L. C. Leopold
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ROCKET LABORATORY SAFETY AND DESIGN MANUAL

By

Members of Rocket Laboratory Subcommittee,
Special Fuels and Combustion
Safety Committee

- - -

Lewis Research Center
National Aeronautics and Space Administration
Cleveland, Ohio

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SECTION 1. - GENERAL REGULATIONS - ROCKET LABORATORY

1.1 Visitors

1.1.1 NASA employees visiting the Rocket Laboratory on business are cleared to enter to the Instrument Building except as restricted by barricades and signs described in 1.2. Clearance to specific cell areas is obtained by calling the engineer- or mechanic-in-charge at the cell, or in some cases, may be obtained from the Rocket Laboratory Mechanical Supervisor on duty in the Instrument Building.

1.1.2 Except in emergencies, only assigned personnel may enter danger areas. If other personnel must enter the area, they must first obtain verbal clearance from the test engineer or cell operator in charge either by telephone or by the inter-phone communication system from the central instrument room.

1.1.3 Non-NASA visitors must be accompanied by NASA escort. The provisions noted in 1.1.1 (above) then apply.

1.1.4 Smoking is permitted, except in posted areas. Areas normally blocked off for rocket loading and firing, and propellant storage areas shall be posted "NO SMOKING". Other areas as specifically mentioned in this manual or designated by the Rocket Laboratory Safety Subcommittee shall be similarly posted.

1.2 Safety System Signals

1.2.1 Safety system signals comprise flashing lights, portable signs, and a horn.

1.2.2 Yellow flasher lights at each test cell will flash when propellant tanks in the cell are pressurized. In addition, cell 11 causes a yellow flasher light along the south roadway entering the Rocket Laboratory to flash, and cell 14 causes a similar light along the north roadway to flash. Unless you are on duty in the operating cell do not enter that cell area when the lights are flashing.

1.2.3 In addition to flasher lights, portable signs are posted around danger areas and chain barricades are placed across roadways (see 3.4.5). Only personnel on duty in the operating test cell may pass these signs and barricades; all other personnel must first obtain clearance from the test engineer or cell operator in charge. Approximate locations for portable signs will be determined by the Safety Committee as the need arises. A special sign will be posted at the roadways when tests with extremely hazardous fluids (e.g., fluorine) are in progress. These signs are posted to warn other personnel of hazards and are to be removed as soon as danger has passed.

1.2.4 The horn warning must be started at least 60 seconds prior to rocket firing and continued until the rocket firing (or other hazardous operation) is completed for all runs before 5 PM on week days. After 5 PM and on Saturdays the warning will be sounded only 30 seconds before the run. Personnel working within or near barricaded areas are warned of an impending hazardous operation and must leave immediately. All personnel in the Rocket Laboratory area must take cover in one of the buildings, at the sound of the horn, and must remain there for the duration of the horn. Special permission can be granted by the mechanical supervisor in the area to continue outside activities if the particular location of the activities is remote from the cell being fired. Appropriate signs notifying visitors of this regulation shall be posted throughout the area.

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1.2.5 In the event of serious explosion, uncontrolled fire, or other emergency, the siren will be sounded. The Lewis Laboratory fire department will be notified and the Rocket Laboratory Emergency Crew (Section 1.3) will go into action.

1.3 Emergency Crew

1.3.1 During working periods an emergency crew will be on duty at the Rocket Laboratory. This crew, composed of Rocket Laboratory personnel, is appointed and directed by an Emergency Crew Captain, and names of personnel assigned to the crew will be posted in the central instrument room and cell service areas. An Alternate Captain is appointed to direct the emergency crew in the absence of the Captain. This crew will fight fires and do rescue work until the regular Lewis Laboratory fire department arrives.

1.3.2 In the event of an emergency, which is indicated by intermittent sounding of the siren, the emergency crew will proceed to stations assigned by the Emergency Crew Captain. The test engineers and test cell operators in the emergency area will act as part of the emergency crew. The Captain, acting on advice from the test engineer or operator in charge, will direct actions, and may recruit volunteer emergency workers from the Rocket Laboratory staff, if necessary. All others, with the exception of the Lewis Laboratory fire department personnel, must remain a safe distance away as directed by the Emergency Crew Captain.

1.3.3 In case of any emergency within a rocket cell area the project engineer is responsible for initiating emergency actions. If he calls in the fire department he is to meet the fire fighters at the entrance to the Rocket Laboratory, inform their Captain as to the nature of the emergency and the hazards involved, and make suggestions regarding method of attack. The project engineer will designate the mechanics crew chief on duty to handle special emergency actions such as cutting power and other utilities to the cell, as necessary. The direction of the fire fighting is to be handled by the captain of the fire fighters, assisted by the project engineer. If the project engineer is not on duty at the time of the emergency the crew chief is in charge. In an emergency not involving a specific cell area the Mechanical Services foreman in the area is in charge.

1.3.4 Visitors and onlookers are prohibited from entering the Rocket Laboratory area during an emergency. Plant Protection personnel, aided by Rocket Laboratory personnel, will patrol the entrances to prevent unauthorized entry.

1.4 Propellant Handling

1.4.1 Never transport or store fuels and oxidants together. (Quantities up to one liter may be used and stored in the chemical laboratory but with separate facilities for oxidants and fuels.)

1.4.2 Label all propellant containers plainly and properly.

1.4.3 Do not leave drums of propellants standing on aprons longer than necessary. Do not accumulate hazardous materials in the chemical laboratory.

1.4.4 Use no more than 6 psig in pressurizing drums; use a low-range pressure regulator with safety disk designed to burst at 8 psig.

1.4.5 Know the propellants you are handling. Refer to this manual whenever you are required to load, transfer, or store fuels or oxidants. If in doubt as to safe procedure, consult your supervisor. If any doubt remains, refer problem to the Safety Committee.

SECTION 2. - GENERAL REGULATIONS - SOUTH 40

2.1 Entrance to the South 40 area will be through special badge only. This badge may be obtained in exchange for the regular NASA badge from the South Gate guard.

2.2 Safety system signals will consist of portable signs and barricades and PA system announcements and tone signals throughout the area.

2.3 Danger areas will be designated by portable signs and chain barricades. Except in emergencies, only personnel having the permission of the engineer-in-charge may pass these signs and barricades. Permission must be obtained each time before entering a danger area.

2.4 When danger areas exist, access to the South 40 will be limited to assigned operating personnel. The South Gate guard will refuse entrance to all unauthorized persons.

2.5 Permission for entering restricted areas may be obtained through the facility control room.

2.6 A tone signal will be broadcast through the PA system at about one second intervals for at least 60 seconds prior to a rocket firing and continued until the rocket firing (or other hazardous operation) is completed. 5188

2.7 Regulations concerning propellant handling (Section 1.4) apply also to the South 40 area.

SECTION 3. - DESIGN AND OPERATION OF ROCKET TEST STANDS

3.1 Safety Committee Approval

3.1.1 All new rocket cell layouts, propellant and control systems, electrical systems, special cleaning procedures, and operational check lists, and all modifications to the above must have prior approval by the cognizant safety committee.

3.1.2 The specific procedure to be used in obtaining approvals is as follows:

1. Project engineer prepares schematic layouts of electrical and mechanical systems, space layouts showing pertinent buildings and pieces of equipment, operational procedures necessary to check out cell before run, and run check list.

2. Project engineer consults with Chairman of the appropriate safety committee to determine if formal review by the committee is necessary.

3. If formal review is necessary, six copies of (1) above are prepared and submitted to chairman of the committee.

4. After allowing 1-2 days for members to review, the committee reviews proposal in meeting with project engineer and arrives at conditions for approval.

5. A copy of the approval drawings, together with setup and operating procedures must be filed by the Chairman of the safety committee. Any changed drawings or procedures made at a later date must also be filed.

3.2 Fluid Systems

3.2.1 All pressure vessels, lines, fittings, and valves should be designed or selected according to the specifications of the report entitled "Design Specifications for Rocket Propellant Pressure Vessels", Project Report by Mr. W. G. Anderson, Equipment Engineering Section, Mechanical Engineering Division, November 17, 1952. Experience has shown stainless steel of type AISI 347 to be crack sensitive in weldments, and should not be used in critical areas.

3.2.2 Pressure vessels, lines, fittings, and valves (this does not include high pressure gas cylinders - commercial or NACA) should be pressure checked in accordance with the specifications of the above report. Pressure vessels are to be hydrostatically tested before installation and are to be hydrostatically pressure checked at least once a year after being put into use unless the safety committee makes a specific exemption for the unit in question.

3.2.3 Pressure vessels are to be tagged as shown in the above report (see 3.2.1).

3.2.4 Vent fuel and oxidant tanks separately outdoors. Place vents so they cannot cover the working area with droplets or fumes.

3.2.5 All pressure vessels are to be equipped with burst diaphragms set for a pressure which is not less than midway between the design working pressure and the design test pressure and is not more than the design test pressure. The design pressures selected shall be those corresponding to the normal working temperature. When the working temperature is changed, the burst diaphragms shall be changed accordingly. The burst disk and housing should be located so that their temperature does not vary appreciably, and their materials and design should be selected according to this temperature. The outlet of the burst diaphragm should be ducted away from the work area in the same manner as the tank vent lines.

3.2.6 A burst diaphragm should be installed in any section of a liquid line that can at any time be full of liquid capable of expanding. This condition exists most often between two valves in series. A burst diaphragm may not be required if at least one of the valves will, by its design, relieve at a pressure less than the design pressure of the liquid line. This procedure is most appropriate in situations where bursting of the diaphragm could create a serious hazard.

3.2.7 In pressure checking tanks, lines, fittings, and valves with gas pressure, first bring the pressure to the design test pressure (block the burst diaphragm) and watch for drop in pressure. No personnel shall be in the cell when the test pressure is applied. If a leak is detected, apply a very low positive pressure and inspect for leaks, then raise pressure to about 50 psig. Inspect for leaks. Bring pressure up to design working pressure in steps of 100 psig. At each step wait five minutes before inspecting the setup closely. It shall always be preferable to conduct the pressure check at the working temperature. If this is not feasible, the check may be carried out at some other convenient temperature and the results extrapolated to the working temperature. When the latter procedure is followed, the record and name plate shall be so marked.

3.2.8 Have no personnel around setup when it is being pressurized by any method.

3.2.9 Tube fittings greater than 3/4-inch nominal diameter are not permitted on propellant systems or other high pressure systems that will exceed 50 psi pressure. Use welded joints or flanges for pressures above 50 psi.

3.2.10 Flared tube fittings in all new cryogenic systems shall be stainless steel. In any new system hard fittings shall be used with hard tubings. Where, for any reason, soft fittings are installed on hard tubing or in cryogenic systems periodic (approx. 3 months) inspection for cracks shall be made. Tightening of fittings shall not exceed the manufacturer's recommended limits.

3.2.11 Never attempt to tighten or loosen a fitting or bend a tube for observation when it is under pressure.

3.2.12 If purge or ignition gas lines are "teed" into the main propellant lines, they must have check valves so arranged that at least two check valves will prevent the flow of propellant into these lines. A pressure regulating valve that allows flow in one direction only will serve as one of these check valves. The check valve must have a soft seat ("O" ring type). If it is not desirable to expose the soft seat to the propellant (e.g., liquid fluorine) then an additional metal-to-metal seat check valve must be used in front of the soft seat check valve. If purge lines and ignition gas lines are "teed" before entering main propellant line a check valve must be in each of these lines to prevent cross-contamination.

3.3 Rocket Installation

3.3.1 Provide barriers that will protect personnel from explosions. Note: The ability of a wall to withstand explosions depends partially on relieving the pressure by collapse of other walls and roof.

3.3.2 Where possible install water sprays at base of engine to dilute unburned propellants that emerge from the engine in order to minimize explosion and fire hazard.

3.3.3 Where possible set up rocket engine to prevent accumulation of unburned propellants in the chamber; if possible provide a water or gas flush to sweep propellants from the chamber at the end of run or provide dump valves to cut off propellant flow rapidly at the end of a run.

3.3.4 There should be a green light to show that the control panel is not energized (condition safe) and a red light to show the control panel is energized (condition unsafe). Both lights should be visible from the entrances of the test cell.

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3.3.5 A holding relay and push button must be installed in the main power supply so arranged that if, for any reason, the main supply is interrupted, the system will not be re-energized when the power resumes. The push button is used to re-energize the system.

3.3.6 It is suggested that the following safety devices be used if suitable.

1. A relay actuated by coolant flow may be installed in each system so that the motor cannot be fired if sufficient coolant is not supplied to the chamber.

2. All parts of the system that may burn through may be wrapped with insulated wire connected to a relay so as to shut down the motor.

3. In motors with two-stage starts a pressure switch may be arranged so as to shut down the motor if proper combustion pressure for the first stage is not attained. Alarm on Brown

3.3.7 A safety shower should be installed at the entrance of each test cell. An eye-wash fountain should be near each rocket test cell.

3.3.8 Mufflers and scrubbers used with rockets must incorporate the following safety precautions:

1. All fuels extremely soluble in water may be exhausted into mufflers or scrubbers if the whole volume of the scrubber is sprayed with a finely divided water spray so that all gases from the fuel are dissolved in the water and all metal surfaces are cooled by this spray. Jet wheels associated with these installations should have a ten-second override.

2. Fuels not soluble in water shall be exhausted into mufflers that are inerted by CO_2. Tests of the atmosphere should be made by suitable sniffers and the concentration of oxygen should be kept below the flammable limit for the fuel used. Finely divided water sprays should be used throughout the whole volume of the exhaust system and jet wheels should be given a ten-second override. Fluid temperatures in the sump should not exceed values producing flammable fuel-air mixtures. When running fluorine, the sump water temperature should not exceed 150° F.

3.3.9 Rocket test cells shall be neat and orderly at all times. Remove all equipment and material not needed for the operations. Particular attention should be given to removal of combustible materials from the cell area. Good housekeeping habits will make it easier and safer to work in the area, will avoid unnecessary fire hazards, and will make emergency actions (such as fire-fighting) easier and safer.

3.4 Rocket Operation - General

3.4.1 The project engineer has full responsibility for all matters 5188
relating to operations of research equipment assigned to his project and is, therefore, responsible for safety of personnel and equipment.

3.4.2 Have up-to-date check sheet for each run. A check sheet should be provided for any other operation such as cleaning or calibrating systems. These check sheets should be approved and filed by the safety committee.

3.4.3 Have proper safety equipment on hand before loading or firing test setup. This includes such things as fire extinguishers, gas masks, no-smoking signs, first-aid burn solutions, and other safety equipment as specified for propellants being used.

3.4.4 The minimum safety clothing is a face shield which shall be worn when loading, handling, or transporting propellants and when working in the vicinity of stored, loaded, or pressurized propellant systems or gas pressurized lines such as control lines or calibration systems. Additional safety clothing as specified for various propellants shall also be worn.

3.4.5 Road barriers and warning signs shall be placed for the individual cells as shown in figure 1. These signs and barriers shall be installed whenever a rocket is to be fired. If these barriers are in place, access to the blocked off area can only be had by obtaining permission to enter from the project engineer in charge. In addition to barricades shown in figure 1, warning to prohibit smoking or open lights signs must be placed on each entrance to a cell that has tanks loaded with propellants. If any equipment in a test cell is to be pressurized for any reason other than running or if propellants are placed in the tanks, the local area endangered shall be barricaded. When the hazard for which an area is posted is eliminated, all signs and barricades must be immediately removed.

3.4.6 Never load, handle, or transport oxidant and fuel simultaneously.

3.4.7 The handling of hazardous materials requires at least two persons. One person doing the actual handling must be fully protected in accordance with safety regulations pertaining to the particular material being handled. The second person, if not required in the actual handling, stays at a safe distance away to aid in case of an emergency. He may not, in this case, require full protection, but shall have necessary safety equipment readily available.

3.4.8 All open flames shall be extinguished before propellants are loaded.

3.4.9 Clear the area of personnel before operation.

3.4.10 Personnel shall not enter a test cell in which the propellant system is pressurized unless absolutely necessary in the opinion of the project engineer, and shall never enter a test cell when the system pressure is greater than the design working pressure for room temperature service.

3.4.11 Hoses, pipes, or other obstacles shall not be permitted in doorways so as to prevent closing the door in case of accidents.

3.4.12 Propellants shall not be stored in test cell tanks overnight except by prior safety committee approval. This approval will never eliminate the need for extinguishing all open flames such as heater pilot lights while propellants are in the tanks.

3.4.13 The safety committee may, at any time, set up special restrictions for the operation of specific cells and specific propellant combinations that are especially hazardous. These restrictions will cover time of operation, evacuation of the area, and wind conditions.

3.5 Rocket Operation - Fluorine

3.5.1 Fluorine rocket firings in the Rocket Laboratory shall, in all cases, be made outside regular working hours. Operations in the South 40 facility are not restricted in this manner.

3.5.2 The following people must be notified prior to operation of all setups (including South 40) with fluorine:

Head, Plant Protection

Head, Medical Services

Safety Officer

Designated representative of Plant Services

3.5.3 Special procedures regarding area evacuation are established by the Rocket Laboratory Safety Subcommittee when project is first approved.

3.5.4 Any employee of the Research, Engineering, or Plant Services Divisions working in an area in which he might become exposed to fluorine must have a chest X-ray and an examination by a doctor. If the X-ray or examination shows no history of respiratory troubles, the employee's badge will be punched to indicate this fact. If, at any time, the possibility exists that fluorine fumes may be released in a particular area, the supervisor in charge of the area shall declare the area off-limits to all those not having a punched badge. This condition is not considered to exist if the fluorine is contained in its regular storage dewar or gas storage cylinders. 5188

3.5.5 Personnel regularly assigned to projects involving frequent use of fluorine must have periodic chest X-ray, pelvic X-ray, urinalysis, blood tests, and examination by doctor.

3.5.6 If any employee is exposed to fluorine fumes of such a concentration that watering of the eyes or irritation of the mucous membrane occurs, special lab tests and urinalysis shall be made as soon as possible. All areas using fluorine shall have a supply of large urine sample bottles and all urine voided for 36 hours after exposure shall be kept in these sample bottles. These bottles should be well marked with the user's name and will be used for his analysis. At the earliest possible time after the exposure, lab tests and a physical examination shall be given to all those exposed.

SECTION 4 - PROPELLANT SYSTEMS (FUELS)

The fuels used in rocket engines are all highly flammable and easily ignited. In addition, many of the fuels are also toxic or irritating to the skin and mucous membrane so that it is mandatory to avoid inhalation of the vapors or contamination of the clothing. In the case of fuels which ignite spontaneously on contact with certain oxidizers, handling and storage should be carried out in such a way as to eliminate any chance for the fuel and oxidizer to mix.

In this section, the several different fuels that are, or may be used at the Rocket Laboratory and South 40 are described with respect to their general properties, hazards, necessary handling precautions, and storage requirements. In addition, schematic drawings of typical propellant systems now used at the laboratory and descriptions of recommended components are included. Handling and storage procedures, and propellant systems shown are to be used as guides only. Individual installations will frequently require deviations from the systems shown; close adherence to the systems shown does not eliminate the necessity for safety committee approval of proposed propellant systems. In any case, know the materials you are handling, the capabilities of the equipment, and the situations that will or may arise.

Additional detailed information on rocket fuels and oxidizers may be found in the rocket propellant handbook prepared by Battelle Memorial Institute.

4.1 Non-Aromatic Hydrocarbons

4.1.1 General Properties: Hydrocarbons include gasoline, JP-4, JP-5, and kerosene. Gasoline is a clear, water-white, volatile liquid composed of a mixture of hydrocarbons. It has a freezing point of lower than -40° Fahrenheit, boils at approximately 280° F, and has a flash point of approximately 0° F (closed-cup test). JP-4 has a higher average boiling point and is equivalent to a mixture of gasoline and kerosene. JP-5 has volatility characteristics similar to that of kerosene. The hydrocarbon mixtures vary considerably in characteristics, depending upon the nature of the crude oil from which they are processed and the nature of the process of preparation. Other hydrocarbons such as heptane, octane, methylcychohexane, etc., are similar to gasoline and are to be handled in the same way.

4.1.2 Hazards: The principal hazard with regard to hydrocarbons is their high degree of flammability. Personal contact with hydrocarbons or their fumes is generally harmless; however, prolonged breathing of fumes or excessive contact with the skin may be injurious. This is especially true of leaded gasoline.

4.1.3 Handling precautions: Prior to bringing hydrocarbon fuels into an area for handling, as in the loading of a rocket, "No Smoking" signs shall be displayed in conspicuous places. These signs shall be retained throughout the handling operation. No open flames or spark-causing devices shall be allowed in the working area. Hydrocarbon vapors dissipate slowly from low or confined places and may be ignited by a spark at a considerable distance from their source and cause an explosion at the point where the vapor originated. It is therefore desirable to ventilate the work place well to prevent collections of vapor.

Metal containers, rather than glass, should be used in the handling procedure to eliminate the possibility of breakage. All containers should be labeled or painted with appropriate color.

Pouring hydrocarbons from one container to another shall be carried out with the two containers grounded to prevent the accumulation of static electricity and the resulting possibility of a spark. During a transfer process involving the pumping of hydrocarbons, a ground attached to the tank being emptied will remove the static electricity hazard. All transfer processes and handling procedures must be carried out with adequate fire extinguishing equipment at hand.

Hydrocarbon-soaked clothing shall be removed immediately to reduce fire hazard and eliminate possible skin irritation.

4.1.4 Storage: Large amounts of hydrocarbons are best stored in underground tanks. Small amounts shall be placed in well-marked containers which are stored in either an approved fuel storage building, in fireproofed rooms, or in fireproof cabinets.

4.1.5 Typical Rocket System: Figure 2 shows a typical hydrocarbon propellant system and recommended valve types. Systems for hydrocarbons shall be cleaned of all greases and foreign particles so that contamination of the fuel or blockage of the injector will not occur. Any hydrocarbon systems that exhaust the products of combustion of the rocket into a scrubber or muffler must follow the instructions on muffler inerting (section 3.3.5).

4.2 Ammonia (NH_3)

4.2.1 General Properties: Ammonia is a colorless gas at standard conditions and has a strong suffocating odor. Its critical temperature is 269° F, hence it is easily liquefied by pressurization to about 150 psi when at normal temperatures. Liquid ammonia is colorless and boils at -27° F. It is extremely soluble in water and unites with it to form ammonium hydroxide.

4.2.2 Hazards: Ammonia forms explosive or flammable mixtures with air. "No Smoking" signs shall be up when this material is being transferred or when a rocket tank contains ammonia. No sparks or flames shall be permitted, and good ventilation shall be provided.

The fumes are somewhat poisonous but so obnoxious that a very small fraction of the lethal concentration is immediately apparent. The odor of ammonia is very strong and serves as a warning of the presence of the fumes. Gas masks equipped with the green ammonia canister shall be readily available. The ammonia canister shall be destroyed after use. All masks shall be equipped with unused canisters before they are put away. The tape on the bottom of the canister should not be removed until the mask is required. This type mask may be used where the concentration of ammonia is not too high. For high concentrations the fumes penetrate this mask and a Scott Air Pak or equivalent must be used. The liquid on the skin will cause burns. Personnel handling ammonia shall be fully clothed and shall wear rubber gloves and face shields (when masks are not required).

4.2.3 Storage and Handling: Ammonia is stored as a liquid under pressure. Transfer of the material must be made in a closed system which will stand pressure up to 500 psi. Care must be taken not to trap the liquid in a line between two valves. Make sure packing nuts on valves and fittings are tight before opening cylinder valve. Spilled liquids must be flushed with copious quantities of water. Materials made of, or plated with copper, brass, zinc, aluminum, cadmium, are not to be used with ammonia.

5188 4.2.4 Typical Rocket System: Figure 3 shows a typical ammonia propellant system and recommended valve types. Since ammonia is extremely soluble in water any systems that exhaust into a muffler or scrubber will comply with regulations.

4.3 Hydrazine (N_2H_4), Hydrazine Hydrate, and Alkyl Hydrazines

4.3.1 General properties: Hydrazine is a colorless fuming liquid at standard conditions having a negative heat of formation. The boiling point of hydrazine is 113.5° C (236.3° F), freezing point is 1.4° C (34.5° F), and vapor pressure at 56° C (132.8° F), 1.366 pounds per square inch.

4.3.2 Explosive Hazards: Hydrazine vapors in air can form a highly explosive atmosphere. Hydrazine is sensitive to temperature, and will decompose if heated in a closed system. Hydrazine is sensitive to the detonation produced by the discharge of a number 6 electric detonator cap; however, since liquid hydrazine will not propagate a detonation wave, it is believed that the hydrazine vapor rather than the liquid is sensitive to detonation.

4.3.3 Health Hazards: Hydrazine has a toxic effect on the formed elements of blood, probably exerting its effect on the red corpuscles. In addition, hydrazine produces severe liver damage with fatty degeneration, death of live tissue and lack of growth. Recent evidence indicates that the inhalation of hydrazine vapor is not to be classed among substances which are dangerously toxic during short exposure. The inhalation of small quantities of hydrazine vapor causes a slight transitory dizziness and nausea. The effect of hydrazine vapor on the eyes is extremely disagreeable, becoming noticeable a few hours after exposure. The eyes begin to itch and finally become completely swollen, showing the symptoms of conjunctivitis.

In recent experiments on laboratory animals, when anhydrous hydrazine was placed on the skin and allowed to remain for periods as short as 1 minute, the animals all died within periods ranging from 1 to 2 hours.

4.3.4 Storage and Handling: Hydrazine may be transported and stored in a manner similar to that used for acids. In addition, hydrazine may be stored and handled in stainless steel equipment. Materials made of, or plated with copper, brass, zinc, aluminum, cadmium, are not to be used with N_2H_4. Personnel shall wear goggles and respirator or gas masks with a filter designed for an ammonia atmosphere when dealing with large quantities of hydrazine. Personnel shall wear gloves and be fully clothed. All personnel working with hydrazine shall wash thoroughly with water.

4.3.5 Typical Rocket System: Figure 4 shows a typical hydrazine propellant system and recommended valve types.

4.4 Alcohol (Ethyl)

4.4.1 General Properties: Ethyl alcohol (grain alcohol) is a colorless, inflammable, volatile liquid with an intense characteristic odor. It has a freezing point of -174° F and a boiling point of 173° F. Flash point is 57° F.

4.4.2 Hazards: If proper ventilation is maintained, ethyl alcohol is relatively innocuous, but prolonged exposures to too high a concentration may produce irritation of the mucous membrane, irritation of the upper respiratory tract, headache, nervousness, dizziness, tremors, fatigue, and narcosis. Inhalation can reduce the power of concentration and alertness and thus lead to accidents. An additional hazard is the flammable nature of the material.

4.4.3 Handling Precautions: "No Smoking" signs shall be conspicuously located throughout the working area. All electrical devices which might cause sparking and all open flames must be eliminated while handling alcohol. The area must be well ventilated and a respirator shall be worn when exposure time is to be longer than 15 minutes. The possibility of sparking from static electricity must be eliminated by contact between containers when pouring from one to the other and providing a ground to a tank being pumped empty. Have proper fire extinguishing equipment readily at hand.

4.4.4 Storage: Refer to Hydrocarbon Storage

4.4.5 Other Alcohols: Alcohols such as butyl, isopropyl, and methyl are also flammable and shall be handled in the same way as ethyl alcohol. Methyl alcohol is considerably more volatile and extremely poisonous and respirators shall be worn at all times when handling this alcohol. Furfuryl alcohol is not as volatile as ethyl, but is poisonous and flammable, and must be handled like methyl alcohol. Acetone may be regarded as an extremely volatile and flammable alcohol.

4.4.6 Typical Rocket System: The rocket propellant system is basically the same as that for hydrocarbons (fig. 2).

4.5 Aromatic Amines (Aniline)

4.5.1 General Properties: Aromatic amines include toluidines, xylidines, diallylaniline as well as aniline. Aniline (aniline oil, phenylamine, aminobenzene) is a colorless, oily, volatile, flammable liquid. It has an aromatic odor. Its flash point varies from 79° to 183° F. On exposure to the air it gradually turns brown. The freezing point is 21° F. It is readily absorbed by the unbroken skin and mucous memberanes. Poisoning by absorption may occur when the liquid is spilled upon the clothing, by inhalation of the fumes, and by swallowing the liquid mixed with dust and saliva or food.

4.5.2 Hazard: The principal hazard in aniline is that of poisoning by absorption of the liquid or fumes through the skin, the nose, or the mouth. The symptoms of poisoning: Pallor followed by blueness, especially of lips and finger tips, somnolence, irritability, mental confusion, headache, nausea, vomiting, unsteady gait, weakness, muscular tremor and convulsions, anemia, weak pulse, visual disturbances, brownish discoloration of the blood and urine.

4.5.3 Handling Precautions: When aniline is being handled as in the case of transferring it to tanks for rocket tests, personnel shall be fully protected by proper clothing. A complete outfit of rubber or synthetic rubber shall be used. This consists of gloves, coat, overalls, rubber boots and some form of head coverage. A complete gas mask shall be used and the selection of this protection shall be made with thought to good vision and incorporating proper protection for the head and face. Small quantities may be handled in well-ventilated places with the face protected by a shield. Cartridges for the gas mask should be changed at the faintest suspicion of aniline fumes.

A well-organized system shall be used in loading aniline for rocket tests. A team of two men is required. One man is used to carry on the preparations for loading. The placement of storage tanks, scales, and pressurizing equipment, and the line connections should be made by this man. This allows the second man to be fully clothed with protective clothing without necessitating work which would result in sweating and discomfort. The first man of the team after completing the preparations stays out of the range of fumes and in a position where he is safe from splash. He should be clothed in such a way that he can assist the second man in case of accident. This requires a minimum of a rubber apron and gloves and a gas mask should be handy for use. It is the duty of this man to oversee the loading operation and keep a constant check on the procedure. This man also should have a hose with water running handy to use. If aniline is spilled, quick dilution with water is desired. A 3 percent solution of acetic acid is kept readily available at the loading. Acetic solution is used in any case where the operator comes in contact with aniline.

Any person addicted to alcoholic liquors is especially sensitive to aniline poisoning and should not be used for handling aniline.

Aniline storage shall be treated exactly the same as the storage of any other flammable fluid. It must never be near nitric acid storage. 5188 Aniline shall be kept on a well-curbed platform with a drainage sump so that in cases of fire or explosions there will be no chance of liquids being splashed.

Loading lines, fittings, etc., shall be clearly marked so that there can be no chance of confusing them with those used for other propellants. They shall be thoroughly flushed with water after use. Saran tubing has been found convenient for use as aniline loading lines. They should be inspected each time before use to make sure that they are undamaged and the saran is not brittle. Aniline causes a brown discoloration of the saran. Lines should be replaced after about ten uses or two months as a general precaution.

4.5.4 Other Aromatic Compounds: Compounds such as monoethyl aniline, toluidine, xylidine, and also benzene, toluene, and xylenes shall be handled in the same way as aniline. Benzine is a nonaromatic hydrocarbon and shall be treated accordingly. It is much more volatile and has a much lower flashpoint than gasoline.

4.5.5 Typical Rocket System: Aromatic amines are not used at the Rocket Laboratory (or S-40) at the present time.

4.6 Hydrogen (H_2)

4.6.1 General Properties: Liquid hydrogen is a transparent, colorless, odorless liquid that boils at -422.9° F at one atmosphere pressure. Its critical temperature is -399.8° F, so that it cannot be maintained in the liquid state at temperatures higher than this no matter how high the pressure. The density of the liquid is 4.37 pounds per cubic foot at the normal boiling point (density of water at 32° F is approximately 62.4 pounds per cubic foot).

4.6.2 Hazards: The hazards are fires, explosions, and resulting burns, and burns caused by contact of the liquid with the skin.

Liquid hydrogen is not especially reactive and is stable against detonation and mechanical shock. It is apparently nontoxic.

Gaseous hydrogen is highly inflammable and forms explosive mixtures in air over a range of compositions from 4.1 percent to 74.2 percent by volume. In oxygen, the explosive limits are 4.6 percent to 93.9 percent. Liquid hydrogen ignites spontaneously with liquid fluorine.

If spilled on the skin, liquid hydrogen will benave much like liquid oxygen or nitrogen (see Section 5). It should be expected that the burns due to trapping of the liquid by watchbands, rings, etc., will be more severe because of the much lower temperature of the liquid as compared with liquid oxygen or nitrogen.

Liquid hydrogen is cold enough to freeze air or oxygen; the mixture of hydrogen and solid air or oxygen is extremely sensitive to mechanical shock and constitutes a detonation hazard. The effect of contamination of hydrogen by organic materials is generally insignificant, i.e., no danger from fire or explosion results from the presence of organic material in hydrogen.

4.6.3 Treatment

4.6.3.1 Fires or Burns on Skin or Clothing. - Flood with water. Treat burns according to general procedure for such wounds and remove patient to dispensary or doctor.

4.6.3.2 Liquid Hydrogen in Eyes. - Flood with water. Apply opthalmic ointment. Call or remove to doctor or dispensary without delay.

4.6.4 Handling Precautions

4.6.4.1 Necessary safety clothing includes face shield and asbestos gloves.

4.6.4.2 No matches, smoking, or open lights shall be allowed in the vicinity of the liquefier area or within fifty (50) feet of a loaded container.

4.6.4.3 Containers shall be grounded before entering the liquefier area and maintained in a grounded condition while therein. Containers shall also be grounded before being connected at the test cell and maintained in a grounded condition while so connected.

4.6.4.4 All lines, valves, fittings, and tanks shall be cleaned and dried before being contacted by liquid hydrogen. Best lubricant for valves and fittings is graphite.

4.6.4.5 Containers shall be evacuated or purged with helium or hydrogen.

4.6.4.6 Containers and work areas shall be adequately vented in such a way that hydrogen gas cannot collect to form an explosive mixture.

4.6.4.7 Storage:-

Use only specially designed, cleaned and approved containers.

Store only in designated areas and vent containers so as to prevent accumulation of gaseous hydrogen.

Stationary equipment in the liquefier area shall be grounded at all times.

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4.6.5 Typical Rocket System

A typical gaseous hydrogen propellant system, together with descriptions of recommended valve types, is shown in figure 5. Similar information for a liquid hydrogen propellant system is shown in figure 6.

4.6.5.1 Permissible materials of construction for liquid hydrogen propellant systems include aluminum, copper, monel, inconel, austenitic stainless steels (types 304, 308, 316, 321, and 347) and brass or bronze.

4.6.5.2 With either gaseous or liquid hydrogen systems, avoiding the formation of a flammable fuel-air mixture is of primary concern. Hydrogen vents shall be located at least 20 feet above the roof peak. An inert gas shall be used to inert the vent stack. A check valve at the exit end may be used to keep out rain and also reduce the amount of inert purge gas used. High pressure hydrogen vented rapidly can become ignited from static discharges. If possible, a low rate of depressurization should be used. Exhaust mufflers used with hydrogen must be inerted in the manner described in section 3.3.8.2.

4.6.5.3 Wherever possible, propellant tank discharge should be through dip tubes rather than bottom outlets to avoid dumping the entire contents in case of leaks in the discharge system.

4.6.5.4 Rapid charging of hydrogen into an air-filled flow line can result in an explosion. Flow lines to be charged with hydrogen shall be pre-purged with an inert gas or low pressure hydrogen.

4.6.5.5 The amount of hydrogen piping, valves, etc., located within the test cell shall be minimized. Rooms containing hydrogen systems shall be designed to vent well and allow no pockets of hydrogen to accumulate. A combustible gas detector system must be used continuously to sample the the cell area for hydrogen.

4.6.5.6 Wherever possible, electrical equipment installed within and around the test cell should conform to Class 1, Division 1, Group B fixtures, or should be pressurized with an inert gas. Since availability of Group B fixtures is very limited, and pressurizing may not be feasible, it may be necessary to compromise this requirement in some instances.

Particular attention should be given to lighting fixtures, switches, and motors. In all cases Safety Committee approval of the electrical equipment is required.

4.6.5.7 No open flames shall be allowed within or around the test cell.

4.7 Alkyl Thiophosphites

4.7.1 General Properties: - Alkyl thiophosphites have the general formula: $(RS)_3P$. This discussion will be restricted to triethyltrithiophosphite (TETP) and trimethyltrithiophosphite (TMTP). At 1-2 mm pressure, TETP has a boiling point of approximately 197° F, while TMTP has a boiling point of approximately 196° F. The freezing points are approximately -85° and -72° F respectively. Densities of the materials at 75° F are 69 pounds per cubic foot and 77.1 pounds per cubic foot, respectively. Both materials have very disagreeable odors, similar to those of mercaptans.

4.7.2 Hazards: - The hazards are fires resulting from ignition of vapors in air and from spontaneous ignition with nitric acid, and toxic effects accompanying oral or intravenous intake of these materials.

Breathing of air saturated with thiophosphites (about 20 ppm) has no apparent toxic effect. Higher concentrations (200 ppm) may be toxic with prolonged exposure.

Contact of thiophosphites with the skin can result in absorption of toxic quantities into the blood stream. Such contact can also result in loss of hair.

4.7.3 Treatment:-

Treat burns resulting from fires according to general procedures and remove to dispensary.

When the liquid has splashed into the eyes, flood with water and remove to doctor or dispensary.

For ocular, oral, or intravenous intake of thiophosphites, neosynephrine appears to be an antidote and this fact should be brought to the attention of the doctor (see Occupational and Environmental Health Information Letter No. 4, Headquarters, Air Materiel Command, W-PAFB, Ohio, Office of the Surgeon, August 27, 1953.

4.7.4 Handling:-

Necessary safety clothing including face shield or goggles, covering for hands and arms, and protective covering of the head.

Thiophosphites should be handled only in well-ventilated areas and never under conditions where contact with nitric acid is possible.

No matches, smoking, or open lights are permissible in areas where thiphosphites are being transferred or stored. 5188

When thiophosphites are being transferred in an open system, running water shall be available to flood any spillage on personnel.

4.7.5 Storage:

Store in closed containers in well-ventilated areas.

No matches, smoking, or open light shall be allowed in storage areas.

Permissible construction materials are carbon steel, stainless steel, aluminum alloys, Kel-F, and Teflon. Fluorolube S appears to be the best lubricant.

Phospholanes (e.g., 4 methyl- 3 dimethylamino- 1,3,2-dioxaphospholane, RF-208) have properties similar to those of the thiophosphites and should be handled in the same manner; however, they appear to be less toxic than the thiophosphites.

4.7.6 Typical Rocket System: - There are no alkyl thiophosphite propellant systems at the Rocket Laboratory at the present time.

SECTION V - PROPELLANT SYSTEMS (OXIDANTS)

In this section the several different oxidants that are or may be used at the Rocket Laboratory and South 40 are described with respect to their general properties, hazards, necessary handling precautions, and storage requirements. In addition, schematic drawings of typical oxidant systems and descriptions of recommended components are included. These are to be used as guides only. Individual installations will require deviations from the systems shown; these are to be approved by the safety committee. Close adherence to the systems shown does not eliminate the necessity for safety committee approval of proposed propellant systems.

5.1 Liquid Oxygen

5.1.1 General Properties: - Liquid oxygen (O_2) is a clear, slightly bluish liquid that boils at -297° F (-183° C) at atmospheric pressure.

Its critical temperature is -182° F (-118.8° C), which means that it cannot be kept liquid by pressurization above this temperature. Because pressurized storage at the very low temperatures of liquid oxygen could be dangerous if the refrigeration failed, liquid oxygen is usually stored in Dewar flasks at atmospheric pressure and allowed to boil slowly. The vaporization of part of the liquid oxygen takes heat away from the remaining oxygen and offsets the heat gain into the Dewar flask. Loss of the liquid generally amounts to 2 percent to 5 percent per day. The density of liquid oxygen, which varies greatly with temperature, is 1.143 at the atmospheric boiling temperature (-297° F).

The use of liquid oxygen as a coolant should be avoided. Liquid nitrogen is less dangerous for cooling in such a temperature range.

5.1.2 Hazards: The hazards are fires, explosions, and resulting burns, and burns resulting from contact of the liquid on the skin.

Liquid oxygen is non-toxic but is dangerous because of its very low temperature and because it reacts with (often explodes with) most oxidizable materials particularly organic materials, such as oil, clothing, etc.

Liquid oxygen if spilled on the skin will glance off like water on a hot iron. If it is held in contact with the skin by a watchband, ring, etc., however, it can almost instantly cause a severe "burn" by freezing the flesh. Any metal which has been in contact with liquid oxygen and which is brought in contact with the skin will likewise freeze the flesh and may necessitate tearing skin and flesh away to loose oneself from the metal.

The constant boiling off of liquid oxygen causes an oxygen-enriched atmosphere in the vicinity of the vent. Several workmen have been crisped like a wiener in a charcoal fire when their clothing, which was saturated by gaseous oxygen from such a vent or from an unlit oxygen torch, was ignited.

Liquid oxygen in contact with any carbonaceous or organic materials (clothes, wood, paper, pencils, oil, grease, dirty pipe, etc.) will burn violently or may explode; although such mixtures are seldom self-igniting. A mixture of oxygen with oils, grease, or other combustibles may explode from a variety of causes such as sparks, electrostatic charges, friction, etc.

A mixture of liquid oxygen and carbon black is fourteen times more sensitive to detonation than dynamite. Because of violent boiling that occurs whenever liquid oxygen hits a warm surface, it is desirable to transfer it in a system that is entirely enclosed except for vents. In filling a warm tank, large quantities of (gaseous) oxygen are boiled off, hence the tank should have vents with 3-4 times the area of the filler lines. Frequently one-third to one-half of the tank capacity is boiled off in cooling the tank. The operator should have face protection and gloves to avoid frostbite from the cold lines and fittings.

5.1.3 Treatment: 5188

Fires or Burns on Skins or Clothing. - Flood with water. Treat burns according to general procedure for burns. Remove to dispensary or doctor.

Liquid Oxygen in Eyes. - Flood with water. Apply opthalmic ointment. Call or remove to doctor or dispensary without delay.

5.1.4 Handling Precautions:

5.1.4.1 Necessary safety clothing includes face shield and asbestos gloves.

5.1.4.2 All lines, valves, fittings, and tanks shall be carefully cleansed to remove all traces of oil and grease before being brought in contact with liquid oxygen. Cleaning is best accomplished by soaking in hot caustic (lye) solution, but small parts may be cleaned in carbon tetrachloride.

5.1.4.3 Best lubricant for valves and fittings is graphite. Even the noninflammable silicone oils and greases form explosive mixtures with liquid oxygen. Dry or water-base molybdenum disulfide may be used or AN-C-86 Anti-Seize and Sealing Compound.

5.1.4.4 Pour slowly when filling containers to avoid "bumping" and spilling out the filler pipe. Containers may be precooled with liquid nitrogen.

5.1.4.5 Keep containers adequately vented.

5.1.4.6 Operators should avoid standing near vents.

5.1.4.7 Carbon steels and many nonferrous alloys become extremely brittle at low temperatures and cannot be used for handling liquid oxygen. Permissible materials for use are aluminum, copper, monel, inconel, stainless steel numbers 304, 308, 316, 321, 347, and brass in heavy fittings not highly stressed. In general, the purer metals are most satisfactory.

5.1.5 Storage:

Use only specially designed, cleaned, and approved containers.

Keep containers vented.

Keep away from all sparks, flames, and other ignition sources. There shall be no oil grease, or other combustible material or fumes present.

5.1.6 Typical Rocket System: Figure 7 shows a typical liquid oxygen system and recommended valve types.

5.2 Nitric Acid Oxidants

5.2.1 General Properties: The following acids are used as oxidants for rocket engines:

1. White fuming nitric acid (HNO_3) which is the strongest commercial nitric acid and contains about 95 percent nitric acid plus 5 percent water. Commonly abbreviated WFNA.

2. Red fuming nitric acid which consists of commercial nitric acid with from 5 to 15 percent nitrogen dioxide (NO_2) dissolved in it. The nitrogen dioxide gives it the brownish color and causes it to fume copiously. Commonly abbreviated RFNA.

3. Mixed acid which consists of white fuming nitric acid plus about 2 to 17 percent fuming sulfuric acid.

These acids are liquid at normal conditions, have specific gravities around 1.5 and freeze about -40° F. The white fuming nitric and mixed acids are nearly colorless. All mix with water but with evolution of considerable heat which may cause spattering.

5.2.2 Hazards: Chief hazard with all the acids is from burns caused by direct contact with the skin or with the lung mucous membrane caused by breathing. The red fuming nitric acid is the most hazardous as it is the fastest acting and gives off copious fumes. Symptoms of internal burns are irritation of breathing passages, spasmodic cough, bronchitis, feeling of suffocation, pain in chest, digestive disturbance, possible faintness or fainting, corrosion of teeth.

All acids are very corrosive and will readily attack metals and will ignite spontaneously with many oxidizable materials. Certain metals (nickel, aluminum) form a passive oxide coat when subjected to concentrated acid attack. This coat resists further action of the acid on the metal. Copper alloys, however, are quickly consumed by acids.

5.2.3 Treatment:

5.2.3.1. General Procedure. - Remove to fresh air, treat for shock (warmth, rest, head down) and if patient is not breathing, apply artificial respiration.

5.2.3.2. Acid on Skin or Clothing. - Flood with water. Remove clothing if soaked with acid and neutralize with saturated sodium bicarbonate solution. If burned, treat as ordinary burn. Remove to dispensary or summon nurse.

5.2.3.3. Acid in Eyes. - Flood with water immediately or wash the eye with 2 percent sodium bicarbonate, whichever can be reached first. Remove to dispensary or summon doctor or nurse.

5.2.3.4. Acid Fumes Breathed. - Follow general procedure.

5.2.4 Handling Precautions

5.2.4.1 Protective clothing consists of a rubber of vinylite suit, gloves, and boots. A gas mask or respirator and face shield shall always be worn with red fuming nitric acid. A respirator and face shield shall be worn when handling large quantities of white fuming nitric. Small quantities of white fuming nitric acid or mixed acid may be handled with the face protected by a shield. Small quantities can be defined as quantities of 1 liter or less. Remember that all acids liberate poisonous NO_2 fumes when diluted with water. In washing down spillage provide adequate face and respiratory protection. Stay out of NO_2 fumes. Keep gas masks available when handling acids for emergencies. All rubber clothing, tools, and other equipment shall be flushed with water after using. Gas masks shall be cleaned with alcohol.

5.2.4.2 Acids shall be transferred through a closed system by slight pressurization or by siphons.

5.2.4.3 Safety showers are required near handling and storage areas. In addition, handling stations shall be equipped with a saturated solution of sodium bicarbonate, together with a 2 percent solution for treatment of eye splashing.

5.2.4.4 Acid plumbing systems in test cells shall have a test section which is to be inspected for corrosion every three (3) months and pressure checked hydraulically. When the calculated working pressure of the test section is equal to, or less than the working pressure of the test cell or when the test section fails hydraulically, the plumbing shall be replaced. Test section working pressure shall be calculated by the formula:

$$P = \frac{2\ St}{D}$$

where P = working pressure, psi

S = working stress, psi

5188 t = wall thickness, inches

D = inside tube diameter, inches

Values of S shall be taken from the following table:

Material	Working Stress, psi	
	Static loading	Shock loading
347 SS	18,200	9,100
304 SS	15,940	7,970
Inconel	16,000	8,000
2SO Aluminum	1,836	918

If personnel are inside the test cell while flow valves are being actuated, use the shock loading stresses; otherwise, use the static loading stresses. It is also recommended that acid plumbing systems be constructed with heavy walled tubing or pipe.

5.2.4.5 Materials of construction include aluminum, stainless steel, and glass. Kel-F, Teflon, and aluminum may be used for gaskets, and permissible lubricants include Fluorolube GR greases, graphite, and molybdenum disulfide (preferably in water base).

5.2.5 Storage:

Store acids away from fuels or other oxidants.

Storage drums are generally stainless steel or aluminum. Mild steel has been used for concentrated mixed acids.

Mixed acids stored for considerable time will form a sludge.

Follow suppliers instructions for storing and periodic pressure relieving of tanks. (Use safety clothing and gas masks).

5.2.6 Typical Rocket System

Figure 8 shows details of a typical nitric acid propellant system, together with recommended valve type.

5.3 Fluorine and Chlorine Trifluoride

5.3.1 General Properties: Fluorine (F_2) is a greenish yellow gas which can be liquefied by sufficient cooling to a yellow liquid. The liquid boils at -304° F and freezes at -369° F (-223° C). A characteristic unpleasant odor can be detected when fluorine is present in concentrations of one to three parts per million. 5188

Most organic materials ignite violently on contact with fluorine. Fluorine reacts violently with water, most solvents, and even with 95 percent sulfuric acid. Steel will burn in fluorine gas when heated. Certain metals such as copper, nickel, monel, aluminum, magnesium, and iron form protective fluoride coats which protect the metal from further attack. Under flow conditions this protective coating may be removed. Asbestos and rubber articles may burn with fluorine.

5.3.2 Hazards: Fluorine will react violently with most oxidizable materials with evolution of great amounts of heat. It has toxic effects when in contact with the skin or any external part of the body, or when inhaled. Many of its reaction products (particularly hydrofluoric acid, which is formed by the reaction of fluorine and water) are likewise poisonous.

Fluorine can be detected by its odor at concentrations as low as 1 ppm. Personnel should not remain in an area where fluorine odor is noticeable. It is immediately irritating at concentrations of 25 ppm. It is very toxic and also intolerable even for short exposure in concentrations of 50 ppm.

Fluorine jets striking the body will cause severe burns that are difficult to heal. The tissue destruction is a result of three factors:

a) Destructive oxidation by the fluorine itself.
b) Thermal damage from the heat of oxidation
c) Tissue poisoning by the hydrofluoric acid formed.

Hydrofluoric acid is a poison with great penetrating power and results in deep burns that heal with difficulty. As a respiratory irritant, fluorine has a toxicity approximately that of phosgene.

No worker with doubtful chest X-ray or suffering from asthma or other pulmonary complaint, or from cardiovascular disease, should be employed in operations where exposure to fluorine compounds of the acid or acid-forming variety is involved.

5.3.3 Treatment: A fluorine burn on the skin should be treated as a combination of chemical and thermal burn. After contact with the skin there is a latent period varying with the degrees of exposure. If the exposure is slight, several hours may elapse before the patient is conscious of pain or injury. The lesion first becomes reddened, then swollen and pale with a macerated appearance, which is accompanied by a severe throbbing pain. Adequate treatment will usually stop pathological changes at this stage; if not, necrosis and ulceration will ensue.

Treatment of the burn is specific and highly efficient. It should be instituted immediately, even in cases of questionable severity. Skin should be flushed with copious amounts of water for 15 minutes. If a physician considers that the burn is mild, a water base paste of magnesium hydroxide is then applied. If there is a slight chance of more serious burn, the tissue below and around the affected area should be infiltrated with 10 percent calcium gluconate. This precipitates the fluorine as inert calcium fluoride. The injection is painless but may be preceded by procaine infiltration.

Fluorine in eyes requires copious and prolonged irrigation with water. Following this, the eye should be irrigated with 3 percent boric acid solution. Subsequent treatment should be directed by an opthalmologist and consists of application of pontocaine to relieve pain, mydriatics, and the removal of any necrotic tissue in the cornea. Under no circumstances should ointments be applied either to eye or skin.

Any person inhaling fluorine gas should be removed from the area and placed under competent medical care immediately.

5.3.4 <u>Handling Precautions</u>:

5.3.4.1 Wear complete body clothing and face shield. Gas masks are not necessary, unless otherwise specified, for your nose will give you sufficient safe warning of a fluorine atmosphere, and you should not remain in such an atmosphere. If it is necessary to enter area contaminated with fluorine, an oxygen generating mask, air-bottle mask, or air-line mask must be worn.

5.3.4.2 Safety shower and safety equipment must be provided.

5.3.4.3 Keep area in which fluorine is to be used free of any oxidizable materials. Any spillage must be inerted to prevent contamination of surrounding areas.

5.3.4.4 Only equipment and materials designed and tested for fluorine service are permitted.

5.3.4.5 The materials for handling fluorine shall be cleaned according to the following procedure:

Fr cleaning

a) Degrease with carbon tetrachloride or other acceptable degreasing agent. (Note: Carbon tetrachloride fumes are toxic.)
b) Flush with acetone first
c) Rinse with clean water
d) Clean with hot caustic solution or nitric acid
e) Rinse with clean water
f) Flush with acetone
g) Purge and dry with helium
h) For tanks and completed flow systems to contain fluorine, evacuate for several hours and then passivate with gaseous fluorine; introduce the fluorine directly into the vacuum to obtain high fluorine concentration, then maintain the fluorine pressure at 50 psig for at least 12 hours.

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Not all of the above steps are required for all situations. It is important to note that carbon tetrachloride, as well as other chlorinated degreasing materials, can hydrolyze in the presence of water to form hydrochloric acid which may, in turn, react with materials in the system.

5.3.4.6 At present, the materials to be used with fluorine are nickel, monel, and copper, and stainless steels 304L or 304 in the order given. Stainless steel of type 347 should not be used.

5.3.4.7 Fluorine must be maintained in a liquid form by surrounding the fluorine tank with liquid nitrogen. Should the supply of the coolant suddenly disappear, the fluorine tank must be vented to the atmosphere to prevent the building of excessive pressures.

5.3.4.8 Wherever possible, propellant tank discharge should be through dip tubes rather than bottom outlets to avoid dumping the entire contents in case of leaks in the discharge system.

5.3.4.9 Fluorine gas must not be vented directly to the atmosphere in any appreciable quantities. A scrubber or carbon burner may be used to dispose of vented gas.

5.3.4.10 Oxygen-fluorine mixtures and chlorine trifluoride shall be treated like fluorine.

5.3.5 Fire-Fighting: The following steps are recommended for fighting fluorine fires:

1. Do nothing until the engineer in charge is sure that conditions permit action. Let the fire burn itself out if the fluorine hazard is such as to make fire fighting unusually dangerous.

2. Do not ventilate cell until fume, fire and explosion hazards are gone, in the opinion of the engineer in charge.

3. Fill cell with blanket of CO_2. This will not stop the burning of fluorine, which will continue to exhaustion, but it will serve to exclude oxygen.

4. Use foam on secondary fires, e.g., on the roof, after engineer in charge is satisfied that escaped fluorine has been exhausted.

5. If other attacks have failed use <u>large</u> quantities of water.

6. When engineer in charge considers conditions to be safe, the cell may be entered by two men, one a trained Plant Protection man and the other an experienced rocket man, who must wear air-bottle masks and rubber clothing. These men will ventilate the cell, observe conditions, and take any necessary action.

7. Because of the toxicity of fluorides, <u>no one</u> shall be permitted to enter the cell at any time without authorization of the engineer in charge until the entire cell has been washed down.

5.3.6 <u>Typical Rocket System</u>: Figure 9 shows a typical fluorine propellant system and recommended valve types.

5.4 Mixed Oxides of Nitrogen

5.4.1 <u>General Properties</u>: Mixed oxides of nitrogen (M.O.N.) as used for rocket oxidizer is a mixture of nitrogen dioxide (NO_2) and nitric oxide (NO). The proportions used in rocket propulsion are usually 70 percent NO_2 plus 30 percent NO. Pure NO_2 has a boiling point of 70° F and pure NO has a boiling point of -240° F. At 70° F, the mixture has a vapor pressure of about 100 psia, and will flash vaporize unless confined. Density of the 70-30 mixture is 85 pounds per cubic foot at 70° F.

5.4.2 <u>Hazards</u>: Hazards include toxic effects due to inhalation and burns of the skin and mucous membranes from acid formed by interaction of water and NO_2. Inhalation of NO_2 in sufficient quantity results in pulmonary edema, which is a blistering of the lungs followed by effusion of body waters. In acute cases, death by drowning results. The toxic effects of NO_2 are apparent only after a delay of 6 to 24 hours, so that aggravated exposure cases should be treated even though no poisoning symptoms are apparent immediately.

There is no agreement on the maximum allowable concentrations of NO_2 at the present time, but preliminary evidence indicates that for <u>continuous exposure</u>, a concentration of 5 ppm is the maximum allowable.

The toxicity of NO is very slight compared to NO_2. Large quantities can cause death by asphyxiation. In the presence of air, however, NO slowly is converted to NO_2, so that evolution of NO from mixtures of NO and NO_2 constitutes a hazard almost as great as evolution of NO_2. The following treatments are specified:

1. For asphyxiation due to NO, apply artificial respiration, following which remove to dispensary or doctor.

2. For inhalation of NO_2, keep the patient quiet and supply pure oxygen for breathing. Call a doctor immediately.

3. For splashing of NO_2 or mixed oxides on the skin, flush rapidly with large quantities of water and remove to dispensary or doctor. Injuries should be treated as acid burns. 5188

4. In general, accidents involving mixed oxides should be treated like those involving NO_2.

5.4.3 Handling Precautions:

Mixed oxides of nitrogen shall be handled in closed systems.

Transfer areas shall be well ventilated with a supply of running water near by.

"All purpose" gas masks for NO and NO_2 fumes shall be worn or be available in the event of leakage.

Use full protective clothing when a hazard exists.

Materials of construction include stainless steel, carbon steel (for anhydrous oxides only), aluminum, nickel, and inconel. Non-metallics which are suitable include teflon, Kel-F, and asbestos or graphite-asbestos composites.

5.4.4 Storage: Store in closed containers of I.C.C. or equal design in a well ventilated area.

5.4.5 Typical Rocket System: Figure 8 shows a typical M.O.N. propellant system, together with recommended valve types.

5.5 Ozone

5.5.1 General Properties: Ozone (O_3) is a bluish gas at normal temperature and pressure. Its normal boiling point is -170° F (-112° C) at which temperature it condenses to a dark blue liquid. At -183° F the density is 1.46. Both the liquid and gas are unstable and may explode violently. Dilution with an "inert" material like oxygen decreases the explosive tendency in proportion to the amount added. At temperatures below about -290° F, however, ozone-oxygen mixtures form two phases, one of which is rich in ozone. The ozone-rich phase will concentrate in the bottom of a propellant tank and hence will be the first material discharged through the propellant line, creating a very hazardous condition. The separation can be avoided by adding a third material such as Freon.

5188 Ozone has a pungent, irritating odor; it is smelled in the neighborhood of electric discharges in air.

5.5.2 Hazards: In addition to the explosive hazard and the hazards associated with the low temperature of the liquid, ozone is equivalent to fluorine in toxicity. The recommended maximum allowable concentration for continuous 8 hours exposure is 0.1 parts per million. Allowable concentrations for shorter exposures may be calculated on a concentration-time basis.

Two factors operate to alleviate the toxicity hazard: Ozone is detectable by smell at one-tenth the maximum allowable concentration for 8 hours (0.01 ppm) and exposure to low concentrations act to increase body tolerance to this material over a period of several weeks.

5.5.3 Treatment: The following treatments are prescribed:

1. "Burns" due to splashing of liquid on skin or in eyes should be treated like oxygen "burns".

2. Treatment for inhalation is the same as for fluorine, except that follow-up treatment for HF effect is, of course, not required. Remove the victim to an uncontaminated area, make him as comfortable as possible, and call a physician immediately. Oxygen should not be administered except on advice of a physician.

5.5.4 Handling Precautions and Storage:

5.5.4.1 Wear complete body clothing and face shield. Gas masks are not necessary unless otherwise specified since your nose will give you sufficient safe warning. When it is necessary to enter an area contaminated with ozone, an oxygen generating mask, air-bottle mask, or air-line mask must be worn.

5.5.4.2 Only properly cleaned equipment and materials designed for ozone service are permitted.

5.5.4.3 All ozone handling and generating equipment (including the oxygen supply system to the ozonator) shall be cleaned as follows:

a) Before assembly, degrease the parts in a fresh batch of solvent; avoid solvents which may leave a residue. leave a residue.

b) Soak or scrub with a fresh trisodium phosphate solution in distilled water.

c) Rinse thoroughly with oil-free distilled water.

d) Allow to dry in a dust-free atmosphere, or assemble wet and then dry with nitrogen from the central system or cylinder helium, or by evacuation. 5188

e) Surfaces to be in contact with ozone are not to be touched with hands or rubber gloves; if handling is necessary use lint-free, freshly-laundered gloves; tools shall be cleaned in the above manner.

f) If washing with trisodiumphosphite is not practical, one of the following procedures may be used:

(1) Evacuate the assembly and fill slowly with fluorine gas to a pressure of 10-30 pounds per square inch gage; allow to stand for at least 1/2 hour and then purge by pressurizing 5 or 6 times to 15-30 psig. with <u>filtered or purified</u> oxygen, nitrogen, or helium.

(2) Contact the assembly for several hours with ozone-oxygen gas from the ozonator while warming the assembly to about 100° F starting at the upstream end and proceeding downstream.

g) Glass equipment may be cleaned in chromic-sulfuric acid mixture and rinsed with freshly distilled water.

5.5.4.4 4. Operation and servicing of the large ozonator shall be done according to factory-furnished instructions. The high voltage leads shall be enclosed by shields which are at least 4 inches from the leads. The ozonator, transformer, and shields shall be well grounded, and the transformer primary circuit shall be locked open when the ozonator is not operating.

5.5.5 <u>Typical Rocket System</u>: The recommended ozone propellant system is basically similar to that for fluorine (figure 9). Material and valve type requirements are the same.

Systems for ozone-oxygen mixtures must be designed without dead ends where concentrated ozone can accumulate. Vent gases containing ozone shall be passed through a heater or catalyst bed such as specially treated alumina to decompose the ozone to oxygen. Stainless steel, teflon, and glass, are the suitable materials of construction. Silver solder may be used sparingly, but special care must be taken to remove all flux. Flared or swedgelock fittings shall be used when possible. Teflon gasketed flanged fittings are permitted and preferred over pipe connections. Pipe threads and other areas where galling can occur may be lubricated with Kel-F grease or a slurry of Teflon in distilled water. Avoid excess lubricant.

5.6 Hydrogen Peroxide (H_2O_2)

5.6.1 General Properties: Concentrated hydrogen peroxide is a water solution of hydrogen peroxide in concentrations from 52 to 100 percent. "Hi-test" peroxide, most frequently used in rocket application, contains 90 percent hydrogen peroxide. It is a clear, colorless liquid, slightly more viscous than water. If moderate decomposition is occurring, it will resemble soda water. Ninety percent hydrogen peroxide has a specific gravity of 1.39, boils at 286° F, freezes at 11° F (supercooling, however, frequently occurs), and has a vapor pressure at 70° F of about 0.05 psia. Hydrogen peroxide solutions contract on freezing and will not burst containers. It is soluble in all proportions with water, and with a large number of organic liquids that are also soluble in water, such as alcohol, actone, and glycols. It is not soluble in carbon tetrachloride, gasoline, or kerosene. With many organic liquids explosive mixtures are formed. Concentrated hydrogen peroxide solutions are weak acids.

Hydrogen peroxide decomposes to water and oxygen, liberating considerable heat. At concentrations above 67 percent, the products of decomposition are oxygen and steam. The rate of decomposition at 85° F is only about 1 percent per year. The rate approximately doubles for each 15° F temperature rise. Near the boiling temperature (286° F), the rate of decomposition is very rapid and explosion may occur in a confined container. Since the decomposition itself generates heat, a rise in temperature, accompanied by a further increase in decomposition rate occurs. This "self-heating" can cause runaway decomposition. Contamination of hydrogen peroxide also changes its decomposition rate, and runaway decomposition may occur. Many of the heavy metals are active decomposition catalysts. The initiation of decomposition by soil, cigarette ashes, rust, etc. is due largely to the presence of heavy metal catalysts. Concentrated peroxide decomposes readily on contact with many inorganic compounds such as potassium permanganate and ferrous sulfate. Silver-plated screens are used in high output peroxide gas generators for rocket engines.

5.6.2 Health Hazards: Hydrogen peroxide is a powerful oxidizing agent. Skin or eye contact, breathing, or swallowing of H_2O_2 are hazardous in the liquid, mist, and vapor phases. Contact with the skin produces a burning sensation and bleaching. Burns may result from prolonged exposure. A fine mist or aerosol can cause injury of a permanent nature to the eye. Inhalation of fumes causes irritation of the respiratory tract. Contact of vapors with the eye causes irritation, burning, and watering. The MAC is 1.0 ppm. Utmost speed is essential in removing H_2O_2 liquid in any exposure. Removal of any wetted clothing and washing skin or eyes with large quantities of water is required. Flushing of eyes with water should be continued for 15 minutes. In case of vapor in the air, get into fresh air at once. Treat skin burns as any other burns.

5.6.3 <u>Fire and Explosion Hazard</u>: H_2O_2 itself will not burn. Heat generated by its decomposition can, of course, ignite combustible materials in the immediate area. H_2O_2 will actively support combustion due to the liberation of oxygen. Fires involving H_2O_2 and jet fuel may explode, and so extreme caution is required. Explosions can result from mixing H_2O_2 with common fuels or organic solvents. Materials containing silver or iron rust cause immediate, rapid decomposition. In a closed vessel contaminated H_2O_2 may decompose so fast that the container vent will not handle the resulting gas, and the container may rupture.

5.6.4 <u>Handling Precautions</u>:

5.6.4.1 All combustible materials must be kept away from H_2O_2 areas. Confined areas must be ventilated. All spills must be flushed at once with large amounts of water.

5.6.4.2 Temperature of H_2O_2 must be kept well below 220° F at atmosphere pressures to prevent the formation of vapor in explosive concentrations.

5.6.4.3 Any peroxide that has become contaminated or shows an abnormal temperature rise must be promptly diluted with at least two parts of water and disposed.

5.6.4.4 Impermeable gloves and boots and face shield must be worn to protect the skin and eyes. Masks are not ordinarily required. Permeable clothing of dacron is normally satisfactory; for emergencies vinyl coveralls, apron, and hood may be added. The clothing must cover all parts of the operator's body.

5.6.4.5 <u>Passivation Procedure</u>:

(a) Disassemble and clean parts with trichoroethylene or equivalent. Fill tank, propellant system with same and let set for one-half hour.

(b) Drain and rinse with hot tap water.

(c) 300-Series stainless steel parts immersed in, or system filled with 70 percent nitric acid for 5 hours. This step should be preceded by a one-half hour immersion in 50 percent hydrochloric acid in cases where excessive weld scale or metal oxides may be present.

(d) Aluminum or aluminum alloy parts immersed in or filled with 1/15-normal sodium hydroxide solution and let stand for 20 minutes. (NOTE: Hydrogen gas is given off during this treatment - no smoking, open flames, or other ignition sources). Rinse with distilled or deionized water. Immerse or fill with 45 percent nitric acid and let stand for one hour.

(e) Rinse with distilled or deionized water and condition with 35 percent H_2O_2 for 1-3 days. Do not leave system unattended for first 8 hours. Drain.

(f) Condition with 90 percent H_2O_2 for 6 hours.

In all conditioning operations the parts should be carefully observed.
Many bubbles, or heat formation indicates excessive decomposition, and
the parts should be drained, washed, inspected, and retreated with acid.
Watch for discoloration of H_2O_2 (drained from system) caused by impuri-
5188 ties dissolved from stainless steel, or rust or other corrosion. If
rust is found, repeat the acid treatment.

5.6.5 Storage:

5.6.5.1 Pure hydrogen peroxide in properly passivated containers decomposes at a very slow rate. If stored in containers of unsuitable material, or if contaminated, it can decompose at a much more rapid rate.

5.6.5.2 Storage containers should be shielded from direct rays of the sun. Provisions for deluging the containers, and draining them into a body of water are necessary. Cleanliness is of utmost importance in the storage areas.

5.6.5.3 At least two trained operators are required for the handling, transfer, or storage of H_2O_2.

5.6.5.4 Do not return drained H_2O_2 to a storage container, but dilute and dispose of it.

5.6.5.5 Drums should not be tilted or rolled. Transfer H_2O_2 by siphoning or applying vacuum to receiver. Never apply pressure to drums. Empty drums should be flushed with clean water and drained.

5.6.5.6 Tanks for long-term storage are constructed of 1060 or 1260 aluminum (99.6 percent purity). Teflon and Kel-F are suitable for flexible long-term storage containers. 300-series stainless steels are suitable for short-term storage. Monel is not permitted. Bottom connections are not permitted on storage tanks.

5.6.5.7 Safety showers are required near handling and storage areas.

5.6.6 Typical Rocket System: Figure 10 shows a typical hydrogen peroxide propellant system. Prime concerns in a peroxide system are cleanliness and avoiding trapping peroxide between closed valves.

Only approved materials may be used in hydrogen peroxide systems. Piping of 1060 aluminum or of polyethylene may be used. Stainless

300-series may be used for short-term exposure. Monel is not permitted. Gaskets and seals may be polyethylene, certain silicone rubbers, some polyvinyl plastics, Kel-F, Teflon, pure tin, or aluminum. Wherever possible, contact between dissimilar materials should be avoided to prevent electrolytic action. Valve design should be such that peroxide is not trapped in any part of the valve. A Teflon disk must be used to prevent metal-to-metal contact of plug and seat. Pumps of 300-series stainless steel or aluminum alloy 43 or 356 are satisfactory. A chevron-type Teflon seal is recommended. Where packing glands are used, care must be taken to keep it clean and to avoid overheating from friction from too tight a gland. Mercury is an extremely active catalyst for H_2O_2 decomposition. Mercury thermometers must not be used to measure H_2O_2 temperatures. 5188

SECTION VI - NON-PROPELLANTS

6.1 Compressed Gases

6.1.1 Do not transport cylinders unless valve is covered with protective bonnet. Never handle cylinders roughly. Secure cylinders in an upright position with a chain, cable, or strap. Store cylinders in places where not subjected to physical damage and protect from direct summer sunlight.

6.1.2 Do not use leaky or damaged cylinders. Mark as defective and return. Fluorine cylinders in the above condition should not be returned. A member of the safety committee should be notified and he will arrange for disposal of the cylinder.

6.1.3 Never alter, repair, change, or take apart a valve or safety disk on a cylinder.

6.1.4 Do not use oil or grease on oxygen or fluorine cylinders, valves, or fittings.

6.1.5 Use proper regulator for each type of gas. Tag regulator to indicate its use.

6.1.6 Do not use a wrench to open a cylinder. If it can't be opened by hand, tag it as a bad valve and return it to receiving.

6.1.7 High pressure gas manifolds are to be constructed of heavy-walled tubing and are to be welded construction wherever possible. Where metal pigtails are used they are to be clamped so as to minimize stresses at the welds. Design and testing of gas manifolds shall be in accordance with specifications of report entitled "Design Specifications for Rocket Propellant Pressure Vessels" by W. G. Anderson, NACA, Lewis.

6.1.8 High-pressure gas manifolds are to be tested every ten years. A hydrostatic check at $1\frac{1}{2}$ times working pressure shall be made at this time. A metal tag as described in the above report should be attached to the manifold in a prominent place,

6.1.9 Pressurizing gas for propellants shall be of such a nature that it will not react with the propellant used. To fulfill this requirement, it has been prescribed that helium used for pressurizing fluorine shall be purified by passing through a drier packed with
5188 suitable dessicant. Dew point determinations of the dried gas shall be made periodically; if the dew point rises above -100° F the dessicant must be regenerated. Oil content of the helium should be reduced to an acceptable amount by the dessicant treatment; however, if an oil film is observed on the inside walls of any pipes in the system, further purifications must be made.

6.1.10 A remote control shut-off valve shall be installed on each gas tube trailer. Each group of gas tube trailers used for a specific gas shall have a different type of connecting fitting at its outlet point.

6.1.11 Where danger of contamination exists, an O-ring type check valve shall be installed on main pressurizing gas supply lines so as to prevent gas flow back.

6.1.12 Seats, seals, gaskets, and packing used in gaseous oxygen systems shall be of a material insensitive to impact in oxygen. It is suggested that Teflon or Kel-F be used for these purposes.

6.2 Liquid Nitrogen

6.2.1 General Properties: Liquid nitrogen (N_2) is a clear liquid with a boiling point of -320° F (-195.8° C) at atmospheric pressure, which is slightly lower than for liquid oxygen. Its critical temperature is sufficiently low that it is not practical to keep it liquid by pressurization. Like liquid oxygen it is stored in vented, insulated tanks. Its prime use is as a cooling agent.

6.2.2 Hazards: Principal hazard is from "burns" caused by freezing. It is harmless in other respects. Because liquid nitrogen is colder than liquid oxygen, a vessel containing liquid nitrogen will have a gradually increasing concentration of oxygen but tests by the General Electric Co. have indicated that this would not amount to more than about 5 percent in the time nitrogen would normally be stored. Repeated refilling of a part empty liquid nitrogen container might permit the oxygen concentration to build up to a dangerous concentration.

In case of "burns" (severe frostbite), treat as frostbite. Do not rub area. Remove to dispensary or to doctor immediately.

6.2.3 Handling Precautions:

6.2.3.1 Necessary safety clothing includes face shield and asbestos gloves.

6.2.3.2 All lines, valves, fittings, and tanks shall be clean. Cleaning may be accomplished by using any solvent or detergent, rinsing well, and then drying thoroughly.

6.2.3.3 Pour slowly when filling container. 5188

6.2.3.4 Containers shall have adequate venting but they should not be left fully exposed to the atmosphere. A cover with a vent pipe sized so that the internal pressure is kept slightly above atmospheric is required to prevent oxygen contamination.

6.2.3.5 Permissible materials for use with liquid nitrogen are aluminum, copper, monel, inconel, stainless steels numbers 304, 308, 316, 321, 347 and brass in heavy fittings not highly stressed. Pure metals are most satisfactory.

6.3 Refrigerant Chemicals

6.3.1 Dry ice (solid carbon dioxide) liberates carbon dioxide gas in storage, and while this is not a poisonous substance, asphyxiation can be caused by dilution of the oxygen in the air. Adequate ventilation of confined storage areas is required. Asphyxiation should be treated by artificial respiration.

6.3.2 Dry ice plus alcohol is a mixture of very low temperature which can cause freezing burns if splashed on skin or in the eyes. Ethyl alcohol shall be used in preference to methyl alcohol. When not in use, alcohol baths constitute a fire hazard (flash point: 55°- 60° F) and consequently ignition sources are not to be permitted in the vicinity of such a refrigeration bath.

6.3.3 Dry ice plus acetone shall be considered the same as dry ice plus alcohol. In this case, the flash point of the unrefrigerated liquid varies from -4° F to 15° F. Avoid inhalation of acetone vapors or prolonged contact with skin. Spillage of acetone or alcohol on the skin shall be flushed with water.

6.3.4 Methylene chloride is almost incombustible but its vapor is very poisonous. It is similar to carbon tetrachloride and the same general precautions are recommended. Methylene chloride shall be handled in closed systems unless refrigerated sufficiently to avoid appreciable vaporization.

SECTION VII - FIRST AID

7.1 Safety Equipment

The following equipment will be maintained for the use of the personnel at the Rocket Laboratory:

a) <u>Fire blankets</u> - one in each cell. To be used in the event that clothing catches on fire.

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b) <u>Fire extinguishers</u> - fifteen pound CO_2 extinguishers at the rear entrance to each cell. Seventy-five pound CO_2 extinguishers near any cell that is in operation.

c) <u>Gas masks, respirators, and rubber suits and gloves</u> - available from each service room or the shop. These shall be worn as prescribed in sections IV and V, or in the general safety chart.

d) <u>Face shields</u> - available for all cells.

e) <u>Sodium bicarbonate solution</u> - for acid burns. Bottles of this solution are to be kept in each cell where acid is being handled.

f) <u>Burn kits</u> - available in control rooms 11A, 12A, 13A, 14A, 21A, and 23A.

g) <u>Stretcher and blankets</u> - available in the main shop.

h) <u>Showers</u> - located near the rear door of each cell and in special locations where the hazards are greater.

7.2 <u>Emergency Action - General</u>

The first and foremost duty of an able person at the scene of an accident is to summon aid. Each person should know the PAX numbers of the Fire Department and the Dispensary. Dial "7" for fire or accidents requiring the ambulance. For minor accidents requiring the presence of the nurse or the summoning of a doctor, call the Dispensary, "2143".

The second procedure is to take care of the injured and keep the following suggestions in mind:

a) Do not get excited, but act quickly and calmly.

b) Remember the three "B's" of First Aid: "Bleeding, Breathing, and Broken Bones", which present the correct order for attending to injuries. A person can bleed to death in less than a minute while it takes five to ten minutes or longer to suffocate.

c) Do not try to do too much.

d) Do not move an injured person unless absolutely necessary, particularly if there is evidence of broken bones.

e) Do not try to bring an unconscious injured person to consciousness. Let him lie quietly, face down, with his head turned to one side. Apply artificial respiration if breathing has stopped. 5188

f) Do not pour liquids into the mouth of an unconscious person; to do this may choke him.

7.3 Emergency Actions - Wounds

7.3.1 General:

1. How to treat Wounds:

a) stop bleeding
b) prevent shock
c) relieve pain
d) prevent infection

2. Expose the Wound:

a) If an explosion has occurred and fragments have caused a casualty, open the clothing where the fragment entered and then look for a spot where it may have come out.

b) Cut or tear the clothing away from the wound. Do not drag clothes over a wound; carefully lift them off.

7.3.2 Bleeding:

(A) There are two types - arterial and venous. - Arterial is the most dangerous because the blood flows fast and will soon cause a person to bleed to death. The first-aid methods to stop bleeding are to press directly over the wound, to elevate the wound, or to use a tourniquet.

1. Direct pressure over the wound should be tried first. To do this, put a sterile dressing over the wound and press firmly for at least five minutes and then hold the dressing in place by bandaging.

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2. Raising a wounded arm or leg high above the body will help to stop bleeding. The wounded person must lie down and the arm or leg must be held up as high as possible while direct pressure is made on the wound and a sterile dressing is put on.

(B) Do not use a tourniquet unless bleeding cannot be stopped by other means.

1. For bleeding from arm or hand, put the tourniquet a hand's breadth below the armpit. For the thigh and leg put the tourniquet a hand's breadth below the crotch.

2. If a regular tourniquet is not available a tie, belt, or handkerchief will work with the aid of a stick or rod to tighten it by twisting.

Tighten a tourniquet only as much as is necessary to stop bleeding.

If a tourniquet is left too long, gangrene may develop. It should be loosened every 15 minutes and allowed to bleed for about 10 or 15 seconds.

Do not cover a tourniquet because it may be forgotten.

7.3.3 Shock:

Shock is a condition of weakness which usually follows wounds, burns, or other injuries. When severe shock has developed, the injured person is pale, and his skin is cold and wet with sweat. A mild degree of shock may not show these signs. First aid for shock should be started before the injured person has developed any signs. Shock can be most easily prevented by first stopping the bleeding and then making the injured person as comfortable as possible. To overcome shock, put the injured person on his back with his head and shoulders lower than his legs and hips. If he is unconscious, keep him face down, with his head turned to one side, and with his head and shoulders lower than his legs and hips. Keep the injured person warm, but be sure not to overheat him because overheating can increase shock instead of preventing or overcoming it. Warm drinks are helpful in shock.

7.3.4 Pain Relief:

Pain can often be prevented or relieved by simple measures such as keeping the injured person quiet and warm.

7.3.5 Infection:

Do not touch a wound with dirty hands or clothing. Do not allow a wound to touch anything but a sterile bandage. Do not wash a wound.

EMERGENCY ACTION - ARTIFICIAL RESPIRATION

7.4 Emergency Action - Artificial Respiration

7.4.1 How to Administer: The Schafer method is no longer recommended. The new method is the back pressure arm lift or Neilson method.

1. Examine the patient to determine if he is breathing. If he is, do not use artificial respiration.

2. Do not stop to loosen the patient's clothing, but immediately begin actual resuscitation. Every moment of delay is serious. As soon as possible, feel in the patient's mouth and throat and remove any foreign body (tobacco, false teeth, gum, etc.). If the mouth is shut tightly, pay no more attention to it until later. 5188

3. Position of the Subject

a) Kneel on either the right or left knee at the head of the subject and facing him. Place the knee at the side of the subject's head, close to the forearm. Place the opposite foot near the elbow. If it is more comfortable, kneel on both knees, one on either side of the subject's head. Place your hands upon the flat of the subject's back in such a way that the heels lie just below a line running between the armpits. With the tips of the thumbs just touching, spread the fingers downward and outward.

c) Rock forward until the arms are approximately vertical and allow the weight of the upper part of your body to exert slow, steady, even pressure downward upon the hands. This forces air out of the lungs. Your elbows should be kept straight and the pressure exerted almost directly downward on the back.

d) Release the pressure, avoiding a final thrust, and commence to rock slowly backward. Place your hands upon the subject's arms just above his elbows.

e) Draw his arms upward and toward you. Apply just enough lift to feel resistance and tension at the subject's shoulders. Do not bend your elbows, and as you rock backward the subject's arms will be drawn toward you.

f) Then drop the arms to the ground. This completes the full cycle. The arm lift expands the chest by pulling on the chest muscles, arching the back, and relieving the weight on the chest.

g) The cycle should be repeated 12 times per minute at a steady, uniform rate. The compression and expansion phases should occupy about equal time; the release periods being of minimum duration.

h) Continue artificial respiration without interruption until natural breathing is restored; if necessary, four hours or longer, or until a physician declares the patient is dead. Of course, if rigor mortis sets in, you can be certain the patient is dead.

i) As soon as possible after artificial respiration has been started and while it is being continued, an assistant should loosen any tight clothing about the patient's neck, chest, or waist. Also examine the patient's mouth and throat if this has not already been done.

j) Notify the dispensary as quickly as possible without stopping resuscitation.

k) Keep the patient warm.

l) If natural breathing stops after being restored, use artificial respiration again.

m) To avoid strain on the heart when the patient revives, he should be kept lying down. Do not allow him to sit up or to stand. Use force if necessary.

n) When the patient becomes conscious, he may be given an internal stimulant such as black coffee or tea.

o) In carrying out resuscitation, it may be necessary to change the operator. This change should be made without losing the regular rhythm of respiration.

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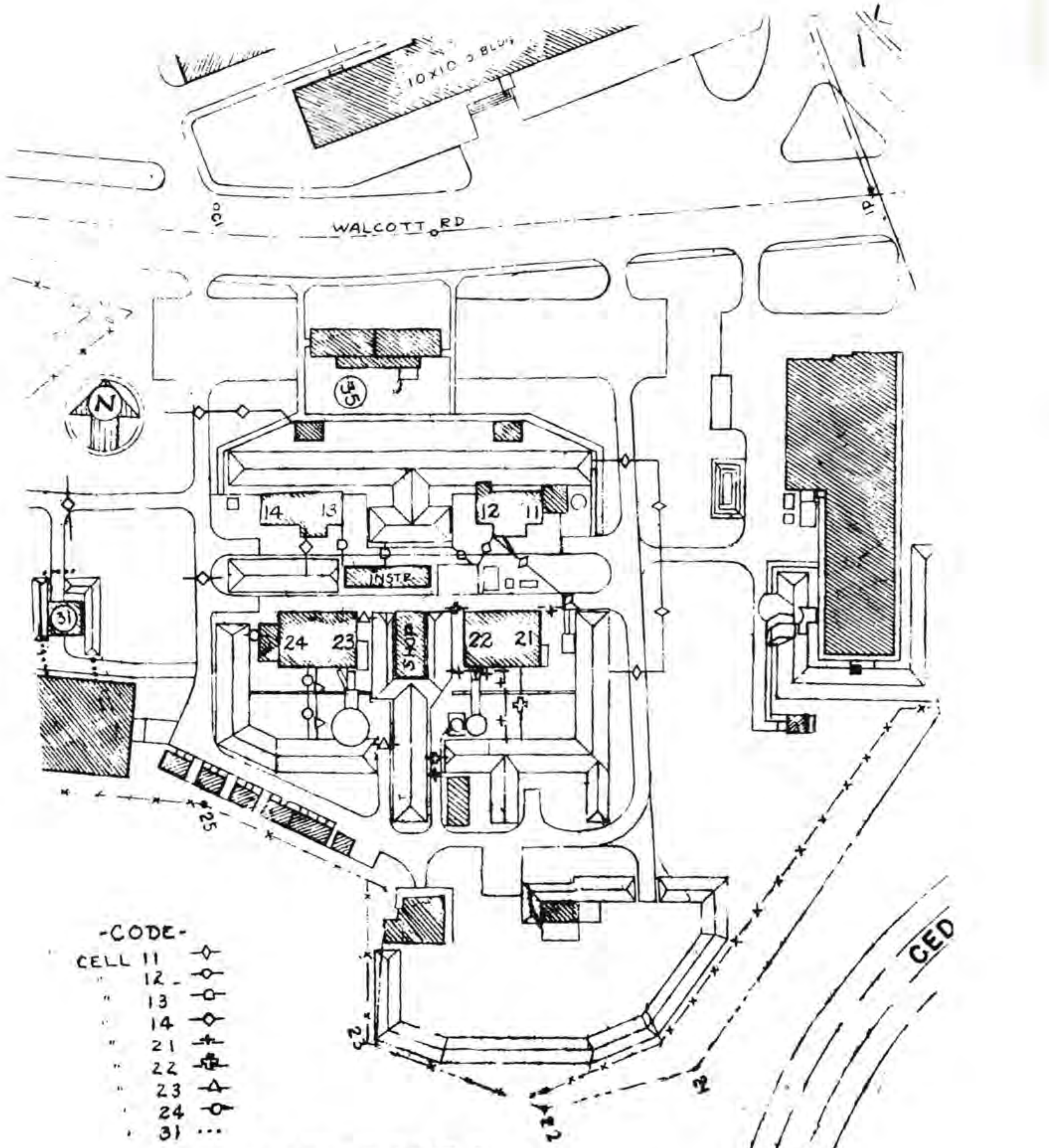

FIG. 1. - BARRICADES

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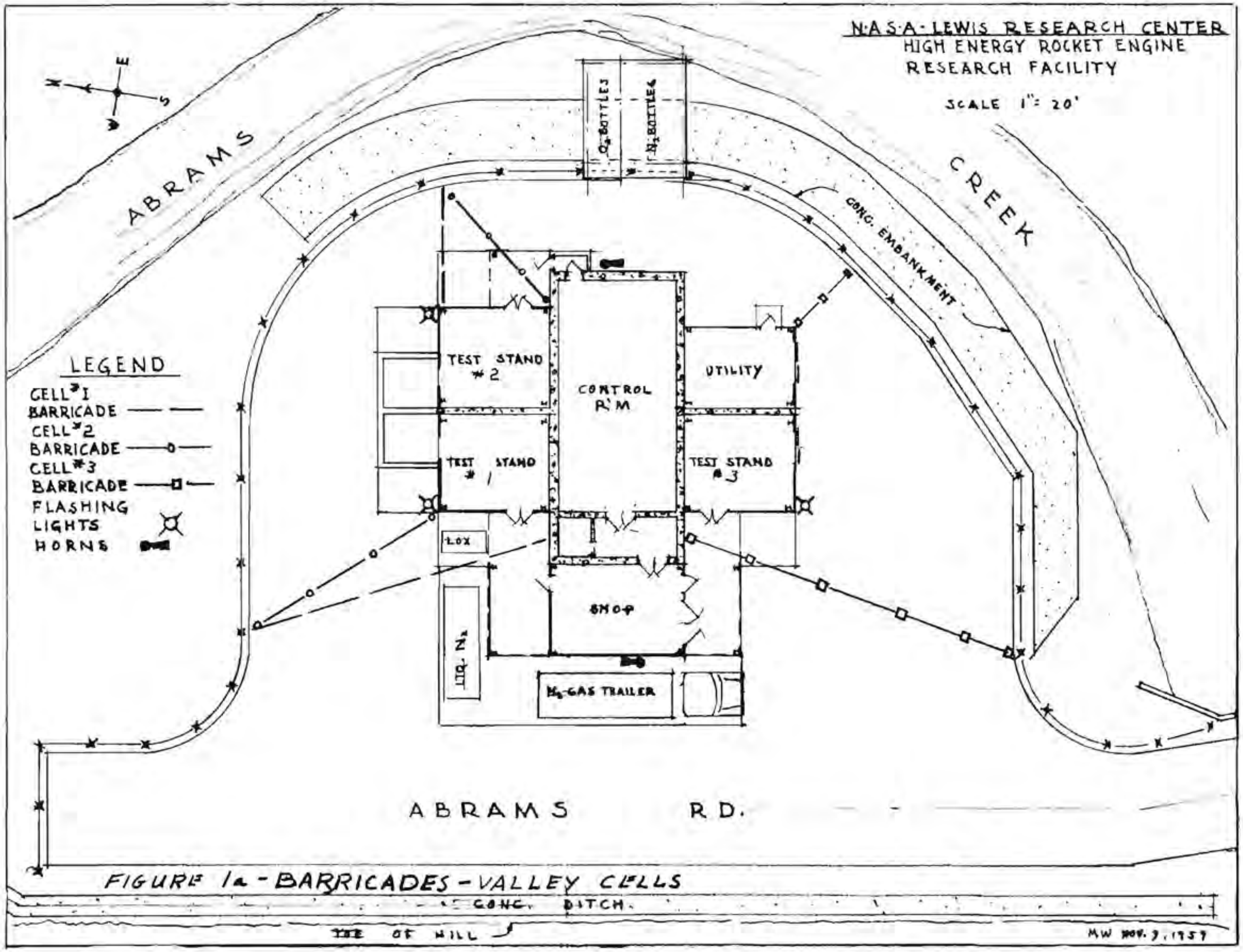


FIGURE 1a - BARRICADES - VALLEY CELLS

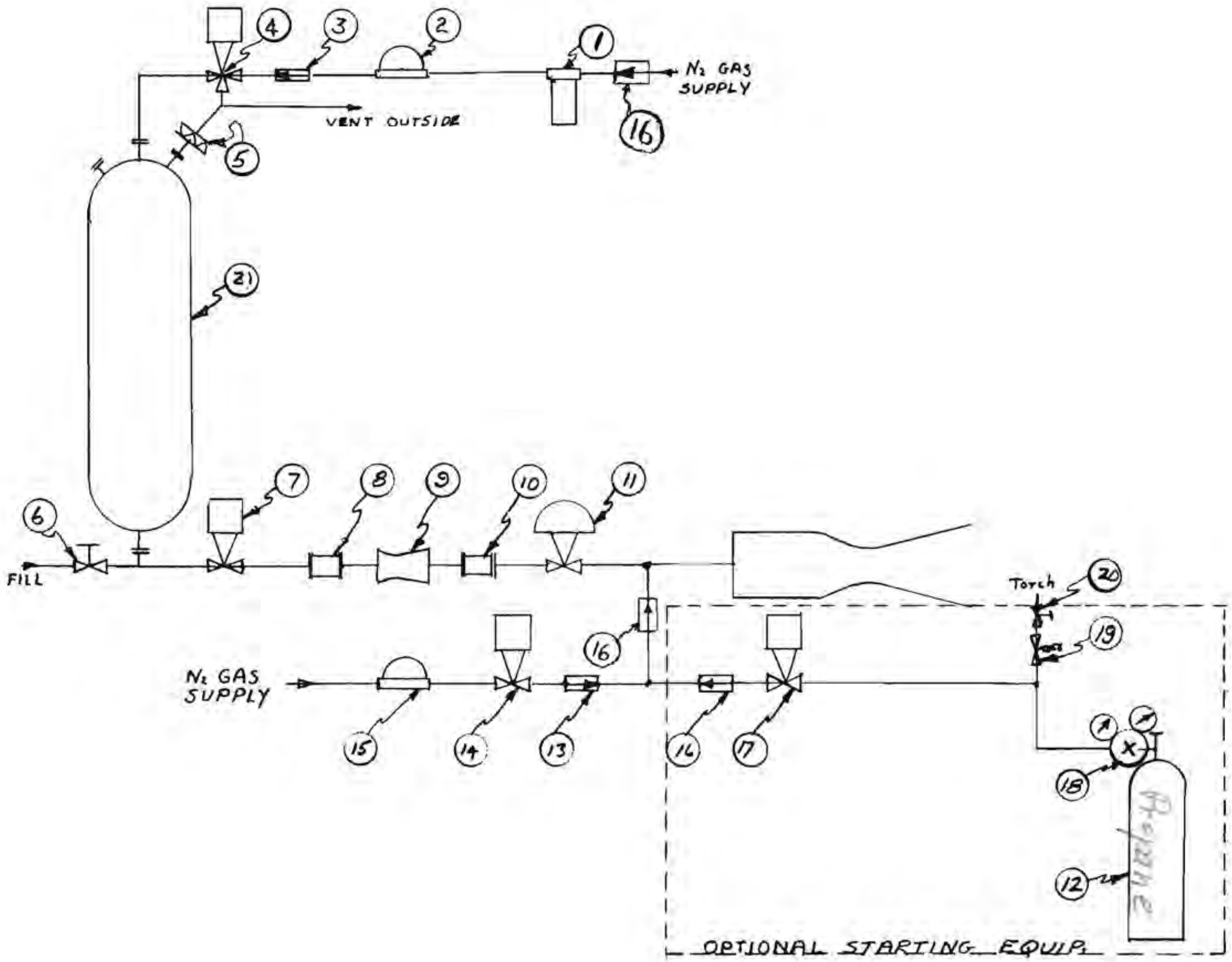


FIG 2.- HYDROCARBON SYSTEM

HYDROCARBON SYSTEM

Item	Description	Recommended Type
1	High Pressure Porous Filters	NASA Design
2	Pressure regulator	Grove
3	Check valve	Circle Seal -"O" ring type
4	Remote- Three way valve	Annin-Teflon seat & packing
5	Blow out disc	Black, Sivalls & Bryson
6	Hand valve - globe	Powell or Vogt - metal to metal seat
7	Remote-on-off valve	Annin - Teflon seat & packing
8	Screen	NASA design
9	Venturi	NASA design
10	Turbine type flowmeter	Potter
11	Remote Flow control Valve	Annin - Teflon seat & packing-dome control
12	Propane cylinder	
13	Check valve	Circle Seal - "O" ring
14	Remote on-off valve	Annin-Teflon seat & packing
15	Press regulator	Grove
16	Check valve	Circle seal - "O" ring
17	Remote on-off valve	Annin-Teflon seat & packing
18	Press regulator	Propane bottle regulator
19	Solenoid valve	Asco
20	Hand valve - needle	Hoke
21	High pressure tank	NASA design

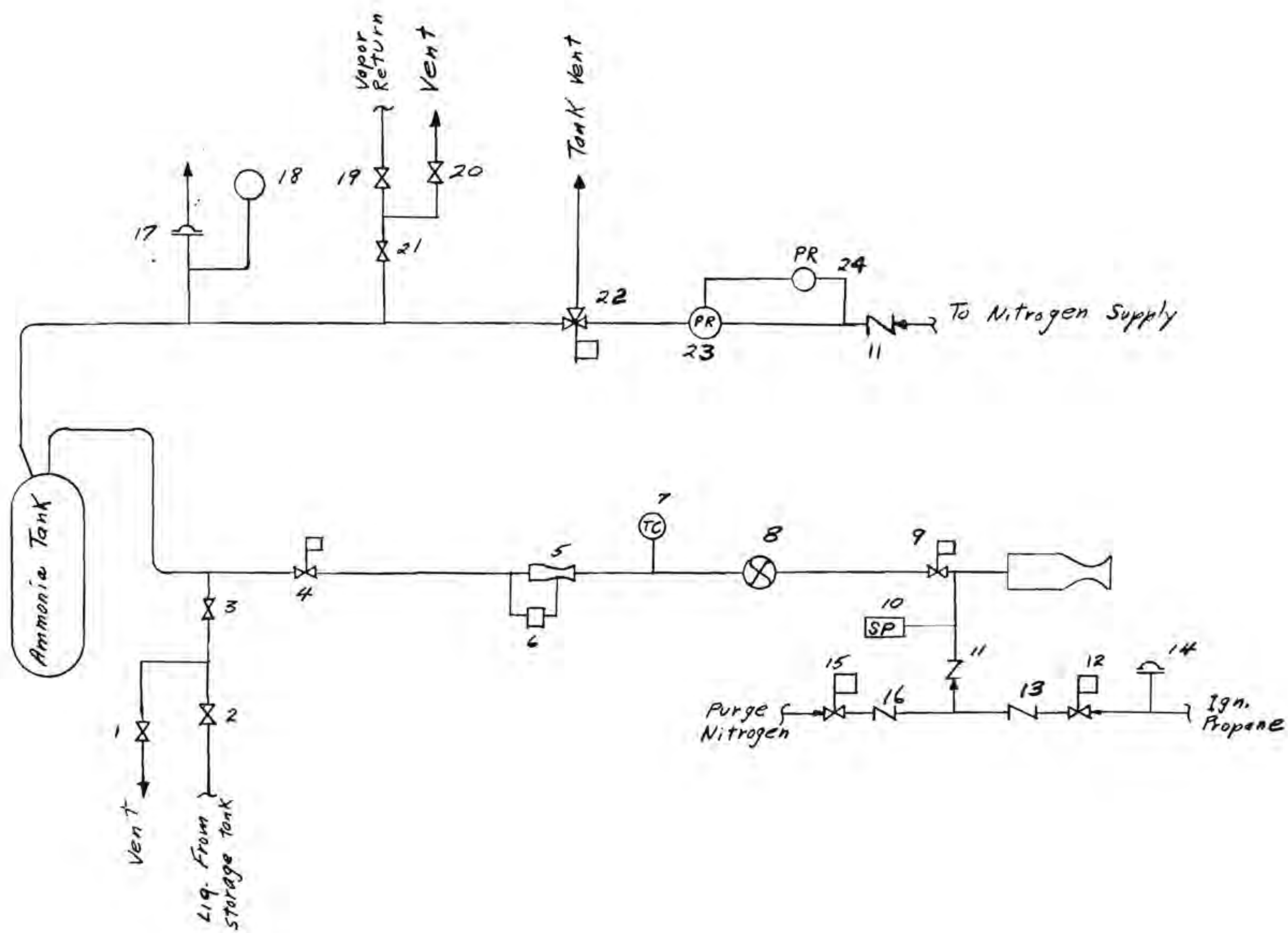
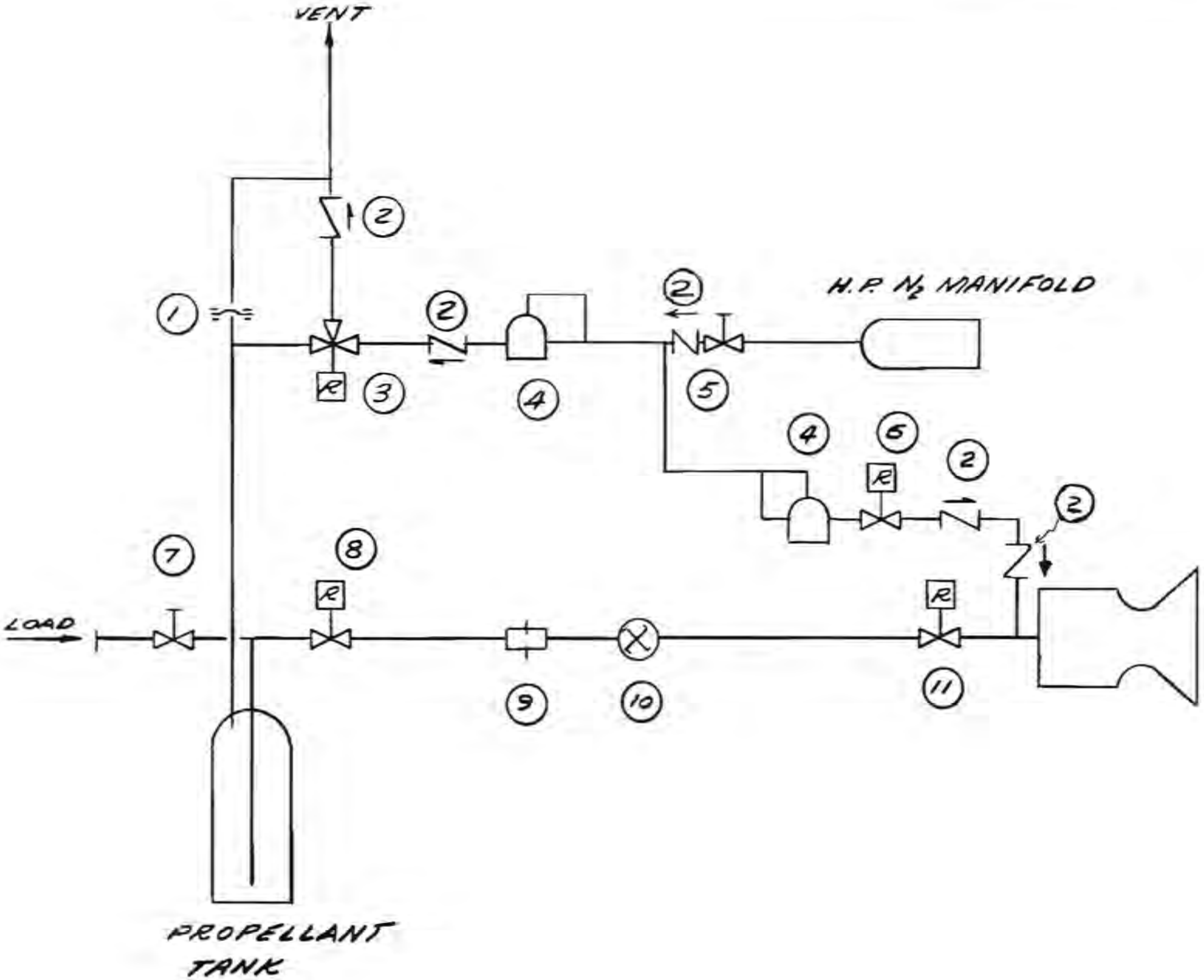


FIG. 3.- LIQUID AMMONIA SYSTEM

LIQUID AMMONIA SYSTEM

Item	Description	Recommended Type
1	Bleed Valve-Barstock	Crane, Kerotest, Hoke
2	300 psi Ammonia Valve	Crane
3	High Press. shutoff valve for loading	Crane
4	Remote Operated Shut-off valve	Annin
5	Flowmeter- Venturi	NASA
6	Press. Transducer	Statham
7	Thermocouple	NASA
8	Flowmeter-Turbine type	Potter, F & P, Waugh
9	Remote operated fire valve	Annin
10	Pressure transducer	Statham
11	Check valve	Circleseal, Republic, Powell
12	Remote operated ign. valve	Annin
13	Check Valve	Circleseal, Republic, Powell
14	Safety head or pop-off valve	Block, Sivalls & Bryson
15	Remote Operated Purge Valve	Annin
16	Check valve	Circleseal, Republic, Powell
17	Safety Head	Black Sivalls & Bryson
18	Tank Press. Gage	U. S. Gage Co.
19	300 psi ammonia valve	Crane
20	Bleed valve- Barstock	Crane, Kerotest, Hoke
21	High Press. Vapor Shutoff valve for loading	Crane
22	Remote operated valve for press. & venting	Annin
23	High Capacity Press. Regulator	Grove, Apco
24	Low capacity Press. Regulator	Grove, Atlas

FIG. 4.-HYDRAZINE PROPELLANT SYSTEM



HYDRAZINE PROPELLANT SYSTEM

Item	Description	Recommended Type
1	Burst Disk	Stainless
2	Check Valve	Stainless - Teflon Seat
3	3-Way Press. - Vent Valve	Stainless - Teflon Seat Annin
4	Pressure Regulator	Nylon Seat Grove
5	Handvalve	Nylon Seat Walworth
6	Purge Valve	Nylon Seat Merit
7	Gate Valve	Stainless
8	Flow Control Valve	Teflon Seat Annin - Stainless
9	Venturi or Orifice	Stainless
10	Vane Type Flowmeter	Waugh - Stainless
11	Fire Valve	Stainless - Teflon Seat Annin

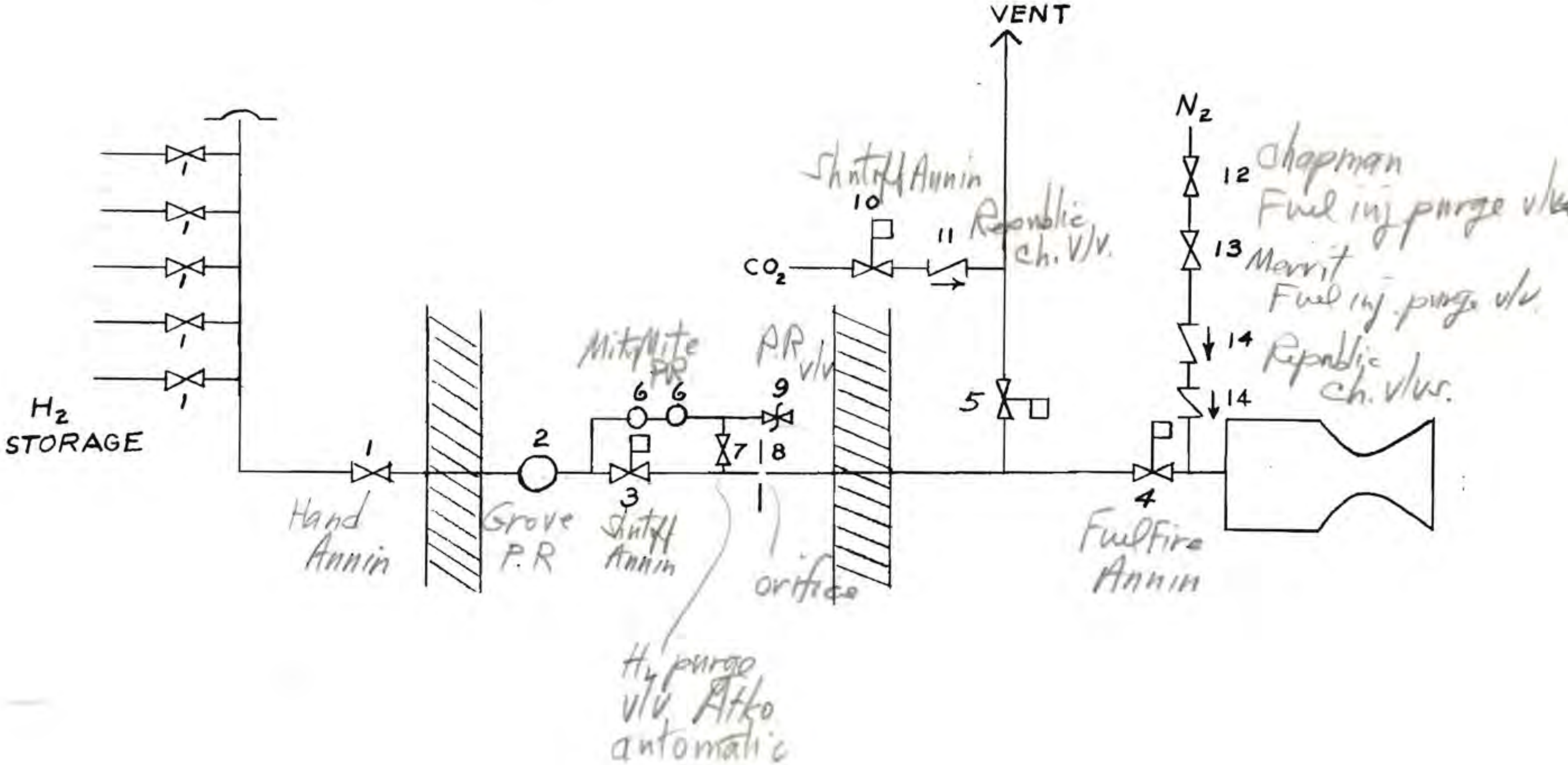


FIG. 5. - GASEOUS HYDROGEN SYSTEM

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GASEOUS HYDROGEN SYSTEM

Item	Description	Recommended Type
1	Hand shut-off valves	Hand operated Annin
2	Pressure regulator	Grove
3	Shut-off valve	Annin
4	Fuel fire valve	Annin
6	Pressure regulator	Mity-Mite
7	H_2 purge valve	Atkomatic
8	Orifice	NASA
9	Pressure relief valve	Republic
10	Shut-off valve	Annin
11	Check valve	Republic
12	Fuel injector purge hand valve	Chapman
13	Fuel injector purge	Merrit
14	Check valve	Republic

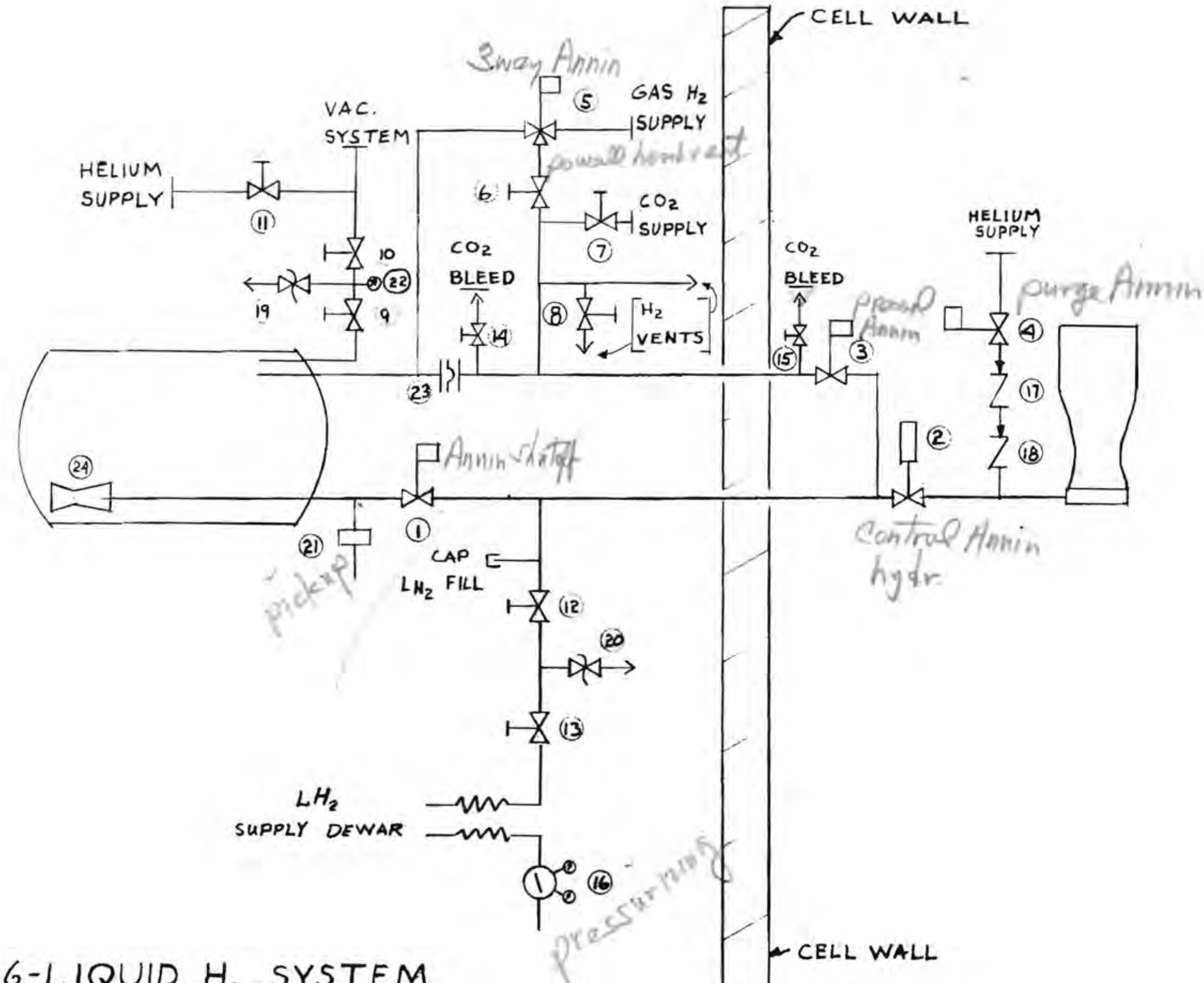

FIG. 6.-LIQUID H_2 SYSTEM

LIQUID HYDROGEN SYSTEM

Item	Description	Recommended Type
1	Liq. H_2 Shut-off valve (High pressure)	Annin - SS body - (on-off) Teflon seat Teflon seal
2	Control valve (fire valve) (High pressure)	Annin - SS body metal seats Hydraulic control
3	Pre-cool valve - used to vent (liq. H_2 - gas. H_2) in order to cool flow line prior to firing (High pressure)	Annin - SS body (control head) Teflon seats Teflon seal
4	Purge valve	Annin - brass body Teflon seat Teflon Seal (on-off)
5	3-way-pressure-vent valve (High pressure) H_2 gas	Annin- brass or SS body Teflon seat Teflon seal 3-way
6	Hand vent valve shut-off	Powell-modified-extended stem metal seats Teflon Seal
7	CO_2 valve	Valve may be used with solenoid $\longrightarrow CO_2$ is put into vent only when 3-way valve is in the vent position. (Helium could be used instead of CO_2)
8	Hand vent valve (used to vent H_2 during liq. H_2 - filling - after filling, valve is closed.	Powell- modified, extended stem metal seat teflon seal
9	High pressure valve used to protect vacuum valve (10)	Valve - part of liq. H_2 tank spec. - see drawing of liq. H_2 tank
10	Vacuum valve	Valve - see drawing of liq. H_2 tank.
11	Low pressure valve for helium purge tank & H_2 lines	Hoke valve

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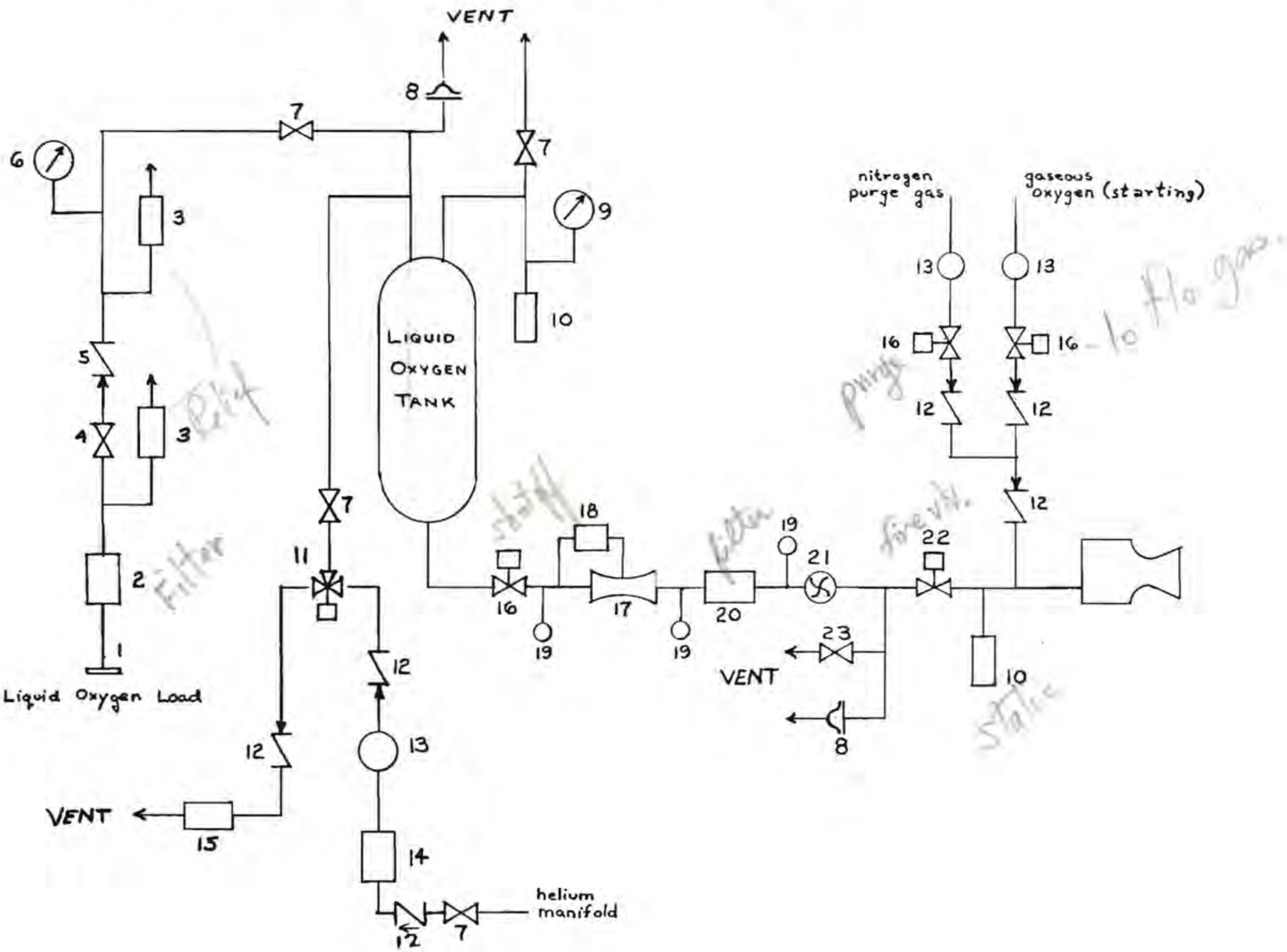
LIQUID HYDROGEN SYSTEM

Item	Description	Recommended Type
12	Load valve - shut off (High pressure)	Crane - modified extended stem metal seats teflon seal
13	Load valve - shut off - in liq. H_2 load line	Campco - vac. jacketed hand valve
14	CO_2 bleed valve - purge dead spot in H_2 line	Hoke valve
15	CO_2 bleed valve - purge dead spot in H_2 line	Hoke valve
16	H_2 bottle regulator pressure to liq. H_2 load trailer (low pressure H_2)	H_2 bottle regulator
17	Check valve ; back-up for check valve (18)	Circle seal - rubber seat
18	Check valve - purge line	Circle seal - SS seat
19	Relief valve protect Vac valve (10) in case valve (9) leaks	Standard relief (pressure below 100 psi)
20	Relief valve in liq. H_2 load line - unload pressure build up	Circle-Seal built into vac. jacketed line
21	Pressure pick-up	Statham
22	Compound gage reads vacuum and reads helium purge pressure.	Standard gage 20 in to 60 lbs
23	Safety head	SS body vac. support 1050 psi
24	Venturi	NASA design

FIG. 7 - LIQUID OXYGEN SYSTEM



LIQUID OXYGEN SYSTEM

Item	Description	Suggested Type
1	Bar Flange	Supplied by Linde
2	Filter	Supplied by Linde
3	Relief Valve	Supplied by Linde
4	Hand Valve	Supplied by Linde
5	Check Valve	Supplied by Linde
6	Gage	Supplied by Linde
7	High Pressure Hand Valve	Crane, Powell
8	Safety Head	Black, Sivalls, & Bryson
9	Tank Pressure Gage	U. S. Gage
10	Static Pressure Transducer	Statham
11	3-Way remote control valve	Annin
12	Check Valve	Republic, Circleseal
13	Pressure Regulator	Grove, Apco
14	Helium Filter	NASA
15	LOX Vent Muffler	NASA
16	2-Way remote control valve	Annin
17	Flowmeter-Venturi	NASA
18	Differential Pressure Transducer	Statham
19	Thermocouple - IC	NASA
20	LOX Filter	NASA
21	Flowmeter-Turbine Type	Potter, Waugh, Fischer & Porter
22	Remote Control Fire Valve	Annin Dowmotor
23	High Pressure Hand Valve	Hoke, Crane

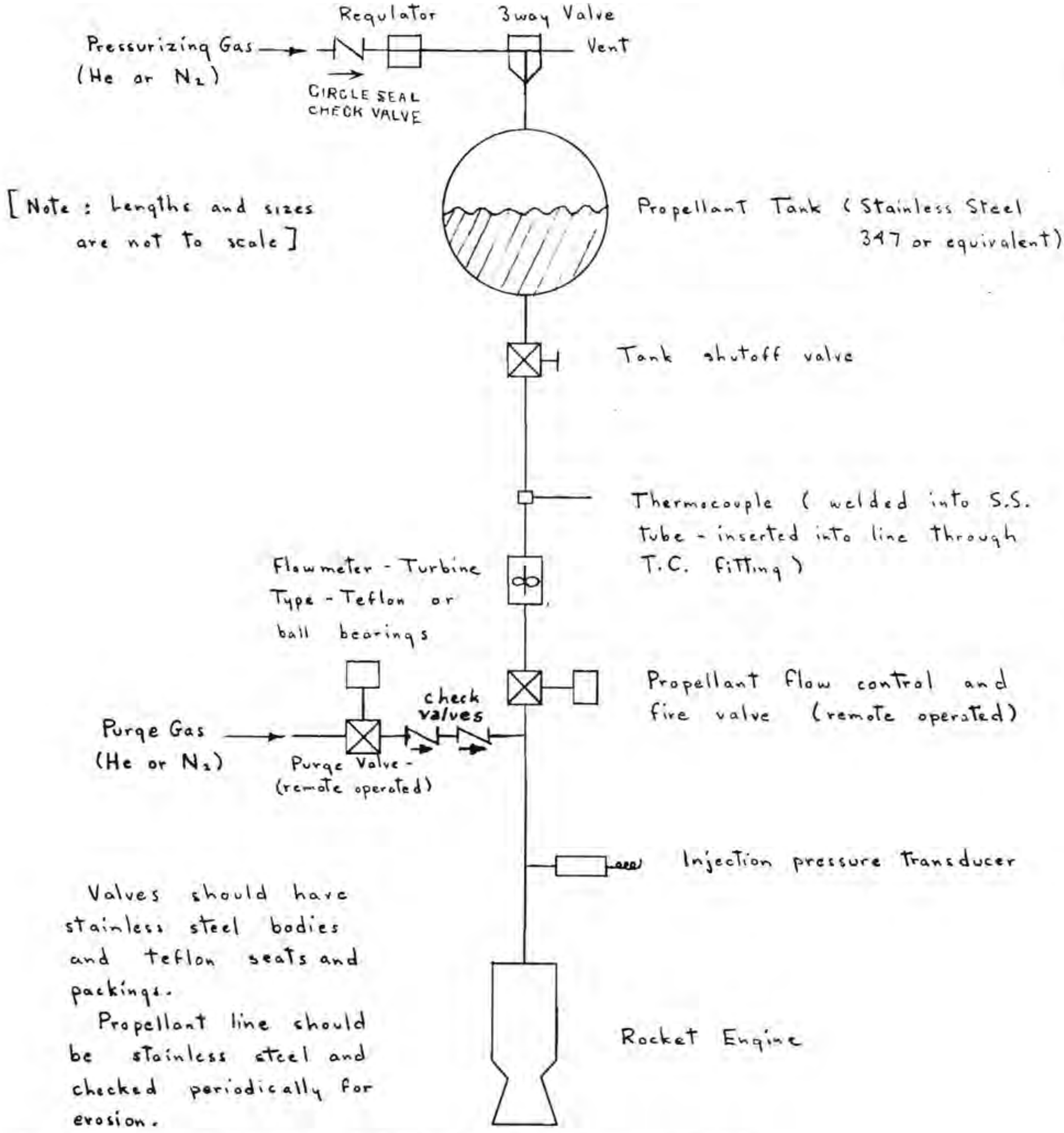


FIG. 8.- MON AND NITRIC ACID SYSTEM

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LIQUID FLUORINE SYSTEM

Item	Description	Recommended type	
13	Shut off valve - to prevent relief valve from popping off during F_2 pickling of burner system	Kerotest (modified)	Hand valve copper seat Diaphragm Brass body Back seating
14	By pass valve - bleed liq. F_2 trailer vent side to 0 psi	Same as above	
15-19	Shut off valve on burners	Crane (modified)	Teflon seat Brass body Teflon packing
20	Vent valve for helium system backing up F_2 gas system	Bar Stock Needle valve	Brass stem Teflon packing SS body
21	Pressure regulator→purge F_2 gas manifold system	Mity Mite	Kel F Seat
22	Pressure regulator→purge liq. F_2 gas transfer system	Same as above	
23	Pressure regulator→pressure for F_2 ox. tank	Grove	
24	Check valve for Helium purge (Installed in ox. line)	NASA	Monel-high pressure metal-metal seat
25	Check valve - backing up check valve (24)		Circle Seal Teflon seat SS body
26	Check valve - prevent air backing up to vent side of F_2 trailer		Circle Seal Teflon Seat SS body
27	Check valve - checks flow of F_2 gas to helium bottles	Circle Seal	Teflon seat
28	Relief valve - relieves in case of pressure building up in trailer	Republic	Teflon seat
29	Safety head	Monel body Monel disk vacuum support 2250 psi	

LIQUID FLUORINE SYSTEM

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Item	Description	Recommended Type
30	Venturi - F_2 Flow	NASA - Nickel
31	Statham	P-80 M-43 oil
32	Check valve - Helium supply to purge valve	Circle seal Teflon seat
33	Remote electric gage - read helium purge pressure remotely	Bourns
34	Remote electric gage - read gas F_2 pressure in manifold & transfer system	Schaevitz

1- Vent valve (Item 7) need not be located outside.

2- Vent located away from H_2 vent (100-200 yds)

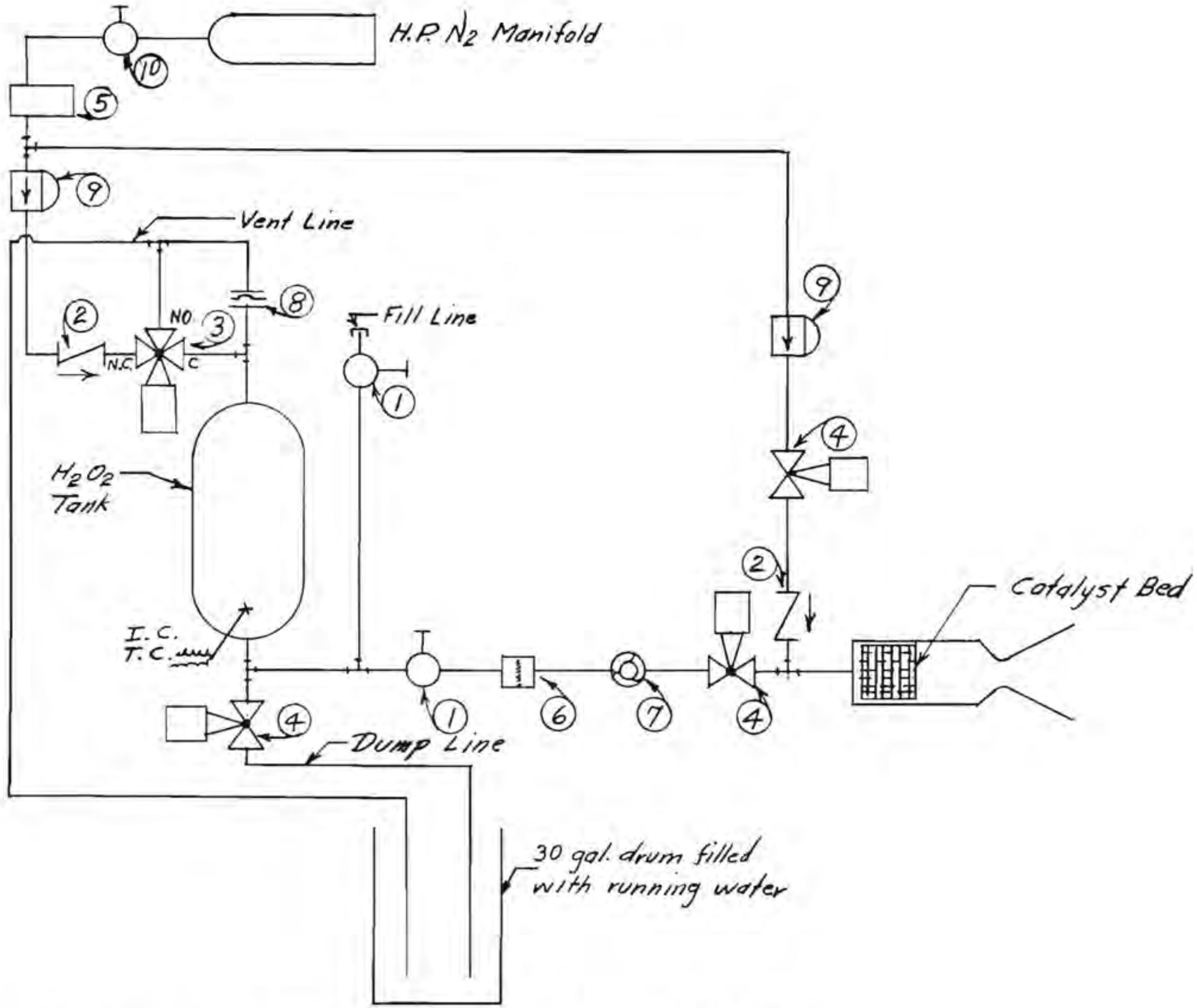

FIG 10 - HYDROGEN PEROXIDE SYSTEM

HYDROGEN PEROXIDE SYSTEM

Item	Description	Recommended Type
1.	Hand Valve	Stainless - Teflon Seat
2.	Check Valve	Stainless - Teflon Seat
3.	3 Way-Press-Vent Valve	Stainless - Teflon Seat - Annin
4.	Fire Valve	Stainless - Teflon Seat - Annin
5.	High-Press. Filter	Porous Element - NASA. Design
6.	In-Line Filter	Stainless - Screen Filter
7.	Flow Meter	Potter
8.	Blow-Out Disk	Black-Sivalls & Bryson - Stainless
9.	Pressure Regulator	Groves
10.	Hand Valve	Crane