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Moscow, USSR, 19 September – 9 October 1968

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COLLECTION AND PROCESSING OF IRON AND STEEL SCRAP FOR IRON AND STEEL INDUSTRY 1/

by

K.N.P. Rao
India

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COLLECTION AND PROCESSING OF IRON AND STEEL SCRAP FOR IRON AND STEEL INDUSTRY[1/]

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K. N. P. Rao,
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SUMMARY

The paper deals with the problems, achievements and opportunities for the collection and processing of various types of ferrous scrap. Steel scrap is one of the vital raw materials of the iron and steel industry and is consumed in millions of tons annually. There are vast opportunities in iron and steel industries, including the foundries, for instituting control on the economical operation of scrap processing for achieving saving in costs and improving quality. This can be accomplished by sound engineering practice as well as by scientific research.

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* This is a summary of a paper issued under the same title as ID/WG.14/55.

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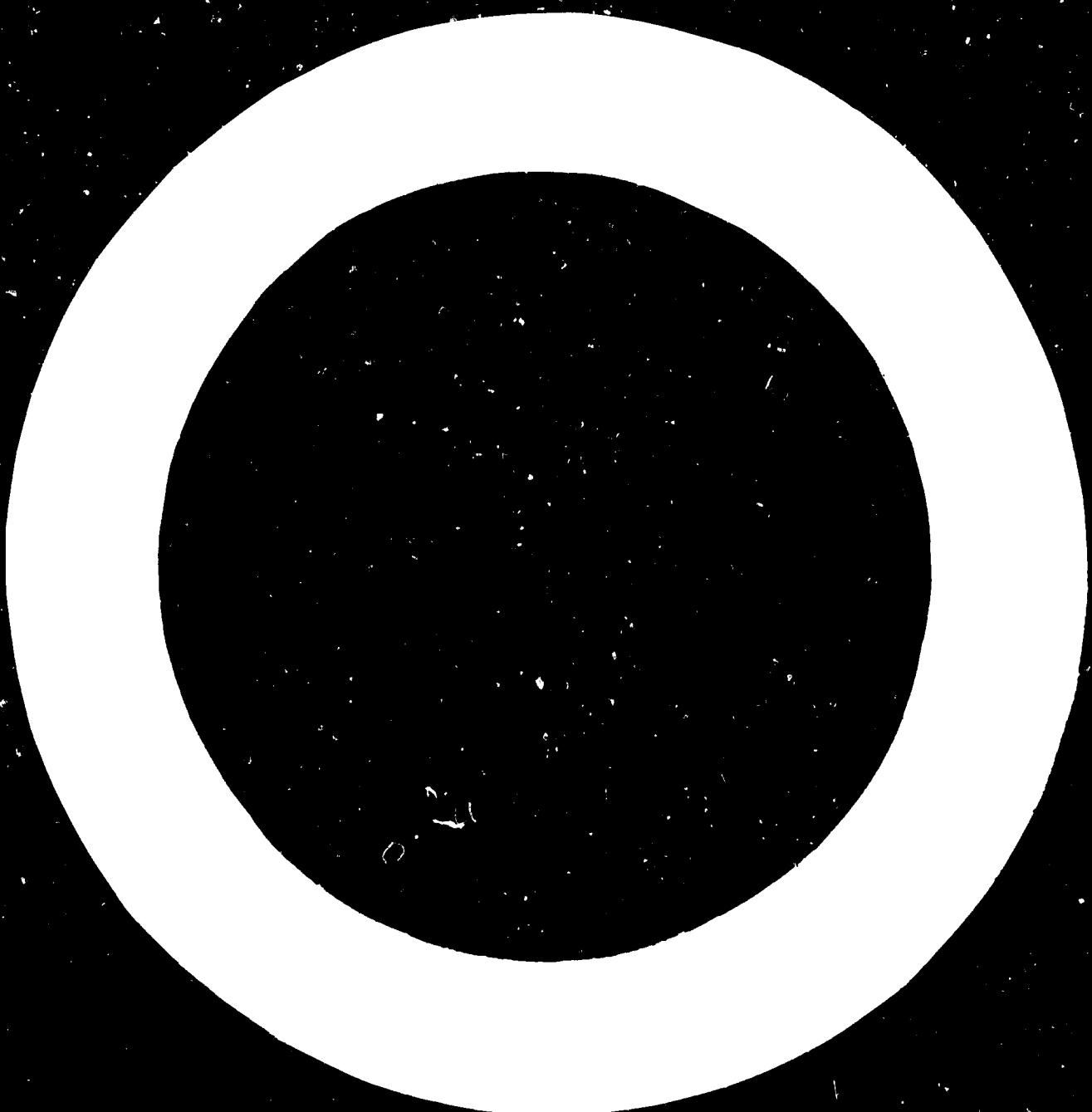

There are a number of recognized specifications for iron and steel scrap which have been adopted by the steel plants and the scrap processing industries. These specifications include grades for the basic open hearth and blast furnaces, electric furnaces and foundries, cast iron and special grades, including alloy steels. The Institute of Scrap Iron and Steel of the United States of America has classified 43 different types of iron and steel scrap, as standard grades. In addition, there are a large number of specifications for alloy bearing scrap with limitations for certain alloying elements. In addition to the grading of the material according to the physical shape and size, the specifications have laid great stress on the chemical composition. While the standard specifications closely define the physical and chemical requirements, there is always a saving clause included in the specification or contract which would recognize certain tolerances with regard to sizes and the physical state of the scrap, such as the material being rusty and containing some amount of foreign matter. It is also a widely prevalent practice, while the standard scrap specifications are invariably followed for the purposes of processing, when buying and inspecting scrap, the consumers insist on following a practice to satisfy their individual needs.

In addition to the 'home' or 'revert' scrap generated in the steel plants, the specifications of the scrap used for steel making covers by-products of steel fabrication and obsolete items of iron and steel. Apart from iron or 'hot metal' from the blast furnaces, steel scrap is the second important source of the metallic constituents for steel making. In view of its great practical value, the economics of a steel plant is based on the ready availability of steel scrap. Apart from the favourable cost factor, scrap can constitute up to 100% of the furnace charge in electric and open hearth steel furnaces. In fact, scrap is sometimes known as 'Instant Steel'. For every ton of scrap utilized in steel making, it either replaces and/or conserves for use approximately $3\frac{1}{2}$ to 4 tons of other raw materials such as iron ore, coke and limestone. In an integrated steel plant, about 30% of the output will be available as 'home' scrap or 'revert' scrap as a by-product of various operations. All this scrap can be recycled effecting direct economy in production costs.

The selection and proper processing of steel scrap can be a valuable source for the recovery of expensive alloying elements, such as Nickel, Molybdenum, Tungsten, etc. It is often economical to recover scrap from steel plant slags by adopting suitable processing methods, such as crushing, screening and magnetic separation.

The consumption of scrap in the different steel making processes varies. Whereas an electric furnace can take 100% scrap as cold charge, basic open hearth practice consumes scrap in varying proportions from 100% down to about 50%, or even less. The LD or basic oxygen steel making process, however, operates with as low as 25% scrap.

In addition to the 'home' scrap or inter-plant scrap generated in an integrated iron and steel works, a fairly large tonnage of iron and steel scrap is thrown up during the fabrication and manufacture of various products in the metal consuming industries. In blast furnace operations, iron scrap is generated as runner scrap, ladle skulls, splashing, spilling, etc., while casting and pouring liquid metal in ladles and pig casting machines. With regard to steel scrap, the arisings are generally from the pit scrap, short ingots, rejected ingots, crop ends and discards of blooms and billets, cuttings and sheared pieces from the rolling of finished products as from plates, sheets, pipes, etc. Materials which are rejected because of defects are cut into short lengths for remelting.

There is also a large variety of purchased scrap consisting of unusable materials resulting from natural or forced obsolescence of plant, machinery and other iron and steel articles. This is generally known as 'dormant' scrap and consists of miscellaneous products such as old ships, junked motor cars, machinery, including loose and light materials such as tin cans and crown corks. The steel fabricating industry and the dismantling of structures give rise to steel scrap such as structural cuttings, railings, grills, pipes, etc. Other sources of scrap are dismantled, broken or damaged industrial machinery of various types, rail road materials, such as old rails, sleepers, chains and other permanent way fittings. It would be difficult to catalogue the items as practically every iron and steel product from large ships to tin cans, including borings and turnings obtained in machining operations, are charged in steel melting furnaces after putting the scrap through suitable processing operations.

Because of its varied nature, the dormant and industrial scrap require careful sorting and classification. The steel maker would insist on steel scrap to be cut into suitable sizes for loading into charging boxes or peels. The bulk density of the scrap should be the maximum attainable. The denser the material, the greater the advantage as fewer number of boxes have to be handled in charging the steel furnaces. This necessitates elaborate processing. Iron and steel scrap would have to be cut into proper sizes by employing specialized equipment and the operation generally consists of reducing the scrap to smaller sizes by shears, gas cutting and baling or bundling of loose and light, thin scrap such as sheet cuttings, turnings and borings in hydraulic presses. The transport and handling are important factors in reducing the cost of the materials.

In view of the complexity of the problem of processing scrap materials, a detailed and expert engineering knowledge of the type of the materials to be handled and processed, to meet the individual requirements of various consuming steel plants, is essential. Generally, such a study would take into account:

a) Availability and analyses of purchased scrap.

b) Source from which the scrap is available and the specification of the end product.

c) Design and selection of processing equipment including plant lay-out for flow of materials.

d) Planning of yard organization including the study of construction and operating costs.

The trade in iron and steel scrap is varied and extensive. All the countries with a high output of steel production have been importing or exporting scrap in various forms. However, in recent years, the importance of steel scrap as a raw material for steel making is lessening on account of the advances made in the iron and steel technology. The beneficiation of iron ore and conversion into pellets or sinter with a high percentage of iron content, with the addition of suitable flux, has reduced the dependency on steel scrap. The LD or the basic oxygen process has made phenomenal progress in recent years and as this process of steel making depends mainly on 'hot metal' or 'liquid iron', the need for scrap is not so great. Correspondingly, the importance of the basic open hearth process is gradually receding. Further, the growth of the continuous casting process is also reducing the output of primary scrap as the yield from ingot to bloom is almost 95%, as compared to about 80% in the normal blooming mill operation.

In addition to the use of scrap in foundries and steel plants for purposes of remelting, the developing countries are establishing a number of re-rolling mills and several small industrial units where steel scrap is used for conversion into various finished products. This conversion may take the form of re-rolled reinforcing bars, structural sections, fabricated products such as hardware, simple domestic and agricultural implements made from plate and sheet cuttings. There is also a demand from the under-developed countries for high carbon steel scrap such as old files for making simple agricultural implements as plough shares, chisels and other articles of rural craft.

The world trade in iron and steel scrap, including trade within a particular country and from export, comes to an enormous figure in terms of tonnage handled as well as on the purchase value of the material, when it is realized that more than 50% of the total steel production depends on the use of iron and steel scrap. The collection and processing of steel scrap call for a thorough study of the economic implications and research for the industrial growth of the developing countries, particularly those countries who are embarking on the manufacture of iron and steel products.

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INTRODUCTION: Iron and steel scrap is one of the vital raw materials for the iron and steel industry. It forms approximately 50 per cent of the total input as metallic charge, in the production of steel. Every ton of scrap utilised in steel making is estimated to save or conserve about 3 to 4 tons of other natural resources, such as iron ore, coal and limestone. The importance and status of steel scrap, has fluctuated with the technological changes that have taken place in the steel industry in the last decade or two. However, with its built-in basic advantages, iron and steel scrap has stood its ground. In addition to steel scrap being a raw material for the steel plants, the secondary scrap is of economic importance to the under developed countries as a cheap source of the raw material for the metal working industries, because of its relatively low price and versatility of use in different processing methods. The world trade in steel scrap amounts to billions of dollars, and the phenomenal growth of the steel industry in Japan owes not to a little extent to the imports of iron and steel scrap from different countries. The competitive position of various raw materials and technological innovations have given new dimensions to the steel scrap processing industry, requiring huge capital investment and a constant search for more efficient

methods of processing and utilisation. In fact, the engineering knowledge and research demanded is often no less important than that for the production of the primary products in integrated steel plants.

Sources of Iron and Steel Scrap

Scrap is collected from a vast variety of sources, including domestic refuse, garbage and disposals from municipalities wherefrom tin cans and crown corks are obtained to large wrecking yards, where discarded ships are cup up and processed. In normal trade practice, ferrous scrap has been marketed under different groups such as prompt industrial scrap, revert scrap, circulating scrap, dormant scrap, capital scrap, house hold scrap etc., depending on the usage in different countries. Prompt industrial scrap is available from engineering work-shops and steel processing industries and it includes machine turnings borings as well as rejected plant and machinery. All types of iron and steel scrap, more particularly prompt industrial and dormant scrap are bought by large corporations and small merchants and brokers, which are taken into the scrap yards where they are sorted out and processed for supplying to steel plants and scrap consuming industries. The reclamation and processing of scrap in the yards and factories involves a number of methods - from the physical breaking of the products to the compacting of loose and light materials; by chemical treatment; by incineration

and other thermal methods.

The accompanying schematic diagram (I) illustrates broadly, the sources from where iron and steel scrap is normally generated and from which it is collected.

Integrated steel plants throw about 25% to 30% of their total ingot production as scrap in various forms and shapes which is mostly utilised by the steel plants for remelting. This scrap is known as 'Home' or 'Revert' scrap. The 'home' scrap includes scrap produced in the pit side of steel melting shops, such as splashing, skulls, spill overs, as well as ingots that are too short for rolling, rejected ingots, etc. At the primary and finishing mills, ingot crop ends, bloom butts, crop ends from billets, shear cuttings, cobbles, fish tails and side scrap from sheets and plates, and other rejected mill products, are all collected and segregated for returning to the steel melting shops. As the scrap is to be charged in the melting furnaces in suitable containers, whether in peels or charging boxes, or discharge buckets, it is the normal practice to load the containers directly and thus effect economics in handling and transport. Sometimes, the scrap is also sent to a central processing yard, where it is converted into the requisite shape and size by baling, bundling, shearing or gas-cutting and loaded into containers or suitable wagons, to be sent over to the steel melting shops. In addition to the revert scrap produced during the manufacturing process, a fair amount of scrap is also

obtained from the maintenance and repair shops of the steel plant, including foundries. The scrap available in various forms is sorted out on the basis of chemical composition and processed into suitable physical size and shapes, for sending over to the steel furnaces.

While the 'home' scrap or 'revert' scrap can be segregated and processed without much difficulty, it is the "bought-out" scrap, constituting an innumerable variety of products which are difficult to classify and process. The purchased scrap (Prompt & Dormant Scrap) constitutes mostly worn out, broken or obsolete parts of steel fabricating industry such as beams, angles, railings, pipes, furniture, damaged or discarded broken and other types of unwanted machinery. Railways also generate a large quantity of scrap such as old rails and rolling stock, broken and damaged wagons, carriages and other miscellaneous items including components of locomotives and carriages. The automobile industry has created a formidable problem in industrially advanced countries, such as the United States, where more than a million automobiles are discarded as scrap, every year. Apart from disfiguring the countryside and taking up valuable space, the transport and processing of such scrap has become a national problem which is causing tremendous concern to the Government and the public alike. A great deal of engineering skill has gone into the most economical and speedy methods of 'processing' the discarded automobiles so as to make them suitable for remelting

in the steel furnaces. The removal of unwanted materials like non-ferrous metals, plastic, rubber and other meterials from discarded automobiles has created a critical situation, as the process involves enormous capital investment, handling and the transport of a large volume of material in a condition suitable for remelting. Another important source of industrial scrap is the metal fabricating industries and the scrap is generally in the form of cut pieces of pipes, sheets, plates, arisings from shearing operations, and also trimmings, from stamping and pressing work turnings, borings and swarf from machining operations.

CLASSIFICATION OF IRON AND STEEL SCRAP.

Iron scrap is obtained as a bye-product or as rejects and discarded materials from iron foundries, blast furnaces and other iron producing plants. Obsolete cast iron products and other types of iron scrap, contribute sizable sources of supply and the extent to which such scrap could be utilised depends on their chemical compositions and their physical structure, including their size and shape. However, practically all types of iron scrap finds their way back for remelting, either in the foundries or as charge in the blast furnaces.

Steel scrap presents a more complex picture. The quality of scrap is hard to define and it is even harder to bring it up a standard specification. Traditionally, iron and steel scrap has been bought and sold under different groupings or classifications, which were drawn up to meet the convenience of individual requirements. This practice has resulted in innumerable classifications to meet varying types of demands, and such conditions naturally cause unnecessary confusion,

resulting in misunderstanding, litigation and loss. As far back as 1923, the United States Department of Commerce in consultation with the interested parties such as scrap producers, dealers, brokers and the consumers, formed a committee to recommend a simplified practice for the classification of iron and steel scrap. This classification and general categorisation of scrap have been in vogue since then, and have been modified and improved upon from time to time to suit the changing needs. Extracts giving details of the specification or classification of scrap for use in blast furnaces, open-hearth furnaces and electric furnaces and gray iron foundry practice are given in Appendix "A". Similar classification of iron and steel scrap have also been made in the leading iron and steel producing countries like the U.S.S.R., Japan, the U.K. and Germany. Such approved recommendations or specifications have led to more uniform and simplified practice of classifying scrap, affording a better basis for negotiations, less expenses in sorting and grading, and in the accepted method of packing and shipment resulting in greater economies all round. The elimination of an excessive and varying types of classification is as important to sellers as it is to purchasers and processing units. The value or benefits to be derived for following a standard practice or accepted recommendation would depend on the active support and acceptance by all parties concerned. While the standard classifications cannot satisfy all requirements and situations, they serve to satisfy most of the normal demands for products of such a complex nature.

It is however often found that steel plants know what they want in 'scrap' and therefore determine what they should buy rather than allow themselves to be guided by any written down specification or description of the product.

More often than not, it is the purchasing practice that results in obtaining scrap of a particular quality. It would appear that the prevailing trading conditions and the demand/supply position that have brought about changes in the commercial aspects of scrap processing and classifications, rather than through any accepted industry standards. Although in the United States, official classification or specifications have been drawn by the Institute of Scrap Iron and Steel and U.S.Department of Commerce which are followed generally by the industry, the following extract (A) gives and idea of the difficulties in determining the quality of a particular type of scrap and how trade practices have altered or watered down the official specification to meet the particular needs of a buyer:-

"Official specifications for iron and steel scrap have been revised as recently as July 1961, when the Institute of Scrap Iron and Steel (ISIS) adopted the present standards. These specifications includes scrap grades for basic open hearth and blast furnaces, electric furnaces, and foundries, cast iron and special grades. There are 17, 13, 11 and 2 separate scrap designations, respectively, in the above grade classes, making 43 different types of iron and steel scrap that might be considered

standard. In addition, there are numerious specifications for "ferrous" alloy scrap in the high nickel and nickel-chromium ranges (the industry has established the interesting custom for these alloys of alphabetical code names like Aroma, Burly, Negus, Peach and Sabot).

In the Iron and steel scrap grades official ISIS residual alloy restrictions apply primarily to the electric furnace and foundry grades, and have the following limits:

Element	Maximum percent
Nickel	0.45
Chromium	0.20
Molybdenum	0.10
Combined elements other than Manganese	0.60
Manganese	1.65

It would be expected that copper limits should be specified by ISIS, since copper is watched as a control for residual alloy content in scrap. The ISIS specifications are almost identical to those of the Commodity Standards Division, U.S.Department of Commerce.

In addition to the 43 iron and steel scrap designations of ISIS, the Association of American Railroads has 56 specifications for railroad ferrous scrap which the railroads sell to the scrap or steel industry."

Scrap Quality

In discussing the quality of the material, one cannot overlook the vital role of inspection and testing methods followed in determining or deciding upon a particular grade or quality of scrap. There have been innumerable disputes on this score because of the large variety and complexity of the scrap and the difficulty in carrying out an accurate and proper representative sampling of the materials. While chemical testing was the accepted method, in view of the time-consuming nature of these tests and the difficulty of segregation, in chemical methods have given place to more precise and quick methods, such as spectographic analyses. While the main chemical limits are separately satisfied, it is the 'tramp' element that may be detrimental to a particular method of steel making, which creates arguments and disputes. Elements such as chromium, nickel, tin, copper, zinc and lead are aften limited by purchasing specifications. Copper for instance, is considered acceptable even upto 0.5% for the manufacture of concrete reinforcing bars, and is accepted up to 0.3% in normal structural steel specifications, but even as low as 0.1% will not be tolerated for the manufacture of steel required for making deep drawing sheets and such other products. Very often, a number of tests are undertaken by independent organizations on the basis of accepted methods to prevent the intrusion of personnel factors. But to determine the quality of large consignments of scrap, no satisfactory solution has yet been found for the

reason that it is not possible to obtain a scientifically representative sample of the scrap. The only satisfactory method is by the remelting of the scrap and then analysing the finished product. This method is impracticable for economic reasons as remelting and further breaking of the material into usable sizes would make its cost prohibitive. A number of rough and ready methods, such as spark tests and spot tests have been developed which are fairly reliable for all practical purposes. Not withstanding the innumerable difficulties to be contended with and despite the prevalence of unethical methods sometimes, the world trade in steel scrap is gaining strength because of the mutual trust and confidence of reputable steel buyers and suppliers. Statitics of the import and export of scrap of various countries are given in Appendix B.

Scrap in Steel Production

The different methods of making steel necessarily call for selected types of scrap and also for specified physical make-up of the material to suit efficient and economical steel melting operations. The electric melting furnaces use almost 100 per cent scrap as their basic charge and in order that the furnaces can be charged fully and to the maximum weight that they can take, the melting scrap is loaded in suitable buckets or containers, the scrap having been compacted in baling presses or cut to suitable sizes in shears or guillotines. When the scrap contains costly alloying elements such as nickel, tungsten, molybdenum, and the composition of the scrap is known, the

electric furnace offers excellent scope for the recovery of these elements in making alloy steels.

The basic open hearth furnace consumes steel scrap in large quantities and the percentage of such consumption varies almost 30 per cent to 100 per cent. The steel melting shops expect the scrap to be heavy and densely packed in the charging boxes so that the maximum quantity can be charged in the furnaces within the minimum of time and at the same time lead to the utmost utilisation of the loading capacity. If the scrap is obtained from the steel plant itself, it would be easy to segregate, collect and transport it, as the charging boxes can be loaded at site and brought to the furnace platform as and when required. The steel melters are very particular about the quality of the scrap, and they insist on the correct chemical composition and the avoidance of 'tramp' elements in the scrap. In preparing the charge for steel melting furnaces, the density of the 'charge' is an important factor as the steel melter, can save on melting and refining time and handling costs, if the material is packed tightly so as to give the maximum weight for unit space. Apart from the space occupied by loose material in the furnace, the time taken for melting, and the loss due to oxidation acts adversely thus adding to the cost of production.

Scrap and L.D.Process

With the advent of the LD or basic oxygen process, the utilisation of scrap has undergone considerable changes. The primary raw material used in the basic oxygen converters is hot metal

or molten iron from the blast furnace (sometimes from hot blast cupolas). Solid steel scrap is used mostly as a coolant to decrease and control the temperature through a regulated addition of scrap. A constant endeavour is being made to develop an operation practice to utilise upto 100 per cent of cold scrap charge in the LD convertors and if this attempt succeeds steel scrap would regain its place as a primary raw material. The tonnage of steel produced by the LD process is increasing rapidly throughout the world, and this has had a set-back on the essentiality of steel scrap as a raw material. The scrap trade has suffered considerably on this score.

Hot blast cupola is also being used increasingly for the remelting of both iron and steel scrap. The primary advantage of this process is the comparatively lower capital investment and the different grades of high quality iron that can be produced. The hot blast cupola along with LD covertors would appear to offer certain advantages to the newly developing countries where the requirements of iron and steel products are relatively small and the capital available for investment is also limited.

The continuous casting process has also an adverse effect on the quantum of scrap arising in the steel plants since the yield from the molten metal to blooms is almost 99% compared to 80% or so in the conventional blooming mill practice.

Processing of Scrap

The primary consideration for the processing of scrap is the segregation or grouping to be carried out (a) on the basis of the chemical composition and (b) on the physical structure and the shape and size of the scrap. As the grouping is made from a very large variety of shapes and sizes depending on the nature of the scrap, the equipment for processing has to be large and varied. Special purpose equipment and machines like electro-magnets, cranes, derricks, shears, oxy-acetylene and other gas cutting machines, are employed in the sizing and processing of scrap. In addition to the utilisation of electric cranes and hoists, oxygen burners, guillotines, shears, specialised equipment such as fragmentisers, shredders, hammer mills, pulverisors, balers, presses and incinerators to process certain types of scrap are also used. Scrap processing has now assumed the status of a specialised branch of the engineering industry. Scrap dealers and processors now use computers for inventory and operation control, to improve yard inspection techniques and to find new methods for collecting and distribution of scrap, including market research.

The use of thin gauge sheets and strips for the manufacture of many durables, tin cans and such other articles has in turn given rise to a vast tonnage of loose and light steel scrap. The disposal of millions of junked autos is a huge problem in itself. Fragmentisers have been designed and built primarily to handle automobiles and some of the machines have a capacity to take 300 to 600 autos per day. The use of magnetically separating drums, along with fragmentisers, which work more or less on the

principle of undershot water wheels, helps to separate the non-magnetic materials, not wanted in the steel plants. Another possible way of reclaiming metallic materials is by pyro-treatment. Metallics are melted in furnaces or hot blast cupolas or separated by solution treatment. The latter methods are too expensive for use currently although in certain special cases some plants resort to these processing methods.

One of the highly developed techniques or methods for reclaiming and processing of scrap from steel plants is the "Heckett" process, which is in operation in a number of countries. The 'Heckett' process was developed for the recovery of iron and steel scrap from waste products in integrated steel plants such as slag, and refuse. In this process slag and refuse from the steel melting shops are transported and dumped in suitably prepared pits. More than one pit is necessary to ensure the cooling of the hot slag dumped in the pits. The hot slag is cooled by means of water sprayed over it, after which the mass of slag is broken and reduced to small sizes by dropping heavy steel "drop balls" over it from appropriate heights. In some cases the slag and refuse are dumped in a yard designed for the purpose and after digging the material by a drag line it is swept with magnets to collect the iron and steel pieces. Large pieces collected by electro-magnets are fed into a huge tumbler barrel for further cleaning and removal of adherent slag. The cleaned material which has more than 85% Fe is loaded straight into wagons for being transported to the steel melting shops. Similarly, small sized materials which are still mixed with

slag are fed through magnetic separators for further refinement, and these are sized and screened to remove slag and other deletarious material. The process is an economical method of recovering scrap and the steel plants have found to their great advantage that this process would, apart from economy and the added financial benefits it would bring, assist in the easy disposal of slag in a suitable form and shape. Methods similar to the Heckett process, along with the careful engineering of the entire recovery process have been developed to suit the needs of particular steel plants.

SCRAP QUALITY AND RESEARCH

In the appraisal of steel scrap as a secondary, yet, vital raw material for the steel industry, the status should be viewed from different stand points. It should be recognised that the generation of scrap is inevitable in an intregrated steel plant, because obsolescence of iron and steel material is something which cannot be stopped altogether. There is no steel plant where the production of scrap has been totally eliminated. The technological developments, particularly with the on set of the LD process have brought about revolutionary changes, which, in turn, have rendered scrap as a marginal raw material for steel production. In working out steel plant economics, the cost of hot metal is equated to that of the cold scrap charge. The basic open hearth furnace, with the recent advances made for obtaining a very high output by the employment of oxygen lancing or oxy-fuel burners, is levelling up with the LD in the matter of

tonnage production, and an out put as high as 110 tonnes per hour have been obtained in the basic open hearth practice. Added to this, the progress made in the beneficiation of iron ore and in the use of self-fluxing sinter and pellets has had a significant bearing on bringing down the cost of the blast furnace hot metal. There is a continuous race between the employment of hot metal and steel scrap whether it be home scrap or purchased scrap, to reduce the cost of steel making. The rate of consumption of scrap in the steel plants will determine the health and profitability of the scrap industry, and therefore the quality of scrap must keep pace with the advancing steel technology.

Apart from the consideration of economy in the utilisation of scrap for steelmaking, there are other social considerations to be taken into account in the disposal of scrap thrown out in urban and rural areas. It has been estimated that scrap such as tin cans, containers and other materials thrown up as garbage has been menacing the health of the people as they harbour vermin and other pests. This scrap problem is a direct result of higher standards of living and it is the responsibility of the Government and it is also the duty of the guardians of public health, to sponsor research for the most effective and economical use of this form of scrap. With the progressive fall in the demand of light and loose scrap by the steel industry, the problem has assumed a national or even international importance calling for intensive scientific research.

Some of the research projects (B) and their objectives, which have received attention of the U.S.Government authorities are out lined below:

	Project	Objective
1.	Investigation of the secondary material resources of the U.S. with particular attention to old automobiles and other discarded material eyesores.	To obtain and interpret information and data on a regional and national basis to determine the extent to which old autos and other unused metal resources are accumulated in the U.S. will complement Dept. of Commerce data on auto wrecking yards adjacent to public highways by identifying off-highway yards in co-operation with the Assoc. of American Railroads and urban officials.
2.	Engineering economic study of the supply, markets, transportation and use of scrap in the U.S. with particular attention to old automobile scrap.	Establish the economics and review the technology of each element of the scrap iron and steel industry from accumulation through marketing to ultimate use to develop methods for reducing the cost of scrap and increasing its value, thus assist existing industry in

	cleaning up the old auto blight.
3. Use of scrap iron in the reduction roasting of non-magnetic iron-bearing ores.	This project is continuing after the initial demonstration. The potential is indicated on the basis that a small processing plant, producing 5 million tons of high grade concentrates annually, would require more than 600,000 tonnes of scrap iron. The addition of this scrap would generate about 850,000 additional tons of magnetite at a total value of $ 13.6 million.
4. Total oxidation of auto-scrap	To develop a convenient method for removing impurities from auto scrap by total oxidation in order to convert the iron to a magnetic oxide which can be separated from contaminating materials by magnetic separation. The oxide would thus represent a premium synthetic ore for the iron blast furnace. The potential use of auto scrap would be limited only by the range of economical transportation.
5. Removal of impurities from scrap. Back-up for project above.	Melted batches of auto scrap will be treated with various additives in an effort to form solid separable intermetallic compounds. The major impurity of concern is copper. Although the

	technical promise may be slight, the investigation is included in order to cover all technical possibilities.
6. Scrap salvage by chemical processing.	This project is concerned with any chemical process by which the impurities (mainly copper) could be economically removed from auto hulks in order to prevent contamination in subsequent use.
7. Use of scrap and directly reduced iron ore in the production of steel.	This project considers the potential use of melted scrap as a substitute for pig iron to refine directly reduced iron ore. If successful, this method would probably consume all available scrap within range of economic transportation.
8. Production of mild steel from scrap in the electric furnace.	Exploration of financing techniques for producing mild steel from melted auto scrap. The substitution of heat for mechanical energy will be investigated as a method for upgrading scrap.

Miscellaneous Uses Of Scrap

The problem of the utilisation of steel scrap available in the industrially advanced countries, where steel

production has reached a very high level, is very different from that of under-developed or newly developing countries. The low level of economy in the developing countries with their poor standard of living, and with no major industries, the needs of manufactured products for the vast population are few and it is generally confined to simple articles. In such countries, steel scrap forms an essential or important raw material for a number of small scale or cottage industries. Sheet and plate scrap, consisting of mill cuttings, cut down, cut-pieces of billets and structural sections and such other mill products find a ready use in the manufacture of simple and crude agricultural implements and a variety of articles of domestic use needed by villagers. Firstly, scrap from the steel rolling mills is very much cheaper than the primary products, and very often scrap and rejects sell for less than 50% of the price of first class materials. Steel plants would not obviously hesitate to sell the mill scrap, if it were to fetch higher profits, when the choice is between its utilisation in the steel melting furnaces and having cheaper hot metal in its place. There is an international trade in mill scrap for industrial uses and many under developed countries import such scrap, considering the rather crude and hand operated methods employed in the manufacture of the products, which are generally simple in design and do not require any great accuracy or special finishing operations. Several examples of such articles can be mentioned and a few of the popular articles are steel boxes, trunks, water storing and handling vessels such as buckets, pails, storage tanks, water cans, pots and pans. An innumerable variety of goods are manufactured depending on the habits of the

people and usage, in the different countries. Agricultural uses such as animal drawn ploughs, water lifting equipment like Persian wheels for irrigation, implements for farming operations like digging, tilling, cutting and pruning, including equipment for animal husbandry and dairies, are manufactured. Implements and working tools of thousands of shapes and sizes for village craftsmen like blacksmiths, tin smiths, carpenters, masons, are made from scrap to suit the particular manufacturing method and the service requirements. There is an established trade in old steel files and railway axles and other high carbon materials, which are used for the manufacture of sickles, pruning knives, chisels and similar implements requiring high hardness and sharp cutting edge. Stainless steel scrap too is imported for making domestic kitchenware and for use in foundries.

The industrial growth of many of the developing countries is taking shape, by the installation of small re-rolling mills, which cater to the requirements of the building industry by rolling reinforcing bars, light angles and other small structural sections. The raw material used by the re-rolling mills is either billets or very often scrap materials such as billet crop-ends and cuttings, plate scrap, old rails, rejected axles and a variety of rerollable steel products.

As the re-rolling mills expand and the demand for steel increases, it is to be expected that mills with larger outputs for producing a greater variety and more sophisticated products would be established in the developing countries.

Future of Scrap

The prosperity or otherwise of the steel scrap processing industry is closely linked up with the advances made in steel technology and the ability of scrap to compete with that of the hot metal cost-wise. Scrap has certain inherent advantages which pig iron cannot have. Some one has called scrap "Instant steel". No ore, coke, blast furnace combination can compete with the direct melting of scrap in the steel furnaces. It is the cost of handling and efficient preparation of the scrap that will give it a competitive edge. The written-down or depreciated value of the basic hearth furnace would render production from such plants more economical than the high capital investment required for new production units based on 'hot metal' processes. As against this, one cannot help taking note of the fact that the proportion of steel produced in the basic oxygen or LD process is progressively increasing throughout the world and the open hearth plants are being pushed to the back ground. Electric Arc furnaces, although designed to handle large tonnages are viable mostly in respect of special quality steels which command higher prices. The technology of scrap preparation is also becoming extremely complex because of the powerful and sophisticated machinery that need to be installed to process large tonnages of scrap to meet the exacting demands of the steel melting shops. The scrap processing industry which was in the hands of a large number of small units, has now grown into giant proportions which can be

successfully organized and run by a few large concerns only.

The scrap preparation plants are now being transformed into well organized engineering enterprises whose main object is to serve steel mills. The main concern of the steel plants is in the making of steel and as such, they generally leave the problems of handling and preparation of scrap to specialists who have a wide knowledge of the trade and who can also provide themselves with necessary equipment and machinery.

CONCLUSION:

Iron and steel scrap is of great importance to the industrially advanced countries as well as to the economically backward countries. The efficient utilisation of scrap, apart from keeping an essential commodity in circulation, is a powerful and effective factor to conserve the natural resources, which are fast depleting. There is an urgent need towards a better appreciation and understanding of the complex problem - the generation, supply and demand of ferrous scrap. The total trade in iron and steel scrap considered on an international basis and within a country itself, is of a gigantic magnitude. A comprehensive scientific and technological study of ferrous scrap is warranted to make the most efficient use of the material for the betterment of the iron and steel manufacturing and consuming industries. It has a great impact on the economic well-being and industrial growth of the nations and poses an interesting and challenging problem.

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Diagram I

Sources of iron and steel scrap

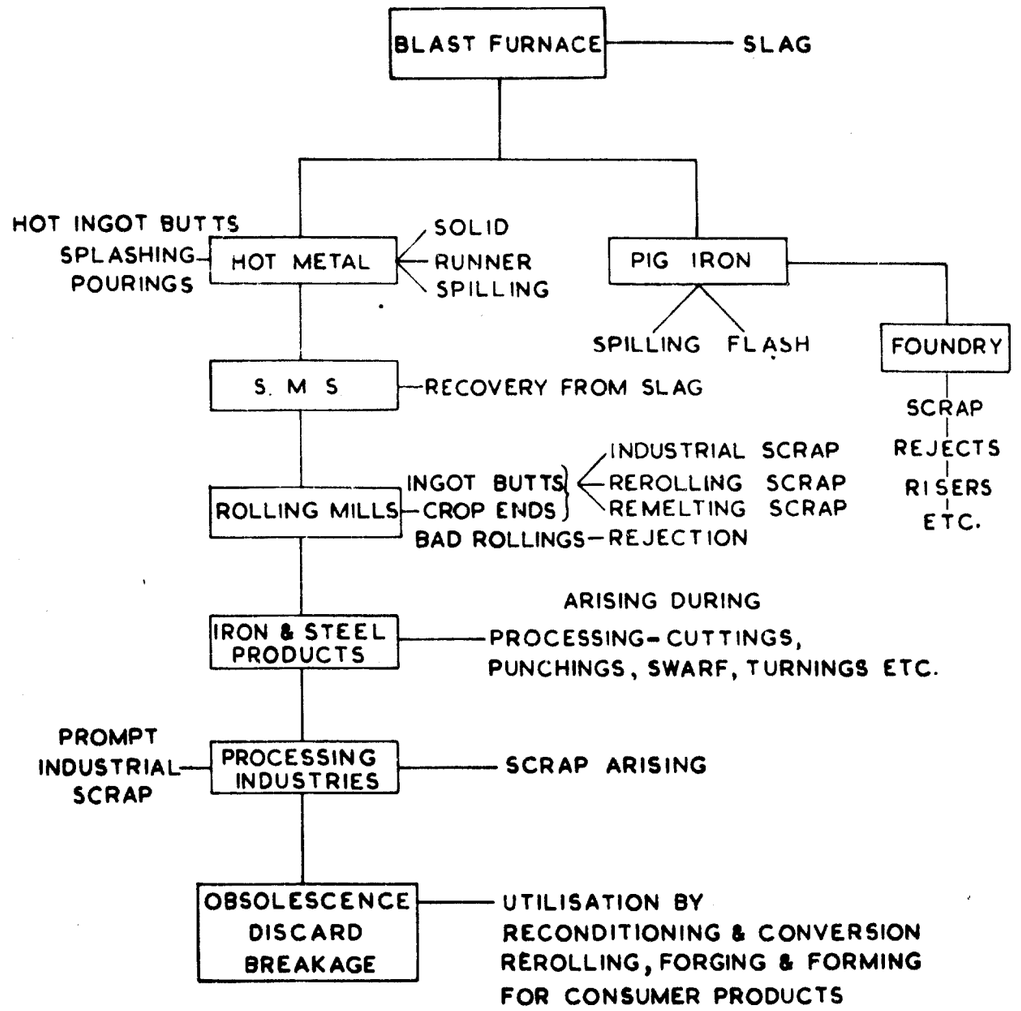

Figure 1

The Heckett Process

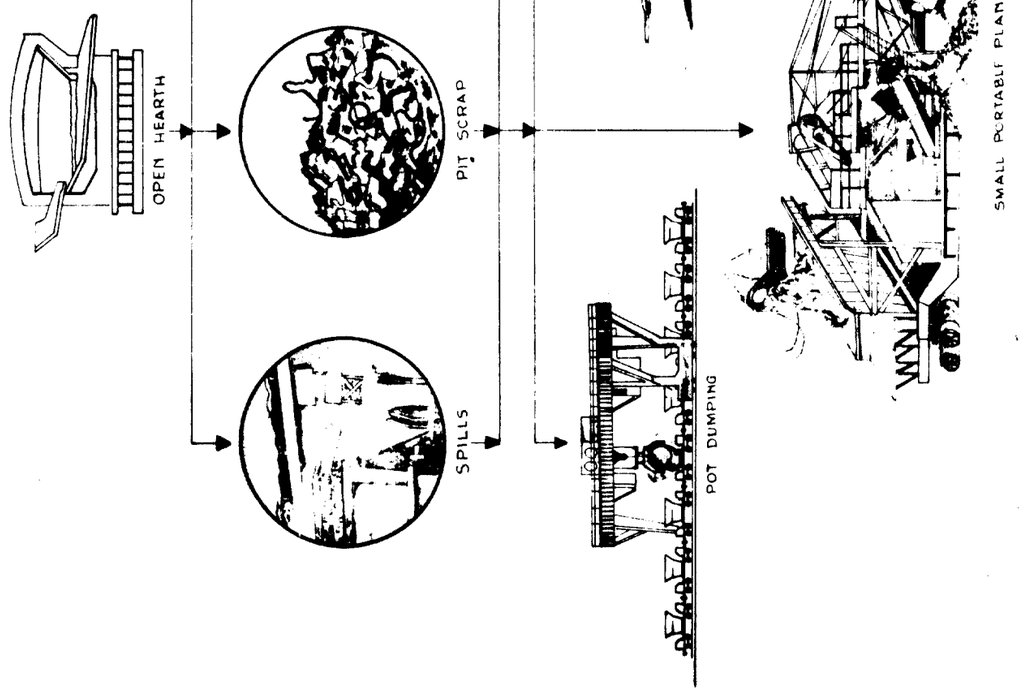

Figure 2

Buckets made from scrap sheets

Figure 3

Watering cans made from sheet scrap

Figure 4

Ovens made from old drums and paint kegs

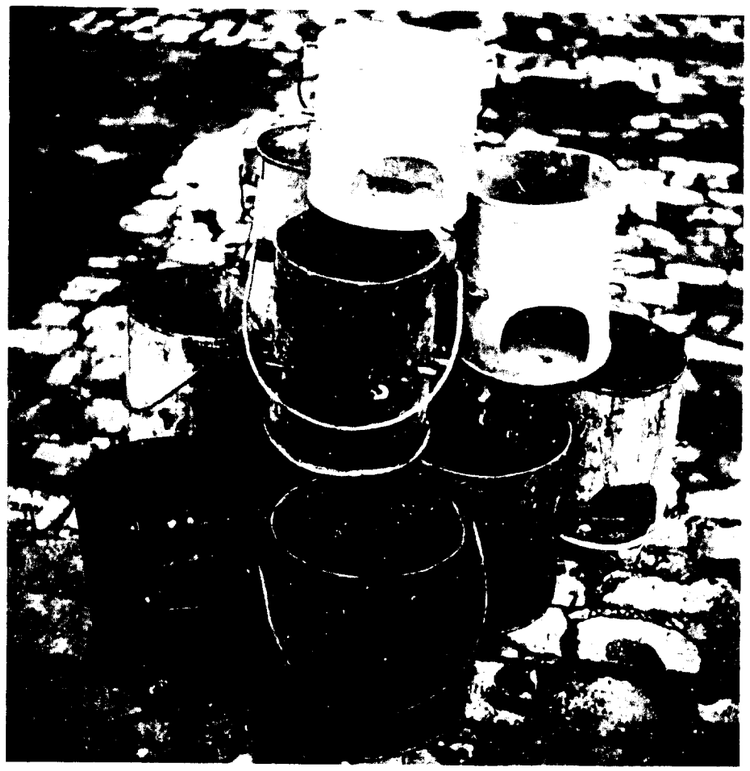

Figure 5

Kitchenware and other household articles made from steel scrap

(Ref. from Classification of Iron & Steel scrap of 1936)

SPECIFICATIONS FOR CLASSES OF SCRAP FOR USE IN BLAST FURNACES.

1. Pipe busheling scrap - Iron and steel pipe and flues (clean), bedstead tubing, and similar material cut 8 inches and under, in length, free from galvanized material and foreign metals.

2. Cast-iron borings - Clean cast-iron borings free from badly corroded material, lumps, scale, other metals, dirt, or foreign material of any kind.

3. Shoveling turnings - Clean, short, steel and wrought-iron turnings, drillings, or screw cuttings free from stringy, bushy, or tangled material, corroded or rusty lumps, excessive o oil, scale, other metals, dirt, or foreign material of any kind.

4. Mixed borings and turnings - Clean, short steel and wrought-iron turnings, drillings, screw cuttings, and cast or malleable iron borings and drillings, free from stringy, bushy, tangled, corroded material, lumps, excessive oil, scale, other metals, dirt, or foreign material of any kind.

5. Corroded borings and turnings - Corroded and lump borings, turnings, and similar stock, free from scale, other metals, dirt or foreign material of any kind. No dimensions to exceed 9 inches.

6. Burnt iron scrap - Old annealing boxes, stools and pots, grate bars, and similar burnt iron. No dimension to exceed 9 inches, except brake shoes which may be inclueded.

7. Mill scale. - Iron oxide produced in rolling-mill practice, from drop-forge hammers or from a busheling mill squeezer. Should contain not less than 65 percent metallic iron, and must be reson-

ably free from dirt, grease, and other foreign material. Scale from alloy steel may be excluded from these specifications by mutual agreement between buyer and seller.

8. Mill cinder - Cinder from puddling furnaces, heating furnaces, and soaking pits. Should contain not less than 50 percent iron, and be reasonably free from dirt and other foreign material. Cinder from alloy steel may be excluded from these specifications by mutual agreement between buyer and seller.

SPECIFICATIONS FOR CLASSES OF SCRAP FOR USE IN BASIC OPEN-HEARTH FURNACES

9. No. 1 heavy melting steel scrap - Steel scrap ¼ inch and over in thickness, not over 18 inches in width, and not over 5 feet long. Individual pieces must be cut into such shape that they will be free from attachments and will lie flat in a charging box. Cut boiler plat must be practically clean and free from stay bolts and not over 3 feet long and lie reasonably flat in charging box. Smaller dimensions of plate scrap may be required upon mutual agreement between buyer and seller. No piece to weigh less than 5 pounds.

May include structural shapes, angle bars and plates, steel castings, heavy chain, carbon tool steel, heavy forgings, forge butts, and similar heavy material.

This grade may also include new mashed pipe ends, original diameter 4 inches and over, thoroughly flattened, sheet bars, billets, blooms, rail ends, railroad steel, and wrought scrap, such as angles, splices, couplers, knuckles, short rails, drawbars, cut cast-steel bolsters, coil and leaf springs (all

coil springs to be 3/8 inch or larger in diameter).

No needle or skeleton plate scrap, agricultural shapes, annealing pots, boiler tubes, grate bars, cast iron, malleable iron, or curly or unwieldy pieces will be accepted.

Must be free from dirt, excessive rust or scale, or foreign material of any kind.

10. No.2 melting steel - Plate scrap, such as car sides, automobile frame stock, tank, and skelp crops, 1/8 inch and heavier, steel parts of agricultural implements, wagons, buggies, and scrapped automobiles, auto and buggy springs cut apart, rods and bars, ½ inch and heavier, punchings, ¼ inch and over in thickness, heavy clippings, new unmashed pipe ends, under 4 inches in diameter, horseshoes, and similar material. Car sides and all light plates to be sheared 15 by 15 inches or under and all tires and light rods to be 12 inches and under in length. Any curved or twisted pieces must be sheared into such shape that they will lie flat in a charging box and not tangle in handling with a magnet, all to be free from brass, copper, lead, zinc, tin terneplate, cast iron, malleable iron, burnt scrap, dirt, or foreign material of any kind.

Maximum size 15 inches wide by 3 feet long, excepting car sides.

11. Heavy shoveling steel scrap - Heavy, clean, wrought-iron and steel scrap, ¼ inch and over in thickness, not exceeding 8 inches in breadth or length, and no piece to be less than the equivalent of ½ inch square, 3 inches long. May include clean horseshoes, railroad spikes, bolts, nuts, tie-plates, etc., boiler,

bridge, and structural punchings and clippings, small bar and shafting crop ends, and other similar material.

To contain no burnt material, cast or malleable scrap, cut pipe and tank, skeleton stock, badly corroded material, or any twisted or tangled scrap. Must be free from foreing metals of all kinds, from galvanized, painted, enameled, or other coated stock, and from dirt and rubbish of all kinds. Must be loaded in separate cars from other grades of scrap.

12. Short shoveling flashings - Flashings or trimmings from iron or steel forgings to be 10 inches or under in length, suitable for hand shoveling, to include no tangled or twisted material.

13. Long flashings - Flashings or trimmings from iron or steel forgings, which have been strictly separated to a minimum length of 20 inches and not to exceed a maximum of 36 inches. There must be a thickness in some section of each of these flashings of not less than 3/16 inch.

14. Mixed flashings - Flashings or trimmings from iron or steel forgings, not over 36 inches in length.

15. No.1 busheling - Clean iron and soft-steel pipes and flues, tank, cut hoops and bands no. 12 gage and heavier, steel-plate punchings and clippings, soft-steel and iron forgings, and flashings; no dimension over 8 inches. To be free from burnt material, hard steel, cast, malleable, and galvanized or metal coated stock of any kind.

16. No.2 busheling - Cut hoops, netting, cotton ties, sheet and similar material lighter than no. 12 gage, no dimension over 8 inches. To be free from hard steel, cast, malleable, and galvanized or metal coated material of any kind.

17. No.1 selected rail scrap - Standard section T and guard rails, 40 pounds and heavier per yard, not less than 36 inches lo long, to be free from frog and switch rails not cut apart, and contain no manganese-steel scrap or cast welds or attachments of any kind, concrete, dirt or foreign material of any kind.

18. No.1 selected shearing scrap - Angles from 2 inches up to 8 inches, structural shapes in single members from 4 inches up to 9 inches, bars ½ inch and over up to 4 inches diameter, and flats ½ inch to 2 inches thick and from 1 to 10 inches wide. To be in straight lengths and free from dirt and foreign material of any kind. Long length girder rails free from cast welds and attachements may be included by mutual agreement between the buyer and seller.

19. Axle turnings - Heavy, short, first-cut turnings from wrought-iron and steel railroad axles or heavy forgings, and rail chips, to weigh not less than 75 pounds per cubic foot, free from dirt or other foreign material of any kind.

20. No.1 machine-shop turnings - New, clean steel or wrought-iron turnings, free from lumps, badly tangled or matted material, cast-iron borings, other metals, excessive oil, dirt, or foreign material of any kind. Badly rusted or corroded stock will not be accepted.

21. No.2 machine-shop turnings - New, clean steel or wrought-iron turnings, curly, bushy stock; may contain tangled material b but must be free from badly rusted, lumpy, and corroded stock. To contain no cast-iron borings, other metals, excessive oil, dirt, or foreign material of any kind.

22. Cast-iron borings - New, clean cast-iron borings and drillings, free from steel turnings and from badly corroded or rusty material, lumps, oil, scale, other metals, dirt, or foreign material of any kind.

23. Hydraulically compressed sheet scrap - New, black steel sheet clippings, shearings, skelton stamping scrap, side and end sheet scrap, hydraulically compressed into compact, rectangular packages not to exceed 20 inches longest dimensions, weighing not less than 75 pounds per cubic foot; must be clean and free from excessive rust, paint, or protective coating of any kind. No detinned scrap, electrical sheets, or material over 0.5 percent of silicon will be accepted. Further limitation of silicon content may be made by mutual agreement between buyer and seller.

24. Baled sheet scrap - New, black steel sheet clippings, shearings, skeleton stamping scrap, side and end sheet and tin-mill scrap, machine baled into angular or rectangular packages, tied with wire or bands, or sufficiently compact not to come apart in handling with a magnet, not over 24 inches longest dimension, weighing not less than 45 pounds per cubic foot; must be clean and free from excessive rust, paint or protective coating of any kind. No detinned scrap, electrical sheets, or material over 0.5 percent of silicon will be accepted. Further limitation of silicon content may be made by mutual agreement between buyer and seller.

25. Hand-bundled sheet scrap - New, black steel clippings, shearings, skelton stamping scrap, side and end sheet and tin-mill scrap, securely tied with not less than two wires or bands into packages not over 18 by 18 inches by 3 feet, weighing not over 125 pounds, to be bundled in such a manner that packages will not

come apart in handling with a magnet; must be clean and free from excessive rust, paint, or protective coating of any kind. No detinned scrap, electrical sheets, or material over 0.5 percent of silicon will be accepted. Further limitation of silicon content may be made by mutual agreement between buyer and seller.

26. Loose sheet clippings - New, black steel sheet clippings, shearings, and stampings, 3/16 inch and lighter, free from excessive rust, paint, or protective coating of any kind, to be not over 18 inches wide or long, or if edge trimmings or shearings, to be not over 12 inches wide by 5 feet long. No detinned scrap, electrical sheets, or material over 0.5 percent of silicon will be accepted. Further limitation of silicon content may be made by mutual agreement between buyer and seller.

27. Galvanized or coated sheet scrap - New, clean steel sheet scrap, composed in whole or in part of material having a coating of zinc, paint, or protective material. Must be clearly specified as "galvanized or coated scrap" and be classified as above under items 23, 24, 25, or 26, according to the manner in which it is prepared for shipment. No material over 0.5 percent of silicon will be accepted. Further limitation of silicon content may be made by mutual agreement between buyer and seller.

28. Detinned sheet scrap - Sheet steel clippings and shearings, originally covered with a protective coating of tin or lead and tin, but from which such foreign metals have been removed. Must be clean, contain no material over 0.5 percent of silicon and be free from badly rusted and corroded stock. Must be clearly specified as "detinned scrap" and classified as above under items 23, 24,

25, or 26, according to the manner in which it is prepared for shipment. Further limitation of silicon content may be made by mutual agreement between buyer and seller.

29. Electrical sheet scrap - New, clean steel sheet scrap, composed in whole or in part of material from 0.5 percent to 1 percent of silicon. Must be clearly specified as "electrical sheet scrap" and be classified as above under items 23, 24, 25, or 26, according to the manner in which it is prepared for shipment.

30. High-silicon sheet scrap - New, clean steel sheet scrap, composed in whole or in part of material over 1 percent of silicon. Must be clearly specified as "high- silicon sheet scrap" and be classified as above under items 23,24, 25, or 26, according to the manner in which it is prepared.

31. No.1 Cast-iron scrap - To contain all kinds of machinery and sililar cast-iron scrap, nothing under 10 pounds or over 500 pounds in weight, nor over 48 inches long or 18 inches wide. To contain no brake shoes, cast-iron soil or water pipe, stove scrap, or burnt iron of any description, and be free from steel parts.

32. No.2 cast-iron scrap - To contain all kinds of agricultural implements of cast iron, free from steel parts, nothing under 10 pounds or over 500 pounds in weight, nor over 48 inches long or 18 inches wide. To contain no stove scrap or burnt iron of any description.

33. No.3 cast-iron scrap - To consist of cast-iron scrap with steel parts attached, nothing under 10 pounds or over 500 pounds in weight, nor over 48 inches long or 18 inches wide.

34. Heavy breakable cast scrap - Heavy cast iron suitable for breaking under and with buyer's drop. Pieces not to exceed 10 tons in weight. Free from anvil blocks, hammer bases, and like material, over charging box size and containing no burnt iron.

SPECIFICATIONS FOR CLASSES OF SCRAP FOR USE IN ELECTRICAL FURNACES.

53. Punchings and clippings - Open-hearth steel punchings and clippings, ¼ inch and heavier, 4 inches and under in lenght. Not over 0.04 percent of phosphorus or sulphur and suitable for shovel charging. Must be clean and free from galvanized or coated stock, dirt, and excessive rust or corrosion.

54. Guaranteed heavy scrap - Open-hearth steel plates, structural shapes, crop ends, shearings, broken steel tires, knuckles, tool steel, and spring steel. To be not less than ¼ inch thick, other dimensions subject to agreement Not over 0.04 percent of phosphorus or sulphur, clean, free from excessive rust and corrosion, and to contain no foreign material.

55. Unguarangeed scrap - Steel plate, shearings, nut and bolt puhchings, short rails, and other similar material, not less than ¼ inch in thickness and not over 12 inches in width or length. Not guaranteed under 0.04 percent of phosphorus or sulphur. To be suitable for hand charging. Must be free from galvanized and coated stock, foreign material, and excessive rust or corrosion.

56. Guaranteed axle turnings - Heavy steel or iron axle or forge turnings, guaranteed not over 0.04 percent of phosphorus or sulphur. To contain no foreing material and must be clean and free from excessive rust and corrosion. To weigh not less than 75 pounds per cubic foot.

57. Unguaranteed turnings - Short, heavy shoveling steel or wrought-iron turnings, or rail chips, not guaranteed under 0.04 percent of phosphorus or sulphur. To contain no foreign material and must be free from excessive rust or corrosion. To weigh not less than 75 pounds per cubic foot.

SPECIFICATIONS FOR CLASSES OF SCRAP FOR USE IN GRAY IRON FOUNDRY PRACTICE.

58. No.1 machinery cupola scrap - Clean machinery cast-iron scrap. Must be cupola size, not over 24 by 30 inches in dimensions, and no piece to weigh over 150 pounds.

59. No.1 machinery breakable scrap - Clean machinery cast-iron scrap, weighing over 150 pounds, and which can be easily broken by an ordinary drop into cupola size.

60. No.1 standard cupola scrap - Clean cast-iron scrap, such as columns, pipes, plates, and castings of miscellaneous nature, but free from stove plate and agriculatural scrap. Must be cupola size, not over 24 by 30 inches in dimensions, and no piece to weigh over 150 pounds. Must be free from foreign material.

61. No.1 standard breakable scrap - Clean cast-iron scrap, such as columns, pipes, and castings of miscellaneous nature, weighing over 150 pounds, and which can be broken by an ordinary drop into cupola size.

62. Burnt cast scrap - Burnt cast-iron scrap, such as grate bars, stove parts, and any miscellaneous burnt scrap.

63. Stove plate scrap - Clean cast-iron stove plate. Must be free from malleable and steel parts, window weights, plow points, grates, burnt iron, etc.

64. Agricultural scrap - Cast-iron parts of agricultural machinery, including plow points. Must be free from steel, malleable, and full-chilled iron.

65. Cast-iron car wheels - Cast-iron car and locomotive wheels.

66. Brake shoes - Driving and car brake shoes of all types, except composition filled shoes.

67. No.1 radiator scrap - Broken radiator castings, cupola size, with all steel parts removed. Must be free from excessive scale, rust, and corrosion.

68. No.2 radiator scrap - Unbroken radiator castings. Must be free from excessive scale, rust, and corrosion.

69. No.1 malleable scrap - Malleable parts of automobiles, railroad cars, and miscellaneous malleable castings. Must be free from steel and cast-iron parts.

70. No.2 malleable scrap - Malleable parts of agricultural implements and other miscellaneous malleable castings. Must be free from steel and cast-iron parts. May include no.2 rail steel, cropped rail ends under 3 feet long, 50-pound and over standard section.

APPENDIX B

	World Scrap Imports		World Scrap Exports	
	1963	1964	1963	1964
Australia ...	-----	-----	219,100	351,600
Austria ...	52,361	141,326	3,386	3,825
Belgium-Lux ...	87,300	156,700	520,500	612,700
Canada ...	580,971	766,296	383,919	554,081
Denmark ...	5,000	9,500	39,700	55,200
Egypt ...	50,962	46,653	------	-----
Finland ...	82,400	140,900	-----	-----
Formosa ...	170,944	246,196	-----	-----
France ...	577,200	584,500	111955400	1,501,800
Germany, W ...	638,300	1,764,600	1,298,700	1,308,600
Hong Kong ...	40,712	59,353	133,126	149,429
India ...	------	-----	377,863	470,175
Iran ...	5,012	5,547	-----	-----
Irish Republic ...	------	------	26,000	44,900
Italy ...	3,844,600	3,149,400	-----	-----
Japan ...	4,367,600	5,098,800	-----	-----
Kenya ...	-----	-----	2,908	22,562
Malaya ...	-----	-----	51,365	49,718
Mexico ...	445,400	734,600	-----	-----
Morocco ...	-----	-----	27,152	30,884
Netherlands ...	89,500	43,600	282,100	422,600
Nigeria ...	-----	-----	5,232	10,755
Norway ...	33,900	27,300	4,600	8,600
Portugal ...	-----	-----	18,400	57,700
S.Africa ...	22,600	31,700	-----	-----
Spain ...	145,188	303,755	-----	-----
Sweden ...	121,059	235,680	11,616	21,469
Switzerland ...	11,200	5,400	14,900	31,000
Tunis ...	-----	-----	7,978	10,926
U. K. ...	4,755	13,672	1,067,091	705,304
U. S. A. ...	193,900	251,500	5,571,900	6,948,100
U.S.S.R. ...	-----	-----	266,800	464,200
Yugoslavia ...	48,500	120,500	-----	-----

(Ref. from Quin's Metal Handbook, 1965)

74.10.15