Substitution of Percent Load for Manifold Vacuum and Analysis of Time in Mode in the Gasoline Test Procedure

Substitution of Percent Load for Manifold Vacuum:

The present nine-mode FTP defines power points in terms of manifold vacuum. However, with the advent of supercharged and turbocharged engines, EGR, and other advanced emission control systems, manifold vacuum can no longer be used as the sole parameter in defining an engine's power points. It would be desirable to redefine the nine-mode FTP power points in terms of percent torque or power. This redefinition is expected to alleviate problems encountered from engine to engine variation in manifold vacuum versus horsepower (torque) relationships. The new nine-mode test procedure would then be similar to the method used by the 13-mode diesel procedure.

As a basis for the conversion to percent of load from the manifold vacuum test points currently in use, data from nineteen engines used in past contractual work were used. Four of the nineteen engines were involved in testing by Southwest Research Institute under Contract EHS 70-110 (Exhaust Emissions from Gasoline-Powered Vehicles Above 6,000-lbs Gross Vehicle Weight, April 1972). Six engines were tested under Contract EHS 70-110 (Baseline Characterization and Emissions Control Technology Assessment of HD Gasoline Engines, November 1972), again conducted by Southwest Research Institute. The remaining nine engines were tested under Contract 68-01-0472 entitled, "Emission Control Technology Assessment of Heavy Duty Vehicle Engines," December 1972.

Percentages of 10, 30, 60, and 90 percent of torque were earlier derived by EPA personnel for the 19, 16, 10, and 3 in-Hg modes based on four of the nineteen engines mentioned above. Primarily, these percentages of torque were derived for SwRI use in Contract 68-01-0472 (Emissions Control Technology Assessment of Heavy Duty Vehicle Engines, December 1973). These percent power values, however, were at best, approximations based on several manifold vacuum versus horsepower plots and empirical judgement. Upon further detailed investigation different percentages were arrived at.

Using the data from the nineteen engines, linear regressions were performed on each set of data for each engine. This resulted in the best fit line for each set of data. That is, an equation ($y = mx + b$) was derived with manifold vacuum as a linear function of percent power. All of the data used were taken at an engine speed of 2000 rpm (2300 rpm in the case of the six engines tested under Contract EHS 70-110, "Baseline Characterization and Emissions Control Technology Assessment of HD Gasoline Engines," November 1972). This is the same engine rpm at which the present nine-mode FTP is conducted. Subsequently, the percent power values corresponding to 3, 10, 16, and 19 in-Hg were determined for each individual engine. The percent power values representing the different power points as presently defined by manifold vacuum, were averaged together for each of the four power levels for all of the engines. The percent power points resulting were 10.8, 25.5, 55.0, and 89.5 percent. These percent power points are analogous to the 19, 16, 10 and 3 in-Hg manifold vacuum respectively. The 10 and 90 percent power points were verified. However, the above analysis demonstrated that 25 percent and 55 percent should be used in place of 30 percent and 60 percent power.

As can be seen from Figure 1, (Pg.4) there is considerable range in manifold vacuum for a particular percent load point. In redefining the 3 in-Hg mode as 90 percent torque, a range of 1 1/4 to 4 3/4 inches of mercury for manifold vacuum could be encountered. Also, at the 10 percent torque level, formerly the 19 in-Hg mode, there is -1 to +1 1/2 in-Hg variation from the 19 in-Hg reading depending on the particular engine. The variability can be attributed to induction systems, valving, carburetion, and timing.

Due to the variation, it might be expected that some large differences in emission concentration will be encountered, particularly in the 10 and 90 percent torque mode. As can be seen from Figures 2, 3 and 4, (Pgs 5,6 and 7) emission rates experience drastic changes. These changes in emissions rates appear to be most serious in the proximity of the 10 and 90 percent power level. When using the redefined power point of 10% (formerly 3 in-Hg), a 1972 GM 427 CID, V-8 encountered decreases of 44%, 18%, and 35% in the HC, CO, and NOx emission levels respectively. Also, at the 90% power level (formerly 19 in-Hg), a 1972 GM 250 CID, I-6 experienced increases of 41% and 63% in HC and CO, and a decrease of 14% in NOx. Although the engines above are examples of extreme variation, it should be expected that some engines will produce different emission levels when tested using the percent load procedure. However, there is no simple solution, and the 10, 25, 55, and 90 percent torque levels seem to be an adequate compromise.

The revised nine-mode gasoline test cycle would be as follows:

Sequence No.	Mode	Observed Torque (% of max. observed)	Manifold Vacuum in-Hg	Time in Mode-secs.	Cumulative Time-secs.	Weighting Factors
1	Idle	Idle	↑	70	70	.232
2	Cruise	25		23	93	.077
3	PTA	55	Determined	44	137	.147
4	Cruise	25	At Time of	23	160	.077
5	PTD	10	Test	17	177	.057
6	Cruise	25		23	200	.077
7	FL	90		34	234	.113
8	Cruise	25		23	257	.077
9	CT	CT	↓	43	300	.143

Using the above cycle and two EPA engines (1967 Ford 361 cu. in. V-8 and 1970 Chevrolet 350 cu. in. V-8) for testing, an operating procedure was determined. The proposed nine-mode gasoline test cycle and procedural changes to the regulations are attached (refer to the appendix).

Analysis of Time in Mode:

With regard to emission and fuel flow rates stabilization times, the question arose whether the present times in mode for the nine-mode test cycle were adequate in length for stabilization. Initially, a 1967 Ford 361 cu. in. V-8 and a 1970 Chevrolet 350 cu. in. V-8 were investigated for their emission and fuel flow rates stabilization characteristics during the nine-mode test cycle. The fuel flow rates stabilized in the allotted times for all the modes and for both engines. However, the emission rates did not stabilize sufficiently for all the modes. Further, there were no apparent trends when comparing the two engines.

It should be noted that inadvertently, the nine-mode FTP times in mode, as they are currently structured, encourage the engine manufacturers to have their engines stabilize quickly. That is, there is the possibility that if the engine emission rates do not stabilize, the emission traces could be integrated (integration is performed during the final three seconds of modes one through eight) while they were still decreasing. Higher values of emission rates would result, thus penalizing the manufacturer. It is therefore, to the engine manufacturers' advantage to have their engines stabilize quickly after the transition from one mode to another. This is to EPA's advantage and should not be done away with arbitrarily.

In looking at several 1974 and 1975 gasoline engines, the emission and fuel flow rates stabilization times were well within the present times in mode. With this in mind, it would be very difficult to justify any change in the times in mode as they now exist.

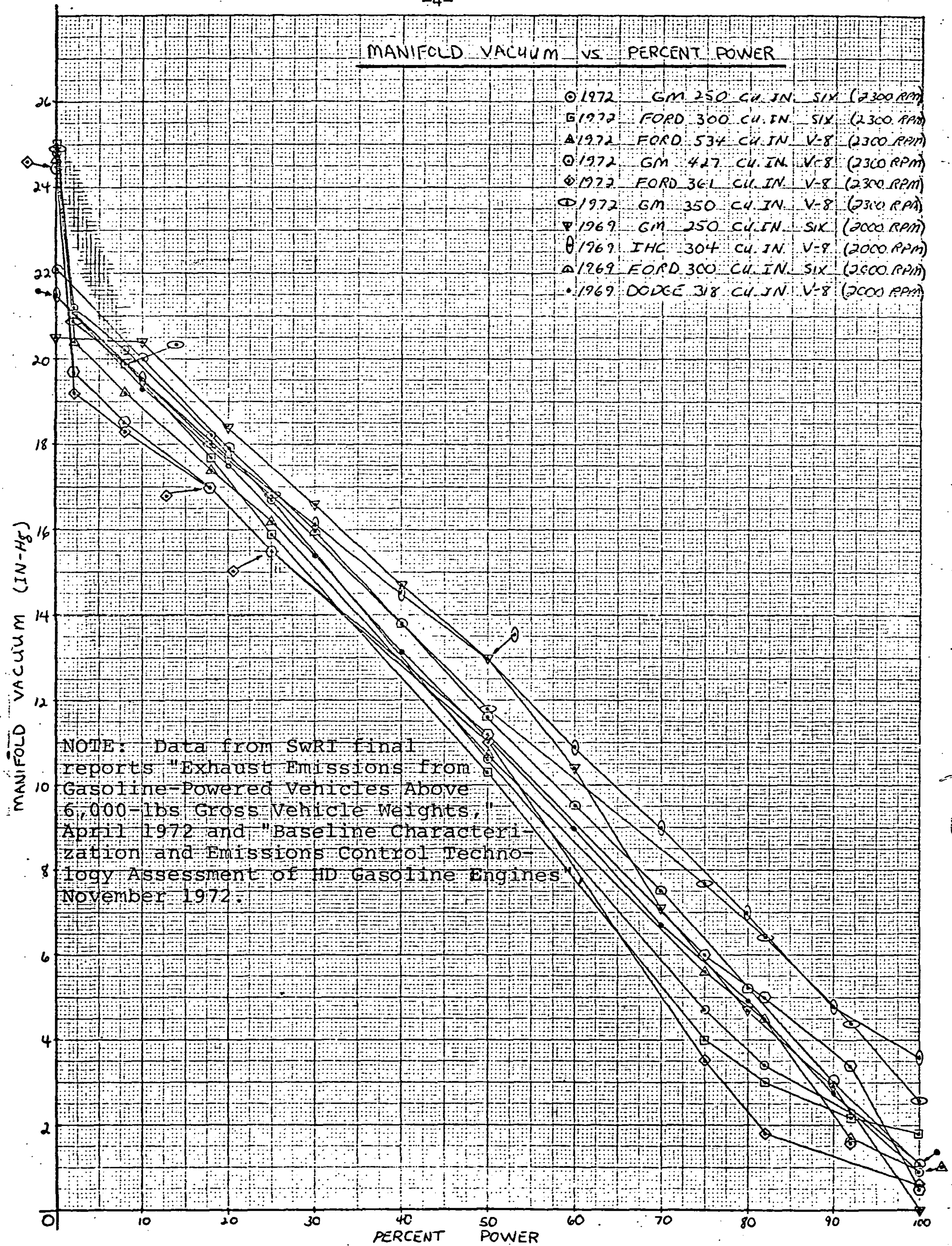
MANIFOLD VACUUM VS PERCENT POWER
1972 GM 250 CU. IN. SIX (2300 RPM)
1972 FORD 300 CU. IN. SIX (2300 RPM)
1972 FORD 534 CU. IN. V-8 (2300 RPM)
1972 GM 427 CU. IN. V-8 (2300 RPM)
1972 FORD 361 CU. IN. V-8 (2300 RPM)
1972 GM 350 CU. IN. V-8 (2300 RPM)
1969 GM 250 CU. IN. SIX (2000 RPM)
1969 IHC 304 CU. IN. V-8 (2000 RPM)
1969 FORD 300 CU. IN. SIX (2000 RPM)
1969 DODGE 318 CU. IN. V-8 (2000 RPM)
MANIFOLD VACUUM (IN-Hg)
PERCENT POWER
NOTE: Data from SwRI final reports "Exhaust Emissions from Gasoline-Powered Vehicles Above 6,000-lbs Gross Vehicle Weights," April 1972 and "Baseline Characterization and Emissions Control Technology Assessment of HD Gasoline Engines", November 1972.

Figure 1

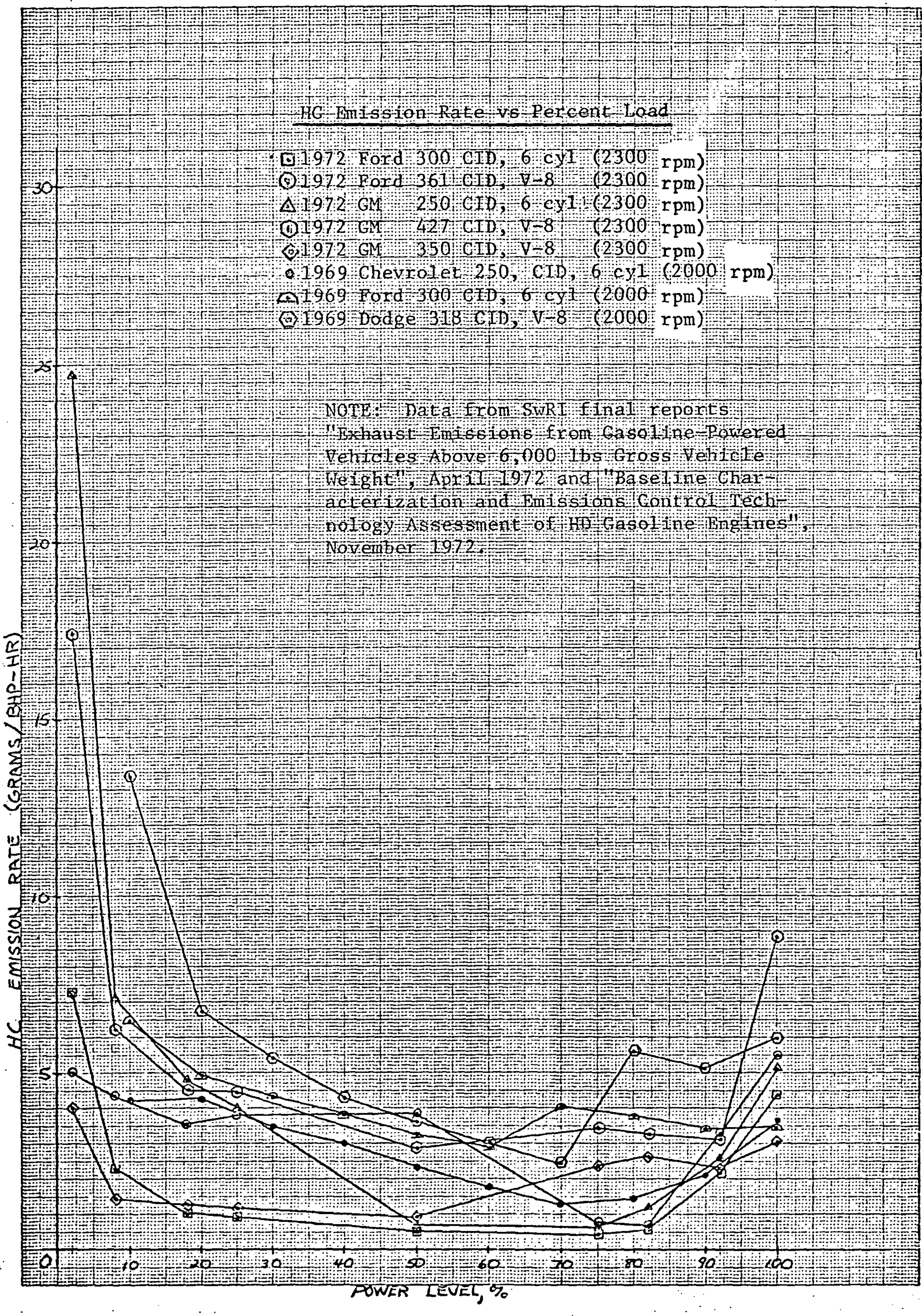
HC Emission Rate vs Percent Load
1972 Ford 300 CID, 6 cyl (2300 rpm)
1972 Ford 361 CID, V-8 (2300 rpm)
1972 GM 250 CID, 6 cyl (2300 rpm)
1972 GM 427 CID, V-8 (2300 rpm)
1972 GM 350 CID, V-8 (2300 rpm)
1969 Chevrolet 250, CID, 6 cyl (2000 rpm)
1969 Ford 300 CID, 6 cyl (2000 rpm)
1969 Dodge 318 CID, V-8 (2000 rpm)
NOTE: Data from SwRI final reports "Exhaust Emissions from Gasoline-Powered Vehicles Above 6,000 lbs Gross Vehicle Weight", April 1972 and "Baseline Characterization and Emissions Control Technology Assessment of HD Gasoline Engines", November 1972.
HC EMISSION RATE (GRAMS/BHP-HR)
0
5
10
15
20
25
30
10
20
30
40
50
60
70
80
90
100
POWER LEVEL, %

Figure 2

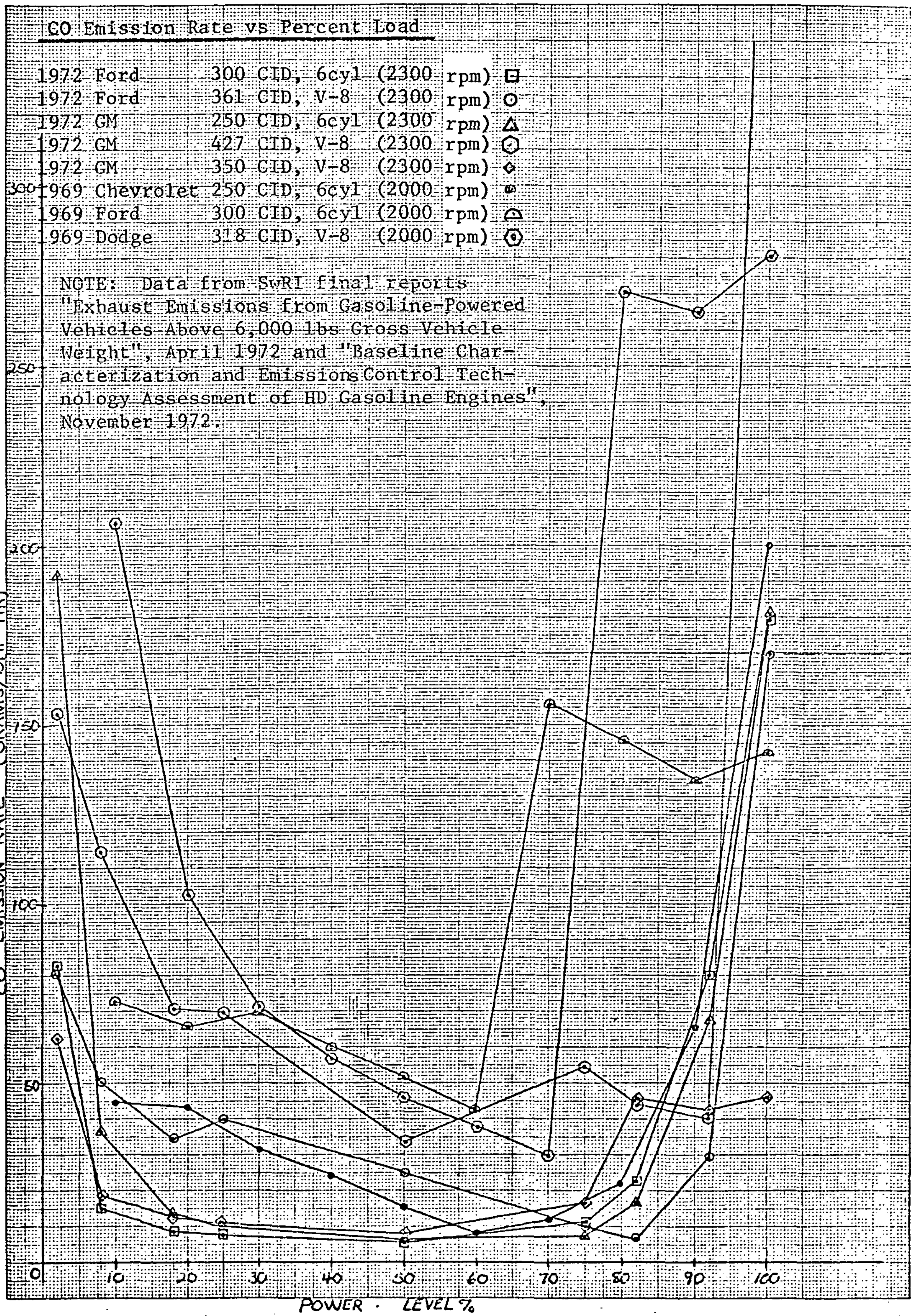
CO Emission Rate vs Percent Load
1972 Ford 300 CID, 6cyl (2300 rpm)
1972 Ford 361 CID, V-8 (2300 rpm)
1972 GM 250 CID, 6cyl (2300 rpm)
1972 GM 427 CID, V-8 (2300 rpm)
1972 GM 350 CID, V-8 (2300 rpm)
1969 Chevrolet 250 CID, 6cyl (2000 rpm)
1969 Ford 300 CID, 6cyl (2000 rpm)
1969 Dodge 318 CID, V-8 (2000 rpm)
NOTE: Data from SwRI final reports "Exhaust Emissions from Gasoline-Powered Vehicles Above 6,000 lbs Gross Vehicle Weight", April 1972 and "Baseline Characterization and Emissions Control Technology Assessment of HD Gasoline Engines", November 1972.
CO EMISSION RATE (GRAMS/BHP-HR)
300
250
200
150
100
50
0
10
20
30
40
50
60
70
80
90
100
POWER LEVEL %

Figure 3

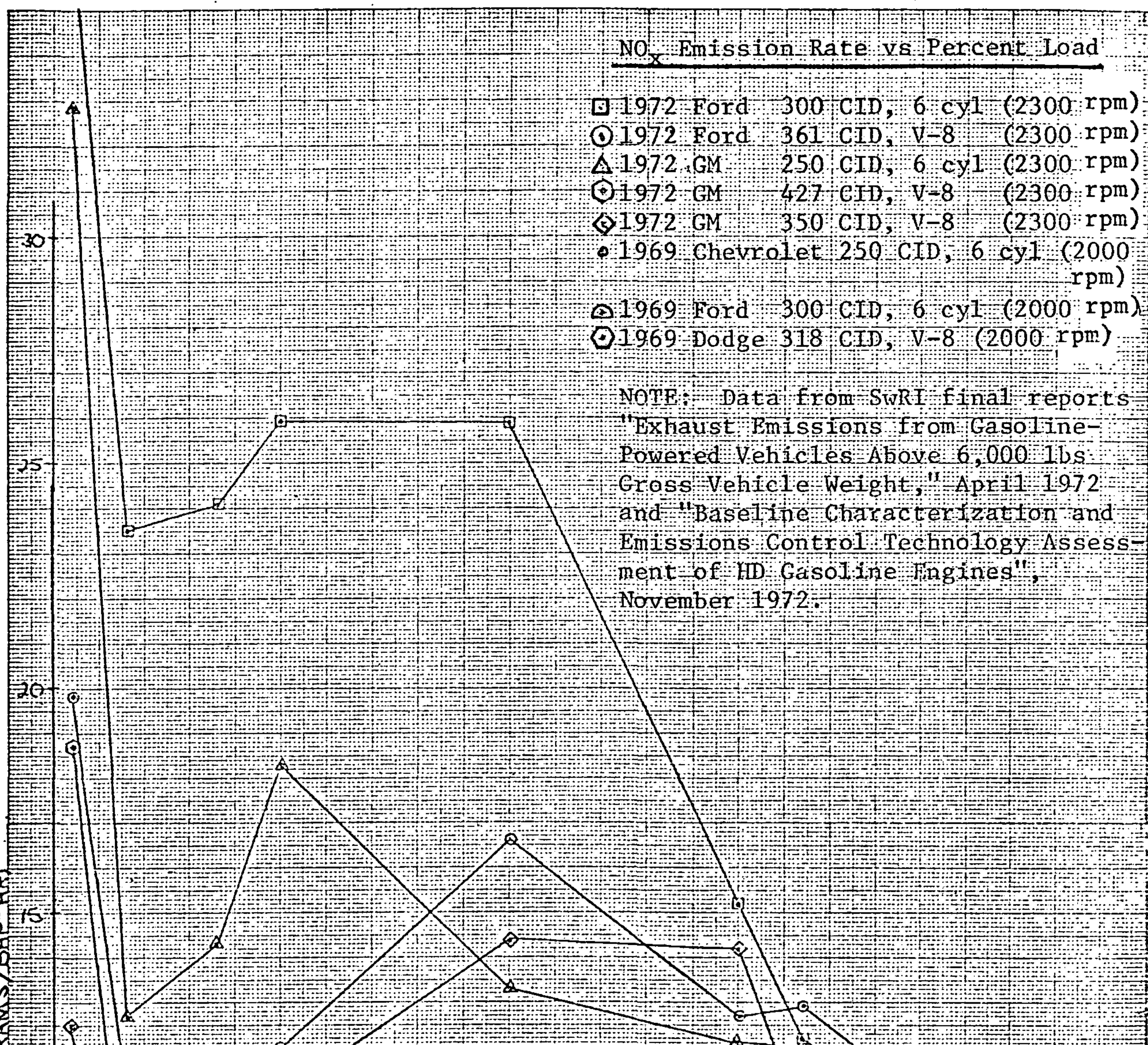
NOx Emission Rate vs Percent Load
1972 Ford 300 CID, 6 cyl (2300 rpm)
1972 Ford 361 CID, V-8 (2300 rpm)
1972 GM 250 CID, 6 cyl (2300 rpm)
1972 GM 427 CID, V-8 (2300 rpm)
1972 GM 350 CID, V-8 (2300 rpm)
1969 Chevrolet 250 CID, 6 cyl (2000 rpm)
1969 Ford 300 CID, 6 cyl (2000 rpm)
1969 Dodge 318 CID, V-8 (2000 rpm)
NOTE: Data from SwRI final reports "Exhaust Emissions from Gasoline-Powered Vehicles Above 6,000 lbs Gross Vehicle Weight," April 1972 and "Baseline Characterization and Emissions Control Technology Assessment of HD Gasoline Engines", November 1972.
NOx EMISSION RATE (GRAMS/BHP-HR)
POWER LEVEL, %
0
5
10
15
20
25
30
10
20
30
40
50
60
70
80
90
100

Figure 4