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Health and Safety Executive

A study of current working practices for refrigeration field service engineers

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A study of current working practices for refrigeration field service engineers

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As a result of a refrigeration related fatality in Stevenage in 2004 HSL has been requested by Stevenage Borough Council under the Local Authority Funding Scheme, to carry out a study of current working practices for refrigeration service engineers. This text focuses primarily on the equipment, practices and procedures employed in order to carry out leak detection and other repair work on refrigeration systems in the field. This definition is further classified as service engineers working on equipment with a refrigerant load of less than 3kg in service on commercial or public premises which may be subject to inspection by local authority inspectors.

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1 EXECUTIVE SUMMARY

As a result of a refrigeration related fatality in Stevenage in 2004 HSL has been requested by Stevenage Borough Council under the Local Authority Funding Scheme, to carry out a study of current working practices for refrigeration service engineers. This text focuses primarily on the equipment, practices and procedures employed in order to carry out leak detection and other repair work on refrigeration systems in the field. This definition is further classified as service engineers working on equipment with a refrigerant load of less than 3kg in service on commercial or public premises which may be subject to inspection by local authority inspectors.

OBJECTIVES

To identify and clarify the procedures practices and risks associated with refrigerant leak detection and repair in the field in order to facilitate a better understanding for local authority inspectors by means of the following.

Identification of the correct equipment required to carry out the work.

Explanation of the procedures and methodology employed.

Identification of the legal requirements incumbent upon refrigeration engineers.

Clarification of the terminology used in industry guidance and regulatory literature.

Identification of the current guidance issued by various industry bodies.

Identification of industry bodies including contact information.

2 BACK GROUND

There have been a number of incidents within the refrigeration service industry in recent years that potentially may have been avoided with improved training or better management. Several of these incidents have occurred whilst refrigeration engineers were carrying out leak detection and or strength testing of refrigeration equipment in the field. The practice of leak testing and system strength testing with an inert gas, most commonly oxygen free dry nitrogen (OFN), has led in some cases to refrigeration systems being unintentionally critically over pressurised. This over pressurisation has then led to explosive failure of the refrigeration system or one of its components resulting in loss of life in some instances and serious injury in others. There have also been incidents resulting in serious injury following the use of incorrect gasses for leak testing and the use of equipment unfit or unsuitable for purpose.

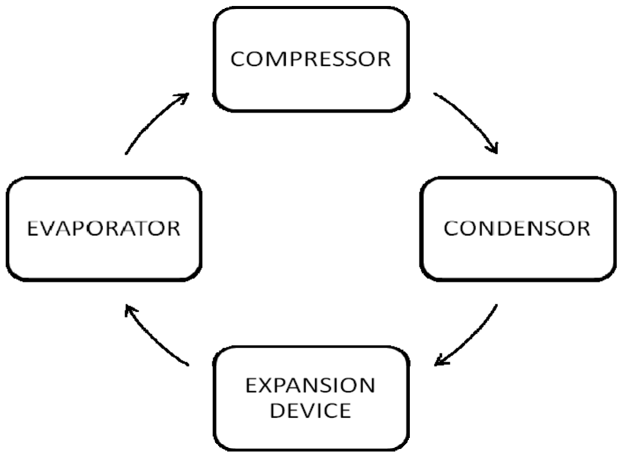
The main hazard associated with leak testing and system strength testing during service, repair or commissioning of refrigeration systems is the close proximity to a pressurised system that is required to locate a leak so a repair can be affected. When a refrigeration unit is operating under normal conditions the risk of injury to users, by-standers or engineers is mitigated to a residual level as the system is operating at range of pressures well within its designed range of tolerance. When a refrigeration engineer is carrying out leak detecting with OFN or system strength testing however, the internal pressure of the refrigeration system is entirely under the control of the refrigeration engineer. This places the safety of the engineers and those in the immediate vicinity in the hands of the refrigeration engineer. If the correct equipment is used and the proper procedures are followed the risk of injury is mitigated to an acceptable level. The incidents recorded so far are attributable to human error, inadequate equipment or the use of an incompatible gas.

3 INTRODUCTION

In order to understand the procedures used during the service and or repair of refrigeration systems it is first necessary to understand in broad terms how a refrigeration system works. It is important to note at this point that this text is specific to small commercial refrigeration systems which would be most familiar in terms of cold cabinets seen in commercial high street shops and larger catering style refrigeration units found in commercial kitchens, bars, restaurants, sandwich shops and many other commercial or high street premises.

Figure 1 below is a diagram of the refrigeration cycle. In essence refrigeration works by taking advantage of the corresponding decrease in temperature that comes with a rapid decrease in pressure and the accompanying change in state of the refrigerant contained within the system. The cycle starts at the compressor where the refrigerant in a gaseous state flows to the condenser and, as the name suggests, is condensed to a liquid state. Condensation is achieved by passing the refrigerant through an aluminium finned copper cooling coil where heat is removed via airflow generated from electric fans. From here the flow of liquid refrigerant is carefully controlled either by means of an expansion valve or a measured length of small bore copper pipe called a capillary. This device delivers the liquid refrigerant to the evaporator. Here an immediate drop in pressure gives rise to a rapid expansion of the liquid refrigerant and a change in state from liquid back to gas once again. This rapid change in state requires energy, which is drawn from the immediate environment resulting in a corresponding and considerable drop in temperature. The evaporated refrigerant, now in a gaseous state again, is drawn back to the compressor under suction and the start of the cycle.

FIGURE 1



The refrigeration cycle

As you can see from Figure 1 above the process of refrigeration is a continuous cycle which is contained within a gas tight system. This is referred to as a hermetic system. All systems of this type rely completely on the integrity of the refrigeration system and the components therein. When the need arises to carry out work on these systems due to component failure it will be necessary to break into this sealed system. When performing work of this nature it is necessary by good working practice and law to extract the refrigerant from the system in such a way that it is not vented to the atmosphere and can be stored either for reuse, recycling or professional and environmentally responsible destruction.

4 LEAK DETECTION

Carrying out leak detection has been a common thread running through many of the more serious refrigeration related incidents in recent years. The risks are personal injury or death due to the refrigeration systems being over pressurised resulting in explosive failure of the one or more of the components with the system, most commonly the compressor. Broadly, the causes of these incidents can be categorized in two ways. Firstly, and most commonly are incidents in which an experienced and qualified engineer, conversant with the current guidance and working practices, unintentionally over pressurises the system they are working on resulting in an explosive failure. Less common are incidents where the incorrect gas has been introduced into the system, most notably pure oxygen, the introduction of which induces a reaction with the lubricants and internal components within the system resulting in explosive failure.

A procedure for leak detection is outlined in the following text, this includes identification and illustration of the correct equipment and inert gas containers that should be present on a job site if the procedure is to be carried in the correct manner and in accordance with current legislation. A refrigeration service engineer has at his or her disposal several direct methods of detecting leaking refrigerant gas, the most widely used are as listed below.

- Portable electronic leak detection. An electronic probe is used to detect and pinpoint leaking refrigerant as it escapes the system. These devices are typically small handheld units that emit and audible signal when refrigerant is detected. Good electronic detectors can typically detect leaks as small as 3 grams per year. Electronic detectors will be used in direct inspections and during tracer gas method.

- Ultraviolet (UV) indication fluids. A type specific dye is introduced into the system and mixes with the refrigerant. The dye is pumped around the system and escapes along with the refrigerant at the point of the leak giving a visual indication of the leak location under specific lighting conditions.

- Proprietary bubble solutions. This method is commonly referred to as the bubble method. This method involves applying a soapy solution directly to areas of a refrigeration system suspected or favoured for leaking. Any escaping gas will create bubbles in the solution indicating the location of the leak.

BS EN 378-4:2008 Annex D provides information on when leak tightness testing should be carried out. The interval between inspections is dependant on the size of the system and the quantity of refrigerant it contains. For refrigeration systems with a refrigerant load of less than 3kg leak tightness testing or inspections is required only when serious suspicion of a leak exists. For the purposes of demonstration and ease of explanation we will assume that a leak does exist and a refrigeration engineer has attended the job site to find a refrigeration system completely devoid of any refrigerant and at a neutral pressure. At this point the engineer is legally obliged to assume a leak exists and to locate and repair it before the system is recharged with refrigerant. It is illegal to add refrigerant to a system where suspicion of a leak exists. It is also illegal to charge a refrigeration system with refrigerant for the purposes of leak detection. The only circumstance in which refrigerant can be introduced to a system suspected of leaking is when the tracer gas method is being employed. This method requires a very small amount of refrigerant be introduced into the system, i.e. for a system with a total refrigerant load of

400grams an amount of 8 to 10grams could be introduced. The system would then be pressurised to normal working pressure with OFN and the leaking refrigerant detected via electronic means. Although this is a legitimate method of leak detection it is still technically at odds with the legislation on deliberate venting of ozone depleting substances. Taking this into account and the protracted nature of the procedure, it is not a practice that is in widespread use. Far more likely is that an engineer will pressurise the system to a normal working pressure entirely with Oxygen Free dry Nitrogen (OFN) and then manually detect the leak by means of the bubble method. Below, **Figure 2** shows of what an engineer would most likely find employing either a soap and water solution or a proprietary foam product. Although this method may appear simplistic, it is the most commonly used method for leak detection and is itself defined and approved in a British Standard. BS EN: 1593 1999. Bubble Emission Techniques, NDT. **Figure 3** shows two of the many proprietary products available for use in leak detection via the bubble method.

Figure 2

A leaking fitting observed under the bubble method

Figure 3

Proprietary leak detection solutions

5 REGULATORS

The OFN used in leak detecting is supplied in standard type gas bottles typically at a pressure range, when full of 230 to 300 bar dependant on the size of the cylinder. The maximum working pressure of an average small commercial refrigeration system could be anything from 5 to 45 bar, it is the disparity between these two pressure ranges that makes regulator selection potentially a critical factor to safety. Due to the broad range of pressures that may be encountered by a refrigeration engineer it is necessary to carry a regulator that will accommodate that range. Efforts have been made to encourage refrigeration engineers to use a regulator with a maximum outlet pressure of 10 bar which, whilst adequate on some systems when the bubble method of leak detection is used, does not deliver sufficient pressure for use with the tracer gas method or on higher pressure rated systems. Whilst it may not un reasonable to expect an engineer to carry several regulators with differing maximum outlet pressures so the most suitable regulator can be selected for any given system, this is not common practice and may be considered impractical. Currently there is no specific legal requirement placed on refrigeration engineers that requires them to use a regulator with a specified maximum outlet pressure range relative to the pressure of the system they are working on. The good practice guide issued by the Institute of Refrigeration titled Pressurising Installed System with Nitrogen to Find Leaks offers the following advice under the heading Using The Correct Equipment,

“The nitrogen used must be oxygen free (OFN) or High Purity. Oxygen must **never** be used as it can explode when mixed with oil, causing serious damage to equipment and injury or death to those in the vicinity.

It is essential to use a suitable regulator with nitrogen cylinder. The regulator has an output limiting device to prevent the over pressuring of systems. The rating of this must be higher than the test pressure to be used but not excessively so”

In practice regulators with pressure ranges of 0-10 bar, 0-42 bar and 0-50 bar 0-100 bar are used and often only one is carried. Whilst these higher outlet pressures do have the potential to over pressurise a system they are safe when used properly by a competent engineer. Illustrated in **Figure 4** is a typical nitrogen bottle regulator with a pressure range of 0-10 bar. This type of regulator is available from suppliers of refrigeration equipment or directly from BOC and other gas equipment suppliers. Regulators with higher outlet pressures will be of the same design and constructed from the same materials as those with a lower maximum outlet pressure. The maximum inlet and outlet pressures will be printed on either the outlet pressure adjustment knob or the body of the regulator. The regulator will have two gauges fitted to it, one indicates the internal pressure of the bottle and is used to indicate the amount of gas remaining in the bottle. The second indicates the pressure being delivered at the outlet of the regulator and should have a scale of sufficient resolution to display the outlet pressure accurately relative to the pressure required to test the system. The easiest way to differentiate between these two gauges is to look at the dial faces, the gauge that is indicating the internal pressure of the gas bottle will have a red coloured section around the zero to one portion of the scale.

A critical step for safe operation of regulators fitted to pressurised gas bottles is to always ensure that the outlet pressure control knob is wound fully out, turning in an anti-clockwise direction, so the outlet pressure is set to zero before the gas bottle isolator is opened and any pressure is applied to the system. Pressure should then be applied progressively in small increments until the required outlet pressure is reached. A detailed knowledge of the system that is to be worked on is also essential, including the maximum pressure that the system can safely be pressurised to for testing.

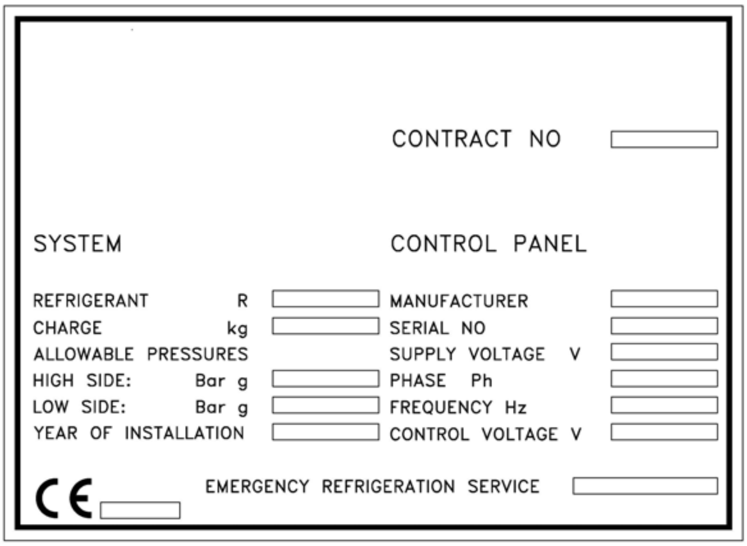
Figure 4

A modern type nitrogen regulator. Many other types of regulator will be seen in use

6 DATA PLATES

Figure 5 below is an example of typical data plate that should be fitted to all refrigeration equipment. All though the size, typeface, style and the material they are made from will differ widely between manufacturers the content should be broadly the same. Minimum requirements for the data fields are given in BS EN 378-2:2008 section 6.4. It is these data plates that an engineer will refer to in order to ascertain a safe pressure to which the system can be charged with an inert gas for the purposes of leak detection.

Figure 5

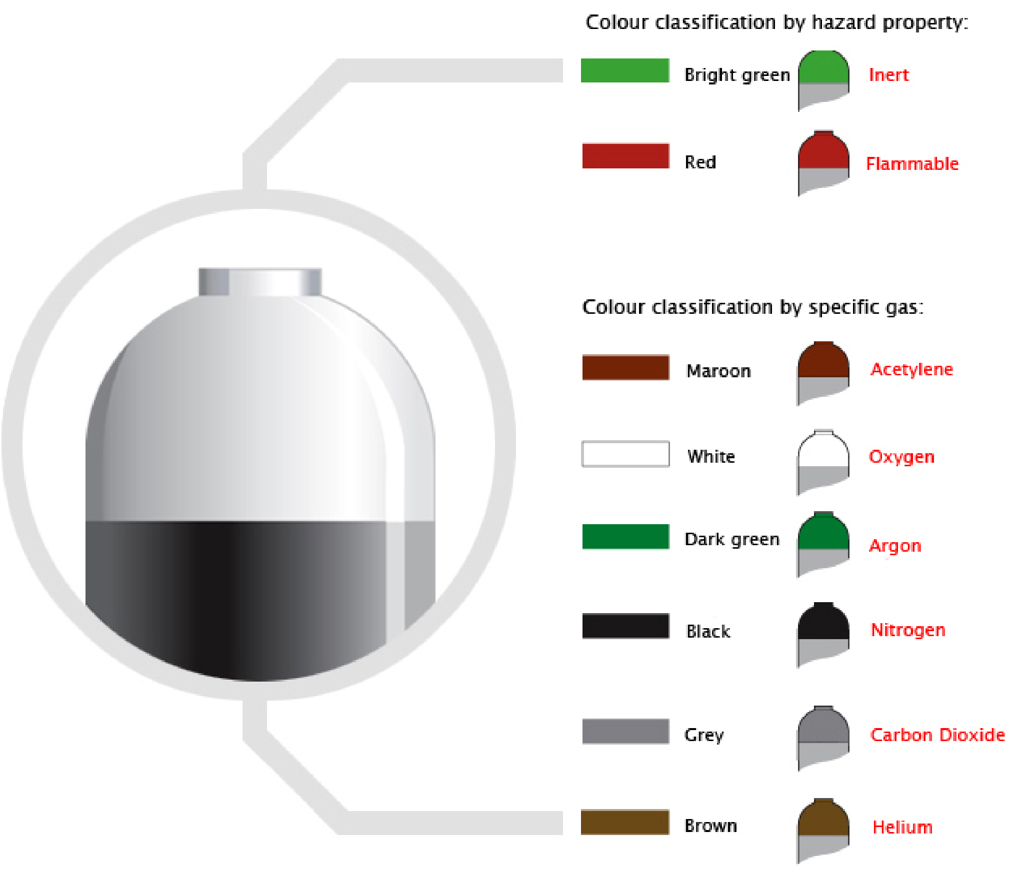


An example of a typical data plate

7 GAS BOTTLE IDENTIFICATION

Gas bottles are identified by a colour-coding scheme as per the relevant harmonised British and European standards BS EN 1089-3, 2004. The vast majority of cylinders from reputable suppliers will be predominately grey in colour with the top six to eight inches, referred to as the shoulder, painted a different colour to denote the bottle content. Specifically for OFN, this top portion is black. The cylinder may also be fitted with a yellow plastic valve guard collar. All new gas bottles will also be labelled indicating the contents and the cylinder pressure, but as these labels are of a self-adhesive paper type they can quickly become illegible or detached. For this reason it is advisable to familiarise oneself with the colour coding system. To this effect commercial gas suppliers make freely available bottle identification charts shown in **Figure 6**.

Figure 6



A gas cylinder identification table. Reproduced with permission by BOC

8 COMMON REPAIR PROCEDURE

This section describes a typical procedure for a common repair to a refrigeration system. The example we will be using is the replacement of the refrigeration compressor as this is a comparatively common mode of failure for refrigeration systems and when carried out correctly, employs many of the type specific tools associated with the industry. **Figure 7** below shows a typical small system type compressor.

Figure 7

A typical compressor

Due to the nature of this type of repair it will be necessary for the engineer to completely recover all of the refrigerant from the system. The engineer is legally obliged to recover the refrigerant in a safe manner and take all reasonable precautions against the venting to atmosphere of refrigerant. The first step is to identify the type and quantity of refrigerant contained in the system. This is achieved by consulting the system data plate. It is a legal requirement that a refrigeration unit is fitted with a data plate, which should contain, as a minimum, the type of refrigerant in use, the load of refrigerant by weight and the manufactures name and address. More recently manufactured refrigeration systems are required by law to be fitted with more comprehensive data plate. The data plate is most commonly located inside the cold compartment of the unit. Some manufacturers also include a duplicate data plate fitted to the actual refrigeration unit base plate so if the two are separated the engineer still has access to the information.

Once the type of refrigerant has been established a compatible refrigerant recovery machine must be used to recover the refrigerant into a suitable vessel that is either empty or has sufficient spare capacity and contains only refrigerant identical to that which is to be recovered. Recovery of refrigerant in this manner is a legal requirement. If the engineer is following good practice guidelines and working within the law a refrigerant recovery machine and vessel will be on the job site. **Figures 8** and **9** show a typical refrigerant recovery machine and refrigerant vessel

Figure 8

A typical recovery machine

Figure 9

A typical recovery cylinder, these can come in a variety of sizes.

Once all of these criteria are met the engineer can begin to set up the refrigerant recovery operation. The recovery machine and recovery cylinder are connected to each other and in turn to the refrigeration system by means of type specific hoses directly to the recovery machine, or connected through the engineers gauge set referred to as manifold. This of all the pieces of equipment is perhaps the one indispensable item for the refrigeration engineer. There are very few procedures performed by the engineer that do not require the use of a manifold set and hoses. **Figure 10** shows a typical engineers manifold set.

Figure 10

A typical engineers manifold.

A manifold set can facilitate the charging and recovery of refrigerant from a system via means of a common block comprising three ports and two valves which enables the engineer to control the flow of refrigerant. All manifold sets will be fitted with two gauges as seen in **Figure 10**, the blue gauge will indicate pressures from a vacuum to typically 8 or 10 bar and is commonly referred to as the low side or low pressure line. The red gauge will indicate pressures from 0 to typically 30 or 40 bar and is referred to as the high side or high pressure line. The central or common port usage is dependant the operation being carried out. For re gassing a system the common port or line would be connected a cylinder of refrigerant. For evacuating a system the common line would be connected directly to the refrigeration system via a service port most commonly located on the compressor. Some gauges will also be fitted with a sight glass; this can be seen in the dead centre of the black block in **Figure 10** and is used for observing the flow and condition of refrigerant. A sight glass is not a required feature and is not common to all gauges. There are recorded incidents of these sight glasses failing under excessive pressure and causing significant injury to the user. Anecdotally these incidents again appear to be associated with the activity of leak detecting at higher pressures whilst using OFN. The Institute of Refrigeration issued the following warning on their Good Practice Guide 24

“**Warning-use of Manifolds with sight glasses**

This guide assumes the use of Refrigerant Manifold and Gauges. It is essential that the manifold **does not** have a sight glass. These sight glasses have been known to fail and risk causing serious injury to the engineer carrying out the test. The manifold, gauges and service lines must be in good condition. Manifolds with sight glasses are only suitable for refrigerant recovery”

More research in this area will be required in the future to obtain meaningful data before I am able to comment on this further.

Once the recovery machine and cylinder are in place the recovery of refrigerant can begin. This is achieved via means of suction through the recovery machine into the waiting recovery cylinder. The type and quantity by weight of refrigerant recovered will be recorded in the refrigeration unit logbook. This again is a legal requirement. Now that the refrigeration system has been emptied of gas the defective component can be safely de-brazed and removed. The defective compressor should be removed from site and disposed of responsibly. A new compressor will be fitted and brazed at this point. Once the new component is fitted and the connecting pipe work brazed the engineer should now carry out a *strength test* using OFN gas. The purpose of this procedure is to asses the structural integrity of the repair carried out in order to confirm that the components fitted and the brazing techniques and filler material employed are to a standard which will tolerate the pressure and conditions equal to and above the normal operating parameters of the refrigeration system, again this is a legal requirement. The complete refrigeration system should be pressurised to a minimum of 1.1 times the normal system working pressure of the system. The maximum allowable pressure for the system will be noted as a numerical value in the data field PS. If the test pressure is given it will either be a numerical value or will be referred to as 1.1 or 1.43 x PS and should have its own data field. This work should be carried out in accordance with pressure testing good practice and great care should be taken that all increases in pressure are gradual. There is some grey area here as to the actual working practice reality that occurs in the field. Although BS EN 378: 2008 states that a strength test should be performed after any significant modification or repair to a system it is more likely that the system is charged to a normal working pressure to asses the integrity of the repair in respect of leakage rather than structural integrity. What is certain however is that the system should be tested for leak tightness or strength using only an inert gas and not refrigerant. On completion of a successful test the system can be charged with refrigerant. This is achieved via means of creating a vacuum with a type specific pump and then allowing the refrigerant to be drawn into the system by that vacuum. To ensure the correct refrigerant load is introduced into the system an electronic scale is most commonly employed to weigh the refrigerant in. This final step represents the completion of the repair and the refrigeration unit can be returned to operation. Details of the work carried out and the quantities of refrigerant recovered and charged to the system must be recorded in the system logbook.

9 EQUIPMENT CHECK LIST

Below is a list of equipment that should be present at the job site to enable a qualified refrigeration engineer to safely undertake repair and maintenance work on small commercial systems which involve the recovery and re-charge of refrigerant and OFN based leak detection. The list is not exclusive and is not type specific. Examples of the correct use of this equipment is provided in sections 4,54 and 8

REQUIRED

Refrigerant Recovery Machine

An example is illustrated in **Figure 8**

Refrigerant Recovery Cylinder

An example is illustrated in **Figure 9**

Refrigeration Engineers Manifold and Hoses

An example is illustrated in **Figure 10**

A bottle of Oxygen Free Nitrogen compressed gas

A suitable gas bottle regulator

An example is illustrated in **Figure 4**

Leak detection – electronic, UV dye system or more commonly bubble solution

PPE suitable for the type of work being undertaken, e.g. gloves, goggles RPE etc

DESIRABLE

Brazing equipment

Heat protective brazing mats

Fire Extinguisher

Electronic refrigerant weighing scales

Vacuum Pump

10 STANDARDS AND GUIDANCE

If a further in depth understanding is required of the legal obligations of refrigeration service personnel and those involved in the commission, design and manufacture of refrigeration equipment, below is a list of relevant standards and guidance that may be of use. The list inclusive but not exclusive.

Institute of Refrigeration

Good Practice Guide 24

Pressurising installed systems with nitrogen to find leaks

DEFRA

Department for Environment Food and Rural Affairs is a very useful resource and provides a large amount of information through its website. Information sheets **RAC 1** to **8** offer advice and guidance on the practical application of the F Gas regulations for refrigeration engineers and companies

BS EN: 378: 2008, 1	Refrigerating systems and heat pumps. Safety and environmental requirements. Basic requirements, definitions, classifications and selection criteria
BS EN: 378: 2008, 2	Refrigerating systems and heat pumps. Safety and environmental requirements. Design, construction, testing, marking and documentation
BS EN: 378: 2008, 3	Refrigerating systems and heat pumps. Safety and environmental requirements. Installation site and personal protection
BS EN: 378: 2008, 4	Refrigerating systems and heat pumps. Safety and environmental requirements. Operation maintenance and repair
BS EN: 1593: 1999	Non-destructive testing. Leak testing. Bubble emission techniques

The Fluorinated Greenhouse Gases Regulations: 2008 (F Gas)

11 INDUSTRY BODIES

Institute of Refrigeration

and

Air Conditioning and Refrigeration Industry Board (ACRIB)

Kelvin House

76 Mill Lane

Carshalton

Surrey

SM5 2JR

British Refrigeration Association

Federation of Environmental Trade Associations Ltd

2 Waltham Court

Hare Hatch

Reading

Berkshire

RG10 9TH

12 REFERENCES

BS EN: 378: 2008, 1 Refrigeration systems and heat pumps – safety and environmental requirements – Part 1: Basic requirements, definitions, classifications and selection criteria

BS EN: 378: 2008, 2 Refrigeration systems and heat pumps – safety and environmental requirements – Part 2: Design, construction, testing, marking and documentation

BS EN: 378: 2008, 3 Refrigeration systems and heat pumps – safety and environmental requirements – Part 3: Installation site and personal protection

BS EN: 378: 2008, 4 Refrigeration systems and heat pumps – safety and environmental requirements – Part 4: Operation maintenance and repair

BS EN: 1593: 1999 Non destructive testing - Leak testing – Bubble emission techniques

BS EN: 13185: 2001 Non destructive testing - Leak testing – Tracer gas method

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