INITIATION

SENSITIVITY OF LIQUID MATERIALS

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INTRODUCTION

If a liquid material which is compression sensitive is subjected to rapid adiabatic high-order explosion. This evaluating the sensitivity compression, the result could be a paper discusses the method for of liquid materials (that could detonate) to initiation of decomposition in the presence of rapidly compressed gas bubbles. The liquid may or may not be flammable, may be pure chemical compounds, homogenous mixtures or multilayer combinations of immiscible liquids.

To investigate the potential of liquid ignition, Safety Consulting Engineers, Inc. (SCE) set up various methods to evaluate the sensitivity of liquid materials to initiation. Nethods utilize systematic testing and analysis of hazard detection. A test method describing adiabatic compression of a gas or vapor bubble (in the liquid) as the potential ignition source of liquid explosives and propellants is discussed herewith.

BASIC HAZARDS DEFINITION

A hazard exists in liquid materials if the material is flammable or material develops incompatibility with the surroundings. The reaction may result in high output (explosion) once heat is generated as a result of combustion or reaction with other material. Hazardous conditions may occur if one or more of the following exist:

- Liquid material is flammable
- Liquid material is incompatible with materials utilized in the system
- Liquid materials is sensitive to heat, electrostatic discharge, impact and adiabatic compression
- Liquid composition contains free radicals

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When liquid is transferred or processed in a given system, the system should be designed or examined for failure. Excessive pressures developed in the field handling system has unusual effects on the field and the system itself. There are many sources of excessive pressure; wherein, one or more are present in the field handling system. The pressures commonly referred to as "surge pressures" are as follows:

- Pressure waves caused by opening a valve between high pressure and low pressure domain
- Pressure surges produced by the application of external static load
- Pressure surges caused by deceleration of moving masses.
- Pressure waves related to pump characteristics commonly referred to as "pump ripple".
- Rapid compression of gas bubble in contact with liquid force due to mechanical shock.

Pressure waves produced by the opening of a valve between high pressure and low pressure can be expressed as:

$P_{max}/\Delta P$ = maximum pressure at peak/applied pressure differential =2
= 2

For static load, the pressure surge can be determined from:

$$P_{max} = W/A$$

where: W = applied load
A = piston area supported by fluid

Pressure surges produced by the deceleration of moving masses are described by the relationship:

$$\Delta P = mv^2 E/Vg$$

where: ΔP = excess pressure produced
m = weight being decelerated
v = velocity at which the weight moves
E = bulk module of the fluid
V = volume of fluid being compressed
g = acceleration due to gravity

An expression for the piston velocity was developed in terms of the rate of pressure rise on the driving side of the piston and distance travelled by the piston. Simplifying the expression and inserting the necessary conversion factor and physical constants leads to the following expression for piston velocity:

$$n = 14.9\,(dP/dt)^{1/3}\,X^{2/3}$$

where: n = in inch/sec
(dP/dt) = in psi/sec
X = in inches

During compression, heat is lost to the mass of the liquid sample and to parts of test equipment in contact with a gas bubble. If the compression is fast enough, the heat lost will be negligible.

As indicated in the source of excessive pressure, it appears that the sensitivity of the liquid fuel as measured by the adiabatic compression should be a good indication of sensitivity of the liquid material.

LIOUID CHARACTERIZATIONS - TESTS AND EVALUATION

Rapid compression can result from mechanical shock to containers of fuel, or from rapid closing of valves (as described above) in propellant lines containing entrained gas bubbles. Such phenomena are thought to be responsible for a number of accidental explosions. Therefore, sensitivity of liquid materials to the initiation of decomposition in the presence of rapidly compressed (air) gas bubbles is evaluated.

SCE's adiabatic compression sensitivity test apparatus shown in Figure 1, is similar to the Bureau of Explosives compression apparatus (Refer to Figure 2) and the NAVORD OD 44811 adiabatic sensitivity test machine. This apparatus was designed to simulate conditions which might occur in an actual propellant line, and incorporates a device for applying pressure very rapidly to a gas bubble in contact with a liquid propellant. During 'the test, the gas or vapor in contact with the liquid is rapidly compressed using a known drop weight system. Drop heights are varied to change the ignition conditions. The 50% point determination is calculated from the following equation:

50% Point = (lowest normalized height) + (log interval) $(\Sigma AN/\Sigma AN \pm 1/2)$

The instantaneous compression in the chamber is measured by a pressure transducer. Since the pressure rise in the test chamber is rapid (10,000 - 1,000,000 psi/sec), the compression will be nearly adiabatic and rapid temperature rise will result.

A typical example of an adiabatic compression problem was the incident at Bird Creek in 1971 wherein nitromethane, EDA sensitizer, gelling agent and aluminum powder mixtures in an oil well exhibited incompatibility with the environment and generated high output (explosion). Under pressure and in bore hole, the gelling agent broke down due to high PH of rock (limestone) causing the EDA sensitizer to attack the aluminum powder, generating exothermic decomposition and eventually the accidental explosion. Th)

Figure l. Adiabatic compression sensitivity tester setup with impact tester.

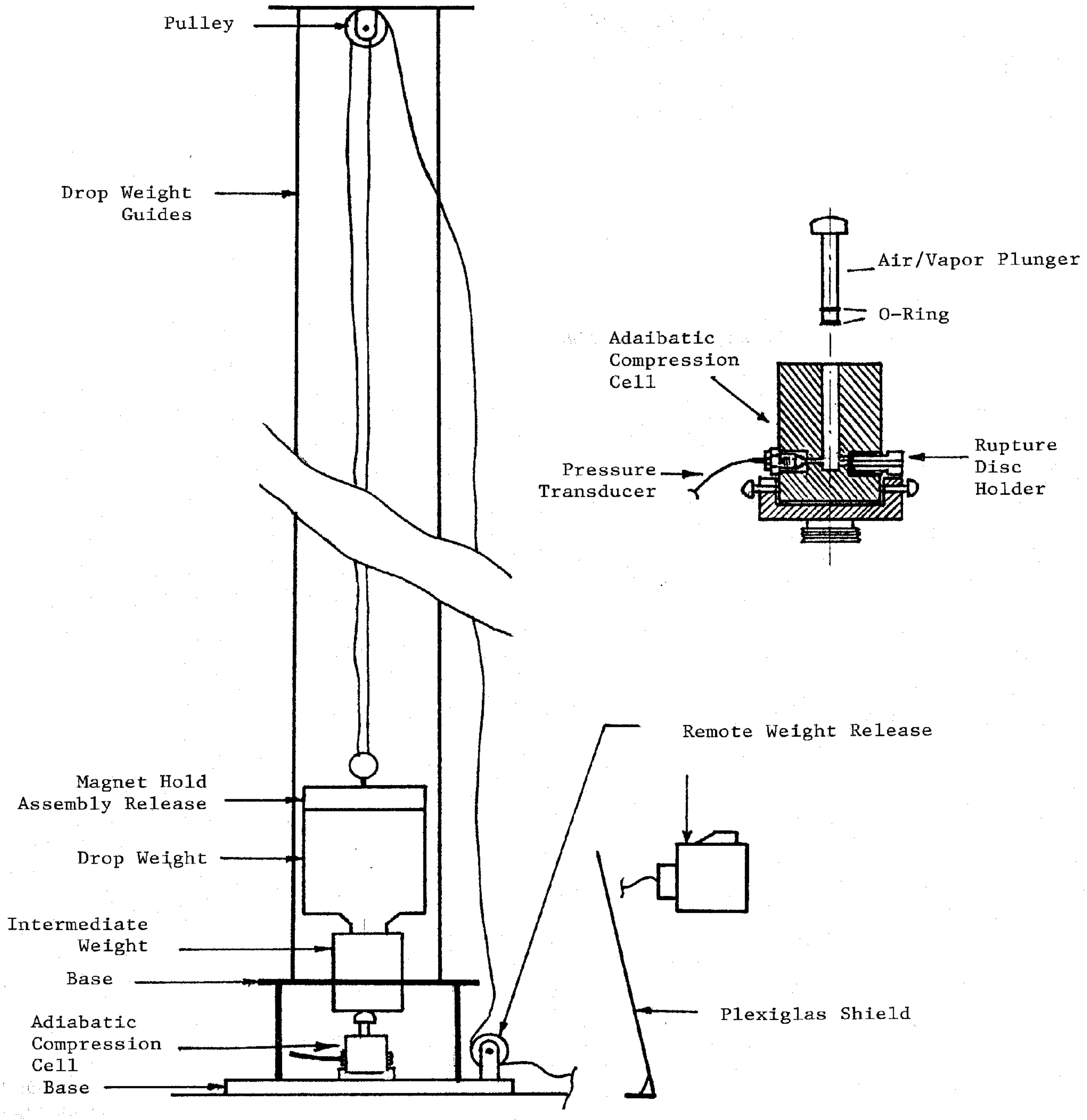

Figure 1. Adiabatic compression sensitivity tester setup with impact tester.

Figure 2. Compression Test Apparatus - Bureau of Explosives using Impact Tester.

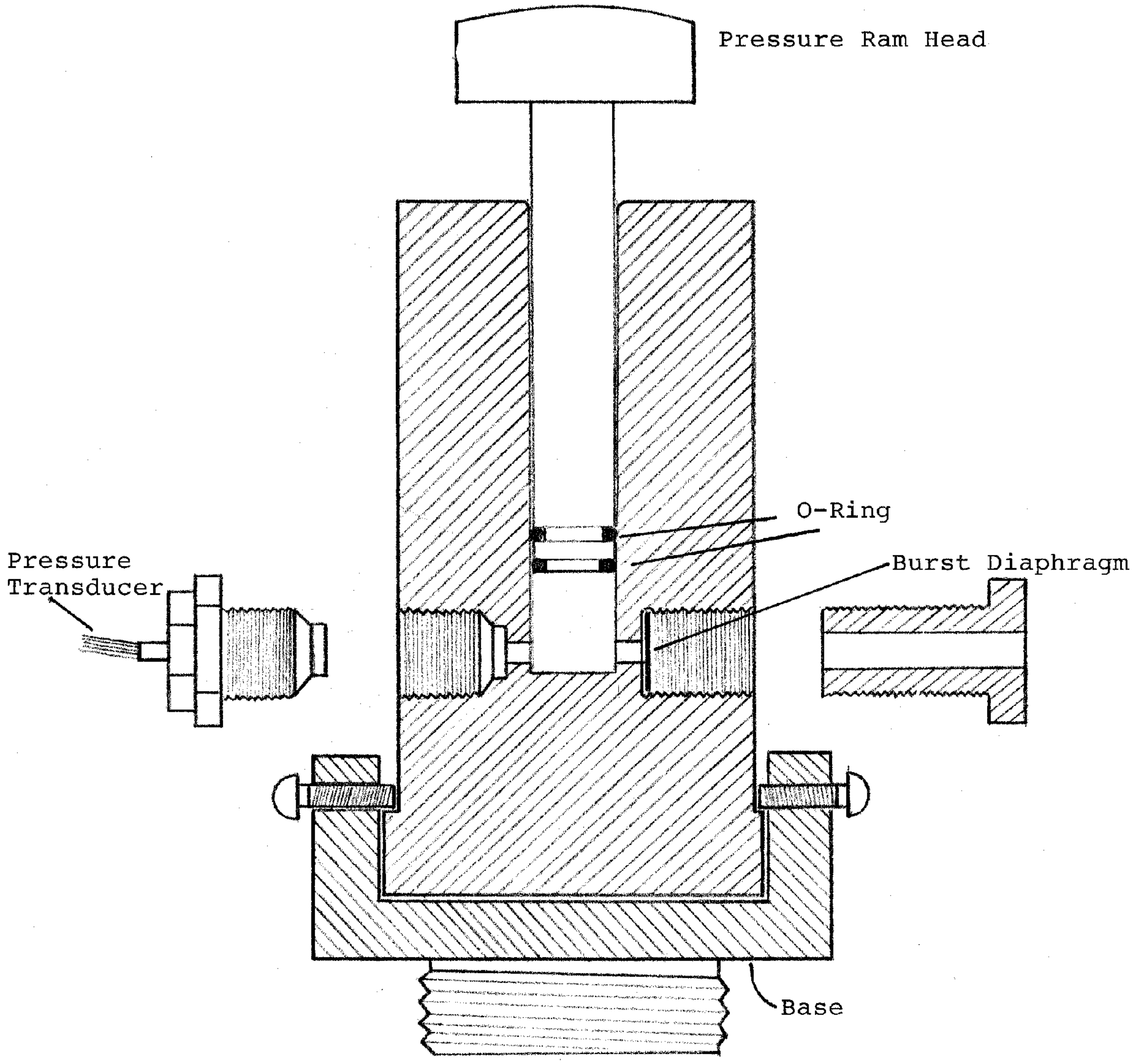

Figure 2. Compression Test Apparatus - Bureau of Explosives using Impact Tester.

Reference materials tested using an SCE adiabatic compression tester are shown as follows:

MATERIAL	**MOISTURE CONTENT (%)**	**50% FIRE POINT (cm)**
Nitrocellulose	Dry	5.5
Nitrocellulose	10	16.0
Nitromethane	-	23.0
Lacquer	-	36.0
Nitroethane	-	37.0
N-propyl nitrate	-	4.0

Drop Weight: 5.0 Kg
Intermediate Weight: 2.0 Kg

CONCLUSIONS

The sensitivity of a material to adiabatic compression is of great importance to rate numerically the sensitivity of liquids to ignition in the presence of rapidly compressed air bubbles. The parameter is based on the 50% point determination necessary to cause gas phase ignition followed by propagation to the liquid. The sensitivity data is also useful in the design of equipment and processes involving manufacture, handling and use of the material. Precaution is also recommended when mixing materials so they do not introduce additional hazards. Compatibility should be considered when mixing materials.