



Standard Test Method for Carbon Tetrachloride and Chloroform in Liquid Chlorine by Direct Injection (Gas Chromatographic Procedure)¹

This standard is issued under the fixed designation E 806; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method is designed for the determination of carbon tetrachloride (CCl_4) and chloroform (CHCl_3) in liquid chlorine. The lower limit of detection is dependent on the sample size and the instrument used; five ppm (w/w) is achievable.

1.2 Review the current material safety data sheet (MSDS) for detailed information concerning toxicity, first aid procedures, and safety precautions.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific hazards statements are given in Section 7 and in 9.2.3.

2. Referenced Documents

2.1 ASTM Standards:²

E 180 Practice for Determining the Precision of ASTM Methods for Analysis and Testing of Industrial and Specialty Chemicals

2.2 Federal Standard:³

49 CFR 173 Code of Federal Regulations Title 49 Transportation; Shippers' General Requirements for Shipments and Packagings, including Sections:

173.304 Charging of Cylinders with Liquefied Compressed Gas

173.314 Requirements for Compressed Gases in Tank Cars

173.315 Compressed Gases in Cargo Tanks and Portable Tank Containers

2.3 Other Document:

Chlorine Institute Pamphlet No. 77 Sampling Liquid Chlorine⁴

3. Summary of Test Method

3.1 A sample of liquid chlorine is injected into a gas chromatograph (GC), equipped with a column capable of separating CCl_4 and CHCl_3 from Cl_2 and other impurities, using a suitable syringe. The amounts of CCl_4 and CHCl_3 in the sample are determined by comparison of the areas of the peaks, obtained with the samples, to areas of peaks obtained with suitable calibration standards, under the same conditions.

4. Significance and Use

4.1 CCl_4 and CHCl_3 may be present in trace amounts in liquid chlorine. The use of chlorine to purify water would then transfer these compounds to the water. Therefore, when the concentrations of the CCl_4 and CHCl_3 in the liquid chlorine are known, the maximum amounts contributed to the water by the chlorine can be estimated.

5. Apparatus

5.1 *Gas Chromatograph*, equipped with:

5.1.1 *Injection Port*, must be lined with glass, Monel,⁵ or nickel; or column must be installed for on-column injection.

5.1.2 *Septa*, from Viton.⁶ Silicone septa may produce artifacts that may interfere with the analysis.

¹ This test method is under the jurisdiction of ASTM Committee E15 on Industrial and Specialty Chemicals and is the direct responsibility of Subcommittee E15.02 on Product Standards.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from the U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402.

⁴ Available from The Chlorine Institute Inc., 70 W. 40th St., New York, NY 10018.

⁵ Available from the International Nickel Company, Park 80 West, Plaza 2, Saddlebrook, NJ 07662.

⁶ Viton® septa can be prepared from Pierce No. 13235 Viton® hypo vial seals, available from the Pierce Chemical Co., Rockford, IL 61105. The septum is prepared by using a sharp blade to cut off the tip of the seal and then punching out a septum from the remaining flat disc. A cork borer or leather punch can be used to punch out the septum. Viton® septa are also available from Canton Bio-Medical Products, P.O. Box 2017, Boulder, CO 80302, Catalog No. V-101.

5.1.3 *Column, Column Materials, and Packing*, must be compatible with chlorine. Silanized supports and silanized glass wool must be avoided. Column must be able to separate Cl_2 , CCl_4 , and CHCl_3 . Columns that have been found to be suitable are:

5.1.3.1 *Nickel Tubing*, 10 ft by $\frac{1}{8}$ in. outside diameter, packed with 10 % sodium chloride solution on Porasil C (see Appendix X1 for packing preparation). This is the preferred packing.

5.1.3.2 *Polytetrafluoroethylene Tubing*, 10 ft by 2 mm inside diameter, packed with 20 % Kel-F[®] No. 10 oil on 60/80 mesh Chromosorb[®] W AW.

5.1.3.3 *Glass Tubing*, 10 ft by 2 mm inside diameter, packed with 20 % Halocarbon[®] 1025 on 60/80 mesh Chromosorb[®] W AW.

5.1.4 *Flame Ionization Detector*.

5.1.5 *Recorder*, compatible with the GC detector output.

5.1.6 *Electronic Integrator* (optional), compatible with the GC detector output.

5.2 *Balance*, capacity 5000 g, reading to ± 1 g.⁷

6. Reagents and Materials

6.1 *Purity of Reagents*—Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.⁸ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 *Chlorine*, liquid, with less than 10 ppm each of CCl_4 and CHCl_3 . This may be prepared by condensing the gaseous phase above regular production chlorine.⁹

6.3 *Carbon Tetrachloride*, reagent grade.⁹

6.4 *Chloroform*, reagent grade.⁹

6.5 *Sample Cylinder Assembly* (Fig. 1), consisting of:

6.5.1 *Sample Cylinders*¹⁰; nickel, Monel[®], or tantalum (Note 1), 400-mL capacity, double-ended, specially cleaned (Note 2).

6.5.2 *Valves*, having a packing resistant to liquid chlorine.¹¹

6.5.3 *Holder for a Septum*, that can be easily assembled.¹²

NOTE 1—Carbon or stainless steel cylinders and fittings are not suitable as CHCl_3 is unstable in the presence of FeCl_3 and Cl_2 .

NOTE 2—A procedure for cleaning cylinders and valves, for use with liquid chlorine, is given in Appendix X2.

⁷ A 400-mL nickel cylinder filled with liquid chlorine weighs about 4000 g.

⁸ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

⁹ This reagent is used for calibration purposes only.

¹⁰ If samples are to be shipped outside any plant, cylinders approved by the U.S. Department of Transportation must be used. DoT-approved (1979) nickel cylinders are available from Crown Controls, Inc., 388 Getty Ave., Clifton, NJ 07011, Hoke quotation SP78-12-26.

¹¹ Packing made from Teflon[®], Viton[®], or Kel-F[®] have been found suitable for this purpose.

¹² Swagelok[®] fittings have been found suitable for this purpose.

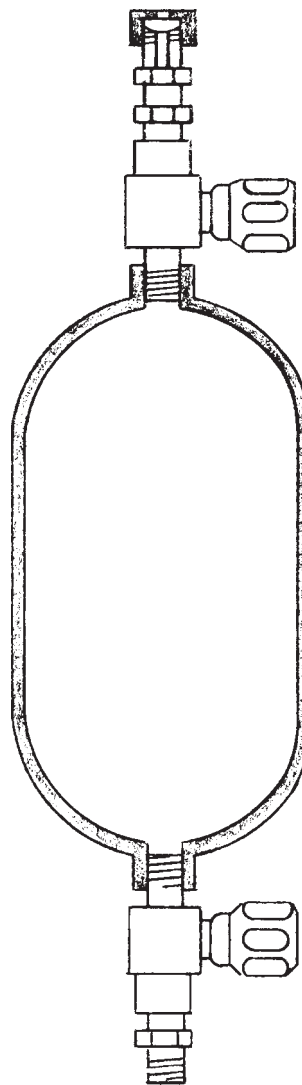


FIG. 1 Sample Cylinder Assembly

6.6 *Fittings*, for transferring chlorine from one cylinder to another.

6.7 *Syringe*, 10 to 100- μL , capable of holding liquid chlorine under pressure, with 26-gage disposable needle.¹³

NOTE 3—Disposable needles are recommended because corrosion with permanent needles may cause problems.

7. Hazards

7.1 Chlorine is a corrosive and toxic material. A well-ventilated fume hood should be used to house all test equipment, except the gas chromatograph, when this product is analyzed in the laboratory.

7.2 The analysis should be attempted only by persons who are thoroughly familiar with the handling of chlorine, and even an experienced person should not work alone. The operator

¹³ Two sources have been found to be suitable: Glenco Scientific Inc., 2802 Oak Drive, Houston, TX 77007, model 925-MV-2 micro valve and model KFL Luer lock adapter; and Precision Sampling Co., P.O. Box 15119, Baton Rouge, LA 70815, Pressure-Lok, series A.

must be provided with adequate eye protection and a respirator. Splashes of liquid chlorine destroy clothing and, if such clothing is next to the skin, will produce irritations and burns.

7.3 When sampling and working with chlorine out of doors, people downwind from such operation should be warned of the possible release of chlorine vapors.

7.4 It is recommended that means be available for disposal of excess chlorine in an environmentally safe and acceptable manner. If chlorine cannot be disposed of in a chlorine consuming process, a chlorine absorption system should be provided. When the analysis and sampling regimen requires an initial purging of chlorine from a container, the purged chlorine should be similarly handled. Purging to the atmosphere should be avoided.

7.5 In the event chlorine is inhaled, first aid should be summoned immediately and oxygen administered without delay.

8. Sampling

8.1 Sampling from tank cars, barges, storage tanks, and large cylinders presents unique problems. Each facility, however, must be capable of delivering a liquid sample (not gas) for test. Acceptable samples can be obtained by sampling in accordance with the Chlorine Institute Pamphlet No. 77.

8.2 Since the location of these larger facilities may not be at the immediate site of analysis, sample collection in a suitable secondary container is recommended to facilitate its safe transport to the laboratory for tests (DOT regulations may be applicable).

8.3 It is recommended that samples be collected from these facilities in small-size cylinders, with cylinders and valves fabricated of tantalum, monel, or nickel (carbon or stainless steel are unsuitable), and capable of being negotiated in the laboratory fume hood. Proper and safe sampling techniques must be followed. Do not allow the sample cylinder to become liquid full. A good rule is that the weight of the chlorine in the cylinder should not be more than 125 % of the weight of the water that the cylinder could contain. This rule is stated in accordance with 49 CFR 173.

9. Preparation of Standards for Calibration

9.1 Prepare standards in liquid chlorine, so that matrix effects of the chlorine on the gas chromatographic column and detector are compensated.

9.2 *Method of Additions*—Add CCl₄ and CHCl₃ to cylinder containing liquid chlorine as follows:

9.2.1 Obtain a supply cylinder of liquid chlorine that has less than 10 ppm each of CCl₄ and CHCl₃, and that contains at least 5000 g of chlorine. Label this cylinder No. 1.

9.2.2 Obtain a clean, evacuated, sample cylinder equipped with a septum on one of the valves. Label this cylinder No. 2 and weigh it to ± 1 g.

9.2.3 Connect cylinder No. 1 to cylinder No. 2 by means of fittings (6.6) such that the liquid phase of chlorine can flow from 1 to 2. Open the valves between the cylinders and cool cylinder No. 2 with ice. Liquid chlorine will be transferred from cylinder No. 1 to cylinder No. 2. Close the valves when sufficient chlorine has been transferred. Disconnect the cylinders and weigh cylinder No. 2 to ± 1 g to determine the weight

of chlorine transferred. (**Warning**—Do not allow cylinder No. 2 to become liquid full. A good rule is that the weight of chlorine in the cylinder should not be more than 125 % of the weight of water that the cylinder could contain.)

9.2.4 Retain cylinder No. 1 to prepare further standards.

9.2.5 Prepare an approximately 50/50 mix of CCl₄ and CHCl₃ and record amounts of each added. Calculate the volume of this mixture needed to prepare one level of standard for calibration, using a calculation similar to that given in 9.3.

9.2.6 Fill the high-pressure syringe (6.7) with approximately the volume of the CCl₄/CHCl₃ mixture as calculated in 9.3.3. Weigh the syringe plus liquid to ± 0.1 mg. Transfer the liquid mixture through the septum into the vapor space of cylinder No. 2. Keep a finger tightly over the plunger to prevent blow out. Immediately remove and reweigh the syringe to ± 0.1 mg. The difference between the two weights is the total weight of CCl₄ and CHCl₃ added.

9.2.7 Shake cylinder No. 2 to assure complete solution of the CCl₄ and CHCl₃ in the chlorine.

9.2.8 Calculate the added concentration of CCl₄ and CHCl₃ in the spiked standard as indicated in 9.4.

9.2.9 Prepare at least three standards containing three different levels of CCl₄ and CHCl₃, bracketing the expected level. Also, transfer some of the original chlorine into a sample cylinder without adding CCl₄ or CHCl₃.

9.2.10 The long term stability of the calibration standards has not been evaluated.

9.3 Example of amounts of CCl₄ and CHCl₃ to be added to liquid chlorine to produce desired standard:

9.3.1 Proposed mixture of CCl₄ and CHCl₃ (average density about 1.5 g/mL, or 1.5 mg/μL)

CCl ₄	47.55 g
CHCl ₃	44.40 g
Total	91.95 g

9.3.2 To prepare 500 g of chlorine with spiked levels of 20 ppm each of CCl₄ and CHCl₃ (total of 40 ppm), the necessary grams (*W*) of the CCl₄/CHCl₃ mixture is as follows:

$$\frac{W}{500} = \frac{40}{10^6} \tag{1}$$

or

$$W = 0.020 \text{ g} = 20 \text{ mg} \tag{2}$$

9.3.3 The necessary volume in μL (*V*) is then:

$$V = \frac{W}{\text{density}} = \frac{20}{1.5} = 13 \mu\text{L} \tag{3}$$

9.4 Example of calculation of spiked amounts of CCl₄ and CHCl₃ added:

9.4.1 The weight of mixture added is:

Initial syringe weight with 13 μL	17.6715g
Weight of syringe after transfer	17.6529g
CCl ₄ /CHCl ₃ added	0.0186g

9.4.2 The weight of cylinder No. 2:

Weight with chlorine	3575g
Weight empty	3088g
Weight of chlorine	487g

9.4.3 Weight of CCl₄ added:

$$(0.0186) \frac{47.55}{91.95} = 0.0096 \text{ g} \quad (4)$$

9.4.4 Concentration of CCl₄ in the spiked chlorine:

$$\frac{0.0096}{487} (10^6) = 19.7 \text{ ppm (w/w)} \quad (5)$$

9.4.5 Weight of CHCl₃ added:

$$(0.0186) \frac{44.40}{91.95} = 0.0090 \text{ g} \quad (6)$$

9.4.6 Concentration of CHCl₃ in the spiked chlorine:

$$\frac{0.0090}{487} (10^6) = 18.5 \text{ ppm (w/w)} \quad (7)$$

10. Chromatographic Conditions

10.1 Column—NaCl on Porasil:

10.1.1 Detector—Flame ionization.

10.1.2 Detector Temperature—150°C.

10.1.3 Carrier Gas—Nitrogen at 30 mL/min.

10.1.4 Column Temperature—Programmed, 60 to 200°C at 15°C/min.

10.1.5 Injector Temperature—90°C.

10.2 Column—Kel F on Chromosorb:

10.2.1 Detector—Flame ionization.

10.2.2 Detector Temperature—150°C.

10.2.3 Carrier Gas—Nitrogen at 30 mL/min.

10.2.4 Column Temperature—60°C.

10.2.5 Injector Temperature—75°C.

10.3 Column—Halocarbon on Chromosorb:

10.3.1 Detector—Flame ionization.

10.3.2 Detector Temperature—150°C.

10.3.3 Carrier Gas—Nitrogen at 30 mL/min.

10.3.4 Column Temperature—55°C.

10.3.5 Injector Temperature—90°C.

NOTE 4—The conditions listed have produced acceptable results. These parameters serve only as a guide in optimizing conditions for the column used.

11. Preparation of Calibration Curve

11.1 Obtaining Sample from Cylinders Containing Calibration Standards:

11.1.1 Invert the cylinder and open the sampling valve so that there will be liquid chlorine at the septum.

11.1.2 With the plunger in place, close the syringe valve and insert the needle of the syringe through the septum into the sample cylinder.

11.1.3 Open the syringe valve and withdraw a 10-μL sample of liquid chlorine (Note 5). It may be necessary to pump the plunger several times to eliminate bubbles from the sample. Keep a finger tightly over the plunger to prevent blowout. Close the syringe valve and withdraw the syringe from the septum. For best results, the sample cylinder and syringe should be at the same temperature.

NOTE 5—Since chlorine reduces the response of flame ionization detectors to CCl₄ and CHCl₃, and since the effect varies with detectors, better results may be obtained with some gas chromatographs using a sample size other than 10 μL. A smaller sample size may, in fact, result in greater sensitivity. However, precision may suffer from variations in sample size injections with smaller samples.

11.2 Procedure:

11.2.1 Adjust the gas chromatograph to the optimum conditions for the system.

11.2.2 Insert the needle of the syringe containing the sample through the septum on the gas chromatograph. Open the syringe valve and depress the plunger to transfer all the chlorine in the syringe into the gas chromatograph. Close the syringe valve and withdraw the needle from the system.

11.2.3 Measure the areas of the peaks for the CCl₄ (retention time about 5 min with Porasil C/NaCl) and for the CHCl₃ (retention time about 6 min with Porasil C/NaCl).

11.2.4 Inject at least three samples of the same material for replicates and average those which agree within the values as given in Table 1.

NOTE 6—Several injections may be required initially to condition the column and detector before reproducible results can be obtained.

11.2.5 Repeat the injections and measurements for all the spiked samples (at least three) and for the original, unspiked chlorine.

11.3 Plotting Calibration Curve:

11.3.1 Plot the ppm of CCl₄ injected (based on calculations of 9.4) for each spiked sample versus the net peak area for that sample (area of the peak of the spiked sample minus the area of the peak of the original, unspiked chlorine).

11.3.2 Repeat for all spiked samples of CCl₄ and draw in the best curve, for the points entered—curve should go through the origin.

11.3.3 Do the same for all spiked samples of CHCl₃ and draw the curve.

TABLE 1 Precision Values

Level, ppm	Repeatability			Laboratory Precision			Reproducibility		
	Standard Deviation, ppm	Degrees of Freedom	95 % Limit, ppm	Standard Deviation, ppm	Degrees of Freedom	95 % Limit, ppm	Standard Deviation, ppm	Degrees of Freedom	95 % Limit, ppm
Carbon Tetrachloride (CCl ₄)									
9	0.8	44	2	1.9	11	5	5.3	10	15
62	3.9	40	11	4.6	10	13	10.4	9	29
149	6.8	44	19	7.7	11	21	21.4	10	60
Chloroform (CHCl ₃)									
10	1.1	44	3	0.94	11	3	2.7	10	8
48	2.4	44	7	1.5	11	4	8.1	10	23
122	7.1	48	20	4.5	12	13	13.3	11	37

12. Procedure

12.1 Transfer a sample of the chlorine to be analyzed into a sample cylinder containing a septum on one of the valves, using the technique described above for transferring the chlorine for calibration (9.2.3).

12.2 Take a sample from the sample cylinder containing the chlorine that is to be analyzed by means of a high-pressure syringe, as described above under preparation of calibration curve (11.1). This sample volume must be *exactly the same* as that used for preparing the calibration curves.

12.3 Inject the sample into the conditioned gas chromatograph, as described above under preparation of calibration curve (11.2.2). Measure the areas of the peaks for the CCl_4 and CHCl_3 . Repeat with at least three replicates until the replicates are as given in Table 1. Average the areas obtained for each.

12.4 From the calibration curves, determine the ppm of CCl_4 and CHCl_3 present in the sample.

13. Report

13.1 Report the average CCl_4 and CHCl_3 contents to the nearest whole ppm.

14. Precision and Bias

14.1 The following criteria should be used in judging the acceptability of results (Note 7):

14.1.1 *Repeatability (Single Analyst)*—The standard deviation for a single determination has been estimated to be the values in Table 1. The 95 % limit for the difference between two such averages is given in Table 1.

14.1.2 *Laboratory Precision (Within-Laboratory, Between-Days Variability, Formerly Called Repeatability)*—The standard deviation of results (each the average of triplicates), obtained by the same analyst on different days, has been estimated to be the value shown in Table 1. The 95 % limit for the difference between two such averages is also given in Table 1.

14.1.3 *Reproducibility (Multilaboratory)*—The standard deviation of results (each the average of triplicates), obtained by analysts in different laboratories, has been estimated at the values in Table 1. The 95 % limit for the difference between two such averages is given in Table 1.

NOTE 7—These precision statements are based on an interlaboratory study performed in 1979–1980 on three samples of liquid chlorine, containing approximately 9, 62, and 149 ppm of CCl_4 and 10, 48, and 122 ppm of CHCl_3 . One analyst in each of 13 laboratories performed three replicate determinations and repeated on a second day, for a total of 468 determinations.¹⁴ Practice E 180 was used in developing these precision estimates.

14.2 *Bias*—The bias of this test method has not been determined due to the unavailability of suitable reference materials.

15. Keywords

15.1 analysis; carbon tetrachloride; chlorine; chloroform; gas chromatography; liquid injection

¹⁴ Supporting data are available from ASTM Headquarters. Request RR: E15-1030.

APPENDICES

(Nonmandatory Information)

X1. PREPARATION OF PORASIL/NaCl COLUMN PACKING

X1.1 Preparation of Inert Phase

X1.1.1 Weigh 10 g of Porasil C (80/100 mesh) into a 50-mL porcelain evaporating dish. Place the dish containing the Porasil in a muffle furnace at 600°C for 2 min.

NOTE X1.1—Porasil C is believed to contain some organic material as evidenced by charring as the material is heated at high temperatures. While no columns have been prepared using the material without heating, such a heat process may not be necessary. However, it is believed that removing this material would remove the possibility that chlorine might react to form a chlorinated hydrocarbon.

X1.1.2 Remove the dish from the furnace and stir the Porasil thoroughly with a porcelain spatula; then place the dish in the 600°C furnace for another 2 min.

X1.1.3 Repeat the above steps until the carbonaceous material is burned off as indicated by the absence of a grey discoloration. The total time in the furnace must not exceed 10 min. Allow the Porasil to cool to room temperature.

NOTE X1.2—Excessive heating results in a failure of the column to separate methylene chloride and carbon tetrachloride.

X1.2 Loading the Inert Material

X1.2.1 Transfer the 10 g of Porasil C packing to the flask of a rotary evaporation apparatus.

NOTE X1.3—A rotary evaporator is called for in this procedure because superior columns are obtained using this equipment; however, acceptable columns are obtained by evaporation from an evaporating dish.

X1.2.2 Add 1.0 g of NaCl and 50 mL of water and connect the flask to the evaporator.

X1.2.3 Using vacuum and heat, evaporate the water over a 2-h period.

X1.2.4 After the water has evaporated, transfer the mixture to an oven and dry overnight at 110°C.

X1.3 Preparing the Column

X1.3.1 Pack a 1/8-in. by 10-ft nickel column with the prepared mixture in the conventional manner.

X1.3.2 Place the column in the gas chromatograph and condition the column overnight at 200°C.

X2. PROCEDURE FOR CLEANING CYLINDERS AND VALVES

X2.1 Summary

X2.1.1 The cleaning process should remove any material that would react with chlorine to form chlorinated hydrocarbons and any material that would convert one chlorinated hydrocarbon to another.

X2.2 New Cylinders and Valves

X2.2.1 Remove the valves from the cylinder and wash both the cylinder and valves with a degreasing solvent, such as methylene chloride, to remove oils that may have been deposited during manufacture. Allow the cylinder and valves to dry in air.

X2.2.2 Replace the valves on the cylinders using polytetrafluoroethylene tape around all pipe threads.

X2.2.3 Charge the cylinder with about one half its capacity of liquid chlorine and shake the cylinder thoroughly to allow any residual material that might react to do so.

X2.2.4 After at least 30 min, drain the cylinder of its contents and purge the cylinder thoroughly with dry air.

X2.3 Cylinders Previously in Chlorine Service

X2.3.1 Drain the contents of the cylinder and purge thoroughly with dry air.

X2.3.2 Remove the valves and examine them closely to verify their integrity.

X2.3.3 Wash the valves and interior of the cylinder thoroughly with hydrochloric acid (1 + 1) to dissolve any salts that might have formed. Rinse several times with distilled water.

X2.3.4 Allow the parts to dry in the air and replace the valves on the cylinder using polytetrafluoroethylene tape around all pipe threads. Do not use solvents such as acetone to aid in drying.

X2.4 Cylinders Previously in Other Services

X2.4.1 Drain the contents of the cylinder and purge thoroughly with dry air.

X2.4.2 Remove the valves and examine them closely to verify their integrity.

X2.4.3 Wash the valves and cylinder with a degreasing solvent such as methylene chloride, and allow to dry in air.

X2.4.4 Wash the valves and interior of the cylinder thoroughly with hydrochloric acid (1 + 1) to dissolve any salts that might have formed. Rinse several times with distilled water.

X2.4.5 Allow the parts to dry in the air and replace the valves on the cylinder using polytetrafluoroethylene tape around all pipe threads. Do not use solvents such as acetone to aid in drying.

X2.4.6 Charge the cylinder with about one half its capacity of liquid chlorine and shake the cylinder thoroughly to allow any residual material that might react to do so.

X2.4.7 After at least 30 min, drain the cylinder of its contents and purge the cylinder thoroughly with dry air.

NOTE X2.1—For laboratories that have the facilities, steam cleaning has been found to be very effective in removing oil and salt deposits from cylinders.

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