESTING

Each lot of columbium minerals shall be subject to sampling, inspection, and testing by the purchaser or his designee.

EXECUTIVE OFFICE OF THE PRESIDENT
Office of Emergency Planning

Prepared and Issued by the Industrial Materials Staff
Business and Defense Services Administration
Department of Commerce

P-113-R1
Effective Date
May 6, 1968
(To supersede issue of
March 15, 1967)

NATIONAL STOCKPILE
PURCHASE SPECIFICATION

COLUMBIUM AND TANTALUM
SOURCE MATERIALS

I. DESCRIPTION

This Specification covers columbium and tantalum source materials, including natural minerals, chemically processed or enriched ores and concentrates, and high metal oxide content products, satisfactory for the production of ferroalloys, carbides, chemical forms of columbium and tantalum, and metals.

II. CHEMICAL AND PHYSICAL REQUIREMENTS

Each lot of columbium and tantalum source material purchased under this Specification shall conform to the following applicable chemical and physical requirements:

A. Chemical Requirements:

1. Columbium natural mineral and concentrates and chemically processed materials and concentrates.

The columbium pentoxide (Cb_2O_5) content shall exceed the tantalum pentoxide (Ta_2O_5) content.

			Percent or Ratio by Weight Dry Basis	
			Grade A-1	Grade A-2
Columbium Pentoxide	(Cb_2O_5)	Min	55.0	50.0
Ratio of Columbium Pentoxide to Tantalum Pentoxide 1/	(Cb_2O_5) to (Ta_2O_5)	Min	10 to 1	25 to 1
Stannic Dioxide	(SnO_2)	Max	4.00	0.10
Phosphorus Pentoxide	(P_2O_5)	Max	.10	0.03
Titanium Dioxide	(TiO_2)	Max	4.00	2.00
Thorium (ThO_2)	To be determined and reported.		X	X
Uranium (U_3O_8)	To be determined and reported.		X	X

1/ The percentage content of the tantalum pentoxide (Ta_2O_5) shall also be reported.

2. Columbium Oxide.

			Percent by Weight Calcined Basis 1/
Columbium Pentoxide	(Cb_2O_5)	Min	99.7
Tantalum	(Ta)	Max	0.10
Iron	(Fe)	Max	.05
Silicon	(Si)	Max	.02
Zirconium	(Zr)	Max	.02
Titanium	(Ti)	Max	.02
Tungsten	(W)	Max	.05
Tin	(Sn)	Max	.02
Molybdenum	(Mo)	Max	.02
Nickel	(Ni)	Max	.02
Chromium	(Cr)	Max	.02
Thorium (ThO_2) To be determined and reported.			X
Uranium (U_3O_8) To be determined and reported.			X

1/ Although the analysis shall be reported on a calcined basis, the material shall be uncalcined and furnished on an ordinary dry state. In addition, the loss-on-ignition shall not exceed 1 percent in the sample that has been dried at 105° C to a constant weight.

3. Tantalum natural mineral and concentrates and chemically processed materials and concentrates.

The tantalum pentoxide (Ta_2O_5) content shall be equal to or exceed the columbium pentoxide (Cb_2O_5) content.

			Percent by Weight Dry Basis
Tantalum Pentoxide	(Ta_2O_5)	Min	25.0

4. Tantalum Oxide.

			Percent by Weight Calcined Basis 1/	
			Grade 1	Grade 2
Tantalum Pentoxide	(Ta_2O_5)	Min	98.5	99.7
Columbium	(Cb)	Max	.20	.05
Silicon	(Si)	Max	.10	.01
Titanium	(Ti)	Max	.05	.01
Iron	(Fe)	Max	.05	.01
Sodium	(Na)	Max	.05	.03
Tungsten	(W)	Max	--	.01
Nickel	(Ni)	Max	--	.02
Chromium	(Cr)	Max	--	.01
Thorium (ThO_2)	To be determined and reported.		X	X
Uranium (U_3O_8)	To be determined and reported.		X	X

1/ Although the analysis shall be reported on a calcined basis, the material shall be uncalcined and furnished on an ordinary dry state. In addition, the loss-on-ignition shall not exceed 0.20 percent in the sample that has been dried at 105° C to a constant weight.

B. Physical Requirements:

1. Columbium natural mineral and concentrates.

No physical requirements.

2. Columbium chemically processed or enriched concentrates.

No physical requirements.

3. Columbium Oxide.

Passing No. 100 sieve - Min - 98 percent.

4. Tantalum natural mineral and concentrates and chemically processed and enriched concentrates.

No physical requirements.

5. Tantalum Oxide.

The average particle size, as determined in accordance with ASTM B-330 with a Fisher Sub-Sieve Sizer, shall be from 0.5 to 2.0 microns.

III. PACKAGING, MARKING, IDENTIFICATION, AND SHIPPING

A. Packaging:

1. All Cb and Ta minerals, concentrates, and chemically processed materials shall be packed in new 30-gallon or 55-gallon, 16-gauge steel drums, hot-dipped galvanized after fabrication, conforming to the requirements of National Stockpile Container Specification, C-1-R, latest revision, Drums: Steel, Hot-Dip, Galvanized.

2. (a) Columbium Oxide and (b) Tantalum Oxide shall be packed in full round bottom bags made of polyethylene film which have been inserted in steel drums. All drums shall be new, have a 30-gallon nominal capacity, be made of 16-gauge steel, and be hot-dipped galvanized after fabrication. Such drums shall conform to the requirements of National Stockpile Container Specification, C-1, latest revision, Drums: Steel, Hot-Dip, Galvanized. The polyethylene film used for making the bags shall, where applicable and except as modified herein, comply with the requirements of Federal Specification L-P-378a, for Plastic Film (polyethylene thin gage) for the classification of: Type 1, normal impact strength; Grade A--slip not specified; and Finish I--untreated.

   All polyethylene film used in the construction of the bags shall be of virgin stock, and shall contain at least 50 parts per million of a suitable antioxidant. The thickness of the film shall be 0.006 inch with a plus or minus tolerance of 20 percent.

   The sides of the bags shall be cylindrical in shape, be formed by the extrusion of tubing, and shall have no seams. The bottoms shall be circular in shape. The side shall be turned inward at least 1-1/2 inches and overlap on the bottom. The side and bottom shall be joined tightly by one or more seams formed by the application of heat to make what is known in the trade as a "shear" seam. What is referred to as a "peel" or "tear" seam, formed by having the joined edges project outward, is not acceptable.

   The seam(s) shall have as little as possible extruded "leading edges" (ridges and creases) on either side or bottom sections, shall have no skipped spaces and shall not be easy to pull apart, as determined in the customary industry manner. The diameter of the bags shall be approximately one-half inch larger than the inside diameter of the drums. The bags shall be of sufficient length to meet the requirements hereof satisfactorily. Representative samples of the bags shall be tested by filling with water to a height of one foot, and there shall be no evidence of leakage over a period of two hours. If there is any leakage, all bags represented by the leaking bag shall be rejected.

Before inserting the liner, the inside of the drum shall be carefully examined and burrs and projections shall be removed. By use of a mandrel or hollow cylinder with a slightly smaller diameter than that of the drums, the bag shall be carefully inserted into the drum so as to conform evenly to sides and bottom of the drum.

Sufficient columbium oxide or tantalum oxide shall be placed in the bag so that, after allowing room for the top of the bag, the cover can just be fitted onto the drum. During such filling, precautions shall be taken to avoid dusting the surfaces of the bag that are to be heat sealed.

After filling, the bag shall be gathered together and pressed closely to the top of the contents to eliminate as much air as possible. The top of the bag shall be heat sealed--either flat or after it has been folded in several layers (pleated or accordion like) so as to form a compact water tight closure which shall not be easy to pull apart, as determined in the customary industry manner.

The top of the bag shall then be folded over the contents, the cover and ring placed on, and the cover bolt carefully tightened, tapping the ring as it is done, so as to obtain a snug fit. The drums shall be carefully handled so as to avoid denting, scratching or other damage and otherwise be tendered in an excellent condition.

B. Marking:

Drums containing radioactive material shall be permanently labeled as prescribed in the Code of Federal Regulations applying to the Transportation of Radioactive Materials, in such as Titles 46 and 49, as amended or reissued.

All marking shall be in English. Each drum shall have attached to the clamp-ring bolt, by an 0.08-inch diameter zinc wire, a 0.014-inch thick zinc tag, three inches by five inches, on which shall be embossed the following:

Name of Product (whichever is applicable) and Percent of Contents:

Columbium Natural Minerals and Concentrates, Cb_2O_5% - Ta_2O_5%.
Columbium Chemically Processed & Enriched Concentrates, Cb_2O_5% - Ta_2O_5%.
Columbium Oxide, Cb_2O_5%.
Tantalum Natural Minerals and Concentrates, Ta_2O_5% - Cb_2O_5%.
Tantalum Chemically Processed & Enriched Concentrates, Ta_2O_5% - Cb_2O_5%.
Tantalum Oxide, Ta_2O_5%.

Country of Origin
Gross and Net Weights
Government Contract Number
Lot Number and Drum Serial Number (e.g., 1/20, 2/20, etc.)
"DUPLICATE TAG INSIDE DRUM"

A duplicate zinc tag, which is attached to a zinc wire of 0.057 inch in diameter, shall be placed inside of each drum on top or on top of the polyethylene bag. The zinc wire shall be hooked over the edge of the drum, so that the tag will be held in place by the cover and the clamp ring when the drum is closed. The reference to duplicate tag may be omitted from the tags placed inside the drums.

C. Identification:

Appropriate identifying documents shall accompany each shipment.

D. Shipping:

The transport of radioactive materials shall be in accordance with the methods prescribed in the Code of Federal Regulations applying to the Transportation of Radioactive Materials, in such as Titles 46 and 49, as amended or reissued.

All drums containing columbium and tantalum source materials shall be loaded, braced, and blocked in the carrier's conveyance in compliance with applicable rules and regulations set forth in the carrier's classification and other tariffs. For rail shipments of drums, the applicable rules and regulations published by the Association of American Railroads (AAR), in Pamphlets Nos. 4, and 14, and Circular No. 42-C, shall be observed.

IV. SAMPLING, INSPECTION, AND TESTING

Each lot of columbium and tantalum source material shall be subject to sampling, inspection, and testing by the purchaser or his designee.

V. PRECAUTIONS

Columbium and tantalum ores and minerals, as well as columbium and tantalum products derived by chemically or physically processing certain ores such as pyrochlore and euxenite may have naturally radioactive characteristics.

Columbium-tantalum materials containing .05 percent or more or source material, as described in AEC Rules and Regulations, Title 10, Part 40, shall be subject to:

1. AEC Code of Federal Regulations, Title 10, Part 20, Standards for Protection Against Radiation covering Permissible Doses, Levels and Concentrations, Precautionary Procedures, Waste Disposal, Records, Reports, and Notification and Additional Requirements for handling and storing the material.

2. AEC Code of Federal Regulations, Title 10, Part 40, Licensing of Source Material, covering general licenses for limited quantities of source material and specific licenses involving greater quantities than are allowed with the general license, with all pertinent information needed to acquire and administer these licenses.

3. Code of Federal Regulations applying to the Transportation of Radioactive Materials in Title 46 and 49, as amended and reissued.

EXECUTIVE OFFICE OF THE PRESIDENT
Office of Emergency Planning

Prepared and Issued by the Industrial Materials Staff
Business and Defense Services Administration
Department of Commerce

NATIONAL STOCKPILE PURCHASE SPECIFICATION — P-104-R1

October 3, 1966
(Supersedes issue of September 5, 1963)

FERROCOLUMBIUM

I. DESCRIPTION

This specification covers three grades of ferrocolumbium for use as an additive to steel and alloys. Grade A is designed for high temperature alloys and special applications, Grade B is for stainless steel and Grade C is for carbon and other alloys steels. There is some interchangeability of use between grades.

II. CHEMICAL AND PHYSICAL REQUIREMENTS

Each lot of ferrocolumbium purchased under this specification shall conform to the following chemical and physical requirements:

A. Chemical Requirements:

		PERCENT BY WEIGHT					
		Grade "A"		Grade "B"		Grade "C"	
		Min.	Max.	Min.	Max.	Min.	Max.
Columbium	(Cb)	60.00	70.00	60.00	70.00	55.00	70.00
Tantalum	(Ta)		0.75		2.00		3.50
Aluminum	(Al)		1.00		1.50		1.50
Tin	(Sn)		0.03		0.15		0.15
Manganese	(Mn)		0.15		2.00		2.00
Silicon	(Si)		0.50		3.00		4.00
Carbon	(C)		0.10		0.15		0.30
Sulfur	(S)		0.03		0.05		0.10
Phosphorus	(P)		0.03		0.05		0.10
Titanium	(Ti)		0.15		2.00		3.00
Lead	(Pb)		0.005		-		-
Arsenic	(As)		0.005		-		-
Antimony	(Sb)		0.005		-		-

B. Physical Requirements:

All ferrocolumbium shall be furnished crushed to either Size I (large) or Size II (medium).

(I)	Size I (large)	(II)	Size II (medium)
	Two inches X Down		One-half inch X Down

III. PACKAGING, MARKING, IDENTIFICATION, AND SHIPPING

A. Packaging:

All ferrocolumbium shall be packed in new 30-gallon, 16-gauge, steel drums, hot-dipped galvanized after fabrication, conforming to the requirements of National Stockpile Container Specification C-1-R, Latest Revision, Drums: Steel, Hot-Dip, Galvanized.

B. Marking:

All markings shall be in English. Each drum shall have attached to the clamp-ring bolt by an 0.08-inch zinc wire, through a hole at least one-half inch from the edge of a three-inch by five-inch tag of 0.14-inch thickness, on which shall be embossed the following:

Name of Product
Name of Producer
Country of Origin
Gross and Net Weights
Grade and Size
Cb%________Ta%________
Government Contract Number
Lot Number and Drum Serial Number
(e.g., Lot No. 16----1/20, 2/20, etc.)
Duplicate Tag Inside Drum

A duplicate zinc tag shall be placed inside of each drum except the reference to duplicate tag may be omitted from the tags placed inside the drums. The duplicate tag shall be attached to a zinc wire 0.057 inches in diameter. The end of the wire shall be hooked over the edge of the drum so that it will be held in place by the cover and clamp-ring when the drum is closed.

The marking shall not include a security classification or anything indicating National Stockpile ownership other than the contract number.

C. Identification:

Appropriate identifying documents shall accompany each shipment.

D. Shipping:

All drums containing ferrocolumbium shall be loaded, braced, and blocked in the carrier's conveyance in compliance with the applicable rules and regulations set forth in the carrier's classifications and other tariffs. For rail shipments, the applicable rules and regulations published by the Association of American Railroads (AAR) in Pamphlets No. 4 and 14 and Circular No. 42-B, Latest Revisions, shall be followed.

IV. SAMPLING, INSPECTION, AND TESTING

Each lot of ferrocolumbium shall be subject to sampling, inspection, and testing by the purchaser or his designee.

USCOMM-DC-32411

June 10, 1965

Special GSA-DMS Specification
for Columbium Oxide Powder

1. DESCRIPTION

This specification covers a commercial grade of columbium oxide in the form of powder.

2. CHEMICAL AND PHYSICAL REQUIREMENTS

Each lot of columbium oxide powder acquired under this specification shall conform to the following chemical and physical requirements:

a. Chemical Requirements:

Loss-on-Ignition	Max. - 1.0 %	After drying		
Columbium Oxide (Cb_2O_5)	Min. - 99.7 %	After	igniting	(calcining)
Tantalum (Ta)	Max - 0.10%	"	"	"
Iron (Fe)	" - 0.05%	"	"	"
Silicon (Si)	" - 0.02%	"	"	"
Zirconium (Zr)	" - 0.02%	"	"	"
Titanium (Ti)	" - 0.02%	"	"	"
Tungsten (W)	" - 0.05%	"	"	"
Tin (Sn)	" - 0.02%	"	"	"
Molybdenum (Mo)	" - 0.02%	"	"	"
Nickel (Ni)	" - 0.02%	"	"	"

b. Physical Requirements:

Passing 80 mesh - 98% (Min.)

3. PACKAGING, MARKING, IDENTIFICATION AND SHIPPING

a. Packaging:

Columbium oxide powder shall be packed in full round-bottom bags made of polyethylene film which have been inserted in steel drums. All drums shall be new, have a 30-gallon nominal capacity, be made of 16-gauge steel and be hot-dipped galvanized after fabrication.

Such drums shall conform to the requirements of National Stockpile Container Specification C-1-, (Latest Revision) Drums: Steel Hot-Dip, Galvanized. The polyethylene film used for making the bags shall, where applicable and except as modified herein, comply with the requirements of Federal Specification L-P-378a for Plastic Film (Polyethylene Thin Gage) for the classification of: Type 1, Normal impact strength; Grade A - Slip not specified; and Finish I-Untreated. All polyethylene film used in the construction of the bags shall be of virgin stock, and shall contain at least 50 parts per million of a suitable antioxidant. The thickness of the film shall be 0.004 inch with a plus or minus tolerance of 20 percent.

The sides of the bags shall be cylindrical in shape, be formed by the extrusion of tubing and shall have no seams. The bottoms shall be circular in shape. The side shall be turned inward at least ½ inch and over-lap on the bottom. The side and bottom shall be joined tightly by one or more seams formed by the application of heat to make what is known in the trade as a "shear" seam. What is referred to as a "peel" or "tear" seam, formed by having the joined edges project outward, is not acceptable.

The seam(s) shall have as little as possible extruded "leading edges" (ridges and creases) on either the side or bottom sections, not have skipped spaces and not be easy to pull apart. The diameter of the bags shall be approximately one-half inch larger than the inside diameter of the drums. The bags shall be of sufficient length to meet the requirements hereof satisfactorily. When the bag is filled with water to a height of one foot, there shall be no evidence of leakage over a period of two hours.

Before inserting the liner, the inside of the drum shall be carefully examined and burrs and projections shall be removed. By use of a mandrel or hollow cylinder with a slightly smaller diameter than that of the drums, the bag shall be carefully inserted into the drum so as to conform evenly to sides and bottom of the drum. Sufficient columbium oxide powder shall be placed in the bag so that, after allowing room for the top of the bag, the cover can just be fitted onto the drum. During such filling, precautions shall be taken to avoid dusting the surfaces of the bag that are to be heat sealed.

After filling, the bag shall be gathered together and pressed closely to the top of the contents to eliminate as much air as possible. The top of the bag shall be heat sealed - either flat or after it has been folded in several layers (pleated or accordion-like) - so as to form a water tight closure that is not easy to pull apart.

The top of the bag shall then be folded over the contents, the cover and ring placed on, and the cover bolt carefully tightened, tapping the ring as it is done, so as to obtain a snug fit. The drums shall be carefully handled so as to avoid denting, scratching or other damage and otherwise be tendered in an excellent condition.

b. Marking:

All markings shall be in English. Each drum shall have attached to the clamp ring bolt, by a 0.08" diameter zinc wire, a three-inch by five-inch zinc tag of 0.014" thickness on which shall be embossed the following:

Name of Product
Name of Producer
Type
Date Packed (Month and Year)
Gross and Net Weights
Government Contract Number
Lot Number and Drum Serial Number (e.g., 1/20, 2/20, etc.)
The Notice "DUPLICATE TAG INSIDE DRUM"

A duplicate zinc tag which is attached to a zinc wire of 0.057" in diameter shall be placed inside of each drum on top of the polyethylene bag. The zinc wire shall be hooked over the edge of the drum so that the tag will be held in place by the cover and the clamp ring when the drum is closed. The reference to duplicate tag may be omitted from the tag placed inside the drum.

Each drum shall be further marked "Keep Airtight."

The drums shall not carry a security classification or any marking, other than the contract number, indicating National Stockpile ownership.

Appropriate identifying documents shall accompany each shipment.

c. Shipping:

"All drums containing columbium oxide powder shall be loaded, braced and blocked in the carrier's conveyance in compliance with applicable rules and regulations set forth in the carrier's classification and other tariffs. For rail shipments of drums, the applicable rules and regulations published by the Association of American Railroads (AAR) in such as Pamphlet Nos. 4 and 14 and Circular No. 42 B, shall be observed."

4. SAMPLING, INSPECTION, AND TESTING

The sample taken for each lot shall be divided into three portions: one for the contractor, one for the Government and one for umpire. The contractor shall determine the physical characteristics in the presence of and to the satisfaction of the Government's inspector, the results of which shall be final. The contractor and the Government shall each have its portion of the sample analyzed for the chemical constituents listed above.

P-105-R1

September 3, 1963
(Supersedes issue of
March 21, 1963)

NATIONAL STOCKPILE
PURCHASE SPECIFICATION

COLUMBIUM CARBIDE POWDER

1. DESCRIPTION

This specification covers columbium carbide powder suitable for use in alloying with other carbide bearing hard metals.

2. CHEMICAL AND PHYSICAL REQUIREMENTS

Each lot of columbium carbide powder purchased under this specification shall conform to the following chemical and physical requirements:

a. Chemical Requirements:

			Percent by Weight
Columbium	(Cb)	Minimum	88.00
Tantalum	(Ta)	Maximum	0.10
Iron	(Fe)	Maximum	0.20
Titanium	(Ti)	Maximum	0.05
Silicon	(Si)	Maximum	0.05
Carbon (Total)	(C)	Range	11.1 - 11.5
Carbon (Free)	(C)	Maximum	0.10
Calcium	(Ca)	Maximum	0.03

b. Physical Requirements:

All columbium carbide powder shall pass a U. S. Standard Sieve No. 200 (ASTM Designation E 11).

3. PACKAGING, MARKING, AND SHIPPING

a. Packaging:

Columbium carbide powder shall be packed in new polyethylene bags not less than 0.006-inch in thickness which have been inserted in new steel drums.

All drums shall be equal to the requirements for Type II, Class S, Size 5, Military Specification MIL-D-6055A: (as modified by GSA) Drums; Metal, with Removable Head, Reusable Interior Shipping. (Appended Hereto)

The polyethylene bag shall be carefully inserted in the drum and after filling with enough columbium carbide powder to completely fill the drum, the top of the bag shall be either heat sealed or spirally twisted and bound with a paper or cloth coated nonferrous wire tie.

The closure bolts of all drums shall be very carefully tightened so that the drums will be airtight.

Six drums shall be packed in a new wooden box which shall be equal to the requirements for Style B, Type III, Federal Specification PPP-B-601a: Boxes, Wood, Cleated-plywood, except that the plywood shall be not less than ½-inch thick, and except 2" x 4" material shall be used for the skids and lifting cleats of not less than 1" x 2" material shall be fastened near the top on both ends. Before the drums are placed in the box a sheet of polyethylene not less than 0.006-inches thick shall be placed in the box. This sheet of polyethylene shall be large enough so that its sides and ends, after the drums are placed in the box, will overlap not less than 6-inches. Cushioning or internal bracing shall be used, if necessary, to prevent shifting of the drums in a box. Each box shall be strapped with four steel bands, two cross-wise and two length-wise. The bands shall be not less than 3/4-inch wide and 0.020-inch thick. All boxes under the same contract shall be of the same nominal size and shape.

b. Marking:

Each drum furnished under a contract shall be marked with the lot number, serial number, and net weight of contents.

One side of each box shall be permanently and legibly marked with capital letters. The letters shall be not less than 3/4-inch and of equal height. The marking shall include the following:

Name of Product
Name of Producer
Month and Year Produced
Gross and Net Weights
Government Contract Number
Lot Number and Serial Numbers of Drums in the Box

On the top of each box shall be stenciled "This Side Up" in the same letters as required on the side of the box.

A waterproof envelope, containing a document in permanent ink showing the contents of the drums in the box shall be placed in each box. A duplicate waterproof envelope and document shall be fastened to the end of each box.

The boxes shall not carry a security classification or any marking, other than the contract number, indicating National Stockpile ownership.

Appropriate identifying document shall accompany each shipment.

c. Shipping:

Boxes of columbium carbide powder shall be loaded and braced in a manner satisfactory to the carrier concerned.

4. SAMPLING, INSPECTION, AND TESTING

Each lot of columbium carbide powder shall be subject to sampling, inspection, and testing by the purchaser or his designee.

P-103-R1

July 12, 1963
(Supersedes issue of
October 26, 1962)

NATIONAL STOCKPILE PURCHASE SPECIFICATION

COLUMBIUM - COMMERCIAL GRADE

1. DESCRIPTION

This specification covers a commercial grade of columbium metal in the form of powder (or granules), hereinafter referred to as powder.

2. CHEMICAL AND PHYSICAL REQUIREMENTS

Each lot of columbium powder purchased under this specification shall conform to the following chemical and physical requirements:

a. Chemical Requirements

			Percent by Weight Powder
Columbium	(Cb)	Minimum	99.40
Tantalum	(Ta)	Maximum	0.15
Carbon	(C)	Maximum	0.08
Nitrogen	(N)	Maximum	0.04
Oxygen	(O)	Maximum	0.15
Hydrogen	(H)	Maximum	0.01
Iron	(Fe)	Maximum	0.05
Silicon	(Si)	Maximum	0.05
Zirconium	(Zr)	Maximum	0.10
Titanium	(Ti)	Maximum	0.05
Tungsten	(W)	Maximum	0.05
Tin	(Sn)	Maximum	0.05

b. Physical Requirements:

All columbium powder shall pass a U. S. Standard Sieve No. 20 and a minimum of 95 percent by weight shall be retained on a U. S. Standard Sieve No. 200 (ASTM Designation E 11). Each lot shall have been blended by any suitable means so that uniformity as to chemical analysis and particle size is maintained in every portion of the lot.

3. PACKAGING, MARKING, IDENTIFICATION AND SHIPPING

a. Packaging:

Columbium powder shall be packed in full round-bottom bags made of polyethylene film which have been inserted in steel drums.

All drums shall be new 15-gallon, 18-gauge, steel drums, hot-dipped galvanized after fabrication, conforming to the requirements of National Stockpile Container Specification C-1-R (Latest Revision) Drums: Steel, Hot-Dip, Galvanized.

The polyethylene film used for making the bags shall, where applicable and except as modified herein, comply with the requirements of Federal Specification L-P-378a: Plastic Film (Polyethylene Thin Gage), for: Type I-Normal impact strength; Grade A-Slip not specified; and Finish 1-Untreated. The thickness of the film shall be 0.006-inch with a plus or minus tolerance of 10 percent. All polyethylene film used in the construction of the bags shall be of virgin stock, and shall contain not less that 50 parts per million of a suitable anti-oxidant.

The sides of the bags shall be cylindrical in shape, formed by extrusion of tubing, and shall have no seams. The bottoms shall be circular in shape. The side shall be turned inward at least 1½-inches and overlap on the bottom. The side and bottom shall be jointed tightly by one or more seams formed by the application of heat to make what is known in the trade as a "shear" seam. What is referred to as a "peel or tear" seam, formed by having the side project outward, is not acceptable. The seam(s) shall not have skipped spaces and shall not be easy to pull apart. When the bag is filled with water to a height of two feet, there shall be no evidence of leakage over a period of two hours. The seam(s) shall be made in such a manner that they will have as little extruded "leading edge" (ridges and creases) on either surface as possible. The diameter of the bags shall be approximately one inch larger than the inside diameter of the drums and shall be of sufficient length to conform to the requirements specified herein.

The polyethylene bag shall be carefully inserted into the drum so as to conform snugly to the bottom and sides of the drum. Enough columbium powder shall be packed in the bag so that, after the top of the bag has been heat-sealed flat to form a water-tight closure, the top of the bag can be folded over and the cover will just fit snugly on the drum. Prior to the completion of this closure; the top of the bag shall be squeezed together to force out as much of the air as possible. Any necessary precautions shall be taken to avoid dusting the surfaces to be sealed.

All drums shall have the cover bolts very carefully tightened. The drums shall be carefully handled to prevent denting or other damage and shall be delivered in excellent condition.

b. Marking:

All markings shall be in English. Each drum shall have attached to the clamp ring bolt, by a 12-gauge zinc wire through a hole at least ½-inch from the edge of the tag, a 26-gauge three-inch by five-inch zinc tag on which shall be embossed the following:

Name of Product
Name of Producer
Country of Origin
Gross and New Weights
Government Contract Number
Lot Number and Drum Serial Number (e.g., 1/20, 2/20, etc.)
The Notice "DUPLICATE TAG INSIDE DRUM"

A duplicate zinc tag shall be placed inside of each drum on top of the polyethylene bag. The reference to duplicate tag may be omitted from tags placed inside drums.

The marking shall not include a security classification or anything indicating National Stockpile ownership other than the contract number.

c. Identification:

Appropriate identifying documents shall accompany each shipment.

d. Shipping:

All drums containing columbium powder shall be loaded, braced, and blocked in the carrier's conveyance in compliance with applicable rules and regulations set forth in the carrier's classifications and other tariffs. For rail shipments, the applicable rules and regulations published by the Association of American Railroads (AAR) in such as Pamphlets Nos. 4 and 14 and Circular No. 42-B (Latest Revisions) shall be followed.

4. SAMPLING, INSPECTION, AND TESTING

Each lot of columbium powder shall be subject to sampling, inspection, and testing by the purchaser or his designee.

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10. DISTRIBUTION STATEMENT

11. SUPPLEMENTARY NOTES	

13. ABSTRACT

Uses of columbium in various applications are reviewed and estimates are made of future requirements. Currently, major applications are as additions to ferrous alloys and superalloys, with superalloy consumption expected to experience very rapid growth until 1972, with aerospace requirements probably utilizing the columbium-base alloys to a large extent in the future. Some possible substitutes for columbium are also reviewed. Basic to the demand for columbium is its availability. Both foreign and domestic resources are reviewed in light of past production and mineral reserves. The quantity and quality of columbium in the National Stockpile have also been reviewed. Current resources exceed present demands, but the anticipated 20% annual increase in superalloy production is expected to put some strain on the availability of high purity Cb_2O_5, unless pyrochlore concentrate becomes a source.

Unclassified
Security Classification