SUPERALLOY RECYCLING 1976 - 1986

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Abstract

About 55 million pounds of clean and contaminated superalloy scrap were processed in 1986; about 92 pct (50 million pounds) went to domestic buyers, and 8 pct (4.3 million pounds) was exported. About 93 pct (4.0 million pounds) of the exported material was refinery-destined grindings and 7 pct (0.3 million pounds) was vacuum-melting-grade superalloy scrap. Of the 55 million pounds of superalloy scrap processed in 1986, about 70 pct (38.5 million pounds) was recycled into the same superalloy, 20 pct (11 million pounds) was downgraded, and 10 pct (5.5 million pounds) was sold to refineries. The average element content of superalloy scrap processed in 1986 was about 44 pct Ni, 16 pct Cr, 5 pct Co, 2 pct Cb, less than 1 pct each of Mn and Ta, and nil for Re. The remaining 30 pct was primarily Al, Fe, Mo, Ti, W, and other minor constituents.

The major changes in the superalloy recycling industry since 1976 were the introduction of premelted superalloy scrap as a material supply source and increased use of closed loop recycling agreements among forger-scrap processor-alloy producer-engine manufacturer groups. Since 1976 Inconel 718 has become the predominantly produced superalloy.

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Introduction

The Bureau of Mines has long been interested in recycling as part of its minerals program. Chromium and superalloys have been the subject of previous Bureau studies because chromium is a critical and strategic metal and superalloys represent a strategic use for chromium (1-5). The objective of this study was to characterize the superalloy recycling industry. An industry structure was determined; major superalloy producing, consuming, and processing companies were identified; and superalloy material flow was estimated. Information was collected through personal interviews and site visits to companies that volunteered to participate. Data were collected both by Bureau of Mines commodity specialists and by industry analysts contracted by the Bureau. Data were organized and presented in material flow circuit diagrams.

The superalloy recycling industry was found to be composed of scrap generators, scrap dealers, superalloy processors, and scrap consumers. Scrap is generated when superalloys are produced, cast or wrought into semifinished products, and cut or ground into finished products, and when finished products become obsolete. Superalloy scrap is collected and processed by scrap collectors, scrap dealers, wholesale scrap dealers, and superalloy scrap processors. Superalloy scrap is sorted, cleaned, sized, and certified for chemical composition by a superalloy scrap processor before it re-enters the use cycle as a superalloy. The numerous material flow relationships between scrap industry and scrap generator, and among scrap collectors, scrap dealers, wholesale scrap dealers, superalloy scrap processors, and scrap brokers obscure the quantity of superalloy scrap available for recycling, the quantity downgraded, and the quantity exported. A superalloy industry diagram based on material flow between processing steps was constructed. A previous Bureau of Mines study (IC 8821, reference 3) of the superalloy industry was used as a reference to which 1986 data were compared. Thus the terminology, industry structure, and material flow patterns used in this study are similar to those of IC 8821.

Results

Companies

No major change in superalloy producing, consuming, and recycling companies was found to have taken place since 1976. Only a few company name changes have taken place. About 75 companies were identified as significantly involved in the U.S. superalloy industry. They were classified by their major role in the superalloy industry as a superalloy producer (AP), casting producer (CP), forger (F), end user (EU), gas turbine manufacturer (GTM), metals producer (MP), product manufacturer (PM), scrap dealer (SD), or scrap processor (SP). Table 1 lists these industries.

Table 1.--Companies and Organizations identified as part of this study.

Company	Activity code
Abex Corp., New York, NY	AP, CP
Abex Research, Mahwah, NJ	CP
Air Force Materials Laboratory, Dayton, OH	EU
AiResearch Manufacturing Co. (see Garrett Corp)	GTM, PM
Allegheny Ludlum Industries, Special Metals Div., Lockport, NY	AP
Atlas Metals & Iron Corp., Denver, CO	SD, SP
Brush Wellman Inc., Cleveland, OH	CP
Cameron Iron Works Inc., Houston, TX	F
Canon-Muskegon Corp., Muskegon, MI	AP, CP

Carpenter Technology Corp., Reading, PA...................... AP
Certified Alloy Products, Inc., Long Beach, CA.............. AP, CP
Chromalloy Corp., St. Louis, MO............................ AP, PM
Cytemp Specialty Steel, Division of Cyclops Corp.,
Pittsburgh, PA.. AP
Degussa Electronics Inc., Vallejo, CA...................... AP
Detroit Diesel, Allison Division, Detroit, MI............... GTM, PM
Duraloy Co., Division of Blaw-Knox Corp., Scottdale, PA...... AP
Eaton Corp., Cleveland, OH.................................. PM
Electralloy Corp. (see Michael Kral Industries)
Electrometals (see Degussa)
Elkem Metals Co., Pittsburgh, PA............................ MP, AP
Ford Motor Co., Aeronutronic Div., Detroit, MI.............. GTM, PM
Garrett Corp, Airesearch, Torrance, CA...................... AP
General Electric Co., Cincinnati, OH........................ GTM, PM
General Motors Corp.(see Detroit Diesel).................... GTM, PM
Haynes International Inc., Kokomo, IN....................... AP
Howmet Turbine Components Corp., Plymouth, MI,
Dover, NJ, Norfolk, VA.................................... AP, CP
Inco Ltd., Toronto, Canada.................................. MP
Inco Alloys International Inc., Huntington, WV.............. AP
Ireland Alloys Inc., Houston, TX............................ SD, SP
Kaydon Ring & Seal Inc., Baltimore, MD...................... CP
Koppers Co, Sprout Waldron, Muncie, IN....................... CP
Ladish Corp., Cudahy, WI.................................... F
LMC Metals Corp., San Jose, CA.............................. SD, SP
Martin-Marietta Corp., Bethesda, MD......................... AP, PM
Michael Kral Industries, Electralloy Corp., Oil City, PA..... AP, SP
Kokomo Tube Co., Peru, IN................................... AP, CP
Monico Alloys Inc., Los Angeles, CA......................... SD, SP
National Aeronautics and Space Administration, Cleveland, OH. EU
Norco Alloys Corp., Farmington Hills, MI.................... SD, SP
Northeast Alloys & Metals Inc., Utica, NY................... SD, SP
Outokumpu Oy, Kokkola, Finland.............................. MP
PCC Airfoils Inc., Minerva, OH.............................. AP
Powmet Inc., Rockford, IL................................... SD, SP
Pratt & Whitney (see United Aircraft)
Precision Castparts Co., Inc., Portland, OR................. AP, CP
Precision Rolled Products Inc., Florham, NJ................. AP, MP
Quaker Alloy Inc., Myerstown, PA............................ CP
Rainbow Metals Inc., Charlotte, NC.......................... SD, SP
Reading Alloys Inc., Reading, PA............................ MP
Rolls Royce Inc., Miami, FL................................. GTM, PM
S. Wilkoff & Son Co., Cleveland, OH......................... SD, SP
Samuel Keywell, Inc., Detroit, MI........................... SD, SP
Samuel Zuckerman and Co., Front Royal, VA................... SD, SP
Schnitzer Steel, Portland, OR............................... SD, SP
Shieldalloy Metallurgical Corp., Newfield, NJ............... AP, MP
Solar Turbines Inc., San Diego, CA.......................... GTM
Special Metals Corp., New Hartford, NY, Princeton, KY........ AP,CP
Spectrum Alloys Inc., Los Angeles, CA....................... SD, SP
Stoody Deloro Stellite, Inc., Industry, CA.................. CP
Suissman and Blumenthal,Inc., Hartford, CT.................. SD, SP
Techni Cast Corp., South Gate, CA........................... CP
Teledyne Allvac, Monroe, NC................................. AP
Textron Lycoming, Stratford, CT............................. GTM
TRW, Inc., Cleveland, OH.................................... AP, CP
Unico Alloys Inc., Columbus, OH............................. SP
United Aircraft Corp., Pratt & Whitney, East Hartford, CT.... GTM, PM
United Airlines, Chicago, IL................................ EU
United Alloys Inc., Los Angeles, CA......................... SD, SP
Universal Metals Inc., Worchester, MA....................... SP
Utica Alloys, Utica, NY..................................... SP
Vac Air Alloys, Frewsburg, NY............................... SD, SP
Venango Metallurgical Products, Oil City, PA................ CP
Wells Mfg. Co., Skokie, IL.................................. AP

Westinghouse Electric Corp., Pittsburgh, PA.................. GTM, PM
Wisconsin Centrifugal Inc., Waukesha, WI..................... AP, CP
Wyman-Gordon Co., Worchester, MA............................. F

Scrap Disposition

Superalloy materials resulting from the production and manufacturing process were classified as product, scrap, or waste. Superalloy scrap was further subdivided into solids, turnings, or grindings. Superalloy scrap domestically processed was subdivided into scrap that was used domestically and that exported, and into scrap graded for superalloy use, graded for other alloy use, and graded for refinery use. Figures 1 and 2 show the distribution of domestically processed superalloy scrap in 1986 based on these categories.

Figure 1 shows that a small amount of processed superalloy scrap was exported and that most of it was refinery-grade material. Figure 2 shows that most of the superalloy scrap processed was returned to superalloy use, some was used in other alloys, and the remainder required refining before reuse.

Production

The relative fraction of superalloy production by grade changed significantly for both wrought and cast superalloys. For both types of superalloy processing, Inconel 718 has become the dominant grade. Wrought superalloy production in 1986 declined about 30 pct compared to that of 1976, while cast superalloy production increased about 10 pct. Table 2 shows the changes in production by alloy class and fabrication method from 1976 to 1986.

Table 2.--Alloy production in 1976 and 1986 by alloy class and by fabrication method.

Alloy designation	Quantity (million pounds)		Percent of total	
	1976	1986	1976	1986
WROUGHT NICKEL-BASE ALLOYS				
Waspaloy..................	10	1.8	11.1	3
Inconel 718...............	10	27.0	11.1	45
Inconel 600 series.........	20	15.0	22.2	25
Inconel X750 and X751......	6	3.0	6.7	5
Other.....................	44	13.2	48.8	22
Total................	90.0	60.0	NAp	NAp
INVESTMENT CAST NICKEL-BASE ALLOYS				
Inconel 713 and 713C.......	5.0	6.8	21.6	26.1
B-1900 and B-1900+Hf.......	2.0	0.7	8.6	2.7
Rene 77....................	2.0	2.2	8.6	8.5
IN 738.....................	1.5	3.8	6.5	14.6
Inconel 718................	1.0	6.5	4.3	25.0
Other......................	11.7	6.0	50.4	23.1

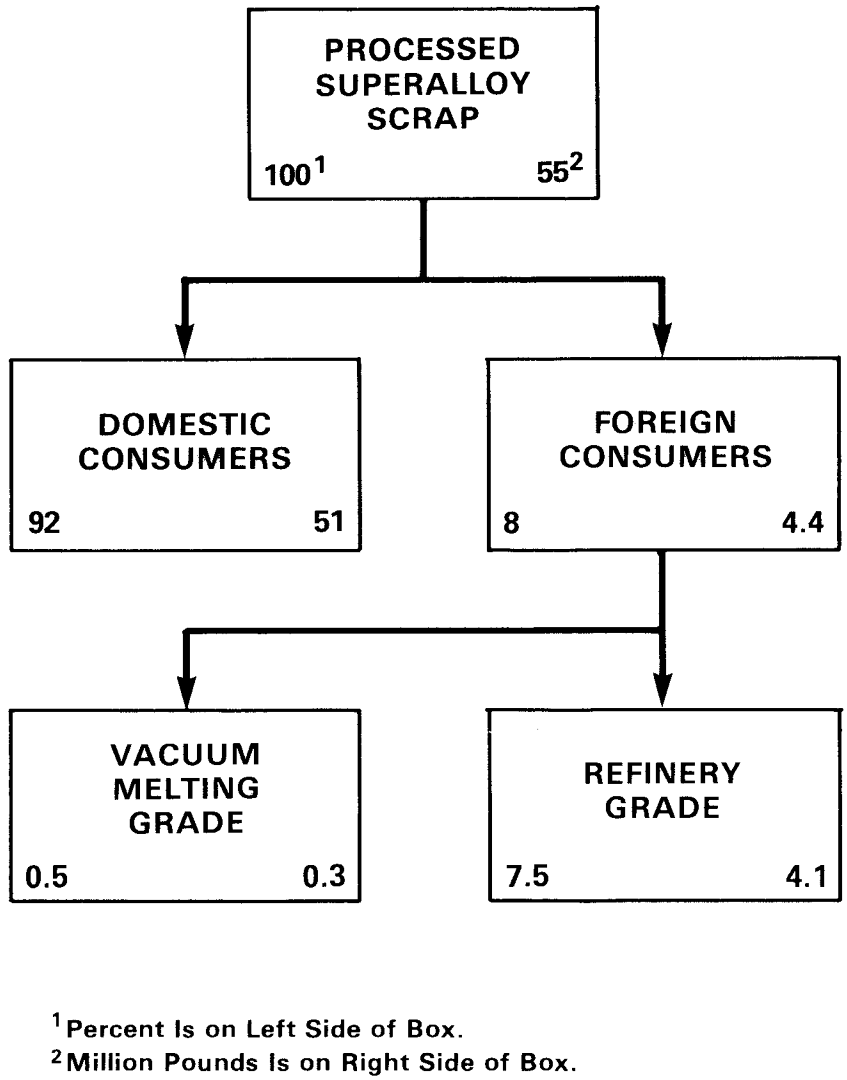
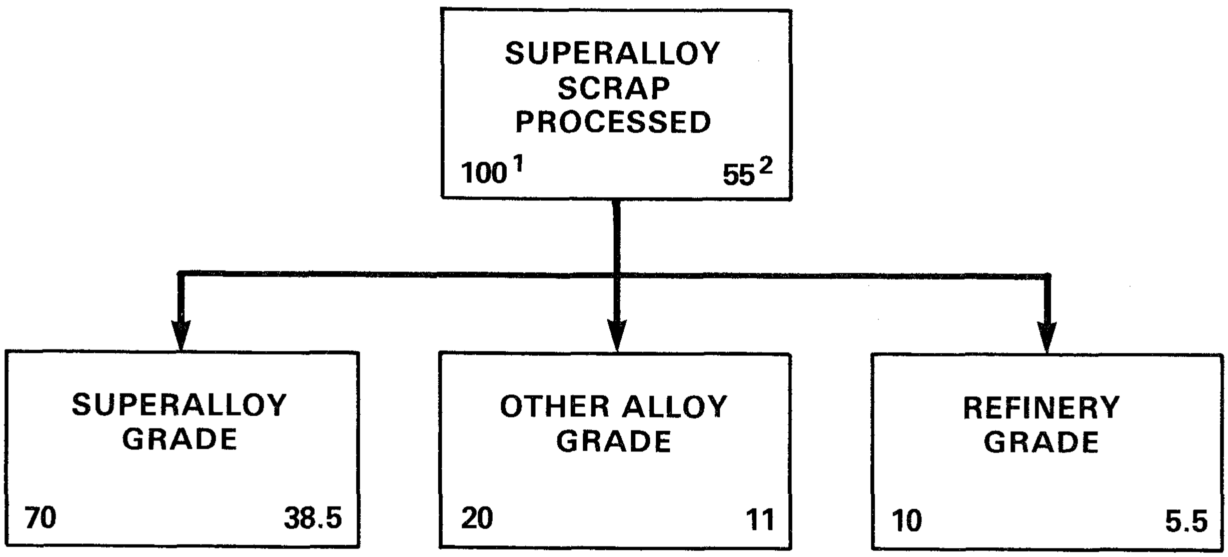


Figure 1.--Domestically processed superalloy scrap material flow circuit for foreign and domestic use.



[1] Percent Is on Left Side of Box.
[2] Million Pounds Is on Right Side of Box.

Figure 2.--Domestically processed superalloy scrap material flow circuit for end uses by grade.

Total	23.2	26.0	NAp	NAp
Grand total	113.3	86.0	NAp	NAp

NAp Not Applicable. 1976 data from IC 8821.

The decline of wrought superalloy production was thought possibly to have resulted from several factors including (1) a decline in chemical industry (rather than turbine engine industry) demand for nickel-base alloys, (2) increased use of powder-metallurgy-produced parts, (3) increased use of casting, and (4) greater end-user efficiency. Greater end-user efficiency results in lower use and stocking, and therefore lower demand for parts and engines. From 1976 to 1986, the major civilian commercial aircraft changed from the three-engine 727 to the two-engine 737. This change may have resulted in reduced demand for original and replacement parts. Cooperative maintenance agreements wherein one engine repair company services many carriers may also have contributed to greater end-user efficiency by reducing the need for each carrier to stock parts.

Demand for superalloys, as for other metals, is cyclic. It is likely that 1976 and 1986 simply fell on different parts of the demand cycle.

The increased use of one superalloy grade suggests that recycling of prompt scrap should be easier because there would be more markets for the processed scrap. A disadvantage results from disuse of previously popular grades. Obsolete scrap of unpopular grades, although technologically recyclable, would not be in demand. Such scrap would, therefore, more likely be downgraded. Where possible, it is industry practice to use excess scrap of one grade to produce another grade.

The shift to Inconel 718 was thought to have resulted from (1) the shift away from cobalt caused by the high cobalt prices of 1979, and (2) the fact that General Electric used Inconel 718 widely in their engines, and they manufacture a large and increasing share of engines. Inconel 718 is a nickel-iron superalloy that can be produced using low-carbon, low-nitrogen ferrochromium in place of chromium metal for the required chromium units. This allows a cost advantage because ferrochromium is less expensive than chromium metal.

Material Flow Circuits

Assumptions required to produce material flow circuits for wrought and cast superalloy recycling included (1) the available obsolete scrap in 1986 was equal to 1976 finished product, (2) purchased scrap was first supplied from prompt scrap, then from obsolete scrap, and (3) half of the balance of solid scrap was exported and the remainder was downgraded.

Casting. Figure 3 shows that the casting superalloy industry material flow in 1986 was essentially the same as in 1976. The 1986 flow circuit shows that product yield per unit of raw material consumed in 1986 increased compared to that of 1976. It was thought that casting nearer to finished dimensions was the reason for improved product yield. The decreased use of scrap in 1986 was thought to have resulted from the imposition of more stringent chemical specifications by engine manufacturers that excluded previously used scrap. More stringent chemical specifications were imposed to reduce contamination by fixture alloys that include bismuth, lead, and tin.

Wrought. Figure 4 shows that the wrought superalloy industry material flow circuit in 1986 was essentially the same as in 1976 except for the addition of premelted scrap as a feed material. It was found that scrap premelted by argon-oxygen decarburization was widely used for vacuum induction melted alloys, allowing the alloy producers to use materials that

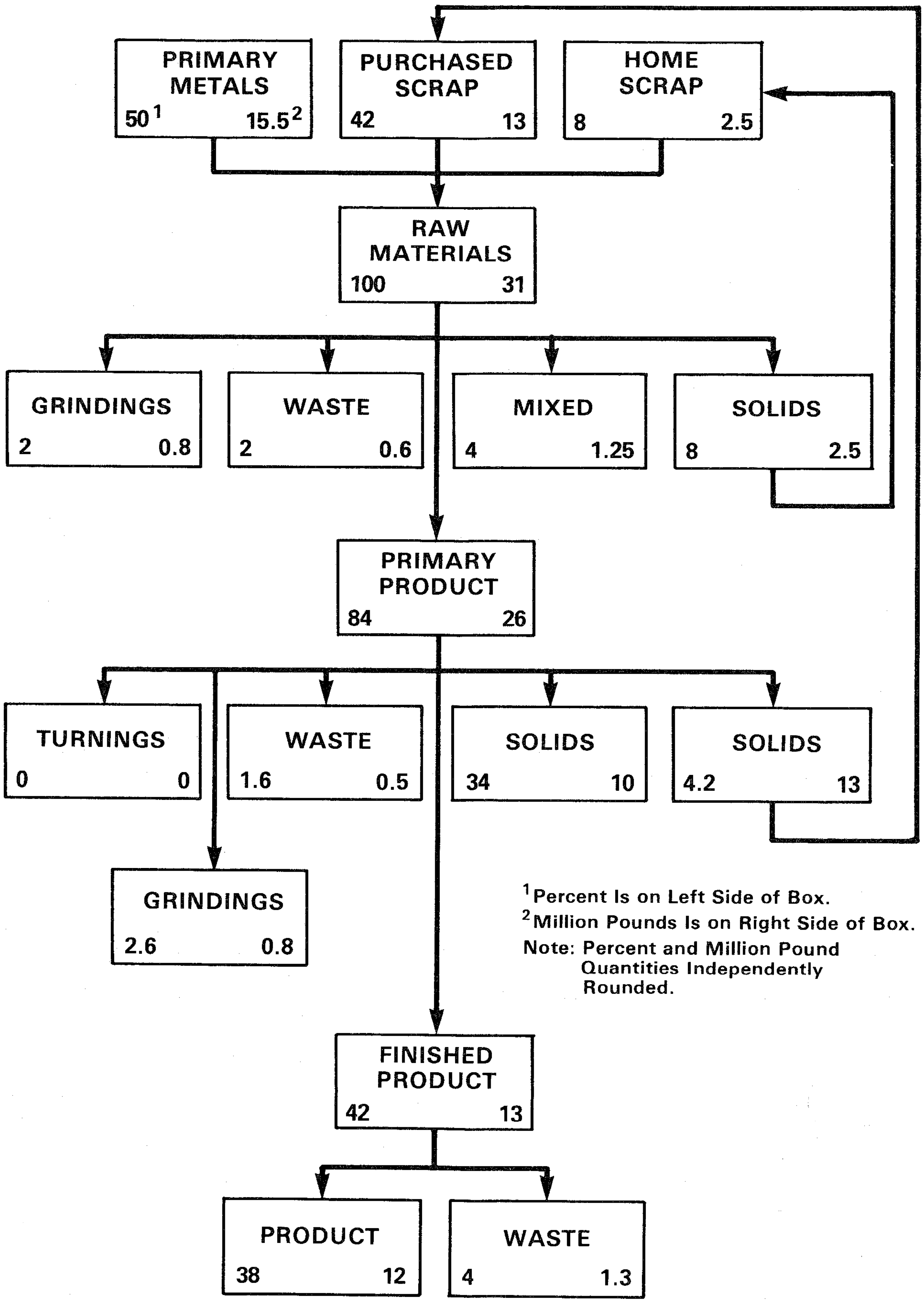


Figure 3.--Cast superalloy material flow circuit in 1986.

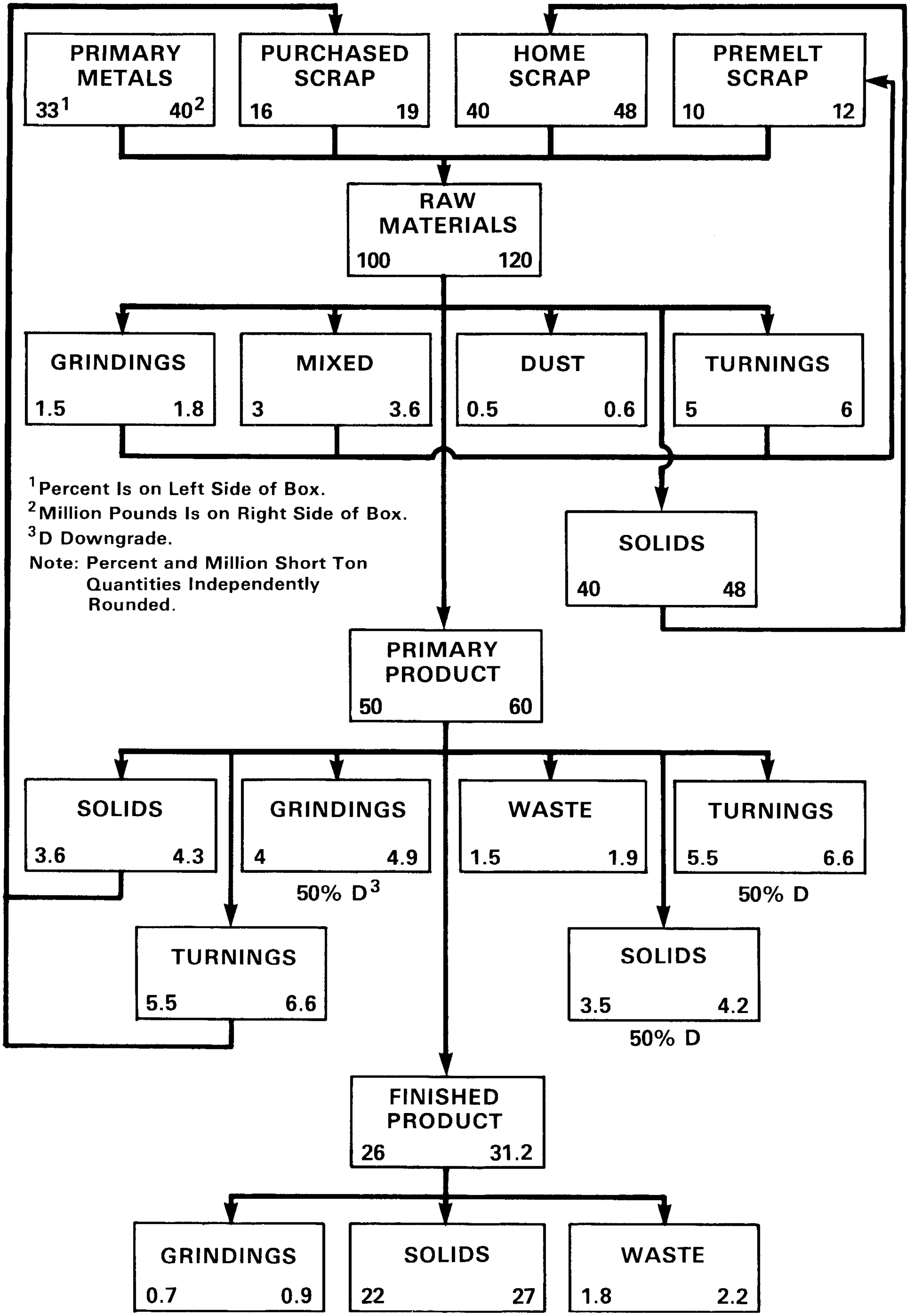


Figure 4.--Wrought superalloy material flow circuit in 1986.

would have been downgraded in 1976. Product yield in 1986 was about the same as in 1976. Scrap use increased in 1986 compared to that of 1976.

The most significant change in the superalloy recycling industry structure was the introduction of argon-oxygen decarburization refining into the recycling process for wrought nickel- and cobalt-base superalloys. The fraction of superalloy scrap recycled increased in 1986 compared to that of 1976. In 1986 49 pct of superalloy scrap generated as a result of primary material production and about 9 pct of scrap resulting from semifinished product production was recycled, compared to 47 and 3 pct respectively in 1976. Waste fraction remained about the same in 1986 as in 1976. A material flow diagram was produced for each year and for each type of superalloy, i.e., wrought and cast.

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