The American Society of
Mechanical Engineers

A N   A M E R I C A N   N A T I O N A L   S T A N D A R D

PERFORMANCE REQUIREMENTS FOR BACKFLOW PROTECTION DEVICES AND SYSTEMS IN PLUMBING FIXTURE FITTINGS

ASME A112.18.3-2002

(Revision of ASME A112.18.3M-1996)

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our dear friend, colleague, and long-standing industry leader,
Thomas P. Konen. His contributions to the plumbing industry at large and to this committee will never be forgotten.

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FOREWORD

In November 1987, Panel 18 of the ASME Committee A112, Plumbing Materials and Equipment, initiated work to develop requirements for the protection against back pressure backflow and back siphonage in an emerging class of fittings, wherein the spout and side spray were combined for efficient use and operation. The increased concern for the protection of drinking water encouraged the Committee to look beyond traditional protection methods and develop a performance standard which excludes the contamination of potable water but gives needed freedom to manufacturers to produce fittings of complex design and construction as demanded by today's worldwide markets.

While the probability of occurrence associated with the contamination of potable water through backflow at various plumbing fixture fittings is minimal, there remains a need for a protection system. This Standard establishes performance requirements with specific criteria for acceptance, to ensure a high degree of reliability for the safety system throughout the useful life of the fitting.

[redacted]

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A112 PROJECT TEAM 18.3 — BACKFLOW DEVICES

R. H. Ackroyd, *Project Team Leader,* Rand Engineering
J. A. Ballanco, JB Engineering & Consulting
S. L. Cavanaugh, United Association
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Table 1 Acceptance Sampling Plan — Devices

Cumulative Sample Size (Specimens)	Failures Allowed
7	0
10	1
13	2
17	3

6 GENERAL REQUIREMENTS FOR BACKFLOW PREVENTION DEVICES

6.1 Functional

Backflow prevention devices shall be designed to prevent pollution and contamination of the potable water system.

6.2 Materials

Materials in contact with potable water shall comply with the requirements of ASME A112.18.1M.

6.3 Environment

6.3.1 Working Pressure. Backflow prevention devices shall be designed to function at water working pressures up to 125 psig (861 kPa gage).

6.3.2 Working Temperature. Backflow prevention devices shall be designed to function at water supply temperatures ranging from 40°F to 160°F (4.4°C to 71°C).

6.4 Reliability

Backflow prevention devices shall be resistant to mechanical wear, deposition of minerals, aging, and corrosion of the materials as determined by the test procedure of para. 7. The manufacturer shall establish the reliability of the individual backflow prevention device, and it shall be confirmed by durability tests in accordance with para. 7.

7 EVALUATION OF BACKFLOW PREVENTION DEVICES

7.1 Sample Size

The minimum initial sample size per set shall be seven specimens. The incremental increases and cumulative sample sizes shall be as shown in Table 1.

7.2 Test Methodology

7.2.1 Facilities. The backflow prevention devices shall be tested individually in fittings or test fixtures representing the dimensions and tolerances specified by the device manufacturer.

7.2.2 Protocol. The functional performance of the device shall be determined before and after the durability test sequence. The functional performance of a device shall be determined in accordance with para. 11. The durability test sequence for a device shall be conducted in accordance with para. 15. The process for evaluation of backflow prevention devices is illustrated in Fig. 1.

Two sample sets, each consisting of a minimum of seven specimens, shall be evaluated for durability by tests defined in para. 15. At the start of the evaluation, both sets samples shall be tested for functional performance (para. 11). Thereafter, one sample set shall be tested for mechanical wear and mineral deposition (para. 15.2), and the second sample set shall be tested for aging and corrosion (para. 15.1). When retested, there shall be a maximum of three incremental increases.

7.3 Conformance

Any physical damage to internal devices known to preclude functional performance shall be cause for rejection. The allowable failures shall not exceed the values shown in Table 1.

8 FIXTURE FITTINGS WITH INTERNAL DEVICES COMPLYING WITH PARAS. 6 AND 7

The purpose of this paragraph is to define the requirements and test procedures for the evaluation of finished products incorporating certified backflow protection devices which have been demonstrated to be in compliance with paras. 6 and 7 of this Standard.

8.1 Health and Safety

8.1.1 There shall be at least two backflow prevention devices, in series proven by tests as in compliance with para. 7 of this Standard. They shall operate independently as integral parts of the fixture fitting. At least one device shall be a check valve, called the primary check in this Standard.

Among the protection devices are

(a) check valves
(b) vents to air
(c) vacuum breakers
(d) automatic diverters

8.1.2 Contaminants shall not enter the potable water system through backflow nor shall contaminants be allowed to enter the fitting beyond the first barrier when the backflow preventer is operating properly. The test shall be in accordance with para. 12.

8.1.3 The manufacturer shall specify the type and location of the backflow protection system in the product literature or in the installation instructions.

8.2 Performance Tests

8.2.1 Selection of Test Specimens. To comply with this Standard, two specimens will be selected at random from a lot of five production fittings. Before mounting the fixture fittings in the test rig, correct installation of

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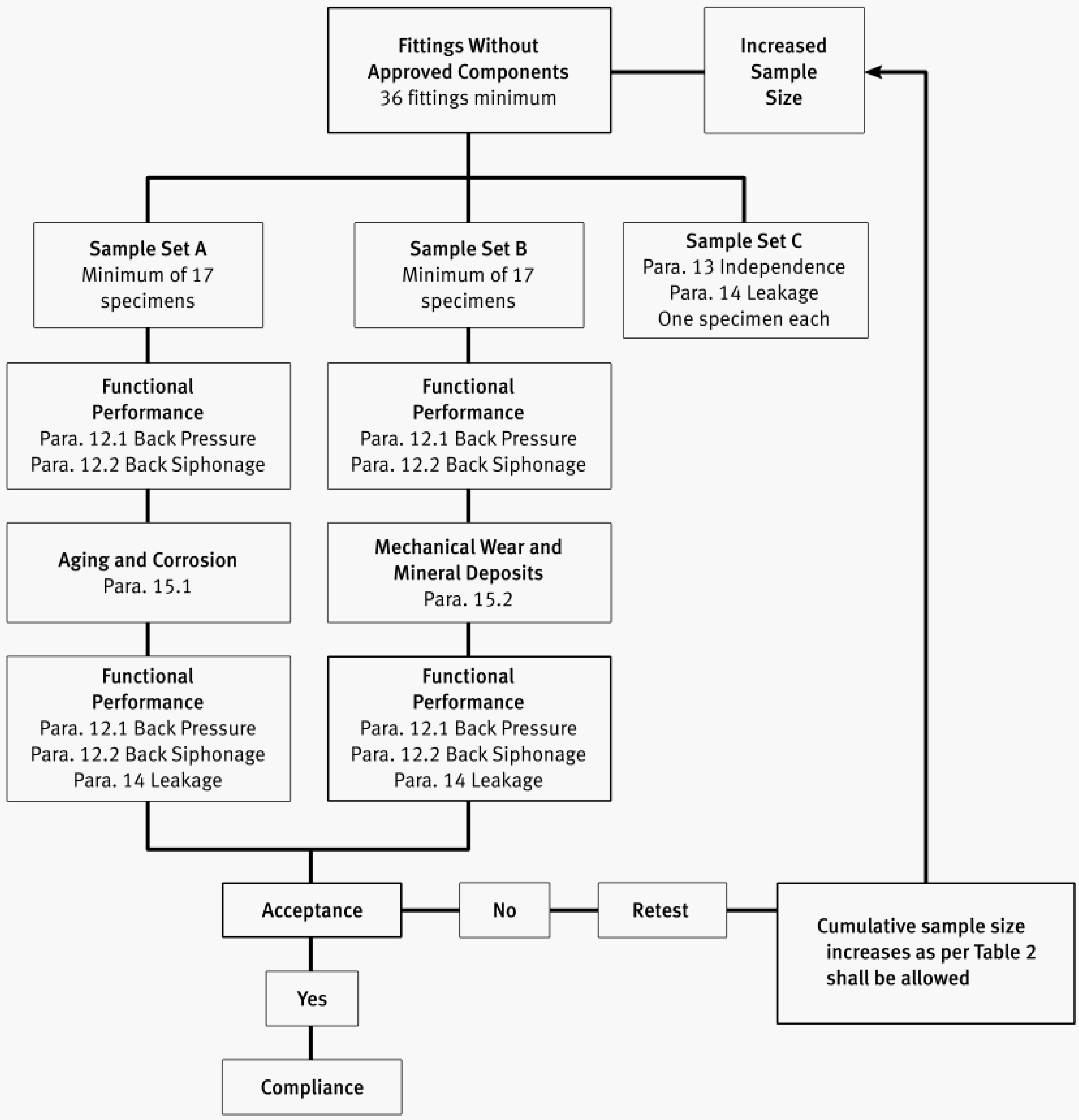


Fig. 2 Test Protocol for Fittings Without Approved Components

maximum opening pressure, the minimum flow rate at 25 in. Hg (84 kPa gage), and the corresponding pressure drop (vacuum gauge reading).

An increase in pressure drop or reduction in air flow rate larger than 20% after completion of the durability tests shall be cause for rejection.

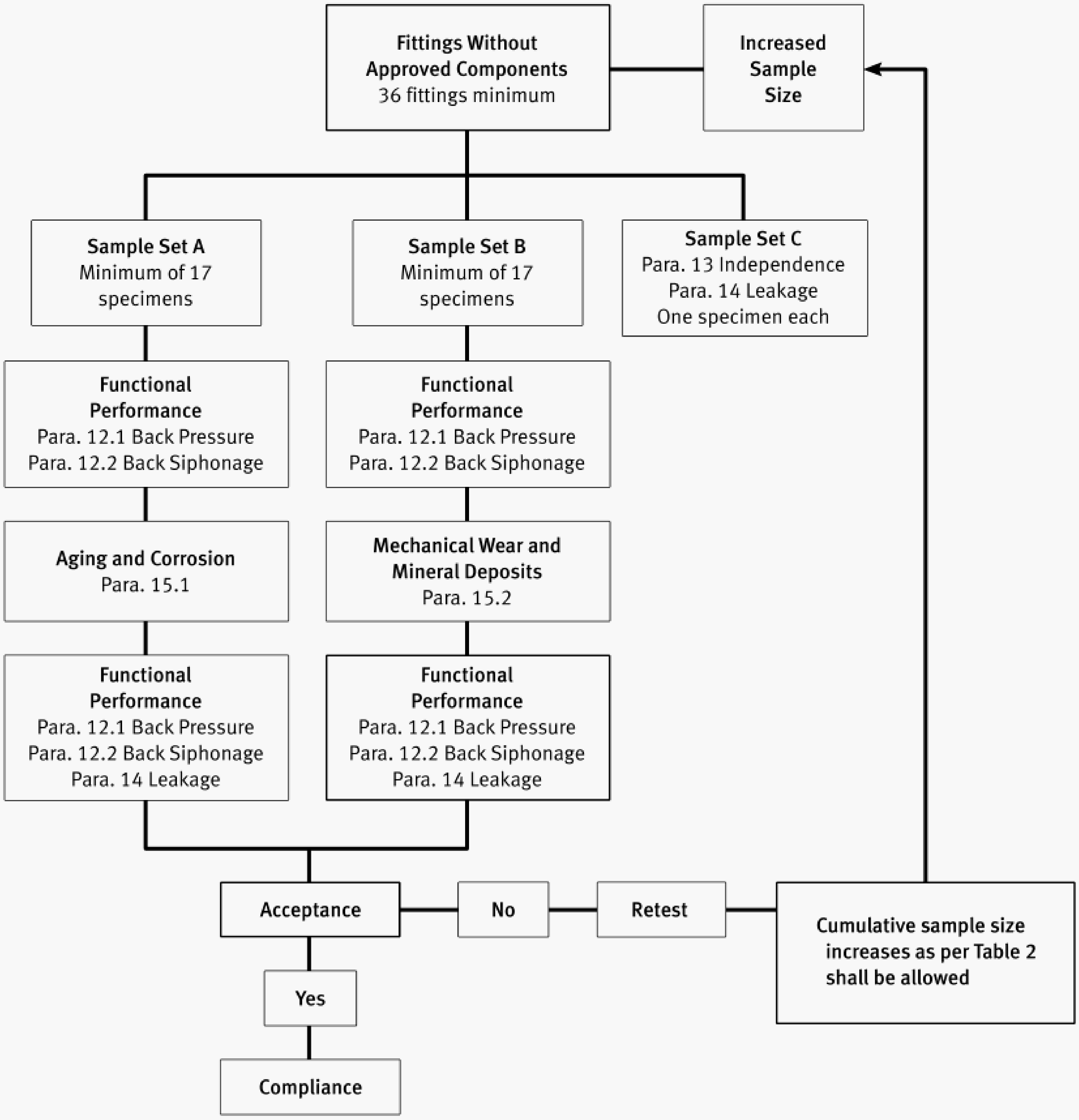
12 FUNCTIONAL TEST OF BACKFLOW PREVENTION SYSTEMS

12.1 Back Pressure

Mount the fixture fitting as received from the manufacturer in its normal position in accordance with the installation instructions. Connect the inlet pipes collectively to a water supply capable of delivering water through each device at a flow of 1.0 gpm to 2.0 gpm (0.063 L/s to 0.126 L/s) to a vacuum system capable of maintaining a vacuum from 0 in. Hg to 25 in. Hg (0 kPa gage to 84 kPa gage). See Fig. 5.

Connect a ½ in. minimum inside diameter transparent sight glass in a leakproof manner to the hose connected outlet. Open Valve 1 with Valve 2 and Valve 3 closed and flush the fitting to purge air from it. Close Valve 1. Adjust the water level in the sight glass to be ½ in. (13 mm) above the highest level of the fitting. Open Valve 2. Observe the level of water in the sight glass for a 5 min period as an indication of leakage. Raise and hold the hose outlet for 5 min at its maximum vertical extension. Inspect for leakage.

There shall be no leakage.



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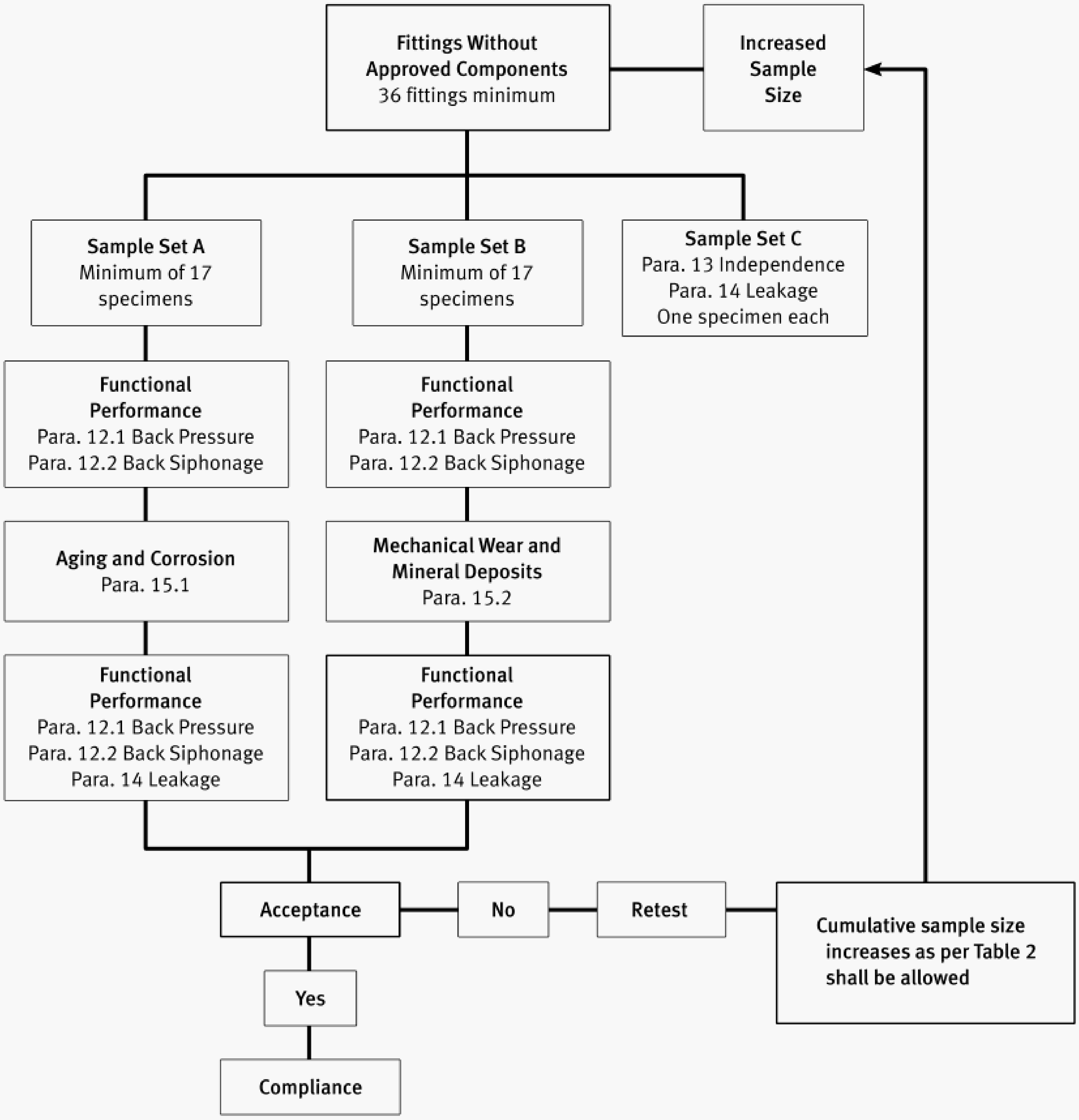

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Connect a $\frac{1}{2}$ in. minimum inside diameter transparent sight glass in a leakproof manner to the hose connected outlet. Open Valve 1 with Valve 2 and Valve 3 closed and flush the fitting to purge air from it. Close Valve 1. Adjust the water level in the sight glass to be $\frac{1}{2}$ in. (13 mm) above the highest level of the fitting. Open Valve 2. Observe the level of water in the sight glass for a 5 min period as an indication of leakage. Raise and hold the hose outlet for 5 min at its maximum vertical extension. Inspect for leakage.

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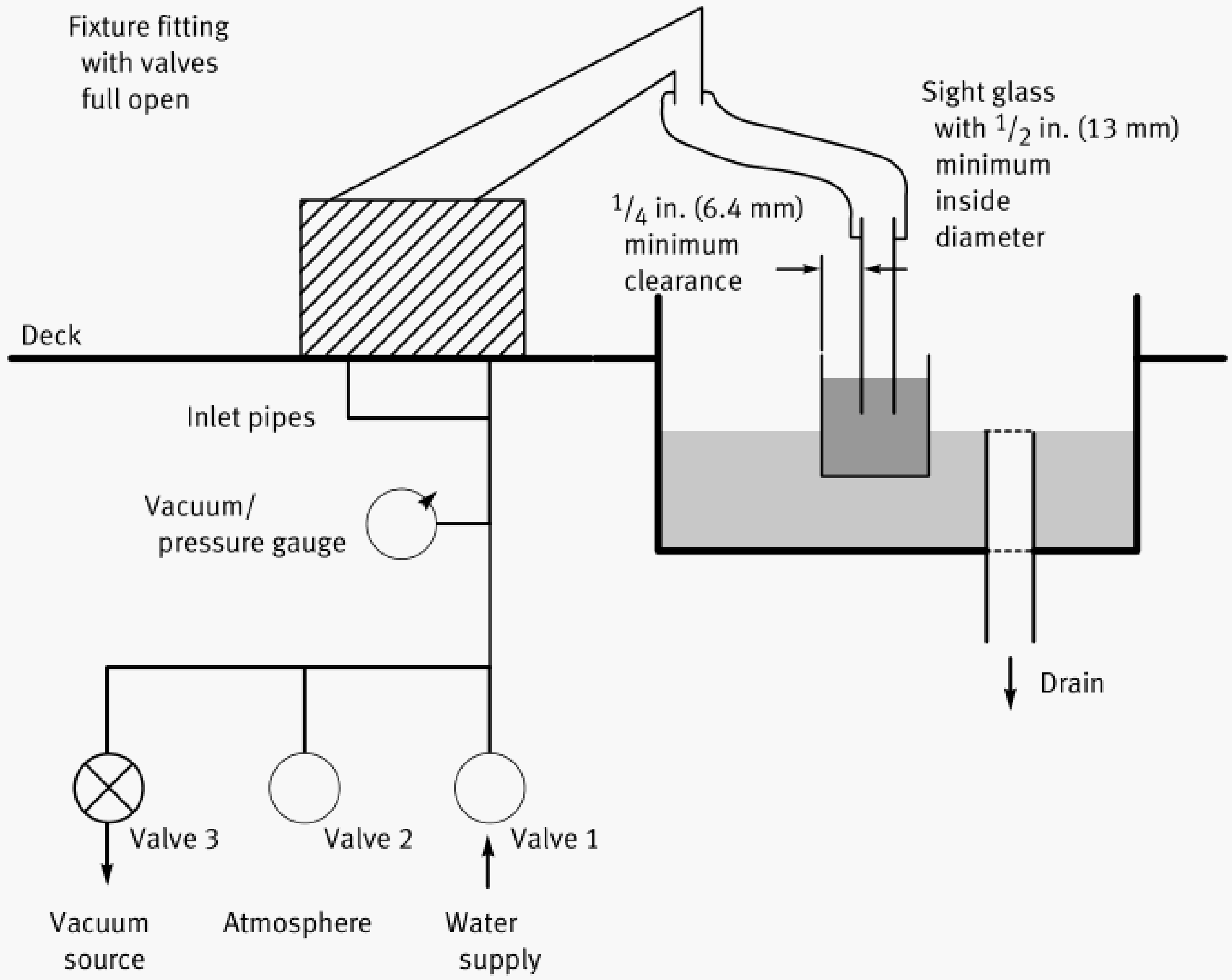

Fig. 6 Functional Performance of Backflow Prevention Systems With Regard to Back Siphonage (Hose Connected Movable Outlet Faucets)

During these periods the supply valve of the test rig or the fitting shall be closed.

Where a vacuum breaker or atmospheric vent is under test, the ambient air temperature to it shall be between 110°F and 115°F (43.3°C and 46.1°C).

Temperature changes encountered in everyday practice shall be simulated by periodically cycling the water supply from hot to cold as described below. Where complete fittings are used, their water supply inlets shall be interconnected, so that hot or cold water flows into the fitting through both inlets.

Further conditions:

Hot water temperature	140°F ± 5°F (60°C ± 3°C)
Cold water temperature	65°F ± 10°F (18.5°C ± 5.5°C)
Period of hot water flow	5 min ± 20 sec
Period of cold water flow	15 min ± 20 sec
Flow pressure	50 psig ± 5 psig (345 kPa gage ± 34 kPa gage)
Water hardness	200 ppm to 270 ppm $CaCO_3$
Saturation index (Langelier)	0.2 to 0.3

The saturation index shall be determined based on values of the parameters measured at the discharge of the water from the devices on test. The pk[1] value shall be based on calcite. The procedure shall be in accordance with Section 2330 of AWWA 10079. The index shall be determined at least once during each 10,000 cycles throughout the test.

The formulation of the test water is given in Table 3. A schematic drawing of the facility is given in Fig. 7.

[1] AWWA 10079, The Standard Methods for the Examination of Water and Wastewater, provides the method for determing the Calcium Carbonate Saturation Index. K is the solubility product constant for $CaCO_3$ at water temperature. The p designates –log10. Calcite is one of several forms of $CaCO_3$ that form in aqueous systems. A table in AWWA 10079 gives values for pK. Note that an upper case K is used in denoting pK.

Table 3 Formulation for ASME A112.18.3 Water

Chemical	Molecular Weight	Weight in DI Water g/50 gal	Weight in DI Water mg/L
$MgSO_4 \cdot 7H_2O$	246.5	28.62	151.21
$MgCl_2 \cdot 6H_2O$	203.8	5.19	27.42
$Ca(NO_3)_2 \cdot 4H_2O$	244.7	0.14	0.074
$CaCl_2 \cdot 6H_2O$	219.1	36.89	194.9
$Ca(OH)_2$	74.1	12.25	64.72
K_2SO_4	174.3	1.16	6.13
$NaHCO_3$	84.0	3.12	16.48

GENERAL NOTES:
(a) Total Hardness = 250 mg/L as $CaCO_3$.
(b) Dissolve $Ca(OH)_2$ separately in 20 gal of DI water by bubbling CO_2; if necessary add tiny amounts of 0.1N HCl. Combine this with 30 gal of DI water containing the remaining chemicals.
(c) All the chemicals are available from laboratory supply houses (e.g., Fischer Scientific).
(d) Source: Stevens Institute of Technology, May 28, 1998.

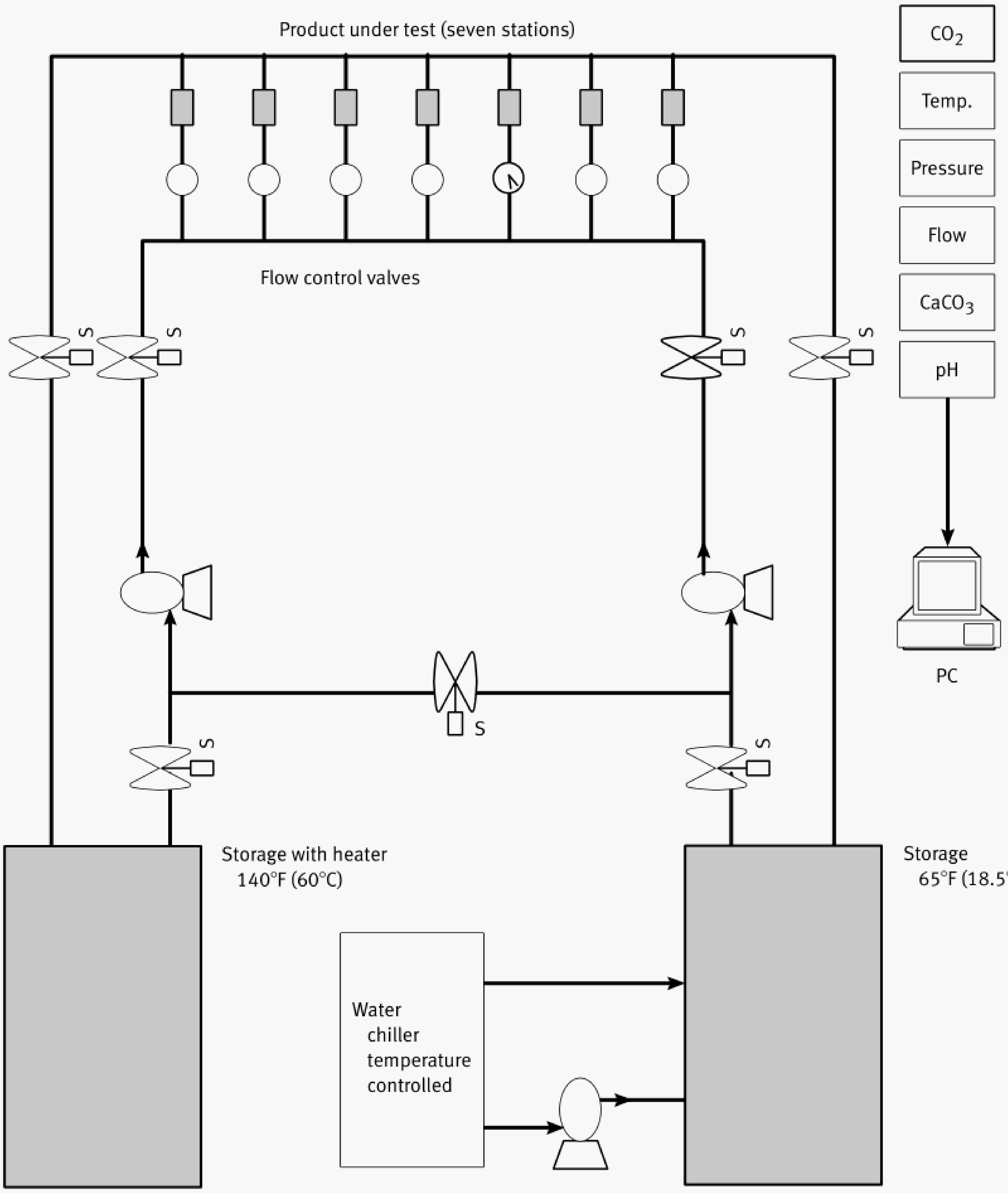

Fig. 7 Schematic Drawing of Test Facility

15.3 Inspection and Evaluation

At the conclusion of the durability tests, the device or the system shall be tested for functional performance in accordance with para. 11, 12, or 14, whichever is applicable, and against the criteria in para. 7.3.

16 VERIFICATION OF CRITICAL LEVEL [HOSE CONNECTED MOVABLE OUTLET FAUCETS WITH ATMOSPHERIC VENTS, PARAS. 8.1.1(B), (C), AND (D)]

The laboratory shall confirm the critical level.

Mount the fixture fitting in a test facility as shown in Fig. 8. Remove all check valves or block them full open. Open the fitting control valve, and place the moveable outlet in its pullout position. Connect a transparent flexible hose [1] and reservoir [2] to the fitting outlet in a leakproof manner. Adjust the fitting to deliver water at full flow with the valve or valves postioned to deliver an equal mix from each side. Flow water through the fitting until it is completely full of water and purged of any air. Fill the reservoir with water such that level [A] is below the manufacturer's specified critical level. Disconnect the inlets from the supplies and allow water

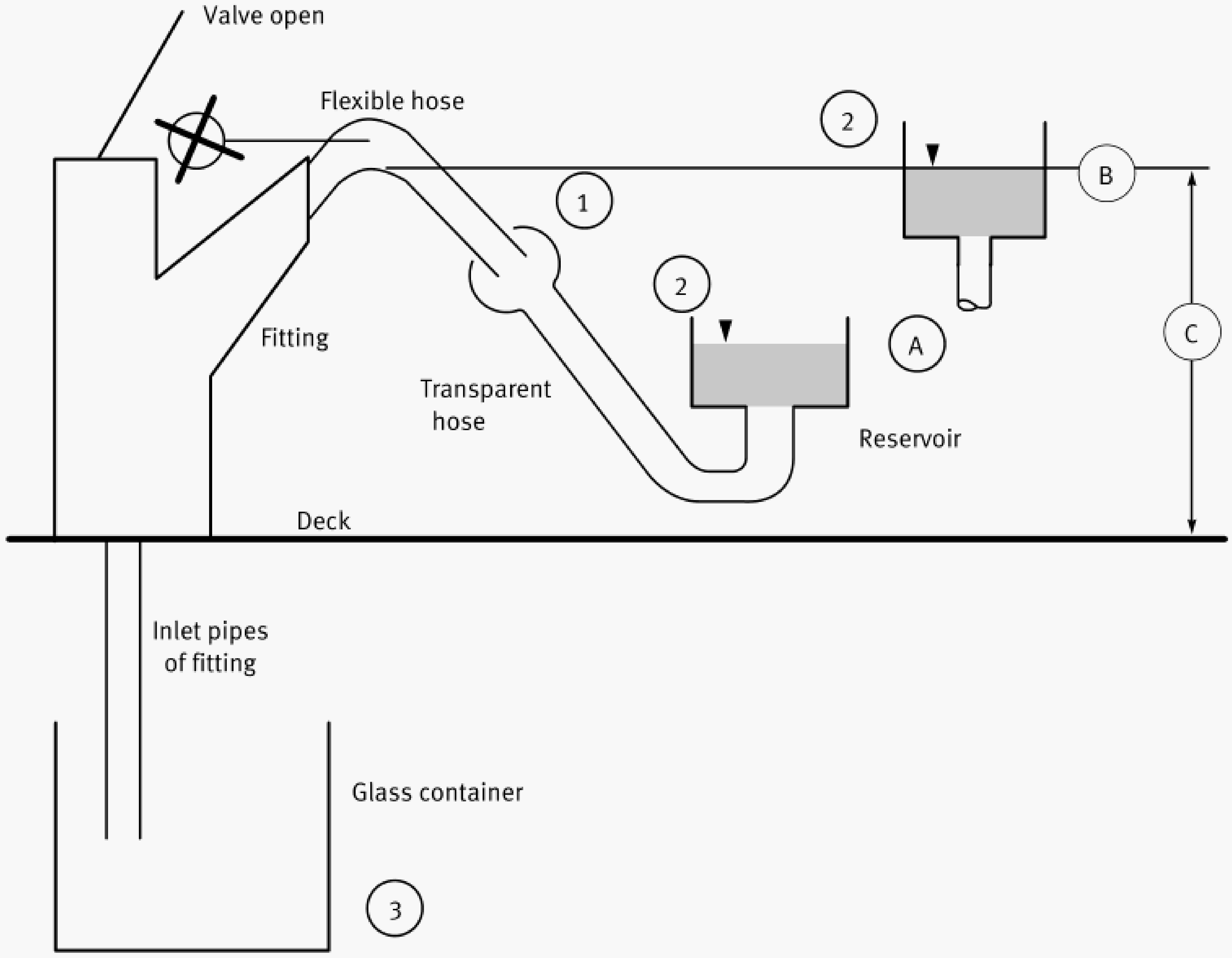

Fig. 8 Verification of the Critical Level (Hose Connected Outlet Faucets With Atmospheric Vents)

to drain from the inlets. Place a glass container [3] under the inlet pipes of the fitting.

The determination of critical level requires that the vent to atmosphere must be open, and it shall be manually opened if required.

Slowly elevate the reservoir upwards. While monitoring the fitting inlet pipes, continue raising the reservoir until the water begins to flow from the fitting inlets. Maintain this level [B] of the reservoir until the flow ceases.

The horizontal plane located at the water surface in the reservoir [2], when the flow from the fitting ceases, is the actual critical level of the fitting.

The distance [C] from the mounting deck of the fitting to the actual critical level shall be a minimum of 1 in.

NOTE: The pullout spout (wand) may be removed from the fitting outlet flexible hose, and the transparent flexible hose connected to the end of the outlet flexible hose.

NONMANDATORY APPENDIX A
RATIONALE FOR SAMPLING SCHEME AND STATISTICAL PROCEDURES

The provisions of ASME A112.18.3-2002 have been written to provide safety systems with a minimum reliability of 80% throughout the useful life of plumbing fixture fittings. This reliability exceeds the performance of traditional plumbing fixture fittings incorporating diverters as protection systems, which have been proven adequate through many years of service (see Reference [1]).

The actual probability of backflow occurring in a faucet equipped with a safety system is calculated from the natural probability multiplied by the upper confidence limits of the individual devices featured in the safety system:

$$P = NR\ C = NR\ (P_{u1}\ P_{u2}\ P_{u3}\ \ldots)$$

where

C = upper confidence limit, i.e., maximum possible percentage of safety assemblies subject to backflow in the field under those conditions defined in the life test

NR = natural reliability, i.e., probability of backflow occurring without the use of safety systems

P = probability of backflow occurring

$P_{u1}, P_{u2}. . .$ = upper confidence limit, i.e., maximum possible percentage of individual safety devices subject to backflow in the field under those conditions defined in the life test

A discussion of the natural reliability may be found in Reference [2].

Safety devices are

(a) check valves

(b) vacuum breakers

(c) vents to air

(d) automatic diverters

The fitting under examination must in all cases be protected by an assembly comprising at least two safety devices, of which the first barrier must be a check valve to safeguard against back pressure and back siphonage backflow.

The reliability of the safety system is defined as:

$$R_d = 1 - P = 1 - (P_{u1}\ P_{u2}\ \ldots)$$

where

R_d = reliability of the safety system based on the upper confidence limits of P_{u1}, P_{u2}. . .

The upper confidence limits are based on measured failure rates for devices subjected to the durability tests defined in ASME A112.18.3-2002.

The upper confidence limits, for a P_a of 97.5% unilateral, being usual for technical products of the type under examination, are given in Table A1 for selected sample sizes and failure rates.

If, for example, 2 out of $n = 10$ specimens (= 20%) fail to meet the requirements in the life test, the upper confidence limit for all of these products in the field is 55.6%. This means the maximum probable failure rate may account for 55.6%.

For devices of the type under examination, it is proposed not to permit an upper confidence limit, i.e., the maximum probable failure rate in the field, in excess of 56%.

It shall also be mathematically possible to add the results of several tests performed to the same specification on differing numbers of specimens. This technique is referred to as a multiple sampling scheme and is widely recognized in quality control work.

Therefore, adding a second test result from 5 test specimens with 1 failure to the above described result produces an upper confidence limit for the final test result of <48.1% and means, with respect to the above assumed limit of 56%, that the product tested in this way has passed the test. It is proposed that the tested device, or the entire product in the case of integrated solutions, be certified.

The described method of computing the reliability of safety systems is mathematically exact, noninterpretable, extremely simple for test engineers and manufacturers to use, and extremely flexible in application. The latter two criteria are of particular significance to pragmatic approval testing.

The failure rate confidence limit, Table A1, is computed from the binomial distribution according to Clopper-Pearson (see Reference [3]) for the upper limit as

$$P_u' = \frac{(i + 1)\ F_p\,(f1{:}\,f2)}{(n - i) + (i + 1)\ F_p\,(f1{:}f2)}$$

Table A1 Failure Rate Upper Confidence Limits, %, With a Confidence Level of 97.5%

Number of Failures for Given Sample Size, i	Sample Size, n													
	6	7	8	9	10	11	12	13	14	15	17	26	35	43
0	46	40	36	33	30	28	26	24	23	21	19	13	9	8
1	64	57	52	48	44	41	38	35	33	31	28	19	14	12
2	77	71	65	60	55	51	45	45	42	40	36	25	19	15
3	88	81	75	70	65	60	57	53	50	48	43	30	23	19
4	95	90	84	78	73	69	65	61	58	55	49	34	26	22
5	99	96	91	86	81	76	72	68	64	61	55	39	30	25
6	100	99	96	92	87	83	78	74	71	67	61	43	33	27
7	...	100	99	97	93	89	84	80	77	73	67	47	36	30
8	...	...	100	99	97	94	90	86	82	78	72	51	40	33
9	...	...	...	100	99	97	94	90	87	83	77	55	43	36
10	...	...	...	...	100	99	97	94	91	88	81	59	46	38

where

F_p = F-distribution threshold value, calculated with the degrees of freedom $f1$ and $f2$ (see Table A2)

i = number of failed parts after test

n = sample batch size

The F-distribution is a test distribution used in mathematical statistics and is applied in test evaluations of the type in hand. The nomograph, Fig. A1, provides a graphical solution.

SAMPLE CALCULATION

Determine the upper confidence limit for a device that has been evaluated in accordance with paras. 6 and 7 of ASME A112.18.3-2002. The sample size n was 13 and the number of failures $i = 2$.

$$P_u' = \frac{(i+1)\,F_p}{(n-i) + (i+1)\,F_p}$$

F_p is determined from Table A2 using the values for $f1$ and $f2$ calculated from:

$$f1 = 2\,(i+1)$$

$$f2 = 2\,(n-i)$$

$$f1 = 2\,(2+1) = 6$$

$$f2 = 2\,(13-2) = 22$$

$$F_p \text{ (read from Table A2)} = 3.05$$

$$P_u' = \frac{(i+1)\,F_p}{(n-i) + (i+1)\,F_p}$$

$$= \frac{(2+1)\,(3.05)}{(13-2) + (2+1)\,(3.05)}$$

$$= 0.45 \text{ or } 45\%$$

ALTERNATIVE SOLUTION USING CLOPPER–PEARSON NOMOGRAPH (REFERENCE [4])

Determine the failure rate: $(i/n)100 = (2/13)100 = 15.4\%$. Enter the graph at 15.4% on the abscissa (x axis). Follow a vertical path and intersect with sample size line (13). Follow a horizontal line to the ordinate (y axis), and read the upper confidence limit as 45%.

NOTES APPLICABLE TO SPECIFIC PARAGRAPHS OF ASME A112.18.3-2002

(a) *Paragraph 7.3*

(1) *Upper Confidence Limit.* The upper confidence limit of the individual backflow prevention device subject to backflow in the field shall not exceed 45% with a 97.5 confidence level, and shall be confirmed using the multiple sampling scheme described in para. 7.2 and the durability tests which are defined in para. 15.

(2) *Table 1.* Table 1 is based on the binomial distribution of the lower and upper confidence limits, i.e., the confidence interval versus failure rates, established with a 97.5% confidence level.

(b) *Paragraph 8*

(1) *Reliability Evaluation.* Conformance to the requirements of ASME A112.18.3-2002 shall be based on reliability data and the corresponding laboratory confirmed quality level of the individual devices.

(c) *Paragraph 9*

Table A2 *F*-Distribution Threshold Values, With Upper Threshold Values for $P = 0.975$ (Unilateral)

$f2 =$	$f1 = 2\,(i + 1)$																
$2\,(n-i)$	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24
1	648	800	864	900	922	937	948	957	963	969	977	983	987	990	993	995	997
2	38.5	39.0	39.2	39.2	39.3	39.3	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.5	39.5
3	17.4	16.0	15.4	15.1	14.9	14.7	14.6	14.5	14.5	14.4	14.3	14.3	14.2	14.2	14.2	14.2	14.1
4	12.2	10.6	9.98	9.61	9.36	9.20	9.07	8.98	8.91	8.85	8.75	8.68	8.63	8.59	8.56	8.53	8.51
5	10.0	8.43	7.76	7.39	7.15	6.98	6.85	6.76	6.68	6.62	6.53	6.46	6.40	6.36	6.33	6.30	6.28
6	8.81	7.26	6.60	6.23	5.99	5.82	5.70	5.60	5.52	5.46	5.37	5.30	5.24	5.20	5.17	5.14	5.12
7	8.07	6.54	5.89	5.52	5.29	5.12	5.00	4.90	4.82	4.76	4.67	4.60	4.54	4.50	4.47	4.44	4.42
8	7.57	6.06	5.42	5.05	4.82	4.65	4.53	4.43	4.36	4.30	4.20	4.13	4.08	4.03	4.00	3.97	3.95
9	7.21	5.72	5.08	4.72	4.48	4.32	4.20	4.10	4.03	3.96	3.87	3.80	3.74	3.70	3.67	3.64	3.61
10	6.94	5.46	4.83	4.47	4.24	4.07	3.95	3.86	3.78	3.72	3.62	3.55	3.50	3.45	3.42	3.39	3.37
12	6.55	5.10	4.47	4.12	3.89	3.73	3.61	3.51	3.44	3.37	3.28	3.21	3.15	3.11	3.07	3.04	3.02
14	6.30	4.86	4.24	3.89	3.66	3.50	3.38	3.29	3.21	3.15	3.05	2.98	2.92	2.88	2.84	2.81	2.79
16	6.12	4.69	4.08	3.73	3.50	3.34	3.22	3.13	3.05	2.99	2.89	2.82	2.76	2.72	2.68	2.65	2.63
18	5.98	4.56	3.95	3.61	3.38	3.22	3.10	3.01	2.93	2.87	2.77	2.70	2.64	2.60	2.56	2.53	2.50
20	5.87	4.46	3.86	3.52	3.29	3.13	3.01	2.91	2.84	2.77	2.68	2.60	2.55	2.50	2.46	2.43	2.41
22	5.79	4.38	3.78	3.44	3.22	3.06	2.93	2.84	2.76	2.70	2.60	2.53	2.47	2.43	2.39	2.36	2.33
24	5.72	4.32	3.72	3.38	3.16	3.00	2.87	2.78	2.70	2.64	2.54	2.47	2.41	2.37	2.33	2.30	2.27
26	5.66	4.27	3.67	3.33	3.11	2.95	2.82	2.73	2.65	2.59	2.49	2.42	2.36	2.31	2.28	2.24	2.22
28	5.61	4.22	3.63	3.29	3.06	2.90	2.78	2.69	2.61	2.55	2.45	2.37	2.32	2.27	2.23	2.20	2.17
30	5.57	4.18	3.59	3.25	3.03	2.87	2.75	2.65	2.58	2.51	2.41	2.34	2.28	2.23	2.20	2.16	2.14
32	5.53	4.15	3.56	3.22	3.00	2.84	2.72	2.62	2.54	2.48	2.38	2.31	2.25	2.20	2.16	2.13	2.10
34	5.50	4.12	3.53	3.19	2.97	2.81	2.69	2.59	2.52	2.45	2.35	2.28	2.22	2.17	2.14	2.10	2.08
36	5.47	4.09	3.51	3.17	2.94	2.78	2.66	2.57	2.49	2.43	2.33	2.25	2.20	2.15	2.11	2.08	2.05
38	5.45	4.07	3.48	3.15	2.92	2.76	2.64	2.55	2.47	2.41	2.31	2.23	2.17	2.13	2.09	2.06	2.03
40	5.42	4.05	3.46	3.13	2.90	2.74	2.62	2.53	2.45	2.39	2.29	2.21	2.15	2.11	2.07	2.04	2.01
42	5.40	4.03	3.45	3.11	2.89	2.73	2.61	2.51	2.44	2.37	2.27	2.20	2.14	2.09	2.05	2.02	1.99
44	5.39	4.02	3.43	3.09	2.87	2.71	2.59	2.50	2.42	2.36	2.26	2.18	2.12	2.07	2.03	2.00	1.97
46	5.37	4.00	3.42	3.08	2.86	2.70	2.58	2.48	2.41	2.34	2.24	2.17	2.11	2.06	2.02	1.99	1.96
48	5.35	3.99	3.40	3.07	2.84	2.69	2.57	2.47	2.39	2.33	2.23	2.15	2.09	2.05	2.01	1.97	1.94
50	5.34	3.98	3.39	3.05	2.83	2.67	2.55	2.46	2.38	2.32	2.22	2.14	2.08	2.03	1.99	1.96	1.93
52	5.33	3.96	3.38	3.04	2.82	2.66	2.54	2.45	2.37	2.31	2.21	2.13	2.07	2.02	1.98	1.95	1.92
54	5.32	3.95	3.37	3.03	2.81	2.65	2.53	2.44	2.36	2.30	2.20	2.12	2.06	2.01	1.97	1.94	1.91
56	5.31	3.94	3.36	3.02	2.80	2.64	2.52	2.43	2.35	2.29	2.19	2.11	2.05	2.00	1.96	1.93	1.90
58	5.30	3.93	3.35	3.02	2.79	2.64	2.52	2.42	2.34	2.28	2.18	2.10	2.04	1.99	1.95	1.92	1.89
60	5.29	3.93	3.34	3.01	2.79	2.63	2.51	2.41	2.33	2.27	2.17	2.09	2.03	1.99	1.94	1.91	1.88
62	5.28	3.92	3.34	3.00	2.78	2.62	2.50	2.40	2.33	2.26	2.16	2.09	2.03	1.98	1.94	1.90	1.87
64	5.27	3.91	3.33	2.99	2.77	2.61	2.49	2.40	2.32	2.26	2.16	2.08	2.02	1.97	1.93	1.90	1.87
66	5.26	3.90	3.32	2.99	2.77	2.61	2.49	2.39	2.31	2.25	2.15	2.07	2.01	1.96	1.92	1.89	1.86
68	5.25	3.90	3.32	2.98	2.76	2.60	2.48	2.39	2.31	2.24	2.14	2.07	2.01	1.96	1.92	1.88	1.85
70	5.25	3.89	3.31	2.98	2.75	2.60	2.47	2.38	2.30	2.24	2.14	2.06	2.00	1.95	1.91	1.88	1.85

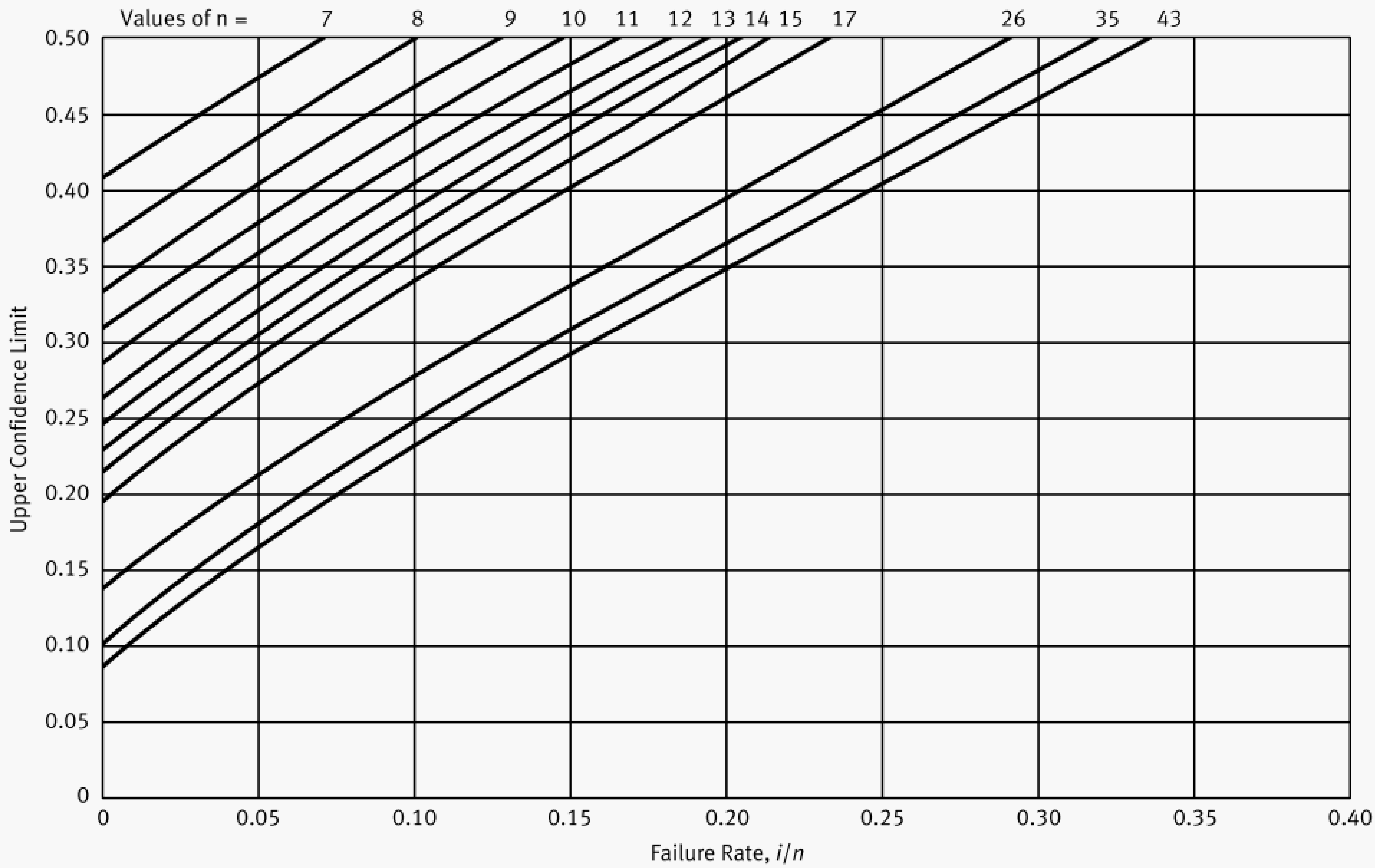

Fig. A1 Clopper-Pearson Nomograph (Confidence Limit 97.5%)

(1) *Minimum Reliability of the Backflow Prevention System.* The backflow prevention system shall have a minimum reliability of 0.80. The minimum reliability shall be the resultant of the quality level of the individual devices and determined by the following equation:

$$R_d = 1 - (P_{u1}\ P_{u2}\ \ldots\ P_{un})$$

where

P_{un} = upper confidence limit, i.e., maximum possible percentage of the individual safety devices subject to backflow in the field under those conditions defined in the life test

R_d = reliability of the backflow prevention system

(2) *Reliability.* The backflow prevention system shall have a minimum reliability of 0.80. This shall be determined by the following equation:

$$R_d = 1 - P_{un}$$

where

P_{un} = upper confidence limit, i.e., maximum possible percentage of the individual safety devices subject to backflow in the field under those conditions defined in the life test

R_d = reliability of the backflow prevention system

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