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# TECHNICAL PAPER # 10

# UNDERSTANDING SCRAP METAL RECYCLING

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## PREFACE

This paper is one of a series publisher by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Leslie Gottschalk and Maria Giannuzzi as editors, Julie Berman handling typesetting and layout, and Margaret Crouch as project manager.

VITA Volunteer Jon Vogler, the author of this paper, is widely published in the field of recycling. His book Work From Waste, published by the Intermediate Technology Development Group, Ltd., London, England, describes how to recycle paper, plastics, textiles, rubber, minerals, chemicals, oil, human and household wastes, as well as metals. Mr. Vogler, an engineer, worked in Oxfam's "Wastesaver" program in developing countries. He has done much research in the field of recycling waste materials. The VITA Volunteer reviewer of this paper, David Reins, has been an industrial arts teacher for several years. He has also been a mechanic and has worked with precision machines and sheet metal.

VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers.

# UNDERSTANDING SCRAP METAL RECYCLING

by VITA Volunteer Jon Vogler

## I. INTRODUCTION

### A WIDESPREAD AND ANCIENT INDUSTRY

The recycling of metals is probably as old as other forms of metal working, which the book of Genesis gives as the occupation of Tubal Cain, eight generations after Adam, who "made all kinds

**of tools out of bronze and iron." Perhaps the earliest reference is in Isaiah: "[they] shall beat their swords into plough shares and their spears into pruning hooks." This is probably because the recycling of metals uses the same processes as the production of metal from ore. So important were these processes, that civilizations were labeled by them. The "bronze age" covers man's first production of tools (other than primitive stone axes) and the 'iron age' of tools that would cut without losing their edge. Gold and silver money likewise has been repeatedly recycled: by melting down and casting or stamping new coins. Much of the history of the modern world has been caused by the recyclability of metals: the Spanish Conquest of Latin America in the fifteenth century was carried out because the gold and silver that had been produced from ore by the Mayas and Incas could be melted down and converted into jewelry and bullion for the King of Spain.**

**Little attention was paid to recycling during the industrial revolution. Bessemer's invention of the blast furnace (published 1856) made it possible to produce new steel in huge volume: only in times of war when the importation of metal ores has been prevented, has recycling flourished. The campaign to collect aluminum saucepans to make Spitfire airplanes was enormously popular in Britain in 1940. However, metal recycling is still politically significant: it was the presence of scrap-metal collectors on a remote South Atlantic Island that triggered the war over the Falklands/Malvinas Islands.**

**Metal scrap, although unfamiliar to most people, is one of the**

world's larger industries with regard to the number of companies and people employed, weight of material handled and value of equipment used. It offers exceptionally good opportunities, for creating new businesses in developing countries, whose production or generation of scrap will increase rapidly with industrial and urban growth. Governments like it because it saves foreign exchange, conserves energy (recycling metals uses far less energy than primary metal production from ores), and creates substantial employment.

THE METALS THAT ARE RECYCLED

It is convenient to split them into three categories: ferrous, non-ferrous, and precious. Ferrous metals are those that contain iron and the main difference is that these are cheap and are recycled in huge quantities: hundreds, thousands, or even tens of thousands of metric tons. Non-ferrous are those with no iron: they include copper, aluminum, lead, and so on and quantities are much smaller: tens of tons or even a few kilograms may be worth large sums of money. Precious metals include gold, silver, platinum, etc., and just a few grams may be very valuable.

Table 1. Typical Scrap Metal Prices: Britain 1984

Price per Ton
Metal Grade (US$)

Ferrous HMS1 61.00
HMS2 49.00

**Light 31.00**
**New or detinned bales 73.00**
**Cast iron 61.00**

**Copper New scrap 976.00**
**Old scrap 854.00**
**Brass 732.00**
**Car radiators 671.00**
**Bronze 1098.00**

**Aluminum New cuttings 915.00**
**Old 732.00**

**Lead Old scrap 305.00**
**Car battery plates 85.00**
**Car batteries 61.00**

**Zinc Old scrap 427.00**
**New cuttings 488.00**

**Because of these differences, the sources of scrap, the markets into which they can be sold, and the methods, equipment, and skills needed for recycling also differ greatly. In the main body of this paper the categories will be discussed separately, but the reader should note that there is much overlapping: for example, certain furnace types may be used for all categories of scrap and some types of scrap, such as tinplate which contains steel (ferrous) and tin (non-ferrous), bridge two categories. In the latter part of the paper, general principles of metals recycling**

**will be discussed and these are applicable to all categories. Much metals recycling feeds recovered material (sometimes called secondary) back into the same industries that produced it in the first place (primary industries). To establish a business that will recycle metals profitably it is therefore essential to be familiar with the primary industries, especially with the giant steel industry, so the sections on each metal will describe these in outline.**

## II. IRON AND STEEL

### PRIMARY PRODUCTION

#### The Production of Iron

**Iron is a natural element, usually found as an "oxide" of iron mixed with other minerals and called iron ore. This is heated in a blast furnace to produce metallic iron called pig iron (so called because the molds in which it used to be cast were arranged around a central channel like piglets suckling a sow!)**

**Pig iron has two uses. It can be melted in a foundry where it is cast into molds to produce solid, heavy objects and objects with complicated shapes such as are listed below in the section, "The Forge and the Foundry." It can also be made into steel.**

#### The Production of Steel

**Pig iron contains another material: carbon (familiar as coal or**

charcoal). Steel is iron with little carbon; steel making is simply the removal of the carbon by burning. This makes the steel stronger, more flexible, and easier to cut than iron.

There are many different processes for making; steel from pig iron. All produce molten steel, which may then be cast to produce an end-product. Steel castings are not as common as iron but are stronger. Steel may be cast into ingots for forging, the process of hammering hot steel, to make items of extreme toughness; and strength. It may also be cast into slabs blooms, or billets for rolling. (Slabs, blooms, and billets are chunks of steel ready for further shaping.) Rolling is the most common process for shaping steel. The billet is heated until it glows yellow, then passed forwards and backwards between powerful steel rollers of the correct size and shape to produce the cross-section that is required. Steel sections in turn may be cut, cold-rolled, forged, welded, electroplated, or treated in many other ways to form the huge variety of steel components in use in the world today.

IRON AND STEEL SCRAP

Ferrous scrap can be fed back into the iron and steel manufacturing processes already described at any of a number of stages:

Foundry Scrap

Scrap iron or steel may be melted in a cupola or rotary furnace(see below for descriptions) to make iron or steel castings. It is usually mixed with pig iron.

### Steel Mill Scrap

Scrap steel, but not cast iron, may be melted in an electric-arc steel-making furnace and cast as billets for rolling.

### Rerolling Scrap

Large pieces of scrap steel may be cut to regular shapes and hot-rolled into new sections of a smaller size. Rerolling is practiced widely in parts of Asia, but less elsewhere. Thick scrap is flame cut into parallel-sided slabs that are heated in an oil-fired furnace (but not melted, so the furnace is simpler and cheaper than that used in a steel mill and less energy is used). It is then rolled in a four or five stand mill (a stand is one pair of rollers). Capital cost of the plant may be as little as US $180,000 (or even less for a used plant).

Rerolling is very suitable for thick plates from shipbreaking (cutting up of old ships), an industry being adopted by many Third World countries short of heavy scrap. It requires a very high degree of technical and manual skill and is not recommended as an activity to anyone without previous rolling mill experience.

### Re-using Scrap

Steel may be used as a raw material and cut, formed, forged, or treated in any other way to fabricate new objects. Rerolling and re-use yield far more value from a given weight of scrap) and should be tried wherever possible. Two waste materials justify special mention because they are so commonly used in this way: oil drums and reinforcing steel.

Oil Drums. The standard 45-gallon (200-liter) oil drum can be used as a container for liquids or soilds; as a waste bin; converted into a small (but short lived) furnace; mounted on a cart or truck or cut open to make an animal feeding trough. It is even more widely used as a source of raw material. When flattened out, an oil drum makes a rectangular sheet of steel 180 x 90 cm, plus two circular pieces 57 cm in diameter.

Reinforcing Steel. Concrete is often strengthened with steel reinforcing bars. These are made in standard lengths and cut to size on the construction site. The off-cuts are a useful material that can be cut with an ordinary hacksaw, bent across the knee or heated in a simple charcoal forge to flatten or shape an end.

In Kenya, a number of workers have developed a whole industry using reinforcing bars and similar materials. These enterprising men have made hand-operated punches, folders, and other metalworking machinery, all from scrap metal. From these they manufacture such products as heavy-duty bicycle carriers, stands and foreguards (strengthener between forks and handlebars), small agricultural tools, and metal working tools.

THE FORGE AND THE FOUNDRY

The forge and the foundry are two processes that can use ferrous scrap to produce finished goods for re-sale. They therefore provide excellent markets for the metal scrap reclaimer. However, many Third World towns do not have a local foundry or forge and the nearest is often many miles away. Not only is there no market for scrap metal, but all types of iron and steel objects have to be brought in and are very expensive. This situation may justify setting up a small forge or foundry locally, which will create employment, provide a market for scrap metal (and employment for scrap collectors and sorters); and provide cheaper iron and steel goods with less delay and difficulty.

## The Forge

In order to flatten or shape a piece of solid steel it must be heated to red and then yellow heat, at which point it becomes softer and more workable. The furnace in which pieces of steel may be heated is called a forge and the word is also used to describe the complete workshop in which forging is done. For working with reinforcing steel and similar sizes of scrap, a forge may be very small with simple requirements, namely:

* A bed of coal, coke, or charcoal
* A source of draft (wind) through the bed
* An anvil
* Tools for handling and hammering the hot workpiece.

## Products That Can be Made by Forging

**Agricultural tools such as hoes, rakes, mattocks, axes, plow blades**

**Axles for carts, trolleys, trailers**

**Carpenter's tools such as hammers, pincers, screwdrivers, chisels, adzes, drill bits**

**Mason's tools such as stone chisels, trowels, hammers, crowbars**

**Garage equipment such as ramps, brackets, tow hooks**

**Fittings for boats such as rowlocks and cleats**

**Machine parts of all sorts, especially for the many items described in this paper such as baling presses, shears, furnaces, etc.**

**Horseshoes**

## The Small Iron Foundry

**Foundry work requires long training. The quality of locally produced goods may be low, until skill and experience are obtained. Mass produced goods, even those imported, may still turn**

out cheaper despite the cost of transport. Foundry management needs organizing ability, practical skill, and determination.

## Equipment Needed for a Small Foundry

* Storage space for scrap metal and means of carrying and loading

* Furnace for melting the metal

* Wooden patterns and a workshop for making them

* Molding and sand preparation equipment

* Casting equipment

* Finishing equipment

* Safety equipment

## Products That Can be Made In a Small Foundry

Table 2 is taken from a report on the foundry industry undertaken by a developing country in the South American Andes and may be regarded as typical. No other process can produce complicated shapes so readily.

Table 2. Products That Can Be Made In a Small Foundry

spare parts for machinery sand mixers shoe lasts
manhole and drain covers motor casings coffee machinery
weigh scales well covers bench ends
car and truck parts burners wheels
weights and counterweights shelving brackets bed brackets
bearings stoves and heaters shears
molding presses textile machinery grinders

FURNACES FOR MELTING FERROUS SCRAP

Some of the major types of furnaces are described below and compared in Table 3.

Electric Arc Furnace

The electric arc furnaces used in steel mills are huge, capable of melting seven tons of metal per day upwards, and very expensive. However, it is possible to construct a tiny model for foundry work. It comprises a cylindrical pot, less than a meter high, of alumina brick and magnesite. The brickwork is held within a steel hoop mounted on a shaft that rotates in simple vee-blocks. The lid, of fireclay encompassed by a steel band, is penetrated by two graphite electrodes, which in turn are held in copper clamps mounted on a tilting and lifting mechanism. A pair of parallel- connected, direct-current arc welding generators (such as those manufactured by Lincoln Electric Company) provide current (of up to 1000 amps each at 40 volts) by thick flexible cooper cables to the electroded clamps. The generators are run off the three-phase main electric supply.

The furnace is charged with small pieces of scrap and the lid lowered. The arc strikes from one electrode to the scrap and back to the other electrode. As the charge melts, the electrodes are lowered by hand wheels. It takes about one hour to melt a charge. The electrodes are used up in the course of operations and have to be renewed, so the unit is not cheap to run compared with other types of small furnaces. On the other hand, it is flexible, handy to use for small batch work, and of comparatively low capital cost.

The Cupola

A cupola is not unlike a small blast-furnace: a vertical cylinder of steel plates, lined with bricks or other heat-resistant material to protect the steel from the intense heat generated. It has a vertical, cyclindrical steel shell, with air holes above the bottom doors.

The smallest practical size can produce just over one ton of iron per hour from a charge of 140 kilos of iron and 20 kilos of coke in each layer. One kilo of lime or sea-shells is added to flux the iron (prevent oxidation and allow slag to drain away more easily through the slag hole at the back, which is opened from time to time). It is cheap to build and operate but too laborious to use for small quantitites of material. Once at full stretch it can melt about four and one-half tons of metal in half a working day. So, it is only operated about once a fortnight.

Casting molds are stockpiled in preparation and the cupola kept on heat until every mold has been filled.

Rotary Oil Fired Furnace

This consists of a steel cylinder with conical ends and the point of the cone cut off to leave a hole about half the diameter of the cylinder. The cylinder is mounted inside circular turning wheels that fun on slow, electrically driven rollers. The turning agitates the scrap and speeds melting. Scrap and pig iron are charged in through one circular end hole. At the other end is the burner, which uses gas or bunker oil blown through a nozzle with air from a power fan. Pouring takes place through a spout in the middle of the cylinder wall. Slag is removed through a spout in one end. A separate cylinder is used for each different type of metal to prevent contamination.

The Crucible Furnace

The crucible furnace is used for small-scale operations, more often with non-ferrous metals but also for cast iron and steel. It differs from the furnaces just described in that the fuel and the metal are kept totally separate, giving much better control over purity and composition. This is achieved by holding the metal in a fire clay crucible that is seated inside the bucket-shaped furnace. Although the furnace can be coke-fired, oil or gas are more convenient as they heat more quickly than coke, are more widely available, and are simpler to use in a tilting furnace.

The furnace and its lid are lined with firebrick and mounted on strong bearings at the center of gravity. The oil burner flame enters through a hole in the bottom while the burner pump is behind the screen to prevent damage from slag or hot metal during work. The crucible is suspended in the center so that it is surrounded on all sides by a jacket of heated air. Tilting is by hand wheel action through a reduction gear box. For higher temperature work, crucibles are made from graphite mixed with the fire clay. They are fragile when cold but strong when heated. Each crucible should be used only for one type of metal.

Induction Furnace

This is similar to the crucible furnace except that the crucible is set permanently in the furnace, surrounded by a water-cooled electric coil. A high frequency (1000 cycles per second) alternating current is applied by a special generator. The coil creates a magnetic field that induces electric currents in the charge to generate heat and melt the scrap. A large unit can contain up to four tons of scrap and takes a little over an hour to heat, but much smaller units are commonly used, even down to the laboratory models holding only a few pounds. However, they are expensive for their size.

Induction furnaces are very clean and there is no possiblity of chemical changes due to contact with fuel or the high temperatures of the electric arc furnace, so they are very suitable for non-ferrous metal and alloy steels. Another advantage is that cast iron can be made from steel scrap without the need for imported pig-iron. The process is called recarburizing and requires graphite charcoal and ferro-silicon additions.

A good combination for starting a small foundry would be a cupola for cheap, large volume casting, plus a small electric arc or induction furnace for small quantity work required quickly.

Table 3. Furnaces for Melting Ferrous Scrap

Other
Type of Charge Capital
Furnace Fuel Material Product Size Cost

Cupola Coke or Solid pig Cast iron Medium Low
hard iron
charcoal

Rotary Oil Solid pig Cast iron Medium Medium
furnace iron

Crucible Gas, oil, None Steel and Small Low
or coke cast iron

Electric Electricity None Steel and Small Medium
arc cast iron or high
furnace

Induction Electricity None Steel and Small Medium furnace cast iron or high

Air or Pulverized Molten or Cast iron Medium Medium
reverberatory coal or oil solid pig or large or high
iron

THE SCRAP HANDLING PROCESS

Scrap is recovered from a variety of sources. Scrap handling covers the processes of collection, grading, and preparation.

Sources of Steel Scrap

Construction sites. Off-cuts of reinforcing steel, rods and mesh, wire and nails.

Demolition sites. Poles, girders, joists, steel doors and windows, drain covers, pipes, railings, grills, etc.

Engineering workshops. Off-cuts, swarf (turnings and chips from lathes, drills, etc. , discarded motor parts, scrap cars.

Factories, mines, quarries, drilling sites, farms, technical colleges, etc. Discarded machinery, construction steel, partitioning, drums and containers, pipes, tanks, carts, motors, in fact--anything!

Streets, parks, and waste land. Discarded railings, manhole covers, pipes, etc.

Households. Domestic appliances (cookers, refrigerators, etc.), tin cans, broken bicycles, perambulators (prams), toys, tools, furniture, etc.

Refuse dumps. Any of the above.

Scrap Collection

This involves three main activities:

Negotiation. To buy scrap, demolish machinery, clear scrap lying in public places.

Handling. By laborer or by crane, often with equipment for metal cutting, unbolting, and loading onto vehicles.

Transport. By cart, truck, railway, wagon, etc.

The use of skips can reduce costs significantly. A skip is a steel container in which the supplier stores scrap for the dealer to collect with a specially adapted skip loader truck.

The equipment for collecting scrap metal includes the following:

* a strong cart or vehicle is essential
* leather gloves
* boots with steel-reinforced toe-caps
* block and tackle

* a hacksaw
* bolt croppers
* axe

Grading of Scrap

The following list of ferrous scrap grades should serve anyone selling scrap in a Third World country that has one or more steel rolling mills, usually with electric arc furnaces, and a number of small or large iron foundries, plus workshops of different kinds. In countries without such industry, different grading, possibly aimed at export, will be needed. The grades include:

* cast iron
* heavy melting scrap, also known as HMS or "No. 1"
* medium scrap (or "No. 2")
* light scrap (or "No. 2 bundles" or "No. 3")

These may be in the form of:

* swarf
* re-rollable pieces (only if re-rolling mills exist)
* re-usable pieces

Cast Iron. Cast iron can be identified by its dull grey color, comparative weakness (it can often be broken by a hammer blow), and complicated cast shapes, sometimes with numbers or words cast proud of (higher than) the surface. It is one of the most valuable, highly priced forms of scrap and can be sold to a local iron foundry.

Heavy Melting Scrap. Whenever possible, steel scrap should be sold directly to a steel mill. In Third World countries these are mostly mini mills, using electric arc furnaces, which operate as follows: a first charge of scrap is melted, the glowing electrodes withdrawn, the top cover swivelled away and a second load of scrap discharged into the furnace from the charge basket. molten metal that determines the economics of furnace operation. Valuable time and energy are saved by reducing the number of times the furnace has to recharge. For this reason, steelmakers will pay far higher prices for smallish pieces of solid, heavy scrap more than 6mm thick which will form a heavy, dense charge. Scrap that fills this requirement is HMS and fetches an excellent price; bales of new or detinned sheet steel are even better (see below).

Obviously, large furnaces can accept much longer pieces than can mini mills. In Britain, the maximum length of HMS is 1.5m. Elsewhere, mini mill furnace diameters are often not more than 2m and charge baskets 1.5m, in which case material of about two-thirds of a meter in length is preferable.

Medium Scrap. This includes material which is thinner than 6mm but is reasonably free from rust, dirt, and any metals that cause difficulties in steel-making, especially tin and copper. Medium scrap may be sold to a foundry or steel mill. The pieces should be cut into lengths that will make a dense furnace charge easy to obtain. It is not economical to cut No. 2 scrap with expensive gases; an alligator shear is essential.

Light Scrap (No. 2 bundles or No. 3). This is the lowest acceptable quality and fetches the lowest price. It contains sheet material that is not able to be included in No. 2 because:

* it is too thin
* it is too rusty
* it is coated or contaminated with tin, and
* it is heavily coated with paint or oil.

Scrap Preparation Processes

Three mechanical processes are commonly used to prepare the scrap-baling, shearing, and shredding. Chemical processes are also used in certain circumstances.

Baling. The material is compressed in a powerful mechanical or hydraulic press, to produce dense, cubical blocks called bales. Light scrap such as large, rusty sheets of galvanized (zinc coated) steel are the worst forms of furnace feed, but even they can be made more acceptable (and that means a better price, by baling them. The advantages of baling are:

* more weight can be loaded on a truck so transport cost is cut

* more material can be stored in a given space so a better price can be negotiated for the larger quantity

* the buyer finds storage is easier so will pay a little more

* handling and loading are easier, quicker and cheaper

* a denser furnace charge is obtained.

Shearing. The material is chopped to length by a powerful blade. The cheapest machine is an alligator shear that will cut HMS of 20cm thickness. Larger shears are even more powerful.

Shredding. Used on thin steel that may contain other materials (glass, plastic, rubber, any non-ferrous metals, etc.) such as automobiles and household appliances. Hardened steel hammers or knives, driven by electric motors of enormous power, reduce the object to small pieces that can then be sorted, mainly by magnets that remove the steel scrap and leave all other material. Shredders are usually very expensive to buy and run and are only justified when huge numbers of objects are available to feed through them. Most industrial countries have one shredding plant for between two and five million people. Most non-industrialized countries do not have enough motor vehicles or household appliances to justify the installation of shredding plants.

Chemical Methods. Used when metals are mixed (or mixed with nonmetals) and not simply mechanically joined. Chemical methods are often combined with electrolysis (the passing of an electric current through a solution containing the metal compounds). Important examples are:

* detinning of tin plate scrap

* recovery of silver from photographic wastes. This will be described under IV. PRECIOUS METALS below.

RECYCLING OF TIN CANS AND SCRAP FROM CAN MANUFACTURING

"Tin" cans are actually made of steel coated with a very thin layer of tin and often with lacquer as well. They are a problem to steel makers as the tin, which has a lower melting point, causes zones of weakness in the hot steel, leading to hot shortness" and other problems. For this reason, cans are not used by steel makers in the industralized countries unless the tin has been removed (or at least reduced) by detinning. Alternatively, their use is restricted to the production of low-quality products such as reinforcing steel.

In many developing countries where there is a shortage of steel scrap, used cans are accepted, provided they form less than ten percent of the total scrap charge and are evenly dispersed throughout: one steelmaker claims to use up to 50 percent cans to make reinforcing bars! Some steel makers prefer cans rusted in the weather for some weeks before use.

In the original manufacture tin is applied to the steel sheet by either of two industrial processes. The more modern is electrolytic deposition, which results in an extremely thin layer of tin (thickness 0.0015mm and weight 0.5 percent to 1.0 percent). In the older process, the steel was dipped in a bath of molten tin resulting in a much thicker layer of tin: by weight 1.5 percent to 7.0 percent. Hot dipped tinplate scrap causes worse contamination in steelmaking. Also, the amount of pure tin that can be recovered from it is greater, which makes the removal process more profitable. Detinning is applied to scrap from can manufacturing, but because they are dirty, which upsets the process, only occasionally to used cans.

Detinning of Scrap Tinplate

This can be carried out in countries where tinplate cans and boxes are locally manufactured in volume and where local steel rolling mills or foundries export the steel scrap. Local markets for tin are not essential as this metal can be sold internationally. It finds virtually unlimited markets if the quality is correct (this means composition of not less than 99.75 percent tin). If it is contaminated with lead (which often occurs in can-manufacturing scrap) it may be sold for solder manufacture at only slightly lower prices.

Detinned steel scrap, if it is press-packed into rectangular bales in a hydraulic press, fetches almost the highest price that is paid for steel scrap. The tin content must be kept to below 0.05 percent but this is not difficult using the process described.

The major items of such a plant are a furnace constructed of brick, with flues and grates firebrick-lined, containing mild steel vats about one meter deep and in diameter, complete with chimney and forced draft fan. Around the furnace is arranged a low voltage electrical distribution system, to make the vat slide into a cathode. The anode is retractable so that it may be lowered to make electrical contact with the scrap charge and raised clear when the charge is positioned or withdrawn. A crane to handle the full charge baskets is needed, as are pre-wash and post-rinse water tanks, a tin smelting furnace and refining furnace with hand tools, and a scrap metal baling press. The process requires a competent standard of technical and commercial management.

Economics of Detinning

These will vary widely depending on local factors and, in particular: steel scrap prices, local electricity tariffs, cheap fuel availability, location and transport arrangements, and whether tin metal can be sold locally. However, based on actual costings for a 6,000 ton per annum plant in East Africa in 1981 it appears that:

* At a scale of over 1000 tons per annum a detinning plant of this kind can operate at a profit, given typical costs and prices for developing countries that have their own steel industry.

* Profitability is substantially higher if the thickness of tin coating is greater, for example, where cans are

**made for export of acid fruits.**

*** Between 250 and 1000 tons per annum plants are only profitable if tin coatings are thicker than those used for non-corrosive contents.**

*** Below 250 tons per annum, micro scale plants make no significant profit but can provide self-financing employment.**

**However, these principles are general; each country's individual situation should be studied. Table 4 presents a comparison of the investment required and returns expected on various sizes of small detinning plants.**

**Table 4. Investment and Profitability of Small Detinning Plants**

**(All figures in thousands of U.S. dollars)**

| Plant Capacity in Tons per Annum | 50 | 250 | 1000 | 6000 |
|---|---|---|---|---|
| Capital costs | 13 | 45 | 127 | 396 |
| Sales - Baled detinned steel | 3 | 15 | 60 | 360 |
| - Tin metal (0.5 percent) | 3 | 16 | 63 | 378 |
| Total variable costs | 4 | 17 | 57 | 300 |

**Total fixed costs 2 7 20 70**

**Total costs 6 24 77 370**

**Net profit before tax 0 7 46 368**

**Return on investment before tax 0 15 36 93 (percent)**

**Number of workers 1 3 8 32**

**RECLAMATION OF MOTOR CARS AND SIMILAR VEHICLES**

**The junk motor car is an important source of steel scrap in developing countries. It is fully discussed in Jobs from Junk (See bibliography).**

**Car parts can be recovered by removal and sale of some components, use of parts for scrap, and use of the shell for scrap.**

**Recovery of Saleable Components**

**Parts are worth much more when re-used rather than scrapped. Every city in the world has dealers in second-hand car parts and in some towns a complete commercial district is devoted to nothing else.**

**Recovery for Scrap**

**Unsaleable parts can often be used as raw material, e.g., leaf springs can be cut and ground to make excellent chisels and hoes. What is unusable goes for scrap: engines as cast iron or aluminum, radiators as copper, etc.**

**Recovery of Auto Shells**

**The shell is all that remains of the car when the parts have been removed. Shells abound in many parts of the Third World, not only in cities and suburbs but also in rural areas. They are a hazard to traffic and to children and serve as breeding areas for mosquitoes and other pests. However, their large size and low weight of metal make them uneconomic to transport to a distant steel mill or foundry. Neither are there sufficient numbers to justify investment in hugh car-crushers or shredders such as those used in the industrialized countries.**

**Because people in some Third World countries are so resourceful in car repair and obtaining used spare parts, cars often run for 30 or 40 years, also diminishing the scrap supply.**

**Where large numbers of shells are accumulating, simple labor-intenstive methods may be used to reduce them to pieces small enough for economic transport to the scrap buyers.**

**III. NON-FERROUS METALS**

Metals other than iron and steel are described as non-ferious. The most interesting as regards scrap are aluminum, copper, brasses and bronzes, zinc, and lead.

One problem facing the collector is how to identify all these different metals. They are used by quite different markets and the best prices are paid by the final users, normally foundries or refiners, who will not buy mixed or unidentified metals. There are simple tests to identify a metal:

* Find out where it came from

* Consider the size, shape, and former use of the item

* Test it with a magnet; ferrous metals are attracted by or to it; non-ferrous metals are generally not

* Look at the color

* Drill or take filings.

COPPER

Copper is the perfect material for recycling. It is valuable, easy to identify, easy to clean, and heavy. Moreover, it can be readily sold to small foundries or larger companies that refine and produce copper sheet, wire, or bars. It has many important alloys, particularly bronze (which contains copper, tin, and zinc) and brass (which contains copper-and zinc only). Scrap from either is easy to sell.

## Grading of Copper Scrap

Copper may be graded as follows:

* Pure copper

* Copper cables with plastic covering. The plastic or rubber covering has to be removed and this can be done in one of three ways: by hand, by burning, or by using a cable stripper--a machine that chews off plastic, leaving the copper wire unharmed.

* Copper contaminated with tin

* Copper contaminated with solder

* Electrical machinery

* Chromium-plated copper.

## Refining of Copper Scrap

This needs specialist skills. The copper is furnace-melted and molten sand added to form a slag. Air is blown into the molten mixture and iron, tin, and lead are all oxidized and float in the slag. Cadmium, sulphur, and other impurities are then given off as gases. Some of the copper also becomes oxidized and has to be reduced by poling: floating green tree trunks in the hot molten copper (as in the smelting of copper ore).

Casting of Copper into Ingots

In a foundry, pure copper can be melted in any of the small furnaces described above, and cast into ingots. It is worth investing in cast iron molds. Special equipment to measure the furnace temperature is necessary and specialist advice should be obtained if possible.

ALUMINUM

Sources of Aluminum Scrap

Aluminum is one of the most widely used metals because it is cheap to produce, lightweight, and very easy to work. The main sources are:

* cooking pots
* car parts
* airplane parts
* domestic appliances
* tubes, boxes, containers for medicines and other packaging
* door and window frames
* electric cable
* some drink cans
* cooking foil, take-away food trays and milk bottle tops.

**Markets for Aluminum Scrap**

**In developing countries the largest market will be small foundries, but there may also be mills that melt the scrap to produce ingots for conversion into sheets, extrusions, castings, etc. Most of these will buy aluminum scrap if its composition is known, but may refuse to buy foil unless baled. Foil may also be sold to steelmakers, who use it as a deoxidant; it is ground and thrown into the crucible to reduce slag.**

**Grading of Aluminum**

**When collecting, keep known alloys separate from commercially pure aluminum. Thereafter, the main task is to remove all non-aluminum materials such as plastics, oil, iron or steel, copper, dirt, or the contents of containers.**

**The aluminum is then graded to:**

* **clean heavy**
* **dirty or "irony" heavy**
* **foil and other thin material such as cans and containers.**

**Manufacture of Aluminum Ingots**

**The market for aluminum scrap can be improved by casting ingots. A furnace is needed with a sloping hearth capable of reaching temperatures 200-300[degrees]C above that at which aluminum melts**

(660[degrees]C.) The aluminum will melt before any ferrous metals. and will run down the furnace hearth into a trough, from which it may be poured into open sand molds. The ferrous metals remain on the hearth, avoiding the need to remove them from the scrap beforehand. For suitable furnaces, see 'Equipment Suppliers' at the end of this paper.

**An Aluminum Foundry**

Having successfully cast aluminum ingots, it may be possible to cast finished products. This is not, however, an easy process and some knowledge of foundry operations is vital. Of the furnaces described above, the rotary, induction, or crucible may be used for aluminum.

It is possible to sand-cast aluminum in a manner similar to cast iron, but, as aluminum is often used to make smaller components in far larger numbers, it may be economic to use die-casting. This replaces the sand mold with one of steel, accurately machined and expertly designed, so that the metal will flow, solidify, and shrink correctly. Therefore, dies can be extremely costly.

The simplest process is gravity die-casting: the metal is ladled into the heated die and the only pressure is from its own weight. A more complicated but faster process uses a pressure die-caster that forces the molten metal into the die, ejects the finished casting, and closes the die ready for the next cycle.

**ZINC**

**Zinc is a cheap, easily-cast metal used for castings where strength is not important. It is widely used for galvanizing (protecting steel from rusting) and making brasses alloys of copper and zinc). Zinc casts easily and is widely used for die castings but not all factories with die-casting machinery can use zinc scrap. Metal of high purity is required and is alloyed with carefully controlled additions of aluminum (and sometimes copper).**

**Zinc can easily be melted in a furnace at 400' to 500[degrees]C with a chloride flux, but the metal obtained may not be pure. Almost pure metal can be obtained by evaporating the metal in a controlled atmosphere and collecting the vapor in a condenser (a steel drum, cooled by water will do) from which it may be remelted and cast into ingots.**

**Products made from zinc include:**

*** parts for cars (especially door handles, brackets, casings for small gear boxes, carburetors, etc.**

*** washing machines and refrigerators**

*** slot machines**

*** radios and televisions**

*** oil burners**

* printers' plates and type.

## LEAD

Lead, like copper, is an easy material to recycle if only you can obtain enough of it. Its grey color when oxidized, great density, softness, and flexibility make it easy to identify. These same properties make it valuable. It is easy to store, transport, and work into its final shape. Because it melts at a low temperature (325[degrees]C) no special furnace is needed and it is cast by any industry that uses it. Thus, the sources of lead scrap are also the markets into which you can sell it, for example:

* car battery plate solder
* pipes for plumbing
* flashings (waterproof joints) for roofs
* gutters and spouts for rainwater
* weights and counter-weights
* wine bottle tops and seals
* bearings of white metal (lead and tin)
* printing metals
* lead covered cable.

Although lead is easy to melt, care is needed to ensure that as little lead scrap as possible is lost as fumes and dross (rubbish that floats on the molten metal). This can be achieved by using a flux and a reducing agent. The scrap is first washed in a concentrated solution of sodium carbonate, to remove sulphur, and then smelted in a furnace at 800[degrees]-900[degrees]C, using coke as the reducing agent, and flux of soda ash, borax, and fluorspar.

DANGER

Lead is a poison and can cause fatal illness.
Any workshop handling molten lead should have fume extraction fans fitted and employees should wear effective face masks, wash before eating, and have regular medical examinations.

IV. PRECIOUS METALS

Normally these are recycled by gold- and silversmiths. There is, however, one important source of silver available to the public: the recovery of silver from photographic materials.

The silver present in a wide range of photographic and X-ray materials can be recovered as metal and sold. The materials in questions are of two kinds. First, there are those used to process photographs and x-rays, in particular, fixer solutions. Silver is also contained in the actual photographs and x-rays themselves, after they have been developed. It can only be recovered by destroying them when they are no longer required.

CHEMISTRY OF SILVER RECOVERY

In a photographic or x-ray film, silver bromide grains are contained within a layer of gelatin known as emulsion. The gelatin is thinly spread on a sheet of transparent plastic film, known as the support. When the light from a camera lens falls on the film, the silver bromide grains are sensitized in the same pattern as that of the light. The places that receive the most light have the most grains sensitized and, after developing, contain the greatest amount of silver. The silver is not in the bright, shiny, metallic form with which we are familiar in jewelry and cutlery, but has the appearance of a fine, black or dark grey powder. Thus, the areas that were exposed to the most light become darkest and such film is called negative.

The grains of silver bromide that have not been converted to silver are next removed by making them soluble in water, by treating them with a fixer. This is a solution containing a chemical: most commonly sodium thiosulphate, often known as hypo. After fixing, the negative is washed and all the soluble silver thiosulphate removed, to leave only the metallic silver in the emulsion. To convert from the transparent negative to a positive print, print paper coated with emulsion on a paper backing is exposed to light that has passed through the negative. The exposed paper is then developed, fixed, and washed in exactly the same way.

It will be seen that a large proportion of the silver, which begins life as silver bromide within the photographic gelatin, is removed during the fixing process. If only a little light fell on the film, almost all the silver will end up in the fixer. If a large amount of light fell, most of the silver will remain within the gelatin on the film. There are, therefore, two significant procedures for recovering silver from x-ray and photographic wastes: first, to extract it from the spent fixing bath, and second, to recover it from the film, when this is no longer needed.

X-rays behave exactly like rays of light and identical emulsion and support can be used for x-ray film, although it is common for the support to be coated with emulsion on both sides, whereas in photography, only one side is coated.

There is an important difference between color and black-and-white photography from the point of view of the recovery of silver. Whereas in black and white or x-rays a large percentage of the metallic silver remains within the emulsion, in color photography it is all removed, in a solution called bleach-fix. Color bleach-fix may therefore be very rich in silver but is rarely available outside laboratories.

SILVER RECOVERY

From Spent Fixer Bath

There are a number of ways in which metallic silver can be recovered:

Electrolysis. A small direct electric current is passed through the fixer so that the silver is plated onto the cathode from which it can later be removed.

**Metal Ion Replacement. The silver in the solution is replaced by a more reactive metal such as zinc or iron.**

**Chemical Methods. Chemicals are added to the fixer, which precipitates either silver or an insoluble silver salt, which is then extracted by filtering, contrifuging, etc.**

**From Film**

**It is only necessary to release the silver from the emulsion. There are four principal ways in which this may be done:**

**1. By burning the support film and gelatin to leave a silver-containing ash, which can be reduced to silver metal. This creates air pollution and much of the silver is lost as smoke.**

**2. Oxidizing the silver to a soluble oxide, which can be washed out of the emulsion.**

**3. Dissolving the gelatin using an enzyme (a biochemical substance) of the proteolytic (which means protein eating) type or an acid or alkali and then recovering the pure silver from the residual sludge.**

**4. Reversal of the silver grains back to silver bromide, followed by dissolving in a fixer and electrolytic recovery.**

**SOURCES OF PHOTOGRAPHIC WASTES**

* advertising agents, newspapers, cinema, television

* photographic services, aerial photography, aerial surveys

* engineering contractors, foundries, welding laboratories

* film studios

* clinics, dentists, hospitals

* laboratories, micro-filming services

* x-rays and film manufacturers and stockists

## V. GENERAL PRINCIPLES

### WHAT IS NEEDED FOR METAL RECYCLING

#### Space

The space can be unroofed but non-ferrous metals, which are valuable, should be secure from theft. Because the process is ugly, screening by belts of trees or fences is common.

#### Stockholding Finance

Prices for the sale of recycled metals increase as the quantity delivered increases. To achieve these improved prices it is necessary to finance purchasing and collection (and often the preparation and further processing) before any sale is made.

Skills

Knowing the Customer. Dealers in scrap metal sell to a small number of large and powerful customers and are often in competition with many other scrap metal merchants. This weak bargaining situation can be overcome only by knowing the customer and his business. The merchant should understand what each different grade of scrap is used for and keep himself informed of changes in the supply and demand of this product so that he can predict shortages (and high prices) and surpluses (low prices).

Knowing the Collectors and Suppliers. For supplies of material the dealer is dependent on:

* industrial producers of scrap who want regular collection to keep their premises clear, prompt payment, and no fuss, and

* gypsies and scavengers who want fair prices and prompt payment--or often advance loans or help with purchasing hand-carts, etc.

Knowledge of Metals. The dealer must be able to distinguish different grades of metals at a glance or know what tests to apply.

Commercial Management Sense. Especially when handling liquidity

--ensuring enough cash to pay today's suppliers and labor even though the scrap may not be sold for days or weeks ahead.

Ability to Manage and Operate Plant. Small-scale scrap handling can be done by hand but for the enterprise to grow, machinery is essential: mechanical, electrical, and hydraulic systems to work under very rugged and difficult conditions. The successful scrap merchant must be able to obtain the services of qualified mechanics, obtain or stock necessary spare parts, operate regular maintenance schedules, etc.

Awareness of International Markets. Knowledge of the grades of scrap in which the merchant deals and the economics of selling to international markets when prices are depressed.

COSTS AND ECONOMICS

The main costs of collecting, dealing, and processing scrap metals are:

Purchasing - scrap from suppliers.

Transportation - both to the sorting yard and from the yard to the customer (or to the docks for export).
The economics of iron and steel scrap are
dominated by transportation costs as the
tonages and volumes are so large.

Energy Costs - such as cutting gases, electrical power, or furnace fuel.

Labor Costs - in industrialized (high wage) countries are significant unless reduced by heavy investment in capital equipment. In developing countries, both these costs will be lower.

Value Added - profitability is higher if the dealer produces a finished or partly finished product. For example, a factory in Papua New Guinea that recycled lead found it more profitable to cast fishing weights, which they sold direct to marine stores.

Scrap Metal - vary from one week to the next and from Prices one country to another. Changes in international markets may be found by consulting Materials Reclamation Weekly and Metal Bulletin (See bibliography). Table 1 above gives current prices in Britain which may be used for guidance only to show how the values of different materials compare. It is stressed that local prices may differ from these by many hundred percent and anyone dealing in scrap metals must obtain local, up to date commercial information.

CHOICE OF SCRAP PROCESSING TECHNOLOGY

**Unsuitable technology can kill a promising scrap metal (or any other) business. Technology should be introduced in three phases. Only when one phase has been fully mastered, free of technical and maintenance problems for at least a year, and shows a clear profit should the next phase be started. The phases are:**

**Phase 1**

**Establish suppliers, markets, and scrap grading operations, using manual labor and simple vehicles.**

**Phase 2**

**Merchandise scrap handling and sorting, using:**

*** skip-loader vehicles and skips, or trucks with hydraulic grab cranes for collection**

*** cranes with hydraulic or magnetic grabs for sorting**

*** shearing and baling machines for scrap preparations.**

**Phase 3**

**Further processing of selected kinds of scrap in foundry, forge, etc., to add value to the product.**

**Before Phase 1 is started the decision must be made on what kind of metal to recycle. The decision will affect the whole operation**

for years to come and should be based on:

* a survey of the markets for scrap metals or products that can be made from them

* a survey of the available supplies

* a calculation of the volume of metal that car be handled

* a feasibility study (calculation of the likely costs and income showing whether the business will have good cash flow and profitability) in all three phases.

LAWS AND REGULATIONS

Dealers in scrap metal may be particularly affected by three kinds of law:

Export restrictions

Scrap metals are often so important to a country's economy that they may not be sold overseas. There may be restrictions on imports of processing machinery and fuels.

Licensing

Some scrap metal, especially copper, used for telephone and electric power cables, is frequently stolen. Police after, control this by requiring scrap dealers to be licensed and to record every purchase they make. The municipality or police may be the licensing authority.

Safety of Employees

Handling scrap metal is dangerous! In many countries the, law requires the employer to safeguard his employees from all such dangers by providing safe working methods, protective clothing, medical checks, etc. Even if no laws apply, the victim of an accident may have legal rights to sue the employer for negligence. The dangers are very widespread and include:

* fire
* injury from falling objects
* injury and disease from poisonous chemicals and gasses
* explosion (of gasoline tanks, gas cylinders)
* burns and scalding, and
* infection of wounds.

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**EQUIPMENT SUPPLIERS**

**Foundry Equipment**

Pioneer Equipment Co., Ltd.
Old Padra Road,
Akota, Baroda
Gujarat, India

**Gas Cutting Torches**

British Oxygen Co., Ltd.
W. Pimbo, Skelmersdale, U.K.

**Metal Scrap Machinery**

J. McIntyre (Machinery) Ltd.

Acorn Park Industrial Estate
Harrimans Lane, Dunkirk
Nottingham, U.K.

Vanesco Ltd.
165 Garth Road
Morden Surrey, SM4 4LH U.K.

Hydraulic and Engineering Works
10066, First Floor
D.B. Gupta Road
Pahar Ganj, New Delhi 110055, India

Furnaces

Hindustan Brown Boveri Baroda Ltd.
264 Dr Annie Besant Road
Bombay 43005 India

G.E.C. of India, Ltd.
Chitarajan Avenue
Calcutta, India

Rerolling Mills

Mukand Iron and Steel works
Belapur Road
Kalvew, Thana
Maharashtra, India

**Davey Ashmore India Ltd.**
**Kharagpur G-19**
**Middleton Street**
**Calcutta, India**

**A.C.C. Vickers-Babcock Durgapur, Ltd.**
**Express Tower**
**18th Shahabad Floor**
**Nariman Point**
**Bombay 430021, India**

**Cable Strippers**

**G.L. Murphy Ltd.**
**Imperial Works**
**Menston LS29 6AA**
**W. Yorkshire, U.K.**

**Metpro Machinery Ltd.**
**North Road Industrial Estate**
**Bridgend, Mid Glamorgan U.K.**

**Aluminum Furnaces**

**Chine Furnaces**
**Units 4 & 5**
**New Road, Newhaven**
**East Sussex, U.K.**

**Silver Recovery**

**The X-Rite Company**
**4101 Rogers B. Chaffee Drive**
**S.E. Grand Rapids, Michigan 39508 USA**

**Photographic Silver Recovery Ltd.**
**Saxon Way**
**Melbourn**
**Royston Herts SG8 6DN, U.K.**

**Vogler, Jon. Detinning. INTERWASTE, 40 The Avenue, Roundhay, Leeds, LS8 1JG, U. K.**

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**Weygers, Alexander G. Recycling, Use and Repari of Tools, Van Nostrand Reinhold Company. 450 West 33rd Street, New York, New York 10001 USA.**

**ORGANIZATIONS**

**1. British Secondary Metals Associations, 40 Oxford Street, London Wl, United Kingdom. Telephone 01-580-5228.**

**2. British Scrap Federation, 16 High Street, Brampton, Huntingdon, Cambs PE18 BTU, United Kingdom. Telephone: 0480-55249.**

**3. Bureau International de la Recuperation, Place du Samedi, 13-BTE 4, 1000 Brussels, Belgium. Telephone (02) 217-82-51.**

**4. Interwaste, 40 The Avenue, Roundhay, Leeds LS8 1JG, United Kingdom Telephone: 0532-661885.**

**5. The Institute of Scrap Iron and Steel, Inc. 1627 "K" Street N.W., Washington, D.C. 20036 USA**

**6. National Association of Recycling Industries, 330 Madison Avenue, New York, New York 10017 USA**

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