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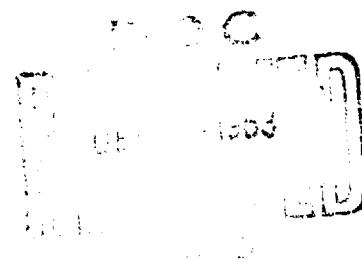
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INTERAGENCY CHEMICAL ROCKET PROPULSION GROUP
WORKING GROUP ON STATIC TESTING

ASAC No. 1
**static test
safety manual**

... a standard of good practice



Published
by

Chemical Propulsion Information Agency

INTERAGENCY CHEMICAL ROCKET PROPULSION GROUP
WORKING GROUP ON STATIC TESTING *(Successor to the JANAF Solid
Propellant Rocket Static Test Panel)*

static test safety manual

... a standard of good practice



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Chemical Propulsion Information Agency

THE JOHNS HOPKINS UNIVERSITY/APPLIED PHYSICS LABORATORY

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FOREWORD

This Manual was written to establish a standard of good practice for companies involved in the static testing of propellant rocket motors. It is intended as a guide only, and may require slight modification for use at a specific test facility. The information in this Manual should therefore not be incorporated into specifications or standards without further analysis.

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I. INTRODUCTION

Static test safety has been a field of rapid growth during recent years. New test procedures and equipment have vastly enlarged the scope of safety requirements. Since its inception in 1953, the Joint-Army-Navy-Air Force Solid Propellant Rocket Static Test Panel has always been interested in ballistic safety. In early 1961 it established the Committee on Ballistic Safety with Mr. Dewey A. Sherar as Chairman and this group has directed its efforts toward determining what is good practice in ballistic range safety. For this purpose, the Panel agreed that preparation of this document was necessary.

Because safety is a primary responsibility of each company, stringent requirements must be established for the welfare of personnel and property. A well established accident prevention program can save time and money for any company. Also, each employee must be well informed of safety procedures and requirements. Personnel who know the safe method of performing their work are less likely to have accidents. This manual is intended as a supplement to specific safety requirements unique to each individual company.

This manual was prepared from contributions by six major companies in the production of solid propellant rocket motors. The first section, submitted by Thiokol Chemical Corporation, briefly explains the purpose of the text. Lockheed Propulsion Company has contributed sections containing static test firings and mechanical safety. The sections concerning protective equipment and chemical and radiological safety were compiled by Aerojet-General Corporation. Welding operations, environmental and special testing methods are discussed in sections submitted by Rocketdyne, A Division of North American Aviation. Sections concerning personnel control and electrical safety were submitted by Hercules Powder Company. Facility layouts for ballistic static testing were contributed by United Technology Corporation and are contained in the final section.

II. PERSONNEL CONTROL

The success of a test area safety program depends on the proper conduct of personnel in the test environment. The following procedures are regarded as common practices in the solid propellant industry and are presented as the minimum requirements for the safe control of personnel within the test area.

A. WARNING LIGHTS

1. Traffic control lights should be provided at all normal entrances to each test area to designate the progress of testing.
 - a. Green light or no light indicates the normal status of the test area with no restriction on traffic.
 - b. Amber light indicates the presence of a loaded test unit in the test area. Traffic is limited.
 - c. Red light indicates an imminent firing or a hazardous test in progress. Traffic is prohibited.
2. Flashing red warning lights with 360 degree visibility should be mounted prominently in the immediate area of the test.
3. Aircraft warning lights should be mounted on the highest structure in the test area, if required. (U.S. Department of Commerce Civil Aeronautic Administration, "Obstruction Marking.")

B. BARRIER GATES

1. Personnel traffic into restricted test areas should be controlled by the best available means.
2. Suitable signs should be displayed at the entrance to the test area indicating the following.
 - a. "TURN OFF RADIO TRANSMITTERS BEFORE PROCEEDING BEYOND THIS POINT."
 - b. "THIS IS A CONTROLLED AREA; FLAME OR SPARK PRODUCING DEVICES ARE PROHIBITED BEYOND THIS POINT."
 - c. "TEST AREA IS CLOSED TO ALL UNAUTHORIZED VEHICLES AND PERSONNEL."
3. When a bay contains a motor, or a hazardous test is being prepared, special precautions may be taken to insure that unauthorized personnel do not gain access to the hazardous area.

C. AUDIBLE WARNING

A suitable audible warning system should be activated at least five minutes before the start of a hazardous test to clear personnel from the area.

D. PERSONNEL LIMITS

In any operation dealing with potentially hazardous materials or situations, only the personnel necessary to perform the work should be allowed in the area. Therefore, a determination must be made to establish personnel limits in the various operating areas, consistent with safe and efficient operation of the area.

Personnel limit signs should be prominently displayed at the entrances to any hazardous building or area. The number of people in the area should be strictly controlled by the test supervisor. Personnel limit signs should be periodically updated as required by changes in operations.

E. ACOUSTIC NOISE

Acoustic noise should be an important factor in the operation of a ballistic test facility. Noise should be controlled, when practical, because of its effect on the surrounding community, the health of the employee, and the quantity and quality of the work output of the employee.

Ballistic testing has unique noise problems that are not easily solved. For example: Temperature inversion of the area surrounding the test site serves as a sounding board to reflect and accentuate sounds that are not normally bothersome.

When test units are tested, or a particularly noisy test is imminent, the local fire department and radio stations should be alerted. This procedure will assist in reducing the number of inquiry calls usually made after a test of this nature.

Additionally, sound level measurements should be made within the test area and selected locations in the community during a ballistic test. These measurements will assist in determining the effect of acoustic noise on the test itself, and they will also assist in negotiating any legal disputes with the community.

Personnel exposed to harmful sound levels should wear proper type ear protective devices.

Sound levels tentatively accepted as the permissible limit and the sound levels at which noise produces a sensation of pain in the ears are shown in Figure 1 on page 5. This figure was taken from the National

F. OBSERVATION CONTROL

Visual observation of tests is desirable for the following reasons.

1. The observer is allowed to assess property damage, recommend type of fire fighting, and direct control of postfiring operations in the event of a motor malfunction.
2. The observer is allowed to note any unusual features of a test.
3. Insurance that the test area is clear is provided.
4. Visitors are allowed to observe tests.

Subscale tests may be observed via mirrors or other optical devices.

Traffic to and from observation areas should be controlled. Signs that define the conduct of the observers should be displayed in the observation area.

Some consideration should be given to the control of air traffic over the test area.

Exhaust gases of high energy propellant sometimes create high intensity light that may temporarily blind observers. Tinted glasses should be provided to observers when required.

G. SMOKING REGULATIONS

1. Smoking is permitted in the test area, but only in designated areas.
2. Electrical lighters may be provided in designated smoking areas.
3. Signs bearing the inscription "SMOKING IS NOT PERMITTED BEYOND THIS POINT" should be prominently displayed near all exits in the smoking area.

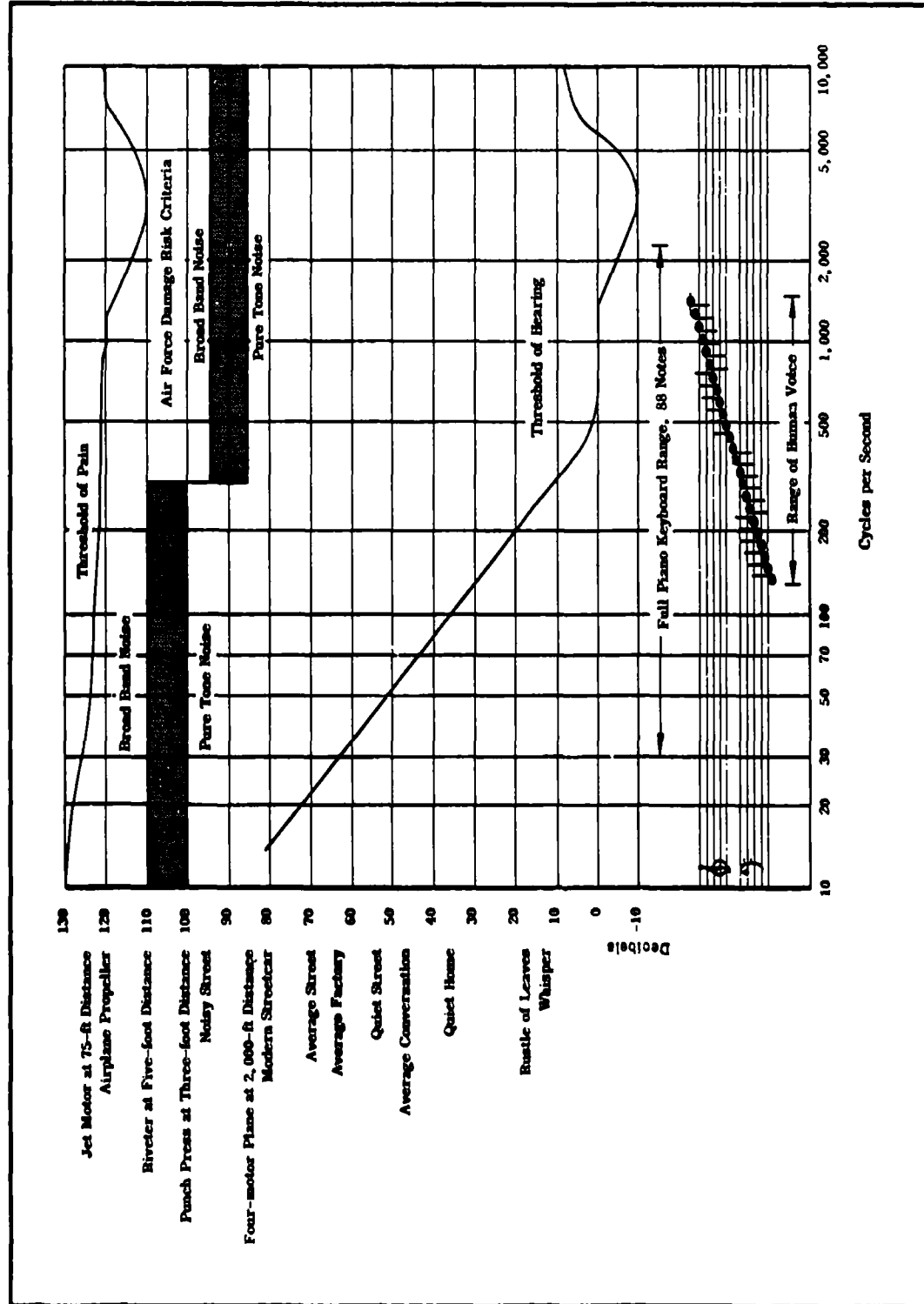


Figure 1. Acoustic Levels

III. STATIC TEST FIRINGS

A. TEST PREPARATION AND SETUP

1. Before the test unit is taken to the test bay, the bay should be cleaned and all equipment removed that is not necessary for the given test, and the test unit should be subjected to a general safety inspection.
2. Only the people required to prepare for the test will be allowed in the bay when the test unit is present.
3. An amber light should be used to indicate that the test unit is in the bay area.
4. The test unit should be secured as soon as practical in a holddown fixture or the thrust stand to prepare the motor for firing.

ARM: Connect the electrical firing circuit to the test unit in the bay.

5. All restraining fixtures should be in place before arming preparations start.
6. All personnel except arming crew must be evacuated from the test bay, and the area will be cleared before arming procedures are started.
7. A red warning light will be used to indicate that the test unit is armed.

B. SPECIAL INSTRUCTIONS FOR FIRING MOTORS

1. Countdown will continue after all personnel are in approved safe areas.
 - a. The countdown should consist of voice communication over the public address system in the test area.
 - b. Regular and frequent announcements should be made to indicate the remaining before the start of the test and the progress of the test.
2. The test unit will be fired on the command, "Fire!!"

C. ABNORMAL TEST CONDITIONS

1. Misfire
 - a. A misfire is defined as any failure to ignite the test unit.
 - b. In the event of misfire, a wait will be required as determined by the test conductor. (Hang fires have lasted 25 minutes.)
 - c. After the approved waiting period, and after removing the

firing jumper, an inspection team consisting of only two persons will proceed to the test bay.

- (1) The area security will be maintained while the inspection team examines the motor.
- (2) Disposition of the motor will be determined by the test site supervision.
- (3) The "all clear" will not be sounded until after one of the following conditions has been complied with:
 - (a) The inspection team has isolated and corrected the discrepancy.
 - (b) The motor has been placed in a "safe" condition to permit additional personnel to enter the bay and correct the trouble.
 - (c) The misfire has been corrected by firing the motor with a new igniter.
 - (d) The motor has been removed from the test bay.

2. Hang Fire

- a. A hang fire is defined as a firing with undue ignition delay.
- b. The hang fire will be treated as a normal firing after the motor has been fired.

3. Malfunction

- a. A malfunction involves a case separation, nozzle failure, or head-end failure.
- b. In the event of a malfunction, the area will be checked for fires by the test personnel, and appropriate action will be taken to alert the fire crew if required.
- c. In the event of a malfunction, a wait will be required as determined by the test conductor.
- d. After the approved waiting period, and after removing the firing jumper, a two man inspection team will proceed to the test bay to investigate the hazardous conditions.
- e. Hazardous debris will be cleared before the "all clear" is sounded.
- f. The test area should be policed for unburned propellant.

D. PROCEDURES FOR POST-TEST OPERATIONS

1. After a successful motor firing, a waiting period will be determined at the discretion of the test conductor.
2. After the waiting period, one man will enter and check the bay.
3. If the bay is safe to enter, the "all clear" signal will be given.
4. The number of persons in the bay will be held to the posted limits.

IV. ENVIRONMENTAL AND SPECIAL TESTS

A. DEFINITIONS OF TERMS

1. Amplitude ratio is the amplitude of motion of some part of a test specimen divided by the input amplitude.
2. Autoignition temperature is that temperature at which the propellant will spontaneously ignite.
3. Hazardous tests are those tests that experience and engineering judgment indicate should be conducted as unattended remote controlled tests.
4. Out-gassing is the process in which some material gives off a vapor under low vacuum conditions. This process may change the physical nature of the material.
5. Passive tests are tests that experience and engineering judgment indicate are reasonably safe to be conducted as attendant tests.
6. Temperature cycling is the repeated process of successively temperature conditioning specimens to different temperature environments.

B. PASSIVE TESTS

Passive tests are tests that experience and engineering judgment indicate are reasonably safe to be conducted as manned tests (i.e., personnel may be in the immediate vicinity of the test unit when necessary) These types of tests are only slightly, if any, more hazardous than the specimen not in test. The autoignition temperature should be determined for any propellant before a passive test is conducted with it.

1. Humidity

Humidity testing is used primarily to test the reaction of the test unit to cyclic combined temperature and humidity tests. Humidity testing may result in moisture contamination if the test unit is free to breathe. The temperature limits should be as specified under the following paragraph on temperature cycling. The effect of moisture on the specific propellant under test should be checked before any major scale testing is begun.

2. Temperature Cycling

Temperature cycling places two stresses on the test specimen. One stress is the actual temperature of the propellant and its relation to the auto-ignition temperature. The second stress is caused by thermal expansion and contraction as related to the temperature gradients and rate of change of temperature.

Temperature cycling tests should be considered passive tests as long as the chamber and propellant temperature does not exceed one half of the autoignition temperature (°F). If one-half of the autoignition temperature is exceeded, the test should be classified as a hazardous test. Failures caused by temperature gradients normally produce only structural failures and do not result in any particular hazard.

3. Salt Spray

Salt spray testing should produce no hazards unless the test unit is unsealed and is susceptible to moisture or sodium chloride.

4. Altitude Cycling

Altitude cycling produces a pressure gradient between the inside and outside of the specimen and produces breathing of the test unit if the specimen is unsealed.

5. Rainfall

The only hazard from simulated rainfall would be contamination of the grain or test unit in an unsealed specimen. Rainfall tests need only the regular handling restrictions for the test unit.

6. Leak Tests

Leak tests are low pressure or vacuum tests to check the test unit for effective seals. These tests should constitute no safety problems beyond normal handling of the test specimen.

7. Temperature Conditioning and Aging

Temperature conditioning and aging tests involve the storage of test units for short or long periods at selected temperatures. The temperature for passive tests should be limited to a maximum of one-half of the auto-ignition temperature (°F) of the test units. The same restrictions as given in the above paragraph for temperature cycling should be considered for temperature conditioning and aging.

8. Road Test

Road tests are normally considered passive tests. A road test provides an energy input to the test unit that may result in a temperature rise and cause autoignition. A test unit should be checked to determine whether any internal vibration natural frequencies are in the frequency spectrum produced by a road test. This check may be conducted by acceleration amplitude ratios and frequency measurements during a drop or shock test. If the natural

frequencies are in the spectrum of the road test, the test unit should be instrumented for temperature rise at the most critical locations. Should the temperature exceed one-half of the auto-ignition temperature ($^{\circ}\text{F}$), the test should be reclassified as a hazardous test, and a remote method should be used to produce the acceleration versus time history of a road test. This limitation is recommended because no way is known for determining whether the hottest location is being measured. Care should be exercised in attaching a test unit to the road test vehicle so that the specimen does not become loose during the road test.

C. HAZARDOUS TESTS

Hazardous tests are those tests that experience and engineering judgment have indicated should be unattended tests. These tests should be conducted and controlled by remote means. The degree of hazard depends on the size and sensitivity of the test unit. If possible, all specimens should be in a nonpropulsive condition for these hazardous tests.

1. Vibration

All vibration testing should be conducted remotely with the same safety provisions as when firing a solid propellant unit. The heat energy input from vibration energy can increase a propellant temperature to the auto-ignition level. The auto-ignition temperature of propellant under test should have been previously determined.

Temperature measuring devices such as thermocouples should be used to continuously monitor the propellant temperature at the most critical locations.

The time required to reach autoignition temperature may be as short as five minutes. The rate of temperature rise, as well as the temperature level, should be considered in test evaluation. Temperature rise can sometimes be detected by changing amplitude ratios of parts of the propellant to other propellant or the case as time progresses in endurance testing.

A vibration survey should always be conducted the first time at some low level input, e.g., one-g acceleration or less. After the resonant frequencies at the low level input have been determined, the frequency bands that contain these resonant frequencies should be surveyed at the desired test level. The internal vibration levels do not scale up as a direct ratio of input levels.

Transducers should not be capable of generating energies great enough to ignite the propellant. Extreme precautions should be used in all signal leads to or from transducers mounted inside the test unit to prevent sufficient electrical current flow into

the specimen to produce ignition. These electrical circuits should be given the same consideration as shorted and isolated firing lines (i.e., they should be positively isolated from a source of power). A test unit should be inspected for propellant cracks or breakage as well as for propellant powdering before other testing and firing.

Before personnel enter a cell after vibration testing, the waiting time should be at least ten minutes after vibration has ceased. This is to allow the propellant temperature to stabilize in any region near a flexing (and, therefore, heat producing) area in the specimen. If the stabilization time for the particular specimen is judged to be longer than ten minutes, a longer waiting period should be reserved.

2. Shock

Shock tests will not generate heat in the test unit as will the vibration tests above unless the repetitive rate of shocking is very rapid (i.e., one shock or more every few seconds). One of the hazards from shock testing is possible ignition caused by impact load. The impact sensitivity should be determined and studied by laboratory methods before full-scale testing.

Autoignition can be caused from impact loads on the test unit proper or from impact loads on powdered propellant generated from repeated shock testing. Each test unit should be checked for propellant cracks or finely powdered propellant after testing and before a specimen is fired.

3. Drop

Drop test precautions are much the same as for the shock tests. When a drop test is free-fall of the test unit, the device may ignite and be propulsive with no restraint. If free-fall is used, personnel should be restricted to a minimum in the possible propulsive area.

4. Pressure

Pressure tests normally produce only structural failures; however, these failures may produce flying particles that could cause injuries to personnel. Pressure tests should be conducted with totally liquid filled systems (when possible) to keep potential energy in the specimen to a minimum.

5. Explosive Classification

Explosive tests should be conducted in an area with a greater intraline distance than the regular test area.

Explosive classification tests are conducted to determine the explosive characteristics of the test units so that other testing and shipping may be safely conducted. Laboratory scale testing results should be studied before explosive classification tests are conducted. Remotely controlled photography should be used rather than direct viewing of the test.

6. Linear Acceleration

Linear acceleration may be produced by a centrifuge, acceleration sleds, or actual flight tests. Linear acceleration may produce ignition failure, flameout of propellant, or breakup caused by acceleration forces. Careful consideration must be given to the loads produced by both the acceleration and the firing specimen and their interrelationship. Thrust level may vary or be controlled in some test units by the acceleration level.

V. ELECTRICAL SAFETY

A. USE OF PORTABLE ELECTRICAL EQUIPMENT AT SOLID ROCKET TEST BAYS

Portable electrical equipment includes, but is not limited to, the following equipment not permanently installed: portable electrical power tools, soldering devices, welding equipment, recording equipment, extension cords, motor generator sets, emergency pumping devices, electrical test equipment, heating equipment, emergency lighting units, and ventilating equipment. Portable electrical equipment should comply with the requirements of the National Electrical Code and be approved for use in hazardous environments. Portable electrical equipment used by outside agencies should be controlled by work permit.

B. STATIC TEST AND ENVIRONMENTAL TEST FIRING CIRCUITS

Safety pertaining to firing circuits cannot be overemphasized because human lives are at stake if a test unit should fire prematurely.

Firing circuits are defined as those independent electrical systems that are required to safely deliver electrical power to igniters, destruct packages, thrust termination devices, safety and arming devices, and other initiating devices.

Firing circuits should be electrically isolated from all other circuits and grounding systems. Firing lines should be physically located as far from power lines and electrical equipment as possible. Firing circuitry should be shielded from electrostatic and electromagnetic interference. All firing circuitry should have fail-safe logic.

Cabinets, racks, etc., housing components of the firing circuit, should be segregated from other circuitry and should be easily recognized.

Test area operating procedures should be explicit in describing the manner by which firing systems are operated, maintained, installed, and altered.

The ends of the firing line should be shorted to ground and insulated from all stray voltage sources prior to connecting the firing line to the unit and should remain so until immediately prior to the firing command.

Before the test unit is armed, the firing line resistance and continuity measurements should be recorded. Firing relays should be checked for frozen contacts. To eliminate the danger of the presence of stray voltage on the firing lines, a voltage measurement for deleterious voltages should be made.

The firing lines should have two or more interlocks to break the circuit. One of these interlocks should be a key switch, the key being in the possession of the test foreman. Other interlocks may be gap switches, warning system interlocks, and others as required.

C. ELECTROMAGNETIC RADIATION

Electromagnetic radiation, as concerns this section, is defined as including the spectrum within the limits of 10^5 to 10^{15} cps. This includes AM, FM, TV, and radar frequencies as well as visible light.

Igniters, squibs, blasting caps, and other initiating devices present an additional hazard when they are in the presence of a strong electromagnetic field. Blasting caps have been detonated under optimum conditions with RF energy. Also, when initiating devices are within short distances from the transmitter, combined with optimum antenna geometry, sufficient energy may be induced into the blasting cap to cause detonation.

The following data are acceptable, minimum distances of blasting caps from radio transmitters. They are taken from Pamphlet No. 20 of the Institute of Makers of Explosives, "Radio Frequency Energy, a Potential Hazard in the Use and Transportation of Electric Blasting Caps" (revised).

<u>AM Mobile Transmitter Power (watts)</u>	<u>Minimum Distance (ft)</u>
5 to 25	100
25 to 50	150
50 to 100	220
100 to 250	350
250 to 500	450
500 to 1,000	650
1,000 to 2,500	1,000
2,500 to 5,000	1,500
5,000 to 10,000	2,200
10,000 to 25,000	3,500
25,000 to 50,000	5,000
50,000 to 100,000	7,000

<u>FM Mobile Transmitter Power (watts)</u>	<u>Minimum Distance (ft)</u>
1 to 10	5
10 to 30	10
30 to 60	15
60 to 250	30

Signs should be posted at the test area entrance and within the test area to remind vehicle drivers that radio transmissions are prohibited.

TV and radar transmissions are high in frequency and present little danger in inductively coupling dangerous amounts of energy to initiating devices.

D. ELECTRICAL STORMS

The area supervisor may suspend ballistic tests and clear the area when an electrical storm is imminent. Operations should not commence until the storm has passed. Electrostatic recording instrumentation is recommended to assist the ballistic test operations to determine when and how long to secure operations. Lightning protection should be provided for all test area buildings housing hazardous materials in accordance with ORD-M-7-774 Section 8.

E. ELECTRICAL EQUIPMENT GROUNDING

The electrical ground of a system is defined as a fixed physical location in the system that is at the lowest potential (near zero). A grounding system provides a permanent low resistance return path for current flow to the electrical ground.

All electrical equipment within the test area shall be grounded in accordance with the National Electrical Code. Electrical equipment (as defined here) includes, but is not limited to, the following permanently installed equipment: data acquisition systems, control equipment, warning systems, lighting systems, switch gear, heating and ventilating equipment, power supplies, lightning protection systems, photographic control systems, closed circuit TV systems, emergency lighting systems, electric stoves, electric coffee makers, motor generators, environmental test chambers, static test stands, and all metal fixtures in the vicinity of a hazardous test.

The neutral of all secondary circuits of AC distribution systems shall be grounded at the transformer and at the switchboard. The noncurrent-carrying metal enclosures for all electrical equipment shall be grounded. DC circuits (excluding firing circuits) shall be grounded on the negative side to minimize electrolytic corrosion of underground metal parts.

Grounding systems may be made by connecting to existing water systems or by driving electrodes into the earth. In cases where earth conductance is very low, a good ground may be obtained by percolating salt solution into the earth surrounding the electrode.

Earth conductance measurements shall be made to determine the optimum method of grounding. It is important that the study include the maximum and minimum seasonal fluctuations in water table and earth moisture content.

It is also important to maintain an active program for ground testing of all electrical equipment. The maximum acceptable value for electrical resistance of electrical equipment to ground shall be two ohms.

VI. MECHANICAL SAFETY

A. LIFTING EQUIPMENT

1. All lifting equipment such as slings, chains, spreader bars, etc., shall be checked after any alteration or redesign and at least every six months to 150 percent of rated maximum capacity.
2. Spreader bars shall be loaded during check in the same manner that they are used, and they are to be loaded to 150 percent of usable load.
3. Commercial straps and chains shall be loaded along their full length rather than folded or doubled.
4. Test personnel should not fabricate slings and general lifting equipment that are commercially available.
5. Commercial lifting straps and chains shall not be altered or repaired by test personnel.
6. All lifting equipment should be properly identified to indicate capacity and should carry the date that it was checked.

B. SOLID ROCKET MOTOR RESTRAINING (ANTI-FLIGHT) GEAR

Test restraint should be provided for all active tests (static firing, vibration, structural, etc). The design loads should be:

1. Four times the nominal thrust applied axially forward or aft.
2. Two times the nominal thrust applied in any direction in the transverse plane at any retainer. Resulting stresses should not exceed ultimate material allowables.

C. TRANSPORTATION OF SOLID ROCKET MOTORS, IGNITERS, AND EXPLOSIVES

1. "Explosive" signs, 8 by 30-in. or larger, should be attached to motor trucks when transporting solid rocket motors, igniters, and explosives. These signs, one on each side, one on the front, and one on the rear, should be attached to trucks in such a manner that whenever the vehicle is not loaded the placards can be easily removed.
2. Solid rocket motors, igniters, and explosives loaded onto or into a vehicle must be properly secured.
3. Solid rocket motors, igniters, and explosives must not be hauled inside the cab of a vehicle.

D. OPERATION AND MAINTENANCE OF MOTOR VEHICLES

1. Motor trucks will not stop, start, or park with engines running within five feet of any open door in any building containing explosives.
2. After loading or unloading, the door of the magazine or service building must be closed before starting engine.
3. All vehicles transporting solid rocket motors, igniters, and explosives must be inspected according to ICC regulations or other specific regulations, as applicable, before leaving plant property.
4. The beds of trucks transporting solid rocket motors, igniters, and explosives must be on nonsparking materials unless the materials are contained in packages that are ICC approved, or equivalent.
5. Each motor truck transporting solid rocket motors, igniters, and explosives shall be equipped with at least two fire extinguishers of the approved type and a spark arrester.
6. Vehicles shall be driven in a manner that will insure minimum shock to its load of solid rocket motors, igniters, and explosives.
7. When two or more vehicles transporting solid rocket motors, igniters, and explosives are traveling in the same direction, they must remain at least 300 feet apart.
8. Motor vehicles transporting solid rocket motors, igniters, and explosives on public roads will not exceed the speed limit set for this type of vehicle.

E. SAFETY REGULATIONS FOR UNFIRED PRESSURE VESSELS

1. Education of Personnel

The increasing use of toxic liquids or gases as secondary injection fluids for thrust vector control make it necessary that solid propellant static test personnel be familiar with safe handling methods for them.

The following subjects shall be explained to all persons designated to handle, store, or transfer any/or all pressure vessels:

- a. Emphasis must be placed on the extreme toxicity of the subject material on contact by skin absorption, breathing of any vapors, or swallowing of it.
- b. The use of protective equipment and clothing is mandatory in all operations by personnel.
- c. All pressure vessels must be clearly labeled to indicate the flammability and toxicity of their contents in accordance to applicable standard color code.

- d. Applicable Standard Operating Procedure must be approved for handling equipment before the operation is undertaken.
- e. Fundamentals of self-aid and first-aid for exposure in the event of a mishap must be explained to all concerned.

2. Storage Areas

Storage, transfer, and/or test areas must be kept free from open flame or spark producing devices. An inspection must be conducted frequently to check for leaks, spills, decontamination, etc.

An adequate supply of water and other fire fighting aids must be available at all locations. This would include approved deluge-type showers and eye-wash stations located in the most suitable locations to accommodate any or all emergencies.

Approved storage areas (controlled) shall be provided with areas large enough to move assigned mobile or motor vehicles to and from the various locations without causing collision damage to vessels or equipment. At least two access roads should be provided, one of which would permit safe exit in the event of fire or other incidents occurring in the area.

All buildings used for inside storage facilities shall be made of non-combustible materials and have adequate ventilation. All installations must be in accordance with the M.B.F.U. or other approving agencies which are familiar with specific types of installations.

All electrical installations in transfer or storage areas shall conform to the National Electrical Code requirements. All lines and equipment, fixed or movable must be grounded to guard against static electricity. Lightning protection system shall conform with the applicable code of underwriters.

Good housekeeping is one of the best precautions and must be strictly enforced for all type storage areas. All fire hazard danger must be given immediate attention and corrected promptly.

Fire classifications must be in all areas to enable emergency crews attempting to combat fire to use proper extinguishing agents without endangering the lives of personnel.

Area limits must be established and posted to give maximum storage and personnel limits.

Storage areas should be located a safe distance from established structures to prevent the danger of chain reaction in the event of a mishap.

Storage tanks should be diked and protected from the effects of direct sunlight, and ventilation should take advantage of the prevailing winds and natural terrain.

Segregated storage is a must. All fuels and oxidizers must be separated by distance or adequate barriers.

Supervisors must devise and enforce a system of inspection and maintenance of all safety equipment so that it is in a constant state of readiness. Revision of practices and improvement of equipment should be constantly sought in the light of experience at the storage area.

3. Personnel Training - Supervision and Health

All operating personnel must be instructed on the nature of propellants and the general principles of safe conduct in handling, storing, and using of such materials described above.

VII. CHEMICAL SAFETY

A. INTRODUCTION

1. This section outlines a format that should be followed in the preparation of a safety procedure on any hazardous chemical materials proposed for use in conjunction with static tests on solid rocket motors. It is recognized that each hazardous chemical has inherent hazards peculiar to its specific properties. Because space does not permit an outline of every hazardous chemical used in industry, this section presents only the primary safety considerations common to most hazardous chemicals.
2. Every reasonable effort must be made to protect personnel against exposure from hazardous chemical materials. Primary protection lies in well designed and carefully operated systems for containment and control of the material involved. Preparations are necessary, however, against exposure during operations requiring the controlled release of a hazardous material into the atmosphere or development of an unforeseen combination of circumstances that would result in an inadvertent release.
3. In support of containment and control of a hazardous material, adequate safety equipment and operational procedures, including complete drawings of transfer systems, are prescribed. Further, a detailed safety procedure describing the hazardous nature of the chemical material and protective measures required for its use shall be provided as an aid to the design and preparation of operational procedures.

B. SAFETY PROCEDURE FORMAT

Items in this format are suggestions for consideration for the safe use of a hazardous chemical material. Any or all of the items suggested may be necessary to the evaluation; however, the format should not be construed so as to limit an evaluation nor does it mean that all items covered apply to any one chemical.

1. Description of the chemical material
 - a. Color
 - b. Odor
 - c. Form--solid, liquid, vapor (temperature and pressure)
 - d. Oxidizer
 - e. Fuel
 - f. General uses

2. Toxicity

- a. Maximum allowable concentration in air in parts per million.
- b. Physiological effects from inhalation, ingestion, or contact with skin and mucous membranes.

3. Flammability

- a. Explosive range (percent by volume in air)
- b. Reactivity with organic and inorganic materials
- c. Oxidizable
- d. Autoignitable
- e. ICC classification
- f. Special fire fighting practices

4. Compatibility

- a. Permissible storage with other chemicals
- b. Materials of construction permissible for transfer systems
- c. Shipping and storing containers

5. Properties

- a. Molecular formula
- b. Molecular weight
- c. Specific gravity
- d. Density of gas
- e. Boiling point
- f. Freezing point
- g. Critical temperature
- h. Critical pressure
- i. Vapor pressure
- j. Solubility
- k. Flammability limits
- l. Compatibility
- m. Shelf life (deterioration and decomposition)

C. HEALTH HAZARDS AND TREATMENT

1. Detection by odor (parts per million)

- a. Low concentrations
- b. High concentrations
- c. Maximum allowable concentrations

2. First Aid Treatment

- a. Contact
- b. Inhalation
- c. Ingestion
- d. Prompt medical treatment (regardless of first aid in the field)

D. PROTECTIVE MEASURES AND SAFETY EQUIPMENT

1. Signs posted as to safety equipment required
2. Remotely operated valves
3. Extension handles through barriers for safe valve operation
4. Use of public address system, telephones, and employees to clear downwind path prior to test
5. Unobstructed escape route for employees
6. Employment of the buddy system (two or more employees)
7. Easily accessible safety showers and eye wash fountains
8. Self-contained breathing air equipment, gas masks, and chemical cartridge respirators.
9. Personal protective clothing and safety equipment (see Section IX) required for the following.
 - a. Startup or transfer of a hazardous chemical in a system
 - b. Opening lines or fittings to atmosphere
 - c. Removing disconnected lines or equipment that contained a hazardous chemical material
 - d. Opening any valve that allows material or its vapors to escape in a work area
 - e. Tightening connections on a system containing a hazardous chemical material
 - f. Sampling liquid
 - g. Fighting a fire involving a hazardous chemical
 - h. Cleanup or repair work to correct a spill or leak
 - i. Leak checking under gas pressure if a system has contained a hazardous chemical but has been drained
 - j. Transfer of a hazardous chemical after tartup and checkout of a system
 - k. Use of vapor detector or otherwise entering areas of known or suspected contamination for investigation
 - l. Work in areas in the downwind path of the operations
 - m. Decontamination
 - n. Acting as a "buddy"

E. FIRE HAZARDS AND PROTECTION

1. Sources of ignition should be eliminated.
2. Sources of spontaneous ignition should be eliminated.

3. Storage areas should be of noncombustible construction, well ventilated, and isolated from all sources of fire and heat.
4. Electrical equipment in storage and handling areas should be of explosion-proof type.
5. Drums, tanks, lines, and systems should be electrically grounded at all times.
6. "No Smoking" signs should be prominently displayed.
7. Transfer systems must be clean and purged. Liquid inlet lines should enter, or be extended to, the bottom of the container to prevent the generation of static electricity; and both transfer lines and containers must be grounded. Vents should extend to a safe area and be equipped with flame arresters.
8. Ample water supplies should be provided for dilution of the material, with basins to confine spills or leaks.
9. Equipment and material to be used in storage or transfer systems should be cleaned, pickled, and otherwise prepared for use before being placed in service. All equipment including valves, lines, fittings, gaskets, sealants, and lubricants should be compatible with the chemical involved.
10. Housekeeping of the highest order should be maintained, with permitted equipment restricted to that necessary for storage and transfer operations.
11. Containers should be maintained tightly sealed when not in use.
12. Periodic inspections should be made to discover any leakage.
13. A leaking container should be removed to an isolated area and the contents transferred to other suitable containers.
14. Care should be taken to avoid spillage. If a spill does occur, or if a leak is discovered, the material should be thoroughly flushed to drain.
15. Containers, transfer systems, protective clothing, and all associated equipment should be decontaminated after disassembly and use or should be identified by an appropriate contamination certificate until decontamination can be accomplished.
16. The decontamination agent best suited for cleaning the specific chemical involved should be employed. Waste products should be contained and identified for proper disposal.

F. GENERAL PRECAUTIONS

1. Each employee assigned to work with a hazardous chemical material should be acquainted with the safety procedures and specific operating instructions. In addition, supervisory followup should be used to insure personnel safety during the course of handling operations.
2. An employee should not work alone on equipment in use with a hazardous chemical material. When work is of an emergency nature or places an employee in a precarious position with regard to escape, one employee should position himself at a distance to observe the operation, acting as a "buddy" to alert help and/or effect a rescue.
3. Equipment should be carefully checked and made ready before the operation starts to afford the protection intended.
4. Safety showers should be tested before the start of operations and charged hoses made ready for use.
5. Food should not be stored or eaten in any hazardous chemical storage or handling area.
6. Employees should thoroughly wash their hands after working with any hazardous chemical material.
7. Leaks must be corrected at once.
8. The continuity of all ground wires should be checked to prevent faulty ground.
9. A written Toxic Gas Emergency Procedure should be prepared designating steps to be taken by personnel in areas that may be contaminated by inadvertent release of a toxic gas into the atmosphere.
10. A safety work permit should be required by outside agencies in all hazardous chemical handling and storage areas. The safety work permit form should be completed by supervision having jurisdiction over the work to be performed, and should indicate the safety equipment required, special precautions to be taken, the number of persons covered by the permit, and the duration of the permit.

VII. RADIOLOGICAL SAFETY

A. INTRODUCTION

1. This section outlines the precautions that should be observed during use of radioactive materials or X-ray equipment in conjunction with a solid rocket motor test.
2. The use of radioactive materials or X-ray equipment potentially involves exposure of personnel and/or contamination of the test site and its environs. The latter may include not only the external radiation hazard of body exposure to penetrating radiation but also the internal radiation hazard of radioactive material taken within the body through inhalation, ingestion, or absorption.
3. Primary protection of personnel against radiation exposure lies in equipment design and operation wherein radiation is normally confined and shielded. Where this is impractical, adequate safety equipment and procedures are prescribed, and acceptable limits for radiation exposure are recommended.
4. The principal radiation danger anticipated would be that presented by motors that arrive at the test site containing radioactive materials; a high intensity radioactive source is installed into a motor as part of test preparation and setup, and a motor is subjected to X-ray equipment. In addition, post-test operations require consideration of the hazards of motor firing exhaust dispersion and expulsion of radiation sources in the event of a malfunction during a test.
5. All uses of radioactive sources should conform to the requirements of the U.S. Atomic Energy Commission (AEC), and AEC licensee should be present to monitor all phases of an operation involving radioactive materials or X-ray equipment.

B. DEFINITION OF TERMS

1. Air Sampling--Collecting by means of an air sampling device, such as a Hi-Volume Sampler to measure concentrations of particulate matter in the atmosphere.
2. Alpha Particle--The alpha particle has a large mass and a double charge, both of which limit its travel in matter. For this reason, alpha particle control means the prevention of ingestion, inhalation, and spread of alpha particle contamination.
3. Beta Particle--A charge particle (penetrating radiation) emitted from the nucleus of an atom and having a mass equal in magnitude to that of an electron.

4. Contamination--Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful.
5. Dosimeter--An instrument used to detect and measure an accumulated dosage of radiation; in common usage, it is a pencil size ionization chamber with built-in self-reading electrometer used for personnel monitoring.
6. External Radiation Hazard--Exposure of the body to penetrating radiation.
7. Film Badge--A packet of photographic film used for approximate measurement of radiation exposure for personnel monitoring purposes.
8. Gamma Ray--A short wave length electromagnetic (penetrating) radiation of nuclear origin.
9. Geiger-Mueller (G-M) Counter--A highly sensitive gas-filled measuring device used to measure radiation.
10. High Intensity Source--A radioactive source equivalent in radiation to that of two millicuries or more of radiation (approximately 1.0 millicurie of cobalt 60).
11. Internal Radiation Hazard--The danger to an individual from ionizing radiations taken within the body.
12. Permissible Dose--The amount of radiation that may be received by an individual within a specified period in accordance with acceptable limits established by the AEC.
13. Scintillation Counter--A highly efficient photomultiplier measuring device used for measuring high energy gamma radiation and also for counting other nuclear radiations.
14. Swipe Activity-- The swipe count is determined by swiping the surface of equipment or deck with a piece of paper hand towel and holding the paper under a survey meter. This test is a relative indication of the amount of transferable radioactive activity that could be picked up by personnel.

C. PROTECTIVE MEASURES

1. The exposure to the worker from tests on solid rocket motors involving radioactive materials or X-ray equipment may come from two directions. Radiation may be external to the body: directly from a source, contamination outside the source container, or contamination on the person or clothing of the worker. The other direction from which exposure may come is inside the worker's body through inhalation, ingestion, or absorption through the skin.

2. To limit external exposure, the following measures should be taken.
 - a. Prior to handling, test preparation, and setup, determine the rate of exposure, either from a motor containing radioactive sources or a radioactive source external to the motor, and limit the amount of time the worker will spend at the motor or source to that giving him only his maximum permissible exposure. Each worker shall be provided personal monitoring equipment such as a dosimeter and/or film badge to record the exposure he will receive.
 - b. Reduce the rate of exposure. Interposing shielding between the source and the worker or moving the worker farther from the source will reduce the rate of exposure to the worker. For unrestricted work areas, the distance from the source shall be calculated in accordance with maximum permissible dose rates and the entire area around the source portended by the established distance shall be roped off and identified by radioactive symbol placards. Personnel should be rotated when radiation levels are high and shielding is impossible.
 - c. Each worker shall be given protective clothing that provides enough coverage to protect him as well as his personal clothing, and that can be washed in a laundry equipped to handle contaminated clothing and dispose of contaminated wash water.
3. Internal exposure can be controlled only by preventing the entry of radioactive materials into the body. During a test firing, personnel shall be evacuated from the test zone in accordance with quantity-distance requirements for the amount of propellant involved; personnel downwind from the test site shall be provided with protective gear or evacuated to sheltered areas; and employees directly connected with the test shall seek shelter in the operating control room, which shall be sealed off from the outside and provided with a means for recirculating existing air or introducing an air supply independent of the outside atmosphere.
4. Following the test, workers equipped with protective clothing may enter the test bay for monitoring purposes. The zone remains closed to all other persons. Respiratory protection for this operation and during any decontaminating later found necessary may consist of respirators that filter the air to the mouth and nose for short periods in low concentrations of airborne contamination. For higher concentrations (50 times the maximum permissible concentration) and longer periods, supplied air masks (such as the Scott-Air Paks) are recommended. The way any mask fits the face is extremely important because only the air that is filtered or supplied is not contaminated. Any leakage, which usually occurs around the nose or chin, is unfiltered and, perhaps, contaminated air.

5. Before a test firing, a network of air samplers shall be set up in predetermined locations around and downwind from the test site. The air samplers shall operate continuously during the test. Following the test, filter paper from the samplers, plus swipes of the test site, shall be collected for analysis. (In the event of malfunction and expulsion of radioactive sources from a motor during a test, the entire area involved in the test shall be monitored with a scintillation counter, or equivalent, to locate every source.) The test zone and test area shall remain closed until contamination is established to be below permissible limits. Firefighting personnel should also be instructed and have proper equipment available for use in the event they are called upon when a serious malfunction occurs.
6. If air swipe samples show contamination of the test area to be above maximum permissible limits, employees shall be provided with all necessary protective gear and equipment for decontamination areas. Training to teach cleanliness and care will do much to prevent ingestion of material by the worker. Workers should wash thoroughly after all decontaminating work and showers should be provided for this purpose. All equipment and clothing used in decontamination operations shall be identified covered containers for cleaning or disposal.
7. The amount of radioactive material ingested by an employee can be estimated by the quantity found in the body fluids. The urine is the most available body fluid. Whenever an internal exposure is suspected, a urine specimen should be requested and analyzed as soon as possible.
8. Radiation sources in containers should be leak-tested whenever dropped, or when deterioration of the container is suspected. Polonium sources are especially dangerous because of the great tendency of polonium to escape and spread. Swipe tests (a piece of tissue paper rubbed over the surface of a container and counted for beta and gamma particles on a G-M counter) can be made of most sources. A count on the paper in excess of 50 cpm for beta and gamma may be considered to indicate the source is leaking and should be returned to the supplier for resealing. All radioactive source containers, including solid rocket motors and radiation areas, shall be properly identified by caution signs, labels, or symbols as specified by the AEC.

D. GENERAL RESPONSIBILITIES

1. Each person who has any contact with radioactive materials or radiation is responsible for the following.
 - a. Keeping his own exposure to radiation, as well as that of others, as low as possible and, specifically, below the maximum permissible levels established by the AEC.

- b. Wearing the prescribed monitoring equipment (pocket dosimeters and film badges) in radiation areas. Surveying hands, shoes, and body for radioactivity; and removing, in accordance with prescribed decontamination procedures, loose contamination to tolerance levels before leaving radiation area.
 - c. Wearing appropriate protective clothing whenever clothing contamination is possible, and not wearing such clothing outside a specific recommended area of control. Using gloves, hoods, coveralls, shoe covers, and respiratory protection (respirators or supplied air masks) where necessary. Using proper techniques and facilities involving radioactive materials as prescribed by documented operating procedure for the specific operation.
 - d. Observing recommended rules in regard to eating and smoking.
 - e. Reporting injuries and ingestion or inhalation accidents promptly to the Medical Department and cooperating in any and all attempts to evaluate exposures.
 - f. Carrying out recommendations of roping off hazardous areas, posting warning signs, and otherwise helping to control special hazards.
 - g. Cleaning up contamination and carrying out decontamination in accordance with prescribed procedures.
 - h. Assuring that radioactive materials are properly stored and labeled.
 - i. Packing in a closed container (sealed, whenever possible), and labeling the container as to origin and date, contaminated articles for cleaning or contaminated waste disposal.
2. Supervisors are responsible for insuring the above individual responsibilities are discharged by those under their control, and are further responsible for the following.
- a. Instructing those workers for whom they are responsible in the use of safe techniques and in the application of approved radiation safety practices.
 - b. Providing for packaging contaminated waste and decontaminating anything for which he is responsible.
 - c. Assuring radiation areas are properly monitored and maintaining an adequate record of radiation data collected from air samples, detection instruments, etc., as required by the AEC.

IX. PROTECTIVE EQUIPMENT

A. INTRODUCTION

1. This section is designed to cover adequate protection for employees who are exposed to hazards created from work associated with the testing of solid rocket motors.
2. Established requirements are based on sound experience and, in each case, are the minimum for personnel protection.
3. In addition to insuring his own personal protection by conscientious use of protective equipment, each person should feel free to warn anyone else if a violation is involved.
4. Operations and equipment in some areas introduce significant hazards not only to personnel performing the work but also to others who enter or pass through such areas. Areas in which the hazards are judged to be of this magnitude should be specified as mandatory protective equipment areas, and signs to this effect should be posted. Any person entering or working in these areas must wear appropriate protection.

B. DEFINITION OF TERMS

1. Barricades or ropes may be considered as safety devices that find extensive application in preventing injury. They are used in conjunction with danger or caution signs to prevent entrance of personnel who are not involved in the work in progress. They are also used to protect against the hazards of falls.
2. Ear protection consists of approved type ear muffs for use in locations having harmful sound levels. Rubber ear plugs are not preferred because they might be driven into the head in case of an explosion.
3. Eye protection includes safety glasses, face shields, dust, chemical, and grinder's goggles. The minimum eye protection to be worn in a mandatory eye protection area is safety glasses; other items of eye protection shall be worn as required by the specific hazards of the job being performed.
4. Foot protection consists of both conductive and nonconductive footwear with any of the types of steel foot guards or steel toe insert safety shoes to protect the wearer's toes from injury during the course of handling material and equipment.

5. Gloves of proper type and material are provided for hand protection in work involving the handling of sharp or rough objects, corrosive liquids, and materials or equipment in extreme temperatures.
6. Head protection consists of safety hard hats with full brims to protect the wearer from injury to the head from falling objects and inadvertent bumping. Safety hard hats shall conform to tests required by Federal Specification Z2.1-1959.
7. Protection against chemical exposure consists of an acid suit worn in conjunction with gas mask, acid hood, neoprene gloves, and rubber footwear as required by area rules.
8. Protection against exposure to airborne radiation consists of ultrafilter, dust respirator, head cover, coveralls, boots, and gloves for protection against submicron size radioactive particles in the atmosphere.
9. Respiratory protection includes mechanical filter and cartridge masks, canister masks, air-line respirators, and self-contained breathing equipment to protect the wearer in contaminated or oxygen-deficient atmospheres.
10. Safety belts and harnesses are safety devices often required as an added precaution against serious injury from a fall. The wearing of a safety harness with lifeline manned by another employee is also a requirement when tanks or vessels are entered, to provide a means of rescue in the event of an unforeseen accident.
11. Safety showers and eye wash fountains are designed for immediate field first aid to dilute and flush away toxic materials before serious effects occur. This equipment shall be provided in all locations where the possibility of contact with hazardous material exists.

C. EYE PROTECTION ON SPECIFIC JOBS

1. Eye protection should be worn on those specific jobs that introduce significant eye hazards, regardless of the location at which they are performed.
2. In general, jobs involving the following operations require the wearing of appropriate eye protection.

a. Heavy grinding (stationary)	Goggles
b. Chipping, breaking, buffing, crushing polishing, and grinding (portable)	Chipping goggles

c. Drilling, filling, milling machining, sawing, cutting, and forging	Safety glasses
d. Cutting, welding, burning, silver soldering, and brazing	Welding goggles or hood
e. Use of air or electrical driven tools	Safety glasses
f. Use of compressed air or nitrogen	Safety glasses
g. Use of impact tools such as hammers	Safety glasses
h. Handling corrosive and hazardous liquids	Chemical goggles
i. Handling or working on equipment, lines and vessels containing gases or liquids under pressure	Chemical goggles
j. Mixing, transferring or combining reactive and corrosive chemicals; handling or mixing of flammable or explosive materials	Chemical goggles or face shield
k. Switching operations involving possibility of electric arcs	Safety glasses or face shield

D. HEAD PROTECTION

Posted area Requirements: "Safety Hats Required For Work In This Area"

1. All test stand and test cells
2. All motor preparation areas

E. HEAD PROTECTION ON SPECIFIC JOBS

1. In addition to wearing head protection in the areas designated above, personnel should wear safety hats on those jobs that present significant hazards from falling tools or equipment.
2. In general, the following operations require the wearing of safety hats.
 - a. Operations below personnel working directly overhead on platforms, ladders, scaffolding, etc.
 - b. Operations involved in the hoisting of motors, heavy materials or equipment

F. FOOT PROTECTION

Posted Area Requirements: "Safety Shoes Required For Work In This Area"

1. Machine shops
2. All test stands and test cells
3. All motor preparation areas
4. All instrument electrical shops (nonconductive)

G. FOOT PROTECTION ON SPECIFIC JOBS

1. In addition to wearing foot protection in the areas designated above, personnel should wear foot protection on those specific jobs that present significant hazards in lifting, handling, or using heavy materials and equipment.
2. In general, jobs involving the following operations require the wearing of foot protection.
 - a. Handling compressed gas cylinders
 - b. Handling drums
 - c. Handling motors and hardware
 - d. Handling instruments or cameras
 - e. Use of portable tools
 - f. Handling other heavy material or equipment

H. RESPIRATORY PROTECTION

1. Mechanical filter masks provide breathing protection against nuisance dusts and other particulate matter in the atmosphere. Respirators with ultrafilter dust cartridges are used as protection against respiratory exposure to radiation and toxic particles in the atmosphere after tests using these materials with solid rocket motors.
2. Canister masks with proper organic or inorganic canister and full face piece provide respiratory and eye protection in atmosphere of limited contamination, having at least 16 percent oxygen content. This type of mask is used in chemical exposure atmospheres where eye protection is required. These masks are selective with respect to contaminants removed from the air and are limited by canister capacity. Canister masks are not to be used in fighting fires involving hazardous materials nor for any vessel entry.
3. Air-line respirators with half masks supplied with plant air, embody an organic vapor filter and manual regulator for continuous flow of air. They are suitable in atmospheres deficient in oxygen or containing toxic vapors other than eye irritants. They offer a quick disconnect for leaving the area of use, but are limited to a definite area by the length of the supply hose.
4. Self-contained breathing air equipment does not depend on outside air or a fixed location of supply. It offers complete respiratory and eye protection during work in, and escape from, contaminated areas regardless of concentration or type of vapors. Use of the air supply is only on demand. Duration of use is limited by the volume of the supply bottle.

5. Serviceability of respiratory equipment depends upon reasonable care and inspection before use as follows.

- a. Supervision whose employees may be exposed to hazardous vapors or oxygen-deficient atmospheres shall maintain suitable respiratory protective equipment for all anticipated exposures.
- b. All personnel required to wear respiratory protection shall be trained in the proper method of donning the equipment and testing for leaks.
- c. The issuing agency shall maintain face masks in serviceable, clean, and sterile condition, ready for use.
- d. Masks shall be inspected for faults, cleaned, sterilized, and placed in plastic bags after each use. Rubber parts shall be protected from excessive heat and contact with oil or chemicals.
- e. Canisters and filters shall be replaced on the basis of frequency and duration of use.

I. PROTECTION AGAINST CHEMICAL EXPOSURE

1. Posted Area Requirements: "Chemical Goggles Required for Work In This Area"
 - a. All hazardous chemical storage areas
 - b. All hazardous chemical handling areas
2. In addition to the use of chemical goggles in the areas designated above, complete protection against chemical exposure shall consist of a canister mask equipped with an approved canister, a two-piece acid suit, acid hood, gloves, and neoprene or rubber footwear.
3. In general, jobs involving the following operations require the wearing of complete protection against chemical exposure. Self-contained breathing air gas masks should be at the work site when the following tasks are performed.
 - a. When removing disconnected lines that have contained a hazardous chemical material.
 - b. When opening any valve that allows the chemical or its vapor to escape into a work area.
 - c. When tightening connections in a system.
 - d. When sampling liquid.
 - e. When acting as a "buddy" for the tasks described above.
4. The complete protection wearing apparel described above, including respiratory protection consisting of a self-contained breathing air gas mask, should also be required for the operations listed below.
 - a. During startup or transfer of a hazardous chemical in a system.
 - b. When opening lines or fittings to atmosphere.

- c. When fighting a fire involving a hazardous chemical.
 - d. During cleanup or repair work to correct a spill or a leak.
 - e. During leak checking under gas pressure if a system has contained a hazardous material but has been drained.
 - f. During transfer of a hazardous material after startup and checkout of a system.
 - g. While using a vapor detector, or otherwise entering areas of known or suspected contamination for investigation.
 - h. During decontamination.
 - i. While acting as a "buddy".
5. Personnel working in areas downwind from an operation involving a hazardous chemical shall wear a canister mask in readiness for use.

J. PROTECTION AGAINST RADIATION EXPOSURE

1. Protection against exposure from radioactive particles in the atmosphere shall consist of coveralls, boots, gloves, and ultra-filter dust respirators capable of filtering submicron size particles in low concentrations of particulate contaminants in the atmosphere. Self-contained breathing air equipment shall be used in concentrations 50 times greater than maximum permissible limits.
2. In general, jobs involving the following operations require the wearing of the complete protection described above.
 - a. To survey an area of suspected or unknown contamination.
 - b. To take swipe samples of the facility or equipment that may be contaminated.
 - c. During decontamination operations.

K. GLOVES

1. Gloves of proper type and material shall be provided to protect personnel against hand injuries. Gloves shall not be worn in work at machining that presents the hazard of rotating parts.
2. The types of gloves commonly used for specific jobs are listed below.
 - a. Work gloves for handling rough materials or sharp objects, for hand protection while surveying atmospheres contaminated with beryllium or radioactive particles, and during decontamination.
 - b. Suitable protective gloves for working with corrosive liquids or in atmospheres contaminated by chemical materials.
 - c. Surgical type rubber gloves where finger dexterity is required for cleaning small parts by using corrosive solvents or liquids.

3. An evaluation of the hazards and chemicals involved in a specific operation is necessary to determine the most suitable glove required for proper hand protection.

L. SAFETY SHOWERS AND EYE WASH FOUNTAINS

Safety showers and eye wash fountains should be provided in all hazardous chemical storage and handling locations or where the possibility of contact with hazardous materials exists. The requirements for safety and eye wash facilities are as follows.

1. Safety showers and eye wash facilities should be checked at the start of each shift to insure that they will be operable if needed.
2. Safety showers and eye wash fountains should be accessible at all times.
3. Treatment under a shower or an eye wash fountain should be continued, in every case, for at least 15 minutes and shall be followed by a prompt visit to the first aid station.

M. SAFETY BELTS

Safety belts and harnesses are used primarily as an added precaution against serious injury from a fall. A decision as to the need for this equipment in a particular case depends upon such factors as location, type of work platform, etc. Life lines should be used for work in all closed vessels. Generally, the following rules apply.

1. Employees should not be placed in a precarious position without the protection of a safety belt, safety harness, or life line.
2. Safety belts, harnesses, or life lines should be inspected before each use.
3. When a safety harness or belt is recommended, it should be used with as little slack in the tail as possible.

N. BARRICADES

Barricades or ropes, preferably of a distinctive color or type, are used to prevent entrance of personnel who are not involved in the work in progress.

Barricades or ropes may require warning signs depicting the hazard, and generally are used as follows.

1. Barricades should be erected or the area roped off to protect personnel from entering work areas that present a hazard. For example, protection of personnel from overhead work, e.g., oxy-acetylene cutting, shall require roping off below. Removal of

grating sections in a catwalk on a vertical test stand shall require barricades. X-ray of motors shall require the area to be roped off a safe distance from the operation, etc.

2. Barricades and ropes should be removed promptly when their need ceases to exist.

X. WELDING

A. DEFINITION OF TERMS

Capacitance spot welding is the process of using energy stored in a condenser to produce a weld. This process provides a very definite limit on the total energy available for each weld because the condensers have to be recharged for each weld.

B. WELDING, CUTTING, AND BURNING

1. Welding in a test area constitutes a possible hazard from heat, sparks, or electrical current potentials. When any welding is conducted in a test area containing loaded solid propellant units, careful consideration should be given to each individual requirements. A system employing the use of Safety Work Permits should be used.
2. Commercial welding methods employing a gas or an electrical welding machine should be conducted in the vicinity of a solid propellant unit only if the solid propellant is totally enclosed in a non-combustible container. An opening in the unit should be closed with a soft noncombustible seal or plug. When possible, all welding in a test area should be accomplished when no solid propellant units are present in the immediate test area.
3. If any commercial type welding is to be conducted on the actual solid propellant unit, it should be accomplished by remote control with the same protection as used in a hazardous test.

When welding is necessary adjacent to a solid propellant unit, careful consideration should be given to the spark distribution, conduction of heat through physical members, and possible local heating caused by passage of electrical current from the ground electrode of the arc electrode through the structure being welded.

C. FIRE SAFETY DURING WELDING AND BURNING OPERATIONS

1. Oxy-Acetylene Welding

Fire safety should insure that no combustible materials are in the region of welding. A proper type fire extinguisher should be present in the immediate vicinity of the welding operation. In the event of a small fire not involving a solid propellant unit, every effort should be made by the workmen present to extinguish this fire.

2. Electric and Heli-Arc Welding

In addition to the precautions listed under gas welding, a dry chemical type fire extinguisher should be located in the vicinity of the work. If a small fire does not involve a solid propellant unit, every effort should be made by the workmen present to extinguish this fire.

3. Spot Welding on Solid Rocket Motor Chambers

Capacitance spot welding is used to weld thermocouples or other instruments to solid propellant chambers and enclosures. Experience shows that this welding process does not generate sufficient heat to discolor normal paint on one side of 0.010-in. thick sheet metal when a weld is made on the other side. Tests have indicated that the depth of the weld does not exceed one-fourth the diameter of the thermocouple wire used. The calculation of energy involved indicates that the total energy input will raise the temperature of one-fourth ounce of water only 1°F per weld. All transformers, switches, and storage condensers that must be in the vicinity of the solid propellant unit should be enclosed in an auxiliary case to confine any fire to this equipment enclosure. Surface spots on the case to be welded should be cleaned to bare metal to minimize contact sparks.

XI. BALLISTIC FACILITY DESIGN

A. INTRODUCTION

The following criteria are the basic considerations for layout and design of a solid rocket motor test facility. Once the facility becomes operational, additional data should be gathered, whenever possible, to augment these primary requirements and aid in future designs.

B. ITEMS TO BE CONSIDERED CONCERNING SAFETY

1. Natural terrain versus earth revetments for protection against ballistic projectiles.
2. Proximity to inhabited buildings, railroads, and highways.
3. Quantity-distance requirements.
4. Effects of noise on surrounding areas and neighbors.
5. Perimeter control to keep out personnel, animals, etc. from the neighboring area.
6. Predominate wind direction in relation to the surrounding area.
7. Air pollution control as dictated by local government agencies.
8. Underground water pollution control as dictated by local government agencies.
9. Disposal or dispersion of contaminated items or products.
10. Climate conditions that would include unsafe operations, e.g., ice, electrical storms, excessive rains, temperature variations, etc.
11. Aircraft patterns, both commercial and military, that would involve aircraft overhead at low altitudes during vertical nose-up firings or first order detonations.
12. Test bays that will sustain the least amount of damage during a major malfunction are listed below in decreasing desirability.
 - a. One-hundred percent open test bay, concrete base with a steel plate or rails.
 - b. Test bay, open on two sides and top.
 - c. Double open ended horizontal or one side and top open vertical test bay.
 - d. Closed test bay (usually underground), with only the firing end open.