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**WALL DEFLECTION ANALYSIS FOR  
STEEL STUD/GYPSUM WALLBOARD ASSEMBLIES  
(REVISED)**

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# **WALL DEFLECTION ANALYSIS FOR STEEL STUD/GYPSUM WALLBOARD ASSEMBLIES (REVISED)**

## **1.0 INTRODUCTION**

Trakloc International (TLI) has recently conducted a series of ASTM E119, "Standard Test Methods for Fire Tests of Building and Construction Materials," fire tests to demonstrate the fire resistance rating of a 1-hour wall assembly incorporating the proprietary Trakloc steel framing system. The Trakloc steel framing system consists of a Trakloc stud open (TSO) and a Trakloc Stud Extension (TSE) together forming a Trakloc Stud Assembly (TSA). Located at each end of the steel framing system are swaged ends which fit into a patented "V" groove track. This design permits the steel framing system to twist and lock into the top and bottom tracks, and be adjustable to match the height of the wall assembly. No screws are required to secure the steel framing system into the top or bottom tracks per the International Code Council Evaluation Services, Inc. (ICC-ES) Report No. ESR-1464, issued May 1, 2005. This type of steel framing system is different from conventional fixed length steel studs which are required to be cut to within specific tolerances of the actual wall height and secured in-place using screws.

TLI has contended that the fire resistance rating of a wall assembly is influenced more by the performance of the gypsum wallboard than the steel stud framing system. To provide documentation to support this contention, TLI conducted a series of full-scale ASTM E119 fire resistance tests to demonstrate that the TLI steel framing system will not degrade the fire resistance rating of existing listed wall assembly designs. During the course of conducting the full-scale ASTM E119 fire resistance tests, two nearly identical wall assemblies were constructed and instrumented to measure the deflection of the wall assembly. The standard unexposed surface instrumentation required by ASTM E119 was installed on each wall assembly. Additional thermocouples (TCs) were installed within each test assembly to monitor steel stud/gypsum wallboard interface temperatures (essentially finish ratings) and steel stud cavity temperatures.

## **2.0 OBJECTIVES**

The objective of conducting these tests was to generate deflection data for two nearly identical full-scale ASTM E119 1 hour wall assemblies; one constructed with the proprietary Trakloc steel framing system and one with conventional fixed length steel studs. A comparison of the deflection data generated from both tests was conducted to determine if the wall assembly incorporating the Trakloc steel framing system performed similarly to the wall assembly incorporating the conventional steel studs.

## **3.0 APPROACH**

To meet the objective above, two nearly identical full-scale 1-hour fire resistance rated ASTM E119 wall assemblies were constructed. Both wall assemblies used 20 gauge steel studs spaced 24 inches on center (OC) in a 10 ft wide x 10 ft high wall. Each side of the wall was covered with one layer of United States Gypsum Company (USG) 5/8 inch thick SHEETROCK® Brand FIRECODE® Type "X" core gypsum wallboard (UL designation Type SCX) installed

vertically on the wall. Installation of the steel studs and the wallboard was in accordance with UL Design Nos. U419 and U465. Upon completion of construction, both walls were subjected to the fire exposure conditions specified in ASTM E119 for 1-hour duration. The furnace temperatures, exposed flange of steel stud temperatures (under the gypsum wallboard, similar to the finish rating), stud cavity temperatures, unexposed surface temperatures and wall deflection were continuously monitored throughout the test. A comparison of all measured temperature data was conducted to insure the exposures to each wall were similar, therefore reducing the test variables to the wall studs only. The deflection as a function of time was then compared to determine if both types of steel studs reacted similarly to the fire exposure.

#### **4.0 WALL CONSTRUCTION DETAILS**

Two nearly identical wall assemblies were constructed to meet the requirements of ASTM E119. Each wall assembly was constructed in accordance with UL Design Nos. U 419 and U 465 as follows:

1. 20 gauge steel studs spaced 24 inches OC (4 studs in the field of the wall);
2. Wall dimensions per ASTM E 119 (10 ft x 10 ft);
3. 1 layer of USG SHEETROCK® Brand FIRECODE® Type "X" core gypsum wallboard (UL designation Type SCX) installed vertically on each side of the wall assembly;
4. Wallboard obtained directly from local USG manufacturing plant, from same production run, and imprinted with UL listing label on backside of each sheet of wallboard;
5. Wallboard joints staggered on each side of the wall assembly;
6. Screw spacing in accordance with UL Design Nos. U 419 and U 465; and
7. Level 3 finishing of all joints and screw heads using USG 90 minute dry joint compound mixture.

The Trakloc wall assembly utilized the 20 gauge proprietary Trakloc steel framing system installed in accordance with the manufacturer's installation instructions (screws in corners of wall assembly only, no screws in the field). The conventional fixed length steel stud wall assembly used commercially available 20 gauge "drywall" studs cut short of the overall wall assembly height as described in UL Design Nos. U 419 and U465, with the gap at the top of the wall assembly. A single screw was installed in the top of each steel stud, through the top track, on the unexposed surface of the wall assembly. Once the wallboard was installed on the exposed side of the wall, the screws holding the steel studs to the top track were removed. This resulted in no mechanical attachment of the steel studs to the top or bottom track.

## **5.0 INSTRUMENTATION**

Instrumentation installed on each wall assembly included TCs placed within the wall assembly to measure steel flange temperatures and air cavity temperatures, unexposed surface TCs as required by ASTM E119, and wall deflection measured using Linear Voltage Displacement Transducers (LVDT) connected to the two middle studs and the right most stud. The temperature measurements were used to insure the fire exposure and heat transfer through the wall assembly was similar. The deflection measurements were then directly compared to one another, presuming the exposure was similar.

### **5.1 Internal Wall Thermocouples**

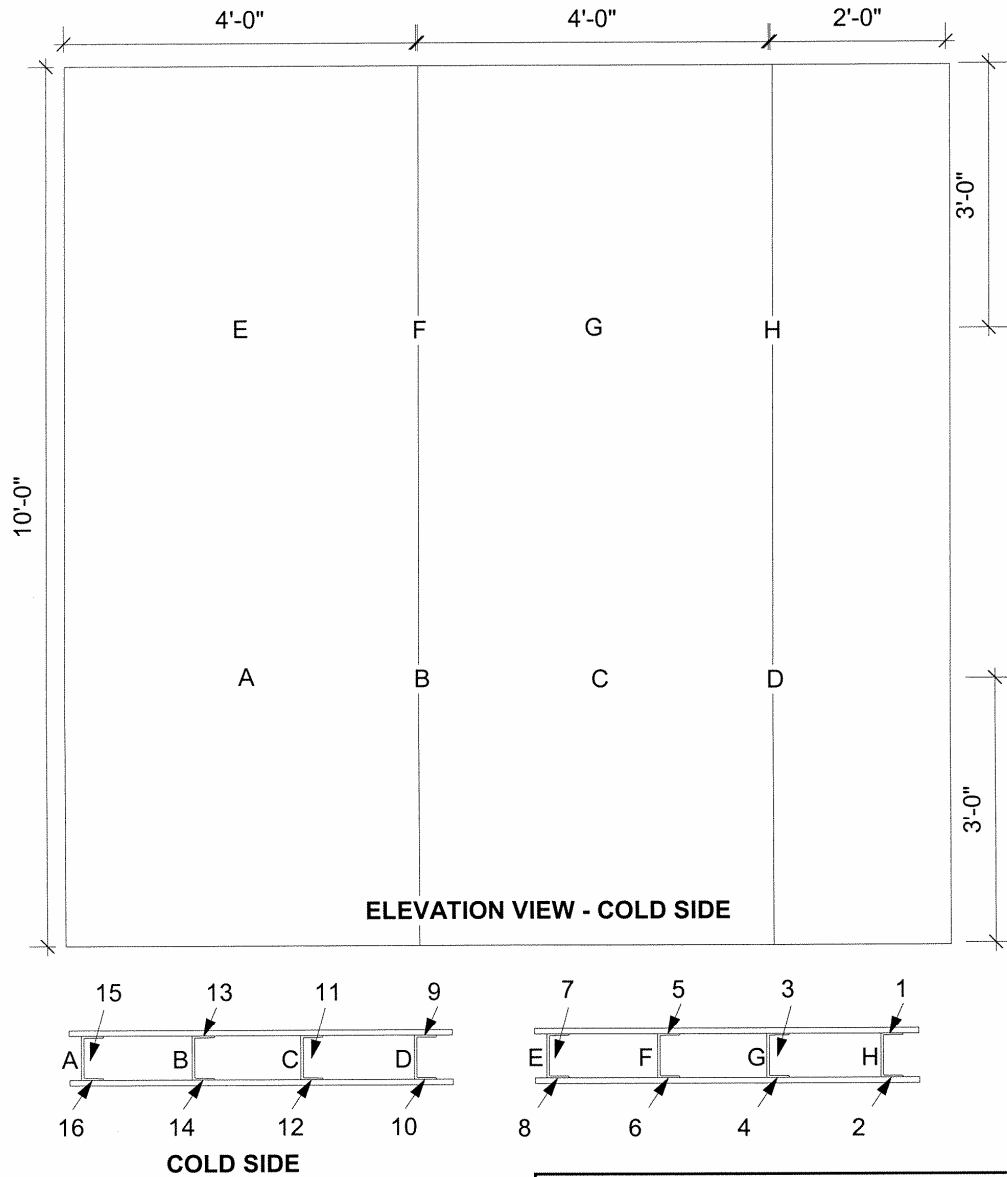
A total of sixteen 22 gauge Type K (Chromel-Alumel) bare bead welded junction TCs were installed within the wall assembly as shown in Figure 1 to provide additional engineering data. One set of eight TCs were installed in a horizontal plane 3 ft down from the top of the wall (locations E through H) and a second set of eight TCs were installed in a horizontal plane 3 ft up from the bottom of the wall (locations A through D). At each location, one TC was positioned on the exposed side of the steel stud flange, under the gypsum wallboard. When the TC was located under a joint in the gypsum wallboard (locations A, C, E, and G), the TC was re-positioned to measure the air cavity temperature adjacent to the steel stud web. A second TC was located on the opposite side of the steel stud flange (on the unexposed side), under the gypsum wallboard. The TCs located on the unexposed side were not re-positioned when the TC was located under a joint in the wallboard (locations B, D, F and H). The TCs were numbered such that odd numbered TCs were located on the exposed side/in the stud cavity and even numbered TCs were located on the unexposed side of the steel stud. The TCs located on the steel stud flange under the gypsum wallboard were similar to finish rating TCs installed on wood stud wall assemblies and intended to provide steel stud temperature as a function of location (exposed/unexposed side) and exposure (located under wallboard joint/continuous section of wallboard).

### **5.2 Unexposed Surface Thermocouples**

Unexposed surface temperatures were measured with 14 TCs distributed over the surface of the wall assembly, as shown in Figure 2. Four TCs were located in the center of each of the 4 quadrants of the wall assembly (TCs 17, 19, 23, and 25), and TC 25 was located in the center of the wall assembly. TCs 20, 27 and 29 were located over studs, in the field of a sheet of gypsum wallboard. TCs 22, 26 and 28 were located over joints in the gypsum wallboard and TCs 18, 24 and 30 were located between the steel studs. All unexposed surface TCs were located under dry felt pads as required by ASTM E119.

### **5.3 Linear Voltage Displacement Transducers**

Three National Oilwell linear voltage displacement transducers (LVDTs), with an input voltage of 32.5 mV/V/inch and a displacement range of 0 to 30 inches were attached to the center two studs and the rightmost stud at mid height of the wall (5 ft above the floor), as shown in Figure 2. The LVDTs provided continuous deflection measurements of the wall assembly into the plane of the furnace (positive displacement).



Note:

TCs at locations A-H were used for information only.

Intertek Testing Services NA, Inc. Project No. 3094652A
Trakloc
Internal TCs - Vertical gypsum

Scale = 1:20

Figure 1. Internal Wall TC Placement

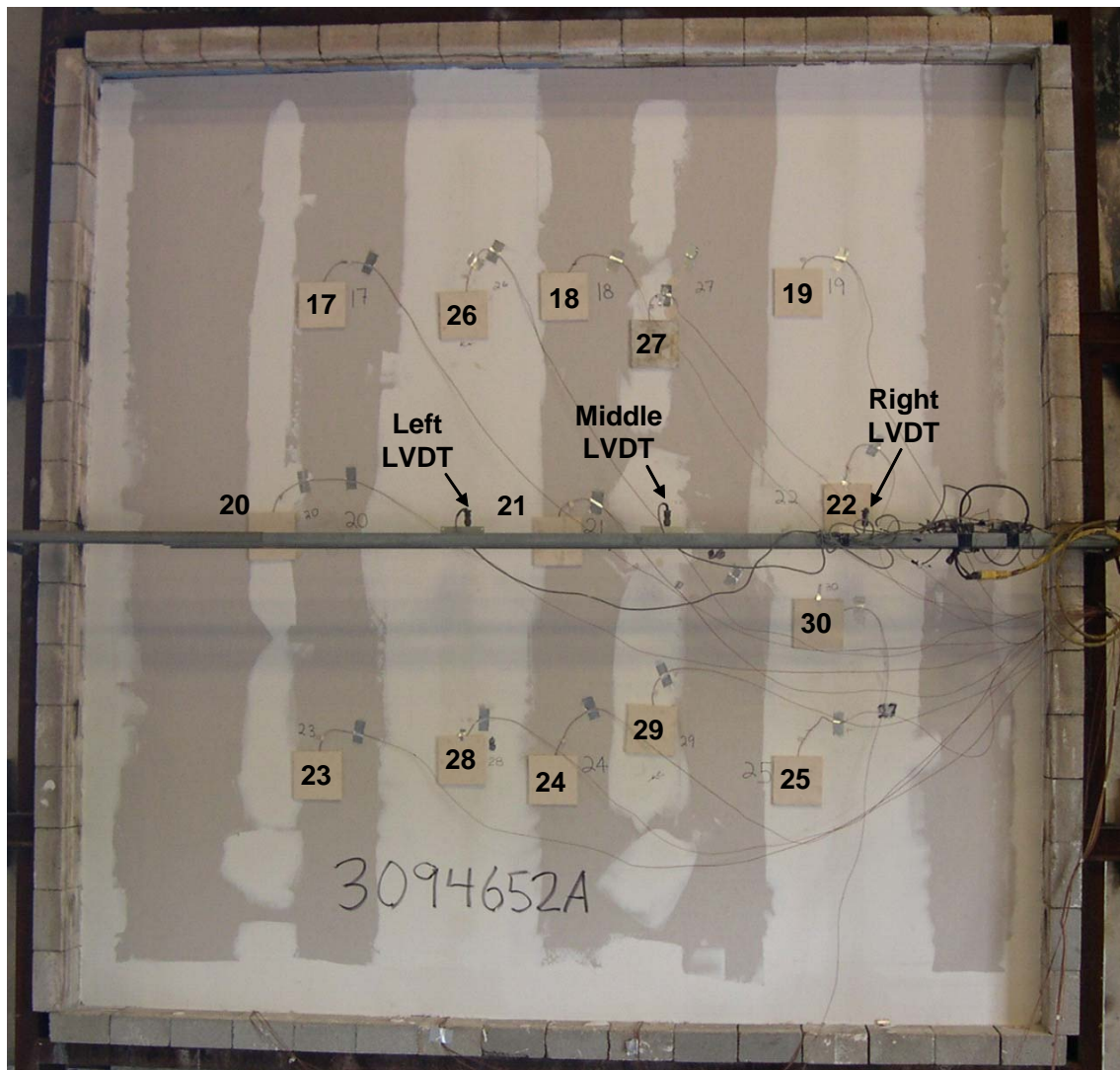


Figure 2. Unexposed Surface TCs

## 6.0 TEST RESULTS

The wall assembly constructed using the proprietary Trakloc steel framing system was tested on April 19, 2006 and the wall assembly constructed using the fixed length conventional studs was tested in April 20, 2006. Both tests were subjected to the fire exposure conditions as specified in ASTM E119 for a minimum of 1 hour.

### 6.1 Furnace Temperatures

Figure 3 shows the average furnace curves for both wall tests compared to the ASTM E 119 standard furnace curve. The test data indicated that both furnace curves closely matched the standard time-temperature curve. Both tests were well within the

furnace control accuracy limits for a 1 hour test as specified in Section 6.3 of ASTM E119.

## **6.2 Steel Stud and Air Cavity Temperatures**

Each wall assembly was instrumented with TCs placed on the exposed side of the steel stud flange, underneath the exposed layer of gypsum wallboard in the air cavity between the steel studs, and on the unexposed side of the steel stud flange, underneath the unexposed layer of gypsum wallboard. The internal steel stud and air cavity temperatures were measured by the 16 TCs located as described in Section 5.1.

The average temperature profile of the exposed side steel stud flange TCs (similar to finish rating TCs) for each wall assembly (TCs 1, 5, 9, and 13) for each test are provided in Figure 4. The temperature profile for the exposed side steel flange temperatures for each test were very similar for the first approximately 35 minutes. After 35 minutes, the exposed side layer of gypsum wallboard was fully calcined. As the wallboard further deteriorated and joints continued to open, more heat transferred through the wall assembly resulting in some variation with temperatures, as a function of the gypsum wallboard performance/condition.

The average measured air cavity temperature by TCs 3, 7, 11 and 15 for each test are provided in Figure 5. Similar to the unexposed side steel stud flange temperatures shown in Figure 4, the air cavity temperatures are very similar for the first 35 to 40 minutes of the fire exposure. After this time, the heat transfer through the fully calcined exposed layer of gypsum wallboard varied slightly, likely due to the exposed side layer of gypsum wallboard joints opening up.

The temperature of the unexposed steel stud flange, located under the unexposed layer of gypsum wallboard tracked very similar for both tests as shown in Figure 6. The heat transferred through the wall assembly stabilized approximately 45 to 50 minutes into the test and remained relatively steady for the remaining fire exposure period. The variation in measured temperatures was likely due to normal variations in the gypsum wallboard.

## **6.3 Unexposed Surface Temperatures**

The unexposed surface temperature was measured by 14 TCs installed in accordance with ASTM E119 and located as described in Section 5.2. Figure 7 provides a graph of the average unexposed surface temperature for both tests. The data shown in Figure 7 demonstrated that the unexposed surface temperatures for both tests were nearly identical for the entire duration of the fire exposure. Table 1 provides the times to reach the single point and average temperature limits as required by ASTM E 119 for both wall assemblies. The data in Table 1 matches the temperature profiles in Figure 7, supporting the similar performance of the unexposed side layer of gypsum wallboard in both tests.

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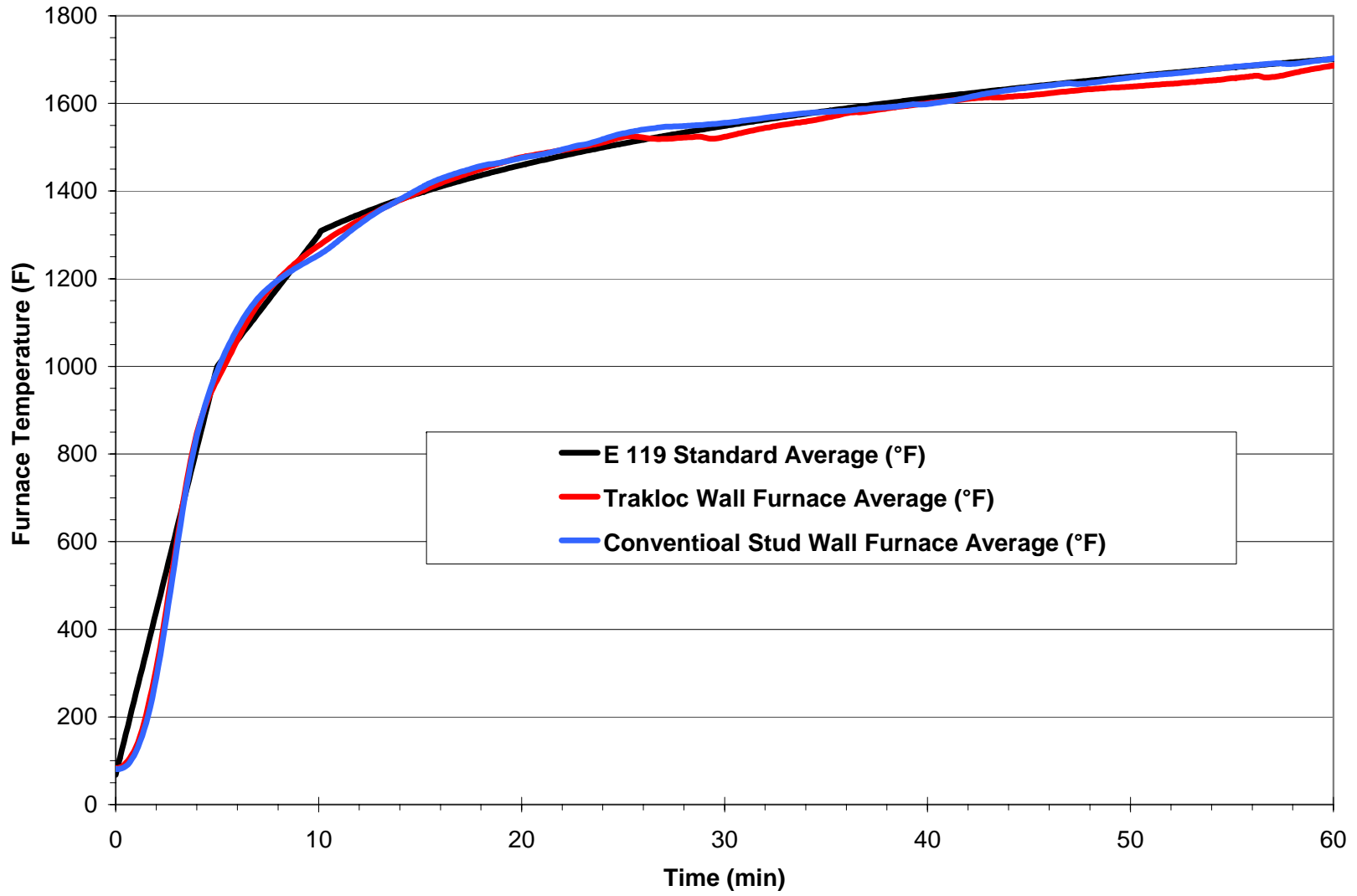


Figure 3. Furnace Time-Temperature Curves

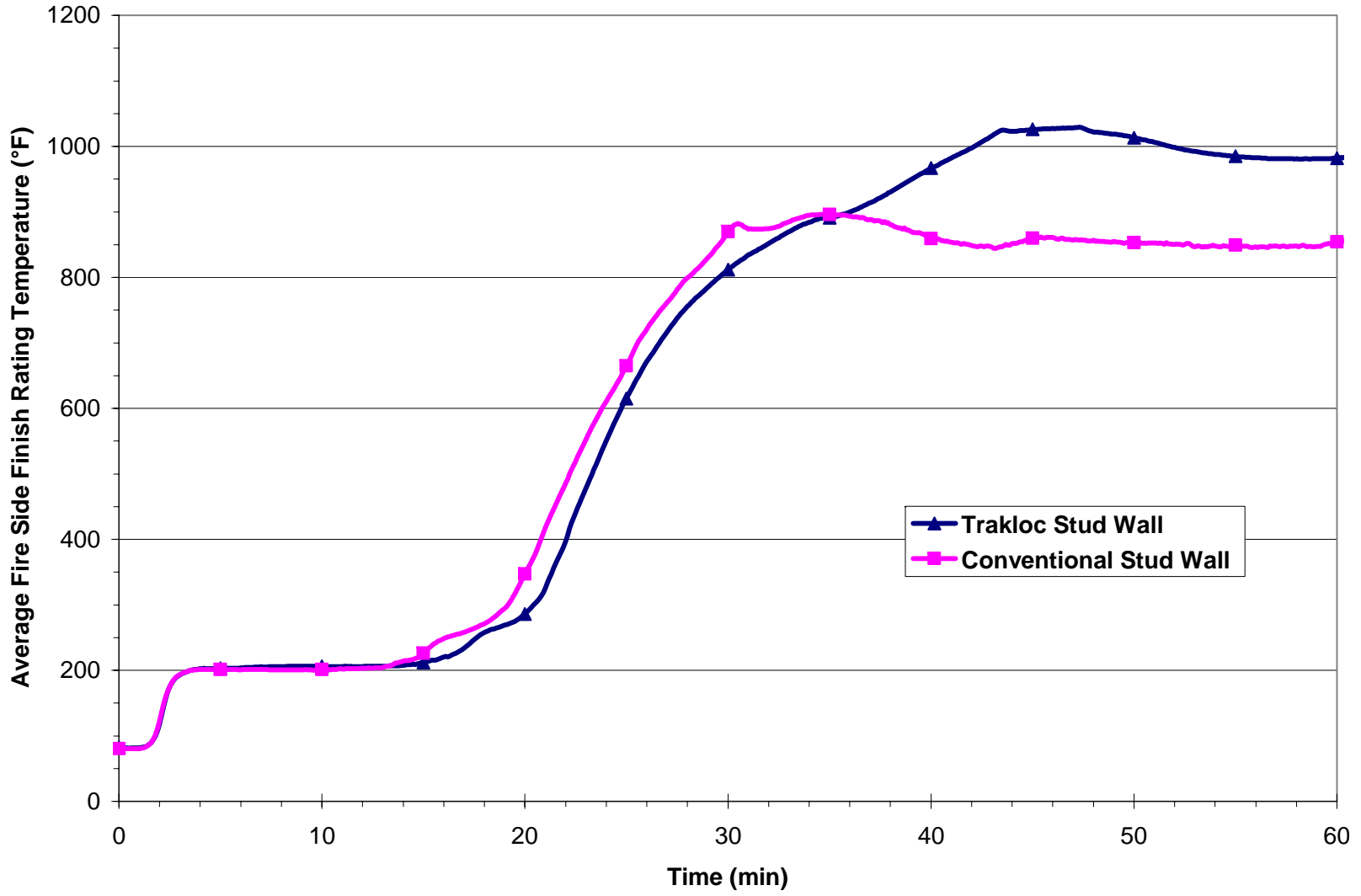


Figure 4. Exposed Side Steel Flange Temperatures

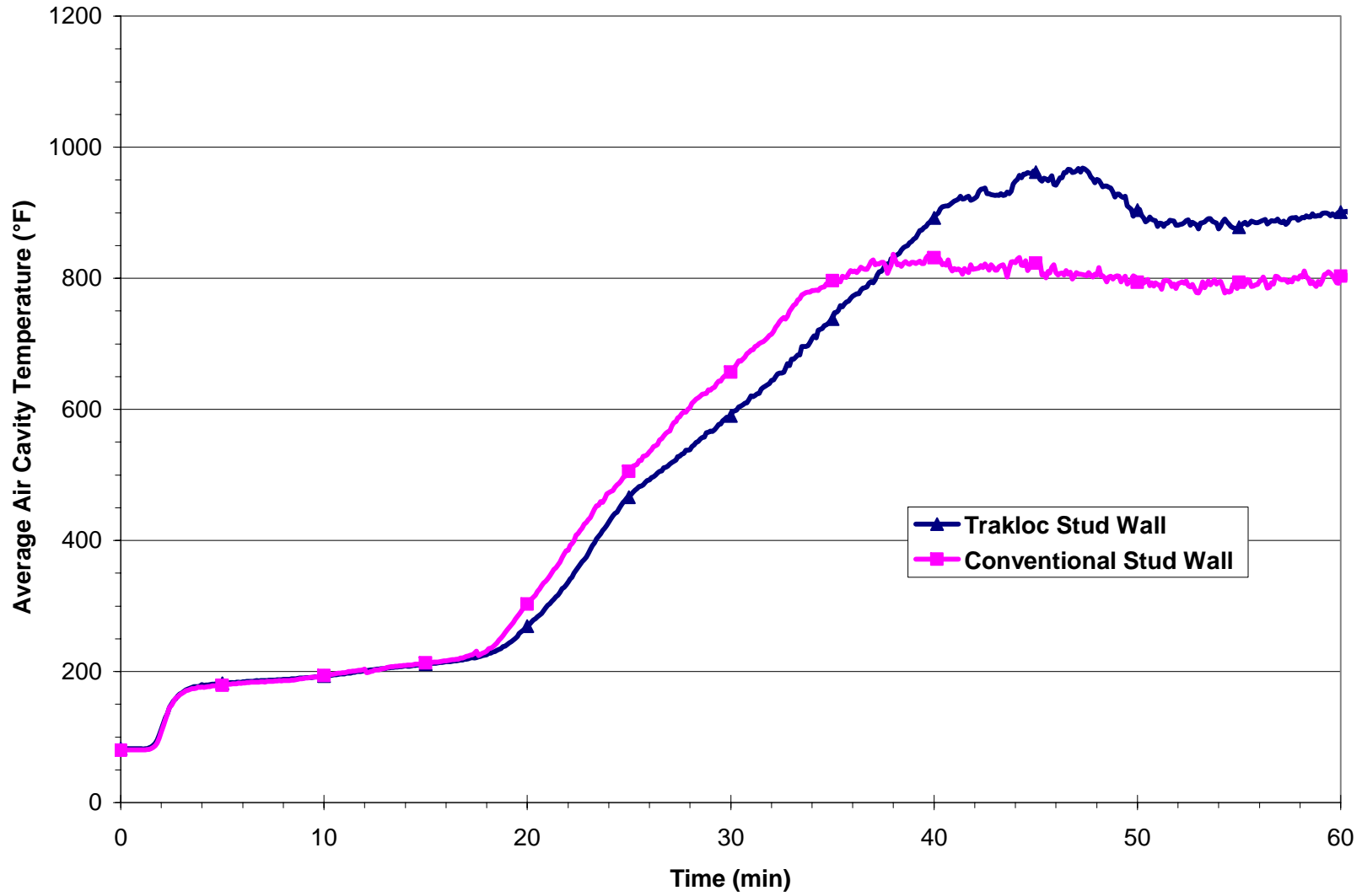


Figure 5. Air Cavity Temperatures

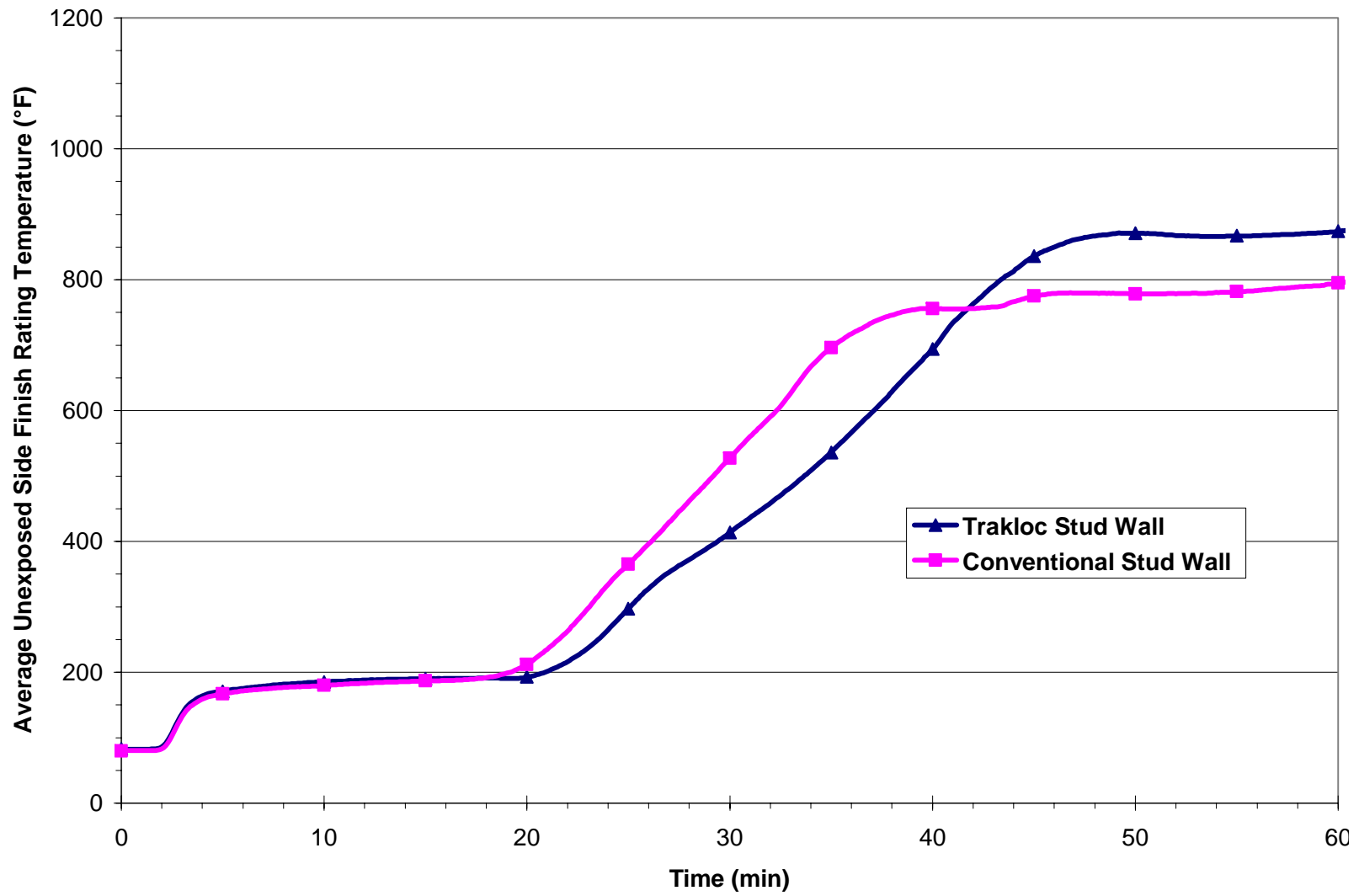


Figure 6. Unexposed Side Steel Stud Flange Temperatures

Table 1. Wall Assembly Performance

Wall Assembly Description	Time to reach average temperature limit (250°F rise above ambient)	Time to reach single point temperature limit (325°F rise above ambient)
Trakloc proprietary steel framing system wall	> 61.3 min	60.7 min
Conventional stud wall	> 61.3 min	60.4 min

#### 6.4 Displacement Measurements

Displacement measurements recorded by the left, middle, and right LVDTs, located as shown in Figure 1, are provided in Figure 8, 9, and 10, respectively. The maximum displacement measurements recorded by the LVDTs are provided in Table 2. The middle LVDT was attached to a stud which had a joint in the gypsum wallboard on the exposed side of the wall assembly. As this gypsum wallboard joint opened up, the exposed side of the steel stud heated up at a faster rate than the unexposed side, resulting in increased wall deflection. Comparatively, the left and right LVDTs were attached to studs protected with a solid piece of gypsum wallboard on the exposed side. The differential heating was not as much as the middle LVDT with respect to the unexposed side, resulting in less overall deflection. The deflection measurements recorded by the left and right LVDTs were similar for the duration of the fire exposure test.

Table 2. Maximum Wall Displacement Measurements

Wall Assembly Description	Left LVDT (inch)	Middle LVDT (inch)	Right LVDT (inch)
Trakloc proprietary steel framing system wall	1.39	1.59	1.32
Conventional stud wall	1.30	1.45	1.19

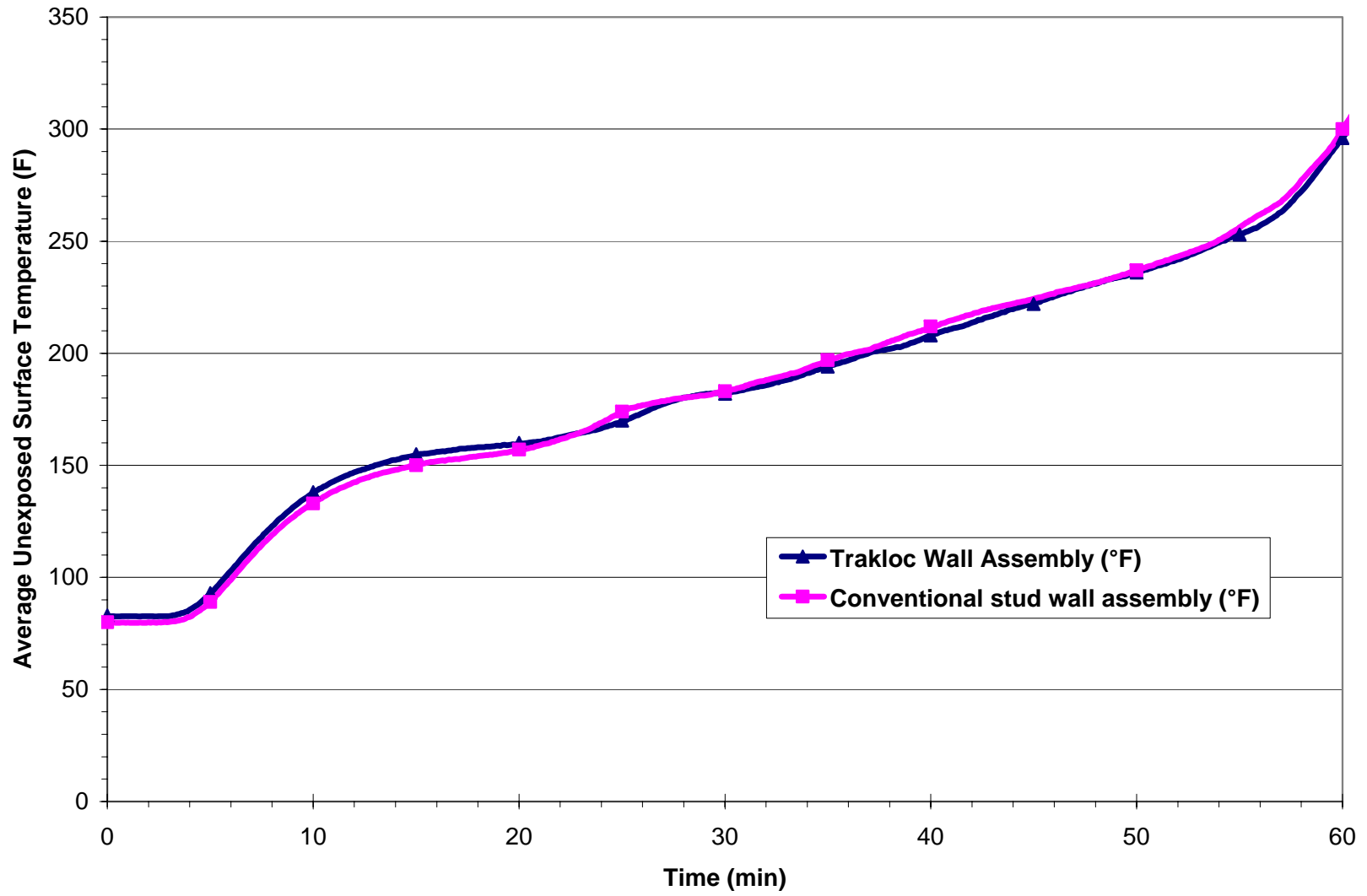


Figure 7. Average Unexposed Surface Temperatures

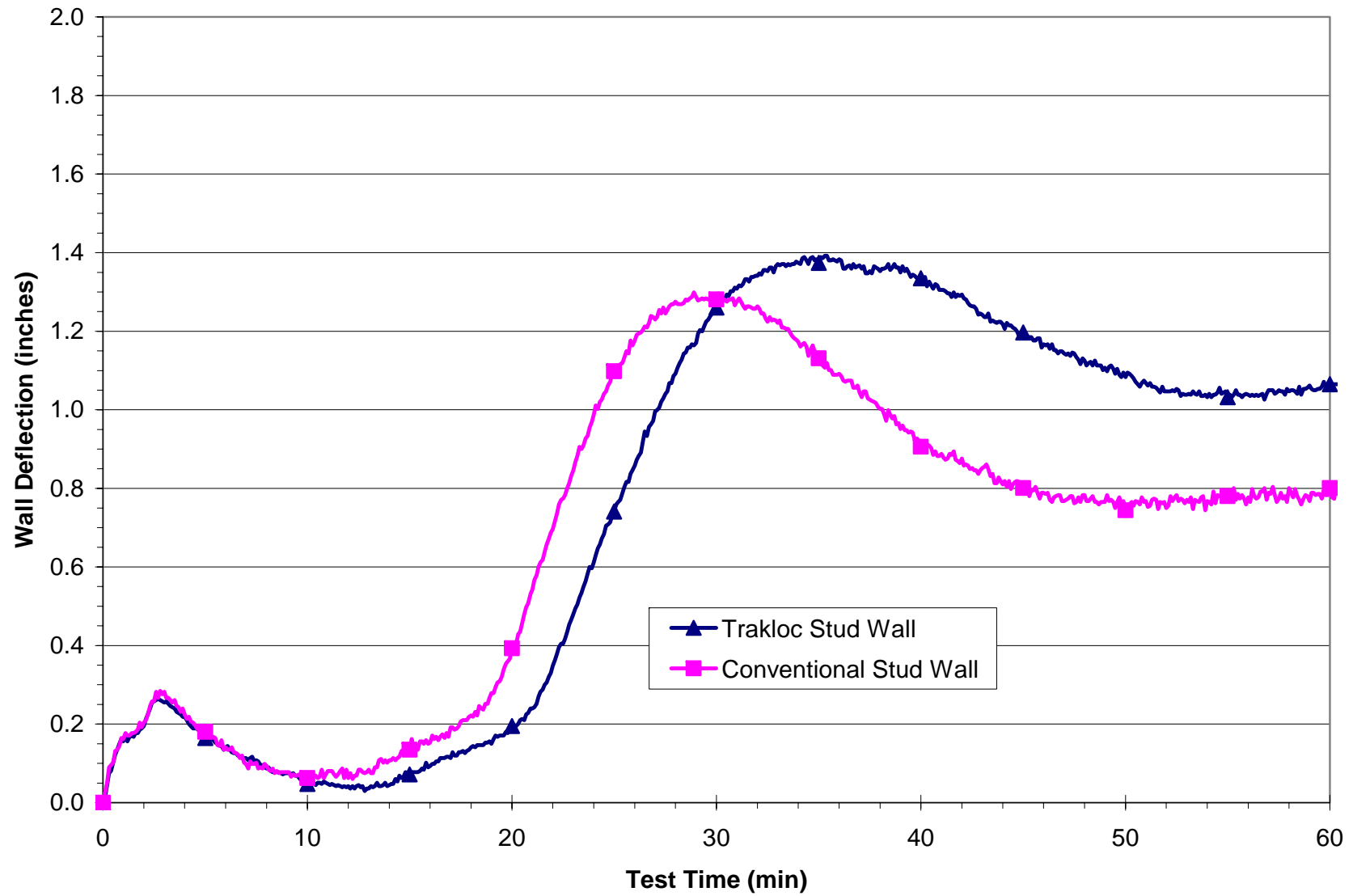


Figure 8. Left LVDT Wall Deflection

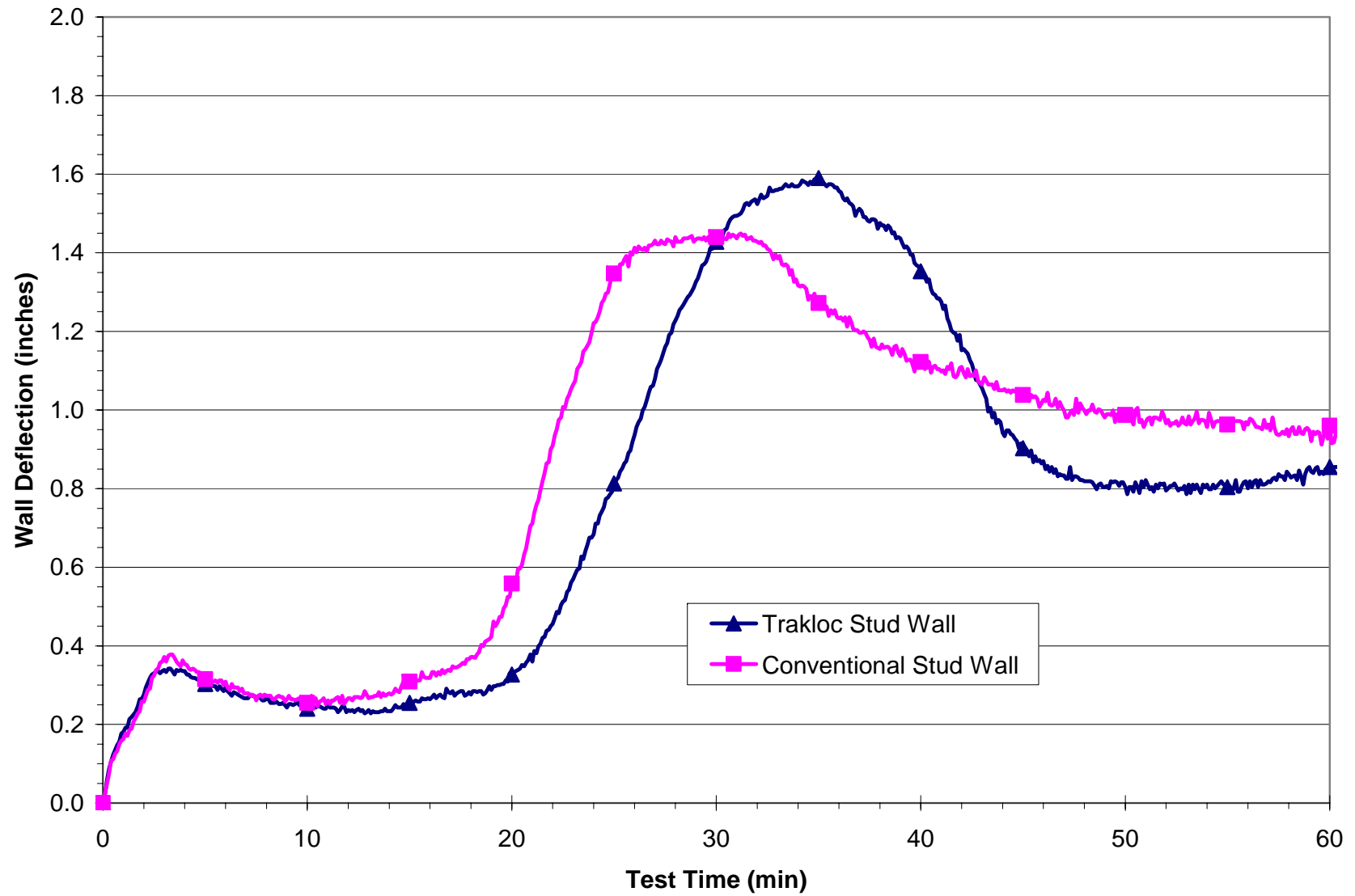


Figure 9. Middle LVDT Wall Deflection

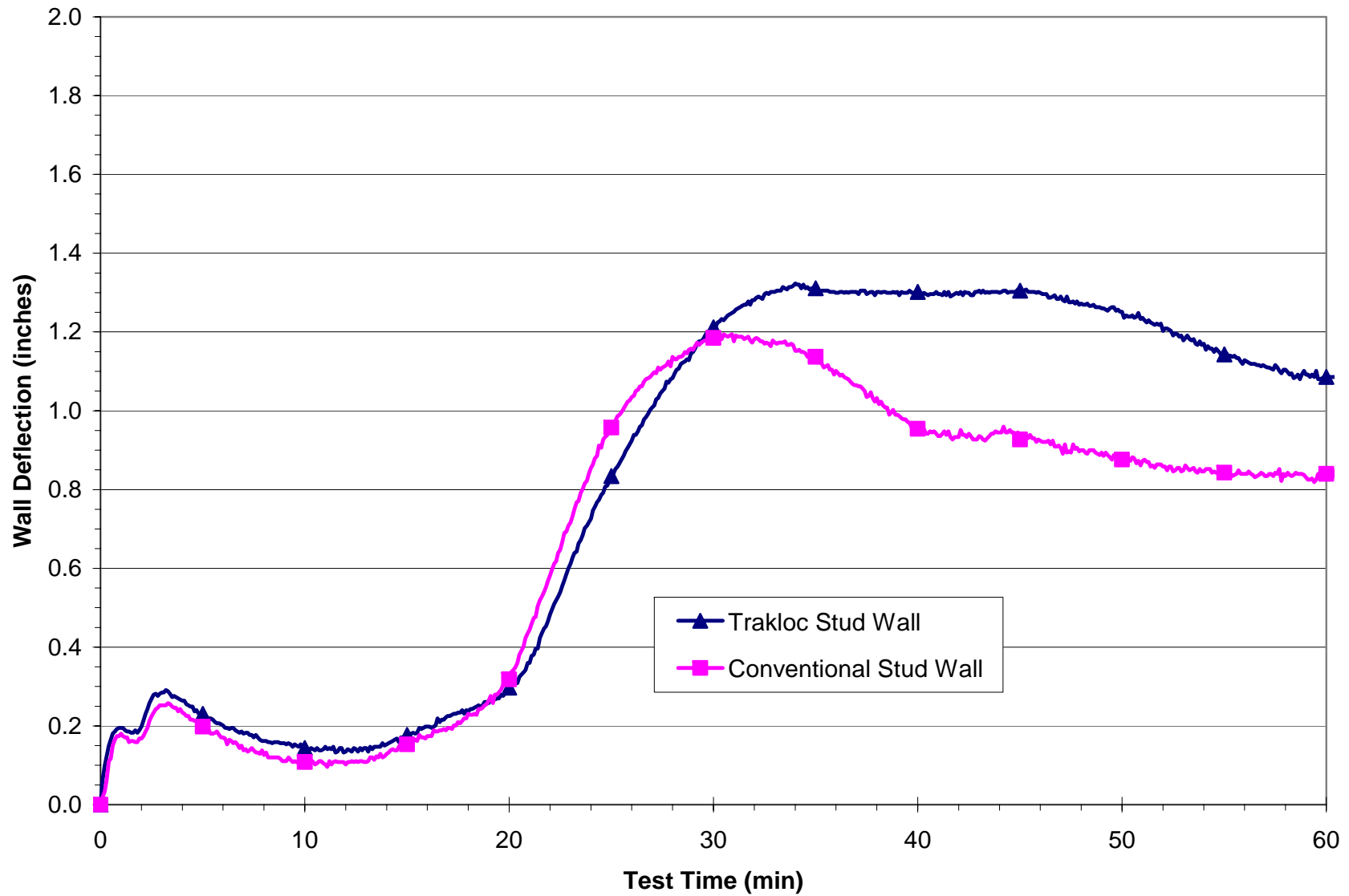


Figure 10. Right LVDT Wall Deflection

## 7.0 CONCLUSIONS

The data presented in Section 6 have resulted in the following conclusions being developed:

1. The average furnace exposure curves for both wall assembly tests were very similar and well within the accuracy limits specified in ASTM E119 for 1-hour fire exposure duration.
2. The average exposed side steel stud temperatures (essentially finish ratings) and air cavity temperatures were similar until the exposed layer of gypsum wallboard temperatures became fully calcined (approximately 30 to 40 minutes into the test. This indicated that both of the steel studs did not adversely effect the installation or performance of the exposed layer gypsum wallboard. Variations in the measured temperatures after the exposed side gypsum wallboard was fully calcined were attributed to normal variations in the gypsum wallboard.
3. The average unexposed surface temperatures for both tests were nearly identical, indicating that the unexposed layer of gypsum wallboard was subjected to a very similar time-temperature exposure, indicative of the exposed layer of gypsum wallboard and steel studs reacting similarly to the fire exposure.
4. The deflection measurements were similar given the slight variations in the exposure to the steel studs due to stud location with respect to gypsum wallboard joints and the normal variations in the gypsum wallboard.

Given that the exposure to the steel studs was similar for both tests, both of the unexposed surface temperatures were very similar and the deflection measurements were also similar, it was concluded that the proprietary Trakloc steel framing system did not appear to perform differently than the conventional fixed length steel studs. Variations in deflections were more likely a function of normal variations in gypsum wallboard than the steel stud performance.