FEBRUARY 1977 EQUIPMENT DEVELOPMENT & TEST REPORT 5100-17

# CATALYTIC CONVERTER EXHAUST SYSTEM TEMPERATURE TESTS

USDA FOREST SERVICE
EQUIPMENT DEVELOPMENT CENTER • SAN DIMAS

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# *CATALYTIC CONVERTER EXHAUST SYSTEM TEMPERATURE TESTS*

*by*

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*ABSTRACT*

In June 1975, the Forest Service Equipment Development Center at San Dimas, Calif., conducted tests to determine exhaust system temperatures on late-model vehicles. Test results showed that for normal vehicle operation, only small temperature differences occurred at any point on the exhaust system between those vehicles equipped with catalytic converters and those vehicles without catalytic converters. Both kinds of exhaust systems develop temperatures higher than those necessary to ignite ground cover. However, unless certain engine malfunctions occur, peak temperatures of converter-equipped vehicles are not appreciably higher than peak temperatures of other vehicles.

*NOTE:* The term "automobile" or "car," as used in this report, implies a sedan, sedan delivery, or station wagon. A "pickup" is a pickup truck of less than 6,000-lb GVW. "Vehicle" implies any of the above.

KEY WORDS: **Catalytic converters, exhaust system temperatures, motor vehicle fire hazard.**

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*A report on ED&T 2546–*
*Danger of ignition of ground*
*cover by catalytic converter*
*equipped vehicles.*

## *COOPERATORS*

Forest Service funds to support this study were provided by the Northern and Eastern Regions and by the Cooperative Forest Protection Division of State and Private Forestry of the Forest Service. Additional funds were provided by the California Division of Forestry and the National Highway Traffic Safety Administration, Department of Transportation.

The California Air Resources Board provided technical staff assistance for the entire study. The Environmental Protection Agency assisted in planning the test program and providing advice and suggestions on procedures. The test fleet of rented vehicles was enlarged by the loan of additional vehicles for test by both Los Angeles County and the State of California.

## *INTRODUCTION*

Starting with the 1975 model year, all U.S. and many foreign automobile manufacturers began installing catalytic converter exhaust pollution controls (converters) on vehicles of 6,000-lb gross weight, or less, as one measure to comply with Federal regulations that are a part of the continuing nationwide effort to reduce automobile exhaust pollutants. Almost immediately, concerns were expressed by fire protection personnel that converter-equipped vehicles would exhibit increased exhaust system temperatures and would increase the probability of wildfires if these vehicles were operated or parked in areas where forest fuels might contact the exhaust system. Another concern expressed was that increased exhaust system temperatures could lead to vehicle fires and be a personnel safety problem. Because of Forest Service responsibilities in both of these areas, the San Dimas Equipment Development Center (SDEDC) conducted tests to determine whether converter-equipped vehicles run at significantly hotter temperatures than other vehicles.

The problem of the fire hazard of hot vehicle exhaust systems is not a new one. It was first studied by Fairbank and Bainer (1) in 1934 and then by SDEDC in 1952, 1962, and again in 1970. In addition, studies have been accomplished on the associated problem of surface ignition temperatures of various forest fuels (2, 3, 5). Pertinent conclusions from these reports are abstracted in the appendix.

This report does not deal with ignition temperatures, incidence of malfunctioning vehicles in the fleet, or other related items, nor does it address possible problems of the ejection of catalyst under extreme conditions, catalyst aging, etc. Instead, it concentrates on the measurement of exhaust system surface temperatures of 1974-1975 passenger vehicles and whether or not these temperatures are higher than those of earlier model vehicles.

## *TEST PROGRAM OBJECTIVES*

This report presents the results of tests that were designed to obtain answers to the following specific questions:

1. Are the peak equilibrium exhaust system temperatures obtained during road and dynamometer tests higher on converter-equipped vehicles than those vehicles not equipped with converters?

2. What is the hottest point on the exhaust system of both converter-equipped vehicles and those without converters?

3. Do severe operating conditions cause more significant increases in exhaust system temperatures of converter-equipped vehicles than those without converters?

4. How do exhaust system temperatures of converter-equipped vehicles compare with other vehicles at maximum horsepower, cruise, and coasting modes?

5. What is the effect of mistuning or engine malfunction (spark plug misfire, air pump disconnection, etc.) and operating mode on exhaust system temperatures for converter-equipped vehicles and those without converters?

6. Do catalytic converters cause exhaust system temperatures that would lead to hazard to personnel under certain operating conditions?

To determine completely whether or not the wildfire hazard is increased by the introduction of converters, it would also be necessary to know the ignition characteristics of forest fuels (this point is covered by a brief literature review in the appendix), incidence of engine malfunction in the vehicle population used on the National Forests, and number, duration, and location of vehicle trips both on-road and off-road in the National Forests. No data were gathered on these items as they were beyond the scope of this study.

To evaluate possible personnel hazards, information would be needed on the configuration of, and materials used in, fuel systems, interiors, and underbody parts of vehicles. The collection of temperature data at a few points considered critical near the fuel tank and on the floor pan was included in the test plan.

## *PROCEDURES*

### *Test Fleet*

A fleet of 37 cars was selected representing, as far as possible, the 1974-1975 nationwide population. The 1975 models were mostly California cars since California has more stringent exhaust pollution control requirements than the other 49 States. Most 1975 models operated in the other 49 States are equipped with a different emission control system. The cars tested were procured from local rental agencies or loaned to SDEDC by other units of the Forest Service, State of California, County of Los Angeles, and other Government agencies. Table 1 shows the test fleet along with the average maximum exhaust system temperature for three operating modes (these temperatures are explained later).

### *Road Tests*

The road tests were conducted on the Mt. Baldy test course, Angeles National Forest, Calif. This test course is laid out on a 7-mile section of road with an average 4-percent grade. Its starting elevation is about 2,000 ft, and the end of the test section is about 3,500 ft. Maximum temperatures were obtained on a portion of the test section where the grade is about 7½ percent. This test course was long enough to insure that starting exhaust system temperatures would not affect final results. The road tests were run in "Drive" gear (automatic transmission) at 40 mph and on the sections of the course where 40 mph could not be maintained, the vehicle was run at wide-open throttle.

Previous testing (2) has shown that when grade and load are such, wide-open throttle operation leads to about 40 mph road speed in one gear lower than direct drive (i.e., second gear for a vehicle equipped with a three-speed manual transmission). All test vehicles considered here were equipped with automatic transmissions which automatically selected the most appropriate engine speed-gear ratio combination available. This led to engine speeds for the test vehicles which were very nearly equivalent to speeds which would have been obtained in one gear lower than direct drive had the vehicles been equipped with manual transmissions. Therefore, the road test data obtained with this present test program were comparable to those obtained during the previous testing.

All vehicles were run "as received;" no engine tuning or adjustment was made. Each vehicle was loaded with two test technicians, approximately 80 lb of instrumentation, and a full gasoline tank. No attempt was made to load the vehicle to its maximum permissible gross vehicle weight. In addition to the "as received" tests, selected vehicles were run with one spark plug wire disconnected. The test sequence began at the bottom of the test section. The fully warmed-up vehicle was driven "as received" up the test course at 40 mph (or as close to it as possible). At the end of the course, the vehicle was pulled off the road and allowed to idle. As the vehicle idled, exhaust system temperature cool-down rates were monitored. The vehicle was then allowed to coast down the test course and at the bottom was again pulled to the side of the road; its engine was stopped, and one spark plug wire was disconnected. The entire test procedure was then repeated.

The 1970 tests (2) have shown that operation on the Mt. Baldy test course leads to higher exhaust system temperatures than any other type of driving including freeway, around town, country road in mountainous terrain with an average grade of 8 percent, or a Forest Service unpaved road with an average 9 to 11 percent grade.

### *Dynamometer Tests*

Dynamometer tests simulating running vehicles under different road conditions were made. The modes and conditions they were intended to simulate are described in table 2. Figure 1 shows a test vehicle in place on the dynamometer.

*Figure 1. Test vehicle undergoing dynamometer phase of test program.*

A 15-hp axial fan provided cooling during the dynamometer tests. It is recognized that this fan did not provide wind velocities comparable to those obtained during the road tests (2). The fan was positioned with its axis parallel to the waistline of the test vehicle and the front of the fan assembly 18 inches directly in front of the vehicle grill.

Several engine malfunctions (one at a time) were induced in some of the test vehicles to evaluate the effect of these malfunctions on exhaust system temperatures. These malfunctions are described in table 3.

*Table 1. Test fleet and average maximum exhaust system surface temperature*

| Year | Vehicle | Quantity | Road peak temp °F | Mode B 1/ peak temp °F | Mode M 1/ peak temp °F |
|---|---|---|---|---|---|
| 75 | AMC Gremlin 2/ 3/ | 1 | 1,025 | 1,080 | – |
| 75 | AMC Gremlin | 2 | 948 | 1,028 | 465 |
| 74 | AMC Hornet 3/ | 1 | 960 | 1,045 | – |
| 75 | AMC Hornet | 2 | 850 | 985 | 465 |
| 75 | AMC Matador | 1 | 840 | – | – |
| 74 | Plymouth Satellite 3/ | 3 | 865 | 970 | 478 |
| 75 | Plymouth Fury 2/ | 1 | 810 | 950 | – |
| 75 | Plymouth Fury | 4 | 1,040 | 1,124 | 420 |
| 75 | Chrysler Newport | 1 | 865 | 1,030 | 475 |
| 74 | Ford Pinto 3/ | 1 | 935 | 1,035 | 295 |
| 75 | Ford Pinto | 1 | 1,045 | – | – |
| 74 | Ford Torino 3/ | 2 | 835 | 965 | 500 |
| 75 | Ford Torino | 2 | 958 | 1,035 | 543 |
| 74 | Chevrolet Nova 3/ | 2 | 730 | 947 | 365 |
| 75 | Chevrolet Nova | 2 | 1,073 | 1,110 | 390 |
| 74 | Chevrolet Impala 3/ | 1 | 1,110 | 1,115 | 550 |
| 75 | Chevrolet Impala 2/ | 2 | 842 | 915 | 405 |
| 75 | Chevrolet Impala | 3 | 1,197 | 1,295 | 442 |
| 75 | Chevrolet Monte Carlo | 1 | 1,010 | 1,115 | – |
| 75 | Buick Regal 2/ | 2 | 845 | 1,005 | 440 |
| 75 | Buick Regal | 1 | 840 | 1,010 | – |
| 75 | VW Rabbit | 1 | 1,190 | – | – |

1/ See table 2 for explanation of mode.

2/ 49-State vehicle; all other 1975's are Calif.

3/ Not equipped with converter.

The efficiency of the converter was measured on some vehicles during dynamometer tests. The reason for this was concern that the severe operating conditions of this test would alter the effectiveness of converters (this was unfounded for any of the test vehicles). In addition, on four cars, the ignition timing, idle speed, idle mixture, ignition dwell, dwell variation, distributor advance, and the operation of the choke valve rod and coil were checked to determine whether or not they were within manufacturer's specifications. (They were.)

*Table 2. Dynamometer test modes and corresponding road conditions*

| Mode | Speed/mph | Load/hp | Gear | Fan | Road conditions simulated |
|---|---|---|---|---|---|
| A | 20 | 7 | D | On | Light duty driving, "around town" |
| B | 40 | Calculated from test weight | D | On | Mt. Baldy course |
| C | 40 | Maximum | L2 | On | Maximum temperature, wide-open throttle, grade climbing, towing a trailer |
| D | 50 | 30 | D | On | "Clayton High Cruise." (This mode used in California Air Resources Board in their testing ) |
| E | 60 | 12 | D | On | Normal highway cruise |
| I | Idle | 0 | N | Off | Roadside idling |
| M | 30 | Motoring | D | On | Coasting down a long grade |

*Table 3. Induced malfunctions*

| Identifier | Description |
|---|---|
| 0 | "As received"—no malfunctions induced |
| 1 | Choke stuck (1/3 closed) |
| 2 | One plug wire pulled |
| 3 | Two plug wires pulled |
| PD | Air pump disconnected |
| TR | Ignition timing retarded $5^{o}$ |

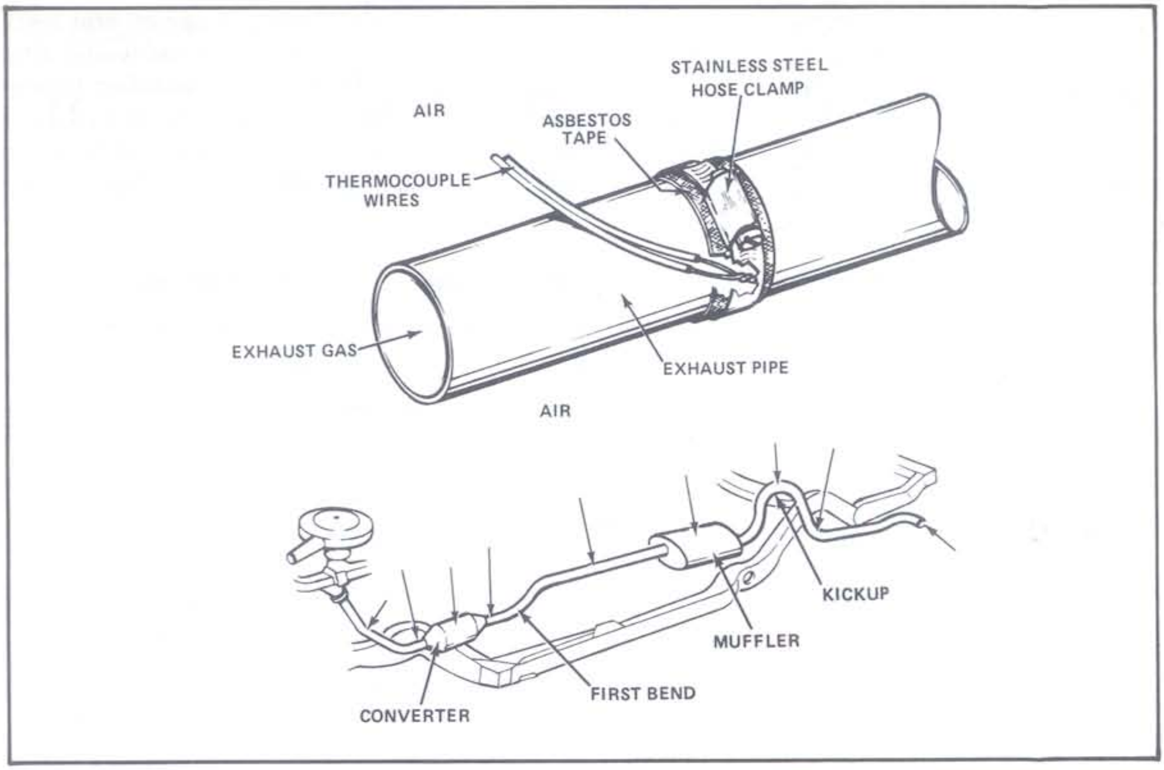


*Figure 2. Approximate location of thermocouples on lower surfaces of tailpipe, catalytic converter, heat shields, and muffler, and method used to attach the thermocouples.*

### *Instrumentation*

Each test vehicle's exhaust system was instrumented at several locations (lower surface of the tailpipe, converter, and muffler) with Chromel-Alumel thermocouples. Figure 2 shows typical locations of thermocouples for a typical exhaust system as well as the method used to attach the thermocouples. Where heat shields were installed, thermocouples were also attached both under the heat shield (directly upon the exhaust system) and on the lower side of the heat shield.

The readout devices were Easterline-Angus, Model 1124E, $0^{\circ}$ to $2{,}000^{\circ}$ F multipoint recorders, run at ½ ipm. The calibration of these recorders is traceable to the National Bureau of Standards (NBS). A sample of the readout from this instrumentation system is shown in figure 3. Equilibrium or peak temperatures, as appropriate, were read directly from these readouts. In a few cases, the tests were shut down before peak temperatures were reached. When this happened, peak values were extrapolated. All thermocouple wire was certified traceable to NBS. Also, calibration at three known temperature points was made for each entire instrumentation system before and after testing. The calibration points were the ice point, steam point of water, and the zinc point—$32^{\circ}$, $212^{\circ}$, and $787^{\circ}$ F, respectively.

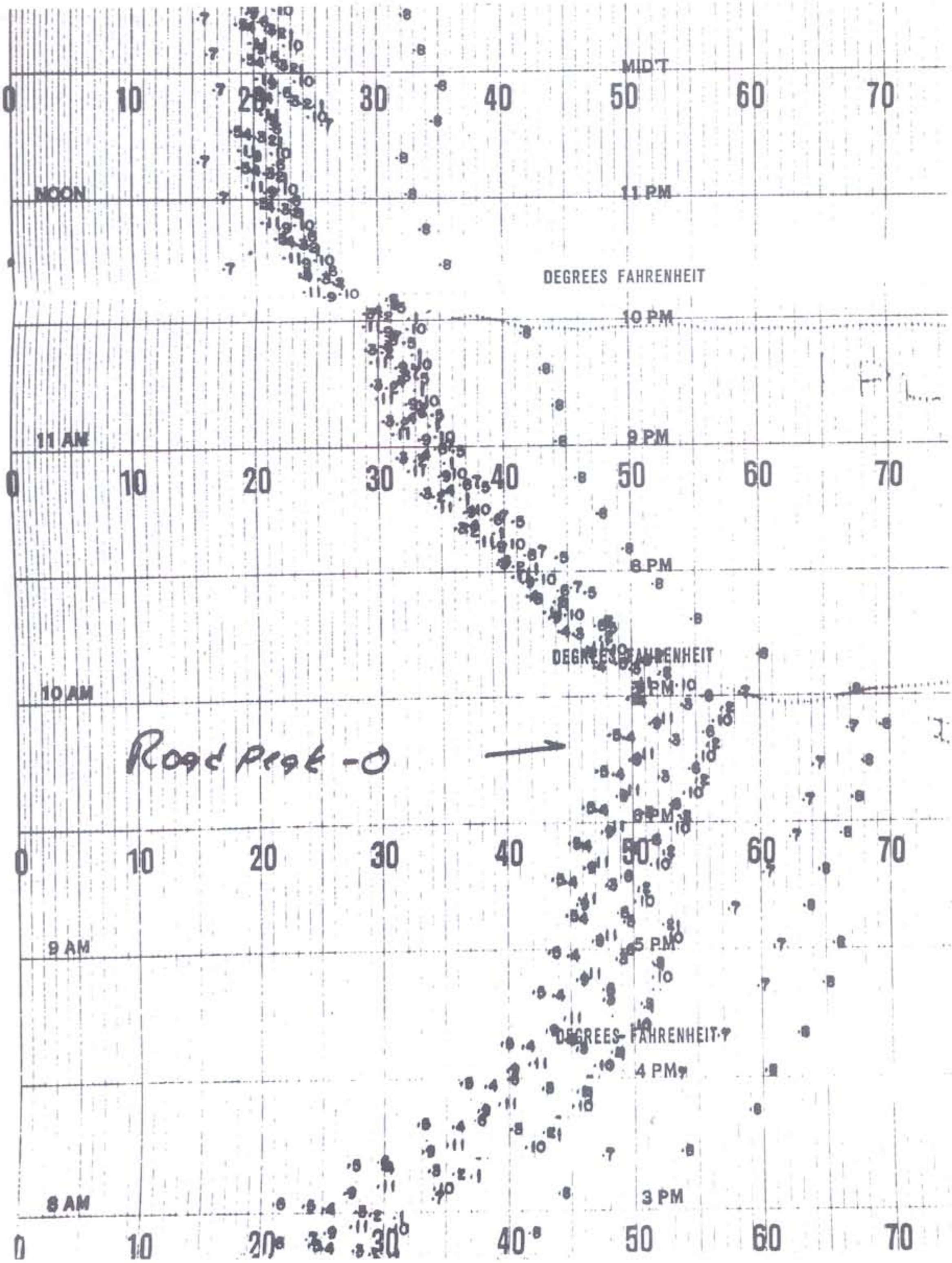


*Figure 3. Data readout sample.*

## *RESULTS AND ANALYSIS*

### *Exhaust System Surface Peak Temperatures*

Table 1 shows average exhaust system surface temperatures for each type of vehicle tested in the "as received" condition. The "road peak" temperatures were obtained on the Mt. Baldy test run. The Mode B peak temperatures are the maximum equilibrium temperatures obtained during the dynamometer mode which simulated the Mt. Baldy test run conditions and were, in most cases, achieved in between 4 and 9 minutes. Generally, dynamometer temperatures are about 100° F higher. The Mode M peak temperatures were taken during the dynamometer mode which simulated coasting in gear at 30 mph. The maximum Mode M temperature obtained was 550° F, well below the hazardous temperature for most ground-cover fuels (2, 3, 5).

Table 4 compares exhaust system temperatures measured at the hottest location of the exhaust system for various groups of vehicles. Data cited for the 1952 vehicles are taken from the 1952 Forest Service report on vehicle exhaust temperatures (7); for the 1960 through 1969 vehicles, from the 1970 Forest Service ED&T Report 5100-15 (2); and for the other three groups, from the current testing program. The standard deviation (std devn) is an indication of the range above or below the mean within which the temperatures for each group would be expected to fall if further individual vehicles were sampled. The probable error of the mean (pem) indicates that about one half of any number of test vehicles the same size as the present sample would show approximately the same mean maximum exhaust system temperature during dynamometer tests. For example, the 1975 California cars showed a mean maximum exhaust system temperature of 1,079° F and if eight more were tested, four of them would show a mean maximum exhaust system temperature of 1,079° F, plus or minus 25°.

*Table 4. Comparison of exhaust system surface maximum temperatures for various groups of vehicles*

| Group | Dynamometer tests temp °F | | | Road tests temp °F | | |
|---|---|---|---|---|---|---|
| | mean | std devn | pem | mean | std devn | pem |
| 1952 vehicles | 760 | 123 | 37 | – | – | – |
| 1960-66 cars | 1,091 | 101 | 16 | 954 | 106 | 16 |
| 1968-69 pickups | 1,016 | 71 | 17 | 879 | 71 | 17 |
| 1974 cars | 999 | 72 | 16 | 856 | 142 | 32 |
| 1975 cars (49-State) | 960 | 65 | 17 | 823 | 44 | 11 |
| 1975 cars (Calif.) | 1,079 | 158 | 25 | 991 | 155 | 23 |

*Table 5. Exhaust system surface maximum temperatures exceeded by 84 percent for each group*

| Group | Dynamometer tests temp °F | Road tests temp °F |
|---|---|---|
| 1952 vehicles | 637 | – |
| 1960-66 cars | 990 | 848 |
| 1968-69 pickups | 945 | 808 |
| 1974 cars | 927 | 714 |
| 1975 cars (49-State) | 895 | 779 |
| 1975 cars (Calif.) | 921 | 836 |

The standard normal variable for all groups in table 4 was calculated using the Kruskal-Wallis method, an approximation of the $chi^2$ distribution (8). The differences in dynamometer and road test mean temperatures between groups were found to be significant at a level greater than 99.5 percent. In a similar manner, the Wilcoxon test was applied to the two groups of 1975 vehicles to determine the significance in mean temperature differences. Differences were significant at a 92-percent level. Therefore, even though small, the differences in mean temperatures shown in table 4 are real.

Table 5 shows the mean minus one std devn, or the maximum exhaust surface temperature exceeded by 84 percent for each group listed. It can be seen that for all vehicle groups except the 1952 vehicles, a dynamometer test maximum exhaust system temperature of 895° F or more is achieved by 84 percent of the vehicles, while a maximum exhaust system surface temperature of 714° F or greater is achieved during road tests.

### *Temperature Distribution Along Exhaust Systems*

Figure 4 shows the temperature distribution along the lower surface of the exhaust system for Chevrolet Impalas. These curves are typical of vehicles tested. Characteristically, 1975 model cars equipped with converters to operate in the 49 States, other than California, and 1974 model cars, without air pumps, show the hottest surface temperatures at the first bend of the exhaust system (where the general direction of gas flow first becomes horizontal). It is apparent that temperatures remain high from the first bend to a point 100 inches or so along the exhaust system (generally about the area of the muffler). For 1975 California cars, all of which have an air pump as well as a converter, the first bend temperatures are somewhat lower than those vehicles without converters, with the highest temperature recorded at the converter outlet. The temperatures then decrease along the exhaust system until the kickup area (that area where the exhaust pipe "kicks up" over the rear axle).

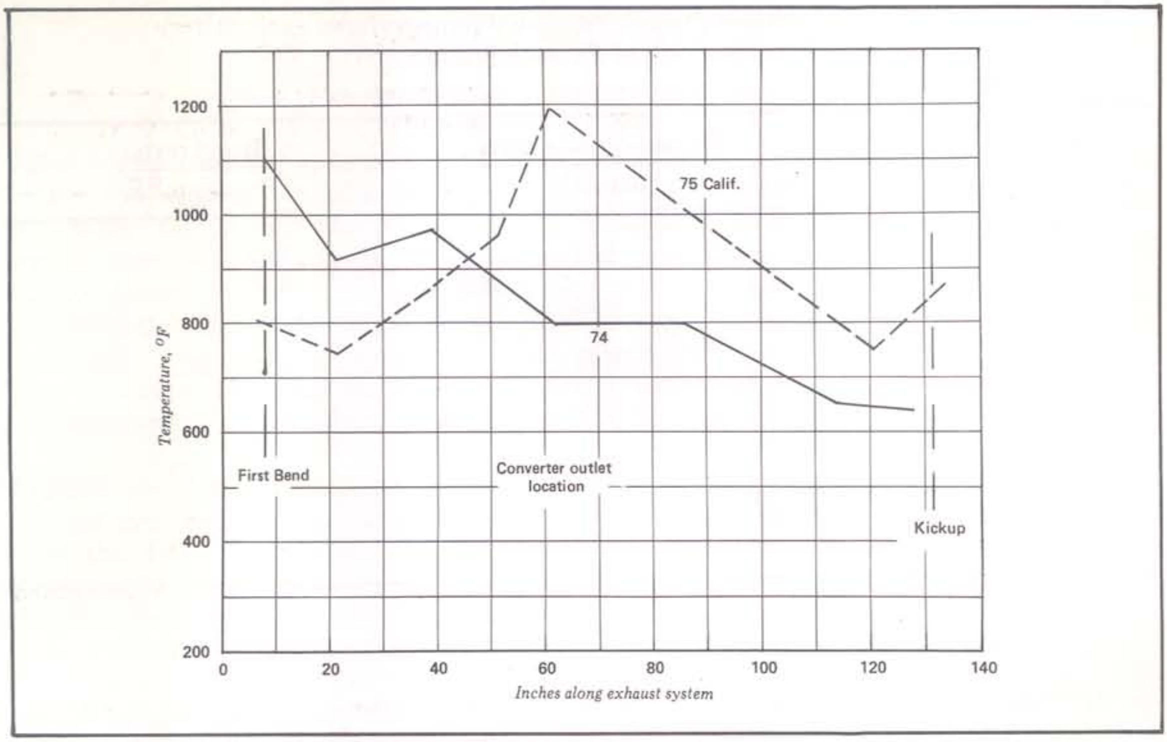


*Figure 4. Temperature distribution along exhaust system (Chevrolet Impalas).*

### *Effect of Operating Mode on Exhaust System Surface Temperatures*

Table 6 shows the effect of various operating modes on maximum exhaust system surface temperatures for Chevrolet cars. These are representative of the entire test fleet. Operating modes are described in table 2. Generally speaking, the operating modes which lead to highest exhaust system temperatures are those which employ large throttle openings at maximum torque rpm (2). Table 6 data show this to be true for both converter-equipped vehicles and those without converters. The coasting mode (M) shows the lowest temperatures seen in any of the test modes for all three classes of vehicles.

### *Effect of Engine Malfunctions on Maximum Exhaust System Surface Temperatures*

Table 7 shows the effect of engine malfunctions on maximum exhaust system surface temperatures. With vehicles not equipped with converters, all of the malfunctions, each of which results in richer mixtures entering the exhaust system, lead to lower temperatures. However, with converter-equipped vehicles, this enrichening leads to higher temperatures, the most severe temperature increase being seen with malfunction Mode 3 (two spark plug wires disconnected). This situation prevails under both the wide-open throttle and motoring (coasting) conditions, although as can be seen from table 7, the motoring temperatures are much lower than wide-open throttle temperatures.

Mode 1 (choke stuck) does not lead to temperatures much higher than Mode 0 (as received), because, with the choke stuck, the high flow rates (wide-open throttle) necessary to achieve high gas stream temperatures are impossible.

*Table 6. Maximum exhaust system surface temperatures for various operating modes for Chevrolet Impalas and Monte Carlos*

| Mode | 1974 Model temp °F | 1975 49-State model temp °F | 1975 California model temp °F |
|---|---|---|---|
| A | 730 | 583 | 719 |
| B | 1,115 | 915 | 1,216 |
| C | 1,160 | 1,100 | 1,237 |
| D | 1,195 | 850 | 992 |
| E | 1,065 | 817 | 831 |
| I | 660 | 468 | 489 |
| M | 550 | 405 | 428 |

*Table 7. Effect of engine malfunctions on exhaust system temperatures*

| Mfr 1/ | Road tests 3/ °F | Temperature change 2/ Dynamometer tests 3/ °F | | | Dynamometer tests 4/ °F | | |
|---|---|---|---|---|---|---|---|
| | Malfunction induced 5/ | | | | | | |
| | 2 | 1 | 2 | 3 | 1 | 2 | 3 |
| AMC | 217 | 158 | 263 | 463 | – | 237 | 280 |
| GM | 271 | 20 | 220 | 415 | 194 | 84 | 280 |
| Ford | 72 | 67 | 237 | 337 | 110 | 150 | 325 |
| Chrysler | 240 | –25 | 174 | 320 | 52 | 85 | 80 |
| AMC | –107 | –200 | –137 | –330 | – | – | – |
| GM | –7 | –63 | –37 | –37 | 182 | 67 | 37 |
| Ford | –67 | –68 | –70 | – | –20 | –20 | –20 |
| Chrysler | –21 | –73 | –115 | –118 | –13 | –83 | –138 |

1/ First four listed, converter-equipped; remainder without converters.

2/ Minus sign (–) indicates malfunction results in cooler temperatures.

3/ Wide-open throttle, 40 mph, 7½-percent grade.

4/ Motoring, 30 mph

5/ See table 3 for induced malfunction identifier and description.

The failure of a converter air pump was simulated (air hose disconnected) on two vehicles, and the exhaust system temperatures dropped an average of about 100° F from as received conditions.

Retarding the ignition timing would be expected to increase exhaust stream temperatures (2, 6), and tests on two vehicles verified this, with an average rise of about 100° F for a 5-degree retardation.

### *Cooling Characteristics*

Figures 5 through 7 show the results of the cooling tests. These curves were taken directly from the data traces for the "as received" tests on the Mt. Baldy test course. At the top of the test course, the vehicle was pulled over to the side of the road and allowed to idle. The figures represent the averages of data traces taken while idling and show that all exhaust systems remain above temperatures which could ignite ground cover for several times longer than the time required for ignition (2, 3, 5).

### *Exhaust Gas Temperatures*

The hot exhaust gas is not expected to be a significant fire hazard. Data from measurements made of exhaust gas temperatures on one vehicle 1 inch inside the tailpipe and 1 inch from the end of the tailpipe in the free atmosphere are shown in table 8. In all cases, the temperature dropped to below 550° F at 1 inch from the end of the tailpipe.

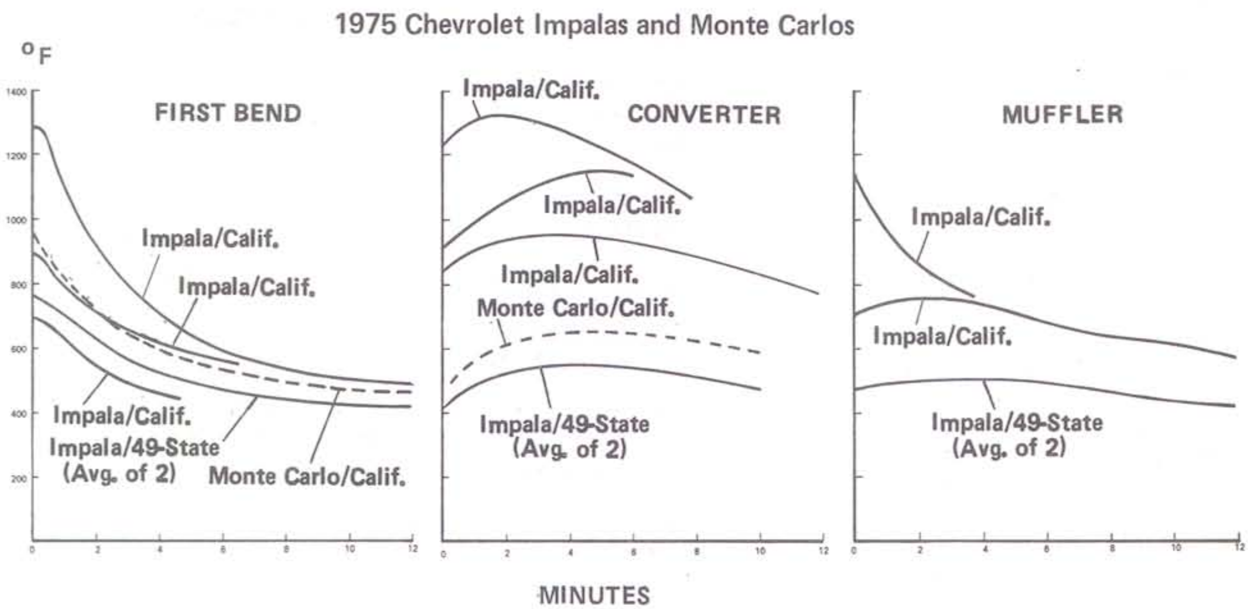


*Figure 5. Cool-down temperature time curves for 1975 Chevrolet Impalas and Monte Carlos.*

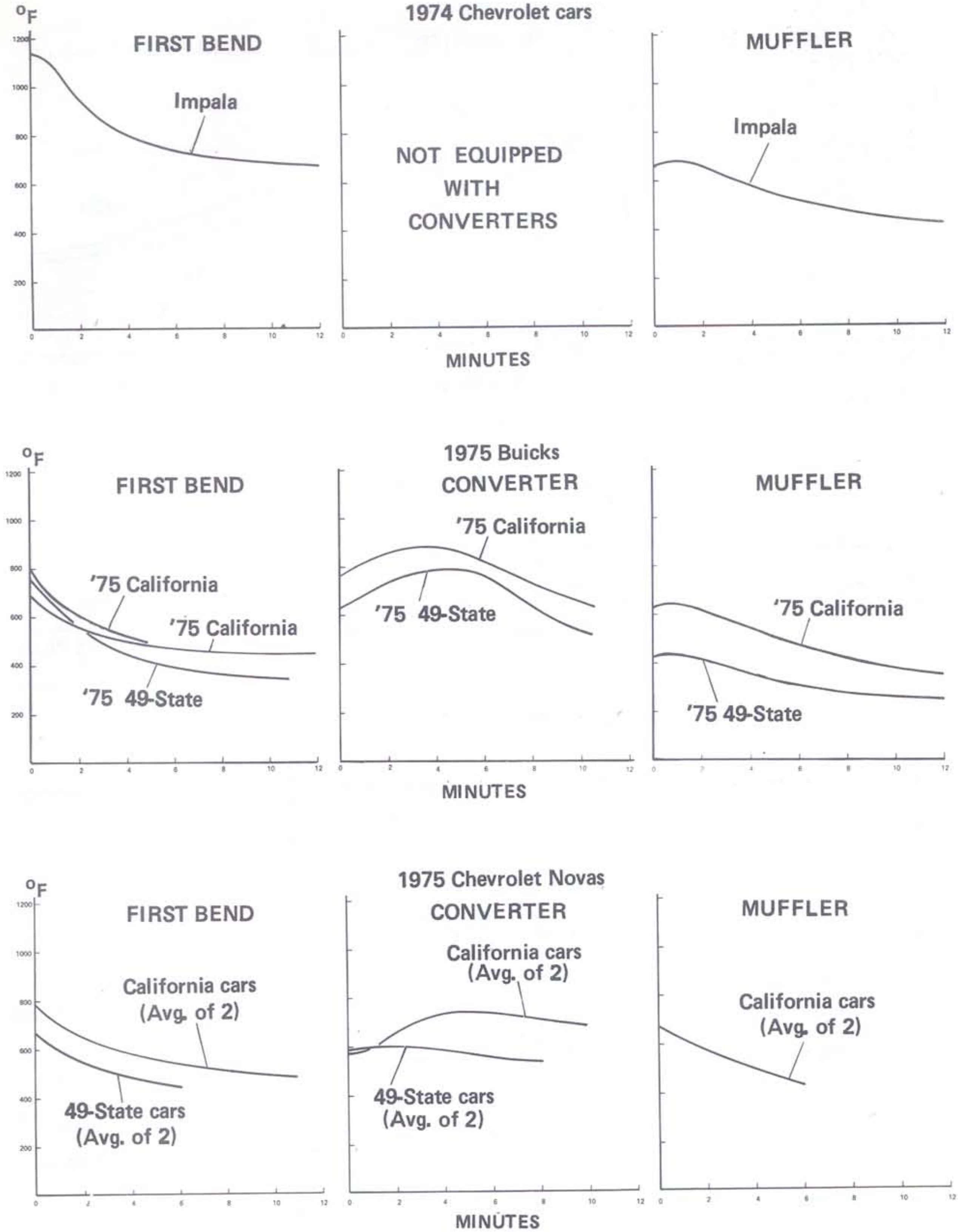


*Figure 6. Cool-down temperature time curves for 1974 Chevrolets, 1975 Buicks, and 1975 Chevrolet Novas.*

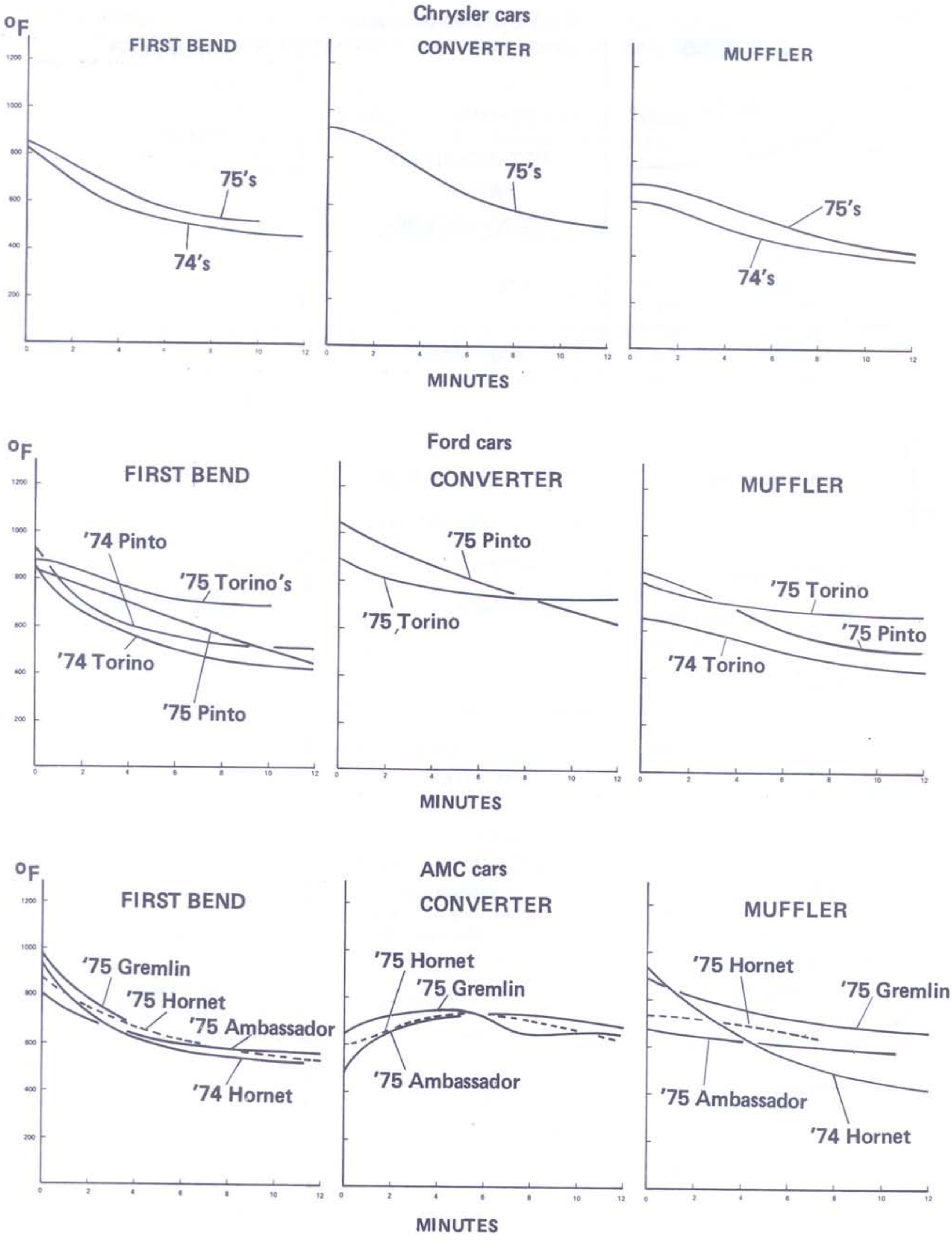


*Figure 7. Cool-down temperature time curves for Chrysler, Ford, and AMC cars.*

*Table 8. Exhaust gas cooling, 1974 Hornet*

| Mode | Temp °F 1 inch inside tailpipe | Temp °F 1 inch from end of tailpipe |
|---|---|---|
| Road 0 | 923 | 460 |
| A 0 | 652 | 265 |
| B 0 | 1,015 | 450 |
| C 0 | 1,160 | 520 |
| D 0 | 1,107 | 495 |
| E 0 | 1,065 | 470 |
| I 0 | 505 | 220 |
| M 0 | 395 | 175 |
| B 2 | 900 | 370 |
| D 2 | 1,010 | 415 |
| M 2 | 250 | 150 |

### *Personnel Hazards and Danger of Property Damage Observations*

On a few vehicles, thermocouples were placed on the floor pan inside the vehicle to determine whether temperatures would rise to the point where they might ignite interior materials. The temperatures shown in table 9 are those maxima obtained during road tests. Dynamometer test temperatures at these locations were somewhat higher, but it is felt that dynamometer testing of this situation is not completely valid, because the underbody airflow obtained during dynamometer testing does not adequately simulate that obtained during actual on-road operation.

Under some combinations of operating condition and malfunction, exhaust system temperatures can become hot enough to cause burning of nonmetallic fuel line elements. These conditions caused burning of undercoating and minor rubber underbody parts (fig. 8) during the test program under wide-open throttle dynamometer testing. Table 10 shows the hottest temperature obtained at the thermocouple closest to the fuel tank during road tests with one spark plug wire disconnected for converter-equipped vehicles and "as received" for vehicles not equipped with converters.

*Table 9. Floor pan maximum temperatures obtained during road tests*

| Vehicle 1/ | Temp °F over converter or converter location 2/ | Temp °F over muffler | Temp °F over kickup | Temp °F in area where exhaust pipe passes closest to floor pan |
|---|---|---|---|---|
| 1975 Matador | 140 | 270 | 155 | 270 |
| 1974 Impala | 170 | 180 | 180 | – |
| 1975 Monte Carlo | 165 | 360 | 200 | 390 |
| 1974 Pinto | 190 | 220 | 155 | – |
| 1975 Pinto | 240 | 210 | 280 | 335 |
| 1974 Torino | – | 250 | 150 | – |
| 1975 Fury | 155 | 160 | 180 | 190 |

1/ All 1975 vehicles are California converter-equipped.

2/ For vehicles not equipped with converters, temperatures were measured over the location where the converter would be, if so equipped.

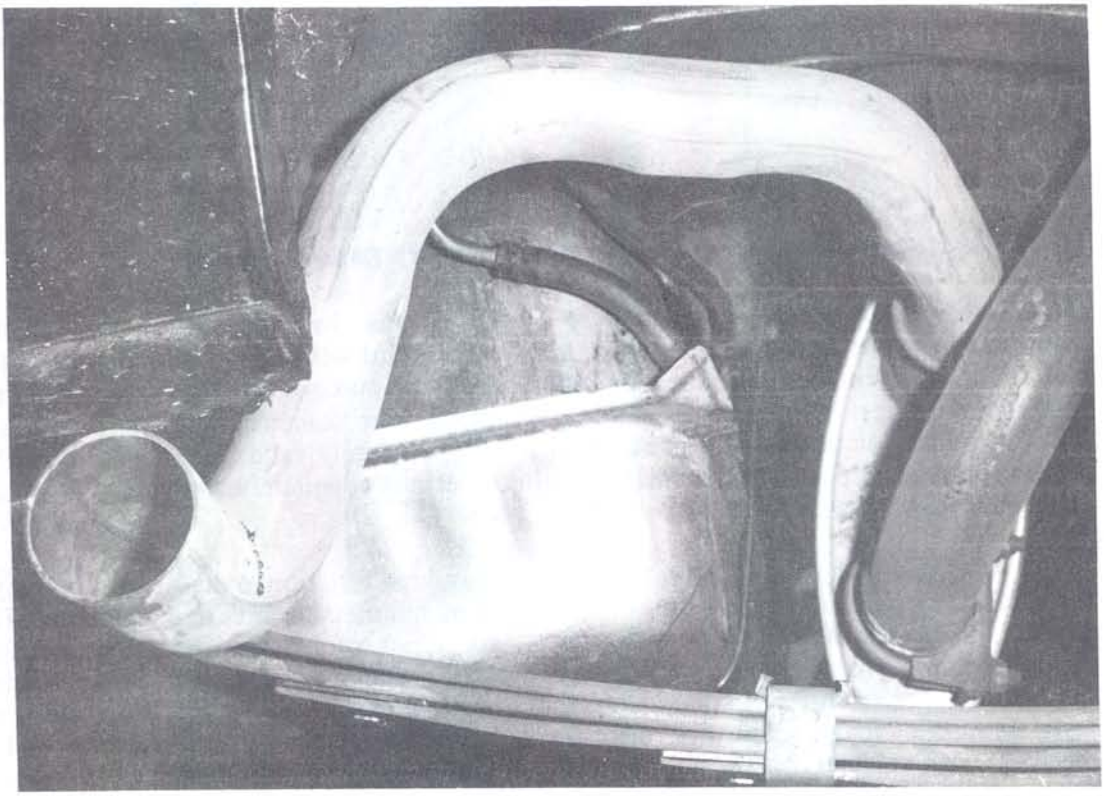

*Figure 8. Charred underbody parts on a test vehicle.*

*Table 10. Hottest temperature near gasoline tank obtained during road tests*

| Vehicle | Temperature °F | Remarks |
|---|---|---|
| **As received, without converter** | | |
| 1975 Gremlin 1/ | 820 | |
| 1974 Hornet (2) | 815, 790 | |
| 1974 Satellite (3) | 750, 700, 700 | |
| 1974 Pinto | 660 | |
| 1974 Torino (2) | 805, 760 | |
| 1974 Nova | 380 | |
| 1974 Impala | 850 | |
| **Converter-equipped, 1 plug wire pulled** | | |
| 1975 Gremlin (2) | 1,010, 1,115 | Rear seat rug smoldering |
| 1975 Hornet | 1,120 | |
| 1975 Matador | 970 | |
| 1975 Fury (2) | 1,155, 1,150 | |
| 1975 Chrysler Newport 1/ | 875 | |
| 1975 Pinto | 900 | |
| 1975 Torino (2) | 970, 1,020 | |
| 1975 Nova | 1,260 | Fire under vehicle, melting undercoating, burning of rubber parts |
| 1975 Monte Carlo | 1,140 | Melting undercoating, trunk mats smoldering |
| 1975 Impala (2) | 995, 1,125 | Both vehicles probably malfunctioning–missing under load–trunk mats smoking, rear seat rugs scorched, spare tire burned |
| 1975 Impala (2) 1/ | 890, 860 | |
| 1975 Regal (2) 1/ | 950, 935 | |

1/ 1975 49-State vehicle; all other 1975's are California.

## *CONCLUSIONS*

1. If both converter-equipped vehicles and those without converters are operated and tuned properly, the difference in the maximum equilibrium exhaust system temperatures of either type vehicle is insignificant.

2. The hottest point on the exhaust system of converter-equipped vehicles is likely to be the outlet of the converter. The hottest point on the exhaust system of vehicles not equipped with converters is likely to be the first bend.

3. Severe operating conditions cause a significant increase in exhaust system temperatures, over normal operation, in both converter-equipped vehicles and those without converters. However, even under severe operating conditions, the exhaust gas from either type vehicle is cooled to a safe temperature by mixing with air within 1 inch of the exhaust system exit.

4. Maximum exhaust system temperatures are obtained for both converter-equipped vehicles and those without converters during high flow (wide-open throttle), high load operation. For either type vehicle, the coasting and cruise modes of operation do not lead to excessively high exhaust system temperatures, even with one or more spark plugs misfiring.

5. On converter-equipped vehicles, ignition system failures can be expected to significantly increase exhaust system temperatures. Common carburetion system and exhaust system failures do not have significant effects. However, in vehicles not equipped with converters, any engine malfunction is likely to lower exhaust system temperatures.

6. On certain converter-equipped vehicles when the engine malfunctions, elevated exhaust system temperatures could pose a real danger to the occupants.

## *RECOMMENDATIONS*

1. Any policy changes or statements intended to prevent vehicle-caused fires should address all vehicles, both converter-equipped and those without converters. Emphasis on converter-equipped cars is not justified and may cause the public to think other vehicles do not cause fires.

2. Fleet managers should be informed of the potential fire and personnel injury hazard which could arise if ignition system malfunctions go undetected in 1975 model vehicles, particularly 1975 California vehicles.

3. Any fuel lines near any part of the exhaust system on converter-equipped vehicles downstream from the converter or any nonmetallic line segments should be repositioned or replaced.

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*APPENDIX*

*Literature Review (Surface Ignition Characteristics of Ground Cover Fuels)*

The problem of the ignition of ground cover by hot exhaust systems was first systematically investigated by Fairbank and Bainer (1). The literature concludes that, for various types of vegetation, fires are unlikely to start at surface temperatures of less than 800° F with contact times of as long as 2 minutes duration. Practically instantaneous ignition occurred in 5 out of 18 trials in the 1,100° to 1,199° F range and in 14 out of 17 trials in the 1,200° to 1,299° F range. The lowest temperature at which a fire started was 838° F with 2 minutes contact, but at 844° F, a fire started in 1 minute, 10 seconds.

Two other studies (2, 3) have investigated the contact time versus temperature relationship for the surface ignition of forest fuels. The results are summarized in figure A-1.

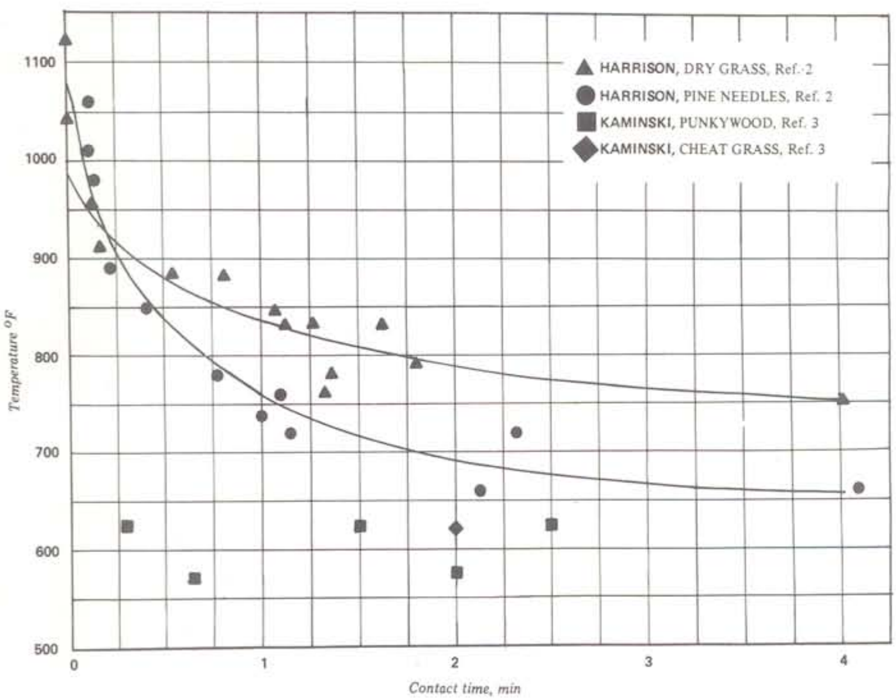


*Figure A-1. Time temperature ignition curves—various forest fuels.*

*Effect of Exhaust System Geometry*

Concern has been expressed about catalytic converter geometry, plus the possibility of converter shields catching and holding flammable debris. The effect of exhaust system geometry on ground cover was not part of the test program objectives; however, some data were obtained and are presented here.

Measurements made on the exhaust systems of all vehicles tested revealed that there is very little difference in the elevation above the ground plane of all points along each exhaust system from the first bend back to the beginning of the kickup. The converter, the muffler, and all interconnecting pipe between the first bend and the kickup are essentially equidistant from the ground plane. This measurement varied from about 5½ to 8 inches for all vehicles observed. Thus, all points on the exhaust system between the first bend and the kickup are equally likely to come in contact with the ground cover. Therefore, when comparing exhaust system temperatures from vehicle-to-vehicle, the hottest point on the exhaust system between the first bend and the kickup should be considered.

Some vehicles in the test fleet were equipped with exhaust system shields. In general, the temperatures outside the shields were quite low (400° F). However, none of the shields observed would have been effective in preventing ground cover from contacting the exhaust system underneath; in fact, most would serve effectively as grass catchers, thereby increasing the wildfire hazard.

### *Observations on Effect of Engine Malfunction*

Stuck carburetor power enrichment valve, a very common malfunction, appeared to be an engine malfunction which would lead to excessive richness, since power valves nearly always fail in the "on" (fully enriched) position (6). However, at high flow, high load conditions which lead to high exhaust system temperatures, the power valve is "on" anyway and only comes off at light load. Therefore, stuck power valves would not appear to increase exhaust system temperatures and were not investigated directly.

One other malfunction that would increase exhaust temperature is a stuck heat riser valve. This would probably increase exhaust pressure no more than 3 or 4 psi, even at wide-open throttle operation, but because of the difficulty in inducing this malfunction, it was not investigated directly. However, earlier work (2, 4) indicates that a 1 psi increase in exhaust pressure results in about a 5° F increase in exhaust system temperature. Therefore, the effect of a stuck heat riser would be minimal.

### *Test Repeatability*

Several vehicles were replicated to establish the repeatability of the measurement technique. In one case, the agency supplying vehicles inadvertently sent a previously tested vehicle back. The temperature distribution data for all modes of the first and second tests agreed within less than 100° F, thus establishing excellent test repeatability.