Boiler Explosion: 
Analysis of Steam vs Gas Failure

In October of 2008, a boiler exploded inside a small residential frame house causing severe damage to the structure and contents. Fortunately, nobody was present in the house at the time. The utility room containing the boiler was between the kitchen on the left side and the master bedroom on the right. The back wall of the utility room was the back wall of the house. A can of light blue paint was sitting on the washing machine at the back wall when the boiler exploded.

There was absolutely no fire/heat damage from the explosion. The walls of the utility room were pushed outward and the back wall of the house was separated from the rest of the structure by about half a foot at the bottom. The blue paint spattered over everything, showing the outward flow of explosion gases from the utility room on the back wall of the bedroom, as shown by a “starburst” spatter pattern.

Source of the Explosion

All sources of the explosion could be eliminated with the exception of the boiler. Obviously, the question is whether a gas (fuel) versus steam (phase change) was the root cause of the failure. The boiler was a vintage residential design, about 30 years old, with a cast iron heat exchanger above the combustion chamber. A large section of the cast iron wall of the heat exchanger housing was missing (Fig. 1).

Figure 2 shows several large pieces of blue painted cast iron that were uncovered at the back wall of the utility room in the open space between the house slab and the wall that had been pushed outward. Figure 3 shows how the largest piece fit into the opening in the cast iron wall of the boiler.

Types of Boiler Explosions

There are two types of boiler explosions, combustion explosions and steam explosions. Combustion explosions involve creation of a flammable cloud inside the unit; e.g., due to a significant amount of fuel flowing into the combustion chamber with late ignition. Steam explosions involve the phase change of superheated water into steam with the consequent tremendous increase in volume due to the phase change. Steam explosions release high energy with significant damage possible.

Figure 4 shows the exhibit submitted by the authors in the International Metallography Contest of the International Metallographic Society during the M&M 2009 show in Richmond, Va., as an illustration of the failure process. The optical metallography of the gray cast iron microstructure graphically indicates that the outside diameter of the cast boiler plate failed by a twisting motion through the steadite phase, while

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Fig. 4 — Montage showing possible boiler failure process.

the individual sections of the boiler plate failed by bending due to the massive phase-change expansion of the steam. ☺

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