Standard Practices for
Simulated Service Testing for Corrosion of Metallic Containment Materials for Use With Heat-Transfer Fluids in Solar Heating and Cooling Systems[1]

This standard is issued under the fixed designation E745; 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 These practices cover test procedures simulating field service for evaluating the performance under corrosive conditions of metallic containment materials in solar heating and cooling systems. All test results relate to the performance of the metallic containment material only as a part of a metal/fluid pair. Performance in these test procedures, taken by itself, does not necessarily constitute an adequate basis for acceptance or rejection of a particular metal/fluid pair in solar heating and cooling systems, either in general or in a particular design.

1.2 These practices describe test procedures used to evaluate the resistance to deterioration of metallic containment materials in the several conditions that may occur in operation of solar heating and cooling systems. These conditions include: (*1*) operating full flow; (*2*) stagnant empty vented; (*3*) stagnant, closed to atmosphere, non-draindown; and (*4*) stagnant, closed to atmosphere, draindown.

1.3 The recommended practices cover the following three tests:

1.3.1 *Practice A*—Laboratory Exposure Test for Coupon Specimens.

1.3.2 *Practice B*—Laboratory Exposure Test of Components or Subcomponents.

1.3.3 *Practice C*—Field Exposure Test of Components or Subcomponents.

1.4 Practice A provides a laboratory simulation of various operating conditions of solar heating and cooling systems. It utilizes coupon test specimens and does not provide for heating of the fluid by the containment material. Practice B provides a laboratory simulation of various operating conditions of a solar heating and cooling system utilizing a component or a simulated subcomponent construction, and does provide for heating of the fluid by the containment material. Practice C provides a field simulation of various operating conditions of solar heating and cooling systems utilizing a component or a simulated subcomponent construction. It utilizes controlled schedules of operation in a field test.

1.5 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.6 *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.* For a specific safety precaution statement see Section 6.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E712 Practice for Laboratory Screening of Metallic Containment Materials for Use With Liquids in Solar Heating and Cooling Systems

3. Terminology

3.1 *Definitions:*

3.1.1 *collector, n*—a device designed to absorb incident solar radiation and transfer the energy to a heat-transfer fluid. A collector has an absorber surface, a containment membrane, and may or may not have insulation and glazing.

3.1.2 *component, n*—an individually distinguishable product that forms part of a more complex product, that is, a subsystem or system. The panel and collector are each components.

3.1.3 *panel, n*—the absorber surface and containment membrane within the collector.

3.1.4 *simulated subcomponent, n*—a specimen fabricated in such a manner as to embody the major characteristics of a

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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.

component with regard to material selection, design, forming, joining, and surface condition.

4. Significance and Use

4.1 At this time none of these practices have been demonstrated to correlate with field service.

4.2 Because these procedures do not restrict the selection of either the containment material or the fluid for testing, it is essential that consideration be given to the appropriate pairing of metal and fluid. Likewise, knowledge of the corrosion protection mechanism and the probable mode of failure of a particular metal is helpful in the selection of test conditions and the observation, interpretation, and reporting of test results.

4.3 It is important that consideration be given to each of the permitted variables in test procedure so that the results will be meaningfully related to field performance. It is especially important that the time of testing selected be adequate to correctly measure the rate of corrosion of the containment material.

NOTE 1—Corrosion, whether general or localized, is a time-dependent phenomenon. This time dependence can show substantial nonlinearity. For example, formation of a protective oxide will diminish corrosion with time, while certain forms of localized attack accelerate corrosion with time. The minimum time required for a test to provide a corrosion rate that can be extrapolated for the prediction of long-term performance varies widely, depending on the selection of metal and fluid, and on the form of corrosion attack. Therefore, it is not possible to establish a single minimum length of test applicable to all materials and conditions. However, it is recommended that for the tests described in these practices, a test period of no less than 6 months be used. Furthermore, it is recommended that the effect of time of testing be evaluated to detect any significant time dependence of corrosion attack.

4.4 It is essential for the meaningful application of these procedures that the length of test be adequate to detect changes in the nature of the fluid that might significantly alter the corrosivity of the fluid. For example, exhaustion of chemical inhibitor or chemical breakdown of the fluid may occur after periods of months in selected cycles of operation.

NOTE 2—Many fluids that may be considered for solar applications contain additives to minimize the corrosivity of the fluid. Many such additives are useful only within a specific concentration range, and some additives may actually accelerate corrosion if the concentration falls below a critical level. Depletion kinetics can be a strong function of the exposed metal surface area. Therefore, for tests involving fluids with such additives, consideration must be given to the ratio of metal surface area to fluid volume as it may relate to an operating system.

5. Materials

5.1 Any metallic material may be selected for evaluation. The material must be capable of being described with sufficient accuracy to permit reproduction of the test.

5.2 Any heat-transfer fluid may be selected for evaluation. However, it is expected that the fluid will be selected with consideration given to possible interactions of material and fluid under the conditions of testing. The fluid should be capable of being described chemically, as to its basic components and as to the presence or absence of minor components that affect the interaction with the metal. It is permitted to precondition the fluid before testing. Any such preconditioning treatment shall be described in the report.

6. Safety Precautions

6.1 Particular attention must be directed to avoidance of materials, fluids, or metal/fluid pairs that can be hazardous to the operator. The flammability, vapor pressure, and toxicity of the heat transfer fluid shall be known prior to initiation of testing and appropriate precautionary measures shall be taken to ensure the safety of all test personnel.

7. Calculations and Interpretation of Results

7.1 Determine the deterioration of the containment material by measurement of weight loss when possible, by measurement of metal thinning, and by examination at 10× magnification for incidence of localized attack.

7.1.1 Whatever cleaning method is used, the possibility of removal of solid metal is present; this results in error in the determination of the corrosion rate. One or more cleaned and examined specimens should be recleaned by the same method and reexamined. Loss due to this second cleaning may be used as a correction to the first one.

7.1.2 To determine the corrosion rates based on weight loss, calculate the total surface area (making allowance for the change in surface area due to mounting holes) and divide the weight loss by the area to obtain the weight loss per unit area. This result may be divided by the duration of the test to obtain the corrosion rate in weight loss per unit area per unit time (such as $\text{mg/dm}^2\cdot\text{day} = \text{mdd}$). This result may be divided by the density of the metal to obtain a rate of loss in terms of thickness of the specimen (mils per year = mpy), for instance:

$$R_{\text{mdd}} = 100\ 000\left(W_o - W_t\right)/AT) \tag{1}$$

where:

R_{mdd} = the corrosion rate, mdd,
W_o = original weight, g,
W_t = final weight, g,
A = area, cm^2, and
T = duration, days.

or

$$R_{\text{mpy}} = 393.7\left(W_o - W_t/ATD\right) \tag{2}$$

where:

R_{mpy} = corrosion rate, mpy,
W_o = original weight, g,
W_t = final weight, g,
A = area, cm^2,
T = duration, years, and
D = density, g/cm^3.

7.1.3 Identify any incidence of localized corrosion, whether pitting, crevice attack, intergranular attack, cracking, or any other form of localized attack, rate under at least 10× magnification, and report. Report the location, distribution, and maximum depth of attack for any localized attack.

7.2 Report any changes of the heat-transfer fluid, for example, appearance or odor, and include the results. Describe any changes in the appearance or condition of the test apparatus indicative of interaction with the metal specimen or fluid.

7.3 In the event of film formation and buildup, report the nature of the film and its degree of buildup.

7.4 For the evaluation of a containment material couple, an effort should be made to utilize the same procedures as for a single material test. However, because of the variability permitted in the design of the specimen for the couple, it may not be appropriate to report weight loss or penetration. For all tests of metal couple/fluid performance, special attention should be given to observation and reporting of localized corrosion and evidence of galvanic attack.

8. Report

8.1 Identify the containment material using a recognized standard test method, where applicable, or by chemical analysis. In case of identification by a standard method, supplemental identification by typical analysis for that standard, or by chemical analysis of the specimen is desirable.

8.2 Report the dimensions and configuration of the specimen. In the case of a metal couple, the report shall include at least the following elements: (*1*) description of the individual components of the couple; (*2*) description of the method of attachment or association of the couple including any third material introduced as a binder or for other function and the procedures or connection, for example, surface preparation, conditions of attachment, and cleaning; (*3*) any change of the containment materials resulting from the coupling procedure; and (*4*) description of the relative areas of exposure of the components of the couple to the heat-transfer medium.

8.3 The heat-transfer fluid shall be identified by standard methods where applicable, by initial chemical analysis, or by proprietary designation. Use of trademarks, or names of patented or proprietary products, without accompanying chemical description is discouraged but not prohibited. For aqueous transfer fluids, the analysis of the water used shall be reported.

8.4 Identify the procedure used. Specify the test conditions used, including specimen preparation, time and temperature schedule, degree of atmospheric exposure of the heat transfer fluid, stirring, and flow rate, where applicable. Describe the method of temperature measurement and control, with comment on its accuracy and precision. Report any deviation from the standard procedure and so identify as a deviation.

8.5 Report the weight loss and average penetration rate, when applicable. If the time dependence of the corrosion rate is significant, (see Note 1), note this in the report, and include a plot of the corrosion rate as a function of time. Report all instances of localized deterioration of the test specimen. In the event of pitting or other non-uniform attack, report the frequency of attack and maximum penetration.

8.6 A commentary on the results and their interpretation, particularly their applicability to various designs for solar heating and cooling systems, is optional but desirable.

PRACTICE A LABORATORY EXPOSURE TEST FOR COUPON SPECIMENS

9. Scope

9.1 This procedure is intended to evaluate the resistance to deterioration of metallic containment materials in contact with various heat-transfer fluids. By proper selection of test conditions, a wide range of operating conditions may be evaluated. However, the test procedure does not provide for a condition wherein heat is transferred from the containment material into the fluid.

10. Test Specimens and Sample

10.1 Select the test specimens from material that may reasonably represent that material as it would be applied in a solar heating and cooling system.

10.2 For laboratory corrosion tests that simulate exposure to service environments, a commercial surface such as a mill finish, closely resembling the one that would be used in service, will yield the most significant results. For more searching tests of either the metal or the environment, standard surface finishes may be preferred. Ideally, the surface finish should be recorded in surface roughness terms, such as rms·in.

10.3 *General Cleaning:*

10.3.1 General cleaning may be accomplished with a wide variety of cleaning media. Water-based cleaners should be followed by an alcohol dip after thorough rinsing. Solvent cleaners such as petroleum fractions, aromatic hydrocarbons, and chlorinated hydrocarbons are generally acceptable. Chlorinated solvents, however, should not be used on titanium, staininless steel, or aluminum. Mechanical cleaning of very smooth surfaces may be accomplished by using a pase of magnesium oxide or aluminum oxide.

10.3.2 Any of the methods suitable for cleaning a given corroded specimen may be used to complete the cleaning of specimens prior to test, provided that they do not cause localized attack. The cleaned specimens should be measured and weighted. Dimensions determined to the third significant figure and weight determined to the fifth significant figure are usually satisfactory.

10.4 *Metallurgical Condition*—Specimen preparation may change the metallurgical condition of the metal. For example, shearing a specimen to size will cold work and possibly fracture the edges. The specimen may be tested in this condition if it is believed that such condition may be encountered in service. In such case, the condition shall be described in the report of results. However, it is recommended that changes in metallurgical condition be corrected for customary testing. For example, sheared edges should be machined or the specimen annealed.

10.5 *Alternative Specimen Designs*—Alternative specimen designs, particularly those incorporating crevices or metal coupling as may be encountered in service, are recommended.

10.6 *Electrolytic Cleaning*—For many metals, electrolytic cleaning is a satisfactory method for cleaning after testing.

10.6.1 The following method is typical: after scrubbing to remove loosely attached corrosion products, treat the specimen as a cathode in hot, dilute sulfuric acid under the following conditions:

10.6.1.1 *Electrolyte*—Sulfuric acid (5 weight %),

10.6.1.2 *Inhibitor*—0.2 volume % organic inhibitor (see Note 3),

10.6.1.3 *Anode*—Carbon or lead (see Note 4), 10.6.1.4 *Cathode*—Test specimen,

10.6.1.5 *Cathode Current Density*—2000 A/m^2,

10.6.1.6 *Temperature*—165°F (75°C), and

10.6.1.7 *Exposure Period*—3 min.

NOTE 3—Instead of using 0.2 volume % of any proprietary inhibitor, about 0.5 kg/m^3 of inhibitors such as diorthotolyl thiourea, quinoline ethiodide, or betanaphthol quinoline may be used.

NOTE 4—If lead anodes are used, lead may deposit on the specimen and cause an error in the weight loss. If the specimen is resistant to nitric acid, the lead may be removed by a flash dip in 1 + 1 nitric acid. Except for the possible source of error, lead is preferred as an anode as it gives more efficient corrosion product removal.

10.6.2 After the electrolytic treatment, scrub the specimens with a brush, rinse thoroughly, and dry.

10.6.3 This electrolytic treatment may result in the redeposition of metal, such as copper, from reducible corrosion products and, thus, lower the apparent weight loss.

10.7 *Chemical Cleaning*—Chemical cleaning of specimens after testing is satisfactory provided the following methods are used:

10.7.1 *Copper and Nickel Alloys*—Dip for 1 to 3 min in HCl (1 + 1) or H_2SO_4 (1 + 10) at room temperature. Scrub lightly with bristle brush under running water, using fine scouring powder if needed.

10.7.2 *Aluminum Alloys*—Dip for 5 to 10 min in a water solution containing 2 weight % of chromic acid (chromium trioxide, CrO_3) and 5 vol % of orthophosphoric acid (H_3PO_4, 85 %) maintained at 175°F (80°C). Ultrasonic agitation will facilitate this procedure. Rinse in water to remove the acid, brush very lightly with a soft bristle brush to remove any loose film, and rinse again. If film remains, immerse 1 min in concentrated nitric acid and repeat previous steps. Nitric acid alone may be used if there are no deposits.

10.7.3 *Tin Alloys*—Dip for 10 min in boiling trisodium phosphate solution (15 %). Scrub lightly with bristle brush under running water, and dry.

10.7.4 *Iron and Steel*—Suitable methods are as follows:

10.7.4.1 Preferably, use electrolytic cleaning (see 10.6).

10.7.4.2 Immerse in Clark's solution (100 parts hydrochloric acid, 2 parts antimonious oxide, 5 parts stannous chloride) for up to 25 min. Solution may be cold, but it should be stirred vigorously.

10.7.4.3 Remove scales formed on steel under oxidizing conditions in 15 volume % concentrated phosphoric acid containing 0.15 volume % of organic inhibitor at room temperature.

10.7.4.4 Clean stainless steel in 20 % nitric acid at 140°F (60°C) for 20 min.

10.7.4.5 In place of chemical cleaning, use a brass scraper or brass bristle brush, or both, followed by scrubbing with a wet bristle brush and fine scouring powder.

NOTE 5—Such vigorous mechanical cleaning is applicable when weight losses are large and hence errors in weight loss will produce only small errors in corrosion rates. Blank connections will be difficult to apply.

10.7.4.6 Other methods of cleaning iron and steel include immersion in hot sodium hydride, and cathodic pickling in molten caustic soda.

NOTE 6—These methods may be hazardous to personnel. They should not be carried out by the uninitiated or without professional supervision.

10.7.5 After cleaning and thorough rinsing, dry and weigh the samples.

11. Apparatus

11.1 *Test Cell*—For those portions of the test procedure that may be performed at atmospheric pressure, the test cell is typically a 4-L container of heat-resistant glass (see Note 7). Provision is made for closing the top of the test cell with a machinable nonmetallic cover (for example, polypropylene, acetal copolymers), while providing opening for temperature-measuring devices, tubes for simulating draindown, and tubes for gas sparging (see Fig. 1). All materials used in the apparatus shall be selected so that there is no significant interaction, other than the possibility of a mechanically imposed crevice, with the containment material or the heat-transfer fluid.

NOTE 7—For certain containment materials, there exists the possibility that silicate from the glass of the apparatus contaminating an aqueous heat-transfer fluid would significantly affect the corrosion observed in this test. The effect of silicate from this source would be minimal in those cases in which silicates are a part of the corrosion inhibitor system, or in which silicates are otherwise present in the heat-transfer fluid. However, for those cases in which the effect of silicate from glassware could have a significant effect on the results, it is recommended that other materials be used for the apparatus, such that no significant extraneous effects will be introduced in the results of the test.

11.2 *Specimen Holders*—Specimens shall be secured to nonmetallic holders utilizing a nonmetallic fastener or a fastener of the same material, similar in composition and processing. The specimen holders are in turn secured to the mixing shaft. For the purpose of simulating field service conditions, dissimilar metals that exist in operating systems (for example, steel storage tanks, Pb-Sn solders, copper plumbing) may be included in the cell. Galvanic couples may be established between materials that are in electrical contact in operating systems.

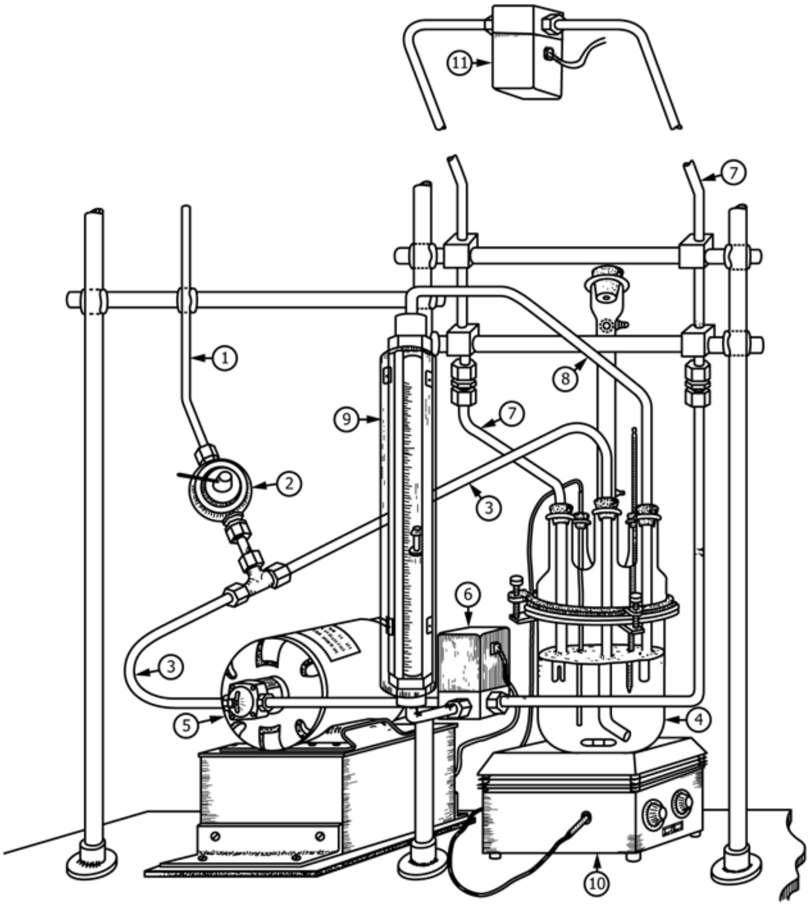
11.3 *Mixing Shaft,* capable of rotating, such that the outer edge of the specimen encounters a fluid-to-metal speed approximately equivalent to fluid flow rates encountered in service.

11.4 *Heating Device*—The test cell may be heated by mantle, hot plate, or bath. Use of the bath may minimize the variation in heating and cooling rates when metal/fluid pairs are being evaluated. For certain fluids, the more localized heating typical of a hot plate in comparison with the other methods, may produce changes in the heat-transfer fluid.

11.5 Metal/fluid heating and cooling rates, and the upper and lower temperature limits, should be selected to simulate field service conditions. Control of temperature at the upper and lower limits should be ±5°F (3°C). Cooling below ambient may be accomplished by a refrigeration unit.

11.6 Conditions of aeration and deaeration may be accomplished by gas sparging.

11.7 *Autoclave*—For test conditions that cannot be achieved in open atmosphere, the mixing shaft and attached specimens can be transferred to an autoclave.



NOTE 1—The systems are initially charged with liquid through the priming port (*1*) by opening the manual two-way valve (*2*). The common flow path (*3*) is from the reservoir (*4*), through the pump (*5*), to the three-way solenoid valve (*6*). The primary flow path (*7*) is across the samples. The flow path is changed from primary to secondary by activating the three-way solenoid valve (*6*) and the secondary path (*8*) during loop stagnation is through the flowmeter (*9*). The hot plate (*10*) maintains the liquid temperature during stagnation. In systems which stagnate above the boiling point of the liquid, a two-way solenoid valve (*11*) placed at the top of the loop is activated during stagnation. In continuous flow systems, a manual three-way valve replaces the three-way solenoid valve (*6*).

FIG. 1 Schematic Showing the Various Components of the Loop Systems

12. Procedure

12.1 Cut metallic containment test specimens from sheet having a gage similar to the wall of the solar absorber channel. The metallurgical condition of the test specimen should be similar to that of the finished absorber product. Typical test specimen dimensions are 1⅝ in. (41 mm) long by 1 in. (25 mm) wide. Dimensions should be maintained to within ±0.005 in. (0.10 mm).

12.2 Clean specimens and weigh to an accuracy of 0.1 mg immediately prior to testing. Multiple similar specimens may be prepared to facilitate a withdrawal schedule for the purpose of examining the time dependence of metal/fluid interaction. Assemble the apparatus and fill the test cell with a volume of the selected heat-transfer fluid sufficient to cover all specimens (for example, 15 cm^3/cm^2). A sufficient volume of the heat-transfer fluid should be retained to permit later chemical analysis as desired. During testing, should significant evaporation occur, it is permitted to add solvent periodically (that is, in aqueous systems, either potable or distilled water; in nonaqueous systems, the heat-transfer fluid at full strength) to maintain the fluid volume-to-specimen surface area ratio.

12.3 Any schedule of operation may be selected; however, it is recommended that the schedule reflect the range of condition that may be typically encountered in field service. For example:

12.3.1 Test cells are at 50°F (10°C). Pump fluids from reservoirs to test cells and heat test cells to 200°F (93°C) in 1 h.

12.3.2 Maintain test cells at 200°F (93°C) for 6 h.

12.3.3 Allow test cells to cool for 1 h.

12.3.4 Pump fluid from test cell to reservoir. Cool test cells to 50°F (10°C) in 1½ h and maintain until cycle is repeated the following day.

12.3.5 On a regular schedule, that is, once every two weeks, replace the daily cycle with an autoclave cycle. For example, transfer the mixing shaft to the autoclave and secure so as to avoid galvanic contact. Heat the autoclave to 400°F (204°C), hold for 4 h at 400°F and then allow to cool. Then return the specimens to the test cell. This procedure is intended to simulate the stagnant empty condition.

12.4 Specimens may be withdrawn at interim periods, for example, at 1 month and 3 months, and at the conclusion of the test, typically 6 months (see Note 1).

13. Precision and Bias

13.1 This procedure has been used by a laboratory for screening of copper and aluminum containment materials and various aqueous and nonaqueous heat-transfer fluids. The results are reported to have satisfactory repeatability and reproducibility. No supporting data are provided; therefore, the precision and bias of this procedure are unknown. The procedure is set down here for the purpose of regularizing testing in order to develop meaningful precision and bias data.

PRACTICE B LABORATORY EXPOSURE TEST OF COMPONENTS OR SUBCOMPONENTS

14. Scope

14.1 This procedure is intended to evaluate the performance under corrosive conditions of containment materials in components, or simulated subcomponents, in simulations of various conditions of field service achieved under laboratory procedures.

15. Test Specimens and Sample

15.1 Select the test specimen from material that would reasonably represent the material as it would be applied in a solar heating and cooling system.

15.2 The test specimen may be a tube or pipe, a section of flow channel cut from a panel, or a simulated subcomponent. It is recommended that the specimen be constructed to permit weight loss measurements.

16. Apparatus

16.1 The apparatus shall consist of a storage tank, a pump, suitable plumbing, a process controller, monitoring equipment, a refrigeration unit, and a suitable means of heating the metallic containment loop (see Fig. 1 and Fig. 2).

16.2 *Tank,* of sufficient size to receive the thermal output of the collector without reaching temperatures appreciably in excess of those expected in service. For those systems in which ratio of fluid volume to absorber contact surface is thought to be significant, the tank size shall be adjusted accordingly. The tank material shall be that which would customarily be encountered in service, or an alternative material inert with respect to the heat-transfer fluid.

16.3 *Pump,* of appropriate size and control to provide a flow rate, expressed in volume per time, that would be typical of anticipated service conditions. The material of construction of the pump shall be that which would customarily be encountered in service, or an alternative material inert with respect to the heat-transfer fluid.

16.4 The system shall be plumbed with the same materials as would be typically employed in service conditions. The nature of these materials and the manner of their attachment to the absorber shall be reported.

16.5 *Timing Device*—The test shall be operated by a controller, typically a timer that will activate the pump on a daily cycle of operation.

16.6 *Temperature-Monitoring Device*—Provision shall be made for monitoring the temperature of the exterior surface of

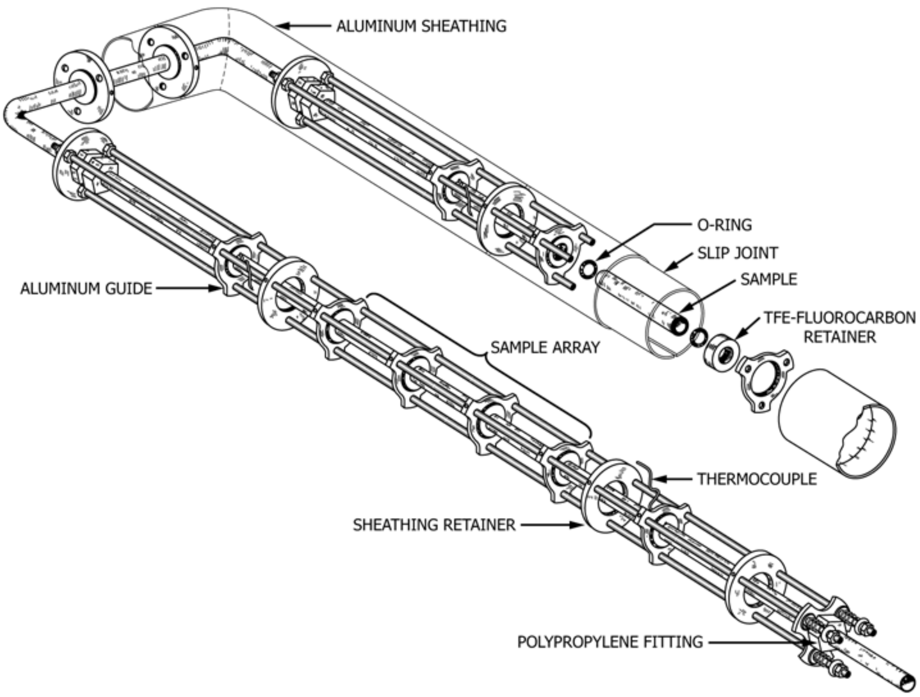


FIG. 2 Schematic of a Typical Loop Showing the Samples, the Sample Support System, and the Sheathing Support System

the test specimens, other parts of the containment system, and the liquid in the tank at various points in the system.

16.7 Provision shall be made for aeration or deaeration of the heat-transfer liquid.

17. Procedure

17.1 If the specimen is suitable for weight loss measurements, then the specimen shall be cleaned in accordance with Practice E712.

17.2 Assemble the apparatus and charge with heat-transfer fluid.

17.3 Any schedule of operation is permitted; however, it is recommended that consideration be given to the anticipated field operation in the selection of a schedule of full operation and stagnation cycles. For systems in which stagnation is considered to be the condition most likely to cause metal deterioration, the scheduling of stagnation periods more often than would typically be encountered in service provides a method of accelerated testing.

17.4 It is recommended that the test be conducted on a specified cycle for at least 90 days. For example:

17.4.1 Initiate the cycle at the minimum expected service temperature.

17.4.2 Heat the containment system to a maximum service temperature over a 1-h period.

17.4.3 Maintain the containment system at the maximum service temperature for 2 h under designated stagnation conditions.

17.4.4 Permit flow to resume and cool the containment system to the minimum service temperature over a period of 1 h.

17.5 Provide for periodic withdrawal of samples of the heat-transfer fluid for chemical analysis.

17.6 At the end of the test period, disassemble the apparatus and visually inspect for indications of corrosion or accumulation of deposits.

18. Precision and Bias

18.1 The precision and bias of this procedure are unknown at this time.

PRACTICE C FIELD EXPOSURE TEST OF COMPONENTS OR SUBCOMPONENTS

19. Scope

19.1 This test procedure is intended to evaluate the performance under corrosive conditions of containment materials in components or simulated subcomponents in simulation of various conditions of field service achieved by controlled operation in a field test.

20. Test Specimens and Sample

20.1 The test specimen shall be a metallic absorber panel of a solar collector, either a full-size unit, or a subsize unit constructed to simulate the full-size unit. The panel and the collector shall be of materials and construction that would represent the unit as it would be typically applied in a solar heating and cooling system.

21. Apparatus

21.1 The apparatus shall consist of the collector, a storage tank, a pump, suitable plumbing, a process controller, and monitoring equipment.

21.2 *Collector*—It is recommended that the collector be mounted with the aperture aligned with true south and tilted at an angle equal to the latitude of the test site, as nearly as practicable.

21.3 *Tank,* of sufficient size to receive the thermal output of the collector without reaching temperatures appreciably in excess of those expected in service. For those systems in which the ratio of fluid volume to absorber contact surface is thought to be significant, the tank size shall be adjusted accordingly. The tank material shall be that which would customarily be encountered in service, or an alternative material inert with respect to the heat-transfer fluid.

21.4 *Pump,* of appropriate size and control to provide a flow rate, expressed in volume per time, that would be typical of anticipated service conditions. The material of construction of the pump shall be that which would customarily be encountered in service, or an alternative material inert with respect to the heat-transfer fluid.

21.5 The system shall be plumbed with piping and fittings of the same materials as would be typically employed in service conditions. The nature of these materials and the manner of their attachment to the absorber shall be reported.

21.6 *Timing Device*—The test shall be operated by a controller, typically a timer that will activate the pump on a daily cycle of operation.

21.7 *Temperature-Monitoring Device*—It is recommended that provision be made for monitoring the temperature of the absorber panel, other parts of the collector, and the fluid at various points in the system.

21.8 Several test collectors may be operated at the same time on a single system provided the collectors are plumbed in parallel, and provided there is no likelihood of interaction through alteration of fluid chemistry.

22. Procedure

22.1 Assemble the apparatus and charge the heat-transfer fluid in a manner similar to that which would be employed in service.

22.2 Any schedule of operation is permitted; however, it is recommended that consideration be given to the anticipated field operation in the selection of a schedule of full operation and stagnation cycles. For systems in which stagnation is considered to be the condition most likely to cause metal deterioration, the scheduling of stagnation periods more often than would typically be encountered in service provides a method of accelerated testing. For example:

22.2.1 Pump the system overnight to cool the fluid, except under conditions that would lead to freezing of the fluid.

22.2.2 Continue pumping through the morning until solar noon.

22.2.3 Interrupt pumping at solar noon. The fluid may be allowed to remain in the panel or to draindown, depending on the condition being evaluated.

22.2.4 Resume pumping 1½ h after solar noon.

22.2.5 Continue pumping thereafter until the next cycle.

22.3 It is recommended that the test be operated on the specified daily cycle for at least 1 year. Shorter periods may be employed if effort is made to characterize the severity of the solar exposure with respect to the season of the year.

22.4 In the event that leakage is observed on the face of the panel, repair the panel by applying a sealer that is compatible with the panel. Report the nature of the leakage, its time of occurrence, and repair procedure.

22.5 It is recommended that the temperatures of the panel and fluid be measured at various times in the operating schedule to characterize the cycle of operation. It is also recommended that such measurements be made on a regular schedule within the period of testing to characterize the exposure period.

22.6 At the end of the test period, open the panel and inspect for indications of deterioration, including general corrosion, any form of localized corrosion, erosion, or other physical changes of the containment material. Report the presence and nature of any deposits.

23. Report

23.1 In addition to the requirements of Section 8, report the dimensions and configurations of the test panel, along with the method of assembly. Include a description of the collector design and construction, including all materials. Identify the materials of the tank, pump, and piping, and describe the methods and materials of connection. Specify the test location and provide information on the solar conditions during testing.

24. Precision and Bias

24.1 This procedure is specific to panel and collector design and construction, the schedule of operation, and the location of testing. The test is used for the evaluation of stainless steel panels but the repeatability and reproducibility of the test are not yet established. Therefore, the precision and bias are unknown.

25. Keywords

25.1 corrosion; field exposure; heat transfer fluids; immersion metallic containment materials; solar heating and cooling