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THE EFFECTS OF 2,2 DICHLOROVINYL DIMETHYL PHOSPHATE (DDVP) USED AS AN AIRCRAFT DISINSECTANT

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Flight Standards Technical Division
FAA Aeronautical Center
Oklahoma City, Oklahoma

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Final Report

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FEDERAL AVIATION ADMINISTRATION

Flight Standards Service
Washington, D. C.

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16. Abstract

Pursuant to disagreements between the U.S. Public Health Service and elements of the U.S. aircraft and airline industry, the FAA undertook a study to assess alleged hazards of exposing aircraft and passengers/crew to DDVP vapor for insecticidal purposes on international flights. The study criteria focused on the effects of multiple exposure to the proposed disinsection environment under representative flight conditions. Particular relationships considered were: (1) human toxicology at cabin altitude, (2) flammability characteristics of cabin decorative materials, (3) performance of electronic/avionic equipment, and (4) corrosion of airframe components. Human subjects exposed to a conservative DDVP environment exhibited no characteristics of DDVP toxicity at ground level or at 8,000 ft. altitude. Cabin interior materials showed no measurable change in flammability characteristics after a DDVP treatment equivalent to 3 and 12 months operational exposure. Functional testing of representative avionics equipment produced no premature malfunction under conditions of cyclic altitude with concurrent DDVP exposure. Laboratory corrosion tests coupled with in-flight and laboratory deposition studies indicated that quantities of DDVP that would remain in contact with airframe components are insignificant with respect to the existing corrosive contamination of commercial aircraft. It was concluded that the proposed DDVP disinsection environment would have no degrading effects on safety of flight.

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December 1971

Final Report

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The DDVP study program led to extensive coordination and planning between various governmental agencies. Due to the complexity of the program, the personnel responsible for the coordination and program planning deserve recognition for their efforts in resolving a problem of international concern.

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The scope of the DDVP study program required the assistance of technical expertise in many fields. Various organizations outside the FAA, as well as within, contributed to the study according to their speciality fields. The participating personnel deserve a special thanks for their invaluable aid and commendable cooperation. These deserving organizations and personnel are recognized as follows:

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   Lee Alderman, Physical Science Aid
   David B. Weathers, Res. Chemical Engineer
   Edward Dale, Research Chemist

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   T. S. Humphries, Corrosion Engineer
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   Warren Gardner, Materials Chemist
   Jerry D. Osborne, Chemist

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SUMMARY

The objective of the DDVP study program was to assess the effects of DDVP vapor, on flight safety and airframe airworthiness, when dispensed in transport category airplanes for insecticidal purposes.

Background for the study involves data presented by elements of the U. S. aircraft and airline industry. These data indicated that prohibitive levels of metal corrosion would develop from exposure to the DDVP vapor. Allegations of probable toxic effects on humans were also made. However, the U. S. Public Health Service contended that the corrosion data were derived from unrealistic conditions, and the alleged toxic effects were invalidated by previous toxicology studies done by the USPHS.

Consistent with the Federal Aviation Regulations governing aircraft airworthiness, and in view of the industry data, the FAA could not approve the use of the DDVP system in aircraft. The USPHS contentions had merit, but more data were needed to validate these contentions. Therefore, based on various critiques of the existing data, an objective study program was undertaken to evaluate the effects of DDVP under conditions representative of airline operation.

The DDVP program encompassed aspects of toxicity, material flammability, performance of avionics equipment, and corrosion.

Human subjects exposed to conservative levels of DDVP vapor at a pressure altitude of 8000 feet exhibited no toxic effects. Furthermore, DDVP is a biologically transient compound. Hence, no toxic effects are expected from DDVP buildup in humans through daily exposure.

Typical materials used for cabin decoration and upholstery were treated with DDVP in amounts equivalent to 3 and 12 months operational exposure. Flammability testing of these materials indicated no measurable change in flammability characteristics. DDVP is non-flammable. Fire exposure testing of the DDVP dispensing cartridge indicated that the cartridge presents no fire and/or explosion hazard.

Representative avionics equipment was functionally tested under conditions of cyclic altitude with concurrent DDVP vapor exposure. The overall DDVP exposure was conservative with respect to the proposed disinsection environment. Testing duration consisted of 1000 cycles of one hour each. As verified by the equipment manufacturers, the DDVP exposure produced no effects on equipment performance.

Evaluation of the DDVP corrosion potential included a review of the DDVP decomposition time and volatility, laboratory corrosion testing, in-flight and laboratory deposition surveys, and a comparative study of existing corrosive contaminants aboard aircraft.

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The deposition studies showed that the volatilities of DDVP and its decomposition products preclude extensive buildup under conditions of normal aircraft operation. Frequently disinsected aircraft can attain an average deposition in water of .003 percent DDVP with short duration fluctuations not expected to exceed .006 percent. These quantities of DDVP are insiginificant when compared to the corrosion test data. Also, the possible chloride production from these DDVP levels is less than one percent of the average chloride levels found on in-service aircraft. With the fluctuation found in the normal aircraft chloride levels, any corrosion resulting from DDVP will be undetectable on a comparative basis.

A supplemental finding of the in-flight studies concerns the amount of DDVP dispensed. The initial prototype dispensing system used a DDVP cartridge containing 4.2 grams of DDVP. Initial flight tests resulted in large amounts of DDVP residue remaining in the cabin for long periods after disinsection. It was subsequently discovered that much of the DDVP was condensing immediately upon entering the cabin air due to the temperature differential. The condensed DDVP fell to various surfaces and re-evaporated as the cabin air would support more DDVP vapor. Consequently, the DDVP content of the dispensing cartridge was reduced to 1.4 grams, and dispensed at a lower temperature. Flight testing of the modified dispensing system demonstrated adequate insecticidal capabilities with nil residual DDVP after disinsection. Therefore, a revised system will be proposed for commercial use, which dispenses only 1/4 the amount of DDVP originally proposed.

Specifications on the required DDVP purity and the manufacturing of the dispensing cartridge were prepared by the USPHS to prevent dispensing unnecessarily contaminated DDVP. DDVP of 97% purity can be tolerated, because the bulk of contaminants are trapped in the cartridge. Shelf life studies have shown that negligible DDVP decomposition occurs during storage for a 6-month period. Consequently, the shelf life of bulk DDVP and the dispensing cartridge is presently set at 6 months. Continuing studies by the USPHS may permit this limit to be extended.

It was concluded that the proposed DDVP vapor disinsection environment will have no degrading effects on safety of flight.

1.0 INTRODUCTION

1.1 The objective of the DDVP study program was to assess the effects of DDVP vapor on flight safety and airframe airworthiness when dispensed in commerical aircraft for insecticidal purposes.

1.2 The scope of the study includes flight safety aspects of the toxicity to humans, flammability of materials, performance of avionics and corrosion of metals.

1.3 As background, DDVP is technically named 2, 2-dichlorovinyl dimethyl phosphate which is also known by the trade name, Dichlorvos. DDVP is an organophosphorous compound related to insecticides such as parathion. Certain exposure levels of this compound are considered toxic through attack of the nervous system. However, toxicity of any such compound must consider dosage and exposure time relative to the particular organism. Studies conducted by the U. S. Public Health Service (USPHS) indicated that concentrations of DDVP vapor required for lethal effects on insects had no adverse effects on humans in a ground level environment.[1] Consequently, the USPHS, in collaboration with the World Health Organization (WHO), developed an automatic system for dispensing DDVP vapor in aircraft. This system was considered far superior to the aerosol spray method of disinsection.

1.4 Development of the DDVP aircraft disinsection system resulted in a World Health Assembly (WHA) resolution 21:51 (24 May 1968). This resolution stipulated implementation of the automatic DDVP system as a means for controlling the transport of disease carrying vectors (insects) by aircraft. Subsequent to this resolution, elements of the aircraft and airlines industry conducted studies which indicated that DDVP was highly corrosive to aircraft metals.[2,3] Allegations of a toxic effect on humans under repeated exposure were also made.[3,4] However, the USPHS contended that the corrosion studies were unrealistic, and the alleged toxic effects were unfounded. Both contentions appeared to have merit, but neither were fully substantiated. Consequently, the FAA agreed to assist in resolving various questions regarding the effects of DDVP. The World Health Organization followed by postponing resolution WHA 21:51 (24 May 1968) until the various aspects of DDVP were fully investigated.

1.5 The FAA's interest in the DDVP disinsection system involves the Federal Aviation Regulations which govern the airworthiness of aircraft, and the various systems which contribute to the airworthiness. With the corrosion information provided by industry, the FAA could not accept the DDVP system for use in aircraft without further investigation. The FAA was also interested in the effects of DDVP on other aircraft components,

such as avionics equipment and interior materials. Toxicity at cabin altitude was also an unresolved question. Therefore, with technical assistance from the USPHS Technical Development Laboratories (TDL), the FAA undertook the direction of a rigorous study program to assess the effects of DDVP under conditions proposed for aircraft disinsection. The complexity of this study program required coordination of facilities and expertise from several technically oriented government organizations. This report constitutes a correlation of the various study categories and the associated contributions of the participating organizations.

2.0 DDVP STUDY PROGRAM OUTLINE

2.1 The DDVP study program focused on the four basic categories of:

(1) Toxicity at cabin altitudes,

(2) Flammability effects,

(3) Effects on avionics equipment,

(4) Corrosive potential of DDVP disinsection.

2.1.1 The first three categories of study were straight forward laboratory studies. The corrosive effects of DDVP required several subcategories of study as follows:

Corrosive Effects - Associated Categories of Study

a. DDVP decomposition chemistry

b. Laboratory corrosion testing

c. Flight testing-DDVP deposition and contamination

d. Laboratory deposition study

e. Contamination of in-service airline aircraft

f. Manufacturing specifications for DDVP and shelf-life studies

2.2 The study criteria were based on the exposure environment proposed for aircraft disinsection. This environment consists of a average DDVP vapor concentration of 0.25 micrograms per liter of cabin air for a thirty-minute period beginning during or shortly after take-off.

Study Category No. 1

3.0 DDVP TOXICOLOGY

3.1 INTRODUCTION

Early studies conducted by the USPHS demonstrated that DDVP had no toxic effects on animals and human subjects exposed to several times the proposed disinsection environment.[1] However, all of these studies were conducted at pressure altitudes near sea level. Since passenger carrying aircraft often experience pressure altitudes of about 8,000 feet, the FAA was interested in possible toxic effects under the low pressure conditions. Hence, a study was undertaken by the FAA Civil Aeromedical Institute (CAMI), Oklahoma City, Oklahoma, to evaluate these effects.[5] Personnel from USPHS Technical Development Laboratories, Savannah, Georgia, assisted in the study. The study procedures and results are outlined below.

3.2 TOXICOLOGY OUTLINE[5]

(1) Method - Biochemical and physiological parameters were measured on eight human subjects exposed to varying levels of DDVP vapor.

(2) Physical Condition - Test group consisted of two females and six males ranging in age from 21 to 40 years. Five were moderate to heavy smokers. Three reported histories of allergies, hay fever, or sinusitis, but were in normal state of health during the test period.

(3) Test Exposure - Each test subject was exposed twice to a three phase test with approximately one week between exposures. Parameters were first tested at ground level for base line measurements. Parameters were then tested at 8,000 feet pressure altitude without DDVP exposure to measure effects of altitude alone. The third test phase consisted of DDVP exposure at 8,000 feet altitude. The DDVP concentration-time product ranged from 5 to 10 times that proposed for aircraft disinsection.

(4) Parameters Tested

a. Dark adaptation

b. Blood cholinestorase

c. Sweating rate, and

d. Bronchiolar resistance

(5) Results - The only discernible effects noted were those normally produced by the reduced pressure at altitude.

(6) Reliability - Statistical reliability of no toxic effect on humans is extremely high. Probability of allergic reactions is remote since one of the test subjects was known to be allergy sensitive.

3.3 CONCLUSIONS ON TOXICOLOGY

3.3.1 From the toxicology study, it is concluded that DDVP will have no toxic effect on humans with the proposed disinsection environment. Also, DDVP is a transient chemical in humans. Therefore, toxic effects are not expected from DDVP buildup in the human system through daily exposure.

Study Category No. 2

4.0 DDVP FLAMMABILITY EFFECTS

4.1 INTRODUCTION

4.1.1 Prior to FAA involvement in the DDVP study program USPHS-TDL conducted exposure tests on a variety of 32 materials commonly used for aircraft cabin upholstery and decoration. Exposure was equivalent to 1624 hours of the proposed disinsection environment. There were no visible effects on these materials. However, consistent with the flammability requirements for interior materials, the FAA was interested in how DDVP might affect the flame characteristics of various decorative materials. Also of interest was the fire and explosion potential of the concentrated DDVP in the dispensing cartridge.

4.2 FLAMMABILITY TESTING

4.2.1 It was determined early in the study program by TDL that DDVP concentrate is non-flammable. Also, cartridges placed in hot fires or in a 700°F muffle furnace did not explode. The filter element charred and the plastic valve melted, releasing the fluorocarbon propellant slowly. Aerosol cans currently used for manual spray disinsection are potentially explosive at temperatures above 120°F. Therefore, the fire and explosion hazard of the DDVP dispensing cartridge is considered to be nil, and considerably less than explosion potential of the aerosol cans currently used for "blocks away" disinsection.

4.2.2 A flammability study of interior materials was conducted by the FAA National Aviation Facilities Experimental Center (NAFEC) at Atlantic City, New Jersey. In brief, the flammability studies involved eight materials commonly used in modern commercial aircraft interiors. Samples were treated by TDL with DDVP concentrate to represent cumulative exposure of three months and 12 months, respectively. Exposure time was based on airline estimates of cleaning or replacement intervals. The treatment quantity was based on the assumption that surfaces would retain .25 mcg/in^2 per disinsection with three disinsections per day. NAFEC tested the treated samples in accordance with Federal Standard 191, Test Method 5903 (vertical). Untreated samples were tested concurrently for comparison. Within the limits of the test method measurements, no increase in flammability could be attributed to the application of DDVP.

4.3 CONCLUSION ON FLAMMABILITY

4.3.1 It is concluded that DDVP presents no fire hazard or degradation in the flammability characteristics of cabin decorative materials.

Study Category No. 3

5.0 DDVP EFFECTS ON AVIONICS EQUIPMENT

5.1 INTRODUCTION

5.1.1 Functional testing of electronic/avionics equipment in a DDVP environment was related somewhat to the alleged corrosion problem; i.e., corroded contacts and terminals could cause premature malfunctions. Also, it was known that plastics and phenolics have some degree of affinity for DDVP. In this event, consideration was given to possible changes in dielectric properties of insulators with possible premature arcing. Therefore, functional testing of avionics gear was considered the best approach to determining the effects of DDVP in an operational environment.

5.2 AVIONICS TEST EQUIPMENT

5.2.1 The avionics testing was conducted at the FAA Aeronautical Center, Oklahoma City, Oklahoma, using the Tenny Environmental Chamber shown in figure 5-1. The chamber served as a means of simulating conditions in an aircraft. Air flow through the chamber was regulated to provide a 4-minute air exchange rate. This rate is considered typical of modern jet aircraft. Pressure altitude was also regulated from ground level (1,280 feet) to 8,000 feet.

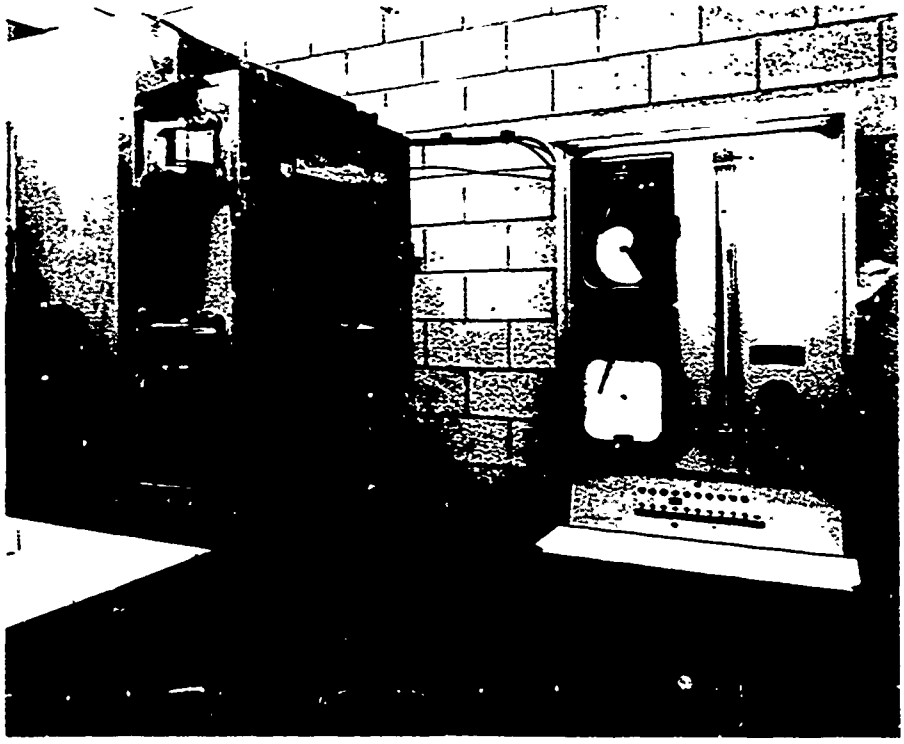


FIGURE 5-1: AVIONICS TEST CHAMBER

5.2.2 The system used for dispensing DDVP into the avionics test chamber was designed by TDL personnel. TDL also provided air sampling equipment for monitoring the DDVP/air concentration in the chamber. The arrangement of these units is shown in figure 5-2.

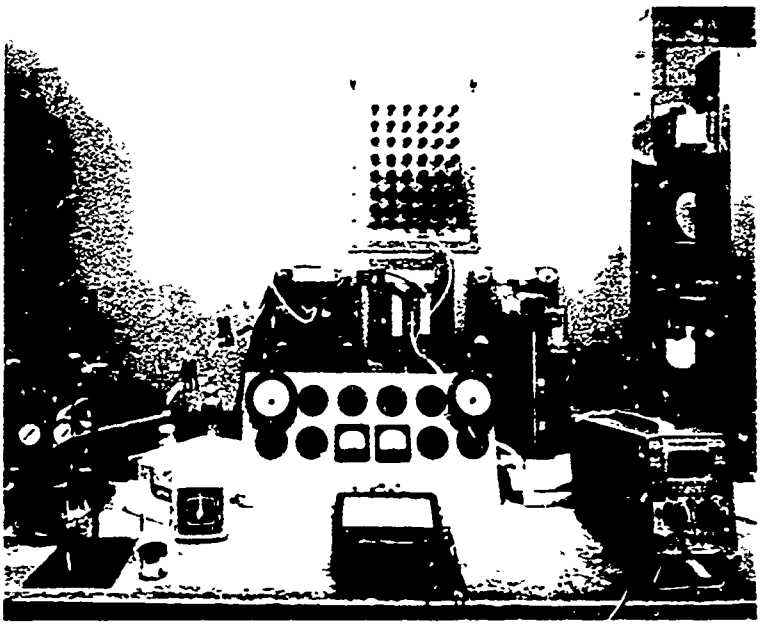


FIGURE 5-2: AVIONICS TESTING-DDVP DISPENSING UNIT AND MONITORING EQUIPMENT

5.2.3 The electronic equipment selected for testing was considered to contain components typical of all electronic gear on an aircraft. Particular items of avionics gear used for testing were as follows:

(1)	VHF Omni Range Receiver (VOR)	Bendix Avionics Model RNA-26c
(2)	Localizer Receiver (LOC)	Bendix Avionics Model RNA-26c
(3)	Glide Slope Receiver (GS)	Bendix Avionics Model RNA-26c
(4)	Distance Measuring Equipment (DME)	King Radio Model KDM-2000

5.2.4 The avionics equipment tested is shown mounted on a plywood base plate in figure 5-3. Positioning of the equipment within the test chamber is shown in figure 5-4.

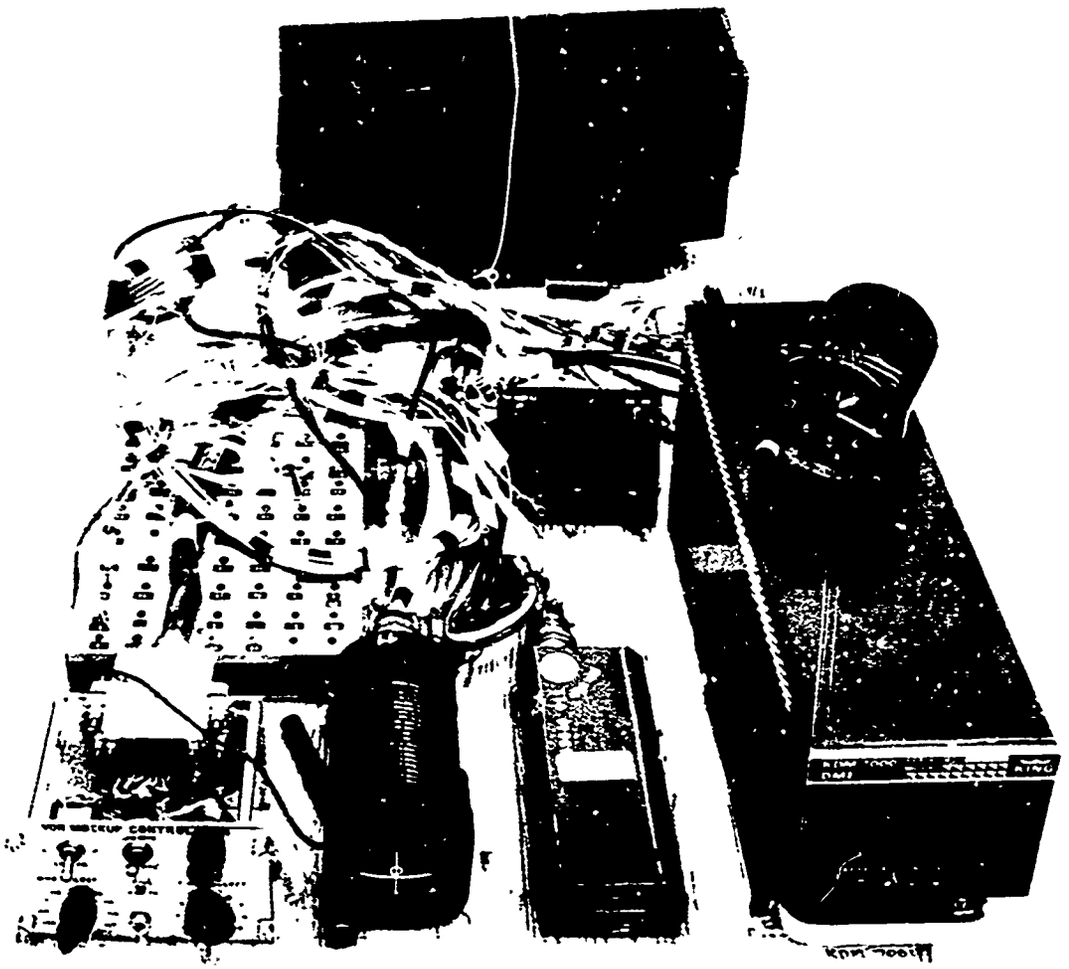


FIGURE 5-3: AVIONICS TESTING-TESTED COMPONENT ARRANGEMENT

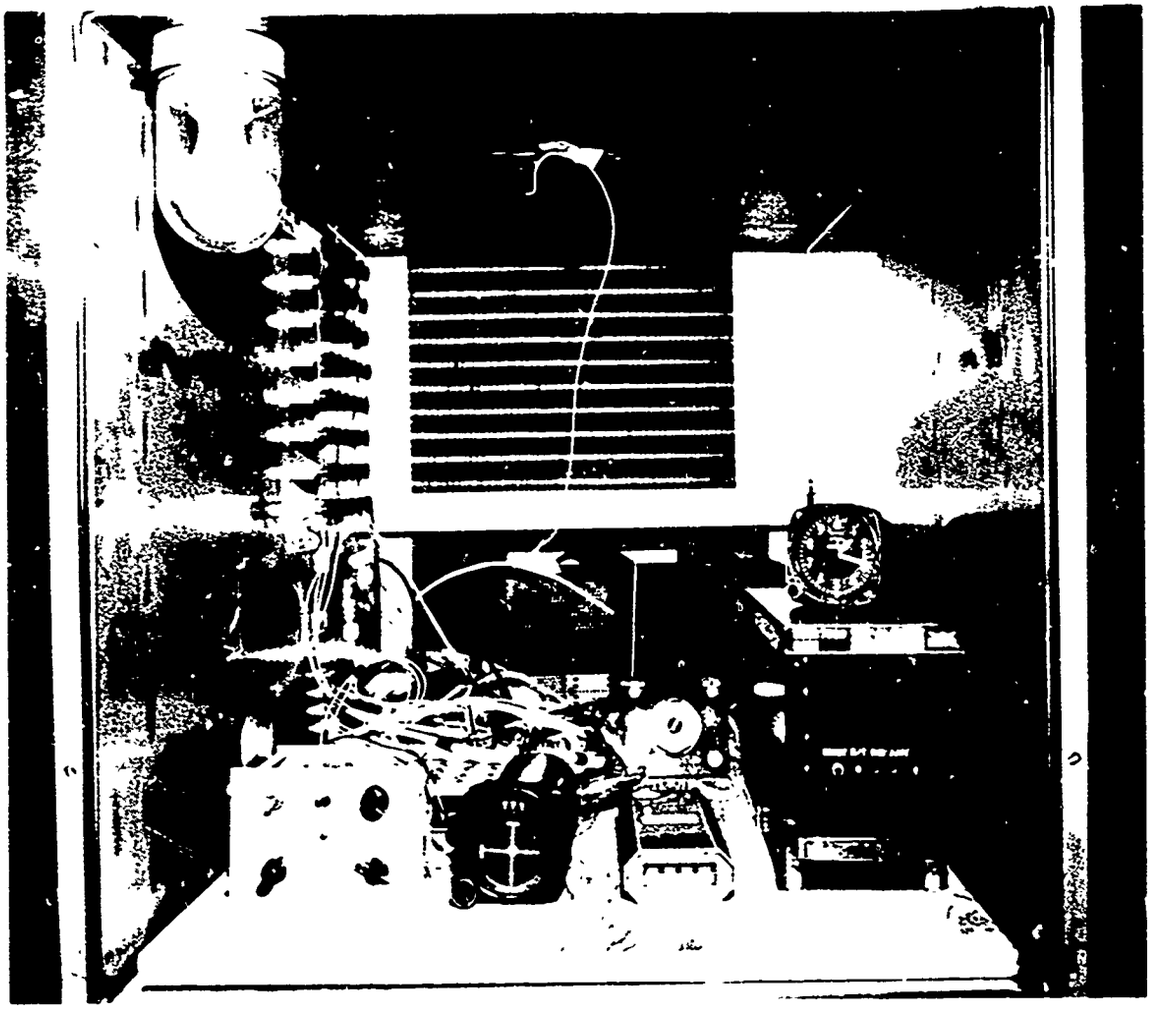


FIGURE 5-4: AVIONICS TESTING-EQUIPMENT ARRANGEMENT IN TEST CHAMBER

5.3 AVIONICS TEST PROCEDURE

5.3.1 Avionics testing comprised 1,000 disinsection cycles of 1 hour ± 1 minute duration. The 1,000-hour test duration was selected on the basis of average operational time in an aircraft between overhauls as indicated by maintenance records and suggested by the equipment manufacturers. Each cycle involved a 30-minute DDVP injection period followed by a 30-minute purging period with the chamber altitude at 8,000 ± 500 feet. DDVP injection was begun when the chamber altitude reached approximately 7,000 feet. After the one hour at altitude, the chamber pressure was returned to ground level for functional checks of the equipment.

5.3.2 The pressure profiles produced by the avionics test chamber did not correspond with cabin pressure profiles normally experienced in jet transport aircraft. Test chamber evacuation was governed by a constant speed pump and a fixed exhaust rate to provide the desired 8,000 feet pressure altitude. Pump down time for the chamber was approximately one minute from ground level to 8,000 feet. Once the dump valve was opened, it took about 1/2 minute for the chamber altitude pressure to reach ground level. Typical flight profiles of a jet transport indicate a climb-out time to 8,000 feet in about five to eight minutes; descent time from 8,000 feet is about the same. However, the primary purpose of the altitude cycles was to create representative pressure differentials which would cause closed components to "breathe." Hence, the rate of pressure change is relatively insignificant since volumes were constant.

5.3.3 DDVP concentrations in the test chamber were monitored by sampling during each 7th disinsection period (30 minutes). Testing progressed at 14 cycles per week day and seven cycles on Saturdays. The chamber was opened for aeration after each 7th cycle. However, even with aeration, the air samples showed a buildup of DDVP in the chamber during each day's testing. This buildup was generally between 10 and 30 percent.

5.3.4 The chamber air samples were shipped to TDL-Savannah, Georgia, for analysis in batches of one week's sampling (11 samples). TDL reported DDVP/air concentrations ranging from .022 mcg/l to 1.04 mcg/l. These concentrations were exceptions. The general average DDVP/air concentration was about .40 mcg/l. This exposure concentration was about 60% higher than the proposed disinsection concentration. Furthermore, the daily cyclic exposure was several times the expected frequency in service. Therefore, the test was conservative with respect to the DDVP exposure proposed for aircraft disinsection.

5.3.5 The test chamber temperature and laboratory relative humidity were monitored during the last 105 cycles. During each day's testing, a notable increase in chamber temperature occurred with each successive cycle. The general temperature range was about 70°F on the first

cycle to as high as 114°F on the 14th cycle. The equipment manufacturers reported that normal operating temperatures in a B-707 is about 131°F with short periods of possibly 212°F. Therefore, temperatures in the equipment cases were probably close to normal during the chamber tests. Relative humidity in the laboratory ranged from 36% to 54% with a general average of about 46%.

5.3.6 The avionics equipment was in operation during each exposure cycle. Functional checks of the equipment were made as follows:

Avionics Functional Checks at Each Cycle End

a. DME fault indicators oberved.

b. DME, AGC voltages logged.

c. DME response to AUTO and MANUAL functional checks.

d. LOC and G.S. crosspointers observed.

e. ILS omnimag crosspointers and flags observed for proper positioning via test switch.

Once Daily

a. DME tuning voltages logged.

b. NAV tuning for 10 different frequencies logged.

c. DME measurement of a known range via outside antenna.

d. VOR course errors for 0°, 90°, 180° and 270°.

e. LOC and G.S. sensitivities logged.

f. DME pulse width and amplitude logged.

5.4 AVIONICS TEST RESULTS

5.4.1 Discrepancies noted during the avionics testing were as follows:

(1) DME performance deterioration was detected during the first day's testing, cycle no. 11. DME became inoperative during the 4th cycle of the second day's testing. During the third day's testing the DME performed satisfactorily. The DME receiver/transmitter was returned to King Radio on the fourth day. The fourth and fifth days' testing continued with only the DME control head and indicator. King Radio serviced the DME replacing several temperature sensitive components. Testing with the complete DME unit resumed on the sixth day.

(2) A momentary lock and track problem occurred with the DME on cycle 101; cause was undetermined.

(3) The localizer crosspointer became unstable during cycle 335. Problem was traced to a local generator which was supplying a redundant signal to the chamber.

(4) The glide slope flag in the omnimag began to stick in view during cycles 364 and 366; cause was undetermined.

(5) The glide slope flag would not show following cycles 380 and 384; cause was undetermined.

(6) An R/T fault occurred on the DME and would not reset following cycle 708; cause was undetermined, but normal operation occurred during subsequent cycles.

(7) DME again became inoperative during the 71st day's testing, cycle 979. The R/T fault indicator was showing and would not reset. DME remained inoperative during the last 21 cycles.

5.4.2 King Radio examined the DME following each failure. They found that malfunction of the DME was caused by failure of an integrated circuit which was known to be a design weakness. (Subsequent models have been modified.) In their opinion, the failure was a random heat generated failure and in no way associated with DDVP exposure. They also felt that other minor discrepancies noted in the DME performance were not related to DDVP exposure.

5.4.3 The Bendix equipment was also returned to the manufacturer for examination. Functional checks performed by Bendix were reported to be within the requirements for the RNA-26c unit, and no deterioration of components was detected.

5.4.4 Prior to returning the avionics equipment to the manufacturers, it was examined visually at the FAA Aeronautical Center for component deterioration, signs of arcing or shorting, and corroded contacts or terminals. No visible discrepancies were found in the electronic circuitry as verified by the manufacturers.

5.5 CONCLUSIONS ON AVIONICS EQUIPMENT PERFORMANCE

5.5.1 The 1,000-hour test duration is considered representative of the operational duration of the avionics equipment in an aircraft. The overall DDVP exposure of the equipment was about 60% conservative. Exposure frequency exceeded that expected in service. No functional discrepancies of the equipment were attributed to the DDVP exposure. Therefore, the DDVP exposure proposed for aircraft disinsection is not expected to affect the performance of electronic/avionic equipment within the normal operational life span of the components.

Study Category No. 4

6.0 CORROSIVE POTENTIAL OF DDVP DISINSECTION

6.1 INTRODUCTION

6.1.1 A cursory examination of the DDVP chemical composition generally created concern with respect to corrosive potential. The concern was caused primarily by the oxygen (O) and chloride (Cl) content. These elements are known corrosive elements, and an analysis of the DDVP decomposition process indicated that these elements can be produced in a form which will react corrosively with aircraft metals.

6.1.2 Although corrosive elements could evolve from DDVP, it was deemed necessary to assess the corrosion potential with respect to conditions encountered in an aircraft environment. Important factors of DDVP-to-metal contact time, as well as the contact quantities, were unknown for the proposed disinsection criteria. A quantitive evaluation of the corrosive potential (corrosion testing) was also desirable for defining the consequences of these factors. Therefore, various studies were undertaken to determine the unknown factors and assess the corrosion potential of DDVP under conditions representative of commercial aircraft operation.

6.1.3 The various corrosion oriented studies progressed concurrently under the direction of the FAA, with specialized assistance from the USPHS Technical Development Laboratories (TDL). Technical expertise in corrosion testing was provided by the NASA Astronautics Laboratory at the Marshall Space Flight Center, Huntsville, Alabama, and the OCAMA Service Engineering Division at Tinker Air Force Base, Oklahoma. In-flight testing and a survey of in-service aircraft were joint efforts of the FAA Flight Standards Technical Division at the FAA Aeronautical Center, Oklahoma City, and the USPHS Technical Development Laboratories at Savannah, Georgia.

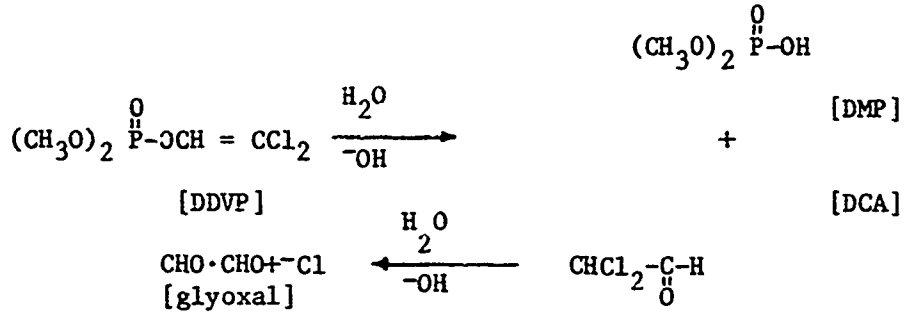
6.2 DDVP DECOMPOSITION CHEMISTRY

6.2.1 To determine amounts of corrosive elements involved, it is important to know what these elements are and in what form they are available. TDL provided the following explanation of DDVP chemical breakdown.

Hydrolysis of DDVP

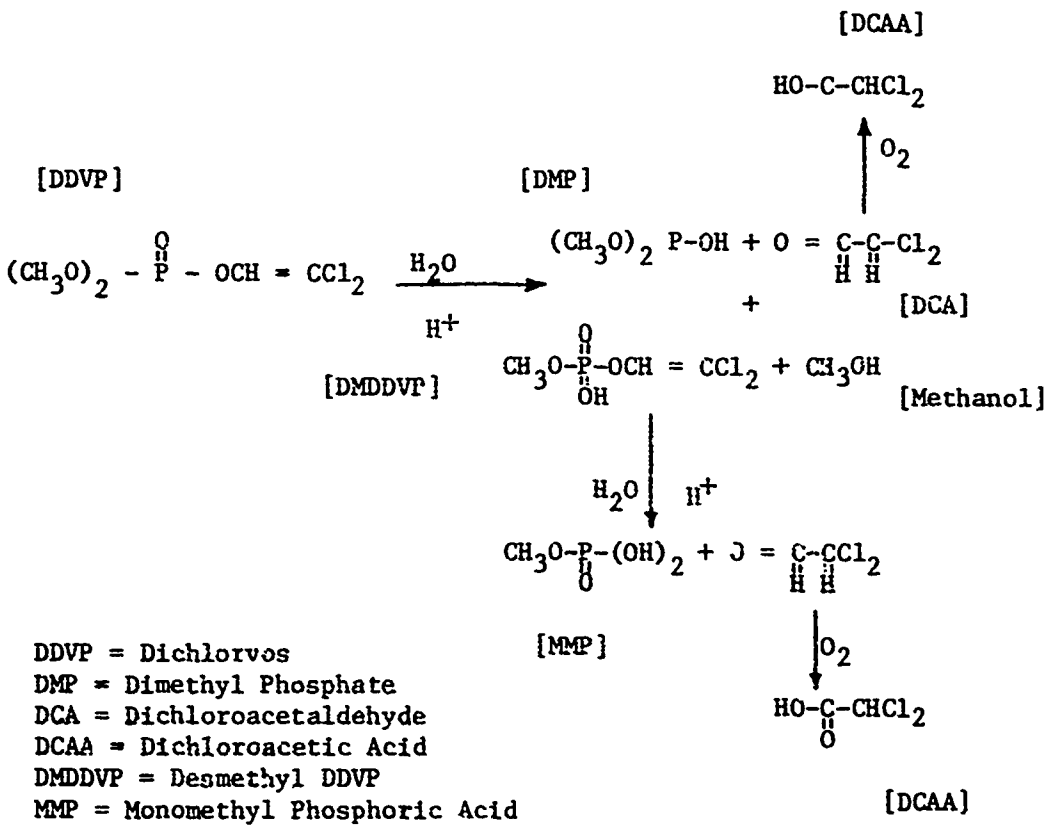
6.2.2 Under basic conditions, DDVP is hydrolyzed (reacts with water) rapidly to form dimethyl phosphate (DMP) and dichloroacetaldehyde (DCA).[7,8] The DCA is then decomposed further to form glyoxal and chlorides, as illustrated in the following equation:

DDVP HYDROLYSIS - BASIC



6.2.3 Under acidic conditions, the hydrolysis proceeds slowly giving principally DMP and DCA. Desmethyl DDVP [$CH_3O \cdot HO \cdot P(O) \cdot OCH : CCl_2$] is also produced which further decomposes to monomethyl phosphoric acid and DCA.[8] Oxidation of the DCA will also occur under certain conditions to form dichloroacetic acid (DCAA). This process is illustrated by the following formula:

DDVP HYDROLYSIS - ACIDIC



DDVP = Dichlorvos
DMP = Dimethyl Phosphate
DCA = Dichloroacetaldehyde
DCAA = Dichloroacetic Acid
DMDDVP = Desmethyl DDVP
MMP = Monomethyl Phosphoric Acid

6.2.4 Volatile chlorides have been produced experimentally by passing air over the surface of liquid DDVP. This phenomenon is not fully understood, but it indicates that oxidation of DDVP or its breakdown products can produce volatile chlorides under these conditions.

Characteristics of Decomposition Products

6.2.5 DMP or dimethyl phosphoric acid is a rather strong acid. Even in a dry state it attacks metals in an etching or milling fashion. DMP is nonvolatile and will remain on surfaces until washed off. It is very water soluble and stable in aqueous solution over a wide range of pH.[8]

6.2.6 Dichloroacetaldhyde (DCA) is a highly reactive compound. In concentrated form, it polymerizes readily making it difficult to prepare and maintain. A freshly prepared sample of concentrated DCA will polymerize extensively within an hour at room temperature. However, polymerization is hindered by contaminants such as air or solution mixture. The rate of polymerization decreases as DCA dilution increases. The polymer is a white, nonvolatile, inert solid. Therefore, rapid polymerization of DCA could prevent the formation of glyoxal and chlorides in an aircraft environment.

6.2.7 Chlorides produced from decomposition of DDVP can corrosively attack aluminum alloys in the presence of moisture. It has been explained that the aqueous chloride attack of aluminum has a multiplying effect. The initial reaction produces Aluminum Chloride [$AlCl_3 \cdot 6H_2O$] and Aluminum Hydroxide [$Al(OH)_3$]. The $Al(OH)_3$ is hydrated Aluminum Oxide [Al_2O_3] and precipitates out. However, $AlCl_3 \cdot 6H_2O$ disassociates to form more $Al(OH)_3$ plus HCl. This $Al(OH)_3$ also precipitates as Al_2O_3 and the HCl attacks aluminum to repeat the cycle as long as moisture is available. Therefore, the introduction of chloride became the predominant concern.

6.2.8 In summary, decomposition of DDVP can produce three corrosive elements: dimethyl phosphate, dichloroacetic acid, and chlorides. DMP in water forms dimethyl phosphoric acid. In the presence of moisture, the free chlorides can react corrosively with aluminum and propagate the formation of HCl. Therefore, the evoluation of three acids is possible from DDVP decomposition, providing sufficient moisture and time are available for complete reaction.

Chemical Availability

6.2.9 Chemical availability must be considered when evaluating the potential for corrosion from DDVP. A corrosive element must be available in sufficient quantity and must be in contact with a metal for a time period equal to the reaction time between the corrosive element and the metal. In the case of DDVP, decomposition must occur before corrosive elements are available. Therefore, DDVP must be in contact with a metal for a time period equal to decomposition time plus the reaction time for the decomposition products.

6.2.10 The relative half-life (decomposition rate) for DDVP through hydrolysis is given in Table 6-1. In addition, the half-lives of DMP and DCA are in excess of 100 days under acidic conditions.[8] Corrosive reaction times for the decomposition products are unknown, but the vapor pressures of the products give some clue to their availability. Vapor pressures for DDVP and its decomposition products are qualitatively compared to water in Table 6-2.

TABLE 6-1

DDVP HALF-LIFE

DDVP (pH 1-5) Hydrolysis

TEMP. °F	HALF-LIFE, DAYS
32	1030
50	240
68	61.5
86	17.3
104	5.8
122	1.66
140	.58
158	.154

TABLE 6-2

RELATIVE VOLATILITIES OF DDVP AND DECOMPOSITION PRODUCTS

ELEMENT	V.P. @ 80°F mm Hg	RELATIVE VOLATILITY
DDVP	0.023	1
H_2O	26.70	1161
DCA	66.00	2870
DCAA	0.37	16
DMP	0.00	0

6.2.11 From Table 6-1, the half-life of DDVP through hydrolysis is in the order of days at temperatures expeced in an aircraft environment (120°F or less). It appears that the higher temperatures are more critical with respect to the production of corrosive elements. However, the higher temperatures will also produce a higher evaporation rate, which would reduce the available DDVP in contact with metal structure. Considering the temperature spectrum that an aircraft experiences, it is again difficult to determine how much and how long DDVP would remain in contact with metal structure.

6.2.12 The relative volatilities of Table 6-2 indicate that two of the major decomposition products, DCA and DCAA, would evaporate more readily than DDVP. Therefore, if DDVP evaporates rapidly from a structural surface, only slight amounts, if any, of DMP would be expected to remain. On the other hand, if DDVP remains in an aqueous solution for an extended time period, larger quantities of DMP would be expected to remain along with chlorides released by the DCA. With this rationale, it appeared that DDVP dissolved in condensation within the aircraft would pose the major corrosion threat.

6.2.13 Since the quantities of corrosive elements available was a key factor in the corrosion potential of DDVP, it was necessary to develop methods of measuring these quantities. Analytical techniques were developed by TDL which were capable of detecting extremely small quantities of DDVP or its decomposition products. Quantity analysis relied on gaschromotography or microcoulometric titration. Both methods required that the particular element be collected in a solvent for analysis. A summary of the methods and sensitivities is given in Table 6-3.

TABLE 6-3

CHEMICAL ANALYTICAL CAPABILITIES

COMPOUND	SAMPLING TECHNIQUE	SOLVENT	METHOD	SENSITIVITY
DDVP	Air Impinger	Soltrol	GLC Chrom 101	1 ng
DDVP	Acetone Wash	Acetone	GLC Chrom 101	1 ng
DCA	Air Impinger	Water	GLC OV-17	10 ng
DCAA	Swab or Runoff	Water	GLC (Me ester) OV-210	25 pg
DMP	Swab or Runoff	Water	GLC (TMA reaction) Chrom 101	100 pg
Cl^-	Swab or Runoff or Air Impinger	Water	Microcoulometric Titration	2 ng

Conclusions on DDVP Chemistry

6.2.14 Since conditions in an aircraft will not allow an accumulation of pure DDVP, the primary concern is the corrosion potential of contaminated DDVP. Water contamination produces hydrolysis of DDVP to form dimethyl phosphoric acid (DMP) and dichloroacetaldehyde (DCA). Oxidation of DCA can produce dichloroacetic acid (DCAA). DCA can also be reduced to form free chlorides in a basic environment. However, polymerization of DCA may prevent further reduction of DCA under certain conditions. Therefore, with proper conditions three acids can evolve through decomposition of DDVP which will react corrosively with metals. However, key questions regarding quantities and DDVP-to-metal contact time under conditions prevalent in aircraft cannot be resolved by a chemical analysis alone.

6.3 LABORATORY CORROSION TESTING

Introduction

6.3.1 TDL personnel considered the methods used by industry in DDVP corrosion testing to be invalid.[2,3] DDVP solution concentrations used in immersion tests were considered too high, although the concentrations that might develop in aircraft condensation were unknown. Industry corrosion testing of DDVP vapor showed more severe corrosion characteristics than the aqueous solution tests.[2] However, TDL established that the test method used was in effect a chloride generator with no resemblance to the aircraft dispensing system.[6]

6.3.2 Preliminary studies by TDL indicated that DDVP will not remain on a dry structural surface.[6] Therefore, an aqueous solution of DDVP was considered to be the primary mode of DDVP-to-metal contact. Hence, major corrosion studies were aimed at assessing the corrosive characteristics of DDVP in water solutions.

DDVP Vapor Corrosion Testing

6.3.3 No extensive efforts were made to assess the corrosion characteristics of DDVP vapor, except those related to the avionics testing. However, the avionics testing provided the opportunity for a simplified vapor corrosion test of typical aircraft metals.

6.3.4 Coupons of 7075-T6 bare aluminum and 2024-T3 clad aluminum were placed in the test chamber during the avionics testing. These coupons received the same DDVP exposure as the avionics equipment. One coupon of each material was isolated to observe any etching effects of the DDVP vapor. Two other coupons, one of each material, were placed in contact with each other to observe possible galvanic action. After the 1000-hour exposure, the metal coupons were not even discolored. After 9 months in a covered petri dish, the samples still showed no signs of corrosion.

DDVP Stress Corrosion Testing

6.3.5 Stress corrosion testing of DDVP was conducted by the National Aeronautics and Space Administration, Astronautics Laboratory, located at the NASA Marshall Space Flight Center, Huntsville, Alabama. NASA's report[10] on the testing was published as NASA TMX-64617, titled "Stress Corrosion Cracking of Aluminum and Steel in Dimethyl Dichlorovinyl Phosphate," September 1971.

[Context of Stress Corrosion Tests]

6.3.6 In summary, the purpose of the NASA testing was to assess the severity of stress corrosion induced by various concentrations of DDVP in

water, as compared to the severity produced by other solutions. Testing of a concentration spectrum was necessary, because the DDVP concentration that might develop in an aircraft was unknown at the time testing began. Through collaboration between NASA corrosion specialists and the FAA, stress corrosion test criteria were established to suit the available NASA facilities and acceptable workload. The criteria and test procedure are outlined below.

STRESS CORROSION TEST CRITERIA

(1) Materials

a. 2024-T3 bare alum.

b. 7075-T6 bare alum.

c. 18 nickel maraging steel (18 N.M.), H.T. 220-240 Ksi.

(2) Specimen Configuration

a. Size - 1/8 in. diameter by 1 1/2 in. long plus 1/2 in. of thread on each end for attaching to stress fixture.

b. Fabrication - Aluminum specimens milled from 2 to 3 in. thick plate to attain end grain exposure with the short transverse grain direction perpendicular to the specimen tensile axis.

Lack of available thick steel plate necessitated that the 18 N.M. steel specimen be milled with the short transverse grain direction parallel to the specimen tensile axis.

(3) Test Solutions

a. 0.001% DDVP by weight in distilled H_2O.

b. 0.01% DDVP by weight in distilled H_2O.

c. 0.10% DDVP by weight in distilled H_2O.

d. Distilled H_2O.

e. 3-1/2% NaCl to represent sea water.

(4) Test Conditions

a. Environment - Ambient laboratory temperature, pressure and relative humidity.

b. Stress Level - 50% and 75% yield strength.

(5) Test Procedure

a. Test each material in triplicate, in each test solution, and under each stress level.

b. Suspend each test sample half way into test solution to obtain surface effects.

c. Maintain solution level by adding distilled water when solution is lost through evaporation.

d. When a test sample is removed, bring the solution level to the original level by adding the specific test solution prepared at the beginning of testing.

e. Solution containers remain uncovered for test duration.

6.3.7 Stress corrosion testing was necessarily limited by the additional outside workload that NASA could accept. Therefore, the selection of metals was limited to some of the more predominant in aircraft; namely, 2024 and 7075 aluminum. The 18 N.M. steel was selected by NASA on the basis of availability to satisfy the FAA's request for testing of a high strength steel representative of steel fasteners and landing gear components.

6.3.8 The number of DDVP concentrations was also limited to reduce the number of metal specimens. Eighteen specimens were required per test solution to test the three metals in triplicate at the two stress levels.

6.3.9 The stress levels used for stress corrosion testing were not designed to represent aircraft conditions. They were selected by NASA on the basis of stress corrosion cracking threshold of aluminum alloys in distilled water. Stress levels of 50% and 75% yield stress were considered well above this threshold and would insure failure in distilled water for comparison with the results in the DDVP solutions. Therefore, data provided by the NASA tests provide only a qualitative comparison between the effects of DDVP and distilled water or laboratory sea water (3-1/2% NaCl). The stressing fixture and specimen holding assemblies are shown in Figure 6-1. Figure 6-2 shows a typical test setup for the stress corrosion testing.

[Results of DDVP Stress Corrosion Tests]

6.3.10 NASA provided the results of the DDVP stress corrosion tests as shown in Table 6-4, with the following conclusion:

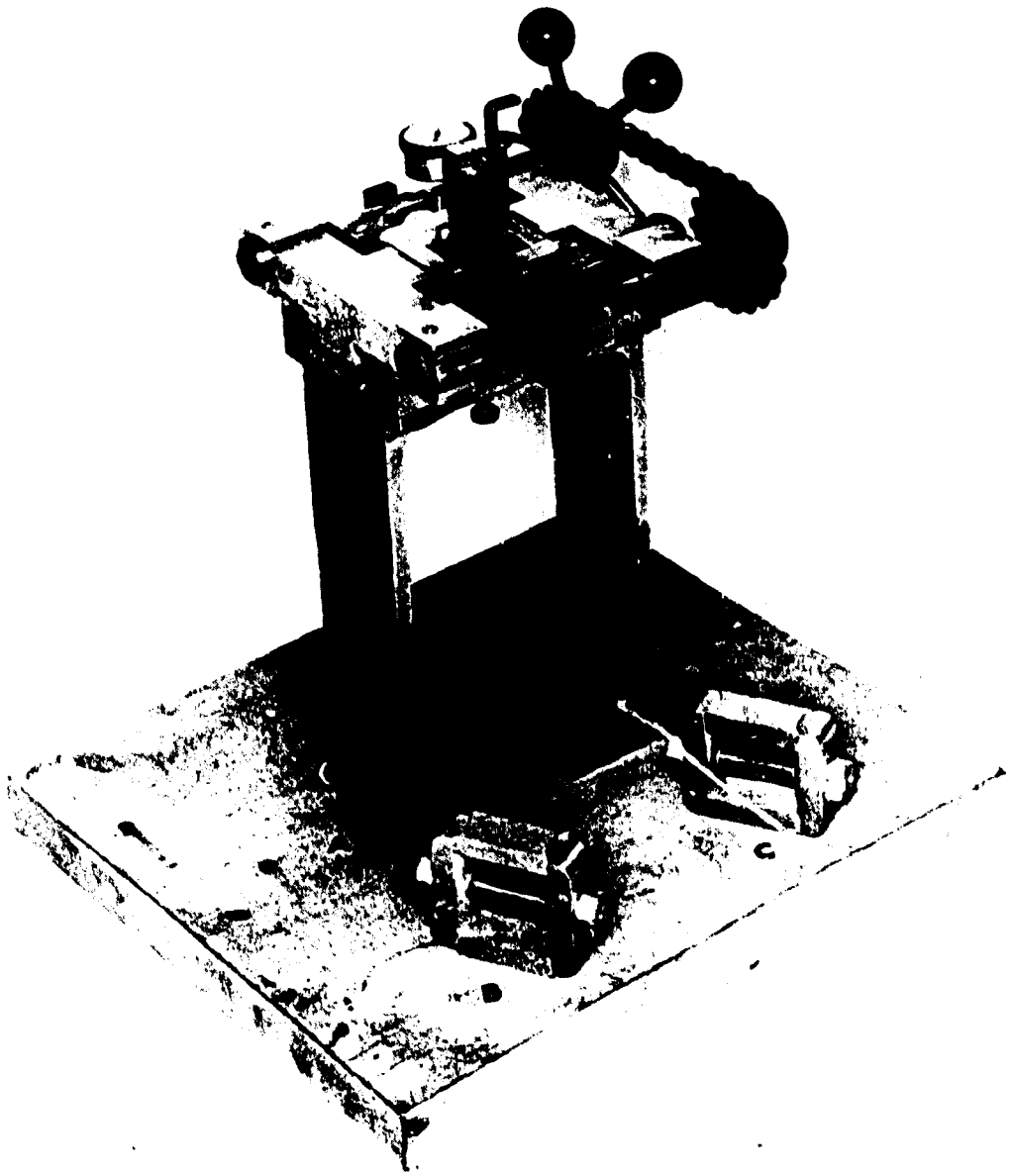


FIGURE 6-1: FIXTURE AND ASSEMBLIES FOR STRESSING ROUND TENSILE SPECIMENS [NASA TMX-64617]

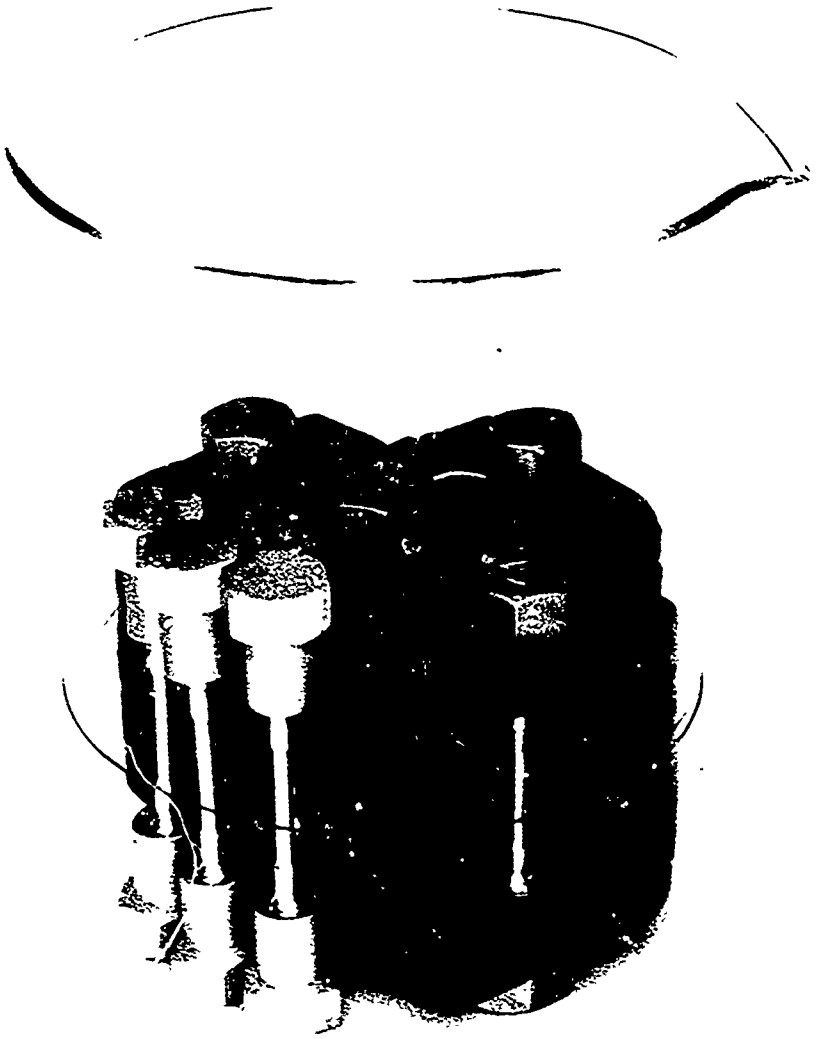


FIGURE 6-2: STRESS CORROSION EXPOSURE METHOD [NASA TMX-64617]

TABLE 6-4

[NASA TMX-64617]

THE PERFORMANCE OF ALUMINUM AND STEEL IN DDVP

Applied Stress (% Y.S.) (1)	Distilled Water		0.001 % DDVP		0.01% DDVP		0.1% DDVP		3.5% NaCl	
	Failure Ratio	Days to Failure	Failure Ratio	Days to Failure	Failure Ratio	Days to Failure	Failure Ratio	Days to Failure	Failure Ratio	Days to Failure
Alloy 2024-T351 Aluminum										
50	2/3	32,41	2/3	11,32	3/3	26,32,36	3/3	27,32,32	3/3	3,3,14
75	2/3	18,22	3/3	13,18,29	1/3	19	3/3	8,11.18	2/3	18,40
Alloy 7075-T651 Aluminum										
50	3/3	18.25,25	1/3	35	3/3	18,25,39	3/3	11,18,19	3/3	3,3,7
75	3/3	3,11,13	2/3	3.18	2/3	3,18	3/3	3,11,19	3/3	3,3,3
Alloy 18 Nickel Maraging Steel										
50	0/3	-	0/3	-	0/3	-	0/3	-	2/3	<42, <42
75	1/3	25	0/3	-	0/3	-	2/3	25,36	3/3	3,18,<42

Note: (1) Initial Mechanical Properties

Alloy	Tensile Str. MN/m^2(ksi)	Yield Str. MN/m^2(ksi)	% El
2024-T351	393 (57)	304 (44)	6
7075-T651	490 (71)	428 (62)	3
Maraging Steel	1600 (232)	1511 (219)	19

DEFINITIONS

FAILURE RATIO = NO. OF FAILURES DIVIDED BY SAMPLE SIZE.

FAILURE = COMPLETE FRACTURE IN MOST CASES.

= CRACKING ONLY IN THE CASE OF STEEL IN 3 1/2% NACL.

> The results obtained in this investigation indicated that the stress corrosion cracking susceptibility of 2024-T351 and 7075-T651 aluminum and 18 nickel maraging steel is not accelerated by exposure to low concentrations up to 0.1 percent DDVP. That is, SCC susceptibility was found to be no worse in DDVP than in pure distilled water and better (longer life and less degradation of tensile strength) than in a 3.5 percent salt solution.[10]

6.3.11 The NASA report[10] does not include the rationale for their interpretation of the DDVP stress corrosion test results. The data (Table 6-4) are difficult to interpret; primarily due to the broad scatter in "Days to Failure" for a given metal under the same exposure conditions. The scatter indicates overlapping effects on failure time of the various test solutions. The data are further complicated by an inconsistent number of sample failures between test solutions.

6.3.12 NASA personnel verbally explained that the results of the DDVP stress corrosion tests are characteristic of their experience with the test technique. They consider the test sample too small for a meaningful statistical analysis. Consequently, their interpretation of the data took a rational approach based on their experience with the test method and the normal response of the materials; in particular, the response induced by distilled water and 3.5 percent NaCl. This rational follows that the overlapping failure times are indicative of similar effects. From Table 6-4, the span of "Days to Failure" in DDVP overlapped or exceeded the respective span of "Days to Failure" in distilled water for all cases. Hence, with respect to stress corrosion, NASA concluded that the tested concentrations of DDVP had no degrading effects in excess of distilled water.

6.3.13 The NASA conclusion on the effects of DDVP with respect to the 3.5 percent NaCl is clearly indicated by the data in Table 6-4, except in the case of 2024-T351 at 75% Y.S. Discussion of this point with NASA personnel revealed that they consider the salt water results invalid for the 2024-T351 test at 75% Y.S. The results did not correspond with their previous experience, and they feel that extraneous factors (pitting, chemical evaporation, etc.) become involved when this type of test extends for more than 35 to 40 days. Consequently, they based their conclusion on the trends indicated by the other tests in 3.5 percent NaCl.

[Conclusions on DDVP Stress Corrosion Testing]

6.3.14 The experience of the NASA personnel must be considered when interpreting the DDVP stress corrosion data shown in Table 6-4.

In view of the complex nature of the stress corrosion process, the NASA rationale follows technical logic, and their conclusions regarding the effects of DDVP are considered valid. Therefore, the stress corrosion tests indicate that aqueous solutions of up to 0.1 percent DDVP have no effects, in excess of distilled water, on the stress corrosion cracking susceptibility of 2024-T351 and 7075-T651 aluminum or 18 nickle maraging steel, and the same DDVP solutions are less degrading than 3.5 percent salt water (NaCl) in the same respect. Furthermore, any conditions experienced on aircraft which differ from the test conditions are expected to have paralleling effects with respect to the various test solutions.

DDVP Electrochemical and Weight Loss Corrosion Testing

6.3.15 Electrochemical and "weight loss" corrosion tests were performed in efforts to establish quantitative measures of the DDVP corrosion potential. These tests were performed by the Service Engineering Division of the Oklahoma City Air Materiel Area (OCAMA) located at Tinker Air Force Base, Oklahoma City, Oklahoma.

6.3.16 Electrochemical action occurs when a D.C. current flow is established between two dissimilar metals through a common electrolyte. Measurement of this current and the application of Faraday's Law of Electrolysis provides a method of calculating the amount of displaced metal (corrosion) over a period of time. Metal displacement with respect to time is defined as "corrosion rate." Electrochemical tests were performed using a spectrum of DDVP concentrations in water as the electrolyte.

6.3.17 "Weight loss" testing consists of simply immersing metal specimens in a chemical solution. The specimen weight is measured before testing and after a period of immersion. The weight difference can then be converted mathematically to a uniform milling or etching rate. DDVP in solution was again required for these tests.

[Context of Electrochemical and Weight Loss Tests]

6.3.18 Electrochemical testing with DDVP was designed primarily to establish experimental corrosion rates created by the galvanic coupling of the more common aircraft metals. A spectrum of DDVP concentrations in water was tested, since the concentration/s applicable to aircraft disinsection were yet undetermined at the time testing began.

6.3.19 The weight loss tests were designed primarily to compare the influence of protective coatings on the corrosion rates produced by DDVP. Duplicate test setups were required due to the 15- and 30-day tests. For post test weighing, corrosion products were removed from the test specimen by scrubbing with distilled water and a soft bristle brush. Since corrosion products hinder corrosion progression, it would be unrealistic to continue testing with specimens subjected to an

intermediate cleaning.

6.3.20 With technical guidance from the OCAMA Corrosion Manager, test plans were developed, then carried out at Tinker AFB as follows:

ELECTROCHEMICAL TEST CRITERIA

(1) Test metal couples

a. 2024-T3 Bare Alum↔4130 Cad. Plate Stl., H.T. 180 Ksi.

b. 7075-T6 Bare Alum↔4130 Cad. Plate Stl., H.T. 180 Ksi.

c. 2024-T3 Bare Alum↔7075-T6 Bare Alum.

d. 2024-T3 Bare Alum↔1145 Alum. Cladding.

(2) Test Solutions

a. 0.0001 % DDVP by wt. in deionized water.

b. 0.001 % DDVP by wt. in deionized water.

c. 0.005 % DDVP by wt. in deionized water.

d. 0.01 % DDVP by wt. in deionized water.

e. 0.05 % DDVP by wt. in deionized water.

f. 0.10 % DDVP by wt. in deionized water.

g. 0.50 % DDVP by wt. in deionized water.

h. 1.00 % DDVP by wt. in deionized water.

i. 2000 ohm-cm. water as an estimate of average resistivity of water accumulations in an aircraft; also termed laboratory tap water as control solution (232 parts per million NaCl in deionized water).

(3) Metal specimens exposed with an area ratio of 1.

(4) Testing done at ambient laboratory temperature, relative humidity and pressure in closed, static containers.

(5) Maintain solution level in containers by adding deionized water.

(6) Each metal couple tested in each test solution.

(7) Voltage measurements taken daily (except week ends) and converted to current flow via Ohms Law.

(8) Test duration - 30 days.

WEIGHT LOSS TEST CRITERIA

(1) Metals tested

a. 2024-T3 Clad Aluminum.

b. 2024-T3 Bare Alum.

c. 7075-T6 Clad Alum.

d. 7075-T6 Bare Alum.

e. 2024-T3 Bare Alum. with alodine 1200.

f. 7075-T6 Bare Alum. with alodine 1200.

g. 1145 Aluminum Cladding alloy.

(2) Test solutions

a. 0.005 % DDVP by wt. in deionized water.

b. 0.05 % DDVP by wt. in deionized water.

c. 1.0 % DDVP by wt. in deionized water.

(3) Metal specimens completely immersed in each solution in covered, static containers.

(4) Testing done at ambient laboratory temperature, relative humidity, and pressure.

(5) Test duration

a. One group of each metal specimen. 15 days.

b. Second group of each metal specimen, 30 days.

(6) Maintain solution level in containers by adding deionized water, if necessary, to keep specimens immersed.

6.3.2i As in the stress corrosion tests, the number of metals tested electrochemically and by "weight loss" were limited to the predominant structural metals in commercial aircraft; namely, 7075-T6 and 2024-T3 or T4 aluminum. The 4130 cadmium plated

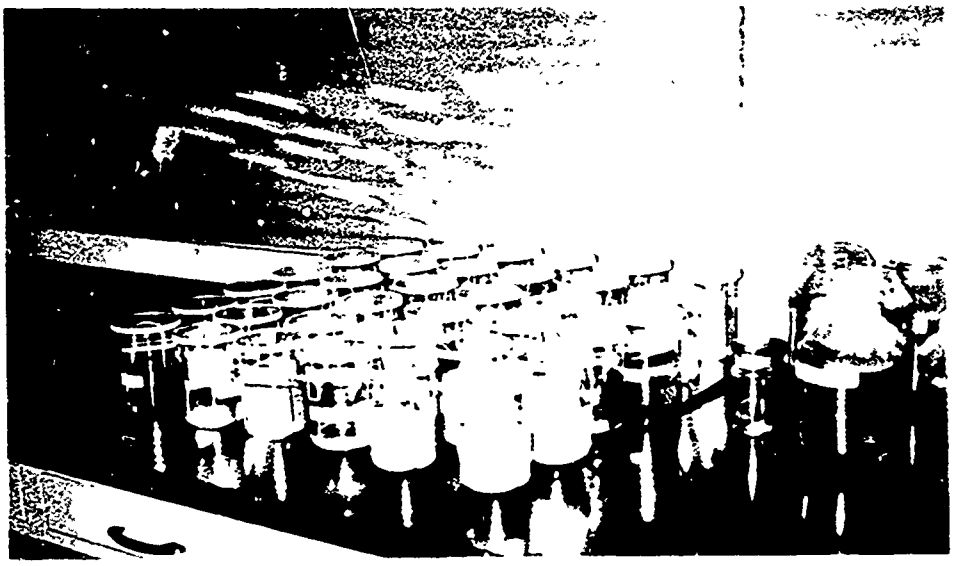
steel, H.T. 180 Ksi or better, was selected to represent high strength steel fasteners.

6.3.22 Clad aluminum was omitted from the electrochemical tests because the primary interest was in the corrosion rates set up in the base metals. Cladding material (1145 aluminum) was tested separately. Corrosion rates for the cladding could then be used to estimate the time required before corrosion began on the base metal if desired. This time would be dependent on the cladding thickness of the particular component of interest.

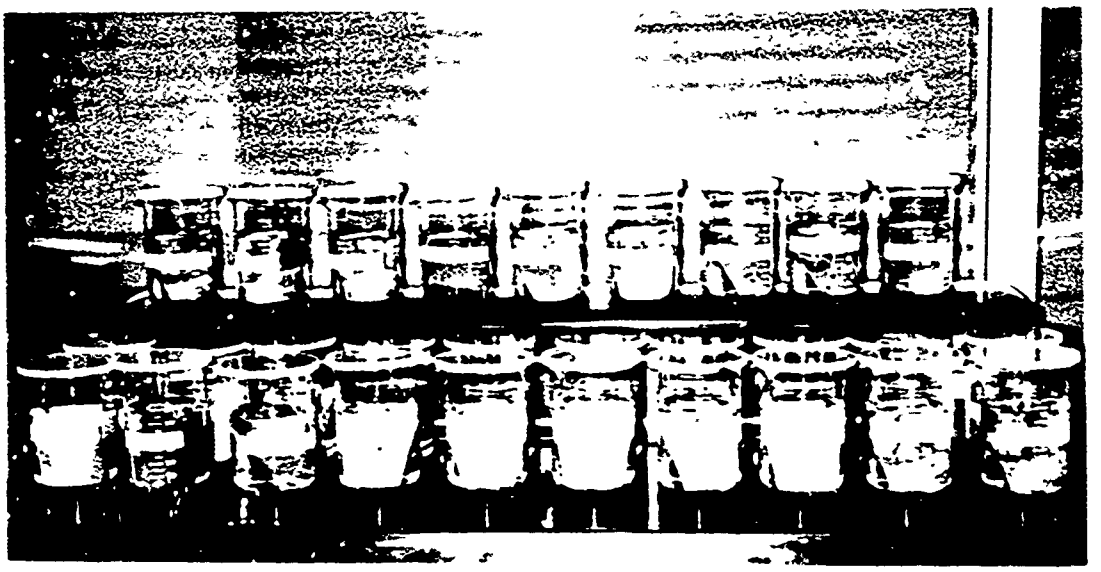
6.3.23 The number of protective coatings tested by the weight loss method was limited by the acceptable workload at Tinker AFB and the need for test duplication. Cladding and alodine 1200 were selected on the basis that these coatings are fairly common but are known to be inferior to some of the modern coatings such as epoxy and polyurethane base primers and paints. Steel was not tested by the "weight loss" method because the OCAMA Corrosion Manager felt that no measurable weight loss would occur on steel in a 30-day test period.

6.3.24 A typical test setup for the electrochemical tests is shown in figure 6-3. Figure 6-4 shows the electrochemical and "weight loss" tests in progress.

FIGURE 6-3: ELECTROCHEMICAL CORROSION TEST SETUP



(a) Electrochemical Tests



(b) Weight Loss Tests

FIGURE C-4: DDVF CORROSION TESTING AT TINKER AFB, OKLAHOMA

[Results of Electrochemical Tests]

6.3.25 Results of the DDVP electrochemical corrosion tests are consolidated in figure 6-5. The points plotted in this figure are the values obtained from the test data using the following equation:

$$\text{MILS/Year} = \frac{3.6 \times 24 \times 365 \times \text{FC} \times \text{Aver. current flow}}{2.54 \times \text{WA}}$$

Where: MILS/Year = Uniform corrosion rate. One MIL = .001 inch.

FC = Faraday constant for metal sacrificed, cm^3/Amp.-Sec.

FC for Aluminum - 3.45×10^{-5}

FC for Cadmium = 6.77×10^{-5}

WA = Wetted area of metal sacrificed cm^2.

6.3.26 The electrochemical data indicate that galvanic action between aluminum alloys and cadmium plated steel increases in severity with increasing DDVP concentration up to the DDVP saturation level (1.0%). In the case of galvanic action between dissimilar aluminum alloys, corrosion rates were highest at about 0.10% DDVP, rather than at the DDVP saturation level. This phenomenon is explained as a critical balance between available oxygen and reacting substance (DDVP or decomposition products). Under these conditions, unaccountable chemical etching releases additional ions into the solution, which increases ion exchange frequency. Since galvanic action is basically ion exchange, a higher corrosion rate evolves.

6.3.27 A significant point illustrated in figure 6-5 is the corrosion rate of DDVP relative to the corrosion rate produced by the laboratory tap water (2000 ohm-cm). In general, the data indicate that DDVP concentrations less than 0.01% in water produce less corrosion than 2000 ohm-cm salt water.*

[Results of the Weight Loss Tests]

6.3.28 Results of the DDVP "weight loss" corrosion tests are consolidated in figures 6-6 and 6-7. Measured weight losses were converted to uniform corrosion rates with the following formula:

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*The 2000 ohm-cm water used in the electrochemical corrosion tests was equivalent to 0.0232% salt water (NaCl).

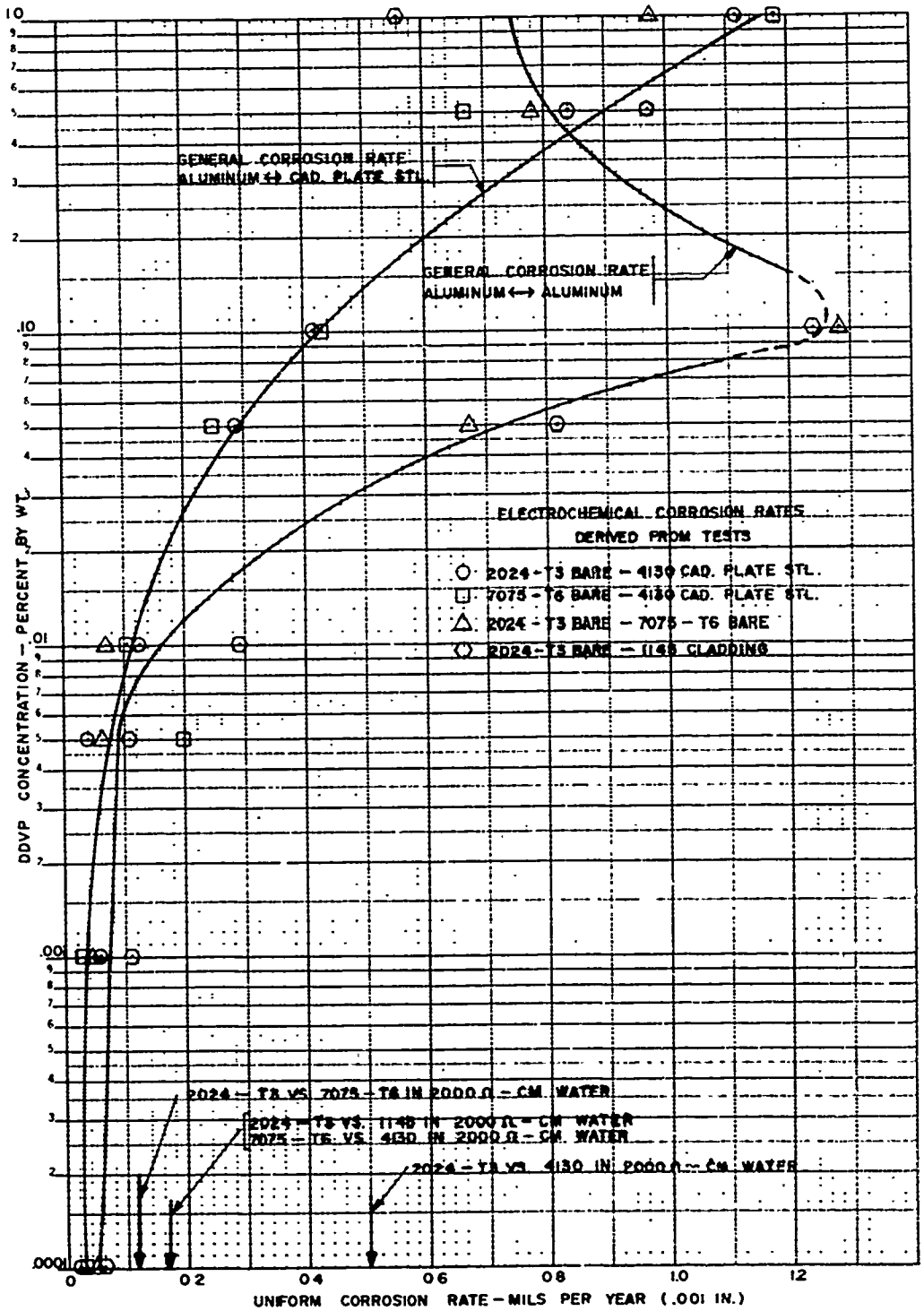

FIGURE 6-5: ELECTROCHEMICAL CORROSION RATES FOR DDVP CONCENTRATIONS - Experimental

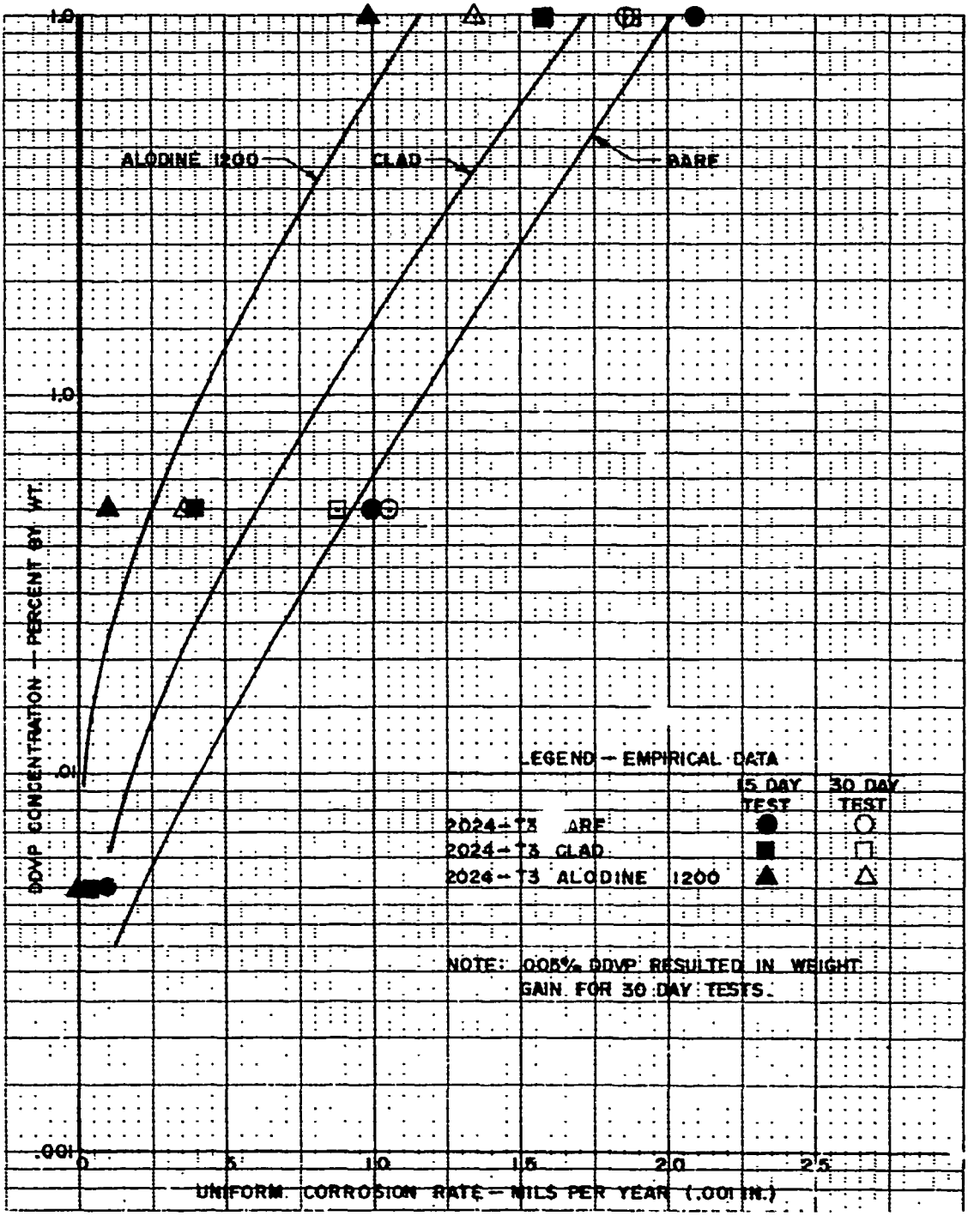

FIGURE 6-6: 2024-T3 ALUMINUM - CORROSION RATE VS. DDVP CONCENTRATION - EFFECTS OF PROTECTIVE COATINGS. [DDVP Wt. Loss Corrosion Tests]

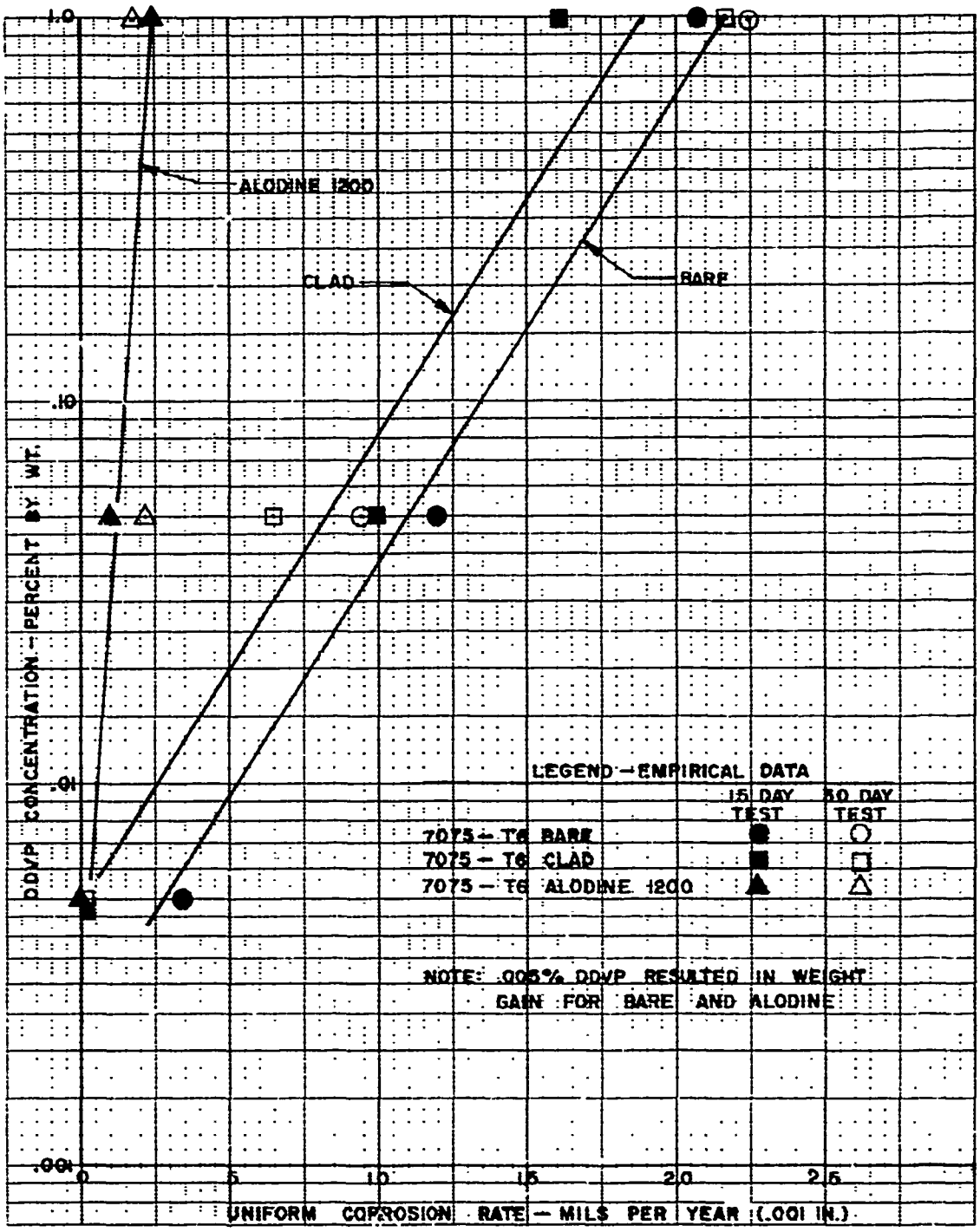

FIGURE 6-7: 7075-T6 ALUMINUM - CORROSION RATE VS. DDVP CONCENTRATION - EFFECTS OF PROTECTIVE COATINGS. [DDVP Wt. Loss Corrosion Tests]

$$1 = \frac{2.54^3 \text{ (Den) Rt}}{30000 \text{ W}} \left[A_4 - \frac{A_2 \text{ Rt}}{30000} + \frac{R^2 t^2}{(9)(10^8)} \right]$$

Where: R = Corrosion rate, MILS per hour (One MIL = .001 in.)

Den = Metal density, grams per cm^3

t = Test time for weight loss, minutes

W = Weight loss in time t, grams

A_4 = a (h + b) + hb, in^2

A_2 = a + h + b, in.

a = plate length, in.

b = plate width, in.

h = plate thickness, in.

6.3.29 Figures 6-6 and 6-7 illustrate a significant improvement in the resistance provided by even relatively poor protective coatings. They also illustrate that corrosion produced by DDVP is relatively insignificant for DDVP concentrations of .005% or less.

[Applicability of Electrochemical and Weight Loss Data]

6.3.30 Caution should be exercised in applying the DDVP electrochemical and "weight loss" corrosion rates. The rates were established under the two basic assumptions of uniform corrosion and no chemical depletion in the corrosion process. However, these assumptions seldom hold true in actual cases.

6.3.31 Uniform corrosion seldom occurs because of the non-homogeneous nature of metal alloys. Soft spots or anodic alloying elements generally produce corrosion pitting. Stress concentrations develop at the corrosion pits. If local stress levels exceed the material strength, local failures evolve until the stress concentration is relieved. Further corrosion within the fracture recreates the stress concentration phenomenon, which evolves into the stress corrosion process.

6.3.32 To account for corrosion pitting, a pitting factor should be applied to the corrosion rates shown in figures 6-5, 6-6, and 6-7. These pitting factors are unknown. They were not determined on the advice of the OCAMA Corrosion Manager. He assessed that no method was available for confidently measuring the corrosion pits developed in the short-term (30 days) tests.

The test specimens exhibited from no pitting to only slightly visible pitting, observed with the naked eye. No equipment was available for accurate measuring pits of the minute magnitude observed.

6.3.33 Gradual reduction of the DDVP quantity will occur in the corrosion process unless it is continually replenished. Chemical depletion naturally reduces the corrosion rate. Therefore, a chemical depletion factor should be applied to the test corrosion rates if the DDVP concentration is assumed constant. This factor was not determined.

6.3.34 Another factor to consider is combined electrochemical action and "weight loss" etching. The DDVP corrosion testing at Tinker AFB was not set up to establish these combined effects. Consequently, these effects are unknown.

6.3.35 To summarize the effects of the unknowns, inclusion of a pitting factor, and accounting for concurrent modes of corrosion would tend to produce corrosion rates in excess of those for a given DDVP concentration shown in figure 6-5, 6-6 or 6-7. The pitting factor is normally significant in evaluating corrosion. However, since the NASA stress corrosion tests indicated no effects from DDVP, the potential for stress corrosion induced by corrosion pitting is not considered critical for DDVP concentrations of 0.1% or less. Furthermore, introduction of a chemical depletion factor would tend to counteract the effects of a pitting factor. Also, intermittent DDVP exposure is expected to further counteract the pitting factor as well as reduce the yearly uniform corrosion rate.* On this basis, the corrosion rates given in figures 6-5, 6-6 and 6-7 are considered to be within the realm of reality for the two modes separately.

6.3.36 Since combined effects of electrochemical action and "weight loss" etching are uncertain, the criteria for judging the corrosive effects of DDVP should be based on a compromise of the two modes. With even a minimal of corrosion protection, the etching rate of DDVP approaches a nil value at a DDVP concentration of about .005% (Ref. figure 6-6 & 6-7). It is notable that the bare material experienced a weight gain, rather than a weight loss, at the .005% concentrations. In comparison, electrochemical action is insignificant with essentially no change for DDVP concentrations of .01% or less (Ref. figure 6-5). Therefore, both modes of corrosion are nil for aqueous DDVP concentrations of .005% or less.

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*Findings discussed subsequently in the section "DDVP Deposition Studies" indicate that continuous DDVP-to-metal contact will not normally occur.

[Conclusions on DDVP Electrochemical and Weight Loss Tests]

6.3.37 The electrochemical and "weight loss" tests were designed to provide a quantitative evaluation of the corrosive effects of aqueous DDVP. On a comparison basis, aqueous solutions of less than 0.01% DDVP are less corrosive electrochemically than 0.0232% salt water (NaCl), when the common aluminum alloys and cadmium plated steel fasteners are involved. Also, electrochemical action is insignificant with essentially no change for DDVP concentrations up to 0.01% (Ref. fig. 6-5)

6.3.38 The "weight loss" data show marked improvement in resistance to DDVP corrosion offered by even the poor protective coatings of cladding and alodine 1200 (Ref. fig. 6-6 & 6-7). With the improved epoxy and polyurethane base coatings used on current aircraft, it is expected that any general corrosive effects of aqueous DDVP would be nullified except at points of coating failure. The "weight loss" data also indicate that the etching effects of DDVP approach a nil value for DDVP concentrations of 0.005% or less.

6.3.39 Unknown factors of corrosion pitting, and chemical depletion complicate application of the test data for the two modes of corrosion. However, with intermittent exposure, the unknown factors are counteracting.

6.3.40 The combined effects of electrochemical action and "weight loss" etching is another unknown factor. With this factor unknown, a judgement on the corrosive effects of DDVP should be based on the DDVP concentration at which the data indicate no significant corrosion by either mode. This point is at a DDVP concentration of about 0.005%.

6.4 DDVP DEPOSITION STUDIES

Introduction

6.4.1 As mentioned in the discussion of DDVP chemistry, DDVP availability is a primary factor in assessing the corrosion potential under conditions proposed for aircraft disinsection. Availability consists of two components; quantity and contact time.

6.4.2 The quantities of DDVP that would be in contact with metal structural components proved to be a major problem. Methods of solving this problem were incorporated with in-flight tests and laboratory studies. DDVP-to-metal contact time was also a part of the in-flight tests, but the bulk of studies on contact time were conducted by TDL at the Savannah laboratories.

DDVP Flight Testing - General

[Flight Test Objective]

6.4.3 DDVP flight testing was a joint FAA-USPHS (TDL) effort to acquire knowledge regarding amounts of DDVP deposition and/or decomposition under representative airline operational conditions. This objective was essential for relating the DDVP environment in an aircraft to the corrosion test data. The test aircraft also provided the opportunity to measure the existing chloride contamination of an aircraft for comparison with the chlorides that may evolve from DDVP deposition.

[Scope of Flight Tests]

6.4.4 All DDVP flight testing was conducted in the FAA's Boeing 727 aircraft shown in figure 6-6. This aircraft is based at the FAA Aeronautical Center. It is operated by the FAA Academy for flight training purposes. Use of the aircraft for DDVP testing was limited to the normal flight training schedule on a non-interference basis. Consequently, the DDVP testing was incorporated with scheduled cross-country area navigational training flight. These flights were selected because commercial routes and flight profiles were followed, and three to four takeoffs and landings at commercial airports were involved. This combination offered representative airliner environments plus the opportunity to investigate the consequences of successive disinsections.

6.4.5 The DDVP flight test series involved 6 primary flights. The first 4 flights were conducted to measure the effects of the initially proposed disinsection system; the last 2 flights were designed to evaluate a revised dispensing procedure. Each flight originated and terminated at Oklahoma City, Oklahoma, with 2 to 3 intermediate stops or flight legs. Disinsections were performed a minimum of 3 consecutive times on each flight. Each disinsection was usually begun

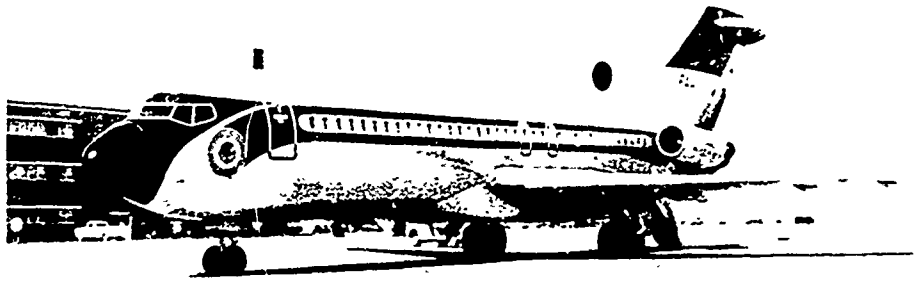

FIGURE 6-8: DDVP FLIGHT TEST AIRCRAFT FAA B-727

as soon as possible after a flight leg takeoff. Individual studies were as follows:

a. DDVP/air concentration survey.

b. Dynamic mass balance.

c. Post disinsection DDVP concentrations.

d. DDVP deposits on dry structure.

e. DDVP deposits on wet and dry filter papers.

f. DDVP deposits on water condensation.

g. Chloride contamination of the aircraft.

[Flight Test Configuration]

6.1.6 Configuration of the FAA B-727 cabin was representative of an air carrier configuration with a full complement of seats, galleys, coat closet, etc. as shown in Figures 6-9 and 6-10.

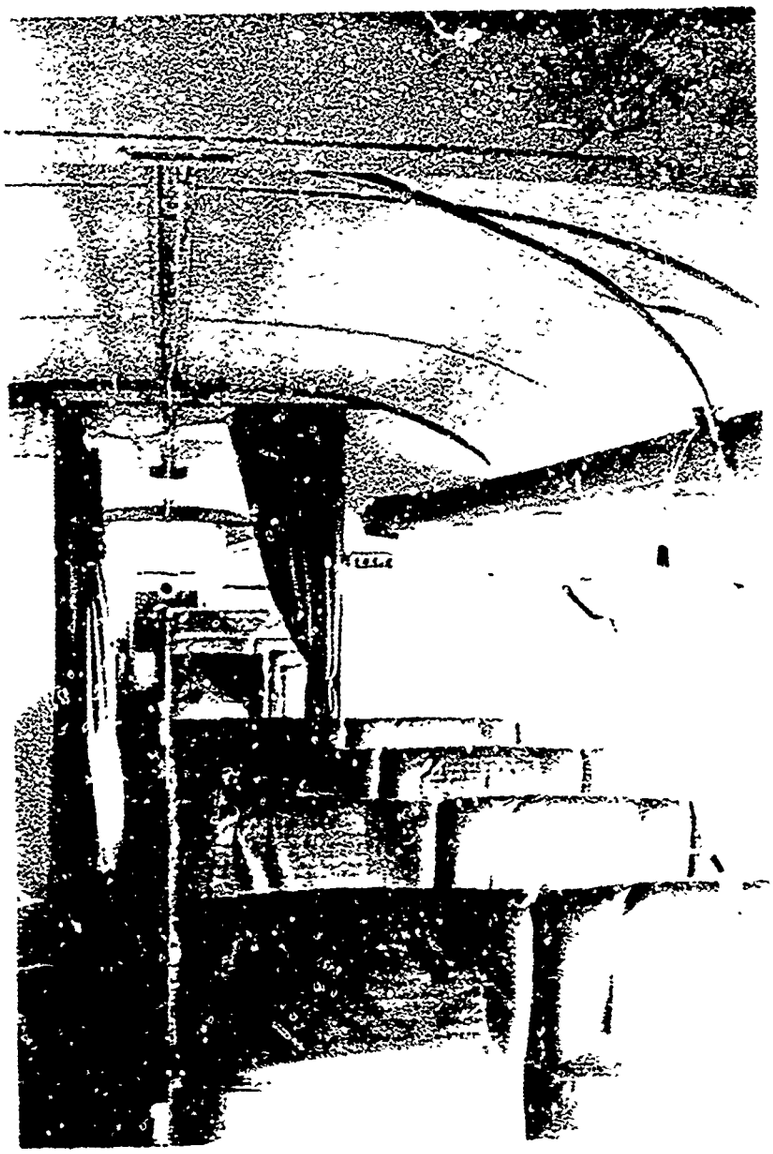

FIGURE 6-9: DDVP FLIGHT TEST CABIN CONFIGURATION LOOKING AFT

6.4.7 Figures 6-9 and 6-10 also show the arrangement of the DDVP dispensing manifold suspended from the cabin ceiling centerline. This manifold extended from station 440 to station 1100 with orifices every 40 inches. The manifold was electrically heated to approximately 130°F while DDVP was being dispensed.

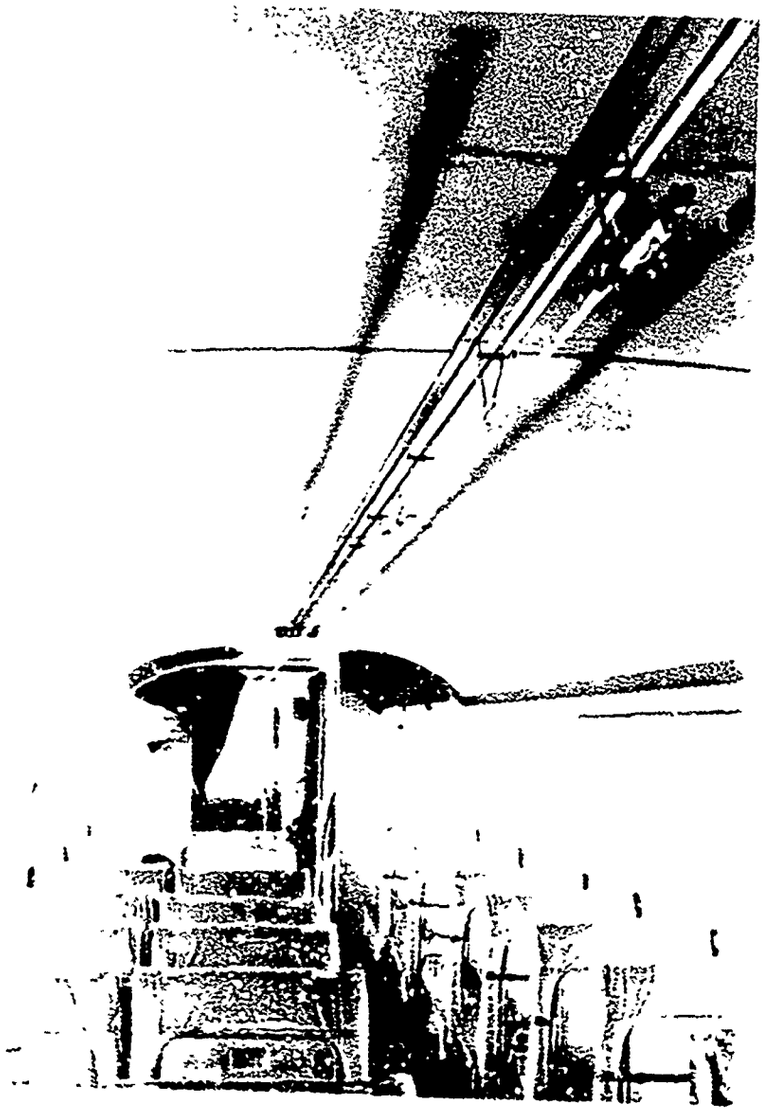

FIGURE 6-10: DDVP FLIGHT TEST CABIN CONFIGURATION LOOKING FORWARD

6.4.8 For the first 4 flight tests, the manifold was supplied by a 3 psi compressor at station 440. Compressor and Teflon tube connection to the manifold are shown in figure 6-11. Data from the first 4 flight tests indicated that the DDVP charge in the dispensing cartridge could be reduced and still obtain an effective disinsection. Consequently, the dispensing system was modified to use a higher volume pump supplying the manifold with lower temperature air at mid-cabin, using reduced charge cartridges. The modified compressor and cartridge arrangements are shown in figures 6-12 and 6-13, respectively. This aspect of the flight test data is discussed further in the "Mass Balance Studies."

FIGURE 6-11: DDVP FLIGHT TEST - COMPRESSOR AND CONNECTION TO MANIFOLD

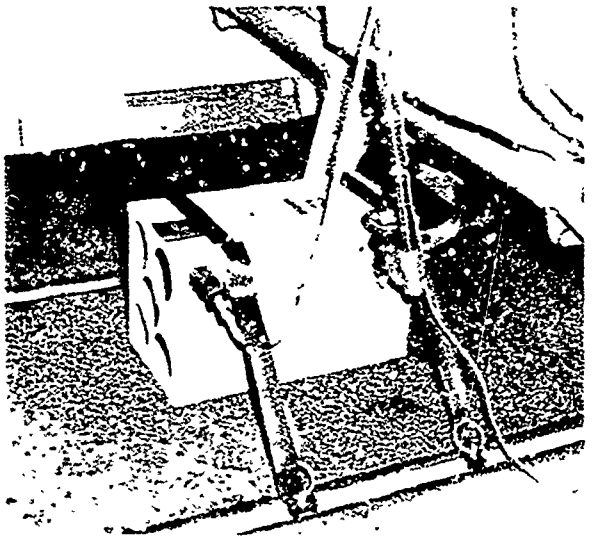

FIGURE 6-12: DDVP FLIGHT TEST - MODIFIED COMPRESSOR

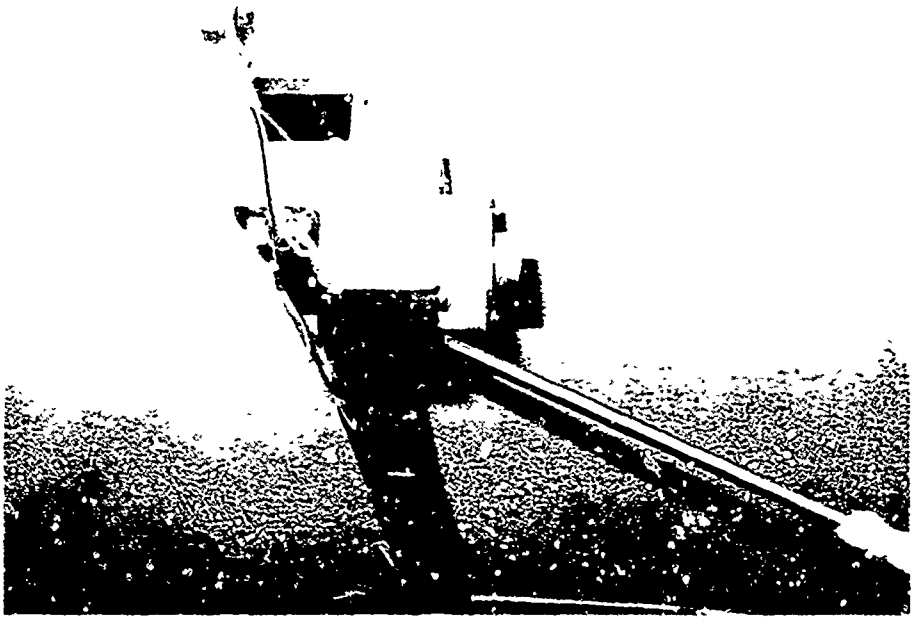

FIGURE 6-13: DDVP FLIGHT TEST - MODIFIED CARTRIDGE AND MANIFOLD CONFIGURATION AT MID CABIN

Individual Flight Test Studies - Procedures and Results

[Cabin Air Sampling]

6.4.9 Impinger air sampling was the method used to monitor DDVP/air concentrations and measure chloride content of cabin air. When a measure of only DDVP was taken, a single impinger and pump were used with soltrol as the DDVP solvent. This method was considered 95% to 98% efficient. When a measure of chloride was desired, three impingers were connected in series to a single air pump. The first two impingers contained soltrol to remove at least 99% of the DDVP. The third impinger contained water as the chloride solvent. Typical configurations of the single and triple impingers are shown in figure 6-14.

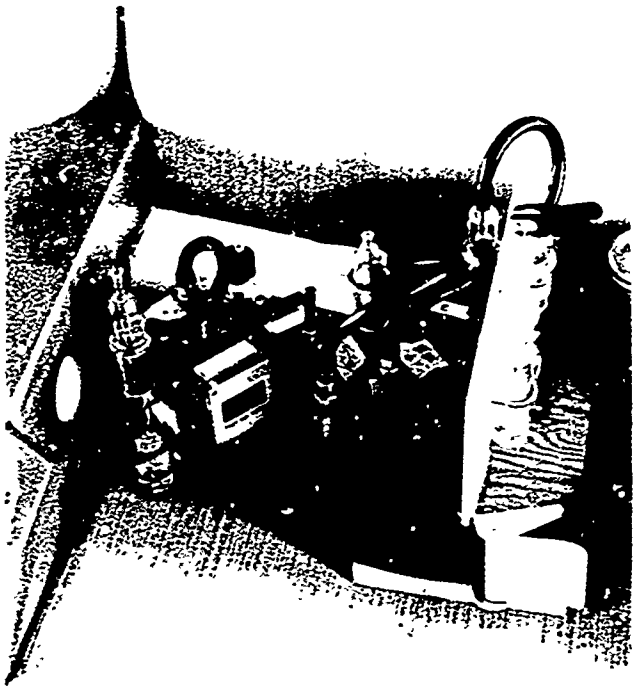

FIGURE 6-14: DDVP FLIGHT TEST - TYPICAL AIR IMPINGER CONFIGURATION
1 TRIPLE-2 SOLTROLS & 1 WATER, 2 SINGLE-1 SOLTROL EACH

6.4.10 Impinger locations were not always consistent between flight tests, except for at least one impinger sampling air from the cabin air exhaust duct Sampling of the cabin exhaust air was always necessary to obtain a mass balance between the DDVP dispensed and the DDVP

exhausted. All air samples were analyzed by TDL using the gas chromatograph for DDVP and microcoulometric methods for chlorides. Air sampling locations and impinger configuration used are consolidated in Table 6-5 with the analytical results from all DDVP flight tests.

[Mass Balance and Decay Studies]

6.4.11 The air sampling results shown in Table 6-5 were important in determining the dynamic mass balance between the DDVP dispensed and the DDVP exhausted from the aircraft. Air samples taken after disinsection were also important as a check on the mass balance results. As designated in Table 6-5, these post-disinsection samples are termed "decay." The average mass balance, or residue, is given in Table 6-6. The available decay values are repeated in Table 6-6 for comparison.

6.4.12 The mass balance data in Table 6-6 show two important aspects of the DDVP disinsection. The first of these aspects is that a DDVP residue of 18 to 80 percent remained in the cabin during disinsection. An indication of some residue was expected due to the time lag of DDVP circulation in the cabin before it entered the exhaust duct. The second aspect is indicated by the decay measurements. Decay measurements for flight test numbers 2 and 4 were very similar to the residue measured during the last disinsection of the same flights (24% to 55%; reference the bracketed values in Table 6-6). This aspect was disturbing, because the decay measurements were taken for periods in excess of an hour after the last disinsection which indicated that the aircraft was exposed to DDVP for a considerably longer period than anticipated.

6.4.13 The cause of the lingering DDVP concentrations was first suspected to be an air exchange rate in the cabin of less than the published 3 to 5-minute rate. This deviation was quite possible since the published rates are for stabilized conditions of altitude and outside temperature. During climb-out to cruise altitude, the altitude and temperature parameters are not stable, and the automatic pressurization and temperature control valves will compensate accordingly. Hence, a reduced cabin air exchange rate might be expected during the ascent phase of a flight. Recalling that the flight test disinsections began right after take-off tends to explain the variation in the measured DDVP residue (Table 6-6), but it does not explain the cause of the lingering DDVP concentrations. A study of the air conditioning system and its operation ruled out the possibility that cabin exhaust air was sampled in the wrong location. The answer to the problem was obtained through a study of the DDVP/air saturation characteristics.

TABLE 6-5

DDVP FLIGHT TEST

CABIN AIR SAMPLE RESULTS

ORIGINAL PROTOTYPE DISPENSING SYSTEM

Flight Test No.	Flight Leg	Location	Impinger Configuration	Analysis DDVP (mcg/1)	Analysis Cl⁻ (mcg/1)
1	1	Seat 11F	Single and	.17 & .15	.032
	2	Mid Cabin	Triple	.20 & .17	.042
	3	F.S 720		.23 & .15	.043
1	1	Cabin Air	Single and	.06 & .05	.045
	2	Exhaust Duct	Triple	.09 & .06	.035
	3	F.S. 1120		.08 & .06	.040
1	1	Pilot Deck		.20	
	2	F.S. 360	Single	.14	
	3			.28	
1	1	Electronic		.12	
	2	Bay,	Single	.25	
	3	F.S. 420		.21	
	Preflight	Seat Row 11	Single	0 & .02	None
2	1	Mid Cabin	and	.15 & .15	None
	2	F.S. 720	Triple	.21 & .21	None
	3			.14 & .14	.03
	4 (decay)			.04 & .04	None
2	Preflight			.00	
	1	Floor	Single	.17	
	2	F.S. 720		.17	
	3			.15	
	4 (decay)			.04	
2	Preflight			No Analysis	None
	1	Cabin Air	Single	.06 & .09	.01
	2	Exhaust Duct	and	.11 & .20	None
	3	F.S. 1120	Triple	.10 & .11	None
	4 (Decay)			.03 & .03	.03

TABLE 6-5 CONT'D

Flight Test No.	Flight Leg	Location	Impinger Configuration	Analysis DDVP (mcg/l)	Analysis Cl^- (mcg/l)
2	1	Pilot Deck		.11	
	2	F.S. 360	Single	.17	
	3			.21	
	4 (Decay)			.09	
3	1	Seat Row 11	Single	.70 & .90	.015
	2	F.S. 720	and	.40 & .40	.240
	3		Triple	.50 & .50	.200
3	1	Adjacent to		.95	
	2	Cold Plate	Single	.40	
	3	Tests		.40	
3	1	Adjacent to		.90	
	2	Exhaust Port	Single	.30	
	3	F.S. 1120		.30	
3	1	Cabin Air		.60	
	2	Exhaust Duct	Single	.20	
	3	F.S. 1120		.20	
4	1	Seat Row 11	Single	.50 & .50	.22
	2	F.S. 720	and	.30 & .30	.045
	3		Triple	.20 & .15	.015
	4 (Decay)			.07 & .06	.10
4	1	Adjacent to		.40	
	2	Cold Plate	Single	.40	
	3	Tests		.40	
	4 (Decay)			.13	
4	1	Adjacent to		.30	
	2	Exhaust Port	Single	.20	
	3	F.S. 1120		.20	
	4 (Decay)			.14	

TABLE 6-5 CONT'D

Flight Test No.	Flight Leg	Location	Impinger Configuration	Analysis DDVP (mcg/1)	Analysis Cl^- (mcg/1)
4	1	Cabin Air		.30	
	2	Exhaust Duct	Single	.20	
	3			.10	
	4 (Decay)			.05	
		MODIFIED DISPENSING SYSTEM			
2/					
	Preflight	Forward		.00	
5	1	Cabin	Single	.096	
	2			Malfunction	
	3			Malfunction	
2/					
	Preflight			.00	
5	1	Mid	Single	.073	
	2	Cabin		.155	
	3 4/			.154	
	3 (Decay)			.009	
2/					
	Preflight			.00	
5	1	Aft		.084	
	2	Cabin	Single	.153	
	3 4/			.185	
	3 (Decay)			.007	
2/					
5	1	Cabin Air		.018	
	2	Exhaust Duct	Single	.031	
	3	F.S. 1120		.087	
3					
6	1	Forward		.27	
	2	Cabin	Single	.25	
	3			.19	
3/					
6	1	Mid		.39	
	2	Cabin	Single	.29	
	3			.18	

TABLE 6-5 CONT'D

Flight Test No.	Flight Leg	Location	Impinger Configuration	DDVP (mcg/1)	Analysis Cl^- (mcg/1)
3/ 6	1	Aft		.31	
	2	Cabin	Single	.38	
	3			.23	
3/ 6	1	Cabin Air		.09	
	2	Exhaust Duct	Single	.13	
	3	F.S. 720		.06	
3/ 6	1	Cabin Air		.18	
	2	Exhaust Duct	Single	.12	
	3	F.S. 1120		.05	
6	4/ Decay #1	Cabin	Single	.038	
		Exhaust	Single	.01	
6	5/ Decay #2	Cabin	Single	0	
		Exhaust	Single	0	

Notes to Table 6-5

1/ Initial prototype DDVP dispensing system used for flight tests 1, 2, 3, and 4: 3.0 psi compressed air @ 130°F; cartridge DDVP charge 4.2 grams; dispensing manifold supplied at forward end. Flight tests 5 and 6 used a modified dispensing system as noted.

2/ Modified DDVP dispensing system used: 3.5 psi compressed air @ 90°F; cartridge mounted horizontally supplying dispensing manifold at mid cabin; flight legs 1 and 2 used a DDVP cartridge charge of 1.4 grams, flight leg 3 used a DDVP cartridge charge of 1.0 grams.

3/ Modified dispensing system used: 3.5 psi compressed air @ 100°F; cartridge mounted vertically supplying dispensing manifold at mid cabin; flight leg 1 used a DDVP cartridge charge of 1.4 grams, flight legs 2 and 3 used a DDVP cartridge charge of 1.0 grams.

4/ Decay measurements taken during flight leg 3 immediately following disinsection.

5/ Decay measurements taken 6 hours after third disinsection.

TABLE 6-6

DDVP FLIGHT TESTS

DYNAMIC MASS BALANCE

ORIGINAL PROTOTYPE DISPENSING SYSTEM

Flight Test No.	Flight Leg	Average DDVP in Cabin Air (mcg/1)	Average DDVP in Exhaust Air (mcg/1)	DDVP Residue (mcg/1)	(1%)
1	1	.18	.07	.11	61
	2	.20	.085	.115	58
	3	.205	.075	.130	63
2	1	.12	.075	.045	38
	2	.19	.155	.035	18
	3	.16	.105	[.055]	24
	4 (Decay)	[.05]	.03	.	
3	1	.90	.60	.30	33
	2	.40	.20	.20	50
	3	.40	.20	.20	50
4	1	.40	.30	.10	25
	2	.30	.20	.10	30
	3	.22	.10	[.12]	55
	4 (Decay)	[.10]			
MODIFIED DISPENSING SYSTEM					
5	1	.084	.020	.064	74
	2	.152	.029	.121	80
	3	.170	.059	.111	65
	3 (Decay)	.008			
6	1	.33	.13	.20	60
	2	.31	.13	.18	58
	3	.20	.06	.14	70
	3 (Decay)	.038	.01		

6.4.14 TDL had long theorized that an aircraft of the B-707 category could be disinsected with less than one gram of DDVP. The disinsection cartridge had nevertheless been standardized to contain 4.2 grams (3 ml), because that amount had been found to consistently yield the desired cabin concentration of 0.25 mcg/l. An evaluation of cartridge content after disinsection showed that about 3 grams of DDVP were dispensed during flight tests 1 through 4. In theory, this amount should yield an average cabin concentration of more than 1 mcg/l in a B-707, or about 4 times the desired concentration. On this basis, it was theorized that the excess DDVP was condensed as it exited the distribution tubing during the first four flight tests. The excess was then distributed within the cabin as microscopic liquid droplets. This phenomenon is termed "DDVP fall-out."

6.4.15 In order to investigate the "fall-out" theory, TDL developed a saturation curve for DDVP in air as shown in figure 6-15. Laboratory studies were then performed to determine the actual DDVP concentrations present in the distribution tubing under varying dispensing conditions. A cartridge charge of 4.2 grams produced a DDVP concentration of about 600 mcg/l in the distribution tubing at 120°F. About 1.2 gr. DDVP remained in the cartridge. Figure 6-15 illustrates the DDVP condensation or "fall-out" that could occur when the 120°F DDVP is subjected to 70°F cabin air. Through a series of mock-up and wind tunnel studies by TDL, it was determined that satisfactory disinsection of a B-707 could probably be attained with a cartridge charge of about 1.4 gram dispensed at 100°F. This combination produced a DDVP concentration of about 140 mcg/l in the distribution tubing with 0.6 grams DDVP remaining in the cartridge. Figure 6-15 illustrates that no "fall-out" should occur under these conditions. Since the revised procedure involved a 75% to 80% reduction in DDVP per disinsection, it was considered advisable to flight test the revised procedure to evaluate its biological effectiveness and contamination potential under flight conditions.

6.4.16 Flight tests 5 and 6 incorporated the revised DDVP dispensing system with the higher volume compressor and reduced charge in the DDVP cartridge. Houseflies were exposed during these tests to check insecticidal capabilities. Fly mortality was 100% within the 30-minute disinsection period in all cases, even though the DDVP/air concentrations were considerably less than the desired .25 mcg/l during test no. 5. The DDVP/air concentrations were approximately doubled in flight test no. 6 by mounting the dispensing cartridge vertically instead of horizontally. Vertical mounting improves dispersion of the DDVP onto the cartridge filter element.

6.4.17 As shown in Table 6-5, the reduced DDVP charge still produced a DDVP residue during disinsection, but the lingering concentrations, shortly after disinsection, were reduced to only traces (.008 mcg/l). Air samples taken 6 hours after the last disinsection of test no. 6 picked up no detectable DDVP. Therefore, DDVP exposure time with the revised

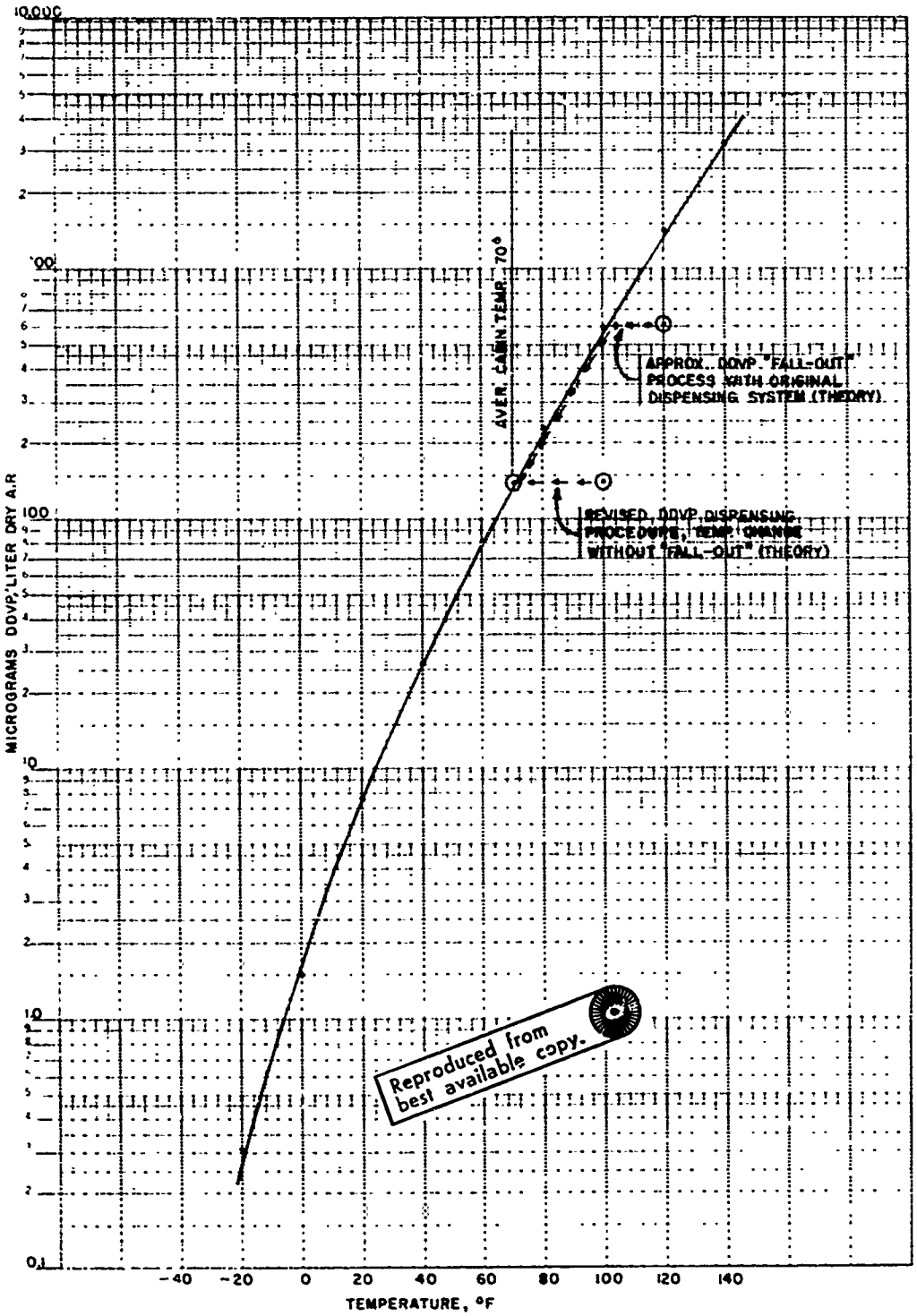

FIGURE 6-15: DDVP SATURATION VS. TEMPERATURE
[USPHS-CDC-TJL]

dispensing system is approximately equal to the dispensing time plus the time required for a complete air exchange within the exposed areas. Since the published air exchange rate for jet transports is 3 to 5 minutes, 35 minutes was selected as the approximate total exposure time per disinsection.

[DDVP Deposits on Dry Structure]

6.4.18 Prior to flight testing, it was speculated that DDVP may be condensed on cold structural components external of the pressure vessel by leakage through fastener holes, skin joints, etc. Swab samples were taken from the following dry structural surfaces during the first flight test to check for DDVP deposits:

a. Door sill - aft baggage compartment (bare stainless steel)

b. Pin and clevis - main landing gear supt. (primed steel forging)

c. Forward wing spar web - 20 in. outbd of wing root (primed aluminum)

d. Electronic equipment bay floor - F.S. 420 (primed aluminum)

e. Fuselage side skin - inner surface, F.S. 1120 (primed aluminum)

f. Fuselage crown skin - inner surface, F.S. 380 (primed aluminum)

g. Galley door frame - between inner and outer seals, F.S. 680 (painted alum.)

h. Galley counter top - F.S. 640 (bare stainless steel).

6.4.19 The baggage compartment door sill, the front spar location and the wheel well area were external of the disinsected cabin area and were readily accessible from the ground. However, a 15-minute to 1-hour time lapse occurred between the end of disinsection and taking the sample due to the flight time. These areas were necessarily sampled as soon as possible after landing. Swabbing of components in the cabin and electronic bay was accomplished between the end of disinsection and landing.

6.4.20 The swabbing technique consisted of simply scrubbing a measured area with a cotton swab saturated with a solvent. The solvent used in this case was slightly acidified water. The water extract was analyzed for DDVP content, which could be reduced to mcg of DDVP per square inch of surface.

6.4.21 Since the results could not be predicted, the structural swabbing was designed to assess DDVP deposition through cumulative disinsections as well as single disinsections. Adjacent areas were marked off at

each location. One of these areas was swabbed after each disinsection while the other areas were swabbed only after two or three disinsections.

6.4.22 Analysis of all structural swab samples from the first flight test were negative. Although the technique may not retrieve 100% of a DDVP deposit, laboratory development of the technique by TDL proved it to be an excellent method of detecting elements on dry surfaces. The time delay in swabbing certain areas permitted some warming of the component which may have allowed any condensed DDVP to evaporate. However, this phenomenon is associated with the DDVP-to-metal contact time, and 15 minutes to 1 hour contact time is considered insignificant. Consequently, the swab samples from the first flight test were considered conclusive, and no further efforts were made to detect DDVP on dry surfaces until test numbers 5 and 6.

[DDVP Deposition on Wet and Dry Filter Paper]

6.4.23 Prior to the DDVP flight tests, elements of industry predicted that DDVP concentrations would build up on damp structural surfaces. This prediction was based on multiple exposure of moist laboratory filter paper to DDVP vapor which resulted in a buildup. However, TDL contended that the absorption/adsorption characteristics of laboratory filter paper were not representative of a non-absorbing metal surface. Therefore, wet and dry filter papers were exposed during DDVP flight tests 1, 2, 5 and 6 to determine its affinity for DDVP under representative disinsection conditions.

6.4.24 For the wet filter paper tests, the papers were moistened manually with distilled water. Even though efforts were made to minimize the amount of water applied, varying degrees of wetness occurred. In some cases, the amount of water applied was measured. A typical filter paper test arrangement is shown in figure 6-16. Results of the filter paper tests are shown in Table 6-7.

6.4.25 From Table 6-7, it is interesting that the wet filter paper of flight test no. 2 showed no DDVP buildup, while flight test no. 5 showed a near linear buildup. Test no. 6 also showed a buildup in the wet filter paper, but it was not linear. The dry papers of test numbers 5 and 6 also showed an erratic buildup. With reference to Table 6-5, there is no discernible relationship between DDVP/air concentration and the filter paper deposits. This indicates that prevailing cabin temperature, relative humidity, and altitude are factors in DDVP deposition.

6.4.26 The applicability of DDVP deposition on filter paper could not be assessed without concurrent measure of DDVP deposition on metal structure. Therefore, cold plate tests were devised in efforts to obtain this measure as discussed in the following DDVP deposition in water condensate.

TABLE 6-7
DDVP FLIGHT TEST
FILTER PAPER TESTS

Flight Test No.	Flight Leg	Paper Location	Water Applied (ml)	DDVP Surface Density (mcg/in²)
1	1	Seat 11F	–	.58
		F.S. 720		1.33
				1.77
1	1	Pilot	–	.58
	2	Deck		.78
	3	F.S. 360		.72
1	1	Seat 6A	–	1.86
	2	F.S. 460		2.30
	3			3.68
2	1	(2 papers	3 & 7	.15 & .09
	2	respectively)	3 & 5	.12 & .13
	3	Seat Row 11	3 & 5	.18 & .21
	4	F.S. 720	3 & 5	.025 & .025
2	1 thru 4	(2 papers	12 & 12	.13 & .09
	Cum.	respectively)	12 & 12	.13 & .09
		F.S. 720		
2	1 thru 4	Seat Row 11F	0 (dry)	.025
	Cum.	F.S. 720		
5	1	Seat Row 11	–	.087
	2	F.S. 760		.111
	3			.145
	1 thru 3 Cum.			.340
	Math Tot. 1, 2, & 3			.343
5	1	Seat Row 11		.120
	2	F.S. 760	Dry	.210
	3			.154
	1 thru 3 Cum.			.259
	Math Tot. 1, 2, & 3			.484
6	1	Seat Row 11		1.18
	2	F.S. 760	–	.78
	3			.39
	1 thru 3 Cum.			1.41
	Math Tot. 1, 2, & 3			2.35
6	1	Seat Row 11		.97
	2	F.S. 760	Dry	.94
	3			.42
	1 thru 3 Cum.			1.65
	Math Tot. 1, 2, & 3			2.33

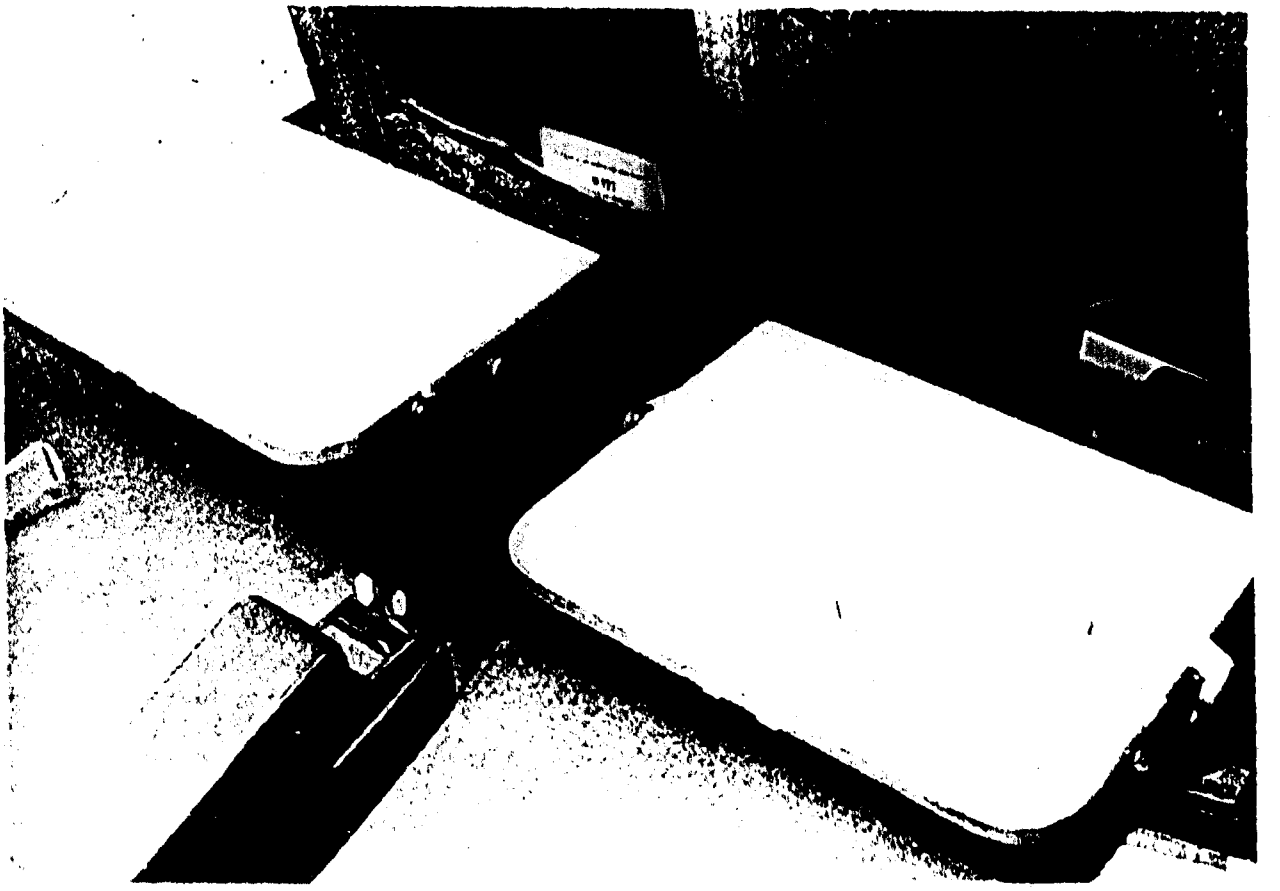

FIGURE 6-16: DDVP FLIGHT TEST-TYPICAL ARRANGEMENT OF FILTER PAPER TESTS

[DDVP Deposition in Natural Water Condensation]

6.4.27 Since the dry structure swab samples were negative, the degree of DDVP deposition in condensed water was a primary question. Several methods were used in efforts to answer this question.

6.4.28 Elements of industry had said that water condensate was always present in aircraft. It is common to design drain holes in the lower fuselage to prevent undesirable accumulations of water. Therefore, prior to the flight tests, it was planned to collect drainage from these holes in the test aircraft after each disinsection, and analyze it for DDVP content.

6.4.29 Efforts were made to collect water drainage from the pressurized fuselage during flight tests 1, 2 and 5. These efforts were unsuccessful. The bottom fuselage drain holes were checked upon each flight leg landing. The only drainage found came from the air conditioning water

separator bay. This bay is unpressurized, but the drainage was analyzed for DDVP to check for possible leakage from the cabin. No DDVP was found in the water separator bay drainage. This finding reinforces the results of the dry structure swab samples discussed previously.

6.4.30 During flight tests 2, 3, 4, 5 and 6, fuselage structure accessible from the cabin was checked periodically for visible water condensation. Accessible areas were limited to the left side fuselage skin, stringers and frames at stations 670 and 1120, and the crown skin in the life raft stowage compartment, station 380. These areas were given particular attention during ascent and descent. No visible condensation was ever detected. Therefore, a measure of DDVP deposition in natural water condensation was not obtained.

[DDVP Deposition on Cold Plates]

6.4.31 The lack of natural water condensation in the flight test aircraft created an unexpected problem. It was desirable to obtain DDVP deposition in terms of percent concentration in water. This form of deposition was needed for correlation with the DDVP corrosion test data supplied by NASA and Tinker AFB. Therefore, a method of creating artificial condensation during disinsection was applied during flight tests 2, 3, and 4.

6.4.32 The method of exposing artificial condensation consisted of taping aluminum plates to the inner surface of the fuselage skin and spraying the plates with deionized water via Freon atomizer. The fuselage skin served as the cold sink. The plates served as a convenient tool for collecting the water after DDVP exposure. All tests involving plates taped to the fuselage skin are termed "cold plate tests" Some of the wetted plates are shown in position in figures 6-17 and 6-18.

6.4.33 The plate spraying schedule varied between flight tests to check DDVP deposition under varying conditions. Some plates were kept wet throughout the respective flight test to detect possible DDVP buildup from successive disinsections. Other plates were kept wet for only one disinsection period with the plate removed and the sample collected at the end of the respective disinsection period. All plates removed during the flight test were replaced with fresh plates for subsequent disinsections.

6.4.34 Another cold plate test was designed to determine if any DDVP is retained on a surface that is wet during disinsection but subsequently dries. This was accomplished by spraying the plate one time during the respective test period; total flight, 1 flight leg, or once each flight leg.

FIGURE 6-17: DDVP FLIGHT TEST-COLD PLATE TESTS - STATION 670

6.4.35 Results of the various wetted cold plate tests are consolidated in Table 6-8.

6.4.36 The data from the wetted cold plate tests (Table 6-8) are difficult to interpret because there is no consistency in the data nor any correlation with the DDVP/air concentrations. It is suspected that varying environmental conditions and inconsistent water application were the major factors in these data inconsistencies. It is obvious that plate temperatures differed, because ice was formed in some cases. Difficulty was also experienced in maintaining a constant degree of wetness due to evaporation. Repeated spraying of the plates throughout the exposure period undoubtedly created a shortened exposure time for the final samples from the plate.

6.4.37 Although the cold plate data are inconsistent, they indicate one significant point. DDVP buildup on the chilled damp surfaces did not occur. The cumulative DDVP deposits were equal to, or less than, the deposits found on the last singly exposed plate at the same location in all cases.

TABLE 6-8

DDVP FLIGHT TEST

DDVP ON WETTED COLD PLATES

Flight Test No.	Flight Leg	Location	Wetting Schedule	Condition Upon Removal	DDVP Deposit Concentration, %	
2	1	F.S. 1120	Once	Dry	0	
2	1	F.S. 1120	Continuous Wet	Ice	.000037	
2	2	F.S. 1120	Continuous Wet	Ice	.00007	
2	2	F.S. 1120	Continuous Wet	Ice	.000049	
2	3	F.S. 1120	Continuous Wet	Ice	.00011	
2	2 & 3 Cum.	F.S. 1120	Continuous Wet	Ice	.00011	
2	4	F.S. 1120	Continuous Wet	Ice	.000041	
2	3 & 4 Cum.	F.S. 1120	Continuous Wet	Ice	.000070	
3	1	F.S. 670*	Continuous Wet	Wet	.00024*	Accelerated Air Flow Comparison
3	3	F.S. 670*	Continuous Wet	Wet	.00070*	
3	1 & 2 & 3 Cum.	F.S. 670*	Continuous Wet	Wet	.00033*	
3	1	F.S. 1120	Continuous Wet	Ice	.00030	
3	2	F.S. 1120	Continuous Wet	Wet	.00046	
3	3	F.S. 1120	Continuous Wet	Wet	.00017	
4	1	F.S. 670*	Once	Wet	.00027*	
4	1 & 2 & 3 Cum.	F.S. 670*	Once Each Disinsection	Wet	.00018*	
4	1	F.S. 670*	Continuous Wet	Wet	.00051*	Accelerated Air Flow Comparison
4	2	F.S. 670*	Continuous Wet	Wet	.00110*	
4	1 & 2 & 3 Cum.	F.S. 670*	Continuous Wet	Wet	.00025*	
4	1	F.S. 1120	Continuous Wet	Wet	.00019	
4	3	F.S. 1120	Continuous Wet	Wet	.00039	
4	1 & 2 & 3 Cum.	F.S. 1120	Continuous Wet	Wet	.00009	
4	Decay	F.S. 670	Continuous Wet	Ice	.00027	

*Auxiliary fan forced air flow over plates at station 670.

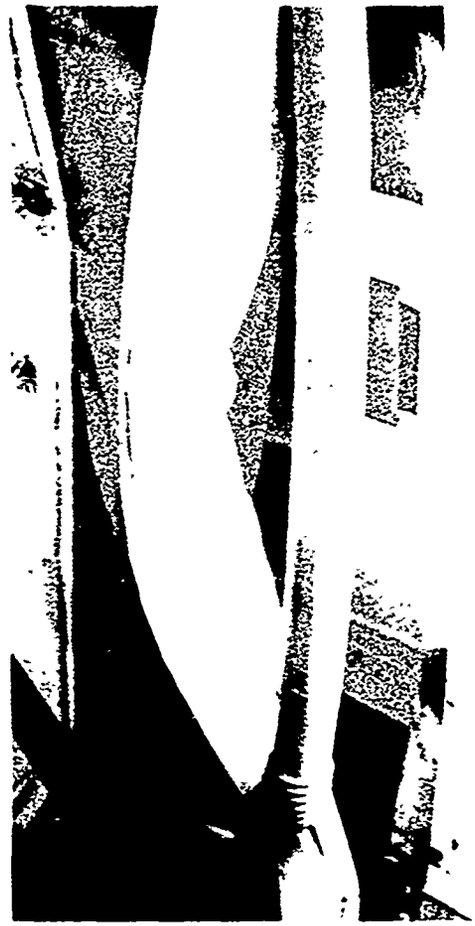

FIGURE 6-18: DDVP FLIGHT TEST-COLD PLATE TESTS - STATION 1120

6.4.38 Another point to consider is the influence of an accelerated air flow on DDVP deposition. This would occur when cabin air is exhausted into the annular space between the baggage compartment liner and lower fuselage skin. In this process, the flow cross sectional area is reduced, resulting in a higher velocity air flow in the annular space to maintain equal volume exchange.

6.4.39 Since there was no access to the annular space of the test aircraft during flight, fans were used in the cabin to simulate the accelerated flow. Two 8-inch axial fans were used. One fan was situated on the cabin ceiling to blow toward the second fan across the DDVP dispensing manifold tube. The second fan served as a relay toward the cold plates at station 670. Air velocity across the plates without the fans was 90 fpm. With the fans operating, the air velocity across the plates was about 550 fpm.

6.4.40 Results of the cold plate tests with fan forced air flow are noted in Table 6-8, flight tests 3 and 4. Comparison of these results with simultaneous deposition obtained at station 1120 indicate that the accelerated air flow tended to increase DDVP deposition concentrations. Comparable cases are coupled in Table 6-8 for reference. The increased concentrations were probably a result of higher mass flow, coupled with a higher water evaporation rate, induced by the high energy air flow. With these results, initial DDVP deposition within the annular space of the lower fuselage is considered to be the most critical.

6.4.41 Because of the inconsistent nature of the water spray tests, no additional spraying of plates was done during flight tests 5 and 6. However, the outside air temperatures encountered during the first four flights generally reached -30°F, and approached -60°F in some cases. With these temperatures, it was considered that perhaps trace amounts of condensation did occur, but were too slight to detect with the naked eye.

6.4.42 To check the possibility of trace condensation, plates were exposed to DDVP vapor during flight tests 5 and 6. These tests differed from previous cold plate tests in three ways: (1) no water was sprayed on the plates, (2) the plates at station 1120 were covered with the original insulation blanket, and (3) samples for measuring DDVP deposits were obtained by rinsing and swabbing the plates with acetone. These tests were again designed to obtain cumulative deposits as well as single exposure deposits.

6.4.43 The results of the cold plate tests of flight test numbers 5 and 6 are given in Table 6-9. Since DDVP was detected on the plates, it is possible that the DDVP was dissolved by trace water condensation, but this is uncertain. Skin temperatures approached 0°F. No visible amounts of water were detected on the plates except in the case of flight test 5, flight leg 1, station 1120. Very slight frosting was detected in this case. Regardless of whether the DDVP was dissolved by water condensation, or was deposited by simple condensation of the DDVP, it is reasonable to assume that similar deposit densities occurred on the cabin structure.

6.4.44 Another point indicated by the data of Table 6-9 is the covered plates generally attained a lower DDVP deposit density. Therefore, the fully exposed plate data are considered conservative because it is unlikely that structure will be fully exposed during disinsection in an air carrier aircraft.

TABLE 6-9

DDVP FLIGHT TEST

NATURAL CONDENSATION COLD PLATE TESTS

Flight Test No.	Flight Leg	Location and Condition	DDVP Deposit Density, mcg/in^2
5	1	F.S. 670	.08
	2	Full Exposed	.04
	3		.12
	1 & 2 & 3 Cum.	----------	.10
	Math Tot. 1, 2, & 3	----------	.24
5	1	F.S. 1120	.012
	2	Insulation	.024
	3	Covered	.021
	1 & 2 & 3 Cum.	----------	.034
	Math Tot. 1, 2, & 3	----------	.057
6	1	F.S. 670	.140
	2	Full Exposed	.024
	3		.011
	1 & 2 & 3 Cum.	----------	.180
	Math Tot. 1, 2, & 3	----------	.175
6	1	F.S. 1120	.060
	2	Insulation	.032
	3	Covered	.050
	1 & 2 & 3 Cum.	----------	.055
	Math Tot. 1, 2, & 3	----------	.142

6.4.45 A third significant point is shown by a comparison of the simultaneously exposed filter paper and cold plate results for flight tests 5 and 6 (Tables 6-7 and 6-9). The filter paper deposits exceeded the cold plate deposits by 100 times or more. Therefore, DDVP deposits in either wet or dry filter paper are considered ultra conservative with respect to deposition on metal structure. In either case, DDVP contact time must be considered in evaluating the corrosion potential.

6.4.46 To obtain an estimate on DDVP-to-metal contact time from the flight test, additional plates (2 each) were attached to the fuselage skin at stations 670 and 1120, flight test 6. These plates were exposed to the 3 consecutive disinsections of the flight test but were left in place for 6 hours after the last disinsection. The aircraft was flying during this period. The acetone rinse of these plates showed no detectable levels of DDVP. Therefore, it can be said that DDVP deposits not accompanied by heavy water condensation will dissipate within 6 hours.

DDVP Deposition - Laboratory Studies

[Introduction]

6.4.47 Due to inconsistencies in the wetted cold plate data from flight tests 2, 3, and 4, the validity of the data was uncertain. Therefore, it was decided to accumulate laboratory deposition data for comparison with the flight test data, and possibly develop a relationship between the DDVP deposition corrosion potential and the laboratory corrosion test data.

6.4.48 Two modes of DDVP deposition were considered in developing the laboratory deposition tests. These modes were DDVP absorbed by free standing water and the DDVP deposited with concurrent frost formation. It was desirable to determine DDVP deposition quantities under average environmental conditions in an aircraft during disinsection. However, previous testing had indicated that deposition quantities are so small that data conformity was extremely difficult to attain due to slight variations in manual handling and rapid sample evaporation. Therefore, a deposition survey under an environmental spectrum was undertaken to develop statistical deposition curves related to the environmental parameters. The parameters involved were ambient air temperature, relative humidity, and DDVP exposure concentration.

[Laboratory Deposition Method]

6.4.49 The DDVP spectrum deposition survey was conducted in the TDL cabin mock-up. Air flow through the mock-up is similar to an aircraft cabin; i.e., air is exchanged approximately every 4 minutes. The mock-up was equipped with a refrigerated panel to serve as the cold

sink similar to the aircraft fuselage skin. Panel temperatures were 10-18°F. Aluminum discs were exposed in triplicate as the tool for collecting frost samples. One disc was weighed to determine the amount of frost accumulated (1ml H_2O = 1 gr. H_2O). The other two discs were rinsed with acetone immediately after exposure to minimize evaporation. The frost accumulated on the weighed disc was assumed to equal the frost accumulated on the other two discs, and DDVP deposit concentrations were calculated accordingly. A typical arrangement of the frosted discs is shown in figure 6-19.

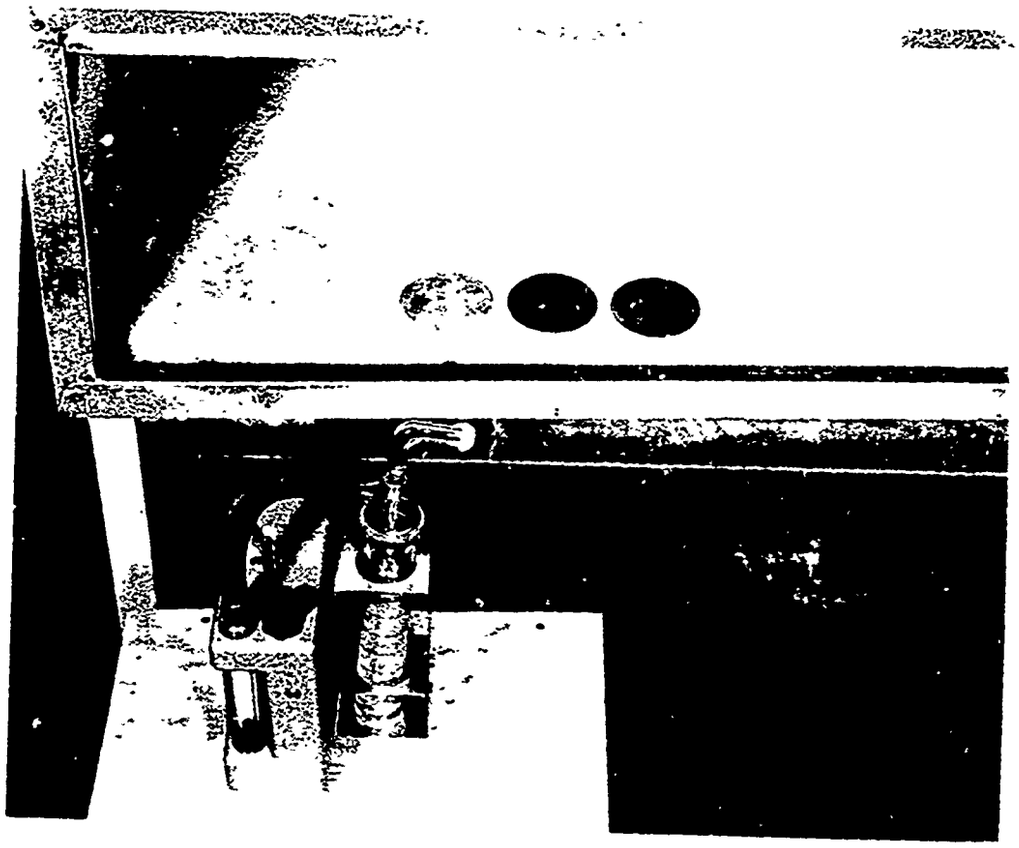

FIGURE 6-19: DDVP LAB FROST DEPOSITION
ARRANGEMENT OF TEST PLATES ON CHILLED PANEL

6.4.50 The spectrum deposition survey in free standing water was accomplished by exposing measured amounts of chilled water (40°F) concurrent with the frost deposition survey. The sample water was placed into duplicate petri dishes which were placed in an ice cooled pan for each DDVP exposure. The possibility of increased DDVP deposition by agitated water was explored, but a difference in the data of static and agitated water deposits was indistinguishable. Deposition in both cases was approximately proportional to the exposed surface area. Consequently, data runs were made with static water samples only. The exploratory test setup for static and agitated water exposure is shown in figure 6-20; the data run setup for the static water was identical.

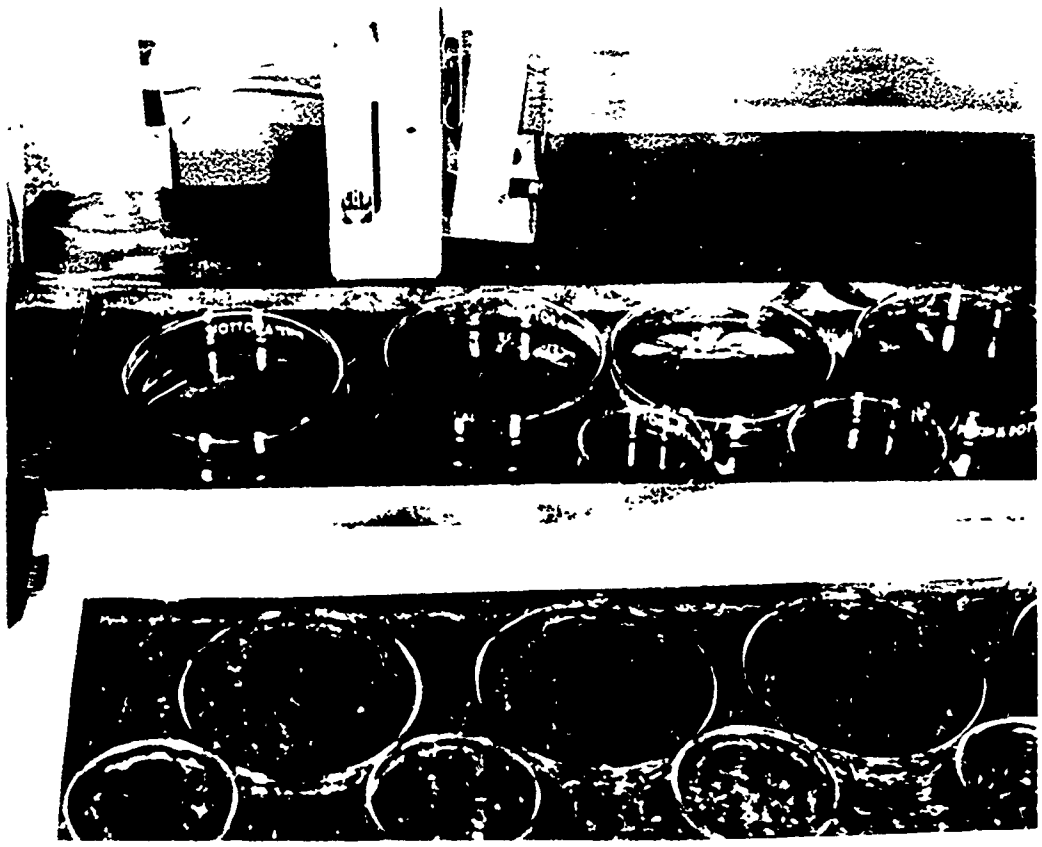

FIGURE 6-20: DDVP LAB DEPOSITION
CHILLED WATER SAMPLE ARRANGEMENT FOR EXPLORATORY STATIC AND AGITATED WATER

6.4.51 Exploratory work was also done on the precision of the combined sample gathering procedure and analytical technique used for the frost and water deposition survey. Variation was about 12 percent. This variation is insignificant with respect to the micro-quantities of DDVP involved.

6.4.52 Variables of the laboratory DDVP deposition survey were ambient temperature, relative humidity and DDVP/air concentration. The spectrum included 60°F to 80°F, 40% to 80% R.H. and .04 mcg/l to .57 mcg/l DDVP/air concentrations. All samples of the survey were analyzed in terms of percent concentration in moisture.

[Results of Laboratory Deposition Survey]

6.4.53 The percent concentrations produced by the deposition survey were statistically averaged to develop the curves of figure 6-21. These curves provide a tool for predicting the DDVP deposited by a single disinsection based on any particular set of environmental conditions.

6.4.54 Environmental conditions for DDVP are expressed in the exposure time product of figure 6-21, where:

Exposure Time Product = E_r x Exposure Time.

$$E_r = \frac{\text{Relative DDVP Saturation}}{\text{Relative Humidity}} \times 100 = \frac{\text{R.S.}}{\text{R.H.}} \times 100 = \%$$

$$\text{R.S.} = \frac{\text{DDVP/Air Concentration}}{\text{DDVP Saturation @ Ambient Temp.}}$$

(DDVP Saturation @ Ambient Temp. from DDVP Saturation curve, figure 6-15)

6.4.55 From the DDVP deposition curves (figure 6-21), DDVP deposited with concurrent frost formation is far more critical than DDVP deposited in free standing chilled water. Temperature differential has an obvious effect on the amount of deposition in both cases. This effect may have been a factor in the wide deviation in the flight test cold plate data. The cold plate data (Table 6-8) were reduced and plotted in figure 6-21 for comparison with the lab results.

[Laboratory Deposition vs. Flight Test Deposition]

6.4.56 A comparison of the cold plate data with the lab deposition data lends more credence to the cold plate data. As shown in figure 6-21, the majority of the flight test deposits fall between the lab frost and lab water deposits. This aspect indicates that the variable

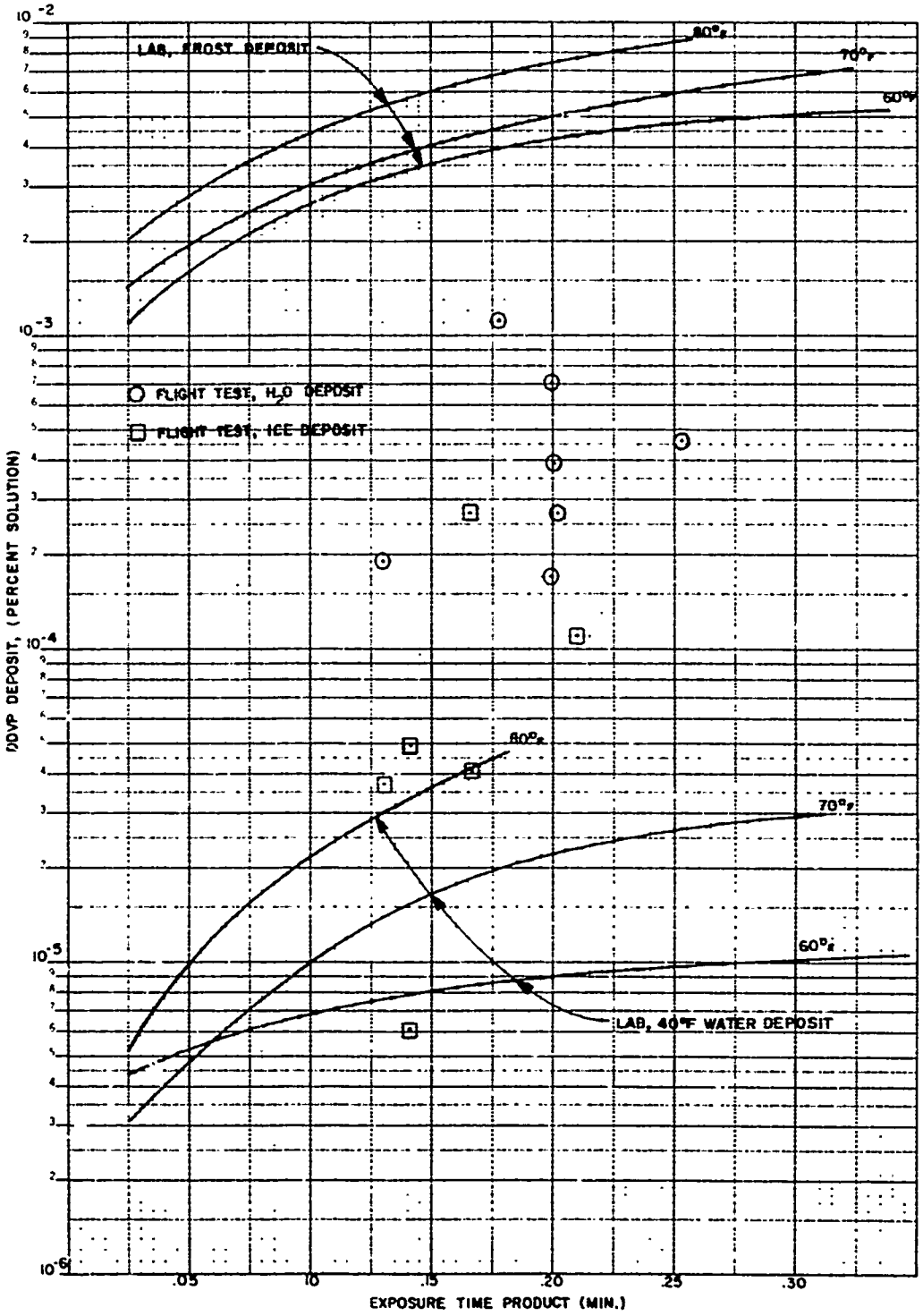

FIGURE 6-21: DDVP DEPOSITION IN MOISTURE
EXPERIMENTAL SPECTRUM

conditions in an aircraft during disinsection have an averaging effect.* With this indication DDVP deposition should be defined in terms of an average with possible deviation. The deviation would be governed by the deposition values for each media under the particular environmental conditions. For the case of DDVP disinsection of aircraft, these deposition values are calculated below.

DDVP DEPOSITION ON AIRCRAFT STRUCTURE
PER DISINSECTION

Exposure

Average DDVP/Air Concentration = .25 mcg/l

Total Average Exposure Time = 35 min.

Environment

Average Cabin Temperature = 70°F

Average Relative Humidity = 25%

Deposit and Corrosion Factors

$$\text{Relative DDVP Saturation} = \frac{\text{DDVP/Air Concentration}}{\text{DDVP Saturation @ 70°F}} \times 100 = \frac{.25}{13} \times 100 = .185\%$$

$$E_r = \frac{R.S.}{R.H.} = \frac{.185}{25} = 0.0074$$

$$E_t = E_r \times \text{Time} = (.0074 \times 35) = .259 \text{ min.}$$

From Figure 6-21

@ E_t = .259 min. and Temp. = 70°F;

Average Deposit in Frost = .0061% solution

Average Deposit in Chilled Water = .000027% solution.

Therefore

Average deposit per disinsection is predicted to be

$$\frac{.0061 + .000027}{2} = .003\% \text{ in water with deviations of } \pm .003\%.$$

*Conditions in an aircraft, such as R.H., pressure, and skin temperature were in a state of constant change during ascent, resulting in partial water and partial frost or ice exposure during disinsection.

Conclusions on DDVP Deposition

6.4.57 Based on flight test indications and laboratory deposition studies, the amounts of DDVP deposited in an aircraft per disinsection are expected to result in an average DDVP/water concentration of 0.003%. Recalling from the electrochemical and weight loss corrosion tests, DDVP/water concentrations of less than 0.005% pose an insignificant corrosion potential; the potential is considerably less than .0232% salt water (lab tap water).

6.4.58 Deviations of up to ± 0.003% from the average DDVP/water concentration are expected, depending on the moisture phase; i.e., frost or liquid or a combination of the two media. However, these deviations are expected to be brief in duration due to evaporation. The inability to find natural water condensation in the flight test aircraft supports this expectation. The difficulty experienced in maintaining uniform wetness on the cold plates during flight tests 2, 3 and 4 also suggests that evaporation is a balancing factor, if not a diminishing factor, in the DDVP-to-metal contact time.

6.4.59 DDVP will also deposit on cold structure without appreciable water condensation. These deposits were necessarily assessed in terms of surface density (mcg/in^2). As determined from flight test no. 6, DDVP deposit densities of .06 to .18 mcg/in^2 are expected with the revised dispensing system. The deposit quantity will vary, depending on environment and/or time between disinsections. Slight accumulations will occur if multiple disinsections are performed in rapid succession (30 minutes to 1 hour apart). However, without further DDVP exposure, all such deposits will dissipate under flight conditions within a 6-hour period. DDVP hydrolysis by water vapor in the air is insignificantly slow, and a 6-hour DDVP-to-metal contact time is of no consequence.

6.5 CHLORIDE CONTAMINATION OF AIRCRAFT

Introduction

6.5.1 Another avenue of studying the corrosion hazard of DDVP concerns a relationship between existing aircraft contamination and the contamination potential of DDVP under the proposed disinsection criteria. The presence and production of chlorides were used for this relationship.

Cabin Air Contamination through DDVP Decomposition

6.5.2 As mentioned in the flight test [Cabin Air Sampling], impinger arrangements were set up to measure chlorides in the air as well as DDVP during the disinsection period. Sampling for cabin air chlorides was done during flight tests 1 through 4. The resulting chloride measures are given in Table 6-5.

6.5.3 The chloride measurements of the cabin air (Table 6-5) show no consistent relationship with the DDVP/air concentrations. They do, however, show a distinct relationship to flight locale. Varying chloride levels were measured in the cabin air when the southern route was flown; i.e., Oklahoma City to New Orleans and return with intermediate landings at Dallas and/or Houston, Texas. This route was flown for the 1st, 3rd and 4th flight tests. Flight test no. 2 followed a flight path from Oklahoma City to Dulles International Airport and return, with intermediate landings as Louisville, Kentucky, and Nashville, Tennessee. This route was remote from coastal areas, and the influence of salt laden air from sea water evaporation was probably not encountered. Consequently, the chloride level of the air was nil during flight test no. 2.

6.5.4 Detection of dichloroacetaldehyde (DCA) was a supplemental approach to assaying DDVP decomposition in the cabin air during the flight tests. Water solvent from the triple impinger arrangements used during flight tests 2, 3, and 4 were analyzed for DCA also. The results were negative in all cases.

Conclusion on DDVP Decomposition in Cabin Air

6.5.5 Since nil chlorides were found in the cabin air during at least 3 disinsections and 1 decay period, it is concluded that no appreciable chlorides are produced through decomposition of DDVP in the cabin air, either during disinsection or for at least 1 hour after disinsection. In addition, the lack of DCA indicates that no detectable decomposition of any kind occurs in this time period.

Chlorides in Aircraft Condensation

6.5.6 As previously mentioned, the only water condensation found on the flight test aircraft was the water from the air conditioning water separator bay. This water was analyzed for chloride content as well as DDVP content. No DDVP was found in this drainage. Hence, chlorides found in the water were not from decomposition of DDVP. The chloride levels found in the samples collected (flight test 1 and 2) are given in Table 6-10.

TABLE 6-10

DDVP FLIGHT TEST

CHLORIDE LEVELS IN WATER SEPARATOR DRAINAGE

Flight Test No.	Flight Leg	Chlorides mcg/ml H_2O	Chlorides % Solution
1	Preflight	.91	.00009
	1	.65	.00007
	2	.87	.00009
	3	1.01	.00010
2	1	2.3	.00023
	2	1.2	.00012
	3	No sample	
	4	2.3	.00023

6.5.7 Table 6-11 gives the chloride levels found in the artificial condensation applied to the cold plate tests of flight tests 2, 3 and 4. The plates were chemically cleaned prior to the tests to minimize chlorides from sources other than the aircraft. Cleaning constituted an acetone-swab scrub and a deionized water rinse with air drying.

6.5.8 It is notable that the chlorides obtained from the singly exposed cold plates (Table 6-11, Test #2) are not unlike the chloride levels in the drainage from the water separator bay (Table 6-10, Test #2). The cumulative chloride levels from the cold plates should not be compared to water separator bay drainage. The separator bay is continually flushed, and chlorides contained at the end of a flight are indicative of stabilized levels of normal contaminants for the particular flight. Therefore, the similarity in chloride levels from the cold plate tests and from the water separator bay gives another sound indication that DDVP decomposition does not occur during the disinsection period.

TABLE 6-11

DDVP FLIGHT TESTS

CHLORIDE LEVELS FROM CONTINUOUSLY WETTED COLD PLATE TESTS

Flight Test No.	Flight Leg	Station	Chlorides mcg/ml H_2O	Chlorides % Solution
2	2 & 3 Cum.	1120	6.5	.00065
	3 & 4 Cum.	1120	2.1	.00021
	4 (Decay)	1120	2.2	.00022
3	1	670	1.94	.00019
	2	670	2.23	.00022
	3	670	2.08	.00021
	1 & 2 & 3 Cum.	670	67.64 ↯	.00676
3	1	1120	2.64	.00026
	2	1120	1.08	.00011
	3	1120	1.15	.00012
	1 & 2 & 3 Cum.	1120	5.76	.00058
4	1	670	1.584	.00016
	2	670	.864	.00009
	3	670	1.584	.00016
	1 & 2 & 3 Cum.	670	4.464	.00045
4	1	1120	.864	.00009
	2	1120	2.018	.00020
	3	1120	3.384	.00034
	1 & 2 & 3 Cum.	1120	0	0
5	Decay	670	4.140	.00041

Note to Table 6-11

↯ Probable handling contamination.

6.5.9 In addition to the flight test studies of chloride concentrations, three air carrier aircraft were examined for chloride contamination. These aircraft were B-707's operated by Pan American World Airways. Examination took place at the Pan American Maintenance facility, Miami, Florida. Each aircraft was examined within 24 hours after landing at the facility. Primary fuselage structure was near fully exposed with baggage compartment liners, cabin flooring, and wall insulation removed.

6.5.10 Residue condensation was found in only two of the Pan American aircraft, and only in extremely small amounts. Location and chloride content of the water found are given in Table 6-12.

TABLE 6-12

Pan American B-707

CHLORIDES IN WATER

Aircraft No.	Water Sample Location	Concentration, %
1	B.B.L-0 Skin, Aft baggage, sta. 1000	0.15
1	B.B.L-0 Skin, Aft baggage, sta. 1040	0.05
1	Broken insulation blanket Air conditioning Bay, sta. 700	0.50
3	B.B.L-0 Skin, Aft baggage, sta. 1330	0.15
	Average	.21

6.5.11 Recalling from the discussion on DDVP deposition, the average deposit concentration of DDVP/water is expected to be 0.003%, or a maximum of 0.006% and a minimum of nil deposit. If the total maximum DDVP deposit hydrolyzes, the resulting chloride concentration will be about 32% of the DDVP concentration or .0019%. This chloride concentration would be less than 1 percent of the average chloride level found in solution in commercial aircraft (Table 6-12).*

*$Cl^- = \frac{.0019}{.21} \times 100 = 0.9\% < 1.0\%$

With the chloride level fluctuations found in the commercial aircraft, an increase of 1 percent from DDVP hydrolysis would be undetectable in terms of increased corrosion.

Conclusion on Chlorides in Aircraft Condensation

6.5.12 Studies of chloride/water concentrations during the flight tests reinforce the finding of the air contamination studies that DDVP does not decompose during the disinsection period.

6.5.13 From chloride/water concentrations found on commercial aircraft, the maximum expected increase in these concentrations is less than 1 percent. Any additional corrosion by this increase will be undetectable because of the demonstrated fluctuation in normal chloride levels aboard aircraft.

Chlorides on Essentially Dry Structural Surfaces

6.5.14 The three Pan American B-707's were also sampled in a multitude of locations for chloride deposits on essentially dry structure. The water swabbing technique and collection of solid matter were used for this evaluation. The range of results are given in Table 6-13.

TABLE 6-13

PAN AMERICAN B-707

DRY CHLORIDES

Aircraft No.	Technique or Substance	Chlorides (Range)
1	Dry Structure Swab.	1.0 - 640 mcg/in^2
2	Dry Structure Swab.	1.8 - 51 mcg/in^2
3	Dry Structure Swab.	.18 - 916 mcg/in^2
1	Lint, and/or dirt	.93 - 1.65% by wt.
2	Lint, and/or dirt	.09 - .17% by wt.
3	Lint, and/or dirt	.15 - 58.3% by wt.

6.5.15 For comparison with Table 6-13, the DDVP deposits attained by the dry cold plate tests, flight tests 5 and 6, ranged from .06 to .18 mcg/in^2 with the revised dispensing system. Even though these deposits are not expected to remain, the corrosion they could produce with only a 32 percent application is totally insignificant with respect to the chloride densities shown in Table 6-13. Fluctuation in the existing chloride levels would again render any DDVP induced corrosion undetectable.

Conclusion on Dry Structure Chlorides

6.5.16 Chloride levels found on dry structural surfaces of in-service aircraft render the temporary DDVP deposits on dry structure undetectable and insignificant.

6.6 CONDENSED WATER AVAILABILITY IN PRESSURIZED FUSELAGE

Context of Search for Water Accumulation

6.6.1 As mentioned previously, all efforts to detect natural water condensation in the pressure vessel of the flight test aircraft were futile. Relative humidity was monitored in the cabin throughout each test flight. The humidity levels tended to vary inversely with altitude. During disinsection, the cabin R.H. continually decreased ranging from 60% to 8%. The general average R.H. was about 20 to 25%. From the rate of R.H. decrease, it was apparent that the dehumidifying characteristics of the air conditioning system at altitude preclude detectable water condensation in the aircraft.

6.6.2 Also mentioned previously, three Pan American B-707's were examined for condensed water accumulations within 24 hours after landing at the Miami maintenance facility. Aircraft no. 1 was examined jointly by TDL and the FAA. It had traces of water adjacent to 2 frames in the aft baggage compartment. A small insulation blanket, about 10" x 18", was also found saturated in the air conditioning compartment just aft of sta. 700. Water streaks on the inner surfaces of the cabin structure were clear evidence that a quantity of condensation had been present at least once, but the aircraft was basically dry at the time of examination.

6.6.3 Aircraft nos. 2 and 3 were examined by Pan American chemists. Not even a trace of water was found in aircraft no. 2. For the 3rd aircraft, the Pan American personnel commented that the insulation blankets throughout the air conditioning bay showed evidence of heavy condensation. However, the blankets had dried to the extent that no water could be squeezed out, even though they were damp to the touch. Pan American personnel explained that saturated insulation blankets were common in the air conditioner bays because of frequent maintenance to the air conditioner. The blankets are exposed, and personnel must work directly on the blanket. Consequently, torn covers occur. At the same time, the Pan Am personnel said that torn blankets are replaced during each mod/overhaul. Therefore, indefinite contact of wet blanket and structure does not occur.

6.6.4 While in Miami to examine aircraft no. 1, the FAA and TDL personnel met a Pan American B-707 flight at the gate arriving non-stop from San Juan, Puerto Rico. The purpose of meeting the flight was to observe and collect samples of any condensate drainage from the bottom of the fuselage. No drainage occurred. The lavatory water tanks were also checked for condensation on the outside of the tank. Only very slight condensation was present. It was concluded that the aircraft was basically dry.

Conclusion on Water Accumulation

6.6.5 From examining in-service air carrier aircraft and the DDVP flight test aircraft, it is obvious that large quantities of water are occasionally condensed on the fuselage structure. It is also obvious that large quantities of water are not retained for a significant length of time, except when it is soaked up by a broken insulation blanket. General water retention is prevented in part by the strategically located drain holes. However, the dehumidifying characteristics of the air conditioning systems on modern jet transports was observed to be the primary factor for the inability to locate significant amounts of water. This observation is based on the measured operational humidities in the aircraft cabin, which averaged at about 20 to 25 percent R.H. The low R.H. coupled with elevated cabin altitudes inhibit condensation and encourage evaporation. Consequently, large quantities of water are only temporary.

6.7 DDVP PURITY, QUALITY CONTROL AND SHELF LIFE

DDVP Purity and Quality Control

6.7.1 Early in the DDVP study program, it was considered that contamination of DDVP during the manufacturing process could be critical with respect to chloride production. However, subsequent evaluation of the disinsection process led to the conclusion that DDVP produced under Shell Oil Company's drug grade specification (98 + % pure) presents no problem regarding excessive decomposition products. This evaluation was as follows:

$$(CH_3O)_2 - P(O) - OCH = C\begin{matrix} Cl \\ Cl \end{matrix} \xrightarrow{HOH} \begin{matrix} [DMP] \\ (CH_3O)_2 - P(O)OH \\ + \\ CHCl_2 - C(O)H \\ [DCA] \end{matrix}$$

$(CH_3O)_2 - P(O)OH$: DMP dispensed from the aerosol can onto the paper filter in the cartridge remains unvaporized due to low vapor pressure and is thrown away in spent cartridge.

$CHCl_2 - C(O)H$: Most of DCA polymerizes to form a white coating inside the dispensing cartridge. A small amount of the DCA vaporizes and is dispensed with the DDVP. However, it is much more volatile than DDVP and condensed deposits of DCA will be undetectable for the individual disinsection.

Therefore, manufacturing quality control of the DDVP compound should be governed by Shell Oil Company's drug grade specification. The essence of this specification was adopted by the USPHS in their specification for the manufacture of the DDVP dispensing cartridge, which adds a restriction on maximum chloride content (reference Attachment No. 1).

6.7.2 USPHS (TDL) has established the specification given in Attachment #1 for preventing undue contamination during and after assembly of the DDVP dispensing cartridge for use in aircraft disinsection.

DDVP Shelf Life

6.7.3 Shelf life studies conducted by TDL indicate no degradation of DDVP concentrate stored under nitrogen at room temperatures (70°F–80°F). No depletion in DDVP concentration was detected in 224 days of storage. Only slight increase in acidity was detected. These studies are still in progress aimed at a 1-year assessment.

However, it is now justificable to set a shelf life of 6 months.

6.7.4 Shelf life assessments of DDVP stored in the dispensing cartridge were also conducted by TDL. These studies showed the importance of a properly sealed aerosol cannister. In 30 days storage at 100°F, chlorides increased variably from a base of 40 ppm to 50 and 350 ppm. In 60 days storage at 70°F-80°F, chlorides again increased variably from a base of 40 ppm to 60 and 180 ppm. Fluorocarbon sealing of the aerosol cannister decreased chloride production over an 8-month period to only 46 and 79 ppm compared to the base of 40 ppm. Therefore, extended storage of the charged DDVP cartridges should be done at room temperature or lower, and limited to a 6-month period for the present.

Conclusions on DDVP Purity, Quality Control, and Shelf Life

6.7.5 DDVP purity is less significant than first believed, because most impurities are trapped in the dispensing cartridge. Consequently, the purity of DDVP manufactured in accordance with Shell Oil Company's drug grade specification is considered adequate with an additional restriction on maximum chloride content.

6.7.6 TDL has developed the specification in attachment #1 for manufacture of the DDVP dispensing cartridge. These requirements are designed to prevent undue contamination of the DDVP during or after assembly of the cartridge.

6.7.7 For the present, shelf life of bulk DDVP stored under nitrogen at room temperatures is limited to 6 months. This limit is subject to possible extension, depending on the outcome of continuing shelf life studies. The same shelf life limitation should also apply to the charged DDVP dispensing cartridge.

7.0 REVIEW OF FINDINGS FROM DDVP STUDY CATEGORIES

Study Category No. 1

7.1 TOXICOLOGY (Ref. 3.0)

DDVP will have no toxic effect on humans under the proposed disinsection environment. This conclusion is based on complete toxicological studies conducted by USPHS at ground level and by the FAA Civil Aeromedical Institute at cabin altitude (8000 ft.). Furthermore, no toxic effects are expected due to DDVP buildup in humans through repeated exposure, since DDVP is a transient chemical.

Study Category No. 2

7.2 DDVP FLAMMABILITY EFFECTS (Ref. 4.0)

The DDVP concentrate is non-flammable. Therefore, fire and explosion potential of the DDVP dispensing cartridge is less than the aerosol cans currently used for spray, or "blocks away," disinsection. In addition, studies conducted cooperatively by NAFEC and TDL showed no deterioration in the flammability characteristics of 8 common interior decorative materials.

Study Category No. 3

7.3 DDVP EFFECTS ON AVIONICS EQUIPMENT (Ref. 5.0)

Functional testing of representative avionics equipment in a conservative DDVP environment showed no effects on the performance of the equipment. Testing was accomplished at the FAA Aeronautical Center. The test duration was 1000 disinsection cycles with concurrent cycles to 8000 ft. altitude. Therefore, the DDVP exposure proposed for aircraft disinsection is not expected to effect the performance of electronic/avionic equipment within the normal operational life span of the components.

Study Category No. 4

7.4 CORROSIVE POTENTIAL OF DDVP DISINSECTION (Ref. 6.0)

DDVP Decomposition Chemistry (Ref. 6.2)

7.4.1 Hydrolysis of DDVP can produce the three corrosive elements of (1) dimethyl phosphate (DMP), (2) dichloroacetic acid (DCAA),

and chlorides. DMP in water forms dimethyl phosphoric acid. The free chlorides react corrosively with aluminum, which propagates the formation of HCl in the presence of moisture. The HCl can then react with aluminum to propagate more HCl as long as sufficient moisture and time are available. Therefore, chloride reaction with aluminum has a multiple corrosive effect, which made chloride production the primary concern.

7.4.1a Chemical-to-metal contact time, as well as chemical quantity, must be considered in evaluating the DDVP corrosion potential. Extremely sensitive methods of measuring DDVP and decomposition products were devised by TDL to assess chemical availability. Chemical-to-metal contact time is a function of DDVP decomposition time and volatility. Subsequent studies were aimed at these parameters under conditions proposed for aircraft disinsection.

Laboratory Corrosion Testing (Ref. 6.3)

7.4.2 A simplified DDVP vapor corrosion test was conducted concurrent with the avionics testing. The 1000-hr. exposure produced no corrosion.

7.4.3 Laboratory corrosion testing of DDVP solutions involved stress corrosion testing by NASA, and electrochemical and "weight loss" corrosion testing by Tinker AFB Service Engineering Division. Metals tested were limited to the predominant aircraft metals of 2024-T3 and 7075-T6 aluminum alloys and a high strength steel (H.T. 180 ksi or better).

7.4.4 The results of the NASA stress corrosion tests require some interpretation. However, following the NASA rationale, the data indicate that aqueous DDVP solutions of 0.10% or less have no effects in excess of distilled water on the stress corrosion cracking susceptibility of 2024-T3 and 7075-T6 aluminum or 18 nickel maraging steel.

7.4.5 Electrochemical corrosion tests at Tinker AFB provided corrosion rates for a spectrum of DDVP concentrations ranging from .0001% to 1.0%. Unknown factors of pitting, chemical depletion, and the combined effects of galvanic action and chemical milling were not accounted for in the test results. Therefore, the corrosion rates determined should not be considered as absolute values, and should be used on a comparative basis only. The electrochemical data show, however, that corrosion rates produced by DDVP concentrations of less than .01% are less than the corrosion rates produced by laboratory tap water (.0232% NaCl).

7.4.6 The "weight loss" corrosion tests were set up primarily to check the effects of common, but relatively poor, protective coatings. Significant improvement in resistance to DDVP corrosion was demonstrated for coatings of cladding and alodine 1200. Modern coatings of epoxy and polyurethane base are expected to provide sufficient protection

from any DDVP attack except at points of coating failure.

7.4.7 Any judgement on the corrosive potential of DDVP disinsection should be based on the aqueous DDVP concentration at which testing demonstrated no significant effects. This value was 0.005% DDVP by weight.

DDVP Deposition Studies (Ref. 6.4)

[DDVP Flight Tests]

7.4.8 A primary effort to assess DDVP deposition under representative conditions was undertaken in a series of 6 DDVP flight tests. Attempts to collect natural water condensation from the pressure vessel were unsuccessful. DDVP deposits in artificial condensation (cold plate tests) were inconsistent with respect to the DDVP dispensed, but indicated that DDVP will not build up in available condensation. It was established that DDVP-to-metal contact time on dry structure is insufficient to produce detectable corrosion. Swab samples of dry structure and unwetted cold plate tests were used for this determination.

7.4.9 An important supplement from the DDVP flight tests was the discovery that the original prototype dispensed about four times more DDVP than was necessary to effect disinsection. The cartridge charge was reduced from 4.2 grams to 1.4 grams and dispensed with a slightly higher air volume. Effective disinsections were obtained without the previously undesirable concentrations of DDVP lingering in the cabin after disinsection.

7.4.10 Comparisons of simultaneously exposed filter papers and unwetted cold plates showed that wet or dry filter paper deposits exceeded the cold skin deposits by at least 100 times. Also, the filter paper deposits exhibited a multiple disinsection buildup uncharacteristic of the DDVP build up on cold dry structure or damp structure. Therefore, judgements on DDVP deposition based on filter paper deposits are considered ultraconservative and inappropriate.

[Laboratory Deposition Studies]

7.4.11 Due to the inconsistency in the flight test cold plate data, a laboratory deposition survey was conducted at TDL. Parameters of temperature, relative humidity and DDVP concentrations were varied to develop DDVP deposition characteristic charts. Applications of these charts provides an average DDVP deposition in aircraft of .003%,$\pm$.003% in water solution. As compared to the corrosion test data, these quantities would produce an undetectable and insignificant amount of corrosion.

Chloride Contamination of Aircraft (Ref. 6.5)

[Cabin Air Contamination]

7.4.12 Assays of cabin air for DDVP decomposition products during the flight test showed that decomposition does not occur in the cabin air during the disinsection period.

[Chlorides in Aircraft Condensation]

7.4.13 Water samples were collected from the air conditioner water separator bay of the flight test aircraft and from commercial aircraft. These samples show that any chlorides produced by DDVP hydrolysis are insignificant under conditions of disinsection. The maximum potential increase in chloride concentration from DDVP is expected to be less than 1%. Any additional corrosion by this increase would be undetectable because of the demonstrated fluctuation in normal chloride levels.

[Chlorides on Essentially Dry Structure]

7.4.14 In terms of corrosion potential, chloride samples from dry structural surfaces of commercial aircraft rendered the temporary DDVP deposits on dry structure undetectable and insignificant.

8.0 CONCLUSIONS ON DDVP USED AS AN AIRCRAFT DISINSECTANT

GENERAL

8.1 DDVP will have no degrading effects on safety of flight when dispensed in accordance with the criteria proposed for aircraft disinsection.

TOXICOLOGY

8.2 DDVP will have no toxic effects on humans, when exposure follows the designated disinsection criteria.

FLAMMABILITY

8.3 Fire and/or explosion hazard of the DDVP dispensing cartridge is nil, and is less than the aerosol cans currently used for "blocks away" disinsection.

8.4 DDVP absorption by interior fabrics and furnishings produces no measurable change in the material flammability characteristics.

AVIONICS

8.5 DDVP vapor will not affect the performance of electronics/avionics equipment within 1000 hour operation of such equipment and is not expected to affect the performance of components within their normal operational life span.

CORROSION PARAMETERS

8.6 DDVP dispensed in accordance with the proposed disinsection criteria will produce no corrosion hazard to airframe airworthiness.

8.7 Disinsection is expected to deposit trace amounts of DDVP on aircraft structure on a temporary basis only.

8.8 Fuselage drain holes and dehumidifying characteristics of air conditioning systems prevent prolonged availability of water condensation for DDVP adsorption/absorption.

8.9 DDVP used under the proposed disinsection criteria will not contribute a discernible amount of corrosive contamination with respect to existing contamination levels aboard air carrier aircraft.

8.10 DDVP-to-metal contact time is considered insufficient for detectable corrosive attack under normal aircraft operating conditions.

PRECAUTIONARY MEASURES

8.11 DDVP disinsection should be accomplished via the revised dispensing procedure established during the DDVP flight tests.

8.12 Dispensing hardware performance requirements should be coordinated by the designer with TDL for each particular model aircraft.

8.13 Dispensing cartridge and DDVP purity should comply with Public Health Service Specification PHS/CDC-ADC-20000(a).

8.14 Shelf life of stored DDVP and the DDVP dispensing cartridge should be limited to 6 months pending the results of the continuing shelf life study by TDL.

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ATTACHMENT

NO. 1

[SPECIFICATION NO. PHS/CDC-ADC-20000(a)]

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Specification No.
PHS/CDC-ADC-20000(a)

DICHLORVOS VAPOR AIRCRAFT DISINSECTION CARTRIDGE

1. SCOPE AND CLASSIFICATION

1.1 Scope: This specification covers one type and size of a dichlorvos vapor cartridge, usable only on the PHS Dichlorvos Aircraft Disinsection System. This system and the cartridge are used against mosquitoes (WHO International Sanitary Regulations), and other small flying insects present in the cabin, baggage compartments, and pilot deck of the aircraft.

1.2 Classification: This dichlorvos insecticide cartridge is a vapor dispensing unit in which the liquid dichlorvos is applied to a filter matrix a few seconds before vaporization is initiated. The vaporization of the dichlorvos and the dissemination of the vapor into the cabin, the baggage compartments, and the pilot deck are accomplished by passing a regulated volume of warm air through the cartridge and into the distribution tubing.

2. APPLICABLE SPECIFICATIONS AND OTHER PUBLICATIONS

2.1 Federal Specifications: The following Federal Specifications, of the issues in effect on date of invitation for bids, form a part of the specification:

BB-F-671	Freon Gas Compressed
TT-I-558	Ink, Marking Stencil, Opaque for Non-Porous Surfaces

2.2 Other Publications: The following publications, of the issues in effect on the date of invitation for bids, form a part of this specification:

2.2.1 Governmental:

Code of Federal Regulations, Title 49, Transportation, Chapter I, Interstate Commerce Commission, Parts 71-78; Explosives and Other Dangerous Articles - 49 CFR 71-73.

Federal Insecticide, Fungicide, and Rodenticide Act.

2.2.2 International Regulations:

International Air Transport Association Regulations covering shipment by air of poisonous substances.

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Specifications for Pesticides Used in Public Health - Geneva - World Health Organization - Geneva (1967).

3. REQUIREMENTS

3.1 Description of Complete Assembly: The dichlorvos cartridge shall be fabricated as shown in drawings listed in paragr. . . 2 and these are a part of this specification. The cartridge is a assembly of major elements as follows: (1) An outer cylindrical aluminum container with a locking collar to facilitate its attachment to a quick-connect receptacle; (2) A hollow cylinder of fluted porous and absorbent paper sealed to the end cover of the outer cylinder and to an upper end cap; and (3) A miniature aerosol dispenser assembly housed in the cylinder section of the end cover.

3.1.1 Description of Aerosol Unit: The aerosol unit consists of a stub-cylindrical aluminum can, a standard one-inch aerosol valve, and a slit-type orifice spray button.

3.2 Drawings:

ADC-20000-1	Cut-away cartridge assembly
ADC-20000-2	Cross section of cartridge assembly
ADC-20000-3	Aerosol dispenser
ADC-20000-4	Spray button

All tolerances shall be effective.

3.3 Materials:

3.3.1 Cartridge Structural Components:

Outer cylinder	1100F Aluminum
Aerosol can	1100F Aluminum
Filter end cover and cap	Tinplate
Valve mounting cup	3003 Aluminum
Valve body	Nylon
Valve stem	Nylon
Valve stem gasket	Buna N 50 Durometer
Valve stem spring	Type 316 Stainless Steel

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Mounting cup gasket	Cut Buna N 50 Durometer
Filter element	Cotton line and resin
Sealing compound	Thermosetting resin
Gaskets	O-Rings
Spray button	Nylon or Delrin
Grommet	Buna N Rubber

3.4 Chemical Content of Cartridge:

3.4.1 Active Ingredient:

The material shall be essentially purified 2,2-dichlorovinyl dimethyl phosphate, and shall be a colorless liquid free from extraneous impurities or added modifying agents.

3.4.2 Chemical and Physical Requirements:

The material sampled from any part of a consignment shall comply with the requirements in Section 3.4.1, and also with the following requirements:

	Minimum	Maximum
2,2-Dichlorovinyl dimethyl phosphate content % by weight	98	-
Acidity meq sodium hydroxide per gram	-	.01
Water p.p.m.	-	80
Chloral % by weight		.5
Particulate matter	none	-
Chlorides p.p.m.	-	100

3.4.3 Methods for Determination of Chemical and Physical Properties:

3.4.3.1 Infra-Red Method for 2,2-Dichlorovinyl Dimethyl Phosphate

Content:

WHO/SIT/16 (Sections 2.1; 2.1.1; 2.1.2; 2.1.3; 2.1.4; 2.1.5). 1/

3.4.3.2 Acidity:

WHO/M/3 (Sections 1.1; 1.1.1). 2/

3.4.3.3 Water:

WHO/M/7 and WHO/SIT/16, pp 74-75, and 266. 3/

3.4.3.4 Chloral:

Shell Chemical Company Method No. JH-L-63/61 AH. 4/

3.5 Inactive Ingredient (Propellant):

The material shall be dichlorodifluoromethane, refrigeration grade, and shall further meet the following requirements:

Initial boiling point (760 m.m.) :-	-21.6°F
End boiling point (85% vaporized):-	-20.7°F
Moisture content by weight - maximum:-	.001%
Non-absorbable gases by volume - maximum:-	2.0%
Chlorides:-	None

3.5.1 Methods for Testing:

(See U.S. Federal Specifications BB-F-671(a) 3 July 1952)

3.5.2 Quantities of Dichlorvos and Propellant:

Each aerosol unit shall contain 1.4±.05 g of dichlorvos and 7±1 g of dichlorodifluoromethane.

1/ Specifications for Pesticides (1967), WHO, Geneva; pp 70-72.

2/ Ibid, page 250.

3/ Ibid, pp 74-75, and 266.

4/ Shell Chemical Company Technical Information Services.

4. WORKMANSHIP

4.1 Leakage:

4.1.1 Cartridge Assembly: The cartridge assembly shall not leak air in excess of 5 cubic inches when subjected to an internal air pressure of 5 psi and tested as described in paragraph 7.1.

4.1.2 Aerosol Can Assembly: The aerosol unit shall not leak propellant in excess of 8 mg per 24 hours and determined by 4 consecutive weighings at 2-day (48 hours) intervals.

4.2 Finish:

4.2.1 Cartridge Assembly: The assembly shall be free of sharp edges and points and it shall also be free of metal slivers and other elements that can cause injury to people. Further, it shall be free of unsightly marrings and scratches.

5. SAMPLING, INSPECTION, AND TEST PROCEDURES

5.1 Production Control Sampling and Inspection:

5.1.1 Final Assemblies: The manufacturer shall be required to take a sample from the assembly line for each consecutive lot of 500 units in a final assembly production run. The manufacturer shall conduct tests as necessary on each sample to insure that all requirements of this specification are met. Specifically, the leak test described in paragraph 7.1.1 shall be applied.

5.1.2 Aerosol Units: One sample shall be taken from each lot of 100 filled and sealed aerosol can units without the propellant. The sample shall be weighed, and the weight of the contents determined by the difference between gross and tare weights. The tare weight shall be the average value of 100 units (can and valve) without the dichlorvos and propellant. The net weight shall be 1.4 $\pm$ .05 g. If it is more or less, all of the units in the batch shall be weighed individually and those having a net weight less than 1.35 or more than 1.45 g shall be discarded. Weights shall be recorded and kept for inspection by Regulatory Agencies for a period of one year.

5.2 Regulatory Agency Sampling and Inspection: A Government Inspector will inspect and take samples of the cartridge assemblies either during assembly, in transit, or in the stock supply of the purchaser to ascertain that the product meets all registry label requirements.

6. PREPARATION FOR SHIPPING

6.1 Packing: Each cartridge shall have a plastic plug or cap closure, with a pinhole aperture for "breathing" with changes in cabin pressure. The closure shall be press-fit and easily removed by hand. The shipping box shall contain 12 cartridges placed in a single layer, cushioned, and partitioned. Larger shipments shall be multiples of the smallest box.

6.2 Marking:

6.2.1 Assembled Cartridge: Each cartridge shall have the label data and registration number affixed by silk-screening. Each shipping container shall carry the same information either in stencil or on printed label. Paper labels shall be affixed with water insoluble adhesive and coated with a weather resistant, transparent compound. The labels on the individual cartridges and on the shipping containers shall have the complete data in Appendix (A) (Label and Registration Number).

6.2.2 Aerosol Can: This unit shall be stampled on the bottom with the date of filling.

6.2.3 Expiration Date: All cartridges and shipping containers shall carry the date of expiration which shall be 6 months from date of filling of aerosol can, and the print shall be indelible.

7. TESTING PROCEDURES

7.1 Physical:

7.1.1 Cartridge Assembly Leak Test: Attach cartridge to manifold of test equipment (See Drawing AD-116). Apply air pressure at 5 psig and submerge cartridge in water bath and observe air bubbles forming. The rate of release shall not exceed 60 bubbles per minute.