REPORT TO THE CONGRESS

Costly Replacement Of Faulty Potting Compounds -- A Protective Material -- In Major Weapon Systems

B-163058

Department of Defense

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

JAN. 5, 1972

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

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To the President of the Senate and the
Speaker of the House of Representatives

This is our report on the costly replacement of faulty potting compounds--a protective material--in major weapon systems by the Department of Defense.

Our review was made pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

Copies of this report are being sent to the Director, Office of Management and Budget; the Secretary of Defense; the Secretaries of the Army, Navy, and Air Force; and the Director, Defense Supply Agency.

Comptroller General
of the United States

Contents

ABBREVIATIONS

DOD	Department of Defense
GAO	General Accounting Office
GIDEP	Government-Industry Data Exchange Program
MIL-STD	Military Standard

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

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D I G E S T

WHY THE REVIEW WAS MADE

Potting compounds protect electrical connections and other components from contaminants, such as moisture and corrosion. These compounds, which are installed as liquids, harden to form a solid mass around the connections or components to be protected.

Substantial costs were being incurred by the Department of Defense (DOD) to replace potting compounds which had failed prematurely in a number of major weapon systems. This prompted the General Accounting Office (GAO) to review the extent to which these compounds had been used, the circumstances surrounding their approval for use, and the actions taken by DOD to correct the problem and to prevent its future occurrence. (See p. 5.)

FINDINGS AND CONCLUSIONS

After prolonged exposure to high heat and humidity, some potting compounds revert to liquids and leave potted components unprotected. (See p. 7.)

Because of reversion a potting compound used in about 775 active F-4 aircraft is being replaced at a cost of about $39 million. In addition, 1,575 other active F-4's contain another potting compound which is also susceptible to failure by reversion. General failure of this compound is not expected to occur until 1976, and costs for partial repair may be limited to a few million dollars. GAO estimates, however, that, if reversion occurs earlier and if total replacement is required, the cost to replace this compound could reach $85 million. (See p. 16.)

Additional millions have been or may be incurred to replace compounds used in other weapon systems. For example, submarines built by the Mare Island Naval Shipyard in California during the period 1961-66 contain a considerable amount of a reversion-prone potting compound. DOD estimates that $6 million will be required to replace this defective compound with a suitable material. (See p. 26.)

GAO attributes the use of these faulty potting compounds to a lack of Government testing and evaluation. The compounds were newly developed at the time of use and were not covered by military specifications. Government personnel approved their use solely on the basis of recommendations and test data furnished by the equipment and compound manufacturers. The data did not identify the reversion characteristics of the compounds. (See p. 11.)

One military laboratory, however, which already was aware that a similar compound was reversion prone, was not requested to evaluate these compounds. The use of military laboratories to evaluate the acceptability of materials and components not covered by military specifications is presently not required. (See p. 23.)

Contributing to this problem was the inability of DOD to quickly disseminate information to all users. After field experience and Government testing confirmed that these compounds would revert, their use in the F-4 aircraft was continued for several months. (See p. 17.) The Air Force currently is using a reversion-prone compound in the F-111 aircraft. The system project office for this aircraft (which had been notified by Air Force laboratory personnel of the potential failure with this compound) has decided to continue its use. (See p. 20.)

The lack of effective coordination among the services for developing repair techniques to remove and replace one kind of potting compound in the F-4 aircraft may have increased repair costs. After recognizing the reversion problem with the compound, Air Force and Navy activities concurrently developed different methods of repair. In fact, different techniques were used by two activities within the Navy. (See p. 18.)

In regard to the difficulties experienced in the F-4 aircraft which are inherent in the approved material rather than in its use by the contractor, the Navy has concluded, and GAO agrees, that there is no basis for a claim by the Government against the F-4 contractor. The Navy, however, is pressing a claim against the F-4 contractor in regard to the improper mixing and use of some of the compound, which the Navy believes hastened its reversion. (See p. 16.)

RECOMMENDATIONS OR SUGGESTIONS

The Secretary of Defense should see that actions are taken so that:

--New, untried materials not covered by military specifications are tested adequately. GAO suggests that such newly developed materials be approved for their intended uses by a military laboratory.

--Deficiencies in materials and equipment having DOD-wide application, disclosed by one service through test, evaluation, or experience, will be disseminated to other DOD users.

AGENCY ACTIONS AND UNRESOLVED ISSUES

DOD agreed that the use of faulty potting compounds in defense equipment had resulted in considerable expense but stated that the GAO estimate of cost associated with the use of faulty compounds in the F-4 aircraft was too high. (See p. 22.)

After discussing this matter with DOD officials, GAO concluded that its estimate of $39 million to replace one of the compounds was reasonable. (See p. 24.) GAO agrees that its estimate of $85 million to replace another potting compound in 1,575 additional F-4 aircraft is subject to reduction if less than total replacement is required. The exact amount of replacement, however, will not be known for several years. DOD did not provide an alternative estimate of this cost. (See p. 24.)

DOD stated that several existing procedures provided sufficient guidance for the test and evaluation of newly developed materials and components and that military program and project offices had access to DOD laboratories for assistance. GAO believes, however, that the existing procedures are inadequate. These procedures basically are directed toward performance of tests by contractors and do not provide criteria for determining when Government personnel should request independent test and evaluation assistance from DOD laboratories. (See p. 23.)

DOD agreed that there was a need for better communications among the military services and stated that, although an existing Government-Industry Data Exchange Program provided for the exchange of test data, steps were being taken to revitalize this program. GAO believes that the usefulness of this program is limited since both contractor and military participation is voluntary. (See p. 24.)

MATTERS FOR CONSIDERATION BY THE CONGRESS

This report is being issued to advise the Congress of the need for DOD to improve its control over the approval and use of new materials in military equipment to avoid increased repair costs.

CHAPTER 1

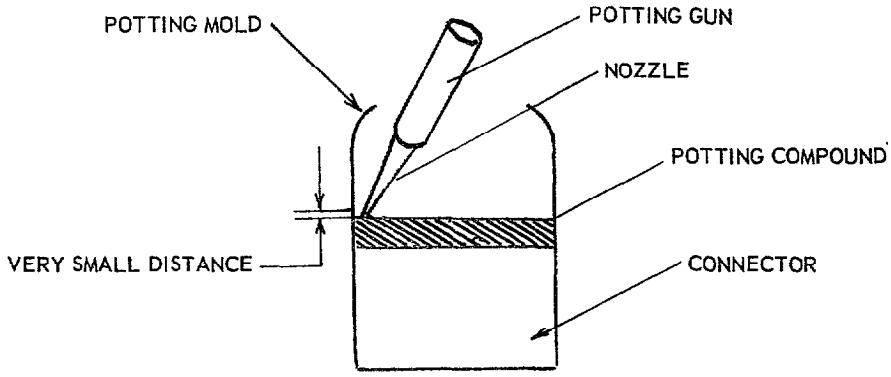
INTRODUCTION

In a recent review of contracts for the repair of aircraft, we found that substantial costs were being incurred to replace potting compounds which had failed prematurely in a number of weapon systems. These compounds, which were used to protect electrical connectors, cables, or other electrical components of military equipment, failed when their solid masses reverted to liquids.

We made the current examination to find out why and where the faulty potting compounds had been used; the cost to replace them; and the measures taken, or those that could be taken, by the Department of Defense to prevent continued or future use of these or other defective materials and compounds. Although we concentrated on the failure of compounds in the F-4 aircraft, we collected supplementary information for other weapon systems, particularly the F-111 aircraft and submarines built by the Mare Island Naval Shipyard.

A search was begun about 1950 by industry for a method to protect electrical connections in military equipment after connection failures in aircraft were attributed to moisture and other contaminants. Since that time industry has developed polysulfide, silicone, and polyurethane potting compounds as well as proprietary compounds whose contents have not been identified.

These compounds are designed to be installed in a liquid state at the points where a wire or wires are joined to terminal connectors. The compounds are poured into molds placed around the connectors. (See illus. 1 and 2 below.) Once cured to hardened, rubberlike forms, the compounds function to maintain operational integrity of the electrical units by insulating, sealing, and reinforcing electrical connectors and wiring and by protecting the connectors and wiring from corrosion. The compounds may be used for molding and encapsulating cables, circuit boards, and other electrical components.



(WIRES OMITTED FROM THIS FIGURE FOR CLARITY)

ILLUSTRATION 1. APPLICATION OF POTTING COMPOUND WITHIN POTTING MOLD.

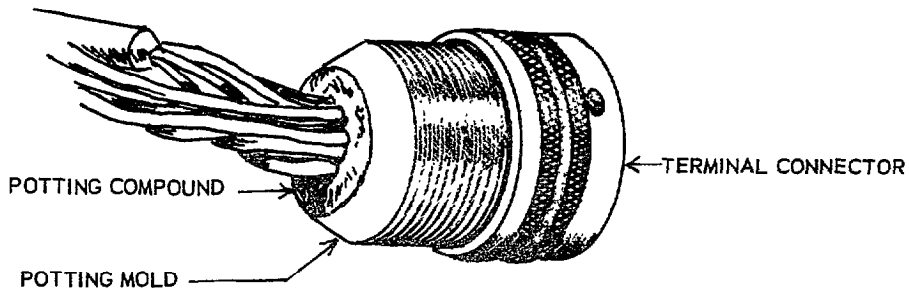
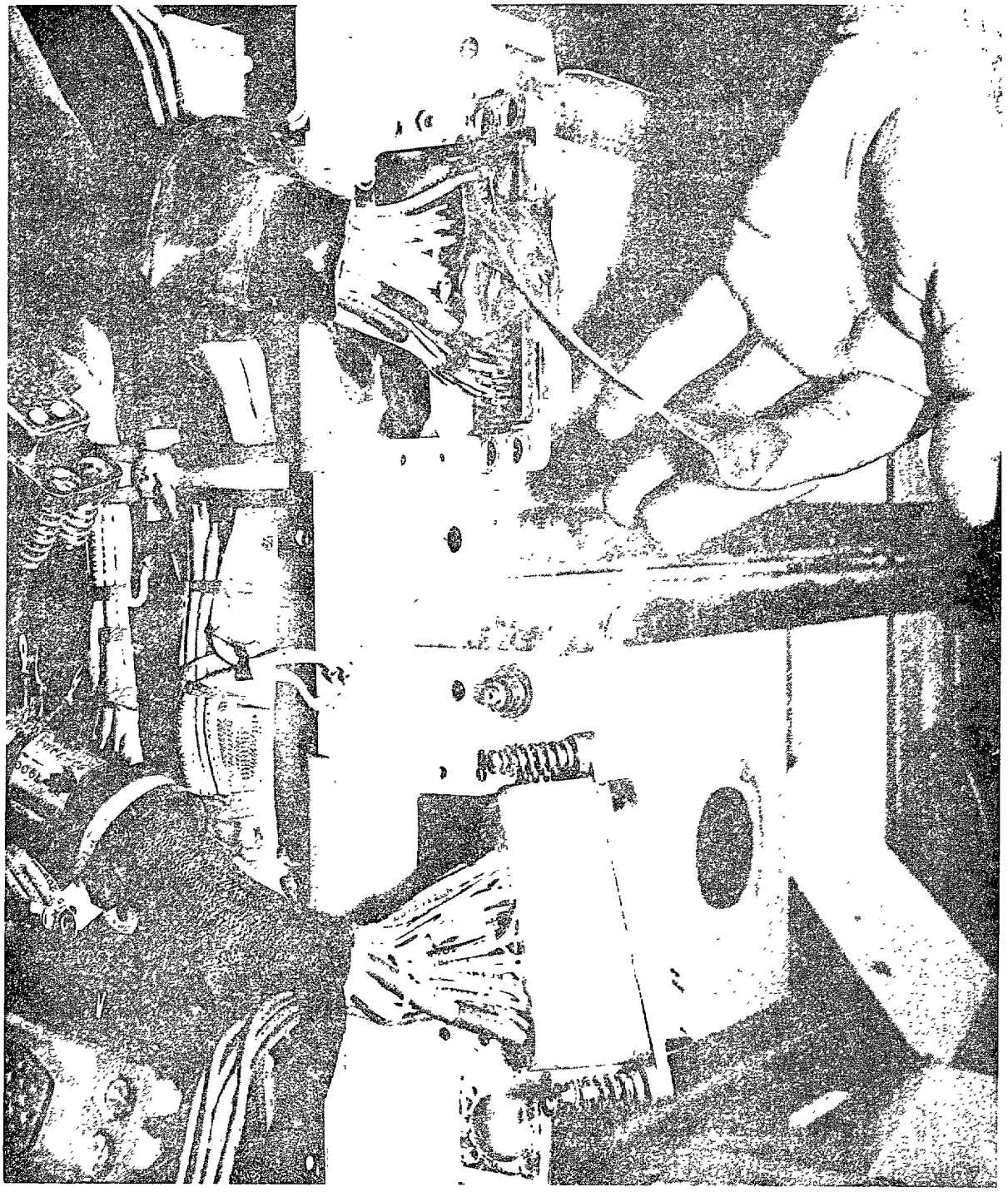


ILLUSTRATION 2. POTTED CONNECTORS AFTER CURING THE COMPOUND.

Many compounds used for these purposes have some limitations. For example, the polysulfide compounds may melt at temperatures over 200° F. Some polyurethane and proprietary compounds revert to their original liquid states after being exposed to heat and humidity for varying periods of time. The protection afforded by the hardened compounds is lost once the compounds revert and flow from the points of application. Secondary failures may be caused if the reverted compounds flow into other nearby components and equipment. The success of these compounds depends to a considerable extent on whether their use can be restricted to those applications in which they will not be adversely affected by their limitations. For example, places where the polysulfide compounds can be used safely depend on the temperatures to which the compounds will be subjected. The safe use of some polyurethane and proprietary compounds is less predictable because of the varying periods during which reversion may occur.

A study made early in 1968 by a military laboratory stated that one of the polyurethane-based compounds could revert after 3 months and that one of the proprietary compounds could revert after 1 year of exposure to conditions that might be encountered in a tropical climate. This and other studies pinpointed the cause of reversion as an attack on the chemical linkage of the compounds by a combination of heat and humidity. The greater the heat and humidity encountered, the faster the reversion. Therefore reversion would occur more quickly in Southeast Asia or southern Florida than in the northern regions of the United States.

The reversion of potting compounds was mentioned during hearings before a subcommittee of the Committee on Appropriations, House of Representatives, held on March 5, April 22, May 15, and May 26, 1969, and on March 16, 1970. The records of these hearings showed that the discussion of potting compounds centered on the F-4 aircraft. Although it was mentioned that this problem involved other aircraft, no information was furnished on the use of similar faulty compounds on ships, submarines, or missiles. The hearing records showed also that discussion of the cost to replace the faulty compounds was limited to that required for the replacement of compounds used in the F-4 aircraft.



REVERTED POTTING COMPOUND

INSUFFICIENT TESTING OF NEW COMPOUNDS

Adequate tests for reversion characteristics of some polyurethane and proprietary compounds were not made before use. Contractors and military installations planning to use these compounds were concerned with such characteristics as electrical properties, strength, and workability.

Government personnel approved the use of these newly developed compounds from recommendations and data furnished by the contractors or by compound manufacturers. Government personnel did not consider it necessary to obtain independent tests or evaluations of the compounds.

A report by one user stated that there was no reason to anticipate that some of the polyurethane and proprietary compounds would revert to liquids when exposed to high heat and humidity, since such reversion had not been encountered previously with other compounds. The report emphasized that military specifications did not exist for these compounds and that military specifications for other types of compounds did not prescribe tests severe enough to disclose their susceptibility to reversion.

Test and usage data from Government organizations, as well as available findings published by industry, however, indicated that there was a need for testing the compounds in a high-heat and high-humidity environment. Early recognition of the reversion characterisitics of the compounds through comprehensive testing and evaluation could have significantly reduced their use and resulting repair costs.

We were informed by Navy personnel that time and monetary restrictions might have been factors in influencing decisions not to request independent testing and evaluation of the compounds before approving their use. An even greater limiting factor may have been the lack of guidance for determining when such tests or evaluations should be conducted.

Military specifications for specific types of potting compounds now incorporate tests designed to disclose reversion characteristics of compounds. DOD, however, has not developed formal procedures to be followed by Government personnel in determining the extent to which newly developed

compounds or other materials or components, not covered by military specifications, should be tested or evaluated prior to use.

As described below the selection and continued use of two reversion-prone potting compounds in the F-4 indicate that inadequate attention was given to these highly complex compounds by prime contractors and Government personnel prior to full-scale failure.

FAULTY COMPOUNDS USED IN F-4 AIRCRAFT

Initially a polysulfide-based compound was specified for use in F-4 aircraft. After a limited number of F-4's were completed, inspections of the aircraft disclosed that this compound was not effective in high-temperature areas of the aircraft, such as the area around the engines. Extreme heat, in excess of 200° F., was causing the compound to boil out of the connectors. This disclosure prompted the manufacturer of the F-4 to search for a compound which could be used where temperatures exceeded 200° F.

After testing at least 15 available compounds, the F-4 manufacturer selected a polyurethane-based compound. The tests included measurement of a number of physical and performance qualities, as well as separate heat and humidity checks. A combined heat and humidity test designed to disclose resistance to reversion was not performed. A data sheet prepared by the manufacturer of the polyurethane compound contained no information on the resistance of the compound to reversion. The data sheet did state, however, that users assumed all risk and liability resulting from the use of the product and must confirm the adaptability of it by their own tests.

The Government first approved the use of the new polyurethane compound in the F-4 aircraft on February 25, 1959. This approval provided for the use of the compound only in those areas where the temperature would exceed 200° F. The use of the polysulfide compound was to be continued in those areas not exceeding 200° F. Early in 1961 the F-4 manufacturer requested the Government's approval to use the polyurethane compound throughout the aircraft. This request, which was approved by the Government in April 1961, stated

that the polyurethane compound would provide firmer support of the wires and would provide for uniform potting throughout the aircraft.

Government personnel apparently approved both the limited and the extended use of the polyurethane compound from test results initially furnished by the F-4 manufacturer. Additional testing and evaluation either by the F-4 manufacturer or by an independent activity was not requested. One Navy official told us that, because of limited manpower, this type of contractor proposal generally was given only a limited review.

Contractor personnel stated that resistance to reversion had not been a consideration in evaluating this polyurethane compound since little was known about its chemical composition and since reversion had not been encountered previously with other compounds. Various reports and articles published from 1957 through 1959, however, stated that a high temperature combined with water or moisture would have some degrading effect on this type of material. Also a report prepared by the Naval Avionics Facility, Indianapolis, Indiana, on March 2, 1961, stated that a polyurethane potting compound had been destroyed after 4 days of exposure to a combined high-heat and high-humidity environment. This report was not distributed formally outside the Naval Avionics Facility.

A representative of the manufacturer of the compound said that, during a 1957 test of the compound for electrical properties, it was noted that the compound had softened after 14 days of exposure to a combined high-heat and high-humidity environment. Since the compound had passed the electrical test, this condition was not recognized as a problem and apparently was not disclosed to buyers of the compound.

The polyurethane compound was used in the F-4 aircraft until about August 1964. On July 27, 1964, the F-4 manufacturer requested approval to change from the polyurethane compound to a newly developed proprietary compound, EC-2273, which had a lighter weight, a better service life, better adhesion, and better insulation properties. The request stated that the proposed compound was interchangeable with the compound being used and that there would be no effect on aircraft operation. As with the polyurethane compound,

Government representatives apparently approved this change on the basis of the manufacturer's recommendation and test data. No request was made for additional contractor or independent studies.

It seems that events during the period in which the polyurethane compound was used (April 1961 to August 1964) should have indicated that there was a need to perform thorough tests of the new compound before extensive use. For example, an April 1962 Naval Avionics Facility report, furnished to one aircraft company on request, described the reversion of a polyurethane compound after exposure to an environment of 212° F. and 97-percent humidity for 7 days. An August 1963 Army Rock Island Arsenal (Illinois) laboratory report, which received widespread distribution, stated that the service life of some urethane materials could be drastically shortened by exposure to high humidity. In November 1963 a representative of a compound manufacturer conferred with Navy officials on the reversion of polyurethanes.

The Navy, furthermore, was experiencing some reversion of the polyurethane compound used in the F-4 aircraft from 1962 through 1964. In response to reports of reversion, the manufacturer of the polyurethane compound informed a customer that prolonged exposure to a temperature of 300° F. and humidity of 90 to 95 percent would cause reversion of this type of material. This information also was furnished to the F-4 manufacturer on August 27, 1964. The F-4 manufacturer concluded that the above reversion had been an isolated instance.

According to the F-4 manufacturer, reversion of the polyurethane material was not a factor in requesting approval to use the EC-2273 compound. Nevertheless the manufacturer did consider its resistance to reversion prior to requesting approval for its use. Tests of several compounds, including EC-2273, were conducted to investigate the ability of the compounds to withstand conditions of high humidity and high temperatures for long periods of time.

Although EC-2273 was found to exhibit superior humidity resistance compared with other compounds tested, it was subjected only to a temperature of 100° F. and a humidity of

95 percent for a period of 12 days. We could not ascertain why the F-4 manufacturer had chosen to test the compound to only 100° F. and 95-percent humidity. Previous reports showed that reversion of some compounds had occurred at temperatures of 158° F. and 212° F. It was known that high-temperature areas in the F-4 would approach 300° F.

Additional information on the reversion of the polyurethane and some proprietary compounds became available between 1964 and mid-1968. Although this information, as illustrated below, continued to reflect the susceptibility of the compounds to reversion, the Navy did not initiate action to stop the use of EC-2273 in the F-4 until July 1968.

--July 1965	The manufacturer of the polyurethane compound tested the compound at 158° F. and 98-percent humidity for 14 days and found a noticeable softening of the compound.
--February 1967	The Navy encountered extensive reversion of the polyurethane compound used in the F-4 aircraft.
--March 1967	The Navy noted the first reversion of EC-2273 in the F-4 aircraft. Numerous connectors were found in which the compound had reverted.
--April 1968	The Naval Avionics Facility reported that the EC-2273 compound exhibited a marked tendency to revert after exposure to an environment of 160° F. and 95-percent humidity for 42 days.

In July 1968 the Navy notified the manufacturer to discontinue use of the EC-2273 compound in the F-4. The contractor was asked to use a polysulfide-based compound in low-temperature areas and a silicone-based compound in high-temperature areas. The polysulfide or silicone compounds conform to military specifications, and no serious problems have been encountered in their use.

COST TO REPLACE FAULTY COMPOUNDS USED IN F-4 AIRCRAFT

To ensure reliability of the aircraft, the Navy and the Air Force have determined that the polyurethane compound must be removed from about 775 active F-4's. This work is expected to be completed early in 1972. We estimate from data furnished by the services that it will cost $39 million.

About 1,575 active F-4's contain connectors potted with the EC-2273 compound. The extent to which this compound will require replacement presently is uncertain, it currently is being replaced on an as-needed basis, and general failure is not expected to occur until 1976. If projected conditions should change materially, however--for example, if there would be greater use of the aircraft in a tropical climate or a general accelerated failure of the compound--total replacement on an emergency basis could become necessary. We estimate that the cost to remove this compound from all affected F-4's could reach $85 million.

GOVERNMENT'S RIGHT TO PRICE ADJUSTMENT

As discussed above reversion of both the polyurethane and EC-2273 compounds is attributable to prolonged exposure to high heat and high humidity. These materials were used with the approval of the contracting officer's authorized representative. Since the difficulties experienced appear to be inherent in the material rather than in its use, the Navy has concluded, and we agree, that there is no basis for a claim by the Government against the manufacturer of the F-4.

Government tests of samples of the EC-2273 compound show, however, that this reversion process can be hastened by the improper mixing of the compound. Some of the EC-2273 compound used in the F-4 aircraft has reverted. The Navy believes that this reversion was hastened by improper mixing or installation.

The Navy notified the F-4 contractor on June 24, 1970, of "defects or failure to comply with contract requirements" in maintaining the proper compound mix ratio or in applying the compound. In October 1970 the F-4 contractor replied

to the Navy's claim by stating that quality control procedures had been diligently followed and that there was no evidence to indicate improper application of the compound. The Navy, however, maintained its original position and in December 1970 notified the contractor that the Government intended to pursue its rights under the contracts for an equitable price adjustment. In November 1971 we were informed by a Navy official that this matter still was being negotiated with the contractor.

LACK OF COORDINATED EFFORT IN RESOLVING COMPOUND PROBLEM

After encountering numerous instances of reversion of one polyurethane compound, the Bureau of Naval Weapons in October 1965 issued a bulletin to its activities stating that this type of compound should not be used in Navy aircraft electrical systems. This instruction did not caution against the use of other compounds of unknown composition or quality, nor was it directed to other defense activities involved in assembling or repairing electrical systems. Neither did the Navy ask the manufacturer of the F-4 aircraft to stop using the EC-2273 compound until July 1968, more than a year after the Navy received reports that the compound was reverting. Moreover the Navy then permitted the manufacturer to continue using the compound until the vendor's stocks were exhausted.

In several instances use of these compounds continued well after experience and laboratory tests confirmed their reversion tendencies. In fact, the compounds were being used in the F-4 aircraft as late as September 1970 and one such compound still is being used in the F-111 aircraft. (See p. 20.)

After the significance of this reversion problem became clear, the search for other equipment containing the faulty compounds was left to individual activities. Apparently the Army never has been officially notified of the problem. At the time of our visit to the Mare Island Naval Shipyard, the shipyard command had not notified the Naval Ship Systems Command that a number of submarines contained faulty compounds in a significant number of inboard applications. It appears possible that other military equipment on which these compounds were used still may be unidentified.

The lack of a general coordinated approach to the repair of equipment containing faulty compounds was especially evident in the removal of the polyurethane compound from the F-4 aircraft. The Navy, for example, first approached the problem by repairing only those electrical connections on the F-4 where the compound was in an advanced stage of deterioration. Thus a single plane might have been taken out of active service and repaired several times. The Air Force, in contrast, almost immediately began a program of total removal of the faulty compound from the aircraft. The Navy eventually adopted this approach.

Several activities tried to develop effective repair programs. Two Navy repair activities conducted separate research programs, and each eventually used a different repair process. The Air Force developed and used other repair processes.

CHAPTER 3

SOME PROBLEMS REMAIN

As discussed in chapter 2, DOD already has spent several million dollars to replace faulty potting compound in F-4 aircraft. Additional millions may be required to completely eliminate this problem in the F-4 and in other weapon systems.

Although considerable top-level attention has been given to this matter by the military services, some problems still exist. These are discussed below.

NEED FOR CONTINUED MONITORING OF CONDITION OF EC-2273 COMPOUND USED IN F-4 AIRCRAFT

The first of the two faulty compounds used in the F-4 aircraft, a polyurethane, is being replaced regardless of its condition. At the time our fieldwork was completed, the EC-2273 compound was being replaced only on an as-required basis.

A military laboratory, after sampling 20 F-4 aircraft, reported in December 1970 that general reversion of the EC-2273 compound would not occur in the older aircraft for at least 6 years (until about 1976). It reported also, on the basis of the limited test, that the only rework required in the next few years would be that necessary for the prematurely reverted compound resulting from improper mixing. (See p. 16). It cautioned that this opinion was based on the premise that a limited amount of premature reversion could be tolerated on an operational aircraft until it could be detected and reworked. The laboratory recommended that random sampling of these aircraft be continued indefinitely to spot changes in the condition of this potting compound.

CONTINUED USE OF REVERSION-PRONE COMPOUND IN F-111 AIRCRAFT

A compound similar to the EC-2273 compound used in the F-4 aircraft currently is being used in the F-111 aircraft as a sealant for fuel cells and as a general-purpose sealant. A letter dated April 13, 1970, from the Air Force Materials Laboratory to the F-111 System Project Office (both located at Wright-Patterson Air Force Base in Ohio) stated that this compound would revert when subjected to conditions of high temperature and high humidity and that the potential need for rework of the F-111, similar to programs now in existence on the F-4, was all too evident. In April 1968 the Naval Avionics Facility reported that the compound would revert under an adverse environment of heat and humidity even faster than the EC-2273 compound used in the F-4 aircraft.

Air Force officials at the F-111 System Project Office concluded, however, that the compound would have a life comparable to that of the aircraft; that other available compounds would not make good substitutes; and that, in any event, because of required design changes, the cost to switch to any other compound would be too high. Air Force Materials Laboratory personnel believe, however, that a suitable substitute compound is available and that redesign work would be unnecessary.

UNAUTHORIZED USE OF REVERSION-PRONE COMPOUND IN SHIPS AND SUBMARINES

The Mare Island Naval Shipyard, California, used a reversion-prone polyurethane compound from 1961 through 1966. Reversion of the compound has occurred on ships and submarines constructed or repaired at the shipyard during this period.

Mare Island and Naval Ships Systems Command personnel were aware of the use of this compound in certain outboard (exterior of ship) applications, and Naval activities had been instructed to replace the deteriorated compound as necessary. The shipyard command also found that the compound had been used for inboard (interior of ship) applications when the first reports of inboard reversion were

received during 1966. The shipyard personnel used this compound in a number of instances in lieu of metal connectors which had been specified. Actions were not taken by the shipyard, however, to notify the systems command or other activities of the inboard use of this compound or to determine how extensively the compound had been used.

After our review the shipyard, on November 18, 1970, alerted the systems command to the fact that this compound had been used in electrical systems through 1966 and that other shipyards also might have used the compound. The shipyard proposed a program to identify inboard applications of the compound for all vessels.

In turn, by letter dated February 22, 1971, the systems command notified the Commanders, Atlantic and Pacific Fleets, of the impending problem and proposed that each conduct an inspection program to determine how extensively the compound had been used in those ships and submarines constructed or repaired at Mare Island from 1960 through 1967. The command also requested that spot checks be made of vessels repaired or constructed at other shipyards to make certain that their components did not contain the faulty compound.

CHAPTER 4

AGENCY COMMENTS AND OUR EVALUATION

By draft report dated June 28, 1971, we requested DOD to advise us of the measures which should be taken to ensure that (1) new, untried materials not covered by military specifications are tested adequately and (2) deficiencies in materials and equipment having DOD-wide application, disclosed by one service through test, evaluation, or experience, are immediately identified to other DOD users.

DOD, by letter dated September 2, 1971, commented on our draft report. (See app. I.) DOD agreed that the use of faulty potting compounds in defense equipment had resulted in considerable expense and outlined certain actions being taken to improve the dissemination of test data among the services. DOD disagreed, however, on the need for further guidance or control over the testing of newly developed materials and components. DOD also stated that our repair cost projection of $125 million for the F-4 aircraft was too high and that our comments with respect to other weapon systems were unduly apprehensive. These matters are discussed in the following paragraphs.

DOD stated that several procedures, to be followed by Government personnel in determining the extent to which newly developed materials and components should be tested and evaluated, did exist. The most notable of these were:

1. The procedures for review and approval of nonstandard parts and materials (MIL-STD (Military Standard)-749).

2. The uniformity program governing the design and construction of electrical and electronic devices (MIL-STD-454). Procedure 47 of this standard, which pertains to potting compounds, prohibits the use of unqualified materials. All general military specifications relating to compounds are being revised to refer to the procedure.

3. The use of contractor parts control boards (MIL-STD-891).

DOD stated also that program and project offices had access to DOD laboratories for consultation and assistance. Likewise, development and production contractors had access to the laboratory network.

We recognize that some guidance does exist for the review and approval of nonstandard parts and materials and that the program and project offices have access to the military laboratories. The existing guidance, however, does not aid Government personnel in determining when the expert assistance of the appropriate military laboratory should be obtained in evaluating the acceptability for use of new materials and components.

MIL-STD-749 contains procedures to be followed by contractors for preparing and submitting data needed by the contracting agency in evaluating and approving the use of new materials and parts. This standard does not provide guidance to Government personnel responsible for approving the use of such parts for determining the extent to which the parts should be independently tested (independent of contractor-originated tests) prior to approval. The approval of the faulty potting compounds by Government personnel did not result from a failure of the contractor to submit the proper documents in requesting approval to use the compounds.

MIL-STD-454 covers some of the common requirements for electronic equipment. Procedure 47 of this standard states that potting compounds shall be of a nonreversion type and should be selected from an approved list of military specification compounds. It permits, however, the use of nonspecification compounds subject to approval by the procuring activity. This standard does not provide guidance to Government personnel for obtaining review and evaluation of the proposed materials by a military or an independent laboratory prior to such approval. Therefore military activities could approve the use of potting compounds without obtaining adequate tests.

MIL-STD-891 establishes the criteria and guidelines for the preparation and implementation of a planned

contractor electronic parts control and standardization program. Its intended use is described as enhancing reliability, maintainability, and cost effectiveness through the promotion of parts commonality in the electronic system-subsystem equipment area. No criteria is given, however, for the testing of newly developed materials and components not covered by military specifications prior to granting approval for use.

DOD agreed with our comments on the need for better communications among the services and stated that the Government-Industry Data Exchange Program (GIDEP), established as a means of making available to subscribers the results of tests conducted by equipment manufacturers on products supplied to them for use in their product lines, was being revitalized.

GIDEP is not new; its forerunner, the Interdepartmental Data Exchange Program, was established in 1962. Although GIDEP promotes the exchange of some contractor- and Government-originated test and usage data, its effectiveness in making available information on defective materials and components is limited because (1) contractor participation is voluntary, (2) military organizations are not required to enter test result and usage data into the systems, and (3) only GIDEP participants are notified of reported material problems.

DOD, although recognizing that the cost to replace the polyurethane compound in all affected F-4 aircraft was substantial, stated that the cost would be about $23.8 million rather than the $39 million we had estimated.

Our estimate, which was based on detailed information furnished by DOD officials and Air Force and Navy repair activities, compared favorably with information presented by DOD to a congressional subcommittee. We questioned the basis for the DOD estimate of $23.8 million and were advised that the estimate was based solely on summary data furnished by the Navy and Air Force.

In regard to the about 1,575 F-4 aircraft in which the EC-2273 compound had been used, DOD disagreed with our

estimate of $85 million. DOD stated that, due to the limited number of reversion instances experienced by both Air Force and Navy F-4 aircraft, the policy had been established that the EC-2273 potting compound would be replaced on an as-required basis. The cost to repair these aircraft was estimated at $215,000 on the basis of a quantity of 207 aircraft, a cost of $10 for each connector, and the need to repair 13 percent of the connectors on each aircraft.

We discussed these comments with DOD officials. We were advised that tests of 207 aircraft had shown that about 13 percent of the connectors were in various stages of unsatisfactory condition. We were advised also that the estimate was based on the 207 aircraft tested rather than the about 1,575 F-4's on hand as of November 1970 which contained the faulty compound. Support was not available for the estimated cost of $10 to repair each defective connector.

In establishing the repair-as-required program, DOD apparently has not taken into consideration the fact that it is likely that all the EC-2273 compound used in the F-4 aircraft is susceptible to reversion, not just the small quantity found to be already defective. A military laboratory reported that general reversion of the compound could be expected to start in about 6 years.

Also DOD's repair-as-required approach may result in the same aircraft's undergoing rework for compound replacement more than once; that is, each time a repair is required because of deteriorating compound. Since the major part of the repair cost concerns disassembly and reassembly of the aircraft, it may be more economical to replace all the reversion-prone compound at one time.

Our estimate of $85 million is based on the cost to repair all 1,575 active F-4's in the inventory as of November 1970. If a number of the aircraft are removed from active inventory prior to the general reversion of the compound or if the rate of reversion is less than anticipated, total costs could be substantially less than $85 million.

DOD stated that our comments with respect to other weapon systems were unduly apprehensive but agreed that the

compound used on the F-111 would degrade and would require replacement; that about $6 million would be required to replace faulty compounds used on submarines; that replacement of the faulty compound used on the B-52 aircraft, for materials only, had cost about $17,000; and that a limited amount of faulty compound had been used on some surface ships.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The military services approved the use of potting compounds in such major weapon systems as the F-4, F-111, and B-52 aircraft; submarines; and missiles without knowledge of their reversionary tendencies. To replace the compound in about one third of the F-4 aircraft will cost about $39 million. Additional millions will be spent to repair the remaining F-4 aircraft and other affected equipment.

The use of these newly developed compounds, which had not been controlled by military specifications, was approved by Government personnel simply from a review of test data furnished by the compound manufacturers or system contractors. Assistance of military laboratories in evaluating the acceptability of the compounds was not requested, nor is there a DOD requirement for obtaining such assistance. One of these military laboratories had already found a similar compound susceptible to failure by reversion.

We believe that maximum use of these laboratories in evaluating the acceptability of such materials and components could prevent repetition of a similar situation with other newly developed materials and components.

We also found that the use of the defective compounds had been extended and that the cost to repair the affected equipment had been increased because of the lack of coordination among the military services. The general use of the compounds continued long after some military activities were aware of their defective nature. A number of the activities possessing equipment containing the defective compounds developed different repair programs and compound removal techniques. It appears that DOD lacks effective means to quickly accumulate and disseminate to all defense users information regarding defective materials and components and to coordinate the repair of such materials and components on a DOD-wide basis.

DOD stated that sufficient guidance for the testing and evaluation of newly developed materials and components already existed. DOD, although it agreed that improved communications among the services was needed, did not propose any specific action.

RECOMMENDATIONS

We recommend that the Secretary of Defense see that actions are taken so that:

--New, untried materials not covered by military specifications are tested adequately. We suggest that such newly developed materials be approved for their intended uses by a military laboratory.

--Deficiencies in materials and equipment having DOD-wide application, disclosed by one service through test, evaluation, or experience, will be disseminated to other DOD users.

CHAPTER 6

SCOPE OF REVIEW

We reviewed problems associated with potting compounds in military equipment from 1959 to the present. Although we were concerned primarily with the failure of compounds used in the F-4 aircraft, we developed supplementary information on the use of the same or similar compounds in such weapons as the F-111 aircraft and submarines built by the Mare Island Naval Shipyard. During our review we discussed potting compound problems with more than a hundred persons at the following Government activities and private corporations.

Government

Department of the Air Force, Headquarters, Washington, D.C.
Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio
Air Force Materials Laboratory, Wright-Patterson Air Force Base, Ohio
Ogden Air Material Area, Hill Air Force Base, Utah
Naval Air Systems Command, Washington, D.C.
Naval Ship Systems Command, Washington, D.C.
Naval Avionics Facility, Indianapolis, Indiana
Mare Island Naval Shipyard, California
Naval Air Rework Facility, Naval Air Station, California
Department of the Army, Headquarters, Washington, D.C.
Army Materiel Command, Washington, D.C.
Defense Supply Agency, Alexandria, Virginia
General Services Administration, Washington, D.C.
Federal Aviation Administration, Washington, D.C.
National Bureau of Standards, Gaithersburg, Maryland

Corporations

Dow Chemical Corporation, Washington, D.C.
E. I. duPont de Nemours and Company, Inc., Wilmington, Delaware
B. F. Goodrich Chemical Company, Cleveland, Ohio
McDonnell Douglas Corporation, St. Louis, Missouri

Teledyne Coast Pro Seal Company, Compton, California
Thiokol Chemical Corporation, Bethesda, Maryland

These organizations were associated in some manner with the production, testing, or use of potting compounds. Our review included (1) an examination of all pertinent records made available to us, (2) discussions with those persons having knowledge about potting compounds, and (3) research of various technical publications.

ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

INSTALLATIONS AND LOGISTICS

2 SEP 1971

Mr. James H. Hammond
Associate Director, Defense Division
General Accounting Office
Washington, D. C. 20548

Dear Mr. Hammond:

This is in response to your letter of 28 June 1971 which forwarded for comment your report titled "Costly Replacement of Faulty Potting Compounds in Major Weapons Systems," Code 81719. (OSD Case 3300).

Although the report is substantively factual, there are a number of discrepancies which unduly exaggerate the costs and scope of the problem. The attached comments are intended to place this matter in a more realistic perspective. As indicated therein, the cost projection of $125 million to repair the F-4 is much too high, since our experience to date shows costs of about $25 million. Similarly, comments with respect to other weapon systems are unduly apprehensive.

Notwithstanding the foregoing, we agree that potting compounds used on the F-4 have been a problem. Action taken to resolve these and other problems include the following:

F-4. a. Polyurethane: All aircraft in which the polyester-urethane potting compound was used have been repaired at an average cost of $40,000 per unit. The total cost of this effort when the remaining 78 aircraft are completed will be about $23.8 million as compared to the $39 million projected in your report.

b. Polyacrylate: A decision has been made as to the extent of replacement needed. Due to the limited number of reversion instances experienced by both Air Force and Navy F-4 aircraft the policy has been established that replacement of EC-2273 compound (the term polyacrylate is not appropriate for this compound) will be accomplished on an as-required basis. Coordinated action has been taken by the Air Force and

Navy to resolve the F-4 potting problem. Similar de-potting techniques are being employed by both services. Re-potting with approved compounds and/or environmental connectors is being accomplished.

F-111. The F-111 is being produced using 3M-EC-5106 - a compound of the same family as EC-2273. EC-5106 is being used as an aerodynamic sealer. The environment is not the same as that of the EC-2273 which was used on the F-4. Tests which have been conducted resulted in the decision not to change production (in part due to the limited number of aircraft yet to be produced) since the estimated service life of the compound in this application ranges from five to seven years. It is expected that only minimal degradation will be experienced and the repair easily accommodated in normal maintenance procedures.

Submarines. Submarines processed through Mare Island Naval Shipyard involve 15 in number. Five have already been inspected and corrections have been made. The remaining ten are suspect or have inspections scheduled. The average unit cost for repairing the five submarines was $380,000, comprised of $140,000 for material and $240,000 for labor. To date, nearly $2 million has been spent and if the average holds (2500 connectors per unit) the cost will be under $6 million.

B-52 and Minuteman Missile. Impact of faulty compounds on the B-52 is minimal. Cable assemblies, which were the only potential problem, have all been replaced at a total materiel cost of about $17,000. Tests on the Minuteman show no problem that cannot be resolved during routine recycling of the missile.

Other Ships. A survey conducted on the other ships which were suspected of having faulty potting compounds showed that of 100,000 connectors which were examined only 44 connectors were adversely affected. On the basis of this the Department of Navy feels confident that a rework program would be wasteful and that the best approach is to repair the defects as they occur during normal maintenance.

Changes to Military Specifications. All general military specifications relating to compounds are being revised to reference Requirement 47 of MIL-STD-454, which prohibits the use of unqualified materials. Requirement 47 of MIL-STD-454 will

require that a new material be approved by the three Military Departments before the material can be added to MIL-STD-454. All three Materials Laboratories will analyze and approve a new compound before it can be used in military equipment.

[See GAO note below]

We agree with your comments on the need for better communications among the Services. Our attached comments also delineate a number of steps which have been taken to alleviate this perennial problem of disseminating information on the testing of unknowns.

Your report has been most useful in bringing into focus problems which are receiving immediate attention and correction. We appreciate the opportunity to review the report and to comment upon your findings.

Sincerely,

Barry J. Shillito

BARRY J. SHILLITO
Assistant Secretary of Defense
(Installations and Logistics)

GAO note: We were subsequently advised by a DOD official that this review and approval is directed only to those compounds which are subject to military specifications which have been approved by the three military departments. No change to expand this requirement to compounds not subject to military specifications is anticipated.

APPENDIX I

Department of Defense Position
on
GAO Draft Report PP 349 (OSD Case No. 3300)

"Costly Replacement of Faulty Potting Compounds in Major Weapons Systems"

I. GAO FINDING AND SUGGESTIONS

Potting compounds are used to protect electrical connections and other components from contaminants such as moisture and corrosion. These compounds, which are installed in a fluid state, harden to form a solid mass around the connections or components to be protected. However, after prolonged exposure to high heat and humidity, some potting compounds have reverted to a liquid state, relinquishing the desired protection and sometimes causing secondary failures.

Because of reversion of a polyurethane potting compound used in the F-4 aircraft a cost of $39 million will be incurred. Another potting compound (EC-2273) may have to be replaced also, an overall cost of $125 million will be expended if total replacement is required.

GAO suggests that the Secretary of Defense consider and advise GAO on (1) What actions are necessary to resolve the remaining problems resulting from the use of potting compounds, and (2) what actions should be taken so that (a) new untried materials not covered by military specifications are adequately tested, and (b) deficiencies in materials and equipments having defense-wide application, disclosed by one Service through test, evaluation or experience, will be disseminated to other defense users.

II. GAO ESTIMATE OF UNNECESSARY COSTS

A. $39 million to replace F-4 aircraft polyurethane potting compounds

B. $125 million if total replacement of polyurethane and polyacrylate potting compounds is required in the F-4 aircraft.

III. PERIOD OF INCIDENT

The report portrays the potting compound problems from 1961 to the present.

IV. DOD COMMENTS

Although the report is substantially accurate certain technicalities deserve correction and the perspective of report should be set aright.

1. REFERENCES TO VARIOUS COMPOUNDS (page 6 & 18)

The report concerns two distinct potting compounds. The first is a polyesterurethane; differentiating this type from polyetherurethanes which are not involved in the report and therefore should not be tainted by being related to the problem. The second type compound, erroneously identified as a polyacrylate compound, is not a polyacrylate but, because it is a proprietary item, should be identified as 3M type EC-2273. DoD comments will use the terms "EC-2273" and "polyesterurethane".

2. RECAP OF EVENTS (page 12)

A. The use of potting compounds for sealing electrical connections in aircraft was a relatively new method during the early period of F-4 production.

B. The material covered by the military specification (polysulfide) was determined to be not suitable for high temperature use; the manufacturer was confronted with a high temperature situation.

C. The experience associated with potting compounds did not suggest a reversion problem; there were no established tests or requirements for testing of this characteristic of potting compounds.

D. The availability of the polyesterurethane potting compound which survived the temperature tests suggested that it would be a better product for protecting the integrity of the electrical connectors. Based upon the available experience and knowledge, this was a reasonable conclusion.

Thus, it can be seen that the decision to change from the polysulfide compound to the polyesterurethane at that moment in time was a state-of-the-art change, normally viewed as routine upgrading.

The subsequent change to EC-2273 which made available a better temperature characteristic and a lighter weight product also was a state-of-the-art change normally desired since the change was offered without cost or other disadvantage to the government.

3. CONTROLS OVER THE USE OF NEW MATERIALS AND PARTS

With respect to the absence of a formal procedure to be followed for the determination of the extent to which newly developed materials and components should be tested and evaluated, several procedures do exist. Most notable of these are:

A. The procedures for review and approval of nonstandard parts and materials (MIL-STD-749);

B. The uniformity program governing the design and construction of electrical and electronic devices (MIL-STD-454); (incidentally, procedure 47 of this standard pertains to the use of potting compounds);

C. The use of contractor parts control boards (MIL-STD-891).

In addition to those just mentioned, program and project offices have access to the DoD laboratories for consultation and assistance. Likewise, development and production contractors have access to the laboratory network. The interplay through professional societies, meetings and published reports also provides vehicles for the transfer of information, albeit informal.

4. DISSEMINATION OF TEST DATA

The dissemination of test data is encouraged and supported. The Interdepartmental Data Exchange Program (IDEP) was fostered as a joint government-industry enterprise to eliminate redundant testing by means of making available to subscribers the results of the tests conducted by equipment manufacturers on products supplied to them for use in their product lines. This effort has recently undergone revision and has been renamed the Government-Industry Data Exchange Program (GIDEP). It would appear that the following objectives of the GIDEP do accomplish the intent of the GAO recommendation:

A. Reduce or eliminate duplicative expenditures for developmental parts and components entering the inventory.

B. Increase the confidence level in the reliability of parts and components.

C. Expedite research and development projects by avoiding repetition of accomplished tests, and by providing an advanced indication of possible part and component failure modes.

D. Promote the standardization of procedures for reporting test information.

E. Facilitate direct inter-contractor communication among technical personnel working on related problems.

F. Provide a source for general parts and components test data during research, exploratory development and other preproduction stages of the procurement cycle.

G. Provide an "alert system" for immediate notification of all GIDEP participants when there are significant material, process, or safety problems of general concern.

Steps are being taken by the Joint Logistics Commanders of the Services to revitalize the program and give it added usage and emphasis in the field. The potential of the Program is evidenced by the fact that during Calendar Year 1970 a total of $5,271,354 was reported as having been saved through cost avoidance by use of the program. During the first quarter of Calendar Year 1971 over 400 test reports were received and entered the system. Over 300 calibration procedures were received and entered the system. Twelve alerts and 14 urgent data requests were distributed. Nine reels of test reports and four reels of calibration procedures were distributed to 250 participating organizations in government and industry.

5. BREAKDOWN OF COSTS

The costs for replacing the "faulty potting compounds" seems to be based upon calcualtions showing the worst possible condition. A more realistic portrayal would appear to be as follows:

	(a)Polyesterurethane		(b) EC-2273		Total Cost	
	Unit Price	Quantity	Unit Price	Quantity	(a)	(b)
Air Force	$39,665	368	$1040 @	207 @	$14.6M	$215,000 @
Navy	$40,000 (approx.)	150* 78**			6.2* 3.0**	
					$23.8M	

* Actual

** Scheduled

@ Note: 207 aircraft were surveyed for reversion. An average of 13% of the 800 connectors per aircraft were found defective. The estimated repair cost is $10 per connector.

It can be seen that the costs are still substantial although less than that reflected in the draft report. The lower figure is not presented as a "justification" but rather to illustrate that the report overstates the problem.

PRINCIPAL OFFICIALS OF THE DEPARTMENT OF DEFENSE RESPONSIBLE FOR ADMINISTRATION OF ACTIVITIES DISCUSSED IN THIS REPORT

	Tenure of Office	
	From	To
DEPARTMENT OF DEFENSE		
SECRETARY OF DEFENSE:		
Melvin R. Laird	Jan. 1969	Present
Clark M. Clifford	Mar. 1968	Jan. 1969
Robert S. McNamara	Jan. 1961	Feb. 1968
Thomas S. Gates, Jr.	Dec. 1959	Jan. 1961
Neil H. McElroy	Oct. 1957	Dec. 1959
ASSISTANT SECRETARY OF DEFENSE (INSTALLATIONS AND LOGISTICS):		
Barry J. Shillito	Jan. 1969	Present
Thomas D. Morris	Sept. 1967	Jan. 1969
Paul R. Ignatius	Dec. 1964	Aug. 1967
Thomas D. Morris	Jan. 1961	Dec. 1964
Perkins McGuire	Jan. 1957	Jan. 1961
DEPARTMENT OF THE NAVY		
SECRETARY OF THE NAVY:		
John H. Chafee	Jan. 1969	Present
Paul R. Ignatius	Aug. 1967	Jan. 1969
Paul H. Nitze	Nov. 1963	July 1967
Fred Korth	Jan. 1962	Nov. 1963
John B. Connally	Jan. 1961	Dec. 1961
William B. Franke	June 1959	Jan. 1961
Thomas S. Gates, Jr.	Apr. 1957	June 1959

APPENDIX II

	Tenure of office	
	From	To
DEPARTMENT OF THE AIR FORCE		
SECRETARY OF THE AIR FORCE:		
Robert C. Seamans, Jr.	Jan. 1969	Present
Harold Brown	Oct. 1965	Jan. 1969
Eugene M. Zuckert	Jan. 1961	Sept. 1965
Dudley C. Sharp	Dec. 1959	Jan. 1961
James H. Douglas	May 1957	Dec. 1959
DEPARTMENT OF THE ARMY		
SECRETARY OF THE ARMY:		
Robert F. Froehlke	July 1971	Present
Stanley R. Resor	July 1965	June 1971
Stephen Ailes	Jan. 1964	July 1965
Cyrus R. Vance	July 1962	Jan. 1964
Elvis J. Stahr, Jr.	Jan. 1961	June 1962
Wilber M. Brucker	July 1955	Jan. 1961
DEFENSE SUPPLY AGENCY		
DIRECTOR:		
Lt. Gen. Wallace H. Robinson, Jr.	Aug. 1971	Present
Lt. Gen. Earl G. Hedlund	July 1967	July 1971
Vice Adm. J. M. Lyle	July 1964	July 1967
Lt. Gen. A. T. McNamara	Oct. 1961	June 1964

U.S. GAO, Wash., D.C.

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