This standard gives methods and criteria for tightness testing of environmental engineering concrete structures. It is applicable to liquid and gas containment structures constructed with concrete or a combination of concrete and other materials. It includes hydrostatic, surcharged hydrostatic, and pneumatic tests.

The values stated in inch-pounds are to be regarded as the standard. The values given in parentheses are for information only. The text of this standard is accompanied by a commentary which provides explanatory material. The commentary shall not be considered as requirements of the standard.

This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems 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.

Keywords: hydrostatic; leakage; pneumatic; reservoirs; tanks (containers); tests; tightness; tightness criteria.
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CHAPTER 1 — TIGHTNESS TESTING OF TANKS

STANDARD

1.0—Notations

\[ F = \text{Fahrenheit Temperature} \]
\[ (C = \text{Centigrade Temperature}) \]
\[ P_G = \text{Design gas pressure, psig (kPa gage)} \]
\[ P_V = \text{Vacuum pressure for which the tank has been designed, psig (kPa gage)} \]

1.1—Scope

1.1.1—This Standard is for the tightness testing of concrete environmental engineering liquid and gaseous containment tanks. The included tests are:
(a) Hydrostatic Test for Open or Covered Tanks, HST. See Chapter 2;
(b) Surcharged Hydrostatic Test for Closed Tanks, SHT. See Chapter 3;
(c) Pneumatic Test for Closed Tanks, PNT. See Chapter 4; and
(d) Combination Hydrostatic-Pneumatic Test for Closed Tanks, CPT. See Chapter 5.

COMMENTARY

R1.1—Scope

The American Concrete Institute Committee 350, Environmental Engineering Concrete Structures, recognized the need for standardized procedures of testing of reinforced concrete structures for water tightness. A joint committee of ACI 350 and American Water Works Association Committee 400, Waterproofing, prepared the ACI 350.1R/AWWA 400 Report\(^1\) on recommendations for water tightness of reinforced concrete containment structures. This Standard is an evolution of that report.

The pneumatic tests in this Standard are based on the American Petroleum Institute’s publication API 620 for Large, Welded, Low-Pressure Storage Tanks.\(^2\)

Under most circumstances, only one type of test would be used for a tank. The type of test selected should best represent the design loading condition of the tank. If the tank is designed for several different types of loading conditions, tests should be selected to represent each of the types.

The tank should have the maximum amount of the exterior surface visible during the test. New partially buried or buried tanks should not have the backfill placed against the walls and roof prior to testing. If the structure is not designed to be test loaded prior to backfill placement, the test should only be performed with the backfill in place.

R1.1.2—Tightness testing of concrete tanks for the containment of liquids and low-pressure gases may be necessary to verify that the structure can fulfill its intended purpose. Tanks for environmental facilities often include structures designed with a combination of concrete and other materials. These include concrete digesters with floating steel covers; tanks with aluminum dome roofs; basins with metal, wood or plastic covers; process basins with steel walls and concrete floors; and similar structures. The combination of materials in the tank construction should not preclude performing the tightness testing of the tank nor the tightness testing of the joint between the different materials.
STANDARD

1.1.3—Each cell of multi-cell tanks shall be considered a single tank and tested individually unless otherwise directed by the engineer.

1.1.4—The HST procedures and requirements herein are also applicable for tightness testing of open concrete liquid transmission structures such as cast-in-place concrete channels and conduits.

1.1.5—The HST procedures and requirements, where applicable, can be used for tightness testing of concrete paved structures, such as channels and impoundments.

1.1.6—These provisions are not intended for precast concrete structures such as culverts and pipes, for hazardous material primary containment structures, for cryogenic storage structures, or for high-pressure gas tanks.

1.2—General

1.2.1—Definitions. The following definitions shall apply to words and phrases used in this Standard.

1.2.1.1—Tank—A concrete basin, reservoir, channel, or conduit to be tested regardless of whether it has a closed or open top or is constructed partially or entirely of concrete.

1.2.1.2—Open tank—A tank where the top surface of the tank’s contents is exposed to the atmosphere.

1.2.1.3—Covered tank—A tank where the contents are protected from exterior contamination by the presence of a cover or roof over the top of the tank.

1.2.1.4—Closed tank—A tank where the roof or cover is used to prevent the escape of the contents, including gases emanating from the contents, to the outside atmosphere.

1.2.1.5—Soap suds—Water impregnated with soap or synthetic detergent used to indicate air passage through joints or defects by the formation of soap bubbles.

COMMENTARY

R1.1.3—Multi-cell tanks for water and wastewater facilities are not always designed for water tightness between adjacent cells. During maintenance, it is considered acceptable for these tanks to have some seepage into an empty cell from an adjacent full cell. It is not practical to establish a water loss criterion for testing cells where seepage is acceptable. Therefore, these multi-cell tanks should be tested as a unit. The design of multi-cell tanks should be reviewed to determine that they are multi-cell tanks rather than a single tank with non-structural baffle walls.

R1.1.4—Tightness testing of liquid transmission structures will require the use of major, very tight, temporary bulkheads—a feature usually not defined in the structure design.

R1.1.5—Concrete paving is placed, finished, and jointed in a different manner than are cast-in-place concrete tanks. The differences in design, details, and construction will affect the tightness of the structure and some test procedures may not be applicable.

R1.1.6—Precast concrete structures and structures for the primary containment of hazardous materials, cryogenic fluids, or high-pressure gases require specialized testing methods, procedures, and criteria.

R1.2—General
1.2.1.6—*Fittings*—A material or product, other than concrete, embedded in the concrete or passing through the concrete.

1.2.1.7—*Low-pressure*—A pressure less than 2.5 psig (17 kPa gage).

1.2.1.8—*Vacuum box*—A box with a transparent top, open bottom, and air sealing bottom edges used in conjunction with an air pump capable of creating at least a 3 psi (20 kPa) vacuum within the box.

1.2.2—The structural adequacy of the tank shall be verified for the test pressure or pressures to be applied. One type of test shall not be substituted for another type of test without approval of the engineer.

1.2.3—Unless specifically allowed by the engineer, the tank shall not be tested before all of the structure is complete and the tank’s concrete has attained its specified compressive strength.

R1.2.2—When using the stated procedures and criteria for an existing tank, it should not be assumed that the tank has been designed for the test pressure or for the specific type of test. A tank designed for a triangular hydrostatic pressure may not be able to withstand a uniform pneumatic pressure with the same maximum intensity.

R1.2.3—Pressure testing of a partially completed tank may not be a true test of tightness of the tank. Shrinkage cracks may continue to propagate during the construction period after the test. The fastening of walkways, exterior stairways, roof beams, or other structural elements above or outside of the tank’s liquid containment shell, after the tightness test, may provide additional shell restraint and result in the formation of concrete cracks.
CHAPTER 2—HYDROSTATIC TEST, HST, FOR OPEN OR COVERED TANKS

STANDARD

2.1—Standard Test

2.1.1—The standard hydrostatic test shall have the prefix HST followed by the test criterion expressed as the maximum allowable percent loss per day of the test water volume. Standard criteria for the HST test are:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Tightness Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>HST-NML</td>
<td>No measurable loss</td>
</tr>
<tr>
<td>HST-025</td>
<td>0.025% per day</td>
</tr>
<tr>
<td>HST-050</td>
<td>0.050% per day</td>
</tr>
<tr>
<td>HST-075</td>
<td>0.075% per day</td>
</tr>
<tr>
<td>HST-100</td>
<td>0.100% per day</td>
</tr>
<tr>
<td>HST-VIO</td>
<td>Visual inspection only</td>
</tr>
</tbody>
</table>

2.1.2—Standard test HST-VIO shall be the preliminary test for all other HST tests as well as an individual standard test.

2.1.3—Tanks shall be tested for tightness when required by contract documents, applicable code, regulation, statute, or governing authority. When a hydrostatic tightness test is required and a specific criterion is not stated, the test shall be HST-NML for fully lined tanks or tanks required to have secondary containment, HST-050 for other types of tanks, and HST-100 for concrete paved reservoirs and channels.

2.2—Tank inspection and HST-VIO, Part 1

2.2.1—Clean the exposed concrete surfaces of the tank, including the floor, of all foreign material and debris. Standing water in or outside of the tank that would interfere with the observation of the exposed concrete surfaces of the tank shall be removed. The concrete surfaces and concrete joints shall be thoroughly inspected for potential leakage points. Areas of potential leakage shall be repaired prior to filling the tank with water. Liners, that are mechanically locked to the surface during the placement of the concrete, shall be installed prior to the tank inspection. The inspection and corrective action shall also be performed on in-place interior liners.

COMMENTARY

R2.1—Standard Test

R2.1.1—The test designation system adopted allows for future revision, if necessary, to the tightness criteria. The system makes the tightness criterion used for the test self-evident.

Different materials, methods of construction, and design philosophy may result in different tank tightness. A prestressed concrete tank with the concrete always in compression may have a different tightness than a reinforced concrete tank with the concrete partially in tension. A lined tank will have a different tightness than an unlined tank. Based on reasonable tightness of different types of tank construction, six standard criteria have been established. The selected criterion should consider the tank design, tank construction, and the tightness necessary for the stored contents.

R2.1.2—The visual test, as a preliminary procedure for all tests in this Standard, should minimize the number of tank retests.

R2.1.3—Liners should be considered when HST-NML tightness criterion is required. The tightness criterion should consider that tanks without expansion joints normally have a smaller floor area than tanks with expansion joints. Liquid loss through floor imperfections will be at a higher rate than through wall imperfections due to the higher hydrostatic pressure at the floor level. Expansion joints also can leak due to the detail work required in constructing the joint. Movement at expansion joints during the life of the structure may result in future leakage.

R2.2—Tank inspection and HST-VIO, Part 1

R2.2.1—The requirement to clean the tank surfaces is to allow cracks and defects to be observed and not obscured by mud, material spills, or stains. Sprayed water may be necessary to wash foreign material from the concrete surfaces. Mud, soil, or other foreign material on the tank floor may not only obscure the floor condition but may temporarily fill defects, voids, or cracks, thus giving test results that may not reflect the true condition of the tank. The same inspection procedure is required for the concrete that is to be covered by a liner as for concrete that will be exposed. Liners are generally used to obtain a very tight structure. Therefore, the basic structure should also be reasonably tight to serve as a barrier to the stored material if pinholes occur in the liner. Concrete surfaces to which liners are mechanically locked during the placement of concrete, cannot be visually inspected. Coatings, such as paint, should not be applied until after testing is complete.
2.2.2—All openings, fittings, and pipe penetrations in the tank shell shall be inspected at both faces of the concrete, if practical. Defective or cracked concrete shall be repaired.

2.2.3—Interior liners shall be inspected for pinholes, tears and partially fused splices. Deficiencies shall be repaired.

2.3—Test preparation and HST-VIO, Part 2

2.3.1—All tank penetrations and outlets shall be securely sealed to prevent the loss of water from the tank during the test. If the tank is to be filled using the tank inlet pipe, positive means shall be provided to check that water is not entering or leaving the tank through this pipe once the tank is filled to test level.

2.3.2—Tank penetrations and pipe, channel, and conduit outlets shall be monitored before and during the test to determine the watertightness of these appurtenances. Leakage at these outlets shall be repaired prior to test measurements. No allowance shall be made in test measurements for uncorrected known points of leakage. The flow from the underdrain system shall be monitored during this same period and any increase in flow shall be recorded.

2.3.3—The ground water level shall be brought to a level below the top of the base slab and kept at that elevation or at a lower elevation during the test.

2.3.4—The initial filling of a new tank should not exceed a rate of 4 ft/h (1.2 m/h). Filling shall be continued until the water surface is at the design maximum liquid level or 4 in. (100 mm) below any fixed overflow level, whichever is lower.

2.3.5—The water shall be kept at the test level of unlined concrete tanks for at least three days prior to the actual test.
STANDARD

2.3.6—The exterior surfaces of the tank shall be inspected during the period of filling the tank. If any flow of water is observed from the tank exterior surfaces, including joints or cracks, the defect causing the leakage shall be repaired.

2.4—Test measurements

2.4.1—The test measurements shall not be scheduled for a period when the forecast is for a substantial change in the weather pattern. The test shall also not be scheduled when the weather forecast indicates the water surface would be frozen before the test is completed.

2.4.2—The vertical distance to the water surface shall be measured from a fixed point on the tank above the water surface. Measurements shall be recorded at 24 h intervals.

2.4.3—The test period shall be at least the theoretical time required to lower the water surface 3/8 in. (10 mm) assuming a loss of water at the maximum allowable rate. The test period need not be longer than five days.

2.4.4—The water temperature shall be recorded at a depth of 18 in. (450 mm) below the water surface.

2.4.5—In uncovered tanks, evaporation and precipitation shall be measured. Evaporation shall also be measured in well-ventilated covered tanks.

2.4.6—The tank shall be inspected daily for damp spots, seepage, and leakage.

2.4.7—At the end of the test period, the water surface shall be recorded at the location of the original measurements. The water temperature and the evaporation and precipitation measurements shall be recorded.

COMMENTARY

R2.3.6—Observed leakage should be repaired prior to the start of the actual test. The quantified maximum water loss included in this Standard is for unexplained losses; it is not a criterion for acceptance of leaking tanks.

R2.4—Test measurements

R2.4.1—A substantial change in the weather pattern would be when there would be more than 35 F (20 C) difference between in the temperature readings at the initial measurement and final measurement of the water surface. It is preferable to minimize temperature change of the water during the test. This would minimize computed temperature corrections of measurements. Temperature stratifications can occur in the contained water and affect the test results.

R2.4.2—Measurements taken at two locations, 180 degrees apart, will usually minimize effect of differential settlement on the computed values for small and medium size tanks. Measurements at four points, 90 degrees apart, will give more accurate results. Measurements taken at the same time of day will reduce the probability of temperature difference.

R2.4.3—The test period shall be at least the theoretical time required to lower the water surface 3/8 in. (10 mm) assuming a loss of water at the maximum allowable rate. The test period need not be longer than five days.

R2.4.4—If the specified tightness criterion for the tank is very stringent, the water temperature should be recorded at 5 ft (1.5 m) intervals of depth.

R2.4.5—A floating, restrained, partially filled, calibrated, open container for evaporation and precipitation measurement should be positioned in open tanks and the water level in the container recorded. Determination of evaporation by a shallow pan type measuring devices is discouraged. The heating of the bottom of a shallow pan can cause accelerated evaporation of water as compared to that taking place from a deep tank.

R2.4.6—Observed flow or seepage of water from the exterior surface, including that from cracks and joints, should be considered as a failed test. Flows can be temporarily plugged by dirt or debris being drawn into the defects. Such plugging does not constitute permanent repairs and therefore is not a true measurement of the tank’s tightness. The limits of flowing water or damp spots, observed during daily inspections, should be marked for later repair.

R2.4.7—Measurements taken at the same location will reduce the probability of measurement differences.
2.4.8—The change in water volume in the tank shall be calculated and corrected, if necessary, for evaporation, precipitation, and temperature. If the loss exceeds the required criterion, the tank shall be considered to have failed the test. The tank shall also be considered to have failed the test if water is observed flowing or seeping from the tank or if moisture can be transferred from the exterior surface to a dry hand. Dampness or wetness on top of a footing, in the absence of flowing water, shall not be considered as a failure to meet the acceptance criterion.

2.5—Quantitative criteria

2.5.1—There shall be no measurable loss of water for tanks subjected to the HST-NML tightness test. No measurable loss of water means the drop in the water surface shall not exceed 1/8 in. (3 mm) in three days.

2.5.2—The allowable loss of water for HST-025, HST-050, HST-075, and HST-100 tightness tests shall not exceed 0.025%, 0.050%, 0.075%, and 0.100%, respectively, of the test water volume in 24 hours. The test shall be continued for a duration sufficient to cause a 3/8 in. (10 mm) drop in the water surface assuming the loss of water is at the maximum rate.

2.5.3—There is no numerical value for the allowable loss of water during the HST-VIO tightness test. However, no flow or seepage of water from the tank shall be present on the exterior surfaces for 24 hours after the tank is filled to test level.

2.5.4—A restart of the test shall be required when test measurements become unreliable due to unusual precipitation or other external factors.

2.5.5—The tank builder shall be permitted to immediately retest a tank failing the test when no visible leakage is exhibited. If the tank fails the second test or if the builder does not exercise the option of immediately retesting after the first test failure, the interior of the tank shall be inspected by a diver or by other means to determine probable areas of leakage. The tank shall only be retested after the most probable areas of leakage are repaired.

2.5.6—Tanks shall be retested until they meet the required criterion. Repairs shall be made to the probable leakage areas before each retest.

R2.4.8—Temperature corrections to the water volume should be based on the change in water density but may also include the effect of the thermal change to the structure dimensions. Structure dimension changes may be appropriate for circular tanks that have a sliding joint at the base of the perimeter wall.

R2.5—Quantitative criteria

When numerical limits are given for the allowable loss of water during the tightness test, they are for the undetected loss of water from the tank. Therefore, test values should be corrected for temperature change, evaporation, and precipitation, if present.

R2.5.2—The tests should be of sufficient duration to be certain of the results. An example of the method of calculating the duration of a tightness test is as follows. A flat bottom concrete tank, required to pass the HST-050 tightness test, has a 20 ft (6 m) water depth. The acceptance criterion is a maximum of 0.05% loss of water volume in 24 hours. The required duration of test would be

\[
\frac{0.375 \text{ in}}{0.0005 \text{ in./in./day} \times 20 \text{ ft} \times 12 \text{ in./ft}} = 3.13 \text{ days}
\]

\[
\left( \frac{10 \text{ mm}}{0.0005 \text{ mm/mm/day} \times 6000 \text{ mm}} \right) = 3.33 \text{ days}
\]

Measurements are taken at 24 hour intervals; therefore, the test duration should be at least four days.

R2.5.4—Unusual precipitation would be when the amount of precipitation would exceed the capacity of the precipitation gage, or would plug the precipitation gage with snow, or would cause water to spill over the tank overflow.

R2.5.5—The immediate retest is allowed for confirmation of the first test results. This should minimize the cost of inspections and wasted water due to measurement errors, slower than normal water absorption by the concrete, or slow deflection of structural elements.

Vacuum boxes can be used to locate leaking joints, cracks, and porous spots. Soap suds are applied to the suspect area and the area covered with a vacuum box. A vacuum of at least 3 psig (20 kPa gage) is created within the box. Air leakage through or at the suspect area will result in the formation of soap bubbles. All soap solutions should be thoroughly flushed and rinsed from the concrete and metal surfaces after use.
CHAPTER 3—SURCHARGED HYDROSTATIC TEST, SHT, FOR CLOSED TANKS

STANDARD

3.1—Standard test

3.1.1—The standard surcharged hydrostatic test shall have the prefix SHT followed by the test criterion expressed as the maximum allowable percent loss per day of the test water volume. Standard criteria for the SHT test are:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Tightness Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHT-NML</td>
<td>No measurable loss</td>
</tr>
<tr>
<td>SHT-050</td>
<td>0.050% per day</td>
</tr>
<tr>
<td>SHT-VIO</td>
<td>Visual inspection only</td>
</tr>
</tbody>
</table>

3.1.2—Surcharged hydrostatic testing shall be confined to tanks that have been designed and constructed to be filled with liquid to the underside of the roof and surcharged. The surcharge test pressure, at the underside of the roof high point, shall be within the low pressure range.

3.1.3—Tanks shall be tested for tightness when required by contract documents, applicable code, regulation, statute, or governing authority. When a surcharged hydrostatic tightness test is required and a specific criterion is not stated, the test shall be SHT-NML for tanks that are enclosed or partially enclosed in a building and SHT-050 for tanks that are surrounded by outside air.

3.2—Tank inspection

3.2.1—The tank inspection shall be in accordance with the requirements of test HST-VIO, Part 1 as described in Section 2.2. Concrete joints and cracks shall be tested with a vacuum box.

COMMENTARY

R3.1—Standard test

R3.1.1—The test designation system adopted allows for future revision, if necessary, to the tightness criteria. The system makes the tightness criterion used for the test self-evident.

Different materials, methods of construction, and design philosophy may result in different tank tightness. Based on reasonable tightness of different types of tank construction, three standard criteria have been established. The selected criterion should consider the tank design, tank construction, and the tightness necessary for the stored contents.

R3.1.2—A surcharged hydrostatic test should be used only on tanks that have been structurally analyzed for the test surcharge loading that will be applied. The test should only be performed on tanks with the intended use of storing water or other fluids under low pressure. Composite tanks of concrete and steel should be periodically tested as the loss of corrosion allowance metal may reduce the strength and tightness of the tank. Concrete tanks, particularly concrete roofs, have a limit on the maximum pressure for which they can be economically designed. The low pressure limitation is an attempt to keep the test loading within this range.

R3.1.3—Liners should be considered when SHT-NML tightness criterion is required.

R3.2—Tank inspection

R3.2.1—See R2.2. The stringent criteria for the SHT test requires joint and crack testing for potential leaks. Vacuum boxes are used to locate leaking joints, cracks, and porous spots. Soap suds are applied to the suspect area and the area covered with a vacuum box. A vacuum of at least 3 psig (20 kPa gage) is created within the box. Air leakage through or at the suspect area will result in the formation of soap bubbles. All soap solutions should be thoroughly flushed and rinsed from the concrete and metal surfaces after use.
3.3—Test preparation and SHT-VIO

3.3.1—All tank penetrations and outlets shall be securely sealed to prevent the loss of water from the tank during the test. If the tank is to be filled using the tank inlet pipe, positive means shall be provided to check that water is not entering or leaving the tank through this pipe once the tank is filled to test level.

3.3.2—Tank penetrations and pipe, channel, and conduit outlets shall be monitored before and during the test to determine the watertightness of these appurtenances. Leakage at these outlets shall be repaired prior to test measurements. No allowance shall be made in test measurements for uncorrected known points of leakage. The flow from the underdrain system shall be monitored during this same period and any increase in flow shall be recorded.

3.3.3—The ground water level shall be brought to a level below the top of the base slab and kept at that elevation or at a lower elevation during the test.

3.3.4—After the tank inspection has been completed, the pressure-relief valve or valves shall be plugged and the top of the tank vented to the atmosphere. The tank shall be filled with water, at a rate not exceeding 4 ft/h (1.2 m/h), to the underside of the roof while allowing all air to freely escape. The water level shall be kept near or at the top of unlined or uncoated tanks for a period of at least three days prior to the test.

3.3.5—The tank vent at the roof high point shall be replaced with an open ended pipe to form a standpipe. The diameter of the standpipe shall not be less than the diameter of the vent it replaces nor more than six times the vent diameter. The top of the standpipe shall be located to limit the hydraulic surcharge to 1.25 times the design surcharge at the high point of the underside of the roof. The standpipe shall be slowly filled to the point of overflow.

3.4—Test measurements

3.4.1—The duration of the test shall be 1 hour. The water temperature 18 in. below the water surface shall be taken at the start and end of each test.

R3.3—Test preparation and SHT-VIO

R3.3.1—Leaking or partially seated valves and gates are a source of water loss from tanks. A tank inlet pipe, if connected to a water source, may be difficult to check for leakage.

R3.3.2—An increase in flow from the underdrain system may indicate leakage through the tank floor. However, it may also be due to rain or some other external source of water. The conditions at each event should be evaluated to estimate the most probable cause of the increased flow.

R3.3.3—The ground water can cause a back pressure on the walls and floor of tanks and reduce the outflow of the test water through tank defects. The presence of ground water may indicate a greater watertightness of the tank than is actually present.

R3.3.4—The requirement for the free escape of air while filling the tank is to prevent the water from being pressurized by trapped air. The foundation, venting equipment, or other conditions may limit the water filling to a lower rate. The tank contents should not be surcharged until the test water temperature has stabilized. It is preferred that the test water temperature be 60 °F (15.5 °C) or above. The three-day waiting period for the test is considered sufficient allowance for moisture absorption by the concrete and temperature stabilization of the test water. The waiting period can be extended for unlined or uncoated tanks, if desired, to obtain additional moisture absorption. A waiting period is not required for moisture absorption of lined tanks as the liner should prevent water from reaching the concrete.

R3.3.5—The standpipe protects the tank from unanticipated pressure. If there is not a free water surface at the standpipe, rapid pressure changes can occur due to a water temperature change or a vacuum can occur due to water leakage.

R3.4—Test measurements

R3.4.1—It is not expected that there will be a change in water temperature during the 1 hour test period. The temperature readings are taken primarily to verify that the temperature has not affected the test results.
3.4.2—The water level in the standpipe shall be measured after 1 hour. If the water level has dropped below the top most point of the underside of the roof or to a level, within the standpipe, below the calculated allowable loss of water volume from the tank, the standpipe shall be refilled and the test repeated. However, if the drop of the water surface below the allowable level can be shown to be due to water temperature change, the tank shall be considered to have met the test requirement. If the water level fails to remain within the allowable range in the initial test or up to two retests, the tank shall be reinspected for leaks in the exterior surface and then drained and inspected for defects that are suspected leak locations in the interior surfaces. All leaks or points of suspected leaks shall be repaired and the test repeated.

3.4.3—Once the water level has remained within the allowable range in the standpipe for the test period of 1 hour, the water level shall be kept in the standpipe until a close visual inspection of all visible tank joints and around hatches, manways, nozzles, pipe connections, and other openings and penetrations has been performed.

3.4.4—The water level shall then be lowered below the inlets to the pressure-relief valves, and the plugs shall be removed from the relief valves. The operation of the relief valves shall then be checked by removing the standpipe, plugging the air vent, and injecting air into the top of the tank until the pressure in the vapor space equals the design pressure $P_G$. If the relief valves do not start to release air at the design pressure, they shall be adjusted or repaired.

3.4.5—Upon completion of the test, the pressure in the tank shall be released and the tank emptied. A thorough visual inspection shall be made of both the inside and outside of the tank, giving particular attention on combination metal and concrete tanks to any internal metal ties, braces, trusses, and their attachments to the walls of the tank.

3.5—Quantitative criteria

3.5.1—There shall be no measurable loss of water for tanks subjected to SHT-NML tightness test. No measurable loss of water shall mean a drop in water surface in the standpipe indicating less than 0.01% loss of tank water volume in 24 hours.

3.5.2—The allowable loss of water for the SHT-050 tightness test shall not cause the water in the standpipe to fall below the underside of the top of the roof within the 1 h test period or to a level indicating a loss of tank water volume of more than 0.05% in 24 hours, whichever is the smaller loss.

3.5—Quantitative criteria

R3.5—Quantitative criteria

The criterion for this test tends to be liberal due to the effect a slight temperature change can have on the test measurements. Other criteria may be set by the engineer if needed for the stored liquid. The test should be sufficient for most tanks constructed for the storage of liquids under low pressure; but if, in the opinion of the engineer, additional tests are needed to investigate the safety of a tank under certain other conditions of loading, as determined from the design computations, such tests should also be made on the tank in addition to this test.
3.5.3—There is no numerical value for the allowable loss of water during the SHT-VIO tightness test. However, no flow or seepage of water from the tank shall be present on the exterior surfaces for 24 h after the tank is filled to test level.

3.5.4—A restart of the test shall be required when test measurements become unreliable due to a sudden change in temperature or other external factors.

3.5.5—Retests of tanks are addressed in Section 3.4

3.5.6—Tanks shall be retested until they meet the required criterion. Repairs shall be made to the probable leakage areas before each retest.
CHAPTER 4—PNEUMATIC TEST, PNT, FOR CLOSED TANKS

STANDARD

4.1—Standard Test

4.1.1—The standard pneumatic test shall have the prefix PNT followed by the test criterion expressed as the maximum allowable percent loss per day of the test air volume. Standard criteria for the PNT test are:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Tightness Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>PNT-NML</td>
<td>No measurable loss</td>
</tr>
<tr>
<td>PNT-2000</td>
<td>2.000% per day</td>
</tr>
<tr>
<td>PNT-VIO</td>
<td>Visual inspection only</td>
</tr>
</tbody>
</table>

4.1.2—Pneumatic testing shall be confined to tanks that have been designed and constructed to be tested with a pneumatic pressure. The pneumatic testing of the tanks shall occur after any lining, interior waterproofing membrane, or interior coating is in place. Pneumatic tests shall be limited to test pressures within the low pressure range.

4.1.3—Tanks shall be tested for tightness when required by contract documents, applicable code, regulation, statute, or governing authority. When a pneumatic tightness test is required and a specific criterion is not stated, the test shall be PNT-NML for tanks that are enclosed or partially enclosed in a building and PNT-2000 for tanks that are surrounded by outside air.

4.2—Tank inspection

4.2.1—The tank inspection shall be in accordance with the requirements of test HST-VIO Part 1 as described in Section 2.2. Concrete joints and cracks shall be tested with a vacuum box.

4.2.2—Interior liners (if not already in place), interior waterproofing membranes, and interior coatings shall be installed after the joints or cracks exhibiting leakage of air, through the joint or crack, are repaired and retested.

COMMENTARY

R4.1—Standard Test

R4.1.1—The test designation system adopted allows for future revision, if necessary, to the tightness criteria. The system makes the tightness criterion used for the test self-evident.

Different materials, methods of construction, and design philosophy may result in different tank tightness. Based on reasonable tightness of different types of tank construction, three standard criteria have been established. The selected criterion should consider the tank design, tank construction, and the tightness necessary for the stored contents.

R4.1.2—A pneumatic test should only be used to check the tightness of a tank when specified by an engineer who has structurally analyzed the tank considering the pressure test loading that will be applied. The test should be performed on tanks with the intended use of storing water or gas or a combination of water and gas under low pressure. The low pressure limitation on this test is to limit it to the maximum expected design loading range of reinforced concrete tanks. The test is sometimes used as an alternate test for a hydrostatic test when allowed in the specifications.

R4.1.3—The 2% air loss criteria was selected due to the calculation of air loss being very sensitive to atmospheric pressure. The 2% is consistent with loss at unidentifiable locations. Liners should be considered when PNT-NML or PNT-2000 tightness criterion is required.

R4.2—Tank inspection

R4.2.1—See R2.2. The stringent criterion for this test requires additional checking for potential leaks. Vacuum boxes are used to locate leaking joints, cracks, and porous spots. Soap suds are applied to the suspect area and the area covered with a vacuum box. A vacuum of at least 3 psig (20 kPa gage) is created within the box. Air leakage through or at the suspect area will result in the formation of soap bubbles. All soap solutions should be thoroughly flushed and rinsed from the concrete and metal surfaces after use.

R4.2.2—Liners that are mechanically locked to the surface during concrete placement should be installed prior to the preliminary test. Liners, membranes, or coatings when included in the design should be installed prior to checking the exterior of the tanks for leaks due to the stringent criteria of the test.
4.2.3—The tank shall then be slowly filled with air to a pressure of 1.25 psig (8.5 kPa gage) or one-half the design pressure $P_G$, whichever is smaller. Soap suds shall be applied to the exterior of the tank. If any leaks appear, the defects shall be repaired, and the test repeated. The PNT-VIO test is complete when no leaks are found.

4.3—Test preparation

4.3.1—After the tank has been inspected, a calibrated pressure gage or manometer shall be connected to the tank and the pressure-relief valve or valves and vents shall be plugged. Air shall be slowly injected into the tank until the internal pressure reaches 1.25 $P_G$ or the maximum allowable test pressure, whichever is smaller.

4.4—Test measurements

4.4.1—As the pressure is increased, inspect the tank for signs of distress. If distress is observed, the condition shall be repaired before progressing with the test. After the test pressure is achieved, close the inlet and keep the tank pressurized for 2 hours. Record the barometric pressure and pressurized air temperature at the start and end of the test period. Measure the pressure drop and elapsed time between the start and conclusion of the test for the purpose of calculating the volume change over a 24-hour period. If the tank does not meet the test criterion, the tank shall be retested after repair of any known defect. The pressure shall then be released slowly and the plugs shall be removed from the relief valves. The operation of the relief valves shall then be checked by injecting air into the tank until the pressure equals the design pressure $P_G$. If the relief valves do not start to release air, they shall be adjusted or repaired.

4.4.2—The design pressure shall be held until a close visual inspection of all visible joints in the tank and around manways, nozzles, and other openings and penetrations has been performed. During such inspection, soap suds shall be applied to the surface being inspected.

4.4.3—Upon completion of the test, the pressure in the tank shall be released and a thorough visual inspection made of both the inside and outside of the tank. Give particular attention, on combination metal tanks, to all internal metal ties, braces, trusses, and their attachments to the walls of the tank.

4.3—Test preparation

4.3.1—The requirement for using the smaller pressure is to prevent the structure from becoming overstressed.

4.4—Test measurements

4.4.1—The criterion is very stringent and therefore the 2 h time period should be sufficient to determine the tightness of the tank. The operability of the relief valves is checked to see that the tank will be protected when placed in operation.

4.4.2—The potential for leakage is greater at joints, fittings and accessories. The use of soap suds at these locations, with the tank pressurized, should indicate if leakage is present.

4.4.3—The final inspection is called for to verify that no damage occurred to the tank from the test loading.
4.5—Quantitative criteria

4.5.1—There shall be no measurable loss of test air volume for tanks subjected to the PNT-NML tightness test. No measurable loss shall mean less than 1.0% loss of test air volume after correction for the change in barometric pressure and air temperature.

4.5.2—The allowable loss of air volume for the PNT-2000 tightness test shall not exceed 2% of the test air volume in a 24-hour period after correction for the change in barometric pressure and air temperature.

R4.5—Quantitative criteria

The test is believed to be sufficient for most tanks constructed for the storage of liquids or gases under low-pressure. However, if in the opinion of the engineer, additional tests are needed to investigate the safety of a tank under certain other conditions of loading, as determined from the design computations, such tests should also be made on the tank in addition to this test.

R4.5.2—An example of the calculations for determining the percent of air volume loss for a test would be:

Initial readings: Pressure 2.250 psig
Barometric Pressure 14.70 psi
Temp. of test air 72 F

Final readings: Pressure 2.225 psig
Barometric Pressure 14.67 psi
Temp. of test air 71 F

Test duration: 2 hours

Absolute values:

Initial

$P_1$ (Pressure) $2.25 + 14.70 = 16.95$ psi
$T_1$ (Temperature) $72 + 459.7 = 531.7$ R

Final

$P_2$ (Pressure) $2.225 + 14.67 = 16.895$ psi
$T_2$ (Temperature) $71 + 459.7 = 530.7$ R

$V_2 = P_1 V_1 T_2 / P_2 T_1 = 16.95 V_1 530.7 / 16.895(531.7)$

$V_2 = 1.001369 V_1$

% loss of air volume =
$0.001369(100) / 1.001369 = 0.137\%$ in 2 h
% loss of air volume in 1 day = $0.136(12) = 1.6\%$

SI Units

Initial readings: Pressure 15.513 kPa gage
Barometric Press. 101.353 kPa
Temp. of test air 22.22 C

Final readings: Pressure 15.341 kPa gage
Barometric Pressure 101.146 kPa
Temperature of test air 21.667 C

Test duration: 2 hours

Absolute values:

Initial

$P_1$ (Pressure) $15.513 + 101.353 = 116.866$ kPa
$T_1$ (Temperature) $22.22 + 273.2 = 295.42$ K

Final

$P_2$ (Pressure) $15.341 + 101.146 = 116.487$ kPa
$T_2$ (Temperature) $21.67 + 273.2 = 294.87$ K

$V_2 = P_1 V_1 T_2 / P_2 T_1$

$V_2 = 116.866 V_1 294.87 / 116.487(295.42)$

$V_2 = 1.001386 V_1$

% loss of air volume =
$0.001386(100) / 1.001386 = 0.139\%$ in 2 h
% loss of air volume in 1 day = $0.139(12) = 1.7\%$
4.5.3—Test designation PNT-VIO shall be used for a tank tested only by visual inspection with a vacuum box. The inspection shall be performed while the tank is pressurized to 1.25 psig (8.5 kPa gage) or one-half the design pressure, whichever is smaller.

4.5.4—A restart of the test shall be required when test measurements become unreliable due to a rapid change of barometric pressure or other external factors.

4.5.5—The tank constructor shall be permitted to immediately retest a tank failing the test when no visible leakage is exhibited. If the tank fails the second test or if the builder does not exercise the option of immediately retesting after the first test failure, the tank shall be inspected to determine probable areas of leakage. The tank shall only be retested after the most probable areas of leakage are repaired.

4.5.6—Tanks shall be retested until they meet the required criterion. Repairs shall be made to the probable leakage areas before each retest.

R4.5.3—Test PNT-VIO may be used for exterior tanks that will contain nonhazardous gases.

R4.5.5—The immediate retest is allowed for confirmation of the first test results. This should minimize the cost of inspections due to measurement errors or slow deflection of structural elements.
CHAPTER 5—COMBINATION HYDROSTATIC-PNEUMATIC TEST, CPT, FOR CLOSED TANKS

5.1—Standard Test

5.1.1—The standard combination hydrostatic-pneumatic test shall have the prefix CPT followed by the test criterion expressed as the maximum allowable percent loss per day of the test air volume. Standard criteria for the CPT test are:

<table>
<thead>
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<th>Tightness Criterion</th>
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</thead>
<tbody>
<tr>
<td>CPT-NML</td>
<td>No measurable loss</td>
</tr>
<tr>
<td>CPT-2000</td>
<td>2.000% per day</td>
</tr>
<tr>
<td>CPT-VIO</td>
<td>Visual Inspection only</td>
</tr>
</tbody>
</table>

5.1.2—Combination hydrostatic-pneumatic testing shall be confined to tanks that have been designed and constructed to resist the applied test loading. The combination hydrostatic-pneumatic testing of the tank shall be conducted after any lining, interior waterproofing membrane, or interior coating is in place. Combination hydrostatic-pneumatic tests shall be limited to pneumatic test pressures within the low pressure range.

5.1.3—Tanks shall be tested for tightness when required by contract documents, applicable code, regulation, statute, or governing authority. When a pneumatic tightness test is required and a specific criterion is not stated, the test shall be CPT-NML for tanks that are enclosed or partially enclosed in a building, and CPT-2000 for tanks that are surrounded by outside air.

5.2—Tank inspection

5.2.1—The tank inspection shall be in accordance with the requirements of test HST-VIO, Part 1 as described in Section 2.2. Concrete joints and cracks shall be tested with a vacuum box.

5.2.2—Interior liners (if not already in place), interior waterproofing membranes, and interior coatings shall be installed after the joints and cracks exhibiting leakage of air, through the joint or crack, are repaired and retested.

COMMENTARY

R5.1—Standard Test

R5.1.1—The test designation system adopted allows for future revision, if necessary, to the tightness criteria. The system makes the tightness criterion used for the test self-evident.

Different materials, methods of construction, and design philosophy may result in different tank tightness. Based on reasonable tightness of different types of tank construction, three standard criteria have been established. The selected criterion should consider the tank design, tank construction, and the tightness necessary for the stored contents.

R5.2—Tank inspection

R5.2.1—See R2.2. The stringent criteria for this test requires checking joints and cracks for leakage. Vacuum boxes are used to locate leaking joints, cracks, and porous spots. Soap suds are applied to the suspect area and the area covered with a vacuum box. A vacuum of at least 3 psig (20 kPa gage) is created within the box. Air leakage through or at the suspect area will result in the formation of soap bubbles. All soap solutions should be thoroughly flushed and rinsed from the concrete and metal surfaces after use.

R5.2.2—Liners, membranes, or coatings, when included in the design, should be installed prior to final testing due to the stringent criteria of the test. Liners, mechanically locked to the surface during concrete placement, should be installed prior to preliminary testing.
5.3—Test preparation

5.3.1—After all the joints have been inspected and all defective joints disclosed by such inspection have been repaired and reinspected, the tank shall be filled with water to the design water level. The top of the tank shall be vented to the atmosphere during the filling of the tank to prevent pressurization by trapped air. The rate at which water is introduced into a tank shall not exceed 4 ft/h (1.2 m/h). If any leaks appear, the defects shall be repaired.

5.3.2—The water in unlined or uncoated tanks shall remain at the design water level for at least three days. Pressure shall not be applied above the surface of the water before the tank and its contents are at about the same temperature.

5.3.3—A calibrated pressure gage or manometer shall be connected to the pneumatic portion of the tank and the pressure-relief valve or valves shall be plugged. Vents at the top of the tank shall be closed, and air shall be injected slowly into the top of the tank until the pressure in the vapor space is at the design pressure $P_G$. Soap suds shall be applied to the exterior of the pneumatic portion of the tank to check for air leakage. All defects allowing air or water leakage shall be repaired and the tank rechecked for leakage. The CPT-VIO test is complete when no leaks are found.

5.4—Test measurements

5.4.1—As the pressure is being increased, the tank shall be inspected for signs of distress. If distress is observed, the condition shall be repaired before progressing with the test. After the test pressure of 1.25 times the vapor space design pressure $P_G$ is achieved, it shall be held for sufficient time for the pressurized air to saturate the liquid. The inlet shall then be closed and the pressure held in the tank for 2 hours. Record the barometric pressure and pressurized air temperature at the start and end of the test period. Measure the pressure drop and elapsed time between the start and the conclusion of the test for the purpose of calculating the volume change over a 24-h period. If the tank does not meet the test criterion, the tank shall be retested after repair of any known defect. The pressure shall then be released slowly and the plugs removed from the relief valves. The operation of the relief valves shall then be checked by injecting air into the top of the tank until the pressure in the vapor

R5.3—Test preparation

R5.3.1—The foundation, venting equipment, or other conditions may limit the water filling to a lower rate.

R5.3.2—The three-day waiting period is considered sufficient allowance for moisture absorption by the concrete. The waiting period can be extended for unlined or uncoated tanks, if desired. A change in the air temperature of the pressurized air could affect the results of the test. It is preferred that the test water temperature be 60 F (15.5 C) or higher.

R5.3.3—The exterior test can indicate defects in liners, membranes, and coatings. The requirement for using the smaller pressure is to prevent the structure from becoming overstressed.

R5.4—Test measurements

R5.4.1—It is recognized that the criterion is very stringent and therefore the two-hour time period should be sufficient to determine the tightness of the tank. The operability of the relief valves is checked to see that the tank will be protected when placed in operation.
space equals the design pressure $P_G$. If the relief valves do not start to release air, they shall be adjusted or repaired.

5.4.2—The design pressure shall be held long enough to permit a close visual inspection of joints in the tank and around hatches, manways, nozzles, pipe connections, and other openings and penetrations. During the inspection, soap suds shall be applied to all of the tank’s exterior surface which is opposite the pressurized air.

5.4.3—Upon completion of the test, the tank shall be emptied and a thorough visual inspection shall be made of both the inside and outside of the tank. Give particular attention, on combination concrete and metal tanks, to all internal metal ties, braces, trusses, and their attachments to the walls of the tank.

5.5—Quantitative criteria

5.5.1—There shall have no measurable loss of test air volume for tanks subjected to the CPT-NML tightness test. No measurable loss shall mean less than 1.0% loss of test air volume after correction for the change in barometric pressure and air temperature.

5.5.2—The allowable loss of air volume for the CPT-2000 tightness test shall not exceed 1% of the test air volume in a 24-hour period after correction for the change in barometric pressure and air temperature.

5.5.3—Test designation, CPT-VIO, shall be used for a tank tested only by visual inspection for water leakage and inspection by soap bubbles over the exterior surface of the pneumatic area of the tank while the design pressure is applied.

5.5.4—A restart of the test shall be required when test measurements become unreliable due to a rapid change of barometric pressure or other external factors.

5.5.5—An immediate retest of tank failing the initial test shall be permitted when no leakage is exhibited. If the tank fails the second test or if the tank constructor does not exercise the option of immediately retesting after the first test failure, the interior of the tank shall be inspected by a diver or by other means to determine probable areas of leakage. The tank shall only be retested after the most probable areas of leakage are repaired.

5.5.6—Tanks shall be retested until they meet the required criterion. Repairs shall be made to the probable leakage areas before each retest.
CHAPTER 6—REFERENCES
