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INVESTIGATION OF LATHE
COOLANT SPRAY FIRE
MARCH 25, 1970 - BUILDING 776

E. D. Erickson
J. W. Beltz

T. C. Johnson
K. A. Pocius
J. W. Lindsay

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CHEMISTRY RESEARCH AND DEVELOPMENT
Equipment & Materials Engineering R&D

The Dow Chemical Company
Rocky Flats Division
Golden, Colorado

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ABSTRACT

The following report is concerned with investigation of a flash fire which occurred March 24, 1970, in the development line of Building 776. Results of preliminary investigation into the possible causes of the flash fire are given along with recommendations for future action based on the tentative results.

DISCLAIMER

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SUMMARY

Preliminary studies of the conditions present during the lathe coolant spray fire of March 24, 1970, indicate the following:

1. The lathe coolant that ignited contained about 4 percent by volume carbon tetrachloride.
2. No volatile components were found either in the coolant, in the lathe catch pan, or its source tanks which could create a flammable atmosphere with a lower flash point than that of the cutting oil itself. Flash point of the cutting oil used ranges between 192° and 205°C.
3. Sprays of the lathe coolant in a static air atmosphere are potentially flammable providing the proper ignition source, oil concentration and particle size are obtained. In a static atmosphere no danger of fire or explosion seems to exist in oil - carbon tetrachloride mixtures in which the carbon tetrachloride concentration exceeds 60 percent by volume.
4. Using a scaled down replica, the tape lathe operation in Building 776 was reproduced. Flammable mixtures of lathe coolant were produced in a volume of air immediately surrounding a 2½ inch diameter ball rotating at 2000 rpm

when coolant was supplied to the surface. A heat source of about 540°C was required for the spray ignition. Fire produced in this manner did not cause ignition of bulk oil in the immediate vicinity. Plutonium burns at 800°C or higher.

5. Only minor amounts of flammable pyrolysis products were formed by inserting heated metal into the bulk coolant. Very large ratios of heated metal to oil would be necessary to create a hazardous gas phase above the oil.

RECOMMENDATIONS

Based on evidence uncovered in the oil-coolant fire of March 24, 1970 in the Building 776 development line, it is believed that a potentially hazardous condition does exist in the present operation. Preliminary investigation of the factors leading to the oil fire prompt the following suggestions, both from the standpoint of immediate action and suggested future investigation..

Present Action

1. In the event of a flash fire in the coolant spray surrounding the part, extinguishment can be accomplished by stopping either the coolant flow or the lathe spindle, or both. Addition of CO₂ from the in-line extinguisher should also be used as a precaution against possible flame spread in the oil coated boxes. *present #1*
2. Spray shields should be used at all times during machining to prevent possible flammable spray concentrations from being formed in larger volumes of the box than necessary. *present #1*
3. Compartmentalization by the use of a fire door should be done during any machining operation to prevent possible spread to adjacent lines. This precaution would seem particularly important in light of the close proximity of the existing conveyor line.

Future Action

1. Inerting of the lathe boxes should be seriously considered. This means of safeguarding against fire may have particular merit in light of the limited number of nonflammable cutting oils which could act as a replacement for the presently used DLM "643".
2. Investiation of new cutting oils which might possess reduced ignition behavior should be initiated. One such oil, produced by the Monsanto Chemical Corporation and sold under the trade name of Pydrol[®], has been recommended by the Bureau of Mines for machining in hazardous areas. Any change of oil would necessitate extensive evaluation of its compatibility with plutonium and existing glovebox components.
3. Changing operating parameters, such as rotation velocity of the lathe spindle or rate of addition of the coolant could conceivably lessen the possibility of producing hazardous oil sprays. Much work remains to be done, however, before such critical parameters can be defined.

INTRODUCTION

An oil-carbon tetrachloride lathe coolant mixture was recently involved in a vapor fire during the machining of a plutonium part on a tape controlled lathe. The following report describes the incident as well as the results of preliminary investigations made in regards to the incident. Several experiments have been performed in an attempt to simulate conditions prior and during the event. Because of the large number of variables involved, much work remains to be done before a complete evaluation of the fire and hazards associated with the operation can be made.

Coolant used in the machining process is a standard light cutting oil (DLM-643) which flows over the part and is caught in a reservoir below the lathe spindle. The oil is continually recycled via a small pump during the process. Dimensional measurements are made on the part following a carbon tetrachloride rinse which is similarly caught in the coolant reservoir. Over a period of time the CCl_4 builds to concentrations as high as 50 percent by volume before the coolant is changed. Part rotation during the machining process is normally 1000 rpm. Use of a shield prevents oil spray from splashing throughout the box.

The fire which occurred on March 24, 1970, took place during a routine machining operation. The lathe tool bit was being positioned for a cut when the tool bit accidentally traveled in the reverse direction, and gouged-out coarse pieces of plutonium metal. The resulting chips ignited immediately and a flash fire occurred in the oil spray in the immediate vicinity of the rapidly rotating part. The fire was confined to the coolant spray and did not cause the oil in the underlying catch pan to ignite. The fire which lasted about 30 seconds was extinguished through the use of an in-line carbon dioxide extinguisher. No previous incidents of this nature have been observed. The normal operating procedure calls for the extinguishment of chip fires with the lathe coolant which has a flash point between 192° and 205°C.

EXPERIMENTAL RESULTS

Analyses of the lathe coolant taken from the catch pan following the fire was made by mass spectroscopy. Similar analyses were made on new, unused cutting oil from the source tanks from which the coolant involved in the fire originated. These analyses were compared to results obtained from similar oil obtained from additional sources on hand in the Mass Spectroscopy Laboratory. Additional characterization of the oils was made through infrared analysis. Particular attention was given to the following parameters:

Mass Spectroscopy

- a. cracking pattern
- b. hydrocarbon distribution
- c. additive identification
- d. degree of oxidation

Infrared Spectroscopy

- a. degree of oxidation
- b. oxidation products
- c. hydrocarbon distribution
- d. carbon tetrachloride concentration

Complete results of these tests are given in Appendix A.

In general, the mass spectroscopy and infrared tests showed the following:

1. The coolant removed from the catch pan consisted of the expected DLM "643" light cutting oil which is a product of Standard Oil and is sold under the trade name of American Industrial No. 15. -
2. The coolant found in the catch pan showed a fairly high degree of oxidation indicating extensive use or subjection to elevated temperatures.
3. No volatiles were found in the lathe box or in the source tanks which would cause the oil to have a flash point below its normal value.
4. Concentration of carbon tetrachloride in the lathe box coolant was found to be about 4 percent by volume.

Flash point tests run on the various oils by the Cleveland open cup test gave the following results:

1. Flash point of coolant removed from lathe catch pan ranged between 195° and 198°C.
2. Flash point of unused coolant removed from the source tanks ranged between 192° and 205°C.
3. A 50 percent by volume ratio of CCl_4 in the oil had no effect on the observed flash point. (This is, of course, expected in dynamic atmospheres since CCl_4 boils at a

much lower temperature and should be dissipated prior to oil ignition.)

In addition to mass spectral and infrared analyses tests, mist flammability tests were made by Building 881 laboratories. The tests patterned after dust explosibility tests were made in a cylindrical chamber into which the liquid sample of oil was aspirated by a 15 psig air source. An AC spark produced in the center of the chamber during aspiration served as the ignition source and closely simulated a burning plutonium metal chip which can create temperatures as high as 1300°C. Air entering through the aspirator leaves the chamber via a filter paper diaphragm in the top of the chamber. An explosion is defined as any pressure increase in the chamber capable of rupturing the filter paper. Results of the tests are shown in Table I.

The following estimates the conditions in the chamber during the tests:

1. Pressure in the chamber was estimated to be 10mm Hg above the external pressure due to the pressure drop across the filter paper.
2. The quantity of oil in the air was estimated to be 0.68 gram of oil per liter of air at 72°F and 630mm Hg.

TABLE I

Explosibility of Oil-Carbon
Tetrachloride Mixtures Atomized in Air

LIQUID SAMPLE COMPOSITION (VOLUME PERCENT OIL)	TYPE OF OIL IN MIXTURE	
	American Oil Company Industrial Oil No. 15 DLM 643	Texaco Regal A DLM 643
100	Yes	Yes
96	Yes	Yes
90	Yes	Yes
80	Yes	Yes
60	Yes	Yes
50	Yes	Yes
40	No	No
20	No	No
0	No	No

All tests were run using 15 psig air to produce atomization.

3. The AC spark source voltage was 15,000 volts (60 ma) with a gap of 0.5 cm.

Attempts were made to produce a vapor flash with a laboratory model of the lathe system involved in the incident. The system is diagrammed in Figure 1. Burning lathe coolant sprays were found to be easily produced with the system, and the hot wire source, which was maintained at 540°C. The resulting flame was confined to the spray immediately surrounding the rotating ball and did not travel to the underlying coolant catch pan. Variables affecting vapor ignition were found to include rate of coolant addition, rate of ball rotation, and position of heat source relative to the ball.

Extinguishment of the burning coolant mist was found to be readily accomplished by varying coolant supply or by altering the velocity of the spinning ball. All of the parameters have not yet been fully evaluated, however, part velocity and rate of coolant addition seem significant in producing flammable spray concentrations. Only certain lathe velocities and rates of coolant addition were found capable of creating the flammable sprays. More work in this area is needed, however, before definition of the critical parameters can be defined adequately.

FIGURE 1
Simulation of Tape Lathe
and Lathe Coolant Supply

Tests designed to determine the effect of a hot metal source being inserted into a quantity of the coolant were also made.

In the first of these tests, a stainless steel bar

(10 X $\frac{1}{2}$ X $\frac{1}{8}$ -inch) was heated to 1200°C. The bar was then partially submerged in the coolant leaving a portion of the bar above the surface to act as an ignition source for any volatile gases produced by the hot metal. No evidence of vapor ignition or bulk liquid burning was observed. Gases evolved during a similar experiment were analyzed by vapor phase chromatography. Results of this analysis are given in Appendix B. Quantities of the gases produced by submerging the 1 X 1 X 1/16-inch stainless steel coupon, which was heated to 1200°C, into 200ml of coolant were well below that required for a significant vapor fire.

APPENDIX A

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INFRARED, MASS SPECTROSCOPY DETERMINATIONS OF OIL SAMPLES
TAKEN FROM THE BUILDING 776 CAF LINE AREA
AFTER THE FIRE INCIDENT OF MARCH 24, 1970 -

By R. S. Cichorz and K. J. Grossaint

March 30, 1970

Mass Spectrometry Laboratory
Rocky Flats Division
The Dow Chemical Company
Golden, Colorado 80401

Approved: *J. R. Turbett*

J. R. Turbett
MS Group Leader

Distribution:

H. Johnson
J. W. Lindsay (3)
M. A. Thompson
G. E. White
J. F. Willging
A. K. Williams

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ANALYSIS SUMMARY OF OIL SAMPLES

<u>Oil Sample</u>	<u>*Flash Point (°C)</u>	<u>** C=O (% by volume)</u>	<u>Analysis Results Comments</u>
# 1 "new" "643" (Standard AI No. 15)	205	<0.01	
# 2 "new" "643" (Texaco Regal A)	192	<0.01	
"643": CCl ₄ mixture (1:1 SAI No. 15:CCl ₄)	205	---	CCl ₄ did not affect the flash point as it boiled off prior to reaching 100°C
# 3 "cold" (776 caf line oil)	198	0.19	This sample is Standard AI No. 15 with slight oxidation present as indicated by the C=O determination. The flash point is within the range of the "new" "643" oils examined.
# 4 "hot" (776 caf line oils)			Samples 5-3086 and 5-3087 are identical and contain about 4% by volume CCl ₄ . There is no significant difference between the flash points of the two samples and those of the other "643" oils tested. These oil samples are heavily oxidized indicating they had been used extensively and/or were exposed to elevated temperatures in the presence of air or oxygen. The presence of the carbonyl oxidation products (predominantly esters) did not affect the flash point.
Sample 5-3086	195	>5	
Sample 5-3087	198	>5	

* Cleveland open cup method

** C=O as dibutyl sebacate standard

-5-

"Hot" Oil Samples vs. "645" Oils

Mass Spectrometry

The "hot" oil samples give a cracking pattern essentially identical to that of American Industrial No. 15, a light hydraulic oil. The hydrocarbon distribution of $\approx C_{38}$ and degree of aliphatic-olefinic saturation are identical for the samples. Highly volatile fractions such as toluene and xylenes were absent. Minor differences are apparent in the "hot" samples:

1. There is an absence of some additives present in AI Oil No. 15. For example, 2,6-ditertiarybutyl-4-methyl phenol (an oxidation inhibitor) is a minor constituent of the "new" oil but is largely expended in the "hot" oil.
2. Oxidation is present in the "hot" oil as indicated by certain oxygenated fragments absent in the "new" oil.
3. Carbon tetrachloride is present in the "hot" oil.

Infrared Spectroscopy

The "hot" oil samples are "645" light hydraulic oil that has been heavily oxidized through extensive use and/or high temperature exposure to air. The oxidation products are probably esters and carboxylic acids formed from extreme oxidative attack of unsaturated C-C linkages. The hydrocarbon distribution, though, appears largely unaltered. The "hot" samples contained about 4% by volume carbon tetrachloride.

APPENDIX B

Date 4/1/70

THE DOW CHEMICAL COMPANY
Rocky Flats Division
Laboratory

ANALYSIS REPORT

To KAC Pocius Bldg. 881 Charge 2419

cc: G. E. White

File (A)

Sample Description:

Vapor Formed by Dropping a Hot Steel Chip in Oil

Results of Analyses or Tests:

	<u>ppm by Volume</u>
Methane	40
Ethane	380
Propane	40
Iso-butane	≈10
N-butane	≈10
Iso-pentane	Trace <5
N-pentane	Trace <5

The blank sample taken before dropping the chip in the oil did not show any of the above components.

Analysis By VEM

Reported By W. D. Scheuerman
W. D. Scheuerman

File or Plate No. _____

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