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JUN 11 1974

AC NO: 103-4

DATE: 5/1/74

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DEPARTMENT OF TRANSPORTATION FEDERAL AVIATION ADMINISTRATION

SUBJECT: HAZARD ASSOCIATED WITH SUBLIMATION OF SOLID
CARBON DIOXIDE (DRY ICE) ABOARD AIRCRAFT

1. PURPOSE. This circular discusses the potential hazard associated with the sublimation of dry ice aboard aircraft. Precautionary measures and simple rules of thumb are indicated in order to preclude environmentally hazardous conditions affecting crews and passengers aboard aircraft.
2. GENERAL. There have been reported incidents of Carbon Dioxide (CO₂) hazards aboard aircraft resulting from sublimation of dry ice. These incidents provided sufficient warning to avoid serious difficulty. The physiological effect of an excess amount of CO₂ in the breathing environment is that of oxygen deficiency or simple asphyxia.
3. DEFINITIONS.
 - a. Dry Ice - Solidified carbon dioxide with a melting point of minus 78.5°C (-110°F).
 - b. Sublimation - The process of converting a solid substance (dry ice) into a gas (CO₂ vapor).
4. DISCUSSION. Dry ice is carried aboard aircraft generally for the preservation of food (galley or cargo), medicine, etc. Quantities of dry ice vary depending on the weight of the material being refrigerated. Shipments of dry ice exceeding 2000 lbs. are a matter of record. Dry ice is not regulated nor considered to be a hazardous material by Federal Aviation Regulations 103.

Dry ice gradually releases carbon dioxide which is not poisonous but may present a problem of oxygen dilution in confined spaces where ventilation rates are low. The rate of carbon dioxide release varies with the degree of insulation used in packaging, crushed or solid form, temperature, and atmospheric pressure. Experience during flight

Initiated by: AAM-430

shows that as a rule, a sublimation rate of one pound per hundred pounds of dry ice per hour can be expected.

5. EFFECTS. CO₂ is generally regarded as a simple asphyxiant, symptoms resulting only when such high concentrations are reached that there is insufficient oxygen in the atmosphere to support life. The signs and symptoms are those which precede asphyxia, namely headache, dizziness, shortness of breath, muscular weakness, drowsiness, and ringing in the ears. Removal from exposure results in rapid recovery.

Production of symptoms is related to the effect of CO₂ in the blood on certain bodily processes. No symptoms occur from inhalation of CO₂ if the air contains only slightly more than normal amounts of CO₂. When the concentration of CO₂ approaches 2%, the depth of respiration is increased so that the amount of air into the lungs with each breath increases up to 30%. If the concentration of CO₂ is as high as 4%, there is not only an increase in depth of respiration but also an increase in rate of respiration. Now breathing is deeper and somewhat faster so that considerable discomfort is produced. A concentration of 4.5 - 5% causes breathing to become extremely labored and almost unbearable to some individuals. The most that can be tolerated is 7% to 9%. More than 10% can cause ataxia and unconsciousness.

6. HAZARD. The hazard associated with the carriage of dry ice aboard all aircraft is considered minimal under normal cabin ventilation conditions.

7. PRECAUTIONS AND RECOMMENDATIONS.

- a. A sublimation rate of 8.5 cubic feet (one pound) of CO₂ per 100 pounds of dry ice per hour is recommended for calculation of CO₂ concentration in aircraft spaces.
- b. CO₂ concentration in the aircraft generally should not be allowed to exceed 0.5% (5000 parts per million). This is consistent with the Threshold Limit Values (TLV) in industrial exposures.
- c. Formula: Dry ice loading in pounds = X

$$X = \frac{(\text{CO}_2 \text{ Concentration}) (\text{Aircraft Volume--FT}^3) (\text{Air Changes per hr.})}{.085 (\text{sublimation rate})}$$

Example:

$$\begin{array}{l} \text{Aircraft volume -- } 5000 \text{ FT}^3 \\ \text{Air Changes per hour -- } 5 \\ \text{Allowable CO}_2 \text{ Concentration -- } 0.005 (0.5\%) \\ \text{Sublimation rate -- } 8.5 \text{ FT}^3 \text{ CO}_2 \text{ per 100 lbs. dry ice per hour} \\ X = \frac{(0.005) (5000) (5)}{.085} = 1470 \text{ lbs. dry ice} \end{array}$$

- d. When dry ice is stored aboard aircraft, prior to takeoff, there is a need for cabin ventilation if the normal ventilation system is not functioning. This precludes buildup of CO₂ concentration prior to boarding.

8. REFERENCES.

- a. Pan American Maintenance Engineering Report #ME 124, Feb. 6, 1963, Air Conditions, Dry Ice Quantity Limitations, DC-7CF Flight Test.
- b. Dangerous Properties of Industrial Materials, 1957, N. Irving Sax.
- c. Textbook of Toxicology, 1959, DuBois and Ceiling.
- d. Industrial Hygiene and Toxicology, Vol. II, 1963, Frank A. Patty.

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