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Suggested Procedures for

Safeguarding Aircraft Fuel Tank Atmospheres

(Ground Handling)

May

1957

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NATIONAL FIRE PROTECTION ASSOCIATION

International

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National Fire Protection Association

International

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The National Fire Protection Association was organized in 1896 to promote the science and improve the methods of fire protection and prevention, to obtain and circulate information on these subjects and to secure the cooperation of its members in establishing proper safeguards against loss of life and property by fire. Its membership includes two hundred national and regional societies and associations (list on outside back cover) and seventeen thousand individuals, corporations, and organizations. Anyone interested may become a member; membership information is available on request.

This pamphlet is one of a large number of publications on fire safety issued by the Association including periodicals, books, posters and other publications; a complete list is available without charge on request. All NFPA standards adopted by the Association are published in six volumes of the **National Fire Codes** which are re-issued annually and which are available on an annual subscription basis. The standards, prepared by the technical committees of the National Fire Protection Association and adopted in the annual meetings of the Association, are intended to prescribe reasonable measures for minimizing losses of life and property by fire. All interests concerned have opportunity through the Association to participate in the development of the standards and to secure impartial consideration of matters affecting them.

NFPA standards are purely advisory as far as the Association is concerned, but are widely used by law enforcing authorities in addition to their general use as guides to fire safety.

Definitions

The official NFPA definitions of shall, should and approved are:

SHALL is intended to indicate requirements.

SHOULD is intended to indicate recommendations, or that which is advised but not required.

APPROVED refers to approval by the authority having jurisdiction.

Units of measurements used here are U. S. standard. 1 U. S. gallon = 0.83 Imperial gallons = 3.785 liters.

Approved Equipment

The National Fire Protection Association does not "approve" individual items of fire protection equipment, materials or services. The standards are prepared, as far as practicable, in terms of required performance, avoiding specifications of materials, devices or methods so phrased as to preclude obtaining the desired results by other means. The suitability of devices and materials for installation under these standards is indicated by the listings of nationally recognized testing laboratories, whose findings are customarily used as a guide to approval by agencies applying these standards. Underwriters' Laboratories, Inc., Underwriters' Laboratories of Canada and the Factory Mutual Laboratories test devices and materials for use in accordance with the appropriate standards, and publish lists which are available on request.

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Foreword

Work on these NFPA Suggested Procedures for Safeguarding Aircraft Fuel Tank Atmospheres (Ground Handling) commenced in 1950 following an accident which occurred in Texas early that year during an attempt to accomplish the inerting of an inboard fuel tank on an experimental military aircraft (Reference: NFPA Special Airport Fire Bulletin Series 1950, No. 9). A proposed text on "Inerting of Aircraft Fuel Tanks with Carbon Dioxide (Excluding Airborne Inerting)" was offered for tentative adoption at the 1951 NFPA Annual Meeting but was withdrawn at the meeting and referred back to the Committee for further study after discussion. One of the principal reasons for this action was a technical discussion of the problem by Mr. Howard W. Naulty of the Cornell Aeronautical Laboratory who had conducted exhaustive tests on fuel tank inerting procedures (Reference: NFPA Aviation Bulletin No. 68).

At the 1954 NFPA Annual Meeting the Committee submitted for tentative adoption a revised text under the title "Recommended Safe Practices for Aircraft Fuel Tanks during Certain Maintenance Operations" and this text was tentatively adopted following action by that meeting of the Association. In 1955 the text was again changed as well as the title but again only tentative adoption was requested and secured at the Annual Meeting since the Committee was not satisfied with the recommendations that had been prepared. Further revisions were acted upon favorably at the 1956 Annual Meeting at which time the text was broadened to include air ventilation procedures in addition to the inerting techniques which had previously been tentatively adopted. The Subcommittee in 1956 still desired to investigate more completely certain features of the procedures and to analyze other suggested methods of accomplishing the safeguards so that once again, in 1956, only tentative adoption was secured.

This report was finally adopted at the 1957 NFPA Annual Meeting having been submitted with the unanimous approval of all voting members of the Committee. The importance of the recommendations has become obvious with a number of accidents which have occurred during the seven years since the project was initiated. The work of the Subcommittee has now been turned over to the NFPA Committee on Aircraft Maintenance and Storage for future handling and all persons interested in this phase of safety are invited to correspond with the Committee Chairman or the Committee Secretary concerning any problems associated with the type of work covered by these suggested procedures.

Subcommittee on Aircraft Fuel Tank Protection

This report was prepared by the Subcommittee on Aircraft Fuel Tank Protection, appointed by action of the NFPA Committee on Aviation and Airport Fire Protection in 1953. Following the adoption of this report at the 1957 NFPA Annual Meeting, the Subcommittee has been discharged with the sincere thanks of the Association for their contribution. The text has now been turned over to the NFPA Committee on Aircraft Maintenance and Storage for future handling. The latest list of the sponsoring Subcommittee personnel follows:

Joseph M. Chase, *Chairman*,
Flight Safety Foundation, Fourth Avenue, N. Y.

J. C. Abbott,* British Overseas Airways Corp.

Wm. A. Beirne, Jr., Association of Casualty & Surety Cos.

W. E. Bertram,* Northwest Airlines.

N. L. Christoffel,* United Airlines.

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Ernest Elmgren, United Air Lines Maintenance Base.

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W. B. Little, Civil Aeronautics Board.

William J. Lotzer, National Aviation Maintenance Council.

C. M. Middlesworth,† Civil Aeronautical Administration.

H. W. Naulty, Amherst Manufacturing Company.

A. B. Nehman, Bureau of Aeronautics, Dept. of the Navy.

R. L. Potter,* American Airlines.

J. H. Sellers,* North America Companies.

W. L. Walls, Factory Mutual Engineering Division.

J. H. Waterman,* Trans World Airlines.

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†Non-voting.

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Part I. Scope.

110. These suggested procedures outline three possible methods which may be followed during aircraft ground handling in the interest of fire and explosion prevention when it is desired to reduce the flammable vapor hazard of aircraft fuel tank atmospheres when such tanks contain or did contain a volatile fuel. The circumstances under which any one procedure may be followed are variable and subject to the discretion of the operator (see Paragraphs 150-170). Airborne fuel tank inerting is not included.

120. Establishing the need for treating aircraft fuel tank atmospheres by one of the methods outlined should be the responsibility of a properly qualified person. Normally, preventive measures are taken where flammable vapors in aircraft fuel tanks present a hazard during the handling of aircraft under conditions and in locations where the release of such flammable vapors presents an unacceptable risk, either because of the life hazard involved or the potential magnitude of the property damage which might result from the ignition of such vapors.

130. The three basic procedures suggested herein are:

131. Siphon inerting covered in Parts III, IV, and V.

132. Pressure inerting covered in Parts III, IV, and VI.

133. Air ventilation covered in Parts VII, VIII, and IX.

140. Part X of these suggested procedures covers instrumentation.

150. Generally, siphon inerting is suitable in cases where it is *not* necessary to open the tanks to conduct inspection or work therein and has been found particularly desirable for a series of tanks (metal, integral or bladder) mounted in an aircraft. Siphon inerting requires the draining of the fuel within the tanks to be inerted. There may be cases where siphon inerting would be desirable for safeguarding a tank or tanks adjacent to (but not adjoining) another tank which is to undergo inspection or work. Under such conditions, a combination of procedures might be employed on a single aircraft at the same time.

160. Pressure inerting is also used in cases where it is *not* necessary to open tanks to conduct inspection or work therein. Pressure inerting does not necessarily require the draining of the fuel within the tanks to be inerted. The effectiveness of the method can only be assured when it is possible to sample the fuel tank atmosphere in all void portions of each tank to be treated to determine that a satisfactory concentration of inert gas is secured. Siphon inerting (see Paragraph 150) is considered the most efficient procedure for inerting interconnected tanks in that this method assures even distribution of the inert gases throughout such a fuel tank system. Pressure inerting will find its greatest usefulness for inerting individual tanks but where interconnected tanks are inerted by this method it is important that each individual interconnected tank be probed to determine that efficient distribution of the inert gas has been secured in all portions of such a fuel tank system.

170. Generally, air ventilation is suitable in cases where the tank or an interconnected tank must be opened to conduct inspection or work therein. Air ventilation requires the draining of the fuel within the tanks to be ventilated prior to start of the ventilation. In many cases, the health hazards resulting from the presence of fuel vapors, particularly leaded grades of aviation fuel, determine the extent of ventilation required when human occupancy is necessary for the inspection or work, and fresh air breathing masks are not available or are impractical. An atmosphere safe from the health viewpoint will automatically result in an atmosphere containing a "too lean" mixture of fuel vapors to present a fire or explosion hazard. (See Paragraphs 721 and 722.)

Part II. Definitions.

210. Inerting. Inerting[1], as used herein, means the use of an inert gas to render the atmosphere of an enclosure nonexplosive or nonflammable. Inerting, in effect, reduces the oxygen content (see Paragaph 321 and Table No. 1) of the air in the tank vapor space below the lowest point at which combustion can occur by replacing the oxygen in air with an inert gas.

220. Inert Gas. Inert gas is any gas which is nonflammable, chemically inactive and noncontaminating for the use intended and oxygen-deficient to the extent required.

230. Inert Atmosphere. An inert atmosphere is an atmosphere where combustion cannot occur.

240. Air Ventilation. Air ventilation, as used herein, means to pass undiluted air (air not containing flammable vapors or inert gases) through an aircraft tank to render the atmosphere of the tank more suitable for human occupancy and to reduce the amount of flammable vapors in the tank to below the lower explosive limit of the fuel vapors involved. It is recognized that, at sometime during and, possibly, after, air ventilation, the tank may contain a flammable vapor-air mixture. During such periods, a fire and explosion hazard exists which requires the elimination of ignition sources within the vapor-hazardous areas.

250. Purging. Procedures to accomplish purging[2] are *not* covered herein but it is important to establish the technical difference between inerting (as used herein) and purging to avoid confusion of terminologies, procedures and results. For the above purposes, purging an aircraft fuel tank means to remove the flammable vapor atmospheres, or any residue capable of producing flammable vapors, in the tank and connected distribution lines so that subsequent natural ventilation will not result in the reinstatement of a flammable atmosphere unless or until a flammable liquid is again introduced into the tank or its connected distribution lines.

[1]The term "inerting" is used to avoid the more awkward use of the adjective "inert" throughout the text. "Inerting" is identical in meaning to the phrase: "to render inert".

[2]Dictionary definition: to cleanse or purify by separating and carrying off whatever is impure, heterogeneous, or superfluous.

Part III. Inert Gases and Methods.

310. Inert Gases.

311. Carbon dioxide vapors (as distinguished from carbon dioxide liquid or solid carbon dioxide, dry ice) is a satisfactory inerting medium and is readily available at most locations where work of this type is conducted. The use of solid carbon dioxide (dry ice) is not desirable for inerting aircraft fuel tanks. Carbon dioxide does have a tendency to escape from a tank which has been inerted and sealed. Periodic checks (not to exceed 48 hours) should be conducted to assure the maintenance of an inert atmosphere, particularly in nonmetallic fuel cells, or, in lieu of this, a positive pressure (within the safe working pressure of the tank) should be maintained on the inerted tank from the inert gas supply.

312. Nitrogen is a satisfactory medium and is also normally available at locations where work of this type is conducted. Greater quantities of nitrogen are required than of carbon dioxide to secure the desired inerting effect (see Paragraph 321 and Table No. 1), but, generally, nitrogen can be retained more easily in a sealed tank than can carbon dioxide because of its lighter weight. Periodic checks (not to exceed 48 hours) should be conducted to assure the maintenance of an inert atmosphere, particularly in nonmetallic fuel cells, or in lieu of this, a positive pressure (within the safe working pressure of the tank) should be maintained on the inerted tank from the inert gas supply.

320. Inert Gas Concentrations.

321. Table No. 1 is included as a guide to the maximum permissible oxygen percentages in atmospheres containing various typical aviation fuel vapors with carbon dioxide and nitrogen as the inert gas, both of which are acceptable for inerting of aircraft fuel tanks. The quantity of inert gas provided should reduce oxygen concentrations to *at least* the 20 per cent factor of safety (20 per cent below the lower explosive limit at which combustion can occur). (For exceptions, see Paragraphs 513 and 613.)

322. Prior to certifying that a tank has been inerted, a check should be made to determine that the maximum permissible oxygen content of the tank with the inert gas used does not

Table No. 1

Maximum Permissible Oxygen Percentages and Minimum Inert Gas Concentrations With Various Factors of Safety for Inerting of Aircraft Fuel Tanks Containing Various Typical Aviation Fuels†

Typical Fuels and Factors of Safety	Using Carbon Dioxide as Inerting Medium		Using Nitrogen as Inerting Medium	
	Maximum O_2%	Minimum CO_2%	Maximum O_2%	Minimum N_2%
Aviation Gasoline[1]				
0% Factor of Safety	14.6	27.9	11.9	41.2
10% " " "	13.1	30.7	10.7	45.3
20% " " "	11.6	33.5	9.5	49.4
Aviation Gasoline[2]				
0% Factor of Safety	14.8	27.0	11.9	40.6
10% " " "	13.3	29.7	10.7	44.7
20% " " "	11.8	32.4	9.5	48.7
JP-3[3]				
0% Factor of Safety	14.3	29.2	11.8	41.3
10% " " "	12.8	32.1	10.6	45.4
20% " " "	11.4	35.0	9.4	49.6
JP-4[4]				
0% Factor of Safety	14.3	29.0	11.5	43.0
10% " " "	12.8	31.9	10.3	47.3
20% " " "	11.4	34.8	9.1	51.6

Footnotes to Table No. 1

[1]Figures based on Aviation Gasoline grade 115/145 at atmospheric pressure and 80° ± 2°F.

[2]Figures based on Aviation Gasoline grade 100/130 at atmospheric pressure and 80° ± 2°F.

[3]Figures at atmospheric pressure and about 80°F.

[4]Figures at atmospheric pressure and about 75°F.

Data on other aviation fuels are not currently available. See Paragraph 333.

†Based on information supplied by the Bureau of Mines, U. S. Department of the Interior, Report No. 3460 (July 7, 1955) "Research on the Flammability Characteristics of Aircraft Fuels".

exceed that specified in Table No. 1 with the 20 per cent factor of safety (see Paragraph 321), assuming that the fuel involved is one of those listed in the Table as typical. (For other fuels, consult the appropriate Laboratory.) The instrument used to secure this measurement must be of a type specifically designed to measure the oxygen content of the inerted atmosphere or the inert gas concentration. (See Part X of these suggested procedures. Note particularly that a standard combustible gas indicator cannot be relied upon to give an accurate, easily interpreted reading in an atmosphere heavily charged with an inert gas.)

330. Personnel Skills and Procedures.

331. Personnel selected to supervise inerting work should have considerable knowledge and experience in handling flammable liquids and inert gases. They should be fully informed on the chemistry of combustion and be trained in the handling of explosion hazards.

332. Special caution is required to avoid asphyxiation in concentrations of inert gases and to avoid the toxic effects of gasoline vapors. Air supply breathing masks will be required where tank entry must be made in an inerted tank.

333. **Warning!** The inerting of aircraft fuel tanks containing other fuels than those listed in Table No. 1 may involve hazards not yet fully understood. Consult a qualified Laboratory for data on fuels not listed.

Part IV. Inerting Procedures—General.

410. Location of Work.

411. The aircraft, wing section or tank to be inerted should be located out-of-doors in an established area clearly segregated and indicated as a hazardous area.

420. Precautions Against Exterior Ignition Sources.

421. All open flame and spark producing equipment or devices within the vapor hazard area should be shut down and not operated during the inerting procedures.

422. Procedures to guard against the accumulation of static electrical charges on the aircraft, wing section or tank should be taken in accordance with NFPA Pamphlet No. 404 on "Static Electricity in Aircraft Operations and Maintenance".[3]

423. Wherever possible the aircraft on which the inerting is being accomplished should have its electrical system deenergized and batteries removed.

424. Electrical equipment used in the vapor hazard areas should be approved for use in Class I, Group D, Division 1 hazardous locations as defined by the National Electrical Code.[4]

425. All mechanics and other persons, except those engaged in the inerting procedures, should remain clear of the aircraft and no other maintenance activities should be conducted on the aircraft, the wing section, or tank until after the inerting has been accomplished.

426. Fuel handling should follow the recommendations of the NFPA given in NFPA No. 407 on "Fueling Aircraft on

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[3]Published in National Fire Codes, Vol. VI and in separate pamphlet form.

[4]NFPA No. 70, published in National Fire Codes, Vol. V and in separate pamphlet form.

the Ground".[3] Airport and aircraft radar equipment operations should be controlled as recommended in Section 270 of NFPA No. 407.

427. Warning! These procedures are designed to accomplish satisfactory inerting of aircraft fuel tanks under the conditions discussed in Paragraphs 150 and 160. When aircraft wing or fuselage sections (other than fuel tank areas) contain flammable vapors (as a result of spillage of fuel, leakage in the fuel system or penetration and entrapment of flammable vapors during fueling or defueling), it is important that such flammable vapors be cleared from such areas out-of-doors by either natural or forced ventilation of such spaces.

428. A suitable warning sign should be placed in a conspicuous location on aircraft to indicate that the fuel system has been inerted.

430. Fire Protection.

431. Aircraft hangars, in which work of this type is conducted, should be provided with automatic fire protection equipment in accordance with the recommendations contained in NFPA No. 409 "Aircraft Hangars."[3]

432. Adequate portable fire extinguishing equipment should be provided for the hazards involved. Portable or mobile equipment should include a quick smothering type extinguishing agent (such as carbon dioxide or dry chemical) plus a permanent smothering type extinguishing agent (such as foam). The amount and nature of such equipment depends on the size of the tank being inerted, the size of the aircraft and the life and exposure hazards involved.[5]

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[3]Published in National Fire Codes, Vol. VI and in separate pamphlet form.

[5]See NFPA No. 403 for "Suggestions for Aircraft Rescue and Fire Fighting Services for Airports", NFPA No. 407 for fire extinguisher recommendations for "Fueling Aircraft on the Ground" and NFPA No. 409 for fire protection recommendations for "Aircraft Hangars" which includes adjacent ramp protection. These standards published in National Fire Codes, Vol. VI and in separate pamphlet form.

Part V. Siphon Inerting.

510. Evaluation of Method, General.

511. This is a recommended method of inerting an aircraft fuel tank or tanks; it is particularly desirable for a series of tanks (metal, integral or bladder) mounted in an aircraft.

512. The aircraft fuel tank should first be filled to capacity with fuel (less outage space) and then this fuel drained while the inert gas is siphoned into the tank void spaces through the tank(s) vent line(s). This involves, in some cases, the handling of considerable quantities of fuel.

513. If "hot work" is to be performed on a tank which has been inerted by this method, the oxygen content in the tank vapor space shall be maintained at substantially zero during the entire period when the work is in progress. (Processes included in the category of "hot work" are welding, cutting, soldering, explosive riveting or any similar process involving an open flame, the application of heat or a spark-producing tool.)

520. Apparatus Required.

521. The following equipment is required to accomplish the siphon inerting of an aircraft fuel tank:

a. An inert gas supply. The gas must be delivered to the fuel tank atmosphere in the gaseous state. If the gas is stored in cylinders at high pressure, special precautions must be taken to avoid liquid discharge (see Paragraph 521.d.).

b. If a pressurized gas supply is used, a pressure reducing or regulator valve to accommodate the cylinder or other source of inert gas. This valve must be suitable for the gas being used.

c. A needle type flow control valve to regulate the flow of inert gas.

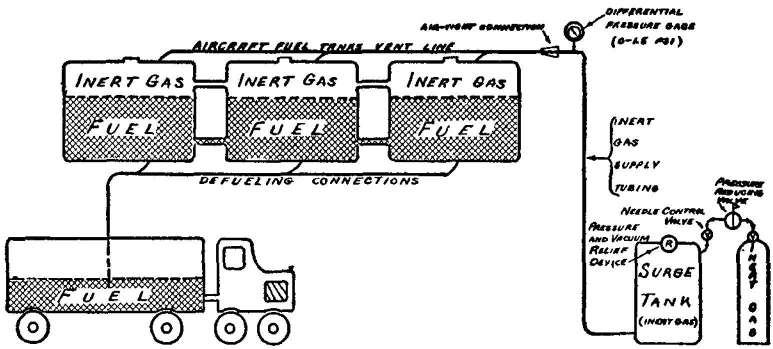
d. If a pressurized gas supply is used, a surge tank (this may be an air-tight oil drum) equipped with adequate pressure and vacuum relief devices should be used.

e. A calibrated differential pressure gage.

f. Tubing to transmit the inert gas to the aircraft tank vent, the tubing equipped with air-tight connectors.

g. Equipment to defuel the aircraft in a safe manner (normally an aircraft fuel servicing vehicle).

522. An oxygen or an appropriate inert gas analyzer or a combustibles detector will be needed for subsequent testing for the maintenance of an inerted atmosphere in a tank (see Part X of these suggested procedures).



Example Flow Diagram of Siphon Inerting Method

530. Example[6] Procedure, Siphon Method.

531. Fill the aircraft fuel tanks to capacity with fuel (less outage space). (This renders the fuel tanks substantially free of air and thereby avoids any possibility of a fuel vapor-air mixture within the flammable range of the fuel vapor.)

532. Crack the pressure reducing valve on the gas pressure cylinder (if used) setting it at one to one-and-a-half pounds pressure per square inch.

533. Open gas needle valve allowing the inert gas to purge the surge tank and connecting lines. Close the needle valve.

534. Conduct a static pressure test on the aircraft vent line system to determine that this system is tight. If the system is not tight it may permit air to enter through the vent lines thereby diluting the inert gas mixture.

[6]The example procedure detailed herein may have to be altered under certain conditions depending upon aircraft design factors and the inerting equipment used.

535. Connect the inert gas line to the fuel tank vent opening making the connection air tight. (This connection can often be made with a one hole rubber, laboratory type, stopper.)

536. Defuel the aircraft fuel tanks into an aircraft fuel servicing truck (or equivalent) while opening the needle valve in the inert gas line, to provide a continuous supply of the inert gas, sufficient to permit continuous siphoning and inerting of the air space created by the defueling operation.

537. Positive pressure must be maintained throughout the fuel system to prevent collapse of the tank (particularly bladder type tanks) but this pressure should not exceed the safe working pressure of the tank (one-and-one-half pounds per square inch maximum is recommended). The calibrated differential pressure gage should be installed in the inert gas supply line as close to the aircraft intake vent as possible.

538. When aircraft fuel tanks have been drained, close the fuel tank drain cocks, disconnect the inert gas supply line at the fuel tank vent opening, insert and secure a solid plug in vent opening and cover with sealing tape. In lieu of sealing the vent intake, a positive pressure (within the safe working pressure of the tank) may be maintained on the inerted tank from the inert gas supply with a pressure gage inserted in the line to indicate the pressure and the maintenance thereof.

539. Warning! The maintenance of an inert atmosphere within the tank depends upon retaining the inert gas which has been thus siphoned into the tank (see also comments in Paragraphs 311 and 312). If at any time any part of the fuel system connected to the inerted tank is opened to the atmosphere, the tank can no longer be considered inerted, and the vapor-content of the tank must then be tested with an oxygen or an appropriate inert gas analyzer or a combustibles detector (see Part X). If the oxygen content of the tank is above the minimums specified in Paragraphs 321 or 513, additional inert gas should be added to reinstate the safe tank atmosphere. In some rubberized fabric bladder type tanks or integral type tanks where sealants are used the tank fabric or sealant deteriorates if the tank is allowed to remain dry for 10 days or longer after defueling. The inside of such tanks should be sprayed with SAE 10 oil or equivalent if they are to remain inerted for 10 days or longer as recommended by the manufacturer. Any loss of inert gas which may be occasioned by this treatment should be replaced to maintain the safe tank atmosphere.

Part VI. Pressure Inerting.

610. Evaluation of Method, General.

611. This method of inerting the vapor space of an aircraft fuel tank or tanks requires careful analysis to assure that all vapor portions of the tank or tanks are reached by the inert gas in sufficient volume to render the non-liquid portions of the tank inert. To assure that such tank atmosphere is inert, it is necessary to thoroughly probe the vapor spaces of the tank with an appropriate instrument (an oxygen analyzer, the appropriate inert gas analyzer, or a combustibles detector — see Part X of these suggested procedures). This method may be used with greatest satisfaction on single tanks, whether mounted in aircraft or not. Interconnected tanks tend to dissipate the inert gas unevenly when introduced by this rather than the siphon method and accordingly a larger volume of gas is needed (see Paragraphs 150 and 160 of these suggested procedures).

612. An advantage of this method is that the tank vapor space can be inerted without a change of level of fuel in the tank assuming that drainage of the fuel is not necessary or desirable for other purposes or that work is not to be performed in the tank.

613. If "hot work" is to be performed on a tank which has been inerted by this method, the oxygen content in the tank vapor space shall be maintained at substantially zero during the entire period when the work is in progress. (Processes included in the category of "hot work" are welding, cutting, soldering, explosive riveting or any similar process involving an open flame, the application of heat or a spark-producing tool.)

620. Apparatus Required.

621. The following equipment is required to accomplish pressure inerting of an aircraft fuel tank.

a. An inert gas supply. The gas must be delivered to the fuel tank atmosphere in the gaseous state. If the gas is stored in cylinders at high pressure, special precautions must be taken to avoid liquid discharge. The supplier of the gas may be consulted as to the proper manner of avoiding liquid discharge from cylinder supplies.

NOTE: Care should be exercised to prevent the inadvertent use of unmodified carbon dioxide fire extinguishers for inerting purposes. Modified cylinders for inerting should be clearly placarded and stored separately from fire extinguisher spares.

b. A pressure reducing or regulating valve to accommodate the cylinders or other source of inert gas. This valve must be suitable for the gas being used.

c. A needle type flow control valve to regulate the flow of inert gas.

d. A length of flexible steel, equivalent metallic or conductive rubber tubing with an electrostatic bonding wire at each end. This tubing should be of sufficient length to situate the inerting equipment at a distance from the aircraft being inerted to permit observation of the entire operation from the pressure regulator position.

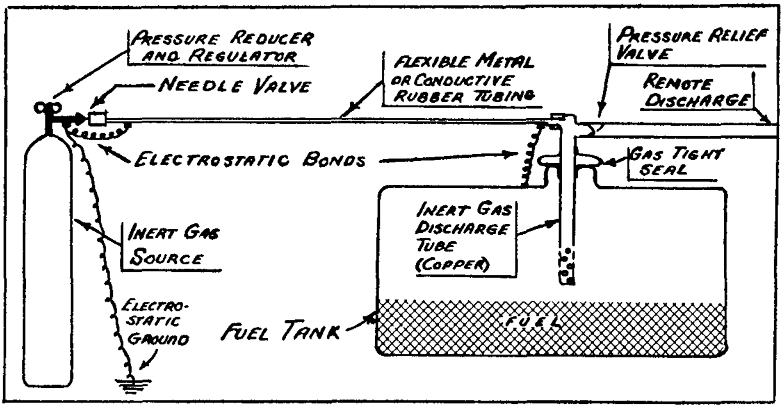
e. A pressure relief valve set to operate at the maximum safe working pressure of the tanks being inerted. The exhaust from this valve shall be directed away from the aircraft. (See Note following Paragraph 621. f.)

f. A fitting to accommodate the filler neck of the tank being inerted, arranged as to form a gas tight seal between the fuel tank opening and the inert gas delivery tube. This fitting must be made of conducting material to form a bond between the tank filler line and the inert gas delivery line. This is in addition to the electrostatic bonding wire and clip on the end of the inert gas delivery line.

NOTE: Since the safe working pressure may vary with each aircraft, it is recommended that a separate fuel tank fitting be made for each different type of aircraft and that the fitting be constructed in such a manner that it will not fit any type of aircraft other than the one for which it is intended. This fitting should contain the pressure relief valve as an integral part thus making it unnecessary to adjust the setting of this valve for the different types of aircraft.

In addition, the fitting shall have a length of copper tubing not less than one inch in diameter and twelve inches in length, closed at its far end and containing many holes or discharge ports along the last three inches of its length to discharge the inert gas.

g. An oxygen or an appropriate inert gas analyzer or a combustibles detector (see Part X of these suggested procedures).



Schematic Diagram of Pressure Inerting Procedure

630. Example[6] Procedure, Pressure Method.

631. Obtain and install on the end of the flexible inert gas delivery tube, the proper fuel tank fitting for the aircraft tank to be inerted.

632. Check the electrostatic bond for continuity from the inert gas source to the tank fitting. There should be no discontinuity.

633. Ground the pressure inerting equipment and the aircraft wing section or fuel tank to an identical electrostatic ground (see Paragraph 422).

634. Before attaching the fuel tank fitting or opening the fuel tank filler cap, clean possible moisture and dust from the inert gas delivery and its associated equipment and fittings by discharging a small quantity of inert gas through the system.

635. Connect the electrostatic bond wire at the delivery end of the inert gas delivery tube to the aircraft or fuel tank prior to removing the fuel tank filler cap.

636. Connect the inert gas delivery fitting to the fuel tank filler assembly so as to obtain the gas tight seal between the inert gas delivery fitting and the fuel tank.

[6] The example procedure detailed herein may have to be altered under certain conditions depending upon aircraft design factors and the inerting equipment used.

637. Close the needle valve in the inert gas delivery line.

638. Adjust, if necessary, the inert gas pressure regulator to the pressure prescribed for the specific aircraft to be inerted. Open the needle valve in the inert gas delivery line. Check the adjustment of the inert gas pressure regulator to be certain that the proper gas pressure is maintained. Check the pressure relief valve at the fuel tank fitting. If inert gas is discharging from this valve, reduce the opening of the needle valve in the inert gas delivery line until the relief valve discharge stops.

639. The flow of inert gas should be continued until a safe tank atmosphere is secured (see Paragraphs 321 or 613). To assure that a safe atmosphere does exist, it is necessary to thoroughly probe the vapor spaces of each tank with an appropriate instrument through access panels. After the desired concentration has been secured, close off the vent line openings with a gas tight seal or plug. Then either remove the inert gas delivery fitting from the fuel tank cap and cover with a safety seal or leave the equipment as is, maintaining, as required, an inert gas pressure on the inerted tank within the safe working pressure of the tank.

Part VII. Air Ventilation — General.

710. Basic Considerations.

711. Under these procedures, air ventilation of aircraft fuel tanks is recommended for the sole purpose of rendering the atmosphere in an aircraft fuel tank more suitable for personnel to enter the tank area for inspection or work purposes. This requires, basically, reducing the fuel tank vapors to below a predetermined toxic threshold (unless respiratory protection is provided) and below the predetermined lower flammability limits of the flammable vapors and, then, maintaining this condition throughout the period of inspection or work. Air ventilation is not a method of inerting an aircraft fuel tank and this distinction must be clearly understood (see Part I).

712. Air ventilation may be accomplished by exhausting the fuel tank atmosphere of toxic and flammable concentrations of fuel vapors through a specified vapor exhaust system with or without a blower designed to augment the "sweeping" of the fuel vapors from the tank. As explained later, the design of the air ventilation system used on any particular aircraft must be "tailor-engineered" to satisfy the requirements of the aircraft in question and detailed specifications will be required for each fuel tank configuration to achieve properly the objectives sought.

713. Under some conditions (particularly in integral type fuel tanks having sealing compounds at tank joints and in baffled tanks where drainage through baffles may not be efficient) it is possible to reinstate a flammable fuel vapor-air concentration after initial ventilation has secured a satisfactory condition. Where flammable solvents are used to remove or replace sealant or where fuel vapors are released by the breaking of sealing compound blisters, a localized toxic and/or flammable vapor atmosphere will most likely be created. When such conditions exist, extreme caution must be exercised to eliminate all possible ignition sources. To minimize this type of hazard, nonflammable solvents should be used wherever possible and air ventilation should be continued during all work periods. Periodic checks should be made with a combustibles detector or other appropriate instrument (see Part

X) in the area of work to assure the maintenance of a safe tank atmosphere.

NOTE: Strict control over the usage of any flammable solvents including limitations on the quantities of such solvents used and the type of container in which they are handled is important in this connection. Nonflammable solvents are recommended where found suitable for the purpose. The periodic checks suggested are for checking any unusual conditions that may develop and for the purpose of maintaining a fire safety consciousness among the employees involved in fuel tank maintenance work.

714. Unless tests show that air ventilation in a particular tank keeps the tank atmosphere below the maximum allowable concentrations of the toxic vapors in use, respirators should be used to protect workers from the vapors. Use of respirators is particularly recommended during any "mopping-up" operations.

715. Air mover equipment used to secure air ventilation should not create fire hazards. Air movers designed to operate by expansion of compressed air or steam are recommended. Where electrical equipment is used, the appliances should conform to the types recommended by Section 5115 of Article 510 of the National Electrical Code (NFPA No. 70)[4]. Compressed air should not be introduced directly into aircraft fuel tanks for air ventilation purposes.

720. Lower Flammability Limits.

721. The following Table is included as a guide to the lower flammability limits of the various aircraft fuels in current usage based on technical information presently available. (See NFPA No. 413-M on "Fire Hazard Properties of Aviation Fuels (Ground Handling)".)

Table No. 2

Lower Flammability Limits of Aviation Fuels

Fuel	Lower Flammability Limit	
	Per Cent by Volume	Parts per Million
Aviation Gasoline (all grades)	1.4	14,000
JP-1	0.6	6,000
JP-4	0.8	8,000
JP-5	0.6	6,000

[4]Published in National Fire Codes, Vol. V and in separate pamphlet form.

722. The determining factor of allowable concentrations may be influenced predominantly, as mentioned previously, by the maximum allowable concentration of vapors permitted from an industrial hygiene viewpoint where respiratory protection for workers is not provided. For leaded gasoline of all grades the limit established is 500 parts per million based on exposures for an eight-hour work day. For gas turbine fuels (such as JP-4 and JP-5), the limits are 400 to 500 parts per million. Solvent vapors may be even lower (e.g. methyl ethyl ketone has a limit of 250 parts per million).

723. It is recommended that a factor of safety be included where the lower flammability limit is the criterion and that 20 per cent of the limits shown in Table No. 2 be considered the maximum allowable concentration of fuel-vapor.

724. Instruments used to measure the lower flammability limit (or maximum allowable toxic limit) should be calibrated accurately for the type of vapors present and checked periodically against standard samples to assure maintenance of calibration. (See also Paragraph 921.c. and Part X of these suggested procedures.) Sampling tubes should be of a type which will be impervious to absorption of the vapors. Instruments depending upon electrical power, if not designed for use in Class I, Group D atmospheres (as defined in the National Electrical Code)[4] or certified intrinsically safe because of their low energy design, should be operated only in non-hazardous locations.

730. Personnel Skills and Procedures.

731. Personnel selected to conduct air ventilation work should have considerable knowledge and experience in handling flammable liquids and should be fully informed on the chemistry of combustion. Since a health hazard is also involved in many cases, knowledge of the importance of industrial hygiene requirements is likewise desirable.

732. Thorough knowledge of the fuel system of the aircraft being treated is essential.

[4]NFPA No. 70 published in National Fire Codes, Vol. V and in separate pamphlet form.

Part VIII. Preparations for Air Ventilation.

810. Location of Work.

811. Prior to conducting work on tanks, it is necessary to defuel the tank or tanks to be inspected or maintained. Such defueling operations should be done outdoors in accordance with the recommendations contained in NFPA No. 407 on Fueling Aircraft on the Ground. Residual fuel which cannot be withdrawn by normal defueling procedures must, most frequently, be drained from the tanks by removal of bottom tank plates. With the opening of the tank, air ventilation procedures should be immediately instituted. Preferably, this operation should be done outdoors when weather conditions permit. This operation is inherently *very hazardous* as there can be little control over the vapors released and frequently liquid fuel escapes as bottom plates are removed. Such fuel must be retrieved in the safest possible manner and the fuel prevented from excessively wetting the underside of the wing or dripping to the ground or ramp to form pools. Furthermore, some of the residual fuel must be siphoned out of the tank or be manually sponged or "mopped-up" from tank low points or where trapped by baffles. Prior to entry into the tank to conduct any manual operation therein, tests should be conducted to determine that a flammable vapor air mixture does not exist or that toxic quantities of vapors are not present (unless adequate respiratory protection is provided and worn). Obviously, as much of this operation as is possible should be conducted outdoors to gain the maximum advantages of free air circulation and the elimination of ignition sources.

812. Hangar docks (open faced structures) are preferable to enclosed hangars for the balance of the air ventilation procedure where such facilities are available and practical. Under all conditions, aircraft undergoing fuel tank ventilation procedures should be segregated or isolated from other aircraft.

813. When air ventilation is done in an enclosed hangar and where a closed ventilating system to discharge vapors from tanks to outside the hangar is *not* used and tank vapors are discharged into the hangar, tests should be conducted to determine that the presence of such fuel vapor laden air in the enclosed hangar does not constitute a hazard under the worst conditions that can normally be anticipated. Any flammable vapor concentration over 20 per cent of the lower flammability limit should result in emergency revisions of procedures.

820. Precautions Against Exterior Ignition Sources.

821. All open flame and spark producing equipment or devices within the vapor hazard area should be shut down and not operated during the ventilation procedures.

822. Electrical equipment used in the vapor hazard areas should be approved for use in Class I, Group D, Division 1 hazardous locations as defined by the National Electrical Code.[4]

823. Procedures to guard against the accumulation of static electrical charges on the aircraft, wing section or tank should be taken in accordance with the recommendations contained in NFPA No. 404 on "Static Electricity in Aircraft Operations and maintenance."[3]

824. Aircraft electrical circuits which are in vapor hazardous areas should be de-energized.

825. Airport and aircraft radar equipment operations should be controlled as recommended in Section 270 of NFPA No. 407.

826. Suitable warning signs should be placed in conspicuous locations around the aircraft to indicate that tank ventilation is in progress.

830. Fire Protection.

831. Aircraft hangars, in which work of this type is conducted, should be provided with automatic fire protection equipment in accordance with the recommendations contained in NFPA No. 409 "Aircraft Hangars."[3]

832. Adequate portable fire extinguishing equipment should be provided for the hazards involved. Portable or mobile equipment should include a quick smothering type extinguishing agent (such as carbon dioxide or dry chemical) plus a permanent smothering type extinguishing agent (such as foam). The amount and nature of such equipment depends on the size of the tank being ventilated, the size of the aircraft and the life and exposure hazards involved.[5]

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[3]Published in National Fire Codes, Vol. VI and in separate pamphlet form.
[4]NFPA No. 70 published in National Fire Codes, Vol. V and in separate pamphlet form.
[5]See footnote page 405-12.

Part IX. Air Ventilation Procedures.

910. Evaluation of Method, General.

911. It must be recognized that in using air ventilation procedures there will be times when the fuel-vapor air mixture in the tank will be within the flammability range. (See also Par. 240.) During such periods a fire and explosion hazard exists. It is thus vitally important that there are no ignition sources within the tank or within reach of the vapors being discharged from the tank.

912. Successful use of air ventilation depends heavily on three basic factors:

a. Complete drainage of the fuel tank to be treated, including siphoning, sponging or "mopping up" of fuel residues which may be trapped in the tank. During the latter operations *extreme caution* is necessary to prevent accidental ignition of the vapors which will be present.

b. Establishment of adequate air circulation through the tank to be treated to assure that the air movement provided rids the entire tank volume of hazardous quantities of fuel vapors. This requires exhaustive tests on each tank configuration to establish the correct tank openings required, the rate of air movement and the time needed to accomplish the objective. Such tests must include combustible vapor measurements of all the tank volume to assure that no vapor hazardous pockets remain, especially in tank corners which may not be properly air ventilated if the air currents established by the exhaust and/or blower systems are ineffective.

c. Continuation of air ventilation during the entire period that the tanks are opened and any work is being done. If additional quantities of flammable vapors are introduced into the tank volume (as during internal cleaning of tank surfaces or resealing of tank seams) adjustments may be needed to maintain the proper amount of ventilation required.

913. Air ventilation should not be relied upon to safeguard fuel tank atmospheres if "hot work" is to be performed on the tank. (Processes included in the category of "hot work" are welding, cutting, soldering, explosive riveting or any similar process involving an open flame, the application of heat or a spark-producing tool.)

914. Where air exhaust only is used, precautions should be taken to prevent building up a negative pressure which might result in tank collapse. Where a blower is used, the volume and pressure of air introduced and discharged should be so balanced that no pressure differential arises which might have an adverse effect on the tank structure.

920. Apparatus Required.

921. The following equipment is required to accomplish air ventilation of aircraft fuel tanks:

a. An air mover (exhaust) and, if circumstances dictate, a blower (see Paragraph 715).

b. If air ventilation is conducted in an enclosed hangar and conditions warrant, an exhaust system designed to discharge the vapors to the outside of the hangar.

c. A properly calibrated combustibles detector designed to take readings of fuel and solvent vapor concentrations within the tank volume being treated and appropriate gas sampling tubing.

WARNING! The reliance placed on combustibles detectors requires great care in the selection of the proper instrument and thorough knowledge of its capabilities and limitations. Expert maintenance is normally required. Only persons specially trained in the use of the instruments selected and in interpreting the measurements secured should be relied upon to perform the required tests. (See Part X of these suggested procedures.)

930. Example[6] Procedure, Air Ventilation (Enclosed Hangar).

931. Place the aircraft in the proper position in the hangar with fuel tanks drained, residual fuel "mopped-up" and the proper underwing tank plates removed; where possible, air ventilation should have been started outdoors and a satisfactory reading secured indicating a non-hazardous tank atmosphere.

932. Guard against static spark hazards by bonding and grounding exhaust equipment and the aircraft to be ventilated. If ducting is used, connect a static bonding wire from each exhaust hose nozzle to the aircraft wing before opening the fuel tank(s).

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[6]The example procedure is illustrative of one method only and may be altered as required for different situations and conditions following the principles enumerated above.