Draft Proposal

based on WP.11 papers TRANS/WP.11/1998/4, TRANS/WP.11/2000/1 and the proposal by CRT dated 16/03/1999

E. Procedure for measuring the cooling and heating capacity and dimensioning the cooling and heating demand of multi-temperature mechanical refrigeration units for multi-compartment equipment

I. Definitions

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1) **Multi-compartment equipment:** Equipment with two or more insulated compartments for different temperatures in each compartment
2) **Multi-temperature mechanical refrigeration unit:** Mechanical refrigeration unit with compressor, condenser and two or more evaporators for the control (cooling and/or heating) of different temperatures in the different compartments of a multi-compartment equipment.
3) **Multi-temperature operation:** Operation of a multi-temperature mechanical refrigeration unit with two or more evaporators working at different temperatures in multi-compartment equipment.
4) **Nominal cooling capacity:** Maximum cooling capacity of the condensing unit in mono-temperature operation with two or three evaporators operating simultaneously at the same temperature.
5) **Individual cooling capacity:** Maximum cooling capacity of each individual evaporator operating alone with the condensing unit.
6) **Individual heating capacity:** Maximum heating capacity of each individual evaporator operating alone with the condensing unit.
7) **Useful cooling capacity:** Cooling capacity of each evaporator with the condensing unit in multi-temperature operation with two or more evaporators at different temperatures.
8) **Useful heating capacity:** Heating capacity of each evaporator with the condensing unit in multi-temperature operation with two or more evaporators at different temperatures.

II Test procedures for multi-temperature mechanical refrigeration units

62) General procedure

The test procedure and accuracy are according to ATP agreement Annex 1, Appendix 2, D and Annex 1, Appendix 2, paragraph 10 the first two sentences with an inside temperature of 12 °C. Accuracy of the heating capacity must be equal or lower than 5 %.

The condensing unit can be tested in combination with a various number of evaporators. In multi-temperature operation each evaporator will be tested in a separate calorimeter.

The individual cooling capacity is measured for each tested evaporator in operation with the condensing unit as described in paragraph 64.

The nominal cooling capacity of the condensing unit as prescribed in paragraph 63 and the useful cooling capacities of the evaporators in multi-temperature operation as prescribed in paragraphs 65 and 66 are tested with two or three evaporators. If the number of tested evaporators is higher than two or three, condensing units for at maximum two evaporators are tested with the largest and smallest evaporator and condensing units for three or more evaporators with the largest, the smallest and a mid-sized evaporator.
In consideration of the multitude of possible combinations of the tested evaporators with the condensing unit, only a limited number of control sample measurements is carried out in multi-temperature operation to verify the calculated results.

For the certification the measured useful cooling capacities of the frozen evaporators in paragraph 65 and 66 shall be in average higher than 90% of the calculated cooling capacities in paragraph 67.

63) Capacity tests of the condensing unit in mono-temperature operation

Nominal cooling capacity of the condensing unit in mono-temperature operation with all evaporators operating simultaneously at the same temperature:
Tests at -20°C and at 0°C air inlet temperature evaporator unit, +30°C air inlet temperature condensing unit.

64) Capacity tests of each individual evaporator in mono-temperature operation with the condensing unit

a) **Individual cooling capacity of each individual evaporator** operating alone with the condensing unit:
   Test at –20°C air inlet temperature evaporator unit and +30°C air inlet temperature condensing unit.
   The individual capacities at 0°C are calculated with the ratio of the capacities at -20°C and 0°C measured in paragraph 63.

b) **Optional: Individual heating capacity of each individual evaporator** operating alone with the condensing unit:
Test at +12°C air inlet temperature evaporator unit and -20°C air inlet temperature condensing unit.

65. Useful Cooling capacity tests of the evaporators in multi-temperature operation

Measurement of the maximum useful cooling capacity of each evaporator at -20°C while the other evaporators are cooling under thermostatic control at 0°C with a fixed heat load of 20% of the nominal cooling capacity of the host unit at -20°C. The air inlet temperature of the condensing unit is +30°C (two tests for condensing units with two evaporators, three tests for condensing units with three evaporators).

66. Useful Cooling and useful heating capacity tests of the evaporators in multi-temperature operation

Parallel measurement of the maximum useful cooling capacity at -20°C of one evaporator and of the maximum useful heating capacity at +12°C of another evaporator. The cooling and heating capacities shall be tested for each evaporator. The air inlet temperature of the condensing unit is +30°C.

In the case of condensing units with three evaporators the third evaporator is cooling under thermostatic control at 0°C with a fixed heat load of 20% of the nominal cooling capacity of the host unit at -20°C (two tests for condensing units with two evaporators, three tests for condensing units with for three evaporators).

67. Calculation of the useful cooling capacities of the evaporators in multi-temperature operation

The useful cooling capacities of each evaporator in multi-temperature operation can be calculated with the individual capacities of the evaporators operating alone with the condensing unit at -20°C and the relative cooling times of the evaporators. The calculation is based on the fact that the evaporator does not cool at -20°C while another evaporator is cooling at 0°C.

Useful cooling capacity = relative cooling time x individual cooling capacity at -20°C

Relative cooling time of frozen evaporator = 1 - relative cooling time of all chilled evaporators

III Dimensioning and certification of multi-temperature mechanical refrigeration units for multi-compartment equipment

68) General procedure

The cooling and heating capacity demand for multi-compartment equipment is based on the ATP agreement Annex 1 Appendix 2 for mono-temperature equipment.

For multi-compartment equipment a k-coefficient lower or equal to 0.40 W/m²K (IR) for the outside surfaces of the body has to be approved according to the ATP agreement Annex 1 Appendix 2, paragraphs 7 - 25.

In accordance to the ATP agreement Annex 1 Appendix 2, C paragraph 41 for refrigerated equipment the multiply-factor is 1.75.

For the certification the calculated useful cooling or heating capacities of the evaporators in each compartment in multi-temperature operation with the condensing unit (paragraph 67) must be at least equal or higher than the calculated maximum cooling or heating demand of the compartments multiplied by the factor of 1.75.

69) Calculation of the cooling and heating demand

The calculation of the matching cooling and heating capacity for each compartment must be based on the maximum possible temperature for the maximum cooling and heating demand. In the case of movable bulkheads, the calculation must be based on the most unfavourable position of the bulkhead and the maximum size of each compartment.

The insulation capacities of the internal bulkheads can be calculated based on the k-coefficient tabled in paragraph 70.

The cooling capacities have to be calculated for +30°C ambient temperature and -20°C in the frozen compartment. The cooling demand in the chilled compartment shall be calculated for 0°C and +12°C.

The heating capacities have to be calculated for a temperature of -20°C ambient and +12°C in the chilled compartment.

The temperature in the dry freight compartment is set to +30°C.

70) Internal bulkheads

The thermal losses of the internal bulkheads can be calculated with the k-coefficents of the following table. Alternatively the insulation capacity (k-coefficient) of the internal bulkheads can be measured on a complete vehicle according to the ATP agreement Annex 1 Appendix 2, paragraphs 7 - 25.

	k-coefficient [W/m²K]		min. foam thickness [mm]
	fixed	movable	
longitudinal	2.5	3.5	25
transversal	1.5	2.5	40

Notes:

a) The k-coefficients of the internal bulkheads are based on calculations including thermal bridges in walls, roof, floor, protection plates, load lock bars and sealings.

IV. Test procedure for multi-temperature mechanical refrigeration units with fan systems for the distribution of cold air in chilled compartments

70. This procedure includes all fan driven air distribution systems like roof mounted or bulkhead fan systems to control the temperature in the chilled compartment by air exchange with the deep frozen compartment that is cooled by a mechanical refrigeration unit.

71. Capacity tests of the mechanical refrigeration unit

If no test report is available the nominal capacity of the host unit is measured at -20/+30°C and 0°C/+30°C conditions in mono-temperature operation according to paragraphs 51 to 59.

72. Air flow measurements of the fan system

The fan delivery volume V and air speed of the fan system shall be measured.

73. Test of the heating capacity of the fan system

The individual heating capacity of the fan system shall be measured by the determination of the electrical power input of the heaters and the motors of the fans.

74. Determination of the cooling capacity of the fan system

The maximum cooling capacity of the fan system can be calculated by the fan delivery volume V and the enthalpy difference Δh of the air in the deep frozen and the chilled compartment. Depending on the operation time in cooling mode the cooling capacity W_{air} of the fan system is defined by

$$W_{air} = \text{relative runtime} * \frac{V * \Delta h}{3.6}$$

V is the air volume in m^3/h delivered from the fan system to the chilled compartment at 0°C or +12°C,

Δh is the enthalpy difference of the air (60% relative humidity) delivered to the chilled compartment for

-20°C/0°C $\Delta h = 41$ kJ/m^3
-20°C/+12°C $\Delta h = 68$ kJ/m^3

75. Determination of the remaining cooling capacity of the mechanical refrigeration unit in multi-temperature operation with the fan system

The useful cooling capacity of the host unit W remaining for the deep frozen compartment is equal to the difference of the nominal capacity of the host unit W_o in mono-temperature operation at +30/-20°C according to paragraph 71 and the required cooling capacity of the fan system unit W_{air} for the chilled compartment according to paragraph 74.

$$W = W_o - W_{air}$$

76. Certification

Based on the test report the calculations in paragraphs 74 and 75 must show that the cooling and/or the heating capacities of the complete multi-temperature mechanical refrigeration unit are at least 1.75 times higher than the thermal losses of the multi-compartment equipment determined according to paragraphs 68 and 69 for each compartment.

The fan system must be sufficient to maintain 0°C or +12°C in the chilled compartment with no more than 50% operational running time in cooling mode.
The cooling capacity and the delivering air volume of the mechanical refrigeration unit must be sufficient to maintain a temperature of -20°C within a variation of ±2 K in the deep frozen compartment. In addition the mechanical refrigeration unit must be equipped with control devices to ensure an average temperature of -20°C in the deep frozen compartment.

In addition the cooling capacities of the host unit in mono-temperature operation must be 1.75 times higher than the thermal losses through the floor, roof, sidewalls, front bulkhead and rear doors of the complete vehicle at +30/-20°C conditions.

With regard to hygiene regulations fan systems can only be applied for transports of packaged foodstuffs and products non sensitive to odors.