

Sample Test Procedure

Tanks with Integral Heat Exchangers

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This procedure applies to tanks with internal or wrap-around heat exchangers. The purpose of these tests is to collect the information needed to run a TRNSYS computer model to estimate the thermal performance of a solar water heating system. The instructions given here are extracted from FSEC standard 105-10 "Solar Thermal System and Components Test Protocols, available at:

http://www.fsec.ucf.edu/en/publications/pdf/standards/FSECstd_105-10.pdf

Physical Measurements

Physical measurements are to be made as follows:

- tank outside dimensions: diameter, height
- insulation thickness: measure at tank jacket openings
- tank volume
- heat exchanger volume
- materials: tank vessel, tank jacket, tank insulation, fittings/nipples

Note any other materials that can be observed. Take photographs of the test unit.

Pressure Tests

Pressure tests shall be conducted as outlined in Standard 105-10:

Storage Tank Pressure Integrity Tests

This test is only required if the tank has not undergone similar testing by an approved certification agency.

The test pressure shall be one and one half times the manufacturer's recommended operating pressure, up to a maximum of 1100 kPa Gauge (160 PSIG).

Heat Exchanger Pressure Integrity Tests

The test pressure shall be:

- for portions of the heat exchanger exposed to street (city/municipal) pressure: 1100 kPa gauge (160 PSIG).
- for heat exchangers not exposed to street pressure: the smaller of one and one half times the manufacturer's rated pressure or 1100 kPa gauge (160 PSIG).

Pressure Integrity Test Procedure

- a. A pressure gauge is attached to the exit port of the heat exchanger or tank and the outlet is sealed.

- b. The supply side is filled with unheated water.
- c. Hydraulic pressure is applied to the inlet port until the gauge indicates the test pressure has been reached.
- d. The inlet pressure port is then closed and the pressure is monitored for 15 minutes.
- e. The final pressure is recorded.

Pressure Drop Test

The flow rates used for measuring the pressure drop across the heat exchanger should adequately represent the anticipated laminar, transition, and turbulent flow regimes experienced during operation. The heat transfer fluids used in the heat exchanger should represent what is expected during use.

Measure the pressure drop across the exchanger at a minimum of three different flow rates for each specified flow/fluid combination. If specific conditions are not specified, conduct these tests at 1, 4, 8, and 16 liters per minute.

Tank Heat Loss Test

1. Installed Capacitance and Draw Stratification Test (Q Initial)

This test is to be performed indoors, preferably in an environment with nearly constant temperature. The tank is to be installed in a manner consistent with the intended system design.

- a. Charge tank:
 - i. Fill may occur at any rate up to manufacturer's recommended maximum flow rate.
 - ii. Heat and fully mix tank to 55°C (131°F).
 - iii. Fill until $|T_{in} - T_{out}| = 0.2^{\circ}\text{C}(0.4^{\circ}\text{F})$ or $\frac{\partial |T_{in} - T_{out}|}{\partial t} = 0.05^{\circ}\text{C}(0.09^{\circ}\text{F})$ for a 10-minute period. Tank shall be maintained at this temperature for a minimum of the tank dwell (fill) time.
- b. Measure ambient temperature during the entire test period.
- c. Purge the energy in the tank by circulating water through the tank with the inlet temperature equal to the ambient temperature at a flow rate of 0.125- 0.189 l/s (2-3 GPM) until $|T_{in} - T_{out}| = 0.2^{\circ}\text{C}(0.4^{\circ}\text{F})$ or $\frac{\partial |T_{in} - T_{out}|}{\partial t} = 0.05^{\circ}\text{C}(0.09^{\circ}\text{F})$ for a 10-minute period.

Conduct real time measurement of M_{drawn} , T_{in} , T_{out} and T_{amb}

Calculate the energy removed from the tank:

$$Q_{\text{initial}} = \int \text{Rho}(t) * C_p(t) * V_{\text{rate}} * [T_{\text{out}}(t) - T_{\text{in}}(t)] dt$$

2. Heat Loss Test [Standard Decay Method]

This test is to be performed indoors, preferably in an environment with nearly constant temperature. Any source of heating including resistance heaters and or solar radiation are to be shut off or blocked.

- a. Charge the tank as in the capacitance test. $T_{\text{tank avg start}}$
- b. Piping connections are to remain, but isolated via valving during the waiting period.
- c. Wait until:

$$\frac{T_{\text{tank avg start}} - T_{\text{amb ave}}}{3} \leq (T_{\text{tank ave final}} - T_{\text{amb ave}}) \leq \frac{2 * (T_{\text{tank ave start}} - T_{\text{amb ave}})}{3}$$

This is estimated before the test is run using the known tank volume and estimated environmental temperatures. Measure the environment temperature during the entire test period.

- d. Open valving.
- e. Purge the remaining energy in the tank as in the capacitance test.
- f. Calculate the energy removed from the tank:

$$Q_{\text{del}} = \int \text{Rho}(t) * C_p(t) * V_{\text{rate}} * [T_{\text{out}}(t) - T_{\text{in}}(t)] dt$$

Analysis:

- a. $Q_{\text{loss}} = Q_{\text{initial}} - Q_{\text{del}}$ (the delivered energy after the purge)

$$b. \quad M_{\text{tank}} * C_p (@T_{\text{max}}) = \frac{Q_{\text{initial}}}{T_{\text{tank ave start}} - T_{\text{tank ave final}}}$$

$$c. \quad T_{\text{tank ave final}} = T_{\text{tank ave start}} + \frac{Q_{\text{del}}}{M_{\text{tank}} * C_p}$$

$$d. \quad UA = \frac{M_{\text{tank}} * C_p}{\text{Time}_{\text{decay}}} * \ln \left[\frac{(T_{\text{tank ave start}} - T_{\text{amb ave}})}{(T_{\text{tank ave final}} - T_{\text{amb ave}})} \right]$$

Heat Exchanger Performance Test

These tests are to be performed with the heat transfer fluid(s) to be used in the actual installation. If multiple fluids are to be used, multiple tests will be required. A minimum of 10 minutes shall be allowed for the stabilization of fluid flows and temperatures for

each set of data points collected in the thermal performance tests. Data during the thermal performance tests shall be reported in 30-second intervals or less.

The flow rates used for testing the heat exchanger shall adequately represent the anticipated laminar, transition, and turbulent flow regimes experienced during system operation. The temperatures should represent what is expected during use. Typically the test is run at three or four conditions representing different differentials between the tank and the heat exchanger inlet temperatures. If specific conditions are not specified, conduct these tests:

Temperature difference between tank and heat exchanger inlet (C)	Flow through heat exchanger (liters/min)
20	1, 4, 8, and 16
40	1, 4, 8, and 16
60	1, 4, 8, and 16

Test Procedure:

- a. Charge the tank to the selected temperature and set the heat exchanger inlet temperature at the selected differential above the tank.
- b. Stabilize heat exchanger flow to within +/- 0.006 l/s (0.1 GPM) and temperature to +/- 0.1°C (0.2°F).
- c. Commence data collection at 30-second intervals. The rate of data collection and/or stabilization time shall be increased for any flows at or below 0.0315 l/s (0.5 GPM). The data will include the inlet and outlet temperatures, ambient temperature, and the flow rate.
- d. Run the test for approximately 60 minutes, so that there is a significant change in tank temperature. Ideally, the time period shall be set so that the amount of input energy is the same for each test and enough energy (2000 kJ minimum) is input to avoid experimental error.
- e. Purge the energy in the tank as described above for the capacitance test.
- f. Repeat steps 1-4 for various flow rates (laminar, transition, and turbulent) and tank temperatures.

Analysis Method:

- a. The data from each of the data point sets in the test will be used to calibrate the TRNSYS rating model using the UA value and exponent in the tank coil heat exchanger model. A fitting routine will be used to fit the observed energy input to the observed data points (one per data point)
- b. The UA knob(s) will be used for modeling the heat exchanger in TRNSYS.