INTERNATIONAL STANDARD 917

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Testing of refrigerant compressors

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

Prior to 1972, the results of the work of the Technical Committees were published as ISO Recommendations; these documents are now in the process of being transformed into International Standards. As part of this process, Technical Committee ISO/TC 86 has reviewed ISO Recommendation R 917 and found it suitable for transformation. International Standard ISO 917 therefore replaces ISO Recommendation R 917-1968.

ISO Recommendation R 917 was approved by the Member Bodies of the following countries :

Australia	France	Poland
Belgium	Germany	Sweden
Canada	Greece	Switzerland
Chile	Hungary	United Kingdom
Czechoslovakia	Italy	U.S.A.
Denmark	Netherlands	Yugoslavia
Egypt, Arab Rep. of	New Zealand	

No Member Body expressed disapproval of the Recommendation.

No Member Body disapproved the transformation of ISO/R 917 into an International Standard.

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Testing of refrigerant compressors

0 INTRODUCTION

This International Standard applies only to refrigerant compressors considered as separate units, independently of a complete refrigeration installation.

Selected methods of test are described for the determination of the refrigerating capacity and power performance factor of a refrigerant compressor, with sufficient accuracy to permit consideration of its suitability to operate satisfactorily under any set of basic test conditions required for a given refrigeration installation.

The methods for the determination of the refrigerating capacity are given in section one.

The methods for the determination of the power performance factor are given in section two.

Attention is particularly drawn to a number of special precautions to be taken in order to reduce testing losses to a minimum.

NOTE — Tests on complete refrigeration installations are dealt with in ISO/R 916, *Testing of refrigerating systems.*

1 SCOPE AND FIELD OF APPLICATION

The provisions of this International Standard apply only to single stage refrigerant compressors of the positive volume displacement type. The methods of test described may however be used as a guide for the testing of other types of refrigerant compressors.

This International Standard applies only to tests carried out at the manufacturer's works, or wherever the necessary equipment for testing to the close limits required can be made available.

2 DEFINITIONS

A complete list of symbols and units used in calculation, together with their definitions, is given in annex B.

2.1 refrigerating capacity of a refrigerant compressor : Product of the mass flow rate of refrigerant through the compressor, as derived from the test, and the difference between the specific enthalpy of the refrigerant in its state at the measuring point at inlet of the compressor, and the specific enthalpy in the state of saturated liquid at the temperature corresponding to the test discharge pressure at the measuring point at outlet of the compressor.

2.2 refrigerating performance factor : Ratio of refrigerating capacity to power supplied.

NOTE — It should be made clear whether the power referred to is measured at the compressor shaft, or is power supplied at the motor terminals.

SECTION ONE

DETERMINATION OF REFRIGERATING CAPACITY

3 GENERAL PROCEDURE

3.1 Determination of refrigerating capacity

The determination of the refrigerating capacity of a compressor comprises

a) the evaluation of the mass flow rate of the refrigerant, obtained for each method used by means of the apparatus inserted in the outer part of the test circuit, between the inlet and the outlet of the compressor, as described in clauses 8 to 18;

b) the determination of the specific enthalpy of the refrigerant in the state of saturated liquid at the compressor discharge pressure, and its specific enthalpy at the compressor suction pressure and temperature, obtained by means of tables or diagrams of the characteristics of the refrigerant.

During the test, the refrigerant compressor should be provided with all auxiliary equipment and accessories necessary for its satisfactory operation in normal use.

3.2 Tests

The tests comprise a PRINCIPAL test and a CONFIRMING test which shall be carried out simultaneously.

3.2.1 The CONFIRMING test shall, wherever possible, be of a different type from the PRINCIPAL test, so that its results are obtained independently from those of the PRINCIPAL test.

3.2.2 The value of the estimated error for the refrigerating capacity, as calculated for the PRINCIPAL test, shall be lower than that calculated from the selected CONFIRMING test (see annex C).

3.2.3 Recommended methods for both types of tests and for possible combinations are given in clause 7.

3.2.4 The results of the PRINCIPAL test are accepted provided that those of the CONFIRMING test are in agreement to within ± 4 %.

3.3 General rules

In order to ensure that the results obtained are within the required limits of accuracy, it is essential to observe the following rules and to take into account the instructions given in the note under 3.3.4.

3.3.1 All instruments and auxiliary measuring apparatus shall have been correctly located in relation to the compressor inlet and outlet, and shall have been calibrated against master instruments of certified accuracy and adjusted if necessary to give readings within the limits of accuracy prescribed in annex A.

3.3.2 Pressure and temperature at suction inlet to the compressor shall both be measured at the same point and as nearly as possible eight pipe diameters of a straight run of pipeline, or 300 mm (12 in), whichever is greater, ahead of the point of entry or of the stop valve, if one is fitted.

3.3.3 Pressure and temperature at the discharge outlet of the compressor shall both be measured at the same point and not less than eight pipe diameters of a straight run of pipeline, or 300 mm (12 in), whichever is greater, after the point of outlet or the stop valve, if one is fitted.

3.3.4 The correct refrigerant and lubricating oil charges shall be in the circulation system. Efficient oil separators shall be fitted in the discharge line of the compressor, and arrangements made to return separated oil direct to the compressor lubricating system.

If the compressor is designed for use on a normal oil returning circuit, the oil from the separator shall be returned to the suction line between the measuring apparatus and the compressor suction connection.

No refrigerant shall be added during the test, and no oil shall be added to enclosed crank cases which communicate with the refrigerant circuit.

During the whole of the test run, the circuit shall contain only the refrigerant and the lubricating oil in such conditions of purity that normal operation in the continuous running of the compressor will be assured, and that the precision of the test measurements will not be affected within the agreed tolerances.

NOTE — The complete elimination of liquid refrigerant and lubricating oil would be difficult to achieve. However, the error arising from these factors at inlet of the compressor can generally be reduced to such an extent as to be negligible by

a) ensuring that the refrigerant vapour is sufficiently superheated at inlet to the compressor. For this purpose a suction superheater may be required, and any heat supplied to it from an external source shall be duly recorded;

b) providing an efficient oil separator on the discharge line of the compressor.

In general, a correction for the effect of lubricating oil is not necessary if the oil content of the oil/liquid refrigerant mixture, determined in the manner described in 12.3.3, is such as to cause an error not exceeding 1 % of the refrigerating capacity.

3.3.5 The system shall be tested for tightness, and all non-condensable gases shall be eliminated.

3.3.6 The compressor shall be protected against abnormal air currents.

3.4 Test period

3.4.1 The tests envisaged refer exclusively to refrigerant compressors operating continuously under conditions such that, for a specified period, fluctuations in all the factors likely to affect the results of a test remain between the limits prescribed, and show no definite tendency to move outside these limits.

These conditions are termed *steady working conditions.*

3.4.2 After the compressor has been started, adjustments should be made during a *preliminary* run until the essential measurements required for the test are within the allowable limits of variation.

3.4.3 The steady working conditions having been reached, the readings for the test period are taken at equal time intervals not exceeding 20 min, for a period of at least 1 h during which at least four readings are taken and plotted as a curve.

Only minor adjustments are permitted during this period.

The use of recording instruments of accuracy compatible with the accuracy of the method used is required.

3.4.4 The arithmetic mean of the successive readings for each measurement is taken as the value of the measurement for the test.

3.4.5 Quantity measurements shall be made at the beginning and end of each interval to check uniformity of operation, the difference between the first and last measurement of the test period being taken as the value for the test.

4 BASIC TEST CONDITIONS AND VARIATIONS

The basic test conditions to be specified for the testing of a refrigerant compressor are as follows :

4.1 The absolute pressure at the measuring points in the suction and discharge pipeline of the compressor. The pressure readings shall not vary by more than ± 1 % throughout the test period.

4.2 The suction temperature at the measuring point in the suction pipeline of the compressor. The temperature readings shall not vary by more than ± 3 °C (± 5 °F) throughout the test period.

4.3 The speed of rotation of the compressor. The speed selected for the test shall not differ by more that ± 10 % from the basic speed.

or

The voltage at the motor terminals and the frequency. The voltage shall be within ± 2 % of the nameplate value and the frequency within ± 2 %.

5 BASIS OF CALCULATIONS

5.1 Specific enthalpy

Subject to the rules and precautions defined under 3.3, the specific enthalpy of the refrigerant liquid at compressor discharge pressure, and the specific enthalpy at compressor suction pressure and temperature, are obtained from recognized tables and diagrams of the thermodynamic properties of the refrigerant used. A correction for the presence of entrained lubricating oil may be necessary in the second case (see 12.3.3).

5.2 Mass flow rate of refrigerant

The mass flow rate is determined by a PRINCIPAL method selected from those described under clauses 8 to 17, and confirmed by a suitable CONFIRMING test, the tests being carried out simultaneously (see clause 7).

5.3 Specific volume of the refrigerant

The actual test value v_{ga} of the specific volume of the refrigerant vapour at compressor inlet shall not differ by more than 2 % from the value v_{g1} corresponding to the specified basic test conditions.

5.4 Value of the measured mass flow rate

Subject to the condition in 5.3, the value of the measured mass flow rate shall be adjusted by multiplying it by the factor v_{ga}/v_{g1}.

6 TEST REPORT

6.1 General information

6.1.1 Date . . . .

Time started . . . .
Time ended . . . .
Duration . . . .

6.1.2 Make and serial number of compressor.

6.1.3 Type of compressor (single or double acting, number of cylinders, etc.).

6.1.4 Cylinder diameter and stroke (if applicable).

6.1.5 Compressor displacement per revolution.

6.1.6 Designation of refrigerant.

6.2 Basic test conditions to be specified (see clause 4)

6.2.1 Absolute pressure at compressor suction.

6.2.2 Temperature at compressor suction.

6.2.3 Absolute pressure at compressor discharge.

6.2.4 Rotational speed of compressor or electric supply details.

6.3 Methods of test used.

6.3.1 PRINCIPAL test.

6.3.2 CONFIRMING test.

6.4 Average values of test readings (see clause 3)

6.4.1 Rotational speed of compressor.

6.4.2 Ambient temperature.

6.4.3 Barometer reading.

6.4.4 Pressure of refrigerant at compressor suction inlet.

6.4.5 Temperature of refrigerant at compressor suction inlet.

6.4.6 Pressure of refrigerant at compressor discharge outlet.

6.4.7 Temperature of refrigerant at compressor discharge outlet.

6.4.8 Inlet temperature of cooling water.

6.4.9 Outlet temperature of cooling water.

6.4.10 Mass flow rate of cooling water.

6.4.11 When possible, compressor lubricating oil temperature.

6.4.12 Voltage and frequency of electrical supply.

NOTE — Additional test information will be required depending on the methods of test used (see clauses 8 to 18).

6.5 Test results

6.5.1 Heat leakage factors.

6.5.2 Mass flow rate of refrigerant.

6.5.3 Relevant enthalpy difference.

6.5.4 Refrigerating capacity of compressor.

6.5.5 Estimated error of results (see annex C).

6.5.6 Remarks.

NOTE — If the test is to include the measurement of power performance, the readings required in accordance with section two shall be taken simultaneously with those of section one.

7 METHODS OF TEST

7.1 Method A (see clause 8) : Secondary fluid calorimeter in *suction* line.

Method B (see clause 9) : Flooded system refrigerant calorimeter in *suction* line.

Method C (see clause 10) : Dry system refrigerant calorimeter in *suction* line.

A heat-insulated calorimeter is installed near the suction inlet of the compressor to act as the evaporator, and the refrigerating effect is produced by the direct transfer of heat to the refrigerant from a suitable controlled source.

NOTE — Methods A, B and C shall, wherever possible, be used as PRINCIPAL METHODS.

7.2 Method G (see clause 14) : Water-cooled condenser method.

The water-cooled condenser in the actual installation is suitably insulated and equipped to act as a calorimeter.

7.3 Method K (see clause 17) : Calorimeter in discharge line.

A heat-insulated calorimeter is installed in the discharge pipeline of the compressor to receive the total flow of refrigerant in the gaseous state.

7.4 Method D (see clause 11) : Refrigerant vapour flow-meter.

A flow-meter of the calibrated orifice or nozzle type is placed in *either* the compressor suction *or* the compressor discharge line.

7.5 Method E (see clause 12) : Refrigerant liquid quantity meter.

Method F (see clause 13) : Refrigerant liquid flow rate meter.

Method H (see clause 15) : Refrigerant vapour cooling.

Method J (see clause 16) : Alternative to Method H.

Methods E and F measure the *total* flow of the refrigerant in the *liquid* state.

Methods H and J measure the flow of *a portion only* of the *liquid* refrigerant obtained from a special condenser.

Methods G, K, D, E, F, H and J shall in general be used as CONFIRMING METHODS. However, in cases where it is not practicable to employ Methods A, B and C as PRINCIPAL METHODS, it is permissible to make use of Methods D, G and K for this purpose provided the total mass flow passes through the measuring apparatus, and the special precautions referred to under 3.3 are strictly observed.

7.6 Possible combinations

The following combinations of PRINCIPAL METHODS and CONFIRMING METHODS are possible, taking into account the conditions set out under 3.2.

PRINCIPAL METHOD	POSSIBLE CONFIRMING METHOD
Method A	E, F, G, K
Method B	E, F, G, K
Method C	E, F, G, K
Method D	H, J, G, K
Method G	E, F, K
Method K	E, F, G, H, J

8 METHOD A : SECONDARY FLUID CALORIMETER (see figure 1)

8.1 Description

The secondary fluid calorimeter consists of a direct expansion coil or set of coils in parallel serving as a primary evaporator. This evaporator is suspended in the upper part of a pressure-tight heat-insulated vessel. A heater is located in the base of this vessel, which is charged with a volatile secondary fluid so that the heater is well below the liquid surface. The refrigerant flow is controlled by either a hand regulator or a constant pressure expansion valve, which shall be located close to the calorimeter. The expansion valve and the refrigerant pipelines connecting it to the calorimeter may be insulated in order to minimize the gain of heat.

The calorimeter is insulated in such a manner that the heat leakage does not exceed 5 % of the capacity of the compressor.

Provision shall be made for measuring the pressure of the secondary fluid with an accuracy of ± 0,05 kgf/cm^2 (± 0.7 lbf/in^2) and for ensuring that this pressure does not exceed the safety limit for the apparatus.

8.2 Calibration

The calorimeter should be calibrated by the following heat loss method :

8.2.1 The heat input to the secondary fluid is adjusted so as to maintain the pressure constant at a value corresponding to a temperature of saturation approximately 14 °C (25 °F) above the ambient air temperature. The ambient air temperature is maintained constant to within ± 1 °C (± 2 °F) at any desired value not exceeding 43 °C (110 °F).

8.2.2 If the heater is operated continuously, the heat input is maintained constant to within ± 1 % and the pressure of the secondary fluid is measured at hourly intervals until four successive values of the corresponding temperature of saturation do not vary by more than ± 0,6 °C (± 1 °F).

8.2.3 If the heater is operated intermittently, the control shall be such that the temperature of saturation corresponding to the secondary fluid pressure is maintained constant to within ± 0,6 °C (± 1 °F) of the desired value and readings of heat input are taken at hourly intervals until four successive readings do not vary by more than ± 4 %.

8.2.4 The heat leakage factor can then be calculated from the formula

$$F_l = \frac{\Phi_h}{t_p - t_a}$$

8.3 Test procedure

The suction pressure is adjusted by means of the refrigerant control, and the temperature of the refrigerant vapour entering the compressor is adjusted by varying the heat input to the secondary fluid. The discharge pressure is adjusted by varying the temperature and flow of the condensing medium, or by a pressure control device in the discharge line.

8.3.1 If the heater is operated continuously, the fluctuation in heat input due to any cause during the test period shall not be such as to cause a variation of more than 1 % in the calculated compressor capacity.

8.3.2 If the heater is operated intermittently, the temperature of saturation corresponding to the secondary fluid pressure shall not vary by more than ± 0,6 °C (± 1 °F).

8.4 Additional information

The following information shall be recorded :

8.4.1 Pressure of refrigerant vapour at evaporator outlet.

8.4.2 Temperature of refrigerant vapour at evaporator outlet.

8.4.3 Pressure of refrigerant liquid entering expansion valve.

8.4.4 Temperature of refrigerant liquid entering expansion valve.

8.4.5 Ambient temperature at calorimeter.

8.4.6 Pressure of secondary fluid.

8.4.7 Heat input to secondary fluid.

8.5 Determination of refrigerating capacity

8.5.1 The mass flow rate of the refrigerant, as determined by the test, is given by the formula

$$m_f = \frac{\Phi_i + F_l (t_a - t_s)}{h_{g2} - h_{f2}}$$

8.5.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = m_f (h_{g1} - h_{f1}) \frac{v_{ga}}{v_{g1}}$$

9 METHOD B : FLOODED SYSTEM REFRIGERANT CALORIMETER (see figure 2)

9.1 Description

The flooded system refrigerant calorimeter consists of a pressure-tight evaporator vessel, or vessels in parallel, in which heat is applied direct to the refrigerant in respect of which the compressor is being tested. The refrigerant flow is controlled by a hand regulator, a constant pressure expansion valve, or a suitable level control device, which shall be located close to the calorimeter. The expansion valve and the refrigerant pipeline connecting it to the calorimeter may be insulated in order to minimize the gain of heat.

The calorimeter shall be insulated in such a manner that the heat leakage does not exceed 5 % of the capacity of the compressor.

Provision shall be made for ensuring that the refrigerant pressure does not exceed the safety limit for the apparatus.

9.2 Calibration

The calorimeter shall be calibrated by one of the following methods :

9.2.1 *Heat loss method*

The heat loss method of calibration is carried out by means of the following procedure :

9.2.1.1 The calorimeter is filled with refrigerant liquid to its normal operating level and the liquid and vapour outlet stop valves closed. The ambient temperature is maintained constant to within ± 1 °C (± 2 °F) at any desired value not exceeding 43 °C (110 °F) and heat is supplied to maintain the refrigerant temperature approximately 14 °C (25 °F) above the ambient temperature. Where liquid is used for heating, the inlet temperature is maintained constant to within ± 0,3 °C (± 0.5 °F) and the flow controlled so that the temperature drop is not less than 6 °C (10 °F). Where electric heating is used, the input is maintained constant to within ± 1 %.

9.2.1.2 After thermal equilibrium has been established, readings are taken for the following periods :

- *for liquid heating*, at hourly intervals until four successive readings of both inlet and outlet temperatures, with constant rate flow, do not vary by more than ± 0,3 °C (± 0.5 °F);

- *for electric heating*, at hourly intervals until four successive values of the temperature of saturation of the refrigerant do not vary by more than ± 0,6 °C (± 1 °F).

9.2.1.3 The heat input to the calorimeter is determined as follows :

- *for liquid heating*

$$\Phi_i = c\,(t_1 - t_2)\,m_l$$

- *for electric heating*

$$\Phi_i = P\,\mathrm{W} = 0{,}86\,P\ \mathrm{kcal/h} = 3.41\ P\ \mathrm{Btu/h}$$

9.2.1.4 The heat leakage factor can then be calculated from the formula

$$F_l = \frac{\Phi_i}{t_r - t_a}$$

9.2.2 *Condensing unit method*

The condensing unit method of calibration is carried out by means of the following procedure :

The ambient temperature of the calorimeter is maintained constant to within ± 1 °C (± 2 °F) at any desired value not exceeding 43 °C (110 °F). A condensing unit of appropriate capacity is operated on the calorimeter until steady conditions are reached with a temperature difference between the ambient temperature and the temperature of saturation of the refrigerant of 22 ± 1 °C (40 ± 2 °F). The condensate is collected and measured in volume measuring vessels by the procedure described in Method E (see clause 12) over such a period of time as to ensure that the height of the liquid accumulated in the measuring vessel is at least 150 mm (6 in). The test is continued until four successive readings taken at hourly intervals do not vary by more than ± 5 %.

The heat leakage factor can then be calculated from the formula

$$F_l = \frac{(h_{g2} - h_{f2})\,m_f}{t_a - t_r}$$

9.3 Test procedure

The suction pressure at the compressor is adjusted by means of the refrigerant control, and the inlet temperature to the compressor is adjusted by varying the heat input, except when a level control is used, in which case the suction pressure is adjusted by means of the heat input to the evaporator, and the inlet temperature to the compressor by the heat input to a superheater. The discharge pressure is controlled by varying the temperature and flow of the condensing medium, or by a pressure control device in the discharge line.

9.3.1 Where liquid is used for heating, the inlet temperature shall be maintained constant to within ± 0,3 °C (± 0.5 °F) and the flow controlled so that the temperature fall is not less than 6 °C (10 °F). The mass of liquid circulated shall be maintained constant to within ± 0,5 %. Where electric heating is used, the input shall be maintained constant to within ± 1 %.

9.3.2 The variation in heat input during the test shall not be sufficient to cause an error of more than 1 % in compressor capacity.

9.4 Additional information

The following information shall be recorded :

9.4.1 Pressure of refrigerant vapour at evaporator outlet.

9.4.2 Temperature of refrigerant vapour at evaporator outlet.

9.4.3 Pressure of refrigerant liquid entering expansion valve.

9.4.4 Temperature of refrigerant liquid entering expansion valve.

9.4.5 Ambient temperature at calorimeter.

9.4.6 Temperature of heating liquid entering calorimeter.

9.4.7 Temperature of heating liquid leaving calorimeter.

9.4.8 Mass flow rate of heating liquid circulated.

9.4.9 Electrical input to calorimeter.

9.5 Determination of refrigerating capacity

9.5.1 The mass flow rate of the refrigerant, as determined by the test, is given by the formula

– *for liquid heating :*

$$m_f = \frac{c\,(t_1 - t_2)\,m_l + F_l\,(t_a - t_r)}{h_{g2} - h_{f2}}$$

– *for electric heating :*

$$m_f = \frac{\Phi_h + F_l\,(t_a - t_r)}{h_{g2} - h_{f2}}$$

9.5.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = m_f\,(h_{g1} - h_{f2})\frac{v_{ga}}{v_{g1}}$$

10 METHOD C : DRY SYSTEM REFRIGERANT CALORIMETER (see figure 3)

10.1 Description

The dry system refrigerant calorimeter consists of an arrangement of refrigerant tubes or tubular vessels of suitable length and diameter to accomplish evaporation of the refrigerant circulated by the compressor. The external surface of the evaporator may be heated, either by means of a liquid circulating in an outer jacket, which may be a concentric tube, or electrically. Alternatively, similar means of heating may be used within the evaporator.

The refrigerant flow is controlled by either a hand regulator or a constant pressure expansion valve, which shall be located close to the calorimeter. The expansion valve and the refrigerant pipeline connecting it to the calorimeter may be insulated in order to minimize the gain of heat.

The calorimeter shall be insulated in such a manner that the heat leakage does not exceed 5 % of the capacity of the compressor.

If the means of heating are external to the evaporator surface, a sufficient number (not less than ten) of suitably spaced temperature measuring devices shall be provided to determine the mean surface temperature for heat leakage calculations.

10.2 Calibration

The calorimeter shall be calibrated by one of the following methods :

10.2.1 *Heat loss method*

The heat loss method of calibration is carried out by means of the following procedure :

10.2.1.1 The ambient temperature is maintained constant to within ± 1 °C (± 2 °F) at any desired value not exceeding 43 °C (110 °F) and heat is supplied to maintain the mean surface temperature approximately 14 °C (25 °C) above the ambient temperature. Where liquid is used for heating, the inlet temperature is maintained constant to within ± 0,3 °C (± 0.5 °F) and the flow controlled so that the temperature drop is not less than 6 °C (10 °F). Where electric heating is used, the input is maintained constant to within ± 1 %.

10.2.1.2 After thermal equilibrium has been established, readings are taken for the following periods :

– *for liquid heating*, at hourly intervals until four successive readings of both inlet and outlet temperatures, with constant rate flow, do not vary by more than ± 0,3 °C (± 0.5 °F);

– *for electric heating*, at hourly intervals until four successive values of the temperature of saturation of the refrigerant do not vary by more than ± 0,6 °C (± 1 °F).

10.2.1.3 The heat input to the calorimeter is determined as follows :

– *for liquid heating :*

$$\Phi_i = c\,(t_1 - t_2)\,m_l$$

– *for electric heating :*

$$\Phi_i = PW = 0{,}86\,P\,\text{kcal/h} = 3.41\,P\,\text{Btu/h}$$

10.2.1.4 The heat leakage factor can then be calculated from the formula

$$F_l = \frac{\Phi_i}{t_c - t_a}$$

10.2.2 *Condensing unit method*

The condensing unit method of calibration is carried out by means of the following procedure :

The ambient temperature of the calorimeter is maintained constant to within ± 1 °C (± 2 °F) at any desired value not exceeding 43 °C (110 °F). A condensing unit of appropriate capacity is operated on the calorimeter until steady conditions are reached with a temperature difference between the ambient temperature and the temperature of saturation of the refrigerant of 22 ± 1 °C (40 ± 2 °F). The condensate is collected and measured in volume measuring vessels by the procedure described in Method E (see clause 12) over a period of time such as will ensure that the height of the liquid accumulated in the measuring vessel is at least 150 mm (6 in). The test is continued until four successive readings taken at hourly intervals do not vary by more than ± 5 %.

The heat leakage factor can then be calculated from the formula

$$F_l = \frac{(h_{g2} - h_{f2})\,m_f}{t_a - t_c}$$

10.3 Test procedure

The suction pressure at the compressor is adjusted by means of the refrigerant control and the inlet temperature to the compressor is adjusted by varying the heat input. The discharge pressure is controlled by varying the temperature and flow of the condensing medium, or by a pressure control device in the discharge line.

10.3.1 Where liquid is used for heating, the inlet temperature shall be maintained constant to within ± 0,3 °C (± 0,5 °F) and the flow controlled so that the temperature fall is not less than 6 °C (10 °F). The mass of liquid circulated shall be maintained constant to within ± 0,5 %. Where electric heating is used, the input shall be maintained constant to within ± 1 %.

10.3.2 The variation in heat input during the test shall not be sufficient to cause an error of more than 1 % in compressor capacity.

10.4 Additional information

The following information shall be recorded :

10.4.1 Pressure of refrigerant vapour at evaporator outlet.

10.4.2 Temperature of refrigerant vapour at evaporator outlet.

10.4.3 Pressure of refrigerant liquid entering expansion valve.

10.4.4 Temperature of refrigerant liquid entering expansion valve.

10.4.5 Ambient temperature at calorimeter.

10.4.6 Temperature of heating liquid entering calorimeter.

10.4.7 Temperature of heating liquid leaving calorimeter.

10.4.8 Mass flow rate of heating liquid circulated.

10.4.9 Electrical input to calorimeter.

10.4.10 Mean surface temperature of calorimeter.

10.5 Determination of refrigerating capacity

10.5.1 The mass flow rate of the refrigerant, as determined by the test, is given by the formula

– *for liquid heating :*

$$m_f = \frac{c\,(t_1 - t_2)\,m_l + F_l\,(t_a - t_c)}{h_{g2} - h_{f2}}$$

– *for electric heating :*

$$m_f = \frac{\Phi_h + F_l\,(t_a - t_c)}{h_{g2} - h_{f2}}$$

10.5.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = m_f\,(h_{g1} - h_{f1})\,\frac{v_{ga}}{v_{g1}}$$

11 METHOD D : REFRIGERANT VAPOUR FLOW-METER (see figure 4)

11.1 Description

The refrigerant vapour flow-meter consists of a nozzle or orifice plate for measuring the volume of refrigerant flowing through it, with an accuracy of ± 2 %. The flow-meter is installed in the suction or delivery pipeline of a closed circuit consisting of the refrigerant compressor, means for reducing the refrigerant pressure from the discharge to the suction level, means for reducing excessive vapour superheat, and means for returning the conditioned vapour to the suction of the compressor. The means for reducing pressure may be either manually operated or controlled by suction pressure. Means for removing the heat of compression may be provided by tapping sufficient refrigerant vapour from the high-pressure side of the circuit, liquefying it in a condenser and re-evaporating it in heat exchange with superheated refrigerant in the low-pressure side of the circuit, to ensure that the resulting superheated vapour is free from entrained droplets of liquid refrigerant.

11.1.1 Refrigerant mass flow rate m_v is measured with an orifice plate or nozzle constructed and installed in accordance with agreed procedures. The orifice is located at a point in the suction or delivery pipeline of the compressor where the full refrigerant flow takes place, and means shall be provided to ensure homogeneous superheated vapour at this point, completely free from entrained droplets of liquid refrigerant.

Where pulsating flow occurs in the pipeline, sufficient means of damping shall be provided to reduce or eliminate the flow wave to the nozzle or orifice, for example by the insertion of a surge vessel (see figure 4).

11.1.2 As the calculations for the determination of refrigerating capacity are based on the measurement of pure vapour, even a small quantity of oil present in the vapour would result in an inaccurate value for the gas flow through the orifice and, therefore, for the refrigerating capacity of the compressor. The use of the refrigerant vapour flow-meter is therefore limited to circuits where the gas flow being measured contains less than 1 % of oil. The oil content is the mass of oil per unit mass of liquid refrigerant/oil mixture (kilogram per kilogram or pound per pound).

11.2 Test procedure

The suction pressure at the compressor is adjusted by means of the refrigerant control and the inlet temperature is adjusted by varying the cooling effect. The discharge pressure is adjusted by varying the temperature and flow of the condensing medium, or by a pressure control device in the discharge line.

11.3 Additional information

The following information shall be recorded : :

11.3.1 Temperature of refrigerant vapour at upstream side of metering device.

11.3.2 Pressure of refrigerant vapour at upstream side of metering device.

11.3.3 Pressure drop between upstream and downstream side of metering device.

11.4 Determination of refrigerating capacity

The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = (h_{g1} - h_{f1})\, m_v \frac{v_{ga}}{v_{g1}}$$

12 METHOD E : REFRIGERANT LIQUID QUANTITY

(see figure 5)

12.1 Description

The apparatus for this method consists of two thermally insulated vertical pressure vessels about 1,25 m (4 ft) high whose diameter is such as to meet the requirements of 12.3. These vessels are connected in parallel by horizontal headers at the top and bottom, having shut-off valves between the headers and the vessels on the tubes entering and leaving each vessel. Pressure is equalized at all times by means of a small vapour pipe-line connecting the tops of the two vessels. Each vessel is fitted with a gauge glass approximately equal in length to the vessel and graduated throughout its entire length.

The upper header is connected to the condenser outlet, and the lower header to the liquid receiver, if one is used, or to the inlet of the refrigerant control. The liquid refrigerant pipeline leaving each vessel is equipped with a temperature measuring well. The vessels and their connections to the condenser and evaporator are thermally insulated.

12.2 Calibration

Each measuring vessel shall be calibrated with a liquid of known density and the gauge glass scales should be graduated in accordance with the calibration. Graduations recommended for various sizes of vessels are as follows :

12.2.1 *For metric sizes*

100 mm diameter in 0,2 l
200 mm diameter in 2,0 l
300 mm diameter in 10,0 l

12.2.2 *For the corresponding non-metric sizes*

4 in diameter in 0.01 ft^3
8 in diameter in 0.1 ft^3
12 in diameter in 0.25 ft^3

12.3 Test procedure

The measurement of flow of liquid refrigerant is made by timing the interval for the collection of a volume of liquid during a period of not less than 2 min. The diameter of the vessel used is such that the height of liquid refrigerant accumulated is not less than 150 mm (6 in).

12.3.1 The volume is collected from the condenser serving the compressor by closing the outlet valve on the collecting vessel and the inlet valve on the other vessel, which then continues the supply of refrigerant to the refrigerant control. Care shall be taken to start timing after a steady flow is established and to finish timing before the level in the vessel supplying the refrigerant control falls to a point which breaks the liquid seal at the outlet. Timing is recorded on the vessel in which the liquid level is rising. The total volume of liquid refrigerant in the two vessels shall be constant within ± 1 % at all times during the test. This total volume is determined by a simultaneous reading of the liquid levels in the vessels.

12.3.2 Readings are taken concurrently with and at the same time intervals as those specified for the PRINCIPAL test.

12.3.3 The proportion of oil present in the refrigerant liquid shall be determined when the operation of the system being tested has reached the conditions given in 12.3.1. A sample of liquid refrigerant is withdrawn into a carefully weighed and evacuated vessel and the vessel and sample are then weighed. The refrigerant is evaporated slowly and evaporation continued until three successive measurements of the mass of the vessel and the remaining oil are within ± 1 %. The exterior of the vessel should be dried before weighing to avoid the introduction of errors due to the condensation of moisture on its surface. The net masses of the mixture and the oils are then determined by deducting from the initial and final masses the mass of the empty vessel.

12.4 Additional information

The following information shall be recorded :

12.4.1 Time during which liquid is collected.

12.4.2 Temperature of liquid in collecting vessel.

12.4.3 Volume of liquid collected.

12.5 Determination of refrigerating capacity

The refrigerating capacity, corrected for oil content and adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = \frac{V\rho}{1 - \chi\,(1 - \mu\rho)}\,[(1 - \chi)\,(h_{g1} - h_{f1}) - c_o\chi\,(t_f - t_g)]\,\frac{v_{ga}}{v_{g1}}$$

NOTE — In this equation, μ is the specific volume of lubricating oil and c_o the specific heat of the oil.

13 METHOD F : REFRIGERANT LIQUID QUANTITY AND FLOW-METERS (see figure 6)

13.1 Description

The refrigerant liquid meter is either a quantity meter consisting of a metering mechanism, accurate to within 1 % for recording the flow of refrigerant on a suitable counting device in units of volume, or a flow-meter consisting of a mechanism, with suitable supplementary devices, for indicating the instantaneous flow rate of the refrigerant.

13.1.1 The refrigerant liquid quantity meter is connected to the liquid pipeline between the liquid receiver outlet and the expansion valve.

13.1.2 In order that the meter used may function properly under all conditions and that it may be protected from abuse and from the effects of an insufficient charge of refrigerant, additional apparatus is provided as follows :

13.1.2.1 A sub-cooler ahead of the meter to prevent vaporization of refrigerant in the meter.

The sub-cooler is provided with a supply of cold water, at constant temperature and pressure, controlled by a throttle valve.

13.1.2.2 Sight glasses located immediately before the sub-cooler and just after the meter to enable a check to be made that vapour bubbles are not mixed with the refrigerant liquid.

13.1.2.3 By-pass valve and tube for by-passing the meter. The valve may be open except when data are being recorded, provided the valve and by-pass circuit have a resistance identical with that of the meter.

13.1.2.4 Thermometers and wells, or alternatively thermocouples, for measuring the temperatures at which the refrigerant liquid enters the sub-cooler and the meter.

13.1.2.5 Pressure gauge connected to the outlet side of the meter.

13.2 Calibration

The meter shall be calibrated periodically at not less than three flow rates in the capacity range used.

The testing fluid used for calibration shall have an absolute viscosity between half and twice that of the refrigerant liquid normally used.

13.3 Procedure

The operation of the system is started with the meter by-pass valve open. After the specified conditions for the performance test have been established, the by-pass valve is closed and the refrigerant liquid entering the flow-meter sub-cooled at least 3 °C (5 °F) below the temperature of saturation corresponding to the pressure at the outlet from the flow-meter.

Readings are taken concurrently with and at the same time intervals as those specified for the PRINCIPAL test.

The proportion of oil present in the refrigerant shall be determined in the manner described in 12.3.3.

13.4 Additional readings

The following additional readings shall be recorded :

13.4.1 Reading of the meter.

13.4.2 Temperature of saturation corresponding to pressure at the outlet of the meter.

13.4.3 Temperature of the liquid at the inlet to the sub-cooler and to the meter.

13.5 Determination of refrigerating capacity

The refrigerating capacity, corrected for oil content and adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = \frac{V\rho}{1 - x\,(1 - \mu\rho)} \left[(1 - x)\,(h_{g1} - h_{f1}) - c_o x\,(t_f - t_g) \right] \frac{v_{ga}}{v_{g1}}$$

NOTE — In this equation, μ is the specific volume of lubricating oil, and c_o the specific heat of the oil.

14 METHOD G : WATER-COOLED CONDENSER METHOD (see figure 7)

14.1 Description

The water-cooled condenser which forms a part of the equipment used with the compressor being tested shall be equipped to act as a calorimeter by the provision of instruments for measuring temperatures, pressures and cooling water flow, within the limits of accuracy prescribed in annex A.

14.2 Test procedure

Adjustment of the condenser pressure is effected by varying the temperature and mass flow rate of the water supply to the condenser.

14.3 Additional information

The following information shall be recorded :

14.3.1 Pressure of refrigerant vapour entering condenser.

14.3.2 Temperature of refrigerant vapour entering condenser.

14.3.3 Pressure of refrigerant liquid leaving condenser.

14.3.4 Temperature of refrigerant liquid leaving condenser.

14.3.5 Temperature of cooling water entering condenser.

14.3.6 Temperature of cooling water leaving condenser.

14.3.7 Mass flow rate of cooling water.

14.3.8 Ambient temperature at condenser.

14.3.9 Mean temperature of external surface of condenser (or its insulation) exposed to the ambient air.

14.4 Determination of refrigerating capacity.

14.4.1 The mass flow rate of the refrigerant, as determined by the test, is given by the formula

$$m_f = \frac{c\,(t_2 - t_1)\,m_c + A\,(t_d - t_a)\,K}{h_{g3} - h_{f3}}$$

NOTE — A value for K of 7,0 (metric units) or 1.5 (non-metric units) shall be used, unless the actual value is determined experimentally.

14.4.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = m_f\,(h_{g1} - h_{f1})\,\frac{v_{ga}}{v_{g1}}$$

14.5 Method G as PRINCIPAL test (see figure 7)

Method G may also be used as a PRINCIPAL test provided the condenser has been calibrated for its heat leakage factor.

14.5.1 *Calibration*

The condenser shall be isolated from the refrigerant circuit, or a condenser of the same type and size shall be used.

14.5.1.1 The condenser is filled with refrigerant liquid to a suitable level and the inlet and outlet stop valves closed. The cooling water circuit is connected to a supply of heated water capable of maintaining a constant temperature of the refrigerant not less than 14 °C (25 °F) above the ambient temperature, but as near as possible to the expected saturation temperature.

Alternatively, the refrigerant may be heated electrically.

The ambient temperature is maintained constant to within ± 1 °C (± 2 °F) of any desired value not exceeding 43 °C (110 °F). After thermal equilibrium has been established, readings are taken at hourly intervals until four successive values of the temperature of the refrigerant do not vary by more than ± 1 °C (± 2 °C).

14.5.1.2 The heat leakage factor is calculated from the formula

$$F_t = \frac{\Phi_i}{t_r - t_a}$$

14.5.2 *Determination of refrigeration capacity.*

14.5.2.1 The mass flow rate of the refrigerant is given by the formula

$$m_f = \frac{c\,(t_2 - t_1)\,m_c + F_t\,(t_c - t_a)}{h_{g3} - h_{f3}}$$

14.5.2.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = m_f \, (h_{g1} - h_{f1}) \frac{v_{ga}}{v_{g1}}$$

15 METHOD H : REFRIGERANT VAPOUR COOLING METHOD (see figure 8)

15.1 Description

In the refrigerant vapour cooling Method H, the total refrigerant flow is determined by condensing, at high pressure, a portion of the vapour circulated, measuring its quantity, and then re-evaporating it in a gas cooler vessel where the remainder of the vapour circulated is cooled after passing through a control expansion valve.

After correction for losses, the ratio of the condensed refrigerant to the uncondensed refrigerant is inverse to the ratio of change in specific enthalpy of the two streams passing through the gas cooler.

15.1.1 The condenser is connected to the discharge pipeline of the compressor through a flow control valve which may be manually controlled or which may operate automatically in response to discharge pressure. The condenser is self-draining and discharges into a refrigerant liquid flow-measuring apparatus, as described in Methods E, F or G, the outlet of which is connected to the inlet of the gas cooler through a high-pressure float valve control. The pipeline from the control valve to the gas cooler is insulated to minimize gain of heat.

15.1.2 The gas cooler may comprise a shell and tube heat exchanger, into the shell of which all the condensed refrigerant is admitted by the high-pressure float valve; the remainder of the vapour discharged from the compressor passes through the tubes, being controlled by a valve at the inlet and/or outlet as may be necessary. The vapour from both the shell and the tubes enters the suction pipelines substantially at suction pressure.

The heat exchange surface shall be such that vapour leaving the evaporator portion of the gas cooler is superheated by at least 8 °C (15 °F) at all times, and the refrigerant charge shall be limited so that the level of evaporating liquid is such that no droplets are entrained in the outgoing vapour.

The gas cooler shall be insulated in such a manner that the leakage is not greater than 5 % of the heat exchanged therein.

15.2 Calibration

The gas cooler shall be calibrated according to the following procedure :

15.2.1 The gas cooler vessel is filled with refrigerant liquid to its normal operating level and the inlet and outlet stop valves closed. The ambient air temperature is maintained constant to within ± 1 °C (± 2 °F) of any desired value not exceeding 43 °C (110 °F) and heat is supplied so that the temperature of the refrigerant is maintained approximately 14 °C (25 °F) above the ambient temperature, but within a range of ± 0,6 °C (± 1 °F).

After thermal equilibrium has been established, readings are taken at hourly intervals until four successive values of the temperature of saturation of the refrigerant do not vary by more than ± 1 °C (± 2 °F).

15.2.2 The heat leakage factor is calculated from the formula

$$F_l = \frac{\Phi_i}{t_r - t_a}$$

15.2.3 Provision shall be made for ensuring that the refrigerant pressure does not exceed the safety limit for the apparatus.

15.3 Test procedure

The suction pressure at the compressor is adjusted by means of the control valve between the discharge pipeline and the vapour inlet to the gas cooler. The inlet temperature to the compressor is adjusted by means of the control valve at the evaporator outlet of the gas cooler. The discharge pressure is controlled by the valve between the discharge pipeline and the condenser and also by varying the temperature and flow rate of the condensing medium.

During the test period, the mass flow rate of condensed refrigerant from the measuring apparatus shall be kept constant. Any fluctuation in the mass flow rate shall not be such as to cause a variation of more than 1 % in the calculated compressor refrigerating capacity.

15.4 Additional information

The following information shall be recorded :

15.4.1 Pressure of refrigerant vapour at evaporator outlet.

15.4.2 Temperature of refrigerant vapour at evaporator outlet.

15.4.3 Pressure of refrigerant liquid in float valve.

15.4.4 Temperature of refrigerant liquid in float valve.

15.4.5 Pressure of refrigerant vapour entering gas cooler.

15.4.6 Temperature of refrigerant vapour entering gas cooler.

15.4.7 Pressure of refrigerant vapour leaving gas cooler.

15.4.8 Temperature of refrigerant vapour leaving gas cooler.

15.4.9 Ambient temperature near gas cooler.

15.4.10 Mass flow rate of refrigerant liquid condensed.

15.5 Determination of refrigerating capacity

15.5.1 The total mass flow rate of the refrigerant, as determined by the test, is given by the formula

$$m_t = m_l \left[1 + \frac{(h_{g2} - h_{f2}) - \frac{F_l}{m_l}(t_a - t_r)}{(h_{g4} - h_{g5})} \right]$$

15.5.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = m_t (h_{g1} - h_{f1}) \frac{v_{ga}}{v_{g1}}$$

16 METHOD J : REFRIGERANT VAPOUR COOLING METHOD (ALTERNATIVE TO METHOD H) (see figure 9)

16.1 Description

In Method J, a modification of the arrangement described for Method H in the first part of 15.1.1 consists of

a) introducing, on the discharge side of the measuring apparatus, a liquid receiver provided with a by-pass and stop valve so that it can be isolated from the liquid circuit and also receive liquid from or supply liquid to the circuit to adjust the mass flow rate;

b) using a gas cooler in which the liquid refrigerant is injected and re-evaporated by mixing intimately with the remainder of the uncondensed vapour from the compressor discharge.

16.1.1 After correction for losses, the ratio of the condensed refrigerant to the uncondensed refrigerant is inverse to the ratio of change in specific enthalpy of the two streams mixing in the gas cooler.

16.1.2 The gas cooler is fitted on the inlet side with a valve to reduce the pressure of the incoming gas; this valve may be operated either manually or automatically in response to the suction pressure. The design of the gas cooler shall be such that outgoing vapour will not entrain droplets of refrigerant and will be superheated by at least 8 °C (15 °F).

The gas cooler shall be insulated in such a manner that the heat leakage is not greater than 5 % of the heat exchanged therein.

16.2 Calibration

The gas cooler shall be calibrated according to the following procedure :

16.2.1 The gas cooler is filled with sufficient liquid refrigerant to ensure that, when both inlet and outlet stop valves are closed, it will not be wholly evaporated under the following conditions :

The ambient temperature is maintained constant to within ± 1 °C (± 2 °F) of any desired value not exceeding 43 °C (110 °F) and heat is supplied so that the temperature of the refrigerant is maintained approximately 14 °C (25 °F) above the ambient temperature but within a range of ± 6 °C (± 1 °F).

After thermal equilibrium has been established, readings are taken at hourly intervals until four successive values of the temperature of saturation of the refrigerant do not vary by more than ± 1 °C (± 2 °F).

16.2.2 The heat leakage factor is calculated from the formula

$$F_l = \frac{\Phi_i}{t_r - t_a}$$

16.3 Test procedure

The regulating valve controlling the flow of the condensed refrigerant liquid to the gas cooler is so adjusted that the liquid is evaporated at the same rate as that at which it is condensed.

The condensing pressure is controlled by the valve between the discharge pipeline and the condenser and also by varying the temperature and rate of flow of the condensing medium. The suction pressure at the compressor and its superheat temperature are adjusted by the valve at the inlet to the gas cooler, and by varying the mass flow rate of refrigerant by adding liquid to or withdrawing it from the liquid receiver.

The fluctuation in the flow of the condensing refrigerant liquid during the test shall not be such as to cause a variation of more than 1 % in the calculated compressor capacity.

In establishing the desired suction and discharge pressures and temperatures for a test, the liquid control valve is adjusted by maintaining a constant level of liquid refrigerant to one of the measuring cylinders.

16.4 Additional readings

The following additional readings shall be recorded :

16.4.1 Pressure of refrigerant vapour at gas cooler outlet.

16.4.2 Temperature of refrigerant vapour at gas cooler outlet.

16.4.3 Pressure of refrigerant liquid at expansion control valve.

16.4.4 Temperature of refrigerant liquid at expansion control valve.

16.4.5 Pressure of refrigerant vapour entering gas cooler.

16.4.6 Temperature of refrigerant vapour entering gas cooler.

16.4.7 Pressure of refrigerant vapour in gas cooler.

16.4.8 Ambient temperature at gas cooler.

16.4.9 Mass flow rate of refrigerant liquid condensed.

16.5 Determination of refrigerating capacity

16.5.1 The total mass flow rate of the refrigerant, as determined by the test, is given by the formula

$$m_t = m_l \left[1 + \frac{(h_{g5} - h_{f2}) - \frac{F_l}{m_l}(t_a - t_r)}{(h_{g4} - h_{g5})} \right]$$

16.5.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = m_t\,(h_{g1} - h_{f1}) \frac{v_{ga}}{v_{g1}}$$

17 METHOD K : CALORIMETER IN COMPRESSOR DISCHARGE LINE (see figure 10)

17.1 Description

The apparatus for this method comprises the following items :

a) A heater exchanger of the calorimetric type inserted in the discharge pipeline from the compressor to receive the total flow of refrigerant in the gaseous state.

The calorimeter vessel is supplied with a controlled circulation of a suitable liquid medium for the cooling (or heating) of the gaseous refrigerant. In order to eliminate the possibility of any condensation of the refrigerant in the calorimeter vessel, the lower temperature of the circulated cooling medium shall be kept well above the temperature of condensation of the refrigerant corresponding to the discharge pressure from the compressor.

Alternatively, the gaseous refrigerant may be heated electrically.

The calorimeter shall be insulated so as to reduce the thermal losses to a minimum.

a) Apparatus for reducing the gaseous refrigerant issuing from the calorimeter to as near as possible the specified basic test conditions at the compressor inlet.

Two suitable arrangements, X and Y, for this purpose are shown in figure 10. A description of the use of arrangement X is given in 17.5.

17.2 Calibration

The calorimeter is calibrated by the heat loss method according to the following procedure :

a) The ambient temperature is maintained constant to within ± 1 °C (± 2 °F) at any desired value not exceeding 43 °C (110 °F) and heat is supplied to maintain the mean surface temperature approximately 14 °C (25 °F) above the ambient temperature. Where liquid is used for heating, the inlet temperature is maintained constant within ± 0,3 °C (± 0,5 °F) and the flow controlled so that the temperature drop is not less than 6 °C (10 °F). Where electric heating is used, the input is maintained constant to within ± 1 %.

NOTE — The mean surface temperature shall be taken as the average of the readings of at least ten temperature-measuring devices suitably distributed on the external surface.

b) After thermal equilibrium has been established, readings are taken for the following periods :

– *for liquid heating*, at hourly intervals until four successive readings of both inlet and outlet temperatures, with constant rate flow, do not vary by more than ± 0,3 °C (± 0.5 °F).

– *for electric heating*, at hourly intervals until four successive values of the temperature of the calorimeter do not vary by more than ± 0,6 °C (± 1 °F).

c) The heat input to the calorimeter is determined as follows :

– *for liquid heating*

$$\Phi_i = c\,(t_1 - t_2)\,m_l$$

– *for electric heating*

$$\Phi_i = PW = 0{,}86\,P\ \text{kcal/h} = 3.41\ P\ \text{Btu/h}$$

d) The heat leakage factor can then be calculated from the formula

$$F_l = \frac{\Phi_i}{t_c - t_a}$$

17.3 Additional information

The following additional information shall be recorded :

17.3.1 Pressure of refrigerant vapour at calorimeter inlet.

17.3.2 Temperature of refrigerant vapour at calorimeter inlet.

17.3.3 Pressure of refrigerant vapour at calorimeter outlet.

17.3.4 Temperature of refrigerant vapour at calorimeter outlet.

17.3.5 Ambient temperature near calorimeter.

For liquid heating

17.3.6 Temperature of liquid entering calorimeter.

17.3.7 Temperature of liquid leaving calorimeter.

17.3.8 Mass flow rate of circulated liquid.

For electrical heating

17.3.9 Electrical power consumption at calorimeter.

17.3.10 Mean temperature of surface of calorimeter.

17.4 Determination of refrigerating capacity

17.4.1 The mass flow of the refrigerant, as determined by test, is given by the formula

$$m_f = \frac{m_l (t_2 - t_1) + F_l (t_c - t_a)}{(h_{g6} - h_{g7})}$$

17.4.2 The refrigerating capacity, adjusted to the specified basic test conditions, is given by the formula

$$\Phi_o = m_f (h_{g1} - h_{f1}) \frac{v_{ga}}{v_{g1}}$$

17.5 Example of reducing apparatus

17.5.1 *Description*

Apparatus X is illustrated in figure 10 and consists of

a) **a surface condenser,** into which a controlled amount of the gaseous refrigerant, after passing the calorimeter, is diverted and condensed;

b) **an expansion valve,** which may be of the constant pressure automatic type, to reduce the pressure of the remaining refrigerant to that required at the compressor suction;

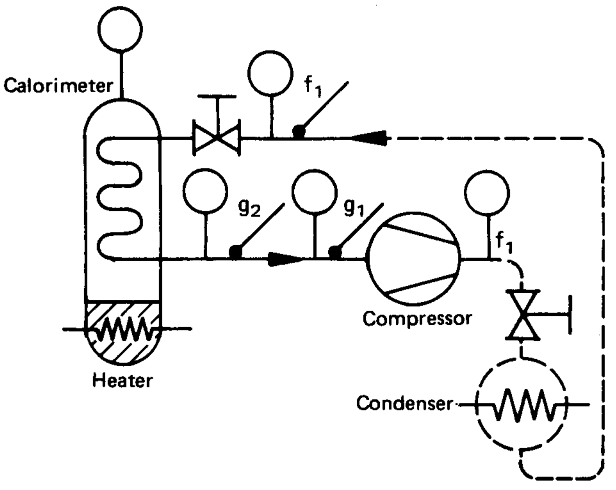
c) **a gas cooler** to reduce the superheat of the expanded refrigerant to that required at the compressor suction.

The reduction in superheat is carried out by the injection into the gas cooler of the amount condensed in the condenser and its evaporation, this amount being adjusted by a suitable liquid throttle valve in the condensate discharge line to the cooler.

17.5.2 *Test procedure*

Adjustment of the suction pressure at compressor inlet is effected by means of the expansion valve placed between the compressor discharge pipe and the vapour inlet to the gas cooler.

Adjustment of the condenser pressure is effected by means of the valve placed between the compressor discharge pipe and the condenser, and also by varying the temperature and mass flow rate of the water supply to the condenser.



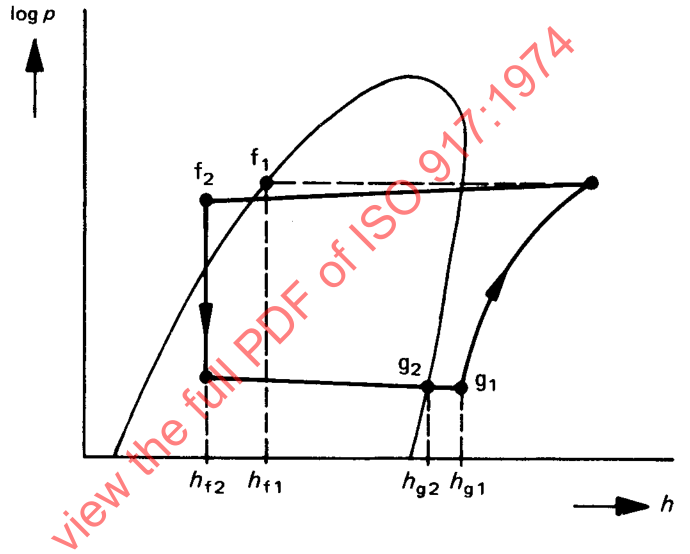


FIGURE 1 — **Method A**

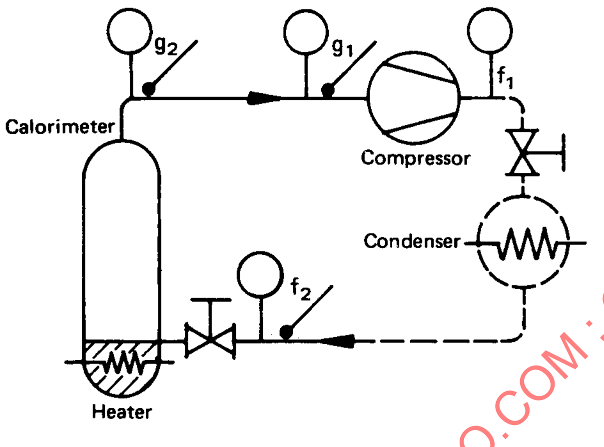
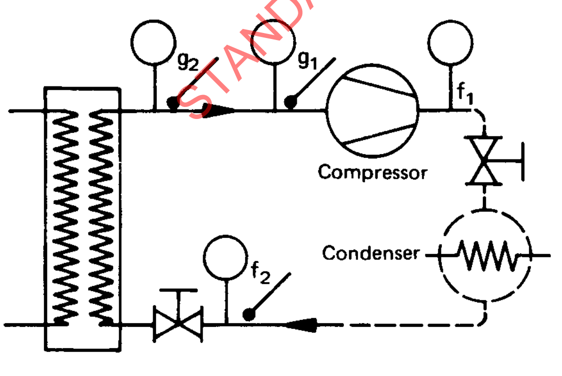


FIGURE 2 — **Method B**



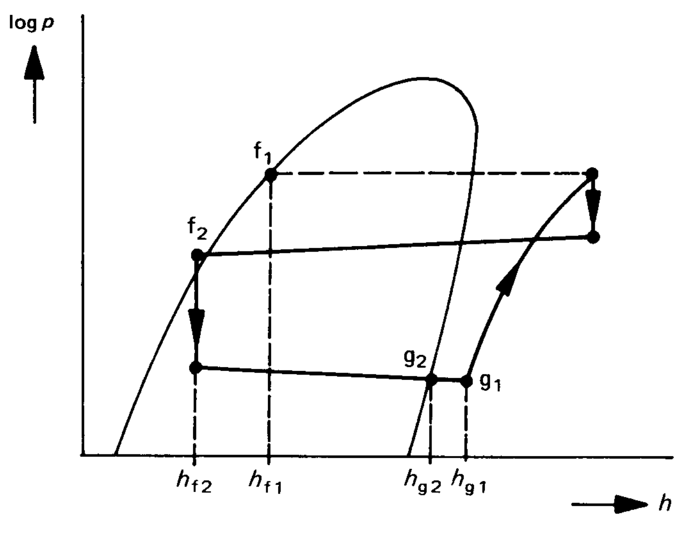


FIGURE 3 — **Method C**

Circuit diagrams for Methods A, B and C

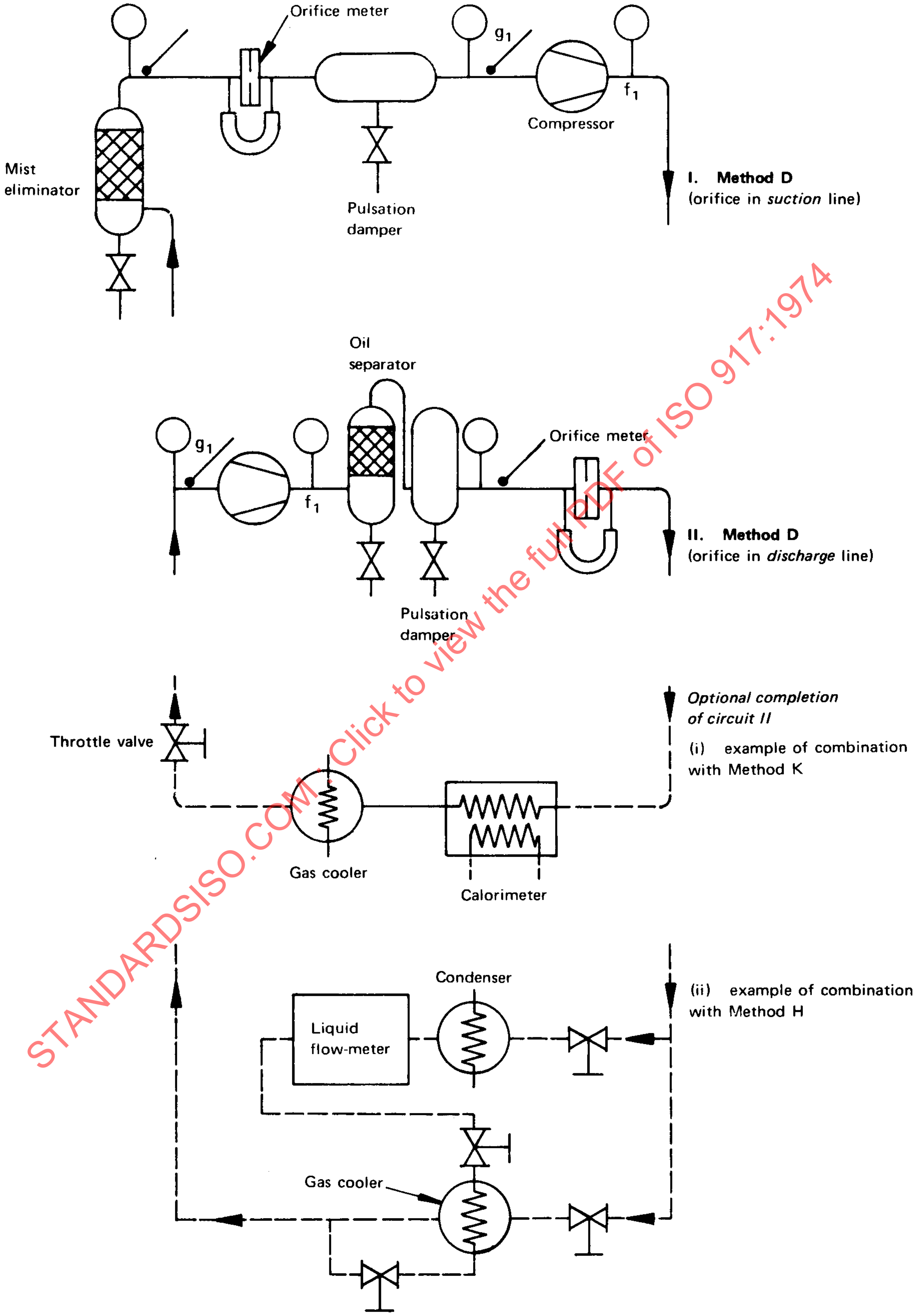


FIGURE 4 — **Circuit diagrams for Method D**

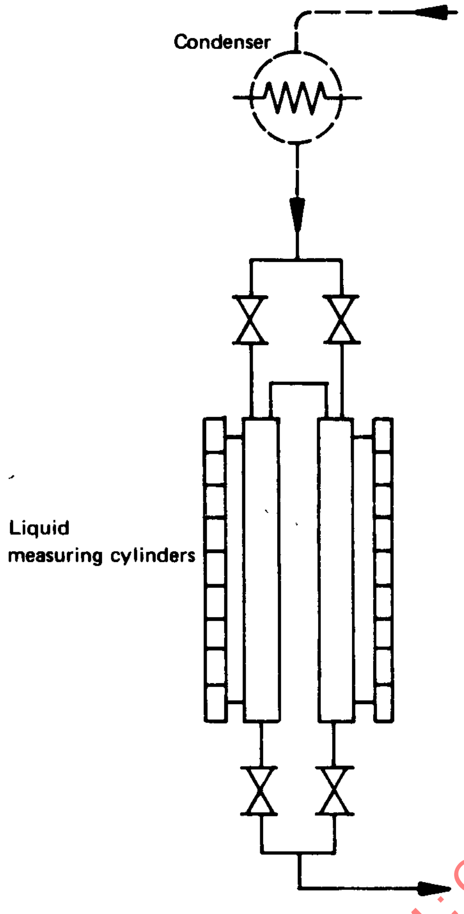


FIGURE 5 — **Method E**

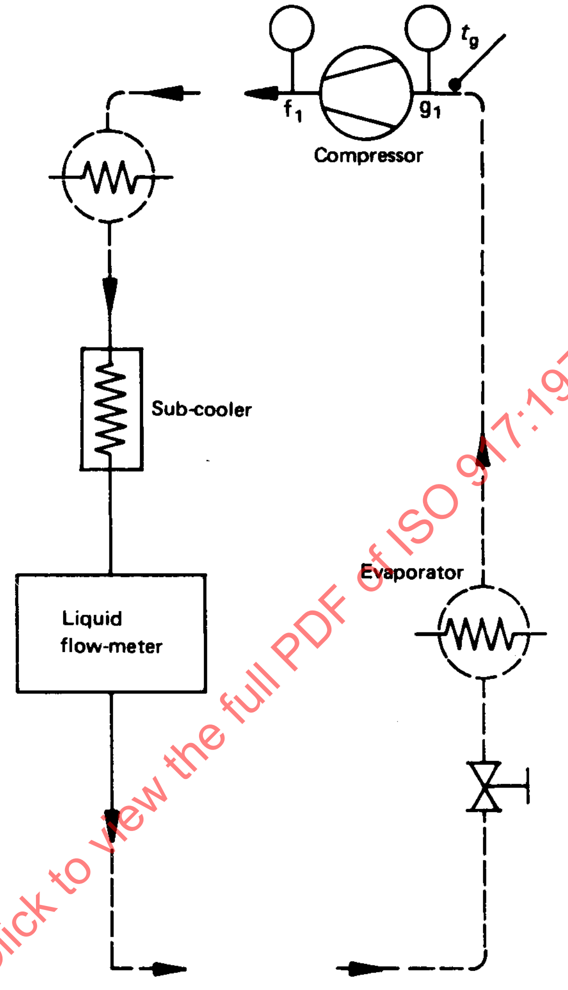
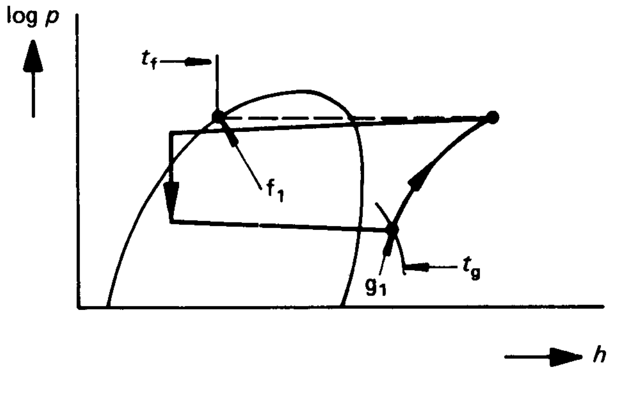
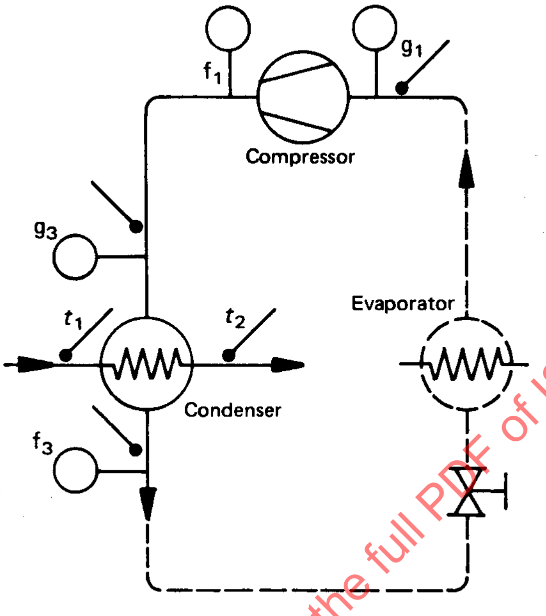


FIGURE 6 — **Method F**



Circuit diagrams for Methods E and F



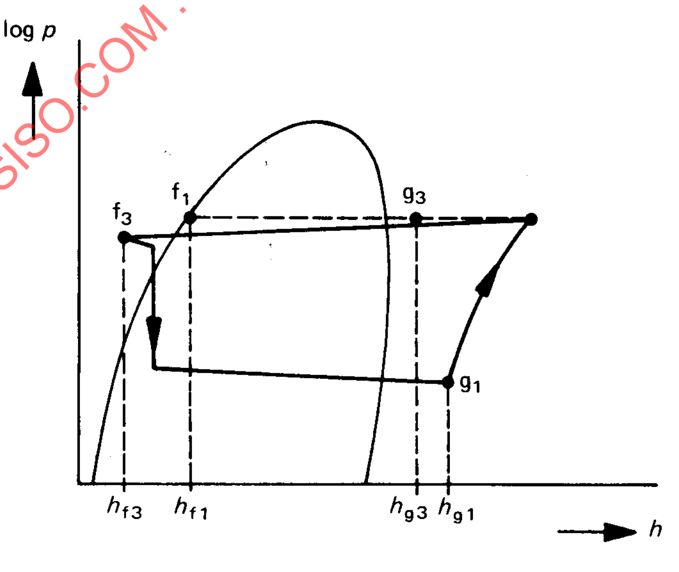
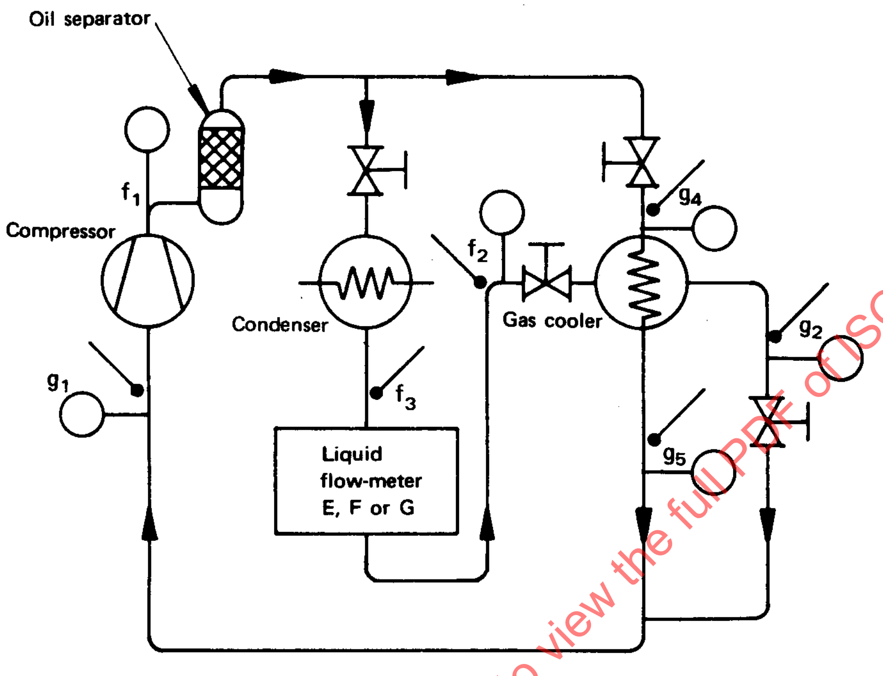


FIGURE 7 — **Circuit diagram for Method G**



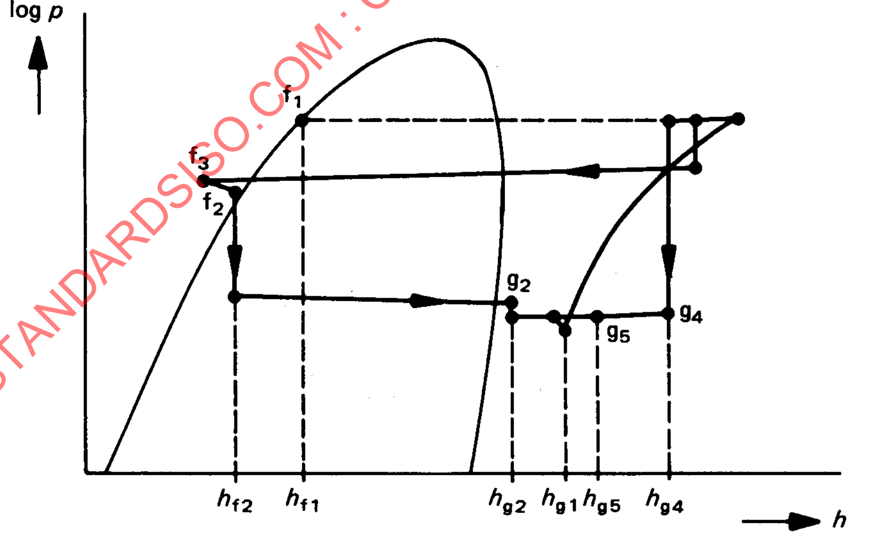


FIGURE 8 — **Circuit diagram for Method H**

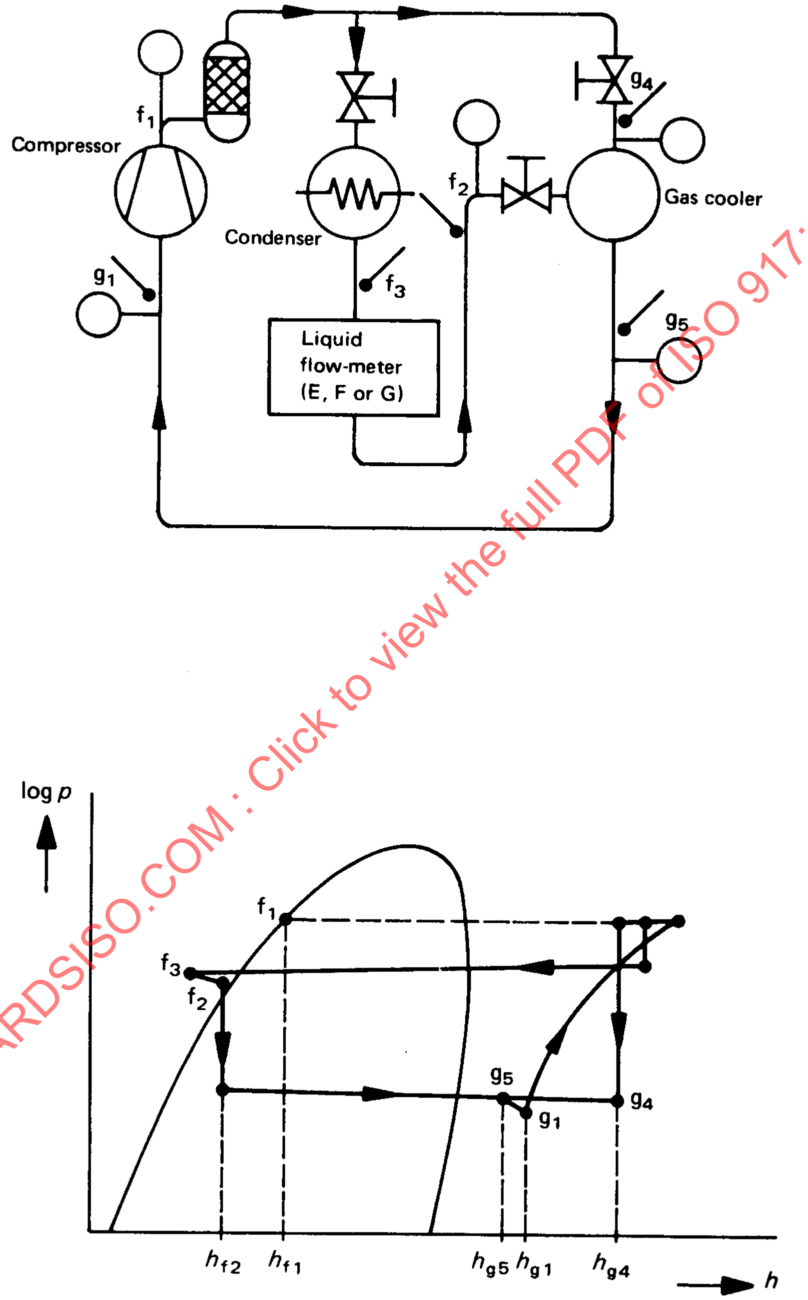


FIGURE 9 – **Circuit diagram for Method J**