

# JIS

**JAPANESE INDUSTRIAL STANDARD**

**Testing Methods for Kinematic  
Viscosity and Calculating Method  
for Viscosity Index of Crude Oil  
and Petroleum Products**

**JIS K 2283—1983**

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## JAPANESE INDUSTRIAL STANDARD

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Testing Methods for Kinematic Viscosity and Calculating K 2283-1983  
Method for Viscosity Index of Crude Oil and  
Petroleum Products

1. Scope

This Japanese Industrial Standard specifies the testing methods for kinematic viscosity of Newtonian fluid crude oil and petroleum products at testing temperature by means of a glass capillary viscometer and the calculating method for viscosity index of petroleum products from the kinematic viscosity at 40°C and 100°C.

Remarks 1. The testing methods for kinematic viscosity of petroleum asphalt shall be in accordance with JIS K 2207.

2. The estimating method for mixing ratio in mixing two kinds of sample so as to obtain the change of kinematic viscosity due to temperature and envisaged kinematic viscosity is given in Appendix 1.

Furthermore, the estimating method for kinematic viscosity of mixed oil of known mixing ratio is shown as informative reference in Appendix 1.

3. The unit and numerical values given in { } in this standard are in accordance with the International System of Units (SI), and are appended for reference.

2. Definitions

For the purpose of this standard, the following definitions apply:

(1) Newtonian liquid The liquid which flows according to the Newtonian viscosity law, that is the liquid in which the shear rate is proportional to shear stress.

Remark: The sample which indicates the same kinematic viscosity independent of size of diameter when remeasured by means of glass capillary viscometer having different diameter of capillary is Newtonian fluid. In the case where the sample is not Newtonian fluid, different kinematic viscosity is shown dependently of the size of diameter.

(2) kinematic viscosity The viscosity divided by the density of the liquid in the same conditions (temperature, pressure). It express the resistance when the fluid flows by action of gravity. The centistokes (cSt) is customarily used as the unit of kinematic viscosity.

In the SI unit the unit of kinematic viscosity is the square meter per second ( $\text{m}^2/\text{s}$ ), and there exists the following relation between them:

$$1 \text{ cSt} = 10^{-6} \text{ m}^2/\text{s} = 1 \text{ mm}^2/\text{s}$$

Applicable Standards, Corresponding International Standards and Reference  
Standard: See page 70.

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Remarks 1. The ratio between the shear stress applied to the liquid and the shear rate is called viscosity (or coefficient of viscosity). As the unit of viscosity, centipoise (cP) is customarily used.

Further, in the SI unit, the unit is the pascal second (Pa·s) and there exists the following relation between them:

$$1 \text{ cP} = 10^{-3} \text{ Pa} \cdot \text{s} = 1 \text{ mPa} \cdot \text{s}$$

2. There exists the following relation between the viscosity, kinematic viscosity and the density:

$$\eta = \nu \rho \dots\dots\dots (1)$$

where  $\eta$  : viscosity at the same temperature and the same pressure (cP) { mPa·s }  
 $\nu$  : kinematic viscosity at the same temperature and the same pressure (cSt) { mm<sup>2</sup>/s }  
 $\rho$  : density at the same temperature and the same pressure (g/cm<sup>3</sup>)

(3) average significant liquid column height The liquid column height of the sample when the flow rate of sample flowing through the capillary of glass capillary viscometer has become equal to the average flow rate. In this standard the average value  $\left(\frac{h_1 + h_2}{2}\right)$  of the liquid column height ( $h_1$ ) of sample at the commencement of measuring the flow time and the liquid column height ( $h_2$ ) of the sample at the completion of measuring the flow time, that is the approximate value of the average significant liquid column height is used.

Remark: The liquid column height of the sample means the vertical distance between the both liquid surfaces of the sample in the viscometer.

(4) coefficient of viscosity The numerical value indicating the degree of change of kinematic viscosity of petroleum products due to temperature. It indicate that as the coefficient of viscosity is higher, the change of kinematic viscosity is smaller.

### 3. Testing Methods for Kinematic Viscosity

3.1 Summary of Testing Methods The sample is taken into a glass capillary type viscometer, stood still in a constant temperature bath to make at the testing temperature, then the time for the definite amount of sample to flow through the capillary is measured, and the flow time is multiplied by the viscosimeter constant obtained preliminarily to obtain the kinematic viscosity.

3.2 Principle of Measuring The measuring method for kinematic viscosity by means of a glass capillary viscometer is a method applied with Hagen-Poiseuille's law, and when the fluid of volume  $V$  has flown down naturally with requiring the time  $t$  in the capillary, the kinematic viscosity  $\nu$  of the liquid is given according to the following formula:

$$\nu = \frac{100\pi g D^4 h t}{128 V l} - \frac{E}{t^2} \dots\dots\dots (2)$$

where

$v$  : kinematic viscosity (cSt) {mm<sup>2</sup>/s}

$g$  : acceleration due to gravity (cm/s<sup>2</sup>)

$D$  : diameter of capillary (cm)

$h$  : average significant liquid column height (cm)

$t$  : time required for the liquid of  $V$  in volume to flow (flow time) (s)

$V$  : volume of the liquid flown in time of  $t$  (approximately equal to the volume of timing bulb (cm<sup>3</sup>))

$l$  : length of capillary (cm)

$E$  : correction coefficient for kinematic energy (cSt.s<sup>2</sup>) {mm<sup>2</sup>.s}

The item  $\frac{E}{t^2}$  in the formula (2) is a correction term for kinematic energy, and if the flow time is made not less than the minimum flow time specified on respective viscometers, it becomes such a small value as to be negligible in measuring accuracy. Further, because the item of  $\frac{100\pi g D^4 h}{128 V l}$  becomes a definite value<sup>(1)</sup> for each viscometer, when it is taken as the viscometer constant, the formula (2) becomes formula (11) of 3.9.

Note <sup>(1)</sup> Concerning the viscometers of three types of Cannon-Fenske, Cannon-Manning semi-micro and Cannon-Fenske opaque,  $h$  (average significant liquid column height) changes due to the difference of temperatures at the time of test and at sampling, therefore, the correction of flow time is necessary for these viscometers.

3.3 Testing Apparatus for Kinematic Viscosity The apparatus consist of following (1) to (6).

Remark: An automatic testing apparatus in accordance with this standard, as appropriate, may be used.

- (1) Glass Capillary Viscometers (hereinafter referred to as the "viscometers") These are the viscometers given in Figs. 190 to 201 specified in JIS K 2839, and their type and characteristics are given in Table 1 (refer to 3.8 concerning the sketch of viscometer and the measuring range of kinematic viscosity, etc.).

Table 1. Types of Viscometers

| Type                         | Name                                                                                                                                                                                    | Characteristics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Suspend-<br>ed-level<br>type | 1. Ubbelohde viscometers<br>2. Cannon-Ubbelohde viscometers<br>3. Cannon-Ubbelohde semi-micro viscometers<br>4. BS/IP small type suspended-level viscometers<br>5. Atlantic viscometers | (1) These are suitable for measurement of transparent sample.<br>(2) The viscometers of 5. require the constant temperature bath for exclusive use, and are not suitable for measurements at testing temperature not higher than the dew point.                                                                                                                                                                                                                                                                       |
| Modified<br>Ostwald<br>type  | 1. Cannon-Fenske viscometers<br>2. Cannon-Manning semi-micro viscometers<br>3. Zeitfuchs viscometers                                                                                    | (1) These are suitable for measurement of transparent sample.<br>(2) The viscometers of 1. and 2. are simple in construction and the measurement and cleaning operation are easy, but correction of flow time is required [refer to Note (1) of 3.2].                                                                                                                                                                                                                                                                 |
| Reverse<br>flow<br>type      | 1. Cannon-Fenske Opaque viscometers<br>2. Zeitfuchs cross-arm viscometers<br>3. Lantz-Zeitfuchs viscometers<br>4. BS/IP U-tube reverse-flow-viscometers                                 | (1) These are suitable for measurement of opaque sample.<br>(2) The viscometers of 1. are simple in construction, the measurement and cleaning operation are easy, and two measured values can be obtained by sampling of once. However, the correction of flow time is necessary [refer to Note (1) of 3.2].<br>(3) The viscometers of 2., 3. and 4. can obtain only one measured value by sampling of once. Further, these are not suitable for measurement at a testing temperature not higher than the dew point. |

Remarks 1. The viscometers used generally in the country are Ubbelohde viscometers, Cannon-Fenske viscometers and Cannon-Fenske opaque viscometers.

2. The following viscometers of 7 types specified in ISO 3105 other than those specified in Table 1 may be used:

Suspended-level viscometers:

BS/IP/SL viscometers

BS/IP/SL (S) viscometers

Fitz Simmons viscometers

## Modified Ostwald viscometers:

BS/U-tube viscometers

BS/U/M small type viscometers

SIL viscometers

Pinkevitch viscometers

- (2) Thermometers The thermometers shall be those specified in JIS B 7410, and the number and the scale range of each thermometer shall be as given in Table 2.

Table 2. Thermometers for Kinematic Viscosity

| Number of thermometer | Scale range °C | Scale interval °C | Immersion       |
|-----------------------|----------------|-------------------|-----------------|
| 14                    | -51.5 to -33.5 | 0.1               | Whole immersion |
| 15                    | -19.2 to -16.4 | 0.05              | Whole immersion |
| 16                    | 18.5 to 21.5   | 0.05              | Whole immersion |
| 17                    | 23.5 to 27.5   | 0.05              | Whole immersion |
| 18                    | 28.5 to 31.5   | 0.05              | Whole immersion |
| 19                    | 36.5 to 39.5   | 0.05              | Whole immersion |
| 20                    | 48.5 to 51.5   | 0.05              | Whole immersion |
| 21                    | 53.5 to 55.5   | 0.05              | Whole immersion |
| 22                    | 73.5 to 76.5   | 0.05              | Whole immersion |
| 23                    | 78.5 to 81.5   | 0.05              | Whole immersion |
| 24                    | 97.5 to 101.5  | 0.05              | Whole immersion |
| 88                    | 38.5 to 41.5   | 0.05              | Whole immersion |
| 98                    | -21.4 to -18.6 | 0.05              | Whole immersion |

- (3) Constant Temperature Bath The construction, performances, etc. shall be as follows:

- (a) The bath shall be of such size that the viscometer can be immersed sufficiently and all portions of sample can be apart by not less than 20 mm from the inner wall of the bath and the liquid surface, and be of such construction that the viscometer and thermometer can be viewed from outside. An example is shown in Fig. 1.
- (b) For the constant temperature performance, in the case of testing temperature at 15 to 100°C, the temperature difference in the range of immersion length of viscometer, between respective viscometers, and between respective places of insertion of thermometers can be kept at not more than 0.01 °C and the temperature variation during measuring the flow time can be kept at not more than 0.01 °C.

At other testing temperature, the temperature difference between respective places and the temperature variation during measuring the flow time can be kept at not more than 0.03 °C.

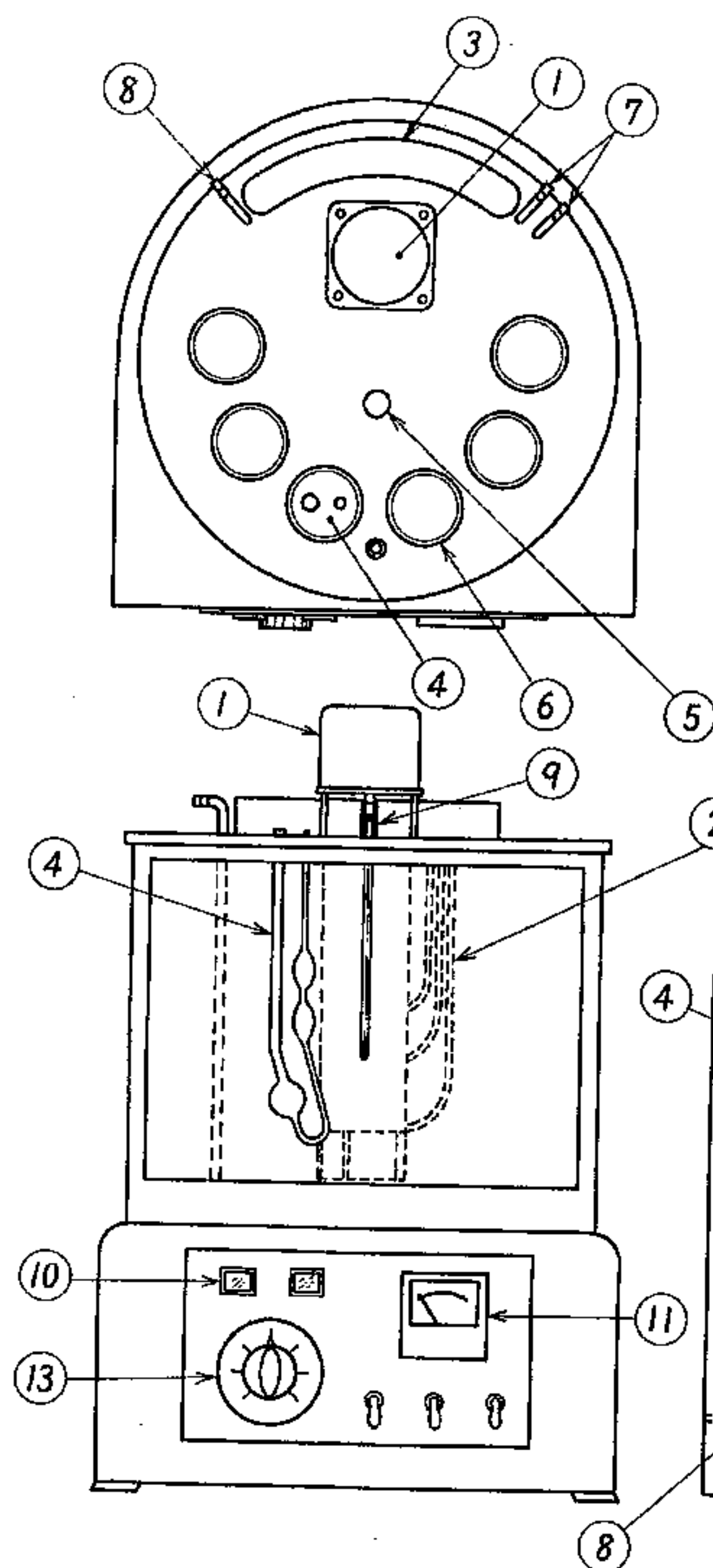
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- (c) For the electrical insulation performance, the insulation resistance between the power-source terminal and the case under the condition of closed electric circuit shall be not less than 5 M $\Omega$  when measured by means of a 500 V insulation resistance tester specified in JIS C 1301 or in JIS C 1302.

Fig. 1. Constant Temperature Bath

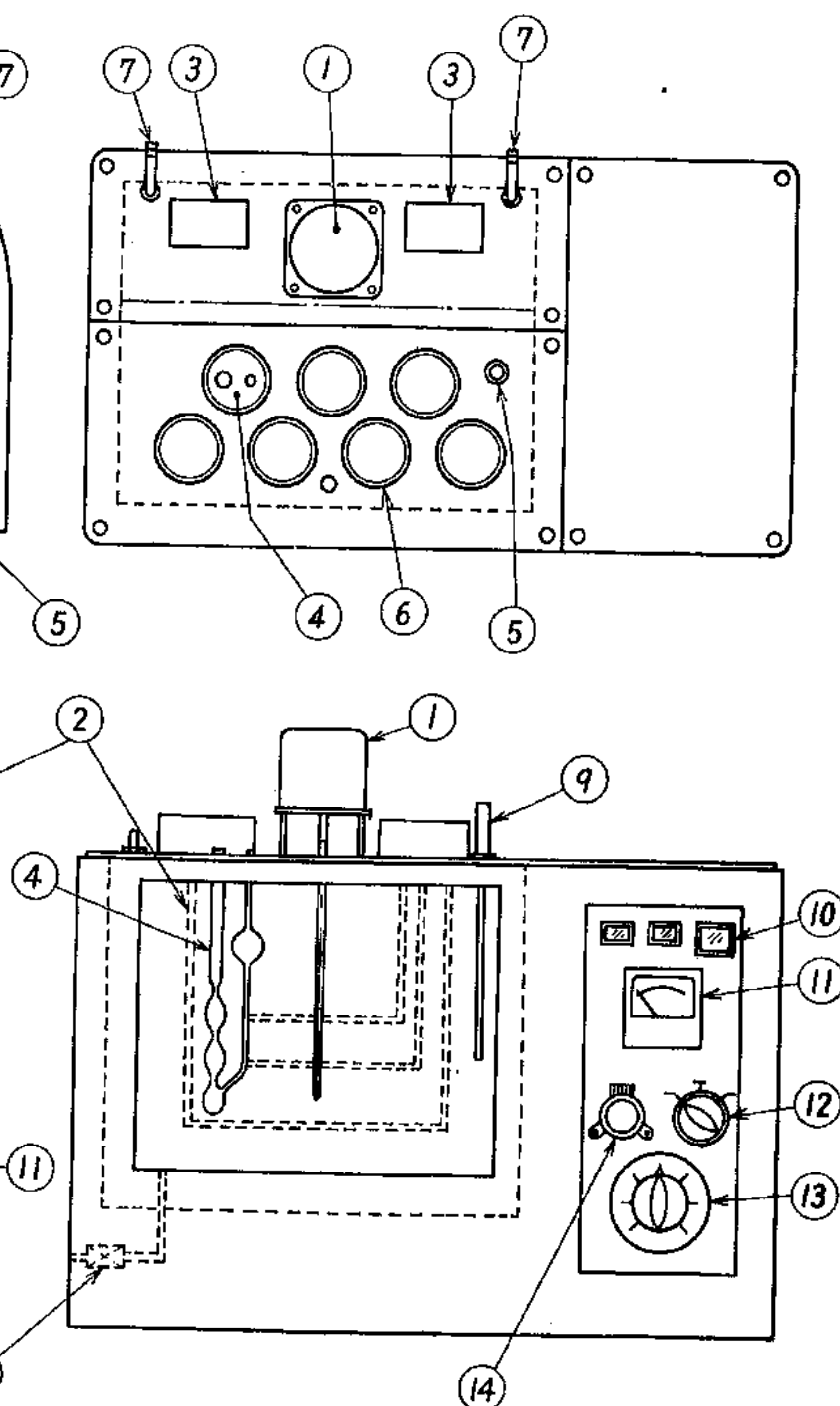
(a) Glass Bath (An Example)

Six Viscometers Supporting

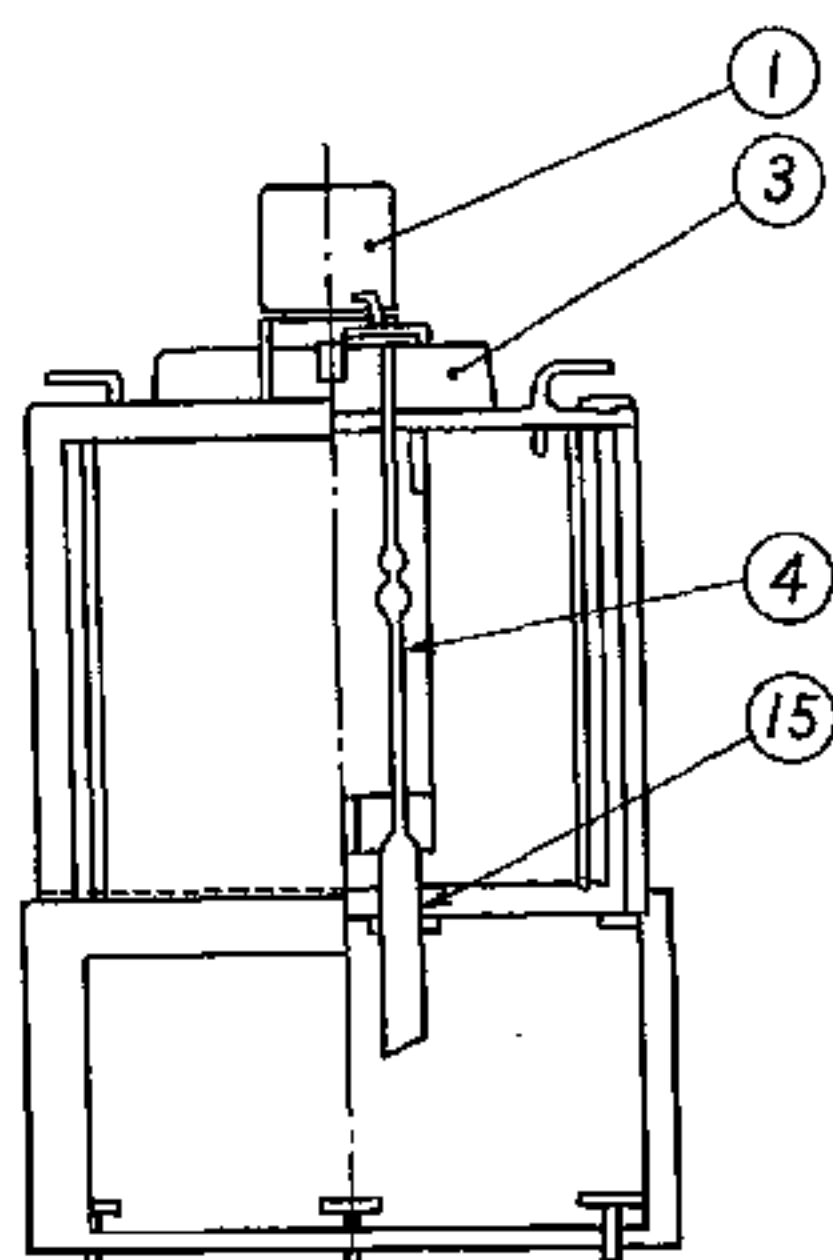


(b) Metal Bath (An Example)

Seven Viscometers Supporting



## (c) Bath for Atlantic Viscometers (An Example)



- ① Electric type stirrer
- ② Heater
- ③ Heater cover
- ④ Viscometer
- ⑤ Temperature-regulator inserting opening
- ⑥ Viscometer inserting opening
- ⑦ Cooling pipe
- ⑧ Drain tube
- ⑨ Temperature regulator
- ⑩ Pilot lamp
- ⑪ Ammeter
- ⑫ Change-over switch
- ⑬ Voltage regulator
- ⑭ Temperature regulator
- ⑮ Viscometer holder

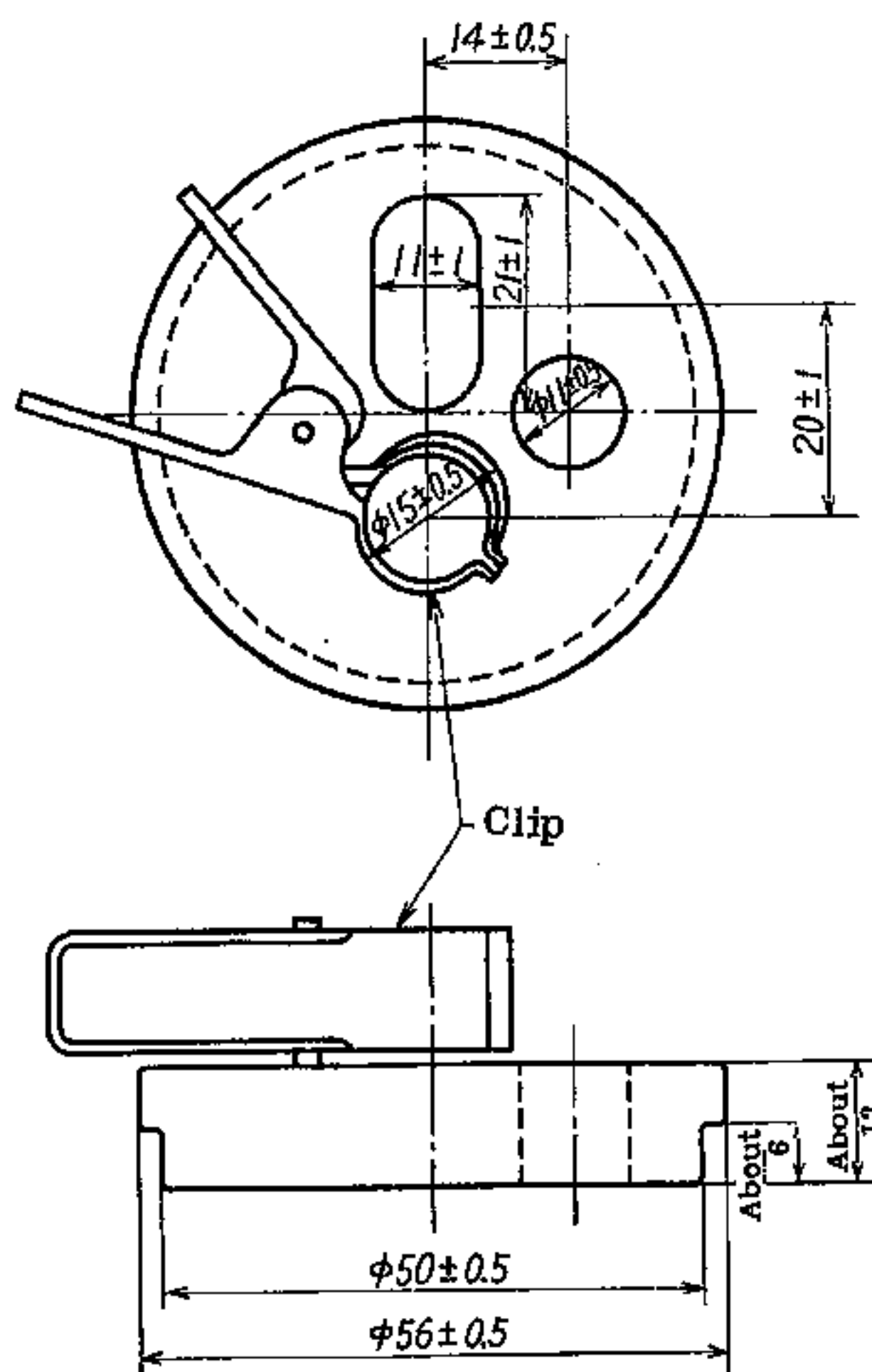
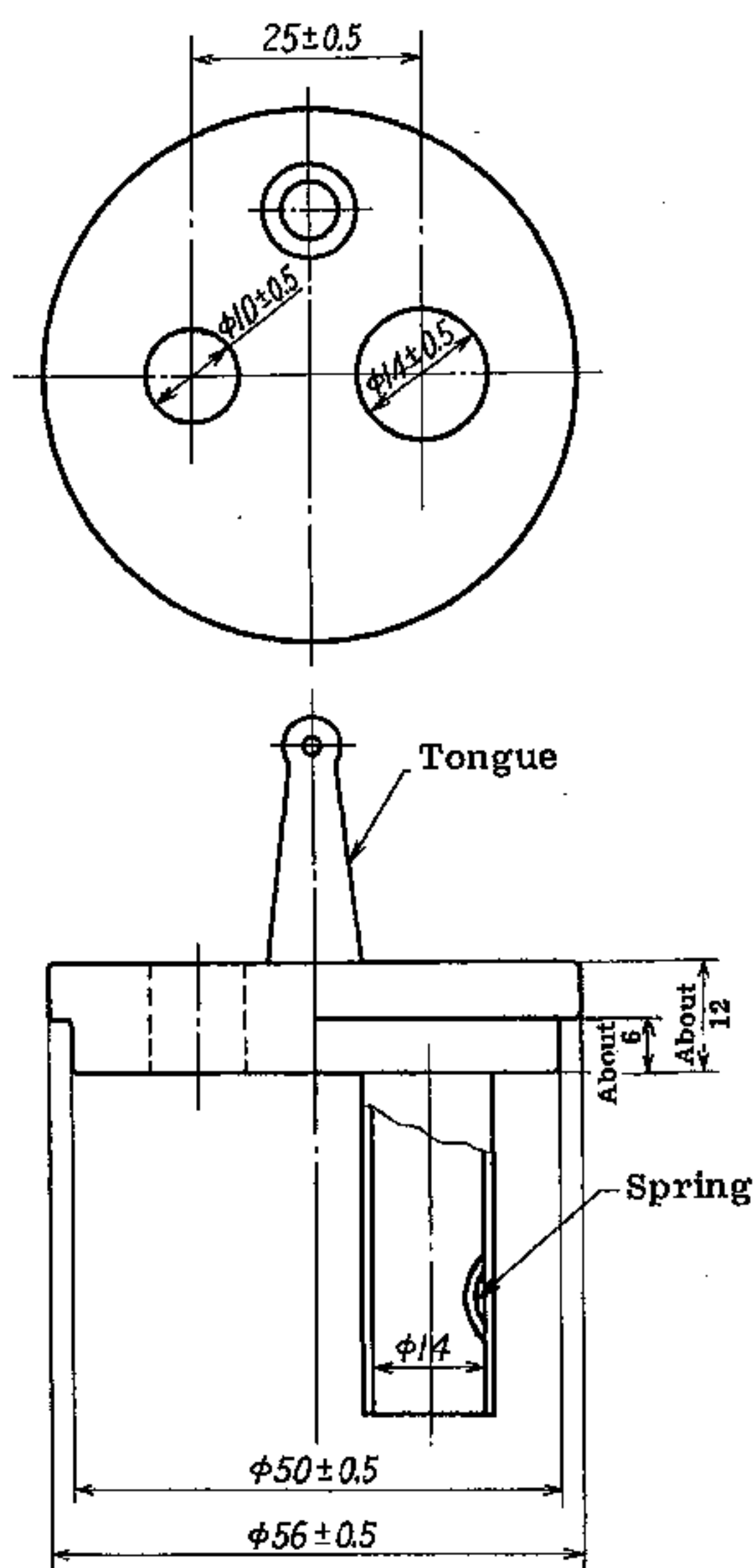
- Reference 1. The lid of bath shall be able to retain the viscometer holder and be provided with thermometer-inserting opening and temperature-regulator inserting opening.
2. The stirrer shall be of electric motor type of not less than 10 W having small vibration and be able to make the temperature distribution in the bath uniform.
3. The heater shall have a capability of rising the temperature in the bath from room temperature up to about 100°C within 100 min. The temperature regulator shall be able to maintain the temperature of solution within the specified accuracy.
- (4) Viscometer Holders The viscometer holders shall be able to hold the viscometers vertically. An example is shown in Fig. 2.

Fig. 2. Viscometer Holder (An Example)

Unit: mm

For Cannon-Fenske

For Cannon-Fenske and Ubbelohde



- (5) Timing Devices The timing devices shall be able to read to the nearest 0.1 s and their instrumental error be within  $\pm 0.05\%$  in testing for 15 min.

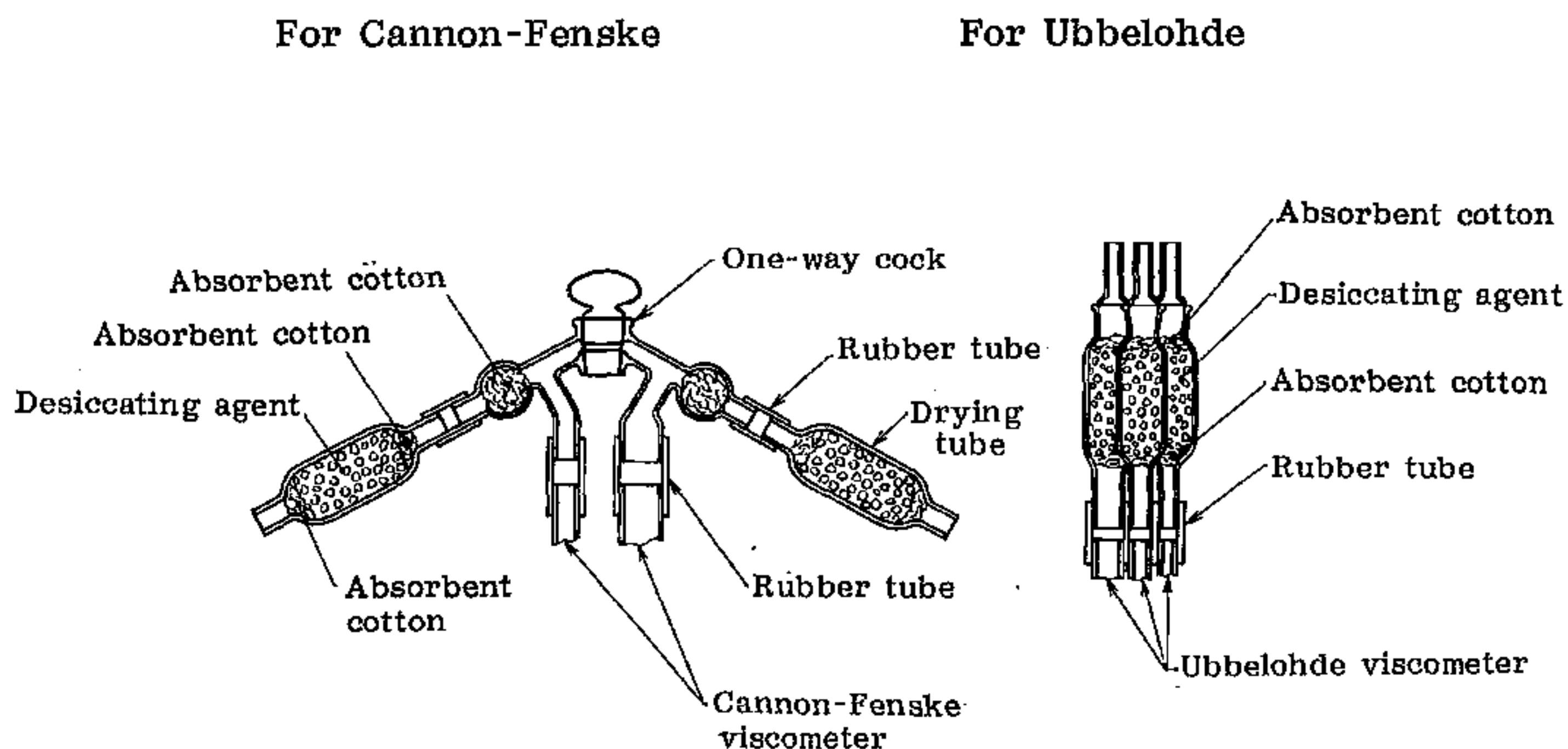
Reference: For calibration of timing devices, it should be preferable to use time signal of telephone.

- (6) Moistureproofing Devices The devices shall be the glass moistureproofing devices to be used for test at a temperature not higher than the dew point, which shall be filled inside loosely with desiccating agent (for example, granular silica gel and the like), and hold the desiccating agent by placing absorbent cotton and the like at the both ends, and be able to be connected with rubber tubes at the tube openings of viscometers.

For Cannon-Fenske or Ubbelohde viscometer, there are moisture-proofing devices given in Fig. 98 specified in JIS K 2839. Its using example is shown in Fig. 3.

The devices for Cannon-Fenske, one-way cock shall be opened at measuring the flow time.

Fig. 3. Using Method for Moistureproofing Device  
(An Example)



**3.4 Standard Liquids for Calibrating Viscometers** (hereinafter referred to as the "standard liquids") These shall be the standard liquid specified in JIS Z 8809 and ISO 3104, and their classification and approximate value of kinematic viscosity are shown in Tables 3 and 4.

The determined values of kinematic viscosity of individual standard liquid are described in the letter of guarantee of results appended to the standard liquid.

Table 3. Standard Liquids for Calibrating Viscometers  
(JIS Z 8809)

| Classification | Approximate value of kinematic viscosity |       |       | St (cm <sup>2</sup> /s) |
|----------------|------------------------------------------|-------|-------|-------------------------|
|                | 20°C                                     | 25°C  | 30°C  | 40°C                    |
| JS 2.5         | 0.025                                    | —     | 0.021 | 0.017                   |
| JS 5           | 0.05                                     | —     | 0.04  | 0.03                    |
| JS 10          | 0.1                                      | —     | 0.07  | 0.06                    |
| JS 20          | 0.2                                      | —     | 0.14  | 0.1                     |
| JS 50          | 0.5                                      | —     | 0.3   | 0.21                    |
| JS 100         | 1                                        | —     | 0.6   | 0.35                    |
| JS 200         | 2                                        | —     | 1.1   | 0.6                     |
| JS 500         | 5                                        | —     | 2.5   | 1.4                     |
| JS 1000        | 10                                       | —     | 5     | 2.5                     |
| JS 2000        | 20                                       | —     | 9     | 4.4                     |
| JS 20 H        | 180                                      | —     | 70    | 30                      |
| JS 60 H        | 560                                      | —     | 210   | 90                      |
| JS 200 H       | 1 700                                    | 1 000 | —     | —                       |

Remark: 1 St {cm<sup>2</sup>/s} = 100 cSt {mm<sup>2</sup>/s}Table 4. Standard Liquids for Calibrating Viscometers  
(ISO 3104)

| Classification | Approximate value of kinematic viscosity |       |        |        |         |        |        | cSt (mm <sup>2</sup> /s) |       |
|----------------|------------------------------------------|-------|--------|--------|---------|--------|--------|--------------------------|-------|
|                | -53.89°C                                 | -40°C | 20°C   | 25°C   | 37.78°C | 40°C   | 50°C   | 98.89°C                  | 100°C |
| 3              | 300                                      | 80    | 4.6    | 4.0    | 3.0     | 2.9    | —      | 1.2                      | 1.2   |
| 6              | —                                        | —     | 11     | 8.9    | 6.0     | 5.7    | —      | 1.8                      | 1.8   |
| 20             | —                                        | —     | 44     | 34     | 20      | 18     | —      | 4.0                      | 3.9   |
| 60             | —                                        | —     | 170    | 120    | 60      | 54     | —      | 7.4                      | 7.2   |
| 200            | —                                        | —     | 640    | 450    | 200     | 180    | —      | 17                       | 17    |
| 600            | —                                        | —     | 2 400  | 1 600  | 600     | 520    | 280    | 33                       | 32    |
| 2 000          | —                                        | —     | 8 700  | 5 600  | 2 000   | 1 700  | —      | 78                       | 75    |
| 8 000          | —                                        | —     | 37 000 | 23 000 | 8 000   | 6 700  | —      | —                        | —     |
| 30 000         | —                                        | —     | —      | 81 000 | 27 000  | 23 000 | 11 000 | —                        | —     |

**3.5 Calibration of Viscometers** The calibration of viscometers shall be carried out according to the following by use of standard liquid specified in 3.4. In the case where the difference of accelerations due to gravity at the calibrated place and the place for the viscometer to be used is not less than 0.1 %, the viscometer shall be used after the viscometer constant has been corrected according to the following formula:

$$C = \frac{g}{g_1} \times C_1 \dots \dots \dots (3)$$

where  $C$  : viscometer constant corrected at the using place (cSt/s)  
          { mm<sup>2</sup>/s<sup>2</sup> }  
 $g$  : acceleration due to gravity at the using place (cm/s<sup>2</sup>)

$C$ : viscometer constant at the calibrating place (cSt/s)  
{mm<sup>2</sup>/s}

$g_1$ : acceleration due to gravity at the calibrating place  
(cm/s<sup>2</sup>)

Reference: The accelerations due to gravity at respective places are described in chronological table of science and the like.

(1) In the Case of Viscometer Requiring No Correction of Flow Time The calibration of viscometer shall be carried out according to the following:

- (a) Select the calibration temperature from either temperatures at the determination of kinematic viscosity of standard liquid.
- (b) Select such standard liquid that will give a flow time not less than 200 sec (in the case of viscometer specified with the minimum flow time, not less than the specified time) and not more than 1000 sec from Table 3 or Table 4.
- (c) Measure the flow time to the nearest 0.1 sec according to the procedure of 3.8, as appropriate, by sampling the standard liquid at an arbitrary temperature in the viscometer.
- (d) Calculate the viscometer constant according to the following formula and round off to 4 places of significant figures.

$$C = \frac{v}{t} \dots \dots \dots (4)$$

where

$C$ : viscometer constant (cSt/s) {mm<sup>2</sup>/s<sup>2</sup>}

$v$ : kinematic viscosity of standard liquid (cSt)  
{mm<sup>2</sup>/s}

$t$ : flow time (s)

(2) In the Case of Viscometer Requiring Correction of Flow Time (See Table 1)  
The correction shall be carried out according to either Method A or Method B of the following. However, the viscometer calibrated by Method B shall not apply to the sample requiring preheat operation of 3.7.3, the sample, which is difficult to sample at a temperature of 20 to 30°C, and to the measurement where the test temperature is different from the calibration temperature.

(2.1) Method A (method to sample the standard liquid at the calibration temperature) The calibration by Method A shall be carried out according to the following:

- (a) Select the calibration temperature from either temperatures at the determination of kinematic viscosity of the standard liquid.
- (b) Select such standard liquid that the flow time becomes not less than 200 sec, (in the case of viscometer specified with the minimum flow time, not less than the specified time) and not more than 1000 sec from Table 3 or Table 4.

- (c) After making the temperature of the standard liquid and the viscometer approximately the same temperature, sample the standard liquid in the viscometer and measure the flow time to the nearest 0.1 sec according to the procedure of 3.8, as appropriate.
- (d) Calculate the viscometer constant according to formula (4), and round off to 4 places of significant figures. In this case, append the fact that the value is in accordance with Method A.

Remark: In the case where the kinematic viscosity is calculated by the use of viscometer constant obtained by this method, it is necessary to correct the flow time according to formulae (7) and (8) or (9) and (10) depending on the difference of temperatures at the test and at the sampling.

- (2.2) Method B (The method to make the calibration temperature equal to the test temperature by sampling the standard liquid at 20 to 30°C). The calibration shall be carried out according to the method of (2.2.1) where the determined value of kinematic viscosity of standard liquid at the calibration temperature exists, and according to the method of (2.2.2) by the use of calibrated viscometer where the determined value of kinematic viscosity does not exist.

Remark: Method B is the method in which it is taken into consideration that the change of  $h$  shown in Note (1) of 3.2 becomes same at the calibration and at the test, and the correction of flow time is contained in the obtained viscometer constant. Therefore, it is applicable to the case where the test is carried out at the same temperature as that at the calibration by sampling at 20 to 30°C.

- (2.2.1) Where Determined Value of Kinematic Viscosity of Standard Liquid at Calibration Temperature Exists The calibration shall be carried out according to the following methods:

- (a) Set the calibration temperature same as the test temperature.
- (b) Select such standard liquid that the flow time becomes not less than 200 sec (in the case of viscometer specified with the minimum flow time, not less than the specified time) and not more than 1000 sec from Table 3 or Table 4.
- (c) Measure the flow time to the nearest 0.1 sec according to the procedure of 3.8, as appropriate, by sampling the standard liquid at 20 to 30°C.
- (d) Calculate the viscometer constant according to formula (4), and round off to 4 places of significant figures. In this case, append the fact that the value is in accordance with Method B, and the calibration temperature.

- (2.2.2) Where Determined Value of Kinematic Viscosity of Standard Liquid at Calibration Temperature Does Not Exist The calibration shall be carried out according to the following methods:

- (a) Calibrate either of the suspended-level viscometers specified in 3.3 (1) according to the following to make it the calibrated viscometer.

By using two kinds of standard liquids different by 2 to 3 times in determined value of kinematic viscosity, carry out the calibrating operation specified in (1), and if the difference of two viscometer constants obtained is not more than 0.35 % of the average value, take the average value as the viscometer constant.

Remark: A viscometer, the average significant liquid column height of which is not less than 400 mm and which is calibrated based on the kinematic viscosity of water, may be used as the calibrated viscometer.

- (b) Set the calibration temperature at the test temperature.
- (c) Select the viscometer having the approximately same degree of viscometer constant as that of the viscometer to be calibrated.
- (d) Select such standard liquid<sup>(2)</sup> that the flow time becomes not less than 200 sec (in the case of viscometer specified with the minimum flow time, not less than the specified time) and not more than 1000 sec from Table 3 or Table 4 for all viscometers of calibrated and to be calibrated viscometers at the calibrating temperature.

Note (2) Where there is no suitable standard liquid, hydrocarbon oil which contains no solid matter and is transparent may be used.

- (e) Measure respectively the flow time to the nearest 0.1 sec according to the procedure of 3.8, as appropriate, by taking the standard liquid<sup>(2)</sup> at 20 to 30°C into both of the calibrated viscometer and the viscometer to be calibrated and by putting simultaneously into a constant temperature bath.
- (f) Calculate the viscometer constant according to the following formula, and round off to 4 places of significant figures. In this case, append the fact that the value is in accordance with Method B, and the calibration temperature.

$$C = \frac{t_1 G_1}{t} \dots \dots \dots (5)$$

where  $C$  : viscometer constant (cSt/s) { mm<sup>2</sup>/s<sup>2</sup> }

$t_1$  : flow time in calibrated viscometer (s)

$G_1$  : viscometer constant of the calibrated viscometer (cSt/s) { mm<sup>2</sup>/s<sup>2</sup> }

$t$  : flow time in viscometer to be calibrated (s)

3.6 Calibration of Thermometers The calibration of thermometers shall be carried out to the nearest 0.01 °C in comparison with the standard thermometer<sup>(3)</sup> according to Appendix (correction test method) of JIS B 7410. The calibrated thermometers shall be recalibrated periodically.

Note (3) Instead of the standard thermometer, the double tube mercury-in-glass thermometer having the scale interval of 0.05°C or less calibrated to the nearest 0.01°C in the National Research Laboratory of Metrology of the Agency of Industrial Science and Technology may be used.

Remark: The periodical calibration may be carried out according to the method by measuring the freezing point [refer to JIS Z 8705].

### 3.7 Preparation for Tests

3.7.1 Cleaning of Viscometer The cleaning of viscometer shall be carried out according to the following:

- (1) Clean the viscometer used in the test thoroughly by several rinsings with an appropriate solvent completely miscible with the sample, followed by a completely volatile solvent. Dry the tube by passing filtrated dry air through the viscometer for 2 min or until the last trace of solution is removed.
- (2) For viscometer to be calibrated and the viscometer which is incapable of cleaning by the method of (1) due to large amount of stain, remove organic deposits with chromic acid or appropriate detergent, rinse thoroughly the viscometer with water and acetone in this sequence, and dry with passing filtered dry air. In case of doubt of inorganic deposits, they shall be removed preliminarily by hydrochloric acid.

Remark: The chromic acid mixed solution shall be treated to remove nuisance.

- (3) Recalibrate often the viscometer to be used for sample (for example, silicon oil, fluorocarbon, etc.) which is difficult to be removed even by using the detergent as exclusive use.

3.7.2 Setting of Test Temperature Setting of test temperature shall be carried out according to the following:

- (1) Put an appropriate bath liquid into a constant temperature bath corresponding to the test temperature, and adjust the level to be not less than 20 mm above the upper sample reservoir bulb of the viscometer.

Reference: The kind of bath liquids corresponding to the test temperature is shown in Reference Table 1.

Reference Table 1

| Test temperature °C  | Kind of bath liquids         | Remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15 max.              | Methanol<br>Ethanol<br>Water | Division of using of bath liquids should preferably be as follows:<br>-25°C max. .... methanol<br>-25 to 5°C .... ethanol<br>5 to 15°C .... water                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Over 15 to 100 incl. | Water                        | (1) Distilled water or demineralized water is more difficult to change in quality. Because the city water is easy to be changed in quality, it should preferably not be used.<br>(2) For test temperature of 80 to 100°C, the mixed solution of water soluble matters such as glycerol, ethylene glycol, etc. and water should preferably be used. However, this mixed solution is more corrosive to metals in comparison with water.<br>(3) For test temperature of 100°C, mineral oil of small viscosity and of tint should preferably be used instead of water. |
| Over 100             | Mineral oil                  | Mineral oil shall be that of small viscosity and of tint (for example, liquid paraffin, turbine oil, etc. are suitable).                                                                                                                                                                                                                                                                                                                                                                                                                                           |

- (2) Confirm whether the thermometer is calibrated according to 3.6 or not.

Attach the thermometer so that the top of mercury column becomes under the surface of bath liquid of the constant temperature bath and the swelling chamber becomes above the lid of constant temperature bath.

- (3) Maintain the temperature of constant temperature bath at test temperature  $\pm 0.01^\circ\text{C}$  where the test temperature is 15 to 100°C, and at test temperature  $\pm 0.03^\circ\text{C}$  where the test temperature is under 15°C or exceeds 100°C.

Remarks 1. Test temperatures are different according to the kind of sample, but test temperatures specified in individual product standard and JIS K 2601 are shown in Table 5.

2. Because the sample does not become Newtonian fluid when the test temperature is near the pour point, dispersion is caused in test results, and therefore it is preferable to measure at a temperature at which the sample flows sufficiently. For example in the case of high pour point fuel oil and high viscosity fuel oil, it is suitable to measure at 75°C or 100°C.

Table 5. Test Temperature Depending upon Classification of Oils

| Classification of oils                         | Test temperature °C | Classification of oils | Test temperature °C |
|------------------------------------------------|---------------------|------------------------|---------------------|
| Crude oil                                      | 30, 50              | Liquid paraffin        | 40                  |
| Electric insulation oil                        | 40, 75, 100         | Machine oil            | 40, 100             |
| Gas oil                                        | 30                  | Bearing oil            | 40, 100             |
| Fuel oil                                       | 50                  | Cutting oil            | 40                  |
| Aviation turbine fuel                          | -20                 | Heat-treatment oil     | 40, 100             |
| Refrigerator oil                               | 40                  | Air filter oil         | 40                  |
| Turbine oil                                    | 40, 100             | Rust preventive oil    | -18, 40, 100        |
| Lubricating oil for internal-combustion engine | 40, 100             | Petrolatum             | 100                 |
| Gear oil                                       | 40, 100             | Automobile brake oil   | -40, 50, 100        |

3.7.3 Preparation of Sample The preparation of sample shall be carried out according to the following:

- (1) Confirm the fact that the sample is uniform liquid and does not contain dusts, solid matters, water, etc. If dusts and solid matters are mixed-in, filter out them with gauze of 75  $\mu$ m meshes. Further, if moisture exists in suspension, remove it with a suitable method such as filtering by filter paper, centrifugal separation, etc.
- (2) The kinematic viscosity of lubricating oil containing much asphaltene, high pour point fuel oil, high viscosity fuel oil and the sample containing much wax may be affected by thermal hysteresis, and therefore the following preheating operation shall be carried out when tested at a temperature not higher than 95°C. However, for the sample which is known preliminarily that it is not to be affected by thermal hysteresis, the preheating operation may be omitted.
  - (a) Mix with shaking the vessel containing the sample by heating to 50°C or higher. In this case, confirm whether the sample has become completely liquid or not by inserting a rod till the bottom of the vessel.
  - (b) Take about 100 ml of sample into a 150 ml Erlenmeyer flask, stopper lightly with a rubber stopper or cork stopper. Immerse the Erlenmeyer flask into the boiling water bath for 30 min.
  - (c) After mixing with stirring sufficiently the sample, filter with gauge of 75  $\mu$ m meshes, take into a viscometer which has been put in a constant temperature bath preliminarily kept at the test temperature, and complete the test within 1 h.

3.8 Procedure of Tests

3.8.1 Operation for Suspended-Level Viscometer The measuring operation shall be carried out according to the following:

(1) In the Case of Ubbelohde, Cannon-Ubbelohde and Cannon-Ubbelohde Semi-Micro Viscometers The measuring operation shall be carried out according to the following:

- (a) According to the estimated kinematic viscosity of sample at the test temperature, select<sup>(4)</sup> such a viscometer that will give a flow time not less than 200 sec (however, not less than 300 sec for Ubbelohde viscometer of viscometer No. 0, and not less than 250 sec for Cannon-Ubbelohde viscometer of viscometer No. 25) and not more than 1000 sec, from Table 6, Table 7 and Table 8.

Note (4) The selection of viscometer should preferably be carried out, being based on the viscometer constant calculated according to the following formula:

$$C = \frac{v_E}{t} \dots \dots \dots (6)$$

where  $C$ : viscometer constant to be selection reference of viscometer (cSt/s) { mm<sup>2</sup>/s<sup>2</sup> }

$v_E$ : estimated kinematic viscosity of sample (cSt){ mm<sup>2</sup>/s }

$t$ : flow time (200 ≤  $t$  ≤ 1000) (s)

- (b) Incline the viscometer at an angle of about 30° to the vertical, put in the sample at an arbitrary temperature<sup>(5)</sup> from holder-attaching tube L until the liquid surface approximately align with the marked line for sampling H, and make it vertical. In this case, the liquid surface shall not exceed the marked line for sampling G due to flow-down of sample adhering on the holder-attaching tube L, and the bubbles shall not enter the connecting tube P. In the case of very sticky sample, it may be sucked up by immersing the opening of holder-attaching tube L in the sample. In this case, stop up the lower vent pipe M with a finger or rubber stopper and introduce the sample into the lower sample reservoir bulb A by sucking from the upper vent pipe N.

Note (5) In the case of test temperature of 0°C or lower, take the sample at room temperature.

- (c) Put a viscometer<sup>(6)</sup> into the constant temperature bath kept at the test temperature, and after setting the capillary R so as to be vertical<sup>(7)</sup>, stand still it until the sample reaches the test temperature.

Notes (6) In the case of test temperature of dew point or lower, attach a moistureproofing device to the viscometer so as to prevent condensation of water in the viscometer. Specially in case of test temperature of 0°C or lower, put the capillary with the sample filled into the constant temperature bath in order to prevent icing in capillary.

Notes (7) It should be preferable to view from two directions at right angles to compare with the weight suspended in order to confirm whether the viscometer is vertical or not.

Remark: The standing-still time is different according to the kinematic viscosity of sample, type of viscometer, test temperature, etc. For example, about 10 min at 40°C and about 15 min at 100°C for the sample of low viscosity and about twice of them respectively for the sample of high viscosity are suitable.

(d) After confirming that the temperature of constant temperature bath has reached the test temperature, stop up the lower vent pipe M with a finger, and draw up the sample up to about 8 mm above the timing marked line E by suction from the upper vent pipe N (in the case of containing volatile component, by pressurizing from holder-attaching tube L). Stop the suction from the upper vent pipe N (or pressurizing from the holder-attaching tube L), detouch the finger stopping the lower vent pipe M, and immediately stop up the upper vent pipe N with the finger. When the sample at the lower end of capillary R has flowed down, detouch the finger to let the sample flow down naturally.

(e) Read out the time when the meniscus of sample passes from timing marked line E to F to the nearest 0.1 sec.

In case where this flow time comes out of the specification of (a), retest with the viscometer replaced.

(f) Measure the flow time by repeating the procedures of (d) and (e). Where the difference of flow times of twice is within 0.2 % of the average value, use the average value for calculation of kinematic viscosity.

Fig. 4. Sketch of Ubbelohde Viscometer

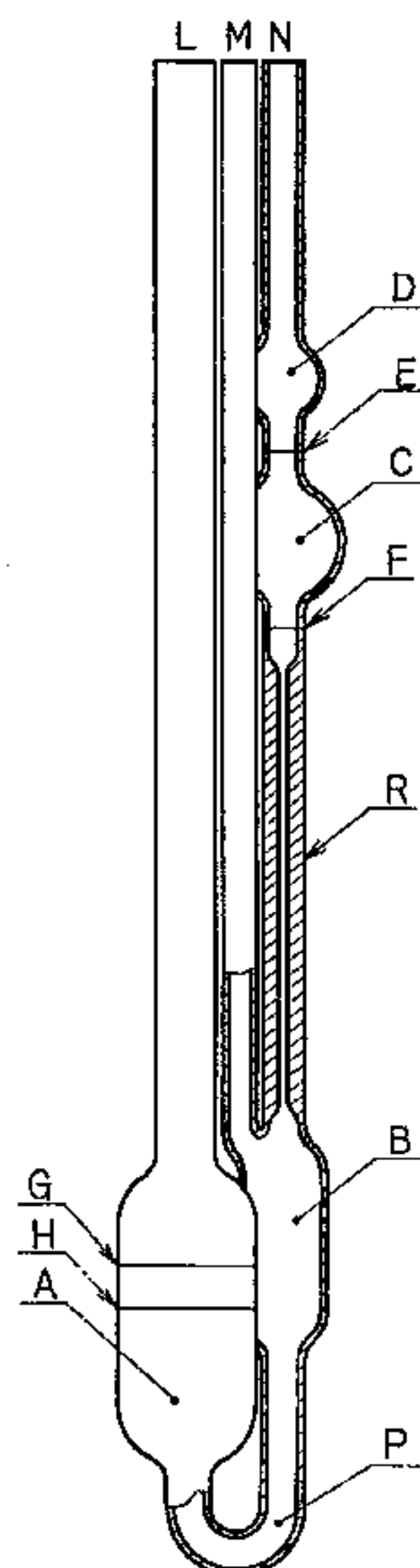


Fig. 5. Sketch of Cannon-Ubbelohde Viscometer

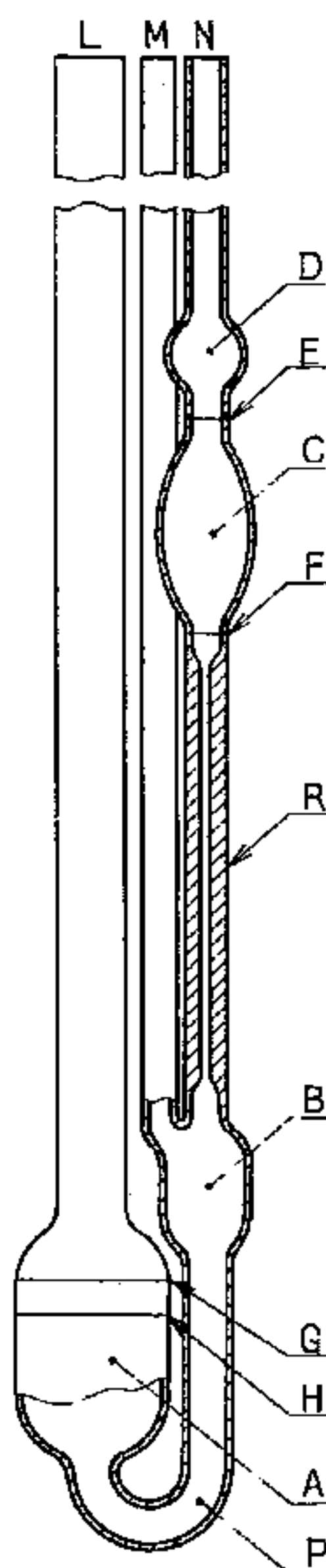
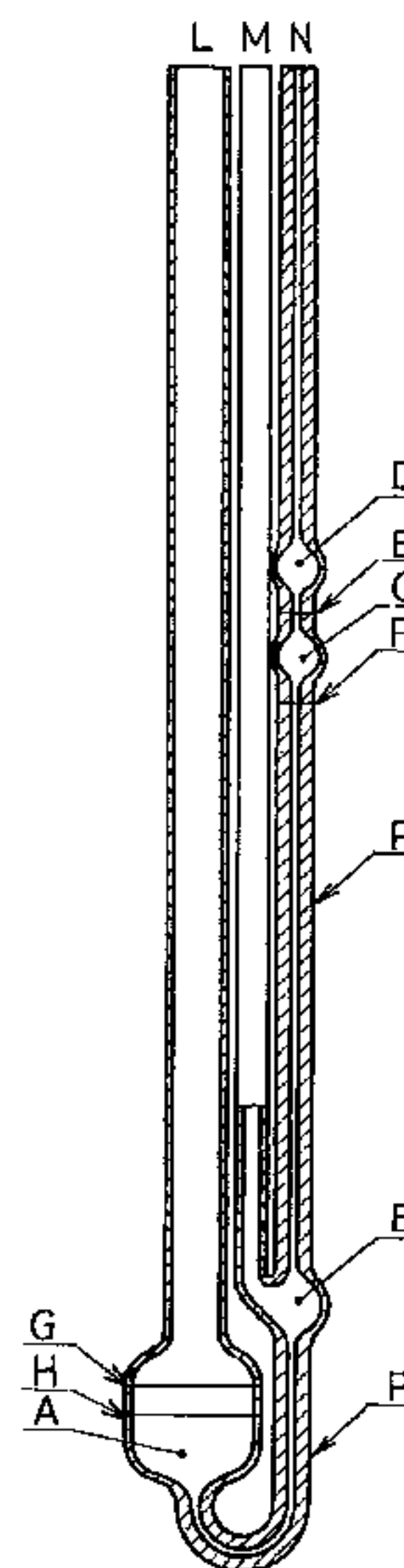


Fig. 6. Sketch of Cannon-Ubbelohde Semi-Micro Viscometer



- A Lower sample reservoir bulb  
 B Suspension liquid bulb  
 C Timing bulb  
 D Upper sample reservoir bulb  
 E and F Timing marked line  
 G and H Sampling marked line

- L Holder-attaching tube  
 M Lower vent pipe  
 N Upper vent pipe  
 P Connecting tube  
 R Capillary