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SURFACE VEHICLE INFORMATION REPORT

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PROVING GROUND VEHICLE CORROSION TESTING

***Foreword*—**This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

***1. Scope*—**The facilities used by domestic automotive manufacturers to provide accelerated corrosion aging of complete vehicles are described in general. The types of vehicles tested, general test methodology, and techniques used to determine test-to-field correlation are discussed. The different procedures used throughout the industry produce different results on various vehicle coatings, components, and systems. The key to successful interpretation of test results is a thorough understanding of the corrosion mechanisms involved and the effects of test limitations on these mechanisms.

1.1 Purpose—The purpose of this information report is to provide a general overview of some proving ground procedures and facilities used in the United States to evaluate the corrosion protection performance of vehicles. Because of limitations involved with any accelerated testing procedure, and despite the use of complete vehicles and attempts to make test environments all-inclusive, test results require knowledgeable interpretation.

Proving grounds are, in effect, large laboratories. As with different laboratory test procedures, different test techniques will produce different results. Consideration of the various techniques and analysis tools discussed in the following sections may give the reader an understanding of the environments that vehicles must be designed to survive and may aid in the further development of accelerated corrosion tests.

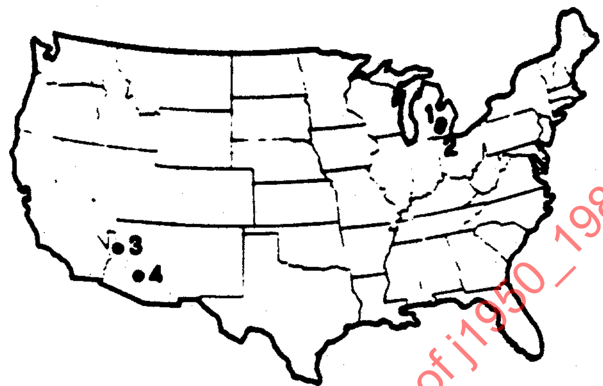
2. References

2.1 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

G. Hook; "The Historical Development of a Proving Ground Accelerated Corrosion Test." Presented at NACE Corrosion/80, March 1980, Chicago, IL.

R. Ericsson, S. Haagenrud, and J. Henriksen; "Simultaneous Measurements of Corrosiveness and Environment on Different Parts of the Automotive Body." Presented at NACE Corrosion/82, March 1982, Houston, Texas (Paper No. 260).

3. ***Locations Of Corrosion Testing Facilities***—Although laboratory tests of vehicle components and systems are conducted at various locations within an automotive company and it may have more than one proving ground facility, each company performs proving ground corrosion tests at one location only. (As of this writing, although Chrysler and AMC have merged, they have not yet consolidated proving ground testing.) The locations of these facilities are shown in Figure 1. They are centered either in southeastern Michigan (GM and Chrysler) or in Arizona (Volkswagen of America, Navistar, American Motors Corporation, Ford).



1. Milford, MI - General Motors
2. Chelsea, MI - Chrysler
3. Kingman, AZ - Ford
4. Phoenix, AZ - Navistar, American Motors, Volkswagen

FIGURE 1—PROVING GROUND CORROSION TESTING LOCATIONS

Each testing location has certain advantages. Locations in Southeast Michigan have the advantage of being near to corporate design and engineering activities so communication of test information may be optimized. Persons responsible for system corrosion performance can easily view interim test results without extensive time or travel. Locations in Arizona have the advantage of fairly consistent weather, particularly humidity. Because ambient environment has a large effect on vehicle corrosion in Michigan, test corrosion rate differences on the order of 2:1 summer-to-winter have been observed if corrective measures are not used. Arizona's low relative humidity ensures that test vehicle corrosion occurs mainly under controlled conditions in temperature/humidity chambers.

4. ***Vehicles Tested***—Various types of vehicles are proving ground tested by the automotive manufacturers. These include audit testing of production vehicles, validation testing of preproduction vehicles (prototype, pilot line, etc.), and development testing for evaluation of new designs, materials, coatings, assembly and processing techniques, etc. Vehicles tested include the full range of each manufacturer's product from subcompact cars to highway trucks and buses.

5. ***Test Methods And Facilities***—Test methods used by the various manufacturers are often different in environmental content because each test evolved separately; thus, the final results are often different. The general test methods presently in use are as follows:

5.1 General Motors—Several different test schedules are used, each having a particular area of emphasis but all having similar corrosive inputs. The "full corrosion/durability" schedule requires approximately 10 months to complete and is intended to relate to 160 000 km (approximately 10 years) of severe customer service. Major test inputs are shown in Figure 2. Rather than driving a totally preset cycle, events are combined to provide proportional corrosion (chemical) and durability (mechanical) input fitting schedule needs. This test can be modified by removing some or most of the "mild" durability inputs while leaving corrosive inputs essentially unchanged. This allows testing to be completed more rapidly while not largely affecting general and cosmetic corrosion results. However, corrosion mechanisms, which are dependent upon stress cycles or other operation cycles, will not be accelerated as greatly. Because it is believed that durability inputs (such as operation on rough roads, brake applications, operation of electrical systems, etc.) can affect corrosion results, and vice versa, these two types of test content (durability and corrosion) usually are run concurrently on a vehicle. The fastest GM Proving Ground corrosion test, which contains only the most significant durability inputs, requires about ten weeks to complete.

General Motors' corrosion test inputs are intended to relate directly to metallic general corrosion, cosmetic corrosion, and functional corrosion of systems, assemblies, electrical connectors, etc. that occur in the field. Actual perforations of body panels usually are not produced within the time frame of these tests. However, these may be predicted with some confidence using metal thickness loss measurements and perforation acceleration factors known from past experience. Some uncertainty always exists because the test time required to cause deterioration of protective organic coatings is not always known.

The General Motors corrosion test environment consists of alternate exposure to a shallow salt splash road (5% NaCl in water), an exterior salt spray (5% NaCl in water), gravel roads (portions treated with calcium chloride), a grit trough (containing sand, clay, and coal cinders in deep water), and 8 h periods of elevated temperature and relative humidity (RH) (49 °C, 100% RH). Near the beginning of each test, the vehicle is driven through deep mud to provide poultice accumulation. (See Reference 1.)

Test vehicle general corrosion exposure is monitored using bare steel coupons. Coupon weight loss is checked periodically throughout the test, and results are compared to test objectives (known general corrosion rates from field vehicles). To adjust for corrosion rate variations which might be caused by weather differences (for example, winter vs. summer testing) or test length (for example, full test or accelerated version), the number of exposures to 49°C/100% RH is varied while all other inputs remain constant.

5.2 Ford—The Ford corrosion test daily cycle is diagrammed in Figure 3. It includes 1.5 h of driving on dirt and gravel roads and a paved road onto which a thin layer of 5% salt solution is sprayed, and through a salt trough (5% NaCl), a salt spray (5% NaCl, 15 min total time), and a mud bath containing 4 parts NaCl to 1 part $CaCl_2$ for a total of 3% salt concentration in the mud. This is followed by 22.5 h in a humidity chamber at 49 °C/85% RH. This constitutes one cycle; five cycles per week are run and the vehicle is left in the humidity chamber on weekends and holidays. Total test duration is 100 cycles which approximates five years of severe field corrosion.

Minimal variation is observed among tests run at different times of the year due to minimal variation in Arizona's climate and the high percentage of time that vehicles spend in controlled temperature and humidity.

The Ford test is intended primarily to disclose perforation-susceptible areas, although some cosmetic corrosion information also is obtained. Because of the severe nature of the test environment (able to cause perforations in body panels), the test is not used to judge the performance of items such as drive shafts, springs, etc. In some cases, trailers with body panel test specimens attached are towed behind test vehicles. Specimens are rotated to ensure that all experience the same conditions. The results obtained in this way correlate well with those from test cars.

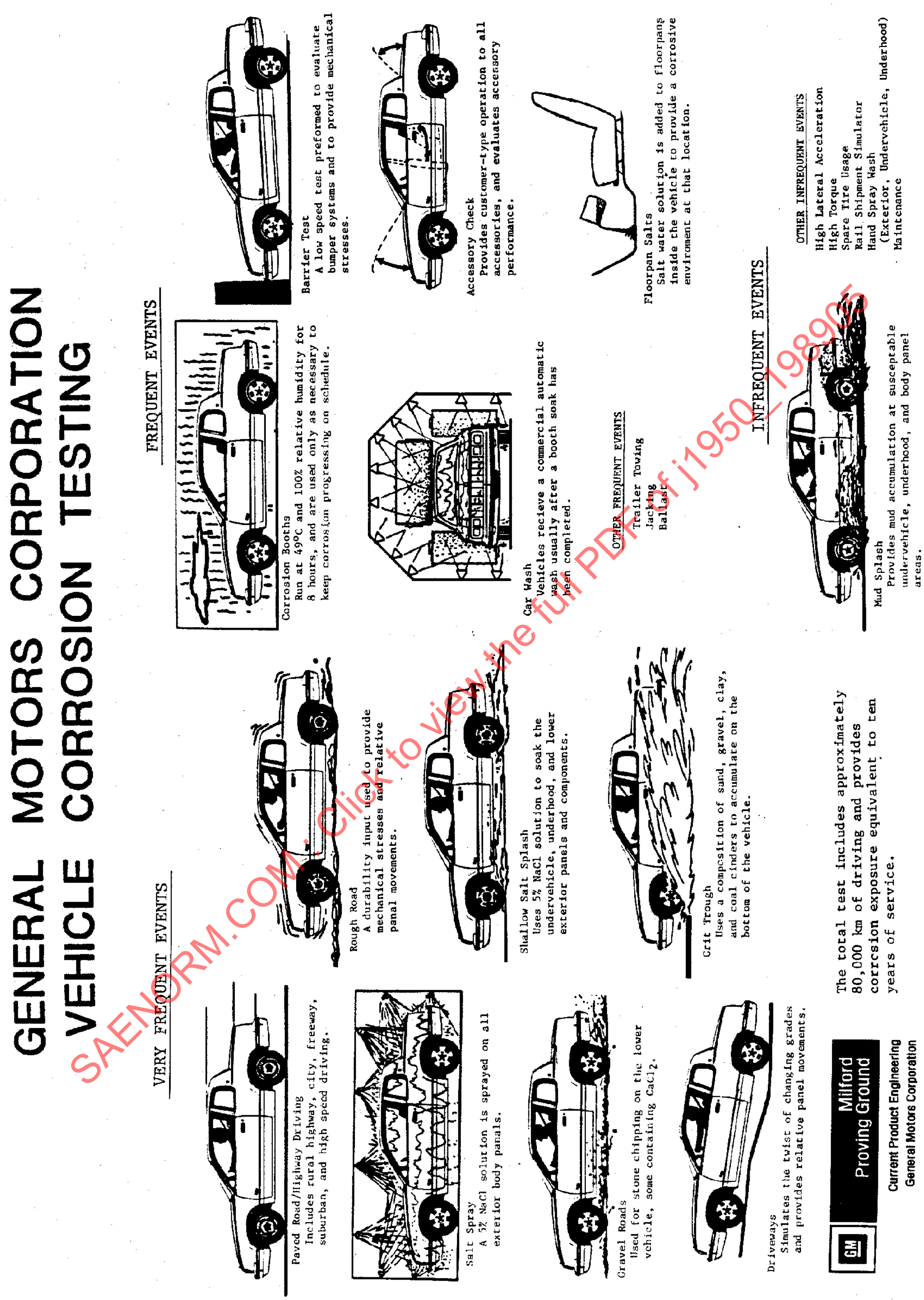


FIGURE 2—GENERAL MOTORS CORPORATION VEHICLE CORROSION TESTING

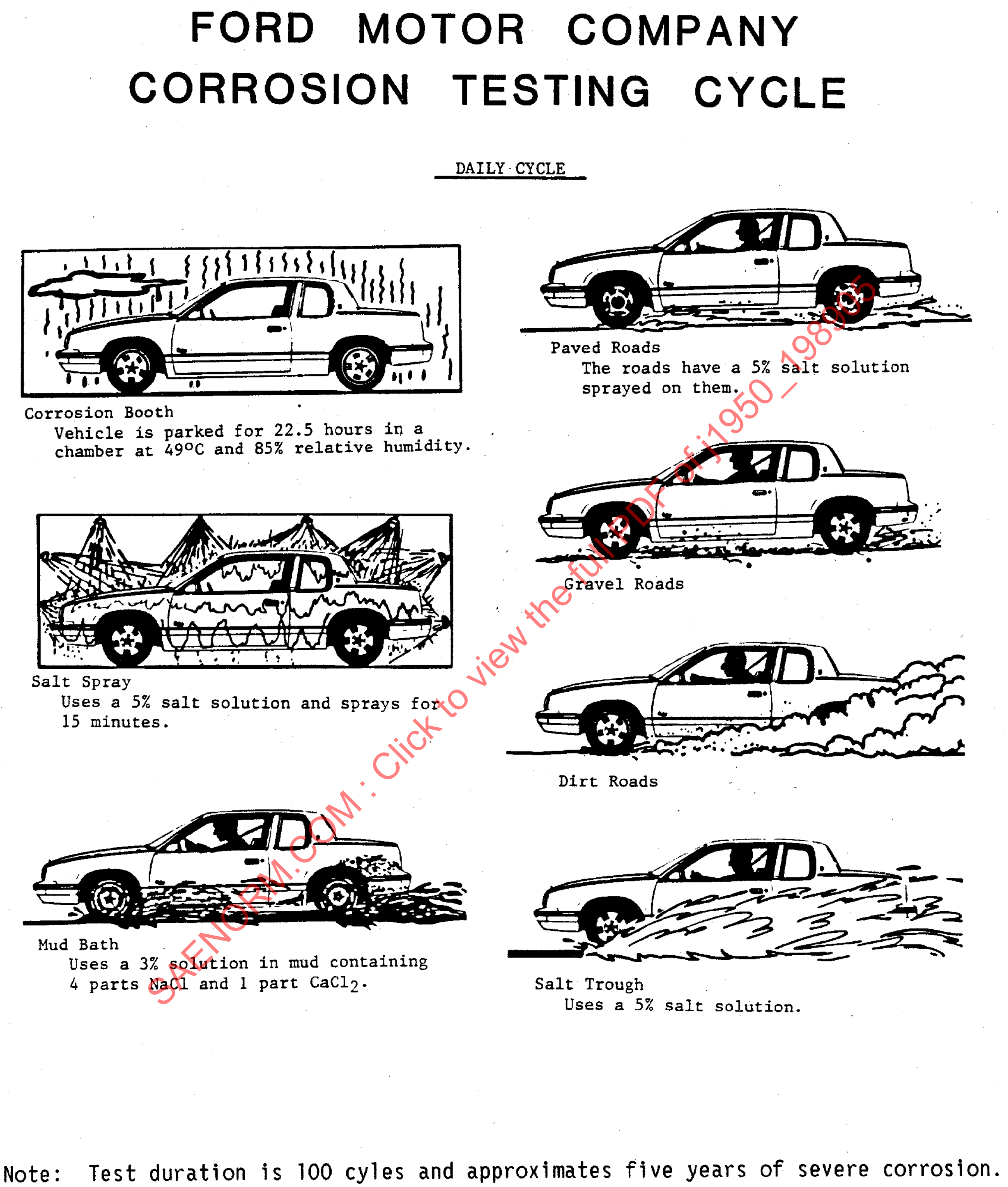


FIGURE 3—FORD MOTOR COMPANY CORROSION TESTING CYCLE

5.3 Chrysler—The Chrysler test is diagrammed in Figure 4. It has a duration of up to two years. It involves a 48 h cycle of driving (contamination), elevated temperature and humidity (38 °C, 100% relative humidity), and drying. Salt splash and spray are provided by a single facility using 0.5% NaCl, 0.5% $CaCl_2$, and 0.125% sodium metabisulfite.

Fifty test cycles are believed to correspond to 2.5-3.0 years of field exposure; tests frequently are run for several hundred cycles in order to evaluate long-term field exposure. Although good cosmetic corrosion results are obtained, some uncertainty exists in evaluating perforation corrosion. Slight differences in the environment have been found to cause relatively large differences in corrosion of bare steel coupons. Chrysler is considering the use of a controlled environment for drying periods. However, the fact that the test may last for two years should tend to minimize long-term test result differences, which might be caused by day-to-day weather variations.

5.4 Navistar—The Navistar test cycle, shown in Figure 5, is designed to indicate perforation corrosion susceptibility of medium and heavy-duty truck cabs. While the test track has facilities for stone pecking and salt and mud splash exposures, previous tests have shown these have little effect on a truck cab. The cab sits high enough off the road to normally avoid this environment. Also, these tests are extremely hard on chassis components which are not the subject of the cab corrosion test. In fact, chassis components are sometimes coated with rust inhibiting compounds or oils to extend their lives for possible use in additional tests.

Cabs are prepared in accordance with the test objectives. Blower motors are installed so that when in operation they will create a vacuum of approximately 25 mm of water inside the cab. This approximates the vehicle traveling in rain, at highway speeds, with the wing vents open. Panels may be scribed and intentional leaks may be added. Observation ports are installed in areas of interest.

Different test cycles have been tried, but the one which has shown the best correlation to actual field data in the shortest test time is alternate exposures to a 5% NaCl salt spray and a dirt road run at 30–35 mph. These are performed with vacuum motors to ensure penetration of the salt solution into every possible crevice. After a final exposure to the salt spray, the test truck is driven into a humidity chamber and exposed to a relative humdity of 100% at 38 °C. This cycle is repeated four times per week and includes an average of approximately 39 h of chamber time per cycle. Test duration is 100 cycles.

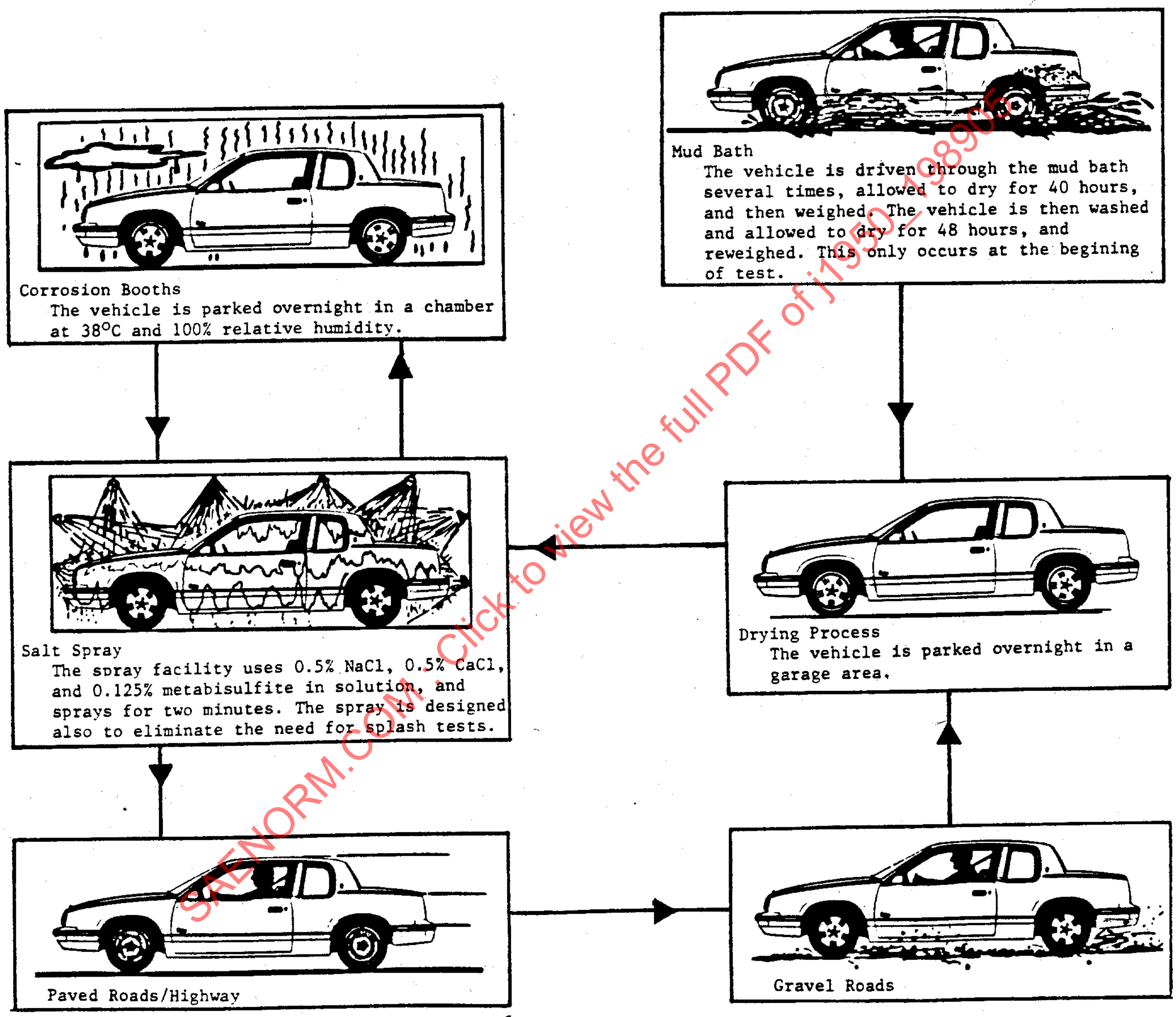
As there is little or no effect from stone pecking or other road hazards in this test, two cabs can be mounted on the same chassis. This reduces total test time and costs. Also, this is very helpful in comparing alternate materials or manufacturing processes as both cabs are exposed to exactly the same environment.

Navistar has recently closed their Phoenix test facility; future corrosion tests will be conducted at a new facility in Ft. Wayne, IN.

5.5 Volkswagen of America—The VWoA corrosion test, diagrammed in Figure 6, is basically the same as the VWAG EK2 (Germany) corrosion test with minor variations. Essentially the EK2 test was developed to comprehensively simulate the extent of corrosion damage on cars in North America for up to six years.

The test consists of subjecting a vehicle to a total of 36 h of low temperature condition at –35 °C, 700 h of dry condition at 20 °C, 1140 h in damp heat chamber at 45/50 °C and 95% RH, 60 h in salt spray chamber at 35 °C and 5% NaCl salt spray plus road cycle of a total of 7500 km on salt splash, gravel/rough, chip, mud and accelerated durability track loops, thus inducing a corrosive stress such as would occur in cars in service for six years in extreme corrosion prone areas.

CHRYSLER CORPORATION ACCELERATED CORROSION CYCLE



Note: 50 cycles approximates 2.5 to 3.0 years of corrosion.

FIGURE 4—CHRYSLER CORPORATION ACCELERATED CORROSION CYCLE

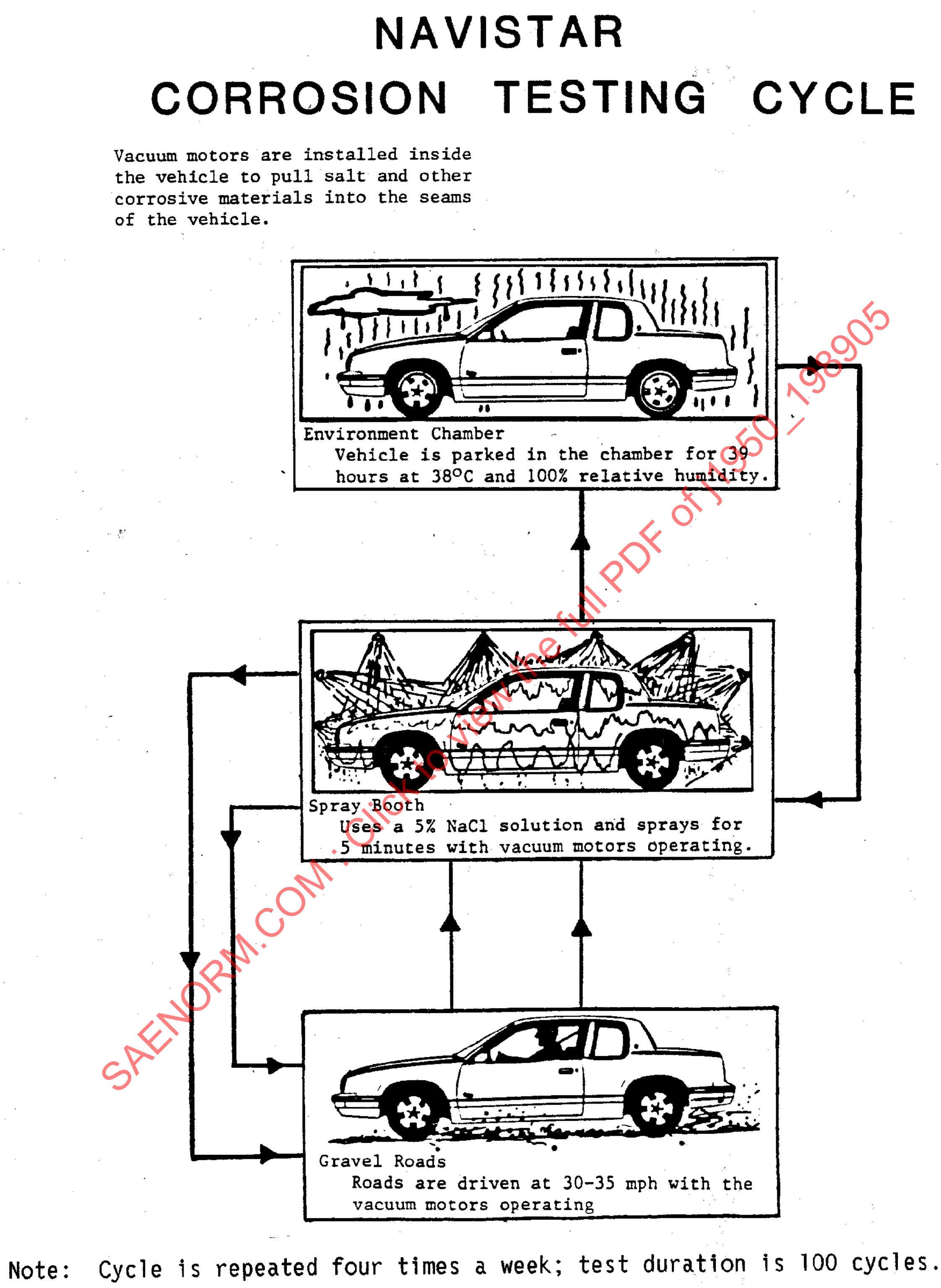


FIGURE 5—NAVISTAR CORROSION TESTING CYCLE

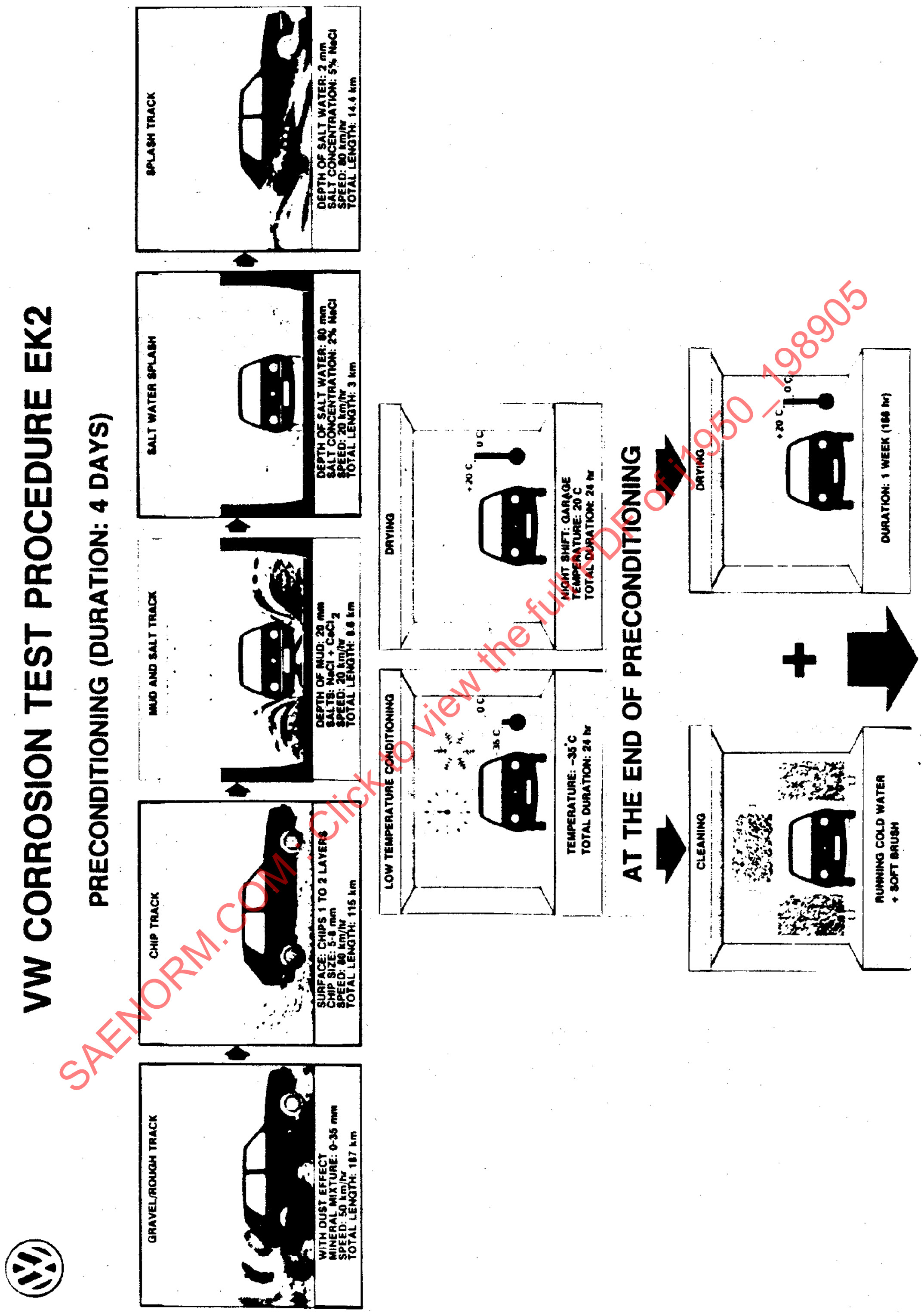


FIGURE 6A—VW CORROSION TEST PROCEDURE EK2 PRECONDITIONING (DURATION: FOUR DAYS)

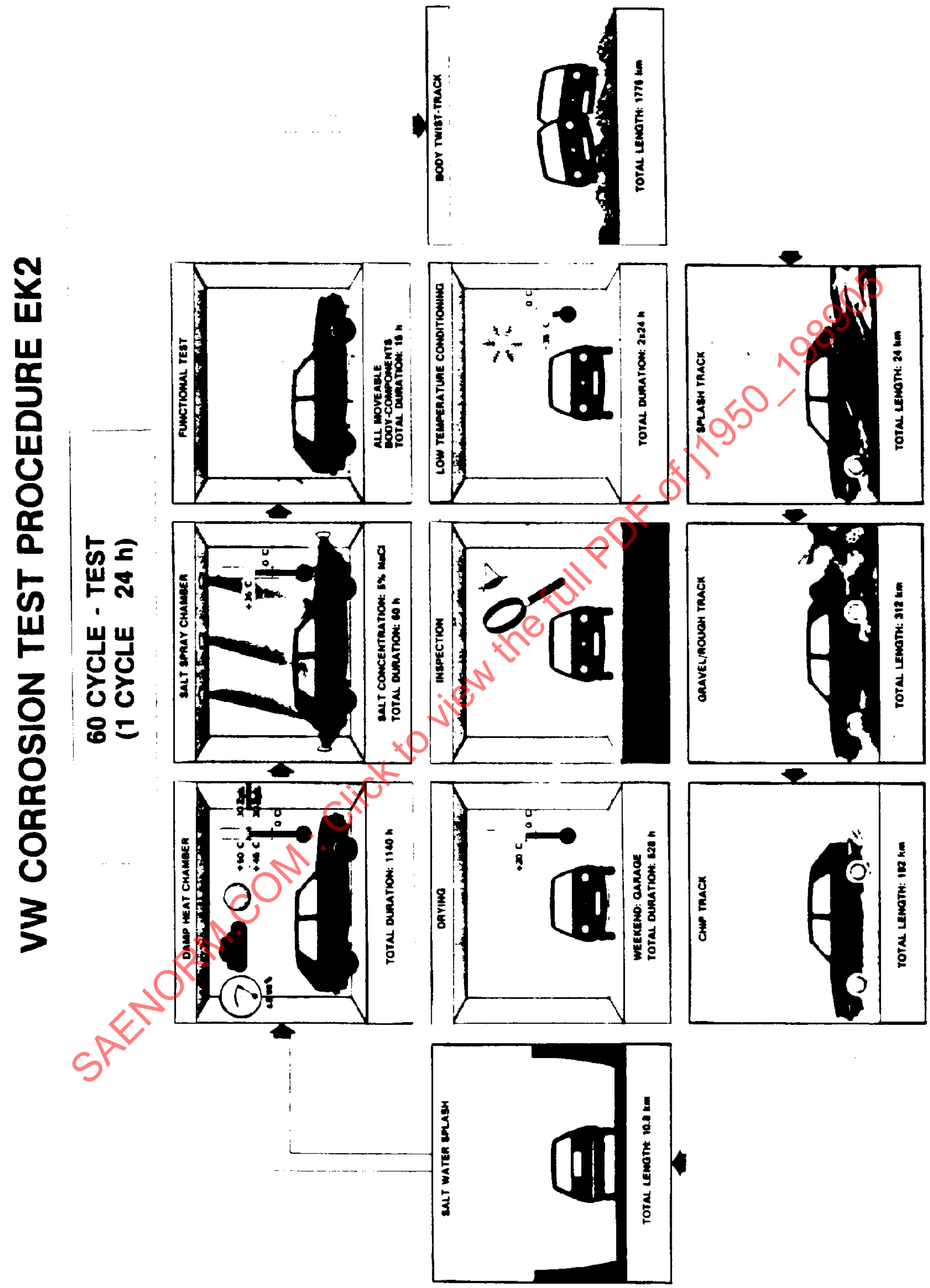


FIGURE 6B—VW CORROSION TEST PROCEDURE EK2 60 CYCLE—TEST (1 CYCLE 24 H) (CONTINUED)

Two control systems (test panels, paint scribes) have been incorporated in the EK2 test to take care of seasonal and weather related deviations and to detect potential fluctuations in the paint system.

The average material loss rate (g/m2) is determined by using 100 x 50 mm panels made of body quality sheet metal. Coupon weight loss is checked after every ten cycles and the weight loss plotted.

Corrosion creepback from paint scribes on body with respect to number of cycles is also determined and plotted.

This yields a basis for comparison with other test facilities like the "IN-Corrosion Test" at Audi and with the VWoA "PIR-Corrosion Test" at Phoenix.

Total test duration is 60 cycles which approximates six years of field corrosion service in North America. Fifteen cycles in the EK2 test corresponds approximately to a three year period in the field, indicating a nonlinear correlation.

5.6 American Motors Corporation—The corrosion test schedule used by American Motors is shown in Figure 7. With the purchase of AMC by Chrysler Corporation, future use of this test is uncertain.

6. Corrosion Effects On Vehicle Systems (Results and Interpretation)—An ideal test would cause the same types of corrosion to occur as in the field and at a known, accelerated rate of aging which is consistent for all of a vehicle's components and systems. In practice, this ideal test does not appear to be achievable. Results require interpretation on the basis of experience and knowledge of the effects of a particular test on vehicle systems and/or corrosion mechanisms.

Vehicle components/systems may be classifield into categories according to how they are affected by proving ground test environments. Categories would include (a) "closed" systems (for example, the inside of the cooling system, hydraulic system, exhaust system, etc.), (b) "open" systems (for example, exterior of body panels and other fully exposed parts), and (c) "semi-closed" systems (for example, interior of body panels, poultice accumulation areas where contaminants are not flushed away and/or where drying is inhibited).

7. Closed Systems—Environmental contaminants (salt, dirt, humidity, etc.) typically do not reach the interior of a closed system; hence, proving ground corrosion tests have little effect on internal corrosion of this type of system. In the field, periods of non-use are a large portion of a vehicle's life, and this time contributes significantly to internal corrosion in closed systems. Unless an internal corrosion mechanism occurs primarily while a vehicle is being driven (such as cavitation or erosion in the cooling system), it should be assumed that corrosion is not accelerated for these areas; that is, an "accelerated" corrosion test which requires six months to complete provides only six months of corrosion aging of closed systems.

AMERICAN MOTORS CORPORATION VEHICLE CORROSION TESTING

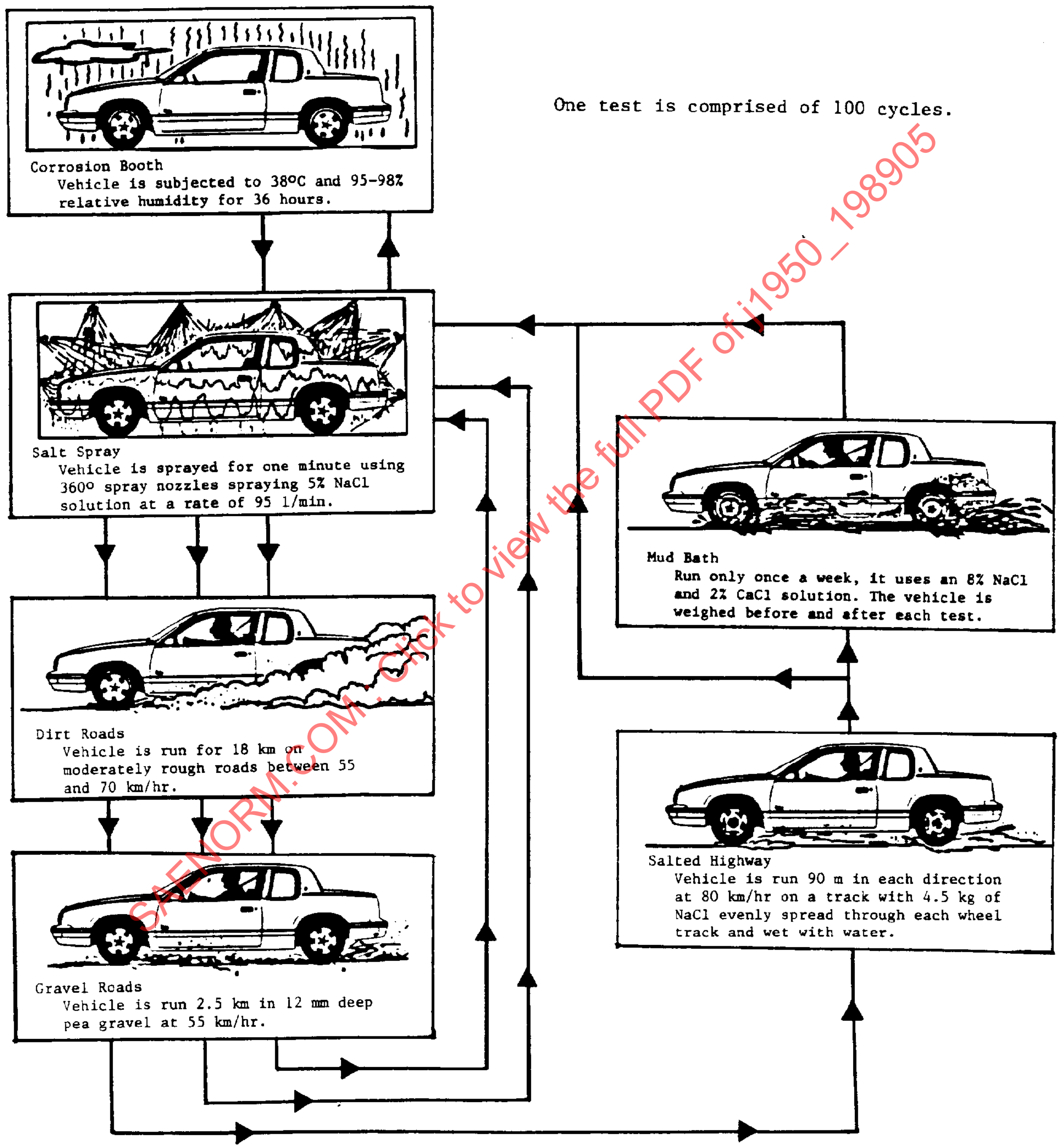


FIGURE 7—AMERICAN MOTORS CORPORATION VEHICLE CORROSION TESTING