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STORAGE, BULK TRANSFER, AND IN-PLANT HANDLING OF ZEOTROPIC REFRIGERANT BLENDS

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ABSTRACT

The refrigeration and air conditioning industries are moving from the use of single component and azeotropic refrigerants to zeotropic blends with varying temperature glides. This paper will discuss the potential impact on zeotropic blend composition from various OEM plant operations, such as bulk delivery, storage system design, in-plant handling, and refrigeration equipment charging. We will examine delivery truck and bulk tank operations using a high glide HCF refrigerant, R-407C, as an example.

INTRODUCTION

Original Equipment Manufacturers (OEMs) who build self contained air conditioning and refrigeration equipment usually charge their equipment with refrigerant while it is still on the production line. This charging operation is accomplished by use of a calibrated charging station which is fed liquid refrigerant from a bulk storage tank, often connected by long piping runs through the plant. Similarly, refrigerant repacking operations take refrigerant from bulk storage tanks and fill smaller packages for service use (e.g. 30 lb. cylinders or 2 lb. cans).

With the phaseout of CFCs at the end of 1995, and future restrictions on the use of R-22, the refrigeration and air conditioning industries have been evaluating the use of zeotropic refrigerant blends for use in new equipment. Traditional storage and bulk transfer operations could potentially affect the composition of zeotropic blends by allowing fractionation to occur.

We will review basic bulk transfer operations, look at the composition of a high glide refrigerant blend during the process of tank truck loading, filling a bulk storage tank for the first time, and subsequent cycles of unloading the storage tank, and refilling by tank truck using vapor equalization. Recommendations will be given on avoiding fractionation during these operations.

REFRIGERANT TRANSFER OPERATIONS AND STORAGE

1. Bulk Delivery by Tank Truck

High pressure refrigerant delivery trailers usually resemble a small, cylindrical bulk storage tank on wheels. The pressure rating, safety device configuration, and testing schedule are all determined by Department of Transportation (DOT) regulations.

The procedure for bulk delivery by tank truck consists of the following steps:

- The trailer is loaded up to 90% liquid full, usually to a round number such as 40,000 lbs (for R-12 deliveries). We used 35,000 lbs for R-407C because of the lower liquid density.
- Unloading is performed by using a liquid pump, which is often permanently attached to the trailer in a compartment underneath. This pump pulls liquid from the bottom of the truck's tank and delivers it via the liquid hose to the storage tank (see Figure 1).
- The top of the tank and truck are connected by another hose to allow refrigerant vapor to move from one vessel to the other. This will avoid a buildup of pressure in the storage tank which would reduce or stop product flow through the liquid line.
- A sight glass is used in the liquid line to tell when no more liquid is being transferred. It is possible to have a small amount of liquid left in the truck at this point.

Evaluation of the Delivery of Zeotropic Blends

Using mathematical models we analyzed the composition of R-407C as it was loaded into a tank truck. We then investigated the shift in composition assuming this tank truck was unloaded into an empty, evacuated storage tank, such as would happen in a "first delivery." In this case there is no vapor equalization. Refrigerant will vaporize from the liquid phase to fill the vapor space above. This vapor will be at a different composition from the liquid, and therefore the liquid will change composition. For 407C, the vapor will contain extra R-32 and R-125, and less R-134a.

NOTE: This mathematical experiment will show the composition of R-407C deviating out of specification. Recommendations will be made on how to avoid this for actual commercial deliveries. Individual plants should be reviewed on a case by case basis.

Table 1: Experimental Parameters and Results for Initial Tank Fill with R-407C

Temperature: 70 F

Initial Liquid Composition 407C: 32/125/134a 23 / 25 / 52 weight%

	<u>Tank Truck</u>	<u>Storage Tank</u>
Volume	5,000 gallons	6,565 gallons
Initial Truck Fill	35,000 lbs 407C (85% liquid full)	0
Liquid Composition:	22.93 / 24.95 / 52.12	--
First Transfer to Tank	- 33,000 lbs (1% liquid + vapor)	33,000 lbs 407C (62% liquid full)
Liquid Composition:	--	22.29 / 24.51 / 53.20

Results of the Initial Fill Study

Table 1 and Figure 2 show the resulting liquid compositions from filling of a tank truck and delivering that load to an empty storage tank.

- Since tank trucks are filled almost all the way with liquid there is little fractionation of the blend to fill the vapor space.
- In this example, the blend delivered to the tank fractionated in two ways: when the liquid level in the truck was reduced, more product had to boil to fill the vapor space, and the liquid delivered to the storage tank had to vaporize to fill the tank's vapor space.

There are several strategies which will avoid this composition shift during first deliveries, including breaking the tank vacuum with R-407C (flashed liquid), then using vapor equalization during delivery, as we will demonstrate in the next section.

2. Use of Product from the Storage Tank and Refilling by Tank Truck

Analysis of Composition Shift

Figure 3 shows the shift in composition of R-407C liquid as product is removed from the storage tank, such as would occur during normal plant operations. The drop in liquid level in the tank means that more product vaporization must occur to fill the vapor space. In any storage container fractionation will alter the liquid composition close to when the container runs empty.

In most OEM plants the tank is refilled before running empty. Bulk deliveries will occur using VAPOR EQUALIZATION. Figure 4 shows the tank truck liquid composition and the storage tank liquid composition during transfer of 33,000 lbs of R-407C from a truck to a tank.

By using vapor equalization there is no need to vaporize liquid 407C from the truck in order to fill the volume left behind in the truck. The liquid product entering the storage tank remains at essentially the same composition (original specification) throughout the transfer process.

Leakage

Leakage of zeotropic blends from the vapor space can cause additional composition shift. The vapor which escapes the storage system will contain a higher proportion of R-32 and R-125 compared to R-134a. Therefore, the liquid which must vaporize to replace the leaked product will remove more of the higher pressure refrigerants from the liquid. Overall the refrigerant blend will shift in composition towards more R-134a.

Recommendations

- Add vapor to tank for first delivery.
- Always use vapor equalization for bulk deliveries.
- Review the laboratory analysis for blend composition on each bulk delivery to ensure product is on spec. If possible, check the composition of the storage tank and at the charging stations frequently to confirm proper blend compositions.
- Review any blend adjustments with your supplier.
- Leak check storage facilities often and repair any leaks promptly.

3. In-Plant Transfer and Charging Stations

Transfer pumps, feed lines, and charging stations are designed to operate best when filled with liquid refrigerant (no refrigerant vapor present). Vapor can cause inefficient pump operation, reduced flow of product, and incorrect charge size delivered to the system being charged. These problems associated with vapor refrigerant in the lines and pumps will outweigh any problems associated with the fractionation which would occur.

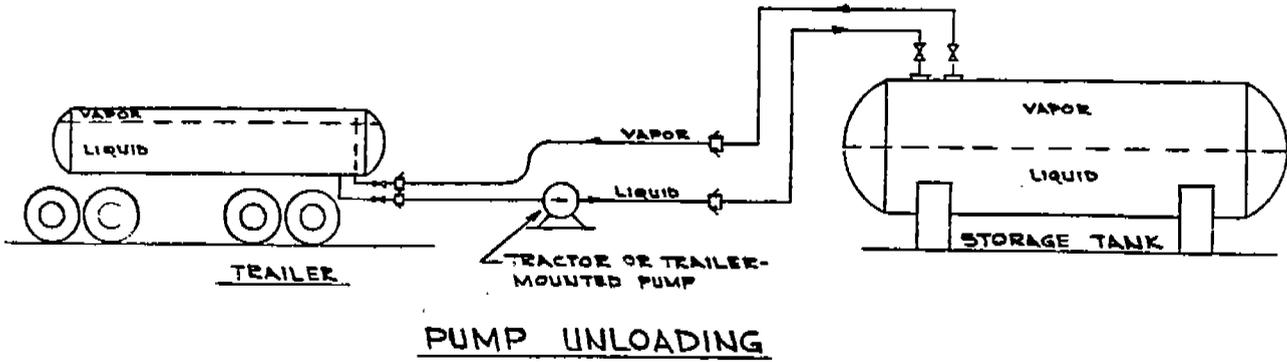
To avoid any flashing of refrigerant in the handling lines and transfer pumps, we recommend the following:

- Use pumps specifically designed for pumping liquid refrigerant under pressure
- Insulate piping to reduce flashing near hot locations
- Locate the charging stations as close to the tank as possible (minimize length of piping)
- Charging stations should have receivers which will hold liquid refrigerant for the charging piston, and the receivers should be maintained liquid full to reduce chance of fractionation.

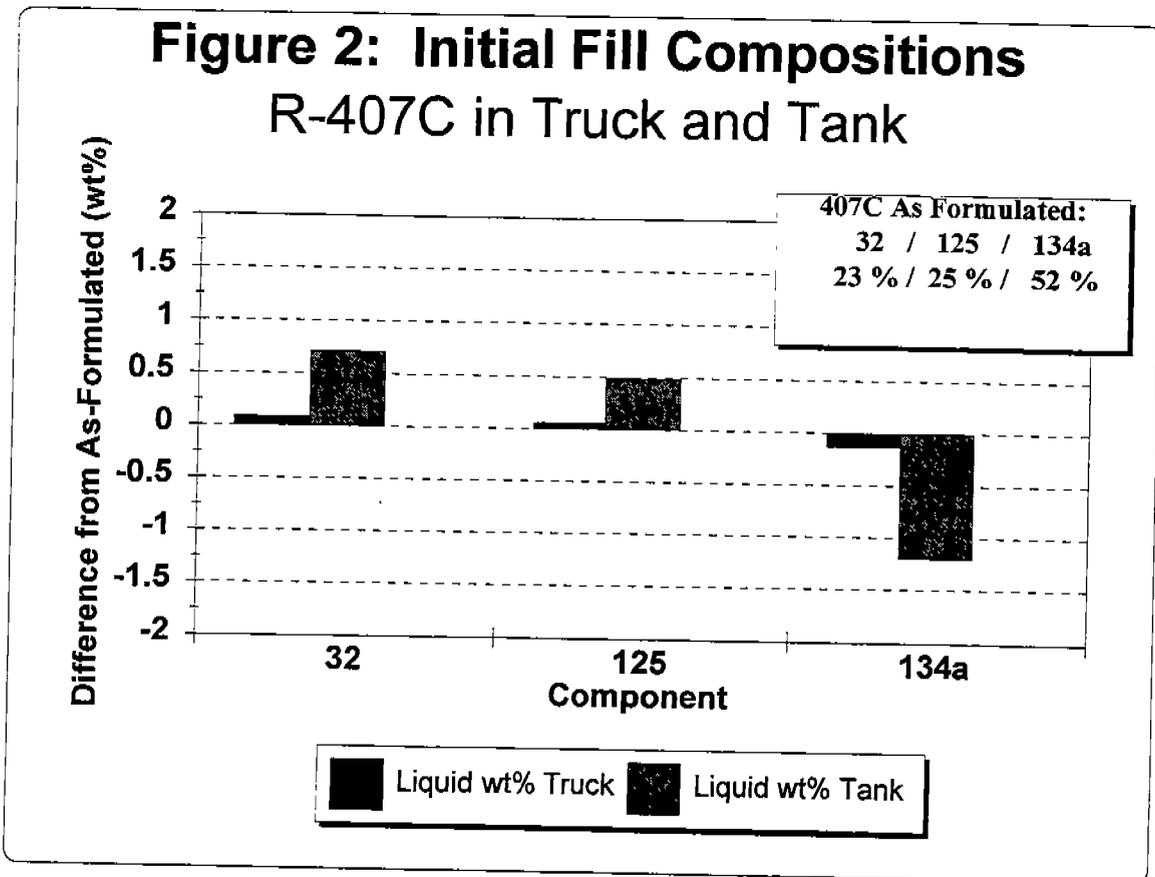
CONCLUSIONS

1. Emptying of bulk delivery and storage tanks will cause fractionation of zeotropic refrigerant blends. The extent of composition change should be evaluated for the specific blend/container combination to establish minimum inventory levels.
2. Vapor equalization on bulk deliveries will eliminate fractionation of the liquid refrigerant being delivered. Repeated bulk deliveries should not cause a progressive change in the composition of a zeotropic blend.
3. Product compositions can be adjusted to maintain proper blend compositions within the storage tank. Frequent monitoring of tank and charging station compositions is recommended.
4. No changes to in-plant delivery or charging systems is needed when using zeotropic blends. It is important to avoid vaporization of refrigerant at any point downstream of the storage tank for smooth production line operation, not just to avoid fractionation.

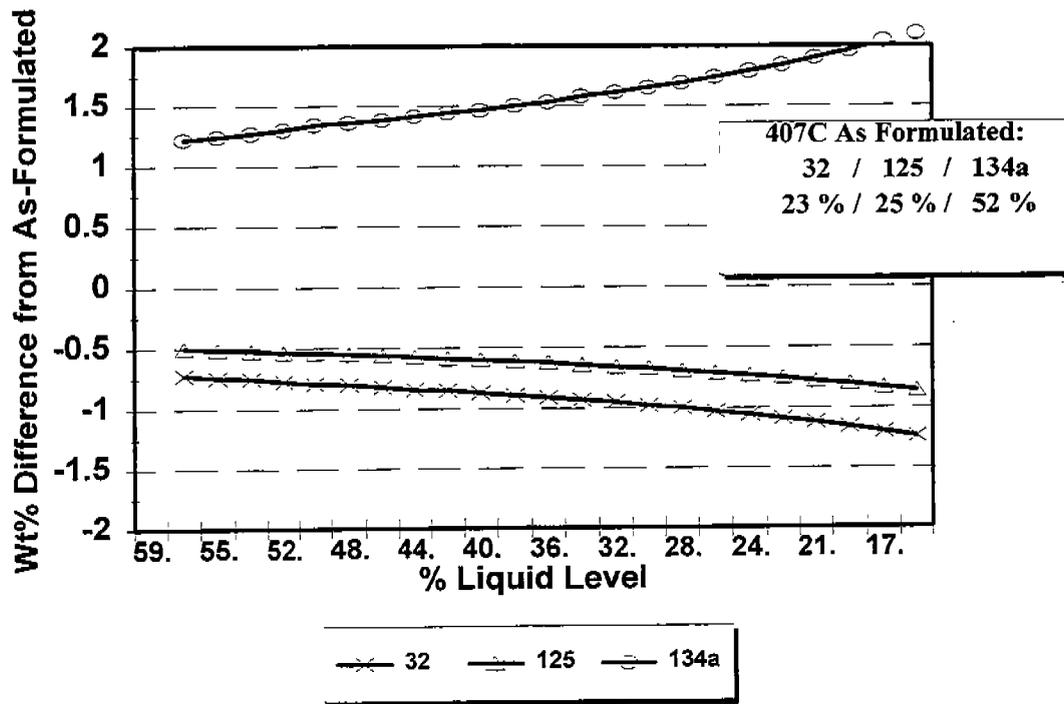
Figure 1: Bulk Delivery Diagram



**Figure 2: Initial Fill Compositions
R-407C in Truck and Tank**



**Figure 3: Composition of R-407C Liquid
As Storage Tank is Emptied**



**Figure 4: Composition During Delivery
Truck and Tank, Vapor Equalization**

