**REPORT**

on the

**MIKE SMITH INJURY**

By:

Ronald D. Schaible, CIH, CSP

June 11, 2010

Robson Forensic

Engineers, Architects, Scientists & Fire Investigators

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**PRELIMINARY REPORT** **JUNE 11, 2010**

## A. INTRODUCTION

On January 15, 2001, an incident occurred in the laser laboratory at ABC Company. Two employees (Mike Smith, Joe Lucky) were working with an Excimer laser supplied by Alpha Industries. A failure of a critical component of the laser resulted in a gas leak that released fluorine gas into the work area and injured Smith.

The purpose of my investigation was to determine if Smith was overexposed to the fluorine gas that escaped from the laser.

## B. MATERIALS AVAILABLE FOR REVIEW

1. Transcript of the Deposition of Michael D. Smith, Volumes 1, 2 and 3 taken March 20, 2006, November 1, 2007 and February 15, 2008, respectively.
2. Transcript of the Deposition of Terri Smith taken February 15, 2008.
3. Transcript of the Deposition of John Mix taken March 21, 2006.
4. Transcript of the Deposition of John Baylor taken March 21, 2006.
5. Transcript of the Deposition of Steven Duke taken June 6, 2009.
6. Transcript of the Deposition of Brett Cosgrove taken July 9, July 9, 2008.
1. Telephone interview with Mike Smith on January 31, 2006.
2. LTA Report by John Mix dated February 9, 2001.
3. Fractology report by John F. Baylor dated February 8, 2001.
4. Various Corning documents.
5. Email from Michael Roderick dated January 19, 2001.
6. Expert report by Craig Carmody dated February 25, 2010.
7. Deposition Exhibits Nos. 1 through 9 dated March 20, 2006.
8. Deposition Exhibits Nos. 1A, 10 through 14 dated March 21, 2006.
9. Deposition Exhibit No. 15 dated November 1, 2007.
10. Deposition Exhibits Nos. 16 though 18 dated July 9, 2008.
11. Alpha Industries documents.
12. Site inspection information.

## C. BACKGROUND AND DESCRIPTION OF THE INCIDENT

The Excimer laser discharge tube contained 99.9% pure 5% fluorine gas in Neon, Xenon and Argon at a pressure of 3-3.5 bar. A 5% gas concentration is equivalent to 50,000 parts per million (ppm) of that gas. The laboratory measured approximately 20 feet by 25 feet by 10 feet.

Alignment of the laser optics was necessary after each installation of a new laser discharge tube. This function was performed by Mike Smith and Joe Lucky as a routine part of their work duties. They were trained and instructed by Alpha Industries to perform these alignments. The cabinet enclosure was required to be open during this procedure. The ventilation system for the laser was inoperative, by design, while in the open position.

Smith was at the end of the laser discharge tube where the calcium fluoride (CaF2) Brewster window failed, and in close proximity to the Brewster window, while performing his alignment of the optics to achieve optimum power output. The side access panel was open while Smith was working as he had been trained by Alpha Industries. Smith stated during the telephone interview that his head was very close to the CaF2 window at the end of the laser discharge tube while performing his alignment of the optics. He was within approximately 12 inches of the window. He was seated with his knees against the cabinet and leaning forward at the waist with his head inside the cabinet. Smith was suffering from a cold on the date of the incident and his sense of smell was impaired.

Smith stated that he was concentrating on adjusting the laser power output during the alignment process. He was unaware that the CaF2 window had failed and fluorine gas had escaped from the laser discharge tube. Joe Lucky, a fellow laser operator, was in the same laboratory as Smith. Lucky was standing several feet away from Smith. Eventually, Lucky detected a strong sharp smell characteristic of fluorine. It is not known how long before Lucky smelled the odor indicating that a gas leak occurred. He mentioned the odor to Smith who could not smell anything. They checked the laser device and noticed a significant pressure drop. They powered down and sealed the laser. They evacuated the laboratory within a minute or two of Lucky's comment.

**D. CAUSE OF THE INCIDENT**

Basic safety principles are useful in identifying causes and related conditions. These include that an incident is a loss that results from a series of events; that danger is a function of hazard (the ability to cause harm) and risk (the likelihood of exposure); and that when an owner knows about a hazard, the owner should eliminate it, guard against it, or warn about it, in that order. This thought process has been a cornerstone of safety product or process design since at least 1964. According to the National Safety Council[1], the basic measures for preventing accidental injury, in order of effectiveness and preference, are:

1. Eliminate the hazard from the machine, method, material, or plant structure.
2. Control the hazard by enclosing or guarding it at its source.
3. Train personnel to be aware of the hazard and to follow safe job procedures to avoid it.
4. Prescribe personal protective equipment for personnel to shield them against the hazard.

The cause of Smith's injury was his exposure to fluorine gas that exceeded accepted occupational health criteria due to a failure of the CaF2 window.

## E. ANALYSIS

### Fluorine Is a Hazardous Material

Fluorine is a highly toxic and hazardous gas. The Material Safety Data Sheet (MSDS) for the gas mixture supplied by XYZ Gases states:

> The major health hazard with this mixture is that it contains fluorine. Fluorine is a toxic gas with a sharp, pungent odor that helps provide ample warning of toxic levels in the atmosphere. Fluorine readily reacts with moisture to form hydrofluoric acid. Hydrofluoric acid is irritating and highly corrosive to all living tissue. Normal atmospheric moisture and that contained in skin, eyes, lungs and nasal passages is sufficient for the formation of hydrofluoric acid. Fluorine is an extremely strong oxidizer that will cause acid-like burns on skin, eyes, and the mucus membranes of the lung and nose.

The MSDS states in bold print:

> **Because specific toxicology data is not available for this mixture, it should be handled carefully and with the assumption that it is a toxic, corrosive gas.**

Proper engineering design controls, such as local exhaust ventilation, is required when a foreseeable failure could release a toxic gas into the breathing zone of a worker. A fluorine gas sensor provided by Corning was located in the middle of the laser laboratory. It was not interlocked or otherwise connected to the laser system and never activated during the leak event. There was a ventilation system present to exhaust internally generated waste gases out of the room. However, Alpha Industries did not provide a detection system tied to an engineering control at the Brewster windows, which were consumable items and known failure points. A suitable engineering control would have included a fluorine gas sensor and alarm that would have sounded and simultaneously activated local exhaust ventilation at each Brewster window when a fluorine leak occurred.

### Toxicity and Warning Properties of Fluorine

OSHA has established the following Time Weighted Average (TWA) Permissible Exposure Level (PEL): 0.2 mg/m3 = 0.1 parts of contaminant per million parts of air (ppm).

The American Conference of Governmental Industrial Hygienists (ACGIH) has established the following Threshold Limit Values (TLV). The TWA =1.6 mg/m3 = 1 ppm. The Short-Term Exposure Level (STEL) = 3.1 mg/m3 = 2 ppm.[2] The STEL is usually a 15-minute time-weighted average exposure that should not be exceeded at any time during a workday, even if the 8-hour TWA is within the Threshold Limit Values (TLV) TWA, Permissible Exposure Level (PEL) TWA, or REL-TWA.[3]

Fluorine does not have an accepted odor threshold. However, the range of all referenced values in odor detection studies has also been reported as 0.097 – 0.193 ppm = 0.16 – 0.315 mg/m3.[4] An odor threshold for fluorine has been reported[5] as 6.0 mg/m3 = 3.7 ppm, with an irritating concentration of 50 mg/m3 = 30.6 ppm.

The lowest detectable odor level of 0.097 ppm is essentially equivalent to the OSHA PEL. The upper detection level of 0.193 ppm is approximately two times the OSHA PEL. An undetermined time lapse occurred between the failure of the CaF2 window with its release of fluorine gas, and Lucky's detection of the fluorine odor. Lucky first noticed the sharp, pungent odor while he was a few feet from Smith. This indicates that Lucky was more likely than not exposed to fluorine in excess of the OSHA Permissible Exposure Limits (PEL) = 0.1 ppm, and possibly exposed to two or more times the PEL despite his distance from the gas leak and the larger volume of air into which the fluorine gas had to diffuse to reach those concentrations. It was during this time that Smith was exposed. Smith was positioned at the point of fluorine gas release. He was therefore exposed for the time it took for the pressure to drop, the gas to be released, Lucky to detect the odor, Lucky's mention of the odor to Smith, and then their shutting down the laser and evacuation of the laboratory. There have been reviews[6] of the acute toxicity of fluorine exposure to humans at 10 ppm that resulted in slight irritation to the eyes and skin. Smith was likely exposed to a daily equivalent dose that exceeded the OSHA time-weighted average PEL = 0.1 ppm within a few minutes, and likely upwards of a concentration of 10 ppm of fluorine.

In view of his respiratory injury, Smith was likely exposed to a concentration of fluorine that exceeded 10 ppm of fluorine, and perhaps greatly exceeded a concentration of 10 ppm. This would have created a violation of OSHA under 29 CFR 1910.1000.

## F. FINDINGS

Within the bounds of reasonable professional certainty, and subject to change if additional information becomes available, it is my professional opinion that:

1. The laser window failed and released toxic fluorine gas into the breathing zone of Smith.
2. Smith was operating the laser in accordance with instructions and training he received from Alpha Industries.
3. Alpha Industries failed to provide proper engineering controls to prevent Smith's exposure to a known hazardous chemical contained in their laser, and which had this identified failure mode.
4. The amount of fluorine gas that was released from the laser tube into Smith's breathing zone was substantially likely in excess of allowable occupational health criteria, and caused Smith's injury.
5. The accident responsible for the injury to Mike Smith was foreseeable and preventable, and was caused by the defective design and operating procedures provided by Alpha Industries.

**ENDNOTES**

[1] McElroy, Frank E., Editor. *Accident Prevention Manual for Industrial Operations, 5th Edition.* (March 1964). National Safety Council, Chicago, IL. P. **4**-1.
[2] *Documentation of the Threshold Limit Values and Biological Exposure Indices, Sixth Edition.* (1991). American Conference of Governmental Industrial Hygienists, Cincinnati, OH.
[3] *Guide to Occupational Exposure Values*. (2000). American Conference of Governmental Industrial Hygienists, Cincinnati, OH.
[4] "Odor Thresholds for Chemicals with Established Occupational Health Standards". (1989). American Industrial Hygiene Association, Fairfax, VA.
[5] Ruth, Jon H. "Odor Thresholds and Irritation Levels of Several Chemical Substances: A Review." (March 1986). *Am. Ind. Hyg. Assoc. J (47).*
[6] Op.Cit. *Documentation of the Threshold Limit Values and Biological Exposure Indices, Sixth Edition.* (1991).

Ronald D Schaible

**Digitally Signed By: Ronald D. Schaible**

Ronald D. Schaible, CIH, CSP