# MJU-8 IR FLARE MIX FIRE AT LONGHORN AAP, 28 SEPT 91

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# ABSTRACT OF THE INCIDENT SUMMARY FOR LONGHORN AAP FLARE MIX FIRE

The incident is best characterized by noting that meeting compliance requirements is not sufficient to prevent accidents. In this case, a death and a serious injury resulted from an operation which was well analyzed and thought to be well protected.

The operation is explained to provide a basic understanding of the factors which came into play during the fire. Details on building layout and construction, the installed deluge system, operator location, hexane use and properties, bonding and grounding, and the hazard analysis effort are covered to demonstrate how individual factors were addressed. Significant interrelationships are identified to illustrate the failures involved in the fire.

Significant lessons learned are covered, concentrating on the solutions to the identified areas of failure. The most significant lesson is that regulatory compliance is only the first step toward accident prevention.

# ACCIDENT SUMMARY

## MJU-8 IR FLARE MIX FIRE AT LONGHORN ARMY AMMUNITION PLANT

## 28 SEPTEMBER 1991

On 28 September 1991, the U.S. Army Armament, Munitions and Chemical Command (AMCCOM) experienced a serious incident. The incident involved 187 pounds of MJU-8 IR flare mix in the production facility, building 54-H, at Longhorn Army Ammunition Plant (AAP). The seriousness of the incident can not be measured exclusively by the amount of damage to the facility, it was relatively minimal, or even in the serious personnel injuries, one man was severely burned and another subsequently died. A significant measure of the seriousness of this incident was the fact that virtually all compliance related requirements were met and the fire still occurred, and with serious results.

The MJU-8 flare mix involved in the incident is a mixture of magnesium, teflon and binder. During the mixing process, acetone is used as a solvent to promote mixing. Hexane is used at the end of mixing to drive off the acetone and promote precipitation of the mix solids. After precipitation of the mix, the hexane is dumped off the mix in an open pan and allowed to run into a collection bowl. Following hexane collection, the collector bowl is moved from the end of the dump pan and the mix is dumped into the open pan for further processing. The fire occurred when the hexane dumping was just being completed and the bay was about to be prepared for mix dumping. The operator who would be entering the bay was already making sure his aluminized suit was on properly in preparation to enter.

(See Diagram 1.)

Diagram 1 cross-sections the mixing bowl in upright and dump positions. In the first case, the MJU-8 mix is shown covered by a layer of hexane liquid as the mix precipitates out in the absence of agitation. The second illustration shows the mixing bowl as pouring off of hexane liquid is completed. (Actually, the liquid is about 93 percent hexane and 7 percent acetone at the time of dumping.) The second illustration shows the mixing bowl in the position it was in at the time of the incident. The fact that the side of the bowl is turned about five or ten degrees past horizontal is significant.

The dump operation was conducted remotely. The operator at the dump controls watched the operation through a lexan window. Operations were viewed indirectly in a mirror. No personnel were allowed into the dump bay or allowed to pass in front of the dump bay opening during actual dump operations. Access was restricted by operating procedures and controlled by the use of rope barriers on either side of the bay. Personnel in protective aluminized suits brought the mixing bowl full of mix into the bay. Personnel in aluminized suits later entered between the liquid and the mix dumps to prepare the equipment for mix dumping and after the mix dump entered to containerize the mix.

Investigation after the incident located the point of ignition of the fire as the area of hexane dumping and collection and tracked the path of the fire as it spread. The path and speed of fire spread during the incident was determined by a number of factors, including the presence of hexane vapor, the type and amount of mix in the bowl, the building construction and wind direction. Diagram 2 shows the path of the fire and indicates the location of the personnel in the building at the time of the fire. Evidence in the building indicted that the expanding fireball carried particles of burning mix as it bounced off the dump bay wall and swept out into other building areas. Size of the arrows is used to denote the relative amount of flame and heat as the fireball expanded.

(See Diagram 2.)

Personnel at locations one through three were near exits and exited immediately as the fire initiated in the dumping bay, before the fireball could spread completely into the control room. Personnel at locations four and five were not in positions to immediately exit and had to fight their way through the fireball and burning mix in the control bay to exit. Both were severely burned and one subsequently died.

The Board of Investigation (BOI) into the incident revealed that there were multiple factors which contributed to the incident and the resulting injuries. The overriding factor which became obvious as the investigation proceeded was that simple compliance with regulatory requirements is not sufficient to provide the safety environment which is required. Thoughtful consideration of all factors and the way each combines with all the others is required for effective safety.

(See Chart 1.)

Chart 1 summarizes the major causes and factors contributing to the severity of the fire. Because of the relationships between the various factors, some factors will come into the discussion more than once. It is important to understand that the BOI found the accident to be the result not of a single factor but of a combination of all the factors.

Building 54-H was modified in 1987 to provide a production facility for MJU-8 IR flare mix. Very few structural changes were made to prepare the building for IR flare production. In terms of this incident, the single most significant change was dividing Bay 108 into Bays 108 and 108A by the installation of a steel barricade wall floor to ceiling. This barricade installation divided the process of preparing components for flare mix from the dumping operations. Other noteworthy modifications included providing two sliding doors to separate the mixing bays from the control room. The second of these doors was provided after an previous incident where fire in a mixing bay partially vented around the single door.

The mixing area was recognized as a severe hazard to personnel in case of a fire because of the energy added during mixing and confinement by the mixing apparatus. The dumping bay was evaluated as much less hazardous because of the lack of energy input into the bay operations. Limited local testing of the mix demonstrated that hexane wet mix in an upright bowl with deluge coverage burned without significant energy. This testing lead to the conclusion that significant hazards existed only in the mixing bay. Based on this, sliding doors used to isolate the mixing bay were not perceived as necessary for the dump bay. Similarly, the presence of the hexane and the lack of any apparent energy source did not cause concern in transporting the mixing bowl through the control room in its passage from mixing to dumping.

During the evaluation and modification of Building 54-H, the subject of frangible construction was raised as a result of the risk analysis efforts. Because of the recognized hazard potential, frangible construction was recommended for the ramp wall area immediately in front of the dump bay. The recommendation was directed to the local engineering staff, who reviewed the building construction and found the existing wall to be "frangible". On this basis the existing wall was used unmodified.

The original design of the wall was to be frangible for high explosives. The MJU-8 IR flare mix dumped in the bay has many of the properties of mass fire producing material, especially when saturated with hexane, as at this point in the production process. As demonstrated in the subsequent incident, MJU-8 mix wet with hexane creates overpressures so low that the transite on two by four construction of the building was unaffected during an incident. The regulatory requirement for hazard analysis was met but the recommended construction provided no venting in the incident. The transite construction, instead, helped direct the fireball into the area occupied by personnel. Either modifying the wall construction to make it weaker or closing off the opening to the control bay would have provided better personnel protection and prevented the fire damage to the control bay.

One of the first questions asked by the BOI was "Why did this fire get out of hand if an ultra high speed deluge system was in place?" The investigation revealed that a system was in place that met all requirements for response time and testing. However, detector and nozzle positioning was not sufficient to catch the fire during ignition or confine it once the mix was burning. Design and testing was based on an upright bowl at the time of ignition, locating deluge heads almost directly over the bowl position. As previously noted, at the time of the incident the bowl was rotated 95 to 100 degrees from the upright position. The ultra high speed deluge functioned within design parameters once it saw the fire, but the water fell ineffectually on the side of the bowl, unable to attack the mass of burning mix. The mix burned completely in the bowl leaving only a minimal amount of ash. Substantial amounts of ash accumulated on the floor of the dump bay in the area covered by the deluge heads indicating the controlling effect of the deluge when the water could reach the burning mix.

The design of deluge systems must provide coverage for all operations without obstruction for either detectors or water nozzles. Simple compliance with regulatory requirements does not protect operations, the carefully engineered and managed system can. The BOI felt that the properly designed and placed deluge system could have substantially reduced the effect of the incident.

Questions were raised about the requirement for the personnel protective equipment. The injuries occurred in a control room which was considered a safe area and where aluminized protective suits were not required. When operators entered the mixing or dumping bays, they were wearing protective suits and hoods as required by the operating procedure. The lack of isolation of the dump bay by construction of barricades or walls allowed the exposure to the burning mix.

Another operator protection issue is operator location and egress. In this case, the control operator and quality inspector were located where, in the event of an incident in or coming into the control room, rapid egress was not possible. In this incident, three of the personnel in the bay, the two mix operators and the bay leader, were required by their duties to be near doors and these three people escaped unharmed except for minor first aid injuries. The egress route of the dump operator and quality inspector was longer and was hampered by a large ventilation fan blocking the nearest exit. Blinded by the heavy smoke, both of the burned individuals attempted egress through that exit before finding alternate egress routes. The blocking of an egress route was one of the few regulatory violations found during the BOI.

A major factor in the incident was the fire hazard presented by the hexane used to precipitate the mix. Although systems were in place to collect hexane vapors in the dump bay, and to detect potentially dangerous concentrations of hexane vapors in the bay, the fire most likely initiated at the top of the hexane collection bowl.

The lower explosive limit of hexane is 1.2 percent and the upper explosive limit is 7.5 percent. The vapor density is 3.0 with a flash point of -7 degrees Fahrenheit. This means that hexane readily creates a easily ignitable concentration which collects in low areas and on top of surfaces. These features combine with the fact that flowing hexane generates and holds a static charge of about 50 static volts to create a very hazardous situation during production operations.

All permanently installed equipment in the dump bay had been bonded and grounded, and had undergone periodic testing. However, the BOI identified a screen that the hexane flowed through which was electrically isolated due to the addition of a nonconductive rubber gasket. The circular metal screen had not been tested when other equipment was tested. It was determined by the BOI that, most likely, a static spark from the screen ignited the surrounding hexane vapor which in turn ignited the MJU-8 mix.

(See Diagram 3.)

The conclusion reached by the BOI was that the static spark was the root cause in the incident. The day that the incident occurred was the first very low humidity, low temperature day since adding the rubber gasket to the screen, creating a high static environment. A new dump operator, less experienced at the dumping operation was at the controls, possibly causing less smooth flow of hexane compared to operators more practiced at dumping, raising the potential for static generation and discharge. These factors combined to provide the opportunity for the spark. Testing after the incident proved that the dump pan above the screen and the collection bowl below the screen were grounded, so two possible directions existed for the spark to jump. Both possible locations were known to contain hexane vapor even though both were covered by ventilation systems. A direct trail of hexane/hexane vapor led from the collection bowl through the area of the screen and to the mix in the dumping bowl. The entire hexane collection system quickly became involved and immediately ignited the mix in the mix bowl. Once ignited, the mix burned violently, blowing particles of mix out of the bowl, through the dump bay and into the hallway where those burning particles could be pushed by gas pressure into the control bay to surround the two operators.

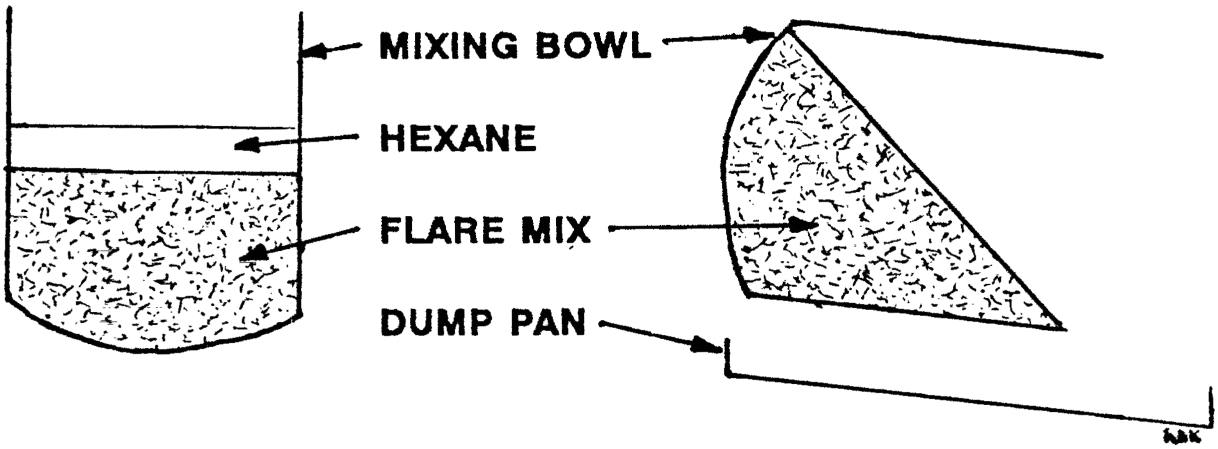
The incident was not caused by gross regulatory violations, but was the result of the combination of many small problems which united to produce, sustain, and spread the fire. The root cause which allowed the minor problems to accumulate to the critical level was the failure to recognize and fully analyze hazards which existed and grew in a symbiotic relationship within the dynamic production process. The lack of recognition of the significance of details and process changes allowed substantial differences to exist between the hazard analysis and the overall process at the time of the incident. Specifically, errors in frangible building construction, safe separation from hazards, the deluge system, operator egress, and the failure to bond the screen to the existing grounding system were all failures in the system which went unrecognized individually. Without constant monitoring of the operational processes such hazard analysis failures will contribute to accidents.

(See Chart 2.)

Each accident is a learning experience. The items listed in chart 2 briefly cover the major lessons learned as a result of this incident. Proper building configuration would have prevented the spread of the fire to the control room area, frangible construction and isolation of hazardous operations being the applicable criteria. Testing completed before the fire demonstrated that the deluge system configuration in use was capable of controlling a mix fire in the bowl, but systems must be designed to cover all operations or fire control is lost as it was in this incident. Operators must be located so as to provide not only protection from incidents but also clear egress if the provided protection fails. This incident was at least partially caused by a failure to understand the properties of MJU-8 flare mix during the production process and the hazards involved with using hexane. Although local procedures very carefully applied the requirements for bonding and grounding equipment in the operation, the screen which helped generate the spark went ungrounded because it was considered as exempt portable equipment. Careful analysis of the total system could have revealed the individual minor weaknesses and probably greatly reduced or even eliminated the incident. The real lesson learned is that regulatory compliance is only the first step toward accident prevention. Careful analysis of the relationship between all factors is required for true accident prevention.

DIAGRAM 1

# MIXING BOWL AND MIX




UPRIGHT POSITION

HEXANE DUMP POSITION

DIAGRAM 2

# BUILDING 54-H, NORTH END
# PATH OF FIRE

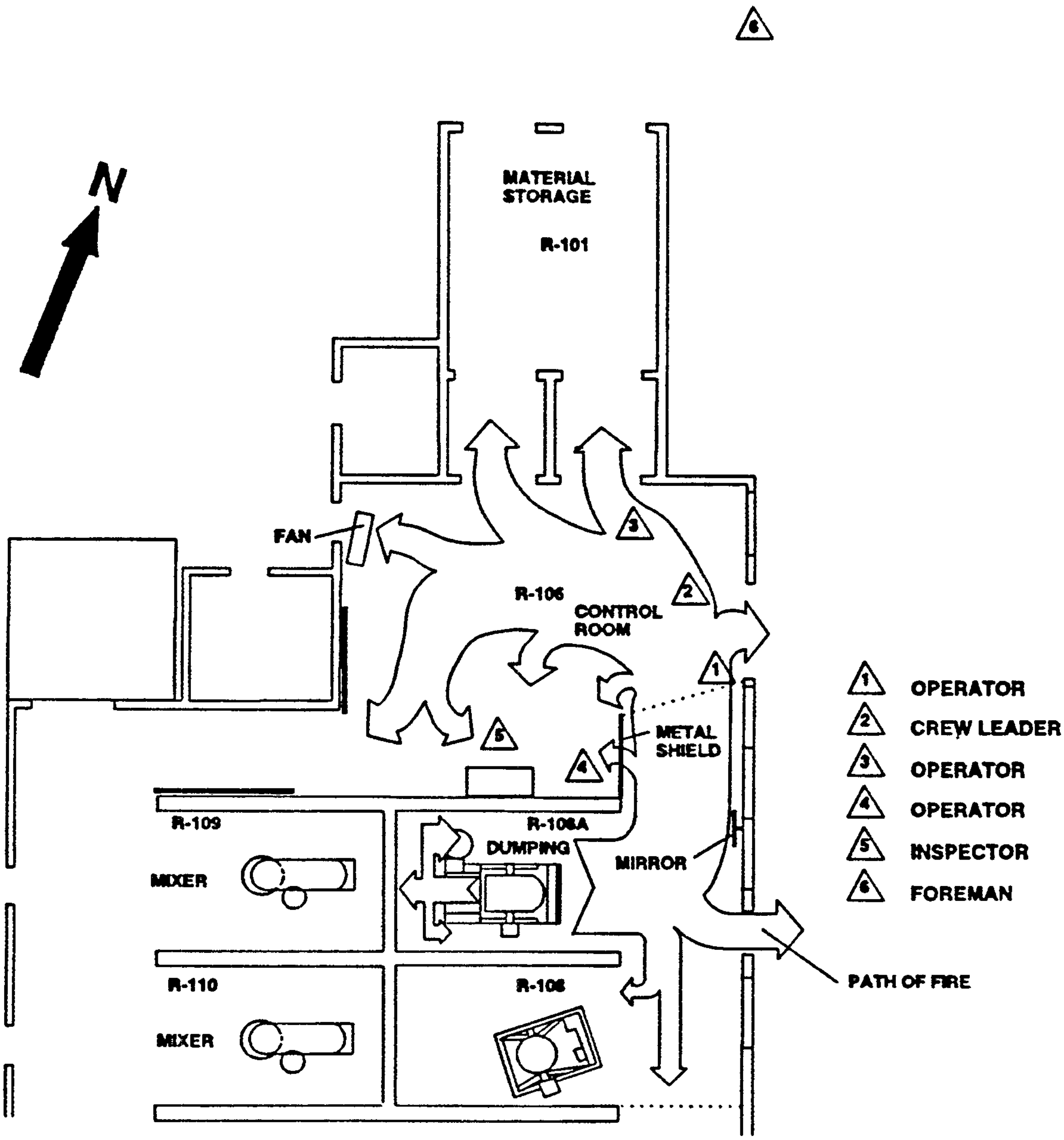


**CHART 1**

# FACTORS INVOLVED IN THE FIRE

BUILDING CONSTRUCTION

DELUGE SYSTEM

OPERATOR PROTECTION

HEXANE

GROUNDING/BONDING

HAZARD ANALYSIS

DIAGRAM 3

# DUMP PAN AND HEXANE COLLECTION BOWL

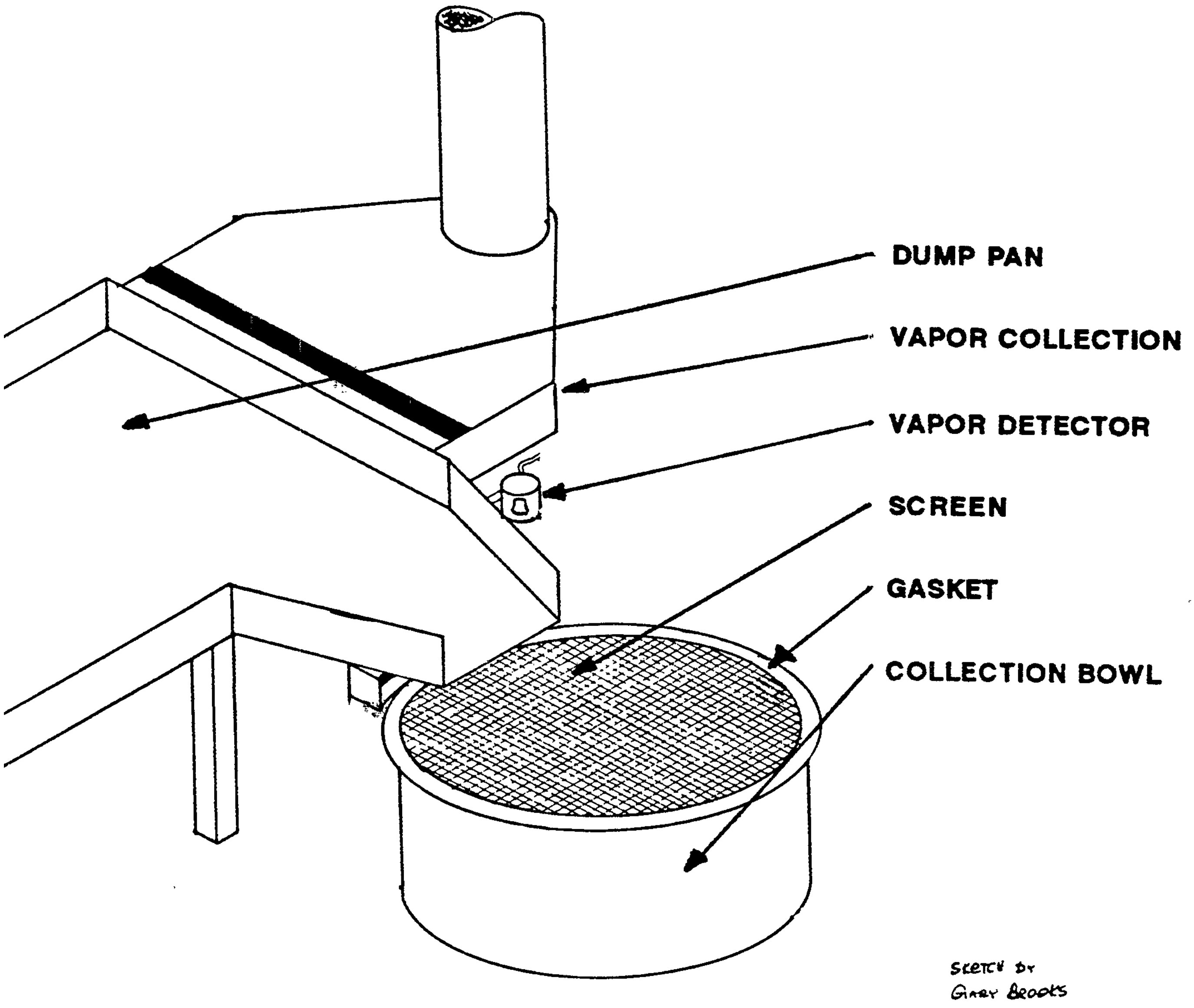


CHART 2

# SIGNIFICANT LESSONS LEARNED

- PROPER BUILDING CONFIGURATION WILL PREVENT FIRE SPREAD.

- DELUGE PROTECTION MUST COVER ALL STEPS OF THE OPERATION.

- PROPER OPERATOR LOCATION AND PROTECTION ARE REQUIRED.

- UNDERSTAND THE MATERIALS IN USE.

- CAREFUL BONDING/GROUNDING OF ALL EQUIPMENT IS NEEDED.

- PROPER ANALYSIS OF THE HAZARDS IS CRITICAL.