# APPENDIX E

## ASTM SPECIFICATIONS

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E.1 ASTM D6489-99

Designation: D 6489 – 99 (Reapproved 2006)

Standard Test Method for Determining the Water Absorption of Hardened Concrete Treated With a Water Repellent Coating

This standard is issued under the fixed designation D6489; 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 reaffirmation.

1. Scope

1.1 This test method provides a procedure for the determination of the water absorption by a core of concrete taken from a surface treated with a water repellent.

1.2 The intended use of the water repellent coating is to reduce the amount of water that absorbs into the substrate.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 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.

2. Referenced Documents

2.1 ASTM Standards:

C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

D 1193 Specification for Reagent Water

D 1763 Specification for Epoxy Resins

D 3924 Specification for Environment for Conditioning and Testing Paint, Varnish, Lacquer, and Related Materials

E 145 Specification for Gravity-Convection And Forced-Ventilation Ovens

E 898 Test Method of Testing Top-Loading, Direct-Reading Laboratory Scales and Balances

3. Summary of Test Method

3.1 The specimen is dried to a constant weight and the portions of the specimen not treated with the water repellent are sealed with an impervious sealing material. The specimens are weighed and immersed in water. The specimens are removed from the water, weighed, and a percent water absorption is calculated.

4. Significance and Use

4.1 Researchers in the field of water repellent coatings have recognized the need for a standardized test for determining the performance of water repellents applied to structures in the field. Many coating manufacturer’s supply warranties for their products based on maintaining a specific water repellency on concrete. This test method can be used to determine the effective water repellency of the coating by comparing its performance to a control uncoated specimen.

5. Apparatus and Materials

5.1 Balance, having a capacity of not less than 4000 g (8.81 lb) and a sensitivity of 0.1 g, (0.0002 lb) as tested in accordance with Test Method E 898.

5.2 Hot Plate, capable of at least 149°C (300°F).

5.3 Metal Pan, at least 20.3 cm long by 15.2 cm wide and 5.1 cm deep (8 in. long by 6 in. wide and 2 in. deep), suitable to melt the wax or mix the epoxy.

5.4 Brush, Duck Tape.

5.5 Container, suitable for holding the water to immerse the specimens.

5.6 Forced Draft Oven, Type IIA or IIB, as defined in Specification E 145.

5.7 Reagent Water, as defined by Type IV of Specification D 1193.

5.8 Sealing Material, having very low permeability to water. Sealing material must meet the requirements of Section 6.

Note: 1—Sealing materials that in general meet the requirements that are defined in Specification D 1763, Type I, Grade 1, two component epoxies, epichlorohydrin/Biplenol A and polyamine + Biplenol A) or waxes used in the investment casting industry. Paraffin waxes are not acceptable.

6. Sealing Material

6.1 Use hardened concrete specimens as described in 7.1.
6.2 Follow the procedures of Section 8, except for 8.4 and 8.5. Instead use the sealing material to completely seal the specimen, top, bottom and sides.

6.3 Follow the procedures of Section 9, except completely submerge the specimens so that the water level is 25.4 mm (1.0 in.) over the top of the specimen.

6.4 After the specimens have been submerged in water for 48 h, acceptable sealing materials shall have a percent absorption of less than 0.1%.

Note 2—It is recommended to recheck the sealing material if a new batch is used or if the formulation of the sealing material has changed.

7. Test Specimen

7.1 Typical test specimens are hardened concrete cores, approximately 7.0 cm (2.75 in.) in diameter and 7.5 cm (2 to 3 in.) in length. A minimum of three cores for each test shall be used. Cores should be pulled in such a manner as not to damage the integrity of the surface. See Test Method C 42 C 42M for guidance.

8. Preparation of Specimens

8.1 Clean the sides and both faces of the specimens of all loose dust or cement paste from the core drilling process. Use compressed air or water and a soft brush only, more vigorous cleaning methods may damage some water repellent coatings.

8.2 Dry the specimens in a forced draft oven for 24 h at 75°C ± 5°C (167°F ± 9°F) until two successive weighings at intervals of 2 h show an increment of loss not greater than 0.2% of the last previously determined weight.

8.3 After drying, remove the specimens from the oven and allow them to cool to room temperature under ambient conditions (see Specification D 3924). Weigh each specimen to the nearest 0.1 g and record weight as \( W_A \).

8.4 Prepare sufficient wax or epoxy material to adequately coat all the specimens. If using wax, melt enough in a suitable container or if using a two-component coating, mix quantities that can be applied during the pot-life of the coating.

8.5 To keep the sealing material from contaminating the treated top surface and the bottom untreated surface of the specimen, place duct tape over these areas and cut the tape around the circumference so that there is no overlap on the longitudinal sides of the core.

8.6 Apply the sealing material to the specimens by either placing the longitudinal side of the specimen in the sealing material (place enough sealing material in the container so it is at least to a depth of 6.4 mm (0.25 in.)) and roll the specimen two to three revolutions, or brush on the sealing material. Be careful not to get any of the sealing material on the treated face.

8.7 Remove the specimen from the sealing material and place treated specimen face up on a firm surface.

8.8 Repeat 8.5 and 8.6 after 3 min have elapsed.

8.9 Carefully remove the duct tape from the specimen.

8.10 Using a brush apply sealing material to any pin holes or holidays that appear in the coating. Allow some of the sealing material to overlap the specimen's top edge.

Note 3—Specimens removed by core drilling may have top surfaces that are chipped. These areas should be coated with the sealing material since some or all of the water repellent may of been removed in these areas.

8.11 Allow the specimens to cool to room temperature.

8.12 When specimens are cooled to room temperature recheck for any pin holes and apply sealing material if necessary.

9. Procedure

9.1 Weight each specimen to the nearest 0.1 g and record weight as \( W_1 \).

9.2 Place specimens treated or exposed side of specimens face down in container. Specimens should be placed on glass rods that are in the bottom of container so water is free to circulate under the specimens.

9.3 Fill container with reagent grade water until level is 6.4 cm (2.5 in.) from the top of the glass rods. Water shall not come in contact with opposite face of the core.

9.4 Soak the cores for 48 h. At the 24 and 48-h immersion period, remove the specimens from the water and wipe with a damp cloth and weight to the nearest 0.1 g and record as \( W_2 \).

9.5 Determine the percent of water absorbed by each specimen as follows:

\[
\text{Percent Absorption} = \frac{100 \times (W_1 - W_d)}{W_A}
\]

10. Report

10.1 Report the following information:

10.1.1 Type and size of concrete specimens.

10.1.2 Water repellent treatment used, application rate and method of application.

10.1.3 Percent water absorption of each specimen, and

10.1.4 Any deviation from this procedure.

11. Precision and Bias

11.1 Precision—Precision for this test method has not been determined at this time.

11.2 Bias—Bias for this test method cannot be determined since there is no reference standard available for comparison.

12. Keywords

12.1 Field treatment evaluation; water absorption; water repellent
E.2  ASTM G109–99a

ASTM G109–99a is used to test the effect of chemical admixtures added to the concrete mix on the corrosion of embedded steel reinforcement. Three concrete prisms (6 x 4.5 x 11 in.), are made for every concrete mix that contains chemical admixtures. Also, three specimens that are made from a concrete mix with no chemical admixture are used as control specimens. Each specimen is provided with three steel bars made of the same size. The bar size can range from #3 to #5. The tips of the bars are covered with electroplater tape. One bar is installed close to the top surface of the specimen and is used as the anode of the circuit. Two bars are installed close to the bottom surface and are used as the cathode of the circuit. The top surface of the specimen is exposed to the salt solution for two weeks and then removed for the next two weeks. The voltage across a 100-ohm resistor is measured at the beginning of the second week of every ponding period, and the corresponding current is calculated.

This ponding-dry periods are repeated until the average integrated macrocell current of the control specimens is 150 Coulombs or greater, and at least half of the specimens show integrated macrocell current equal to 150 Coulombs or greater. ASTM G 109 – 99a states that this limit will be reached in about six months. The total integrated corrosion at various time periods (1, 2, ….and 6 months) is calculated and compared to that of control specimens.
Standard Test Method for Determining the Effects of Chemical Admixtures on the Corrosion of Embedded Steel Reinforcement in Concrete Exposed to Chloride Environments

This standard is issued under the fixed designation G 109; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method describes a procedure for determining the effects of chemical admixtures on the corrosion of metals in concrete. This test method can be used to evaluate materials intended to inhibit chloride-induced corrosion of steel in concrete. It can also be used to evaluate the corrosivity of admixtures in a chloride environment.

1.2 The values stated in SI units are to be regarded as the standard. The inch-pound units in parentheses are provided for information only.

1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards:

A 615/A 615M Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

C 33 Specification for Concrete Aggregates

C 143/C 143M Test Method for Slump of Hydraulic Cement Concrete

C 150 Specification for Portland Cement

C 173 Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 876 Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete

C 881 Specification for Epoxy-Resin-Based Bonding Systems for Concrete

C 1152/C 1152M Test Method for Acid-Soluble Chloride in Mortar and Concrete

D 448 Classification for Sizes of Aggregate for Road and Bridge Construction

D 632 Specification for Sodium Chloride

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

G 3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing

G 15 Terminology Relating to Corrosion and Corrosion Testing

G 33 Practice for Recording Data from Atmospheric Corrosion Tests of Metallic-Coated Steel Specimens

G 46 Guide for Examination and Evaluation of Pitting Corrosion

2.2 NACE Standards:

SSPC SP 5 (NACE No. 1) White Metal Blast Cleaning

3. Significance and Use

3.1 This test method provides a reliable means for predicting the inhibiting or corrosive properties of admixtures to be used in concrete.

3.2 This test method is useful for development studies of corrosion inhibitors to be used in concrete.

3.3 This test method has been used elsewhere with good

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1. Annual Book of ASTM Standards, Vol 04.03.
5. Available from Structural Steel Painting Council, Pittsburgh, PA.
agreement between corrosion as measured by this test method and corrosion damage on the embedded steel. This test method might not properly rank the performance of different corrosion inhibitors, especially at concrete covers over the steel less than 40 mm (1.5 in.) or water-to-cement ratios above 0.45. The concrete mixture proportions and cover over the steel are chosen to accelerate chloride ingress. Some inhibitors might have an effect on this process, which could lead to results that would differ from what would be expected in actual use.

4. Apparatus

4.1 The apparatus required for the evaluation of corrosion inhibitors includes a high impedance voltmeter (at least one Mohm) capable of measuring to 0.01 mV, a 100-ohm (± 5 %) resistor.

5. Reagents and Materials

5.1 Cement, that conforms to Type I or Type II of Specification C 150. Coarse aggregate shall conform to Specification C 33 and Classification D 448, with nominal maximum size between 9.5 and 19 mm (3/8 and 3/4 in.).

5.2 Steel Reinforcement Bars, deformed, meeting the requirement of Specification A 615/A 615M, with a diameter between 10 mm (0.4 in.) and 16 mm (0.6 in.). A length of 360 mm (14 in.), drilled and tapped at one end to be fitted with coarse-thread stainless steel nuts, as described in 5.3 and 5.4. These bars shall be used to manufacture the test specimens, as described in Section 6.

5.3 316 Stainless Steel Screws, with diameter smaller than bar diameter (coarse thread < 5 mm (0.2 in.)), 25 to 35-mm (1 to 1.5 in.) long (one per bar).

5.4 316 Stainless Steel Nuts, two per bar to fit stainless steel screws, as described in 5.3.

5.5 Two-part Waterproof Epoxy — This epoxy shall meet the chemical resistance requirements of a Type IV, Grade 3, Class E of Specification C 881.

6. Preparation of Test Specimens

6.1 Power wire brush or sand blast the bars to near white metal (see Specification SSPC SP-50), clean by soaking in hexane, and allow to air dry.

6.2 Use the same method to clean all bars in the test program.

6.3 Drill and tap one end of each bar, attach a stainless steel screw and two nuts, as described in 5.3 and 5.4, and tape each end of the bar with electrophoretic tape so that a 200-mm (8-in.) portion in the middle of the bar is bare. Place a 90-mm (3.5 in.) length of neoprene tubing, as described in 5.8, over the electrophoretic tape at each end of the bar, and fill the length of tubing protruding from the bar ends with the two-part epoxy, as described in 5.5.

6.4 Specimen size is 280 × 150 × 115 mm (11 × 6 × 4.5 in.).

6.5 Place the bars in the molds so that 40 mm (approximately 1.5 in.) of the bars are protected within each exit end from the concrete (minimizes edge effects). This will expose 200 mm (8 in.) of steel. Place the bars with the longitudinal ribs so that they are near the edge of the beam, that is, both ridges are equidistant from the top or bottom of the specimen.

6.6 Make the concrete specimens (controls and those with admixtures to be tested) in accordance with Practice C 192/ C 192M, using the same source of materials. Determine the air

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13 Minnesota Mining and Manufacturing Company (3M), 1999 Mt. Read Boulevard, Rochester, NY 14615, has been found suitable for this purpose.

14 Epoxy Concrete Scaler #12500 made by Devcon has been found to be suitable for this purpose.
content, using either Test Method C 231 or C 173. The water-to-cement ratio (w/c) shall not exceed 0.5. The minimum slump is 50 mm (2 in.) (see Test Method C 143/C 143M). Place and consolidate the concrete in the molds containing the bars in accordance with Practice C 192/C 192M.

Note 5—The concrete parameters used in the inter-laboratory test were as follows: cement content of $355 \pm 3$ kg/m$^3$ (600 \pm 5 lb/yd$^3$), 0.50 \pm 0.01 w/c (by aggregates), and 6 \pm 1% air.

6.7 Add the admixture to be tested at the manufacturer’s recommended dosages. A water reducer is allowed, if needed, to achieve the desired slump. Record the admixtures used. Except for the test admixtures, use the same admixtures in all mixtures.

6.8 A minimum of three replicates shall be made. Make the same number of replicates per admixture tested and control (see Note 6). An addition cylinder 100 \times 200 mm in diameter (4 \times 8 in.) shall be produced for background chloride analysis.

Note 6—A larger number of replicates is preferred.

6.9 Apply a wood float finish after consolidation. After removal from the forms, cure the specimens for 28 days in a moist room in accordance with Test Method C 192 and Specification C 511.

6.10 Upon removal from the moist room, hand wire brush the specimens on the concrete top surface (wood floated surface). Allow the specimens to dry for two weeks in a 50% relative humidity (RH) environment before sealing the four vertical sides with an epoxy sealer, as described in 5.11, in accordance with the manufacturer’s recommendation. Place a plastic dam with dimensions, as described in 5.12, on the specimen, as shown in Fig. 1, and about 13 mm (0.5 in.) from each side so that it does not extend over the tapered sections of the bars (see Fig. 2). Use a silicone caulk to seal the dam from the outside, and apply epoxy sealer to the top surface outside of the dam.

Note 7—Allowing the specimens to dry before applying the concrete epoxy will make the initial exposure to chloride more severe, and more closely follow the inter-laboratory test program conditions.

7. Procedure

7.1 Support each test specimen on two nonelectrically conducting supports at least 13-mm (0.5-in.) thick, thus allowing air flow under most of the specimen. Start the test one month after the samples are removed from the 100% RH atmosphere (moist room). Pond the specimens for two weeks at 25 \pm 3°C (73 \pm 5°F) with the salt solution, as described in 5.10. The volume of this solution is approximately 400 mL at a depth of 40 mm (1.5 in.). Use a plastic loose fitting cover to minimize evaporation. Maintain a relative humidity around the specimens of 50 \pm 5%. After two weeks, vacuum off the solution and allow the samples to dry for two weeks. Repeat this cycle.

7.2 Measure the voltage across the resistor at the beginning of the second week of ponding using the voltmeter defined in 4.1. Calculate the current, $I_p$, from the measured voltage across the 100-ohm resistor, $V_p$, measured in volts (see Note 8) as:

$$I_p = \frac{V_p}{100}$$

Note 8—With the common terminal on the bottom bar, negative voltages correspond to positive galvanic current (that is, the top bar is the anode).

7.3 At the same time, measure the corrosion potential of the bars against a reference electrode that is placed in the dam containing the salt solution (see Practice G 3 and Test Method C 876). Connect the voltmeter between the reference electrode (ground or common terminal) and the bars.

8. Period of Testing

8.1 Monitor the current as a function of time once every four weeks, as described in 7.2, until the average integrated macrocell current of the control specimens is 150 C or greater, as determined in 10.1.8, and at least half the samples show integrated macrocell currents equal to or greater than 150 C (see Note 9).
Note 9—The value of 150°C is consistent with a macrocell current of 10 μA over six months. The value of 10 μA was measured by all laboratories on all specimens showing corrosion (controls and samples with calcium chloride at 10-mm (3/8-in.) cover). This degree of integrated macrocell current is sufficient to ensure the presence of sufficient corrosion for visual evaluation.

8.2 In those cases where the admixtures being tested are corrosive, end the test three full cycles after an average integrated macrocell current of 75 μA is observed and the integrated macrocell current of at least half the specimens being tested is equal or greater than 75 μA.

9. Examination of Embedded Bars

9.1 At the conclusion of testing, break the specimens and examine the reinforcement bars for extent of corrosion, measure the corroded area, and record the percentage of corroded area recorded, as described in Practice G 33.

Note 10—Photograph the bars at the end of the test to provide a record of the corrosion damage.

9.2 Determine the acid soluble chloride content at the depth corresponding to the cover over the top-reinforcing bar, using Test Method C 1152.

9.3 Determine the acid soluble chloride content in the specimen produced for background chloride analysis, using Test Method C 1152. This value is to be subtracted from the acid soluble chloride, as determined in 9.2, to provide a corrected acid soluble chloride content reflecting ingressed chloride.

10. Report

10.1 Report the following information:

10.1.1 Full details of the concrete proportions, air content, and slump of the concrete used in the control and test specimens,

10.1.2 A plot of the corrosion current and potential for each concrete specimen versus time,

10.1.3 A plot of the average integrated current for each condition of concrete versus time,

10.1.4 Time to failure, as considered to be the time for the average macrocell current to reach 10 μA and at least half the samples showing a current greater than 10 μA,

10.1.5 Results of the visual inspection of each bar. The report shall include the percentage of original exposed steel surface corroded and optionally the number and depths of corrosion pits where present, as described in Practice G 46,

10.1.6 Photographs of the bars at the end of the test (optional), and

10.1.7 Chloride content at the top reinforcing bar depth from the surface. This value is the corrected total chloride content, as corrected 9.3.

10.1.8 The ratio of the total integrated current of the test specimen to that of the control and time the test ended. The total integrated current is:

\[ T_C = T_{C-1} + (t_i - t_f) \times (t_f - t_{C-1}) \]

where:

- \( T_C \) = total corrosion (coulombs),
- \( t_i \) = time (seconds) at which measurement of the macrocell current is carried out, and
- \( t_f \) = macrocell current (amps) at time, \( t_f \).

A sample calculation is given in Appendix X1.

11. Precision and Bias

11.1 Information on the precision of the results obtained by this test method was derived from an inter-laboratory test with two to three specimens per laboratory. Eleven laboratories participated in the study. The repeatability and reproducibility of the test results were dependent on the magnitude of the mean macrocell current.

11.2 Precision is as follows:

11.2.1 95% Repeatability Limit (Within Laboratory)—The within-laboratory precision of the average macrocell current (for each laboratory), as expressed by the repeatability limit, \( r \), is given by the following relation:

\[ \log r = 0.931 \log I_{avg} + 0.441 \]  

11.2.2 95% Reproducibility Limit (Between Laboratories)—The between-laboratory precision of the average macrocell current (for all laboratories), as expressed by the reproducibility, \( R \), is given by the following relation:

\[ \log R = 0.833 \log I_{avg} + 0.624 \]  

11.2.3 The repeatability and reproducibility limits of the average macrocell current were calculated in accordance with Practice E 177. The respective standard deviations of the variation among test results can be obtained by dividing by 2.8 the values of \( r \) and \( R \) calculated using (Eq 1) and (Eq 2). The following equations were then obtained:

\[ \log S_r = 0.931 \log I_{avg} - 0.006 \]  

\[ \log S_R = 0.833 \log I_{avg} + 0.177 \]  

11.2.4 The data used for compiling the test method precision, together with the statistical parameters as defined in Practice E 691, are given in the research report. The graphical representations of the repeatability and reproducibility limits are given in Figs. 3 and 4.

11.2.5 The time to failure has been analyzed using Practice E 691. This analysis is given in the research report.

11.2.6 The maximum end of the 95% confidence interval for time to failure for control specimens with 19-mm (0.75-in.) concrete cover is six months for both intra-laboratory and inter-laboratory tests. The maximum ends of the 95% confidence intervals are two and six months for intra- and inter-laboratory tests respectively for specimens containing calcium chloride.

11.2.7 The complete data for percent area corroded is given in the research report that has been filed with ASTM Headquarters. In all cases where there was corrosion, the macrocell current was greater than 9 μA. However, not enough laboratories reported percent area corroded to carry out a statistical analysis following Practice E 691.

11.3 Bias—The procedure given in this test method has no bias because the effects of chemical admixtures on the corrosion of embedded steel of reinforcement are defined only in

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18 Supporting data have been filed at ASTM Headquarters. Request RR:001-1009.
12. Keywords

12.1 admixtures; concrete; corrosion; corrosivity; inhibitor; reinforcing steel

APPENDIX

(Nonmandatory Information)

XI. TOTAL CORROSION CALCULATION

X1.1 Total Corrosion Calculation:

\[ TC = T_{C_{1-1}} \times \left( f_{1} + f_{2} - 1 \right) \times \left( f_{1} + f_{2} - 2 \right) / 2 \]  \hspace{1cm} (X1.1)

X1.1.1 Assume the following readings were obtained over a 90 day period of time:

<table>
<thead>
<tr>
<th>Days</th>
<th>i_{corr} (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>60</td>
<td>27</td>
</tr>
<tr>
<td>90</td>
<td>35</td>
</tr>
</tbody>
</table>

X1.1.2 At the end of the first 30 day period the total corrosion is:

\[ TC_{1} = 0 + \left( (30 - 0) \times 86400 \times (20 + 0) / 2 \times 10^{-3} \right) = 25.92 \text{ C} \]  \hspace{1cm} (X1.2)

X1.1.3 At the end of the 60 day period:

\[ TC_{2} = 25.92 + \left( 60 - 30 \right) \times 86400 \times (20 + 27)/2 \times 10^{-3} \times 10^{-3} = 86.83 \text{ C} \]  \hspace{1cm} (X1.3)

X1.1.4 At the end of the 90 day period:

\[ TC_{3} = 86.83 + \left( 90 - 60 \right) \times 86400 \times (27 + 35)/2 \times 10^{-3} \times 10^{-3} = 167.18 \text{ C} \]  \hspace{1cm} (X1.4)

Note X1.1—Conversion factor from days to seconds = 24 \times 60 \times 60 = 86,400.
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