Issue Paper
Refrigerated Container (Reefer) Explosion

Background

On 18 October 2011, Maersk Line informed the World Shipping Council's Safe Transport of Containers Working Group that it had recently experienced three cases in which refrigeration units had exploded for no apparent reason. The explosions occurred on three separate occasions in 2011 in Itajai, Brazil and Cat Lai, Vietnam. Two men died in Vietnam and one in Brazil as a result of the explosions. CMA CGM also reported that explosion occurred in one of their refrigerated containers in Qingdao, China, in October.

US reefer technology provider Carrier Transicold has identified the port where the four reefer machines that experienced compressor ruptures received refrigeration system service work at Cat Lai in Vietnam. Maersk Line identified the malfunctioning containers underwent gas system repairs and maintenance at the same repair yard in Vietnam between 30 March 2011 and 25 April 2011.

Investigation into the causes of explosions

While the precise causes of the explosions are still under investigation, preliminary analysis appears to confirm suspicions that the cause of the explosions was contaminated gas in the cooling units. Peter Smidt-Nielsen, General Director of Maersk in Vietnam, tells Financial Times' beyondbrics[1] that the situation is "very unusual" although he knows of one similar case in the 1980s and another one in the 1990s. Consultants Cambridge Refrigeration Technology, which is helping Maersk Line with its investigation, said material recovered from the exploded units had been analysed and evidence pointed to a counterfeit refrigerant being to blame for the explosions[2].

Carrier Transicold stated in their 8 November 2011 letter[3] that "Independent lab analysis of one quarantined reefer container unit has definitively identified R40 as a contaminant." In its 16 November 2011 letter[4], Daikin informed it had analyzed the contents of the gas which was extracted from a compressor and R40 was identified.

R40, also called methyl chloride or chloromethane, is a hazardous chemical compound that is extremely flammable[5]. It was a widely used refrigerant, but its use has been discontinued due to its toxicity and flammability. The most important use of methyl chloride today is as a chemical intermediate in the

[1] http://blogs.ft.com/beyond-brics/2011/11/07/vietnams-exploding-reefers/#axzz1iTWsFCNl
[2] Attachment 1
[3] Attachment 2
[4] Attachment 3
[5] http://www.bocsds.com/uk/sds/special/methyl_chloride.pdf

production of silicone polymers. According to Neutronics Inc.'s R40 alert[6], R40 reacts with aluminum and creates Trimethylaluminum which is a pyrophoric substance that will ignite spontaneously in air.

Summary of actions taken

Various actions have been undertaken by concerned stakeholders to address the safety issues in such situations:

- Maersk Line has grounded 844 refrigerated containers that may contain contaminated coolant fluid, while CMA CGM has grounded 332 and Singapore-based-APL has grounded around 103 as a precaution safety measure.
- Maersk Line has also issued guidelines that any suspect boxes be cross- stuffed, the machinery unplugged and the containers be stored in an isolated position with the machinery facing away from people or traffic.
- Saigon New Port (SNP), operator of Cat Lai container terminal, has appointed Tan Cang Technical Service JSC (TCSC) as the only supplierof refrigerant[7] "for all the items of M & R (maintenance & repair) requiring the refrigerant serving for the reefer containers at SNP's facilities"[8].

Furthermore, fluorocarbon producers have warned customers to only purchase refrigerants from authorized suppliers. They are also adopting measures to address counterfeit refrigerants:

- Honeywell started using new security measures to detect counterfeit refrigerants. The new anti-counterfeit technology allows for the identification of non-authentic products much faster and more easily than was previously possible.
- DuPont Refrigerants has initiated DuPont Brand Assurance Program. The Brand Assurance Program uses a proprietary DuPont technology which involves 3D holographic label.

The boiling point of R40 is similar to that of R134a, hence it is very difficult to detect R40 when they are mixed in the refrigerant system. Various stakeholders are developing methods to check if R40 has been mixed with R134a refrigerant.

- Maersk Container Industry, in its 21 December 2011 Safety Notice[9], suggests the only practical method to ensure that R134a being added during service repairs is free from R40 and any other chemical containing chlorine, is to use a halide lamp to test each R134a cylinder for any chlorine contamination. Star Cool's Service Bulletin[10] provides a guide to test R134a for any chlorine contamination.
- Neutronics' R40 alert states that "the ONLY acceptable readings on Neutronics Ultima ID DX or HV series refrigerant identifiers for a "virgin" R134a cylinder are:

[6] http://www.refrigerantid.com/R40.html
[7] http://vietnambusiness.asia/vietnam-refrigeration-containers-exploded-due-to-technical-problems/
[8] http://maritimeaccident.org/2011/11/exploding-reefers-the-vietnam-connection/
[9] Attachment 4
[10] Attachment 5

R134a	100%
R12	0%
R22	0%
HC	0%
Air/Non	0%

- US-based Society of Automotive Engineers (SAE), in particular SAE's, will be discussing the R40 issue during the January 17, 2012 SAE Interior Climate Control Standards Committee meeting at MACS 2012 Convention in Las Vegas, Nevada.

Issues for National Ozone Unit:

HFC-134a is the widely adopted alternative refrigerants for refrigeration and air-conditioning equipment including domestic refrigerator, Mobile A/C systems, and reefers. There is evidence that R40 has been supplied in 30lb. cylinders and marked as R134a. R40 and R40 mixed with other refrigerants have been used by the refrigeration technicians to service, both stationary and MAC thinking it was the real R134a. It is advisable for the National Ozone Unit to consider various measures to address the issue of counterfeit refrigerants to avoid widespread damage to RAC systems and negative opinions against ODS alternatives in the country.

- Coordinate with RAC equipment manufacturer (mobile A/C, domestic and refrigerator, compressor) to provide notice to their dealers.
- Coordinate with refrigerant importers/distributors to check existing refrigerant stock for contamination and to provide notice to their customers to do the same.
- Inform Customs officials to be more vigilant on fake R134a gas and to use refrigerant identifiers to check for their purity level. Also inform the Customs to be mores careful on checking imported refrigeration systems(not only refrigerants cylinders)for which they will need to work more closely with the standardization institutes and laboratories to increase their controls level.
- Coordinate with refrigeration associations to provide notice to their members.
- Disseminate information to media, in particular those related to refrigeration and air-conditioning, to spread out the news among relevant stakeholders.
- Disseminate safety measures adopted by producers
- Meeting with shipping companies to check if any suspected reefer are quarantined in their shipyard and to check for any contamination.
- Alert Naval/Coast Guard personnel
- Coordinate with National Standardization Institutes or authorities to take necessary action against any produced, imported or exported counterfeit refrigerants and also Refrigeration systems. National standardization institutes' role and responsibilities to set up a screening, compatibility testing and inspection services could be included in the network countries' national ODS rules and licensing systems.

Issues at Regional level for CAP:

- Communicating with those companies which have already taken necessary actions against counterfeit refrigerants (see the attachments) to get more information about their monitoring results and findings which could be shared with all network countries during the forthcoming networks conferences in 2012.
- Coordinate with safety inspection authorities and key beneficiaries to find more details of the root causes of these accidents trying to find the source of the contaminated refrigerants.
- Inform World Intellectual Property Organization(WIPO) to include this issue in their ongoing works on counterfeits.

Attachment 1

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REFRIGERATION
TECHNOLOGY

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24 November 2011

Revised Information Regarding Counterfeit Refrigerant

There have been cases of reefer containers suffering explosions.
Refrigerated container refrigeration units should contain polyolester oil and the refrigerant HFC-134a (1,1,1,2-Tetrafluoroethane) and should therefore be incapable of exploding.

Material recovered from the exploded units have been analysed by a laboratory and were found to be corroded by a chlorinated compound. A pyrophoric liquid (burns in contact with air) and traces of alumina (AL_2O_3) were also found at the sites.

From the above we can be reasonably certain that the pyrophoric liquid is trimethyl aluminium ($Al_2(CH_3)_6$), though it is not yet proven. The explanation is that the system has been contaminated with a counterfeit refrigerant containing methyl chloride (chloromethane, CH_3Cl); this has been proven by testing). This gas works as a refrigerant but reacts with the aluminium in the compressor probably forming trimethyl aluminium, which is a liquid at room temperature.

According to Wiley's Guide to Chemical Incompatibilities, trimethyl aluminium is an extremely reactive liquid, and will react violently with hydroxides; carbon dioxide, carbon tetrachloride, halon, halogens and halogenated hydrocarbons (e.g. refrigerants), oxides of nitrogen and many other substances.

The issues that need to be resolved are:

How can this be prevented from occurring again?
How can withdrawn units be checked for contamination?
What is the procedure for making safe a contaminated reefer unit?

1. How can this be prevented from occurring again?

Refrigerant gas supplied to service depots needs to be from a certified source with a certificate of veracity of contents. Existing refrigerant gas held in stock can easily be checked using a standard halide lamp flame test. If this type of test is undertaken, it needs to be in a well-ventilated area in order that the degradation products of the refrigerants are safely removed, e.g. beneath a fume hood. It should be noted that no manufacture of either electronic refrigerant analysers or refrigeration leak detectors has so far been found that can identify a mixture of HFC-134a and methyl chloride as contaminated.

2. How can the withdrawn units be checked for contamination?

Withdrawn units will need to have their refrigerant gas checked, though the likelihood of identification of a problem unit may be increased by examination of the service records. According to Johnson Controls and Konika, the counterfeit refrigerant is a blend and therefore even if the methyl chloride and dichloromethane were consumed by reaction with aluminium, then the flame test would still detect the HCFC-22 and HCFC-141b. This can be lab verified once further samples have been analysed.

At present, no procedure has been agreed upon for the checking of existent gas within a reefer container.

3. What is the procedure for making safe a contaminated reefer unit?

Once a contaminated unit has been identified a procedure for making them safe needs to be identified. The problem is that trimethyl aluminium is a liquid and will be sitting in the crankcase of the compressor. Adding refrigerant or turning the machine on could cause an explosion.

There are several methods under investigation for the removal of trimethyl aluminium from within the reefer refrigeration circuit but as yet none has been agreed upon.

SUMMARY

It is now clear that the explosions are due to a counterfeit refrigerant containing chloromethane.

Looking forward, the following points need to be addressed:

- Existing refrigerant stock needs to be checked for contamination
- A refrigeration certification scheme needs to be put in place for future purchases
- A method for checking the withdrawn reefer units for contamination is required
- A safe method for compressor removal of contaminated units is to be identified

Source of Information:
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Web Site: www.crtech.co.uk

Attachment 2

Carrier TRANSICOLD

TO: Equipment Owners – Carrier Container Refrigeration Units
Authorized Service Centers – Carrier Container Products

FROM: Michael Dormer
General Manager, Global Container Services
Container Products Group

RE: REEFER SAFETY UPDATE

DATE: November 8, 2011

In our continuing effort to share new information regarding R134a refrigerant contamination in certain reefer units as it becomes available, Carrier provides the following update to our customers and authorized service network partners:

- Independent lab analysis of one quarantined reefer container unit has definitively identified R40 (methyl chloride) as a contaminant. R40 is a hazardous refrigerant that should never be used in a refrigeration system.

- Currently, a test device capable of safely detecting R40 in contaminated reefer systems is not commercially available. Until one becomes available, Carrier reiterates the importance of our previous reefer quarantine recommendations *(see attached Safety Bulletins, 27-Oct-11 and 21-Oct-11).*

- Refrigerant identification tools for checking the purity of gas contained in R134a bottles are commercially available from a number of different suppliers. Carrier does not recommend the use of Flame Halide Detectors for checking the purity of gas contained in R134a refrigerant bottles.

We will continue to monitor the situation, and will share additional information as warranted.

CTR-SER11-008

Attachment 3

DAIKIN INDUSTRIES, LTD.
REFRIGERATION DIVI.
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November 16, 2011

RE: Suspected Refrigerant Contamination in Reefer Containers

Since middle of October 2011, when the compressor rupture cases were known to the industry, Daikin has been conducting investigations to discover the root cause.
Daikin analyzed the contents of the gas which was extracted from a compressor and R40(methyl chloride) was identified. The refrigerant was charged at Cat Lai Terminal in Vietnam recently.

R40 is a hazardous refrigerant which should never be used in a R134a refrigeration system.
Due to the fact that boiling point of R40 is similar to that of R134a, it is very difficult to detect whether they are mixed in the refrigerant system.

R40 reacts with aluminum and creates Trimethyl Aluminum, and Trimethyl Aluminum is flammable.
Like other machine manufacturers, Daikin uses aluminum in some compressor components.

Therefore, Daikin recommends you not to perform any work on reefers, which had recently any refrigerant system work done in Vietnam, regardless of warranty repair or not.

Daikin provides a list of reefer machines which had any refrigerant system service work done in Vietnam under warranty, since January, 2011.
Please contact your Daikin sales representative if the data for a longer period is required.

Daikin is also investigating to find how to detect R40 in a refrigeration system and other safety solutions. We will advise when the details are available.

Yours Sincerely,
Syouhei Tsutsumi
Vice president Reefer Business
Daikin Refrigeration Division

Attachment 4

MAERSK
CONTAINER INDUSTRY

Maersk Container Industry AS
Bjerndrupvej 47
6360 Tinglev
Denmark

www.mdcontainers.com
Reg. No.: DK 1382 3774

Date: 21 Dec 2011

Safety Notice to all Star Cool Service Providers

As more information has become available in relation to the issue of counterfeit and contaminated refrigerant, we would like to provide the following update and recommendations.

It is now widely concluded that contamination of refrigeration systems has been as a result of the addition of a counterfeit refrigerant using a blend of chemicals including R40 (methyl chloride). The methyl chloride will react with aluminium to form trimethylaluminium (TMA), a pyrophoric substance. All hermetic and semi-hermetic compressors use aluminium in their internal construction and are therefore exposed to risk if contaminated with R40.

Work continues in an effort to develop a safe and accurate method of testing suspect machines for both R40 and TMA presence, but until such a test is available we continue to recommend quarantine of any units suspected to be contaminated.

To prevent further occurrences of unit contamination and the associated hazards, it is extremely important that all stocks of R134a are verified as containing no R40, and that all purchases of R134a are verified and certified to be from reliable and genuine sources.

While there are several electronic refrigerant analyzers on the market which are designed to verify the purity of R134a, the manufacturers confirm that **none of the analyzers commercially available today are able to detect R40 and may report contaminated refrigerant as pure**. These electronic analyzers cannot be relied upon or provide any safety in relation to the integrity of the refrigerant.

The only practical method to ensure that R134a being added during service repairs is free from R40 and any other chemical containing chlorine, is to use a halide lamp to test each cylinder. This procedure has been distributed to certain repair vendors by Maersk Line, but we now include the bulletin distribution to our Service Providers and customers.

Maersk Container Industry AS
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www.mcicontainers.com
Reg. No.: DK1382 3774

We strongly recommend the following steps are taken for your entire inventory of R134a as well as future purchases:

Each cylinder is to be tested using a halide torch leak detector and the details of supplier, delivery date, test date, cylinder serial number and result is to be recorded in a log book and the cylinder tagged clearly with the same information.

If a refillable cylinder is used, the cylinder must be retested after each refill.

No R134a is to be used for any Star Cool warranty repairs unless the test procedure, or any updated procedure has been completed and recorded. Further information regarding compliance and reporting to this requirement will be forthcoming.

Further updates will be distributed as information becomes available.

Regards,
Peter Tanner
Director, Global Service
Maersk Container Industry, Star Cool
pnt@maerskbox.com
www.starcool.dk

Attachment 5

Service bulletin

R134a Refrigerant Cylinder testing

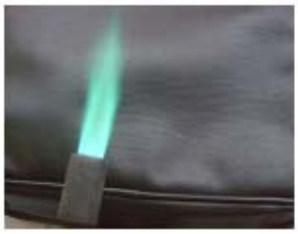
21 December 2011

Guide to testing R-134a cylinder contents for Chlorine Contamination

Flame Halide Detector

The following method is to check a small quantity of gas from each of the refrigerant cylinders in stock using the described Flame Halide Detector. At present no other method has been found that will satisfactorily find mixtures of gases containing chlorinated products.

This test will detect if there are chlorine contaminants in the refrigerant, sensitivity 300ppm (parts per million). HFC-134a is fluorinated and does not change the colour of the flame. A green flame indicates the presence of chlorine. Eg. R-22 will show a green flame because it contains chlorine. Halide detectors were commonly used by service engineers for more than twenty years but became obsolete when chlorine free refrigerants, (like R134a), were introduced.



To familiarise yourselves with this; try a test using a bottle of R-22. The below link shows what you should expect; http://www.youtube.com/watch?v=jHJU6UYM6Ug

Any refrigerant bottles marked as HFC-R134a that show a green flame should be quarantined and NOT USED.

Please notify service@starcool.dk for further advice if such a result is found.

STARCOOL

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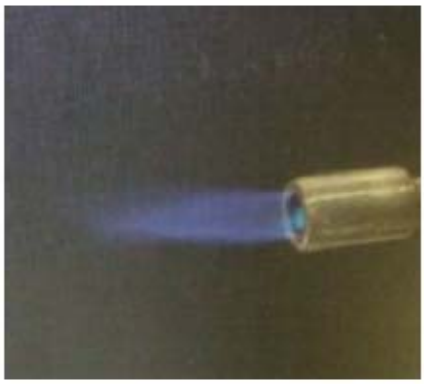
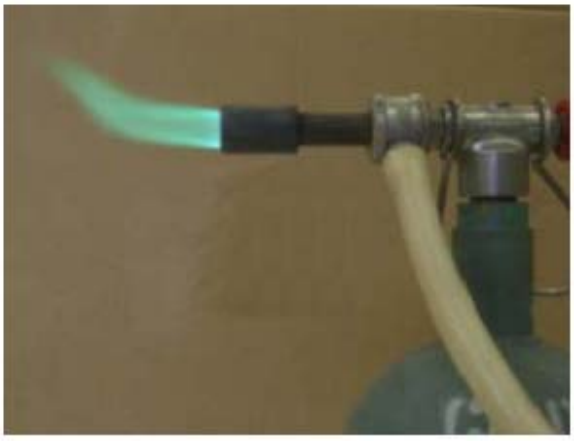
CVR/SE no.: 13 82 37 74 • starcool@starcool.dk • www.starcool.dk

Procedure

	To minimise the risks associated with the product of degradation fumes, fabricate a fume cupboard using an enclosure and extractor fan. Vessels and depots could use existing air extraction devices such as welding or exhaust extractors.
	To minimise the risks associated with flammable gases and to comply with F- gas regulations, use a set of manifold service gauges and a capillary tube as shown. After purging the lines, bubble the gas through some water to ensure the flow rate is minimal. Just a few bubbles will suffice, as the test is very sensitive.



OK ! Blue flame = R134a



Bad ! Green flame = contamination

Appendix 1 List of Decomposition Products

Small quantities of the following chemicals may be produced as a result of the flame test; the following data could be used in any necessary risk assessment:

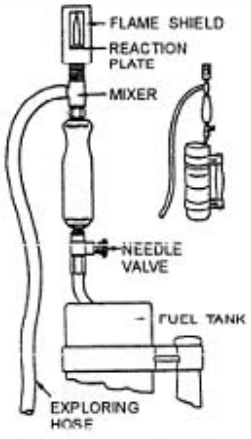
Chemical	Formulae	TLV ppm	Comments
Hydrofluoric acid	HF	5	Degradation acid from fluorinated chemicals
Hydrochloric acid	HCL	3	Degradation acid from chlorinated chemicals
Phosgene	$COCl_2$	0.1	Toxic gas degradation from chlorinated chemicals
Carbonyl fluoride	COF_2	2	Toxic gas degradation from fluorinated chemicals
Carbon monoxide	CO	25	Product of incomplete combustion

The threshold limit value (TLV) of a chemical substance is a level to which it is believed a worker can be exposed day after day for a working lifetime without adverse health effects. Strictly speaking, TLV is a reserved term of the American Conference of Governmental Industrial Hygienists (ACGIH). However, it is sometimes loosely used to refer to other similar concepts used in occupational health and toxicology. TLVs, along with biological exposure indices (BEIs), are published annually by the ACGIH.

Appendix 2 Halide Torch Leak Detection

The use of a halide leak detector is the most positive method of detecting chlorine containing refrigerants, sensitivity about 300ppm. Such a detector consists essentially of a torch burner, a copper reactor plate, and a rubber exploring hose.

Refrigerant gas suspected of containing chlorine is drawn through the hose into the torch burner of the detector. Here the air passes over the copper reactor plate, which is heated to incandescence. If there is a minute trace of a chlorine refrigerant present, the colour of the torch flame changes from blue (neutral) to green as the chlorine containing refrigerant contacts the reactor plate. The shade of green depends upon the amount of halogen refrigerant; a pale green colour shows a small concentration and a darker green colour, a heavier concentration.



Please note a standard blowtorch cannot be used, as the copper reaction plate is required.

*Information courtesy of CRT and Maersk Line.