Stein Atkinson Stordy Ltd

THE ALUMINIUM DECOATING HANDBOOK

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Foreword

We find the subject of decoating fascinating and having worked in this field for many years now it was decided to share our experiences with others. This is not intended to be the "Bible of Decoating" and we would not expect it to be a complete and full account of the subject. Instead it is hoped that the reader may gain a better understanding of the concepts involved in decoating and the problems we, as capital plant designers, must consider and solve. We are sure that there will be others who may have a different approach to some of the things written within these pages but, as with many subjects within the aluminium industry, decoating can be an emotive subject. We would like to thank our partner Companies namely Gillespie & Powers Inc in the United States and Sanken Sangyo in Japan for their belief in our technology and the continuous role they play in moving this technology forward.

Although this publication relates mainly to the aluminium industry the concepts are being extended into other metallurgical areas such as Steel and Copper.

Please feel free to comment on this hand book. We are always open to suggestions of how it can be improved and extended.

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This book is dedicated to Willis Bateman. Without his help, knowledge & understanding over the past ten years it would not have been possible

CHAPTER ONE – INTRODUCTION TO DECOATING

1.1 What is Decoating ?

Decoating is the process by which paint, ink, paper, plastic and oil are removed from the surface of a material, usually metallic, to enhance recyclability. Traditionally, the base material is aluminium although the decoating process has successfully been applied to copper and steel.

Aluminium products are now available in a wide variety of forms and, consequently, they possess a wide range of coatings. Some of the most common products are cans, extrusions, lithographic material, painted sidings, laminates and chips & turnings.

All coatings contain either organic or inorganic compounds and very often both. When released by thermal degradation and / or oxidation they invariably undergo chemical change as the complex compounds are reduced to their basic forms. For example, polypropylene is reduced to carbon monoxide, carbon dioxide, hydrogen and water vapour.

It could be argued that all products exhausting from the decoating process, with the possible exception of water vapour, are harmful to the environment.

As stack emission limits worldwide are progressively reduced by the environmental authorities manufacturers and users of decoating plant have to come to terms with the inevitability of having to install items of equipment specifically for emission reduction.

Stein Atkinson Stordy Ltd is a major supplier of decoating plant and therefore, of necessity, has to be at the forefront of decoating technology. Consequently, experience has been gained both in the field and on pilot decoaters at the Stein Atkinson Stordy Ltd facility in Wombourne, England.

1.2 *Why Decoat ?*

There are many reasons why Companies decoat their scrap, but in general they can be grouped into two main areas:- economical and environmental.

1.2.1 *Economic Reasons for Decoating*

Economic reasons are many and historically have been the main driving force for companies investing in decoating plants. The main considerations are:-

a) Reduction of Metal Loss:- When coated scrap aluminium is melted directly in the furnace there will be a substantial metal loss that will vary depending upon many factors including:-

- *Type of Coating:-* Complex and multilayered coatings can accelerate metal loss.

- *Quantity of Coating*:- As the quantity of coating present on the scrap increases then generally the amount of metal loss increases.

- *The Thickness of the Scrap*:- Thin scraps exhibit a higher metal loss than thick scraps for the same percentage of coating.

- *The Method of Melting:-* Better yields can be experienced by induction melting when compared to direct fired methods. The charging practice also has a great bearing on consequential metal loss. However, this type of furnace is not suitable for everyone due to local variations in the price of electricity.

For a plant operator saving metal loss is one of the main ways of increasing profitability. If we assume that the current market price of ingot aluminium is around $1400 US Dollars/ton then each 1% metal loss is worth $14/ton in lost revenue. This in itself does not appear to be much but based on a US Secondary aluminium company producing 70,000 Ton per year this could be worth $980,000 Dollars per year for each 1% metal loss.

b) Improving scrap value:-Clean scrap ready for melting has a higher resale value than coated or dirty scrap.

c) Decoating can recover some of the energy value "Locked Up" within the coating. In extreme cases of very high coating weights the excess energy released during decoating can be utilised for cogen or local heating applications.

d) Obviously it is not all good news. There are some costs associated with decoating that will offset to a degree the potential savings highlighted above.

1.2.2 *Environmental Reasons for Decoating*

As emission limits world-wide continue to become ever tighter aluminium companies are being forced to clean up the environment. Many companies continue to melt contaminated scrap by direct charging into furnaces. In some cases the exhaust stack goes straight to atmosphere with little waste gas treatment being performed. Depending upon the type of scrap there will be many different types of pollutant released into the atmosphere including volatile organic compounds, acid gases and particulate.

The practice of land filling relatively low metal content scraps such as packaging foils and post consumer waste is becoming unacceptable and inevitably these will have to be dealt with in an environmentally friendly way. Decoating is a demonstrably viable method for reclaiming the metal content of such scrap.

CHAPTER TWO – ALUMINIUM SCRAP

2.1 Origins of Scrap

Scrap can originate from a variety of sources but can be generally catagorised as:-

- Manufacturing:- Material rejected during the primary manufacturing stage. This can be contaminated with rolling/cutting oils, water or waxes.
- Pre Consumer:- Material which has completed the manufacturing stage but has been rejected due to a defect. This may be coated or even filled.
- Post Consumer:- Material that has finished its useful life. This scrap may contain foreign constituents such as water, dirt, dust, sand or any other item. In developing countries scrap is collected as a means of subsistence. Here it is common to find almost any object inserted into the scrap to increase its weight and hence value. This can pose new difficulties for plant designers to remove the foreign objects from the scrap.

2.2 Aluminium Scrap Types

There are many different types of aluminium scrap available today and, as the usage of aluminium continues to grow, more varied types are becoming available. From a plant designers point of view it is easiest to classify scrap types according to their particular level of volatile organic compounds (VOCS). The levels of VOCS are usually expressed in terms of percentage of the total scrap weight. As an example a material containing 5% VOCS means that 5% of the total weight of the scrap will be organic in nature. The volatile organic compounds will have the most profound effect on the design of the plant and consequently the scrap is grouped into three main areas, namely:-

2.2.1 Low Volatile Scrap

Low volatile scrap is classed as having a volatile organic compound content of up to 5% by weight. This group of materials is the easiest to process and consequently the most common. Residual values for these materials tends are high and as such recycling is often done on a small profit margin. Typical materials within this area are listed below.

Aerosols:-Mainly originate from deodorants, hair sprays and cleaning sprays. Pre/Post consumer scrap may contain plastic/steel valve components as well as product contamination.

Chips:- Machining waste including turnings broken into smaller pieces.

Extrusions:- Medium gauge components often of a complex shape. Pre-consumer waste may be presented in awkward long lengths or bundles. Manufacturing scrap will usually contain low levels of contamination. Pre/Post consumer scrap may contain variable levels of contamination.

Frag/Twitch:- Broken or fragmented automotive parts. Because of the large component size the overall contamination level is usually small but concentrated areas may exist, e.g. rubber bushes/seals. Wiring/Printed Circuit Boards are becoming more frequent contaminants.

Lithographic Sheet (Litho):- High grade material used in the printing industry. Pre-consumer is coated in a layer of phenolic resin and plates are separated by paper tissue. Post consumer is further contaminated by printing inks and solvents.

Mill Foil:- This is very variable and is always manufacturing waste. Contaminated with rolling oils.

Mixed Low Copper (MLC):- General manufacturing scrap having a copper content of less than 0.4% by weight.

New Can Stock (New Can Stock):- Waste from the can forming process only contaminated with lacquer

Painted Sidings:- Building sheets contaminated with plastisol, paint or lacquer. Can be Pre or Post consumer.

Squeeze Tubes:- Aluminium tube containing a variety of products. Contaminated with paints, lacquers and the product itself. Can be Pre or Post consumer and is becoming less common as plastic and laminate tubes take over.

Turnings & Borings:- These are generally the residue from large scale machining operations. They contain cutting fluids that are an emulsion of oils and waters and can vary greatly in organic level and calorific value. They can also be classed as medium volatile scrap.

Used Beverage Cans (UBC):- The original total recycled loop product, initiated in America and now used world wide. Generally post consumer and is recycled back into can making alloys. Contaminated with paint, lacquers and can contents, - further contamination can include dirt, sand, water and tramp metals. It is worth noting that the level and composition of the coating can vary from country to country. As an example, cans from Japan will tend to contain around 50% more paint than their European or American counterparts. They also prefer bright colours that give rise to a large inorganic/organic ratio.

2.2.2 Medium Volatile Scrap

Medium volatile scrap is classed as having a volatile organic compound content of 6-25% by weight. This group of materials is becoming more common but is more difficult to process. They tend to have a lower residual value and can be less attractive to recycle. Typical materials within this area are :-

5182 End Stock :- This material is primarily manufacturing scrap rejected from the can making process. It is contaminated with wax and lacquers.

Architectural Extrusions:- These are similar to extrusion scrap but will often contain an insulating layer, known as a thermal break, within it's structure. As they are a fairly new material the majority of scrap is pre consumer. Contamination includes paints, lacquers and plastics. PVC, Epoxy resins or urethanes are commonly used as the thermal break.

Converted Foils:- Lightweight foils, highly decorative, extensively used within the packaging industry. Generally pre consumer scrap. Contaminated by lacquers and printing inks.

Epoxy Strip:- Used to manufacture containers, usually of quite a thick gauge stock and coated with high density epoxy resins.

Heat Seal Lids:- These are the lids from yogurt and butter containers. Generally they are pre consumer scrap but may exist in small quantities in DSD type material (*see section 2.2.3*). Coating is generally vinyl based.

Turnings & Borings:- some of this material may be classed as medium volatile, especially if no centrifuging pretreatment is employed to recycle the cutting fluids.

2.2.3 High Volatile Scrap

High volatile scrap is classed as having a volatile organic compound content of over 25% by weight. This group of materials are the most difficult to process, in fact many of them end up in land fill sites. Values are low and many people actually pay to have the materials removed. As land fill costs continue to rise the economics of recycling these scraps are becoming more attractive despite relatively high processing costs. Typical materials within this group are:-

Capstock:- Painted aluminium bottle tops containing a PE or PVC insert within the cap. Generally pre-consumer but becoming more common as post consumer scrap as separation techniques improve.

Composite Structures:- These are used for architectural or structural purposes, can be of a thick gauge and have a complex structure.

DSD:- Post consumer domestic waste, generally of German origin. Very contaminated with food stuffs and other waste materials. Several grades exist, each with different aluminium contents. Thickness and composition of materials varies widely.

Paper Laminates:- Aluminium with a paper backing used within packaging industry, primarily for cigarettes. Mostly pre-consumer waste.

Plastic Laminates:- Can be single (Monofoil) or multi-layered (Polyfoil) structures. Usually lightweight in nature with a low aluminium content. The aluminium fraction may be present as a surface or internal layer. Generally pre-consumer waste.

Tube Laminates:- This is used as an interim substitute for paste tubes. Becoming increasingly replaced by all plastic versions. Similar in structure to plastic laminates.

A summary of typical scraps and forms is given in Table 1 below.

SCRAP TYPE	ORIGIN	FORM	TYPICAL BULK DENSITY kg/cu m
5182 Endstock	Manufacturing	Bales	500
Aerosols	Manufacturing	Bales	500
Alulite	Manufacturing	Coils	500
Capstock	Pre/Post Consumer	Bales	300
Converted Foil	Manufacturing	Bales	700 – 1331
DSD	Post Consumer	Bales	60 – 520
DSD	Post Consumer	Loose	180
Epoxy Strip	Manufacturing	Bales	700 – 1000
Frag/Twitch	Post Consumer	Loose	670
Heat Seal Lid	Manufacturing	Bales	500 – 800
Hydropulp Cartons	Pre/Post Consumer	Loose	60 – 460
Litho	Manufacturing	Sheets	740
Litho	Manufacturing	Bales	1033
Mill Foil	Manufacturing	Bales	750 – 1275
MLC	Post Consumer	Bales	
Painted Sidings	Post Consumer	Bales	
Paper Laminate	Manufacturing	Bales	500 – 1000
Plastic Laminates	Manufacturing	Coils	1155
Plastic Laminates	Manufacturing	Bales	
Plastic Laminates	Manufacturing	Sheets	
Squeeze Tubes	Manufacturing	Bales	1000
Tube Laminate	Manufacturing	Sheets	200 – 300
Turnings/Swarfe	Manufacturing	Loose	800
Used Beverage Cans	Post Consumer	Ripped	100
Used Beverage Cans	Post Consumer	Bales	170 – 620
Used Litho	Manufacturing	Bales	740 – 1050
Window Frames	Manufacturing	Loose	351

Table 1 Scrap Data

2.3 Aluminium Coating Types

Many types and forms of coating exist on the aluminium product scraps encountered within the recycling industry. The combination of coating composition and scrap structure has a profound effect upon decoating, subsequent processing and emission release characteristics.

Typical coatings include oils, paints, resins, plastics, lacquers, paper and inks, and these can be associated with product scraps as diverse as foils or engine blocks. Each particular scrap type has its own characteristics which must be known and catered for in the process design if adequate decoating coupled with minimum emissions are to be achieved.

Over the past ten years Stein Atkinson Stordy has built up a database covering most individual scrap types, typical selection being given in Table 2.

Scrap Type	Coatings / Structure	Coating Weight %w/w	Al Gauge micron	Form	Source
Aerosols	lacquers / paints	2-3	300-400	Bale	cons / manufact
Capstock	polymers / lacquers	30	250	Bale	cons / manufact
Converted Foil	inks / lacquers	7	12-40	Coil / Bale	manufacturer
DSD	various	<85	-	Bale / Loose	domestic
Epoxy Strip	epoxy / paint	6	85	Bale	manufacturer
Frag	oil / paint /polymers	<4	-	Loose	post consumer
Lid Stock	vinyls	8	38	Bale	manufacturer
Litho Plate	phenolic resin / paper	<4	290-350	Bale / Sheet	manufacturer
Mill Foil	rolling oils	<10	50-400	Bale	manufacturer
Paper Laminate	paper / inks	50 –60	7	Sheet	manufacturer
Plastic Laminate	polymers /inks / wax	40-90	7-14	Coil / Sheet	manufacturer
Sidings	paints	3	-	Bale	cons / manufact
Tube Laminate	polymers / lacquers	70	40	Sheet	manufacturer
Turnings	cutting oils	<20	-	Loose	various
U.B.C / New Can Stock	lacquers / paints	2-3	<300	Bale	cons / manufact
Used Litho	phenolic resin / inks	2	290-350	Bale	end user
Window Frames	thermolacquers / resins	21	-	Loose	manufacturer

Table 2 Scrap Coatings

As can be seen, coating levels vary from 1% to 90% by weight. They can be present purely as a surface coating (e.g. used beverage cans, epoxy strip) or as part of a multi-layered laminated structure (e.g. foils and laminates).

2.3 Aluminium Coating Types

The laminated structures prove the more difficult materials to decoat successfully due to the high proportion of coating combined with the thin, fragile nature of the aluminium layers bound up within the overall structure. Potentially, laminates can also be associated with the greatest risk of toxic emissions due to the higher proportion of plastics, polymers and lacquers present.

Coatings are composed of two basic materials – organic and inorganic .

The organic portion comprises the volatile elements such as oil, solvents and carbon based deposits. This is the material removed by any thermal based decoating system and gives rise to the generation of volatile organic compounds in the waste gas stream from the decoating kiln.

The inorganic portion of the coating is made up of ash, fillers and pigments used mainly for decorative purposes. Typical inorganic pigments are based on titanium dioxide or zinc oxide and are prevalent in brightly coloured packaging materials and beverage cans. No thermally based decoating system can remove these compounds and they usually remain on the scrap surface in the form of a white or lightly coloured friable deposit. Some of this can be removed by the action of the rotating kiln and either gets picked up by the waste gas stream or carried out of the kiln with the scrap flow. Inorganics can make up to 50% of the total coating weight of some types of packaging scrap.

Other contaminants may be present, depending on the type and source of the scrap. Water, oil, sand and product residues are typical contaminants found in post consumer wastes. These play a part in the decoating process and contribute to the composition of waste gases and their subsequent processing.

CHAPTER THREE – SCRAP PREPARATION

Scrap preparation is a large and complex subject in itself and is very scrap specific. Some scraps may need extensive preparation for the decoating process, others may be fed directly into the kiln as-received. The following is a brief outline of the typical requirements and methods met in the decoating industry.

3.1 Requirements for Decoating

The presentation of scrap to the decoating kiln is very important for effective processing. Ideally the scrap feed should consist of individual pieces or shreds having a large surface area / volume ratio. The pieces should be of a size and shape to facilitate transport into the kiln without "bridging" or "sticking". Typically pieces of about 25 – 50 mm (1"-2") square are considered to be ideal.

A large surface area is required to maximise gas / metal contact and so minimise heating rate and reaction time. To ensure intimate gas contact an open structure with no folded or trapped coated surfaces is preferred.

Often poor or inadequate decoating can be traced to poorly shredded or prepared feedstock. Increased metal losses can result from "fines" (produced by incorrect preparation) being lost within the mechanical handling and decoating systems.

Removal of tramp metal and inerts such as foreign bodies, dirt and sand, should be undertaken to prevent abrasion, blockage and subsequent melt cleanliness problems.

3.2 Sizing

The reduction of as-received scrap into a form suitable for decoating is usually undertaken by one of three basic methods:-

3.2.1 *Cropping*

This procedure is employed for cutting long lengths of scrap, usually extruded or folded sections, into short pieces suitable for charging into the kiln. Relatively simple low power machines are utilised and few fines are generated by this method.

3.2.2 *Fragmentation*

Large, high energy machines are used to shatter and crush large sized components such as engine blocks and castings into suitably sized pieces. Fragmenters tend to be of very robust construction to withstand the forces employed by this technique and require substantial foundations. They are very noisy in operation and sound insulation is often employed to reduce exposure. Dust and fines can be generated by this procedure and dust extraction over the feed hopper is a common feature.

3.2.3 *Bale Breaking*

Some types of scrap can be supplied in a dense bale form to facilitate cost effective transport and storage. To aid subsequent shredding dense bales can be broken up into more manageable pieces in a bale breaker. This machine is usually a simplified version of a fragmenter or hammer mill type machine.

3.2.4 *Shredding*

Shredding is the process used on the majority of scrap encountered within the industry. The scrap is cut and torn to produce a sized and open product. Good shredding will also reveal the interior of the scrap to allow the decoating gas stream to contact any coated inner surfaces (e.g. Used Beverage Cans and packaging scrap).

Shredding machines can be grouped conveniently into two basic types:-

- Hammermills
- Rotary Shears (Monoshear / Contrashear)

3.2.4.1 Hammermills

These high energy machines shred by the action of rotating hammers through an anvil type grate arrangement. An acceptable shredding action requires good design coupled with careful setting up and regular maintenance. If these parameters are not met the scrap tends to be flattened or a large amount of fines can be produced, accompanied by an increase in energy consumption and noise. Although the traditional choice for Used Beverage Cans type scrap, Hammermills cannot be used for foil and thin gauge materials without producing excessive fines.

Hammermills require substantial foundations and employ acoustic housings and dust extraction to satisfy environmental health considerations.

Figure 1 Hammer Mill Shredder

3.2.4.2 Shears

This type of machine generates a cutting and tearing action on the scrap by rotating cutters.

Single (Monoshear) types utilise a multi-toothed single rotor working against a fixed anvil, the scrap being forced into the rotor by a controlled hydraulic pusher.

Twin (Contrashear) type machines force the scrap between two contra-rotating toothed rotors. The action of the rotors tends to pull the scrap through the machine as the shredding proceeds.

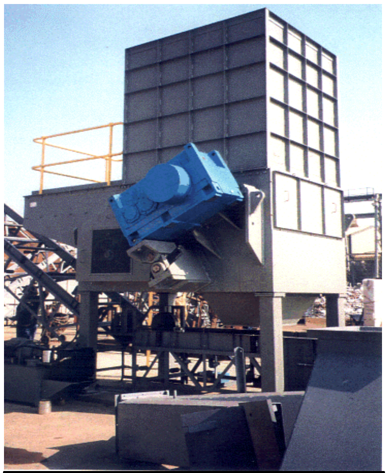


Figure 2a Mono Shear Shredder

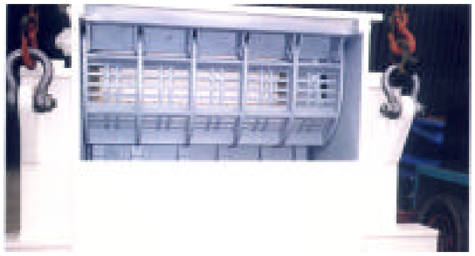


Figure 2b Mono Shear Front Grid

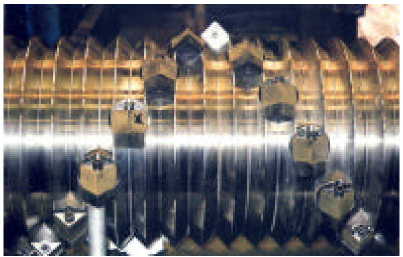


Figure 2c Mono Shear Rotor & Cutters

These machines are characterised by lower energy consumption and quieter mode of operation than Hammermills. Often this type of machine does not need specialised foundations. They are more suited to thinner foil and laminate type scraps where the cutting action produces a more open shred with fewer fines. In some cases hopper dust extraction may be required.

Each of the above sizing methods has its own characteristics and may be suited to a particular scrap type. For plants employing a mixed scrap feedstock the choice of sizing method(s) in order to ensure flexibility becomes a critical issue. In this case there is no substitute for the experience and expertise of the machine supplier.

	Hammer Mill	**Impact Crusher**	**Twin Shaft Contra-Shear**	**Mono-Shear**
Shredding Action	Impact	Impact	Shear	Shear
Compaction of Shredded Product	Medium	Medium	High	Low
Uniformity & size of shredded product	Poor	Poor	Poor	Good
Generation of Fines	High	High	Low	Low
Ability to handle bale & coils	Poor, bales only	Poor bales only	Poor	Good
kWh/t for shredding loose Used Beverage Cans Bales to2” pieces	42.0	N/A	88.0	27.0
Cost of Electricity $/Ton[1]	$2.52	N/A	$5.28	$1.62
Cost of replacement Cutters $/Ton[2]	$3.01	N/A	$1.46	$2.56
Total Running Cost $/Ton[3]	$5.53	N/A	$6.74	$4.18
Noise	Poor	Poor	Good	Good
Safety	Poor	Poor	Good	Good
Purchase Cost	High	Moderate	Moderate	Low

Table 3 A comparison of shredder technologies

Notes

1. Cost of electricity is based on a price of $0.06 per kW/Hr
2. Replacement cutters based on Used Beverage Can material.
3. Running cost (Electricity & Cutters) does not take into account other maintenance costs or capital equipment cost.

3.3 Grading + Separation

For installation utilising post consumer scraps this procedure is essential as the risk of contamination by tramp metals and foreign bodies is high. Normally these scraps are purchased on a weight basis and it is not unknown for scrap to be contaminated by steel and other metals to increase the weight and so the price of baled material.

It is usual practice to undertake these operation after shredding / sizing and before decoating. In some cases however, it is carried out after decoating because the scrap is cleaner, more defined and any "sticky" residues have been removed. The decoated scrap must be allowed to cool before magnetic separation takes place and so this technique is not suitable for continuous processes where the hot decoated material is charged directly into the melting furnace.

3.3.1 Grading

This is the removal of small contaminants and fines from the feed stock. It is undertaken most easily by means of simple vibratory screens of suitable grid size.

3.3.2 Separation

Depending on scrap contamination, two systems can be employed

- Magnetic Separators - are used to remove ferrous metals and ferritic / martensitic stainless steel from the scrap. They are of relatively simple design and can be very effective.

- Eddy-Current Separators - are used to remove austenitic stainless steels, non-ferrous metals and some plastics from the waste stream. They can be more complicated and difficult to set up to give efficient separation. Again separation is a specialist area where the expertise of the equipment manufacturers is critical.

Figure 5 Combination Separator

3.4 Materials Handling

The transfer and holding of the material to and from the decoating kiln is a fundamental part in the success of any plant. It is a complex subject in itself and as such is outside the scope of this handbook, other than a brief outline of the type of equipment available. The final choice will depend on the physical characteristics of the scrap and the layout of the plant. Typical methods of handling are:-

- Bucket conveyors – used for vertical / step lifts in confined spaces.
- Vibratory Spiral Conveyors - used for vertical lifts in confined spaces but restricted to non-bridging scraps. Can be noisy.
- Inclined Conveyors - generally very robust conventional technology but can be very space consuming. Many designs of belt / material available – consideration must be given to material / ambient temperatures.
- Holding Hoppers - Can be a difficult area due to bridging / feed problems. Many proprietary designs are available, utilising vibratory or acoustic methods for preventing blockage. Very scrap specific.
- Screw Conveyors - Very useful for moving granular / uniform scrap. Can be prone to plugging with some type of material

CHAPTER FOUR – THE DECOATING PROCESS

4.1 Methods

Decoating plant generally falls into one of the following process groups:-

4.1.1 *Pyrolysis*

Numerous attempts, some on-going, have been made to remove coatings by pyrolysis. The attraction of pyrolysis is that the coating can be thermally degraded into the basic components, namely carbon, oil and gas. These byproducts can be used to heat the pyrolysis unit or, given good quality, be sold. Pyrolysis is not an economical process for low coating weight material. The future for pyrolysis will be for materials having coating weights sufficient to make the process cost effective and this probably means coating weights in excess of 25%.

4.1.2 *Twin Chamber Furnaces*

In this equipment the coated scrap is charged into one chamber and the evolved gases are either passed directly to the second chamber and combusted or routed to an afterburner for combustion and the heat used for heating the second chamber. This method of decoating has not been widely accepted due to lack of process data and reported mechanical problems. It is more suited to heavy grade scrap types. It should also be remembered that any dirt, dust, water or other contaminants within the scrap will be charged into the furnace. This can give rise to safety issues and potential contamination of the melt composition.

4.1.3 *Bed Type Ovens*

Ovens can be arranged with stationary fixed beds (batch type) or with moving belt beds (continuous type). In each case hot decoating gases are passed through the scrap bed prior to discharging to an afterburner system and returning to the oven or exiting the system.

Ovens suffer from variable decoating quality through the bed due to stratification - there is no agitation or mixing of the scrap within the gas stream.

4.1.4. *Rotary Kilns*

The rotary kiln can be described as the workhorse of present day decoating. Over 90% of decoating is currently carried out in rotary kilns. The choice of rotary kiln is between the concurrent (parallel) and the counterflow types. Which ever type is used, the basic technology remains the same. Hot gas flows through the kiln under controlled conditions of temperature and oxygen content. The kiln exit gas containing evolved combustibles is passed to an afterburner or thermal oxidiser and is combusted. A significant proportion of the combustion products is returned to the kiln for the processing, thus creating a recirculation loop

4.1.4.1 Concurrent (Parallel Flow) Kilns

Environmental regulations often require the afterburner to operate at temperatures in excess of 800°C (1472°F) for the efficient destruction of the volatile organic compounds released from the kiln.

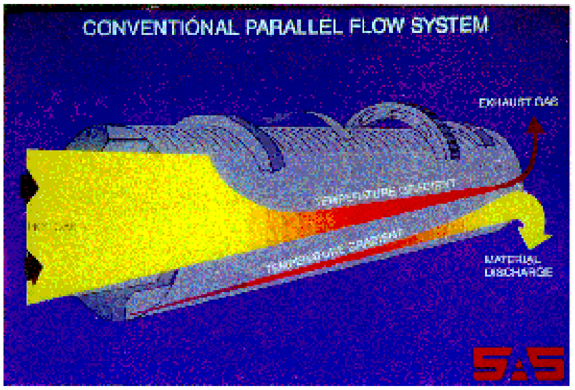


Figure 6 Parallel Flow Type Kiln

In a concurrent system, gas at this temperature is passed directly to the charge end of the kiln and is in immediate contact with the incoming scrap. The gas then travels down the kiln parallel with the scrap and exits at a temperature of around 540°C (1000°F). Simultaneously with the reduction in temperature there is a reduction in oxygen level as oxidation of the organics takes place. Although this reduction is offset, to some extent, by air entering through the kiln seals, good decoating requires the highest oxygen at the discharge end to remove the carbon film remaining after the removal of the volatile component of the coating.

Since temperature and oxygen are highest at the charge end of the kiln, serious temperature excursions can occur necessitating the use of water sprays even with low volatile materials such as used beverage cans. It follows, therefore, that concurrent kilns will have difficulty in processing higher volatile material such as borings and turnings and packaging. Because of the high entry gas temperature concurrent kilns have to be refractory lined. Consequently, there is an energy penalty due to long heating times and a maintenance penalty due to abrasion.

Moisture content has a serious effect on the performance of concurrent kilns. High moisture levels absorb sufficient heat to affect the thermal efficiency of the kiln and necessitating a significantly higher gas flow resulting in increased energy use and erratic control of kiln temperature.

4.1.4.2 Counterflow Kilns

In counterflow kilns the hot gas from the afterburner enters the kiln at the metal discharge end and flows counter to the scrap movement. This ensures the highest temperature and oxygen are in contact with the scrap exactly where it is needed. Consequently, counterflow kilns produce very good quality decoating. As the gas travels from discharge to charge end of the kiln there is an accompanying reduction in temperature and oxygen level thereby avoiding temperature excursions and removing the necessity for water sprays. Counterflow kilns do not require an internal refractory lining. It is common practice to externally insulate the kiln with 50 mm (2") of aluminium clad fibre. This provides for a quick start up and low maintenance.

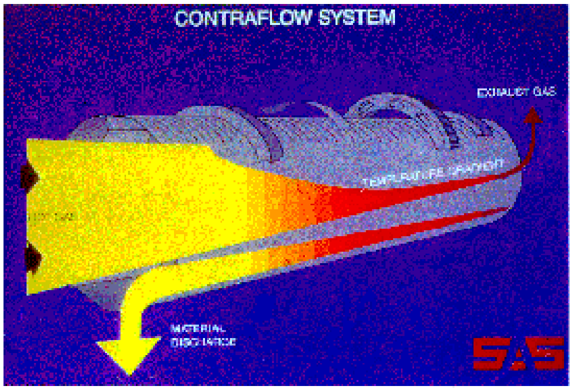


Figure 7 Counter Flow Type Kiln

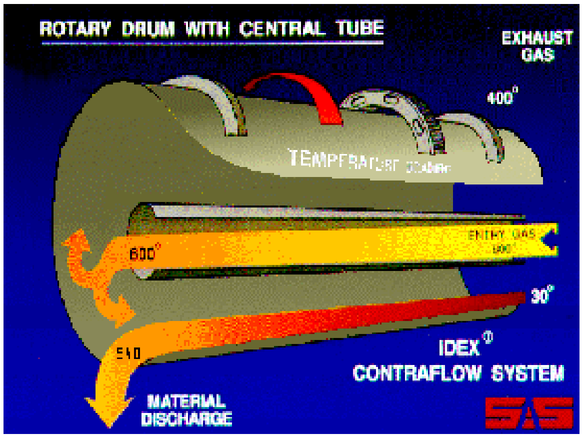


Figure 8 IDEX Type Kiln

The gas containing the volatile organic compounds is extracted at the charge end of the kiln and hence the evolved gases have little or no influence on the decoating process occurring further down the kiln.

Thermally, the counterflow system is more efficient than a parallel system in the same way as counterflow heat exchanger is more efficient than the parallel flow type.

4.1.4.3 Stein Atkinson Stordy Ltd IDEX® System

The traditional counterflow kiln has a high thermal efficiency and as a result the gas exit temperature is generally in the range 125 – 180°C (250 – 350°F). Paint in coatings contains very light oil fractions which are vapourised during processing but subsequently condensed in the exit ductwork. Under certain conditions of temperature and oxygen level the oil deposits would ignite.

The initial Stein Atkinson Stordy Ltd solution to this problem was to install a small burner in the duct immediately after the kiln gas exit. The burner output was sufficient to raise the gas temperature above the condensation point but not high enough to create a hazardous situation.

Whilst the duct burner solved the problem it was not considered a satisfactory engineering solution.

It was from discussions on this situation that the IDEX® design originated. In the IDEX® decoater the hot gas from the afterburner travels down a central tube inside the rotary drum and returns counterflow to the scrap. The tube is in effect an internal heat exchanger. The hot gas from the afterburner creates a highly radiant surface over the first 2 metres (6') of the tube. This is sufficient to raise the exit gas temperature above any oil condensating point whilst still maintaining the benefits of counterflow heating. The kiln processing temperature is controlled at a point adjacent to the end of the IDEX® tube, before the gas returns up the kiln.

An additional benefit from the IDEX® design is a more compact system as the gas inlet and outlet are contained in a single hood at the charge end of the kiln.

4.1.5 *Other Methods*

These include oxyfuel and microwave. Single units have been built, but for various reasons none have found acceptance in the industry.

The following discussions are based primarily on rotating kiln technology but some aspects can be applied to any thermal based decoating process.

4.2 Process Considerations

For any thermal based decoating system the object is to remove the organic coating from the surface of the scrap so that when the material is melted the highest recovery rates will be achieved. To achieve this, four process parameters are required to give optimum results:-

- Temperatures
- Oxygen Levels
- Residence Time
- Gas/Metal Contact

In simple terms decoating can be considered to be a two stage process. The first Stage is to liberate volatile organic compounds from the surface of the scrap by converting them into a gaseous state. This process requires a low temperature and oxygen level to achieve without flaring in the kiln. From our own research work it can be shown that the evaporation of certain coatings can begin at temperatures as low as 60°C. Any water present within the scrap is vaporised and carried from the kiln with the exhaust gases.

Figure 9 shows the effect of temperature on the coating for various Used Beverage Cans at an oxygen level of 11%. In this case there is a relatively dormant period up to around 150°C where mainly the water is removed, the majority of the coating being removed between 150°C – 550°C.

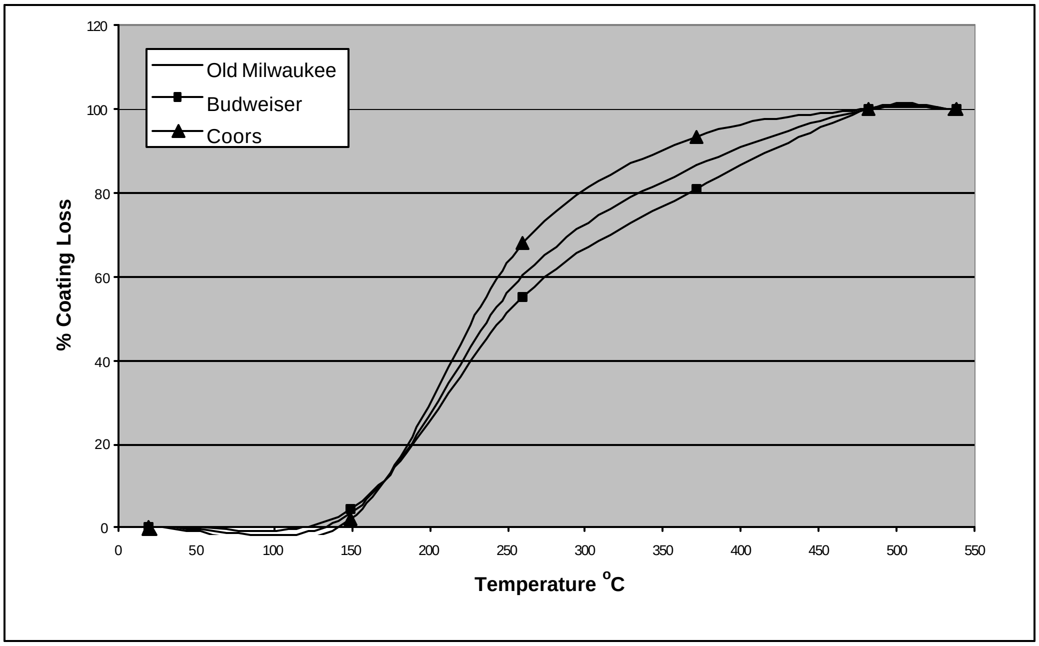


Figure 9 Typical Used Beverage Cans Coating Loss

The second stage of decoating is to remove any carbon based residue remaining on the surface of the scrap by conversion to Carbon Monoxide. This process requires more oxygen and a higher temperature than in stage one to achieve best results, but should be below the point at which oxidation of the scrap will occur. Once scrap begins to oxidise its weight will increase.

Table 4 shows this effect on used beverage cans. It can be seen in this case that increasing temperature from 482°C to 538°C has in fact caused a slight increase in can weight. It is important that this should not be confused with an increase in yield as once this material is melted the apparent gains will become substantial losses.

	Weight of Cans (grams)		
Temperature °C	Old Milwaukee	Budweiser	Coors
22	11.78	12.07	11.44
149	11.77	12.05	11.44
260	11.60	11.84	11.26
371	11.52	11.73	11.19
482	11.48	11.65	11.17
538	11.48	11.66	11.18
Total Weight Loss	0.31	0.42	0.27
Total Weight Loss %	2.60	3.47	2.37

Average Coating Loss = 2.811%

Table 4 Weight Loss of Used Beverage Cans

The data above is only relevant to a specific used beverage can coating. Each coating will have its own characteristic which must be known for successful plant design.

For decoating to proceed as described above sufficient residence time and intimate gas/metal contact as each stage is essential. Too little time or agitation within the kiln will result in incomplete decoating and excessive time and agitation will give rise to oxidation and degradation of the product.

4.3 Controlling the Process

4.3.1 Kiln Temperature

Actual methods of controlling kiln temperatures will vary depending upon the type of decoating system employed. Generally one of the following methods is used:-

- *Heat Exchanger Exit Temperature*

Usually the gases entering the kiln have previously passed through an afterburner system operating at high temperature. These gases are normally cooled by some form of heat exchanger before they re-enter the kiln. By adjusting the heat exchanger the temperatures of the gases entering the kiln can be controlled.

- *Recirculating gas Flow Rate*

The kiln temperature can also be adjusted by controlling the rate of recirculation gases, normally by a variable speed fan. By increasing the recirculation rate the kiln temperatures will rise, providing the temperature of the kiln entry gases is above the required set point.

- *Scrap Feed Rate*

Heat can also be generated with the kiln itself. As the volatile organic compounds are liberated into the gas stream there is a small amount of oxygen present that will support a slow combustion. This generates heat within the kiln and, if not properly controlled, will give rise to severe temperature excursions. This becomes more of a problem when processing high volatile scrap types as the general level of VOCS within the kiln is high.

- *Afterburner Chamber Temperature*

The afterburner needs to operate at a sufficient temperature to destroy the Volatile organic compounds. Heat demand in the afterburner is normally met via a burner system operating on either gas or some form of oil. Heat is also released via the combustion of the VOCS contained within the kin exit gas. As the level of VOCS increases the burner system will turn down to maintain the same energy equilibrium, saving fuel in the process. Should the VOCS drop then the burner will increase its firing rate. Burners should have a good *turndown* to make the most of the free energy contained within the scrap.

It should be noted that if the level of Volatile organic compounds is high then it is possible for their energy release alone to be in excess of the process requirement. This will cause the temperatures in the afterburner to rise and some method of reducing temperature must be employed. This state is often referred to as being *autothermic*.

4.3.2 *Oxygen Levels*

Kiln oxygen levels are generally set by adjusting the oxygen content of the gases being recirculated from the afterburner. These will be of a reduced oxygen level, typically below 10% and actual levels are adjusted by adding air to the gases to increase its oxygen content as necessary.

Basically oxygen is admitted into the process by two ways:-

- By secondary air injection directly into the afterburner chamber.

- By air ingress into the kiln body via gaps between the rotating and stationary sections of the kiln or via scrap input/output mechanisms. The amount of air, and hence oxygen, drawn into the system will depend on the actual clearances and the operating negative pressure of the kiln. Although this is a relatively cheap and simple method of oxygen control, its inertia and lack of precision make it suitable only for low volatile materials. Another significant disadvantage is its detrimental effect on fuel consumption.

4.3.3. *Kiln Residence Time*

The residence time of the scrap within the kiln body is determined by the slope of the barrel, speed of rotation and the design of internal *flights*. Each material has an ideal *residence time* within the kiln barrel. This time is adjusted by changing the speed of rotation of the kiln barrel. The slower the kiln rotates the longer the material remains inside the kiln. In general the thicker and heavier the material the longer the residence time needed for quality decoating. Residence time will effect the final temperature the scrap reaches within the kiln barrel. The velocity of gases passing through the kiln may also effect the progress of material through the kiln. Each material possesses a *lift off velocity*, above which it will be transported within the gas stream. The kiln barrel should be so designed to prevent this critical gas velocity from being approached or exceeded.

4.3.4 *Gas/Metal Contact*

This is a function of kiln rotational speed and internal flight design. Inside the kiln barrel there are a number of flights, or lifters, which are used to raise and drop the scrap material so that it mixes with the process gases. Flight geometry can have a significant effect on metal/gas contact and good design is essential to ensure efficient mixing without material attrition within the kiln.

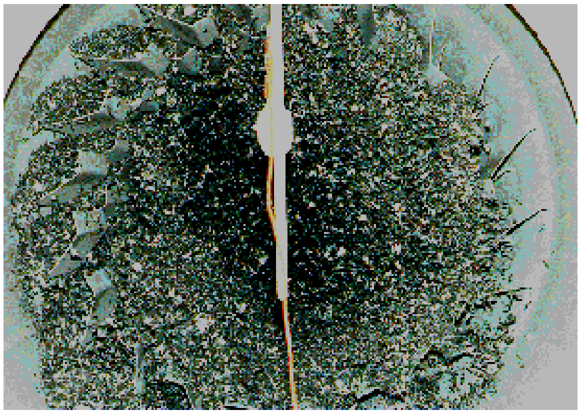


Figure 10 View Inside Kiln Showing Flights

CHAPTER FIVE – IDEX DECOATING PRACTICE

This chapter is concerned with the specific aspects of IDEX kiln operation and control.

5.1 Kiln Discharge End Temperature

The temperature at the kiln discharge is controlled to ensure a well decoated final product. A thermocouple measures the temperature of the process gases and adjusts the speed of the recirculation fan to maintain temperature. If the temperature is lower than the required set point then the fan speed is increased. This will, in turn, increase the flow of hot gases from the afterburner chamber and hence provide more heat. If the temperature is higher than the required set point then the fan speed is decreased. This will, in turn, decrease the flow of hot gases from the afterburner chamber and hence provide less heat. The hot gases from the afterburner pass down the centrally mounted IDEX tube, cooling as they pass. The IDEX tube, therefore, acts as a very simple heat exchanger giving up heat to the scrap and kiln exit gases by radiation. The tube also protects the scrap from high gas temperatures that could give rise to oxidation.

The Gases enter the IDEX tube at near afterburner temperature and exit the tube at around 600^{o}C.

5.2 Kiln Speed

The kiln rotational speed is adjusted by the kiln drive motor. Each material has an ideal residence time within the kiln barrel. This time is varied by changing the speed of rotation of the kiln barrel. The slower the kiln rotates the longer the material remains inside the kiln.

5.3 Kiln Pressure Control

The decoating kiln must be operated at a slightly negative pressure to ensure that process gases remain within the system and that the infiltration of air into the drum is kept to a minimum. High negative pressures will give rise to high system oxygen levels and a reduced thermal efficiency.

Kiln pressure is measured by a pressure transducer at the kiln discharge end. Control of the pressure is achieved by a two stage approach. The bag filter exhaust fan, which is invertor controlled, provides finite adjustment of system pressure. As kiln pressure increases the exhaust fan will increase in speed to pull more gases out of the system and maintain an even pressure. Should the exhaust fan speed reach an upper limit then the pressure control valve is opened slightly to give a coarse adjustment in the flow of gases. As kiln pressure decreases the exhaust fan will decrease in speed to pull less gases out of the system and maintain an even pressure. Should the exhaust fan speed reach a lower limit then the pressure control valve is closed slightly to give a course adjustment in the flow of gases.

This two stage approach to pressure control gives excellent results when used with a variety of scrap types. Each material is different, as the level of Volatile organic compounds increases then there will be more gases to be extracted from the kiln. A single stage approach to pressure control is only suitable when there is minimum variation between material types.

5.4 Afterburner Temperature

Good afterburner temperature and oxygen control are required to ensure that emissions are minimised.

The temperature in the afterburner is controlled via the burner system. A thermocouple at the exit of the afterburner monitors the temperature of the gases leaving the chamber. If the temperature is below the required set point the combustion air and gas valves are opened to increase the output of the burner, providing more heat to the gases. If the temperature is above the required set point the valves are closed to decrease the output of the burner.

As the volatile organic compounds are liberated within the kiln they pass through to the afterburner where they are incinerated. This will cause the burner system to turn down as the VOCs are used to provide a larger portion of the heat required.

Figure 13 shows the theoretical relationship between VOC destruction and afterburner temperature. It can be seen that a minimum temperature of around 760^{o}C is required to give good destruction efficiencies. However, this low temperature can give rise to high CO levels and hence a higher temperature of 800^{o}C is employed to give good VOCs destruction combined with low CO levels. These are theoretical levels and it is our policy to employ the higher afterburner level of 830^{o}C as a design point.

If the heat released by the combustion of volatiles is greater than the process needs the system is said to be "autothermic", resulting in runaway afterburner temperatures and loss of process control. Introduction of dilution air into the afterburner is not possible as this will upset the oxygen balance of the system.

Most scrap containing over 5% volatiles is capable of producing autothemic conditions. To control this situation Stein Atkinson Stordy has developed a number of control techniques that enable the afterburner and oxygen levels to remain constant as the type and quantity of material varies.

CHAPTER SIX – AFTERBURNER DESIGN

Volatile organic compounds, carbon monoxide and carbon are destroyed by controlled incineration or afterburning. The kiln exhaust gas is passed into the afterburner chamber and after incineration a portion is returned to the kiln to drive the decoating process, the excess being directed to atmosphere after appropriate treatment.

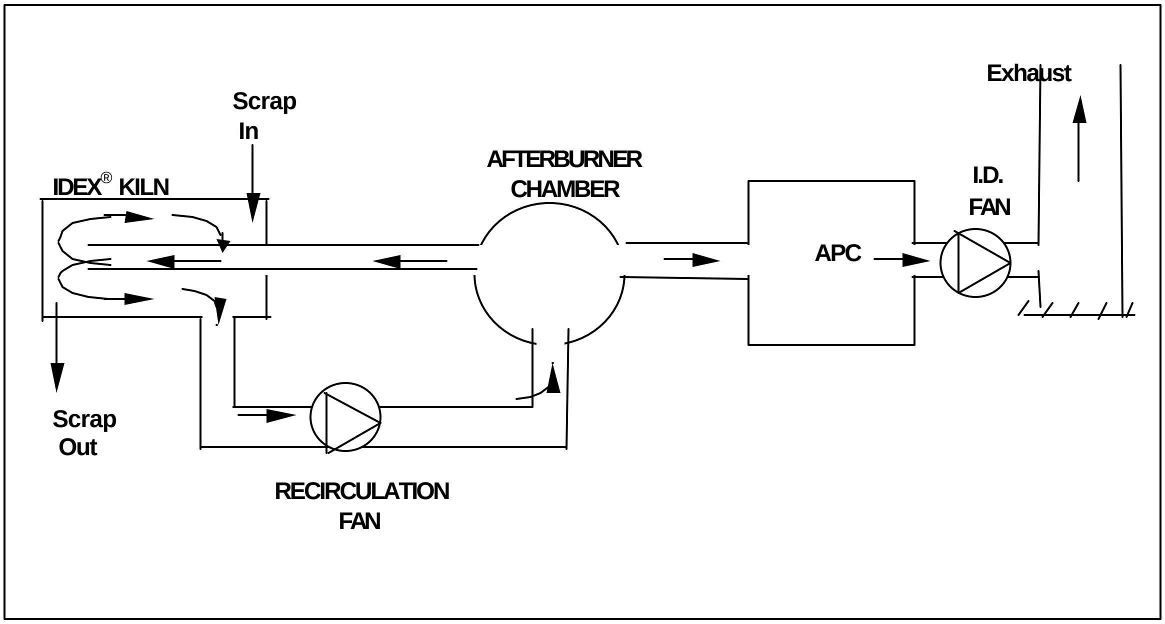


Figure 11 Schematic Of IDEX System

After burner design and operation are crucial to minimise emissions.

6.1 Design Parameters

There are three major design parameters to be considered for successful afterburner operation:–

- Time
- Temperature
- Turbulence

6.1.1 Time

The afterburner chamber needs to be of sufficient internal volume to allow effective combustion of the volatiles at its operating temperature. Excessive times, however, will result in overlarge chambers with a corresponding increase in both capital and energy costs. The general effect of residence time on Volatile organic compound destruction and operation temperature is given in Figure 12.

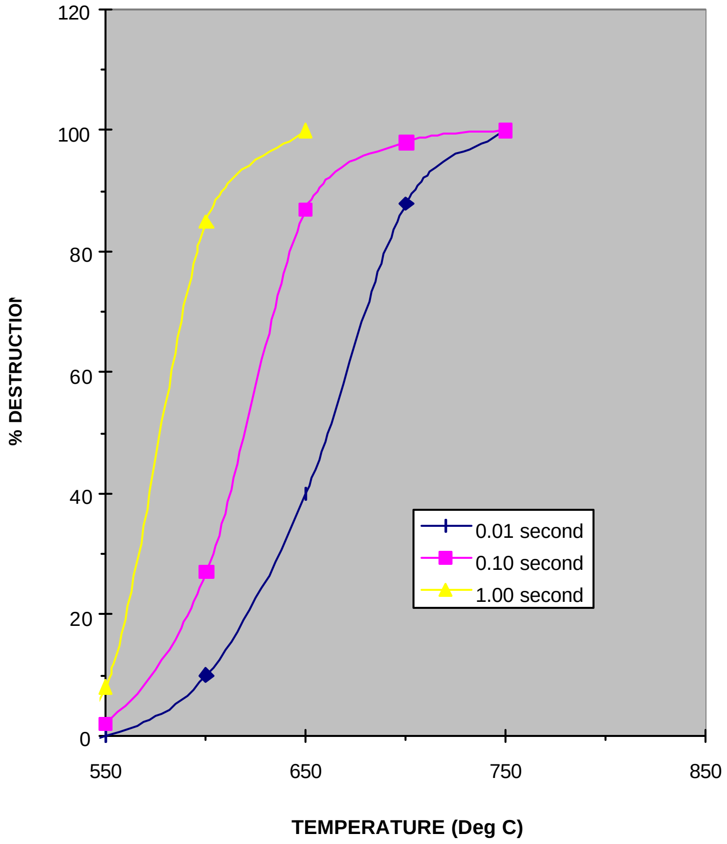


Figure 12 Effect of Residence Time

In specified cases emission regulations may require a minimum residence time to be employed. Practically, residence times of between 1 and 2 seconds are utilised to ensure efficient volatile destruction.

6.1.2 Temperature

Incineration temperature is very important for efficient pollutant destruction as shown in Figure 13.

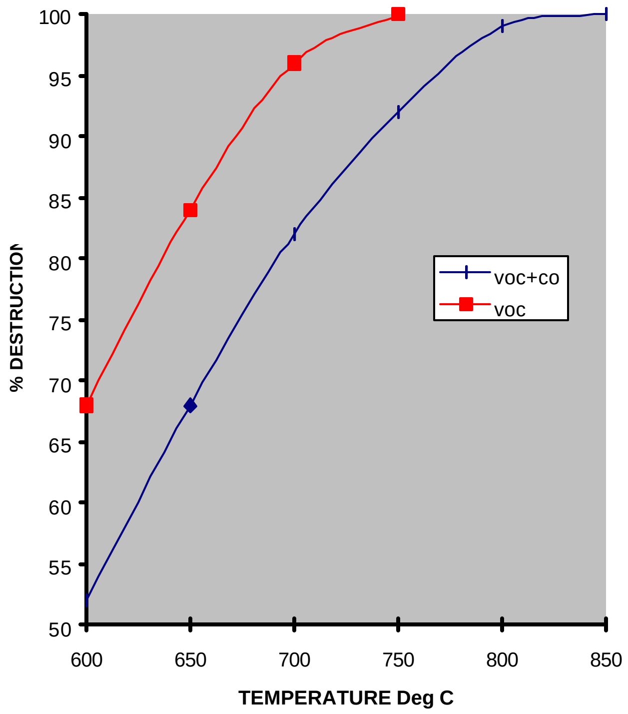


Figure 13 The Effect of Temperature

It can be seen that a minimum afterburner chamber temperature of 750°C is required to maximise Volatile organic compound destruction. However, to ensure the conversion of any CO present to CO_2 a higher temperature is required, usually 800°C / 850°C is employed to give good results.

To prevent problems during start up, the chamber lining should be thoroughly soaked at temperature before processing commences.

Again emission regulations may specify afterburner temperatures in certain cases.

6.1.3 Turbulence

Good mixing of waste gas and any supplementary air within the chamber is essential for good combustion. To ensure effective destruction the inlet ducting should be arranged to direct the volatile laden gas into the flame envelope. The siting of any outlet ductwork should be arranged to prevent any risk of short circuiting part of the afterburner chamber. Chamber shape and geometry is important to encourage good gas flow distribution, and minimise risk of particulate deposition (especially with coatings having a high ash content).

The above considerations rely on there being adequate oxygen present, either via burner combustion air or supplementary air addition directly into the chamber, for complete combustion of the volatiles and carbon monoxide. Emission regulations may specify a minimum oxygen content within the afterburner in certain cases. Typically oxygen contents in the range of 2% to 10% by volume are encountered in decoating, depending on the scrap / coating being processed.

6.2 Fuel Consumption

Fuel consumption of a Kiln type decoating system is governed by the fuel consumption within the afterburner and is very difficult to predict. There are many factors that effect the efficiency of the system. Examples below assume a Used Beverage Cans type operation processing 10,000kg/hr.

6.2.1 *Ambient Temperature*

The ambient temperature will effect the temperature that the scrap is charged into the system and also the heat losses from the decoating system. As an example a change in ambient temperature from 30°C (86°F) to 0°C (32°F) will increase fuel consumption by around 3%.

6.2.2 *Burner System*

The burner system can be designed to accept pre-heated air. Often this can be generated by cooling the waste gases from the afterburner exhaust. A change in burner air temperature from 30°C (86°F) to 400°C (752°F) will yield a fuel saving of around 20%. Also Pre-heating the secondary air (see glossary) will give an overall saving of around 48%. Pre-heated combustion air will give an increased level of NOx in the exhaust gas.

6.2.3 *Plant Layout*

For some plants it is necessary to locate part of the equipment, such as the afterburner, outside to save on space. This will increase the heat loss from the system and hence the overall fuel consumption.

6.2.4 *Processing Oxygen Level*

Different materials will require different oxygen levels to give the best decoating results. As the level of oxygen increases the fuel consumption will also increase.

6.2.5 *Volatile organic compounds Level & Type*

Each scrap has its own type and quantity of coating present on the surface. As the quantity of Volatile organic compounds within the coating increases the fuel consumption decreases.

Specific energy values for different coatings differ widely, from around 7,500 Btu/lb for paper up to 20,000 Btu/lb for polyethylene.

6.2.6 *Water Content of the Scrap*

Any water present within the scrap will be converted to steam within the kiln barrel and pass into the afterburner chamber where it will be superheated to afterburner temperature. As a rough and ready guide each 1% water within the scrap will add between 25-30Btu/lb to the fuel consumption.

CHAPTER SEVEN – AIR POLLUTION CONTROL

7.3 *Environmental Regulations*

Historically, the installation of emission control measures has been forced upon Industry by political and environmental pressure rather than economic or moral issues. The main instruments for driving Industry towards a cleaner environment are legal regulations, both at International and Local level. This section identifies the appropriate regulations that apply to the decoating process within these markets and they are summarised in Table 5.

7.1.1 Europe / UK

Germany has traditionally led the way with environmental regulations, the document "Technical Instructions on Air Quality Control" (Ta Luft) being adopted by most European authorities as the benchmark for air pollution control. Within Europe emission limits are usually set on a process by process basis. Each process group is assigned emission limits for the appropriate pollutants based on concentration under standard reference conditions and oxygen content. The application of reference oxygen levels is to prevent attaining the required pollutant concentration purely by air dilution of the waste gas prior to discharge into the atmosphere.

The Ta Luft standard generally considered applicable to decoating is section 3.3.8.3.1 – "Facilities for the Recovery of Individual Components from Solid Substances by Combustion".

Environmental control within the UK is administered by the Environmental Agency. Generally, these emission limits follow the same format and impose similar limits as Ta Luft concerning airborne pollutants but also include land and waterborne emission aspects. The note considered most applicable to the decoating process (probably due to the afterburning aspect) is IPR 5/1 – "Waste Disposal and Recycling Merchant and In-House Chemical Waste Incineration".

7.1.2 *USA*

Generally, the emission requirements for decoating plants within the USA is less unified than in Europe. They vary from State to State but are usually based on a permit to operate system using a maximum mass of pollutant discharged per specified timebase.

EPA 42 is often used as guidance for processes involving natural gas combustion. Some authorities apply efficiency criteria to the Air Pollution Control systems themselves.

MARKET		U.K	GERMANY	U.S.A
STANDARD No		IPR 5 / 1	Ta Luft 3.3.8.3.1	E.P.A 42
Reference	Temp	0 Deg C	0 Deg C	
	Pressure	1013 mb	1013 mb	
	Oxygen	11% v / v	11% v / v	3% v/v
	Water	0	0	
mg /Nm^3	NO$_X$	350	500	2240 kg/10^6 m^3
	SO$_2$	50	60 kg/h av.	9.6 kg/10^6 m^3
	Volatile organic compounds	20	20	48 kg/10^6 m^3
	CO	50	1000 kg/h av.	560 kg/10^6 m^3
	HCl	10	50	
	HF	2	2	
	Particulate	20	20	16-18 kg/10^6 m^3
mg /Nm^3	Cadmium	0.1 (together)	0.2 (together)	
	Thallium			
	Mercury	0.1	1 (together)	
	Arsenic	1 (together)		
	Cobalt			
	Nickel			
	Antimony		5 (together)	
	Chromium			
	Copper			
	Lead			
	Manganese			
	Nickel			
	Tin			
	Vanadium			
	Beryllium			
ng /Nm^3	Dioxin TEQ	1 *	1 *	

- 0.1 ng/NM^3 to be aimed for.

Table 5 Emission Standards

From December 1999 a new standard takes effect in the USA - EPA 40 CFR Part 63 - “National Emission Standards for Hazardous Air Pollutants for Source Categories; National Emission Standards for Hazardous Air Pollutants for Secondary Aluminium production; proposed rule”. This standard, known as the MACT standard, lays down emission regulations for plant operators dependent upon equipment type. Two sets of emission limits are provided; one for kilns operating as chip dryers and one for those operating as scrap drying/delacquering units. (See Tables 6+7) The following abbreviations have been used:-

PM	Particulate Matter	THC	Total Hydrocarbons
HCl	Hydrochloric Acid	D/F	Dioxins & Furans

Process	PM (lb/ton feed)	HCl (lb/ton feed)	THC (lb/ton feed)	D/F (µg/Mg feed) (1Mg=1,00kg)	Afterburner design & operating criteria	
					Minimum Temperature °F	Minimum Residence Time (seconds)
Scrap dryer, Delacquering Kiln, Decoating Kiln	0.30	1.50	0.20	5.00	1,400	1.00
	0.08	0.80	0.06	0.25	-----	-----

Table 6 MACT Emission Limits (Scrap Drying/Delacquering)

The alternative limits given above are for plant operating with given afterburner operating criteria.

Process	PM (lb/ton feed)	HCl (lb/ton feed)	THC (lb/ton feed)	D/F (µg/Mg feed)
Chip Dryer	----	----	0.80	2.50

Table 7 MACT Emission Limits (Chip Dryer)

Emission limits are linked to actual scrap material feed rates unlike European limits which are usually linked to exhaust gas flow. This regulation also gives guidance with regard to plant design, operation and maintenance. At the time of writing it was understood that these limits would come into effect at the end of 1999 and that plant operators would have three years in which to bring their emissions in line with the limits.

7.2 Potential Pollutants

Emissions arising from the decoating process can be very diverse, depending both on coating type and process design. Examples of typical emissions and their characteristics are given.

7.2.1 *Hydrocarbons (Volatile organic compounds)*

Volatile organic compounds are the main products of the actual thermal degradation process within the kiln. VOCs consist only of carbon and hydrogen in various combinations, and are classed mainly into three groups:-

- Paraffins - methane CH_4, ethane C_2H_6, etc.
- Olefins - ethylene C_2H_4, propylene C_3H_6, etc.
- Aromatics - benzene C_6H_6, toluene C_7H_8, etc.

Most hydrocarbons are considered toxic and harmful to man in high enough concentrations but the olefins and aromatics give rise to the most concern.

The olefin group tend to produce smog by photo-chemical reaction with other gases present in the atmosphere.

A number of the aromatic compounds are thought to be carcinogenic (e.g. benzene) and all give rise to strong odours when released into the atmosphere.

7.2.2 *Oxides of Nitrogen (NOx)*

At the high temperatures experienced in combustion processes, nitrogen and oxygen combine to form nitric oxide (NO). Upon cooling and action of sunlight, further oxidation takes place to produce nitrogen dioxide (NO_2) which is a highly toxic gas. The resultant combination of NO and NO_2 so produced is usually termed NO_x and can act as a catalyst in the production of smog and ozone.

7.2.3 *Acid Gases*

The common acid gases are hydrogen chloride (HCl), sulphur dioxide (SO_2) and hydrogen fluoride (HF).

These toxic gases tend to be produced directly from specific coatings, notably PVC and printing inks, and give rise to respiratory problems in man. They also are a source of potential corrosion problems within the decoating plant, notably in areas using stainless steel construction.

7.2.4 *Carbon Monoxide (CO)*

The presence of carbon monoxide is usually a consequence of incomplete combustion. It is very toxic and can give rise to explosion risks if allowed to accumulate.

7.2.5 *Dioxins + Furans (PCDD + PCDF)*

Polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzo furans (PCDF); otherwise known as dioxins and furans are the subject of much emotive debate. This group of chemicals occur naturally in nature and can arise from several sources, one of which is the combustion process.

Their notoriety concerns their perceived toxicity – potentially they are the most toxic chemical known to man. This reputation is based on animal testing and is proven to be very species dependent. Despite difficulties in extrapolating this animal data to man, dioxins and furans are perceived to be extremely dangerous even in minute quantities.

Available data on the effect on man from industrial or accidental sources of dioxin exposure has proved difficult to interpret. This is made more problematic because each dioxin isomer has a different toxicity and a "Toxic Equivalent" (TEQ) value has to be used to assess overall toxicity of any group of compounds measured.

Practically, dioxins and furans from industrial / combustion processes are difficult to assess because of the following points:-

- Concentrations are low and usually expressed in ng/m^3 (1 ng = 10^{-9}g).
- Sampling is very specialised and expensive (£c1000/sample), so restricting multi-sampling to give representative data.
- Dioxin formation is complex and can give wide variations in concentrations for essentially the same operating conditions.

Although dioxins / furans can be destroyed by dissociation at temperatures above 1100°C they can reform on cooling in the range 450°C – 200°C by denovo synthesis. This has to be taken account of in plant design and operation.

Most interest has centered on municipal type waste incinerators where emissions are traditionally high. The decoating process itself has received less study and is still a relatively grey area within the industry.

7.2.6 *Particulates*

Particulates originate directly from contaminants (sand, soil, etc) charged with the scrap materials or indirectly from inorganics and ash released from the coatings during processing. Another source of particulate in the process gas stream is aluminium fines produced during the pretreatment (shredding) of the scrap prior to charging into the kiln.

Additional particulate burden may arise from waste gas treatment undertaken upstream of the collection device.

Carbon, released by partial combustion of some organics within the kiln can also be produced.

These particulates can either be picked up by the gas stream or carried out with the decoated material.

Depending on the scrap, some of these particulates may contain heavy metals such as lead, chromium, copper, cadmium, etc. Waste disposal then becomes of more concern with landfill to a controlled site a consideration in the process costs.

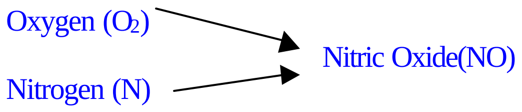
Historically, lb/hour or mg/m^3 of total particulate have been specified to define emission limits but increasingly, authorities are seeking to reduce and specify the PM_{10} (below 10 micron) particulate limits.

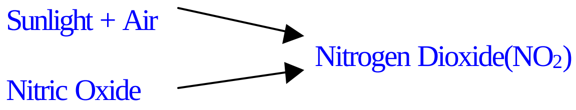
7.3 Pollutant Reduction Techniques

7.3.1 *Oxides of Nitrogen (NOx)*

NO_x will form from nitrogen present in:-

- Combustion air
- Secondary air for oxygen control
- Fuel
- Coating compounds





Methods for reducing NO_x emissions usually revolve around combustion control (reducing excess air or flame temperature by dilution or staged combustion). However, at certain levels of Volatile organic compounds the decoating system becomes "autothermic". This means that the energy released from combustion of the coating volatiles exceeds the energy needed to drive the process. As a consequence no additional fuel is required, only a source of ignition (pilot burner) is needed in the afterburner.

This coupled with the recirculation aspect of the system and good oxygen (excess air) control, minimises NOx production, i.e. a well controlled decoating process is inherently a low NOx process.

Practically, plant suppliers and operators have little absolute control over ultimate burner NOx levels. These are to a great extent dependent upon the burner manufacturer's expertise.

7.3.2 *Acid Gases*

If acid gases are liberated from the coatings, they are traditionally dealt with downstream of the afterburner prior to exhausting to atmosphere. Several options are available, depending on the levels encountered, emission requirements and site constraints. All are based on reacting the acid gas with a suitable alkali reagent to produce a particulate salt product and water vapour. The product is then removed downstream for appropriate disposal.

Dry Scrubbing is perhaps the easiest option and consist of introducing dry powdered reagent into the gas stream prior to the final particulate clean up device. In its simplest for the powder is injected directly into the waste gas ductwork, and is subsequently carried by the gas stream into the particulate filter. In the case of fabric filters the reagent coats the filter elements and can give a worthwhile improvement in scrubbing efficiency. This method is normally used when levels of HCl, SO_2 and HF are relatively low or a less stringent removal is required. To improve efficiency and reagent utilisation a separate reactor vessel can be employed rather than direct injection into the ductwork. This increases capital cost and complexity but enables reagent recycling methods to be used, so minimising raw material costs.

For dry systems the choice of reagent is usually between hydrated lime or sodium bicarbonate. On a straight weight for weight basis hydrated lime is approximately half the price of sodium bicarbonate. Chemical stoichiometry also favours the selection of hydrated lime under normal circumstances. However, if the temperature of the waste gas to be treated exceeds 140°C the reaction efficiency of lime decreases markedly. Sodium bicarbonate becomes more attractive at higher temperatures when higher removal efficiencies are required, see figure 14 below.

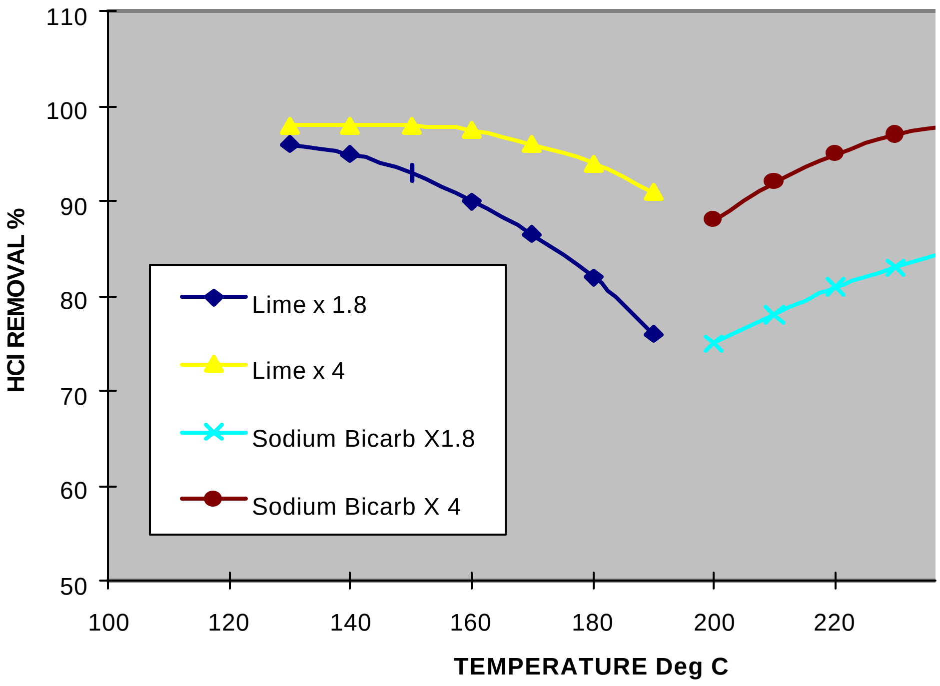


Figure 14 Reagent Efficiencies

For most decoating applications dry scrubbing is the favoured method of treating acid gas laden waste gas. For more stringent or very large plants, semi-dry (spray drier) or wet scrubbing systems may be considered, but these are complex and expensive to install and operate.

7.3.3 *Dioxins + Furans*

There are essentially two methods available for emission control of these compounds:-

- Controlled Incineration / Quench:-

  In this method the waste gases are incinerated at temperatures up to 1100°C for about 2 seconds to destroy the dioxins and furans by disassociation followed by rapid quenching through the temperature range of 500°C to 200°C. It is difficult to ascertain the actual quench rate required but a quench time in the order of 1 second seems to be appropriate.

  To contain costs a two stage approach to the quenching problem may be considered. Hot gas from the afterburner could be cooled to 500°C by a relatively crude slow heat exchanger, followed by a smaller more sophisticated rapid exchanger to cool through the critical range.

  Quenching by alternative methods such as water spray or air dilution are not normally considered acceptable by the regulatory bodies.

- Catalysts:-

  Injection of suitable catalysts into the waste gas stream is a relatively simple operation and has been demonstrated to work well in similar other processes. The catalysts can be used in combination with lime injection systems.

  The most common catalyst is PAC (Powdered Active Carbon) and works by attracting the dioxins to adhere to its very large surface area. The material is then removed via the particle collection device. Some heavy metals (e.g. mercury) can also be removed with this system.

  Removal rates of over 99.9% for dioxins have been claimed for PAC systems with dosage rates in the order of 50 mg/Nm^3 flue gas.

7.3.4 *Particulates*

Fabric filtration is the preferred system of particulate collection for decoating plants. It offers several advantages over the other methods available:-

- Simple technology
- Low operating costs
- Enhanced removal of acid gases and dioxins due to increased contact between waste gas and reagents / catalysts deposited on the filter elements.
- High efficiency.

Selection of suitable fabric filter media is important and will determine the overall system performance and costs. Criteria for media selection will include:-

- Operating temperature – the maximum allowable temperature must be high enough to prevent condensation problems or limit the processing capability of the plant.
- Corrosion – the fabric must be resistant to any chemicals present in both the waste gas and particulate.
- Pore Size – this will determine pressure drop and filtering efficiency.

Ceramic filters are a relatively recent development proposed to overcome the operating temperature restrictions of conventional fabric filters. Commercial elements are available that can operate at temperatures up to 1000°C but available operating data is limited so far. They show promise and should offer advantages in prevention of low exhaust temperatures / condensation problems.

7.4 Actual Plant Emission Data

One of the most difficult practical aspects of this subject is getting good actual site environmental data from operating plants. This can be for a number of reasons, eg:-

- Relatively few plants processing limited scrap types.
- Reluctance of plant operators to release information.
- Expense of performing comprehensive analysis.
- Production taking precedence over environmental issues.

Tables 8 & 9 give typical values of emission levels measured in Stein Atkinson Stordy Ltd plants, processing a variety of scrap types. This information has been built up over the last 10 years, from the first counterflow Used Beverage Cans plant, via in-house pilot plants to the latest IDEX® technology processing plastic laminated foils.

Scrap Type	**Coating**	**mg/ Nm^3 11% oxygendry**							
		VOCS	**CO**	**HCl**	**HF**	**SO$_2$**	**NO$_x$**	**Particulate**	**Dioxin TEQ**
Mill Foil	rolling oils	-	35	124	3	-	-	73	-
Converted Foil	Inks / lacquers	<1	4	<2000	3	3	195	<328	-
Litho Plate	Resin / paper	<1	4	8	2	16	51	<474	0.11×10^{-6}
Used Litho	resin / inks	<1	3	15	-	2	69	202	0.05×10^{-6}
Epoxy Strip	epoxy / paint	<1	0	18	-	12	112	70	$< 0.05 \times 10^{-6}$
Lid Stock	vinyls	24	3	90	-	8	107	32	0.25×10^{-6}
Paper Laminate	paper	<1	4	25	-	4	130	540	$< 0.05 \times 10^{-6}$
Plastic Laminate	Polymers /inks / wax	0	9	194	-	-	-	176	0.14×10^{-6}
Tube Laminate	polymers / lacquers	1	12	11	-	5	56	55	0.05×10^{-6}
Turnings	cutting oils	<20	-	-	-	15	84	-	-
Frag	oil / paint /polymers	<15	4	352	-	<21	<130	450	1.83×10^{-6}
Window Frames	Thermolacquers / resins	-	55	899	3	-	-	540	17.5×10^{-6}
U.B.C	lacquers / paints	0	-	97	<4	-	<100	137	-
Sidings	paints	0	0	-	<4	-	-	776	-

Table 8 Emissions Measured Prior to Gas Treatment Equipment

These independent measurements were taken after the afterburner chamber and prior to any subsequent Air Pollution Control equipment. They indicate the general level of pollutant produced by the decoating process is low and that emission regulations can be met relatively easily.

Actual levels are very scrap specific and in some cases environmental limits can be met by no additional Air Pollution Control equipment other than a particulate filter.

7.4.1 Volatile organic compounds / CO / NOx

It can be seen for all the scrap types indicated, the Stein Atkinson Stordy Ltd afterburner technology is capable of dealing with Volatile organic compounds, CO and NOx emissions with great effect. All Stein Atkinson Stordy Ltd plant to date has surpassed local emission regulations for these compounds.

7.4.2 *HCl / HF / SO_2*

Acid gas levels are very scrap specific but generally SO_2 and HF levels tend to be low for this process. HCl levels can vary greatly and depend usually on PVC content or the type of inks present in the original coating. Converted foils show the greatest variation due to the wide range of printing inks used in their manufacture. In most cases emission regulations can easily be met for the acid gases by simple dry scrubbing using lime or sodium bicarbonate. Reagent consumptions are generally low, around 25-50 kg/h being typical for a medium sized plant.

7.4.3 *Particulates / Heavy Metals*

Particulate limits are usually met by conventional fabric filters with no problems. Any heavy metals present in the vapour phase should condense on particulate and together with the solid phase metals be removed with the filter dust. Levels measured to date indicate that limits are met for most material mixes and landfill to a controlled site is considered the acceptable method of disposal in view of the modest quantities involved.

	Converted Foil	**Litho Plate**	**Used Litho**	**Epoxy Strip**	**Lid Stock**	**Paper Laminate**	**Plastic Laminate**	**Tube Laminate**
	Inks / lacquers	Resin / paper	Resin / inks	Epoxy / paint	Vinyls	Paper	Polymers /inks / wax	Polymers / lacquers
Pb	0.121	0.083	0.26	0.13	0.175	0.05	0.193	0.044
Cd	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001
Hg	0.001	0.003	0.001	0	0.003	0.002	0.004	0.002
Se	0.004	0.007	0.005	0.003	0.005	0.012	0.004	0.006
Sb	0.006	0.003	0.013	0.008	0.002	0.006	0.01	0.003
Ba	1.536	0.608	1.905	1.337	0.555	2.28	2.021	3.522
Cr	0.103	0.199	0.478	0.466	0.104	0.152	0.211	0.106
As	0.001	0.002	0.005	0.004	0.001	0.005	0.007	0.003
Zn	1.352	0.544	1.539	1.061	0.538	2.002	2.078	2.625
Cu	0.06	0.035	0.459	0.051	0.046	0.041	0.087	0.029
Mn	0.012	0.009	0.041	0.019	0.01	0.05	0.096	0.026
Ti	0.025	0.016	0.024	0.113	0.017	0.036	0.054	0.038
Bi	0	0.006	0	0	0	0.001	0	0
Sn	0.012	0.007	0.033	0.004	0.007	0.014	0.014	0.002

Table 9 Heavy Metal Emissions in Waste Gas Stream

7.4.4 *Dioxins / Furans*

All the dioxin measurements to date on Stein Atkinson Stordy Ltd plants have been carried out on those using IDEX® technology. This limited data indicates that the levels are low, especially if compared to waste incinerator applications. Several of the scrap types would meet the existing 1 ng/Nm^3 limit with no further processing. Even the higher levels measured would be easily dealt with by low doses of suitable catalyst, such as powder activated carbon, without resorting to expensive and complicated quenching systems.

CHAPTER EIGHT – SCRAP MELTING METHODS

8.1 Introduction to Melting

The combination of contaminants and their treatment has a profound effect upon the melting process and subsequent metal loss. Materials such as Used Beverage Cans can be recycled in many different ways. Their composition as received at the recycling center is typically 3% Volatile organic compounds (Paint & Lacquer), 1% water and 1% tramp materials. Therefore for every 100kg of scrap Used Beverage Cans we only have a maximum of 95kg of aluminium to begin with. There is an old rule within the recycling industry that for every 1% of contamination charged into the melting furnace there will be at least an equivalent 1% metal loss Applying this rule to this figure suggests that the maximum recovery is around 90%. In practice the losses are often much higher depending upon the type of technology employed to recycle the material. Table 10 below shows typical recoveries for three different methods of recycling Used Beverage Cans. The recovery is measured by weighing the bales arriving at the recycling plant (including all contaminants) and then weighing the metal output from the plant.

Method of Recycling	Overall Recovery (UBC)
Direct Charge into Typical Reverbatory Furnace	70 – 80%
Direct Charge into Rotary Salt Furnace	75 – 83%
Shred, Decoat & Charge into Reverbatory Furnace	85 – 92%

Table 10 Typical Recoveries For Different Melting Methods

Decoating becomes more attractive as the percentage of contamination within the scrap increases. In fact some materials can not be recycled without some form of decoating being employed. Figure 15 below show the results of a simple melting test with baled confectionery wrappings and shows the bales prior to and after melting. It can be seen that a large amount of dross has been formed and the bale has not melted due to the oxide layer formed on the outside. This material has a low coating weight of around 7% by weight.

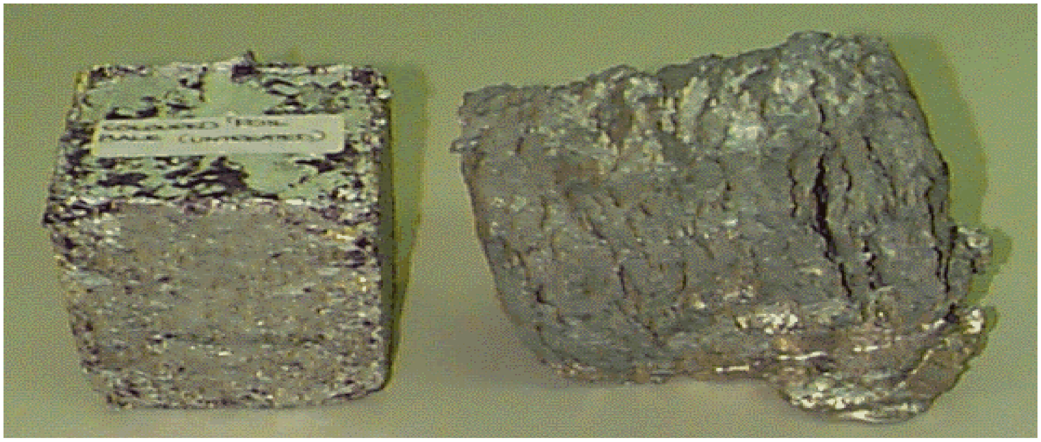


Figure 15 Baled Confectionary Wrapping Melt Test

Table 11 gives the results of melting tests carried out on different materials. The first test was done by direct charging the scrap into a standard reverbatory furnace with out decoating. The second test was done on scrap that had been shredded and then decoated.

Scrap Type	% Volatile organic compounds	Metal Loss (No Decoating)	Metal Loss (With Decoating)
Heat Seal Lid	8%	6.2%	0.7%
Mill Foil	1-10 %	9.7%	3.7%
Used Beverage Cans	3%	24%	Less Than 3%
Steralcon	20%	27%	9%

Table 11 Melt losses for Decoated & Non-Decoated Materials

A saving of one or two percent on metal loss will more than recover the cost of decoating equipment. Decoating can also save in other areas such as Salt/flux usage, land fill, air pollution control and fuel consumption. Another benefit is that clean materials will melt more rapidly giving an increased melt rate with effectively the same furnace. In many cases these savings alone can more than offset the cost of pre-treatment equipment, and give a cleaner working environment combined with lower plant emissions.

In general there are three main types of furnaces that are discussed below.

8.2 Reverbatory Furnaces

Reverbatory furnaces come in many different configurations but can be categorised in three main groups:-

8.2.1 Standard Reverbatory

These are usually of a rectangular or square shape and can be either static or tilting. Scrap is normally charged in through the main furnace door in either a lose or baled format. Dross will float to the surface and, unless removed, can hinder heat transfer to the molten metal. The main furnace door has to be opened to charge material or to dross off, giving rise to a substantial heat loss from the furnace. If decoated material is to be fed in to these types of furnaces the material is usually allowed to cool and then is baled prior to charging. This means that the heat energy contained in the scrap during decoating is lost. Characteristics of this type of furnace include:-

- Batch type operation
- Low capital cost
- Low recoveries
- Exhaust gases may require treatment

8.2.2 Sidewell Reverbatory

The side well furnace is widely used in North America for recycling operations. The furnace consists of reverb chamber as described above, but with the addition of a side well. Scrap metal is charged into the side well and is submerged quickly. Any dross formed collects in the dross well and can be easily removed. This helps to keep the main furnace chamber clean. Some form of pumping system is usually employed to circulate the metal. The most common is the mechanical pumping system (e.g. Vortexer Figure 17) which have a low capital cost. These pumps do require some regular maintenance but this can normally be done without bringing the furnace out of service. Electro-Magnetic systems are now gaining in popularity. These have a higher capital cost but reduced maintenance requirements. Depending upon design, the furnace may have to be taken out of service for maintenance to be performed.

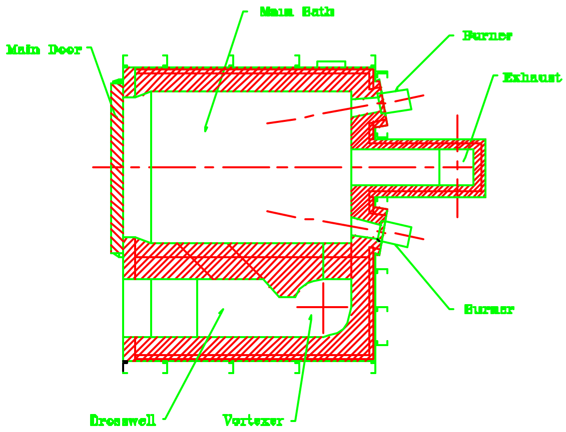


Figure 16 Plan View of Side well Furnace

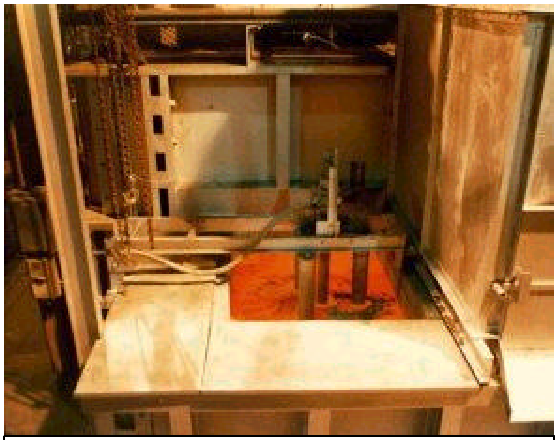


Figure 17 Mechanical Pumping System (Vortexer type courtesy G+P Inc.)

Sidewell furnaces are ideal for decoated product as they allow the scrap to be charged on a continuous basis from the decoating system. If charged quickly the scrap is still hot after decoating (typically 300 – 450°C) which means that the energy required to melt the scrap will reduced markedly. This combined with the submerging action of the side well, promotes melt time and the reduction of dross.

As melting is on a continuous basis, there will often be a mechanical system for automatically feeding flux into the furnace. A hood can be sited above the sidewell to collect any fumes that may arise. If dirty scrap (coated) is charged, these fumes could be an environmental hazard and consideration should be given to treatment of these gases, normally by some form of afterburning.

Characteristics of this type of furnace include:-

- Continuous charging, ideal for us with decoating system
- Moderate capital cost
- Suitable for most scrap types
- Clean Exhaust gases if decoated scrap is used.
- High recoveries when used with good quality decoated scrap

8.2.3 Dual Chamber Reverberatory

The dual chamber furnace consists, as the name suggests, of two separate sections within the main furnace. Scrap is normally charged onto a dry hearth section and left for a period of time for the Volatile organic compounds to evolve. During this time the scrap heats up to close to melting point. The gases are extracted to, and combusted in the rear chamber. As the next batch of scrap is charged, the previous load is pushed into the molten bath to finish melting.

These furnaces typically employ some form of pumping system that again can be either Mechanical or Electromagnetic, often with a separate side well. Some designs utilise the rear chamber of the furnace as an afterburner while other may have a separate afterburner. These furnaces are normally fed with dirty scrap that has not been decoated.

Recoveries for heavy scrap types are claimed to be high but they appear to be unsuitable for lightweight scrap types. One disadvantage with this type of furnace is that as they try to combine the process of decoating and melting within one furnace, requiring very complex process control. As the Volatile organic compounds evolve in a batch then the combustion chamber must be sized for peak loading and there are periods when there may be excessive energy available and others when the burners must operate at a higher level to compensate for lower loadings.

Characteristics of this type of furnace can be summarised as:-

- Batch type operation
- All in one solution for melting scrap
- High Capital Cost
- Good recoveries reported with heavy scrap types, May not be suitable for lightweight scrap types
- Combustion chamber has to be sized for peak loading

8.3 Rotary Furnaces

For many Companies this type of furnace has been the work horse for recycling aluminium scrap. Material is charged in a batch and salts are added. These type of furnaces are normally charged with dirty scrap that has not been decoated. There are now variants using oxyfuel type burners to improve overall recoveries and reduce fuel consumption.

Characteristics include:-

- Batch Type operation
- Low capital cost
- One stop solution
- High Salt Usage
- Low-moderate recoveries
- Exhaust gas may require treatment

8.4 Induction Furnaces

Induction furnaces can be used as either a batch or semi-batch type operation and offer very good recoveries with decoated product. They can be expensive to run, normally being used in areas where electrical power is cheap, often due to Hydro-Electrical generation being used. A feature of this type of melting is very clean melts, with good alloy control

Typical characteristics are:-

- Batch or Semi-Batch operation
- Medium Capital Cost
- Good Recoveries with decoated scrap

CHAPTER NINE –THE ECONOMICS OF DECOATING

It is an unfortunate fact that many Companies are simply throwing money away because they do not decoat their scrap. Often the capital investment required to purchase a decoating plant appears to be prohibitive, especially to small users but in many cases the cost of a decoating plant can be justified by metal loss alone.

As discussed in chapter 1.2 there are many considerations when examining the overall economics of decoating compared to a system of melting decoated scrap directly. In the examples below a comparison is made between melting scrap directly in a Rotary type furnace and delacquering followed by melting in a Side Well type furnace. It should be noted that many of the points raised will also apply to other furnace designs. The actual figures used are for illustrative purposes only.

9.1 Economic Considerations of Decoating

9.1.1 *Savings in Metal Loss*

It is generally acknowledged that decoating will achieve higher recovery rates than non decoating/melting systems. The main reasons for the increase in recovery are:-

- Reduced melting time in furnace

With a traditional Side Well type furnace the melting is continuous and the hot scrap discharged from the decoating process (at around 400 – 500°C) can be melted quickly. The faster a scrap is melted the lower the losses will be. There is a direct relationship between these two factors as shown in Figure 18 below

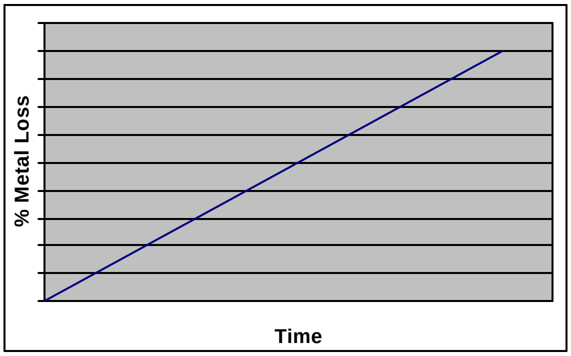


Figure 18 The effect of Melt Rate on Metal Loss

- Cleaner materials charged in to the furnace

It is well documented that the surface coating of a scrap has a profound effect on the subsequent melt loss. In general the higher the % coating the higher the losses will be. The effect differs between alloy types. For example, alloys with higher magnesium contents usually exhibit increased losses.

Metal loss figures for Used Beverage Cans vary between 15-30% for processes that do not decoat prior to melting (take an average figure of 20%). A well set up decoating and melting operation can limit metal loss to less than 6%. That is measured from bales of cans arriving to metal ingots leaving the company. This difference of 14% can yield huge savings even for a small user. Based on an annual production of only 10,000 Ton per year this could still be worth $1.96 Million Dollars per year. Metal loss and recoveries should not be confused. Recovery figures are normally taken as bales arriving (including contaminants) to ingot leaving. A typical set up secondary operation using a decoating kiln and a side well furnace will yield overall recoveries of 89 – 91%. If we assume that the cans contain approximately 3% coating, 1% water and 1% tramp material this equates to a metal loss of 4 – 6%. Not all of the metal is loss in the furnace, there will be losses due to fines generation within the shredding process.

Example: 1

Yearly Input	40,000 Ton per year, Used Beverage Cans
Aluminium Ingot Value	$1,400 per Ton

Melting Method	Rotary Furnace	De-Lacquer & Side Well
Overall recovery	75%	89%
Actual Recovery	30,000 Ton/year	35,600
Yearly Revenue	$42,000,000	$49,840,000

9.1.2 *Reduced Salt/Flux usage in the Melting Furnace*

As a general rule the more contamination a scrap contains then the higher the potential usage of salts/fluxes required in the melting process. Actual salt/flux usage is dependent upon the type of melting process and the material being melted. For Rotary Salt furnaces, usage of up to 25% by weight of scrap charged are not uncommon. For de-lacquered material melted in a reverbatory type side well furnace flux usage's of 2-5% are typical. There is, therefore, a large potential saving in the annual cost of salt :-

Example: 2

Yearly Input	40,000 Ton per year	37,000 into furnace *
Salt/flux Cost	$200 per Ton	

Melting Method	Rotary Furnace	De-Lacquer & Side Well
Salt Usage	25%	5%
Yearly Cost	$2,000,000	$370,000
Cost per Ton Input	$50.00	$9.25

** The actual decoated material weight charged into the furnace will be lower due to the coatings removed and scrap preparation losses in the decoating process.*

A consequence of using salts will be the generation of black salt cake which will need to be disposed of in an environmentally friendly way. In most modern societies there will be some form of tax applied to land filling these types of materials. If we assume that only 50% of the salts end up in salt cake then the disposal costs could be as follows:-

Example: 3

Yearly Throughput	40,000 Ton per year
Salt Cake Disposal Cost	$50 per Ton

Melting Method	Rotary Furnace	De-Lacquer & Side Well
Salt Cake Generation	10,000 T	2,000
Yearly Disposal Cost	$500,000	$100,000

Of course this example does not take into account other issues such as transportation costs which will add to the cost. As environmental laws tighten the disposal of this type of materials can only become more difficult and give an increase in cost. This too is a recurring saving.

9.1.3 *Increased Throughput in Melting Furnace*

Where a decoating system is added to an existing Side Well type furnace there will normally be an increase in the melting capacity when compared to melting dirty scrap due to increased melting rates. The effect of this will be to reduce the processing cost as the fixed costs for the furnace operation (such as standing losses) will remain the same.

9.1.4 *Compliance with Environmental Regulations*

For many Companies direct melting of scrap is no longer an option due to tighter environmental regulations. These Companies are then faced with three options:-

1. Close Down or resell
2. Fit an Air Pollution Control (Air Pollution Control) unit to the existing furnace. (Afterburner technology will be essential if dealing with organics of any significance)
3. Install a decoating system.

9.1.5 *Increased Plant Safety*

For any plant where scrap is direct melted there is a risk of fire/explosion due to trapped water or gas canisters. Where explosion does arise within the melting furnace it can lead to serious damage to equipment and possible fatalities. Decoating removes the risk of explosion due to trapped water. Gas canisters and alike can still cause damage within the pre treatment equipment but the consequences are likely to be less severe. It is difficult to ascertain an actual cost benefit to this area but safety of operators is a very important concern.

9.1.6 *Increased Choice of Materials*

Decoating plants offer greater flexibility in the material choice for Companies to process. This can often extend the possibilities to a range of cheaper scrap types giving potentially higher earnings. As market prices change for various scraps the company can purchase cheaper scrap to process, subject to alloy considerations.

From our point of view as decoating plant manufacturers, it is a reality that the above benefits must be considered along with the disadvantages discussed below:-

9.1.7 *Increased Electrical Energy Consumption*

The actual decoating process itself requires relatively little in the way of electricity. Depending upon the scrap it be processed a pre-treatment system consisting of shredder, conveyors and separators may be required. It is in this area that increased electrical requirements are most prominent.

Example: 4

Yearly Throughput	40,000 Ton per year, Used Beverage Cans
Cost of Electricity	$0.06 per kWh

Shredding Power Requirement		400	kW
Conveyor Power Requirement		40	kW
Separator Power Requirement		45	kW
Decoating Plant	Kiln Drive	25	kW
	Combustion Air Fan	30	kW
	Secondary Air Fan	22	kW
	Recirculation Fan	45	kW
Plant Controls		3	kW
Total		**610**	**kW**

Cost to run per hour	$ 36.60
Cost to run per year (24hrs,365 days)	$320,616.00
Cost per Ton Input	$ 8.01

The above example gives the worst case scenario on a plant with a comprehensive pre treatment section. The shredding power is based on using a Mono-shear type shredder.

9.1.8 *Larger Plant Layout*

The extra equipment will require a larger plant layout and hence a larger plot of land may have to be purchased. There will also be a requirement for a larger building.

Assume that the land is written off over a 10 year period

Example: 5

Yearly Throughput	40,000 Ton per year
Extra area of land required (assume 40m x 80m)	3,200m2
Cost of land (assume $15 per m2)	$ 48,000
Cost of Building (assume $25 per m2)	$ 80,000
Total Cost	$128,000
Cost per year	$ 12,800

9.1.9 *Increased Capital Expenditure*

The decoating plant and pre-treatment equipment have to be purchased. As an example of cost we shall pro-rata the capital investment over a 10 year period.

Example: 6

Yearly Throughput	40,000 Ton per year	
Cost of Decoating / Pre Treatment Equipment		$3,500,000
Cost per year		$350,000.00
Cost per Ton Input		$ 8.75

9.1.10 *Increased Manning Requirements*

Generally there is more equipment required in a decoating plant and consequently this will require more people to run the equipment. Although the decoating plant requires very little intervention from man the pre treatment will require constant charging with materials. For this reason we shall assume that we require one further personnel:-

Example: 7

Yearly Throughput	40,000 Ton per year	
Cost of Labour	$10.0 per hour	
Cost per year (24hrs,365 days)		$87,600.00
Cost per Ton Input		$ 2.19

9.2 Economic Summary of Decoating

If we summarise the information above we can derive an overall theoretical benefit:-

Metal Loss Saving	$7,840,000
Salt Usage Saving	$1,630,000
Salt Disposal Cost Saving	$ 400,000
Total Savings	**$9,870,000**
Electricity Cost	$ 320,616
Labour Cost	$ 87,600
Capital Equipment Cost	$ 350,000
Land/Building Cost	$ 12,800
Total Costs	**$ 771,016**
Overall Saving	**$9,098,984**

It is worth noting that the gas consumption of the plant has not been considered. This is because the extra cost of running the afterburner is offset by subsequent savings in fuel consumption by the melting furnace. The majority of energy for the decoating process is derived from the energy contained within the Volatile organic compounds, as such this energy can be considered to be almost free. The typical outlet temperature for the scrap is in the order of 400-450^{o}C. This , in theory, equates to half the energy required to melt the scrap in the furnace. Therefore, whenever practical, scrap from the decoating system should be charged directly into the melting furnace.

Metal loss is potentially the largest cost saving area. However it should be noted that in the example above even if there was no metal saving the plant would be commercially viable.

GLOSSARY

Afterburner:- The chamber in which combustion of the Volatile organic compounds takes place. Also known as an incinerator or thermal oxidiser.

Autothermic:- When the energy release from the Volatile organic compounds is equal to, or in excess of, what the process requires.

Bag Filter:- Part of the Air pollution control system. Removes particulate from the waste gas stream. Also known as a Bag House.

Flights:- Fixed internal devices arranged and distributed within the kiln barrel to transport material through the kiln and aid better mixing.

Lift Off Velocity:- The velocity of gas required to levitate a piece of scrap.

Reactor Tower:- Part of the Air Pollution Control system. Reagent is introduced into the reactor to react with the waste gas from the IDEX system. This will remove acid gases.

Reagents:- Introduced into the reactor to remove acid gases. Normally either Lime or sodium bicarbonate.

Residence Time:- The amount of time a material spends within the kiln barrel. Is also applied to the afterburner as the time the process gasses dwell in the chamber.

Turndown:- The ratio of the maximum and minimum firing rate of the burner. For example, if a burner has a maximum firing rate of 10,000,000 Btu/hr and a minimum rate of 200,000 Btu/hr then it has a 5:1 turndown ratio.

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47	Photo of Vortexer Unit	Gillespie & Powers Inc

CONTACT DETAILS

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LIST OF APPENDIXES

APPENDIX A
Typical Beverage Can Alloy Data

		BODY (3004)	LID (5182)	PULL TAB (5082)	MIXED
Mg	% Weight	1.100	4.500	4.500	1.880
	(g)	0.132g	0.149g	0.014g	0.293g
Mn	% Weight	1.100	0.350	0.150	0.920
	(g)	0.132g	0.012g	0.000g	0.144g
Si	% Weight	0.300	0.200	0.200	0.500
	(g)	0.036g	0.007g	0.001g	0.078g
Fe	% Weight	0.500	0.350	0.350	0.460
	(g)	0.060g	0.012g	0.001g	0.072g
Cu	% Weight	0.100	0.150	0.150	0.110
	(g)	0.012g	0.005g	0.000g	0.017g
Cr	% Weight	0.000	0.100	0.150	0.020
	(g)	0.000g	0.003g	0.000g	0.003g
Total Weight	(g)	12.00 g	3.30 g	0.30 g	15.60 g

APPENDIX B
Typical Melt Compositions for Defined Scrap Types

Material	**% Si**	**%Fe**	**%Cu**	**%Mg**	**%Zn**	**%Ti**
Litho	0.130	0.310	0.002	0.001	0.010	0.012
Extrusion	0.380	0.180	0.005	0.250	0.010	0.008
Foil with Oil (Chips)	0.160	0.750	0.002	0.001	0.010	0.011
Foil with Oil (Bales)	0.140	0.780	0.003	0.001	0.010	0.010
Converted Foil (Chips)	0.130	0.630	0.002	0.001	0.600	0.008
Converted Foil (Bales)	0.150	0.650	0.003	0.001	0.680	0.012
DSD (No Pretreatment)	0.288	3.720	1.000	0.002	0.696	0.011

APPENDIX C
TEMPERATURE CONVERSION CHARTS

Temp °C=5/9 x (Temp °F-32)

Degree F	Degree C
0	-17.78
50	10.00
100	37.78
150	65.56
200	93.33
250	121.11
300	148.89
350	176.67
400	204.44
450	232.22
500	260.00
550	287.78
600	315.56
650	343.33
700	371.11
750	398.89
800	426.67
850	454.44
900	482.22
950	510.00
1000	537.78
1050	565.56
1100	593.33
1150	621.11
1200	648.89
1250	676.67
1300	704.44
1350	732.22
1400	760.00
1450	787.78
1500	815.56
1550	843.33
1600	871.11
1650	898.89
1700	926.67
1750	954.44
1800	982.22
1850	1010.00
1900	1037.78
1950	1065.56
2000	1093.33
2050	1121.11
2100	1148.89
2150	1176.67
2200	1204.44
2250	1232.22
2300	1260.00

Temp °F=(9/5 x Temp °C) +32

Degree C	Degree F
-200	-328
-150	-238
-100	-148
-50	-58
0	32
50	122
100	212
150	302
200	392
250	482
300	572
350	662
400	752
450	842
500	932
550	1022
600	1112
650	1202
700	1292
750	1382
800	1472
850	1562
900	1652
950	1742
1000	1832
1050	1922
1100	2012
1150	2102
1200	2192
1250	2282
1300	2372
1350	2462
1400	2552
1450	2642
1500	2732
1550	2822
1600	2912
1650	3002
1700	3092
1750	3182
1800	3272
1850	3362
1900	3452
1950	3542
2000	3632
2050	3722
2100	3812

APPENDIX D
METRIC TO IMPERIAL CONVERSIONS

Linear Measurement

1mm	=	0.03937011	inches			
1cm	=	0.3937011	inches			
1m	=	1.0936143	yards	=	3.2808429	feet
1km	=	0.62137	miles			

Square Measurement

1mm^2	=	0.00155	inches^2			
1cm^2	=	0.1550	inches^2			
1m^2	=	1549.9969	inches^2	=	10.7639	feet^2
1km^2	=	0.3861006	miles^2			

Cubic Measurement

1mm^3	=	6.10238x10^{-5}	inches^3			
1cm^3	=	0.0610238	inches^3			
1m^3	=	61024	inches^3	=	35.3156	feet^3
1km^3	=	0.2399113	miles^3			

Weight Measurement

1gram	=	0.56438	Drams		
1kilo gram	=	35.274	Ounces	=	2.204622 Pounds
1Metric Ton	=	2,204.622	Pounds		

Capacity Measurement

1Litre	=	35.2	Fluid Ounces
	=	0.21997	UK Gallons
	=	1.760	Pints

Miscellaneous Measurement

1 Calorie	=	3.96832x10^{-3}	Btu		
1 Calorie/Sec	=	0.23809	Btu/Min		
1 Joule	=	9.4781x10^{4}	Btu	=	0.7375 Foot Pounds Force
1 kilowatt	=	3412.1425	Btu/hour		
	=	1.34102	Horsepower		

APPENDIX E

IMPERIAL TO METRIC CONVERSIONS

Linear Measurement

1 inch	=	2.540	Centimeters			
1 Foot	=	30.48	Centimeters			
1 Yard	=	91.44	Centimeters			
1 Mile	=	1.609	Kilometers			

Square Measurement

1 inch^2	=	6.436	Centimeters^2			
1 Foot^2	=	929.0304	Centimeters^2	=	0.0929030	meters^2
1 Yard^2	=	8361.273	Centimeters^2	=	0.8361273	meters^2
1 Mile^2	=	2.588881	Kilometers^2	=	2588.881	meters^2

Cubic Measurement

1 inch^3	=	16.32653	Centimeters^3			
1 Foot^3	=	28316.84	Centimeters^2			
1 Yard^3	=	764544.8	Centimeters^3	=	0.764543	meters^3
1 Mile^3	=	4.165509	Kilometers^3			

Weight Measurement

1 Pound	=	2.2046223	Kilogram			
1Imperial Ton	=	1016.05	Kilogram	=	1.01605	Metric Ton

Capacity Measurement

1 UK Gallon	=	4.546	Litres			
1 Pint	=	0.568	Litres			

Miscellaneous Measurement

1 Btu	=	251.996	Calorie			
	=	1055.056	Joules			
1Btu/hour	=	0.293071	Watt	=	$2.93\text{x}10^{-4}$	Kilowatt
1Btu/min	=	17.5843	Watt			
1 Horsepower	=	0.7457	Kilowatt	=	745.7	Watt

APPENDIX F
MISCELLANEOUS CONVERSIONS

1 Atmosphere	=	33.89854	Foot H_2O
	=	14.69595	Pound force/ square inch
	=	29.92126	Inches Hg
1 Foot H_2O	=	0.0295	Atmosphere
	=	0.882671	Inches Hg
1 Calorie	=	4.1868	Joules
1 Foot Pnd Force	=	5.05051×10^{-7}	Horsepower-hour
	=	1.35582	Joules
	=	3.76616×10^{-7}	Kilowatt-hour
	=	3.76616×10^{-4}	watt-hour
1 Btu/Lb	=	0.5556	Cal/gram
	=	0.556	Kcal/Kg
	=	2326	Joules/Kg
	=	0.002326	M joules/Kg
1 Btu/Ft^3	=	0.00890	Cal/cm^3
	=	8.899	$Kcal/m^3$
	=	0.03730	$Mjoules/m^3$
1 Btu/hr	=	0.2520	Kcal/hr
	=	0.000393	hp
	=	0.2931	Watts or Joules/Sec