United Nations ECE/TRANS/WP.11/2011/10

Economic and Social Council

Distr.: General
27 July 2011

Original: English

Economic Commission for Europe

Inland Transport Committee

Working Party on the Transport of Perishable Foodstuffs

Sixty-seventh session
Geneva, 25-28 October 2011
Item 5 (a) of the provisional agenda
Proposals of amendments to the ATP: Pending proposals

Multi-compartment multi-temperature equipment[1]

Transmitted by the German Government

I. Initial situation/Justification

1. The ATP agreement, signed in 1970, took into account the equipment which existed on the market at that time. In the 1990s, manufacturers began developing and selling multi-temperature refrigeration units. This equipment is designed to maintain, for the same insulated body, different temperatures in different insulated compartments.

2. The test stations tested this equipment with reference to the ATP. They measured the refrigeration capacity as with mono-temperature refrigeration units.

3. It became clear quite soon that if the global capacity is needed to dimension the equipment as a whole, it is not sufficient to dimension the different compartments and the evaporators used for each of them. Manufacturers and test stations worked on a procedure to test this equipment between 1994 and 1998. They also prepared a methodology to dimension the multi-temperature equipment and a model of the ATP certificate for this equipment.

4. A first ATP amendment proposal was presented to WP.11 in 1997. A revised version was presented to WP.11 in 1998.

5. Unfortunately, when the amendment was sent to Governments for final approval there was no longer unanimity and although the model of the ATP certificate for multi-

[1] Submitted in accordance with the programme of work of the Inland Transport Committee for 2010–2014 (ECE/TRANS/208, para. 106; ECE/TRANS/2010/8, programme activity 02.11).

temperature equipment was approved, the test procedure and the dimensioning methodology were rejected.

6. Since 1997, nearly all the multi-temperature units on the market have been tested following the procedure submitted to WP.11 in 1998. More than 100 multi-temperature test reports have been issued by three official ATP tests stations for all the manufacturers supplying the market. Several countries use these tests results and apply the 1998 dimensioning methodology to deliver certificates for multi-temperature equipment. The test methodology has proven its quality even if it could be improved on some points. On the other hand, the dimensioning method has shown some defects that needed to be corrected without increasing its complexity.

7. Also since 1997, certain manufacturers, dissatisfied with the procedure, have tried to modify it but have never reached unanimity with the other manufacturers on their proposal.

8. In 2009, a new proposal was presented to WP.11 for multi-compartment multi-temperature equipment. This proposal contained three amendments to the ATP:

- A list of specific terms and definitions for multi-compartment and multi-temperature units;
- A test methodology for multi-temperature refrigeration units; and
- A method for dimensioning multi-compartment equipment.

9. After being rejected by one country in WP.11, this proposal was introduced by four countries as a multilateral agreement within the framework of article 7 of ATP.

10. The current proposal is the result of common work between members of Transfrigoroute International and ATP test stations. It is composed of three parts:

- A list of terms and definitions;
- A test methodology for multi-temperature refrigeration units; and
- A dimensioning methodology for multi-compartment multi-temperature equipment.

11. As with mono-temperature equipment, the objective is to measure the capacity of a refrigeration unit in order to verify that it is sufficient to meet the capacity demand of the body with a safety margin.

12. The 1998 methodology and all the proposals made thereafter require:

- For each evaporator:
    - The air flow measurement;
- For the different versions, 2 compartments or 3 compartments:
    - The measurement of:
        - The nominal capacity of the unit with a set of evaporators corresponding to the number of compartments;
        - The individual capacity of each evaporator;
        - The useful capacity of a set of evaporators including the smallest and the largest.
- The calculation of the useful capacity of all the other evaporators.

13. The current methodology has proven in over 100 tests that the interpolation of the useful capacity is correct and possible and that the test of one set is sufficient.

14. The procedure was not very clear on certain points; it is proposed to clarify them. The presentation of the results on useful capacities has been improved over the years; it is proposed to use a clearer presentation.

15. The 1998 methodology aimed to verify the capacity of the unit to provide enough power to the equipment as a whole and to each compartment.

16. For each compartment the K value was considered equal to the global K value of the equipment. The other rules of dimensioning were the same as ATP mono-temperature rules.

17. This methodology underestimated the refrigeration demand of the compartment in some configurations and operation modes. It could result in insufficient capacities in some cases. It was therefore preferable to upgrade this methodology.

18. The main change concerns the calculation of each compartment's refrigeration demand. The K value of the equipment as a whole will no longer be used. The K value of the compartments will be calculated with the measured K value of the body as a whole and the specific K values of the internal dividing walls.

19. In comparison to the proposal presented to WP.11 in 2009, the calculation of refrigeration demand and the remaining refrigerating capacities in real multi-temperature operation will be improved.

20. The refrigerating demands of all evaporators will be calculated for each individual multi-temperature unit using the ATP class temperatures in each compartment. The refrigerating demands, especially for deep frozen evaporators, will result in a lower level, because the outside temperature of all compartment walls including the internal bulkheads are no longer considered to be +30°C.

21. The calculated remaining useful refrigerating capacities in multi-temperature operation will rely on the real refrigerating demand of each compartment.

22. Lastly, the K coefficients of the internal bulkheads will be based on theoretical evaluations taking into account also the boundary effects such as heat transmission through the floor, walls, roof, sealings, etc. Measurements of partition wall K coefficients would result in unacceptable uncertainties and expenses for manufacturers and transporters.

23. There is no need to change the certificate model. The only point concerning multi-temperature equipment adopted in 1998 was for the certificate model. The changes to this model adopted in 2009 and 2010 do not impact on multi-temperature equipment. ATP markings have to be adapted for multi-temperature equipment.

24. The proposal is divided into three parts:

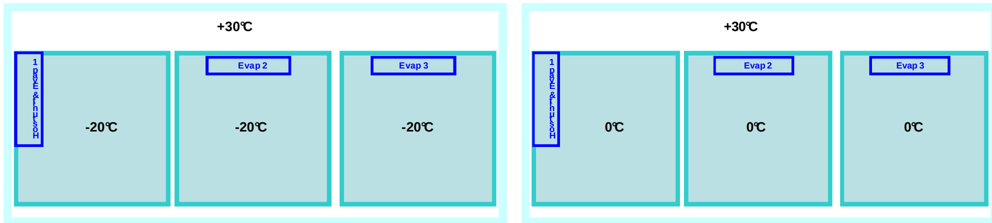
- Terms and definitions;
- Test procedure and test report for multi-temperature refrigeration units;
- Dimensioning methodology for multi-compartment equipment equipped with multi-temperature refrigeration units.

25. The proposal specifies the different terms necessary to introduce multi-compartment and multi-temperature equipment into ATP.

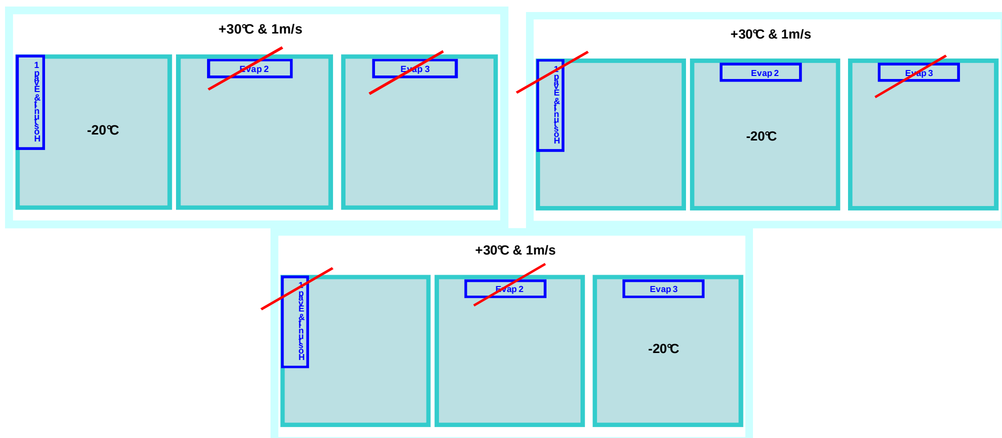
26. The test is carried out under the same conditions as for mono-temperature refrigeration unit tests. Each evaporator is installed in a separate calorimeter. Air flow is measured for each evaporator.

27. Since several measurements are made on the same group, the refrigeration capacity for multi-temperature equipment is only measured at 0 °C and -20 °C. The refrigeration capacity test is divided as follows:

- **Nominal capacity** measurement



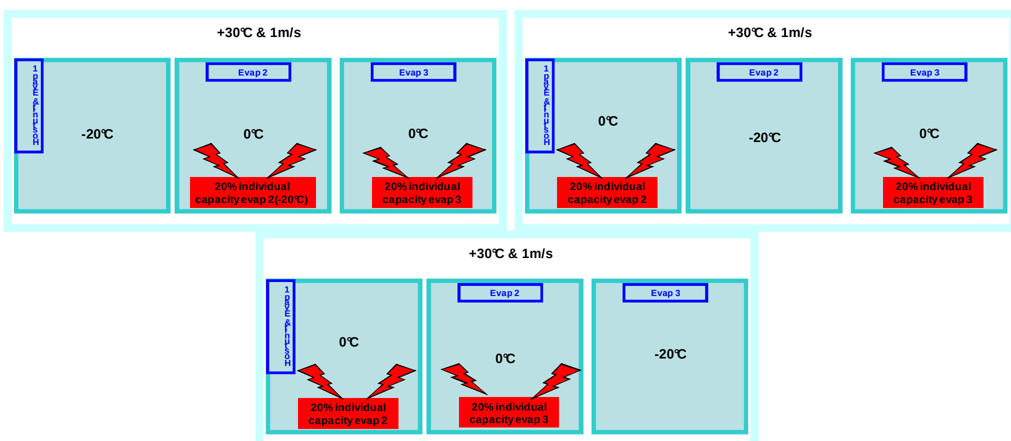
- **Individual capacity** measurement for each evaporator or combination



  - also with other evaporators (No. 4, 5…) and
  - for each of them the test will also be repeated at 0°C.

- **Test of the functionality of the unit in multi-temperature operation**

28. The unit is operated in multi-temperature with a configuration of 2 or 3 evaporators.



29. These tests that are considered only as functional tests should be carried out for a 2-compartment or 3-compartment combination depending on the capacity of the tested refrigeration unit. The effective remaining capacity is measured in each given configuration at -20 °C. All the tests are done in road and standby mode if applicable.

30. The results of this test have to be compared to the theoretical effective refrigeration capacities of the unit in the given configuration.

31. For certification, the dimensioning shall be carried out for each refrigerated multi-temperature vehicle in the most unfavourable conditions resulting in the maximum refrigeration demand for each individual application:

- The worst case operating temperatures in the compartments;
- In the case of movable internal dividing walls, the most unfavourable position of the internal walls for each compartment.

32. The temperatures to be considered for these calculations are +30 °C outside the vehicle, +20 °C in the unconditioned compartments and -20 °C in the frozen compartments. In the chilled compartments 0 and +12 °C both have to be examined.

33. The K values of the internal bulkheads were determined by extensive, external neutral calculation as shown in the table below, because the heat transfer through the internal dividing walls depends not only on the thermal conductivity of the insulation material but to a large extent on boundary effects like heat transfer through the roof, floor, sidewalls and sealings. Measurements of the K values of internal dividing walls are extremely complex and expensive. Therefore no test procedure could be agreed.

Results of the K coefficient calculation for internal bulkheads of multi-temperature vehicles

Partition type	*Inside floor material*	*Foam thickness mm*	*Basic insulation effect W/m².K*	*Boundary insulation effect W/m².K*	*Total K coefficient bulkhead W/m².K*	*K coefficient for ATP agreed by TI W/m².K*
Fixed longitudinal	Alu	25	0.992	0.789	1.781	**2.0**
	GRP			0.152	1.144	**1.5**
Fixed transversal	Alu	40	0.622	1.326	1.948	**2.0**
	GRP			0.662	1.326	**1.5**
Movable longitudinal	Alu	25	0.992	1.141	2.133	**3.0**
	GRP			0.497	1.489	**2.0**
Movable transversal	Alu	40	0.622	1.767	2.389	**3.2**
	GRP			1.085	1.767	**2.6**

34. The K coefficients of movable bulkheads as agreed by TI include a safety margin for specific ageing and unavoidable thermal leakages.

35. For specific designs with additional heat transfer caused by additional thermal bridges compared to a standard design, the partition K coefficient has to be increased.

36. For the determination of the effective refrigerating capacity remaining in multi-temperature operation for all evaporators in the chilled and frozen compartments a simple calculation method is applied. This calculation method was approved by the TI working group and can be used for all individual configurations of multi-temperature vehicles.

37. For the determination of the maximum refrigeration demand of multi-temperature vehicles and the remaining refrigerating capacities of multi-temperature refrigeration units

in real multi-temperature operation, Transfrigoroute International will set up a calculation tool in cooperation with ATP test stations.

38. Concerning refrigeration units, the new version of the test procedure does not change the volume and the duration of the tests. The test reports will be simplified.

39. The new dimensioning method could change the dimensioning of certain types of equipment. These changes will only have a positive impact on the safety of the equipment.

40. There is no economic impact of this proposal on tests because the number and duration of tests is the same or less than in the current procedure.

41. The impact on the equipment's price is negligible for the most part. For equipment which is inadequately dimensioned, the improvement of performance and the reduction of risk will compensate for the possible extra cost of the new dimensioning.

II. Proposal

It is proposed to add a new section 8 to Annex 1, Appendix 2 of ATP as follows:

"8. PROCEDURE FOR MEASURING THE CAPACITY OF MECHANICAL MULTI-TEMPERATURE REFRIGERATION UNITS AND DIMENSIONING MULTI-COMPARTMENT EQUIPMENT

8.1 Definitions

(a) Multi-compartment equipment: Equipment with two or more insulated compartments for maintaining a different temperature in each compartment;

(b) Multi-temperature mechanical refrigeration unit: Mechanical refrigeration unit with compressor and common suction inlet, condenser and two or more evaporators set at different temperatures in the various compartments of multi-compartment equipment;

(c) Host unit: Refrigeration unit with or without an integral evaporator;

(d) Unconditioned compartment: a compartment considered to have no evaporator or for which the evaporator is inactive for the purposes of dimensioning calculations and certification;

(e) Multi-temperature operation: Operation of a multi-temperature mechanical refrigeration unit with two or more evaporators operating at different temperatures in multi-compartment equipment;

(f) Nominal refrigerating capacity: Maximum refrigerating capacity of the refrigeration unit in mono-temperature operation with two or three evaporators operating simultaneously at the same temperature;

(g) Individual refrigerating capacity ($P_{ind\text{-}evap}$): The maximum refrigerating capacity of each evaporator in solo operation with the host unit;

(h) Effective refrigerating capacity ($P_{eff\text{-}frozen\ evap}$): The refrigerating capacity available to the lowest temperature evaporator when two or more evaporators are each operating in multi-temperature mode, as prescribed in paragraph 8.3.5;

8.2. Test procedure for multi-temperature mechanical refrigeration units

8.2.1 General procedure

The test procedure shall be as defined in annex 1, appendix 2, section 4.

The host unit shall be tested in combination with different evaporators. Each evaporator shall be tested on a separate calorimeter, if applicable.

The nominal refrigerating capacity of the host unit in mono-temperature operation, as prescribed in paragraph 8.2.2, shall be measured with a single combination of two or three evaporators including the smallest and largest.

The individual refrigerating capacity shall be measured for all evaporators, each in mono-temperature operation with the host unit, as prescribed in paragraph 8.2.3.

This test shall be conducted with two or three evaporators including the smallest, the largest and, if necessary, a mid-sized evaporator.

If the multi-temperature unit can be operated with more than two evaporators:

- The host unit shall be tested with a combination of three evaporators: the smallest, the largest and a mid-sized evaporator.
- In addition, on demand of the manufacturer, the host unit can be tested optionally with a combination of two evaporators: the largest and smallest.

The tests are done in independent mode and stand by.

8.2.2. Determination of the nominal refrigerating capacity of the host unit

The nominal refrigerating capacity of the host unit in mono-temperature operation shall be measured with a single combination of two or three evaporators operating simultaneously at the same temperature. This test shall be conducted at -20°C and at 0°C.

The air inlet temperature of the host unit shall be +30°C.

The nominal refrigerating capacity at -10°C shall be calculated by linear interpolation from the capacities at -20°C and 0°C.

8.2.3. Determination of the individual refrigerating capacity of each evaporator

The individual refrigerating capacity of each evaporator shall be measured in solo operation with the host unit. The test shall be conducted at -20°C and 0°C. The air inlet temperature of the refrigeration unit shall be +30°C.

The individual refrigerating capacity at -10°C shall be calculated by linear interpolation from the capacities at 0° C and -20°C.

8.2.4. Test of the remaining effective refrigerating capacities of a set of evaporators in multi-temperature operation at a reference heat load

The remaining effective refrigerating capacity shall be measured for each tested evaporator at -20°C with the other evaporator(s) operating under control of a thermostat set at 0 °C with a reference heat load of 20% of the individual refrigerating capacity at -20 °C of the evaporator in question. The air inlet temperature of the host unit shall be +30 °C.

For multi-temperature refrigeration units with more than one compressor such as cascade systems or units with two stage compression systems, where the refrigerating capacities can be simultaneously maintained in the frozen and chilled compartments, the measurement of the effective refrigerating capacity, shall be done at one additional heat load.

8.3. Dimensioning and certification of refrigerated multi-temperature equipment

8.3.1 General procedure

The refrigerating capacity demand of multi-temperature equipment shall be based on the refrigerating capacity demand of mono-temperature equipment as defined in annex 1, appendix 2 of ATP.

For multi-compartment equipment, a K coefficient less than or equal to 0.40 W/m².K for the outer body as a whole shall be approved in accordance with annex 1, appendix 2, subsection 2 to 2.2 of ATP.

The insulation capacities of the outer body walls shall be calculated using the K coefficient of the body approved in accordance with the ATP. The insulation capacities of the internal dividing walls shall be calculated using the K coefficients in the table in paragraph 8.3.7.

For issuance of an ATP certificate:

- The nominal refrigerating capacity of the multi-temperature refrigeration unit shall be at least equal to the heat loss through the internal dividing and outer body walls of the equipment as a whole multiplied by the factor 1.75 as specified in annex 1, appendix 2, paragraph 3.2.6 of ATP.
- In each compartment, the calculated remaining effective refrigerating capacity at the lowest temperature of each evaporator in multi-temperature operation shall be greater than or equal to the maximum refrigeration demand of the compartment in the most unfavourable conditions, as prescribed in paragraphs 8.3.5 and 8.3.6, multiplied by the factor 1.75 as specified in annex 1, appendix 2, paragraph 3.2.6 of ATP.

8.3.2 Conformity of the entire body

The outer body shall have a K value $K \leq 0.40$ W/m^2.K.

The internal surface of the body shall not vary by more than 20 %.

The equipment shall conform to:

$$P_{nominal} > 1.75 * K_{body} * S_{body} * \Delta T$$

Where:

- $P_{nominal}$ is the nominal refrigerating capacity of the multi-temperature refrigeration unit,
- K_{body} is the K value of the outer body,
- S_{body} is the internal surface of the full body,
- ΔT is the difference in temperature between outside and inside the body.

8.3.3 Determination of the refrigerating demand of chilled evaporators

With the bulkheads in given positions, the refrigerating capacity demand of each chilled evaporator is calculated as follows:

$$P_{chilled\ demand} = (S_{chilled\text{-}comp} - \Sigma S_{bulk}) * K_{body} * \Delta T_{ext} + \Sigma\ (S_{bulk} * K_{bulk} * \Delta T_{int})$$

Where:

- K_{body} is the K value given by an ATP test report for the outer body,
- $S_{chilled\text{-}comp}$ is the surface of the chilled compartment for the given positions of the bulkheads,
- S_{bulk} are the surfaces of the bulkheads,
- K_{bulk} are the K values of the bulkheads given by the table in paragraph 8.3.7,
- ΔT_{ext} is the difference in temperatures between the chilled compartment and +30°C outside the body,
- ΔT_{int} is the difference in temperatures between the chilled compartment and other compartments. For unconditioned compartments a temperature of +20°C shall be used for calculations.

8.3.4 Determination of the refrigerating demand of frozen compartments

With the bulkheads in given positions, the refrigerating capacity demand of each frozen compartment is calculated as follows:

$$P_{frozen\ demand} = (S_{frozen\text{-}comp} - \Sigma S_{bulk}) * K_{body} * \Delta T_{ext} + \Sigma (S_{bulk} * K_{bulk} * \Delta T_{int})$$

Where:

- K_{body} is the K value given by an ATP test report for the outer body,
- $S_{frozen\text{-}comp}$ is the surface of the frozen compartment for the given positions of the bulkheads,
- S_{bulk} are the surfaces of the bulkheads,
- K_{bulk} are the K values of the bulkheads given by the table in paragraph 8.3.7,
- ΔT_{ext} is the difference in temperatures between the frozen compartment and +30 °C outside the body,
- ΔT_{int} is the difference in temperatures between the frozen compartment and other compartments. For insulated compartments a temperature of +20°C shall be used for calculations.

8.3.5 Determination of the effective refrigerating capacity of frozen evaporators

The effective refrigerating capacity, in given positions of the bulkheads, is calculated as follows:

$$P_{eff\text{-}frozen\text{-}evap} = P_{ind\text{-}frozen\text{-}evap} * [1 - \Sigma (P_{eff\text{-}chilled\text{-}evap} / P_{ind\text{-}chilled\text{-}evap})]$$

Where:

- $P_{eff\text{-}frozen\text{-}evap}$ is the effective refrigerating capacity of the frozen evaporator with a given configuration,
- $P_{ind\text{-}frozen\text{-}evap}$ is the individual refrigeration capacity of the frozen evaporator at -20 °C,
- $P_{eff\text{-}chilled\text{-}evap}$ is the effective refrigeration capacity of each chilled evaporator in the given configuration as defined in paragraph 8.3.6,
- $P_{ind\text{-}chilled\text{-}evap}$ is the individual refrigerating capacity at -20 °C for each chilled evaporator.

This calculation method is only approved for multi-temperature mechanical refrigeration units with a single one-stage compressor. For multi-temperature refrigeration units with more than one compressor such as cascade systems or units with two stage compression systems, where the refrigerating capacities can be simultaneously maintained in the frozen and the chilled compartments, this calculation method shall not be used, because it will lead to an underestimation of the effective refrigerating capacities. For this equipment, the effective refrigerating capacities shall be interpolated between the effective refrigerating capacities measured with two different heat loads given in the tests reports as prescribed in 8.2.4.

8.3.6 Conformity declaration

The equipment is declared in conformity in multi-temperature if, for each position of the bulkheads, and each distribution of temperature in the compartments:

$$P_{eff\text{-}frozen\text{-}evap} \geq 1.75 * P_{frozen\ demand}$$

$$P_{eff\text{-}chilled\text{-}evap} \geq 1.75 * P_{chilled\ demand}$$

Where:

- $P_{eff\text{-}frozen\text{-}evap}$ is the effective refrigeration capacity of the considered frozen evaporator at the class temperature of the compartment in the given configuration,
- $P_{eff\text{-}chilled\text{-}evap}$ is the effective refrigeration capacity of the considered chilled evaporator at the class temperature of the compartment in the given configuration,
- $P_{frozen\ demand}$ is the refrigerating demand of the considered compartment at the class temperature of the compartment in the given configuration as calculated according to 8.3.4,
- $P_{chilled\ demand}$ is the refrigerating demand of the considered compartment at the class temperature of the compartment in the given configuration as calculated according to 8.3.3.

It shall be considered that all the positions of the bulkheads have been dimensioned if the wall positions from the smallest to the largest compartment sizes are checked by iterative methods whereby no input step change in surface area is greater than 20 %.

8.3.7 Internal dividing walls

Thermal losses through internal dividing walls shall be calculated using the K coefficients in the following table.

	K coefficient – [W/m².K]		*Minimum foam thickness*
	Fixed	Removable	[mm]
Longitudinal – alu floor	2.0	3.0	25
Longitudinal – GRP floor	1.5	2.0	25
Transversal – alu floor	2.0	3.2	40
Transversal – GRP floor	1.5	2.6	40

K coefficients of movable dividing walls include a safety margin for specific ageing and unavoidable thermal leakages.

For specific designs with additional heat transfer caused by additional thermal bridges compared to a standard design, the partition K coefficient shall be increased.