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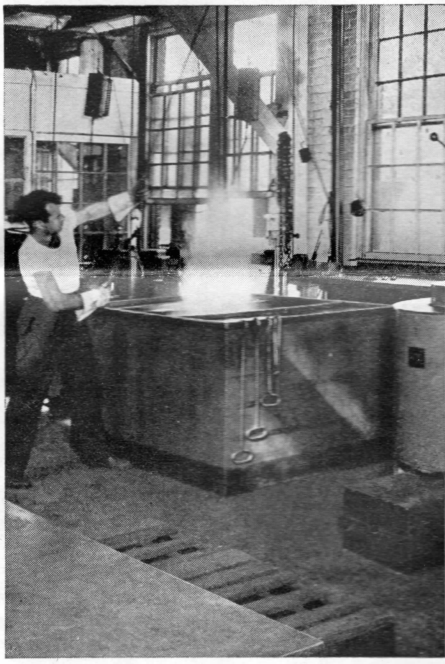
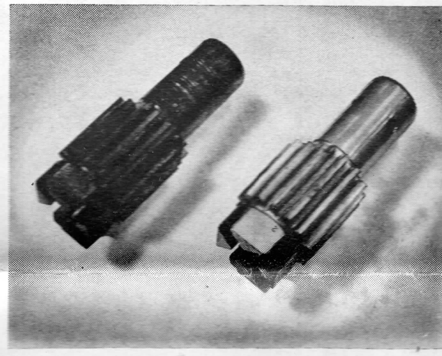
Nickel Steel Topics

Published in the Interest of Producers and Users of Nickel Alloy Steels

Vol. 10, No. 3 The International Nickel Company, Inc. **OCTOBER, 1941** 67 Wall Street, New York, N. Y. **100,000 Circulation**





The two parts above were heated together in a controlled atmosphere furnace. The unscaled part (right) was quenched in the special container shown on page 4. That at the left, exposed to air momentarily between furnace and oil tank, is covered with light scale and soot.

At the left a batch of aircraft engine gears of alloy steel is being quenched into oil, at plant of Indiana Gear Works.

Careful Control Essential in Heat Treatment of Aircraft Engine Gears*

● Aircraft engines are like buggy whips or fly rods. Almost every part is built to deflect with shock load rather than to withstand it. Consequently the factor of safety is about the same through all sections of a complex part, and any point containing a tool mark, scratch, sharp corner, or segregation will probably fail in service due to stress concentration and fatigue.

As a general practice, we require the mill to furnish a foot of each bar size from each heat. We then make a deep etch, a McQuaid-Ehn test, a magnaflux test, a pull bar, and a step hardenability test before taking delivery.

Because most aircraft engine parts are extremely light and fragile, distortion in heat treatment presents a serious problem. As a consequence considerable machining has to be done on material in the hard state. Gears for carburizing, however, must be cut in a fairly soft state, although annealed or normalized steel cannot often be cut satisfactorily, particularly if the material has a banded structure. Grains or bands of pearlite tear out and roll under the tool, while "gummy" ferrite builds up on the tool. Resultant streaks are never acceptable.

Our practice on carburizing steel for maximum machinability usually involves quenching in oil after an hour's soak around 1500°F., then tempering at from 800° to 1200° for several hours, depending on the analysis. The result is a finely spheroidized sorbite, homogeneous and "crisp," that machines with clean hard chips that spring away and do not mar the tooth surfaces. Hardness is 23-24 Rockwell C.

Heating Rate Important

Almost all aircraft engine gears must be hardened without producing pits, scale, decarburization or serious distortion. Only the most accurate equipment

(*Continued on Page Two*)

* From a paper presented before the annual meeting of the American Gear Manufacturers Association, by John L. Buehler, Indiana Gear Works, Indianapolis, Ind. (See also *The Iron Age*, June 26, 1941.)

OPM Urges Salvage of Alloy Scrap

Segregation and Quick Return for Remelting Will Add to Volume Available for Production

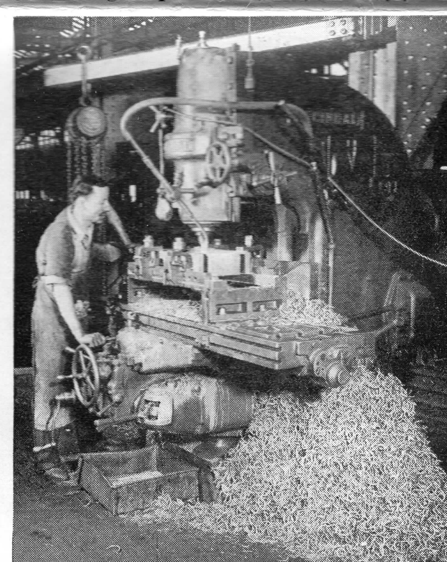
● R. C. Allen, Deputy Chief of the Iron & Steel Branch of the Office of Production Management, in Charge of Raw Materials, has sent out questionnaires to fabricators and manufacturers estimated to be using approximately 96% of the current production of alloy steels, including the stainless steels.

A letter accompanying the questionnaire points out that the indicated demand for such alloying elements as nickel, chromium, molybdenum, etc., exceeds the current supply and that, while facilities for the production of these alloying elements are being expanded, all possible sources of supply must be explored and developed.

In many manufacturing plants from 20% to 40% of the alloy steel or alloy iron delivered is lost as scrap during conversion, and in some products the amount of scrap may run 70% to 80%.

(*Concluded on Page Two*)

The amount of metal lost as scrap in machining operations is indicated by this view of a milling machine working on Diesel engine parts. (*Ewing Galloway photo*)



Nickel Steel Topics

Published in the Interest of Producers and Users of Nickel Alloy Steels

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York, N. Y.
H. S. LEWIS, *Editor*

VOL. 10, No. 3 OCTOBER, 1941

'41 Metal Congress Will Stress Defense Needs

● Government officials and production executives of defense equipment manufacturers plan a series of defense forums as the main feature of this year's National Metal Congress and Exposition to be staged in Philadelphia's Convention Hall and Commercial Museum the week of October 20th. The purpose of these meetings will be the devising of means for increasing defense production and for the conservation of metal resources and substitutes.

Ranking members of the Office of Production Management, Office of Emergency Management, the Army and the Navy will be present at this timely production clinic, while industry will be represented by leading metallurgists, production men, shop superintendents, engineers and operating executives. By a frank discussion of their problems with the government men, an interchange of ideas and a revelation of the most pressing needs of the nation and its sister democracies, it is hoped to iron out throttling difficulties and lend new impetus to defense production.

Exhibitors, too, are cooperating to make the Congress of the greatest service to the nation by showing the newest aids for speeding national defense production. Those in charge of these exhibits will sit in on the defense forums to assist in determining new methods for greater productivity by the manufacturers contributing to the program, and will otherwise assist in making this convocation a vital factor in stocking the American arsenal.

Hundreds of tons of unsegregated iron and steel scrap in this pile. Note comparative size of 50-ton cars at right. (*Ewing Galloway photo*)

Alloy Steel Scrap

(*Concluded from Page One*)

The alloy content of such scrap is to a large extent reclaimable, but at the present time a large part of this alloy content is being permanently lost because it is mixed with other metal scrap. This is particularly true in the case of machine turnings or chips, flashings from forgings, etc. Alloy losses in the case of bar ends, punchings, rejects and similar heavy melting scrap, while smaller, are still relatively high.

The vast amount of alloy scrap produced daily by the industrial plants of this country should, if properly segregated and identified and returned in usable form, free from contamination, to the alloy steel producers, yield a large tonnage of these vital alloying elements. It is to salvage this urgently needed supply that the OPM has launched this conservation drive.

In addition to making a valuable contribution to the defense program, it is felt that most plants will find the premium price obtainable for alloy content to result in definite operating economies, and the quantity of alloying elements available for further production will also be increased.

Many large manufacturers who, because of the nature and volume of materials handled have been operating highly organized salvage departments, have found these operations definitely profitable. Small manufacturers should experience little difficulty segregating and identifying heavy grades of alloy scrap such as rejects, punchings, and bar ends, although some problems may arise in working out economical ways of segregating and storing light scrap such as borings, turnings, and chips. However, the small plants usually keep non-ferrous metals such as brass and aluminum separate from iron and steel, and it should be possible to educate the machine tool operators to carry this a step further and segregate alloy steel scrap from that of simple carbon steels; and knowing the compositions of the parts they are working on, further segregate the alloy steel scrap by types and grades.

Aircraft Gears

(*Continued from Page One*)

is at all suitable. Heating rate must be carefully controlled. In general practice, most of the distortion that is blamed on the steel, on improper quench, on machining strains, etc., occurs principally in heating. As steel heats, it expands. This expansion proceeds at a rather uniform rate until the Ac_1 line on the iron-carbon diagram is reached. As the steel is further heated, it contracts until the Ac_3 line is reached. After that, further heating produces expansion. Therefore, if a piece with appreciable variation in section thickness is heated too rapidly, the heavy sections are still below the critical range and expanding, medium sections are in the critical range and contracting and thin sections already fully in solution will be expanding. If the simultaneous expansion and contraction is severe enough to load the material beyond its hot yield point, a permanent set occurs and the material is warped. On cooling, when the material is at even temperature throughout, parts that have been stretched by distortion will be under compression, and parts that have been hot compressed will be too short and will be under tension. Thus the part

(*Concluded on Page Four*)

Large Diameter Shafting

Q. We are using ordinary medium carbon steel for various shafts which run up to 5″ or 6″ in diameter, and 6 to 8 feet long, but wish to specify a better material. What alloy steel can you suggest?

EH/9-12-40

A. S.A.E. 3140 nickel-chromium steel will give you considerably better properties than carbon steel even in the as-rolled condition. Of course, if you are in position to heat-treat, the properties would be still further improved. This composition is also obtainable from several warehouses already treated to a tensile strength of 125,000 p.s.i., or better. In small sections (up to 1½″ or 2″) this steel would be your best choice, all things considered, as it is one of the lower priced of the alloy steels. In the case of your larger shafts, up to 6″, however, probably the best material obtainable is S.A.E. X-4340, a nickel-chromium-molybdenum steel. It is very deep-hardening and will give you good properties in large sections. It normally is procurable from several of the leading alloy steel warehouses.

▼

Small Gears

Q. We have a 22-tooth gear of .750″ P.D. that is press-fitted on to a 5/16″ diameter shaft, no heat treatment being given after hobbing. We wish to replace the present gear material with a steel that will give ample strength and wear, and also clean up to a better tooth surface than we are now getting.

D/64-12/40

A. S.A.E. 3140 nickel-chromium steel should serve your purpose quite adequately. It is one of the lower priced alloy steels.

You should, however, heat treat the gear blanks before hobbing to get best results, from the standpoint both of better properties and to clean up to a better tooth finish than you are now getting. The recommended treatment would be to quench in oil from a temperature of 1475/1525° F., and temper at 1150/1250° F., which will give a hardness of 222/241 Brinell.

Some of the leading alloy steel warehouses can, under normal conditions, supply this composition heat treated, in case you have no suitable facilities.

▼

Air-Hardening Alloy Steels

Q. We are interested in air-hardening properties of S.A.E. 3345 (3½% nickel—1½% chromium) steel in the form of forged rings of 121″ diameter and 2¼″ thick. Have you any data which would be useful in this connection? We want a minimum Brinell hardness of 300.

D/46-47/40

A. We assume it is your plan to give these forgings a simple heat treatment consisting of air-quenching from above the critical range, probably because of the size of the parts making liquid quenching impractical. It is doubtful whether the 2¼″ thickness will permit sufficiently rapid cooling to secure the minimum hardness you desire, but since 3345 is not a commonly used composition, we have no actual data on its air-hardening properties.

All questions addressed to this section will be answered by letter. Only those of special or broad general interest will be reprinted on this page.

Below are shown some results on some other alloy steels, which may be of some assistance in determining whether you can safely air-quench these rings using the 3345 steel. The compositions listed were subjected to air-cooling after rolling operations, all representing 1½″ round bar sizes:

Spec.	*Brinell*	*Tensile (p.s.i.)*	*Y.P. (p.s.i.)*	*Elong. (%)*	*R.A. (%)*
3150	248	122,000	83,000	18	45
3250	285	144,000	111,000	14	27
2350	245	120,000	87,000	20	39
4340	401	185,000	155,000	10	23

It must be remembered that the 1½″ sizes listed will cool more rapidly than your 2¼″ sections, thus the latter would tend to show relatively lower hardness.

Based on these figures the S.A.E. 4340 steel appears to offer you better possibilities than the 3345, and should provide a hardness of around 350 Brinell in your 2¼″ sizes. You did not state what your ductility requirements are, which would presumably have some bearing on your selection of material.

If ductility is a factor and you must have a certain amount of wear-resistance on one of the faces of the rings, you might use the S.A.E. 3345 or any other of the steels listed, and give the rings a normalize and draw treatment, with a drawing temperature as high as 1000° or 1100°F.; then flame-harden the surface requiring wear-resistance. This practice is being widely used on large equipment parts too cumbersome to liquid-quench, such as base rings for power shovels, etc.

▼

Dowel Pins

Q. Would like recommendations for suitable alloy steels to be used for dowel pins, also lash adjuster stops.

J-DM

A. We have some difficulty in visualizing these parts and their function without more data than you have given us; however, it is assumed that they operate in shear and that a metal of high tensile (and hence torsional) strength is required.

On this basis, both parts could be made from S.A.E. 3145 nickel-chromium steel, heat treated to provide a hardness of Rockwell (C) 45.

A nickel-molybdenum steel, S.A.E. 4650, would probably give even better service life, but it is not generally available from jobbers. If there should be some movement or sliding action in these parts, a casehardening steel would be recommended, such as S.A.E. 4815, a 3½% nickel-molybdenum steel. After carburizing, the hardening temperature used should be sufficiently high to harden the core to about Rockwell 35 (C). The case, of course, would be file-hard.

▼

Case-Hardened Roller Pins

Q. We have been experiencing trouble with tractor roller pins of S.A.E. 2320 steel (of which a fully treated sample is attached for micro-examination). Due to shortage of equipment, and for economy in handling, we have used a somewhat un-orthodox method of heat treatment, as follows: After carburizing in a gas furnace at 1650°F., we remove the cover and permit the batch to cool to 1200/1250°F., then reseal the furnace and heat to 1500°F., from which temperature the lot is quenched in oil for grain refinement, then tempered at 300°F. Please let us know your conclusions and recommendations.

D/46-34/40

A. Micro-examination and hardness tests reveal that your pins are not getting the desired refined structure, either because: (1) the temperature of 1250°F. to which you cool down is still above the critical point of the core, and therefore reheating to 1500°F. cannot provide grain refinement, or (2) the core does not actually cool to 1250°F. before you reheat to 1500°F. The hardness of the core is 25 Rockwell (C). The grain size of the core is large, and the structure seems to be a coarse aggregate of ferrite and low carbon martensite.

The structure of the case is coarse-grained, and incompletely martensitic, with no free cementite present, but showing some free ferrite; thus the case shows a hypo-eutectoid composition. It has a hardness of only 57 Rockwell (C). It seems evident that 1250°F. is above the critical range of the case, and therefore reheating to 1500°F. cannot produce the desired grain refinement. The incompletely martensitic structure also indicates that the actual quenching temperature is below the 1500°F. which you aim for.

To check the above reasoning, the pin was carefully reheated to 1500°F. and oil-quenched, resulting in a fine grained core structure, consisting essentially of low carbon martensite with small patches of ferrite disseminated uniformly through it. The grain size of the case was also considerably refined by this treatment, and the case was completely martensitic, which was reflected in a hardness of 64 Rockwell (C). We then tempered it for one hour at 300°F., resulting in a case hardness of 60 Rockwell (C), and a core hardness of 35 Rockwell (C). Both these values are appreciably higher than as heat treated by your method, and should be satisfactory in service.

It is therefore recommended that you remove your batches of pins from the furnace after carburizing and cool in air to almost room temperature, during which time the temperature of the furnace can be lowered to 1500°F. Recharge the cooled pins and let them soak at this temperature long enough to be sure that the entire lot gets up to heat; then oil-quench and temper at 300°F.

Aircraft Gears

(Concluded from Page Two)

will be internally preloaded. If the internal load is greater than the ultimate strength of the part, it flies apart in the quench or shortly after.

The answer is slow and uniform heating, preferably cutting off the heat during the transformation stage so as to get a soak. If a difference of no more than 5° or 10° is maintained between thick and thin sections during heating, little distortion will occur in fragile parts and no quenching fixture need be used. However, some distortion does occur in some parts during quenching. This, with high alloys, can greatly be mitigated by quenching on a falling heat. Material furnace cooled may drop several degrees before any structural change begins. With high alloys the lag is considerable. Thus, it is possible to heat steel until the desired structure is obtained, then let it cool in the furnace to the lowest point at which the structure will be retained. The quench will then be less drastic. For example, maximum refinement and hardness, physical properties, and minimum distortion, in a number of representative steels can be produced by treating as follows:

Material	*Heat To*	*Quench At*
S.A.E. 4140	1425° F.	1325° F.
S.A.E. 3312	1450 "	1175 "
S.A.E. 2512	1420 "	975 "
S.A.E. 4340	1425 "	725 "

The above data do not apply to furnace temperature but to actual work temperature. A thermocouple must actually touch the load.

Volume Change Minimized

As steel transforms from the annealed pearlite condition through austenite to the final martensite of the hard state, a volumetric change occurs, in part dependent upon quenching temperature. Most alloys have a tendency to grow when quenched from a high temperature and to shrink a little when quenched near the recalescence point. By playing with this variation it is possible on many parts to avert volumetric change almost entirely. No sensitive hardening can be performed in accordance with handbook rules. Critical points on various heats of steel of the same nominal analysis may vary 50°. A time-temperature diagram should be made on a coupon from each mill heat, charting the AC_1, AC_3 and Ar_1 points before any fragile parts from that heat are hardened.

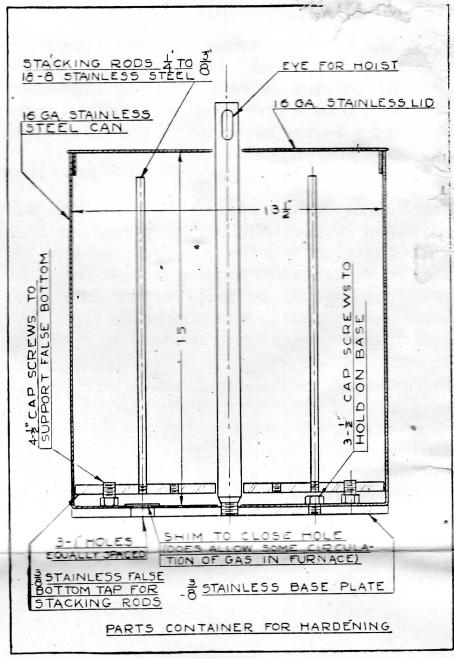
For hardening, we use a very slightly carburizing and very lightly reducing atmosphere. To prevent discoloration and paper scale forming during the transference of work between hardening furnace and oil quench tank, we use for a container a can of 16-gauge "26-20" chromium-nickel alloy resting on a 3/8 in. plate of "18-8" stainless. Bottom plate and can have three coinciding 1-in. holes. Over these is laid shim stock. The load rests on an inside false bottom which has a number of tapped holes into which stacking spikes can be screwed. The lid fits loosely enough to allow slow circulation of furnace atmosphere. On quenching, the oil knocks away the shim stock, and gas in the can condenses, creating a vacuum. Oil fills the can almost instantly. The thermal circulation is great. The lid lifts with the rising oil current. We experience no loss of hardness and get a more uniform circulation than can be obtained otherwise.

Case Carbon Content

About six years ago we were just beginning to realize that only a very narrow range for case carbon content was satisfactory — that a little too much carbon caused retained austenite, which would prevent peak hardness from being attained. The International Nickel Company generously lent us their comprehensive data on properties of 5% nickel steel of from 0.08 to 1.40% carbon. With this excellent material as a background we found that we would have to keep our outer case carbon content between 0.70 and 0.90%. Production carburizing of this type can only be done under laboratory conditions. As the load is heated the atmosphere must be kept neutral. At the moment carburizing temperature is reached, an atmosphere empirically predetermined for the given steel, load density, desired case depth and carbon content is applied. If the load is to carburize for, say, 2½ hours, at the end of two hours we remove one of several included test coupons from the furnace and examine it for case depth and approximate case carbon content. If the load has carburized too rapidly we stop it immediately. If it has carburized too slowly, more time can be allowed. If the carbon content is too low, the atmosphere can be enriched. If it is too high, the atmosphere can be made almost neutral as the carbon diffuses.

Under no circumstances should delicate parts be quenched from the carburizing temperature. A cooling pit should always be used which will allow the load to cool sufficiently slowly to be machinable in later operations, but not so slowly that the case will diffuse.

No free ferrite in the core is ever permitted by the U. S. Army Air Corps. For maximum over-all refinement, quenching on the falling heat a few



Quenching receptacle developed by Indiana Gear Works, which prevents scaling in the brief interval of transference of work from furnace to oil quench tank.

degrees above the Ar_3 point of the core is the best treatment we have yet found. Quenching oil should always be kept at above 100°F. Very hot oil may cause the loss of a point or two of hardness in low alloys, but is conducive to greater uniformity.

Tempering

Tempering is very important, and often improperly executed. Its major purpose is to relieve strain, yet too often it is only used to meet blue print hardness specifications. Strain relief is a function of time and temperature. Hardness is primarily a function of draw temperature and can usually be achieved in a few minutes. Yet strain relief is not complete in thin sections after 5 hr. at 300°F. or after 3 hr. at 500°F. Too often leaving urgently needed parts in a busy furnace for 6 or 8 hours is considered a prodigal waste of time; yet one unrelieved strain in one small part can easily cause an engine failure.

A.S.M. to Publish French's Lectures on Steel

● "Alloy Constructional Steels" was the topic of a series of lectures delivered by H. J. French before the Western Metal Congress last May. Mr. French is in charge of alloy steel development with The International Nickel Company.

The lectures are now available in book form from the offices of the American Society for Metals at Cleveland, Ohio.

Printed in U. S. A.

ALLOY SCRAP CONSERVATION

Since readers of the Nickel Steel Topics will undoubtedly wish to assist in the conservation of alloy scrap by segregating and returning scrap metal in usable forms to the mills either directly or through their scrap dealers, the following letter and questionnaire sent out by the Office of Production Management, Washington, D. C., have been reproduced to assist them in this effort.

* * *

OFFICE OF PRODUCTION MANAGEMENT
SOCIAL SECURITY BUILDING
WASHINGTON, D. C.

September 10, 1941

ATTENTION: PURCHASING AGENT

GENTLEMEN:

Due to the requirements of the defense program, the indicated demand for such alloying elements as nickel, chromium, molybdenum, etc., is considerably in excess of the current supply. While facilities for the production of these elements are being expanded, it is essential that all possible sources of supply be explored and developed.

Since these elements are reclaimable, an important source of supply is the scrap being produced daily by users of these alloys.

The urgency and importance to the defense program of the enclosed questionnaire is obvious. These questionnaires are being mailed to purchasing agents for distribution to the proper plant officials.

In cases of companies operating more than one plant, questionnaires are being sent in duplicate to each plant known to be a substantial user of these alloys. Separate returns should be made for each plant. Duplicate copy may be retained for record. Additional copies will be furnished on request.

Yours very truly,

(Signed) R. C. ALLEN, Deputy Chief
Iron and Steel Branch
In Charge of Raw Materials

(See Reverse Side)

OFFICE OF PRODUCTION MANAGEMENT

SOCIAL SECURITY BUILDING

WASHINGTON, D. C.

SURVEY OF ALLOY STEEL SCRAP

Fill out and return the following questionnaire by September 25, 1941, to Mr. R. C. Allen, Room 4065, Social Security Building, Washington, D. C. This form takes the place of any previous form on alloy steel scrap.

Company Name and Address ____________________

____

1. How much of each of the following types of alloy steel scrap did you produce during August, 1941? If not segregated, give best estimates.

	Net Tons
(a) Chromium-nickel stainless steels ________	________
(b) Chromium base stainless steels ________	________
(c) All compositions of SAE low alloy steels ________	________
(Please list SAE type numbers separately below: Where possible, give estimated tonnage for each) TOTAL	________

2. (a) Do you segregate your alloy steel scrap from your simple carbon steel scrap? ____ Yes ____ No ____
   (b) If yes, do you segregate your alloy steel scrap by types and grades? ____ Yes ____ No ____

3. Check any of the following facilities you have for preparation of scrap:

Shearing ________	Crushing ________	Briquetting ________
Baling ________	Washing ________	Other (specify) ________

4. To whom is your scrap disposed? List names in proper column below:

Steel Producers	Scrap Dealers*

* If disposed to dealer, do you obtain any assurance that scrap will be delivered to a steel mill which will recover the alloy content for production of alloy steel? Yes ________ No ________

Signature of Company Official ____________________

Title ____________________

Date ____________________

* * *

Copies of Price Schedule No. 8 dated June 1, fixing ceiling prices for Pure Nickel Scrap, Monel Scrap, Stainless Steel Scrap, Nickel Steel Scrap and Other Scrap Materials Containing Nickel, Secondary Monel Ingot, Secondary Monel Shot, and Secondary Copper-Nickel Shot by Leon Henderson, Administrator, Office of Price Administration and Civilian Supply, together with subsequent amendments thereto may be obtained by communicating with Mr. R. C. Allen, Iron & Steel Branch, Office of Production Management, New Social Security Building, Washington, D. C.

* * *

If you are regularly producing alloy steel or alloy iron scrap and have not as yet reported on the questionnaire reproduced above, the Iron & Steel Section of the Office of Production Management would appreciate your communicating immediately with them or better still, use the questionnaire reproduced above as a guide and submit the information requested.

PRINTED IN U.S.A.

9-41 108M

(*See Reverse Side*)