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COMPOSITION CHANGES DURING CONTAINER TRANSFERS FOR MULTICOMPONENT REFRIGERANTS

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ABSTRACT

Multicomponent refrigerants are being used in increasing amounts to replace single compound refrigerants such as chlorofluorocarbons. Transportation logistics can lead to several container transfers of refrigerants before being charged into refrigeration and air conditioning systems. For zeotropic mixtures, these transfers can lead to composition changes which vary depending on the type of transfer and the zeotropic characteristics of the mixture. Using a highly accurate model described in another paper (Yokozeki) at this conference, calculations of composition changes during refrigerant transfers have been made for several mixtures. The data trends can be used for management of refrigerant delivery systems to control compositions within prescribed limits.

INTRODUCTION

Handling issues associated with zeotropic refrigerants were discussed in several papers (1-3) at the 1996 International Conference at Purdue. The papers included considerations of bulk transfers (2) and vapor leakage modeling (3). These issues have continued to receive worldwide industry attention as increasing amounts of zeotropic mixtures are being used in commercial refrigeration and air conditioning systems. An analysis of composition changes during liquid refrigerant transfers will be presented in this paper, based on a new model developed by Yokozeki (4).

REFRIGERANT MIXTURES

Two refrigerant mixtures were evaluated for composition changes during container transfers:
(1) R-410A, a near-azeotropic mixture of R-32/R-125; nominal 50/50 weight percent; and
(2) R-407C, a zeotropic mixture of R-32/R-125/R-134a; nominal 23/25/52 weight percent.
The difference between bubble point and dew point temperatures (temperature glide) at 45°C can be used as one measure of near-azeotropic behavior, with temperature glides being 0.14 C for R-410A and 4.8 C for R-407C, respectively. ASHRAE composition tolerances for R-410A are +0.5,-1.5% for R-32 and +1.5,-0.5% for R-125; for R-407C the composition tolerances are +/-2% for all three components.

LIQUID REMOVAL FROM CONTAINERS

As a first indication of composition change during liquid removal of these mixtures from containers, calculations were made for liquid draw of refrigerants beginning at 85% liquid level and continuing down to 2% liquid level. The changing compositions are listed in Table 1 for 25°C conditions, showing a maximum composition change of 0.4% for R-32 and R-125 in R-410A, and a maximum composition change of 1.9% for R-134a in R-407C. At 40°C, the composition changes would be greater: a maximum composition change of 0.5% in R-32 and R-125 in R-410A, and a maximum composition change of 2.4% for R-134a in R-407C (at 2%

liquid level). The temperature influence on composition change can be understood by considering the effect of temperature on liquid density or volume. Liquid volume increases with temperature, and more vapor space is created when a fixed weight of liquid is removed from a container at elevated temperatures. With more vapor space available, a greater amount of refrigerant vaporization occurs, causing larger composition changes.

Table 1. Refrigerant Mixture Compositions during Liquid Removal from Container
Calculations made at 25°C isothermal conditions

	R-410A (wt %)		R-407C (wt %)		
% Liquid Level	R-32	R-125	R-32	R-125	R-134a
85	49.50	50.50	23.0	25.0	52.0
50	49.42	50.58	22.8	24.9	52.3
40	49.39	50.61	22.7	24.8	52.5
30	49.35	50.65	22.6	24.7	52.7
20	49.30	50.70	22.5	24.6	52.9
15	49.26	50.74	22.3	24.6	53.1
10	49.20	50.80	22.2	24.5	53.3
5	49.15	50.85	22.0	24.4	53.6
2	49.10	50.90	21.9	24.2	53.9

Refrigerant mixture composition changes will require attention and control to maintain component compositions within specifications, which will be evident from the next section on liquid removal from storage tanks followed by refilling of refrigerant from tank trucks

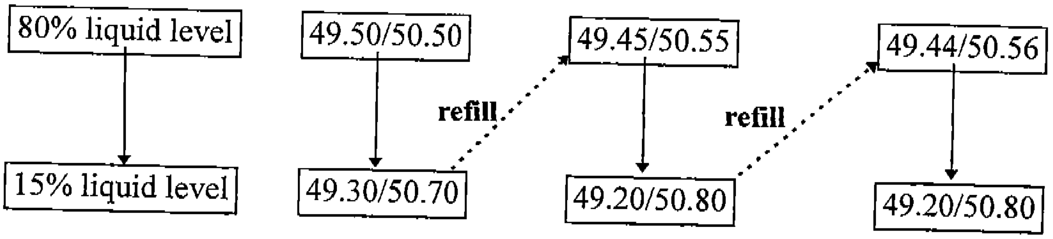
LIQUID REMOVAL AND CONTAINER REFILLING

Simulation calculations were made for typical original equipment manufacturer (OEM) procedures of refrigerant storage, removal from storage tanks for charging into equipment, and storage tank refilling. Results depend on ambient temperatures, container sizes, amount of refrigerant transferred, refrigerant compositions, etc. We have assumed an OEM storage tank volume of 21.7 m^3 (about 6600 gallon). This tank will be filled/refilled with a tank truck having a volume of 16.5 m^3 (about 5,000 gallon). The storage tank will be operated within liquid levels of 80% to 15%, but one case will consider the effect of liquid removal to 5% level. The tank truck will arrive with 85% liquid level and transfers will be made with vapor line equalization. All liquid will be transferred from the tank truck to the storage tank. Ambient temperature will be assumed at 25°C.

Figure 1 illustrates the composition changes for R-32 and R-125 in R-410A during liquid removal from 80% to 15% liquid level, followed by refilling to 80% level with refrigerant from the tank truck having a liquid composition of 49.5/50.5 wt% R-32/R-125 (these are mid-point values of the ASHRAE composition tolerances for R-410A). Vapor line equalization was assumed at 25°C.

Figure 1. OEM Storage Tank: Composition Changes during Liquid Removal and Refilling of R-410A

R-32/R-125 compositions in weight percent

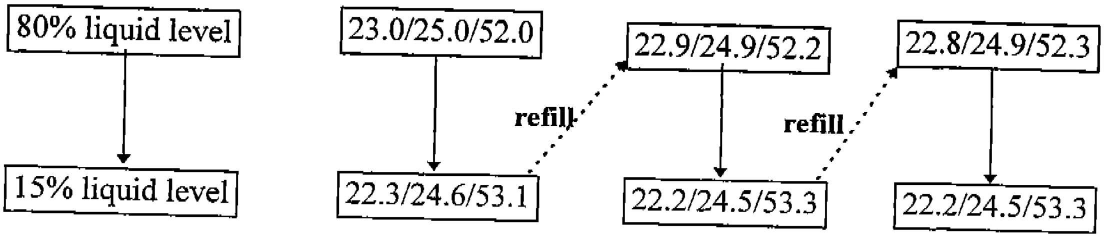


The maximum change in composition is 0.3% at 15% liquid level, and the composition change stabilizes after the second refilling of the OEM storage tank. The compositions are well within the specifications of 48.5 - 50.5% for R-32 and 49.5 - 51.5% for R-125. In case the liquid level in the OEM tank is reduced to 5% due to some emergency situation such as a delay in tank truck delivery, the composition shift would be an additional 0.1%. Considering the composition shift of 0.3 - 0.4%, the tank truck liquid compositions should be controlled in the range of R-32 at 49.0 - 50.5% and R-125 at 49.5 - 51.0%.

Figure 2 illustrates the compositions of R-32, R-125, and R-134a in R-407C during liquid removal from 80% to 15% liquid level, followed by refilling to 80% level with refrigerant from the tank truck having a liquid composition of 23/25/52 wt% R-32/R-125/R-134a. Vapor line equalization assumed at 25°C.

Figure 2. OEM Storage Tank: Composition Changes during Liquid Removal and Refilling of R-407C

R-32/R-125/R-134a compositions in weight percent



The maximum change in composition is 1.3% R-134a at 15% liquid level, and the composition stabilizes after the second refilling of the OEM storage tank. The compositions are within the specifications of 21-25% for R32, 23 - 27% for R-125, and 50 - 54% for R-134a. But there are several situations that could cause the compositions to go outside specifications.

If the liquid composition at 80% liquid level in the OEM tank is 22.8/24.9/52.3 wt.% R-32/R-125/R-134a (Figure 2) and the liquid level is reduced to 5%, the composition shift for R-134a will be up to 53.9%, which is at the specification boundary. Refilling with the tank truck having the nominal 23/25/52 wt% composition will return the OEM tank liquid composition to 22.8/24.9/52.3 wt%.

As another example, begin with the liquid composition at 80% liquid level in the OEM tank of 22.8/24.9/52.3 wt%. Reduce the OEM tank contents to the 15% liquid level composition as shown in Figure 2. For this example case we assume the tank truck of refill refrigerant has a 1% higher R-134a composition, being 22.5/24.5/53.0 wt.% liquid composition. After refill, the OEM tank will have the liquid composition of 22.4/24.5/53.1 wt%. As this refrigerant is being used by the OEM, the specification boundary for R-134a will be reached at a tank liquid level of 20% (21.9/24.1/54.0 wt.% R-32/R-125/R-134a).

These examples suggest that OEM storage tank compositions for R-407C must be closely monitored and controlled, including the effect of compositions in arriving tank trucks of refill refrigerant. One approach is to maintain incoming refrigerant in the lower half of the R-134a composition range (50 - 52 wt%).

EXPORT SHIPMENTS AND REPACKAGING

Refrigerants are export shipped in a wide variety of container sizes, examples being those containing 11, 50, 750, and 14,000 kg refrigerant. It is common practice for the refrigerant to be used directly from these containers for charging equipment, and the refrigerant mixture composition changes of Table 1 can be used for guidelines of potential composition changes. However, there can be repackaging from the larger containers into smaller containers, which represents a more difficult challenge for zeotropic refrigerants. In the following two examples we'll consider repackaging from a 14,000 kg ISO container to containers of 11 or 50 kg.

First considering composition changes with R-410A, we can refer to the data of Table 1. Assume that repackaging will continue from the ISO tank until the tank liquid level is at 5%, where the composition is at 49.15/50.85 wt% R-32/R-125. This composition of refrigerant will exist in filled containers of 11 or 50 kg (we'll fill to 85 or 90% liquid level so we can ignore the composition change from the small amount of vapor in the containers). As liquid refrigerant is removed from the smaller containers, the composition continues to change, and at 5% liquid level, the composition will be 48.8/51.2 wt% R-32/R-125, still within the specification ranges of 48.5 - 50.5% for R-32 and 49.5 - 51.5% for R-125. But the compositions are within 0.3 wt.% of the specification boundary, so the starting ISO container composition should be no higher than 50.5% R-125.

We can also use the data in Table 1 to analyze the same repackaging situation for R-407C. Beginning with the ISO tank having the nominal composition of R-32/R-125/R-134a, at 5% liquid level the composition has changed to 22/24.35/53.65 wt%. If we continue the analysis as was done for R-410A, we reach an out-of-specification situation with a portion of the liquid refrigerant drawn from the small containers packaged with the 22/24.35/53.65 wt% composition. The composition in the small containers when 5% liquid level is reached would be 21/23.7/55.3 wt%, which is above the specification maximum of 54.0% for R-134a.

It should be recognized that these calculations are representative of only a small portion of the refrigerant mixture being repackaged in this example. If we consider refrigerant repackaged and used down to the 15% level in the ISO tank and the smaller containers, the refrigerant mixture compositions stay within specifications. However, we need to manage the range of possible situations, and several mitigation approaches can be considered. If the starting ISO tank liquid refrigerant composition is controlled to a maximum of 51% R-134a, such as 23.5/25.5/51 wt.% R-32/R-125/R-134a, then the composition at 5% liquid level would be 22.5/24.9/52.6 wt.%. This composition loaded into smaller containers would change to 21.7/24.4/53.9 wt% at 10% liquid level, or to 21.5/24.3/54.2 wt.% at 5% liquid level, only slightly above the R-134a specification maximum of 54.0% for R-134a. Administrative controls can also be used to maintain compositions within specifications. When operating at low liquid levels in the ISO tank (less than 10%), the remaining refrigerant could be packaged into containers from which refrigerant will be taken in large quantity increments. This would eliminate the concern for refrigerant composition in "almost empty" small containers.

These evaluations can be extended to refrigerant mixtures having higher temperature glide, such as 12°C to match the air-side temperature glide in air conditioning units. One example refrigerant mixture having this temperature glide would be 45/55 wt.% R-32/R-124. The composition change for this mixture during a container liquid level drop from 85% to 5% would be about 2.6% (to 42.4/57.6 wt% R-32/R-124). If such high glide refrigerant mixtures are to be used in the future, the composition tolerances may have to be increased above the current +/-1% or +/-2% ranges.

CONCLUSIONS

Multicomponent refrigerants which are zeotropic or near-azeotropic undergo composition changes during liquid removal from containers, the extent of which depends on the details of the transfer and the zeotropic characteristic of the mixture. Calculations made with a highly accurate model for R-410A and R-407C illustrate the composition changes that can occur during (1) liquid removal of refrigerant from containers, (2) operation of an OEM storage tank, and (3) repackaging of small containers from a larger container, followed by liquid removal of refrigerant from the small containers. The examples indicate that special attention and control must be applied to maintain refrigerant mixtures within product specifications. As a general observation, one control measure to be applied is to limit composition ranges for the refrigerant delivered in containers, thereby leaving room for composition changes during liquid removal, remaining within product specifications.

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