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DETECTING REFRIGERANT LEAKS

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ABSTRACT

This paper briefly summarizes a variety of low cost traditional methods of leak detection; the halide torch, electronic hand-held sniffers, soap solutions, ultrasonic leak detection, and reviews at length the latest technical advances of ultra violet fluorescent leak detection. This paper also considers the causes and the environmental and economic implications of leaks in refrigeration and air conditioning systems and looks at what might be considered the best available technique offering practical solutions without entailing excessive cost, particularly suited to the refrigerated transport, storage and display industry.

INTRODUCTION

A few years ago, leak detection in refrigeration and air conditioning systems was considered to be a last minute inconvenience. Searching for leaks consisted of a time consuming and monotonous inch by inch search over every potential leak site area. When this job was undertaken the first priorities were the obvious high risk areas - flared joints, mechanical joints, shaft seals, expansion valves, fusible plugs etc.

If, as was often the case, insufficient evidence was found of any major leak, the engineer was then faced with a choice of continuing a possibly fruitless and labour intensive search or withdrawing from site and hoping the leak would not show again, or at least not in the near future.

Most systems leak. Indeed experts agree that as much as 70% of all refrigerant consumed has been for "topping up" refrigeration and air conditioning systems.

In the last few years the state of leak detection has changed dramatically as a result of four factors

- Concern about our environment
- Legislation to phase out and ban CFC's
- The escalating cost of refrigerant
- The introduction of time and labour saving leak detection technology

What causes leaks?

Refrigerant leaks are a physical path or hole usually of irregular dimensions and most frequently caused by vibration and mechanical stress - flare failures, fractured tubing, shaft seals, etc.

The combination of temperature, pressure and vibration often produces intermittent small leaks which will eventually grow to become larger ones. In recent times incompatible material has also become a major cause of leaks.

R134a and many of the fluids put forward as alternatives to CFCs are expensive and, in some cases, leak more readily than the traditional refrigerants they replace.

HFC refrigerants require synthetic polyolester (POE) based lubricants, in addition to being more expensive than the original mineral oil they replace, these products can act as aggressive solvents flushing and cleansing the inside of a system exposing the weaker areas where leaks may, and often do, occur. Too often a previously 'leak free' system has undergone retrofit conversion to become an HFC system only for the operator to find, in a short while, that he has a 'refrigerant free' system having lost a significant proportion of the charge!

Most leaks, even those where a pipe eventually fractures will, in the early stages, be small leaks. Many leaks will also be intermittent where perhaps refrigerant loss only occurs during a defrost period where, with the application of heat, the evaporator pressure is higher than that which is normal. This type of leak may only occur twice a day. Refrigerant loss, therefore, may not be noticed for some while or until the plant performance has degraded to the extent that the cooling cycle is affected. This type of leak, along with what may be a myriad of small leaks, are difficult to locate and it is not uncommon to find that many systems habitually operate short of refrigerant. A recent survey (Tait J. 1997) of 38 commercial "condensing unit type" installations showed that **55%** were short of refrigerant.

Energy costs rise considerably when refrigeration plant operates inefficiently. The Good Practice Guide 178, Cost of Refrigerant Leakage, published by ETSU for the Department of the Environment, gives an indication of the cost born by owners of refrigeration plant who typically suffer annual leakage rates of up to 15%. Energy costs alone are given for a cold store spending £22,000 per year on electricity 90% of this (£19,800) on refrigeration. With a typical annual leakage rate of refrigerant put forward as being 15%, energy wastage amounts to around £4,000 per year. Added to this, of course, is the cost of refrigerant, labour and, if it occurs, product spoilage. The cumulative cost of a small leak are summarized in Fig 1.

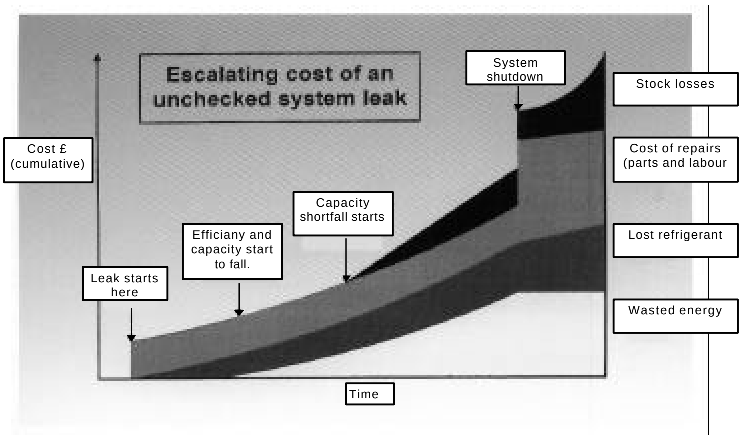

Figure 1 Escalating cost of an unchecked leak
Courtesy of ETSU - Good Practice Guide 178

Efficient leak detection is, therefore, a vital and ongoing factor in reducing cost and system breakdown

1 TRADITIONAL METHODS OF LEAK DETECTION

1.1 Halide Torch (1997 cost c £54)
Introduced over 50 years ago and still extremely popular, the halide torch represents a low cost and effective method of detecting CFC and HCFC refrigerant leaks. Using a copper ring heated by a gas burner, air is drawn through a sampler tube which is used to probe the suspected leak site. If refrigerant gas is present the flame will change from clear to green in the event of a small leak, or purple where heavy concentrations of gas are present. Extreme caution should be used when using a halide torch. CFCs when in contact with a naked flame produce phosgene gas which is very dangerous and the torch itself represents a real fire hazard. The halide torch will not work with chlorine free HFC refrigerants.

1.2 Electronic hand held sniffers (1997 cost c £120 to £700)
Initially considered to be the replacement for halide torches, electronic sniffers have never gained the same level of user trust. Many are perceived to be unreliable and given to false alarms. The sensitivity of an electronic detector is determined by a number of factors, the most important being the type of detector and material concerned.

For example, the ionization detector that demonstrates high sensitivity for CFC-12 may have worse sensitivity for HCFC-123 and very poor sensitivity for HFC-134a. Sensitivity differences of 100X to 1000X have been reported when comparing CFC-12 to HFC-134a with some ionization-based detectors. In this case the variations in sensitivity would be due to lower concentrations of chlorine which is very easily ionized and detected, as one moves from the CFC to HCFC to HFC class of compounds.

In an attempt to resolve the problem, some manufacturers now offer an option that allows an operator to choose various sensitivity settings on a single instrument to suit the application.

1.3 Soap Solutions (1997 cost c £5 for 400ml)
Given the variety of refrigerants available, many contractors have turned to coating suspected leakage areas with soapy water. This can be a messy and time consuming method but one which will work with all refrigerants. Commercially produced foams are better than homemade liquids. One should avoid those based on shampoo, bubble bath liquids or dish washing soaps. Many of these contain chlorides which cause false alarms later when using sniffer leak detectors. Care also needs to be exercised when using soap liquid solutions anywhere near electrical supplies and fittings because of the potential of electric shock.

1.4 Ultrasonic leak detectors
Ultrasonic sound frequencies are sound waves beyond the range of human hearing. Ultrasonic leak detectors detect the sound a gas makes as it escapes from a pressurized system. As the gas is released its flow becomes turbulent. Turbulent flow has a high content of ultrasonic waves which, when detected, can be traced to their source. This turbulence also takes place in vacuum systems. As air leaks into a system under a vacuum it also expands and generates a large volume of ultrasonic frequencies which are detectable by these instruments. Whether ultrasound is present depends on a number of factors - the pressure differential, the size of the leak area, the speed of gas movement and other factors, difficult to use in noisy areas and unable to detect small or multiple leaks; low cost models are a false economy. They may be sensitive to sound in a quiet environment but around running machinery or other competing ultrasounds they are less than efficient.

1.5 Vacuum Tests
Very efficient at determining the presence of a leak, a vacuum test will confirm a leak but not where it is or how many there may be. A vacuum test requires the removal of the refrigerant charge to enable a deep vacuum to be drawn, this in turn adds to the cost of this method of detecting a leak which provides no indication of where the leak is unless used in conjunction with an ultrasonic leak detector.

1.6 Helium Leak Detection
A very practical, fast and efficient method of leak detection for use
mainly on production lines and in combination with fast recovery and refrigerant charging machines. Generally considered impractical for typical service requirements.

Of all the available methods of refrigerant leak detection one has a unique set of user benefits that bear investigation and this paper provides the opportunity to record the research and progress of this method.

2 "ULTRA VIOLET FLUORESCENT LEAK DETECTION AS A TOOL FOR REDUCING REFRIGERANT EMISSIONS"

A major disadvantage of virtually all traditional refrigerant leak detection methods is that to achieve success in finding a leak, refrigerant has to be leaking at the time the operator happens to be looking. Industry experience, confirmed by research, indicates that most leaks start off as small leaks and, at this stage, are very difficult to find. Intermittent leaks, the bane of every engineers life, are very difficult if not impossible to track down and resolve. These leaks, together with persistent small leaks, often lead to inordinate amounts of costly time and labour in trying to resolve the problem, in addition the owner also has had to pay the increased energy costs involved in running an inefficient plant. Ultra Violet fluorescent leak detection offers a method of accurately pinpointing the exact location of every leak at surprisingly low cost.

2.1 How it works

The air conditioning or refrigeration technician introduces a liquid ultra violet fluorescent additive into the AC&R system. The additive mixes and circulates throughout the system with the lubricant. Whenever there is a leak, the additive/lubricant mixture escapes with the refrigerant. The refrigerant evaporates, the additive/lubricant mixture remains at the leak site. The additive residue gives off an unmistakable, bright yellow/green fluorescent glow when illuminated by a hand held mains or battery powered lamp.

Figure 2 Capsules and detection lamp. Courtesy of Spectronics.

The small leaks, so hard to find with most other methods, are inevitably exposed, the dye does not degrade at all when exposed to refrigerants and the fluorescence remains visible for a long period of time when exposed to the outside environment. This is ideal as it produces a cumulative system where even minute leaks will be easily detected as the fluorescent material collects around a leak site over time.

The intermittent leak, the one that occurs at 4 am on Sunday mornings and which cannot be located on Monday (because it is not leaking on Monday) can be pinpointed with an ultra violet fluorescent system. Although the method is simple, it is important to carefully select additives and ultra violet lamps to ensure optimum results.

The most critical factors for any fluorescent leak detection system designed for use within refrigeration equipment are the properties of the dye which will be introduced into the system. The dye must be oil and refrigerant soluble in order to be effective in both the liquid and vapour phases of the refrigeration cycle. The fluorescent response of the dye must be strong enough to allow the final concentration of the dye within the oil to be minimal, assuring that any potential effects on the heat transfer properties of the system will be negligible. The dye must also be suitable enough to withstand the varying pressure and temperature fluctuations it will encounter without losing its fluorescent properties or reacting with the many other materials it will encounter.

Lubricant specific and solvent free additives have been approved by compressor manufacturers and other major refrigeration and refrigerant OEM's and refrigerant reclaimers. The reason for these approvals is that the additives are a solution of colourant (which is a super stable ultra violet fluorescent molecule) and high quality refrigeration oil that is the same as the system lubricant (it may be mineral, polyolester, PAG or alkyl benzene). Once the additive is in the system, the final concentration is 1 part colourant to 350-500 parts (c 0.2%) lubricant.

The stability of the lubricant specific additive's colorant molecule plus its exceeding low concentration in the host lubricant ensure that there will be no deleterious effects to the lubricant's physical or chemical properties or system components. Over 15 million refrigeration and air conditioning systems have been successfully infused with solvent free lubricant specific additives from one US manufacturer.

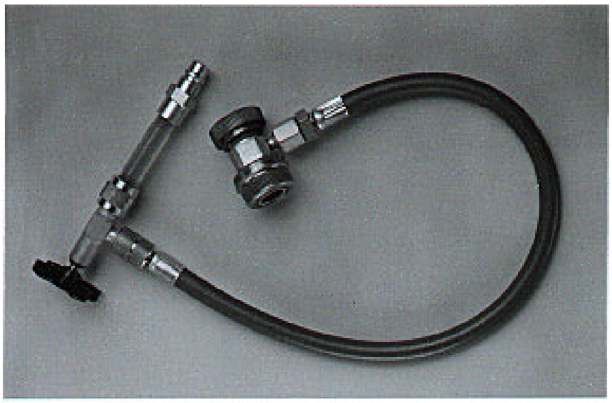

Figure 3 Capsule infusion set up, courtesy of Spectronics Corporation.

The light source used to fluoresce the dye must be very high intensity so that any leakage can be identified at a distance. The light emitted by the bulb must be filtered to transmit a harmless wavelength which will excite the selected dye while blocking other undesired wavelengths. The ultra violet spectrum is the next highest energy level to the visible in the electromagnetic radiation spectrum and, therefore, yields the desired combination of harmless and invisible incident radiation and brilliant visible fluorescence.

Major advances have recently been made to enable both the easy selection of the correct amount of additive and the method of infusing a system. Proprietary "capsules" containing a pre-measured dose of additive afford a clean and simple method of infusing a system ensuring that all of the additive enters the system and at the same time preserving the integrity of the system by denying moisture, air, dirt and other contaminants sometimes associated with the use of bottled dyes.

Table 1 Glo-Stick® Capsule Selection Chart

IMPERIAL			METRIC	
Refrigerant	**Oil**	**GLO-STICK® CAPSULE**	**Refrigerant**	**Oil**
Up to 2.9lbs	Up to 0.75 pints	GS-101	UP to 1.3kg	Up to 0.4Ltrs
Up to 4.9lbs	Up to 2.7 pints	GS-1	Up to 2.2kg	Up to 1.5Ltrs
5 to 9.9lbs	2.8 to 5.4 pints	GS-2	2.3 to 4.5kg	1.6 to 3.0Ltrs
10 to 25lbs	5.5pints to 1.7 gallons	GS-3	4.5 to 11.3kg	3.1 to 7.6Ltrs

2.2 Optimizing Fluorescent Response

Recent research provided, in late 1997, a new range of 12 volt battery lamps capable of competing with high intensity mains operated lamps.

There are presently three categories of light sources which are used to provide the incident radiation which will cause the dyed fluids to fluoresce. These are lamps which can either provide long wave ultra violet light, visible violet and blue light or a combination of both.

There are presently two families of fluorescent dye which are used as leak detection tools. These are the perylenes, which fluoresce a brilliant yellow when illuminated with long wave ultra violet radiation, and the naphthalimides, which fluoresce a brilliant green when exposed to visible violet/blue light. Each of the dyes are usable as a working fluid for purposes of leak detection for any oil based liquid or other fluid in which oil is miscible.

High intensity discharge lamps emitting long wave ultra violet light provide the optimal energy for use with perylene dyes and also cause the naphthalimide dyes to fluoresce. These lamps tend to be larger than those used to provide visible light and are somewhat cumbersome where working space is tight.

Lamps which provide visible violet/blue illumination are optimally suited for use with the naphthalimide dyes, whose excitation peak lies within this range. They will also cause the perylenes to fluoresce, but only poorly. These lamps are typically less expensive than long wave ultra violet lamps and generally more compact.

Figure 4 UV/Blue Leak Detection Lamps. Courtesy of Spectronics.

Broad spectrum lamps provide substantial amounts of both visible violet and blue light as well as long wave ultra violet light. These lamps are the most versatile as they can be used effectively with any fluorescent dye presently on the market and can provide intense illumination even in a compact form.

A technique has been developed which optimizes fluorescent responses of materials by employing lamp filters equipped with optical thin film coatings commonly known as interference filters.

Interference filters which transmit certain regions of the visible spectrum and reflect others are know as dichroic additive or subtractive colour filters. These filters operate by having multiple thin films or coatings applied to a surface of the filter, thus a filter can be designed which will transmit specific wave lengths and reflect those which are undesirable. A filter can, therefore, be designed to transmit significant amounts of ultra violet visible blue light in wave lengths of 360 NM to 470 NM.

The transmission curve of this filter effectively incorporates the peak excitation wave lengths of both the perylene dye and the naphthalimide dye typically used in the industries employing fluorescent inspection.

Ideally suited for both transport and storage refrigeration systems, fluorescent leak detection can offer one of the best available techniques at modest cost.
Requiring no maintenance adjustment or calibration, unaffected by draughts or heavy concentrations of refrigerant, ultra violet fluorescent leak detection works on any size of system and with all refrigerants and does not interfere with other leak detection methods.

Refrigerated transport, like any mobile refrigeration, offers particular challenges in that continuous vibration and varying ambient temperatures inevitably mean systems leak and most often when they are traveling rather than when they are stationary. A single capsule containing fluorescent additive and infused into the system, is sufficient to provide ongoing leak detection for the life of the system or until the oil is changed. Future leak inspections merely require scanning with a high intensity lamp to locate any leaks intermittent or otherwise. Additive costs vary dependent upon the size of the system but would be in the region of £9 to £20 per vehicle or refrigerated container (1997 prices). There is no necessity to add dye in the event of a refrigerant leak as it remains within the system lubricant.

The reduction of labour costs, roadside breakdowns and food spoilage mean payback is very rapidly achieved and true economic savings accrue from the time of first use. The new lamps are a particular boon to transport operators where high light levels reduced the effectiveness of previous lamps and made leak detection difficult on bright days.

A similar story emerges with supermarket and cold store operators. Maintenance costs and the time involved in locating leaks can be drastically reduced. Systems under inspection do not need to be shut down or even have a refrigerant charge remaining whereas with the majority of leak detection devices any significant loss of refrigerant requires the system to be recharged and the pressure raised before leak detection can commence.

Reference sites include ships of the US and British Navy, petrochem sites, refrigerated transport fleets, British Railways, British Telecom, refrigerated display manufacturers, supermarket chains, air conditioning and refrigeration unit manufacturers etc.

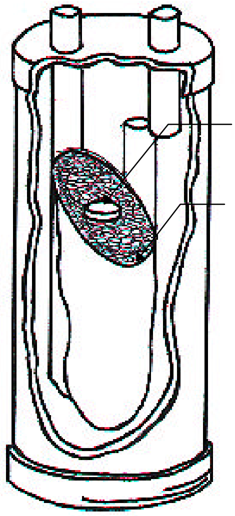

Figure 5 Tracer Wafer in a Dryer/Accumulator, courtesy of Spectronics Corporation.

Not all additives are approved by compressor and equipment manufacturers. Readers should check with their suppliers or the product manufacturer for complete information. For manufacturers who wish to incorporate ultra violet dye leak detection into the manufacturing process, a simple Tracer wafer is available which is composed of a small absorbent pad of inert material which is impregnated with an ultra violet fluorescent leak detection dye. The dye is retained by the wafer until it is diluted and released by the fluid circulating the system.

A prime location for the Tracer wafer is inside the desiccant bag within the dryer, receiver or accumulator of the system. As the desiccant bag is produced separately from other components, the wafer is held in place and there is no opportunity for the dye to come into contact with any contaminants nor to come into contact with any surface which might then be seen as a false leak. Several desiccant bag manufacturers are now equipped to automatically include a Tracer wafer in their bags. This method provides an ideal and economical method of introducing ultra violet fluorescent leak detection to the assembly line.

CONCLUSION

The use of an approved ultra-violet leak detection system provides a simple low cost and effective method of accurately pinpointing refrigerant leaks. Suitable for all refrigerants and any size of system, unaffected by draughts and heavy concentrations of refrigerant. Requiring no particular expertise, the method offers significant and quantifiable benefits both in cost and time saving when compared with traditional methods.

References

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3. Du Pont. Leak Detectors for Alternative Refrigerants.
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Détection de fuites de réfrigérants

EXTRAIT

Cette communication résume brievement diverses méthodes traditionnelles peu onéreuses de détection de fuites, la lampe á halogéne, “sniffers” manuels électroniques, solutions savonneuses, détection ultrasonique de fuites , et expose en détails les progrés techniques les plus récents dans la détection électronique de fuites par rayons ultra-violets fluorescents.

Cette communication considère également les causes et les implications économiques et au niveau de lénvironnement, des fuites dans les systèmes de réfrigération et de climatisation, et se détient sur ce qui pourrait être considéré comme la meilleure technique disponible, offrant des solutions pratiques, sans coûts excessifs, particulièrement utiles pour les transport réfrigéré et lindustrie démmagasinage et déxposition

Postscript

If you have any questions or interests cencerning this paper or would like further information concerning Refrigerant Management and our recommendations, please call our helpline on 01256 460303 or write to Barry Wilson at :-

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