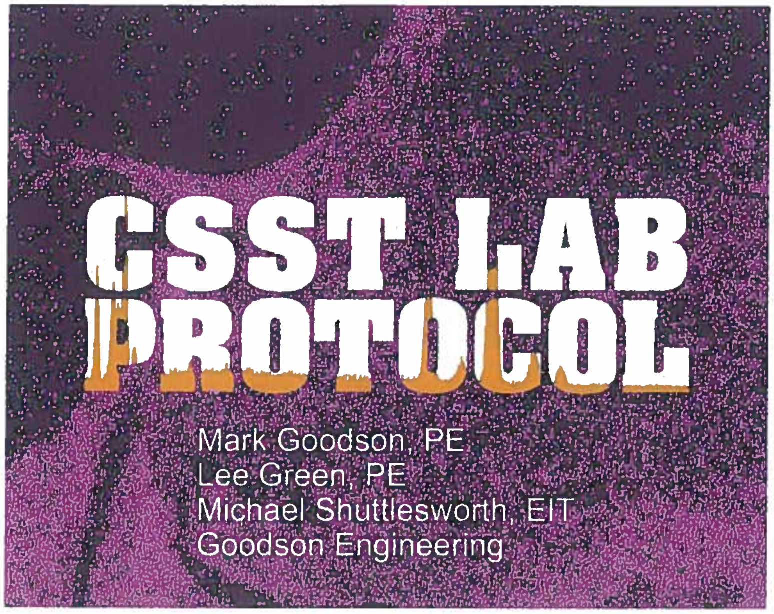

CSST LAB PROTOCOL

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DENTON, TEXAS—During the last six years, the authors have proctored and/or participated in many lab examinations where CSST was suspected of having been involved in a fire. Over this time period, a systematic protocol has been developed for inspecting such CSST. Outlined here is a series of steps that, in general, have been used in conjunction with the major manufacturers of CSST when such a laboratory examination is conducted.

EQUIPMENT NEEDED

The following lab equipment has proved to be both necessary and beneficial during the exam of CSST:

- Gas test kit, to include flow meters, pressure gauges, and a regulated source of air or fuel gas
- Optical stereoscope with digital image capture and with photo splicing capability and motorized zoom
- SEM (Scanning Electron Microscope) with EDX (Energy Dispersive X-ray) capability, as well as software for elemental mapping)
- X-ray (120 KV or greater), real time, with digital image capture
- Ultrasonic cleaner, with Alconox or other surfactant

TECHNIQUES

The CSST is first photographed, followed by leak testing. The leak testing insures that all orifices / holes are located. The leak testing may also include the determination of flow rates. Using a known flow rate, the BTU per hour can be calculated, with appropriate scaling for the molecular weight of the test gas and the flow gauge.

After the leaks are located, a small section of CSST (2 to 4 in, 51 to 102 mm.) is cut, such that the hole is approximately in the center of the small section. Each cut section of CSST is then x-rayed, such that the dispersion of spatter, if any, can be determined.

Following the locating of holes and the sectioning, the CSST is then examined with a stereo microscope. The varying heights of the corrugations make it imperative that a microscope that can acquire and splice photos with different depths of field be used. A Keyence type of digital microscope is capable of this task, as is a Leica MZ series with a motorized zoom stage and Leica Montage software. After the digital images are acquired, the CSST is then sectioned longitudinally.

The CSST sections, prior to each longitudinal cut, are "stuffed" with a clean paper towel or clean cloth. This placement of such a cloth insures that shavings or filings from the metal cutting operation are not later confused with artifacts from the process that created the original hole in the CSST. The longitudinal cuts can then be made with a Dremel type tool with a diamond blade or a metallurgical saw (Struers Accutom or Buehler Isomet).

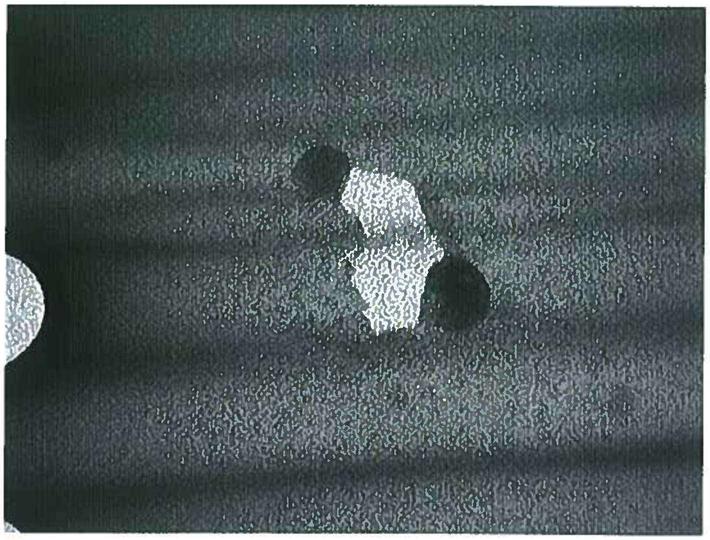

PHOTO 1
Spatter surrounding a CSST hole as viewed via X-ray.

After longitudinal sectioning, the cloth is removed and the interior of the CSST is examined. The presence of spatter, as well as the interior presentations of any hole(s) can be documented microscopically.

PHOTO 2
The interior of a longitudinally sectioned length of CSST.

PHOTO 3
View of spatter on opposing interior wall of same CSST hole

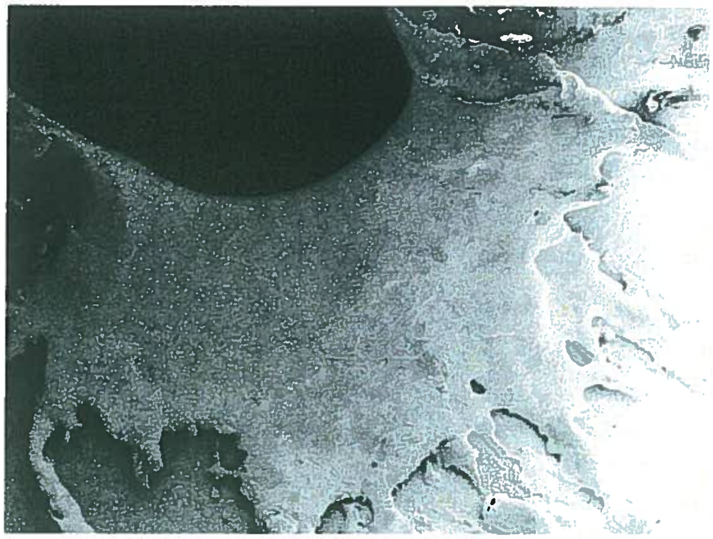

PHOTO 4
The melted material on the exterior edge of a CSST hole. It was found to contain Cu (copper), according to the spectra in Figure 1.

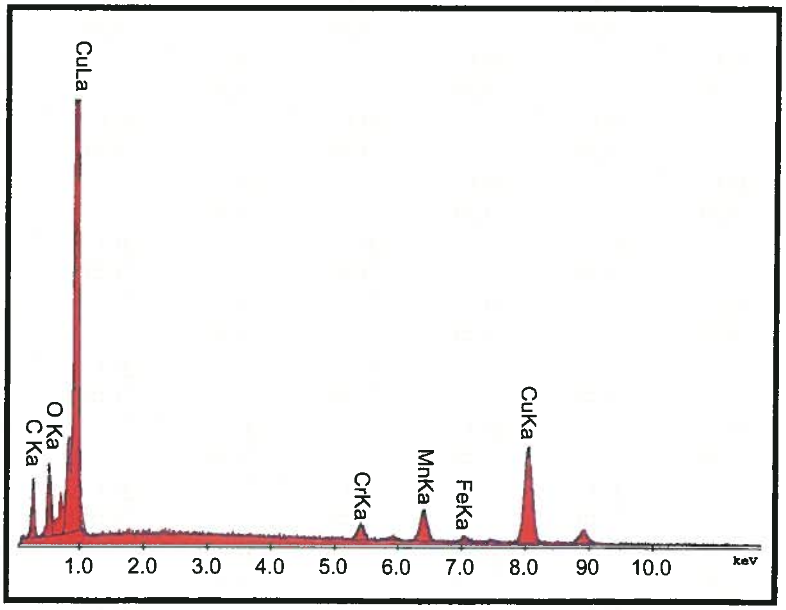

FIGURE 1
The spectra of the flowing material surrounding the hole in Photo 4.

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After the optical microscope has been used to document the exterior and interior of the CSST sections, the CSST can be examined with the SEM. The SEM/EDX will be used to determine what metals are present, to include both the elements of the stainless (type 304), as well as metals such as copper, aluminum, and zinc.

The spectra for the EDX may show such materials as Sulfur (S), Calcium (Ca), and Carbon (C). These elements are often associated with fire debris and sheetrock. These same elements and other fire debris can be partially removed by cleaning the CSST sections for approximately 30 minutes in a heated ultrasonic bath, using an aqueous solution of Alconox; we have also used MEK (Methyl Ethyl Ketone) or isopropyl alcohol as solvents. We would advise against the use of more reactive solvents (Branson OR or similar), due to their ability to etch the metals. After cleaning and removal of fire debris, the SEM/EDX analysis can be conducted again. Elemental mapping software that is part of the EDX can be used to better visualize the location of the elements not usually associated with 304 Stainless Steel (SS).

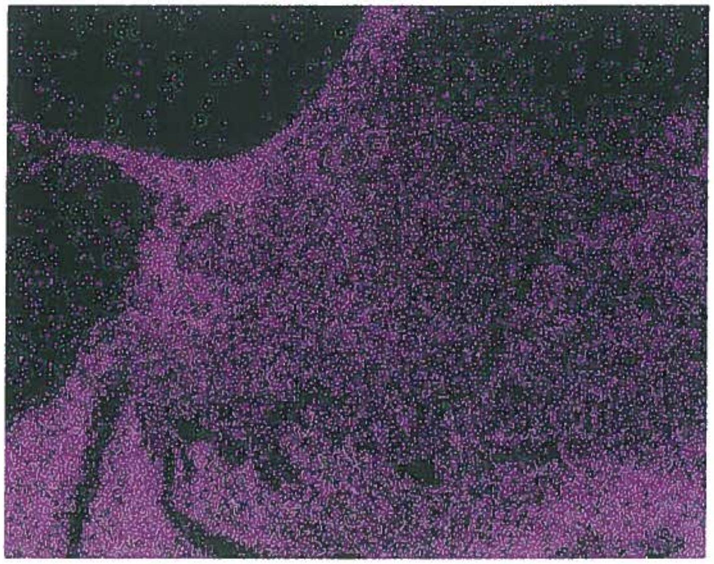

PHOTO 5

EDX map highlighting iron in region surrounding the hole in Photo 4.

PHOTO 6

EDX map highlighting copper in region surrounding the hole in Photo 4.

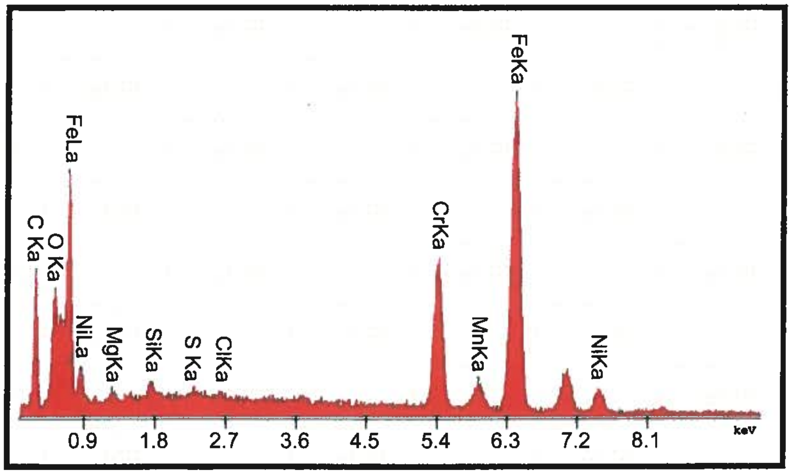

FIGURE 2

The spectra of a length of CSST that has been through a fire, but without copper, zinc, or aluminum present.

For reference purposes, Table I lists the characteristics of type 304 SS. The specific composition of 304 SS varies slightly by manufacturer. The highest composition elements (besides Iron, Fe) are Manganese (Mn), Chromium (Cr), and Nickel (Ni). SS have a minimum of 10.5% of chromium content by mass. The chromium content sets SS apart from carbon steel and also gives the SS its corrosion resistant properties. It is of note that Copper (Cu), Aluminum (Al), and Zinc (Zn) are not elements normally found in 304 SS.

DISCUSSION

The above steps have been seen to provide the data that engineers investigating possible CSST fires need for their analysis. It should be noted, however, that not every step is needed in every examination. As an example, if microscopy shows that a hole was caused by a mechanical gouge (the CSST was nailed into), it is probably not necessary to conduct SEM/EDX analysis. Moreover, there have been joint examinations when engineers agreed that a certain procedure or step was not needed; IE, the engineers agreed, as an example, that there was no need to perform ultrasonic cleaning on a given hole.

The above protocol has proven satisfactory for dozens of CSST exams that the authors have been associated with. The protocol, however, is not meant to be an exhaustive list of all techniques. As an example, FTIR (Fourier Transform Infra Red) analysis of the jacketing can be conducted if there is a question regarding the jacketing's polymeric composition. One metallurgist we have worked with wants to perform metallography on an arc bead; this will involve sectioning the bead, following by polishing of the cut section at a metallurgical polishing station, and then studying grain structure. A recent article by Lisiecke gives an excellent overview of such a technique and analysis[1].

We further note that this technique has been limited to the CSST *only*. Variants of these techniques can also be used with examinations of chimney caps and flue piping, as examples, for evidence of possible lightning or electrical damage.

We have received questions regarding the finding of certain metals in the EDX analysis. If, as an example, an ongoing fire damaged insulation on an energized type NM wire, and this same energized wire arced to the CSST and perforated it, one would reasonably expect to find copper in the EDX analysis of the perforated CSST. If zinc is found in an EDX spectra, the prospect of metal transfer of a galvanized surface to the CSST is raised.

SUMMATION

We outline a protocol for examining CSST in a lab setting. The protocol has been used for many CSST examinations, with little variation. The ultimate goal in these exams is to determine whether or not CSST failed, and the reason(s), if any, for such failure. We think this protocol will assist the engineer who needs to answer these questions. ●

References

1.) Lisiecke, et al, *Investigating The Microstructure Of CSST After Exposure To Electrical Arcing And Corrosion*, FIRE AND ARSON INVESTIGATOR, July 2011.

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