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FEDERAL AVIATION ADMINISTRATION

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TO: Recipients of FAA TR. FS-70-601-120A, "The Effects of 2,2  
Dichlorovinyl Dimethyl Phosphate (DDVP) Used as an Aircraft  
Disinsectant", December 1971.

The attached packet constitutes revised pages for the report on the  
FAA study of DDVP aircraft disinsection (FAA TR. FS-70-601-120A).  
No further revision of the report is anticipated.

Distribution of these revisions follows the distribution list for  
the original report. Those receiving multiple copies should redi-  
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original report.

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DDVP Study

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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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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 quantitative 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.

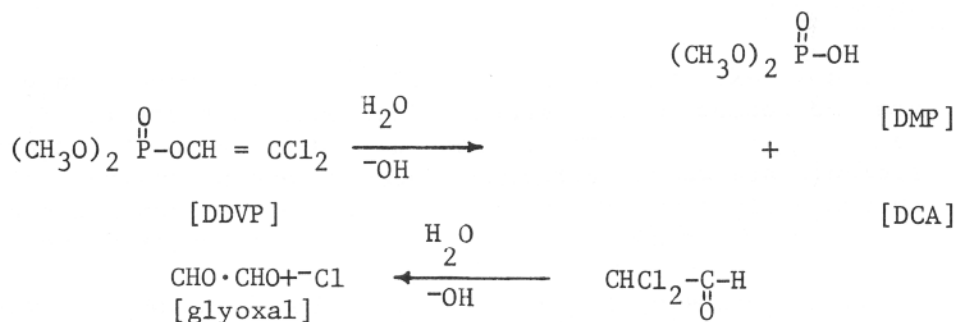
6.2 DDVP DECOMPOSITION CHEMISTRY

- 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

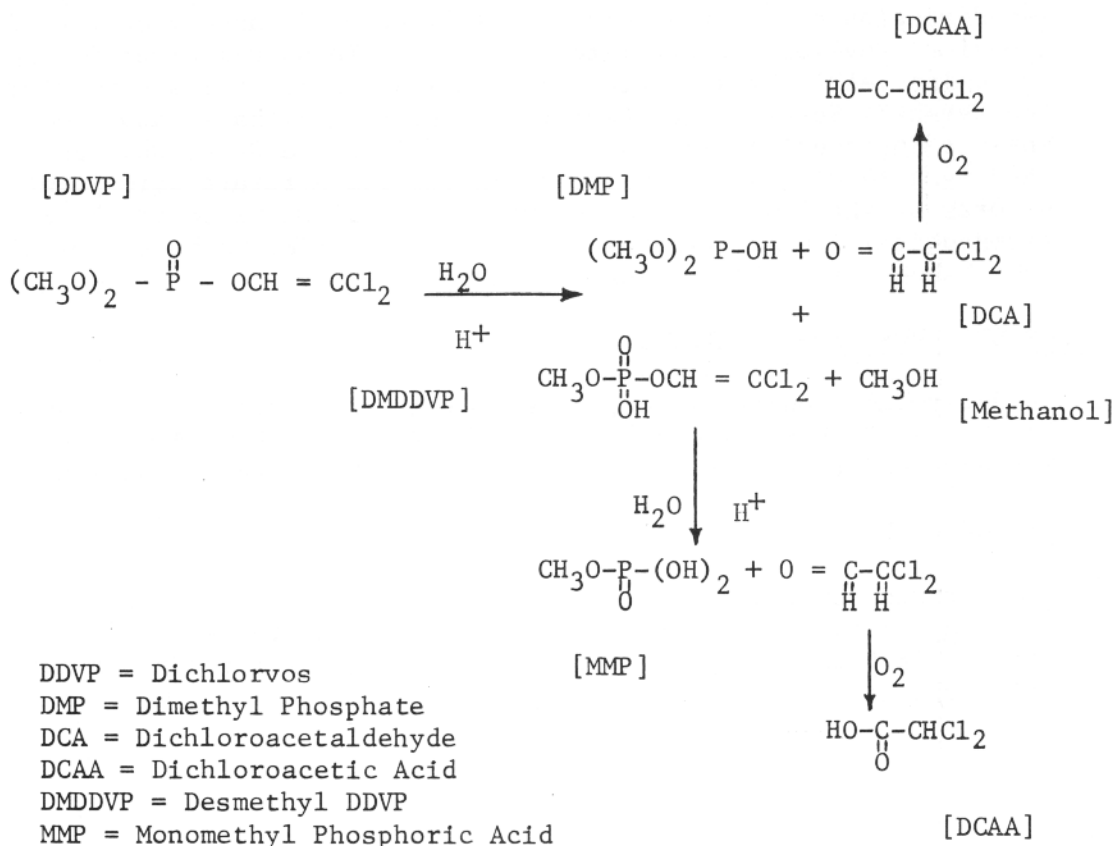
- 6.2.2 Under basic conditions, DDVP is hydrolyzed (reacts with water) rapidly to form dimethyl phosphate (DMP) and dichloroacetaldehyde (DCA).<sup>7,8</sup> The DCA is then decomposed further to form glyoxal and chlorides, as illustrated in the following equation:

DDVP HYDROLYSIS - BASIC



6.2.3 Under acidic conditions, the hydrolysis proceeds slowly giving principally DMP and DCA. Desmethyl DDVP [ $\text{CH}_3\text{O} \cdot \text{HO} \cdot \text{P}(\text{O}) \cdot \text{OCH} : \text{CCl}_2$ ] is also produced which further decomposes to monomethyl phosphoric acid and DCA.<sup>8</sup> 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



- 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.<sup>8</sup>
- 6.2.6 Dichloroacetaldehyde (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 [ $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ ] and Aluminum Hydroxide [ $\text{Al}(\text{OH})_3$ ]. The  $\text{Al}(\text{OH})_3$  is hydrated Aluminum Oxide [ $\text{Al}_2\text{O}_3$ ] and precipitates out. However,  $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$  disassociates to form more  $\text{Al}(\text{OH})_3$  plus HCl. This  $\text{Al}(\text{OH})_3$  also precipitates as  $\text{Al}_2\text{O}_3$  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 evolution 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.<sup>8</sup> 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.

<u>TABLE 6-1</u>		<u>TABLE 6-2</u>		
<u>DDVP HALF-LIFE</u>		<u>RELATIVE VOLATILITIES OF DDVP AND DECOMPOSITION PRODUCTS</u>		
<u>DDVP (pH 1-5) Hydrolysis</u>			<u>V.P. @ 80°F</u>	
<u>TEMP. °F</u>	<u>HALF-LIFE, DAYS</u>	<u>ELEMENT</u>	<u>mm Hg</u>	<u>RELATIVE VOLATILITY</u>
32	1030	DDVP	0.023	1
50	240	H <sub>2</sub> O	26.70	1161
68	61.5	DCA	66.00	2870
86	17.3	DCAA	0.37	16
104	5.8	DMP	0.00	0
122	1.66			
140	.58			
158	.164			

6.2.11 From Table 6-1, the half-life of DDVP through hydrolysis is in the order of days at temperatures expected 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

<u>COMPOUND</u>	<u>SAMPLING TECHNIQUE</u>	<u>SOLVENT</u>	<u>METHOD</u>	<u>SENSITIVITY</u>
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 <sup>-</sup>	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.<sup>2,3</sup> 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.<sup>2</sup> However, TDL established that the test method used was in effect a chloride generator with no resemblance to the aircraft dispensing system.<sup>6</sup>
- 6.3.2 Preliminary studies by TDL indicated that DDVP will not remain on a dry structural surface.<sup>6</sup> 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, Aeronautics Laboratory, located at the NASA Marshall Space Flight Center, Huntsville, Alabama. NASA's report<sup>10</sup> 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<sub>2</sub>O.
- b. 0.01% DDVP by weight in distilled H<sub>2</sub>O.
- c. 0.10% DDVP by weight in distilled H<sub>2</sub>O.
- d. Distilled H<sub>2</sub>O.
- 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:

TABLE 6-6

## DDVP FLIGHT TESTS

DYNAMIC MASS BALANCEORIGINAL 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]			
<u>MODIFIED DISPENSING SYSTEM</u>					
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

TABLE 6-9

## DDVP FLIGHT TEST

NATURAL CONDENSATION COLD PLATE TESTS

Flight Test No.	Flight Leg	Location and Condition	DDVP Deposit Density, mcg/in <sup>2</sup>
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.

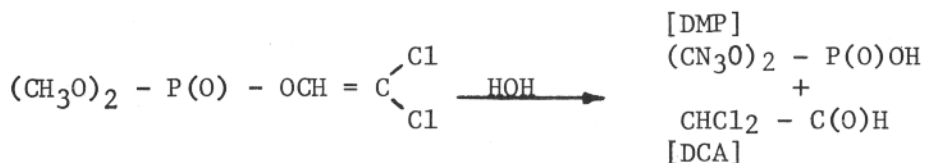
##### [Laboratory Deposition Method]

- 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

## 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:



$(\text{CH}_3\text{O})_2 - \text{P(O)OH}$  : 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.

$\text{CHCl}_2 - \text{C(O)H}$  : 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 justifiable 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.



REVIEW OF FINDINGS  
FROM DDVP STUDY CATEGORIES

7.0

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 Aero-medical 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.

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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

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 $\pm$ .05 g of dichlorvos and 7 $\pm$ 1 g of dichlorodifluoromethane.

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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.