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International Standard



4008/2

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**Road vehicles — Fuel injection pump testing —  
Part 2 : Static conditions**

*Véhicules routiers — Essai de pompe d'injection à gazole — Partie 2 : Conditions statiques*

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## Foreword

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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.

International Standard ISO 4008/2 was developed by Technical Committee ISO/TC 22, *Road vehicles*, and was circulated to the member bodies in October 1990.

It has been approved by the member bodies of the following countries :

Austria	Italy	Sweden
Belgium	Korea, Dem. P. Rep. of	Switzerland
Czechoslovakia	Korea, Rep. of	United Kingdom
Egypt, Arab Rep. of	Netherlands	USA
France	Romania	USSR
Germany, F.R.	South Africa, Rep. of	
Iran	Spain	

The member bodies of the following countries expressed disapproval of the document on technical grounds :

Brazil  
Japan

# Road vehicles — Fuel injection pump testing — Part 2 : Static conditions

## Preamble

International Standard ISO 4008 aims to achieve correct setting and adjustment of fuel injection pumps for compression ignition engines by providing standardized conditions for testing.

This part of ISO 4008 deals with the test bench static elements concerned with the supply and control of calibration fluid to the pump under test and with the measurement of its performance.

Adherence to the other parts of ISO 4008 and to certain other International Standards listed in clause 3 is essential to the total application of this part.

## 0 Introduction

Notwithstanding the demands a fuel injection pump makes of the test bench to fulfil its dynamic requirements as specified in ISO 4008/1, it is also incumbent upon the test bench to control and supply calibration fluid to the injection pump in a satisfactory manner, to establish appropriate conditions in the hydraulic delivery circuits and to make all the necessary measurements, within acceptable tolerances, in order to test and adjust pumps to manufacturer's test specifications.

## 1 Scope

**1.1** This part of ISO 4008 defines only the requirements and characteristics of test benches necessary to ensure consistent results when an injection pump is tested to its manufacturer's test specification regardless of the origin of the test bench.

**1.2** This part of ISO 4008 establishes requirements for control and supply of calibration fluid to the fuel injection pump, for receipt of the fluid from the fuel injection pump, as well as requirements for the accuracy of the measuring equipment of test benches.

## 2 Field of application

**2.1** This part of ISO 4008 is primarily applicable to test benches suitable for calibration of fuel injection pumps for compression ignition engines requiring fuel delivery up to 300 mm<sup>3</sup>/injection/cylinder at full load.

**2.2** No distinction is made between test benches used for different applications, for example, laboratories, manufacturers of fuel injection equipment or service stations.

## 3 References

The following International Standards are essential to the total application of this part of ISO 4008 :

ISO 4008/1, *Road vehicles — Fuel injection pump testing — Part 1 : Dynamic conditions.*

ISO 4008/3, *Road vehicles — Fuel injection pump testing — Part 3: Application and test procedures.*<sup>1)</sup>

ISO 4010, *Road vehicles — Calibrating nozzle, delay pintle type.*

ISO 4020/1, *Road vehicles — Fuel filters for automotive compression ignition engines — Part 1 : Test methods.*

ISO 4020/2, *Road vehicles — Fuel filters for automotive compression ignition engines — Part 2 : Test values and classification.*

ISO 4093, *Road vehicles — Fuel injection pumps — High pressure pipes for testing.*

ISO 4113, *Road vehicles — Calibration fluid for diesel injection equipment.*

## 4 Definitions

For the purpose of this part of ISO 4008, the following definitions apply :

**4.1 supply pipe :** Pipe connecting the calibration fluid pressure source to the injection pump inlet.

**4.2 settling time :** Specific time allowance to be made for fluid to drain down graduate walls between fluid being cut off and the operator reading the volume.

**4.3 drainage time :** Specific time over which graduates shall remain in the draining mode.

**4.4 stroke count; count :** Number of test bench driveshaft turns over which calibration fluid is delivered to the graduates or other form of measuring chamber.

1) At present at the stage of draft.

4.5 Pump delivery measuring system errors

4.5.1 overall error : Error of the indicated value relative to the true value under any one of the type test conditions.

4.5.2 zero error : Difference between the actual quantity of calibration fluid delivered to the test bench measuring system and the quantity indicated by that system.<sup>1)</sup> (See figure 1.)

4.5.3 count error : Difference between actual quantity of calibration fluid delivered to the test bench measuring system over the exact intended number of turns and the quantity, corrected for zero error, indicated by that system.<sup>2)</sup> (See figure 1.)

4.6 delivery value : Injection pump delivery at any specific test condition and expressed in quantity per stroke per cylinder.

4.7 test bench value : Delivery value computed from a test bench (for example, graduate) volume reading and corrected to 40 °C.

4.8 true value : Delivery value computed from a measurement of the total quantity delivered from at least three test injectors, collected concurrently over a number of driveshaft turns (not less than 2 000) sufficient to fill a measuring cylinder to at least 90 % capacity, corrected to 40 °C, and conducted in accordance with the procedure described in A.1.3.3.1.

5 Symbols and units

5.1 Coefficients of cubic expansion, in reciprocal degrees Celsius:

- a) of measuring cylinders (see A.1.2.1 and A.1.2.2) :  $\alpha$ ;
- b) of calibration fluid :  $\beta$ .

5.2 Delivery values of injectors, in cubic millimetres per stroke per cylinder:

5.2.1 Type test

- a) Test bench value of group "A" :  $G_A$
  - b) Test bench value of group "B" :  $G_B$
  - c) True value of group "A" :  $V_A$
  - d) True value of group "B" :  $V_B$
- } Corrected to 40 °C

5.2.2 Field test — Actual value :  $Q$ .

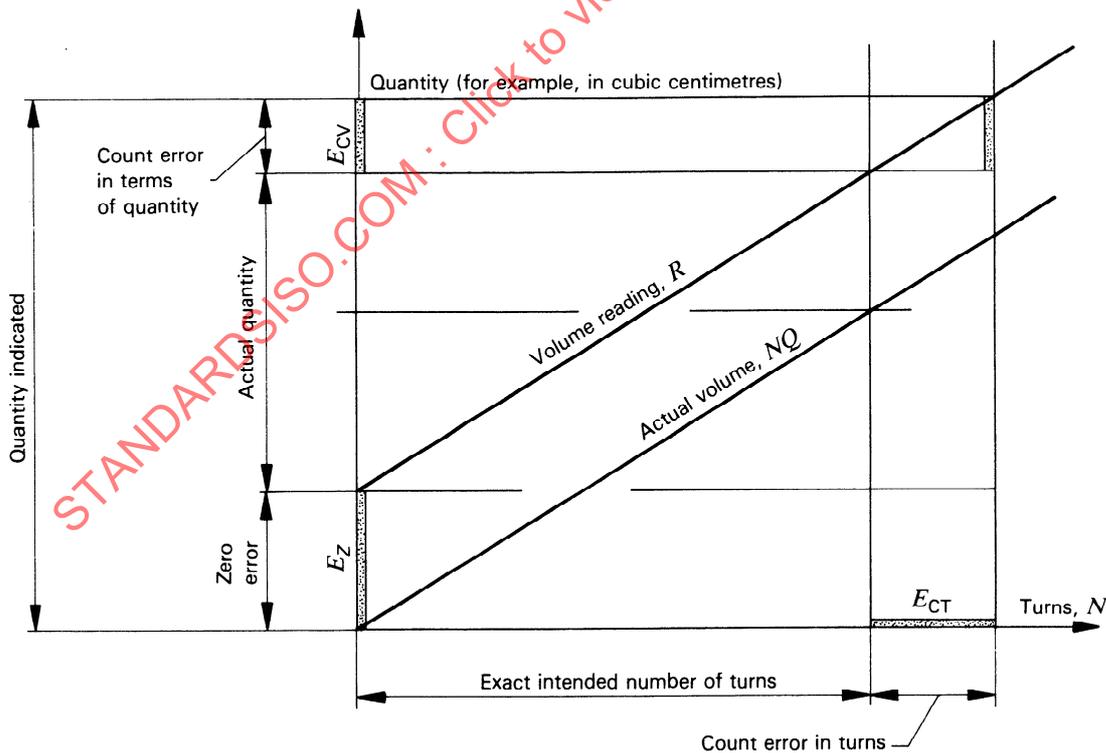


Figure 1 — Zero and count errors

1) A zero error may be caused, for example, by a residual quantity of calibration fluid adhering to the walls of a graduate.  
 2) A count error may be caused, for example, by errors in the counting mechanism itself, the fluid flow interruptor and its actuator.

**5.3 Volume readings of measuring chambers** in cubic centimetres:

- a) of the test bench (for example, graduate) :  $R$ ;
- b) of the external measuring cylinder (see A.1.2.1, A.1.2.2) :  $C$ .

**5.4 Temperature**, in degrees Celsius:

**5.4.1** of calibration fluid at the time of reading :

- a)  $R$  :  $t_R$ ;
- b)  $C$  :  $t_C$ .

**5.4.2** at which measuring cylinder (see A.1.2.1, A.1.2.2) is calibrated :  $t_0$ .

**5.5 Exact stroke count** (turns);  $N$  :

- a) basic stroke count :  $N_0$ ;
- b) for delivery of volume  $R$  :  $N_R$ ;
- c) for delivery of volume  $C$  :  $N_C$ .

**5.6 Errors:**

**5.6.1** Overall error as a percentage :  $e$ .

**5.6.2 a)** Zero error, in cubic centimetres :  $E_Z$ ;

b) Zero error, percentage of measuring chamber capacity,  $M$  :  $e_Z$ .

**5.6.3 a)** Count error, in cubic centimetres :  $E_{CV}$ ;

b) Count error (turns) :  $E_{CT}$ .

**5.7 Relative variation of delivery value readings of a single group of injectors as a percentage :**

- a) by the test bench measuring system :  $\delta_G$ ;
- b) by the external measuring cylinder (see A.1.2.1, A.1.2.2) :  $\delta_V$ .

**5.8 Pump delivery measuring system chamber capacity**, in cubic centimetres :  $M$ .

## 6 Static requirements

### 6.1 Low pressure calibration fluid system

#### 6.1.1 Calibration fluid container

Tanks for containing calibration fluid which passes through the injection equipment in the normal operation of the test bench shall have :

- a) an internal surface resistant to corrosion up to 100 % humidity;
- b) a close fitting lid with connection to atmosphere;
- c) convenient means for draining and cleaning internally.

#### 6.1.2 Calibration fluid supply

As necessitated by the type of injection pump to be tested equipment shall be supplied for :

a) transferring calibration fluid from the tank to a connection point (preferably a bulkhead connection) for connecting the supply pipe to the injection pump, at a flowrate equal to at least 2,5 times the delivery flowrate from the injection pump;

b) controlling the internal hydraulic pressure at the transverse exit plane of the connection for a supply pipe such that, having been set, it cannot, due to change in pump demand, reach a pressure high enough to damage the injection pump on test. In addition, with the injection pump supply pipe fitted to the bulkhead connection and with the remote end blanked off, at any feed pressure there shall be no cyclic fluctuation in excess of 5 % of the feed pressure from peak to peak measured at the bulkhead pressure point. This requirement does not apply when the mean feed pressure is  $\leq 0,3$  bar;

c) pressure measurement of the calibration fluid at the transverse exit plane of the bulkhead connection including a fluctuation damper;

d) temperature control, by heating or cooling, of calibration fluid to within tolerance (see clause 8) measured at the bulkhead connection irrespective of the fluid demand of any of the injection pumps within the range of the test bench and running at any condition specified in the test specification;

e) temperature measurement of calibration fluid, at a point immediately upstream of the transverse exit plane of the bulkhead connection.

### 6.2 High pressure injection pump delivery system

**6.2.1** There shall be suitable provision for holding the test injectors specified in the manufacturer's test specifications of those injection pumps falling within the capacity of the test bench.

**6.2.2** The test injector holder(s) shall be located (or capable of being located) sufficiently close to the injection pump to avoid smaller bend radii in the high pressure pipes than the minimum permitted in ISO 4093. The injector holders shall be sufficiently stable to facilitate tightening the pipe nuts without straining the pipes.

**6.2.3** Direct observation of any leaks from any part of the high pressure system shall be possible.

### 6.3 Injection pump delivery measurement system

**6.3.1** The calibration fluid delivered from each test injector shall be led to apparatus for measuring the delivery by a means displaying (directly or by simple calculation) the average specific delivery,  $Q$ , over not less than 25 strokes, expressed in cubic millimetres per stroke per cylinder.

**6.3.2** There shall be provision for observing visually, or by other suitable means, the moment when flow from any of the test injectors stops.

## 7 Information to be supplied by manufacturers

**7.1** The test bench manufacturer shall supply, with each individual test bench, documents stating :

**7.1.1** Advice, recommendations or mandatory instructions concerning the operation of the injection pump delivery measuring system regarding the stroke count and size of graduate to use (where applicable) in relationship with :

- a) the injection pump delivery,  $Q$  mm<sup>3</sup>/stroke/cylinder;
- b) the test speed,  $n$ , min<sup>-1</sup>;
- c) loss of achievable accuracy.

**7.1.2** Details of any special adjustments or settings which could affect fluid measurement accuracy.

**7.1.3** The servicing instructions necessary to ensure maintenance of performance to the requirements of this part of ISO 4008.

**7.1.4** The performance characteristics detailed in 6.2 of ISO 4008/1.

**7.2** The fuel injection equipment manufacturer shall state, in conjunction with its injection pump test specifications, complete details where appropriate, and the items essential to the proper conduct of the test in accordance with the International Standards listed in clause 3.

In addition :

- a) requirements, or details of any special apparatus or mechanism not covered by any International Standards referenced in this part of ISO 4008 but requiring special features or characteristics;

b) the full load power absorbed at rated pump speed and under test bench conditions;

c) those specific injection pump readings which, if they lie outside the permissible operating envelope (see figure 2 of ISO 4008/1) of any particular test bench, will not preclude the use of that bench;

d) injection pump deliveries in cubic millimetres per stroke per cylinder or cubic centimetres per thousand strokes per cylinder;

e) the numerical value of the stroke count to be used may, but need not, be stated.

## 8 Specifications and tolerances for test bench equipment

**8.1** Calibration fluid supply : pressure and vacuum gauge(s) :  $\pm 1$  % of reading or  $\pm 0,03$  bar<sup>1)</sup> whichever is the greater.

**8.2** Calibration fluid :

Temperature :  $40 \pm 2$  °C

Thermometer tolerance :  $\pm 0,5$  °C at 40 °C

**8.3** Ancillary pressure gauges for recording specified injection equipment pressures :  $\pm 1$  % of reading or  $\pm 0,03$  bar whichever is the greater.

**8.4** Driveshaft tachometer :  $\pm 0,5$  % of reading or  $\pm 5$  min<sup>-1</sup> whichever is the greater.

**8.5** Filtration : particle retention capability in accordance with ISO 4020/1, category 2. No filter by-pass shall be permitted. There shall be means to prevent rupture should blockage occur.

**8.6** Output shaft angular measuring arrangement : error between any two divisions shall not exceed 15'.

Datum mark shall be arranged to produce no parallax error.

**8.7** Calibration fluid heater : if this device is fitted, it shall be designed so as not to cause a breakdown of the fluid.

1) 1 bar =  $10^5$  N/m<sup>2</sup> = 10 kPa

**8.8** Graduates (or other form of measuring system) :  
minimum pitch of graduations : 1 mm.

1 graduation shall not be greater than 1 % of total volume. A certain number of adjacent graduations from zero upwards may be omitted.

**8.9** Supply pipe :

Internal volume elasticity : 500 mm<sup>3</sup>/bar at 40 °C

Length : 1 ± 0,1 m

Internal diameter : not less than 9,5 mm.

### **8.10 Pump delivery measuring system error allowances**

**8.10.1** In the type test [see 9.1.2a)] :

**8.10.1.1** Systems having a free choice of graduate size and/or stroke count without specific instructions given by the test bench manufacturer regarding their selection, and systems having no choice of graduate size and/or stroke count : overall error,  $e < 1$  %.

**8.10.1.2** Systems having a choice of graduate size and/or stroke count but with specific instructions given by the test bench manufacturer regarding their selection with respect to pump delivery and test speed : overall error,  $e < 2$  %.

**8.10.1.3** Either type of the above systems :  $\delta_G < 0,5$  %.

**8.10.2** In the field test [see 9.1.2 b)] :

**8.10.2.1** The zero error,  $E_z$ , shall not exceed 0,5 % of the maximum capacity of the graduate(s) or other measuring system.

**8.10.2.2** The count error,  $E_{CT}$ , shall not exceed 1 % of the basic count increment, or 0,5 turns, whichever is the smaller.

## **9 Method of testing the pump delivery measurement system**

### **9.1 Range of tests**

#### **9.1.1 Acceptance test**

Each type of test bench howsoever characterised by name, make or model and however modified from time to time shall have passed the acceptance test.

**9.1.2** The acceptance test shall comprise a combination of :

a) the type test : to be performed on at least one sample of the test bench and aimed at proving the capability of a design to achieve the desired fundamental accuracy; sophisticated apparatus is needed;

b) the field test : to be performed periodically in the field on all test benches to ensure continued satisfactory operation; this test requires no special apparatus.

### **9.2 Principles**

**9.2.1** Tests shall be made using specified injection pump(s) to feed calibration fluid through the measuring system.

**9.2.2** Test bench readings shall be verified at five nominal delivery levels and pump speeds.

**9.2.3** No reliance shall be placed on the injection pump to give a predetermined delivery when running at any specific test condition. Reliance shall only be placed on the injection pump to give deliveries in the same proportion from each of its delivery connections when running at stable test conditions on one particular test bench.

**9.2.4** The "absolute" delivery (true value) shall be established by collecting a large sample of the delivery to be verified and computing its measured volume against the counted number of turns over which it was collected.

### **9.3 Procedure**

The instructions for conducting all the tests are detailed in the annex, which is an integral part of this part of ISO 4008.

## Annex

## Test methods for type test and field test for pump delivery measuring systems of test benches

(See clause 9)

### A.1 Type test

#### A.1.1 Schedule

Type tests shall be performed on the pump delivery measuring system of the test bench, using a six cylinder fuel injection pump according to A.1.2.10 or A.1.2.11, running at the following conditions with respect to the permissible operating envelope (see figure 3) supplied by the test bench manufacturer. The test conditions shall conform to table 1.

Table 1

Test	1	2	3	4	5	Unit
Speed	500	3 000 <sup>1)</sup>	3 000 <sup>1)</sup>	500	1 200	min <sup>-1</sup>
Nominal delivery	20	20	150 <sup>1)</sup>	300 <sup>1)</sup>	300 <sup>1)</sup>	mm <sup>3</sup> /stroke/ cylinder

#### A.1.2 Apparatus (see figures 4 and 5)

**A.1.2.1 Glass measuring cylinder**, of known coefficient of cubic expansion<sup>2)</sup>; of not less than 2 litre capacity; with graduation accuracy of better than  $\pm 2 \text{ cm}^3$  (or with a check certificate of accuracy better than  $\pm 2 \text{ cm}^3$  in the range between 1 litre and 2 litres); minimum graduated length 400 mm; sub-divisions not more than 20 cm<sup>3</sup> apart.

**A.1.2.2 Glass measuring cylinder**, of known coefficient of cubic expansion<sup>2)</sup>; of not less than 500 cm<sup>3</sup> capacity; with graduation accuracy better than  $\pm 0,5 \text{ cm}^3$  (or with a check certificate of accuracy better than  $\pm 0,5 \text{ cm}^3$  in the range between 250 and 500 cm<sup>3</sup>); minimum graduated length 250 mm; sub-divisions not more than 5 cm<sup>3</sup> apart.

**A.1.2.3 Alternatively** to A.1.2.1 and A.1.2.2 (non-preferred) an **open container** for receiving a quantity of test fluid by gravity and adapted to measure the calibration fluid volume by weighing to an accuracy equatable with A.1.2.1 and A.1.2.2 above.

**A.1.2.4 Thermometer**, to read the temperature of calibration fluid to within  $\pm 1 \text{ }^\circ\text{C}$  between the limits of 15  $^\circ\text{C}$  and 85  $^\circ\text{C}$ .

**A.1.2.5 Manually-gated counter**, with a digital display of a minimum of 4,5 digits.

**A.1.2.6 Suitable contact breaker**, or other form of sensor connected to the test bench and capable of operating the above counter so as to display the number of injection pump turns occurring within the gated period.

**A.1.2.7 Closed spray chambers** (quantity : three), adapted to accept ISO standard test injectors appropriate to the pump in use and without any alteration or additional attachment(s), so as to collect the output and deliver it to a tube. Capacity of internal trapped volume with test injector fitted : 5 to 25 cm<sup>3</sup>. Outlet to be substantially at the highest point of the internal trapped space. Minimum internal diameter of outlet adaptor for the low pressure flexible tubing : 3,5 mm diameter.

**A.1.2.8 Low pressure flexible tubing**, impervious to calibration fluid and having an internal diameter of  $4 \pm 0,5 \text{ mm}$ , and a maximum hardness of 50 IRHD.

**A.1.2.9 Spouts** (quantity : three) for terminating each length of low pressure tubing (see A.1.2.8). Metal tubing : length : 50/60 mm; internal diameter : 4 mm; outside diameter : 6 mm max.

**A.1.2.10 Fuel injection pump No. 1**, for use on all test benches. (See table 2 for specification details.)

Type : six cylinder in-line camshaft injection pump having :

- stable characteristics;
- no governor;
- capability of locking the fuel control rod at any particular position;
- injection order, with 60° increments : 153624.

Table 2

Parameter	Pump No. 1	Pump No. 2
Max. permissible speed not less than	3 000 min <sup>-1</sup>	1 200 min <sup>-1</sup>
Delivery value at between 70 and 80 % control rod setting	150 mm <sup>3</sup> /stroke/ cylinder	300 mm <sup>3</sup> /stroke/ cylinder
Cam type	Eccentric	Tangent

1) If the measuring point is outside the permissible operating envelope of the test bench, the measurement shall be conducted within 95 and 100 % of the permissible operating envelope boundary value for pump delivery and test bench speed respectively.

2) For example, sodium-aluminium-silicate (Pyrex) :  $9,6 \times 10^{-6}/^\circ\text{C}$   
sodium-calcium-silicate :  $28 \times 10^{-6}/^\circ\text{C}$

**A.1.2.11 Fuel injection pump No. 2**, for use on test benches with maximum capacities in excess of 150 mm<sup>3</sup> stroke but not necessarily restricted to a maximum pump delivery of 300 mm<sup>3</sup>/stroke/cylinder. See table 2 for specification details.

**A.1.2.12 Receiver for surplus calibration fluid**, having a flat base for the measuring cylinders and having a means (not shown on figures 4 and 5) for returning the fluid to the test bench tank.

### A.1.3 Preparation

#### A.1.3.1 Preliminaries (see figures 4 and 5)

**A.1.3.1.1** Fit the appropriate injection pump, high pressure pipes and test injectors. Use calibration fluid according to ISO 4113.

**A.1.3.1.2** Fit the contact breaker (see A.1.2.6) so that it commences to operate the counter (A.1.2.5) at the rate of one count per injection pump turn when the "count" control is operated; and so that it stops counting when the "stop" control is operated.

**A.1.3.1.3** Disconnect and remove from the test injector holders of the test bench, injectors relating to pump outlets Nos. 1, 2 and 3. Mark each of these injectors with the letter "A"; mark the remainder with the letter "B". The individual injectors and high pressure pipes shall remain associated with the same pump outlets and the injectors shall bear the same identification letters throughout the test irrespective of which calibration fluid collection system is employed.

**A.1.3.1.4** Remove from test injectors "A" any dampers or spray deflectors necessitated by the measuring system of the test bench. Fit the injectors into the closed spray chambers (A.1.2.7) and reconnect them to their corresponding high pressure pipes.

**A.1.3.1.5** Fit a length of flexible tubing (A.1.2.8) to each of the closed spray chambers and cut the flexible tubing to convenient lengths so that they each fall continuously without sharp bends, inverted "U" bends or kinks; after terminating each tube with a spout (A.1.2.9) and locating them together, they shall swing clear of the rim of the measuring cylinder by approximately 10 mm. A mechanical mechanism controlling this function and interconnected with the counter start and stop controls is permissible.

#### A.1.3.2 Preconditioning

**A.1.3.2.1** Run the pump at conditions (except for delivery and speed) in accordance with the manufacturer's advice. Set the speed and delivery value according to the test sequence to be conducted (see A.1.1).

**A.1.3.2.2** Take delivery readings periodically on group B injectors during a run of 15 min minimum and for any additional period as may be necessary to ensure that successive delivery measurements do not show a discernible rising or falling trend.

#### A.1.3.3 Pump delivery measurement when conducting A.1.1 schedule tests

If a test bench has more than six measuring lines, it is only necessary to perform the type test on any selected six.

##### A.1.3.3.1 Using the external measuring cylinder

a) Follow the preconditioning procedure (see A.1.3.2) prior to taking readings following any change in test condition including interrupting a steady run.

b) Before commencing to deliver calibration fluid into the measuring cylinder, on each occasion, rinse the inside with spirit and dry it.

c) With a finger on the "start count" button on the counter (see figures 4 and 5), hold the flexible tube spouts just clear of the edge of the cylinder. With one action swing the spouts over the cylinder and press the button. Terminate the measurement in a similar manner but pressing the "stop count" button. Note the number of turns displayed.

d) Always fill the cylinder to at least 90 % of its maximum capacity.

e) Stand the cylinder on a level surface.

f) Read the volume of the contents of the cylinder indicated by the bottom of the meniscus. Use its surface to avoid parallax. Assess the last digit to the nearest whole number.

g) Immediately after reading the volume, use the thermometer to stir the contents of the cylinder thoroughly and, with the thermometer immersed to the correct depth, read the temperature.

h) Record volume, temperature and turns count ( $C$ ,  $t_C$ ,  $N_C$ ) on a test record sheet (see figure 7).

##### A.1.3.3.2 Using the test bench pump delivery measuring system

a) Follow the preconditioning procedure (see A.1.3.2) prior to taking readings following any change in test condition including interrupting a steady run.

Before taking the first of a series of readings, always take a preliminary reading to precondition the measuring system.

b) If the test bench manufacturer's instructions for the test bench recommend a particular procedure for taking measurements based on, for example :

- 1) the fuel injection pump delivery to be measured,
- 2) the graduate capacity to use,
- 3) the number of strokes over which to take the measurement,

- 4) the settling time to wait before reading the graduate,
- 5) the drainage time to wait before taking another reading,

then these and/or any other instructions or recommendations made by the test bench manufacturer shall be followed for the purpose of these tests in preference to any instruction given on the pump test schedule or elsewhere.

c) In cases where test bench instructions do not make any recommendations as in b) 1) to 3), then two measurements shall be made over numbers of strokes which will fill the graduates or other form of volume measures, for 1) to approximately 30 % and for 2) to approximately 90 % capacity of all practicable sizes of graduate provided.

d) If graduate capacity requires, in some of the tests, a stroke count in excess of 1 000 in order to fill it to 90 % then 1 000 strokes shall be used.

e) If a count of 100 strokes exceeds 30 % of the graduate capacity in some tests then 100 strokes shall be used.

f) If provision is made for only one value of stroke count, then this count shall be used in all tests.

g) In cases where no recommendation is made for settling and drainage times then 15 and 30 s respectively shall be used.

h) Measure the temperature of the fluid in the graduates during the preconditioning run when accurate volume readings in all graduates are not necessary. Remove the thermometer for subsequent readings relating to the same test number.

j) Enter the readings onto a test record sheet (see figure 7).

**A.1.3.4** Establishing the calibration fluid expansion coefficient  $\beta$  (see figure 6)

**A.1.3.4.1** Nearly fill the 2 l measuring cylinder (A.1.2.1) with calibration fluid at a temperature in excess of 60 °C. Measure the volume and temperature according to A.1.3.3.1 e), f) and g). Do not remove the thermometer.

**A.1.3.4.2** After allowing the temperature to fall approximately 5 °C hold the thermometer against the side wall of the cylinder above the surface. Take a further reading of volume, then immediately stir with the thermometer and read the temperature. At no time remove the thermometer from, or place any other article in the cylinder. Continue this process until the temperature falls to approximately 20 °C.

**A.1.3.4.3** Plot the volume readings against the temperature readings. Draw the "best fit" straight line through the points and calculate the coefficient  $\beta - \alpha$  which yields  $\beta$ , the coefficient of cubic expansion of the calibration fluid.

**A.1.3.5** Formulae

**A.1.3.5.1** The true value expressed in cubic millimetres per stroke per cylinder :

$$V = 10^3 C [1 + \alpha(t_C - t_0) + \beta(40\text{ °C} - t_C)]/3 N_C$$

**A.1.3.5.2** The indicated value expressed in cubic millimetres per stroke per cylinder :

$$G = 10^3 \Sigma R [1 + \beta(40\text{ °C} - t_R)]/3 N_R$$

**A.1.3.5.3** The overall error expressed as a percentage :

$$e = 100 [\sqrt{G_A G_B / V_A V_B} - 1]$$

**A.1.3.5.4** The relative variation expressed as a percentage :

$$\delta_V = 100 (V_{\max} - V_{\min}) / V_{\max}$$

$$\delta_G = 100 (G_{\max} - G_{\min}) / G_{\max}$$

**A.1.4** Procedure

**A.1.4.1** Select injection pump No. 1 (A.1.2.10).

**A.1.4.2** Using the other appropriate apparatus specified in A.1.2 set up the preliminary arrangements specified in A.1.3.1.

**A.1.4.3** Start the test bench, set the supply pressure according to the pump manufacturer's advice and set the temperature to  $40 \pm 2$  °C.

**A.1.4.4** According to the test sequence to be undertaken (see A.1.1) set the pump speed and delivery to the values required. Ensure that the pump control rod is properly secured. Select the graduate size and number of strokes over which to measure [see A.1.3.3.2 a) to g)].

**A.1.4.5** Perform the preconditioning procedure described in A.1.3.2.

**A.1.4.6** Stage 1 (see figure 4)

Take an aggregate reading of delivery  $C$ , of group A injectors into the external measuring cylinder (see A.1.3.3.1).

Use the 500 cm<sup>3</sup> cylinder (A.1.2.2) for deliveries up to 75 mm<sup>3</sup>/stroke/cylinder; use the 2 l cylinder (A.1.2.1) for higher deliveries; the number of pump turns,  $N_C$ , shall not be less than 2 000. Whilst the cylinder is filling, take three readings of the delivery,  $R$ , of each of group B injectors into the selected graduates (or other fluid measures) of the test bench (see A.1.3.3.2). If three consecutive readings cannot be taken during this period, then make the number up to three after the external cylinder is full. Record the readings on a test record sheet (see figure 7).

**A.1.4.7** Repeat A.1.4.6 twice more. Calculate  $\delta_G$  and if it exceeds 0,5 % then calculate  $\delta_V$  and if this exceeds 0,2 % then it may indicate an instability in an area not related to the pump delivery measuring system of the test bench.

**A.1.4.8 Reversal of measuring systems for stage 2**  
(see figure 5)

Remove group "A" injectors from the closed spray chambers; refit to the injector any dampers or other spray deflectors necessitated by the measuring system of the test bench and replace the injectors into their test bench holders. Remove group "B" injectors from their test bench holders, remove any dampers or spray deflectors necessitated by the measuring system of the test bench, and fit the injectors into the closed spray chambers. Make certain that the injectors and their pipes are still fed from the same individual pump outlets and that the other requirements of A.1.3.1.3 are adhered to.

**A.1.4.9 Stage 2**

Interchanging the words "group A" for "group B", but without changing any of the test conditions in any manner whatsoever, repeat A.1.3.2.2, A.1.4.6 and A.1.4.7. Record the results on the test record sheet (see figure 7).

**A.1.4.10 Stage 3 – Analysis of results**

Complete the required calculations on the test record sheets (see figure 7) according to the relevant formulae in A.1.3.5. Enter the results,  $\bar{V}$  and  $\bar{G}$ , and the relative variation  $\delta$  onto the analysis sheet (see figure 8).

**A.1.4.11** The type test shall comprise, in respect of at least one capacity of injection pump delivery measuring system, all the tests herein described in addition to those further tests which may result from the requirements of A.1.3.3.2 b) and c).

**A.2 Field test**

**A.2.1 Application**

Test benches must pass this test as an integral part of the type test (see A.1). It shall also be used as the service field test to ensure continued satisfactory operation of equipment the basic dimensions and design of which have previously been proved by the type test.

**A.2.2 Preparation**

**A.2.2.1** Attach a clearly visible marker, such as a piece of white adhesive tape, to the driveshaft of the test bench and run the bench at a speed just sufficiently low to permit revolutions to be counted reliably visually.

**A.2.2.2** Set the stroke counter to its basic count increment or 50 strokes, whichever is the higher. Operate the count control, listen for, or feel, the operation of the calibration fluid deflecting mechanism and verify that the number of turns between operations is correct.

**A.2.2.3** Set the counter to double the count and repeat A.2.2.2.

**A.2.2.4** Select a stable and reliable type of multicylinder injection pump having a 50 % of maximum possible delivery such that it would nearly fill the graduate size to be tested in either ten times the basic count or 500 strokes whichever is convenient.

Fit the pump to the bench and run at approximately 500 min<sup>-1</sup> and with a calibration fluid temperature of 40 ± 2 °C until ten successive readings of 500 strokes show no discernible difference.

**A.2.2.5** As appropriate, during this stabilizing period, inspect for leaks in pipework, injector chambers or graduate drain valves; also check the operation of the deflector mechanism.

**A.2.3 Procedure**

**A.2.3.1** Let the basic count be  $N_0$  (not less than 50). Fill the graduates to 90 % over 10  $N_0$  strokes at 500 min<sup>-1</sup> and allow the graduates to drain for the specified time (or 30 s if unspecified). Take a reading of each line over 10  $N_0$  strokes allowing 15 s settling time if not specified otherwise. Call these readings  $R_1$  (see field test sheet, figure 9).

**A.2.3.2** Deliver to the graduates for three successive and separate counts of  $N_0$  strokes without draining or reading between counts. After the appropriate settling time, take the readings and call them  $R_2$ . Do not drain.

**A.2.3.3** Deliver to the graduates for seven further successive and separate counts of  $N_0$  strokes without draining or reading between counts. After the appropriate settling time, take the readings and call them  $R_3$ .

**A.2.3.4** Calculate the zero error in terms of volume as follows :

$$E_Z = (10 R_2 - 3 R_3) / 7$$

Examples	a)	b)
Let	$R_1 = 132,2$	$280,8 \text{ cm}^3$
	$R_2 = 41,1$	$81,36 \text{ cm}^3$
	$R_3 = 136,3$	$272,6 \text{ cm}^3$
then	$E_Z = 0,3$	$-0,6 \text{ cm}^3$

**A.2.3.5** Calculate the zero error as a percentage of graduate capacity,  $M$ , as follows :

$$e_Z = 100 E_Z / M$$

Let	$M = 150$	$300 \text{ cm}^3$
then	$e_Z = 0,2$	$-0,2 \%$

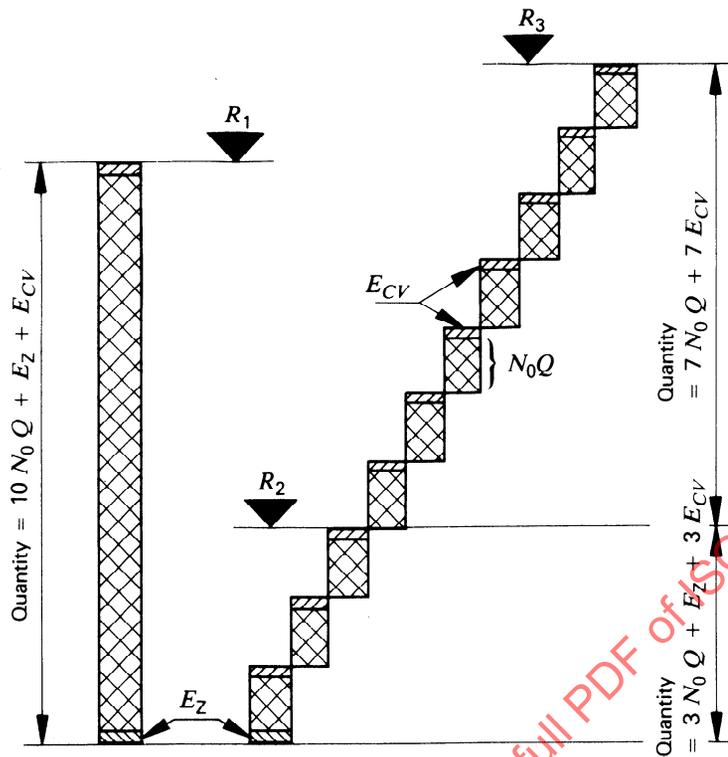


Figure 2 – Diagram showing the principle of the field test

**A.2.3.6** Calculate the count error in terms of volume as follows :

$$E_{CV} = (R_3 - R_1)/9$$

For this particular delivery value :

$$E_{CV} = + 0,46 \quad -0,91 \text{ cm}^3$$

**A.2.3.7** Calculate the count error in terms of driveshaft turns as follows :

$$E_{CT} = 10 N_0 E_{CV} / (R_1 - E_Z - E_{CV})$$

Let the basic count,  $N_0 = 50 \quad 100$  turns

then the count error,  $E_{CT}$  in terms of turns at the particular speed of the test (for example,  $500 \text{ min}^{-1}$ ) =

$$1,75 \quad -3,23 \text{ turns}$$

**A.2.3.8** Calculate, if desired, the delivery value at the temperature of the test as follows :

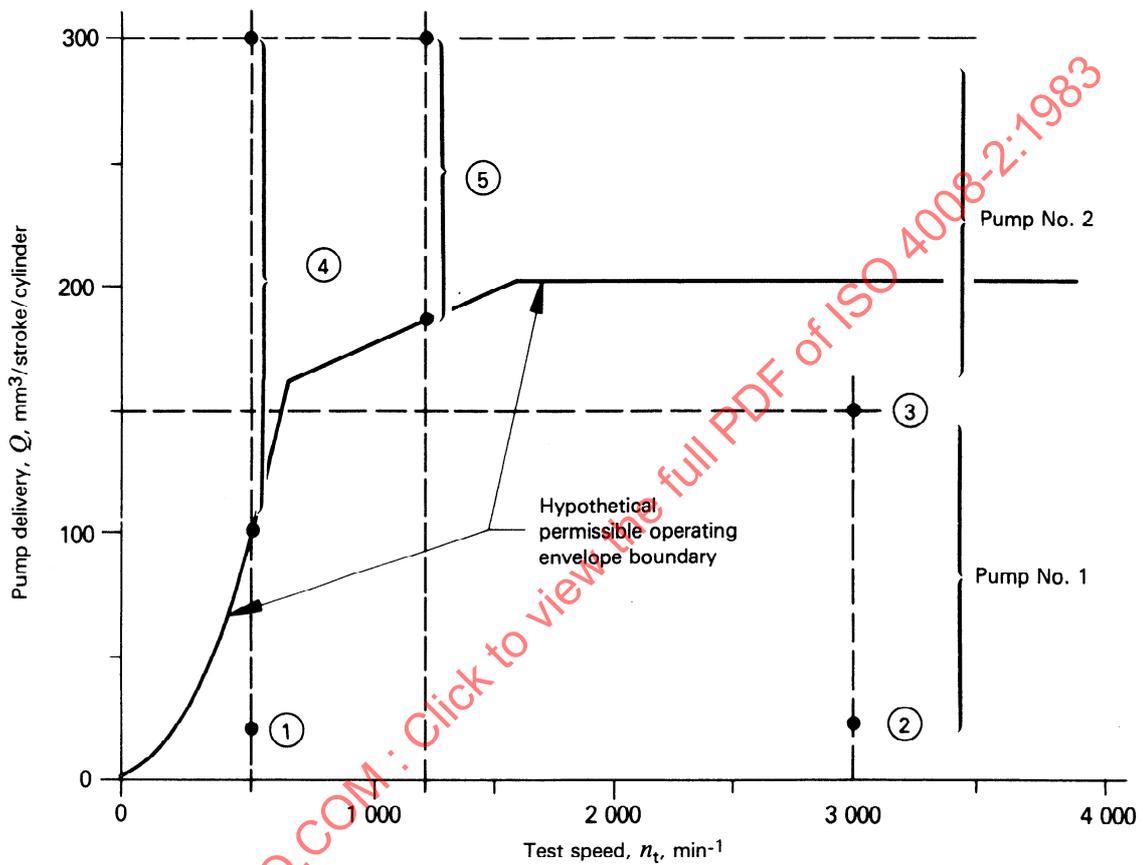
$$Q = (7 R_1 - 9 R_2 + 2 R_3) / 63 N_0$$

For these examples,  $Q = 262,9 \quad 282,3 \text{ mm}^3/\text{stroke}/\text{cylinder}$ .

**A.2.3.9** Complete these calculations for the remaining measuring chambers.

**A.2.4** Repeat A.2.3 at  $1\,000 \text{ min}^{-1}$ .

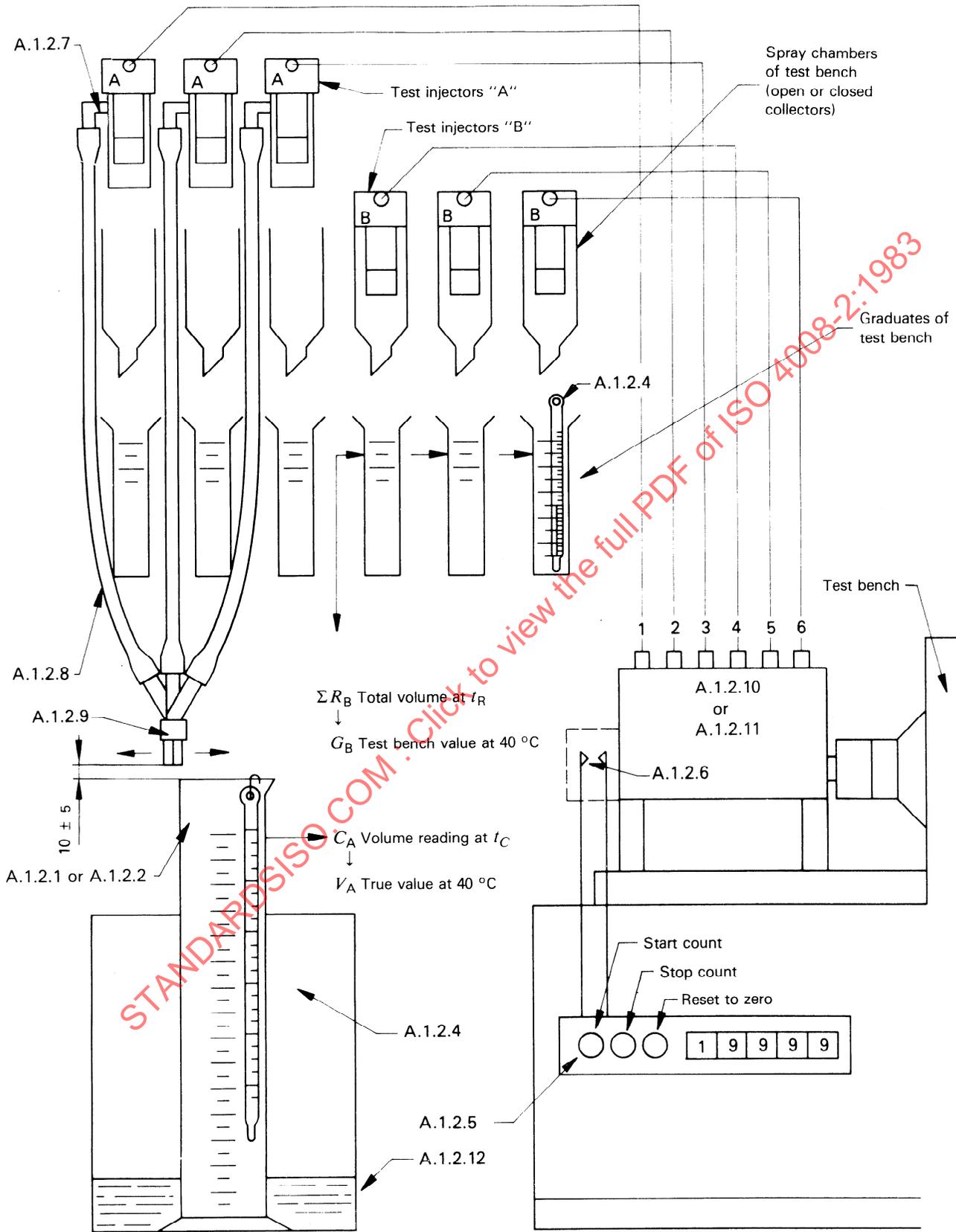
**A.2.5** Repeat A.2.3 for all other sizes of graduate and at both speeds,  $500$  and  $1\,000 \text{ min}^{-1}$ .



NOTES

- 1 Test numbers are shown thus (1). See 1.2 for schedule of values.
- 2 See A.1.2.10 and A.1.2.11 for description of injection pumps 1 and 2 to be used within the ranges indicated above.
- 3 See A.1.4 for description of test procedure.

Figure 3 — Example of the application of the schedule of test conditions based on figure 2 of ISO 4008/1



NOTE — Numbers prefixed "A" refer to sub-clauses of this annex.

Figure 4 — Arrangement of the test apparatus prepared for stage 1

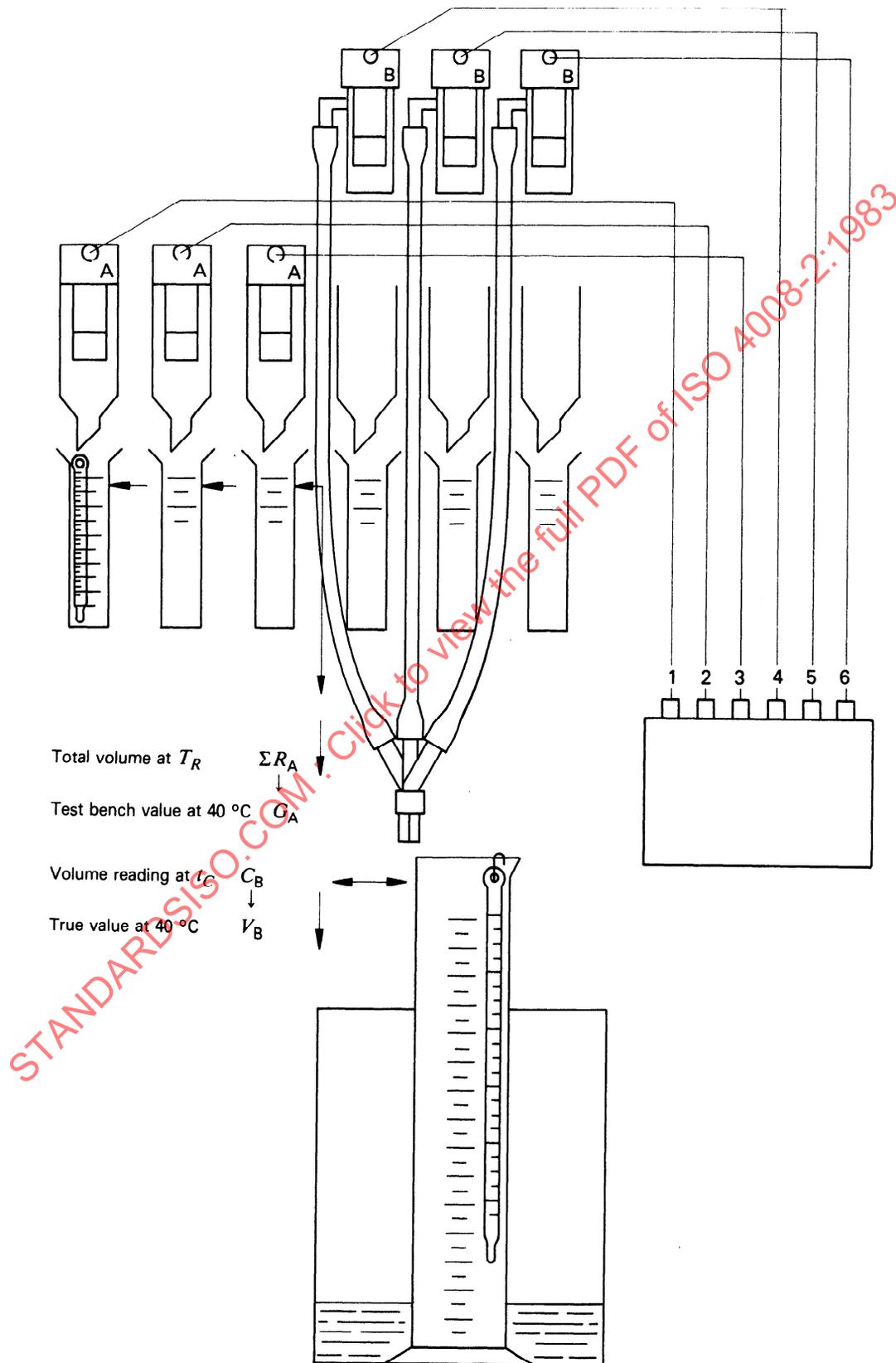
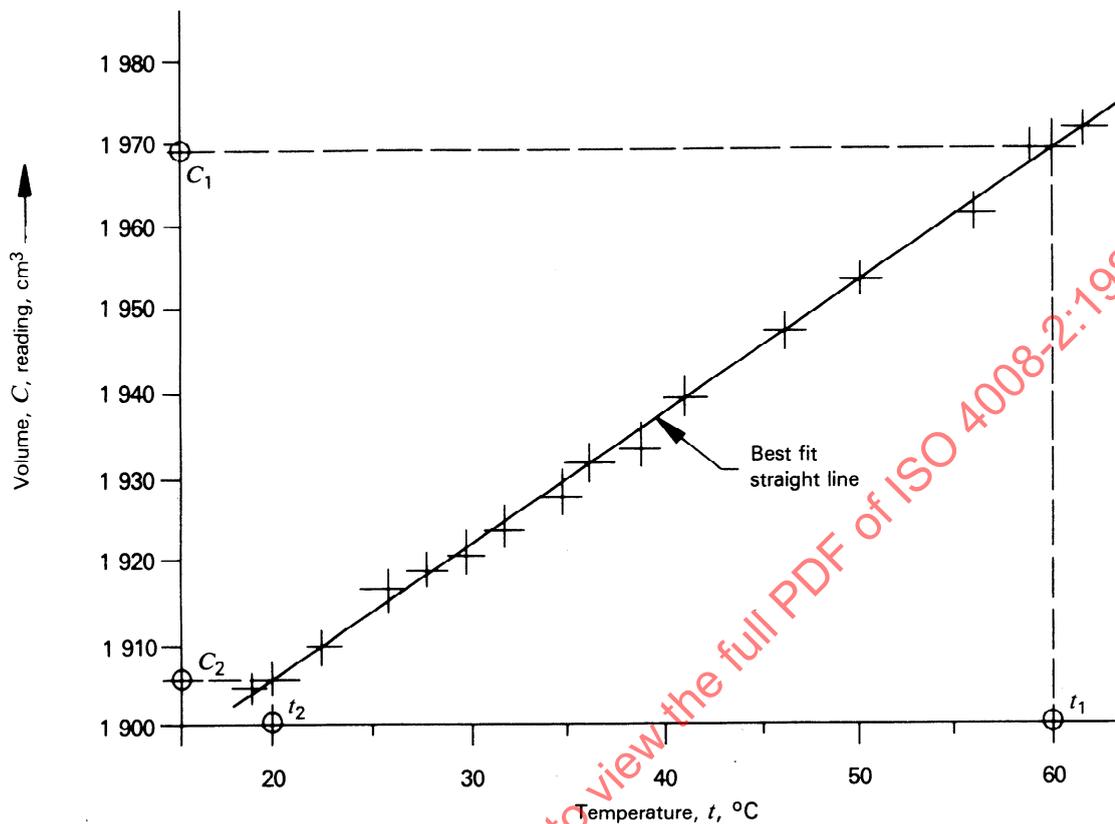


Figure 5 – Reversal of the measuring systems for stage 2



$$\beta - \alpha = \frac{2 (C_1 - C_2)}{(t_1 - t_2) (C_1 + C_2)}$$

In the example above :

$$C_1 = 1\,969 \text{ cm}^3 \text{ at } t_1 = 60 \text{ }^\circ\text{C}$$

$$C_2 = 1\,906 \text{ cm}^3 \text{ at } t_2 = 20 \text{ }^\circ\text{C}$$

$$\beta - \alpha = \frac{2 (1\,969 - 1\,906)}{(60 - 20) (1\,969 + 1\,906)} = 8,129 \times 10^{-4}/^\circ\text{C}$$

If  $\alpha = 9,6 \times 10^{-6}/^\circ\text{C}$ , for example, then :

$$\beta = 8,225 \times 10^{-4}/^\circ\text{C}$$

Figure 6 — Establishing the coefficient  $\beta$