BTS 358: 2021 IS 5844: 2014

གནོན་བཙིར་འབད་པའི་རླུང་གི་རྒྱ་ཛི་གི་ཆུའི་གནོན་ཤུགས་བརྟག་ཞིབ་རྒྱབ་སྐྱོན་ངོ་སྦྱོར།།

BHUTAN STANDARD

Hydrostatic Stretch Testing of Compressed Gas Cylinders- Recommendations

ICS 23.020.30

BHUTAN STANDARDS BUREAU

The National Standards Body of Bhutan

THIMPHU 11001

……, 2021 Price group A

BTS 358: 2021 IS 5844: 2014

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BHUTAN STANDARD

Hydrostatic Stretch Testing of Compressed Gas Cylinders- Recommendations

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Published in Thimphu, Bhutan

NATIONAL FOREWORD

This Bhutan Standard which is identical with IS 5844: 2014-Hydrostatic Stretch Testing of Compressed Gas Cylinders-Recommendations issued by the Indian Standards Bureau (IS) was adopted by Bhutan Standards Bureau by sub-committee on Medical and industrial gases (TC 05/SC 01) and Pharmaceutical and Traditional Medicines Technical Committee (TC 05) and approved by the Bhutan Standards Bureau Board (BSB Board) on ……., 2021.

The text of the IS Standard has been approved as suitable for publication as Bhutan Standard without deviation. Certain conventions are however, not identical to those used in Bhutan Standard.

Attention is particularly drawn to the following:

a) Where the words “IS Standard” appear referring to this standard, they should be read as “Bhutan Standard”.

b) Wherever page numbers are quoted, they are “IS (IS Standard)” page numbers.

संपीडित गैस सिलिंडरों के हायड्रोस्टेटीक स्ट्रैच परीक्षण — अनुशंसाएँ

(पहला पुनरीक्षण)

Hydrostatic Stretch Testing of Compressed Gas Cylinders — Recommendations

(First Revision)

ICS 23.020.30

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
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October 2014 **Price Group 5**

Gas Cylinders Sectional Committee, MED 16

FOREWORD

This Indian Standard (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Gas Cylinders Sectional Committee had been approved by the Mechanical Engineering Division Council.

This standard was first published in 1970. This standard has been revised to incorporate the latest industrial trend. In this revision following modification has been incorporated:

a) For Water Jacketed Method 'Levelling Burette Method' of testing is added.
b) Mentioned use of calibration cylinder for calibrating the system.
c) For Non-Water Jacketed Method 'calculation of compressibility of water' modified.

Manufacture, possession, and use of any gas, when contained in cylinders in a compressed or liquefied state, are regulated by the *Gas Cylinder Rules*, 2004 (as amended from time to time) of the Government of India. This standard has been formulated in consultation and agreement with the statutory authorities under these rules.

Pressures indicated in the various requirements/clauses of this standard are gauge pressure unless otherwise stated.

The composition of the Committee responsible for the formulation of this standard is given in Annex A.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

Indian Standard

HYDROSTATIC STRETCH TESTING OF COMPRESSED GAS CYLINDERS — RECOMMENDATIONS

(First Revision)

1 SCOPE

This standard describes procedures for the hydrostatic stretch testing of cylinders intended for the storage and transport of compressed gases. Two methods, namely, water jacket method and non-jacket method, have been covered.

NOTE — Other methods are acceptable provided that they are capable of measuring the total volumetric expansion and the permanent volumetric expansion, if any, of the cylinder under test reliably and repeatably.

2 TERMINOLOGY

For the purpose of this standard the following definitions shall apply.

2.1 Calibration — It is the process of adjusting and confirming a device to match a known standard so that it indicates to within a specified accuracy limits.

2.2 Calibration Verification — The checking of an individual device or test apparatus by comparison with a given standard to determine the indication error at specified points of the scale.

2.3 Calibration Cylinder — A cylinder that has certified calibration points of pressure with corresponding expansion values.

NOTE — It is a secondary, derived standard used for the verification and demonstration of test system accuracy and integrity. It is a cylinder that has been specially prepared so that it no longer experiences permanent expansion at the pressure for which it has been calibrated. The expansion readings of the cylinder shall be repeatable and linear.

2.4 Condemn — A cylinder or piece of equipment in a state no longer fit for service and for which repair is not allowed.

2.5 Gas Cylinder — Any gas container intended for the storage and transport of compressed gases having a volume exceeding 500 ml but not exceeding 1 000 litre and designed not to be fitted to a special transport or undercarriage.

2.6 Elastic Expansion — A temporary increase in cylinder's volume due to application of pressure that becomes zero when pressure is released.

NOTE — It is the difference between total expansion and permanent expansion.

2.7 Error — The difference between the indicated value and the true value of the variable being measured.

2.8 Hydrostatic Test — The method of pressure testing a cylinder using liquid as the pressurization media.

2.9 Hydrostatic Stretch Test — It is a method of gradually pressuring the cylinder to its test pressure, retaining this pressure at least for specified time and measuring the volumetric expansion. Thereafter releasing the pressure from the cylinder and making it to zero and measuring the permanent expansion. During application and retention of pressure in the cylinder, complete setup is examined for any reduction in pressure and/or leakage and after releasing the pressure; cylinder is examined for visible bulge and/ or deformation.

2.10 Master Gauge — A pressure indicating device used as a calibration standard that has an accuracy grade equal to or better than the requirement specified for the pressure indication device in the test apparatus.

2.11 Percentage Permanent Expansion — It is the ratio of permanent expansion to total expansion, expressed as a percentage.

2.12 Permanent Expansion — An increase in cylinder volume due to application of pressure that is not recovered when pressure is released.

2.13 Test Pressure (P_h) — The pressure at which the cylinder is hydraulically tested.

2.14 Total Expansion — The total increase in a cylinder's volume due to application of the test pressure.

2.15 Volumetric Expansion Test — It is the hydrostatic test to determine the total, permanent and elastic expansion of a cylinder at a given pressure.

2.16 Working Gauge — A pressure indicating device used for measuring the pressure during hydrostatic stretch test that has an accuracy grade equal to or better than the requirement specified in the code.

2.17 Working Pressure (P_w)/Service Pressure — Working pressure means maximum allowed internal pressure of the gas in the cylinder, when converted to equivalent pressure at a temperature of 15°C.

3 METHODS FOR HYDROSTATIC TEST

There are two methods of hydrostatic testing of cylinder that is Water Jacket Method and Non-Water Jacket Method. Calibration cylinder shall be used to establish the accuracy of the testing equipment/system before starting and at pre-determined intervals during the actual testing of cylinders.

The test equipment shall have provision to prevent over pressurization of cylinder more than 10 percent above the test pressure of the cylinder.

3.1 Water Jacket Method

3.1.1 *Apparatus*

The water jacket method is the preferred method for testing cylinders in the gas cylinder industry.

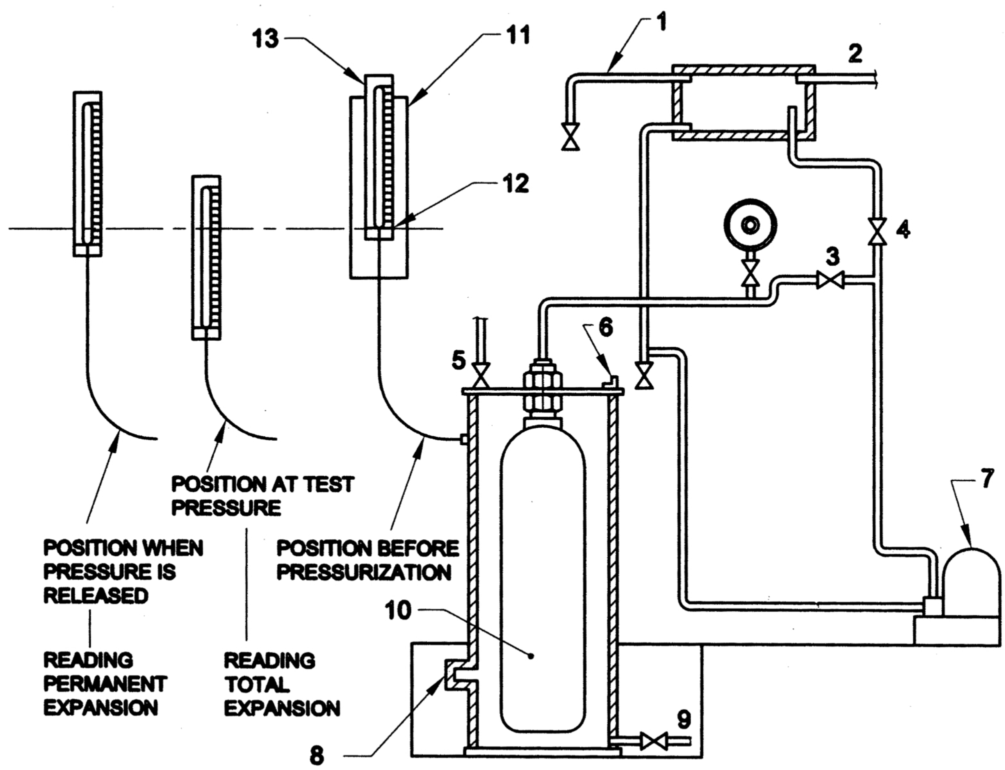
It consists of pressurizing a cylinder filled with water inside a sealed container which is filled with water (the water jacket) and measuring the resulting expansion of cylinder.

There are two methods of testing (a) Levelling burette method, and (b) Fixed burette method.

The general arrangement of apparatus for the test type is indicated in Fig. 1 and Fig. 2 respectively.

Various devices are used for measuring both the expansion and the pressure. Quantity of water displaced due to cylinder Expansion may be read visually with a burette or measured electronically by weight or by height of water column. Pressure may be read using an analog gauge or electronically using a digital pressure transducer.

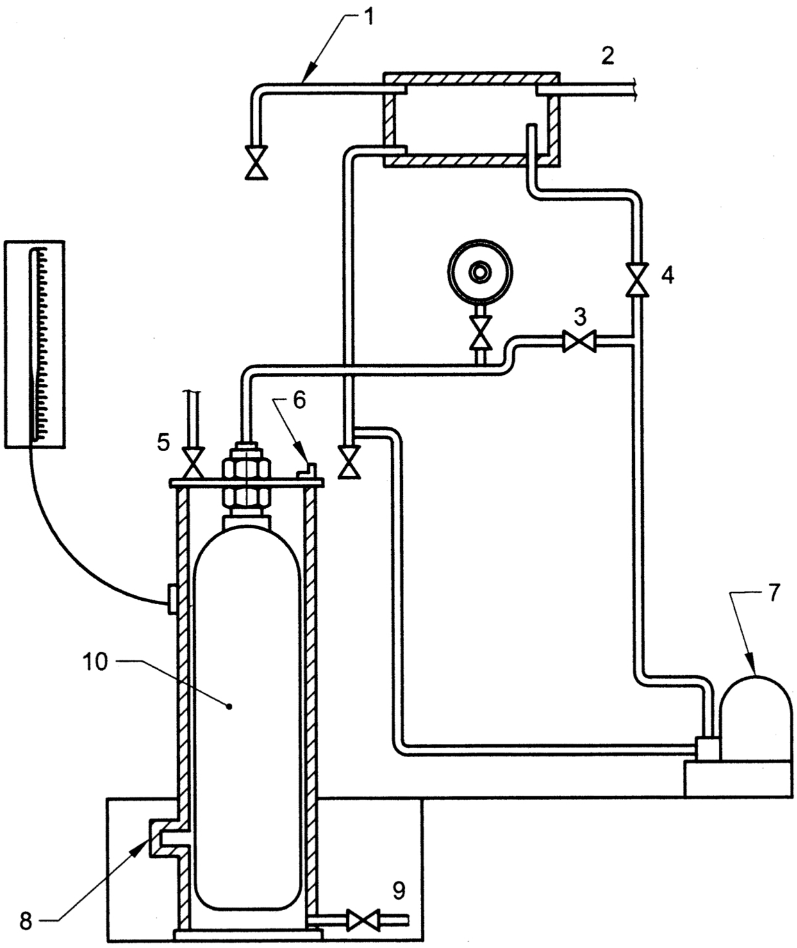
The test system may be operated either manually or may be computer controlled.



Key

1. Overflow
2. Water Supply
3. Hydraulic Line Valve
4. Priming Valve
5. Jacket Filling Valve
6. Air Bleed Valve
7. Pump
8. Relief Device
9. Drain
10. Test Cylinder
11. Fixed Frame
12. Pointer at Tached to Fixed Frame at Water Level
13. Clibrated Burrette Sliding in Fixed Frame

FIG. 1 WATER JACKET VOLUMETRIC EXPANSION TEST (LEVELLING BURETTE METHOD)



Key

1. Overflow
2. Water Supply
3. Hydraulic Line Valve
4. Priming Valve
5. Jacket Filling Valve
6. Air Bleed Valve
7. Pump
8. Relief Device
9. Drain
10. Test Cylinder

FIG. 2 WATER JACKET VOLUMETRIC EXPANSION TEST (FIXED BURETTE METHOD)

3.1.2 *Graduated Measuring Tube/Burette*

Graduated tube used for the measurement shall be of such diameter that a permanent change in volume of the cylinder of the order of 1/20 000 the cylinder water capacity may be readily observed. Also the length of the tube shall be such that its capacity exceeds the total volumetric expansion of the cylinder under test. The diameter of the tube shall be uniform and sufficiently small to permit an accurate reading of the total expansion and permanent expansion. A two stepped tube may be used.

Length of the tube shall be such that the zero reading and total expansion reading can be conveniently taken by the operator.

If weighing equipment is used for measurement of water volumes then the same should meet the above specifications in respect of capacity and accuracy of measurements.

3.1.3 *Pressure Gauge/Pressure Transducer*

Two working pressure gauges or a duplicate gauge shall be used and shall be capable of reading to within 1 percent of the test pressure for pressures up to and including 15 kgf/cm^2 and within 2 percent for pressures above 15 kgf/cm^2. They shall be tested at regular intervals and in any case at least once in a month, by master pressure gauge error not greater than 0.25 percent of full scale deflection.

3.1.4 *Weighing Scale*

Weighing scales shall be to an accuracy of 1 percent or 0.1 g, whichever is greater.

3.1.5 *Connections*

All connections shall be leak-tight and air-free that is, there shall not be air entrapped in the system. Hydraulic test pressure pipelines shall be capable of withstanding a pressure 1.5 times the maximum test pressure of any cylinder that may be tested.

3.1.6 *Precautions*

The pipe line between jacket and expansion measuring device shall be generously sized and sloped to avoid air entrapment and capillary action. Care shall be taken to prevent any leakage through the joint between the cylinder neck and the water jacket cover. Change of temperature of the water in the jacket during the test shall be avoided. Flexible hose shall be capable of withstanding the 1.5 times the maximum test pressure of the cylinder under test and shall not kink. Water used shall be bubble free. Piping shall be as short as possible and of as small a volume as practicable, but with large enough diameter so as to ensure correct readings of expansion. Pump shall be of sufficient capacity to build the required pressure in a reasonable period of time.

3.2 Levelling Burette Method

3.2.1 Fill the jacket with water.

3.2.2 Fill the cylinder with water and attach the water jacket cover to it.

3.2.3 Insert the cylinder in the jacket and clamp the cover to seal. Attach the pressure hose to the cylinder.

3.2.4 Fill the jacket allowing air to bleed off through the air bleed valve. Close the air bleed valve when water is coming out freely from it.

3.2.5 Adjust the zero level on the burette to the datum mark on the burette support stand. Adjust the height of the water to the burette zero level (C_1) by manipulation of the jacket filling valve and the drain valve.

3.2.6 Apply pressure in the cylinder to about two-third of the test pressure. Hold for some time. Confirm that there is no leakage and burette and pressure reading remains constant for 10-30 s.

3.2.7 Apply pressure in the cylinder till the test pressure is reached. Isolate the cylinder. Check that water level is stable for 30 s.

3.2.8 Lower the burette until the water level is at the datum mark on the burette support stand. Take the reading of the water level in the burette (C_2). This reading is the total expansion of the cylinder. Record it.

3.2.9 Release the pressure from the cylinder. Check that pressure is at zero and that the water level is stable.

3.2.10 Raise the burette until the water level is again at the datum line on the burette support stand.

3.2.11 Read the water level in the burette (C_3). This reading is the permanent expansion, if any, of the cylinder. Record it.

3.2.12 Check that the ratio of permanent expansion to the total expansion as determined by the following shall not exceed the percentage given in the design specification.

$$\frac{\text{Permanent expansion} \times 100}{\text{Total expansion}} = \text{Percentage ratio of permanent expansion}$$

3.3 Fixed Burette Method

3.3.1 Fill the cylinder with water and attach the water jacket cover to it.

3.3.2 Insert the cylinder in the jacket and clamp the cover to seal. Attach the pressure hose to the cylinder.

3.3.3 Fill the jacket allowing air to bleed off through the air bleed valve. Close the air bleed valve when water is coming out freely from it.

3.3.4 Adjust the water level to zero mark on the burette (C_1) by operating the jacket filling valve.

3.3.5 Apply pressure in the cylinder to about two-third of the test pressure. Hold for some time. Confirm that there is no leakage and burette and pressure reading remains constant for 30 s.

3.3.6 Apply pressure in the cylinder till the test pressure is reached. Isolate the cylinder. Check that water level is stable for 30 s.

3.3.7 Read the water level in the burette (C_2). This reading is the total expansion of the cylinder. Record it.

3.3.8 Release the pressure from the cylinder. Check that pressure is at zero and that the water level is stable.

3.3.9 Read the water level in the burette (C_3). This reading is the permanent expansion, if any, of the cylinder. Record it.

3.3.10 Check that the permanent expansion to the total expansion as determined by the following shall not exceed the percentage given in the design specification.

$$\frac{\text{Permanent expansion} \times 100}{\text{Total expansion}} = \text{percentage ratio of permanent expansion}$$

3.3.11 *Readings*

The difference between C_1 and C_2 represents the total volumetric expansion and that between C_1 and C_3 represents the permanent expansion.

3.4 Non-Water Jacket Method

3.4.1 *Apparatus*

It is also an acceptable hydrostatic stretch test method to determine the volumetric expansion of a cylinder. However, it has practical limitations in its use.

The general arrangement of apparatus for the test type is indicate in Fig. 3.

This method consists of measuring the amount of water passed into the cylinder under proof pressure, and on release of this pressure, measuring the water returned to the manometer. It is necessary to allow for the compressibility of water and the volume of the cylinder under test to obtain true volumetric expansion. No fall in pressure under this test is permitted.

Water used for test shall be clean and should not have air bubbles separating out during the complete test. Any leakage from the system or the presence of free dissolved air result in false readings.

The high pressure pipe line shall have working pressure greater than 1.5 times the cylinder test pressure.

3.4.2 *Graduated Tube/Weighing Equipment*

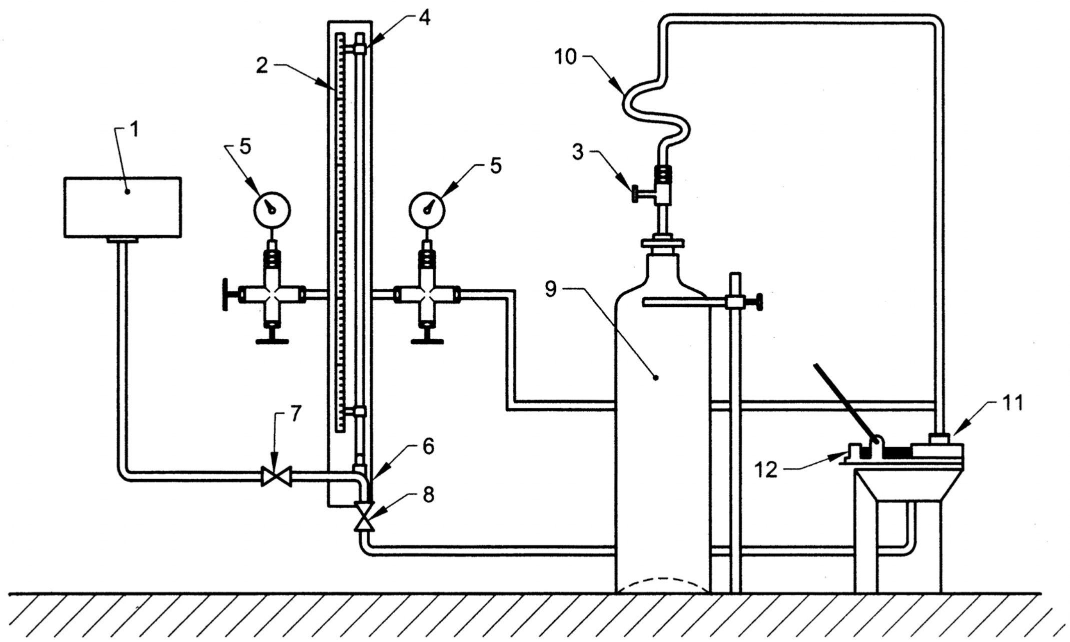
Graduated tube used for the measurement shall be of such diameter that a permanent change in volume of the cylinder of the order of 1/20 000 the cylinder water capacity may be readily observed. Also the length of the tube shall be such that its capacity exceeds the total volumetric expansion of the cylinder under test. The diameter of the tube shall be uniform and sufficiently small to permit an accurate reading of the total expansion and permanent expansion. A two stepped tube may be used.

Length of the tube shall be such that the zero reading and total expansion reading can be conveniently taken by the operator.

If weighing equipment is used for measurement of water volumes then the same should meet the above specifications in respect of capacity and accuracy of measurements.

3.4.3 *Pressure Gauge/Pressure Transducer*

Two working pressure gauges or a duplicate gauge shall be used and shall be capable of reading to within 1 percent of the test pressure for pressures up to and including 15 kgf/cm^2 and within 2 percent for pressures



Key

1. Water Tank	2. Glass Tube
3. Bleed Valve	4. Pointer
5. Pressure Gauge	6. Fixed Frame
7. Valve	8. Valve
9. Test Cylinder	10. Flexible Pipe
11. Valve	12. Pump

FIG. 3 NON-WATER JACKET VOLUMETRIC EXPANSION TEST

above 15 kgf/cm^2. Working pressure gauge and master pressure gauge shall be calibrated not exceeding 1 month and 6 months, respectively. Working pressure gauge error not greater than 1 percent of pressure, the test gauge shall have accuracy of ±0.5 percent.

3.4.4 *Weighing Scale*

Weighing scale error not greater than ±0.1 percent.

3.4.5 *Connections*

All connections shall be leak-tight and air-free that is there shall not be air entrapped in the system. Hydraulic test pressure pipeline shall be capable of withstanding a pressure 1.5 times the maximum test pressure of any cylinder that may be tested.

3.4.6 *Precautions*

Water used shall be air-free and the joints shall be leak-proof as far as possible. However, if necessary, care shall be taken to ensure that the quantity of water in the system is always constant by returning any water leaking past the joints to the system. Piping shall be as short as possible and of as small a volume as practicable. Piping shall be of bore large enough to convey the water without causing errors in PE readings. The routing of the piping shall ensure that there is no entrapment of air in the system. Pump shall be of sufficient capacity to build the required pressure in a reasonable period of time. Pump shall not suck air while operating.

3.4.7 *Procedure before Testing*

Before commencement of testing, ensure there is no entrapped air and the cylinder is fully filled with water.

3.4.8 *Method*

3.4.8.1 Ensure that the cylinder is thoroughly clean from inside and then do the tare weight (w_1).

3.4.8.2 Fill the cylinder with water and do the weight (w_2).

3.4.8.3 Determine mass of water in the cylinder ($m_1 = w_2 - w_1$).

3.4.8.4 Connect the cylinder to the hydraulic test pump by flexible hose.

3.4.8.5 Fill the pump and system with water from overhead tank.

3.4.8.6 Determine volume in the pipe line and pump (m_2).

3.4.8.7 Calculate total water volume/mass under compression, $m = m_1 + m_2$.

3.4.8.8 Ensure that there is no air in the system. This could be done by repeated pressurization and de-pressurization of the system at pressure below working pressure.

3.4.8.9 Fill the system until the water level in the glass tube is at appropriate level below the top of the glass tube. Close the overhead tank valve. Record the level (C_1).

3.4.8.10 Close the system level inlet valve and raise the pressure in the system until the pressure gauge(s) indicates the required test pressure. Stop the pump. Isolate the cylinder.

3.4.8.11 Maintain the pressure for 30 s. There should not be any change in either water level or pressure.

3.4.8.12 Record the fall of water level in the glass tube (C_2). The water drained from the glass tube shall have been pumped into the cylinder to achieve the desired test pressure.

NOTES

1 If the pump for developing pressure is only with single plunger, then while taking the C_1, C_2 and C_3 readings of water level in the burette, it should be ensured that the plunger of the pump is in the identical position. This is necessary to avoid errors in the readings.

2 For every test equipment volume in the pipe line and the pump, the volume in the high pressure water circuit — shall be calculated. At the time of carrying out all the calculations of compressibility compensation, this fixed volume must be added to the water capacity to find the water volume under compression.

3.4.8.13 The total volumetric expansion is the difference in water level C_1 and C_2, corrected by the compressibility of water which is given by equation in **3.4.9**.

3.4.8.14 Release the pressure from the cylinder and allow the water so released to return the glass tube. Record the water level in the glass tube (C_3).

3.4.8.15 The difference between C_1 and C_3 represents the permanent volumetric expansion without the necessity of correcting for the compressibility of water.

3.4.8.16 Note the temperature of water before filling in the cylinder.

3.4.9 *Calculation of Compressibility of Water*

The formula used for the calculation of the compressibility of water is:

$$C = \mathrm{mP}\,(K - 0.68\mathrm{P}/10^5)$$

where

- C = reduction in volume of water due to its compressibility, in cm^3;
- m = total mass of water under compression at test pressure, in kg;
- P = test pressure, in bar; and
- K = factor for individual temperatures as listed in Table 1.

3.4.10 Calculate the percentage ratio of permanent expansion to total expansion determined by the following shall not exceed the percentage given in the design specifications:

$$\frac{\text{Permanent expansion} \times 100}{\text{Total expansion}} = \text{percentage ratio of permanent expansion}$$

3.4.10.1 *Example calculation*

In the following example calculation, allowance for pipe stretch is not taken into account:

a) *Assumed Data*:
   1) Gauge pressure, P = 250 bar
   2) Mass of water in the cylinder at zero gauge pressure, (w_1) = 50 kg
   3) Temperature of water. t = 35°C

b) *Observed Data*:
   1) Mass of water in the pipe line and pump, (w_2) = 2 000 cm^3 = 2 kg
   2) Initial water level in tube before applying pressure in the cylinder, C_1 = 5 cm^3
   3) Water level in the tube after applying the pressure in the cylinder, C_2 = 782 cm^3
   4) Water forced into the cylinder to raise pressure to 250 bar, $A = C_2 - C_1$ = 782 – 5 cm^3 = 777 cm^3; m_2 = 0.777 kg
   5) Water level in the tube after depressurizing the cylinder, C_3 = 9.5 cm_3
   6) Water expelled from cylinder to depressurize, $B = C_2 - C_3$ = 782 – 9.5 cm^3 = 772.5 cm^3

Total mass of water under compression, $m_1 = w_1 + w_2$ = 50 + 2 kg = 52 kg

Total mass of water in cylinder at 250 bar, $m = m_1 + m_2$ = 52 + 0.777 = 52.777 kg

Permanent expansion, $PE = A - B$ = 777 – 777.2 = 4.5 cm^3

From Table 1, K factor for 35°C water temperature = 0.04513

From the formula, C = mP (k – 0.68P/10^5)

Reduction in volume of water due to compressibility at 250 bar and 35°C = 52.827 × 250 × (0.045 13 – 0.68 × 250/100 000) = 573.03 ml = 573.03 cm^3

Total volumetric expansion $TE = A - C$ = 777 – 573.03 = 203.97 ml = 203.97 cm^3

Permanent expansion, percently $= \dfrac{PE \times 100}{\text{Total volumetric expansion}} = \dfrac{4.5 \times 100}{203.97}$ = 2.21 percent

Table 1 'K' Factors for the Compressibility of Water
(*Clause* 3.4.9)

°C	*K*	°C	*K*	°C	*K*
6	0.049 15	21	0.046 43	36	0.045 19
7	0.048 86	22	0.046 33	37	0.045 13
8	0.048 60	23	0.046 23	38	0.045 08
9	0.048 34	24	0.046 13	39	0.045 03
10	0.048 12	25	0.046 04	40	0.044 98
11	0.047 92	26	0.045 94	41	0.044 94
12	0.047 75	27	0.045 85	42	0.044 90
13	0.047 59	28	0.045 76	43	0.044 87
14	0.047 42	29	0.045 68	44	0.044 84
15	0.047 25	30	0.045 60	45	0.044 81
16	0.047 10	31	0.045 52		
17	0.046 95	32	0.045 45		
18	0.046 80	33	0.045 38		
19	0.046 68	34	0.045 31		
20	0.046 54	35	0.045 25		

ANNEX A
(*Foreword*)

COMMITTEE COMPOSITION

Gas Cylinders Sectional Committee, MED 16

Organization	*Representative(s)*
Petroleum and Explosive Safety Organization, Nagpur	SHRI T. R. THOMAS (***Chairman***) SHRI D. K. GUPTA (*Alternate*)
All India Industrial Gases Manufacturers Association, New Delhi	SHRI SAKET TIKU SHRIMATI VEENA PETER (*Alternate*)
Bharat Petroleum Corporation Limited, Mumbai	SHRI J. VEDAGIRI SHRI SANJAY PHULLI (*Alternate*)
Bharat Pumps and Compressors Limited, Allahabad	SHRI MOHAN KUMAR SHRI P. G. CHOUDHURY (*Alternate*)
BOC India Limited, Kolkata	SHRI K. MANOHARAN SHRI RAMANA VUTUKURU (*Alternate*)
Everest Kanto Cylinder Limited, Mumbai	SHRI P. M. SAMVATSAR SHRI A. K. KHAMKAR (*Alternate*)
Hindustan Petroleum Corporation Limited, Mumbai	SHRI M. SELVAKUMAR SHRI ALOK KUMAR GUPTA (*Alternate*)
Indian Oil Corporation Limited, Mumbai	SHRI SHANKAR SHARAN SHRI S. M. RAMBHAL (*Alternate*)
Indraprastha Gas Limited, New Delhi	SHRI PRAVEEN K. PANDEY SHRI UJWAL BHANDARI (*Alternate*)
International Industrial Gases Limited, Kolkata	SHRI DEVENDRA K. GARG SHRI NIKHILESh K. GARG (*Alternate*)
Kabsons Gas Equipments Limited, Hyderabad	SHRI SATISH KABRA SHRI S. GOPALAIAH (*Alternate*)
Kosan Industries Limited, Surat	SHRI S. K. DEY SHRI S. B. BOMAL (*Alternate*)
LPG Equipment Research Centre, Bangalore	SHRI P. KRISHNAN KUTTY SHRIMATI KAROBI MUKHERJEE (*Alternate*)
Mahanagar Gas Limited, Mumbai	SHRI RAGHUNATH KULAI SHRI ARUN NAYAK (*Alternate*)
Maruti Koatsu Cylinders Limited, Mumbai	SHRI NITIN J. THAKKAR SHRI A. S. SARAN (*Alternate*)
Ministry of Defence (DGQA), Pune	SHRI J. P. TIWARI, SHRI K. SUDHAKARAN (*Alternate*)
Praxair India Limited, Bangalore	SHRI MILAN SARKAR SHRI ARINDAM DAS (*Alternate*)
Research and Development Establishment (Engineers), Pune	SHRI P. K. CHATTOPADHYAY SHRI A. BASU (*Alternate*)
Sakha Engineers Private Limited, New Delhi	SHRI AMARJIT S. KOHLI
SICGIL India Limited, Chennai	SHRI FAROOQUE DADABHOY SHRI R. PADMANABAN (*Alternate*)
Society of Indian Automobile Manufacturers (ARAI), New Delhi	SHRI K. K. GANDHI SHRI PANKAJ KUMAR KARN (*Alternate*)
Steel Authority of India Limited, Salem	SHRI M. PRABAKARAN SHRI N. K. VIJAYAVARGIA (*Alternate*)
Steel Authority of India Limited, Ranchi	SHRI DEBASHIS KARMAKAR DR B. K. JHA (*Alternate*)
Supreme Cylinders Limited, Delhi	SHRI M. L. FATHEPURIA
Tata Motors Limited, Pune	SHRI P. K. BANERJEE SHRI AMUL VERMA (*Alternate*)

Organization	*Representative*(*s*)
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