

Guidance on the Recovery and Disposal of Controlled Substances Contained in Refrigerators and Freezers

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1 Introduction

Ozone Depleting Substances Regulations

Council Regulation No. 2037/2000 on Ozone Depleting Substances (ODS) (ODS regulation) came into effect on 1 October 2000 and requires the removal of controlled ODS from refrigeration equipment before such appliances are scrapped. This requirement came into force immediately for commercial appliances and applies to domestic appliances from 1 January 2002. The ODS regulation covers refrigeration equipment which contain ODS both in:

- the refrigerant of the cooling system and
- as a blowing agent in the insulating foam.

The recovery and recycling of refrigerants is not new and has been practised where commercially and environmentally beneficial for a number of years. Good Practice Guidelines at national and international levels have been produced since 1989 and considerable bibliographies have been developed¹. The domestic refrigeration sector has never been a major source of refrigerants for recycling purposes. It is estimated that only around 10% by volume of recovered ODS currently arises from domestic units. This is partly because the quantity of ODS per unit is far less than in commercial installations, thereby making the cost per kg recovered higher and also because the proportion of oil in domestic units is higher, thereby attracting additional reclamation costs.

The recovery of refrigerant from the domestic sector is mainly from processing fridges at established, dedicated recovery units at larger collection points and mobile recovery services at smaller collection points.. For highly automated fixed plants, throughput rates can be higher than 60 units per hour. However, for the mobile recovery facility, a productivity level of 10-15 units per hour is more typical.

This document is primarily aimed at the treatment of domestic appliances, however the principles and objectives expressed are applicable to commercial appliances.

This document will be reviewed six months after issue.

1.1 Key Issues

Best Practical Environmental Option

This Guidance establishes, for the purpose of permitting activity in the UK, the best achievable standard relating to loss of ODS during fridge processing (Stage 1 and Stage 2) as 15g per unit. This is achievable by using a fully automated mechanical recovery with integrated de-gassing unit. Where operators propose activities to be conducted in a non integrated way (for example separate storage, degassing and ODS recovery), they would have to justify the reasons for the selection and specify what measures would be taken to limit the ODS loss to a value less than 25g per unit.

The Emission Limit Value for CFC R11 in the release to atmosphere from the air extraction system after the ODS recovery systems is 150 mg/m³ of air. The loss of ODS from the system should not exceed 75g CFC R11 per hour but this is proportionate to the feed rate of appliances into the system (see section 4.2.1).

Recovery of ODS would be enhanced by the least number of processing steps and the minimisation of the storage time between steps once processing has started. An indicative hierarchy of best practice is given below:

1. Intact undamaged fridges treated at a integrated de-gassing and fully automated ODS recovery plant
2. Whole fridge (intact and undamaged) incineration
3. Non integrated de-gassing followed by ODS recovery and disposal at another site
4. Manual processing, cutting and dismantling for ODS recovery and disposal at another site

Storage

Waste refrigerators must be stored in such a manner so as to prevent damage to the stored unit and to prevent the release of ODS and lubricating oil.

De-gassing

To achieve the best possible outcome, refrigerant and oil must be extracted in the same step with a minimum of 90% by weight of the oil being extracted from the system.

¹ Guidebook for Implementation of Codes of Good Practice – Refrigeration Sector, UNEP (1998)

INTRODUCTION	STORAGE	RECOVERY	DISPOSAL
Key Issues	Legislation	Identification of ODS	

1.2 Legislation

Where fridges are stored pending a Waste Framework Directive ("directive") recovery operation (other than at the site of production) the storage activity will require a Waste Management Licence (WML). Examples of fridge recovery operations are those which separate the metals, foams and plastics for the recycling of some of these materials, usually the metals. The fact that the collected refrigerants are disposed of e.g. incinerated at another location or that small amounts of food wastes are removed for landfill does not detract from the primary activity of recovery of the metal.

There are currently 4 fridge processing approaches being proposed in the UK, these are:

- Mechanical pulverising using activated carbon and cryo-condensation to collect the ODS for disposal;
- Mechanical pulverising using an integrated incinerator to dispose of the refrigerants and foams;
- High temperature incineration to dispose of whole or flat packed fridges (total destruction);
- Mechanical pulverising using activated carbon to recover ODS and catalytic oxidation to treat the ODS.

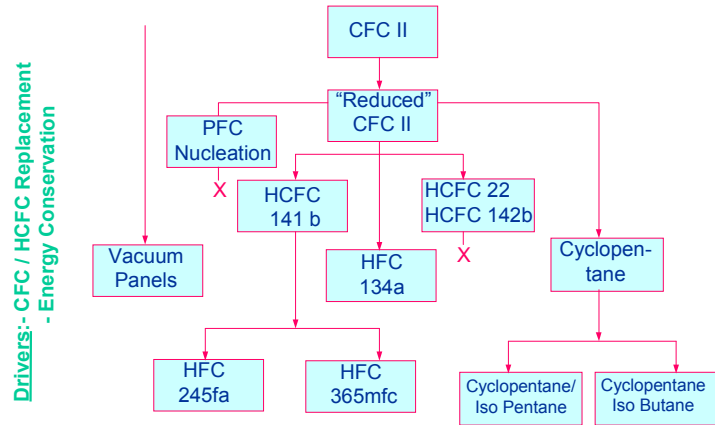
The first approach will require a WML as it is considered to be primarily a directive recovery operation R4 (recycling / reclamation of metal / metal compounds). R4 operations are not listed in Schedule 1 of the PPC regulations.

The second approach is also considered to be primarily a "directive recovery operation" however as incineration of the CFCs is a PPC Schedule 1 listed activity, that activity requires a PPC permit. The pulverising of the fridges and incineration is an integrated activity; a PPC permit would cover these activities and any associated storage.

The third approach is considered to be primarily a "directive **disposal** operation". This activity is required to be authorised under Schedule 1 section 5.1 of the PPC Regulations. The fourth approach may fall within the PPC Regulations if the catalytic oxidation produces certain organic chemicals. The situation will need to be judged on the basis of a particular plant or design.

1.3 Identification of ODS

Different kinds of ODS have been used to blow the insulating foams in refrigerator cabinets.



Source : Huntsman

Determining the blowing agent(s) used in a particular unit would require sampling the foam and testing it, but such sampling is not practicable during a high-volume automated operation. However, the age of the appliance may provide some indication as to the type of blowing agent used.

The UK has been dominated by four prime technologies:

- | | | |
|-----|----------------------------|------------------------------|
| (1) | CFC-11 | pre-1990 |
| (2) | Reduced CFC-11 | 1991-1994 |
| (3) | HCFC-141b | post 1994 |
| (4) | <i>Cyclopentane blends</i> | <i>post 1994²</i> |

While hydrocarbon blends such as (4) were not universally used post-1994, they are emerging now as the technology of choice in the replacement of HCFC-141b, which needs to be eliminated by 1st January 2003. HFC-245fa and HFC-365mfc may also be used as a replacement for HCFC-141b by those UK manufacturers seeking to achieve optimum thermal efficiency. However, these are not commercially available until late 2002.

It is important to note that the mix of units reaching the UK waste stream is not only defined by the manufacturing base. Refrigerators and freezers are highly tradable commodities and imports from mainland Europe represent a substantial share of the overall UK market. In Germany, almost all new production of domestic refrigerators is based on hydrocarbon technology for both blowing agent and refrigerant.

For the refrigerants themselves, the key options have been:

- | | | |
|-----|---|------------------------------|
| (1) | CFC-12 | pre-1994 |
| (2) | HCFC-22 | post 1994 |
| (3) | <i>HFC-134a</i> | <i>post 1995¹</i> |
| (4) | <i>Isobutane and other hydrocarbons</i> | <i>post 1995¹</i> |

In the UK, there was some reticence to move to hydrocarbons because of safety worries. The implication is that there is a higher than average population of refrigerators and freezers containing HCFCs and HFC based refrigerants than in other parts of Europe.

Although labelling of refrigerators in order to identify refrigerant type has been widely practised to allow for ease of servicing (usually listed on the "appliance rating plate") there has been no such practice historically for the insulation foam. Some companies in Germany began labelling foam blowing agents in the late 1990s and the practice is becoming more widespread on new appliances as the need for end-of-life identification has been realised.

As the UK stock continues to turnover, the proportion of non-ODS units being decommissioned will increase as will the proportion of hydrocarbon in the mix. This factor needs to be accommodated in any design. With better labelling, it may be possible to exclude some non-ODS units, but in view of the average product lifetime of around 15 years, it seems most appropriate and cost-effective to consider all units as ODS containing for the next five years or so unless the processor has specific information

² Blowing agents and refrigerants in italics are non-ODS technologies

about the source. Operators must be aware of the safety issues associated with handling hydrocarbon blowing agents.

One of the key issues in assessing the significance of actual emissions is their relationship with the original charge of ODSs and the potential still recoverable. On this subject, significant work has been conducted by the German refrigeration industry during the last five years in order to establish the average amount of foam injected into their units. The existing RAL quality assurance standard³ defines three types of unit. These are:

Type 1:	Domestic refrigerators	typical for domestic use with a load capacity of up to 180 litres
Type 2:	Domestic Fridge-Freezers	typical for domestic use with a load capacity of 180 – 350 litres
Type 3:	Domestic Chest Freezers	typical for domestic use with a load capacity of up to 500 litres

Using these basic 'types' and the product mix sold in the market, the German industry was able to estimate an average of 300-340g of blowing agent across the range of units sold. However, the amount will reduce due to leakage during the operational life of the fridge (about 0.25% per year according to TEAP publications).

As noted in Section 2.3, a typical refrigerant charge is in the order of 110 grams, thereby making it considerably less significant than the foam blowing agent. For a fully-automated mechanical recovery unit, the following chart illustrates the typical emission sources and the relative composition:

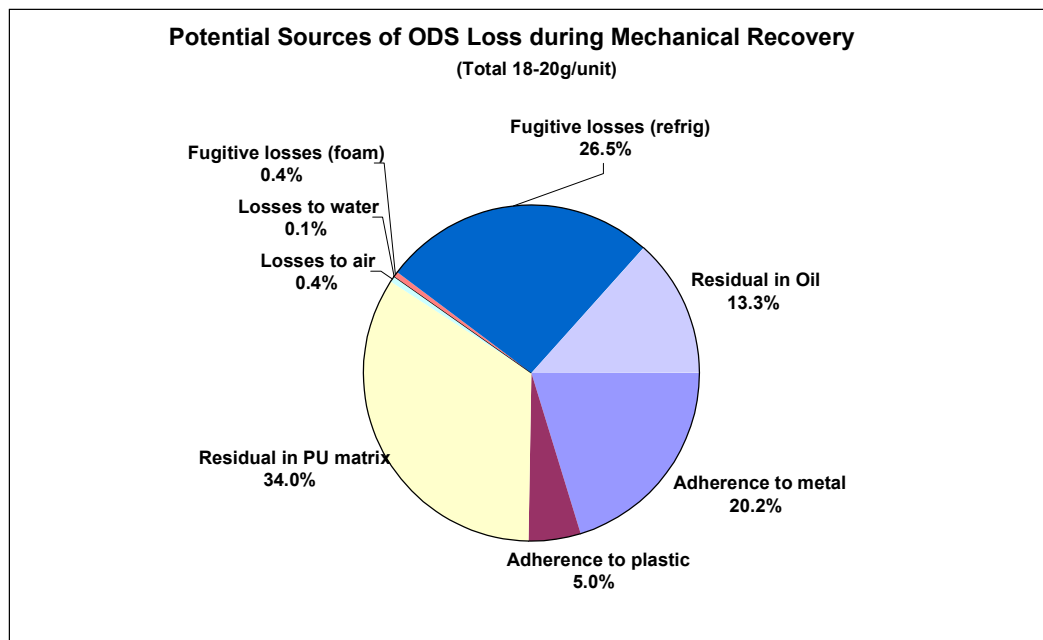


Figure 1 - Potential Sources of ODS Loss during Mechanical Recovery

It can be seen that a total loss of between 18g and 20g might be expected from a combined available quantity for recovery of 410-420g or, to put it another way, losses of less than 5% in total. The Environment Agency considers this acceptable.

The significance of the need for extraction of the oil in STEP 1 (see section 4.1) becomes more evident when it is viewed that a further 15g (assuming a 5% residual refrigerant level) could be left behind, virtually doubling the losses. Accordingly, it is important to extract the maximum amount of oil.

³ 'Reverse Production of Refrigerators Containing ODS' : RAL – GZ 728 (1998)

INTRODUCTION	STORAGE	RECOVERY	DISPOSAL
	Cutting		

2 Storage

Inspection

1. Fridges should be checked on arrival for damage or leaks. Those in a poor state of repair or which pose a significant risk of releasing CFC should be de-gassed immediately.

Storage

2. Where ODS removal will take place in two stages (degassing of refrigerant separate from foam treatment) de-gassing should be carried out prior to long term storage (over 3 months).
3. Storage of fridges prior to de-gassing must take place in an area with an impermeable surface and sealed drainage.
4. Sites that only accept pre-treated (de-gassed) fridges and do not undertake any subsequent treatment will not require impermeable surfacing.
5. Units should be stored whole and upright with a maximum stacking height restriction of the equivalent of 2 upright units (circa 3.5 metres).
6. Where units have been dismantled into panels, suitable precautions must be taken to ensure the foam is not damaged e.g. removal of sharp objects, and stacking height restricted to avoid crushing of the panels.

Site Security

7. All sites must demonstrate that they are secure to avoid unauthorised access.
8. If there is no possibility of unauthorised personnel gaining access to the site, i.e. a fully enclosed building, there is no need to remove fridge doors.
9. In all other cases measures must be taken to prevent children being trapped inside by:
 - removal of doors,
 - removal of the rubber door seal and tape the door shut.
10. Where an old refrigerator has a mechanical latch to hold the door shut, these should always be removed prior to storage.

Fire prevention

11. Adequate fire prevention mechanisms should be used and access for the fire brigade should be maintained at all times.

Cleaning

12. Units should be emptied of all foodstuffs, the trays and shelves removed (to aid cleaning) and cleaned prior to storage to reduce the risk of handlers being exposed to harmful or infectious material by handlers.

3 Cutting

The amount of ODS released when a typical domestic fridge or fridge freezer is cut into flat panels is approximately 3g. The quantity released from cut cold room panels may be estimated using a factor of approximately 7 g/m² of cut foam surface area.

1. Fridges should be degassed prior to cutting.
2. A hand held reciprocating electric saw fitted with a metal cutting blade is a suitable method of cutting fridges and cold room panels where the foam and facing panels are still adhered to each other.
3. Where a cutting device is used, there should be minimisation of the thickness of cut, the number of cuts, and the surface area of foam exposed by the cutting process. Also, the cut edges should be protected from bruising and scraping.
4. Cut panels should be protected from crushing as this damages the foam structure and can cause further ODS release.
5. To reduce the cut area of foam, cutting plans should allow the cut sections from similarly sized fridges to be stacked inside each other.
6. Storing cut panels in excessively hot environments significantly increases the quantity of ODS released. Exposure to air temperatures of 45°C may double the quantity of ODS released compared to storage at 20°C. Poorly ventilated steel containers exposed to direct sunlight would be unsuitable for storing cut fridges and cold room panels.
7. Maintain a transport and storage policy that minimises the amount of time that cut panels spend exposed between de-gassing (see section 4) and recovery (see section 4.2).
8. Shrink wrapping of panels to mitigate ODS loss during storage should not be used where the panels are to be sent for incineration.

4 Recovery

4.1 De-gassing - STEP 1

There are two options for de-gassing

- A) Removal of coolant and oil in the same step for example piercing the base of the compressor with a proprietary degassing unit and extracting refrigerant and oil
 - B) Removal of coolant and oil in separate stages for example "nipping" the cooling circuit and extracting the refrigerant followed by playing a tube to the base of the compressor via the stem of the cooling circuit and pumping out the oil.
1. To achieve the best possible outcome refrigerant and oil should be extracted in the same step using vacuum suction. The reason for this is that the initial pressure of the system is the most effective way of removing the oil. Once the pressure is lost, maximum suction will only produce 1 bar of negative pressure .

Requirements for de-gassing processes

Option A

Proprietary degassing units are capable of removing > 99% of oil and refrigerant mix from the cooling circuit and compressor at typical temperatures of 5-10 degrees Celsius.

2. Prior to de-gassing the temperature of the oil must be at least 5°C.

Option B

3. The extraction steps should be carried out in an enclosed area where emissions can be captured and the controlled substances released recovered (by for example adsorption or condensation) for disposal.
4. The extraction steps should be carried out in immediate sequence without delay in between.
5. Emissions of ODS should be limited to a maximum of 5g per unit from the de-gassing process (as assessed from the captured refrigerant in the controlled environment).
6. Air-flows need to be managed in such a way as to avoid the development of dangerous atmospheric concentrations of refrigerant. This could happen, for example, through the de-gassing of hydrocarbon refrigerators.
7. In order to reduce the viscosity of the oil prior to de-gassing the temperature of the oil must be brought up to a temperature of 20°C prior to de-gassing.
8. When oil/refrigerant mixes are extracted, the fractions should be separated as quickly as possible to allow for maximum extraction of refrigerant from the oil.

Improvement Timetable for Degassing

Many of the standard recovery and recycling units available for decentralised de-gassing (in situ either at the site of the commercial appliance or at civic amenity sites for domestic appliances) are only designed to remove the lighter gaseous fraction of the refrigerant and normally leave the oil in place. Since a typical domestic refrigerator contains approximately 130g of refrigerant gas plus about 310g of oil, a residual level of refrigerant in the oil of say 5% by weight would mean that nearly 12% of the CFC-12 would be lost in this one action alone.

Existing operations will require a transition stage in order to move to an acceptable standard. Specific improvements should be carried out within the timescales given below.

Improvement	By whichever is the later of:
"Nipping" the cooling circuit and extracting the refrigerant followed by playing a tube to the base of the compressor via the stem of the cooling circuit and pumping out the oil in immediate sequence	31 July 2002 or 3 months from the issue of the Licence
Utilisation of a proprietary degassing units capable of removing > 99% of oil and refrigerant mix from the cooling circuit and compressor	31 October 2002 or 6 months from the issue of the Licence
The extraction steps should be carried out in an enclosed area where emissions can be captured and the controlled substances released recovered (by for example adsorption or condensation) for disposal.	31 October 2002 or 6 months from the issue of the Licence

9. The percentage of refrigerant remaining in the oil after separation should not exceed 0.9% by weight.

Handling of removed oil/refrigerant

10. A system must be maintained to record the quantity, nature, origin and destination, frequency of collection, mode of transport and treatment method of oil and refrigerant removed.
11. Records should be maintained of any waste sent off-site (Duty of Care).
12. Storage areas should be clearly marked and signed and containers should be clearly labelled.
13. Storage containers, cylinders and drums etc. should be in sound condition and regularly inspected.

Achievable performance

Gaseous refrigerants are harder to contain than liquid blowing agents. Option A has the best performance with an achievable ODS loss of 1.17g per unit from the coolant and 0.14g of ODS in the oil. Under any circumstances the losses should not exceed the range of 1.5-3.5g per unit.

4.2 Blowing Agent Recovery – STEP 2

Preparation

1. Following the drainage of the cooling system the compressor unit should be removed from the refrigerator unit and placed into a sealed container.
2. Switches or other components containing mercury should be removed from the unit and placed in a suitable container prior to unit destruction.
3. All condensers and electronic drives should be removed from commercial appliances.

4.2.1 Fully automated unit

Unit processes

Fully automated system

A typical fully-automated plant will handle between 60 and 100 cabinets per hour. The installations handle refrigerator units by either crushing or shredding the unit in the first instance and then taking the product through a mill. Ferrous and non-ferrous metals are separated at this stage along with plastic components (e.g. liners). The foam itself, is separated using an air separator and is then further ground, often with the subsequent use of a cyclone, to extract the remaining blowing agent. ODS released in the process are collected via regenerative filter systems and condensers. Due to the differences in boiling point water will condense out initially and then the blowing agents. Refrigerant and water should be recovered separately.

Although the approaches vary a little in detail (particularly when it comes to extraction of blowing agent from the foam matrix), the general schematic of the process is fairly consistent and is set out below:

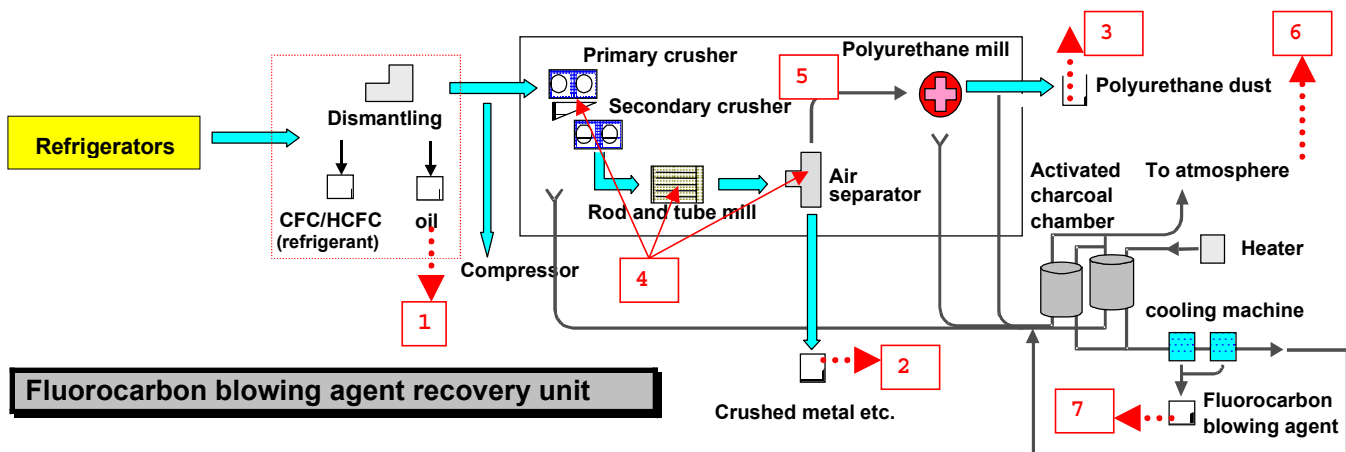


Figure 2 - Fluorocarbon blowing agent recovery unit

Performance of the ODS recovery components, the filters and condensation units depend on satisfactory design. Refer to Appendix 1 for design criteria.

Controlled substances losses

The objective is to reduce ODS loss from the system to at least the benchmark figure of 18g to 20g per unit, therefore;

1. The operator should monitor ODS loss at all points indicated in Figure 2.

Release point see fig. 1	Activity	Parameter	Benchmark or threshold	Monitoring Technique
1	Degassing	ODS in recovered oil	ODS concentration <0.9% wt	See Note 1
2	Crushing and milling	Blowing agent contained in foams remaining attached to the metal fragments	<0.5% wt foam per component	See Note 2
	Foam remaining attached to the plastic fragments		1% wt	See Note 3
3	Recover of polyurethane dust	Blowing agent remaining dissolved in the polyurethane matrix	ODS concentration <0.2%	See Note 4
4	Crushing and milling of refrigerators	ODS present in air extraction system		Continuous monitoring using infra red analysers with multi stream switching could be used to monitor points 4, 5 and 6 plus periodic performance monitoring Emission Limit Value See Note 5
5	Fugitive losses into ambient atmosphere within the unit		Lower limit of detection of the analyser	
6	Loss from the air extraction system	ODS in emissions to air	150 mg/m ³ g CFC R11	
7	Collection of condensed ODS	Liquid ODS	Verify collection of ODS	Photo-ionisation detection or flame ionisation detection
N/A	Losses in the waste water streams	ODS in water Point source release to sewer, watercourse or groundwater		

Note 1: There are no official UK or European test methods for the determination of residual ODS content in lubricant oils at the present time. However, work in Germany has led to the adoption of a DIN standard for this purpose. A precise reference and English translation being sought from RAL (see ref. 1.)

Note 2: While there are no official UK or European test methods for the determination of foam attached to separated metals, the opportunity exists to remove the foam by several high temperature techniques. Consensus is yet to be built on the best technique available and this is currently under review by the UNEP Foams Technical Options Committee.

Note 3: The separation of thermoplastic components from thermo-set residues also requires further consideration as to the best technique available. Opportunities to solvate the thermoplastics, while leaving the thermo-set in tact are being considered. Again this matter is currently under review by the UNEP Foams Technical Options Committee.

Note 4: Again, there are no official UK or European test methods for the determination of residual ODS content in foams at the present time. However, several analytical test methods exist and have been operated successfully. For example a test method developed and successfully operated by Butterworth Laboratories in the UK. An alternative method has been developed in Switzerland by S.EN.S which is a Foundation for Waste Management in the country. Although this method has no formal recognition, it is cited in the RAL –GZ 728 standard. Precise reference and English translation being sought from S.E.N.S.

Note 5: An emission limit value of 150 mg/m³ g CFC R11 equates to a mass loss of 75g/hr. Mass loss of ODS from the system should be proportional to the feed rate of appliances into the system. Therefore mass loss should not exceed these values:-

No. of refrigeration units processed per hour	Maximum mass loss of ODS expressed as CFC R11
< 100	5g per hour
> 100 but < 200	10g per hour
> 200 but < 300	15g per hour
>300 but < 400	20g per hour

>400

30g per hour

ODS Loss Monitoring Protocol

The operator should have in place a protocol that covers both:

- continuous indicative monitoring
- periodical performance monitoring

Continuous indicative monitoring

Proprietary refrigeration gas leak detection systems should be used to monitor ODS (normally CFC R11) at specific points within the ODS recovery process (typically points 4,5 and 6 as shown in Fig 2). These are usually infra red systems providing a parts per million (or ppm) reading.

Periodical performance monitoring

A critical parameter relating to the operation of ODS recovery plant is the mass loss of ODS in both fugitive and point source releases from the system. This benchmark is expressed as grammes CFC R11 per hour. In order to provide performance monitoring information for ODS loss, emission concentrations (continuous indicative monitoring) will need to be converted to mass emissions. It will, therefore, be necessary to determine the gas flow.

Performance monitoring should be carried out when a maximum of 10 000 units have been destroyed or monthly whichever is the sooner, using a feedstock mix which has been agreed with the Environment Agency. Spot samples should be taken from point 6 as shown in Fig 2 and CFC R11 measured and expressed in terms of g ODS/hr. Spot samples should be taken from point 7 as shown in Fig 2 and CFC R11 measured and expressed in terms of mg/l.

Evidence should be provided that quality assurance procedures are in place to ensure that the monitoring results are sufficiently accurate and reliable (for example by reference to British/International standards and accreditation with the UK Accreditation Service (UKAS)).

Refrigerators and freezers containing "hydrocarbon" coolant and blowing agents

Release hydrocarbons, for example cyclopentane, can lead to the risk of explosion. This could occur within the crushing unit or more probably due to a concentration in the filter units.

2. Unless the ODS recovery process is conducted under an inert atmosphere the operator should take measures to prevent appliances containing hydrocarbon coolant and or blowing agents entering the process.

It is sometimes difficult to identify appliances which contain hydrocarbons (see Section 1.3) (the appliance plate may not carry this information). Consequently measures should be taken to mitigate explosion risk.

Levels of hydrocarbons in the treatment system and headspace of the filter units should be maintained below 25% of LEL. This is approximately 2% v/v for cyclopentane which means that the maximum permissible would be 0.5%. There should be detectors with auto shutdown if this level is exceeded.

Wastewater

Most stored refrigerators collect water and up to 1 kg/unit can be extracted. Existing processors sometimes handle this water by collecting into the same "pot" as that used for the recovered ODS. However, this can be an expensive route via special waste incinerators. Accordingly, others separate the water and have it analysed in order to establish how it should be treated.

Waste Handling

The obvious waste streams from a fully-automated plant are the collected ODS and the polyurethane dust. The collected ODS are typically disposed of by incineration. Many suppliers of fluorinated products provide take-back facilities for both refrigerant and blowing agents and, in fully-automated centralised plants, these are often combined.

The polyurethane dust can also be incinerated, or it can be collected for re-use in other applications such as chemical spillage adsorbant and fillers for insulated blocks and screeds.

1. Where re-use is envisaged, levels of blowing agent below 0.2% by weight are required.
2. Where the dust is going directly for incineration, levels as high as 0.5% can be tolerated, provided that the dust remains enclosed in the transportation phase and the period of time to incineration is not prolonged.

3. All extracted blowing agent extracted should be transferred to a suitably authorised disposal facility (typically by controlled incineration).

That appropriate recycling streams are found for all cabinet components (i.e. ferrous, non-ferrous and plastic).

4.2.2 Semi-automated and manual processing

Manual processes are either classified as:

- (1) The manual dismantling of the cabinet taking place as a discreet operation, with the foam components being shipped elsewhere for further processing in a semi-automated or fully-automated plant.

or

- (2) The manual dismantling of a cabinet taking place as a pre-cursor to the direct incineration of the foam and other components.

The principle of reducing ODS loss to a minimum is equally important to this type of processing. It presumes that refrigerator and freezer cabinets can be manually dismantled particularly in order to ensure that losses of foam on the metal and plastic components of the cabinet are kept to a minimum. Polyurethane is a natural adhesive and this characteristic is part of the requirement of the cabinet design. Given that the blowing agent is, to a significant extent, dissolved in the polyurethane matrix, there is no strictly manual process by which the blowing agent can be recovered and destroyed.

Semi-automated and manual processing

Unless the operator can demonstrate that semi-automated or manual process can meet the performance requirements stipulated for fully automated units, semi-automated and manual processing should not be implemented.

5 Disposal

5.1 Direct Incineration

There are two types of direct incineration that need to be considered:

- Direct incineration of foams;
- Direct incineration of whole refrigerators;
- Incineration of recovered ODS

One way of avoiding blowing agent emissions prior to incineration is to incinerate the whole cabinet. Although some plants can cope with whole refrigerators, most would normally be expected to break the cabinet down into panels prior to feeding them in. Although whole refrigerator incineration has been practised in both Municipal Waste and Special Waste units across Europe, problems have been experienced with in the Netherlands with an unmanageable build-up of slag resulting from the metal in the carcass, even after removing the obvious weighty elements such as compressors, following de-gassing.

One of the other obvious drawbacks of such an approach is the loss of any opportunity to recycle the materials of construction. While the current provisions of the WEEE Directive may be met by removing the compressor together with shelves and other demountables, any further increase in the amount of recycled material required will necessitate the recovery and recycling of the cabinet itself. As has been already noted, the after-burning of either re-concentrated ODSs or polyurethane dusts can be carried out either in-line or at a remote location. Most ODS incineration has historically occurred at licensed special waste incineration sites and this is still the pattern most commonly adopted across Europe.

While the Montreal Protocol processes under UNEP have not addressed the management of ODS at end-of-life to any great degree as yet, the management and destruction of concentrated ODS sources has been the subject of attention for many years because of the prospect of legally offsetting consumption by the use of *approved destruction technologies*. In 1991, an Ad hoc Technical Advisory Committee on ODS Destruction Technologies was formed and this reviewed the adequacy of technologies available for ODS destruction. Typical levels of performance were viewed as 99.99% (900°C at 1-2 seconds) or even 99.9999% (1200°C at 1-2 seconds) conversion. This work was updated in 1995 at a UNEP Technical and Economic Assessment Panel ODS Disposal Sub-committee workshop held in Quebec in 1995⁴.

Emission standards

The Waste Incineration Directive (WID) (2000/76/EC) will replace existing Directives on municipal waste incineration and hazardous waste incineration. The existing Directives dealing with municipal and hazardous waste incineration will be repealed on 28 December 2005.

The Hazardous Waste Incineration Directive 94/67/EC (HWID) was implemented in the UK early 1998. When hazardous waste is burned this directive must be complied with, until superseded by WID.

For the relevant emission standards refer to Environment Agency Sector Guidance Note S5.01 Integrated Pollution Prevention and Control (IPPC) & Integrated Pollution Control (IPC). Interim Sector Guidance for the incineration of waste and fuel manufactured from or including waste.

5.2 After-Burning

As has been already noted, the after-burning of either re-concentrated ODSs or polyurethane dusts can be carried out either in-line or at a remote location. Most ODS incineration has historically occurred at licensed special waste incineration sites and this is still the pattern most commonly adopted across Europe. (Refer to [section 5.1](#) for emission standards)

⁴ Both reports available directly through the UNEP Ozone Secretariat in Nairobi

References

- 1 German Institute for Quality Assurance and Certification, Reverse Production of Refrigerators Containing ODS, August 2001, RAL, Sankt Augustin
- 2 Environment Agency Technical Guidance Note (Abatement) A2 Pollution abatement technology for the reduction of solvent vapour emissions, 1994, £5.00, 0-11-752925-7
- 3 Waste Incineration Directive 2000/76/EC – Official Journal L332 28/12/2000 P. 0091 – 0111
- 4 The Hazardous Waste Incineration Directive 94/67/EC - Official Journal L365 31/12/1994 P. 0034 – 0045

Definitions

- Chlorofluorocarbons Chlorofluorocarbons (ODSs) means the controlled substances listed in Group I of Annex I of Regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer, including their isomers.
- Hydrochlorofluorocarbons Hydrochlorofluorocarbons (HCFCs) means the controlled substances listed in Group VIII of Annex I of Regulation (EC) No 2037/2000 of the European Parliament and of the Council of 29 June 2000 on substances that deplete the ozone layer, including their isomers,

**APPENDIX 1 - DESIGN PARAMETERS FOR
ODS RECOVERY EQUIPMENT**

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EQUIPMENT**

Condensation

ODS recovery by reducing the temperature of the air stream below the dew point of the target substance.

Design parameters	
1	Specific information for each unit
1.1	Age of unit(s)
1.2	Heat exchanger type
1.3	Materials of construction Heat transfer surfaces Shell/casing
1.4	Coolant used
1.5	Integrity of coolant supply.
2	Proposed Duty
2.1	Total gas/vapour volumetric flow rate at operating conditions (m ³ /hr)
2.2	Inlet pollutant vapour loading, (mg/Nm ³)
2.3	Gas Temperature (in/out) °C
2.4	Operating pressure (bars absolute)
2.5	Inlet water content in gas stream
2.6	Coolant flow (m ³ /hr and kg/hr)
2.7	Coolant temperature (in/out) °C
2.8	Total effective heat transfer area (m ²)
2.9	How is protection provided during start-up, shut-down and momentary stoppages?
2.10	How is coolant failure detected?
2.11	What measures are taken to prevent compressor failure (i.e. maintenance and redundancy)
2.12	Detail any significant differences between the current duty and design duty and the reason for them. Also comment on whether these differences have an adverse affect on performance.
3	Condenser Cleaning Requirements
3.1	Is the heat transfer surface prone to fouling
3.2	If yes, state frequency and method of cleaning

Adsorption

Adsorption is the phenomenon in which molecules of a gas (adsorbate) contact and adhere to the surface of a solid (the adsorbent). The efficiency of the system and the subsequent regeneration of the adsorbent depends on a number of critical factors including:

- Choice of adsorbent
- Nature of the contaminants
- Operating temperature, pressure and flowrate
- Nature of regeneration

Information required	
1	Specific information for each unit
1.1	Age of unit(s)
1.2	Number of adsorbent cartridges, beds or compartments
1.3	Dimensions of cartridges, beds or compartments i.e. diameter and length (m)
1.4	Materials of construction Cartridges or beds Casing
1.5	Total operating power requirements of the systems (kW)
1.6	Services required and integrity of supplies e.g. Electric power – pumps linked to emergency generator.
2	Proposed Duty
2.1	Volumetric flow rate at operating conditions (m ³ /hr)
2.2	Inlet gas pollutant loading, dry/wet (mg/Nm ³)
2.3	Gas Temperature (in/out) °C
2.4	Gas inlet pressure (Bars abs)
2.5	Number of beds in parallel/series
2.6	Pressure drop across unit (mm/H ₂ O)
2.7	Total effective adsorbent area (m ²)
2.8	How is protection provided during start-up, shut-down and momentary stoppages?
2.9	How is pollutant breakthrough detected?
2.10	Detail any significant differences between the current duty and design duty and the reason for them. Also comment on whether these differences have an adverse affect on performance.
3	Adsorbent Regeneration System (on site)
3.1	Is the adsorbent regenerated. If no what is its fate? If yes answer 3.2 to 3.4.
3.2	Is regeneration done in situ, elsewhere on-site or off-site
3.3	Method employed
3.4	Typical lifetime of adsorbent before disposal required.