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EXECUTIVE COMMITTEE OF  
 THE MULTILATERAL FUND FOR THE  
 IMPLEMENTATION OF THE MONTREAL PROTOCOL  
Seventy-seventh Meeting

Montreal, 28 November - 2 December 2016

**Calculation of the level of incremental costs for the conversion of heat exchangers manufacturing lines in enterprises converting to HC‑290 technology (DECISION 76/51)**

# **Background**

# At the 75th meeting, the Executive Committee considered stage II of the HCFC phase-out management plan (HPMP) for Brazil[[1]](#footnote-1). In presenting the project proposal the Secretariat explained that additional work would be required to assess the incremental cost of the conversion of two heat exchanger lines to replace HCFC-22 with HC-290 refrigerant in air-conditioning (AC) units. The Executive Committee approved stage II of the HPMP for Brazil and, *inter alia*, requested the Secretariat to undertake additional work on the level of incremental costs for the conversion of heat exchangers manufacturing lines in enterprises converting to HC-290 technology, to report to the 76thmeeting, and to adjust the cost of stage II of the HPMP for Brazil, as appropriate, upon receipt of the submission of the request for the second tranche (decision 75/43(f)).

1. Accordingly, the Secretariat hired an independent technical expert to prepare a study to provide factual technical information on required modifications to heat exchangers and to heat exchanger manufacturing lines from the conversion of HCFC-22-based air-conditioners to HC-290, HFC-32 or R‑452B[[2]](#footnote-2) refrigerants, and an estimation of the incremental cost associated with the conversion[[3]](#footnote-3). The study was peer reviewed[[4]](#footnote-4) by two independent refrigeration experts, subsequently adjusted to address all the comments and observations raised by the two peer reviewers, and presented at the 76th meeting.

# Discussion at the 76th meeting

# At the 76th meeting the Executive Committee noted the report and requested the Secretariat to submit to the 77th meeting a revised document that addressed the following specific issues (decision 76/51):

## To further consider, with regard to the HC-290 technology, the technical and cost implications of reducing the tube diameter of the condenser from 7 mm to 5 mm while maintaining the same evaporator; and

## To provide further information on the estimated number of units required for each tool/equipment type when reducing the tube diameter, on the basis of a typical level of production by an enterprise in an Article 5 country.

Additions to the study

# In response to decision 76/51, the Secretariat’s expert has revised the study accordingly. The revised version of the study, which is attached to the present document, clarified the following issues:

## The outside diameter (OD) of evaporator tubes can be decreased from 7mm to 5 mm (as done for the condenser) without increased pressure drop or system performance degradation. This will provide a material cost reduction for the evaporator the same way it occurs with the condenser (see paragraph 4(c)), and will simplify the production process by requiring that coils with only one tube diameter (5 mm) will need to be produced in the facility;

## For a reference production capacity of 200,000 units, the manufacturing equipment and processes used for production of 7 mm tube coils can also be used for 5 mm tube coils with some changes and additions as described in detail in the study. Capital costs for these changes range from US $215,000 to US $975,000 depending on the baseline equipment and path taken for conversion;

## Changing condenser or evaporator tubes from 7 mm to 5 mm results in a copper material reduction of between 30 and 40 per cent depending on the wall thickness of the original (7 mm) and modified (5 mm) tubes. This equates to an overall coil material cost reduction of 20 to 25 per cent. Annex V of the study presented a calculation of the savings in material for a production capacity of 200,000 units;

## Tube expansion is the only manufacturing operation that is expected to result in added complexity or additional problems (i.e., increased coil slab scrap rate) when converting to 5 mm OD tubes. To address this potential issue, information on an alternative pneumatic expander for small or 5 mm OD tube coils have been included. This equipment might be required depending on the baseline equipment and characteristics of the production; and

## While the calculations in the study are a useful reference based on a production capacity of 200,000 units, assessments need to be made on a case-by-case basis based on the details of the coil designs and manufacturing processes of each enterprise.

Conclusions of the study

# The main findings and conclusions of the study, which are similar to those presented to the 76thmeeting and adjusted based on the results of the revised report, are summarized as follows:

## The main refrigerant property that affects heat exchanger physical design is maximum design pressure:

### HFC-32 and R-452B have substantially higher design pressure than HCFC-22, but within 10 per cent of the design pressure for R-410A. Minimal design changes and addition of a pressure cycle test to the coil manufacturing qualification process will allow existing coil designs to be used at the higher design pressures for R-452B and HFC-32;

### The design pressure for HC-290 is lower than that for HCFC-22; therefore, design or manufacturing process changes are not required;

## Other physical and thermodynamic properties of refrigerants determine the operating conditions and performance of the AC system in which they are used. For the three refrigerants considered these parameters result in significant variation between the refrigerants in system efficiency, system capacity, operating temperatures and refrigerant flow rates. These are of importance in making a refrigerant selection for a particular type of product, and for design optimization of the heat exchanger components. However, they do not by themselves result in any required changes to the heat exchanger physical design or manufacturing processes that would require capital expenditures;

## All three refrigerants have properties that allow significant charge and refrigerant flow volume reductions compared to HCFC-22. This allows, but does not require, the redesign of coils to reduce costs by use of smaller diameter tubes, which represents savings in material but additional capital cost for new manufacturing tooling;

## The three alternative refrigerants in the study are considered flammable: HC-290 is highly flammable (A3), while HFC-32 and R-452B are mildly flammable (A2L). The safety codes that govern use of flammable refrigerants in occupied spaces vary widely by locale, and are currently being reviewed and revised to reflect the lower flammability risks associated with use of the class 2L refrigerants. Class 2L refrigerants (HFC-32 and R-452B) will be allowed for use in small (2 kW to 5 kW) split systems located in an occupied space with no mitigation in place, and in larger unitary equipment (30 kW to 1000 kW rooftop) with leak detection and mechanical ventilation mitigation. There will likely be maximum charge limits per circuit but they are not expected to be an issue for application of products in this size range. Therefore charge reduction below the current charge levels is not required for AC equipment using HFC-32 or R-452B;

## Current code restrictions in North America and Europe for use of class 3 refrigerants in occupied spaces are unlikely to change significantly but rather will become more widely applied. These charge volume limits will restrict the application of HC-290 to systems below 2 kW capacity without risk mitigation, and up to a maximum of about 20 kW with an active risk mitigation system. The cost of the automatic risk mitigation systems have been estimated at up to 30 per cent of the small AC unit cost. This has the effect of limiting the size of equipment using HC-290 to refrigerators, small coolers and perhaps small mini-split type AC units;

## Refrigerant charge and material cost reduction is obtained when HCFC-22 is substituted for HC-290 in a refrigeration system and the heat exchanger coil tube OD is reduced. With minor changes to refrigerant circuiting a coil tube OD of 5 mm can be used for both the evaporator and condenser without performance penalty;

## Reducing the tube diameter for a fin and tube coil affects nearly every part of a coil but no major capital equipment such as fin presses, tubing benders, material handling equipment and plant arrangement need to be changed. The study estimated the number of pieces of equipment or tools required to produce 200,000 mini-split units with a capacity of 18,000 BTU/hr, and the cost to make the changes to a coil tube OD of 5 mm. The total cost for manufacturing equipment oscillates between US $215,000 and US $475,000 assuming the existing tube expander is used. If a pneumatic expander is used the cost would be between US $750,000 and US $975,000; and

## Reducing the tube OD from 7mm to 5 mm in both the condenser and evaporator reduces the refrigerant volume, simplifies the coil manufacturing process and provides a significant material cost reduction, namely, copper material content by about 30 per cent, which results in approximately a 15 per cent cost reduction for the completed coil. Based on an annual production volume of 200,000 units with a capacity of 18,000 BTU/hr, total annual copper material cost savings are US $1,150,000, corresponding to US $383,000 for the evaporator and , and US $767,000 for the condenser.

Feedback from the implementing agencies

# The revised study was circulated to the implementing agencies for feedback. Based on their feedback, clarifications were provided and adjustments were made to the report. The main points received and the responses are below:

## The study is considered very useful and addresses the issues raised by the Executive Committee at the 76th meeting;

## According to experience gained through the implementation of projects, the refrigerant charge reduction resulting from the reduction of the OD of the tubes from 7mm to 5mm in the heat exchanger is between 15 to 30 per cent, rather than the 50 per cent calculated in the study. As the 50 per cent in the report was based on calculations made from other studies, a comment was added indicating the experience provided by the agencies from the implementation of projects;

## It was understood that 5 mm tubes can be used for both condenser and evaporator and that redesign of the evaporator is required to avoid pressure drop. In the case of heat pump operation, a redesign of the condenser would also be required. The expert agrees with the comment; circuiting changes would be required in both the condenser and evaporator of heat pumps to maintain performance when tube diameter is decreased, although heat pumps were not in the scope of this report;

## The pneumatic tube expander is mandatory to avoid increase in the scrap rate. On this issue, the expert indicated that if “limited – shrink” rod expansion is used the scrap rate will be similar to pneumatic expansion. Therefore both “limited – shrink” rod expansion and pneumatic expansion are viable tube expansion methods. On this basis, the Secretariat concludes that this will need to be assessed on a case-by-case basis, i.e., the need for a pneumatic tube expander will depend on the baseline equipment and the established process in the plant;

## The cost of tube expander tools (estimated at US $5,000 to US $10,000 - one set for each coil size in production) in China has been up to US $130,000. On this issue, the expert indicated that this would be the case if either multiple expansion stations are used or if the rod expansion equipment needs to be converted to provide “limited – shrink”. This is accomplished by placing the tubes in tension as they are being rod expanded; and

## While there is agreement that by reducing the tube OD to 5 mm there will be savings in copper, the level of savings is lower than that calculated in the study because the heat transfer area must remain unchanged; and hence more 5 mm copper tubes will be needed. On this issue, the expert indicated that the tube pitch, face area and number of tubes do not require changes when going from 7mm to 5mm OD tubes. This is because the majority of the heat transfer resistance is on the fin side of the coil. Therefore the material cost savings shown in the calculations are correct.

**Secretariat’s recommendation**

# The Executive Committee might wish to consider:

## Taking note on the document UNEP/OzL.Pro/ExCom/77/69 on the calculation of the level of incremental costs for the conversion of heat exchangers manufacturing lines in enterprises converting to HC-290 technology (decision 76/51);

## Requesting the Secretariat to adjust the cost of stage II of the HCFC phase-out management plan for Brazil, as appropriate, upon receipt of the submission of the request for the second tranche, in accordance with decision 75/43(f), based on the technical information provided in document UNEP/OzL.Pro/ExCom/77/69; and

## Requesting the Secretariat and the implementing agencies to use the technical information provided in document UNEP/OzL.Pro/ExCom/77/69 as a reference when assessing the incremental costs of conversion of heat exchanger lines from the conversion of HCFC-22-based air-conditioners to HC‑290, HFC-32 and R-452B refrigerants.

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1. UNEP/OzL.Pro/ExCom/75/40 and Add.1. [↑](#footnote-ref-1)
2. R-452B (a blend of HFC-32 (67 per cent), HFC-125 (7 per cent) and HFO-1234yf (26 per cent) was added to the study being a blend expected to be used in the room air-conditioning manufacturing sector. [↑](#footnote-ref-2)
3. The terms of reference of the study are contained in paragraph 3 of document UNEP/OzL.Pro/ExCom/76/59. [↑](#footnote-ref-3)
4. The peer-review provided an assessment of the report, including whether the reviewer agreed with the findings by the expert. The reviews also addressed the extent to which the report has addressed the terms of reference. [↑](#footnote-ref-4)