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Refrigerant Contamination and Counterfeiting - Risks, Experience and Potential Solutions

Why this topic?

- It will help you understand the risks from operating with contaminated and or counterfeit refrigerants
- It looks at how contaminated material can impact the availability of refrigerants for recycling and reclamation leading to increased operating costs and environmental impact
- It provides suggested good practice recommendations for fraud prevention and cylinder stewardship including cleanliness and process monitoring to minimise risk.

1 Introduction

Using contaminated refrigerant will not only affect system thermal performance [1] it can threaten the entire fluid lifecycle. Contaminates from the supply chain, handling equipment and 'human factors' can result in a combination of known and possibly unknown materials resulting in decreased system reliability and poor availability through a potential increase in down time and running costs. The worst case scenario is total system loss.

Contaminated material can impact availability for recycling and reclamation with increased operating costs and environmental impact. The study of contamination in the R245fa supply chain for aircraft ground test equipment is reported including the effect on design requirements for a sustainable reclamation process. The experience is suggested as valid for most common refrigerants.

Once there was a fine line between supplying contaminated refrigerant and deliberate counterfeiting. Now that counterfeiting in the transport sector is a world-wide issue linked to several deaths this is no longer the case. Initially believed to be a route to shortcut phase out and phase down limits criminals are exploiting the increase in market prices and decreased availability to reduce stocks of material that has no legitimate route to market. With R134a counterfeiting using R40 (Methylene Chloride) plus the impact of phase down legislation growth is expected in this crime across market sectors and refrigerant types. Minimising the risk of such fluids entering the supply chain specifically on transport platforms is essential.

2 Background

Changes in regulation of fluorinated greenhouse gases under SI 310/2015 [2] confirmed the future supply and cost of HFC refrigerants would be affected especially for medium to high GWP fluids. As users of HFC R245fa, HFC R134a and HFC R404A Leonardo commenced a pilot study into the reclamation of HFCs especially R245fa as no commercial solution existed. The study highlighted issues with contamination in both the application and the supply chain for refrigerant.

In defining refrigerant purity the USA appear to use the Code of Federal Regulations [3] in respect of the Protection of the Environment and refer to AHRI (ARI) 700 standards [4]. AHRI defines the allowable contaminates and limits thereof leaving the user to 'interpret' the purity. The summary is that no internationally agreed standard for refrigerant purity exists and the market controls the definition.

Legislation on operators and maintainers mandates training for safe handling of refrigerants under SI 310/2015 [2]. Processes such as cylinder cleanliness and recovery unit leak testing being outside any legislation place risks on the refrigerant lifecycle. Even with Category 1 training certification proof of competency is not guaranteed and this adds 'human factors' to the risks from shortcuts to bad practice.

3 Contaminates

The definition of contaminated refrigerant is one where material has been added during the lifecycle that reduces its purity. The purity of refrigerants is typically stated as 99.5% that being the common interpretation under AHRI 700 [4]. That leaves a question of what is the 0.5% of 'volatiles'. Refrigerant suitable for reclamation can be as low as 95.0% [5]. That figure assumes that contaminates are not other fluorocarbon refrigerants. At least one test house certifies refrigerant product at 100% purity plus contaminates this suggests only no other refrigerants present.

Leonardo use 99.5% [6] minimum purity for common HFC refrigerants and 99.9% [6] for the R245fa aerospace application use in high speed compressors with minimal filtration. Experience gained during analysis revealed that conventional gas chromatography testing had minimal granularity when identifying sources of contamination.

Samples subjected to Fourier Transform Infrared Spectroscopy (FTIR) analysis gave complex and detailed results. The source(s) however only became evident if candidate samples were included in any analysis. Contaminates will act upon each other and the refrigerant degrading to a level where their original genesis may not be identifiable. Attempting to start an investigation into how palm oil for example had been introduced into an aircraft could only be avoided by the identification of a plasticiser component.

The principal result of contamination especially unspecified oils/greases and water is the liberation of highly corrosive HF. The resulting degradation is accelerated by heat. Solid contaminates block filters and expansion devices and can also accelerate part wear. No data was identified on the effects of operating with unintentional HFC mixes.

Initial Processing.
The fluid life cycle starts with manufacture then packaging at that facility or bulk shipping to regional wholesalers. Initial risks are the packaging process and shipping methods. Cylinder cleanliness is normally achieved through steam cleaning. Whilst effective for retail packaging the routine cleaning of large ISO containers and road tankers appear to be by evacuation only. Anecdotal evidence suggests water content is a significant issue in non-acceptance of bulk deliveries.

The tendency of R245fa below 15°C to stay where placed was identified as a risk when operators knowledgeable of high pressure refrigerants judged cylinder (and system) content by 'purging' a small sample. Conventional non-return valves may allow a 'backflow' of air into the cylinder of low pressure refrigerants at low ambient.

Delivery cylinders supplied without non return valves were found being used as recovery cylinders. The supplier when queried about cross contamination advised that dedicated delivery cylinders need no cleaning. The potential to contaminate the supply chain was avoided only by specifically requesting cleaning.

Into Service.
Handling equipment and processes are suggested as a major route for contamination. Some operators consider a 'bit' of air entering the system acceptable. Other non-condensable gasses (NCGs) including nitrogen and helium can be introduced through strength and leak testing. Poor housekeeping was identified as a contributor to liquid and solid contaminates with few hose ball end valves, lanyard ends or dust caps (Figure 1). Service manifold sets were frequently found 'stored' on the floor. Leak site are a two way defect with low pressure refrigerants allowing refrigerant out and moisture laden NCGs in.

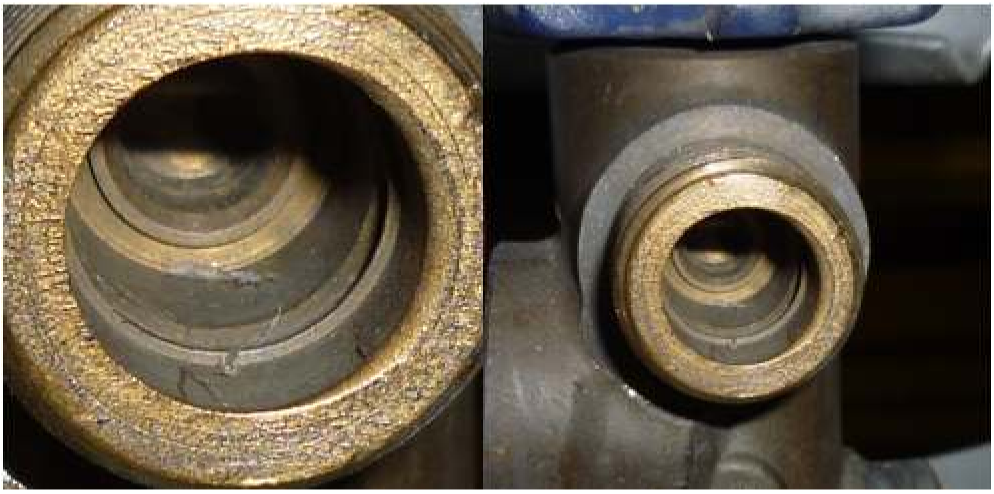

Figure 1. Uncapped Cylinder Valve (Overspray and Lint)

The R245fa application [8] is unusual in using no additional lubrication which allowed easy identification of oil based contaminates. The High Boiling Point Residues (HBPR) materials are the remains after the refrigerant has been extracted during purity testing. Common refrigeration systems are not so fortunate and 'human factors' can introduce lubricant contamination. These may not be identified until failure and or deeper analysis if at all.

Vacuum pump oils were identified in recovered R245fa traced to poor handling equipment maintenance and poor performance of isolation valves. Testing following seal failure identified that when connected to a system in a vacuum conventional solenoid valve seals and pump check valves exposed to R245fa could fail in a weeping condition drawing oil into the system. EPDM seals reacted badly to mineral oil ingress on one installation (Figure 2). The R245fa system is tolerant of some oil contamination if otherwise well maintained.

Figure 2. Mineral Oil Contamination EPDM Seal Failure

The use of hydraulic 'practices' on refrigeration systems were identified when greases were being used to install 'O' ring seals during maintenance and one supplier delivered connectors packed with a silicone lubricant. Both practices have been outlawed being miscible in R245fa.

Occurrences of R245fa 'leeching' the phthalate plasticiser material from elastomers including service hoses, gaskets and 'O' ring seals were identified. These phthalate materials are tenacious by design and once in a system pose significant issues in removal. Whilst hoses are low risk with limited exposure and can be substituted with stainless steel the testing of 'O' ring seals showed the manufacturing process and supplier validity were key to elastomer performance.

Elastomers cured with sulphur (cheaper process) were identified as having a low resistance [9] to this leeching effect and hence higher performance peroxide cured seals were selected. The lower specification and lower cost seals generated more contamination. It was also identified that some wholesalers may offer 'genuine' Parker seals but use an international manufacturing centre that is no longer or never was part of the Parker Hannifin Corporation.

Solid contaminates typically include manufacturing debris and oxides of these, wear debris, fragments of seals, rust, sand and occasionally fragments of PTFE tape with the latter being vulnerable to R245fa. These contaminates were in low volumes.

Waste Cycle.
The industry utilises waste and receiver cylinders for recycling or reclamation of used refrigerant. It is assumed (wrongly) that these cylinders are 'clean' with a view that waste cylinders (yellow tops) may contain small traces of oil and perhaps other materials of no consequence. Receiver cylinders (yellow top and green band) are assumed clean to a higher standard allowing easy reuse/recycling of the refrigerant into the target system or return for reprocessing.

Tests showed a high value for other HFC refrigerants in waste cylinders direct from the supplier. Of five 60lt waste cylinders delivered in a 'good' vacuum all had HFCs present. Three cylinders had over 0.5kg. In addition they had 'free' oil and contributed to the solid particle count with rust, sand and copper. Whilst the difficulty in recovering all refrigerant in large cylinders at low ambient is understood it is questionable how a subsequent evacuation could not be classed as a deliberate release.

'Human factors' may be relevant where waste cylinders on a multi refrigerant site are easily contaminated with a mix of refrigerants. Returned cylinders at reclaim facilities are reported labelled 'mixed' or just 'HFC' indicating some complicity in the corruption?

When working with a refrigerant reclamation partner even a reasonable purity waste material suitable for recycling or reclamation could be contaminated by poor cylinder cleanliness. When returned for credit or reclamation the resulting mix would be unfit for reprocessing rendering it good only for incineration and hence a further contribution to environmental pollution and cost. Claiming a contaminated cylinder with the supplier after filling is unlikely to be successful.

4 R245fa Reclaim

Reclamation is defined as returning used/waste refrigerant to virgin specification by reprocessing. In preparation for the HFC phase down a pilot study for an R245fa reclamation process was undertaken. Due to an accelerating cost the concept was identified as self-funding. This was achieved by using the acceptance test to reprocess waste that allowed savings against the cost of new fluid. There is also the potential of currently six Nations operating Eurofighter Typhoon who may utilise the process for on aircraft refrigerant at a later date.

The pilot study summarised the majority of contaminates as oils and greases as HBPR, particulates of metals, rust, rubber, carbon and PTFE, moisture, NCGs (Air, Helium and Nitrogen) and Mixed Solvents. R245fa poses issues for re-processors not least its high boiling point. A standard distillation column was considered typical of CFC R11 reclamation units. However R245fa processing was found to suffer from HBPR carry over and the effects of NCGs resulting in consideration for a vessel re-design. Testing showed the in-house waste stream for R245fa at 99.7% to 99.8% with the contaminates including water up to 500ppm and HBPR up to 1000ppm.

Good sample testing requires a minimum of 1kg of refrigerant and typically 500ml of oil. Recoverable oil was not in volume so DNA swabs were used hence analysis was comparative not quantitative. FTIR Investigation reported the HBPR as an aliphatic ester, a long chain carboxylate, an aromatic type ester and benzene sulphonamide.

All contaminates traced to the lubricants from handling equipment, dirty cylinders and the phthalate group used in elastomers [10]. The Carboxylate trace lead to the (false) suggestion of palm oil detailed earlier. Scanning Electron Microscope (SEM) examination information supported a degradation of the system stainless steel and aluminium potentially due of low levels of HF as well as wear debris from normal system operation. Whilst acid levels have been low evidence has shown that a combination of contaminates predominately oil and water subjected to overheating from low fluid levels liberate HF (Figure 3). For this reason the reuse and recycling of ECR grade R245fa is prevented on aircraft where only certified virgin purity new or reclaimed fluid is permitted.

Figure 3. Contaminated Refrigerant Damage to Compressor Parts

The pilot trial ran well until the discovery of R365mfc and R227ea lowered the purity analysis to 98.6%. The presence of these refrigerants could not be explained as they were not held onsite. The waste recovery cylinders came under scrutiny and as detailed earlier provided the source. Options were to destroy the entire stock or work to include these two contaminates in the design requirement.

The Praetorian ECR grade R245fa Reclaim Unit (PECR-RU) (Figure 4) now processes waste R245fa through several stages;

Figure 4. PECR-RU R245fa Reclaim Unit

HBPR.
Controlled heating of the fluid for reclamation just above the temperature saturation point and transferring the vapour with oil less compressors at a controlled rate leaves the majority of the HBPR in the first stage vessel. A demister collects any entrained HBPR and returns this to the first vessel. The collected HBPR is then drawn off using a small amount of liquid to a waste cylinder for incineration. Target value is 10ppm (w/w).

Particulates.
The PECR-RU extracts solid particles using an inlet filter at 7μm and a 0.5μm delivery filter. Particulate counts have also been reduced by use of dedicated receiver cylinder stock. Target value is 0.5μm.

Moisture.
Moisture is extracted using high capacity replaceable molecular driers on the inlet and at the process end stage. This is also monitored by an in-line sensor. The target value is 20ppm (w/w).

NCGs.
Referred to as 'de-nagging' NCGs are extracted using a temperature pressure relationship before input from the receiver cylinder. The waste is extracted to a waste cylinder.

Purity & Mixed Solvents.
Low boiling point solvent (R227ea) is drawn off in the 'de-nagging' stage and any remnants extracted in a low temperature condenser stage.

High boiling point solvent (R365mfc) is extracted through fractional condensing in a reflux pot after the phase change to vapour in a boiling vessel. Volatile nucleate boiling encouraging liquid carry over is minimised through the use of glass 'anti bumping' beads in the boiling vessel, tight control of the heating process and graduated distribution of the liquid feed. The vessel is heated to within 3K of the saturation pressure for R245fa this being well below the unwanted solvent boiling point.

The refrigerant passes to the reflux pot and condensed using a close controlled glycol cooling system regulated by the condensing pressure. A second oil less compressor extracts R245fa vapour to the final processing stage. Any liquid present is cooled and rejected back to the first vessel for reprocessing. This minimises re-boiling in process that could re-contaminate the refrigerant.

Delivery.
Once dried and filtered the reclaimed R245fa is delivered to a cleaned delivery cylinder (part of a controlled cylinder fleet). Here a sample is taken for purity testing. Rejected material is reprocessed as required. Compliant cylinders are sealed and each is shipped with a certificate of analysis.

Compliance.
The unit is operated at the HARP International facility in Pontypridd who manage the required waste management certification as well as the waste transport and cylinder fleet.

Operation.
Whilst subject to ambient temperature and contaminate types/levels reprocessing from 99.6% to 99.9% can be achieved with between one and three process passes. Samples below this purity are discussed in terms of cost effectiveness but poor purity materials have been successfully processed at five passes with each pass of 30kg taking around 12 hours. Some 3 tonnes of material has been processed to date with the site inventory having been reprocessed back to 99.9% from waste up to four times. The reclamation unit is now the subject of a patent application [11]

5 Counterfeit Refrigerant

Counterfeit is defined as the imitation of refrigerant with the intention to deceive or defraud for the purpose of financial gain. With interest in the use of refrigerants for transport refrigeration a study was undertaken on risks to the supply chain especially as aerospace has potentially high value returns for suppliers and distributors of counterfeit items combined with the extremely high cost of loss for the victims.

Starting with the phase out of CFC and HCFCs the growth of criminal activity in the distribution of refrigerants accelerated initially to provide refrigerants banned in one country illegally imported from a legitimate source. This supported by the growth of the internet made CFC and HCFC smuggling a potential close second to drug trafficking [12].

Counterfeit material at that time consisted of material imported as HFCs also virgin CFC and HCFC material imported as waste for reclamation with added water and rust to complete the look and feel of 'real waste'[13]. Changes to legislation including the Trans Frontier Shipment (TFS) [14] process for waste material and the accelerated phase out of such refrigerants removing the need have restricted this distribution. Counterfeit material can also include very low purity refrigerant packaged and sold as high purity typically with hydrocarbon components.

In July 2009 DuPont advised [15] that counterfeiting was taking on a nasty side when R134a and R22 in the Middle East market place were being blended for a representative pressure temperature relationship with Methyl Chloride (Chloromethane) R40 [16]. These blends used trace R22 and R142b among other chemicals to complete the 'look and feel' of genuine product. The SAE Organisation reported [17] a 'Southern European' firm had also identified R40 in its R134a stock following a passenger vehicle compressor explosion. A significant distribution of R40 based counterfeit refrigerant and incidents have been documented by the Container Industry [18] including halide torch sampling (Table 1).

Flame Halide Test	Pass	Fail			
Sample of 20,000 units	96.5%	3.5%			
GC Test on 3.5% flame failure	Other CFC/HCFC	R40 <100ppm	R40 >100ppm <5000ppm	R40 >5000ppm	Not analysed
Sample of 20,000 units	46%	10%	7%	9%	28%

Table 1. R40 Halide Torch Sampling of Refrigerated Containers

R40 is used as a precursor for the polymer and tyre industry and is comparatively cheap and easy to manufacture compared to HFCs. The downside is that it is an ozone depleter (low) and more importantly flammable, toxic corrosive/reactive and a carcinogen. The propensity of R40 to kill people was the cause of its fall from favour as the refrigerant of choice as far back as 1929 [19].

The container industry investigations [20] and solutions to the introduction of counterfeit refrigerants followed two explosions (Figure 6) during routine maintenance at the port repair terminal in Cat Lai, Vietnam (3 deaths) and subsequent fires at the US West Coast port facility in Oakland. CRT subsequently reported a survey [20] in Spain of 61 containers indicated 15 were contaminated and of those 11 were positive for R40. Following suggestions that the containers at risk were all serviced in Vietnam the US West Coast longshoremen quarantined over 1000 containers traced to that facility.

Figure 6. Refrigerated Container Destroyed by R40 Explosion with Compressor Remains

Fatalities included a compressor explosion in Brazil (1 death) domestic compressor explosion in Brazil (1 death) India [22] (2 deaths) and a further container compressor explosion in Qingdao China all attributed to counterfeit R134a. Investigations [23] have shown counterfeit R134a distribution is worldwide. South China has been indicated as the potential source of this also corrupting a legitimate home market supplier.

Evidence exits that the container industry this is not alone in the transport sector. The US Army Research, Development and Engineering Command's (RDECOM's) Tank Automotive Research, Development and Engineering Center (TARDEC) investigated R40 in military vehicles returning from operation outside the USA [24]. It reported some 25% of the vehicles (equating to 300 vehicles per brigade strength of typically 1200) were contaminated to some extent.

Investigations by CRT [23] discussed that the mix of products including R40 had become reactive with the system generating a highly corrosive environment. The methyl chloride combines with any aluminium components in the system to form highly volatile chemicals of which Tri Methyl Aluminium (TMA) is the main candidate for both fire and compressor explosions burning spontaneously in damp air (pyrophoric). High levels of HF were also recorded.

No central record of counterfeit refrigerant incidents exists but they are reassuringly low due in part to industry specific publicity. The wide diversity of counterfeiting poses a significant threat to all transport sectors including civil and military vehicles, marine vessels and any aircraft utilising an HFC cooling system. Major container fire incidents in 2015 at Tianjin China [25] and Santos Brazil [26] suggested the damage that one event could initiate. In the case of aircraft any explosion in flight would almost certainly result in total loss.

Forensic investigations tracing causal evidence will be difficult as volatility and resulting fire destroy evidence. Victims may be reluctant to report incidents hence counterfeiters may continue to exploit the supply chain. Maintenance facilities risking bad publicity may not report the use of counterfeit refrigerant even unintentionally.

Attention is drawn to reports of refrigerant 'explosions' as common HFC and HFO systems are highly unlikely to 'explode' during installation or maintenance even if a pressure test failure occurs.

The phase down of HFCs under SI 310/2015 [2] and Europe under Regulation EC517/2014 [27] especially R134a, R404A and the R407 family added to the cost of HFOs such as the R1234 family will promote more opportunities for counterfeiters.

6 Mitigation - Contamination

Leonardo and its reclamation supplier mitigated contamination in R245fa. This may mitigate against counterfeit material in the supply chain. The cost of implementation and testing has to be offset by the throughput, virgin cost and the occurrence of contamination related failures such as corrosion.

- Agree the purity and packaging requirements for the refrigerant with the supplier.
- Encourage challenges on suspect items.
- Request traceable evidence of requirement compliance.
- Adopt a dedicated clean receiver cylinder fleet.
- Mandate leak and pressure testing of all handling equipment.
- Use vacuum service valves for vacuum pump isolation.
- Use hoses with ball end isolation and lanyard hose end caps.
- Fit replaceable sintered filters to the charging line.
- Consider sight glasses on all new handling equipment.
- Request analysis of each waste cylinder returned.
- Competency training in specific refrigerant handling equipment to minimise contamination.

7 Mitigation – Counterfeiting

Counterfeiting is introduced to the lifecycle through business procurement and logistics operations. In attempting a business cost reduction procurement staff may seek out new suppliers, be open to special offers and in less reputable business be subject to encouragement up to bribery/blackmail. Complex business management systems such as SAP can if not used correctly encourage simplification of complex requirements into a simple part number that the unscrupulous can forfill with non-compliant items. Only by use of mandated well known suppliers for major manufacturers who are verified and routinely monitored can such risks be avoided.

The refrigerant industry has been very proactive in reporting suspect sources. It has also introduced visual verification such as holograms and security marking too costly and complex to reproduce by small fraud operations. The downside is that as manufacturers publicise fake product and promote new security measures the criminals will improve their game. Airbus and Boeing are now regularly employing RFID tracking on high value assets. Asset tracking with GPS tags down to individual cylinder levels is possible. The cost of new HFOs may make this cost effective.

Logistics operations are vulnerable to shippers, distribution houses, disgruntled employees and sub-contractors replacing good stock with counterfeit products for large inducements. This gives the criminals a high value genuine product to sell at below market price for a minimal outlay and substantial margin. By example in April 2016 Daofu Zhang of China landed a potential 10 year prison sentence and $2M fine for ‘shelf swapping’ $300k of US military components for counterfeit items [28].

8 R40 Identification and Removal

R40 either as counterfeit product or identified as a possible contaminate poses a substantial risk to any system especially one containing aluminium parts. Starting at delivered cylinders common refrigerant type detectors are unlikely to identify R40. A gas chromatograph test of delivered material is the accepted identification method but impractical for rapid on-site testing.

The container industry [29] resurrected the halide leak detection torch as an R40 test reacting to the chlorine component. Whilst a quick and simple flame colour test the exhaust is toxic. Suppliers have been provoked to develop electronic devices as used by the US Army [25] and simple sampling ‘stick’ detectors. Extraction of the resulting high volatile material from a system may cause fire and or an explosion. Even if only suspected the equipment or system shall be isolated and specialists tasked with making safe. Identification and extraction guidance was also given by SAE International and ILK Dresden in their presentation of 2012 [17].

9 Summary

The contaminates entering the R245fa lifecycle were not considered untypical and the majority could be minimised through good practice and concentration on small changes to equipment and process especially in regards to charging and recovery equipment. The R245fa system allowed visibility of HBPR from vacuum pump lubricants and the leeching of plasticisers. This may not be so obvious in conventional systems. The solid contaminates were not unexpected and were mitigated against through good husbandry, filtration and the control of the HBPR and water ingress. Plasticiser content can be minimised by good material and supplier selection.

Recovery cylinder cleanliness responsible for the complex contamination issues is normally only resolved through destruction but in this case modification to the reclamation capability. It is assumed that a large quantity of reclaimable HFC material is lost to incineration due to deliberate or unintentional refrigerant mixing. Sampling of contaminated systems can generate very granular data that may be difficult to align with the source. The use of candidate samples is beneficial.

The reprocessing of R245fa has been proven to be achievable and at significant payback given the high price for the ECR grade material. The ability to separate three different refrigerants whilst technically satisfying was only undertaken due to contamination in the supply chain.

Counterfeiting is seen as a growing issue in the transport sector as it is in many other domestic, commercial and industrial sectors. The use of R40 and other potentially toxic, corrosive and explosive materials is seen as a significant risk to the industry and end users. Identification and rectification carries risk and financial penalties.

10 Conclusion

It is concluded that awareness of good cleanliness standards and simple changes to equipment can minimise contaminates. Operator competency is suggested as the most significant way to minimise contamination.

The industry appears to have varying standards for cylinder identification and cleanliness and this is one area where small changes could deliver significant cost and environmental savings. Whilst the trade associations, manufacturers and wholesalers continue to increase awareness and effectiveness of deterrents against counterfeiting a competent operator is the last line of defence against this threat. It is also concluded that the cost and availability of HFCs and HFOs could justify high value asset control and tracking measures more common in the aerospace sector.

11 Recommendations

In addition to the mitigation details above a concentration on operator competence, awareness and strength of reporting is recommended. The current safe handling training could be extended to include contamination and counterfeit awareness or an add-on course.

Detailed analysis of all system failures especially related to corrosion and lubrication issues is recommended.

Finally it is recommended also that a common standard for recovery and reclaim cylinders is adopted. Typically a yellow top and a yellow top with a 'dark' band differentiate between recovery and receiver however other formats exist. The suggestion is that a waste cylinder (recovery) is all yellow and marked 'waste'. This cylinder would carry a risk that it contains other contaminates. A receiver cylinder would be a green/yellow cylinder that is cleaned ready for reclaimable material e.g. not waste.

About Steve Rodgers

Steven joined Lightfoot Defence Limited in 2010 after a 28½ year career in the Royal Navy. He has been the Operations Manager since 2015.
Shortly after starting at Lightfoots he was involved with the design enhancements of various equipment to accurately Fill and Recover R245fa into the WTP of the Typhoon aircraft.
He developed oil free systems that could effectively move the High Boiling Point refrigerant at low and high ambient temperatures. The knowledge gained doing this enabled him to undertake a lead role in the R245fa reclaim programme which he has been involved with since it's concept.
Steven has been a member of the IOR for 3 years now and is registered as an Incorporated Engineer.

About Richard Lawton

Richard Lawton is Technical director at Cambridge Refrigeration Technology. He is also president of IIR commission D2.
Richard has worked on a variety of transport systems for more than twenty years including road systems refrigerated marine containers and conventional refrigerated ships.

About Dewi Garcia

Dewi is Technical Services Manager at Harp International Limited.
Dewi has worked in a wide variety of roles in the refrigeration industry but for the last seventeen years has been at Harp International dealing with Harp's customers and distributors on all matter of issues concerning the use of refrigerants from regulatory aspects through to technical application advice and support.
Dewi is an active IoR member and sits on the IOR Service Engineers Section

About Derek Cranvey

Derek has worked for Leonardo MW since 1999 supporting the Eurofighter Typhoon Defensive Aids Sub System Cooling System.
He has specialised in promoting aircraft emission reduction through advanced leak detection and refrigerant reclamation.
Prior to that he worked extensively on CFC and HCFC phase out projects throughout Africa and the Middle and Far East.
Derek is a Chartered Mechanical Engineer and has been a Member of the IOR for 21 years

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