Training guidelines for the Fire Debris Analyst

Lesson Plan (Module) 17

Date: November 2012 **Instructor:** Qualified Instructor

Subject: Self-Heating Processes **Total Time:** 12 hrs.

Learning Objectives

- Identify materials susceptible to self-heating.
- Demonstrate an understanding of the thermodynamics of self-heating.
- Understand the relationship between reactivity, time, mass and temperature.
- Distinguish between the mechanisms of self-heating.

Suggested Reading

1. Bowes PC. Self-heating: Evaluating & Controlling the Hazards, Elsevier, Amsterdam, 1984

2. DeHaan JD. “Spontaneous Combustion: What Really Happens”, Fire & Arson Investigator, Jan & April 1996

3. NFPA, Fire Protection Handbook, 19th Ed. 1998, Table A10

4. Dixon B. “Spontaneous Combustion” The/Le Journal, Canadian Association of Fire Investigators, Toronto, March 1992.

5. Howitt DG, Zhang E, and Sanders BR. “The Spontaneous Combustion of Linseed Oil” Proceedings of the International Conference on Fire Safety, San Francisco, CA, 1995

6. Hicks AJ. “Hay Clinkers as Evidence of Spontaneous Combustion” Fire & Arson Investigator, July 1998, 10-13

7. Mann DC, Fitz M. “Washing machine Effluent May provide Clues in Dryer Fire Investigations” Fire Findings, 7,4, Fall 1999, 4

8. Gray BF. “Interpretstion of Small Scale Test Data for Industrial Spontaneous Ignition Hazards, Proceedings of InterFlam, 2001, 719-29

9. Gaw K. “Autoignition Behaviors of Oiled & Washed Cotton Towels. Proceedings: Fire & Materials, 2005

10. Stauffer E. “A Review of the Analysis of Vegetable Oil Residues from Fire Debris Samples: spontaneous ignition, vegetable oils, and the forensic approach.” J. Forensic Sci., 2005, Vol. 50, No. 5, 1091-1000

11. Stauffer E. “A Review of the Analysis of Vegetable Oil Residues from Fire Debris Samples: Analytical Scheme, Interpretation of the Results, and Future Needs” J. Forensic Sci., 2006, Vol. 51, No. 5, 1016-1032

12. Baylon A, Stauffer E, Delemont O. “Evaluations of the Self-heating Tendency of Vegetable Oils by Differential Scanning Calorimetry” J. Forensic Sci., 2008, Vol. 53, No. 6, 1334-1343

13. Gambrel Abby K, Reardon Michelle R. “Extraction, Derivatization, and Analysis of Vegetable Oils from Fire Debris.” J. Forensic Sci., 2008, Vol. 53, No. 6, 1372-1380

14. Schwenk Lisa M, Reardon Michelle R. “ Practical Aspects of Analyzing vegetable Oils in Fire Debris” J. Forensic Sci., 2009, Vol. 54, No. 4, 874-880

15. Juita, Dlugogorski Bogden Z. Kennedy Eric M, Mackie John C. “Oxidation reactions and spontaneous ignition of linseed oil.” Proceedings of the Combustible Institute 2011, 33, 2625-2632

Introduction

Self heating processes are sometimes the cause of accidental fires in both structures and vehicles. Because such fires occur without the introduction of an external heat source, it is important that investigators (with the aid of laboratory analysis) carefully consider and eliminate self heating before concluding the fire was started by direct flame application. Self heating can occur in a wide variety of materials in residential, commercial and industrial structures and the laboratory analyst must be aware of the process and materials that can self heat. Because much of the starting material is often destroyed in the fire, the lab must consider analysis of ancillary materials. This module addresses the thermodynamics of self heating processes, analyses of starting materials and chemistry and identification of post-fire residues.

Outline

1. Introduction and Definitions
    a. Self-heating
    b. Spontaneous combustion
    c. Reaction rate

d. Activation energy
e. Auto ignition
f. Pyrophoric

2. Thermodynamics of self-heating
   a. Heat production
      Effects of
      - size
      - mass
      - shape
      - ambient temperature
      - reactivity

   b. Heat loss
      Effects of
      - size
      - mass
      - shape
      - ambient temperature
      - reactivity

3. Mechanisms of self heating
   a. Chemical
      1. Oxidative
         Materials susceptible to self heat
         - Drying oils
         - Hot materials
         - Coal
         - Saw dust
         - Finely ground solids (rubber, plastics)
         - Laundry fires
         - Fish oils (cod liver oil, sardine oil)
         - Metal dusts

      2. Catalytic (Polymerization/Cross linking)
         Materials susceptible to self heat
         - Fiberglass

   b. biological
         Materials susceptible to self heat
         - Hay
         - Wool
         - Some seeds
         - Cotton

4. Recognizing evidence of self heating
   a. more damage to center of mass than damage to exterior of mass
   b. nature of substrate
      - Physical characteristics
      - Capable of forming a rigid porous char
      - Adequate mass
      - Presence of clinkers
   c. chemical characterization
      - identify of reacted and unreacted residues

5. Laboratory Analysis
   a. Identification of substrate
      - Microscope
      - -IR
   b. Identification of unreacted and reacted material
      - -extraction and isolation
      - -IR
      - -GC/MS
      - -LC/MS
      - -Derivatization techniques
      - -XRF (clinkers)
      - -SEM (clinkers)

6. Interpretation and Reconstruction

7. Myths
   a) Spontaneous human combustion
   b) Spontaneous combustion of petroleum products
   c) Use of the term “pyrophoric”

7. Report Writing

Teaching Aids

Hand out
PowerPoint
Demonstration of self-heating processes

Summary

Self heating processes are a delicate balance of mass, heat, time and chemical reactivity, highly dependent on the substrate material. The investigator and the lab must appreciate all the components necessary. The lab can play a critical roll in establishing what was originally present.

Test Questions

1. Self-heating by oxidation processes requires:
    a. Reactive materials
    b. Porous substrate
    c. Adequate time
    d. All of the above

2. The “runaway stage” of self-heating occurs:
    a. When the heat being generated exceeds the heat that can escape
    b. When reactive materials are exposed to air
    c. At the same time for each material
    d. Regardless of external temperature

3. Spontaneous combustion
    a. Is not a scientifically plausible event
    b. Is a rare but occasionally seen phenomenon
    c. Occurs with elderly, overweight females
    d. Involves extremely exothermic cellular malfunctions

4. Self-heating can readily occur in:
    a. Cotton rags with linseed oil
    b. Cotton rags with petroleum motor oil
    c. Dry glass clippings
    d. Clean wool clothing

5. “Pyrophoric” ignition refers to:
    a. Ignition at relatively low temperatures (54degC, 130degF)
    b. Decomposition of solid fuels by the application of heat
    c. Ignition of wood at unusually low temperatures (100degC,212degF)
    d. Ignition using energetic materials

6. “Hay clinkers” contain:
    a. A glassy mass of fused inorganic salts from cellulosic materials
    b. Residues of chemical incendiaries
    c. Organic fermentation products
    d. Residues of chloride salts from cellulosic products

7. Laundry fires due to spontaneous combustion occur:
    a. Most often when the laundry is removed from the dryer while still hot
    b. when oily rags are laundered
    c. When wool clothes are left in dryer
    d. When the water temperature is too high

8. Self-heating fires involving wood sanding dust are most likely to occur:
    a. When recently varnished floors are sanded
    b. When old, raw wood is sanded
    c. With residues from hand-sanding
    d. Nearly instantaneously when the dust is bagged

9. The mass of reactive material needed to trigger spontaneous ignition:
    a. Inversely proportional to the chemical reactivity
    b. Directly related to the chemical reactivity
    c. Independent of reactivity
    d. Independent of time factors

10. A fire starting in a large pile of garden clippings and mulch:
    a. Is caused by both biological and chemical processes
    b. Is caused by biological processes only
    c. Is caused by chemical processes only
    d. Cannot be caused by self-heating processes