INVESTIGATION OF RUSTPROOFING
OF AIR FORCE VEHICLES

By
Leslie E. Henton

Prepared for
WARNER ROBINS ALC/MMEMC
Robins AFB, Georgia 31098

Final Report for Period 30 September 1983 — 31 July 1984

July 1984

GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332
INVESTIGATION OF RUSTPROOFING OF AIR FORCE VEHICLES

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WARNER ROBINS ALC/MMEMC
Robins AFB, GA 31098

Mr. M. Eugene Bishop
Project Manager
To obtain the most cost-effective methods for optimum corrosion protection for Air Force Vehicles the Air Force should: (1) Accept the current corrosion protection provided by the major vehicle manufacturers and insist on obtaining the warranties given the commercial consumer, (2) Allow the Base Vehicle Maintenance Officer to make the decision as to whether and/or which of his vehicles should be rustproofed, (3) Perform a study to decide whether the environmental conditions of a particular AF Base requires rustproofing and if it is cost-effective.
NOTICES

The findings in this report are not to be construed as an official Department of the Air Force position.

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SUMMARY

Introduction

The present Air Force policy is to buy vehicles with the manufacturer's standard rustproofing, and to allow individual activities to apply aftermarket rustproofing when the vehicles arrive on base. Since the Air Force does not keep cause-and-effect maintenance records for vehicles, it is difficult to determine if this is the most cost effective method of providing corrosion protection. In addition are the problems of shipping vehicles overseas with no rust protection and shipping to extremely corrosive environments. The Air Force needs to look at the adequacy of manufacturer's rustproofing and at the cost benefit of applying rustproofing compounds to its vehicle fleet. HQ USAF/LEYM has instructed MMEMC, as the Air Force corrosion management office, to task a study to determine the most cost effective method of corrosion prevention. HQ USAF/LET, who control the funding and HQ USAF/LEY, the corrosion control group, have verbally agreed to accept the recommendations of an impartial study and to establish Air Force policy for future vehicle procurements. The results of this study will determine the most cost effective method of providing corrosion protection for Air Force vehicles.

Objectives

a. Investigate what vehicle manufacturers are doing to design and build rust prevention into new vehicles. This could include designing to eliminate corrosion-causing areas, such as eliminating contact between dissimilar metals, or eliminating places where water and road salts will be retained. Other methods could be the use of corrosion resistant materials; such as galvanized sheet metal, plastics, or fiberglass; or application of rust inhibiting coatings during manufacturing.

b. The final report shall include an analysis of how adequate the manufacturer's standard rustproofing procedures are for the needs of the Air Force. We want a long, useful life from our vehicles; and they are exposed to corrosive environments varying from mild to severe, including overseas transport via commercial ships.
c. Review the aftermarket rustproofing concept to determine its protection and cost effectiveness for Air Force usage.

d. Study the application of rustproofing compounds by either inhouse or by local contractor. Include availability of Air Force personnel, adequacy of application, and cost effectiveness.

e. An analysis to determine the most cost effective method of providing optimum corrosion protection to Air Force vehicles.

**Results**

From our investigation of measures to obtain the most cost-effective methods of obtaining optimum corrosion protection of Air Force vehicles, we feel first and foremost the measures taken currently by vehicle manufacturers are sufficient at most Air Force Bases to give the corrosion protection required. Secondly, what corrosion protection required for a particular base's vehicles should be determined by the Base Vehicle Maintenance Officer. Vehicles that are to be shipped overseas should be rustproofed at a facility provided by the Air Force itself to be cost-effective.

However, the only true determination of rustproofing cost-effectiveness can be made by having field testing done in various environmental locations with accurate records taken of the conditions of the vehicles rustproofed and not rustproofed over a period of years. This field testing would then establish guidelines for the Base Vehicle Maintenance Officer to determine the cost-effectiveness of rustproofing at his particular environment.
PREFACE


This contract was initiated by the Warner Robins Air Logistics Center/MMEMC, Robins Air Force Base, Georgia and accomplished under the technical direction of Mr. M. Eugene Bishop. It is published for technical information only and does not necessarily represent the recommendations, conclusions or approval of the Air Force. This project shall:

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e. An analysis to determine the most cost effective method of providing optimum corrosion protection to Air Force vehicles.

Contractual work was conducted in the Energy and Materials Sciences Laboratory, Engineering Experiment Station, Georgia Institute of Technology. Leslie E. Henton was the Project Director. Staff members of the Laboratory who participated in the program were Ms. Carolyn Hodges and Mr. Wayne Case.
We also wish to acknowledge the contributions of the following:

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1.0 **INTRODUCTION**

The present Air Force policy is to buy vehicles with the manufacturer's standard rustproofing, and to allow individual activities to apply aftermarket rustproofing when the vehicles arrive on base. Since the Air Force does not keep cause-and-effect maintenance records for vehicles, it is difficult to determine if this is the most cost effective method of providing corrosion protection. In addition are the problems of shipping vehicles overseas with no rust protection and shipping to extremely corrosive environments. The Air Force needs to look at the adequacy of manufacturer's rustproofing and at the cost benefit of applying rust-proofing compounds to its vehicle fleet. HQ USAF/LEYM has instructed MMEMC, as the Air Force corrosion management office, to task a study to determine the most cost effective method of corrosion prevention. HQ USAF/LET, who control the funding and HQ USAF/LEY, the corrosion control group, have verbally agreed to accept the recommendations of an impartial study and to establish Air Force policy for future vehicle procurements. The results of this study will determine the most cost effective method of providing corrosion protection for Air Force vehicles.

1.1 **Objectives**

a. Investigate what vehicle manufacturers are doing to design and build rust prevention into new vehicles. This could include designing to eliminate corrosion-causing areas, such as eliminating contact between dissimilar metals, or eliminating places where water and road salts will be retained. Other methods could be the use of corrosion resistant materials; such as galvanized sheet metal, plastics, or fiberglass; or application of rust inhibiting coatings during manufacturing.

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e. An analysis to determine the most cost effective method of providing optimum corrosion protection to Air Force vehicles.

1.2 General Research Plan
The project was divided into four principal tasks:

**TASK I.** Investigate what vehicle manufacturers are doing to design and build rust prevention into new vehicles.
A. Review current state-of-the-art.
B. Conduct literature survey.
C. Obtain current specifications.
D. Examine current application procedures.

**TASK II.** Review aftermarket rustproofing concept to determine its protection and cost effectiveness.

**TASK III.** Study the application of rustproofing compounds.
A. Availability of Air Force personnel.
B. Adequacy of application.
C. Cost-effectiveness.

**TASK IV.** Determine an analysis of the most cost-effective method of providing optimum corrosion protection to Air Force vehicles.

1.3 Report Structure
Section 2.0 describes the effort in accomplishing Task I., giving the methods vehicle manufacturers are using to design and build corrosion protection into new vehicles. Section 3.0 is a review of the aftermarket rustproofing concept to determine its protection capabilities and cost effectiveness. Section 4.0 will present our study of the application of rustproofing compounds by Air Force personnel or by local contractor. The analysis of the most cost-effective method of providing optimum corrosion protection for Air Force vehicles is given in Section 5.0. Section 6.0 will give the overall conclusions and recommendations.
2.0 State-of-the-Art Review of Manufacturers Methods of Building Corrosion Protection Into New Vehicles

2.1 Sources of Information

2.1.1 Technical Literature

A computerized literature search was initiated through the services of the Reference Department of Georgia Tech. The data bases queried were the National Technical Information Services (NTIS), Engineering Index (EI), and World Surface Coatings Abstracts (WSCA). The key terms used were vehicle or automotive corrosion prevention, rustproofing vehicles, manufacturers rustproofing techniques, and cost-effectiveness of corrosion proofing automotive vehicles.

A manual search of Corrosion Abstracts (National Association of Corrosion Engineers) was done. This concentrated on articles listed under corrosion in the automotive industry, corrosion preventive procedures for vehicles, and cost effectiveness of corrosion preventive procedures. The following Federal and Military Publications were examined.

Vehicle Rustproofing-AFLMC Project 811106
MIL-STD-1223V Non-Tactical Wheeled Vehicles Treatment, Painting, Rustproofing, Identification Marking and Data-Plate Stamping.
1 September 1981

MIL-C-62218-Corrosion Preventive Compound Cold-Application For Fielded Vehicles.
MIL-C-0083933-Corrosion Preventive Compounds-Cold Application For New Vehicles.

Current specifications, application procedures, test data, and warranties indicating the adequacy (service-life) of their rustproofing procedures were obtained from: Chrysler Corp., General Motors Corp., Ford Motor Co., American Motor Co., Renault and, Volkswagen.

We also examined the following specifications:

"For Rust-Proofing Automotive Equipment," City of Detroit, Department of Public Works, Division of Motor Transportation, Specification.
"Automotive Vehicle Corrosion Prevention Compound, Solvent Cutback,
Cold-Application," Post Office Department, Bureau of Facilities,
Maintenance Division, Performance Specification, POD Specification

2.2 Corrosion of Automotive Vehicles

Vehicle owners all over the world have observed that severe corrosion
can occur on body shells during winter service in northern cities or during
year-round operation in humid, salt-laden environments. The most destruc-
tive type of corrosion originates on the inner surfaces of rocker panels,
fender walls, headlight assemblies, door and quarter panels, and at welded
metal-to-metal junctures. 'Inside-out' corrosion is not related to rela-
tively minor corrosion problems originating on exterior painted surfaces.

Corrosion which starts on vulnerable inner surfaces of vehicle bodies
can completely convert relatively thin body steel to iron oxide in a year
or two. When this point has been reached, the exterior paint finish flakes
off and reveals the metal destruction which has occurred. 'Inside-out'
corrosion destroys the appearance, in some cases the structure reliability,
and in all cases the monetary value of the vehicle.

The basic causes of inside-out corrosion are related to complex body
construction and to the large number of metal-to-metal contact points in
vehicle bodies. Many brackets and panels are welded to the underside of
the body, and there are many closed sections and many unprotected metal
surfaces in welded seams. These metal-to-metal junctures produce galvanic
cells throughout the vehicle body (1).

When reviewing the degree of vehicle corrosion over the last thirty
years, it is recognized that before 1950, that catastrophic corrosion
occurred rarely due to the fact that heavier gauge metal slowed the length
of time of corrosion protection and the lower use of road salt. By 1955,
corrosion was more prevalent. By the late 1960s, Galvanic corrosion was
increasing in prevalence and by 1970s, body perforations were common and
prevalent in cars exposed to areas where salt was widely used for ice and

(1) "Study of Corrosion Prevention Compounds for Automotive Vehicles,"  
snow control. At the same time, the thickness of sheet metal used in manufacturing cars decreased by 40 percent.

Salt usage continues to be used at a rate of at least 9 million tons per year. In 1965, 4,536,000 tons were used, to 9,538,984 tons in 1971. In 1975, usage was 9,492,557. The winter of 1977-1978 used 11,331,686 tons and the winter of 1978-1979 used 12,129,391 tons. These two winters were more severe than normal, thus, the reason for increased salt usage. The winter of 1979-1980 was less severe, and the salt usage was 8,503,154 tons. In 1981, 7,591,633 tons were used and in 1982, 10,456,664 tons. It is estimated that approximately 11,000,000 tons of salt will be used in the winter of 1983-1984 assuming a normal winter (2).

Road salt and salt borne air in coastal areas are the major contributors to vehicle corrosion. Researchers and specialists also believe that to a lesser extent vehicle corrosion is also caused in part by atmospheric pollutants being spread by air and rain. Fall-out corrosion also causes degradation of the chrome plating and a general spotting and breakdown of the paintwork from acid exposure.

The corrosive effects of sulfur-containing atmospheric pollutants, such as hydrogen sulfide (H₂S), are well known. But the magnitude of their impact on the environment now appears to be a function of the company they keep, according to new research by three chemists at AT&T Bell Laboratories in Murray Hill, N. J. The scientists have shown that the ability of these compounds to corrode copper, for instance-forming copper sulfide—can be doubled when exposure to them occurs in the presence of sunlight, and tripled if exposure to the gases occurs in the presence of ozone. Of course, it is virtually impossible to avoid exposure to either or both of these corrosion enhancers.

Ozone is a potent oxidizer, that is, it readily enters into chemical reactions that involve the exchange of electrons. What's not clear, the researchers say, is whether the corrosion enhancement they witnessed with ozone was due to that chemical or reactive products, such as hydroxyl radicals (OH), that form when ozone reacts with water. "Corrosive processes are very much less efficient where it is dry," and except where it is

it is extremely dry, metal surfaces in the environment tend to be covered with a thin film of water.

The researchers "reaction centers" appear to develop within this liquid film; it is here the reactive chemicals combine. These may not end up being the sites that are corroded," he explains, "but sites that contemporarily grab molecules and assist in their transformation" (3).

In the operation of a vehicle, moisture and a variety of contaminants, either liquid or solid, accumulate on these unprotected internal metal surfaces and serve as electrolytes for the galvanic cells. The contaminants include rock salt, calcium chloride, road dirt, mineral matter, absorbed chemicals from industrial atmospheres, and other potentially corrosive agents. The solid matter absorbs water and oxygen and produces chemically active 'poultices' in direct contact with the unprotected inner metal surfaces. Since most metals of construction, especially cold-rolled steel, readily corrode even under mild environmental exposure, it is obvious why severe corrosion of unprotected body steel occurs in service.

The corrosion of vehicles is a problem all are concerned with as automobile owners. The average motorist is usually unaware of corrosion taking place until rust spots and then holes appear in the car body. Every vehicle has certain areas which are vulnerable to corrosion.

Ford conducted a comprehensive study of automobile rust problem areas and determined that six components of cars are the most susceptible to corrosion: doors, quarter panels and wheel housings, trunk lids, lower door pillars, fenders and spare tire wells (4).

A good deal of internal bodywork corrosion has its start when water laden with salt, contaminants and pollutants drains through cracks, crevices and coach joints in body panels. This causes corrosion of lower door panels and sill areas, especially when door drains are plugged. Also, heavy corrosion sometimes develops at the bottom of windshield posts and around the windshield gasket. This can be caused by contaminated rain water dripping from door gutters.

Ice, mud and dirt, which clings to the undersides of vehicles and tends to hold moisture and corrosive salts, also contributes to the vehicle


rusting problem (5). In fact, a lack of underbody maintenance will acce-
erate the corrosion process as road debris collects as wet, salty and
corrosive poultices. Once these poultices dry thoroughly, corrosion stops.
But periodic rewetting increases their corrosive action. To repeat, the 4
main causes of premature vehicle corrosion are due to, (1) Road salt, (2)
Pollution, (3) Contaminated rainwater, and (4) Mud and dirt.

Although essentially all materials are affected by corrosion in the
sense that they can degrade through some interaction with the environment,
the principal emphasis in this discussion will be on metals corrosion.
First, the corrosion of metals is primarily an electrochemical phenomenon,
i.e., corrosion occurs because of an electrical current that passes between
two metal sites. In order for this to occur it is necessary that there be
a metallic path and a conductive liquid path between the two sites as shown
schematically in Figure 1. Secondly, the two metal sites must be at differ-
ent electrochemical potentials to provide the driving force for a current
to flow. The site at which the metal dissolves (oxidation) to form metal
ions is referred to as the anode; that at which an ionic species in the
solution is reduced is the cathode. Both the oxidation and reduction reac-
tions must occur in order for corrosion to take place. It is obvious that
the above conditions can be satisfied either between two sites on the same
metal surface or between separate pieces of metal that are connected
through external metal contacts.

Although this is a simplified version of corrosion, it is the basic
concept that needs to be understood to minimize or prevent it. The objec-
tive in corrosion prevention is to interfere with or disrupt the electrical
continuity through the metallic or solution path, or to decrease the
driving force (potential difference) between the two metallic sites. To
attain this objective, one should have some understanding of the following
areas of interest:

(A) Factors affecting corrosion
(B) Types of corrosion
(C) Variability of materials.

(5) "The Vehicle Corrosion Problem," Bus and Truck Transport, Rolland,
Jerry, Sept. 1967, pp 40.
Fig. 1 - Electrochemical corrosion cell
FACTORS AFFECTING CORROSION

Surface variations tend to have their greatest effect on the initiation of corrosion, whereas the environment to which the material is exposed is more likely to affect the rate of corrosion. Although the environment is usually an uncontrollable parameter, an understanding of how it affects materials may determine their choice or the method of prevention that need to be taken. The environment affects the conductivity of the liquid path or the rates of reactions at the anode or cathode. Acid or alkaline materials, or even the rock salts used to melt the ice on the roads, increase the corrosion rate, often because of better conductivity that increases the electrical current flow. However, some ionic species can penetrate protective films on the metal surface, leading to localized corrosion. The species of salts dissolved in water will often determine whether the corrosion products formed on the surface are adherent and protective or whether they are loose and permeable to the solution, allowing corrosion to continue. Corrosion products, dirt and debris, and some salts may be hygroscopic, i.e., they absorb and retain moisture. This causes the metal surface to become wet at lower relative humidities than normal and to remain wet longer.

Oxygen is often the species that is reduced at the cathode, and its availability can affect the corrosion rate. In stagnant solutions where the oxygen is restricted to the portion near the liquid-air interface, excessive corrosion can occur at the water line because of the non-uniform distribution of oxygen in the solution. Oxygen is important to the corrosion resistance of passive metals, such as aluminum and stainless steel, that require oxygen to maintain a protective oxide film. Unless the film can be repaired when it is ruptured, rapid corrosion can occur.

Temperature is also an important parameter. Normally, the rate of corrosion increases with increasing temperatures until an equilibrium condition is reached. However, under some conditions higher temperatures can be beneficial because they keep the metal surface dry. This accounts in part, for the decrease in corrosion during the summer when metal surfaces tend to be dryer than in the winter.

The severity of corrosion varies considerably from one geographic location to another. The difference is the result of variations in
moisture (humidity and rainfall), temperature, and airborne substances found in the atmosphere. Thus, environmental areas tend to be classified on the basis of the degree of atmospheric contamination, e.g., industrial (high pollution), urban, rural, or marine (sea spray).

Air pollutants are found in any of the three physical forms: gas, liquid, or solid. The gaseous materials, such as the oxides of sulfur or nitrogen, owe their corrosive effect to the formation of acidic compounds that are more aggressive than neutral materials. Liquids are primarily carriers of soluble salts that increase corrosion. Less appreciated are the solids or particulate matter. Some solids, such as airborne salts or fly ash, are corrosive themselves, but even the inert solids can have an indirect effect on corrosion. They may sorb gases and moisture readily, allowing acids to concentrate at the metal surface and cause accelerated corrosion.

The variable effects of the environment on corrosion are manyfold and can even include the contribution from surrounding materials, e.g., corrosive vapors evolved from certain glues, resins, varnishes, and paints. The effect of these vapors usually increases in a semi-closed space; thus electrical equipment may be quite susceptible to this type of exposure.

(B) TYPES OF CORROSION

Corrosion is generally separated into two classifications—general or uniform corrosion and localized corrosion. General corrosion may be of less concern than localized corrosion because the rate of metal penetration is usually slow, less than 100 micrometers per year; however, the corrosion products are detrimental to appearance, and some form of protective coating may be desired. Localized corrosion affects smaller portions of the metal surface than general corrosion, and the rate of penetration at the affected area can be very fast—hundreds to thousands of micrometers per year. Some materials are more susceptible to one form of localized corrosion than another, and this kind of information should be known before a material is selected for a particular application. The following brief descriptions of various types of corrosion are offered as a means of identification.

PITTING CORROSION—A form of localized attack at a metal surface where small areas corrode preferentially leading to the formation of cavities.
Metals, such as aluminum or stainless steel, that form passive films are usually more susceptible to this form of corrosion.

CREVICE OR CONCENTRATION-CELL CORROSION—Localized corrosion caused by the formation of a potential difference between two areas of metal exposed to different concentrations of dissolved ions in the same solution. The attack occurs at shielded areas created by recesses, joints, scale, or surface deposits.

GALVANIC CORROSION—Accelerated attack that occurs when two metals with different potentials or tendencies to corrode are in metal-to-metal contact. One metal becomes the cathode, and its corrosion may be reduced; the other metal, the anode, usually has its corrosion accelerated.

STRESS CORROSION—This form of corrosion occurs when the metal is under the combined influence of sustained tensile stress, either applied or residual, and a corrosive environment. Damage usually appears as cracks which can propagate rapidly.

INTERGRANULAR CORROSION—A selective or localized attack at or adjacent to grain boundaries without appreciable attack on the grain. This type of corrosion is most often associated with austenitic stainless steels.

EXFOLIATION CORROSION—A laminar type of corrosive attack in which flakes of metals are peeled or pushed from the surface of metal because of the internal stresses created by the corrosion products. (Sometimes considered to be a special form of intergranular attack or stress corrosion cracking.) This corrosion is most common to rolled or extruded aluminum alloys in which grains are elongated and flattened.

DEALLOYING OR PARTING CORROSION—A phenomenon associated with the selective removal of one or more components from an alloy. The preferential removal of zinc from brass alloys is referred to as dezincification.

FRETTING CORROSION—This type of corrosion is defined as damage that occurs at the interface of two contacting surfaces, at least one of which is metal, when they are subject to minute slippage relative to each other. It is sometimes referred to as wear or rubbing corrosion, chafing corrosion, or friction oxidation. It is usually characterized by discoloration, formation of debris, and formation of deep pits, where fatigue cracks may be initiated.
CORROSION FATIGUE—The premature fracturing of metal from the exposure to the combined action of corrosion and repeated cyclic stressing.

Although each type of corrosion is important, two that have particular significance to the engineer designing a product that uses a multiplicity of materials are crevice corrosion and galvanic corrosion. Crevices are normally formed at joints associated with lapping operations involving one or more materials. In addition, automobiles are exposed to mud, debris, and snow which can accumulate in pockets or shielded areas, thus forming a crevice under the accumulated material in contact with the metal. Galvanic corrosion must be considered because it is difficult to avoid bimetallic contacts when a wide variety of metals are used.

(C) VARIABILITY OF MATERIALS

Material selection is usually narrowed by considerations of a mechanical or economic nature, but resistance to corrosive attack must be a consideration. A sampling of some of the significant differences are mentioned below:

Aluminum—Due to its protective oxide film, its alloys exhibit good resistance in a variety of environments. Strong acids and bases or halide ions can penetrate this protective layer, however, permitting rapid corrosion. Since aluminum is anodic to most metals, insulation may be required to prevent galvanic attack, though a thick enough anodic film could obviate this need. Some of the high-strength alloys are subject to stress corrosion and may require special precautions.

Copper—Since copper alloys are cathodic to many, care must be taken to protect other metals from corrosion at contact points. High SO₂, and in some cases CO₂, concentrations may have deleterious effects. Dezincification of brasses and stress corrosion require precautions.

Iron and steel—These materials usually require protection if significant resistance is required. This is particularly true where weight considerations require thinner sections. They are subject to corrosion fatigue and, lying in a more central location in the electromotive services, can enter into galvanic couples which can either accelerate their own rate of
attack or that of the adjacent metal. Embrittlement by hydrogen from plating baths can magnify the effects of stress corrosion.

Stainless steel—When improperly heated, as during welding, these materials can become subject to intergranular attack. If the protective oxide film is broken and cannot be reformed, as in some shielded areas, pitting or crevice corrosion may occur and stress corrosion may be initiated at such sites.

Magnesium—These alloys are seldom considered for applications requiring a high degree of resistance to corrosion. Coatings and protective treatments are available, but magnesium's highly anodic nature prevents its application in most situations where galvanic corrosion might occur.

Zinc—This metal is often used as a coating material for steel because of its ability to corrode sacrificially, protecting the substrate. It is vulnerable to the SO₂ in industrial, but resistant to marine or salt environments, and behaves better in acidic, rather than basic environments (7).

2.3 Practices for Preventing Corrosion Used by Vehicle Manufacturers

There are a number of methods that vehicle manufacturers are able to use to help prevent or decrease the rate of vehicle corrosion:

Pitting Corrosion—Use materials with alloying elements designed to minimize pitting susceptibility, e.g., molybdenum in stainless steel. Provide a surface which is as homogeneous as possible through proper cleaning, heat treating, and surface finishing. Reduce exposure to aggressive ions by shielding the part, or by reducing the concentration of these ions. Increase the capability of the solution to make the metal passive when immersed by the use of inhibitors or other additives. Minimize the effects of external factors on those design features that lead to localized corrosion, e.g., the effects of differential aeration on crevices.

Crevice Corrosion—Use welded joints in preference to bolted or riveted joints. Caulk or seal unavoidable crevices, using durable and noncorrosive materials. Minimize the contact between metal and plastics, fabrics, debris, etc. Avoid contact with materials known to contain corrosive elements or which are hygroscopic because they may accelerate the

(7) "The Application of Corrosion Principles to Engineering Design," SAE paper 770292, Leonard C. Rowe, General Motors Corp.
cell effect. Avoid sharp corners, ledges, and pockets where debris can accumulate.

Galvanic Corrosion—Avoid the use of combinations of metals which have potentials widely separated in the galvanic series. Avoid combinations where the area of the anodic metal is small relative to that of the cathode. Use metals for rivets, bolts, and fasteners which are cathodic to the surrounding metal. Insulate joints of dissimilar metals when possible; even paint or plastic coatings will be helpful. Paint or coat all surfaces when possible. Avoid painting the anodic metal only, because corrosion may be accelerated at imperfections or breaks in the coating. Seal faying surfaces. Apply metallic coatings to reduce the potential difference between dissimilar metals. Avoid threaded connections when dissimilar metals are used. Increase the thickness of replaceable sections of corroding metals. Attach sacrificial anodes (Zn, Mg, Al) to the metal to be protected, provided there is electrolytic contact. Use chemical inhibitors to reduce galvanic effects when metals are exposed to fluids.

Stress Corrosion—Substitute more corrosion-resistant materials for the stress-sensitive material. Design to minimize the factors which promote corrosion and residual or applied stresses. Avoid crevices, deep recesses, dissimilar metals, sharp corners, and notches. Alter the metallurgical structure of the metal by aging or tempering. Avoid designs which tend to concentrate specific effects or produce high thermal stresses. Include stress-relieving treatments when residual stresses are likely to occur. (Surface rolling or shot peening to introduce a compressive layer.) Cover the surface with an organic or metallic protective coating. (Coatings should be resistant to the environment and free from cracks or pores.) Modify the environment, if possible, by changing the pH or reducing the oxygen content, e.g., heat exchanger fluids. Use inhibitors or cathodic protection after investigation under conditions of use. (Hydrogen may be evolved from cathodic protection, increasing tendency for hydrogen embrittlement.)

Intergranular Corrosion—Use stainless steel alloys having low carbon content. Anneal the alloy at proper temperature and follow with rapid quenching. Use stainless steel alloys containing stabilizing elements,
such as Ti, Cb, or Ta. Substitute an alloy which has less sensitivity to intergranular attack.

Exfoliation Corrosion—Use exfoliation resistant alloys and tempers. Use natural aging at room temperature or artificial aging at elevated temperatures or a combination of both. Coat surfaces with metallic coatings of Al, Zn, or Mg. Seal faying surfaces and coat the areas in contact with fasteners.

Dealloying or Parting Corrosion—Use copper alloys having copper contents above 85 percent. Use brasses alloyed with Sn, As, or Sb. Avoid environments in which the solution becomes stagnant and deposits can accumulate on the metal surface.

Fretting Corrosion—Use a soft metal surface in contact with a hard one, e.g., Sn, Pb, or silver-coated metals in contact with steel. Roughen the surface to increase friction and reduce slippage. Increase the load to reduce relative motion. (Damage may be increased if the load is insufficient.) Use low-viscosity lubricants in combination with phosphate-treated surfaces. Increase the surface hardness of contacting metals. Use one material with a low coefficient of friction.

Corrosion Fatigue—Reduce stress by changing design, stress relieving with heat treatments or by shot peening the surface. Coat the surface with metallic or nitride coatings, or inhibited paint. Use an inhibitor or cathodic protection when exposure is in solution.

The following is a list of methods currently being used by Vehicle Manufacturers to improve corrosion prevention:

Vehicle manufacturers have made improvements in recent years by designing vehicles with better drainage characteristics and using more rust-resistant metals and coatings. The current trend is toward the use of more galvanized sheet steels and less cold-rolled sheet. By some estimates, it appears that by 1987 or 1988, the amount of galvanized sheet in a car will exceed the amount of cold-rolled sheet (8).

Vehicle manufacturers are also submerging vehicle bodies or truck cabs in corrosion resistance primer paint which is designed to protect inner panels and hidden box sections against early corrosion damage. The use of

more plastic and fiberglass parts, fenderliners, etc. has reduced the degree of corrosion found today.

New and improved methods are being used to coat and inhibit closed-in box sections as well as rocker panels and other inaccessible but vulnerable sheet metal areas. To accomplish a longer length of protection, there are a variety of new external underbody and interior coating materials ranging from improved rubber and asphaltic/bitumen coatings, wax and lanolin base compounds, to spray on plastic films.

Internal spraying, with high quality rust preventives of hidden vehicle body components on areas or structures, has proven to be a successful and effective technique in minimizing corrosion.

Stuart M. Frey, Ford's chief vehicle engineer, reports that the most effective of these corrosion prevention techniques involve the use of zinc. When zinc is applied to the surface of steel it serves both as a barrier to electrochemical corrosion and an anode that will sacrifice itself and protect the steel, even in small bare areas. Zinc can be applied to steel surfaces in a variety of ways. Two of the best known are galvanizing, which is accomplished by dipping steel into a tank of molten zinc, and the use of zinc-rich primers, which are applied to the base of steel before painting. According to Mr. Frey, Ford has been using galvanized steel for more than 15 years. "We began using galvanized steel in 1960 models," says Mr. Frey, "and today it is used in 21 practical body part areas, such as rocker panels located beneath doors, certain chassis parts and other structural components of the car. For example, the Granada and Monarch cars each contain more than 60 square feet of galvanized steel."

Mr. Frey says that zinc-rich paint primers have also been used on Ford products since 1960. "We use zinc-rich paint primers mainly on sheet metal stampings, which are used to produce components that are inaccessible to normal primer applications after assembly," Mr. Frey reports. He says that the zinc-rich primers, called ZRP, are sprayed liberally on such key areas as the inner side of outer door panels, parts of the floor pans and trunk deck lids.

"Proper application of ZRP is vital at Ford," says Mr. Frey. "To accomplish the required zinc-rich primer coating, we have developed special paint spraying equipment. Close surveillance of this equipment throughout
the primer spraying process assures that it covers the metal properly with rust-inhibiting zinc primer."

Ford developed a special process to protect the body shell from corrosion. Called electrocoating, the process involves dipping the entire car body and other parts into a huge tank filled with primer. The metal is given a positive electrical charge, while the primer and tank are negatively charged. As a result, the paint is applied to many areas that are inaccessible to normal spray applications after joining.

Another recent development at Ford is the use of pre-coated steel in such critical areas as inner door panels. The pre-coated steel has an organic coating containing zinc that is baked on before the steel is stamped into panels.

According to Mr. Frey, Ford's fight against rust begins with the basic vehicle design. For example, he says Ford has relocated and enlarged door drain holes to allow for quicker drainage of water from rain and snow. More important, enlarged door drain holes allow salt brine splashed against car windows to flow out rather than seep down into door wells, where some may be trapped and start corrosive action.

Inner and outer door panels have been redesigned to make it easier to coat them with zinc-rich primer. Crevices that allow mud and salt packing have been eliminated, thus preventing destructive attacks on metal caused by salt brine combined with dirt on unpaved roads. The lower quarter panels have also been changed to permit better drainage (9).

In order to slow the growth of corrosion and meet the requirements of the warranties, the average domestic car in 1982 contained 250 pounds of galvanized steel or steel treated with a zinc coating for 14 percent of the total steel (1,800 lbs.) used (10).

Coated steel, and one-sided galvanized as well as pre-coated zinc-rich prime steel are being used in every increasing levels. This procedure began in earnest at Chrysler with its 1978 Plymouth Horizon and Dodge Omni.


Ford Motor Company is deeply involved in Zincrometal development, supplied in part, through their own steel division. GM used one sided galvanized for the 1980 X-body cars and also used aluminized steel for the X-car cradle subframes.

AMC announced a corrosion warranty for their 1980 models. They were able to do this in part because of their increased use of galvanized steel (11).

Vehicle manufacturers in the United States appear to be more concerned with corrosion protection now than ever before. An example of just how they are approaching protection of their vehicles, the following is an excerpt from one of the "Big-3," 1983 sales brochures for mid-size pickup trucks.

"Built In Anti-Corrosion Measures: Front fender skirts, urethane stone shields ahead of wideside rear wheel openings. Hemmed construction of wideside tailgate. Front wheelhousing-to-frame seals to reduce underhood splash. Rubber weatherstripping around doors and windows. Draining system for quick removal of water from some double-wall areas. Special Metals, Zincrometal, zinc-plated steel, one or two-sided galvanized steel, and zinc-iron-alloy coated steel are used for various parts of the front-end sheet metal, cab, doors and cargo box. New for '83 is the use of Zincrometal for the hood inner panel and use of galvanized HSLA steel for the front end panel of wideside pickup box.

Special Thick Paint Treatment applied to many lower inner body surfaces to help resist corrosion from road salt. Also special metals and coatings are used for many nuts, bolts, and assemblies" (12).

The use of Zincrometal by the domestic auto industry is growing, despite the recession, with an increase in consumption of 22 percent predicted for this year. Zincrometal is a two-part proprietary coating which gives corrosion protection to steel sheet. The product was put on the market in 1974 and now licenses and supplies most of the major steel companies and other large steel coaters. It is estimated that consumption of Zincrometal in 1982 would increase 22 percent to 1,050,000 tons, up from


860,000 tons in 1982. Zincrometal consumption hit a peak of 1.2 million tons in 1978, which was a bumper year for the auto industry. Despite a decline in auto production in 1982, Zincrometal consumption rose 14.6 percent (13).

A large variety of chemical compounds are used to reduce corrosion of automotive electrical components, sealing out air, moisture, and harmful chemicals, increasing lubricity and reducing thermal degradation of components. Many serve dual purposes, such as magnet wire enamel and varnish impregnant on an alternator field. The resultant insulation system serves as a dielectric, resists vibration, and protects the copper wire from corrosion.

An example of a varnish system designed for corrosion prevention is the polyester system used on some alternator field coils. Operational problems had been encountered where copper wires on the field coil were open and green corrosion was present. It was found that the phenolic varnish system blistered during curing and left copper areas relatively unprotected. This alternator was used on diesel applications where strong caustic cleaning agents are used in engine degreasing. A varnish impregnation system which would not blister was desired. The polyester system now used fulfills this need (14).

A summary of the major steps taken by the American Motors Corporation in developing methods of corrosion protection were:

"In 1957, American Motors first began dipping its car bodies in primer paints. We were among the first to recognize the obvious advantages of the dip process and to implement this process in our production operations. We did it because we were keenly aware that the increased use of salt could accelerate the rust threat to all automobiles, regardless of the type of construction or the make.

In addition to the primer dip, our 1957 models received asphaltic underbody sealers, which provided a sound and moisture barrier. We also

(13) GMC Pickups, 1983 General Motors Corporation, pp 15.

added weld-thru sealers to fill gaps between joined sheet metal panels — again to seal out moisture.

In 1960, American Motors was among the first to use galvanized steel for rocker panels. We also improved our dip process by converting to an epoxy-type primer as an added protection for hidden areas around the headlamps and rocker panel joints. We reinforced these areas with zinc-rich paint. As a further protective measure, we put in flowable wax compounds as a supplement in the rear quarter and rear wheelhouse seams.

In 1964, we added masticated rubber shields in the under-fender areas to prevent mud and moisture buildup. We also introduced nylon exterior fasteners for ornamentation and moldings.

Six years later, in 1970, we introduced two-side galvanized steel for the front-wheel valance panel, spring seats, front upper wheelhouse structure, rear quarter panel extensions and the rear body crossmember.

In 1976, we added stone-chip resistant coatings to the underside of fenders; wax coatings at the window openings; zinc-rich primer on the hood; nylon and coated metal clips for use in attaching window moldings. And we expanded the use of wax coatings as well.

While we have been super-sensitive to rust prevention for decades, the results of the last three years have been the most rewarding — not only for us, but the auto industry as a whole.

This has been due in large measure to breakthroughs in technology, as well as the commercial availability of certain new materials, such as one-side galvanized steel and other processes for pre-coating steel" (15).

Complete details of AMC's 1980 anti-corrosion process are impossible to fully delineate in this paper. The basis of their anti-corrosion process includes the effective use of corrosion resistant body primers, body sealers, petroleum based anti-corrosion waxes and galvanized steel all properly placed in corrosion sensitive areas. A summary of the major anti-corrosion processes used on each body panel follows:

**FENDERS**

(1) A full plastic fender liner.

(2) Thermoset polyester sealer on the top inner surface.

(3) Zinc primer at the nose and rear of the inner fender.
(4) Wax at the nose and rear of the inner fender.

DOORS
(1) One-side galvanized outer panel.
(2) One-side galvanized inner panel.
(3) Wax applied on the lower interior surfaces of the assembly.
(4) Wax applied on the lower exterior surface of the inner panel.

HOODS
(1) One-side galvanized outer panel.
(2) One-side galvanized inner panel.

ROCKER PANELS
(1) Two-side galvanized outer section.
(2) Zinc primed inner support member.

QUARTER PANELS
(1) One-side galvanized.
(2) Apply wax from the pillar to the top of the wheelhouse.
(3) Apply wax from the top of the wheelhouse to the rear panel.

REAR WHEELHOUSE OUTER
(1) One-side galvanized.
(2) Apply wax to the quarter panel wheelhouse joint.

PILLARS
(1) Zinc prime the entire inner pillar.
(2) Apply wax to the lower "A" pillar.
(3) Apply wax to the lower "B" pillar.
(4) Apply wax to the lower "C" pillar.

COWL
(1) Two-side pre-coated steel outer panel.
(2) Two-side galvanized inner panel.

DECKLIDS AND LIFTGATES
(1) One-side galvanized outer panel.
(2) One-side galvanized inner panel.

FRONT MODESTY PANEL
(1) Two-side galvanized.

REAR FLOOR PLAN EXTENSIONS
(1) Two-side galvanized.
TAIL LIGHT MOUNTING PANEL

(1) One or two-side galvanized.

FRONT SUSPENSION MOUNTING TOWER

(1) Apply wax to front suspension mounting bracket outer surface.

HEM FLANGE SEALING

(1) Apply plastisol sealer to door, decklid and liftgate hem flanges.

STATIONARY GLASS MOUNTING SURFACES

(1) Apply wax to mounting area of stationary glass installations.

These operations are all in addition to multi-stage metal cleaning and phosphating, body sealing, dip priming, spray priming and color coat enamel operations (15).

I have enclosed copies of printed matter listing corrosion protection for a portion of General Motors vehicles, and GM and Chrysler Corporations Warranties (see APPENDIX) (Attachment 1)(Attachments 2 and 3).

GM offers 36-month protection on all cars and trucks since the 1980 models. GM president Elliott M. Estes said, "Under this warranty, your General Motors dealer will repair or replace at no charge those parts found to have perforations due to corrosion." Mr. Estes added that "exhaust system components and corrosion other than perforation ...due to defects in material or workmanship will be covered by the normal 12 month/12,000 mile limited warranty."

Ford Motor Company announced that they will provide a "three-year, unlimited warranty" on all 1980 model cars and light trucks. In addition, the warranty extends down to all 1979 vehicles sold after July 11 of that year. W. O. Bourke, Executive Vice President of Ford North America, explained that "any part which in normal use develops perforations from corrosion within three years of retail delivery or first use, will be repaired or replaced free of charge after inspection by a Ford Motor Company representative."

Both GM's and Ford's corrosion warranties automatically transfer to new owners during the three-year period. Similarly, Chrysler Corporation offers a 36-month corrosion warranty.

American Motors and International Harvester lead the field in this regard, though. Each has developed a new "rust-proofing" approach by adopting a Ziebart approved process on the assembly line. Both can therefore offer a full five-year warranty against corrosion.

Foreign car manufacturers are now providing anti-perforation warranties similar to those offered by GM and Ford, generally covering three years. No manufacturer, foreign or domestic, covers exhaust systems or damage caused by outside sources, such as parking lot chips.

3.0 A Review of the Aftermarket Rustproofing Concept

3.1 Review of the Largest Franchised Rustproofers

The following is a review of the largest or best known of the franchised rustproofers. Crucial differences, if any, revolve around warranties, price, and service—all the chemical formulas will work.

TUFF-KOTE DINOL. Probably the world's largest rustproofer, Tuff-Kote's fibre-and-asphalt undercoating remains supple for the life of the car. The paint coating used is composed of a wax and oil base. However, they require that the job be performed on new cars before 90 days or 3000 miles, and an inspection is necessary every other year during a specified month. A cleaning fee of $25 is possible. The limited warranty is good for as long as you own the car and applies only to "inside-out" rust below the windowsill. Specific restrictions make the warranty limited. Tuff-Kote offers systems for new and used cars, but the warranties are different.

ZIEBART. The nation's largest rustproofer uses a chemical compound similar to that of Tuff-Kote and Rusty Jones. Ziebart has received kudos from AMC's adoption of their approved process on its assembly line. Ziebart's limited warranty lasts as long as you own the car. It is transferable within three years, subject to inspection and a fee. The transfer warranty is good for six years from date of application, and there is a labor charge. The warranty includes "inside-out" rust in body sheet
metal, structural members, and frames. Exterior rust and repaired or replaced areas not treated within 60 days of the damage are not included under the warranty. Service is good, and facilities are readily available.

POLYGLYCOAT. While Ziebart is the nation's largest and Tuff-Kote Dinol is the world's largest, Polyglycoat is the best-marketed. It may also be the least appealing among the well-known rustproofers. Its warranty is limited and good for only seven years. However, it is transferable (for a $15 fee) and reissued for the remainder of the original term. No inspection is required during the warranty period, which will be a plus for many. Beware, though—the coverage is for all areas "properly coated," and that phrase can be interpreted to their advantage.

RUSTY JONES. Among the better-known rustproofers, this is the only one that offers a full warranty. After 20 years, Rusty Jones' formula has proved to be one of the best in the industry. Their paint coatings preserve a new car shine for the life of the car. The application deadline is six months and annual inspections are required. The warranty is transferable, involving special forms, and covers any area of the vehicle that rusts through, excluding the exhaust system and surface rust resulting from chipping, collision, or chemical damage. Customers have the option to repair or application refund (if dissatisfied), limited to the book value of the car. This definitely has the best warranty (16).

3.2 The Aftermarket Rustproofers Views the Necessity for After Market Rustproofing

Building lighter, smaller, more fuel-efficient cars has resulted in reduced steel gauge and reduced percentage of overdesign or corrosion tolerance. Effort to obtain more room from smaller cars calls for reducing clearances between inner and outer panels, further complicating the designer's job of obtaining open areas for access to apply anticorrosive materials.

Dips, sprays, and sacrificial coatings are among the methods for preventing contact between hostile environmental elements and metal. Recent increases in use of cathodic electrocoat dip primers has created a

need for a new type opening, that being for electrical current access to allow proper coating of hidden areas. Though primer liquid will gain entry to all vehicle areas even if a section is boxed-in and has very limited access, larger openings to those boxed-in areas are required to allow the electrical current to perform its function. Since the 1979 model year will find 55 percent of domestic auto production by cathodic electrocoat dip primers, careful design of these access holes is essential (17).

As these processes are total immersion processes, the vehicle "body-in-white" has drainage holes which allow the flow of the paint solution into (and out of) the car body members. There must be displacement of air from these members to achieve total immersion, and also holes which increase the "throw" of the electrocoating process in box members. These holes to the passenger car compartment are filled by rubber grommets, while those to the road surface are left open for "drainage." Those holes to the box members and open to the passenger compartment are usually covered with self-adhesive tape. Holes which link box members to other cavities are left open, e.g., cavities to the rear wheel arch.

However, two vehicles travelling at slightly different speeds and in each other's wheel spray as well as their own, will cause pressure eddies which can draw salt-laden air and moisture through the unfilled exterior drainage holes. The air thus drawn in is expelled with the stale passenger air through the efficient louvres at the rear of the car structure. Thus, when there is little air being supplied to the car passenger compartment by the ram heater effect, a large quantity of moist air can be drawn through the sill drainage holes which are inadvertently directly over the front-wheel track and in the densest wheel spray pattern. Hence, the examination of accident-damaged panels show the deposition of road salts at the drainage hole/electropaint throw holes. The associated corrosion is caused by moisture absorption to the hygroscopic salts forming droplets of corrosive electrolyte which favours the differential aeration cell.

Hence, this corrosion cell contained within an hygroscopic electrolyte may be represented by the elementary set of equations:

$$\begin{align*} \text{Anode} & : \quad \text{Fe} & \rightarrow & \text{Fe}^{2+} & + & 2e \\
& & \text{iron structure} & \text{iron in the liquid state (equivalent to the electrons in the metal)} \\
\text{Cathode} & : \quad \text{O}_2 & + & 2\text{H}_2\text{O} & + & 4e \rightarrow 4\text{OH}^- \\
& & \text{oxygen} & \text{water} & \text{cathode} & \text{reaction 1 reaction product called the hydroxyl ion.} \\
\end{align*}$$

Both anode and cathode must be electrically connected and the product of the anode ($\text{Fe}^{2+}$) must react with the product from the cathode ($\text{OH}^-$), i.e., $\text{Fe}^{2+}$ (anode product) + $\text{OH}^-$ (cathode product) forms rust (18).

In the U.S. A., car manufacturers are currently giving anywhere from 1-6 years perforation guarantees. Moreover, many corrosion experts, from some of these manufacturers, indicate that in many instances the car will exceed their warranty claims.

In fact, based on the survey by Wyandotte Paint, presented to the FOCUS conference in May/83, in Troy, Michigan, since manufacturers have switched to cathodic E Coat, sheet metal perforation failures in the first five years are few.

However, premature corrosion on late model cars can be easily demonstrated. A new car (1983) with 200 miles showed severe rusting on all underside seams and in one area the floor panel itself had severe red rust. Furthermore, examination of hem flange seams on many vehicles after one year show rust and expansion. In one case a 1981 domestic car had severe hem seam expansion on the door and even perforation on the B pillar.

The point is not that all cars are like this, but that the typical vehicle off the assembly line can yield to premature corrosion. It is this kind of risk that aftermarket rustprotection can reduce for the Air Force.

Recently a publication in Automotive World News (19) discussed the need for annual inspection and resprays. Summarizing the benefits of such a program leads the author to the following conclusions:

(1) It encourages the consumer to take an active part in combatting corrosion.

(2) It catches corrosion (if it occurs) at an early stage when repair is easy and effective.

(3) It helps to correct areas where stresses have resulted in coating failure.

(4) It gives the rustproofer the opportunity to correct areas that may have been missed during the original application.

(5) It gives both the rustproofer and the consumer progress reports on how effectively the corrosion protection is working.

(6) It can diagnose design deficiencies in the automobile and enable the rustproofer to make application adjustments.

(7) It can detect product deficiencies which may have to be corrected to ensure long term corrosion protection (20).

Does rustproofing pay? To assess whether the benefit is greater than the cost of the treatment we can consider the following questions:

1. Does rustproofing reduce corrosion?
2. Are some rustproofing products better than others?
3. How important is proper application?
4. Does the rustproofing itself deteriorate? After how many years?
5. Can rustproofing protect the underbody against damage from stones and road dirt?
6. Does rustproofing reduce maintenance cost?
7. Does rustproofing increase trade-in allowance?

A search of the technical literature does not supply unequivocal answers to all these questions. It is clear, however, that rustproofing can be beneficial. Records of commercial fleets and armed service vehicles, for example, have demonstrated that properly rustproofed cars


(20) "Effectiveness of Aftermarket Rust Protection," David C. Vegh, Ziebart International Corp.
last years longer in the snow belt and coastal areas. This is the reason that most governmental departments order rustproofing coating on all new vehicles before delivery.

Several main points emerge:

1. Rustproofing is advisable if the car is to be kept more than 3 or 4 years in a severe environment. An argument can be made to rustproof in any case because the cost can be recovered on resale.

2. Proper application is all-important. Door cavities, rocker panels, and other hollow sections must be injected with rustproofing compound using spray lances designed to reach all interior areas. The rustproofing compound must be suitably formulated to penetrate seams and crevices and to ensure an inhibiting coating on all surfaces after drying. The entire underbody must be coated; an abrasion-resistant coating should be applied to underside areas subject to flying dirt or stones. The present state of the art is unsatisfactory. Most rustproofed cars have missed areas; many don't meet minimum acceptable standards. Because access and inspection may be difficult, areas most in need of protection are frequently missed. Until guidelines for quality control, operator training and certification are instituted, the onus is on the individual purchaser to obtain the best job he/she can. Unfortunately, there is little he/she can do other than to rely on the rust protector's workmanship and competence and return the car for re-coating when non-treated areas or rusting are discovered.

3. No one formulation has yet become established as most effective. The coating should be flexible, adherent, self-healing, non-aging, corrosion inhibiting, abrasion-resistant where required, and able to form a satisfactory layer in hollow sections. Several types of coatings have proven effective provided they are well applied. Bituminous compounds are relatively cheap but may harden and crack with age.
In current practice, two or even three protective materials may be used on different areas.

4. Annual or biennial inspection and re-coating where needed can extend the effective life of the rustproofing treatment. Some contracts require such inspection to maintain the warranty.

5. Rustproofing must be restored after collision repair work. Unless the rustproofing is part of the insurance contract, the underside is generally left unprotected and highly susceptible to corrosion. Rusting can develop within the year (21).

Materials such as galvanized steel, Zincrometal, aluminum and plastics, and improved designs "make our job easier," says Tuff-Kote President Russell Widger. But automotive engineers point out that a corrosion-free car does not exist. As Walter Sennett, supervisor of chemical surface treatment in Chrysler's coating system lab, puts it: "There ain't no such animal."

One auto industry estimate places car makers' spending for corrosion protection at $180 million/year, plus $100 million for engineering, equipment and facilities for applying various protection materials.

But suppliers of after-purchase rustproofing materials cite a number of reasons why they are confident of continued business. For one, the drying process for corrosion protection takes 24 hours, a drawback for assembly-line production. It is also difficult to process a car in paint ovens after it has been rustproofed. And assembly lines are not geared to selectively rustproof cars bound for cold-winter and salty, seacoast areas. (Car buyers in Arizona, for example, wouldn't want to pay $150 extra for corrosion protection that isn't needed.)

In addition, rustproofing suppliers point out that as purchase prices of cars continue to climb, people want to keep their cars longer and consider the extra treatment a sound investment. And if owners keep vehicles longer, fewer cars will be manufactured, which will lower the nation's energy requirements.

More than undercoating: Rustproofing involves what is often called simply undercoating (coating the bottom of the car), plus coating of interiors of doors, frames and seams, where condensation can cause rusting from within. One of the early systems led to the formation of Astra-Dinol by AB Astra, major Swedish pharmaceutical firm. The system, developed during the early 1950s by a worker for the Swedish Auto Owners Assn., employed dinitroresol, which Astra used for rustproofing bone-joining steel spikes and other metal plates in surgical and medical applications.

The technique followed by rustproofers: holes are drilled in doors, door frames and posts, body-frame seams, etc., so the cavities can be sprayed. Thicker versions of the rustproofing compound, or a complementary compound, is sprayed onto the car bottom.

"One product won't impart complete rustproofing to a vehicle. One compound is designed for the underside, the other to meet the needs in the cavities," says Luther Dromgold, manager of new products at Witco Chemical's Kendall-Amalie Division (Bradford, Pa.). The underside coating must provide rust protection, sound deadening and abrasion resistance.

The cavity coating, in addition to providing rust protection, must be able to displace condensed moisture in order to bond to the interior surface where it is applied, Dromgold adds.

Kendall, Mortell Co. (Kankakee, Ill.), Daubert Chemical (Oak Brook, Ill.) and Quaker State Oil Refining Co. (Oil City, Pa.) are major suppliers. Chrysler Chemical (Trenton, Mich.) supplies its parent, Chrysler Motors, and outsiders.

Different Coats: About 3 gal. of rustproofing materials are applied to the average car, adding 21-25 lbs. to weight. Cost: about $125-150. The undercoating, applied to a thickness of about 1/16 in. (1/32 in. dried), is usually a combination of asphalt, corrosion inhibitors and volatile solvent. Some suppliers use other materials, however. Kendall, for example, formulates its coatings around a hydrocarbon resin derived from Pennsylvania crude; Chrysler Chemical developed a new system about two years ago but won't specify the materials.

Cavity coatings, applied in thicknesses of 0.050-0.100 in., are solvent-carried, wax-based formulations, which may include rust-preventive additives such as polyamines.
Also used: aluminized waxes, made by pounding aluminum into thin flakes, wetting with solvent and incorporating in a wax carrier.

Tuff-Kote employs a proprietary chemical penetrant developed by Astra-Dinol. It reportedly cuts through rust, bonds itself to the metal as a primer. About 1/2 pt. is applied to a new car, 1/2 gal. to a used car that has been driven more than 3,000 miles.

Astra-Dinol also stresses nonasphalt systems for undercoating. Gutenvik contends that a thick undercoat can be worse than no coating at all because moisture can collect under the coating and cause corrosion sites to develop. (Some parts are not coated—e.g., catalytic mufflers—and moisture can penetrate at coating edges and cracks.) In the U.S., Chevrolet has recommended against asphalt-containing undercoatings for that reason, says Kendall's Dromgold.

Undercoatings should be inspected every 12-18 months because abrasion can cause wear, may require recoating. This is not required for cavity coatings.

Marketers feel that rustproofing systems are of greatest benefit to new cars, although they are of some help to used cars. And even with Detroit's commitment to improving rust resistance, one automotive engineer points out: "If rustproofing is done properly, it can't do any harm. It's an insurance policy" (22).

Passenger cars and commercial vehicles are scrapped at the rate of about 3 million per year as a result of one of three causes: (i) accidents; (ii) obsolescence; (iii) corrosion. Indeed, the amount of corrosion will often determine whether a car can be economically repaired and so effects (i). The average life of a car has increased both in total miles run and life. The life figures quoted in recent surveys are for 50 percent survival (of the initial registrations). On this basis, figures of 9.9 years are quoted for the average car, whilst some cars, e.g., Volvo use to 17.9 years. During this period of use, the box sections develop their own microclimate. The corrosion associated with this microclimate may go unnoticed until metal perforation occurs.

(22) "Chemicals Give Cars One For The Road," Chemical Week, February 9, 1977, pp 49.
If a car (Figure 2) travels at 95 km/h (60 mph) then the bottom of the tire in contact with the road surface must be stationary at the instant of contact, i.e., its forward velocity is zero and the top of the tire must be travelling at 190 km/h (120 mph). Therefore, any dirt/water thrown off at this point will hit the car body at a speed of 95 km/h (60 mph) (190 km/h minus the car speed of 95 km/h). On a similar analysis, road dirt, ice, salt and stones coming off anywhere else around the circumference of the tire will also sandblast the paintwork and compact any mud onto ledges underneath the wing with the same velocity.

Furthermore, if water hits a plain surface at 95 km/h (60 mph) then this kinetic energy must be dissipated. It is used in the work done against the surface energy (surface tension) of water, by making much smaller water droplets (a mist) (Figure 2). This mist usually leaves the point of impact at an angle of 10° to 15° with the impacting surface. As a result, dissolved salts and aggregates can be deposited in positions where normally road water directly from the wheel would not reach, i.e., those surfaces not washed by rain water. The faster the car goes the more energy is imparted to the water and the smaller the droplets become. Their momentum \( M = m \times v \) (where \( M = \) momentum, \( m = \) mass and \( v = \) velocity) decreases and, therefore, this mist may change direction as a result of very small pressure changes and is more easily drawn into the box members and cavities than larger droplets. The smallest water droplets in the mist will nucleate on insoluble aggregates/particles (road dirt). The deposited road dirt, therefore, produces its own microclimate at deposition sites. The design of the motor car should, therefore, reflect the environment in which it works.

The function of the designer is to produce a rigid structure which in the event of an accident collapses progressively during impact, continuously absorbing energy. Indeed some designs are produced with artificially induced "crumple zones" which "tell" the "new structure" where, and how to collapse. An important question is at what age does the motor vehicle lose the ability to progressively collapse and at the same time absorb energy during accidents?

The number of people killed/seriously injured/injured in a particular make and model of car in the U.S. is a closely guarded secret, available only to manufacturers and particular government officials.
Figure 2. Origin of water spray. (Diagram by courtesy of AB Svensk Bilprovning. 1975-10-60 and 1979 11-14.)
Electrodeposited zinc coatings are suited for a great many automotive components. The electrodeposited zinc acts as a sacrificial anode and protects the more noble steel. The protection available is further extended by the use of a chromate conversion coating on the zinc.

Nevertheless, it has transpired that when faced with the sort of environment presented by modern monitoring conditions, these zinc coatings failed. Failure normally manifesting itself in the form of excessive zinc corrosion products. At best this gives an unsightly appearance and at worst causes malfunction of critical components.

The reason for this poor performance has been investigated and various causes suggested.

However, the literature is by no means unanimous regarding the assessment of corrosion resistance of zinc deposits obtained from the various types of widely used processes. The investigations carried out by Paatsch and Blum (23) on non-chromate passivated zinc deposits having a thickness of 5 microns, based on humidity chamber tests (SWF50017), indicated that the corrosion resistance of the deposits improved in the following order: mild acid, alkaline cyanide free and finally cyanides process. The zinc deposits obtained from mild acid electrolytes performed particularly poorly. Similar results have been obtained during tests in an artificial industrial atmosphere by the addition of sulphur dioxide in accordance with the DIN50018 specification.

According to the same literature source, yellow chromate passivated test panels with a zinc deposit of 20 microns showed a similar tendency in the salt spray test in accordance with the DIN50021 specification. After 240 hours of exposure only the panels plated in a cyanide electrolyte remained fully satisfactory. Samples plated in a low cyanide process failed after 192 hours, those in an alkaline cyanide free bath after 96 hours, and those in a mild acid solution showed the first signs of corrosion after 48 hours.

During similar investigations by Darken (24) in salt spray tests with various chromate conversion films particularly good corrosion resistance


results have been obtained on deposits produced in alkaline cyanide free electrolytes.

Results obtained in another investigation on barrel zinc plated small components, test pieces without after treatment and yellow chromated, tested in salt spray tests in accordance with DIN50021 specification, showed no substantial difference between the deposits from cyanide and mild acid processes.

These contradicting results are almost certainly caused by the variety of the available zinc plating processes and the type of brightener system employed to produce brightness.

3.3 Industrial Constraints Influencing Corrosion Prevention

Before specifying the utilization of a given protection for a vehicle, in addition to the performance criteria, there does exist a certain number of constraints which must be dealt with. The industrial realities cannot be ignored. They can be very different from one manufacturer to the next. Nevertheless, without being exhaustive, the following analysis gives a view of the handicaps and the constraints encountered by the majority of large-production automobile manufacturers.

(a) Investments and surface problems -

If protection by body shell dipping is operational in all the body-assembly plants, the procedure by cataphoresis is not yet totally implanted. One must consider, to this effect, several parameters of which the first and not the least is the importance of the production investments.

It is good, likewise, to take into account the assembly line stoppage necessitated by the change-over from an anaphoresic dipping to a cataphoresic dipping. Such change-overs can generally only be handled upon the start of a new vehicle. Transfers of manufacturing from one plant to another can be considered as well, but only in the case of decline of activity, resulting for example, from the stoppage of the manufacture of another model. In all other cases, line-stoppages necessitate a parts stock buildup in order to be able to feed the assembly line down-stream and avoid reducing the volume of vehicle production. Even though it is constraining, this method is workable and is utilized for some components, but for the entire white bodies, the very large stocking areas required condemn the method.
(b) Compatibility of anti-corrosion solutions and industrial methods

The most flagrant example concerns the incompatibility of the metallic zinc pre-coated sheet metal with the paint system using anaphoresis. In the case of an iron phosphatization followed by electrophoresis of the anaphoresic type, corrosion develops in the area mating with the pre-coated sheet metal. The solution requires the modification of the painting facilities or the utilization of products not having these disadvantages. The problem is complicated when one takes into account the fact that for a vehicle of the same type, the sheet metal assembly, or at least the paintwork, can take place in several different plants, thus facilitating the utilization of different means, from stampings coming from a single plant. For reasons of stock management, standardization and the risk of error, it is inconceivable to have for one same part different specifications dependent upon the plant where the assembly will take place. On one given type of vehicle, they will not use the electro-zinc treated or galvanized sheet metal, for example, and this for as long as all the factories producing this vehicle will not have their paint facilities converted to zinc-phosphatization and cataphoresic dipping.

(c) Constraints when using pre-coated sheet metal

At present, they are using almost exclusively the zincrometal-type pre-coated sheet metal on the white body shell, this product being the only one compatible with the various paint systems utilized by the manufacturers. The one-face coatings are the only ones to be used. It must, however, be realized that there are utilization differences between this type of sheet metal and the bare sheet metal which complicates its use, even precluding it in certain cases. The following remarks are valid whatever the type of pre-coated sheet metal: coated with welding primer or metallic zinc.

-Metal stripping: The optimal placing of the part on the sheet metal strip cannot always be achieved because of the dissymmetry existing between the two sides of the sheet metal. Thus, the head-to-tail imbrications of right and left symmetrical components cannot be achieved. It will be necessary to separately treat first the left parts and then the right when introducing the sheet metal strip in the stamping machine, with the coating above or under in order to ensure protection of the right side. The risk of error then being non-negligible, it is necessary to have different
winding directions of the various coil widths for limiting the risks of utilization of the wrong side of the pre-coated side. The same goes for the head-to-tail imbrications of identical components. All imbrications of this type are then disregarded, therefore the necessity to use more material for each part and consequently, to increase the trimmings.

-Stamping: Some precautions are to be taken, as well, in the course of these operations so as not to harm the coating and impair corrosion resistance. Maintenance of the tools is also to be more attentively adhered to so that the number of corrections of parts barbs due to the accumulation of coating wastes on the tools may be reduced.

-Welding: The pre-protective electrode contact must be avoided as much as possible due to electrode fouling making repairs more and more frequent and incompatible with large-production conditions. This problem is accentuated by the utilization of robot welding which can effect tens of points on the same piece.

-Trimmings recovery: The presence of zinc and/or bonding epoxy is not acceptable by the melters to whom they sell their sheet metal trimmings. It is necessary to sort out the trimmings on the ground or underground when the infrastructure of the plant permits it. In order to ship them towards the various consignees according to whether they were pre-coated or not.

(d) Operation reliability -

Reliability is the essential advance of pre-coated sheet metal: protection is constant and is present on all parts. In the case of powder zinc base paint protection, in order to ensure good regularity of application, they have done away with manual brush application solely for gun spray painting in the paint cabin with a permanent mixing of the products in order to avoid sedimentation. Sectors of specialized application for the pulverization of zinc paint have been set up in certain plants with no longer manual but mechanized application in certain cases.

Owing to these heavy investment precautions, the reliability of zinc paint application has grown, but it is good to take other precautions during handling and stocking the parts due to the relatively low adherence of zinc paint to unprepared sheet metal. This lack of adherence for one point prohibits pulverization in the areas other than mating surfaces and
having in the end the ability to be protected by the electrophoresic primers. Good mastery of the surfaces to be protected and the surrounding elements only renders automated application more necessary.

- The choice of impervious boxes rather than ventilated ones has been previously indicated. For questions of reliability, it is necessary to clarify this position: in industrial production, it is utopian to pretend to obtain absolute imperviousness of all of the hollow bodies. These operations put too many variables into play: dispersion on sheet metal ridges, mastic impervious operations. The Research and Development Department always specifies the solution assuring the best imperviousness possible but holding in account the risks of poor execution has specified parts in the lower section of the boxes assuring the drainage of corrosive agents which, despite all precautions, were able to penetrate them.

- This is equally due to the lack of reliability of the wax injections into the hollow bodies, this work being generally blindly realized in the finished body shell, which they consider as complementary to other anti-corrosion treatments. Thus, the protection by wax agents is never alone but can come to strengthen an already otherwise assured protection, whether it be by mastics, pre-coated sheet metal, etc.

The wax ensuring only a temporary protection, renewal of the injections must be performed approximately every two years: in the case of corrosion protection relying only on wax, the motor vehicle owners neglecting these constraining retreatments would only be properly protected for a short period of time.

(e) Compatibility of protective operations and re-touching -

It is inevitable that some elements or vehicle body shells, in the course of the process of manufacture, may have to undergo re-touching. The eventuality of such operations must be considered upon choosing protective products.

The PVC base mastics cannot be used in the areas in which re-touching using flame heat, may be done. Sheet metal re-touching found essentially in the middle of the panel and in the sheet metal assembly line, it is necessary to limit the PVC base mastic application upstream of the paint application line.

The PVC base mastics, especially used in paint application lines in areas submitted to mechanical aggressions, are nevertheless used to a great
degree and this, in all facilities and on all models. It is indispensable to ensure the initial quality of the delivered products; the specifications of these mastics, in addition, take into consideration the hazards of manufacturing other than flame re-touching: the essential criterion concerns the thermic stability of these products at the time of prolonged passage through the baking ovens, resulting from, for example, an accidental stoppage in the production line.

(f) Work conditions, health and safety -

These parameters cannot be neglected. Upon choice of the solutions, the equipment necessary for the realization of these operations is markably complicated. Thus, upon spot welding the sheet metal pre-coated with welding primer, it is necessary to ventilate the fumes released; the implantation of a zinc paint pulverization station necessitates installation of a paint cabin; the epoxy mastics, due to risks of dermatosis, are segregated for automatic application. It would be fastidious to pursue this enumeration, but as a general rule, one can underline the necessity of having the agreement of relevant departments before commencing a new operation involving paint, mastics, ... etc.

(g) Cost of the various solutions -

It is evident that it is impossible to systematically use the best performing solution; economic considerations play the essential role. For a set anti-corrosion budget, a priority list of the areas to be protected should be made and a study of the cost benefit of the various envisaged solutions. This overall balance sheet must likewise consider the previously cited industrial constraints. It is then natural to find on two different types of vehicles different solutions applied to resolve quite identical problems. Thus, on one type of vehicle, the utilization of pre-coated sheet metal is privileged in relation to that of zinc powder base paint, less costly in application but more so in investment since paint sheds, robots, square meters, etc. are needed.

3.4 The Economics of Improved Durability Attributed to Aftermarket Rustproofing

It can be shown that the annual capital cost for any piece of capital equipment is
\[
\frac{C \cdot r(1 + r)^n}{(1 + r)^n - 1}
\]

where C is the capital cost, r is the discount, and n is the life in years.

It has been estimated that an increase in price of $160 for aftermarket rustproofing will increase life by 3 years to say 14 years. Then for initial costs of say $6,800 and $6,960 using a discount of 12 percent we can see that the annual capital charge for the $6,800 car over 11 years is $1,144 and that for the more expensive car over 14 years is 8 percent lower at $1,052. The extra cost would have to rise to $780 before the annual cost became the same in both cases. Thus, purely from the capital cost per annum it seems that aftermarket rustproofing is well worthwhile.

4.0 A STUDY OF THE APPLICATION OF RUSTPROOFING COMPOUNDS

4.1 Application of Corrosion Preventive Compounds

Corrosion preventive compounds must be applied to exposed underbody surfaces and to normally inaccessible areas, such as closed box sections and welded seams. Unlike most factory applied protective coatings, most corrosion preventive compounds are not sensitive to modest amounts of dirt and contaminants on a metal surface. This is a great advantage in vehicle rustproofing because many vulnerable surfaces are difficult to clean because they are virtually impossible to reach.

Corrosion preventive compounds must have certain rheological and physical properties to satisfy application requirements.

In a study made by the Nissan Motor Co. Ltd (25), it was observed that much of the corrosion that occurred was due to improper application of primer, paint and undercoating which were intended to provide protection. This reference stressed the importance of the application techniques used preserving a vehicle. It was apparent that the application and the coating material are interdependent and must be considered simultaneously.

This implies that the coatings in use are either not applied correctly, or not applied to areas which need to be protected. It also

implies that the technique of application requires reconsideration of the properties of the compound as related to ease of application with suitable equipment.

Underbody coatings which have been used for many years as defined in Specification TT-C-520a (26) are heavy mastic type materials consisting of a mixture of asphalts, asbestos fibers and filler.

The spray guns in use which are suitable for the application of this type of material will only cover large exposed areas. Neither the process nor the product are applicable to inner cavities of vehicles as discussed by Sandler (27). Parts of the vehicle that rapidly corrode from the inside are door pillars, door panels, floor pans, body panels of trucks, etc., where the accumulation of dirt, salt and water form a chemically active "poultice" in direct contact with the body steel.

Some of the deficiencies attributed to underbody coating may be due to poor application of the material or careless preparation of the vehicle prior to applying the coating. The Air Force has a publication (TO 36-1-52) describing the processing of vehicles for storage and shipment which states that special care must be exercised in applying CPCs to insure secure bonding to the surface as loose areas will become moisture retaining trouble spots (28).

The method of applying current CPCs is of paramount importance. The development of application equipment and techniques went hand-in-hand with their adoption. These CPCs must reach normally inaccessible areas to prevent corrosion. More than a decade ago, as pump pressure ratios increased to beyond 8:1, spray equipment manufacturers had developed airless atomization spray techniques. Airless atomization spraying and equipment offered two major advantages for automotive rustproofing: (1) the atomized CPC is not "blown-out" of right angle channels or corners; (2)


the relatively tiny spray heads—orifice tips only—on the end of a hollow wand can be inserted into holes 1/2 to 3/4 inch diameter.

High pressure spraying, however, demands a CPC with more thixotropic or anti-sag body and flow properties. A number of laboratory tests—including spraying over a wide temperature range—were developed to determine the application properties of a CPC intended for vehicle rustproofing.

Several manufacturers have available pumping equipment and special adapters and nozzles which are used to spray rustproofing materials on underbody surfaces and into enclosed areas through small pre-drilled openings. The latter are closed with plastic plugs after the application. Highly trained applicators are not always available, therefore the material must be easy to apply properly.

Application can best be described as where to put the product (corrosion protection material) and how to put it on.

The report by the state of Maine Attorney General's office, "Rust Never Sleeps" (29) addresses the first question effectively. It gives in detail, based on their own studies, where the product should be applied. Briefly, their application requirements dictate that the rustprotection material should be applied to all outer metal surfaces from the glass line down.

As a result of research and field analysis the exterior of hem flanges, particularly on the hood and deck lip seams and the lower door seams have also been included by Ziebart.

A look at the specification chart from "Rust Never Sleeps," clearly shows the most critical areas from a cosmetic point of view and some of the box sections on the underside from a structural point of view, a useful tool for the consumer.

In a recent study the Lubrizol Corporation addressed the issue of how to put the material on and concluded that a holes drilled application procedure is the only way to insure uniform product coverage and corrosion protection.

This is based on corrosion testing on panels that were coated under actual rustprotection application conditions.

The results clearly demonstrate that a no holes application procedure does not give uniform application and does not provide adequate corrosion protection. Even at many times recommended usage, no better corrosion protection was obtained. However, the conventional holes drilled application resulted in uniform product application.

4.2 Application of Rustproofing Compounds by Local Contractor and Cost-Effectiveness

A local contractor "The Reach-All Sales of Atlanta, Georgia" was given the contract to rustproof two special purpose vehicles (10 ton cranes). We observed the application of rustproofing compounds three times. Twice in the presence of an Air Force inspector. The application was done in accordance with MIL-STD-1223U and Technical Manual T.O. 36-1-52. From our observations the Reach-All Company performed the required tasks very well.

Labor and Material Cost Data:

Labor—Two (2) men two (2) days @ $7.50 per hour = $240.00 total
Material: MIL-C-0083933A(MR) — Grade 1 — 16 gals — $180.80
U. S. Rust Control XP-400—Grade 2 — 5 gals. — 61.25
U. S. Rust Control XP-700A and XP-700B —Grade 3 —
2 gals. — 27.90
U. S. Rust Control XP300 — Grade 4 — 12 Aerosal cans — 38.06
Total/Vehicle $548.01

This seemed to be a very labor intensive project, as it took two men two days to completely rustproof a single vehicle. However, this was an unusual special purpose vehicle (Figure 3).

4.3 Application of Rustproofing Compounds by Air Force Bases and Cost-Effectiveness

We visited MACDILL AFB, Tampa, Florida to observe their rustproofing operation. Unfortunately their spray equipment was inoperable and they were not able to rustproof that day. We did observe their rustproofing operation, which was quite small for the size and environmental location of the Base. Shortly after my visit, the Base Vehicle Maintenance Officer
Figure 3. Special Purpose Vehicles (10 Ton Cranes).
supplied me with the cost data on having five (5) 1/4 ton pickup trucks
rustproofed by a local contractor (Ziebart) at a cost of $200.00 each, and
ten (10) M1008 utility trucks were also rustproofed by the same contractor
for the same cost. A copy of the contract and the warranty given are in
the APPENDIX (Attachment 4).

We also observed the rustproofing operation at the Patrick AFB,
Melbourne, Florida. This base is located on a peninsula off the east coast
of Florida. With the base surrounded by salt-water on three sides and the
wind coming primarily from the southeast, this is a very corrosive
environment for vehicles. This requires the Patrick AFB to perform
extensive rustproofing to protect their vehicles. They have a very
creditable installation and appeared to be quite proficient in their
rustproofing operation.

Their cost of rustproofing (in accordance with MIL-STD-1223U and T . O.
36-1-52) an average vehicle, using in-house labor and materials is:

<table>
<thead>
<tr>
<th>Material</th>
<th>Labor (E-4 hourly wage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 gal. @ $20.00/gal. = $80.00</td>
<td>8 hrs. @ $9.58/hr. = $76.64</td>
</tr>
</tbody>
</table>

Inspection Costs

1/3 hr. @ $11.92/hr = $3.97

Total - $80.00 + $76.64 = $3.97 = $160.61

5.0 AN ANALYSIS OF THE MOST COST-EFFECTIVE METHOD OF PROVIDING
OPTIMUM CORROSION PROTECTION FOR AIR FORCE VEHICLES

5.1 Cost of Vehicle Corrosion

Probably nowhere does corrosion strike home with the greater cost to
the Air Force than with the automobile. It affects most consumers by the
higher prices for the corrosion-resistant materials being built into
today's car (30). The rate and cost of depreciation is related to the
degree of corrosion that the vehicle has at replacement time. A vehicle
that is five years old and is corrosion free versus the identical car that
has a high degree of perforation rust may be worth hundreds of dollars
more.

(30) "Metal Corrosion Eats Away at Everyone's Budget," Iron Age,
All the snow belt states have corrosion problems, but probably none of them are any worse than the state of Maine. In Maine, where long winters are typical, vehicles are exposed to corrosive conditions created by salt used to melt icy roads, as well as salt from the Atlantic Ocean and calcium chloride used to keep down road dust in the summer.

Maine's Department of Transportation (MDOT) had an expensive problem in maintaining their fleet of 1,000 vehicles, since corrosive elements were rusting out their vehicles after only two years. This caused a high rate of vehicle turnover, which put an additional strain on their already tight budget (31). Their cost effective solution was to initiate complete rustproofing as soon as possible after the vehicle was purchased. Although rustproofing added an additional initial cost, it has proven so far to have provided additional service life to the vehicles, lowering overall cost of maintenance due to corrosion.

In 1968, vehicle corrosion cost consumers an estimated $5 billion. That estimate climbed to $7.5 billion in 1975. Considering the rapidly rising costs of vehicles today, the cost was estimated to be $10 billion in 1981. These figures do not include the cost of accidents, injuries and deaths caused by rust-damaged brake lines, steering mechanisms and overall breakdown of structural integrity since a determinism of this type is difficult, if not impossible, to obtain (32).

There is wide desparity in the actual estimated costs of automotive corrosion. The National Bureau of Standards (NBS) and Battelle Columbus Laboratories (BCL) estimates that the total cost of automotive corrosion in 1975 in the United States was approximately $16 billion, with an uncertainty of $±6.5 billion (33).

Regardless of the actual amount of cost involved in vehicle corrosion, there is a consensus that the costs are enormous and additional steps need to be taken to reduce or prevent corrosion.


Fleets, where replacement equipment costs runs in the millions of dollars, are being careful to specify a variety of methods to slow or prevent corrosion. A recent survey indicated that an average of 71 percent specify undercoating or rustproofing, 42 percent fiberglass cab sections, 36 percent rust preventing paint, 21 percent aluminum siding, 20 percent aluminum cab sections, and 8 percent FRP siding. (These percentages add up to more than 100 percent due to multiple responses.)

The survey goes on to state that an average of 58 percent of the power units are undercoated, and 39 percent of all trucks are similarly protected. Fifty-two percent of the fleets stated that they rustproof or have rustproofed vehicle sheet-metal cavities (34).

The nation's fleet are interested, perhaps more than ever, in preserving their investment in their valuable money making equipment, i.e., their trucks, buses, and trailers.

In order to improve the quality image of their vehicles, America's big three auto makers are telling steel suppliers that they want to offer a 5-10 year rust warranty on their cars by 1985. The steel manufacturers are under pressure to provide a large quantity of galvanized steel which is not available from some U. S. steel makers.

Steel suppliers are saying that the pressure to meet the corrosion free goals has increased over the past year because of the depressed steel industry. Chrysler now offers a 5-year warranty against rust perforation, as does American Motors.

There is regrettaably an element of truth in the popular belief that Monday morning and Friday afternoon cars can be of inferior quality. One only has to substitute an industrial dispute or any other cause of shutdown for the lost weekend period. After all, it takes time for a plant to cool down and for bringing it up to effective working environment and temperature again. One of the major advantages of some popular Japanese cars is that, though they rarely are of sophisticated design, or have outstandingly good quality paint, they just keep rolling them out of their ultra-modern factories at a steady rate.

In spite of all the advances that have been done at the O.E.M. level, many fleet owners and consumers in corrosion prone areas feel the need to have additional rust preventive treatments performed on their own vehicles. The reasons for doing so is that a specialized or franchised rustproofing product will offer an extended (5 or 6 years) guarantee. However, now the most common guarantee is a "lifetime" guarantee good for as long as the consumer owns the vehicle. As long as the consumer follows the instructions set forth in the warranty, he has reasonable assurance from the rustproofing manufacturers that his vehicle is protected against performance corrosion.

There have been cases where rustproofing warranties were of poor quality or set forth such stringent requirements that it was difficult, if not impossible, for the customer to receive satisfaction on a rustproofing claim, but these problems appear to be in the minority. However, it is very important for the fleet owner or individual consumer to carefully review their warranty to the type of product used prior to having the work done to insure that they received the best value possible.

Aftermarket rustproofing, which is the application of petroleum base specially blended compounds to the internal sections of the vehicle as well as the underbody, continues to be widely used throughout North America. A recent survey, by the author, of automobile dealers in Central Kentucky indicated that over 90 percent "rustproof" the cars and trucks prior to delivery to the customer. It is believed that this percentage is typical of snow-belt areas. Rustproofing also is performed by many independent rustproofing companies that have their own outlets or franchises.

5.2 Economic Evaluation of Corrosion Control

Corrosion control is simply an economic measure; it pays off in dollars and cents. Of course, it also conserves natural resources, contributes to public safety, and prevents unnecessary wastage.

Money invested in corrosion control earns a profit. If the profit on a corrosion control program is greater than that earned by investing the money elsewhere, the expenditure is justified.

Unfortunately, the corrosion engineer and management often do not speak the same language. The engineer is so close to the problem that he
cannot look at it objectively. Management is interested in technical considerations only insofar as they affect the major issues: how much will a project save, how much will it cost, when does the money have to be spent, and will it be expense or capital?

When you assess the values of a contemplated corrosion control program, you must have some means of comparing quantitatively the relative merits and costs of various approaches. When you begin to reduce engineering into dollars and cents, important considerations emerge which might be overlooked or may make the difference in the feasibility of a program. Of vital concern are the interest rate, the tax rate, and the depreciation schedule.

Because our commercial world is dominated by the inexorable fact of interest payments, the timing of any contemplated expenditure (or return) is vital. There are two ways to pay for anticipated costs in the future: (1) you can earmark enough money now to pay for the anticipated expenditure later; or (2) you can borrow the money now to fund the scheme later and pay the bank an equal annual installment which will pay back both interest and capital over the life of the project.

At 10 percent interest, a payment of $1,000 ten years later costs either $385 now or $62.70 per year (Figure 4). Easily used tables of factors are available which convert any sum of money at one point in time to the equivalent sum at another point in time (Tables 1, 2, and 3).

There are special systems for evaluating projects economically. These include the concept of "Payout," "Return on Gross Investment," "Return on Average Investment," "Profitability Index," and the "MAPI Method." These tend to be either invalid, misleading, or unduly laborious. The "Discounted Cash Flow" system, or DCF, is the one discipline which has the widest acceptance.

One of the simplest and most flexible of these systems, a form of DCF, is based on the conversion of all payments associated with a project to the "Equivalent Annual Cost." This makes it possible to compare alternatives of differing lives because the annual payments fund this program in perpetuity and provide capital for infinite replacement. This
Figure 4. At 10 Percent Interest, a Payment of $1000 10 Years Later Costs Either $385 now or $62.50 Year.
### TABLE 1 — Present Value Factors at 12% Interest

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<thead>
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<th>Year</th>
<th>PV</th>
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<tbody>
<tr>
<td>1</td>
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<tr>
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</tr>
<tr>
<td>20</td>
<td>0.1037</td>
</tr>
<tr>
<td>50</td>
<td>0.0035</td>
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\[ PV = \frac{1}{(1 + i)^n} \]

### TABLE 2 — Annual Cost Factors at 12% Interest

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<th>Year</th>
<th>AC</th>
</tr>
</thead>
<tbody>
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<td>3</td>
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<tr>
<td>4</td>
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<td>50</td>
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</table>

\[ AC = PV \frac{(1 + i)^n}{(1 + i)^n - 1} \]

### TABLE 3 — Sinking Fund Factors at 12% Interest

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<thead>
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</tr>
</thead>
<tbody>
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<td>0.0199</td>
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<tr>
<td>50</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

\[ AC = F \frac{1}{(1 + i)^n - 1} \]
does not mean, however, that you expect to continue the program forever. You can stop at the end of any cycle and the comparison is still valid (Figure 5) (35).

5.3 Determination of the Most Cost-Effective Method to Provide Optimum Corrosion Protection for Air Force Vehicles

The cost to the Air Force for O.E.M. rustproofing will be determined by the vehicle type, number of vehicles purchased, and the specific manufacturer. It is costing the Air Force approximately $160.00 per light truck/sedan to rustproof in-house. The cost to commercially rustproof a light truck/sedan ranges from $100.00 to $300.00. This variation is due to what company is doing the rustproofing and the amount of corrosion protection required. This is beneficial to the Air Force as it allows the individual vehicle maintenance officer the latitude to purchase only as much protection as required. Inspection costs could range from $4.00 if done in-house by inspectors at the time of rustproofing to $48.00 if by inspectors on vehicles rustproofed by O.E.M. or their subcontractors. An inspection may necessitate some disassembly on some of the above rustproofed vehicles. However, this inspection cost can be justified if the AFB is located in an extremely corrosive environment.

The Allied Trades/Body Repair Technical School at Aberdeen Proving Ground, Md. is now training AFB personnel in rustproofing procedures. It consists of a video tape technical order review, 20-question appraisal test, and one hour of hands-on laboratory training. This should lower inspection and rustproof training costs, which is approximately $720.00 at Patrick AFB. Again these costs would be justified at AFBs in very corrosive environments (36).

The Air Force Logistics Management Center, Gunter AFS, AL was commissioned by HQ USAF/LETN to do an in-depth study of Air Force vehicle rustproofing (37). For our analysis of the most cost-effective method


(37) Air Force Logistics Management Center, Loc. Cit.
Figure 5. The Discount Cash Flow System, based on the conversion of all payments associated with a project to the "Equivalent Annual Cost", makes it possible to compare alternatives of differing lives.
to provide optimum corrosion protection to AF vehicles, we shall give our
response to some of the questions posed in the above report.

What type vehicles should be rustproofed?

This investigation applies to all newly purchased cars, light trucks,
vans, M-series trucks, medium and heavy trucks, and truck tractors. We
feel that the current measures as outlined in Section 2.3 by vehicle
manufacturers provide sufficient corrosion protection at most CONUS Air
Force Bases. Therefore, we do not recommend the vehicle manufacturer
rustproof any of the above vehicles.

The Air Force Base Vehicle Maintenance Officer should make the
decision to rustproof or not depending upon the Base environment, vehicle
type, and its intended use/storage.

Should all vehicles of a particular type be rustproofed?

Again, we feel the Air Force Base Vehicle Maintenance Officer should
make the decision on which vehicle and type of vehicle should be
rustproofed depending on his locale, and the way the vehicle is to be used
and stored.

Should all vehicles going overseas be rustproofed?

Yes, in recent years manufacturers of motor vehicles have been
attempting to pay more attention to corrosion problems. They use different
metals and plastics in a lot of areas that are prone to rust-thru.

On some vehicles they use galvanize or galvaneal panels. When they
are spot welded in place the surface coating is broken by the weld. The
weld is usually a harder metal than the panel being welded in place. This
is where corrosion often starts. Moisture is the catalyst on different
metals. Vehicles have spot welded door panels, hood edges, trunk lid
edges, roof gutter line edges, etc. These are often painted on outside
edges but have nothing for protection on the folded over inside spot welded
seams. Many vehicles have a hot caulking on the inside of the doors at the
lower seams. Some have this same caulking on the inner door frame where
the outer door panel is spot welded to it. This caulking sometimes traps
moisture and causes rust. Also on some vehicles we find the caulking dries
and shrinks in about 1-1/2 years, thus allowing water to get behind the
caulking and causing the outer door or trunk panel to rust. The same type
of caulking is used between the outer hood panel and the inner supports.
This will come loose and start rusting. On outer hood edges rust will form very quickly at the edge of the spot welded panel. This rust is working 24 hours a day. It is subjected to weather elements continually.

Many new cars have rusted spring hangars, shock absorber mounts, various fasteners underneath the body, emergency brake cables, etc. that are rusted when they come off the assembly line. The chassis should be completely coated including all the brackets and hangars. The unitized chassis has holes which fill up with road dirt and often stay wet. Some vehicles have rusted completely thru in these areas which has then allowed the chassis to sag or collapse. In some states you will find repair shops advertising to repair or rebuild chassis rust-out.

If, in a two year old car, the trunk lid needs rust repair, one could encounter a repair bill of $125 to $200 or more. Same with hood repairs. Door repairs could cost from $75 to $200. We're talking repairs, not replacement. If the repairs are not made properly and also rustproofed on the inner sides, usually the rust condition starts again in about a year or less.

A vehicle in a five year span could easily encounter rust repairs of $100 to $150 average per year.

General Motors Corp. has junked 600 new Chevrolet pickups, worth $5 million dollars retail, made in Japan, exported to Tampa, Fla. and developed underbody rust while parked at the Port of Tampa (APPENDIX - Attachment 5). Also see Section 3.2 - The aftermarket rustproofers views on the necessity for aftermarket rustproofing.

Current Military Traffic Management Command (MTMC) policy requires that all military vehicles be loaded below decks and that deck loading will take place only with approval of the affected service. However, there have been instances where AF vehicles have been top deck loaded (see APPENDIX - Attachment 6)(38). Therefore, we feel that for all vehicles being shipped across salt-laden water, the rustproofing would be cost-effective.

Should all vehicles assigned stateside be rustproofed?

This determination again is best made by the Base Vehicle Maintenance Officer. The Air Force has many bases within CONUS that have low corrosive environments. The Materials Laboratory at Wright-Patterson AFB conducted a

(38) Air Force Logistics Management Center, Loc. cit.
study "Pacer Lime: An Environmental Corrosion Severity Classification System," that compared the corrosion intensity of environments at 158 Air Force and Air National Guard Bases from Shemya AFB, AK, to Howard AFB, Canal Zone (APPENDIX - Attachment 7). They found that of the 158 locations surveyed only 16 percent could be classified as severe corrosion environments.

The map at Attachment 7 shows the bases which are located in the "sun belt." This portion of the CONUS has snow less than five days a year and experiences 90° temperatures at least 60 days per year. Many sections will see an average of 90-120 days of 90° weather each year. Within this sun belt are 32 bases and 21,783 vehicles even after excluding those bases located near the sea coast and all bases in Florida. If a total fleet rustproofing program is adopted, the cost (at 1.5 percent of purchase cost) to rustproof these vehicles at replacement time could reach $7.8 million in current dollars.

The argument that Air Force vehicles are moved around frequently cannot be substantiated. Discussions with major commands with mobility missions (MAC, SAC, TAC, and ANG) found that 90-95 percent of their vehicles remain throughout their life at their original location. For those that are redistributed, it is likely that very few would be sent to a corrosion intensive environment.

Other legitimate issues are:

1. Why should we rustproof vehicles which will be operated and stored inside warehouses, hangars, and bunkers? Warehouse tugs and numerous material handling vehicles are protected from the elements the vast majority of the time. The Air Logistics Centers (ALCs) are the prime examples, but virtually every base has some indoor vehicles.

2. Why should we rustproof vehicles operated primarily on salt-free flightlines? Much of the vehicular equipment assigned to intermediate maintenance, aerial ports, and other flying support activities spend virtually their whole life on parking ramps and taxiways that must, by necessity, be kept free of corrosive materials (39).

Therefore, if the Base Vehicle Maintenance Officer (BVMO) decision is that only a small portion of his vehicles require rustproofing, it would be more cost-effective to contract out the rustproofing rather than do it in-house. Thereby saving the cost of purchasing equipment and training programs for rustproofing and inspecting.

What is the time and cost impact of having rustproofing done by various operations?

If manufacturers are required to rustproof in accordance with MIL-STD-1223V to sell rustproofed vehicles to the Air Force, they have to subcontract the work out to rustproofing firms as they are not equipped to perform this on their assembly lines. This delays delivery of the vehicles from two weeks to thirty days. This cost is passed on to the Air Force and the vehicles are often shipped to AFBs where no or only extremely limited rustproofing would be required.

As far as rustproofing vehicles to be shipped overseas, we feel the most cost-effective method would be to have the Air Force set up its own overseas centralized rustproofing operation. This would eliminate the problems the CORTREAT centers are experiencing such as scheduling Air Force vehicles that are being shipped overseas. We have previously discussed the in-house cost for rustproofing based on Patrick AFB rustproofing operation.

What is the cost of rustproofing?

This question is difficult to answer because of the many different methods used by the Air Force for rustproofing.

The cost of manufacturer's rustproofing will vary by vehicle type, number of vehicles purchased, and the particular manufacturer; however, the Air Force is currently paying an average of $160 per light truck/sedan under MIL STD-1223T. This price does not consider the most comprehensive treatment of 1223U nor the management costs. Estimates by Air Force and industry representatives place the cost of a total fleet MIL STD-1223U rustproofing program as high as 1.5 percent of the purchase price. For the period FY83-87, the Air Force intends to buy $2.5 billion worth of vehicles; thus, a total fleet treatment program for that period could cost as much as $37 million.

The cost to rustproof vehicles through the Navy CORTREAT program can be better substantiated. Discussion with Warner Robins Air Logistics
Center indicate that during 1981 the Air Force processed 800 vehicles through CORTREAT centers with an average cost of $400 per vehicle. This cost includes some minor maintenance actions; however, these are secondary to the requirement for rustproofing and constitute a small percentage of the total cost of $320,000. At Port Hueneme and Norfolk the vehicles were moved directly from the CORTREAT center to the port with little or no transportation expense. At Gulf Port, however, the vehicles had to be transported to New Orleans for shipment. Approximately 600 vehicles were processed through the Gulf Port CORTREAT center last year. With transportation cost averaging $225 per vehicle the total transportation bill amounted to approximately $135,000. Thus the total 1981 CORTREAT for 800 vehicles was $455,000. These funds were taken from the Depot Purchased Equipment Maintenance (DPEM) fund. Assuming that only special purpose vehicles were processed through CORTREAT (administrative vehicles should have been treated under MIL STD-1223U), and assuming the vehicles were in quantities proportional to their fleet inventory percentages, the cost to rustproof these special purpose vehicles equated to 11.5 percent (40).

These figures further substantiate the need for the Air Force to build its own CORTREAT operation.

The cost of rustproofing using in-house Air Force labor and materials was calculated and given in Section 4.3 using Patrick AFB figures as approximately $160.00/per average vehicle.

Another additional reason for allowing the BVMO to make the decision on rustproofing is if the manufacturer or his subcontractor does the rustproofing, the Air Force will occur additional costs to inspect the quality of the product. This may require substantial disassembly and could average four hours labor. At $11.92/hr. the acceptance Limited Technical Inspection for the average new Air Force Vehicle rustproofed by the O.E.M. could cost $47.68. This cost could be avoided at many Air Force Bases.

Personnel performing the initial quality control check would need to be trained, not only to check the manufacturer's work, but to touch up minor flaws in the treatment. Patrick AFB, with their extensive rustproofing experience, found that approximately two weeks of OJT is

(40) Air Force Logistics Management Center, Loc. cit.
required to bring a mechanic to 5-level proficiency. This equals $720.00 at E-4 wages. Once again, this training could be well used at severe corrosion locations like Kadena AFB, Okinawa; it would be extravagant training at Holloman AFB, NM.

By not having each base maintain its own rustproofing vehicle shop, the cost of the equipment and materials would also be saved. Patrick AFB estimates its current equipment replacement costs to be $1,200.00. Of course, there are some AFBs where these costs would be justifiable, however, their are AFBs where they are not.

What are the advantages to rustproofing?

The two most outstanding ones are: (1) It increases the life expectancy of the vehicle, (2) It reduces repairs and increases the safety of the vehicle. Of course these advantages only take place if the vehicle has received quality rustproofing and the vehicle is located in a corrosive environment. There are many other additional reasons given in Section 3.2.

How is rustproofing handled by other agencies?

(1) The Army conducts vehicle rustproofing treatment at three levels: commercial, semi-tropical, and full-tropical. Their program calls for no treatment of construction or combat vehicles and selective treatment of other type vehicles. They have developed a MIL-C-62218 for the rustproofing of vehicles already fielded. This could be useful to the Air Force in those few instances where untreated vehicles are redistributed to severe corrosion environments.

(2) The Navy is concentrating rustproofing treatment on its wheeled highway vehicles, but is not treating construction or MHF vehicles. Follow-on treatment is left to the discretion of the local maintenance manager.

(3) The General Services Administration (GSA) uses a selective approach to rustproofing. Administrative vehicles are treated in accordance with MIL-STD-1223T, with other CONUS vehicles receiving required treatment at destination. Construction equipment is not being treated.

(4) The Postal Service vehicle fleet consists primarily of jeeps. These vehicles receive a special rustproofing specified in their purchase contract. The extent of treatment is somewhat less comprehensive than the
standard commercial rustproofing treatment and significantly less comprehensive than MIL-STD-1223U. According to the American Motors representative who coordinates this treatment with the Postal Service, the rustproofing is applied to approximately eight critical points on the lower body. It must be remembered that these vehicles have no door panels, upholstery, etc., to restrict the application of rustproofing, thus, a low-per unit cost fleet-wide treatment.

(5) American Airlines initially approached the vehicle rustproofing question by initiating a fleet-wide rustproofing program, but later determined it to be a poor investment and discontinued it after a few years. They now follow an extremely selective rustproofing program, focusing treatment on vehicles that work in water/chemical intensive environments (examples: latrine trucks, potable water trucks, deicers, etc.). They treat the vehicles one time and have no follow-up program. They do not treat their "thin-skin" general purpose vehicles, tow tractors, baggage carts, or conveyor trucks. They note that their parking ramps, taxi ways and aprons are kept free of salt and other corrosive chemicals, thus reducing the opportunities for vehicle corrosion (41).

How to determine the most cost-effective method of obtaining optimum corrosion protection of Air Force vehicles?

Since the current costs are not available, because the Vehicle Integrated Management System (VIMS) does not keep records on expenditures for corrosion prevention, VIMS combines this effort along with other body/component repair actions. Electrical failures, replacement of fuel/fluid lines, radiator repair and other mechanical problems are often worked in the general/special repair shops and are not currently reflected in a survey of allied trades work orders. We can safely assume that corrosion control efforts vary widely from location to location.

To determine the true cost-effectiveness on rustproofing and not rustproofing we feel this can only be done by direct comparison of the same vehicle protected as it is purchased and the same vehicle rustproofed. This would have to be done at various bases under different environmental conditions.

(41) Air Force Logistics Management Center, Loc. cit.
When a vehicle is designed and built, the area where it will see service is usually unknown. A recently completed nationwide corrosion survey has revealed that different locales have both common corrosion problems and problems indigenous to their area.

NORTHEAST AREA

Located in the eastern section of the so called "snow-belt," the Northeast with its severe snowfall necessitating large quantities of deicing road salt along with salt-laden sea air poses a severe corrosion environment. According to data obtained from the Salt Institute, the use of deicing salts has risen sharply in the last decade. Its use in all areas of the country where winter spreads its rath will continue since our highly mobile society demands light and fast travel.

Unprotected or poorly protected metal surfaces kept moist for prolonged periods of time by accumulation of dirt and road splash and aggravated by chloride ions suffer severely.

Since the rusting process of an automobile body requires an electrolyte (water), addition of salts or other contaminants increase its electrical conductivity and thus accelerates corrosion. As moisture continues to wet these areas throughout the year, corrosion continues.

EASTERN INDUSTRIAL AREA

In the heart of the "snow-belt," the Eastern Industrial Area not only contributes deicing road salt to promote and accelerate corrosion of automobile bodies but due to the highly urban atmosphere, hygroscopic contaminants emitted during industrial processes and gaseous contaminants such as sulfur dioxide also add to the degradation.

Sulfur dioxides from fossil fuel power plants and industrial plants have long been recognized as potentially corrosive. Literature abounds with data on the effects of sulfur dioxide on metals. Scientists have found that these chemicals recombine in the atmosphere to form sulfuric acid. Similarly, nitrogen oxides form nitric acid in the air. Both acids ultimately fall to earth as components of acid rain. Formerly, these pollutants were thought to affect only the area immediately surrounding their source. But new research in the last ten years indicates the acids do not always fall on the areas where they originate.
Storms and wind currents carry these components many miles from their source. However, the survey revealed that automobiles used for daily commuting to places of employment which emit corrosive contaminants into the atmosphere were found to be more corroded than those used for just general transportation in the same area. There is also a noted increase in acidity of rainfall, New York's rain measured around pH 6.0 in the 1920's. In the 1950's, it averaged a pH of 4.5. Today, some storms drop rain as acidic as pH of 3.0. Thus industrial fallout has the two-pronged effect of working not only from both above and below exterior body panels but also throughout the year.

MIDWEST AND EASTERN CANADA

The Midwest and Eastern Canada are two areas very similar when comparing body corrosion rates. Weather conditions are also comparable, although parts of the eastern Canadian region experience generally lower winter temperatures necessitating the use of calcium chloride. Its use is usually limited, due to economic reasons, to areas which experience consistently low temperatures (below 20° C), the eutectic temperature of NaCl being -21.13° C (-6.0° F).

Summertime finds calcium chloride used on suburban and rural dirt roads as a dust control measure due to its hygroscopic nature. Because of this, it can accelerate corrosion on automobile bodies even when no exterior moisture source is present. Laboratory experimentation has shown that when highly concentrated solutions (50 percent +) are formed, calcium chloride becomes very acidic.

PACIFIC NORTHWEST

The Pacific Northwest has a milder climate than any other part of the United States in the same latitude. Temperature is tempered by the winds which blow over the warm waters of the ocean. The area also has a greater range in rainfall than any other region. Consequently, the relative humidity in the area remains in the "Critically 50 to 70 percent" range throughout the year. Daily rain and/or condensation on automobile bodies combined with the presence of various atmospheric pollutants would lead one to believe that the area should be one with severe corrosion problems. But corrosion is a relatively minor problem.
The few perforated body panels that were observed in this area were found generally near the coast indicating that the presence of the chloride ion, from sea air, does have an accelerating effect on body corrosion.

WEST COAST

Marine fog and sea mist that occur along the West Coast were found to be the main contributors to the auto body corrosion in this region. Also, since corrosion is no exception to the general rule that chemical reactions proceed faster at higher temperatures, the warmer climate caused the larger percentage of perforations than that seen in the Pacific Northwest. However, even with the above corrosive factors, automobile body corrosion was excessively mild when compared to the rest of the country.

SOUTHWEST

The arid Southwest resulted in absolutely no perforated body panels. Vintage automobiles (up to 20 years old) were seen in virtually showroom condition. It is for this reason that the Southwest was not included on any of the charts. Area automobiles that did have corrosion problems were found to be have been delivered and used in other areas of the country prior to their use in this region. A phenomenon observed in this area was the abrasive effect that sand and/or fine dust had on painted surfaces adjacent to or under weatherstripping. Bare sheet metal was evident, but there was no corrosion.

SOUTH AND GULF

High humidity, dew fog, and salt air most are all factors which affected automobile body corrosion in the deep South and Gulf Coast. Salt particles deposited on surfaces are moistened by fog and dew even during the dry summer season. The cycling effect of evening or early morning dew or condensation with warm daytime temperatures on the downward or interior surfaces of horizontal body panels was evident in this area. A marked increase in perforation of hood, cowl top panels, roofs, and deck lids caused by built-in humidity chambers was noted. This was in direct contrast to the "snow belt" area perforation which generally occurred in fenders, doors, and quarter panels; those areas which receive direct salt impingement during the winter months.

Through the comparison of the survey data from each area, it was determined that automobile body corrosion is caused by the presence of such
agents as road dust and dirt, salts, or gases such as sulfur dioxide and the presence of moisture in the form of rain, snow, fog, dew or high humidity.

Corrosion rates in each region, as measured by perforated body panels, were dependent upon the amount of the foreign agents present and the degree and duration of moisture. Also, corrosion rates under dynamic conditions may greatly differ under static conditions in the same environment or electrolyte (42).

In the design, development, and construction of automotive products, the effects of the environment, both natural and man-made, must be considered and evaluated. Those effects which are of concern in this report are the corrosion-related ones.

Historically, materials, treatments, and coatings have been evaluated, screened, and selected using laboratory accelerated corrosion tests such as the Neutral Salt Spray, Cass (copper-accelerated acetic acid salt spray), Humidity, Corrodkote, and Cyclic humidity tests. Each of these tests was designed to evaluate a specific property of a given material under conditions which simulate actual use. These tests are necessary and perform the function for which they were intended. Laboratory testing, no matter how involved or exotic cannot accurately reproduce all the conditions the end product automobile will be exposed to in the field by the Air Force.

It is necessary to validate the results of accelerated corrosion tests by comparing them to the performance of materials in their service environments. If the results correlate well, the accelerated test may be valid. If the results do not correlate well, the accelerated test should not be used to evaluate materials for use in that service environment. Ideally, this validation procedure would involve testing in the actual service environments. Practically, the validation must proceed by comparing accelerated test results to the performance of materials exposed to a reasonable number of representative environments.

(42) "Corrosive Environmental Factors on Automobile Bodies," Andrew M. Kalson, Jr., Metallurgical Engineering Department, Chrysler Corporation.
After monitoring the two vehicles over a period of time, an evaluation can then be made as to the cost-effectiveness of rustproofing for optimum corrosion protection in varying climatic areas.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Vehicle manufacturers have upgraded their corrosion protective methods to sufficiently protect Air Force vehicles from corroding at most Air Force Bases. The Air Force should insist upon receiving the same rustproofing warranties the commercial consumer receives. Any further vehicle rustproofing would be unnecessary at the manufacturers.

One of the most cost-effective measures the Air Force could adopt would be to allow the individual Base Vehicle Maintenance Officer (BVMO) to make the decision as to the number and type of vehicles to be rustproofed depending on the base environments, the use and storage of the vehicle.

This would initiate the following cost-saving measures:
1. This would eliminate rustproofing totally at many Air Force Bases.
2. The BVMO would no longer be required to inspect the quality of the manufacturer's rustproofing during the acceptance inspection. Thereby saving $48.00 for each new vehicle purchased.
3. The BVMO at bases where the environment is not very corrosive would not:
   (a) Have to train personnel to conduct the rustproofing or the inspections. Patrick AFB estimates it requires two weeks of on-the-job training to train a E-4 mechanic for these jobs. This is a savings of $767.00 for each mechanic not trained.
   (b) Have to purchase, maintain and store rustproofing equipment/material. This would mean a savings of approximately $1,200.00 per base in equipment purchase price alone.
   (c) Have to conduct the annual follow-up inspection in accordance with T.O. 36-1-52 for a savings of $9.58 per vehicle.
4. Only those vehicles actually requiring treatment would be treated.
5. The BVMO who elect to rustproof vehicles in their fleets, would be able to control the quality of treatment, whether done in-house or by local contract.
6. The BVMO using the local contract option could obtain and administer a reasonable warranty.

7. Vehicle manufacturers could get back to building a vehicle to commercial standards. No longer would they have to subcontract the rustproofing or maintain rustproofing technical manuals and reports for the government. Vehicle costs and delivery delays should decrease by approximately 1.5 percent and 2-4 weeks respectively.

We also recommend vehicles that are to be shipped overseas especially to corrosive environments should be rustproofed. The 1981 cost of $455,000 spent on processing Air Force vehicles through the Navy CORTREAT program could have gone toward the Air Force setting up its own CORTREAT operation for special purpose vehicles. This would eliminate the problems of timing and delivery delays. This operation would be very cost-effective in a short period of time.

However, we reiterate the only true method to determine the most cost-effective manner to give optimum corrosion protection to Air Force vehicles is Field Testing.

We suggest that the Air Force undertake a project to ascertain the economic value of rustproofing of vehicles, i.e., whether the costs of corrosion prevention by rustproofing would be offset by lower maintenance costs and/or replacement costs. Such a project, to provide trustworthy information, could not be based on any type of accelerated laboratory test, but with field performance. Field performance data would require keeping accurate records on a fleet of vehicles, operated over a period of several years, in areas typical of all road conditions and road maintenance practices. When this approach is applied to corrosion, one encounters the extreme variations in climatological factors, such as temperature, humidity, precipitation, etc. in which Air Force vehicles usually operate.

The Air Force might set up a program whereby two of the same vehicles purchased by them, one would be rustproofed and one not. A record would be kept on each car, either rustproofed or not, comprising accurate chronological and mileage data with annual and cumulative total on:

a. Initial cost of vehicle.

b. Cost and type of undercoating.
c. Cost of repairs (to underbody and fenders only) caused by collision or unusual damage.
d. Cost of repairs caused by stone and gravel impact and abrasion.
e. Cost of repairs caused by corrosion or rusting out.
f. Trade-in value and reason for disposal, such as age, mileage, worn-out engine, damage, etc.

Such a program will depend for its success on the completeness and accuracy of the records, compiled at base of operations of each vehicle, from which comparative statistics may be drawn.

The results derived from this project could then be used as guidelines to enable the BVMO to make his decision on the cost-effectiveness of rustproofing any of his vehicles, and if so, which vehicles would require rustproofing.
APPENDIX
APPENDIX

ATTACHMENTS:

1. Corrosion Protection on General Motors Vehicles.
2. General Motors Warranty.
3. Chrysler Corporation Warranty.
4. MACDILL AFB Contract and Warranty for Contracted Rustproofing.
5. General Motors Junked 600 Pickups after Developing Underbody Rust.
6. Top Deck Loading of AF Vehicles being shipped Overseas.
7. USAF Active Major Installations.
ATTACHMENT 1: Corrosion Protection on General Motors Vehicles.

C-K TRUCK SPECIAL METALS

1973

SUBURBAN

Rear Quarter Inner Panel - Zincrometal
Rear Side Door Rocker Panel - Inner and outer - Zincrometal

1975

ALL C-K

Radiator Support Lower Reinforcement - Zinc Iron Alloy

1976

ALL C-K

Side Door Outer Panel - Zincrometal

1977

ALL C-K

Windshield Opening Frame (Plenum Panel) - Zincrometal

FLEETSIDE P/U

Pickup Box Outer Panel - Zincrometal

1978

FLEETSIDE P/U

Tailgate Inner and Outer - Zincrometal

ALL C-K

Radiator to Grille Filler Panel - Galvanized
Door Opening Frame (Cab Outer Rocker Panel) - Zincrometal
C/V Window Frame and Division Post - Zinc Plate
C-K TRUCK SPECIAL METALS (CONT'D.)

1979

ALL C-K

Front Fender Outer - Zincrometal
Front Door Inner Panel - Zincrometal

SUBURBAN BLAZER

Tailgate Outer Panel - Zincrometal

SUBURBAN

Rear Door Outer Panel - Zincrometal
Rear Side Door Outer Panel - Zincrometal
Rear Side Door Inner Panel - Zincrometal

1981

ALL C-K

Hood Outer Panel - Zincrometal
Front Fender Inner Panel - Zincrometal
Cowl Vent Grille (Eliminated Louvers in Hood) - Galvanized

C-K PICKUP

Floor Pan - Galvanized
Box Floor - Galvanized
Box Wheel House - Galvanized
Box Side Panel Inner - Galvanized

1982

SUBURBAN

Rear Quarter Outer Panel - Zincrometal

1983

C-K PICKUP

Box Front Panel - Galvanized

ALL C-K

Hood Inner Panel - Zincrometal

SUBURBAN

Rear Door Outer Panel - Galvanized
PANELS MADE OF ZINC COATED STEEL
SOP 1981
- Grille Panel
- Hood Assembly
- Cowl Cap Assembly
- Windshield and Q/Window Retainers
- Step Well
- Side Sliding Door
- Door Drip Molding
- Wheel House Front and Rear
- Body Side Panels
- Gas Filler Cup
- Load Floor
- Rear End Panel
- License Plate Pocket
- Rear Doors

OTHER IMPROVEMENTS
- Fastener Coating Upgraded
- Zinc Plated Bumper
- Rubber Gaskets Under Door Handles and Lamps

Chevrolet St Van (Steel)
G TRUCK CORROSION PROTECTION

Special attention is given to corrosion protection during the construction and final finishing of the G truck basic bodies. (Hi-Cube Van/Magnavan add-on bodies are not discussed here as they are of proprietary manufacture.)

The following body design features occur during the construction of the body:

1. Use of special steels (see Pages 20 and 21 for details).
2. Use of one-piece outer panels to minimize exterior joints where corrosion might occur.
3. Use of heavy-gauge steel for main underbody components.
4. Use of weld-through sealers in the assembly process to assure strong welds.

After body construction is completed, additional corrosion preventative measures are taken in the final finishing process. The following occur:

1. The body, doors, and hood are thoroughly cleaned by processing them through a 7-stage zinc phosphate washer.
2. Next, the body, doors, and hood are primed using the Elpo process.
3. Sealers are then applied to all critical interior-exterior joints.
4. Undercoating is sprayed on the undersurfaces of the wheel housings, front door step panels, and body rocker panels.
5. The body, doors, and hood are then given the finish paint (acrylic enamel).
6. Certain lower inside body and door surfaces are sprayed with aluminum filled wax (see Pages 20 and 21 for details).
7. Finally, clear polyurethane film stone shields are added ahead of the rear wheel openings to prevent stone chipping of the finish paint.
G TRUCK CORROSION PROTECTION — Continued

SLIDING DOOR
GALVANIZED TRACK 78 1/2
REMOVABLE COVER SOP 79
(FOR SMALL PARTS PROCESSING)

WINDOW HINGE
CONSTRUCTION CHANGE TO
ELIMINATE CORROSION SOP 77

CV PIVOT HINGE & FRAME
GALVANIZED 78 1/2
CV FRAME CLASS A 336 PAINT
SPEC. 78 1/2

DRIP RAILS
HEMMED SOP 79

COWL SCREEN
GALVANIZED 77 1/2

RADIATOR
SUPPORT BRACKETS
GALVANIZED SOP 78

TIE BAR
GALVANIZED 78 1/2

LOWER FILLER PANEL
BOTH SIDES
GALVANIZED 78 1/2

SIDE DOOR OUTERS
PLASTISOL ON HEMS SOP 77
ALUMINUM WAX SOP 77
ZINCROMETAL 78 1/2

FRONT & SIDE DOOR
STEP WELL PANELS
GALVANIZED SOP 71

ROCKER PANEL OUTER
GALVANIZED SOP 71

ROCKER PANEL INNER
GALVANIZED SOP 71
ALUMINUM WAX SOP 79

URETHANE STONE
PROTECTOR SOP 78

— ZINCROMETAL
— GALVANIZED
— ZINC IRON ALLOY
— URETHANE PROTECTOR
HINGE
ZINC PLATED SOP 77

HINGE & PLATE
ZINC PLATED SOP 77

REAR DOORS
ZINC IRON ALLOY
78 1/2

GAS CAP FILLER DOOR
LARGE BUMPERS SOP 77
ADDITIONAL CLEARANCE SOP 77
ADDITIONAL CLEARANCE SOP 79

SINGLE PIECE
GALVANIZED FRONT
W/HOUSE SOP 78

STEPWELL
GALVANIZED SOP 71

ROCKER PANEL INNER
GALVANIZED SOP 71
ALUMINUM WAX SOP 79

URETHANE-
STONE PROTECTOR SOP 78

ROCKER PANEL OUTER
GALVANIZED SOP 71

REAR W/HOUSE
GALVANIZED SOP 71

G TRUCK CORROSION PROTECTION — Continued

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- ZINCROMETAL
- GALVANIZED
- ZINC IRON ALLOY
- URETHANE PROTECTOR
Improved Corrosion Protection is afforded 1980 models through the use of additional corrosion-resistant metals and refinements to existing designs.

Usage of galvanized steel, which is galvanized on both sides, is extended to the fuel tank filler door, fuel tank filler neck housing inside the body which protects the fuel tank filler neck from cargo damage. The underbody rear cross sill, and rear wheelhouse splash shield (new addition for short wheelbase models).

Zinc-coated steel is employed for the body side outer panels and the rear floor side extensions, or that part of the floor panel assembly directly behind the rear wheelhouse.

A hot-melt type sealer pad is added to the front floor panel at the left hand side for additional corrosion protection. The sealer pad of plastic material is applied to the floor panel prior the placing the body in the topcoat bake oven where the heat causes the pad to be bonded to the metal.

Corrosion protection is improved for rear door hinges by installing the hinge-to-body seals after the prime part operation and by priming the hinge roll pins.
Air flow and condensate drainage are improved for inner rocker panels and the sliding door stepwell assembly by revising the drain depressions.

Also, paint specifications for exterior chrome plated metal parts are improved. And, in interim 1979 specifications for exterior lamp attaching screws and other miscellaneous parts were improved.

ADDITIONAL FEATURES

1C1 Add new vent holes for improved drainage (at rear wheelhouse splash shields).

8A New filler cap assembly for deproliferation and corrosion protection improvement.

10B Wheels Cathodic Elpo primed at source.

12L Foam seal to door jamb switches and anti-theft hood switch.

1980 P 100-200-300

10B Cathodic Elpo Wheels at source rather than assembly plant.
Chevy Van/Vandura/Sportvan/Rally

Corrosion protection is improved with the release of 2-side galvanized steel for rear door outer panels (deferred from 1980).

Improved corrosion protection is afforded brake lines aft of the dash panel with the addition of zinc rich paint over existing terne plate (also fuel lines).

03,32 Models

Corrosion protection measures (811) for steel HiQube and Van/Magnavan and for aluminum units when common parts are employed (ie., rear bumpers)

Use of precoated steel, improved primer paint, cement-sealer on body and rear bumper joints in place of conventional sealer, corrosion resistant coatings on fasteners and piano-type rear door hinges, more corrosion resistant rear door exterior hardware and improved rear bumper paint processing.

Corrosion protection for brake lines aft of dash panel and all fuel lines is zinc rich paint over existing terne plating.

IC5B Cad plate door hinge pins to improve corrosion protection.

IC5D Cad plate lower door hinge pin.
Continue use of GM Elpo electrocoating process.

1C1 Released galvanized steel rear floor panel rear extension to improve corrosion protection.

5F Expanded use of zincroterne coating on front lines to improve corrosion protection.

9E Use of zincroterne coating on line and zinc dichromate plating on tube nuts to improve corrosion protection.

14A1 Use of zinc plated steel for painted bumper to improve corrosion protection plus Elpo prime.
ATTACHMENT 1

1983 "G"

FEATURES

Anti-chip coating on lower body side from front to rear.

UPC1 Addition of anti-chip coating below the lower feature line including the rear end of the front wheelhouse all the way back to the rear door cut line for "Improved Corrosion Protection".

1C1 Spray plastisol is added to the rocker panels to improve corrosion protection.

1C4 Addition of anti-chip coating below the lower feature line to improve corrosion protection (eliminating urethane stone shields ahead of rear wheel openings).

1C5A Same as 1C4

1C5C Same as 1C4
WHAT IS COVERED

DEFECTS
This warranty covers any REPAIRS* needed during the WARRANTY PERIOD due to defects in material or workmanship. Any required adjustments will also be made during the BASIC COVERAGE period.

WARRANTY PERIOD
The warranty period for all coverages begins on the date the vehicle is first delivered or put in use (as shown on the cover of this booklet). It ends at the expiration of the BASIC COVERAGE or other COVERAGE shown below.

BASIC COVERAGE
The basic WARRANTY PERIOD is 12 months or 12,000 miles, whichever comes first. The complete vehicle, except tires, is covered during this period.

AIR CONDITIONING COVERAGE
The sealed refrigerant portion of the factory-installed air conditioning system is covered for 12 months, regardless of mileage.

POWERTRAIN COVERAGE
Following expiration of the BASIC COVERAGE, and subject to a $100 deductible:
- Gasoline engines and drivetrain components are covered up to a total of 24 months or 24,000 miles, whichever comes first.
- Diesel engines are covered up to a total of 36 months or 50,000 miles, whichever comes first.

See Page 8 for coverage details.

CORROSION (RUST-THROUGH) COVERAGE
Any body sheet metal panel that rusts-through due to corrosion is covered for 36 months, regardless of mileage.

REPAIRS*
Your dealer will make the repairs or adjustments, using new or remanufactured parts, including service supplies such as coolant, oils and refrigerant. Sheet metal panels covered under CORROSION may be repaired or replaced. A reasonable time must be allowed after taking the vehicle to the dealer.

NO CHARGE
Warranty repairs and adjustments (parts and/or labor) will be made at no charge (except for $100 POWERTRAIN coverage deductible).

TOWING
Towing service, required when your vehicle is inoperative due to a warranted part failure, is covered to the nearest dealership handling your vehicle line.

WARRANTY APPLIES
This warranty is for GM trucks and chassis registered and normally operated in the United States or Canada.

*If you are not satisfied with the repairs, you should follow the steps shown on pages 14 and 15. In those few cases where our 3-step satisfaction procedure fails to resolve an owner complaint, we also offer (at no cost to you) the GM Mediation/Arbitration Program, which provides for review of the facts by an independent third party. You must use this Program before seeking remedies provided in some laws, including the Magnuson-Moss Warranty Act; however, use of the Program is not required by some other laws. See page 15 for further information about the GM Mediation/Arbitration Program or use the addressed form provided under "Owner Assistance" to write us.
ADJUSTMENTS
The term "adjustments" as used in the warranty refers to minor repairs not usually associated with the replacement of parts. Any adjustment (necessary to correct a defect) is covered during the BASIC WARRANTY period (12 months or 12,000 miles).

POWERTRAIN COMPONENTS
Listed below are the POWERTRAIN components covered under the New Truck and Chassis Limited Warranty:

24-MONTHS/24,000-MILES
- Gasoline Engine — Cylinder block and heads and all internal parts, intake and exhaust manifolds, timing gears, timing gear chain or belt and cover, flywheel, harmonic balancer, valve covers, oil pan, oil pump, engine mounts, seals and gaskets, water pump and fuel pump; also turbocharger housings and internal parts, turbocharger valves, seals and gaskets.
- Transmission — Case and all internal parts, torque converter, vacuum modulator, seals and gaskets and transmission mounts; also transfer case and all internal parts, seals and gaskets.
- Front-Wheel Drive — Final drive housing and all internal parts, axle shafts, constant velocity joints, front hub bearings, seals and gaskets.
- Rear-Wheel Drive — Axle housing and all internal parts, propeller shafts, "U" joints, axle shafts, bearings, supports, seals and gaskets.

36-MONTHS/50,000-MILES
- Diesel Engine — Same components as listed for "Gasoline Engine" above as applicable, plus diesel fuel injection pump external seals.

OWNER'S RESPONSIBILITIES
Your cost for those repairs qualifying under the POWERTRAIN coverage (including towing) is limited to the first $100 of the repair bill for each repair visit.

CORROSION (RUST-THROUGH)
The CORROSION coverage applies to perforation due to corrosion only. Perforation means a rust-through condition, such as an actual hole in a sheet metal panel. Cosmetic or surface corrosion (resulting from stone chips or scratches in the paint, for example) would not be repaired under this coverage.

AFTER-MANUFACTURE "RUST PROOFING"
Since your vehicle was designed and built to resist corrosion, use of additional rust-inhibiting materials is not necessary and not a requirement under the 36 month CORROSION coverage. Whether to obtain such protection is, therefore, your decision.

BATTERIES
The Delco battery installed in your vehicle as original equipment is covered under the New Truck and Chassis Limited Warranty for 12 months or 12,000 miles, whichever comes first.

SHEET METAL, PAINT
AND OTHER APPEARANCE ITEMS
Defects or damage to sheet metal, paint, trim or other appearance items may occur at the factory during assembly or while the vehicle is being shipped to the dealer. Normally, any factory defect or damage is detected and corrected at the factory during the inspection process. In addition, dealers are obligated to inspect each vehicle before delivery. They repair any uncorrected factory defects or damage and any transit damage which they detect before the vehicle is delivered to you.

Sheet metal, paint or appearance defects still present at the time the vehicle is delivered to you are covered by the warranty. However, for your protection, we suggest that if you do find any such defects, you advise your dealer without delay, as normal deterioration due to use and exposure is not covered by the warranty.

WARRANTY SERVICE — UNITED STATES AND CANADA
While any dealer handling your vehicle line will perform warranty service, we recommend that you return to the dealership that sold you your vehicle because of their continued and personal interest in you. If you are touring or move, visit any dealer handling your vehicle line in the United States or Canada for warranty service.

TOURING OWNER SERVICE — FOREIGN COUNTRIES
If you are touring in a foreign country and repairs are needed, it is suggested you make your vehicle available to a General Motors dealer, preferably one that handles your vehicle line. For reimbursement consideration, you should provide your dealer upon your return home with a statement of circumstances, the original repair order and any "paid" receipt indicating the work performed and parts replaced. Please note that repairs made necessary by the use of improper or dirty fuels are not covered under the warranty. See Owner's Manual for additional information on fuel requirements when operating in foreign countries.

WARRANTY REPAIR ORDER
For your records, the servicing dealer will provide a copy of the Warranty Repair Order listing all warranty repairs performed.

PRODUCTION CHANGES
General Motors Corporation and its dealers reserve the right to make changes in vehicles built and/or sold by them at any time without incurring any obligation to make the same or similar changes on vehicles previously built and/or sold by them.
ATTACHMENT 2

WHEELBASES: 16 DIFFERENT LENGTHS
Chevy Mediums give you a big choice to take a big load off your mind. Wheelbases range from 125" to 254". So choose your body. Chances are, Chevy has the wheelbase to match.

SPRINGS:
A smooth ride without a load; strong support when loaded. That's the idea behind Chevy's variable-rate springs. Series C50 front springs are rated at 2,000 lbs. each at the ground, 5,500 lbs. at the rear. Series C60 have 3,000-lb. ratings in front on hydraulic brake models, 3,500-lb. ratings with air brakes. Rear springs are rated at 7,500 lbs. each on hydraulic brake models, 9,200 lbs. each with air brakes. Series C70 front springs have 3,500-lb. capacity each at the ground, 9,250-lb. capacity each at the rear on single-axle models, and 15,000-lb. capacity each on tandems.

CLUTCHES:
What does stopping a rushing airliner have to do with Chevy Mediums? Clutch facings. Cerametalix clutch facings. Incredibly strong, this material was developed as high performance brake material for aircraft. Chevy uses it in all engines with manual transmissions except the 4.8 Liter (292 Cu. In.) Six and 5.7 Liter (350 Cu. In.) nongovernor V8s.

TRANSMISSIONS:
Available transmissions include GM 4-speed and Clark, Spicer and New Process 5-speed in deep-low or short-fourth versions. The Spicer CMS5 Series 5-speed was developed specifically for higher torque diesels and big gas engines. It boasts an input-torque capacity of 550 lbs., easy shifts and quiet operation.

The Allison AT-545 4-speed automatic transmission is available for gas-powered Chevy Mediums. It's a good choice for medium loads in city delivery, lumber hauling or farm use. The Allison MT-643 4-speed and MT-653 5-speed automatics are available with the 8.2 Liter "Fuel Pincher" diesel engine, 6.0 Liter (366 Cu. In.) and 7.0 Liter (427 Cu. In.) V8 gas engines.

MT-643 and MT-653 are good choices for heavier loads in dump, tank, pickup and off-road applications.

STANDARD ALLIGATOR HOOD:
It opens wide and long, provides good overhead clearance, enables mechanics to reach components from either side or front. Standard on C50, C60 and C70 Models with 96° BBC.

AVAILABLE TILT HOOD:
No more reaching over front fenders. One lightweight fiberglass unit. And it's counterbalanced for easy one-man operation. BBC: 96.75".

FIBERGLASS TILT HOOD WITH KODIAK OPTION:
When the Caterpillar 320B engine is ordered on C60 and C70 models, the Kodiak option is required. It features a massive grille and lightweight fiberglass tilt hood. BBC: 92.3".
MIGHTY TOUGH CORROSION-FIGHTER, TOO.

Metal-to-metal seams can be a problem for any cab. They give moisture and road salt a home, inviting rust and corrosion. Chevy cabs are constructed with a minimum of seams. One piece back panel, one-piece inner and outer door panels, one-piece door frame, one-piece windshield frame, one-piece windshield to help prevent leaks and squeaks. Clearly, value-robbing moisture and corrosion aren't welcome here.

Chevy cabs also boast double-wall construction in many areas. This means steel inner and outer walls. And that means rigidity and strength.

WHAT WE HAVE AGAINST CORROSION:

1. Anti-corrosion steels: Zincmetal® galvanized steel, zinc alloy steel and zinc-plated parts are used extensively.

2. Anti-corrosion primers: Zinc chromate primers and other zinc-rich primers are carefully hand-sprayed on critical areas before priming.

3. Final priming: Every cab is completely submerged in a primer bath. Then an electric charge draws primer into hidden seams and crevices.

4. Tectyl® oil spray: Applied to lower inner surfaces to help fight the corrosive action of road salt.

5. Weatherproofing: Tough yet pliable weather stripping, sealing compounds and rubber gaskets.

EVERY CHEVY MEDIUM DUTY'S NEW-VEHICLE LIMITED WARRANTY COVERS PERFORATION FROM CORROSION FOR THREE YEARS.

Exhaust system components not included. Ask your Chevrolet dealer for details and other limitations.
WHAT IS COVERED

Defects
This warranty covers any REPAIRS needed during the WARRANTY PERIOD due to defects in material or workmanship.

Warranty Period
The warranty period for all coverages begins on the date the vehicle is first delivered or put in use (as shown on the cover of this booklet). It ends at the expiration of the BASIC COVERAGE or other COVERAGES shown below.

Basic Coverage
The basic WARRANTY PERIOD is 12 months or 50,000 miles, whichever comes first.
- From 0 to 12,000 miles the coverage is 100% parts and 100% labor.
- From 12,001 to 50,000 miles the coverage is 50% parts and 50% labor.

Air Conditioning Coverage
The sealed refrigerant portion of the factory-installed air conditioning system is covered for 12 months or 100,000 miles, whichever comes first.

Suspension Coverage
After the first 12,000 miles (but within the initial 12 month time period) front and rear suspension components are covered at 100% parts and 100% labor up to 24,000 miles. (See page 8 for coverage details.)

Drivetrain and Frame Coverage
Gas engines, drivetrain and frame components are covered up to 24 months or 50,000 miles, whichever comes first.
- From 0 to 24,000 miles or from 0 to 12 months, whichever comes first, the coverage is 100% parts and 100% labor.
- From 24,001 to 50,000 miles or from 12 to 24 months, whichever comes first, the coverage is 50% parts and 50% labor.

See page 8 for coverage details.

Corrosion (Rust-Through) Coverage
Any body sheet metal panel that rusts-through due to corrosion is covered for 36 months, regardless of mileage.

Repairs
Your dealer will make the repairs or adjustments, using new or remanufactured parts, including service supplies such as coolant, oils and refrigerant. Sheet metal panels covered under CORROSION may be repaired or replaced. A reasonable time must be allowed after taking the vehicle to the dealer.

No Charge
Warranty repairs (parts and/or labor) will be made at no charge, unless otherwise specified under BASIC COVERAGE or DRIVETRAIN AND FRAME COVERAGE.

Towing
Towing service, required when your vehicle is inoperative due to a warranted part failure, is covered to the nearest dealership handling your vehicle line.

Warranty Applies
This warranty is for GM trucks and chassis registered and normally operated in the United States or Canada.
THINGS YOU SHOULD KNOW ABOUT THE NEW TRUCK AND CHASSIS WARRANTY

SUSPENSION COMPONENTS
The SUSPENSION components covered under the New Truck and Chassis Warranty are: front and rear leaf springs and bushings, shock absorbers, spring hanger brackets, and torque arms and bushings.

DRIVETRAIN AND FRAME COMPONENTS
Listed below are the DRIVETRAIN AND FRAME components covered under the New Truck and Chassis Warranty.
- Frame — Frame rails and crossmembers
- Front Axle I-Beam
- Gas Engine — Cylinder block and heads and all internal parts, water pump and intake manifold.
- Flywheel Housing
- Transmission (Except Allison) — Transmission cases and all internal parts.
- Transfer Case — Transfer case and all internal parts.
- Clutch Housing
- Propeller Shafts — Propeller shafts, support bearings and universal joints.
- Drive Axles — Differentials, axle shafts and bearings.

CORROSION (RUST-THROUGH)
The CORROSION coverage applies to perforation due to corrosion only. Perforation means a rust-through condition, such as an actual hole in a sheet metal panel. Cosmetic or surface corrosion (resulting from stone chips or scratches in the paint, for example) would not be repaired under this coverage.

AFTER-MANUFACTURE “RUST PROOFING”
Since your vehicle was designed and built to resist corrosion, use of additional rust-inhibiting materials is not necessary and not a requirement under the 36 month CORROSION coverage. Whether to obtain such protection is, therefore, your decision.

BATTERIES
The Delco battery installed in your vehicle as original equipment is covered under the New Truck and Chassis Warranty for 12 months or 50,000 miles, whichever comes first. After the first 12,000 miles (but within the initial 12 month time period) the battery is covered at 50% parts and 50% labor up to a total of 50,000 miles.

SHEET METAL, PAINT AND OTHER APPEARANCE ITEMS
Defects or damage to sheet metal, paint, trim or other appearance items may occur at the factory during assembly or while the vehicle is being shipped to the dealer. Normally, any factory defect or damage is detected and corrected at the factory during the inspection process. In addition, dealers are obligated to inspect each vehicle before delivery. They repair any uncorrected factory defects or damage and any transit damage which they detect before the vehicle is delivered to you.

Sheet metal, paint or appearance defects still present at the time the vehicle is delivered to you are covered by the warranty. However, for your protection, we suggest that if you do find any such defects, you advise your dealer without delay, as normal deterioration due to use and exposure is not covered by the warranty.

WARRANTY SERVICE — UNITED STATES AND CANADA
While any dealer handling your vehicle line will perform warranty service, we recommend that you return to the dealership that sold you your vehicle because of their continued and personal interest in you. If you are traveling or moving, visit any dealer handling your vehicle in the United States or Canada for warranty service.

WARRANTY SERVICE — FOREIGN COUNTRIES
If you are operating in a foreign country and repairs are needed, it is suggested you make your vehicle available to a General Motors dealer, preferably one that handles your vehicle line. For reimbursement consideration, you should provide your dealer upon your return home with a statement of circumstances, the original repair order and any “paid” receipt indicating the work performed and parts replaced. Please note that repairs made necessary by the use of improper or dirty fuels are not covered under the warranty. See Owner’s and Driver’s Manual for additional information on fuel requirements when operating in foreign countries.

WARRANTY REPAIR ORDER
For your records, the servicing dealer will provide a copy of the Warranty Repair Order listing all warranty repairs performed.

PRODUCTION CHANGES
General Motors Corporation and its dealers reserve the right to make changes in vehicles built and/or sold by them at any time without incurring any obligation to make the same or similar changes on vehicles previously built and/or sold by them.
We think our performance-oriented, aerodynamically styled Five-Star General and General represent the best values of any long conventional built in the USA. They are designed and crafted to meet today's real-world demands for highway and on/off-highway operations of professional operators.

Major engineering effort goes into the areas that count most — fuel efficiency, serviceability, driver comfort, convenience, and GMC value. GMC Generals are built one at a time. Each truck is inspected during and after manufacture to determine quality. What does not measure up is replaced or repaired — it's all part of our total commitment to quality.

Generals with fuel-efficient drive trains are available as trucks and road tractors in single- and tandem-axle models in 108" and 116" BBC dimensions, nonsleeper and sleeper models. Wide-tracking front axles are available up to 18,000 lbs and tandem rear axles up to 65,000 lbs; WWRs up to 90,000 lbs.

The Five-Star General story begins on Page 3; the General on page 18. Read about them in this catalog, then talk to your GMC Dealer. See GMC General for yourself — measure its value against your experience and knowledge — then make your buying decision. The General invites comparison.

LIGHTWEIGHT COMPONENTS
We know as well as you do that the heavier the truck, the more fuel is consumed. So, in the interests of fuel economy we have developed an impressive array of standard and available tough but lightweight equipment that adds to the intrinsic strength and value of our General models. Read on and you will see why General and the Five-Star General are great values.
The Five-Star General is our classic, aerodynamically styled long conventional with eye-catching exterior trim and driver-oriented interior. The prestigious exterior features bright windshield reveal molding, dual headlamps, hood ornament, and Five-Star emblems on the side of the hood and door. See the Five-Star interior on pages 6-9 and General on pages 18-21.

We think the Five-Star General and General models represent remarkable value. We invite you to compare these 1984 STANDARD FEATURES with any competitive heavy-duty long conventional truck:

1. Aerodynamically styled cab of strong, lightweight aluminum
2. Lightweight, corrosion-resistant fiberglass doors with piano type hinges
3. Cab is epoxy dipped to help fight corrosion and for good paint adhesion
4. Stainless steel West Coast mirrors
5. Choice of 10 solid paint colors
6. Five piece fiberglass tilt hood with bolt-on fenders for ease of replacement
7. Molded rubber and nylon hood latches
8. Wet-arm windshield wipers with two air-powered motors
9. Argent-painted aluminum bumper with flexible urethane end caps, saves weight
10. New for '84! Shock-mounted rear lamps
11. Anodized-aluminum assist handle on each side of cab
12. High-style tritone Gray interior
13. New for '84! Bostrom air-suspension low-back driver's seat
14. New for '84! Belt retractor with all seats
15. New for '84! Vinyellow fiberglass headliner and new upper back trim panels
16. Tilt steering column adjusts to driver's most comfortable position
17. Lockable vent windows
18. Insulation under floor and headliner
19. Headliner is vinyl. Rear back panels and door panels are plastic (hard vinyl)
20. New for '84! Donaldson 16" dry-type air cleaner
21. Spicer clutch now standard for '84
22. New for '84! 24" cylindrical aluminum 100-gallon RH fuel tank
23. New for '84! Magnetic transmission drain plug
24. Ether cup and air restriction indicator located in the air-intake system
25. Posi-temp cooling system
26. Electronic coolant-level alarm
27. Freedom batteries never need refilling with water
28. Delcotron generator with built-in, solid-state voltage regulator
29. Coiled trailer brake and electrical connections can be connected while standing on the ground
30. Color-coded air lines for ease of identification
31. Wiring on frame is in harness and clipped for ease of service
32. Manual reset circuit breakers in instrument panel for ease of service
33. Pop-out instruments can be serviced from front of instrument panel
34. Electrical equipment panel between seats helps speed service
35. Pac-Con electrical connectors easily lock together for positive connection
36. Color-coded wiring behind instrument panel in harness groupings for ease of service
37. Electrical junction box on engine wall helps speed service
38. New for '84! Magnetic drain and filler plug, rear axle
39. New for '84! 12,000-lb tapered-leaf front springs
40. Front shock absorbers
41. New for '84! 173" wheelbase for N9F064.
VALUE-CRAFTED GMC GENERALS

We think the Five-Star General is the right truck for today's needs. Many of its features were suggested by professionals who own and operate heavy-duty trucks. They know! Take a good deep-down look at the quality, craftsmanship, fuel efficiency, serviceability, comfort, convenience and value built into the General.

1 Massive frontal area allows efficient airflow through standard 1400-sq-in radiator. Grille attaches to radiator for rigidity and to help control vibration; helps prevent grille damage when tilting hood.
2 Frame front crossmember includes cushion mounts for radiator and standard PTO opening.
3 Available wide-tracking drop-forged I-beam front axles have a capacity of 12,000 and 18,000 lbs.
4 Lightweight deep bumper with aluminum center section and flexible urethane end sections is standard. Chromed and construction-type bumpers are available.
5 The tough 12,000-lb I-beam front axle features oil-lubricated wheel seals. Big, strong multi-leaf springs and big 1¾”-diameter shock absorbers are included.
6 The easy-tilt fiberglass hood saves weight while providing accessibility for routine service. Fenders bolt on to facilitate replacement. Conventional fiberglass repair methods can be used to repair accident damage to the five hood components that are available as separate service parts.
7 In the 6V-92TA Detroit Diesel engine, turbocharger and aftercooler work together to improve thermal efficiency and fuel economy. A broad range of Detroit Diesel and Cummins fuel-efficient engines are available.
8 A standard thermostatically controlled fan clutch engages only when needed for cooling, thereby reducing horsepower demand.
9 New for '84! Standard Donaldson 16” dry-type air cleaner. It's mounted on the cowl, easily accessible for service.
10 Silicone coolant hoses with metal elbows, preferred by some operators, are available.
11 Large windshield offers a luxurious view of the road. Wet-type windshield wiper arms release washer fluid through the arms for impressive coverage.
12 Stainless steel West Coast mirrors are standard.
13 The rugged, lightweight, styled cab is aluminum alloy, welded construction. It has a one-piece door frame, double-wall construction, and aluminum floor.
14 Cab doors are SMC fiberglass-reinforced plastic — lightweight and corrosion resistant. Rugged locks and piano-type hinges with stainless steel hinge pin help keep doors in alignment. Vent windows and ventilator in the driver's door are standard.
15 Low-mounted door handles are easy to reach and easy to grasp, even with a gloved hand.
16 The General cab features a standard rubber-cushioned, elastomeric 3-point mounting system. For added comfort, a Sofrider Cab Mount is available. It
includes an air spring and shock absorber at the rear of the cab. A valve and gage in the cab allow driver to adjust air-spring pressure to suit driving conditions. The Electro-Dip process is an important part of our efforts to fight corrosion and help keep your investment looking good. The cab is thoroughly cleaned and then immersed in a tank of electrically-charged primer paint. The primer is magnetically attracted to the metal surfaces, including hidden corners and crevices. Then a thick coat of acrylic enamel is applied and baked at high temperature. The electrical system is designed with a high degree of reliability. Accessible circuits junctions are color-coded for identification. Manual-reset circuit breakers are located on the instrument panel in front of the driver for fast, easy service. Standard tilt steering column accommodates a wide range of driver sizes. Standard high-ground-clearance structural foam battery box opens easily and closes tightly. Cleated steps provide good footing. High-performance Delco 1110 series standard batteries are maintenance-free, never need refilling. New for '84: 100-gallon cylindrical right hand fuel tank is standard. Tank capacity up to 370 gallons is available. General is built on a straight-channel bolted frame with side rails of 5/16 high-yield-strength steel. 3/4" rails, drop-center rails, and a wide selection of reinforcements are available. If vehicle weight is critical in your application, an aluminum frame and other lightweight components are available. New for '84: Chambers and linings of the standard air brake system matched to the vehicle GAWR for improved performance. S-cam brakes are 15" x 4" and 16 1/2" x 7" rear. Air lines with replacement end fittings are color-coded and routed through a junction plate at the rear of the cab to simplify service procedures. Exa system, designed for low noise level and back pressure, includes standard vertical mounted muffler and heatguard. U-bolt frame-mounted exhaust pipe bracket easily accessible for pipe changing. New for '84: Rockwell SQ 100, 34,000-lb rear with multi-leaf four spring suspension available on tandem models. Single models feature a 23,000-lb radius-leaf suspension.
NEW AIR JUNCTION MANIFOLD
New aluminum manifold air junction is located in the cab floor for ease of service. It eliminates copper plumbing and utilizes "push-in" installation of nylon tubing.

RUGGED DOOR DESIGN
Astro doors are fiberglass reinforced plastic—lightweight, corrosion resistant and tough. Doors are hung on strong stainless steel piano hinges. Also included are tough locks and latches and reliable tape drive window regulators.

NEW INSTRUMENTS
New 2-inch instruments have a high contrast readout with Black background and White numerals or letters. Instruments can be serviced from the front by removing the individual panels.

FRONT ACCESS DOOR
Front access door allows fast checking and servicing of coolant and oil levels. The radiator sight glass permits quick coolant checks.

AVAILABLE DISC BRAKES
Front and rear disc brakes are available as a Special Equipment Order. Ask your GMC dealer for details.

SINGLE-AXLE MODELS
The standard single rear-axle is an Eaton 23121 single-speed rated at 23,000 lbs. Single-axle models feature a new Vari-Rate suspension system that automatically adjusts to load conditions. New suspension is lighter in weight. Provides support for load when needed and a soft ride when empty. Standard radius leaf helps control driving and braking loads. Auxiliary rear are available.

NEW GM SUSPENSION FOR TANDEMS
Standard rear suspension features pressurized riding characteristics and weight. This 34,000-lb. capacity suspension utilizes separate taper-leaf spring for each wheel. The forward and rearward springs are connected by equalizing beams which permit interaxle articulation. Each axle has standard torque rod control driving and braking forces with 40,000-lb. capacity. A full of Reyco or Hendrickson suspensions also available. Capacities range from 34,000- to 44,000-lbs., depending on model. Standard tandem rear axle is 34,000 lb. Rockwell SL 100.
THINGS YOU SHOULD KNOW ABOUT THE NEW TRUCK AND CHASSIS WARRANTY

DRIVETRAIN COMPONENTS
Listed below are the DRIVETRAIN components covered under the New Truck and Chassis Warranty.

- TRANSMISSION (EXCEPT ALLISON)—Transmission cases and all internal parts, clutch housing, transfer case and all internal parts.
- DRIVE AXLES—Differentials, axle shafts, seals and bearings.
- PROPELLER SHAFTS—Propeller shafts, support bearings and universal joints.

CORROSION (RUST-THROUGH)
The CORROSION coverage applies to perforation due to corrosion only. Perforation means a rust-through condition, such as an actual hole in a sheet metal panel. Cosmetic or surface corrosion (resulting from stone chips or scratches in the paint, for example) would not be repaired under this coverage.

AFTER-MANUFACTURE “RUST PROOFING”
Since your vehicle was designed and built to resist corrosion, use of additional rust inhibiting materials is not necessary and not a requirement under the 36 month CORROSION COVERAGE. Whether to obtain such protection is, therefore, your decision.

BATTERIES
The Delco battery installed in your vehicle as original equipment is covered under the New Truck and Chassis Warranty for 12 months or 25,000 miles, whichever comes first.
Dr. M. L. S. A. M. S., an electrical engineer by profession, has been working on the development of new materials for cab interiors. His recent work has focused on the use of Elpo coating for cab surfaces. This coating is lightweight, durable, and resistant to corrosion.

The cab is designed to provide a comfortable driving environment. The interior trim includes dual padded sun visors and large 22" steering wheel with tilt steering column. The massive Astro grille is lightweight with bright trim. The standard engine is the Cummins Big Cam III Series, with capacities ranging from 50 to 300 gallons in 25-gallon increments.

The driveline features the Spicer SST 1372A 7-speed transmission as standard equipment. A tough 12,000-lb. I-beam front axle is standard with taper-leaf springs. The rear axle is the standard Eaton DS381, DS401P, DS440P, and Rockwell SQ 100, SQHP, and SSHD. Single-axle models are available which include the new Cummins Big Cam III Series as well as Caterpillar and larger Detroit Diesel engines.

Features include a thermostatically controlled fan clutch, one-half-inch Tufflex foam panel in contact with the sheet metal, one-quarter-inch insulation, and one-eighth-inch insulating trim. Interlayer materials provide an effective heat control and moisture barrier. The interlayer materials include the standard engine. A bright heat guard is included. Frame mounting helps isolate noise and vibration. Available inboard systems permit larger fuel tanks and eliminate need for heat shields. A back-of-cab battery box is included with inboard systems.

An 11" dry-type air cleaner, mounted on the frame behind the cab, is standard on the Astro. A frontal air intake system is available to save weight on certain Cummins-powered Astros. Bolted frame construction with full-depth, high-performance steel rails is standard on the Astro.

Three high-power Delco 1110 Series Freedom batteries are standard, housed in a weight-saving aluminum battery box. Four-battery systems are available. All batteries are sealed, never require water. Delcotron generator with solid state voltage regulator is standard.

The Rockwell SL 100 is the standard tandem rear-axle in the Astro. Available tandem axles include the Eaton DS381, DS401P, DS440P, and Rockwell SQ 100. CAPS HP and SSHD. On single-axle Astros choose either the standard Eaton 23121 axle or the Rockwell R-170. A 34,000-lb. GM suspension with taper-leaf springs is standard on tandem models. Single-axle models now standard.

Every cab is immersed in Elpo emulsion.
feature a new, lightweight radius-leaf rear suspension. Standard wheels are 24.5 x 8.25 steel disc type. A full selection of cast spoke, steel and aluminum disc wheels is available. Steel-belted radial tires have less rolling resistance than nonradial types, thereby contributing to fuel economy. They're standard on the Astro. Stainless steel West Coast mirrors, supports and attaching hardware are also standard. Also included as standard are color-coded air lines for easy identification, deluxe heater and defogger, new turn signal incorporating the dimmer switch and hydraulic cab tilt system.
WHAT IS COVERED

Defects
This warranty covers any REPAIRS needed during the WARRANTY PERIOD due to defects in material or workmanship.

Warranty Period
The warranty period for all coverages begins on the date the vehicle is first delivered or put in use (as shown on the cover of this booklet.) It ends at the expiration of the BASIC COVERAGE or other COVERAGES shown below.

Basic Coverage
The basic WARRANTY PERIOD is 12 months or 25,000 miles, whichever comes first. The complete vehicle, except tires, is covered during this period.

Air Conditioning Coverage
The sealed refrigerant portion of the factory-installed air conditioning system is covered for 12 months or 100,000 miles, whichever comes first.

Drivetrain Coverage
Drivetrain components are covered for 24 months or 100,000 miles, whichever occurs first.
- Between 25,001 and 50,000 miles—100% parts and 50% labor.
- Between 50,001 and 75,000 miles—100% parts and 25% labor.
- Between 75,001 and 100,000 miles—50% parts and no labor.

GMC Fluid Fan Coverage
The General Motors fluid fan coverage is 100 percent parts and labor for 24 months or 200,000 miles, whichever comes first.

Frame Coverage
Frame rails, cross members, rear axle housing, and front axle I-beams are covered for 36 months or 200,000 miles, whichever occurs first.
- Between 25,001 and 50,000 miles—100% parts and 100% labor.
- Between 50,001 and 100,000 miles—100% parts and 50% labor.
- Between 100,001 and 150,000 miles—100% parts and 25% labor.
- Between 150,001 and 200,000 miles—50% parts and no labor.

Corrosion (Rust-Through) Coverage
Any body sheet metal panel that rusts-through due to corrosion is covered for 36 months, regardless of mileage.

Repairs
Your dealer will make the repairs using new or remanufactured parts, including service supplies such as coolant, oils and refrigerant. Sheet metal panels covered under CORROSION may be repaired or replaced. A reasonable time must be allowed after taking the vehicle to the dealer.

No Charge
Warranty repairs (parts and/or labor) will be made at no charge, unless otherwise specified under DRIVETRAIN AND FRAME COVERAGE.
ATTACHMENT 3: Chrysler Corporation Warranty.

1984 POWERTRAIN LIMITED WARRANTY

WHAT IS COVERED
To the First Retail Purchaser only, upon expiration of the 12 month/12,000 mile Basic New Vehicle Limited Warranty, this powertrain warranty covers components listed below to 5 years or 50,000 miles, whichever occurs first. This powertrain limited warranty is subject to a $100 deductible for each repair visit.

As used, the term "First Retail Purchaser" means the first legal ownership of a vehicle for use and not for resale.

To all subsequent purchasers and vehicles placed in Fleet, Police, Taxi, Limousine or Jitney service, upon expiration of the 12 month/12,000 mile Basic New Vehicle Limited Warranty, the powertrain warranty covers components listed below to 24 months or 24,000 miles, whichever occurs first. This powertrain limited warranty is subject to a $100 deductible for each repair visit.

5 YEAR/50,000 MILE COVERED COMPONENTS
ENGINE - Cylinder block and all internal parts; cylinder head assemblies; core plugs; valve covers; oil pan; timing gear drive belts and/or chains and cover; oil pump; intake and exhaust manifolds; water pump; turbocharger housings and internal parts and turbocharger wastegate actuator. Gaskets and seals for listed components.
TRANSMISSION — Transmission case and all internal parts, gaskets and seals; oil pan; torque converter with starter ring gear and flex plate; clutch housing, flywheel.
FRONT WHEEL DRIVE — Transaxle case and all internal parts, gaskets and seals; oil pan and differential cover; torque converter and drive plate with starter ring gear; clutch housing, flywheel, drive shaft assemblies; universal joints and yokes.
REAR WHEEL DRIVE — Drive axle housing and all internal parts, gaskets and seals; axle shafts; axle shaft bearings and seals, drive shaft assemblies; universal joints and yokes.

This warranty covers repairs made necessary due to a defect in material or workmanship. It applies to Chrysler vehicles registered and normally operated in the 50 United States, Washington, D.C. and Canada.

WHAT IS NOT COVERED
This warranty does not cover any Item listed under "What is Not Covered" in the Basic New Vehicle Limited Warranty.

OWNER'S RESPONSIBILITIES
It is the owner's responsibility under the terms of this warranty to maintain the vehicle as specified in this booklet and Operating Instructions and Product Information booklet.

THE "OTHER TERMS" STATED IN THE BASIC NEW VEHICLE LIMITED WARRANTY ALSO APPLY TO THIS WARRANTY.

1984 ANTI-CORROSION PERFORATION LIMITED WARRANTY

WHAT IS COVERED
Chrysler warranted for 1984 model vehicles that your Chrysler selling dealer will repair or replace at no charge any body sheet metal panel found to have developed perforation (rust-through) due to corrosion in normal use. This warranty begins on the date the vehicle is first delivered or put in use, whichever occurs first, and extends for 36 months regardless of mileage. In addition, outer panel rust-through protection is extended to 5 years or 50,000 miles, whichever occurs first, from the warranty start date.

This warranty applies to vehicles registered and normally operated in the 50 United States, Washington, D.C. and Canada.

WHAT IS NOT COVERED
This warranty does not cover:
- Corrosion due to accident, damage, abuse or vehicle alteration.
- Surface corrosion, such as that caused by industrial fallout, sand, salt, hail or stones; or
- The other Items listed under "What Is Not Covered" in the Basic New Vehicle Limited Warranty.

Corrosion, other than perforation (metal rust-through) due to defects in material or workmanship, is covered by the 12 month or 12,000 mile Basic New Vehicle Limited Warranty.

OWNER'S RESPONSIBILITIES
It is the owner's responsibility under the terms of this warranty to maintain the vehicle as specified in this booklet and Operating Instructions and Product Information booklet.

THE "OTHER TERMS" STATED IN THE BASIC NEW VEHICLE LIMITED WARRANTY ALSO APPLY TO THIS WARRANTY.

THINGS YOU SHOULD KNOW ABOUT THE ANTI-CORROSION PERFORATION LIMITED WARRANTY

WHAT IS COVERED
The anti-corrosion perforation warranty covers perforation due to corrosion only. Perforation means a rust-through condition, such as a hole in a sheet metal panel.
1984 ANTI-CORROSION PERFORATION LIMITED WARRANTY

MAINTAINING YOUR VEHICLE

Washing — The best way to preserve your vehicle’s finish and aid in avoiding rust is to keep the vehicle clean by washing frequently. Wash the vehicle only with lukewarm or cold water. Do not wash the vehicle in the direct rays of the sun, or use strong soap or chemical cleaners. Any cleaning agents used should be washed off promptly and not allowed to dry on the finish.

Foreign Material Deposits — Calcium chloride and other salts, ice melting agents, road oil and tar, tree sap, bird droppings, chemicals from industrial chimneys and other foreign matter may damage the finish if left on the painted surfaces. Prompt washing may not completely remove all these deposits. Additional cleaners may be needed. When using chemical cleaners developed for this purpose, be sure they are safe for use on painted surfaces.

Underbody Maintenance — Corrosive materials used for ice and snow removal and dust control can collect on underbody surfaces. If these materials are not removed, accelerated rusting can occur on the underbody parts such as fuel lines, frame, floor pan and exhaust system. At least every spring, thoroughly flush these materials from the underbody with plain water. Take care to clean well any areas where mud and other debris can collect.

Finish Damage — Any stone chips, fractures or deep scratches in the finish should be repaired promptly. Bare metal will corrode quickly and can develop into major repair expense. Minor chips and scratches can be repaired with touch-up materials available from your Selling Dealer.

Collision Damage — If your vehicle is damaged and requires sheet metal repair or replacement, be sure the body shop applies anti-corrosion materials to the parts repaired or replaced.

1984 EMISSION CONTROL SYSTEM WARRANTIES

1984 EMISSION CONTROL SYSTEMS DEFECT WARRANTY

Chrysler Corporation warrants to owners of its 1984 vehicles that the vehicle (1) was designed, built and equipped so as to conform at the time of sale with applicable regulations issued under the National Emission Standards Act, as amended and (2) is free from defects in material and workmanship at the time of sale which would cause the vehicle to fail to conform with such regulations for a period of use of 50,000 miles or 8 years, whichever occurs first. Any defect covered by this warranty will be repaired or replaced by the Selling Dealer using new or remanufactured parts.

The warranty period begins on the date of original retail delivery of the vehicle, whichever occurs first. This warranty shall not apply to parts other than Chrysler Mopar Parts® (in the case of trucks, 8,500 lb. GVWR or greater, this defect warranty only applies to the engine).

1984 EMISSION CONTROL SYSTEMS PERFORMANCE WARRANTY

Some states and local jurisdictions have established periodic vehicle inspection and maintenance (I/M) programs to encourage proper maintenance of your vehicle. If an I/M program in your area has EPA approval, you may be eligible for Chrysler’s performance warranty coverage under the following conditions:

1. The vehicle must have been maintained and operated in accordance with the scheduled maintenance instructions described in the Operating Instructions and Product Information booklet provided with your vehicle.
2. The vehicle fails to conform for a period of 5 years or 50,000 miles, whichever occurs first, to the applicable emission standards of the U.S. Environmental Protection Agency, as judged by an EPA-approved I/M test, and
3. The failure to conform results or will result in the operation of the vehicle having to bear a penalty or other sanction (including the denial of the right to use the vehicle) under local, state or federal law.

If all the foregoing conditions are met, Chrysler warrants that your Selling Dealer will replace, repair or adjust to Chrysler’s specifications, “at no charge”, any of the listed components, or parts thereof, which may be necessary to cause your vehicle to conform to the applicable emissions standards. Parts “Certified to EPA Standards” shall be covered by this performance warranty.

This Performance Warranty begins on the date the vehicle is first put into use and continues for a period of 5 years or 50,000 miles, whichever occurs first, except that if the vehicle has been in operation for over 24 months or 24,000 miles, whichever occurs first, the repairs or replacement shall be limited to only those components designated with (*) which were installed on or in the vehicle for the sole or primary purpose of reducing vehicle emissions and not in general use prior to model year 1988. Parts listed, not designated by a (*) are covered under the performance Warranty for 24 months or 24,000 miles, whichever occurs first.
REQUEST FOR PURCHASE

TO: CONTRACTING OFFICER

THROUGH ACCOUNTING AND FINANCE

FROM (Insert RCOC, if applicable):

56th TRANSPORTATION SQ./LTN/SSGT HOLTON

IT IS REQUESTED THAT THE SUPPLIES AND SERVICES ENUMERATED BELOW AND IN THE ATTACHED LIST BE PURCHASED FOR

VEHICLE MAINTENANCE FOR DELIVERY TO BLDG $500

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<th>ITEM</th>
<th>DESCRIPTION OF MATERIAL OR SERVICES TO BE PURCHASED</th>
<th>QUANTITY</th>
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<th>ESTIMATED UNIT PRICE</th>
<th>ESTIMATED TOTAL COST</th>
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<td>SERVICES NONPERSONAL: TO FURNISH ALL LABOR, PARTS, MATERIAL, AND FACILITIES TO TEAR DOWN, INSPECT, QUOTE, AND REPAIR ITEMS LISTED BELOW.</td>
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<td>I CERTIFY THAT GOVERNMENT REPAIR CAPABILITIES ARE NOT AND CAN NOT BE MADE AVAILABLE FOR ITEMS LISTED. I FURTHER CERTIFY THAT I HAVE CONTACTED BASE SUPPLY AND DEPOT REPAIRS ARE NOT AUTHORIZED.</td>
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<td>RECOMMENDED SOURCE: ZIERBART AUTO TRUCK RUST PROOFING 6424 N. 40th ST TAMPA FL. PHONE: 229.1697</td>
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Funds Available $1,000.00

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<th>ESP CODE 9N</th>
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DATE 9 Apr 84

Typed Name and Grade of Requesting Official

Ronald G. Holton, SSgt, USAF

Date 830-3160

Typed Name and Grade of Approving Official

Robert L. Kingunder, CMSgt, USAF

Vehicle Maintenance Superintendent

I certify that the supplies and services listed above and in the attached list are properly chargeable to the following allotments, the available balances of which are sufficient to cover the cost thereof, and funds have been committed.

Accounting Classification

<table>
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<tr>
<th>AMOUNT</th>
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</thead>
</table>

Typed Name and Grade of Certifying Official

Signature

Date

AF FORM MAR 77 9
J. F. COOK & COMPANY, INC. DBA ZIEBART of TAMPA
2208 N. FLORIDA AVENUE TAMPA, FL 33602
(813) 229-1697

ORDER NUMBER

DELIVER TO

RECEIVED BY

MANU FACTURE'S INVOICE NO. 2862

DATE OF ISSUE 4/11/84

MONTH DAY YEAR

APPEARANCE & PROTECTION

WARRANTY NUMBERS

AMOUNT

1. RESPRAY

2. PAINT PROTECTION

3. INTERIOR PROTECTION

4. VINYL PROTECTION

5. CHIP STOP

6. PROTECTIVE MOLDINGS

7. SPLASH SET GUARDS, OIL

8. SUN HOOD SIZE

9. ACCENT STRIPE

10. TOTAL TAXABLE

11. TOTAL

12. INVOICE TOTAL

SUB TOTAL

TOTAL AMOUNT

TOTAL TAX

SPECIAL NOTES:

[Handwritten notes:]

- J. F. COOK & COMPANY, INC. DBA ZIEBART of TAMPA
- 2208 N. FLORIDA AVENUE TAMPA, FL 33602
- (813) 229-1697
- ORDER NUMBER
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- MANUFACTURE'S INVOICE NO. 2862
- DATE OF ISSUE 4/11/84
- MONTH DAY YEAR
- APPEARANCE & PROTECTION
- WARRANTY NUMBERS
- AMOUNT
- 1. RESPRAY
- 2. PAINT PROTECTION
- 3. INTERIOR PROTECTION
- 4. VINYL PROTECTION
- 5. CHIP STOP
- 6. PROTECTIVE MOLDINGS
- 7. SPLASH SET GUARDS, OIL
- 8. SUN HOOD SIZE
- 9. ACCENT STRIPE
- 10. TOTAL TAXABLE
- 11. TOTAL
- 12. INVOICE TOTAL
- SUB TOTAL
- TOTAL AMOUNT
- TOTAL TAX
- SIGNED:

[Handwritten notes:]

- J. F. COOK & COMPANY, INC. DBA ZIEBART of TAMPA
- 2208 N. FLORIDA AVENUE TAMPA, FL 33602
- (813) 229-1697
- ORDER NUMBER
- DELIVER TO
- RECEIVED BY
- MANUFACTURE'S INVOICE NO. 2862
- DATE OF ISSUE 4/11/84
- MONTH DAY YEAR
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- SIGNED:
LIMITED WARRANTY
RUST PROTECTION

The body sheet metal, structural members and frame of the new vehicle described above have been rust protected in accordance with ZIEBART engineered specifications and are warranted by the processing ZIEBART Dealer to the original vehicle owner not to rust-through from the inside out. The duration of this Limited Warranty is five (5) years from the date of issue. Should the vehicle rust-through from the inside out, within the terms of this Limited Warranty, the Dealer will repair and rust proof the rusted through area(s) at his expense.

This warranty does not cover exterior rusting due to paint failure, abrasion or collision damage. Any repaired or replaced areas must be ZIEBART Rust Protected within sixty (60) days to be included in this warranty. Fuel tank, exhaust systems, bumpers and areas in which application of rust protection is prohibited by the manufacturer are excluded from the warranty.

Inspections designed to assess the rust protected life of the vehicle are required to be performed by an authorized ZIEBART Dealer annually (plus or minus 30 days) from the date of claim. There is no charge for the inspections and re-strips, other than re-strips of repaired or replaced damaged areas. Please call for inspection appointment and bring this Limited Warranty for revalidation.

There is a charge for pre-cleaning of the underside prior to inspection to remove accumulated road dirt. The pre-cleaning service is necessary in most cases. Charges by the ZIEBART Dealer for pre-cleaning will vary from time to time and by location. Pre-cleaning may be performed by the customer or by any person performing that service.

If at the time this warranty is issued, another rust protection warranty is in effect, the Customer shall look first to the pre-existing Warrantor for warranty service during the term of the pre-existing warranty.

At the first sign of rust-through from the inside out, within the terms and period of this Limited Warranty, the person to whom this Limited Warranty was issued should, to enter a warranty claim:
1. Deliver the vehicle to the ZIEBART Dealer who issued this warranty, or
2. If the processing Dealer is unavailable, to any participating licensed ZIEBART Dealer.
3. If the vehicle is covered by a manufacturer's rust warranty, take the vehicle to the car dealer.
4. Present the original of this warranty to the ZIEBART Dealer to show the description of the vehicle warranted and the performance of the required inspection(s).
5. Complete and sign a standard claim form provided by the ZIEBART Dealer.
6. Make your vehicle available to the ZIEBART Dealer to perform repairs and rust protection as necessary.

Recovery pursuant to this warranty is limited to the repair of areas damaged by rust-through from the inside out. This recovery may be more or less than the original rust protection charge. In no event shall the consumer be entitled to any incidental or consequential damages. ANY IMPLIED WARRANTIES SHALL BE LIMITED TO THE DURATION OF THIS LIMITED WARRANTY. Some states do not allow limitations on how long any implied warranty lasts or exclusion or limitations of any implied or consequential damages, so the above limitations or exclusions may not apply to you. This warranty gives you specific legal rights and you may also have other rights which vary from state to state.

I UNDERSTAND THE WARRANTY TERMS AND CONDITIONS.
600 new but rusty pickups junked at the Port of Tampa

TAMPA — (AP) — General Motors Corp. is junking 600 new Chevrolet pickups, worth $5 million retail, because they developed underbody rust while parked at the Port of Tampa for as long as a year awaiting shipment to dealers along the Eastern Seaboard.

Work crews used fork lifts Thursday to rip off tires and gasoline tanks so the $8,500, 1982-model Chevy Luv pickups could be fed into huge crushers which reduced the two-ton vehicles to 9-inch-high blocks of metal. The metal was loaded onto tractor-trailers for delivery to a shredder.

Bill Stewart, international relations director for Chevrolet in Detroit, said it's company policy to destroy vehicles damaged through "acts of God" rather than jeopardize "dealer integrity" by selling them.

"This is not unusual, though obviously it is expensive," he said, adding that the decision would cost the manufacturer "millions of dollars."

GM agents said the demolition process, which began Wednesday, would take until late Friday to complete, using two crushing machines that can pulverize up to 100 trucks a day.

Tampa has been the port of entry for several years for C. Itoh & Co. of America Inc., a trading company that handles Japanese imports, according to company spokesman Jerry Smith. Isuzu Motors Ltd. of Japan manufactured the trucks for Chevrolet, then exported them here.

The trucks were being held duty-free at the port, awaiting delivery to dealers as far away as New England, Smith said.

Smith and Stewart blamed the rust on heavy rains in Tampa this year. Stewart also said the vehicles were sitting in a low area at the port.

Recently, the Luv inventory grew faster than demand, leaving some trucks at the port for more than a year, officials said. Meanwhile, GM replaced the vehicle with its new S-10 model.

Local Chevrolet dealers were unaware of the demolition process and said they did not know if any of those pickups were earmarked for them. However, they said they have received vehicles in the past from the port.

Meanwhile, Smith said Itoh will shut down its Tampa operation, eliminating 23 jobs.
Top Deck Loading of AF Vehicles Being Shipped Overseas.

ATTACHMENT 6

Subject: Top Deck Loading of Air Force Vehicles

Files:
1. HQ AFLC/LOZ MSG 141800Z SEP 01
2. HQ USAF/LGT MSG 200909Z OCT 01
3. HQ AFLC/LOZ LTR 10 Nov 01
4. TELECON 6. IDAR, HQ USAF/LETT AND AL RUDIS, HQ MTIC/MT-1T 24 Nov 01

1. Reference A addressed an operation listening post visit by AFLC/LOZ to HQ USAF in Jul 01. USAF stated AF vehicles were being deck loaded in CONUS to USAF. AFLC asked for specifics.

Case 62 INLAR#47003 UNCLAS

Reference B, HQ USAF provided info from Rottumed. Reference C, HQ AFLC/LOZ requested HQ USAF assistance. Reference D, HQ USAF/LETT coordinated with HQ MTIC/MT-1T.

HQ MTIC/MT-1T Mr. AL RUDIS stated it was policy not to deck load cargo unless coordinated with the shipper services. However, in the case of the eighteen low joyys, MTIC authorized deck loading because equipment did not have self-propelled engines.

HQ MTIC, WASH DC/MT-1T, by MSG 021700Z UFC 01, directed CHC areas that coordination must be accomplished in all cases, even when off-deck storage of a commodity is considered normal procedures.
ATTACHMENT 6
UNCLASSIFIED

PENTAGON TELECOMMUNICATIONS CENTER

PTTUZYUW RUKGNMA1605 3361820
PRIORITY
P 021700Z DEC 81
FM CDRMTMC WASHDC /MT-IT/
TO RUEOBMA/CDRMTMCEA BAYONNE NJ /MTE-IT/
RUWADMA/CDRMTMCWA OAKLAND CA /MTW-IT/
RUDOROA/CDRMTMCTTCE ROTTERDAM NETHERLANDS /MTC-SPD/
INFO RULSWCA/COMSC WASHDC
RUEAHQA/HQ USAF WASHDC
DA-BHCSVD
BT

UNCLAS
SUBJECT: ON-DECK STOWAGE
A. CDRMTMC, MT-IT, MSG 042030Z OCT 79. SUBJ: MSC BILLING PROCEDURES (NOTAL).
1. REF MSG ADVISED THAT MTMC POLICY CONCERNING SUBJECT STOWAGE WAS THAT ALL ON-DECK STOWAGE OF CARGO WAS TO BE COORDINATED WITH THE SHIPPER SERVICES.
2. BE ADVISED THAT COORDINATION MUST BE ACCOMPLISHED IN ALL CASES, EVEN WHEN ON-DECK STOWAGE OF A COMMODITY IS CONSIDERED "NORMAL" PROCEDURE.

BT

ACTION
INFO DA(1) LET(2) DPR AMT 79(0) FILE CY(1)

MCN=81336/18423 TDR=81336/18423 TAD=81336/20102 CDSN=MAP850

AIR FORCE MESSAGE
SUBJ: DECK LOADING OF AIR FORCE VEHICLES

1. A recent trip report obtained from an Operation Listening Post visit made to HQ USAFE during 6-24 Jul 81 states that Air Force vehicles are being deck loaded in the comus on surface vessels and not properly protected from the elements.

2. The policy between USAF and MTMC has been that deck loading of US Air Force vehicles would not be permitted on surface vessels transiting MTMC ports, and any deviation from this policy would only be permitted with prior approval of the appropriate USAF WPLO.

3. In order for us to pursue this matter with HQ MTMC, request you provide specific information pertaining to instances of deck loading of Air Force vehicles, i.e., TCM, voyage number, vessel received on, arrival date of vessel, POE, POD, type vehicle, water commodity code, damage sustained. Any other information helpful in our investigation would be most appreciated.

ATTACHMENT 6
ATTACHMENT 6

LOZ/C/Col Cross/76435/9 Nov 81/vh

Deck Loading of Air Force Vehicles

HQ USAF/LET

1. References:

a. HQ AFLC/LOZ Msg 14/1600Z Sep 81, Subject: Deck Loading of Air Force Vehicles (Attachment 1)

b. HQ USAF/LGT Msg 20/09092 Oct 81, Subject: Deck Loading of Air Force Vehicles (Attachment 2)

2. During a recent Operation Listening Post visit by members of this command to USAFE, personnel from USAF/LGT complained that some AF vehicles bound for European destinations were being deck loaded aboard ships transiting MTMC ports. The contention was that these vehicles are sustaining damage from heavy seas and prolonged exposure to the elements. In order to investigate this claim, we requested USAFE to provide more specific information that could substantiate instances of such deck loading. Their reply is at Attachment 2.

3. In correlating their reply with data available to our New Orleans WPLO, we found the following about the two voyages which departed Mobile: On Voyage A5397, the only vehicles on the top deck were eighteen low-boy trailers, approved for top deck stow by MTMC. The other vehicles — four forklifts and two sweeper trucks — were on the Number Two Deck. On Voyage 45675, the two low-boy trailers were also on Number Two deck. Since USAFE's reply indicates that Bremerhaven and HQ MTMC Rotterdam are unaware of any restrictions on dock loading of vehicles (other than FOVs), it is possible that some AF vehicles are being transferred to the top deck at some enroute ports of call.

4. Further investigation revealed that past policy — or understanding — between MTMC and USAF did not permit deck loading of such vehicles. Any deviation from this policy was permitted only with prior approval of the appropriate USAF WPLO. However, we are told by cognizant personnel here at HQ AFLC, at NR-ALC/DS and FM, and at our WPLOs that current directives do not cover a deck loading policy for AF vehicles. It would appear the latest guidance on this subject was in HQ USAF message AP5TP 94110, 23 November 65, subject: Deck Loading of Cargo, addressed to Commander, Military Traffic Management and Terminal Service (MTMST). That message delegated the responsibility for authorizing deck loading of certain items of cargo, except uncrated aircraft, to the USAF WPLOs.
5. To clarify the situation and to prevent future incidents, we recommend that an updated message be addressed to HQ MTMC and COMSC reiterating Air Force desires concerning deck loading of its vehicles. We believe there is a need to reaffirm a position that our vehicles should not be loaded on the top deck unless extenuating circumstances prevail, such as too large for the hold, or by not loading on the top deck, there would be an unreasonable amount of time awaiting the next sailing. Deviations or exceptions such as these would only be permitted with prior approval of the appropriate USAF WPLO.

6. Your assistance is appreciated.

FOR THE COMMANDER

DAVID E. BEEGLE
Deputy Director of Distribution
Office of DCS/Logistics Operations

2 Atch
1. LOC Mag 1418883 Sep 81
2. USAF Mag 2000982 Oct 81

ATTACHMENT 6