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Facility Design Consideration for Continuous Mix Production of Class 1.3 Propellant

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Introduction

In November of 1989, NASA awarded the Advanced Solid Rocket Motor (ASRM) contract to Lockheed Missiles and Space Company (LMSC) for prodcution of advanced solid rocket motors using the continuous mix process. Aerojet ASRM Division (AAD) was selected as the facility operator and RUST International Corporation provided the engineering, procurement, and construction management services.

The continuous mix process mandates that the mix and cast facilities be "close-coupled" along with the premix facilities, creating unique and challenging requirements for the facility designer. The classical approach to handling energetic materials -division into manageable quantities, segregation, and isolation-was not available due to these process requirements and quantities involved.

This paper provides a description of the physical facilities, the continuous mix process, and discusses the monitoring and detection techniques used to mitigate hazards and prevent an incident.

General Facility Description

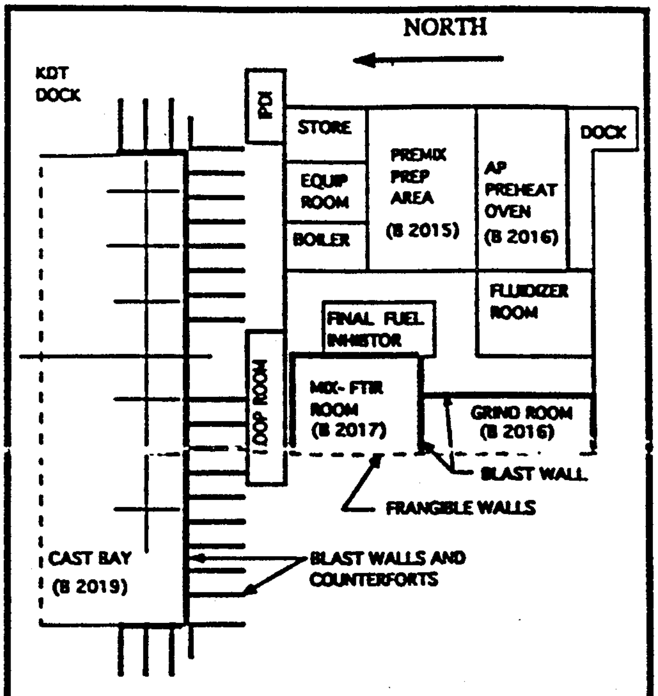
The ASRM Facility is located on a 1,300 acre site in northeast Mississippi, near Iuka. The site fronts on the Tennessee-Tombigbee Waterway about 1/2 mile south of the Tennessee River and includes barge facilities to transport the finished motors to Kennedy Space Center. The site includes approximately 30 major structures to support propellant production, case preparation and refurbishment, core preparation and cleaning, NDE facilities, motor finishing, offices, laboratories, and other required ancillary operations. The largest building on site is the Case Prep Building which covers over 300,000 square feet and has a high bay eave height of 90 feet.

SITE OVERVIEW

The Mix-Cast Complex is sited per DoD STD 6055.9 for 3.3 million pounds of Class 1.3 propellant. The complex is a multistoried structure with an approximate height of 70 feet covering 120,000 square feet and includes four major processing areas:

- Propellant Premix (Bulding 2015).
- Oxidizer Preparation (Building 2016).
- Continuous Mix (Building 2017).
- Cast-Cure (Building 2019).

The Propellant Premix area contains the equipment required to receive and mix the aluminum and iron oxide and submix. Iron oxide is received in totes and stored in Cell 106 prior to use. Aluminum is delivered in bulk by railcars and positioned on a spur to the east of the complex and pneumatically conveyed to storage bins within the building. This area includes in-line mixers and blenders for the iron oxide and storage bins, feeders, and three 7,500 gallon mix tanks for preparation of the premix.



MIX-CAST COMPLEX "B" GROUND FLOOR PLAN

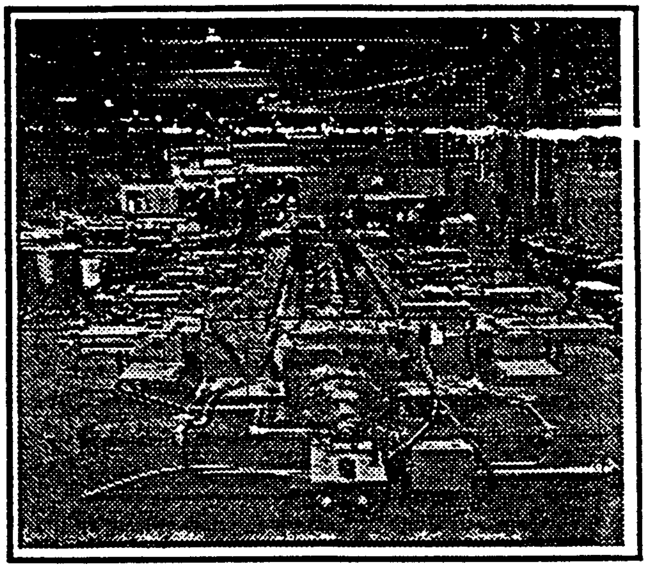
Storage, mixing, and blending of the HX1752, DOA, and Triphenal Bismuth submix also take place in Building 2015.

Building 2016 is dedicated to the preparation of ammonium perchlorate oxidizer. The material is received in 7,000 pound totes and moved via automated handling system into the holding oven where it is maintained at 135°F. The totes are tagged with bar codes and the system automatically maintains a record of receipt, location, dispensing, and inventory.

The five inverters located in this area are used to invert and unload the totes for fluidizing and pneumatic transport to either the unground ammonium perchlorate bins above the mixer or to the grinding area for size reduction.

The Grind Room is also located in the Oxidizer Preparation Building. Two grinders, each with a capacity of 7,500 pounds /hour, are located in this area along with the associated feed bins, dust collectors, product bins, and sampling equipment.

The Continuous Mix Building houses the equipment to accommodate mixing, sampling, and pumping of propellant. The ground and unground ammonium perchlorate bins with associated feeders, dust collecting equipment and sampling equipment and samplers are located above the mixer in this building. The hydraulic drive power unit and mixer control cabinets are located in a room adjacent to the mix room. The surge pot and Rotofeed are positioned next to the mixer. The Fourier Transform Infared (FTIR) analyzer, propellant pump, 30-minute loop, and scrap-propellant divert equipment are also located in Mix Building 2017.



CONTINUOUS MIXER AND ROTOFEED

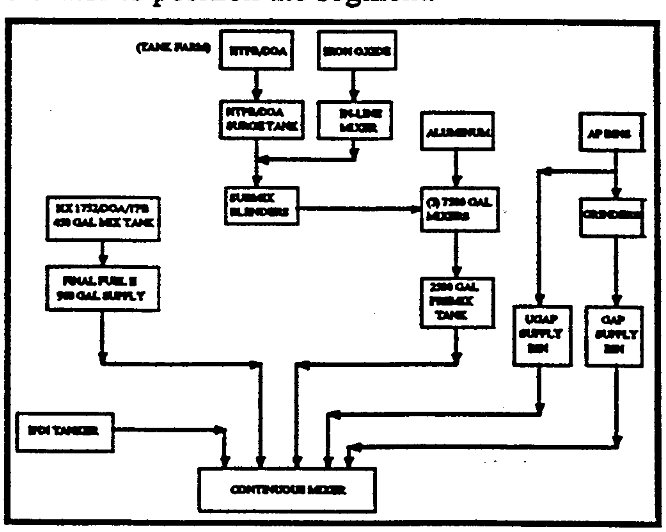
In the Cast-Cure Building, the following operations are performed: receive and load lined segments, inhibitor application, cast and cure propellant, dissolve soluble core, finish and ship segments. The building is a concrete and steel structure with approximately 30,000 square feet of area and a clear height of 90 feet to bottom of truss. A 400-ton remotely operated crane is provided for handling the segments with two 25-ton cranes for other lift operations. All cranes have anticollision protection. Six pits 27 feet in diameter and 64 feet deep house the vacuum cast bells which are designed for a vacuum of 10 torr and are supplied with 135°F air for the curing cycle. The lined segments are received in a special kneel-down transporter (KDT) dock on the east end of the cast bay and are moved by air pallets on specially designed floors. Designated storage areas for distribution piping, tooling, and core storage have been provided. North of the cast bay is an underground emergency egress tunnel that can be accessed from a number of escape doors located in the north wall.

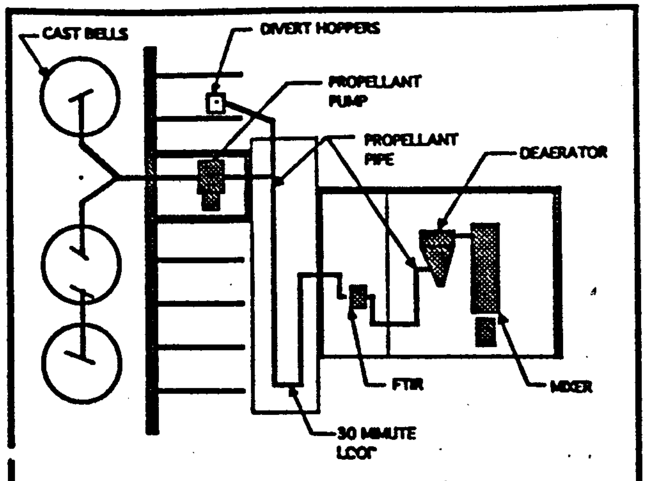
The Continuous Mix Process

Qualified fuel constituents are staged in the following five vessels:

- 2,500-gallon premix tank.
- 900-gallon final fuels II vessel.
- 400-cubic foot unground AP bin.
- 400-cubic foot ground AP bin.
- Final fuel I tanker truck (IPDI).

The premix, final fuel I, and final fuel II are fed to the mixer by metering pumps while the solids are fed by gravity from storage bins above the mixer through loss in weight feeders. The mixer is a single reciprocating screw feeder with a nominal capacity of 20,000 pounds/hour and a maximum rate of 26,000 pounds/hour. As the propellant is discharged from the mixer, it passes through a surge vessel and into the Rotofeed which is held at 15 torr vacuum for the degassing operation. The propellant pipe is arranged such that 30 minutes elapse after the sample is taken at the FTIR unit and before the propellant reaches the divert valve. If the propellant is not acceptable, it is diverted to the scrap propellant system. The scrap propellant is collected in a series of cannisters carried by an automated power and free conveyor that collects scrap at the divert discharge point. If the analysis shows that the propellant is acceptable, the casting operation is initiated directing propellant to the propellant pump which discharges to the casting area. Six bells are available so that two three-segment motors can be cast in one production run of five days duration. Each cast bell has an elevator to position the segment.





CONTINUOUS MIX SCHEMATIC

After positioning the segment and installating the core and distribution piping the casting operation begins. Following the cast, 135°F air is supplied to the bell and the 120-hour cure cycle is begun.

Design Description

The following documents governed the design of the Mix-Cast Complex:

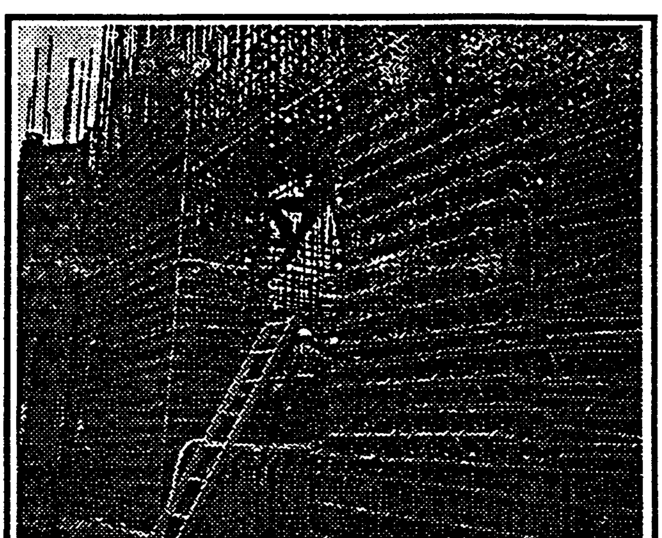
- AMCR 385-100 - American Material Command Regulations Safety Manual.
- 29 CFR 1910 - Occupational Safety and Health Standards.
- DoD 4145.26M - Contractors Safety Manual for Ammunition and Explosives.
- DoD 6055.9 - Ammunition and Explosive Safety Standard.
- NFPA - National Fire Code.
- UBC - Uniform Building Code.
- NHB 7320.1 - NASA Facilities Engineering Handbook.

A number of special consultants were used in the design of the facility. These included Ammann & Whitney and Napandensky Energetics as well as individual consultants. The design was reviewed by the appropriate safety personnel from NASA, LMSC, and AAD at the 30- 60- 90-percent, prefinal and final design review levels for conformance to codes and standards.

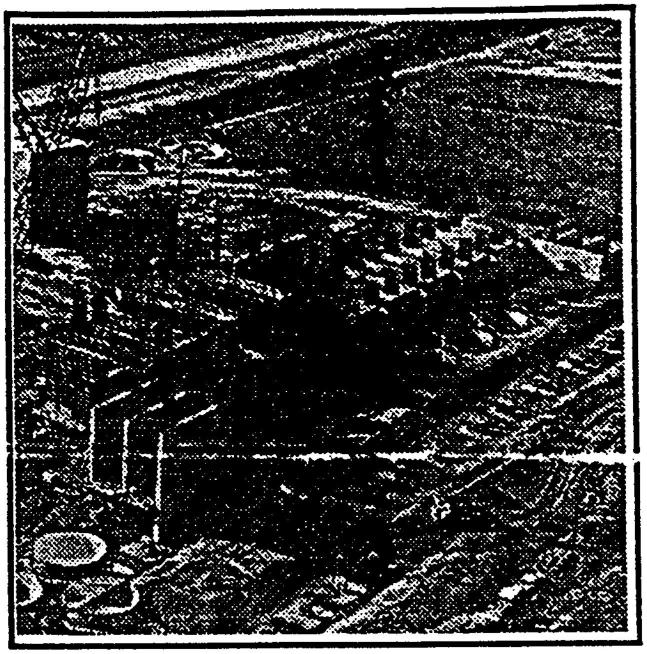
An exhaustive study was undertaken to define the likely credible events that might occur. This analysis showed that sympathetic detonation in an adjacent pit was not a credible event and, therefore, the design was based on detonation of the single largest segment. The analysis also established the near field TNT equivalency of 3 percent and the far field TNT equivalency of 5 percent. The volume of materials present in the cast pits required an extreamly robust design to provide personnel protection and limit damage in the event of an incident. The hazardous areas were segregated using blast walls to protect adjacent areas and frangible walls to direct the blast to open uninhabitated areas. The Cast-Cure Area is separated from the Mix Area by a 2 foot thick by 125 foot tall by 425 foot long blast wall to provide containment and prevent propagation to the Mix Area. The blast wall is stablized with 2 foot thick by 38 foot tall counterforts and capped with a 6 foot deflector designed to prevent 10 inch fire-brand spheres from topping the blast wall and entering the Mix Area. The wall which is designed for a blast emanating from the pits is typically subjected to peak pressures of 600 psi and impluses of 445 psi-ms.

A similar isolation technique was used to isolate the Mix and Grinding Areas from the remainder of the structure. These vaults are constructed of 2' thick concrete. The west wall in this area of building is a frangible wall that would direct any blast away from inhabitated areas.

During the design of the facility, it was realized that the building was too complex to apply the single degree of freedom techniques presented in TM 5-1300. This manual applies primarily to single story bunker type structures. The structural



BLAST WALL CONSTRUCTION



MIX-CAST COMPLEX CONSTRUCTION

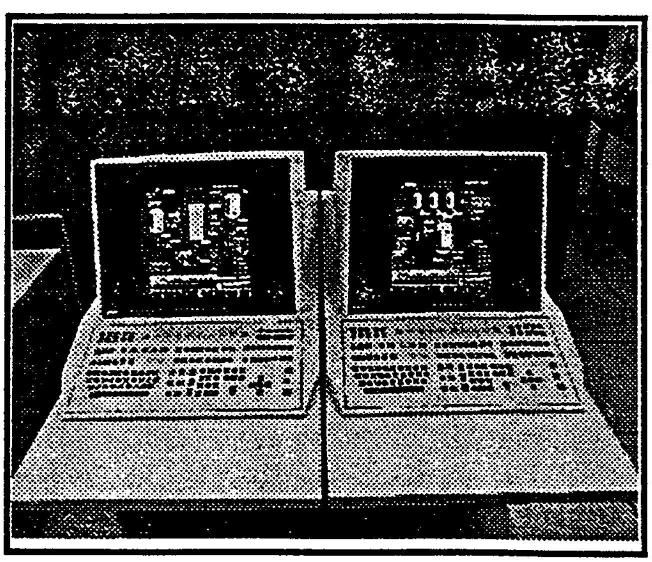
dynamic analysis employed NISA II, a multi degree of freedom system. The concepts presented in TM 5-1300 were applied to the design of individual components. Several computer programs including PROP, SHOCK, FRANG, and SOLVER were used to assist in the structural design. These programs were obtained from the Naval Civil Engineering Labartory.

Not all code and standard requirements could be literally interpreted and strictly applied. The requirement for blast resistant doors could not be practically met due to the 11 psi overpressure exerted on the Mix Bulding in the event of an incident in the cast area. Realistically, designing blast doors would have offered little personnel protection and would have restricted egress from the building due to the mass of the door.

DoD 4145.26M requirements for eliminating dust ledges, hollow walls and the use of smooth interior wall finishes could not be entirely met. The multistory structure and number of adjacet rooms with energetic materials made complete adherence impossible. The approach taken was to meet the intent of the standard to the maximum extent possible by using creative designs, e.g., limiting horizontal surfaces, providing smooth finished walls where possible, and facilitate good housekeeping where strict compliance could not be achieved.

CONTROL AND SAFETY SYSTEMS

Personnel safety can best be provided by removing operators from the hazardous environment. The Mix-Cast Complex is remotely controlled to meet this need. A distributed control system (DCS) located in the Remote Control Building 1,600 feet from the mix building provides visibility to equipment status and control for all systems in the complex. Major subsystems are controlled by a PLC or micro-computers that are linked to the DCS while individual pieces may be controlled directly by the DCS. As an example, the remote operator has the ability to control mixer speed, start/stop, monitor torque, and a myriad of pressure and temperature sensors. In total, the DCS has 1,950 inputs and ouputs for process control. In addition, closed circuit TV cameras are provided at stragetic locations to monitor the facility. The entire mix-cast operating system incorporates a flexible and redundant approach which is fundamental to the casting operation so that the six segment run can be completed without interruption. The facility design incorporates alternate flow paths and standby or multiple-ganged equipment that permits processing to continue in the event of a single point failure. Process equipment is furnished with variable speed drives that adjust flowrate based on feedback loop signals that accommodate flucations and downstream events.



DISTRIBUTED CONTROL SYSTEM

This highly instrumented system provides the operator with real time system status information and provides alternate processsing options if necessary.

The primary protection system for the propellant mix and cast operations is the Damage Control Initiation System (DCIS). The mixer and Rotofeed are equipped with pressure and temperature sensors to detect any abnormal condition that might arise. In the event of an excursion beyond the acceptable operating limits, the mixer is automatically opened and the mixer cavity is flooded with water from the deluge system. Similar protection is provide for the Rotofeed.

The propellant pipeline is also equipped with pressure and temperature sensors to monitor system status. The line is segmented into 14 sections that can be isolated by explosively actuated squib valves. If an abnormal condition should arise, the isolation valves are actuated, the pressure relief valve for each section is opened to vent the line, and the line is flooded with water from the deluge system by operating the deluge valves.

The DCIS is furnished with a back-up power supply for actuating the valves as well as an uninterruptable power supply for the system. The DCIS contains the required discreet and analog I/O to communicate with the building fire protection system. DCIS status is continually reported to the DCS so that the remote control room operator can monitor system status.

The Damage Control Initation System requires maximum reliability and, therefore, has the capability to detect internal faults, prevent propogation, and automatically switch to a back-up device in the event of a failure in an operating device. The following diagnostic capabilities are incorporated in the DCIS:

- Scan failure.
- Memory faults.
- Communication faults.
- I/O faults.

The Mix-Cast Complex Fire Protection System (FPS) operates in conjunction with the DCIS. The FPS is a wet pipe system that varies in application rate from 0.35 GPM/ft.^{2} to 0.75 GPM/f^2 depending on the area. Special deluge nozzles that deliver

30 GPM are located on 4 foot centers approximately 10 feet above the propellant pipe and six high velocity narrow cone nozzles rated at 80 GPM are located above the mixer. The FPS may be manually or automatically activated. It is designed so that the maximum time elapsed from detection to flow at the point of discharge is 0.5 second. The maximum expected demand for the deluge and sprinkler systems of 18,000 GPM is supplied by four centrifugal pumps located in a dedicated fire pumping house. The FPS includes both conventional rate of rise and UV/IR sensors to initiate action. The aluminum mixing and IPDI preparation areas are protected by dry chemical fire protection systems since contact with water presents a danger for these materials.

The ASRM Mix-Cast facilities incorporate several unique systems. The continuous mixer, although used on a limited basis in the late 1960's, has been developed into a mature and complete design. A multistory, close-coupled mix-cast facility handling the volumes of energetic materials used in this facility has proven to be a viable concept. Unique systems such as the aluminum pneumatic conveying system presented challenges answered with an innovative design appproach using dense phase transport in a nitrogen medium; substituting oil bath separation for conventional filters, and implementing hazard isolation using explosively actuated knife-gate valves.

Although Congress failed to continue program funding in October of 1993, the knowledge gained can be applied to any future program. The maturity of the design and construction, 98 percent design completion and 78 percent construction completion, demonstrates that difficult design problems can be satisified with creative designs.

Acknowledgements

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