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Testing of Six Engine Oils in Accordance with the "EPA Recommended Practice for Testing, Grading and Labeling the Fuel Efficiency of Motor Vehicle Engine Oils"

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Background

Requests were received by the EPA from vehicle manufacturers with respect to the use, in certification vehicles, of either; (1) a specific oil additive (early 1977) or (2) engine oils which were starting to be marketed with fuel efficiency claims (December 1977).

In responding to the requests, the EPA acknowledged the need to adopt any and all means which would genuinely contribute to improved fuel economy. The EPA also stressed the need to take reasonable measures to assure that test vehicles used in the certification process were/are representative of production vehicles as they would be built and used in service.

In January 1978, the EPA responded to the request for guidance on the acceptability of "fuel efficient" engine oils. This response enumerated four criteria which, if met, would allow the EPA to make the determination that the certification vehicles were representative of production vehicles with respect to engine lubricants. The four criteria were:

"1. A generic means of defining such oils, so that reference could be made to them as a class rather than (as is now the case) only in terms of brand name

2. General availability of such oils in normal retail channels

3. Retail prices for such oils sufficiently near the retail prices for currently used top-grade oils so as to make it likely that the generically defined synthetic or modified oils will actually be used; and

4. Recommendations by manufacturers in owners manual regarding the use of such oils and, if the retail cost of such oils is higher than the retail cost of other top-grade oils, possibly the conditioning of the manufacturer's warranty on the use of the generically defined synthetic or modified oils."

Users; e.g., vehicle manufacturers, military, etc., and suppliers of motor vehicle lubricants had developed a process which is designed to resolve any identified need for the development of new classification procedures. This process involves the American Society for Testing and Materials (ASTM), which develops the test procedures and the acceptance limits; the Society of Automotive Engineers (SAE), which reviews the ASTM work and the American Petroleum Institute, which prepares the users language.

In response to the need, identified by the EPA, for a generic definition for fuel efficient engine oils, the ASTM/SAE/API initiated programs to address the need. The ASTM Task Force on Fuel Efficient Engine Oils (1) established a reference oil (HR) representative of high sales volume commercial oils, (2) selected a test procedure built around the EPA emissions and fuel economy test procedures and (3) identified two potential test/evaluation protocols reflective of carryover and non-carryover engine oils.[1] Because of the technically predicted problems with the carry-over protocol and because of the need to proceed as quickly as possible, the ASTM Task Force focused on the non-carryover protocol for evaluation. At this time (April 1981), the ASTM Task Force expects (on the basis of test data) that a flushing process will be applicable to carryover oils, thereby permitting the use of the basic non-carryover procedure for all oils. Formal review (balloting) of the Task Force procedure is scheduled to take place in the May/June 1981 time period. If approved, the procedure would become an official ASTM procedure.

The fundamental problems faced by the Task Force centered on the magnitude of testing variability and the magnitude of the change in fuel economy to be measured; i.e., testing variability was normally in the range of 2% to 5% and the expected change in fuel economy attributable to engine oils was in the range of 1% to 3%. Refinement of testing procedures was required (an iterative process) so as to lower the testing variability. This function has been successfully achieved by the ASTM Task Force.

In January/February 1980, the EPA assembled the "EPA Recommended Practice for Evaluating, Grading and Labeling the Fuel Efficiency of Motor Vehicle Engine Oils" (Appendix 1). This procedure used the ASTM approach for carryover oils and incorporated four fuel economy grades for engine oils as well as a label for identification.

In March 1980, the EPA initiated a testing program in accordance with the EPA recommended procedure, using two sets of test vehicles to evaluate the feasibility of the procedure. This report covers the results of that testing.

Conclusions

1. Using the back to back test evaluation approach (non-carryover), differences in fuel economy, attributable to the engine oils, were observed. Directionally, the differences were as expected; i.e., the two single viscosity oils showed a fuel economy penalty relative to HR, the four multiviscosity oils showed a benefit.

2. During the period of the program, several vehicles exhibited changes in fuel economy for which there were no identifiable causes. Because of these changes and their magnitude relative to the change being investigated, use of the extrapolation method for predicting fuel economy can lead to incorrect conclusions. The extrapolation procedure, is therefore, not suitable for this application.

3. A flushing or conditioning oil, which works equally well with all friction modifier additive packages, is required to permit utilization of the back to back (non-carryover) method of analysis. An oil of this type is under evaluation by ASTM.

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[1]A carryover oil is an oil wherein its effects (in total or in part) on fuel economy remain for some period of time following the replacement of that oil. The effects on fuel economy of a non-carryover oil do not remain once the oil is changed.

4. Based on the degree of variability in the data collected in this test program and the small range of difference in measured fuel economy between presently available lubricating oils, it is concluded that the test procedure used was not precise enough to permit classification of oils into the four grades proposed.

5. The largest difference noted between a multiviscosity "fuel efficient" oil and a non-fuel efficient straight weight oil was 3.39%. Various claims as to the benefit of "fuel efficient oils" have been considerably above this number. The conclusion to be drawn from this data is that these claims are not substantiated by this test procedure.

Discussion

Appendix 1 of this report, presents the "EPA Recommended Practice for Evaluating, Grading and Labeling the Fuel Efficiency of Motor Vehicle Engine Oils" as it was distributed on March 10, 1980.

Briefly, the objective of the EPA procedure was to determine the fuel efficiency characteristics of motor vehicle engine oils. The procedure basically conforms to the tentative approach considered by the ASTM Task Force for carryover oils as of February 1980. Both procedures, draw from the 1975 Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HFET). Both FTP and HFET tests are run on a chassis dynamometer. The objective was/is to compare the fuel economy characteristics of a test or candidate oil with respect to a reference oil in each test vehicle. Uniformity of vehicle, dynamometer, ambient conditions, and fuel measurement techniques was stressed to minimize test to test variability. The procedure allows certain options, but it is emphasized that the options selected for the reference oil shall also prevail for the candidate oil(s) in any given vehicle. The data obtained from the use of this test method was intended to provide a comparative index of the fuel economy impact of automotive engine lubricants under repeatable laboratory conditions in complete vehicles.

Under the EPA procedure it was intended that there would be four grades of engine oils based on fuel efficiency characteristics. The four grades, labeled A, B, C, and D, were separated as follows:

Grade "A" Classification specifies that $(CO - TE) > (1.030)(HR)$
Grade "B" Classification specifies that $(1.030)(HR) > (CO-TE) > (1.010)(HR)$
Grade "C" Classification specifies that $(1.010)(HR) > (CO-TE) > (0.990)(HR)$
Grade "D" Classification specifies that $(0.990)(HR) > (CO-TE)$

Where:
TE = Testing Error = LDS_{95}
HR = Fuel economy using High Reference oil (MPG)
CO = Fuel economy using Candidate Oil (MPG)

Test Procedure

The details of the test procedure used are given in Appendix 1 and are not duplicated here.

Test Vehicles

Ten test vehicles (two test fleets) meeting the specifications given in Section 2.1 of the procedure, were procured under contract. Each vehicle was inspected, instrumented and prepared for the test program as described in Section 3 of the procedure.

Vehicle Test Sequence

The basic sequence applied to each vehicle was as follows:

1. Following vehicle check out and adjustment to vehicle manufacturer's specifications, a double oil flush[2] with high reference (HR) oil was performed. The vehicle was tested (city and highway) once with a new (third) charge of HR.

2. Two thousand miles were accumulated on HR. A double oil flush with HR was performed. The vehicle was tested twice with a new (third) charge of HR (this data pair constitute the first set of data for constructing the trend line).

3. One thousand miles were accumulated on HR. A double oil flush with HR was performed. The vehicle was tested twice with a new (third) charge of HR (this data pair constitutes the second set of data for constructing the trend line).

4. Step 3 was repeated to generate the third data set for the trend line. If the trend line met the specified requirements, the vehicle was ready for the first candidate oil. If the trend line did not meet the specified requirements, Step 3 was repeated.

5. Double oil flush with the candidate oil. Two thousand miles were accumulated starting with a new (third) charge of the candidate oil. The vehicle was then tested twice with the used candidate oil.

6. Double oil flush with HR followed by a pair of tests on a new (third) charge of HR.

7. Single oil change with HR followed by a pair of tests. One hundred miles accumulated on this charge of HR.

8. Single oil change with HR followed by a pair of tests.

9. Double oil flush with the next candidate oil. Two thousand miles were accumulated starting with a new (third) charge of the candidate oil. The vehicle was then tested twice with the used candidate oil.

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[2]Double Oil Flush. A flush consists of charging with new oil, operating 10 minutes at idle and draining while hot. A new filter or a filter bypass must be used for every flush.

10. Steps 6, 7, and 8 repeated. Two hundred and fifty miles were accumulated on the road on the charge of HR introduced in Step 8.

11. Single oil change with HR followed by a pair of tests.

12. Steps 9 (another candidate oil), 6, 7, 8, and 11 repeated.

Mileage Accumulation

In the EPA test program, mileage accumulation for the development of the vehicle fuel economy trend lines and ageing of candidate oils was performed on dynamometers. The dynamometers used were single, large roll, electric units. Mileage was accumulated at a constant 55 mph using mechanical drivers. Engine loading was based upon manifold vacuum on the dynamometer being equal to that on the street at the same speed. Downward deviation in loading was employed for those vehicles where engine sump oil temperatures tended to exceed 245°F, i.e., 245°F was selected as the maximum permissible temperature. Every attempt was made to minimize engine loading reduction during mileage accumulation through the use of multiple cooling fans and reduced cell temperature (55° to 60°F).

Fuel Economy Determinations

During approximately the first two thirds of the test program, vehicle fuel economy was determined by both the carbon balance and volumetric procedures. In the latter part of the program, fuel economy was determined by the volumetric procedure only.

Flushing Procedure

Two procedures were used to try to remove the residual (carryover) effects of a candidate oil. In all cases, HR was used as the "flushing" oil. The first procedure used following candidate oils 1 and 2 (carryover effect was not expected) was; (1) a double oil change, followed by duplicate tests on a new charge of HR, (2) an oil change and a pair of tests on that charge of oil followed by 100 miles at 55 mph, and (3) an oil change and a pair of tests on that oil charge. The second procedure used for the remainder of the candidate oils, increased the first procedure by adding an oil change and a pair of tests followed by 250 miles on the road.

Test Oils

The oils used as candidate oils are described in the following tabulation:

Candidate Oil Number	SAE Viscosity	Description
1	30	Commercial oil
2	40	Commercial oil
3	10W40	Commercial oil, advertised as fuel efficient - expected carryover.
4	5W20	Commercial oil, advertised as fuel efficient.
5	5W20	EPA blend of oil #4 plus graphite marketed by Sears

6	10W30	EPA blend of commercial oil, not advertised as fuel efficient plus an additive claimed to improve fuel economy - reportedly consisting of "Teflon" and MoS_2.

Test Results

Tables I through X give the test results by vehicle and candidate oil. Oil 0 in the tabulations was HR. All other oil numbers refer to the candidate oil numbers given under Test Oils.

Summary of Results

Tables XI through XIII show the mean fleet fuel economy percentage change of each candidate oil with respect to HR. The non-carryover fuel economy values for HR and the candidate oils are based on the HR tests run after the candidate oils. The tables present the fleet averages for the four HR test sequences taken after the candidate oil. These sequences are described above and are designed as follows:

HRDF - First HR Double Flush
HRSF1 - Single oil change using HR
100HR - Single oil change following accumulation of 100 miles on HR
250HR - Single oil change following accumulation of 250 miles on HR
FTP - City Cycle
HFET - Highway Cycle

Candidate oils 1, 2, and 4 are not projected to be carry-over oils. The HR comparisons should then be focused on the HRDF tests immediately following the candidate oil tests. Candidate oils 3, 5, and 6 are projected to be carry-over oils. These HR comparisons should be focused on the 100HR and 250HR test results.

Tables XIV and XV show the percentage changes for individual vehicles. This table also indicates the fuel economy benefit/penalty as compared to a trendline drawn through the first two sets of HR tests.

Figures 1 through 35 show the results of both by trend lines determination method (predicting where the vehicle would be on HR) and by the back to back method (used in Tables XI through XV. These trend lines are based on all of the HR tests taken on the vehicle up to introduction of candidate oils #3 and #4.

Table I

Vehicle Test Fleet I Test Vehicle #1

Ford Motor Co. 2.3 litre

Test #	Test Oil	Odomr. (miles)	Fuel Economy: Carbon Balance FTP	Carbon Balance HFET	Carbon Balance Comb.	Volumetric FTP	Volumetric HFET	Volumetric COMB.
1	0	10370.0	20.89267	27.17614	23.31890	19.60452	27.04576	22.37476
2	0	12505.0	20.31605	28.16354	23.22865	20.09291	28.55192	23.18378
3	0	12529.0	20.29390	28.27554	23.24686	20.08301	28.43272	23.14109
6	0	13616.0	20.46132	28.42506	23.41312	20.24614	28.64820	23.32445
7	0	13669.0	20.52717	28.40158	23.45329	19.85684	28.43801	22.97681
8	0	13703.0	20.65215	28.33961	23.52364	20.17614	28.63689	23.26993
9	0	14773.0	20.80615	28.47137	23.67433	20.46981	28.80957	23.53570
10	0	14806.0	20.79692	28.76850	23.75955	20.34207	28.75072	23.42505
11	1	16886.0	20.87514	28.25458	23.65535	20.17717	28.47341	23.22193
12	1	16920.0	20.92209	28.39502	23.73276	20.02321	28.15465	23.01429
13	0	16991.0	21.38768	29.02023	24.25879	20.28716	28.50050	23.31006
14	0	17042.0	21.16456	28.86047	24.05055	20.24780	28.54796	23.29569
15	0	17124.0	21.26998	28.80621	24.10819	20.42553	28.58360	23.43546
16	0	17157.0	21.31140	28.22792	23.95242	20.44055	28.22315	23.33632
17	0	17334.0	21.08585	28.79705	23.97481	20.37938	28.46285	23.36550
18	0	17368.0	20.94481	29.07946	23.96109	20.30580	28.76426	23.40261
19	3	19420.0	20.80615	29.46864	23.97796	20.77459	29.10435	23.84571
20	3	19454.0	21.66274	29.61413	24.63985	20.95967	29.33797	24.05040
21	3	19522.0	21.75244	29.43067	24.64590	20.86858	29.22246	23.94950
22	0	19575.0	21.70841	29.55784	24.65472	20.82895	29.10463	23.88516
23	0	19608.0	21.85467	29.44310	24.72190	20.74396	29.10190	23.82277
24	0	19661.0	21.78063	29.35525	24.64192	20.76196	28.95091	23.79009
25	0	19704.0	21.40429	29.05168	24.28044	20.67912	28.96472	23.73435
26	0	20004.0	21.51841	29.03043	24.35431	20.57058	28.54478	23.52835
27	0	20038.0	22.42499	28.95852	24.95902	20.55269	28.58860	23.52884
28	0	20071.0	21.45654	28.95697	24.28746	20.57639	28.63274	23.55938
29	0	20125.0	21.52906	29.03679	24.36383	20.71916	28.90045	23.74385
30	0	20179.0	21.39149	29.32400	24.35642	20.53698	28.80564	23.58330
31	0	20486.0				20.44350	28.47936	23.41683
32	0	20520.0				20.33133	28.54071	23.35423
33	5	22575.0	22.03150	30.02596	25.03049	21.24067	29.40788	24.27435
34	5	22628.0	22.24391	30.26406	25.25572	21.23196	29.25886	24.22229
35	0	22772.0				20.78802	28.59528	23.69982
36	0	22821.0				20.57887	28.93958	23.65404
37	0	22882.0				20.66776	28.79151	23.67363
38	0	22915.0				20.70759	28.83192	23.71466
39	0	23095.0				20.77121	28.76426	23.73979
40	0	23167.0				20.73266	28.90222	23.75414
41	0	23462.0				20.64003	29.12997	23.75565
42	0	23946.0				20.73159	28.97704	23.77607

Table II

Vehicle Test Fleet I Test Vehicle #2

Chrysler Corp. 225 CID

Test #	Test Oil	Odomr (miles)	Fuel Economy (MPG) Carbon Balance FTP	HFET	Comb.	Volumetric FTP	HFET	COMB.
2	0	16208.0	17.59223	20.68215	18.86021	17.37951	21.36478	18.97204
6	0	18469.0	15.97639	21.47436	18.05673	15.72586	21.72149	17.95621
7	0	18502.0	16.17076	21.42574	18.17694	15.84656	21.59125	18.00192
8	0	19559.0	16.56372	21.84025	18.58416	15.76343	21.57904	17.93900
9	0	19646.5	16.65537	21.36370	18.48903	15.79854	21.69701	18.00066
11	0	20729.0	16.30726	21.83151	18.40275	15.56948	21.64548	17.82052
12	0	21783.0	16.33041	21.94594	18.45548	15.91466	21.51062	18.02477
13	0	21816.3	16.69472	22.26881	18.81390	15.90094	21.54167	18.02487
14	0	22870.0	16.75609	21.92881	18.74596	16.00111	21.60220	18.11469
15	0	22920.0	16.84434	22.01969	18.83659	15.95116	21.78451	18.13660
16	1	24959.0	16.48007	21.71188	18.48442	15.67515	21.62904	17.89141
17	1	24992.0	16.62129	21.88898	18.63989	15.71756	21.81573	17.97914
18	0	25046.0	17.02749	22.05797	18.97480	16.06645	21.90757	18.25695
19	0	25080.0	16.90888	21.91801	18.84717	15.85646	21.85317	18.09033
20	0	25133.0	16.77601	22.05488	18.80104	15.76612	21.91772	18.04524
21	0	25166.0	16.59549	21.67599	18.55225	15.72115	21.86066	17.99544
22	0	25319.0	17.02687	22.11868	18.99455	16.04388	22.01571	18.27455
23	0	25422.0	17.19675	22.14272	19.11845	16.33718	21.89592	18.44429
24	3	27495.0	16.38715	21.55492	18.36892	16.14112	21.11306	18.05436
25	3	27529.0	16.99455	21.64959	18.81506	16.09945	21.33508	18.09802
26	3	27583.0	17.29967	21.62774	19.01172	16.22179	21.42616	18.21249
27	0	27657.0	16.67104	21.15446	18.42861	15.78243	21.04753	17.78440
27	0	27657.0	16.67104	21.15446	18.42861	15.78243	21.04753	17.78440
28	0	27690.0	16.94257	21.28510	18.65527	15.96060	21.00894	17.89571
29	0	27744.0	16.89318	21.75604	18.78236	15.85887	21.58822	18.00971
30	0	27850.0				16.09759	21.73634	18.22514
31	0	28003.0				16.11574	21.55923	18.18154
32	0	28036.0				16.04009	21.39012	18.07441
33	0	28364.0				16.02078	21.58133	18.12193
34	0	28418.0				16.11701	21.74103	18.24031
35	5	30469.0	18.42067	25.03398	20.90592	17.27081	24.13657	19.80609
36	5	30523.0	18.27713	24.97296	20.78495	17.04983	23.79453	19.54259
37	0	30644.0				16.68040	23.08864	19.06108
38	0	30732.0				17.12142	23.62632	19.54268
39	0	30785.0				16.75018	23.96640	19.37543
40	0	30840.0				17.02504	23.23478	19.35251
41	0	30895.0				17.08313	23.99213	19.62645
42	0	31048.0				17.04317	23.99187	19.59734
43	0	31081.0				16.90063	23.70468	19.40739
44	0	31388.0				17.11517	23.37480	19.46028
45	0	31420.0				17.41714	23.88532	19.83414

Table III
Vehicle Test Fleet I Test Vehicle #3
Ford Motor Co. 302 CID

Fuel Economy (MPG)

Test #	Test Oil	Odomr. (miles)	Carbon Balance FTP	Carbon Balance HFET	Carbon Balance COMB.	Volumetric FTP	Volumetric HFET	Volumetric COMB.
1	0	16435.5	15.29604	23.35792	18.10858	15.68115	23.42123	18.42052
4	0	18636.0	15.98026	23.33810	18.62224	15.74995	24.12960	18.66715
5	0	19701.0	15.81523	24.02083	18.68797	15.68349	24.15600	18.62280
6	0	19735.0	15.88086	23.65008	18.63575	15.78789	24.11808	18.69333
7	0	20792.0	15.43148	23.24491	18.18165	15.38170	23.72638	18.27385
8	0	20847.1	15.72916	23.26262	18.41288	15.21471	23.55653	18.09882
9	0	21922.0	15.79466	23.63676	18.56665	15.38007	23.55485	18.22659
10	0	21977.0	15.90467	23.47050	18.60326	15.41566	23.49030	18.23658
12	0	23089.0	15.80381	24.00592	18.67515	15.46936	23.86520	18.37896
13	0	23123.0	15.82692	23.42917	18.53302	15.33770	23.49546	18.17786
14	1	25179.0	15.98043	23.56247	18.68625	15.50677	23.88838	18.41417
15	1	25232.0	16.02555	23.95603	18.83076	15.48448	23.77387	18.36623
16	0	25287.0	16.11535	24.00631	18.91288	15.55008	23.90535	18.45229
17	0	25321.0	16.05813	23.83646	18.82204	15.57085	23.73101	18.42131
18	0	25373.0	16.01542	23.87013	18.79914	15.54326	23.77418	18.41173
19	0	25407.0	15.91233	23.83995	18.71248	15.40521	23.69763	18.28440
20	0	25559.0	15.86316	23.98684	18.71544	15.33359	23.81577	18.26017
21	0	25593.0	15.97503	24.19216	18.85733	15.34260	23.79075	18.26057
22	3	27648.0	17.13681	24.18964	19.72478	15.58118	23.97118	18.49402
23	3	27722.0	16.12796	24.09938	18.94839	15.63778	23.73921	18.47500
24	3	27777.0	16.12079	24.13021	18.95150	15.42135	23.86388	18.34129
25	0	27831.0	15.71062	23.37393	18.42966	15.29483	23.29863	18.09159
26	0	27866.0	15.71730	23.60853	18.49995	15.33005	23.40355	18.14714
27	0	27920.0	15.90680	24.29249	18.83216	15.40343	23.92290	18.34299
28	0	27976.0	15.76747	23.61939	18.54115	15.37591	23.40788	18.18363
29	0	28153.0	15.53247	23.37037	18.29330	14.97237	22.97242	17.75473
30	0	28187.0	15.42872	23.49662	18.24834	14.99967	23.15752	17.82543
31	0	28242.0	15.47106	23.31459	18.23106	15.05749	23.12582	17.86179
32	0	28276.0	15.51782	23.47750	18.31153	15.06702	23.18290	17.88447
33	0	28579.0				14.95855	23.14931	17.79128
34	0	28663.0				14.98[illegible]69	23.04467	17.78133
35	5	30730.0	15.69673	24.10041	18.61815	15.28[illegible]33	23.65344	18.17719
36	5	30787.0	15.85965	24.42381	18.83103	15.31367	23.61478	18.19125
37	0	30947.0				14.901[illegible]8	22.77207	17.64629
38	0	30981.0				14.97190	22.54223	17.63730
40	0	31036.0				14.92901	22.70328	17.64853
41	0	31071.0				14.99898	22.69896	17.70104
41	0	31226.0				15.06[illegible]20	22.87347	17.80025
42	0	31281.0				15.18695	23.13829	17.96507
43	0	31659.0				14.99192	23.09275	17.80213
44	0	31714.0				15.09227	23.28219	17.93061

Table IV
Vehicle Test Fleet I Test Vehicle #4
General Motors 231 CID

Test #	Test Oil	Odomr (miles)	Fuel Economy (MPG) Carbon Balance FTP	HFET	Comb.	Volumetric FTP	HFET	Comb.
1	0	19754.0	17.24278	24.96361	20.03058	16.82788	24.91270	19.70563
4	0	21938.0	17.69323	25.80644	20.60885	17.31217	25.79733	20.31974
5	0	21971.0	17.69785	25.71751	20.58671	17.21299	25.59598	20.18836
6	0	23025.0	17.68606	25.85920	20.61861	17.35792	25.80289	20.35593
7	0	23058.0	17.44917	25.74098	20.40734	17.17177	25.71606	20.19056
8	0	24130.5	17.73361	25.77699	20.63047	16.94433	25.12792	19.85404
9	0	24167.0	18.05596	26.25950	21.00951	17.21420	25.64001	20.20159
10	0	25218.8	18.04599	26.61813	21.10442	17.21740	25.83457	20.25811
11	0	25251.0	17.89666	26.20760	20.87570	17.18708	25.63820	20.18053
12	0	26305.0	17.60297	25.45549	20.44043	17.14336	25.56735	20.12762
13	0	26338.0	17.49541	25.58925	20.39887	17.18702	25.35549	20.10109
14	1	28391.0	17.68138	25.57281	20.53262	17.08697	25.86614	20.16717
15	1	28457.0	17.79952	26.09986	20.77224	17.23571	25.67034	20.22636
16	0	28507.0	17.92730	26.23649	20.90688	17.44156	26.11712	20.50695
17	0	28540.0	17.85172	25.95308	20.76915	17.24553	25.69561	20.24085
18	0	28593.0	18.04247	26.47978	21.06251	17.56300	26.21990	20.62776
19	0	28645.0	17.95321	25.69550	20.76931	17.44212	25.89743	20.44609
20	0	28800.0	18.04476	26.66829	21.11766	17.31768	26.22698	20.44264
21	0	28833.0	18.01644	26.63964	21.08824	17.36212	26.25399	20.48408
22	3	30890.0	17.84296	25.95443	20.76302	17.29858	25.80951	20.31284
23	3	30943.0	17.74580	26.16845	20.75139	17.22320	25.77373	20.24566
24	0	30997.0	18.06701	26.48652	21.08281	17.46724	26.16955	20.54102
25	0	31030.0	17.74880	25.84042	20.66005	17.21115	25.73527	20.22581
26	0	31084.0	17.97640	26.19961	20.93298	17.47020	26.02514	20.50308
27	0	31118.0	17.94987	26.30858	20.94435	17.35791	25.95657	20.39880
28	0	31300.0	17.96443	26.34002	20.96422	17.48391	26.02722	20.51405
29	0	31387.0	18.08823	25.91903	20.93440	17.51172	25.69917	20.44244
30	0	31440.0	18.25763	26.55034	21.24346	17.60289	26.13067	20.63302
31	0	31473.0	18.19043	26.67836	21.22994	17.59729	26.41927	20.70915
32	0	31801.0				17.70249	26.13258	20.70867
33	0	31835.0				17.62840	26.17258	20.66405
34	5	33889.0	18.28534	26.67260	21.29926	17.65955	26.25146	20.70971
35	5	33955.0	18.33447	26.85451	21.38804	17.65963	26.30831	20.72568
36	0	34127.0				17.87427	26.50097	20.94197
36	0	34127.0				17.87427	26.50097	20.94197
37	0	34161.0				17.70430	26.42177	20.79119
38	0	34214.0				17.50316	26.08007	20.54339
39	0	34275.0				17.49950	26.04362	20.53044
40	0	34429.0				17.58593	26.07982	20.60593
41	0	34482.0				17.49881	26.00338	20.51865
42	0	34786.0				17.75393	26.27113	20.78651
43	0	34817.0				17.69177	26.57755	20.82488

Table V
Vehicle Test Fleet I Test Vehicle #5
General Motors 2.8 litre

Test #	Test Oil	Odomr (miles)	Fuel Economy (MPG) Carbon Balance FTP	HFET	Comb.	Volumetric FTP	HFET	COMB.
1	0	13592.6	19.59890	25.93365	22.01927	19.12502	26.19904	21.77020
4	0	15788.0	19.23003	26.10926	21.81674	19.23445	26.96130	22.08231
5	0	15823.0	19.42509	26.81752	22.17591	19.50036	27.25126	22.36256
6	0	16928.8	19.94508	27.21581	22.67048	19.65094	27.37323	22.50838
7	0	16963.8	20.22266	27.44160	22.93806	19.72253	27.41983	22.57419
9	0	18083.0	20.34796	27.42631	23.02167	19.77385	27.30603	22.57622
10	0	18118.0	20.36913	27.46373	23.04844	19.84992	27.51675	22.69550
11	0	19225.0	20.12183	27.38427	22.84863	19.79732	27.43402	22.63236
12	0	19281.0	20.32852	27.47057	23.02198	20.01967	27.77898	22.89783
13	0	20339.0	20.19446	26.93089	22.75591	19.82949	27.56314	22.69497
14	0	20374.0	20.33594	27.49917	23.03626	19.69079	27.21564	22.48887
15	1	22440.0	19.96839	27.68229	22.83135	19.67841	27.61757	22.60225
16	1	22475.0	20.07827	27.37630	22.81523	19.55631	27.44760	22.46243
17	0	22532.0	20.24288	27.68220	23.02769	19.82089	27.66005	22.71826
18	0	22567.0	20.19550	27.70643	23.00146	19.82871	27.71928	22.74188
19	0	22623.0	20.09707	27.47528	22.85948	19.71808	27.52329	22.60246
20	0	22658.0	20.31424	27.57172	23.04377	19.87366	27.64886	22.75294
21	0	22819.0	20.27827	27.49243	22.99339	19.75193	27.46321	22.60861
22	0	22871.0	20.02111	27.00108	22.65673	19.77017	27.38409	22.59755
23	3	25012.0	20.22385	27.89929	23.08133	19.80512	27.79077	22.74639
24	3	25070.0	20.04485	27.49975	22.82987	19.69969	27.62320	22.61938
25	0	25125.0	19.81637	27.52451	22.67373	19.43744	27.39829	22.36122
26	0	25159.0	19.74065	27.11793	22.49442	19.61202	27.37306	22.48023
27	0	25256.0	19.83602	27.18791	22.58417	19.48675	27.34587	22.38129
28	0	25291.0	19.90214	27.43216	22.70698	19.61611	27.36269	22.48003
29	0	25528.0	19.62562	27.05318	22.39215	19.22315	26.94673	22.06972
30	0	25563.0	19.61629	27.30391	22.46228	19.22840	27.16976	22.14053
31	0	25626.0	19.62784	26.70904	22.28678	19.38650	27.13392	22.24463
32	0	25661.0	19.66779	27.29221	22.49581	19.32691	27.21069	22.22452
33	0	25971.0				18.98497	26.75716	21.83969
34	0	26006.0				19.07666	26.97983	21.97311
35	5	28037.0	20.55841	28.36096	23.46320	20.04307	27.86616	22.94129
36	5	28071.0	20.51958	28.19759	23.38499	19.95985	27.74742	22.84511
37	0	28227.0				19.50112	27.25333	22.36373
38	0	28262.0				19.50635	27.33210	22.39135
39	0	28343.0				19.60359	27.19402	22.41959
40	0	28378.0				19.45743	26.98749	22.25128
41	0	28536.0				19.55356	27.01589	22.32904
42	0	28571.0				19.43193	27.16960	22.28832
43	0	28878.0				19.68505	27.51747	22.57682
44	0	28915.0				19.68986	27.33757	22.52556

Table VI
Vehicle Test Fleet II Test Vehicle #7
Chrysler Corp. 225 CID

Test #	Test Oil	Odomr (miles)	Carbon Balance FTP	Carbon Balance HFET	Carbon Balance Comb.	Fuel Economy (MPG) Volumetric FTP	Volumetric HFET	Volumetric C0mb.
1	0	10552.0	18.86407	26.73510	21.74492	18.61485	26.99067	21.63625
2	0	12609.0	19.39983	27.64518	22.40723	18.85293	27.43158	21.94059
3	0	12665.0	19.57179	27.45684	22.47645	18.92489	27.34166	21.96805
5	0	13896.0	19.94408	27.38454	22.72224	19.07766	27.29556	22.06740
6	0	13931.0	19.86782	27.45884	22.69060	18.99680	27.36635	22.02848
7	0	14984.0	19.99440	27.90926	22.91928	19.02857	27.78954	22.17440
8	0	15019.0	19.72694	27.78512	22.68789	18.65540	27.63684	21.85090
9	0	16073.0	19.65076	27.61810	22.58234	18.67131	27.02654	21.68856
10	0	16108.0	19.78352	27.37029	22.60291	18.81897	26.71783	21.70680
11	0	17163.0	19.69878	27.51728	22.58669	18.68926	27.26405	21.77041
12	0	17198.0	19.77508	27.54946	22.65158	18.85762	27.53774	21.97458
14	2	19353.0	20.11456	27.92889	23.01193	19.06384	27.09326	21.99750
15	2	19384.0	19.87290	27.39964	22.67602	18.87771	27.39201	21.94762
16	0	19441.0	20.09906	28.20933	23.08582	19.23524	27.51091	22.24670
17	0	19479.0	19.94521	28.22273	22.97787	19.03644	28.30540	22.32642
18	0	19553.0	20.24932	27.40824	22.94640	19.27766	27.82688	22.37044
19	0	19558.0	19.77712	27.66322	22.68757	18.86379	28.06074	22.12730
20	0	19726.0	20.10511	28.01073	23.03007	19.15960	28.31449	22.42195
21	0	19761.0	20.01291	28.12280	22.99722	19.18583	28.16664	22.39976
22	4	21812.0	20.56999	28.27977	23.44643	19.70891	28.18860	22.79459
23	4	21846.0	20.60471	28.13926	23.42754	19.80806	27.77486	22.74372
24	0	21925.0	20.23877	27.81365	23.06557	19.22868	27.59294	22.26595
25	0	21959.0	20.23950	27.75166	23.04688	19.27118	27.42177	22.24677
26	0	22015.0	20.02007	28.02600	22.97321	19.28188	28.49599	22.56528
27	0	22070.0	20.26371	28.25728	23.21952	19.42155	27.99237	22.52513
28	0	22226.0	20.49264	28.29366	23.39536	19.42556	27.81288	22.47557
29	0	22281.0	20.32649	28.96285	23.47670	19.46515	27.87464	22.52286
30	0	22586.0				19.48413	27.30713	22.36770
31	0	22641.0				19.45032	27.31422	22.34532
32	6	24697.0	20.56209	28.37116	23.46898	19.54868	27.96783	22.61175
33	6	24757.0	20.32016	28.32105	23.27966	19.38444	28.24114	22.56956
34	6	26944.0	19.71461	28.12028	22.77864	18.71001	27.17977	21.76162
35	6	26978.0	20.29702	28.28048	23.25062	18.85910	27.52191	21.97115
36	6	27035.0	20.05655	28.11757	23.02731	19.19186	27.95591	22.34399
37	6	27069.0	20.07609	27.92555	22.98320	18.95693	27.65934	22.08358
38	0	27125.0				18.47222	26.54670	21.40150
39	0	27159.0				18.40706	26.79123	21.42412
40	0	27215.0				18.41154	26.63150	21.38129
41	0	27250.0				18.48914	26.80434	21.48896
42	0	27380.0				18.60452	26.79085	21.57056
43	0	27415.0				18.54949	27.47081	21.72428
44	0	27704.0				18.64074	27.22668	21.72346
45	0	27772.0				18.69316	27.02920	21.70554

Table VII
Vehicle Test Fleet II Test Vehicle #8
Ford Motor Co. 302 CID

Test #	Test Oil	Odomr (miles)	Carbon Balance FTP	Carbon Balance HFET	Carbon Balance Comb.	Volumetric FTP	Volumetric HFET	Volumetric Comb.
						Fuel Economy (MPG)		
1	0	9093.0	15.50551	20.41975	17.38866	15.33889	21.12211	17.49437
3	0	11242.0	15.88019	21.46012	17.98449	15.79885	21.81695	18.03790
4	0	11321.0	15.77683	21.19962	17.82911	15.73994	21.74147	17.97244
5	0	12379.0	15.99066	21.29415	18.00905	15.93705	21.70119	18.10054
7	0	12468.3	16.11205	21.34788	18.11091	15.81582	21.62901	17.99186
8	0	13527.0	16.17042	21.85818	18.31503	15.79583	21.58987	17.96544
9	0	13562.0	16.11862	21.34405	18.11424	15.70863	21.45400	17.86107
10	0	14665.0	16.08126	21.64425	18.18445	15.69355	21.56344	17.88432
11	0	14741.0	16.20290	21.87833	18.34430	15.80788	21.54678	17.96056
12	0	15796.0	16.14948	21.64950	18.23403	15.81707	21.43167	17.93095
13	0	15847.0	16.10619	21.77838	18.24450	15.79126	21.58735	17.96141
14	2	17902.0	15.80038	21.00693	17.78385	15.28192	20.77802	17.34674
15	2	17952.0	15.85955	21.14987	17.87114	15.18162	20.94845	17.32823
16	0	18008.0	15.96425	21.49644	18.05521	15.45137	21.32039	17.63603
17	0	18062.0	15.86521	21.27608	17.91551	15.33612	21.12665	17.49378
18	0	18118.0	15.80498	21.32709	17.88938	15.26390	21.16158	17.45271
19	0	18152.0	15.90782	21.39495	17.98329	15.48641	21.28157	17.64912
20	0	18322.0	15.74772	21.24715	17.82372	15.29791	21.05746	17.44509
21	0	18356.0	15.80656	21.25370	17.86721	15.29476	21.13418	17.46647
22	0	20132.0	14.95155	19.85298	16.82026	14.63452	19.84547	16.59542
23	0	20167.0	14.79207	20.11623	16.79202	14.44323	20.05791	16.52479
23	0	20167.0	14.79207	20.11623	16.79202	14.44323	20.05791	16.52479
24	0	20256.0	15.41463	20.69089	17.41278	15.09711	20.60814	17.16242
25	0	20290.0	15.50739	20.62692	17.45716	15.08187	20.49574	17.11643
26	4	22258.0	16.16072	21.61105	18.22961	15.63583	21.47500	17.81571
27	4	22321.0	16.14491	21.81706	18.28404	15.68194	21.67777	17.91126
28	0	22376.0				15.43889	21.42319	17.65861
29	0	22410.0				15.50816	21.54150	17.74462
30	0	22466.0				15.51992	21.42597	17.71765
31	0	22499.0				15.37926	21.39900	17.60828
32	0	22656.0				15.45138	21.30498	17.63129
33	0	22691.0				15.55275	21.43488	17.74392
34	0	22996.0				15.54507	21.52000	17.76459
35	0	23030.0				15.52459	21.32822	17.69083

Table VIII
Vehicle Test Fleet II Test Vehicle #9
General Motors 2.8 litre

Test #	Test Oil	Odomr (miles)	Fuel Economy (MPG) Carbon Balance FTP	HFET	Comb.	Volumetric FTP	HFET	Comb.
1	0	14781.0	17.04750	21.51800	18.80565	17.66146	24.87005	20.31063
2	0	16831.0	18.45108	25.12114	20.95481	18.24505	25.88764	21.04024
3	0	16866.0	18.45986	24.84421	20.87367	18.17913	25.53441	20.88653
4	0	17923.0	18.72799	25.42767	21.24718	18.36536	26.22981	21.22974
5	0	17958.0	18.33701	24.44204	20.65907	18.10148	25.63262	20.85941
6	0	18040.1	18.68792	25.62153	21.27925	18.30003	25.93197	21.09362
7	0	19117.0	18.83572	25.69537	21.40745	18.43262	26.22988	21.27912
8	0	19151.0	18.62666	25.49494	21.19626	18.47229	25.89443	21.20775
9	0	20207.0	18.69590	25.39322	21.21365	18.27509	25.40413	20.91645
10	0	20260.0	18.67426	25.76109	21.31264	18.49708	26.15784	21.30485
11	0	21341.0	18.64778	25.62472	21.25160	18.19749	25.79794	20.97879
12	0	21375.0	18.63514	25.86668	21.31695	18.29311	25.98049	21.10299
13	2	23432.0	18.63671	25.68874	21.26346	18.28799	26.08381	21.12983
14	2	23467.0	18.62679	25.75970	21.27818	18.18838	25.87246	20.99425
15	0	23577.0	18.77225	25.59299	21.33037	18.32694	25.83584	21.08453
16	0	23612.0	18.57820	25.40788	21.13466	18.22472	25.59504	20.93789
17	0	23668.0	18.88793	25.69712	21.44505	18.52011	25.95571	21.26091
18	0	23703.0	18.70616	25.58161	21.27984	18.31562	25.66832	21.02592
19	0	23859.0	18.81435	25.99821	21.48602	18.55617	26.12442	21.33788
20	0	23894.0	18.82989	25.71416	21.40916	18.45570	25.88603	21.19318
21	4	25980.0	18.84677	25.67780	21.40980	18.65254	25.87329	21.33149
22	4	26014.0	19.17279	26.29496	21.83404	18.93177	26.43062	21.70261
23	0	26071.0	19.36184	26.50197	22.03310	18.86710	26.51454	21.68112
24	0	26106.0	19.25954	26.26843	21.88754	18.74274	26.24008	21.50814
25	0	26182.0				18.26957	25.19394	20.84804
25	0	26182.0				18.26957	25.19394	20.84804
26	0	26217.0				18.45950	26.03653	21.24118
27	0	26252.0				18.55467	25.80785	21.24104
27	0	26409.0				18.42312	25.85261	21.15948
28	0	26444.0				18.50013	25.97736	21.25295
29	0	26784.0				18.42577	25.85304	21.16153
30	0	26842.0				18.48314	25.37100	21.05545
34	0	27139.0				18.32971	25.13374	20.87241
31	6	28899.0	18.84814	26.06839	21.53182	18.57274	26.10153	21.34305
32	6	28956.0	18.88414	25.97571	21.52906	18.43303	25.98622	21.20684
33	0	29107.0				18.46255	25.27401	21.01066
35	0	29230.0				18.31288	25.55816	20.99058
36	0	29286.0				18.31043	25.40296	20.94154
37	0	29443.0				18.17700	24.96616	20.71147
38	0	29478.0				17.95163	24.90980	20.53259
39	0	29803.0				17.88788	24.84879	20.46806
40	0	29860.0				18.02129	25.18723	20.66729

Table IX
Vehicle Test Fleet II Test Vehicle #10
General Motors 213 CID

Test #	Test Oil	Odomr (miles)	Fuel Economy (MPG) Carbon Balance FTP	Carbon Balance HFET	Carbon Balance Comb.	Volumetric FTP	Volumetric HFET	Volumetric Comb.
2	0	18921.8	17.60104	24.06087	20.01973	17.65101	24.14750	20.08227
3	0	20621.0	18.25221	24.38469	20.58141	17.85652	24.56540	20.35850
4	0	20656.0	18.08038	24.35719	20.45210	17.81804	24.51764	20.31623
6	0	21805.0	18.65235	24.56590	20.91833	18.18211	24.87075	20.68549
7	0	22862.0	18.43917	24.42939	20.72614	17.95606	24.35444	20.36351
8	0	22897.0	18.40290	24.53374	20.73455	17.97771	24.52070	20.43098
9	0	23981.0	18.38255	24.19443	20.61048	17.81107	24.25301	20.22897
10	0	24016.0	18.36399	24.41417	20.66891	17.83511	24.15846	20.21629
11	0	25067.0	18.53833	24.87401	20.93827	18.05638	24.57380	20.50343
12	0	25103.0	18.68121	24.78084	21.00817	18.04793	24.66687	20.52650
13	2	27183.0	18.69036	25.36060	21.19947	18.06877	25.19072	20.70266
14	2	27218.0	18.76198	25.21472	21.20382	18.04876	25.06269	20.64922
15	0	27355.0	18.61541	24.84543	20.98310	18.11791	24.83106	20.62742
16	0	27390.0	18.26954	24.55065	20.64656	18.14046	24.55914	20.55833
17	0	27447.0	18.38580	25.03741	20.88228	18.13240	25.03640	20.70124
18	0	27482.0	18.36369	25.15181	20.90224	18.09770	24.86818	20.62450
19	0	27641.0	19.04753	25.43168	21.47324	18.30830	25.24195	20.89057
20	0	27676.0	18.55281	25.04223	21.00189	18.23068	24.93550	20.74022
21	0	27734.0	18.72389	25.09554	21.13910	18.23702	25.15168	20.81170
22	4	29816.0	19.18584	25.45040	21.57571	18.63054	25.24128	21.11961
23	4	29852.0	19.18743	25.40465	21.56200	18.64285	25.22551	21.12333
24	0	29992.0				18.06223	24.82394	20.58548
25	0	30049.0				18.01965	24.91400	20.58276
26	0	30105.0				17.86773	24.57820	20.37047
27	0	30161.0				17.90563	24.88687	20.49247
28	0	30316.0				18.16793	25.15393	20.76284
28	0	30316.0				18.16793	25.15393	20.76284
29	0	30351.0				18.30907	25.27459	20.90118
30	0	30660.0				18.00684	24.84882	20.55352
31	0	30695.0				18.06350	24.84823	20.59389
32	6	32755.0	18.51116	24.80041	20.89573	17.80972	24.45326	20.29037
33	6	32790.0	18.43002	24.75364	20.82389	17.74967	24.53157	20.27156
34	0	32938.0				17.72022	24.51025	20.24387
35	0	32994.0				17.77765	24.05923	20.14441
36	0	33051.0				17.86185	24.60654	20.37503
37	0	33108.0				17.76169	24.57177	20.29253
38	0	33261.0				18.03731	25.01144	20.62532
39	0	33296.0				17.95332	25.01023	20.56444
40	0	33605.0				17.93918	24.75638	20.47658
41	0	33640.0				17.93658	24.59180	20.42385

Table X
Vehicle Test Fleet II Test Vehicle #11
Ford Motor Co. 2.3 litre

Fuel Economy

Test #	Test Oil	Odomr (miles)	Carbon Balance FTP	Carbon Balance HFET	Carbon Balance Comb.	Volumetric FTP	Volumetric HFET	Volumetric Comb.
2	0	11532.0	20.25975	27.22187	22.89469	19.46484	26.98050	22.25448
3	0	13679.0	19.58807	27.20565	22.41198	19.01309	26.99416	21.93093
4	0	13713.0	19.49811	27.12734	22.32328	18.93127	26.91025	21.84612
5	0	14748.0	19.72717	28.03252	22.76188	19.11210	27.60663	22.18376
6	0	14783.0	19.77628	27.40726	22.60904	19.15469	27.32989	22.13414
7	0	15836.0	19.81601	28.03811	22.82849	19.23658	27.70531	22.30464
8	0	15870.0	19.95582	27.96942	22.90957	19.15005	27.57294	22.20205
9	2	17911.0	19.42657	27.52151	22.39011	18.73994	27.19941	21.78955
10	2	17946.0	19.23807	27.63343	22.28474	18.42094	27.23708	21.56152
11	0	18000.0	19.98902	27.81954	22.88812	19.32386	27.54891	22.32302
12	0	18034.0	19.93292	27.46262	22.73841	19.30212	27.22695	22.21135
13	0	18089.0	19.93675	27.12069	22.63481	19.14382	27.02730	22.03627
14	0	18144.0	19.76128	27.51570	22.63134	19.19817	27.15951	22.11541
15	0	18298.0	20.23906	27.78354	23.05645	19.46967	27.46605	22.40498
16	0	18332.0	20.27735	27.69006	23.05466	19.13912	27.40841	22.14581
17	4	20411.0	19.74918	28.31160	22.86038	19.26282	27.94426	22.39346
18	4	20445.0	20.52793	28.81235	23.57875	19.77347	28.17951	22.83935
19	4	20499.0	20.36421	28.56894	23.38660	19.78608	28.03665	22.80620
20	0	20554.0				19.65176	27.77379	22.62974
21	0	20588.0				19.99223	27.80522	22.88608
22	0	20642.0				19.70283	28.04206	22.74687
23	0	20696.0				19.72549	27.76728	22.68148
24	0	20850.0				20.15039	28.24020	23.13236
25	0	20884.0				20.11064	28.19261	23.08919
26	0	21190.0				20.18595	28.19358	23.14400
27	0	21224.0				20.27883	28.34875	23.25820
28	6	23290.0	20.93778	28.17190	23.67330	20.15549	27.90627	23.03444
29	6	23324.0	20.85637	28.34235	23.66969	20.15634	27.92866	23.04191
30	0	23492.0				18.82163	27.63499	21.97542
31	0	23547.0				19.33956	27.87336	22.42979
32	0	23629.0				19.83210	27.94988	22.81383
33	0	23685.0				19.99016	28.25757	23.02107
34	0	23825.0				19.96906	28.22847	22.99698
35	0	23879.0				19.95611	27.99021	22.91605
36	0	24183.0				19.70771	27.60634	22.62011
37	0	24217.0				19.84841	27.70318	22.75124

Table XI
Percent Change in Fleet Fuel Economy
Volumetric Combined MPG

Candidate Oil	HRDF	HRSF1	100 HR	250 HR
1	(-).82	(-).77	(-).87	-
2	(-).96	(-).92	(-)1.4	-
3	(+).88	(+).47	(+)1.46	(+)1.55
4	(+)1.44	(+)1.43	(+).72	(-).66
5	(+)1.63	(+)1.92	(+)1.65	(+)1.03
6	(+)2.43	(+)1.35	(+)1.15	(+)1.63

Table XII
Percent Change in Fleet Fuel Economy
Volumetric FTP MPG

Candidate Oil	HRDF	HRSF1	100 HR	250 HR
1	(-)1.00	(-).99	(-)1.01	-
2	(-)1.29	(-)1.19	(-)1.58	-
3	(+).93	(+).68	(+)1.48	(+)3.27
4	(+)1.35	(+)1.89	(+).92	(+).98
5	(+)1.68	(+)1.80	(+)1.64	(+)1.05
6	(+)2.51	(+)1.38	(+)1.22	(+)1.58

Table XIII
Percent Change in Fleet Fuel Economy
Volumetric Highway MPG

Candidate Oil	HRDF	HRSF1	100 HR	250 HR
1	(-).12	(-).40	(-).68	-
2	(-).39	(-).47	(-)1.09	-
3	(+).82	(+).18	(+)1.45	(+)1.55
4	(+).80	(+).65	(+).38	(+).24
5	(+)1.59	(+)2.14	(+)1.71	(+).99
6	(+)2.26	(+)1.31	(+)1.02	(+)1.71

Table XIV
Tabulated FEO Summary
Volumetric FTP and Highway MPG

Vehicle #	CO#	%Over Trend Line*		HRDF%		HRSF1%		100 mile HR%		HRSF2%		250 Mile HR%	
		FTP	HWY	FTP	HWY	FTP	HWY	FTP	HWY	FTP	HWY	FTP	HWY
1	1	(-)1.25	(-) .85	(-) .83	(-) .74	(-)1.63	(-) .32	(-)1.19	(-)1.06	-	-	-	-
2	1	(-)1.80	(-) .62	(-)1.66	(-) .73	(-) .30	(-) .77	(-)3.05	(-)1.07	-	-	-	-
3	1	(+) .51	(+) .53	(-) .42	(+) .05	(+) .14	(+) .40	(-)1.03	(+) .12	-	-	-	-
4	1	(-)1.03	(-) .76	(-)1.05	(-) .54	(-)1.95	(-)1.13	(-)1.03	(-)1.83	-	-	-	-
5	1	(-)1.05	(-) .12	(-)1.05	(-)5.71	(-) .90	(-) .19	(-) .73	(+) .40	-	-	-	-
7	2	(-) .44	(-)2.27	(-) .87	(-)2.38	(-) .53	(-)2.51	(-)1.06	(-)3.53	-	-	-	-
8	2	(-)1.33	(-)1.72	(-)1.06	(-)1.70	(-) .94	(-)1.69	(-) .42	(-)1.10	-	-	-	-
9	2	(-) .81	(+) .43	(-) .21	(+)1.02	(-) .99	(+) .64	(-)1.47	(-) .10	-	-	-	-
10	2	(-) .40	(+)1.29	(-) .39	(+)1.75	(-) .31	(+) .70	(-) .97	(+) .33	-	-	-	-
11	2	(-)3.54	(-) .55	(-)3.94	(-) .62	(-)3.12	(+) .46	(-)3.90	(-) .79	-	-	-	-
1	3	(+)2.00	(+)2.62	(+) .61	(+) .60	(+) .93	(+)1.10	(+)1.66	(+)2.36	(+)1.39	(+)1.46	(+)2.58	(+)2.63
2	3	(+) .28	(-)3.42	(+)1.95	(+)1.65	(+)1.27	(-)1.32	(+) .64	(-) .44	-	-	(+) .70	(-)1.31
3	3	(+)1.69	(+) .96	(+)1.94	(+)2.11	(+)1.43	(+) .80	(+)4.16	(+)3.31	(+)3.63	(+)2.94	(+)4.27	(+)3.18
4	3	(-) .85	(-)1.31	(-)1.03	(-) .62	(-)1.45	(-) .77	(-)1.92	(-) .28	(-)2.49	(-)1.87	(-)2.85	(-)1.40
5	3	(-) .83	(+) .09	(+) .47	(+)1.16	(+) .34	(+)1.27	(+)2.04	(+)2.34	(+)1.35	(+)1.93	(+)3.08	(+)3.03
7	4	(+)3.24	(-) .54	(+)2.57	(+)1.72	(+)2.06	(-) .93	(+)1.58	(+) .50	-	-	(+)1.47	(+)2.46
8	4	(+)3.57	(+)3.43	(+)1.15	(+) .44	(+)1.30	(+) .76	(+) .96	(+) .96	-	-	(+) .75	(+) .71
9	4	(+)1.92	(+)1.11	(-) .10	(-) .86	(+)1.49	(+) .90	(+)1.73	(+) .91	-	-	(+)1.77	(+)2.11
10	4	(+)2.19	(+)1.06	(+)3.20	(+)1.47	(+)4.02	(+)2.03	(+)2.14	(+) .08	-	-	(+)3.23	(+)1.55
11	4	(+)1.95	(+)2.44	(-) .21	(+)1.15	(+) .33	(+) .73	(-)1.79	(-) .38	-	-	(-)2.29	(-) .58
1	5	(+)2.67	(+)2.91	(+)2.67	(+)1.97	(+)2.65	(+)1.81	(+)2.23	(+)1.73	-	-	(+)2.66	(+) .96
2	5	(+)6.04	(+)8.38	(+)1.33	(+) .71	(+) .62	(+)1.49	(+)1.11	(+) .49	-	-	(-)1.61	(+)1.42
3	5	(+) .20	(+) .42	(+)2.42	(+)4.31	(+)2.23	(+)4.11	(+)1.13	(+)2.73	-	-	(+)1.70	(+)1.93
4	5	(+) .95	(-) .22	(-) .73	(-) .69	(+) .90	(+) .83	(+) .67	(+) .92	-	-	(-) .36	(-) .55
5	5	(-) .13	(-) .05	(+)2.55	(+)1.88	(+)2.41	(+)2.64	(+)2.61	(+)2.64	-	-	(+)1.59	(+)1.38
7	6	(+)1.20	(-)1.17	(+)3.33	(+)4.10	(+)3.27	(+)3.92	(+)2.61	(+)2.44			(+)2.18	(+)2.51
8***	6	-	-	-	-	-	-	-	-	-	-	-	
9	6	(+) .04	(+) .69	(+) .58	(+)3.23	(+)1.04	(+)2.21	(+)2.42	(+)4.43	-	-	(+)3.05	(+)4.10
10	6	(-)3.13	(-)2.60	(+) .17	(+) .86	(-) .18	(-) .39	(-)1.21	(-)2.12	-	-	(-) .88	(-) .03
11	6	(+)3.06	(+)1.46	(+)5.64	(+) .59	(+)1.21	(-) .67	(+) .97	(-)1.26	-	-	(+)1.91	(+) .95

*Trend line established through all HR tests up to CO's #4 and 4.
***Vehicle taken out of program.

Table XV
Tabulated FEO Summary
Combined MPG

Vehicle #	CO#	%Over Trend Line* Vol.	C.B.	HRDF% Vol.	C.B.	HRSF1% Vol.	C.B.	100 mile HR% Vol.	C.B.	HRSF2% Vol.	C.B.	250 Mile HR% Vol.	C.B.
1	1	(-)1.12	(-)1.27	(-) .80	(-)1.91	(-)1.15	(-)1.40	(-)1.14	(-)1.14	-	-	-	-
2	1	(-)1.28	(-)1.76	(-)1.32	(-)1.85	(-) .47	(-) .61	(-)2.31	(-)2.60	-	-	-	-
3	1	(+) .53	(-) .35	(-) .26	(-) .58	(+) .23	(+) .01	(+) .71	(-) .15	-	-	-	-
4	1	(-) .96	(-)1.22	(-) .87	(-) .89	(-)1.66	(-)1.26	(-)1.30	(-)2.14	-	-	-	-
5	1	(-) .71	(-) .48	(-) .87	(-) .83	(-) .64	(-) .56	(-) .31	(-) .01	-	-	-	-
7	2	(-)1.08	(-) .03	(-)1.40	(-) .82	(-)1.24	(+) .12	(-)1.95	(-) .74	-	-	-	-
8	2	(-)1.44	(-)1.03	(-)1.29	(-) .88	(-)1.21	(-) .60	(-) .68	(-) .10	-	-	-	-
9	2	(-) .34	(-) .45	(+) .24	(+) .18	(-) .39	(+) .04	(-) .96	(-) .83	-	-	-	-
10	2	(+) .25	(+) .21	(+) .40	(+)1.86	(+) .06	(+)1.48	(-) .66	(+) .62	-	-	-	-
11	2	(-)2.44	* *	(-)2.66	(-)2.08	(-)1.81	(-)1.31	(-)2.69	(-)3.12	-	-	-	-
1	3	(+)2.20	(+) .83	(+) .40	(-) .18	(+) .79	(+) .74	(+)1.74	(+)1.32	(+)1.29	(+)1.16	(+)2.41	-
2	3	(-)1.04	(-)1.29	(+)1.32	(+)2.00	(-) .23	(+) .70	(-) .29	-	-	-	(-) .58	-
3	3	(+)1.45	(+) .23	(+)1.75	(+)2.63	(+) .95	(+)1.41	(+)3.16	(+)3.72	(+)3.16	(+)3.72	(+)3.66	-
4	3	(-)1.04	(-)1.35	(-) .51	(-) .55	(-) .84	(-) .87	(-) .97	(-) .92	(-)1.90	(-)2.26	(-)1.97	-
5	3	(-) .39	(+) .04	(+)1.17	(+)1.64	(+)1.12	(+)1.37	(+)2.61	(+)2.36	(+)2.01	(+)2.52	(+)3.55	-
7	4	(+)1.88	(+)1.39	(+)2.30	(+)1.65	(+) .99	(+)1.47	(+)1.20	(+) .004	-	-	(+)1.84	-
8	4	(+)3.55	-	(+) .91	-	(+)1.14	-	(+) .99	-	-	-	(+) .77	-
9	4	(+)1.64	(+) .55	(-) .36	(-)1.54	(+)1.30	-	(+)1.47	-	-	-	(+)2.93	-
10	4	(+)1.80	(+)1.91	(+)2.61	-	(+)3.38	-	(+)1.39	-	-	-	(+)2.76	-
11	4	(+)2.16	-	(-) .62	-	(-) .43	-	(-)2.14	-	-	-	(-)2.80	-
1	5	(+)2.72	-	(+)2.41	-	(+)2.34	-	(+)2.11	-	-	-	(+)1.99	-
2	5	(+)7.03	-	(+)1.10	-	(+) .95	-	(+) .88	-	-	-	(+) .14	-
3	5	(+) .29	-	(+)2.98	-	(+)2.88	-	(+)1.69	-	-	-	(+)1.75	-
4	5	(+) .51	-	(-) .71	-	(+) .88	-	(+) .76	-	-	-	(-) .42	-
5	5	(-) .11	-	(+)2.30	-	(+)2.49	-	(+)2.62	-	-	-	(+)1.49	-
7	6	(+) .37	-	(+)3.61	-	(+)3.51	-	(+)2.55	-	-	-	(+)2.30	-
8***	6	-	-	-	-	-	-	-	-	-	-	-	-
9	6	(+) .30	-	(+)1.57	-	(+)1.47	-	(+)3.17	-	-	-	(+)3.44	-
10	6	(-)2.90	-	(+) .43	-	(-) .26	-	(-)1.55	-	-	-	(-) .85	-
11	6	(+)2.50	-	(+)3.76	-	(+) .53	-	(+) .35	-	-	-	(+)1.55	-

*Trend line established through all HR tests up to CO's #3 and 4.
***Vehicle taken out of program.

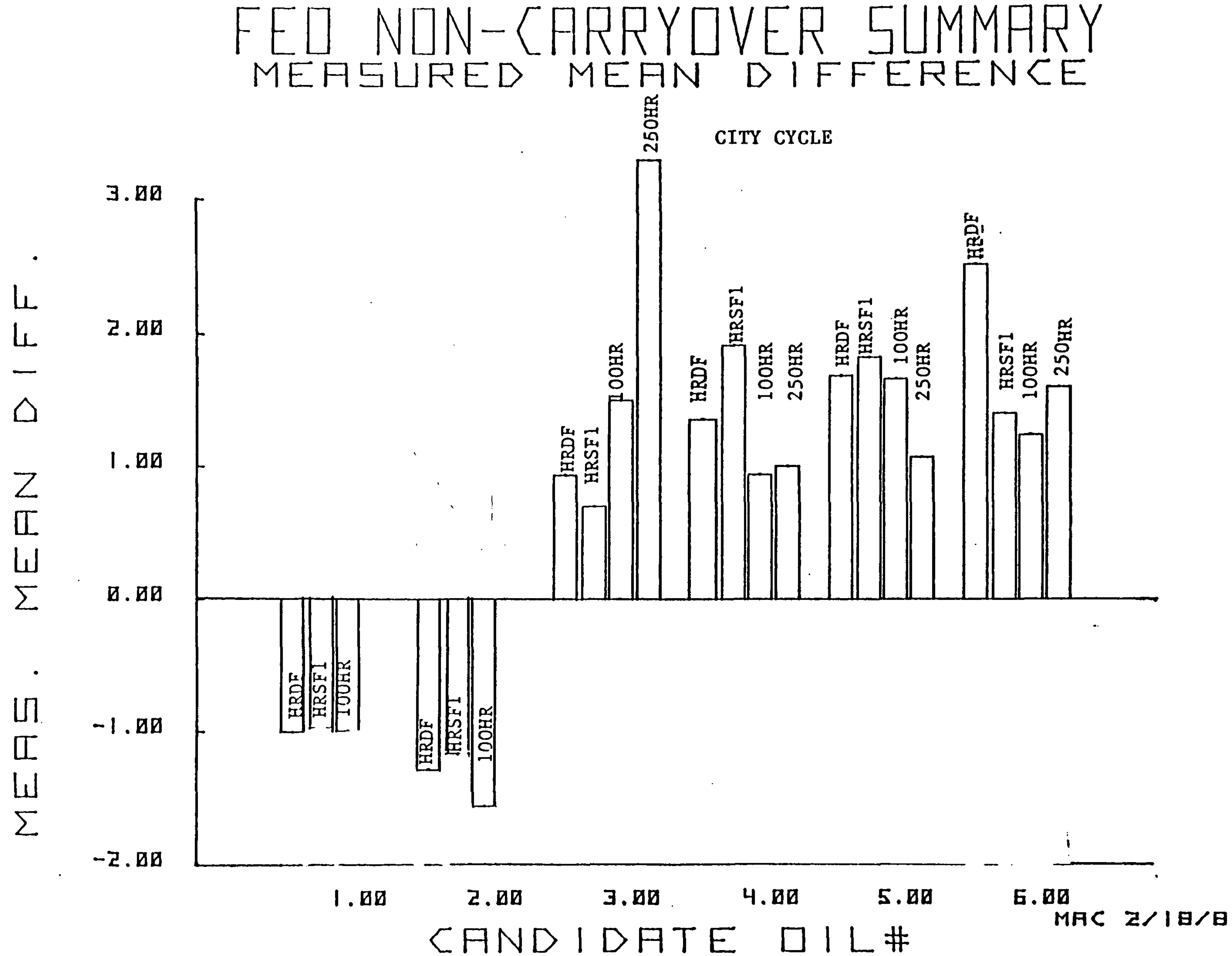

FED NON-CARRYOVER SUMMARY
MEASURED MEAN DIFFERENCE
CITY CYCLE
MEAS. MEAN DIFF.
3.00
2.00
1.00
0.00
-1.00
-2.00
HRDF
HRSF1
100HR
250HR
1.00
2.00
3.00
4.00
5.00
6.00
CANDIDATE OIL#
MAC 2/18/81

Figure 1

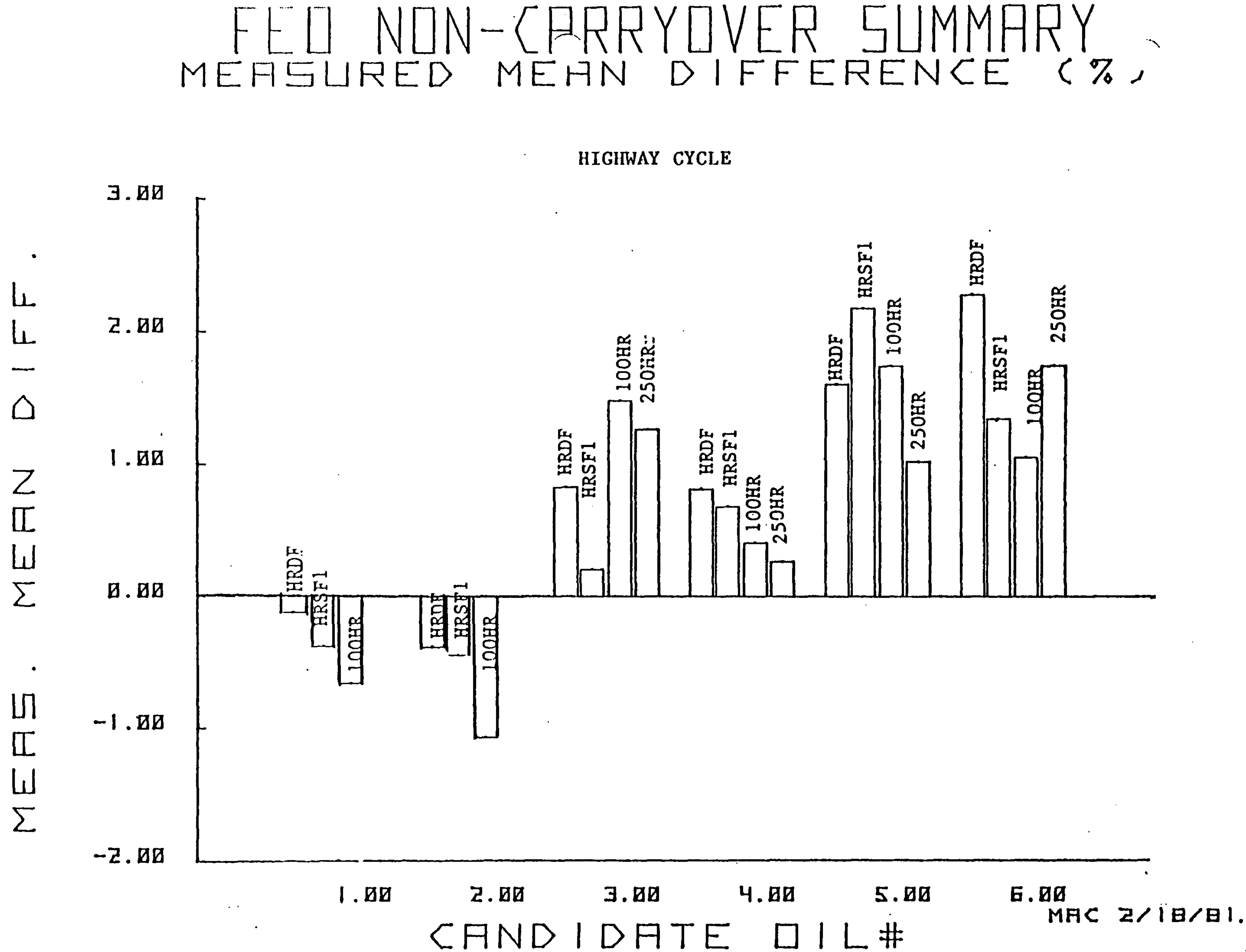
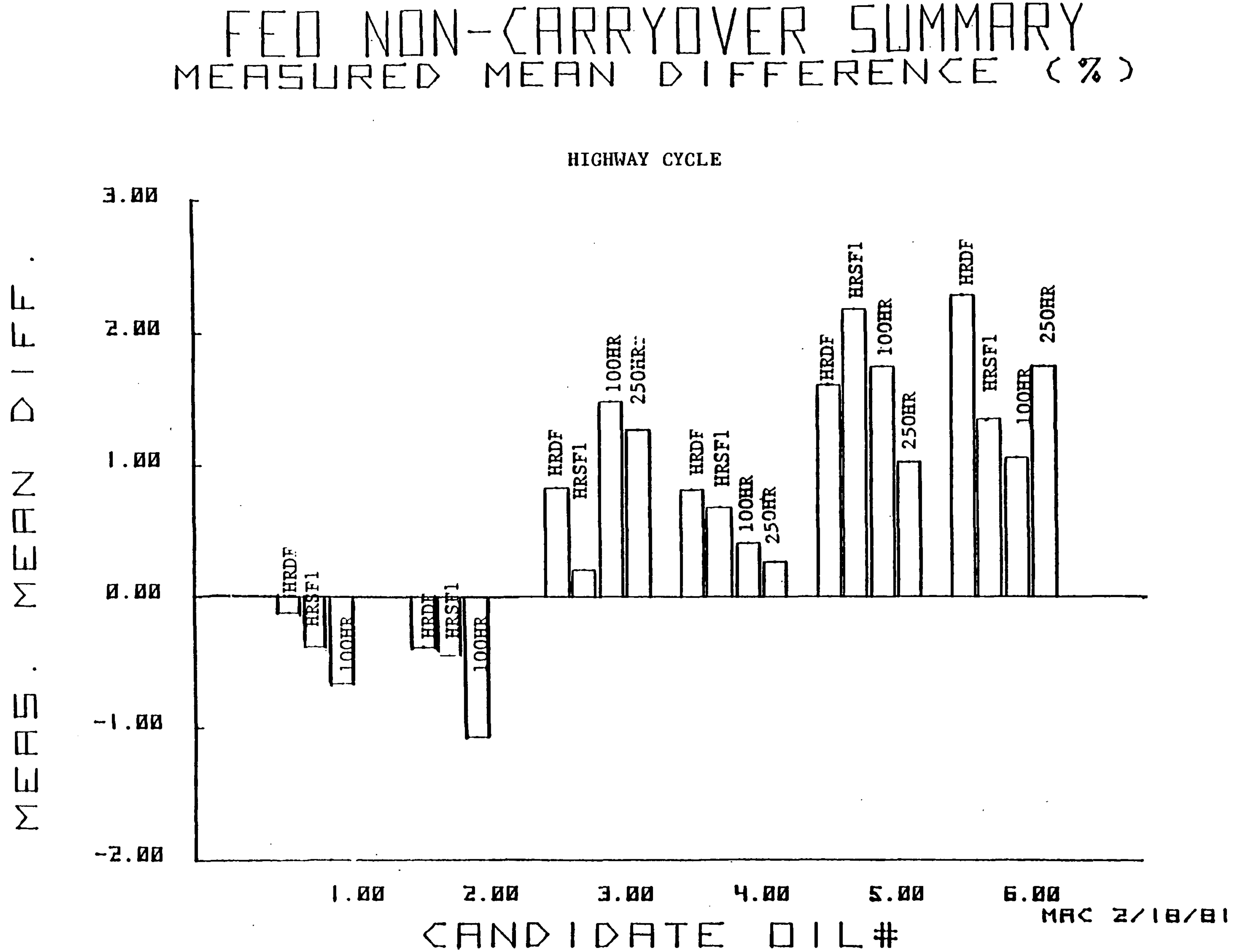
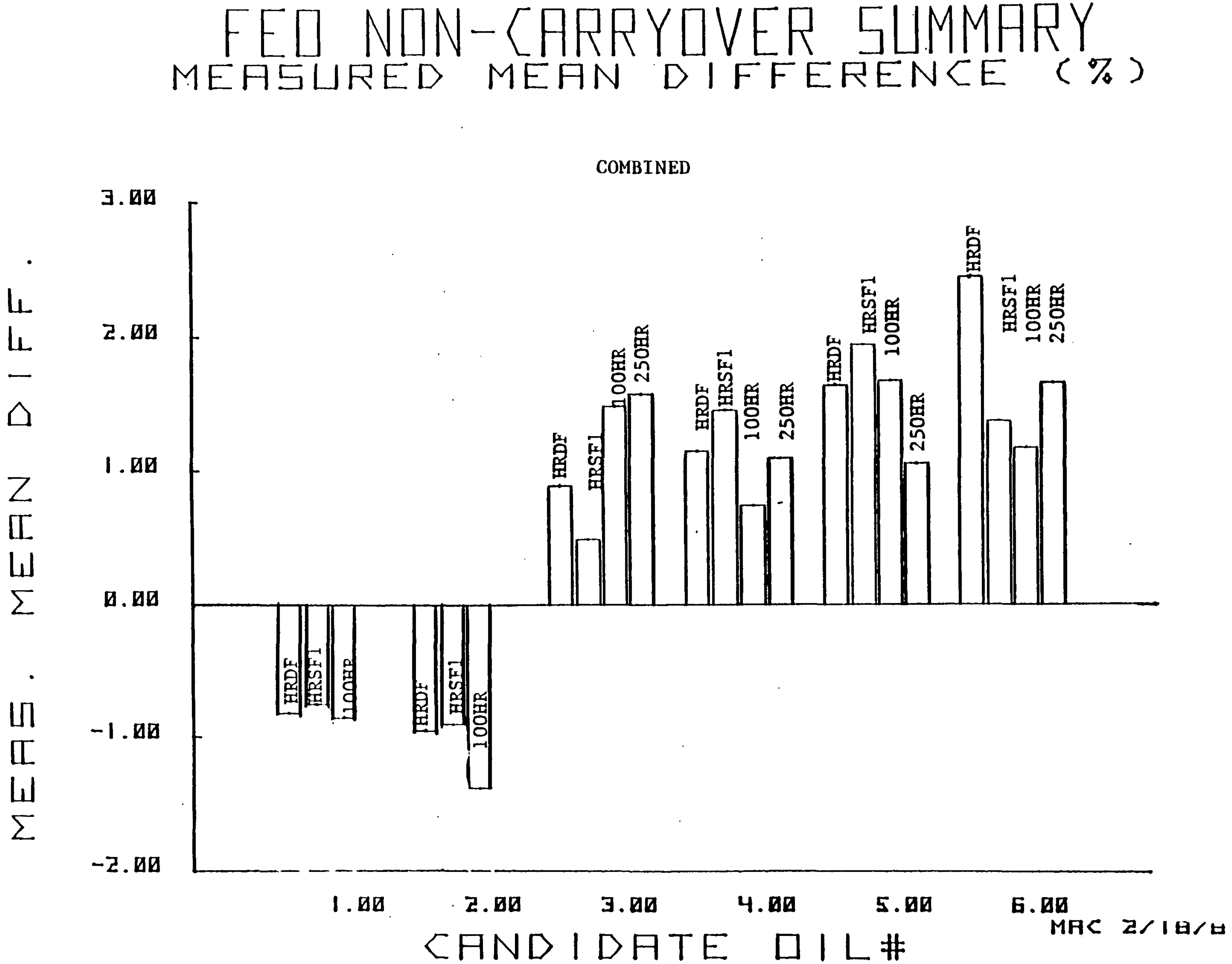

FEO NON-CARRYOVER SUMMARY
MEASURED MEAN DIFFERENCE (%)
HIGHWAY CYCLE
MEAS. MEAN DIFF.
3.00
2.00
1.00
0.00
-1.00
-2.00
HRDF
HRSF1
100HR
250HR
1.00
2.00
3.00
4.00
5.00
6.00
CANDIDATE OIL#
MAC 2/18/81.

Figure 2



FEO NON-CARRYOVER SUMMARY
MEASURED MEAN DIFFERENCE (%)
HIGHWAY CYCLE
MEAS. MEAN DIFF.
3.00
2.00
1.00
0.00
-1.00
-2.00
HRDF
HRSF1
100HR
250HR
1.00
2.00
3.00
4.00
5.00
6.00
CANDIDATE OIL#
MAC 2/18/81.

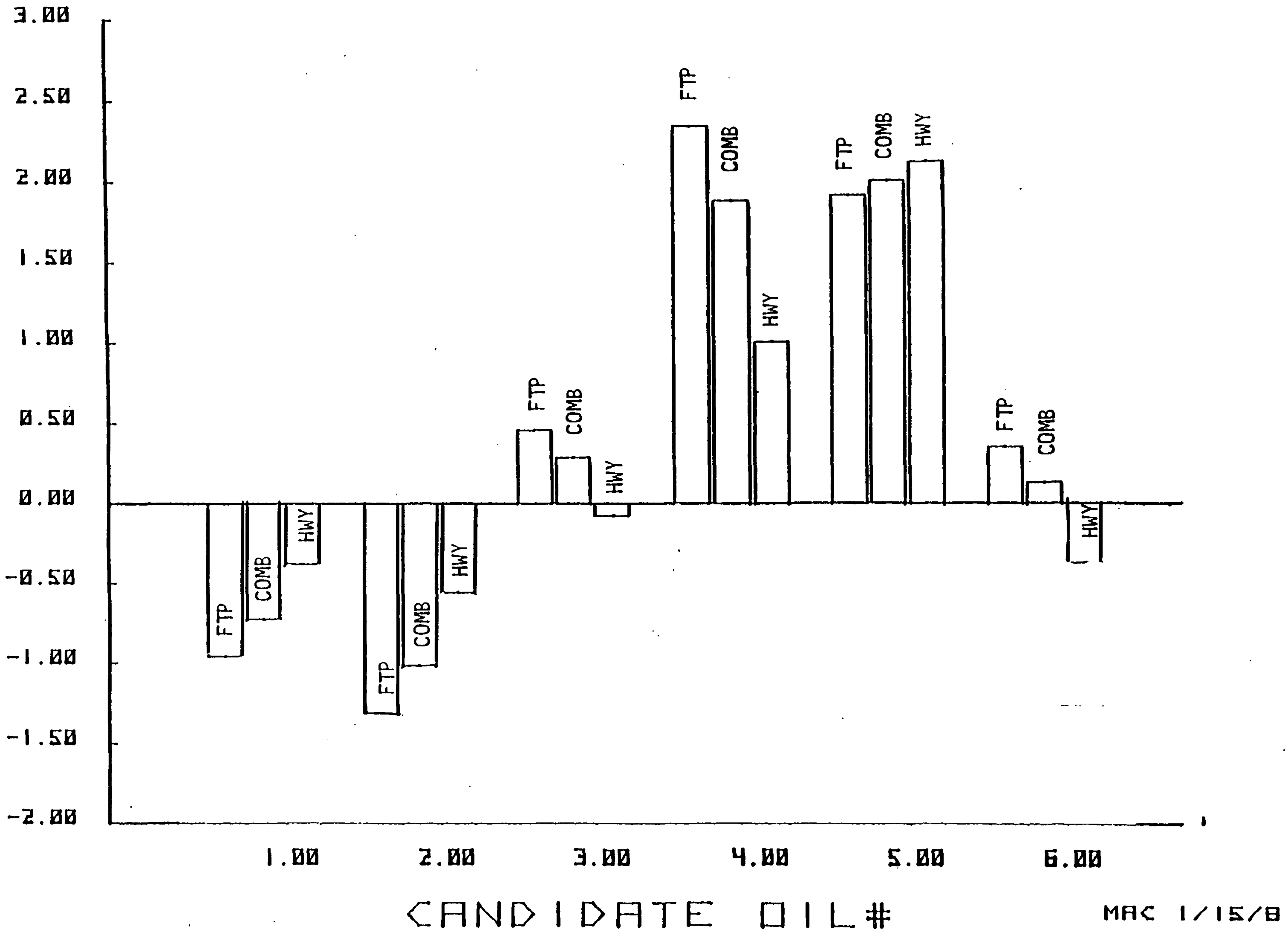
Figure 2

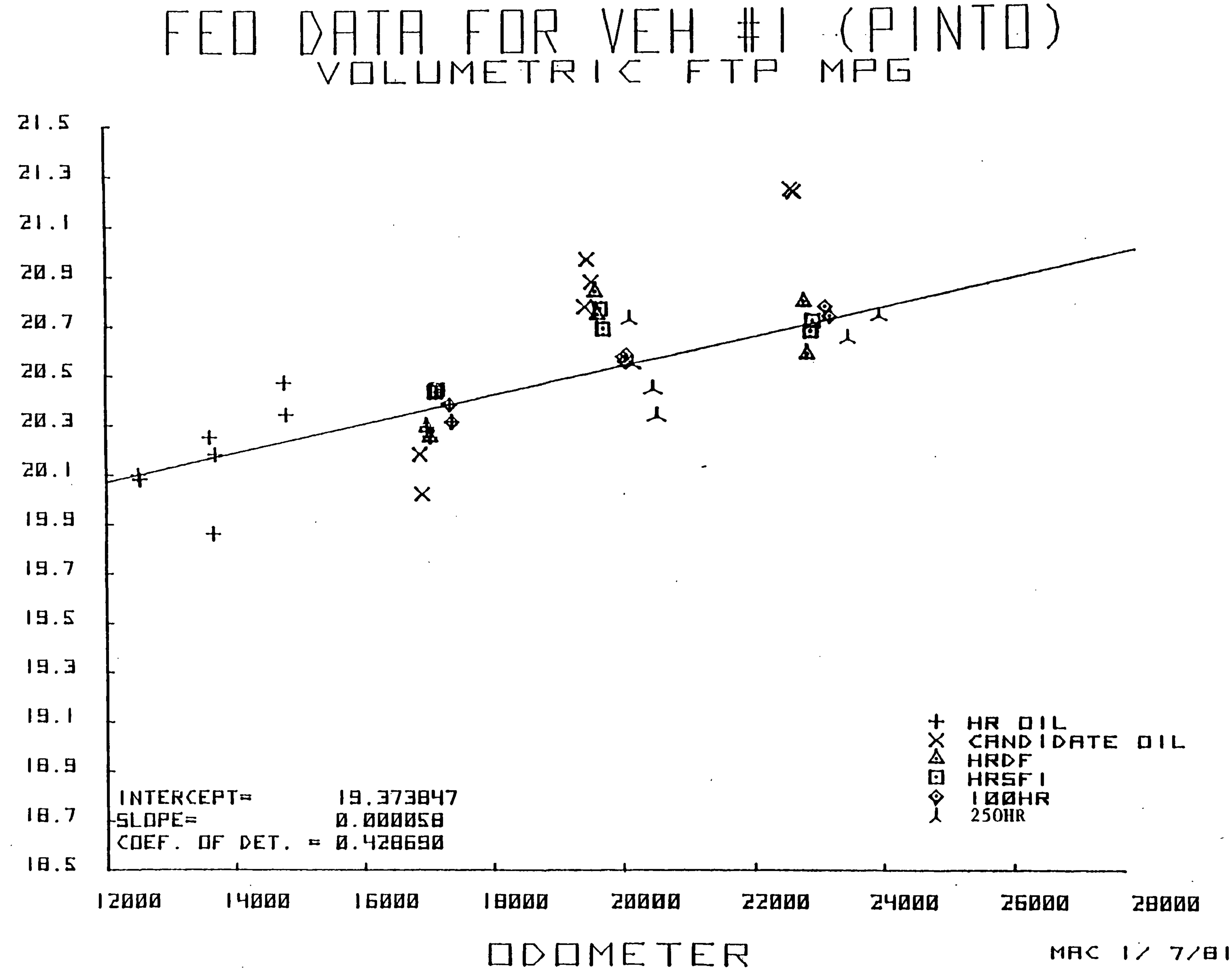


FED NON-CARRYOVER SUMMARY
MEASURED MEAN DIFFERENCE (%)
COMBINED
MEAS. MEAN DIFF.
3.00
2.00
1.00
0.00
-1.00
-2.00
HRDF
HRSF1
100HR
250HR
1.00
2.00
3.00
4.00
5.00
6.00
MAC 2/18/81
CANDIDATE OIL#

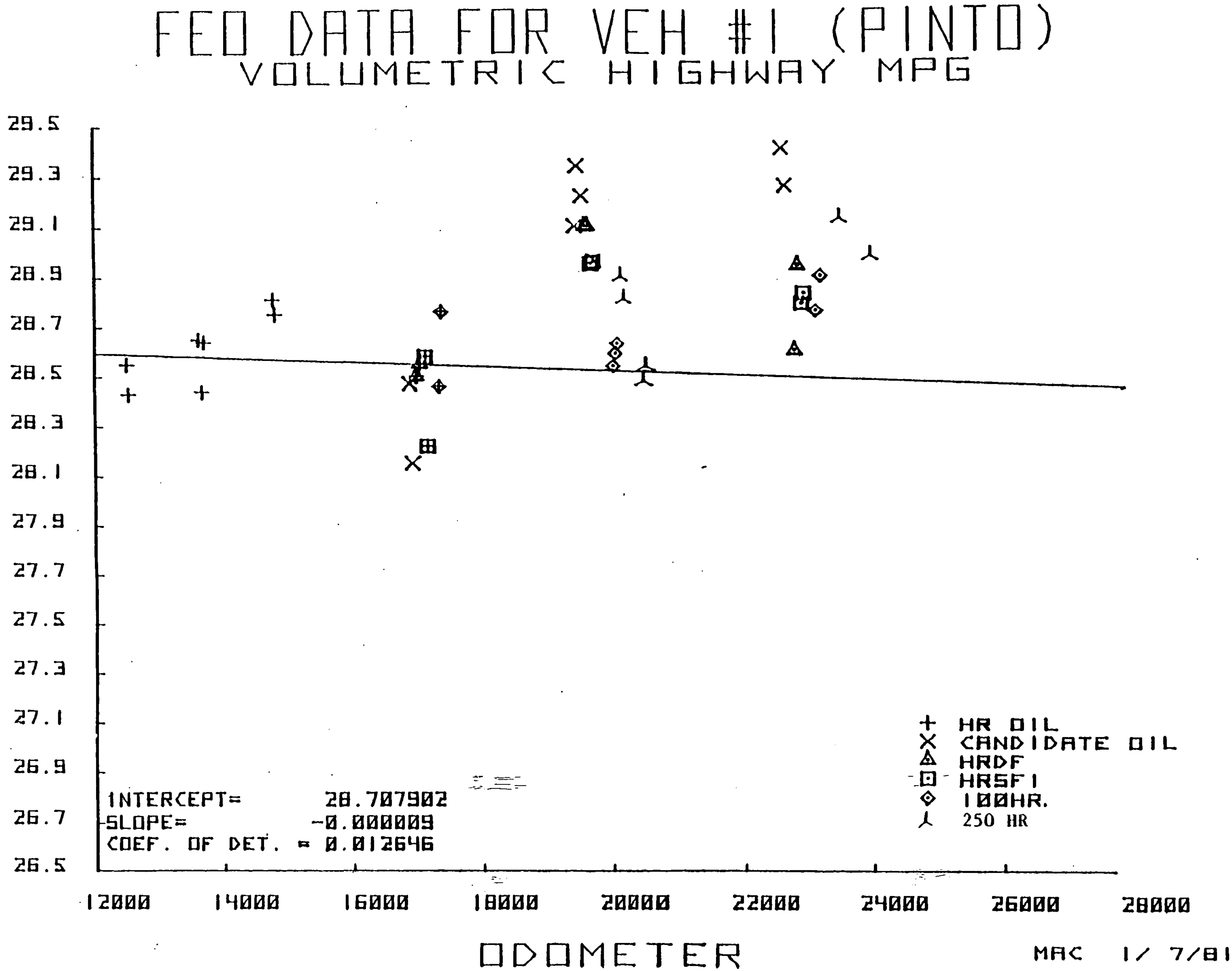
Figure 3

FEO CARRYOVER SUMMARY
ABSOLUTE DIFFERENCE (%)



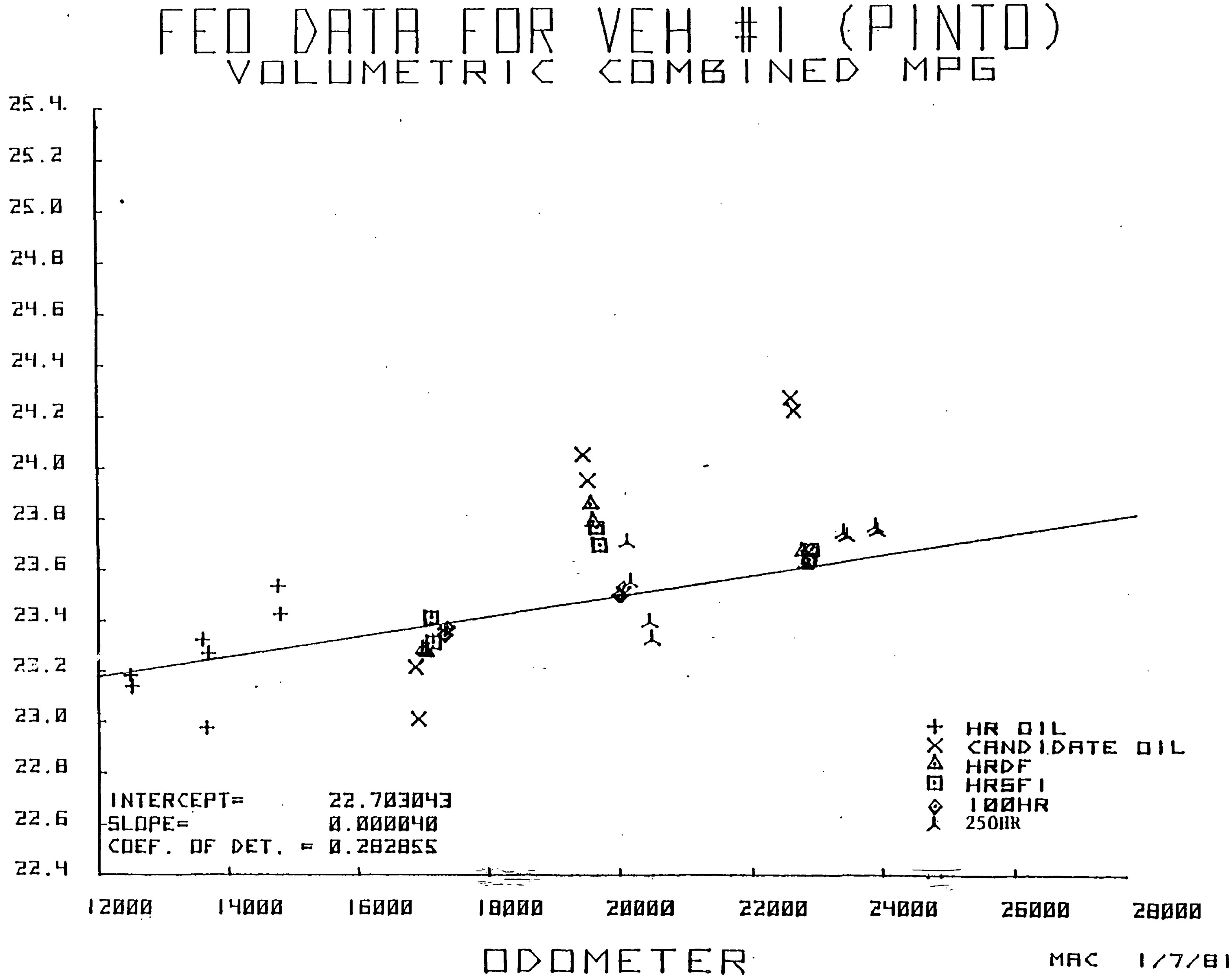


FED DATA FOR VEH #1 (PINTO)
VOLUMETRIC FTP MPG
21.5
21.3
21.1
20.9
20.7
20.5
20.3
20.1
19.9
19.7
19.5
19.3
19.1
18.9
18.7
18.5
12000
14000
16000
18000
20000
22000
24000
26000
28000
ODOMETER
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
INTERCEPT= 19.373847
SLOPE= 0.000058
COEF. OF DET. = 0.428690
MAC 1/ 7/81



FEO DATA FOR VEH #1 (PINTO)
VOLUMETRIC HIGHWAY MPG
29.5
29.3
29.1
28.9
28.7
28.5
28.3
28.1
27.9
27.7
27.5
27.3
27.1
26.9
26.7
26.5
12000
14000
16000
18000
20000
22000
24000
26000
28000
ODOMETER
INTERCEPT= 28.707902
SLOPE= -0.000009
COEF. OF DET. = 0.012646
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR.
250 HR
MAC 1/ 7/81

Figure 6



FEO DATA FOR VEH #1 (PINTO)
VOLUMETRIC COMBINED MPG
25.4
25.2
25.0
24.8
24.6
24.4
24.2
24.0
23.8
23.6
23.4
23.2
23.0
22.8
22.6
22.4
INTERCEPT= 22.703043
SLOPE= 0.000040
COEF. OF DET. = 0.282855
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
12000
14000
16000
18000
20000
22000
24000
26000
28000
ODOMETER
MAC 1/7/81

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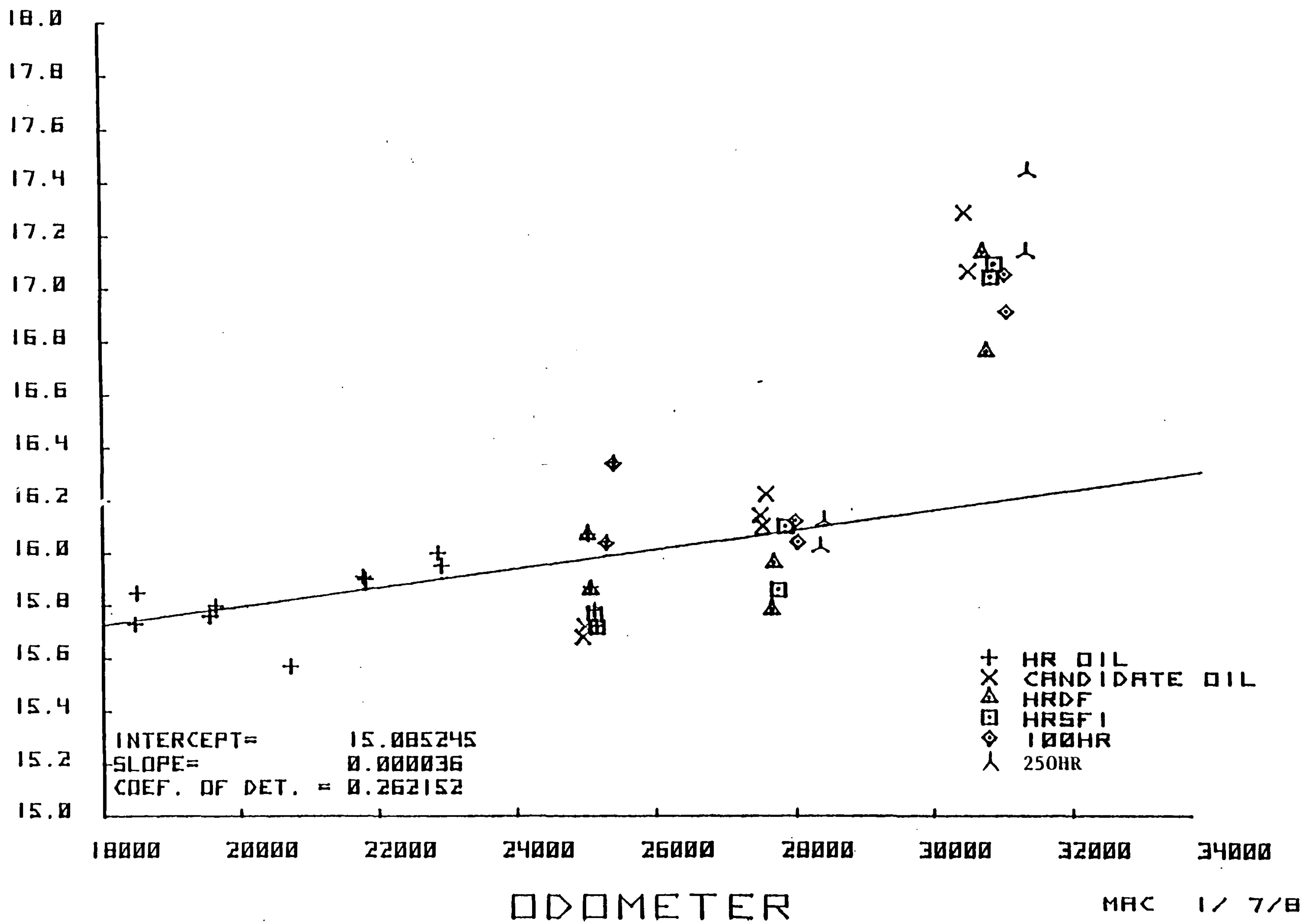
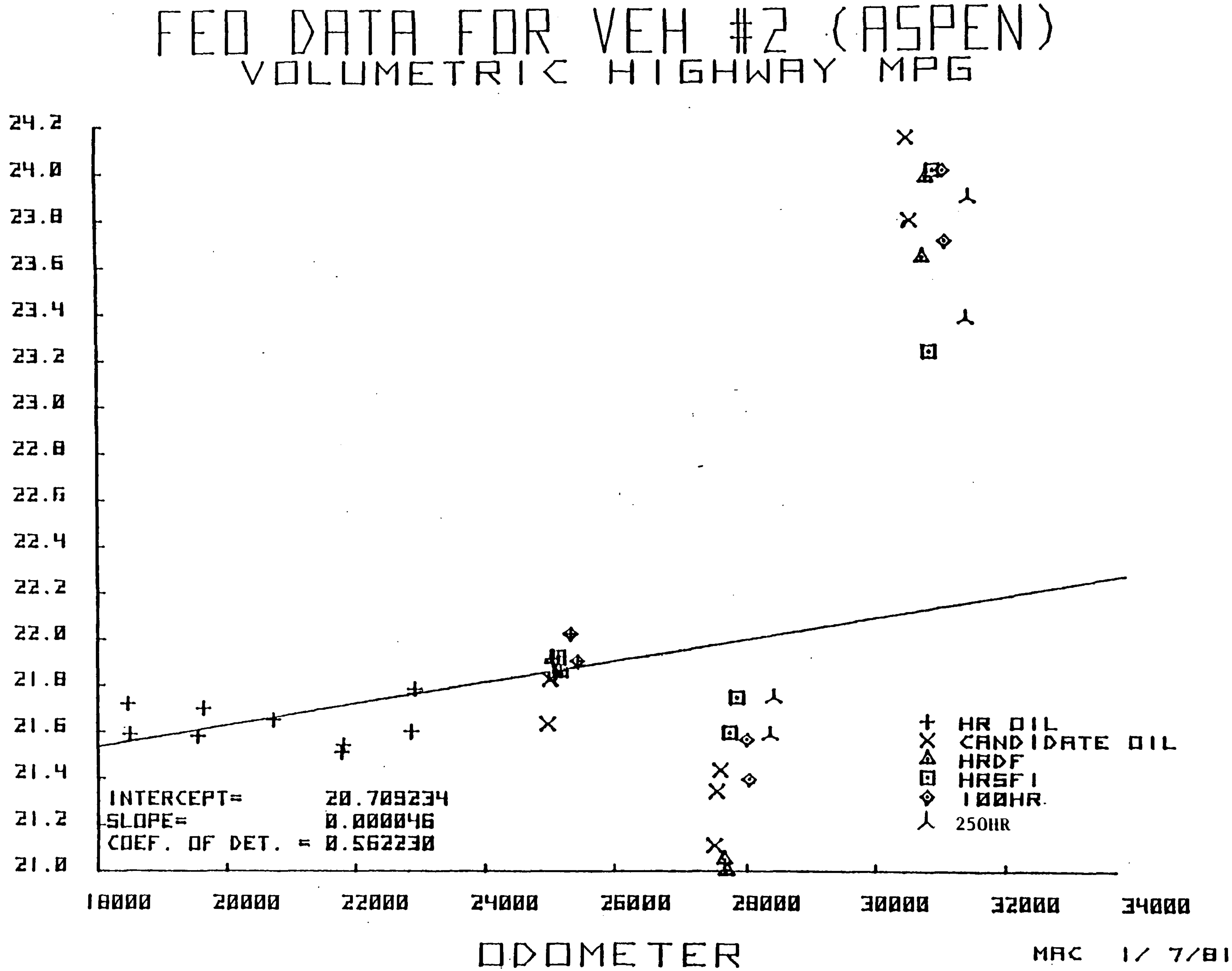
FEO DATA FOR VEH #2 (ASPEN)
VOLUMETRIC FTP MPG

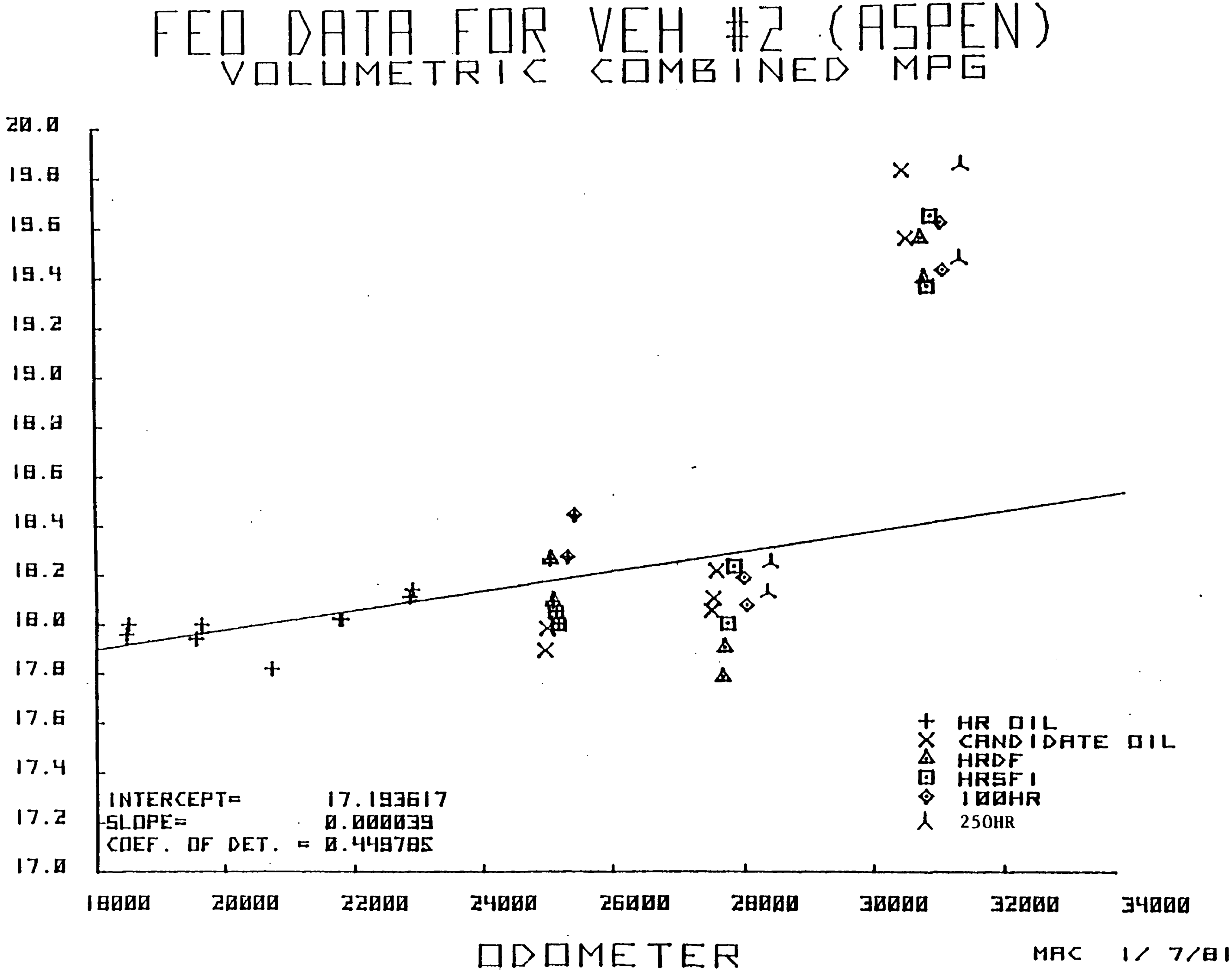




FED DATA FOR VEH #2 (ASPEN)
VOLUMETRIC HIGHWAY MPG
24.2
24.0
23.8
23.6
23.4
23.2
23.0
22.8
22.6
22.4
22.2
22.0
21.8
21.6
21.4
21.2
21.0
INTERCEPT= 20.709234
SLOPE= 0.000046
COEF. OF DET. = 0.562230
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
18000
20000
22000
24000
26000
28000
30000
32000
34000
ODOMETER
MAC 1/ 7/81

Figure 9

29



FEO DATA FOR VEH #2 (ASPEN)
VOLUMETRIC COMBINED MPG
20.0
19.8
19.6
19.4
19.2
19.0
18.8
18.6
18.4
18.2
18.0
17.8
17.6
17.4
17.2
17.0
18000
20000
22000
24000
26000
28000
30000
32000
34000
ODOMETER
INTERCEPT= 17.193617
SLOPE= 0.000039
COEF. OF DET. = 0.449785
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
MAC 1/ 7/81

Figure 10

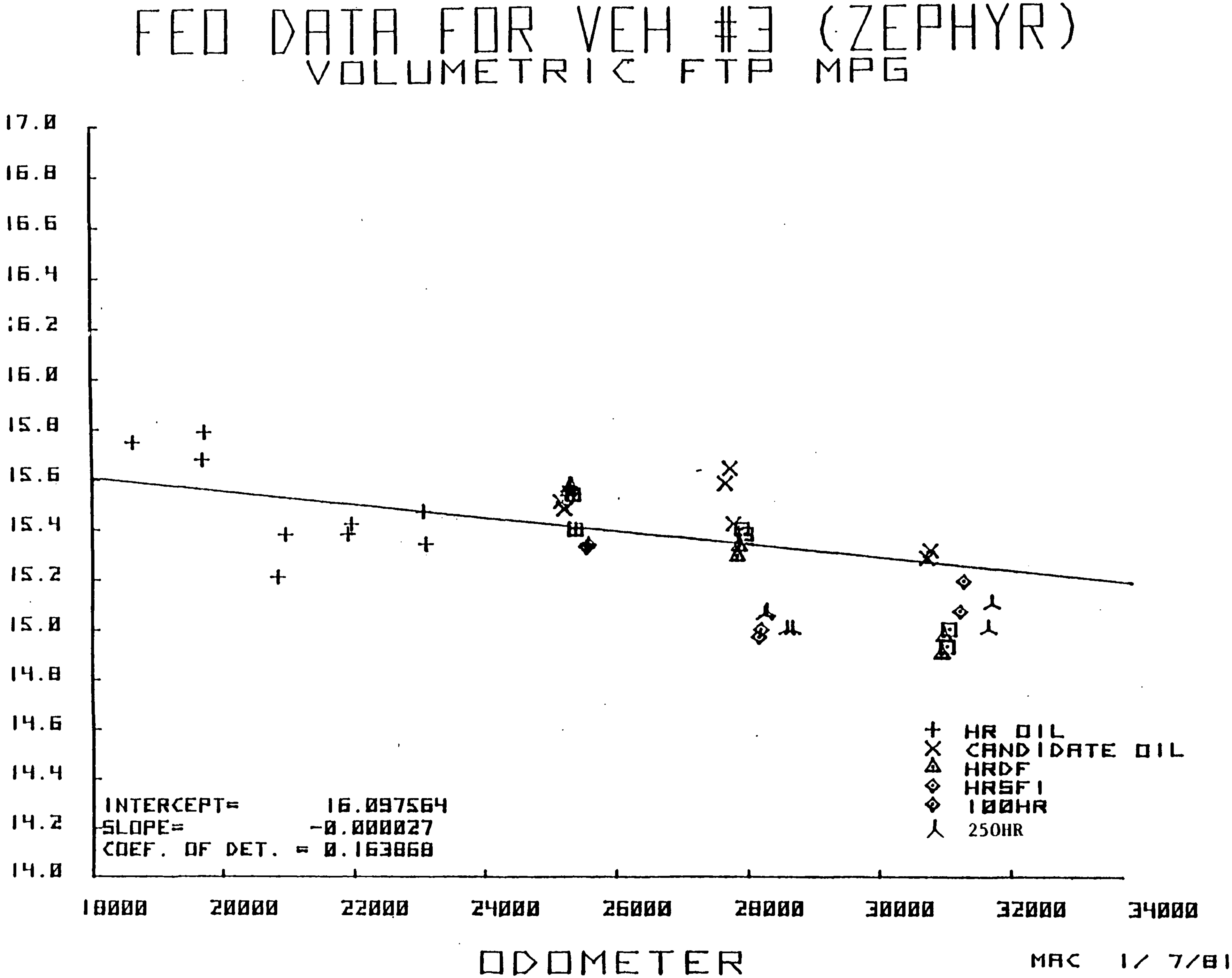

FEO DATA FOR VEH #3 (ZEPHYR)
VOLUMETRIC FTP MPG
17.0
16.8
16.6
16.4
16.2
16.0
15.8
15.6
15.4
15.2
15.0
14.8
14.6
14.4
14.2
14.0
INTERCEPT= 16.097564
SLOPE= -0.000027
COEF. OF DET. = 0.163868
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
18000
20000
22000
24000
26000
28000
30000
32000
34000
ODOMETER
MAC 1/ 7/81

Figure 11

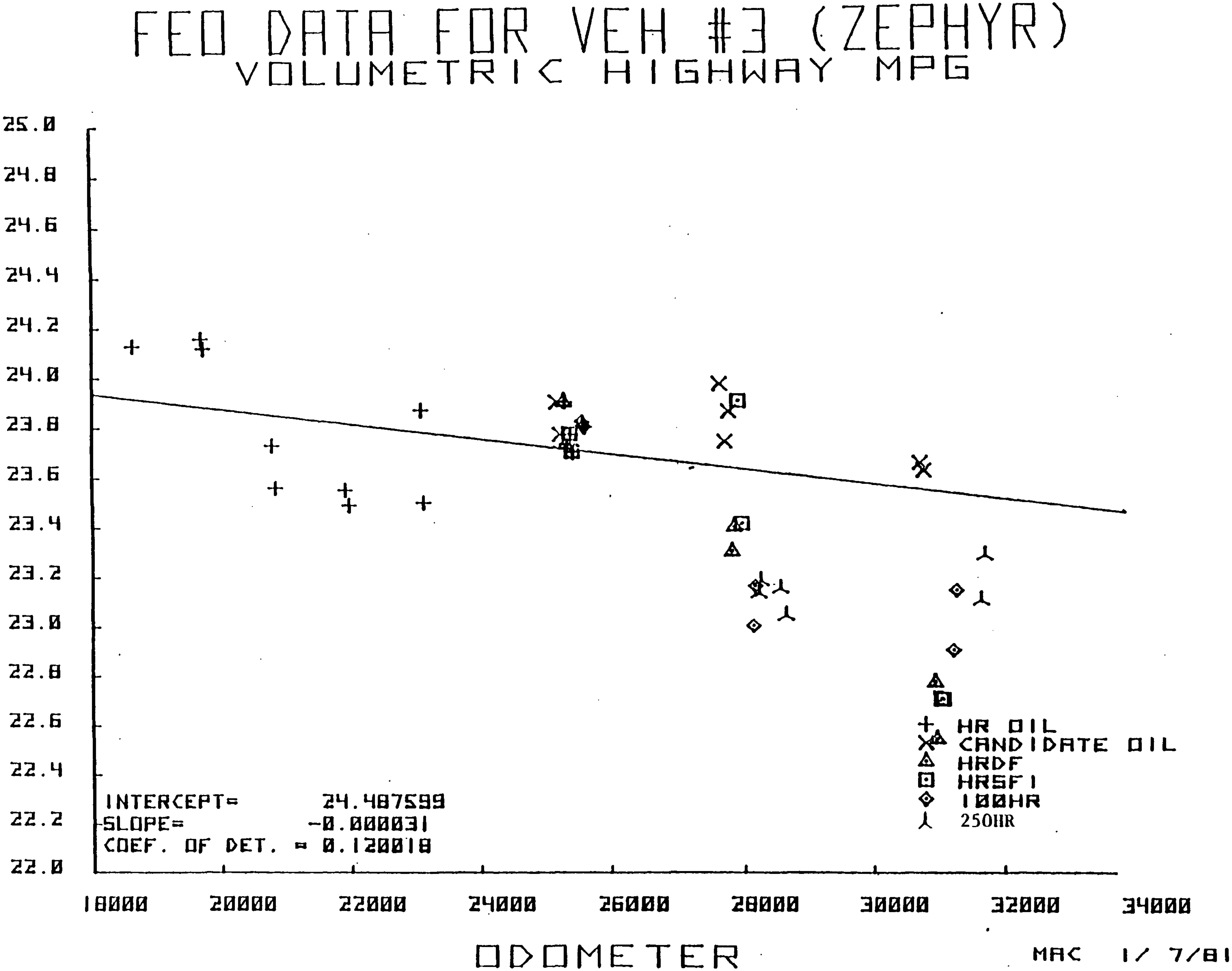
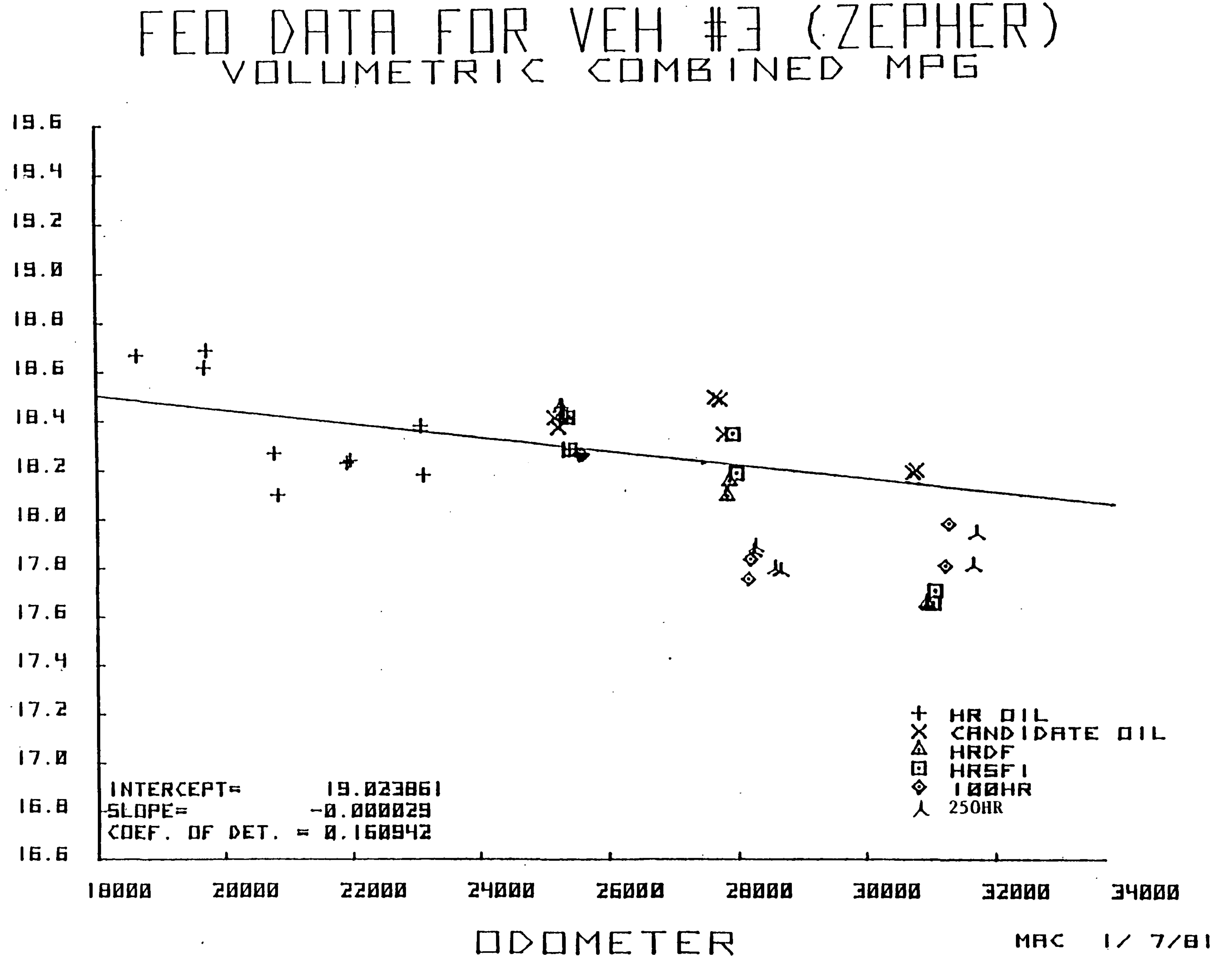

FEO DATA FOR VEH #3 (ZEPHYR)
VOLUMETRIC HIGHWAY MPG
25.0
24.8
24.6
24.4
24.2
24.0
23.8
23.6
23.4
23.2
23.0
22.8
22.6
22.4
22.2
22.0
INTERCEPT= 24.487599
SLOPE= -0.000031
COEF. OF DET. = 0.120018
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
18000
20000
22000
24000
26000
28000
30000
32000
34000
ODOMETER
MAC 1/ 7/81

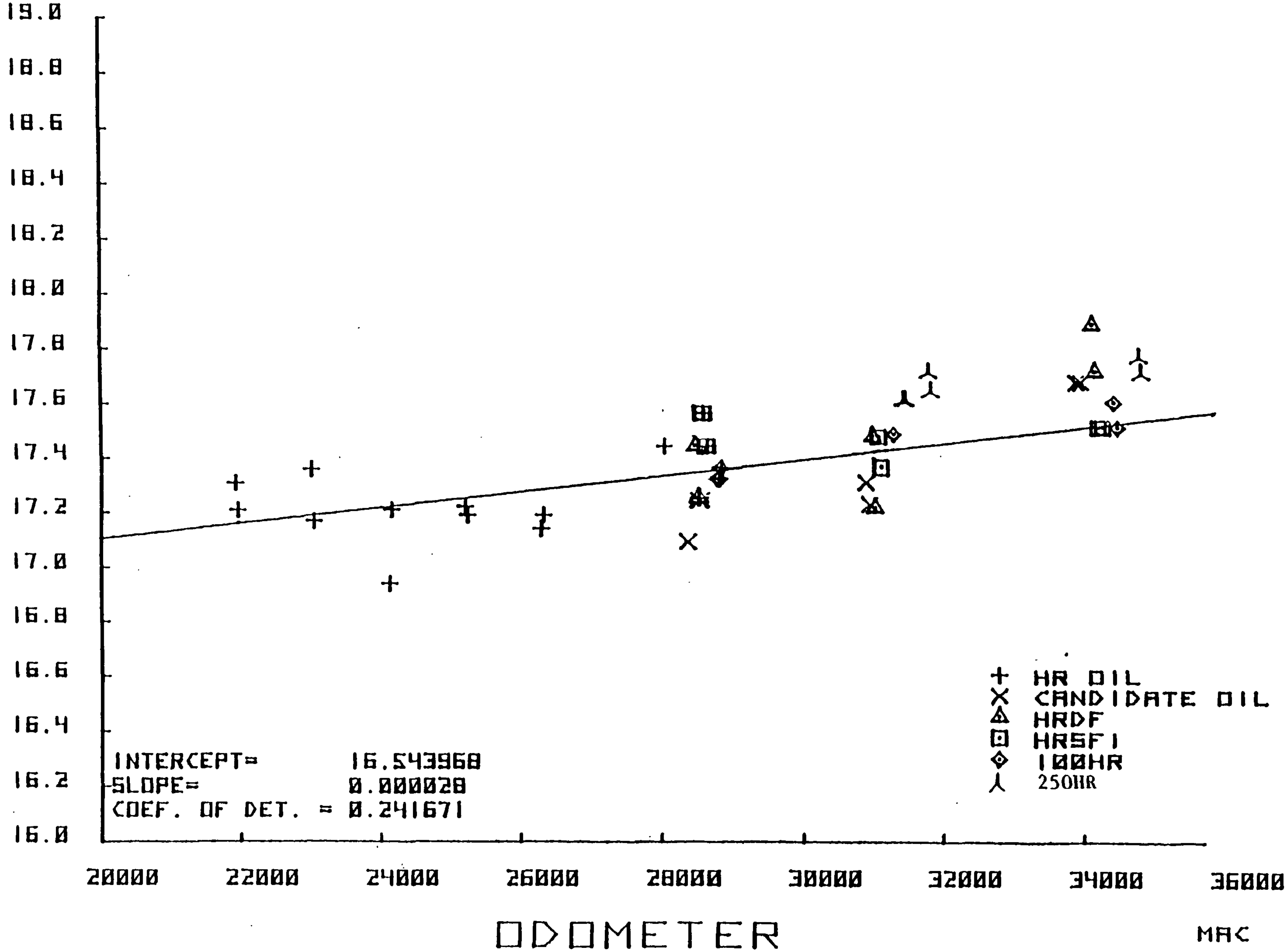
Figure 12



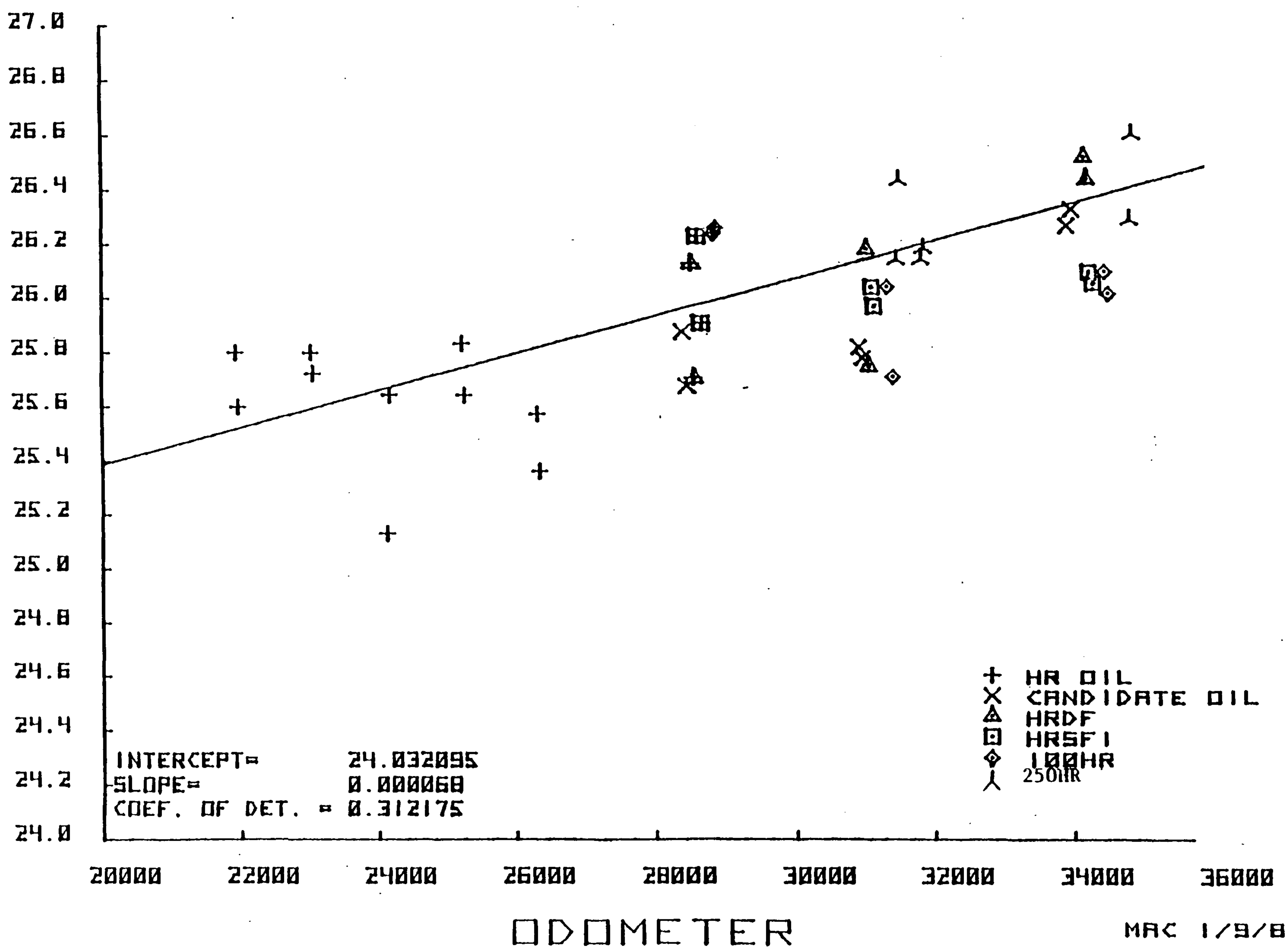
FED DATA FOR VEH #3 (ZEPHER)
VOLUMETRIC COMBINED MPG
19.6
19.4
19.2
19.0
18.8
18.6
18.4
18.2
18.0
17.8
17.6
17.4
17.2
17.0
16.8
16.6
INTERCEPT= 19.023861
SLOPE= -0.000029
COEF. OF DET. = 0.160942
18000
20000
22000
24000
26000
28000
30000
32000
34000
ODOMETER
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
MAC 1/ 7/81

Figure 13

FEO DATA - VEH #4 (CUTLASS)
VOLUMETRIC FTP MPG



FEO DATA - VEH #4 (CUTLASS)
VOLUMETRIC HIGHWAY MPG



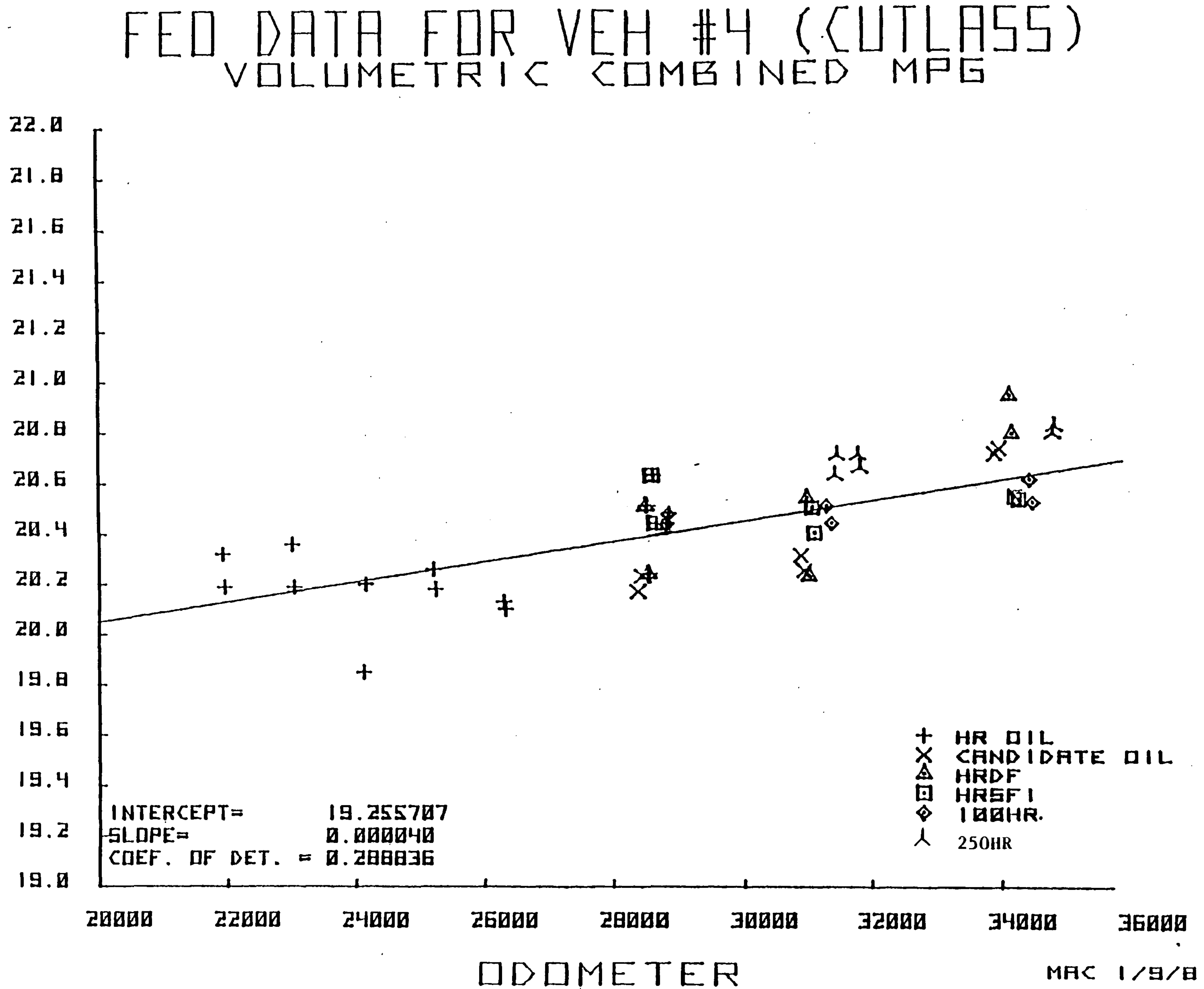
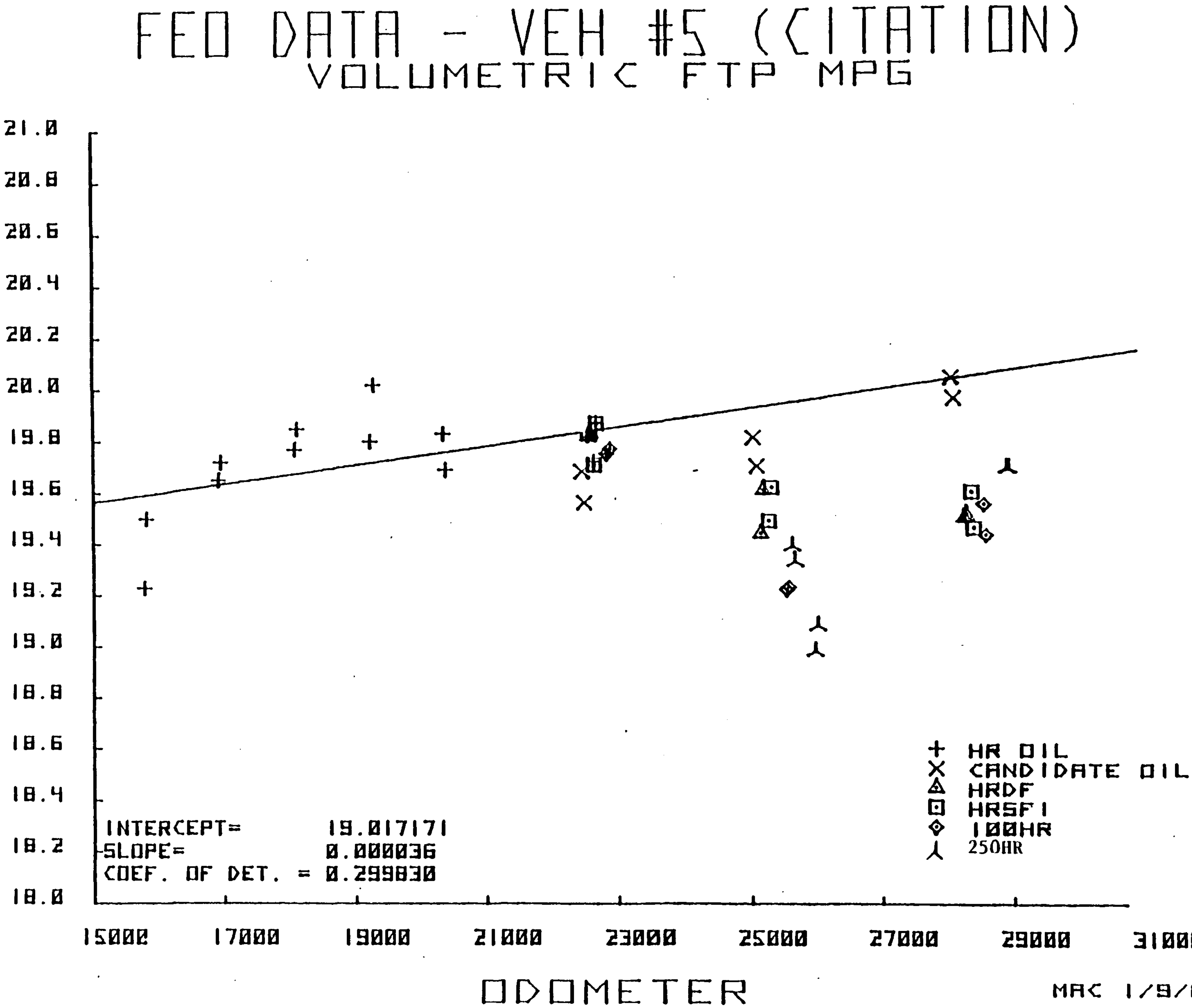
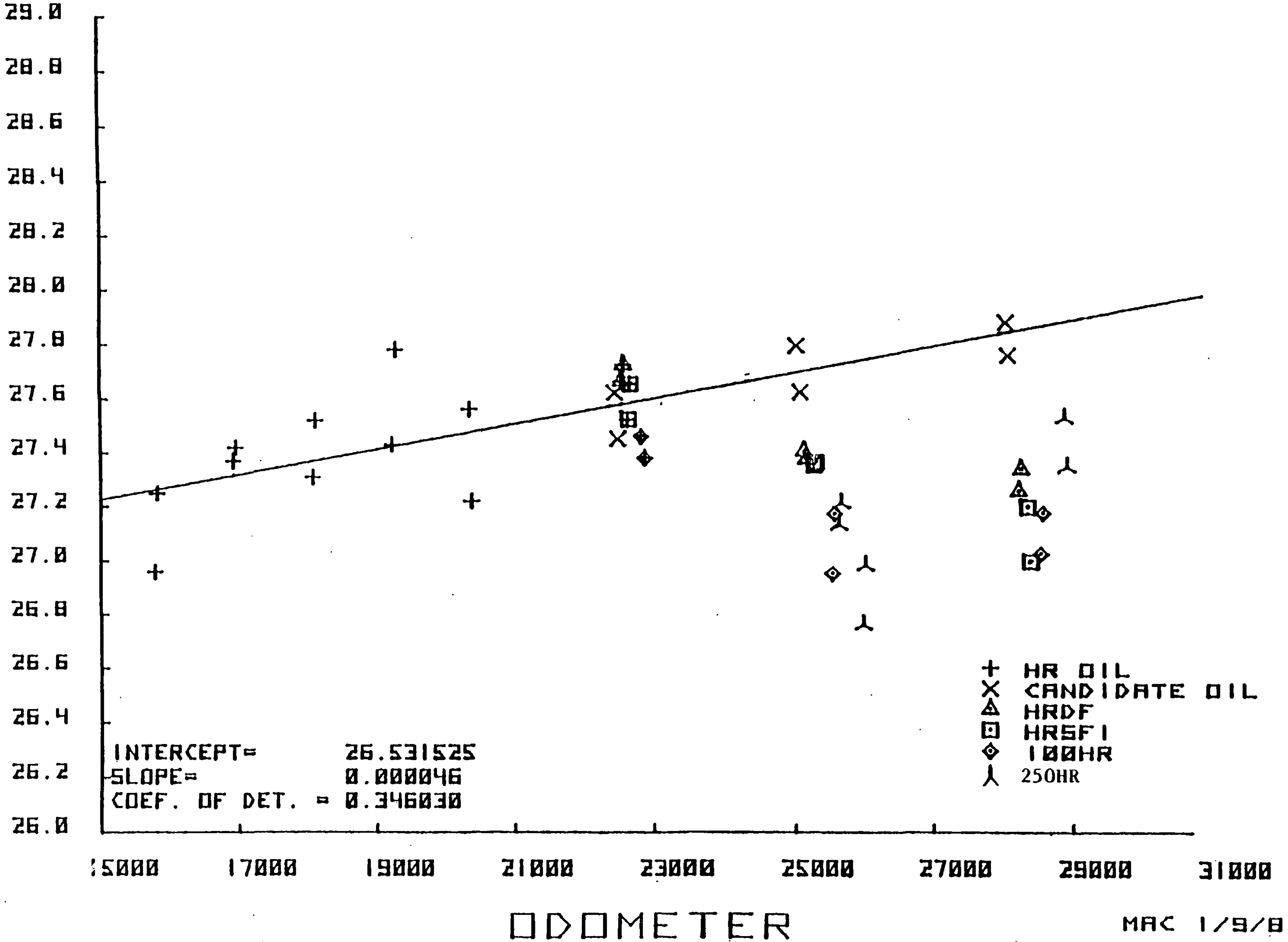

FED DATA FOR VEH #4 (CUTLASS)
VOLUMETRIC COMBINED MPG
22.0
21.8
21.6
21.4
21.2
21.0
20.8
20.6
20.4
20.2
20.0
19.8
19.6
19.4
19.2
19.0
INTERCEPT= 19.255707
SLOPE= 0.000040
COEF. OF DET. = 0.288836
+ HR OIL
X CANDIDATE OIL
HRDF
HRSFI
100HR.
250HR
20000
22000
24000
26000
28000
30000
32000
34000
36000
ODOMETER
MAC 1/9/81

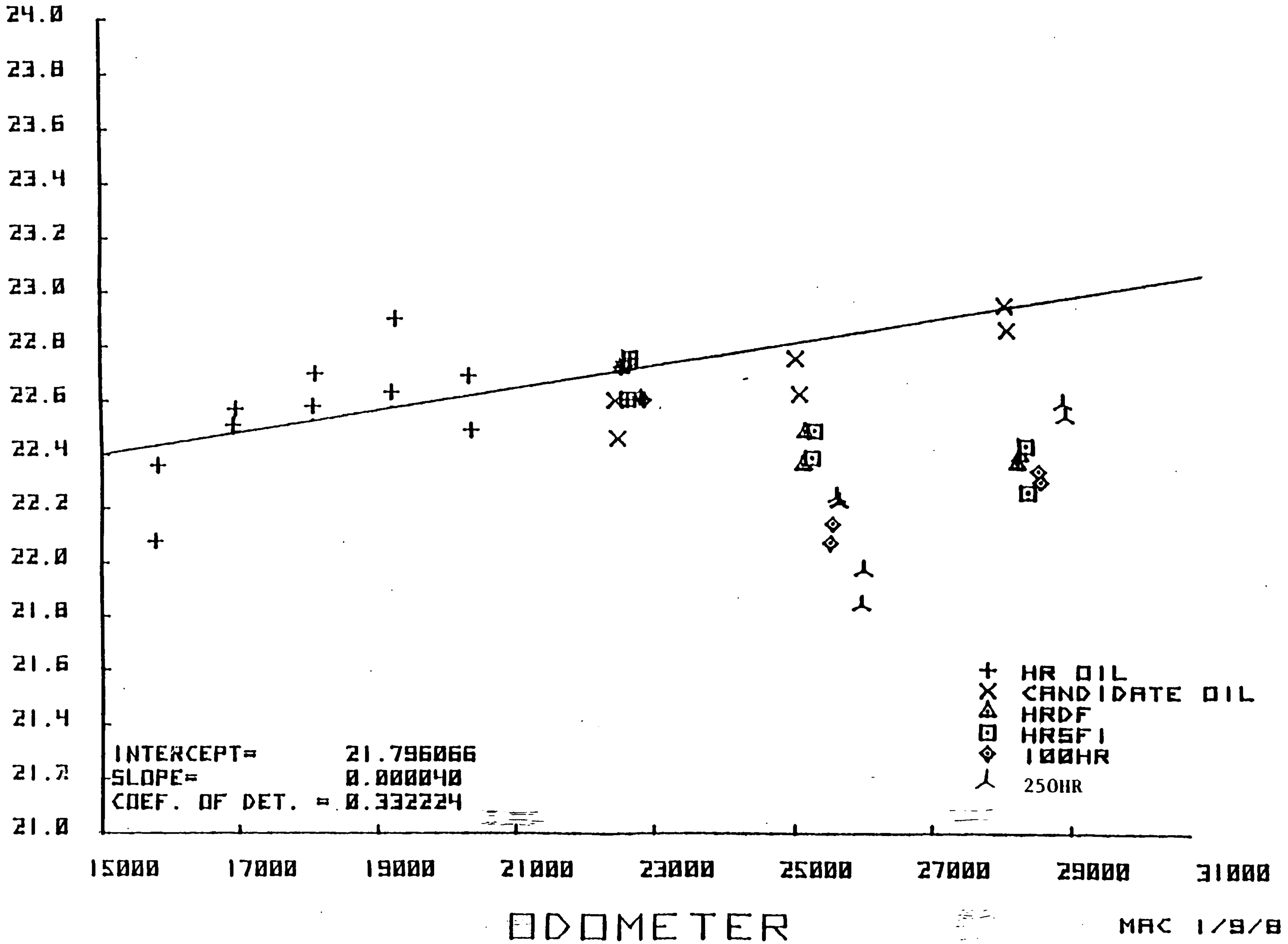
Figure 16


FED DATA - VEH #5 (CITATION)
VOLUMETRIC FTP MPG
21.0
20.8
20.6
20.4
20.2
20.0
19.8
19.6
19.4
19.2
19.0
18.8
18.6
18.4
18.2
18.0
15000
17000
19000
21000
23000
25000
27000
29000
31000
ODOMETER
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
INTERCEPT= 19.017171
SLOPE= 0.000036
COEF. OF DET. = 0.299830
MAC 1/9/81

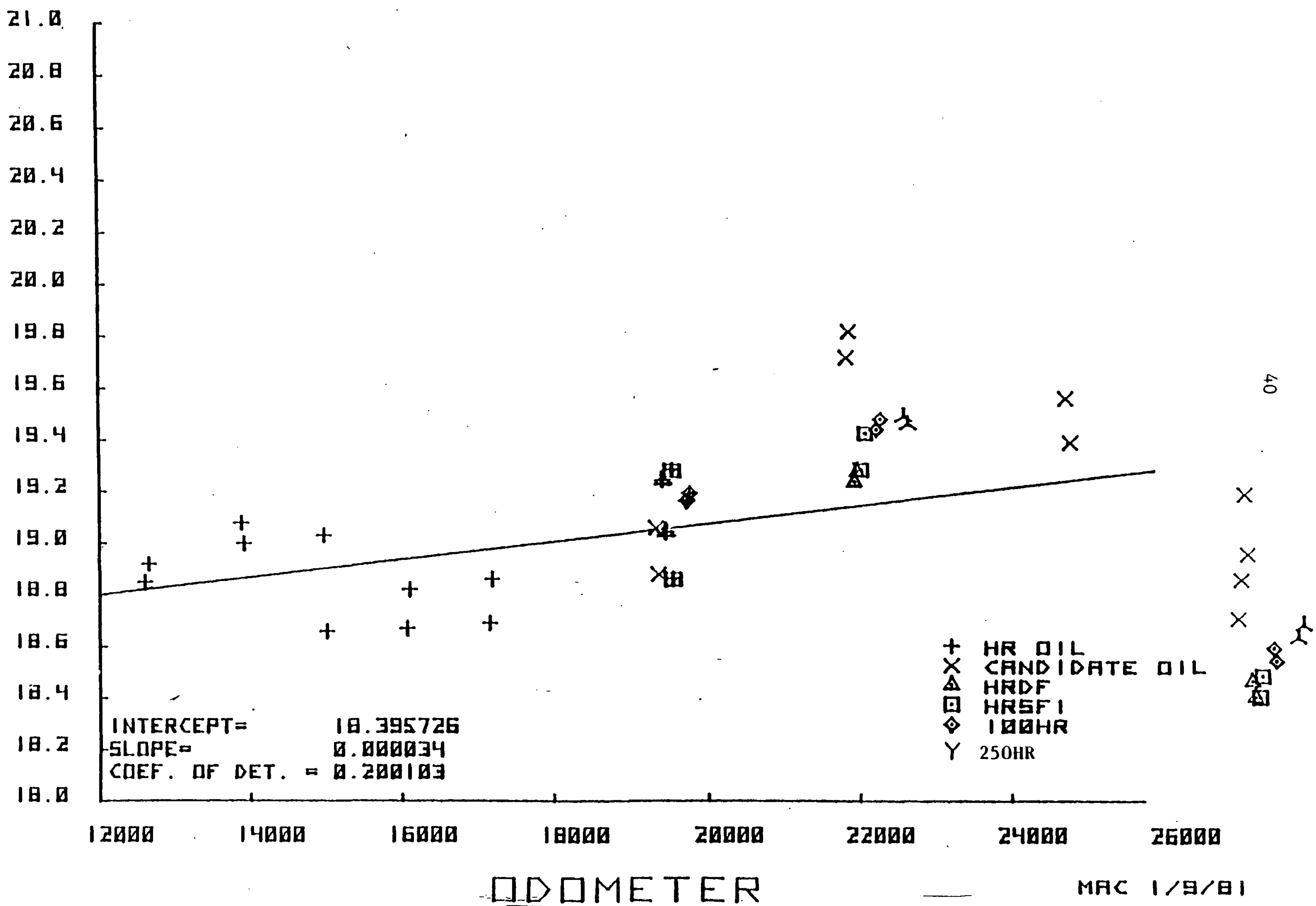
FED DATA - VEH #5 (CITATION)
VOLUMETRIC HIGHWAY MPG

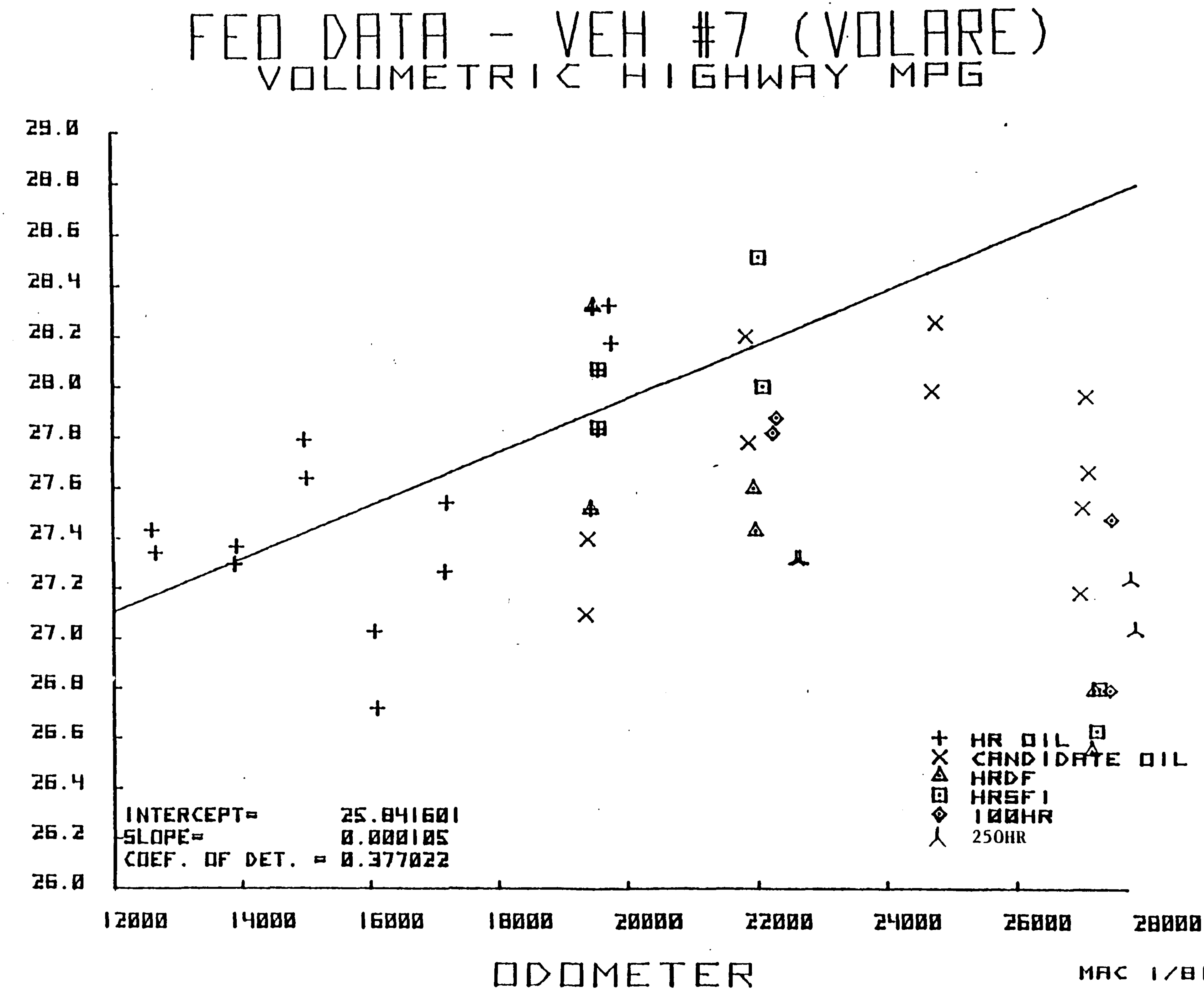


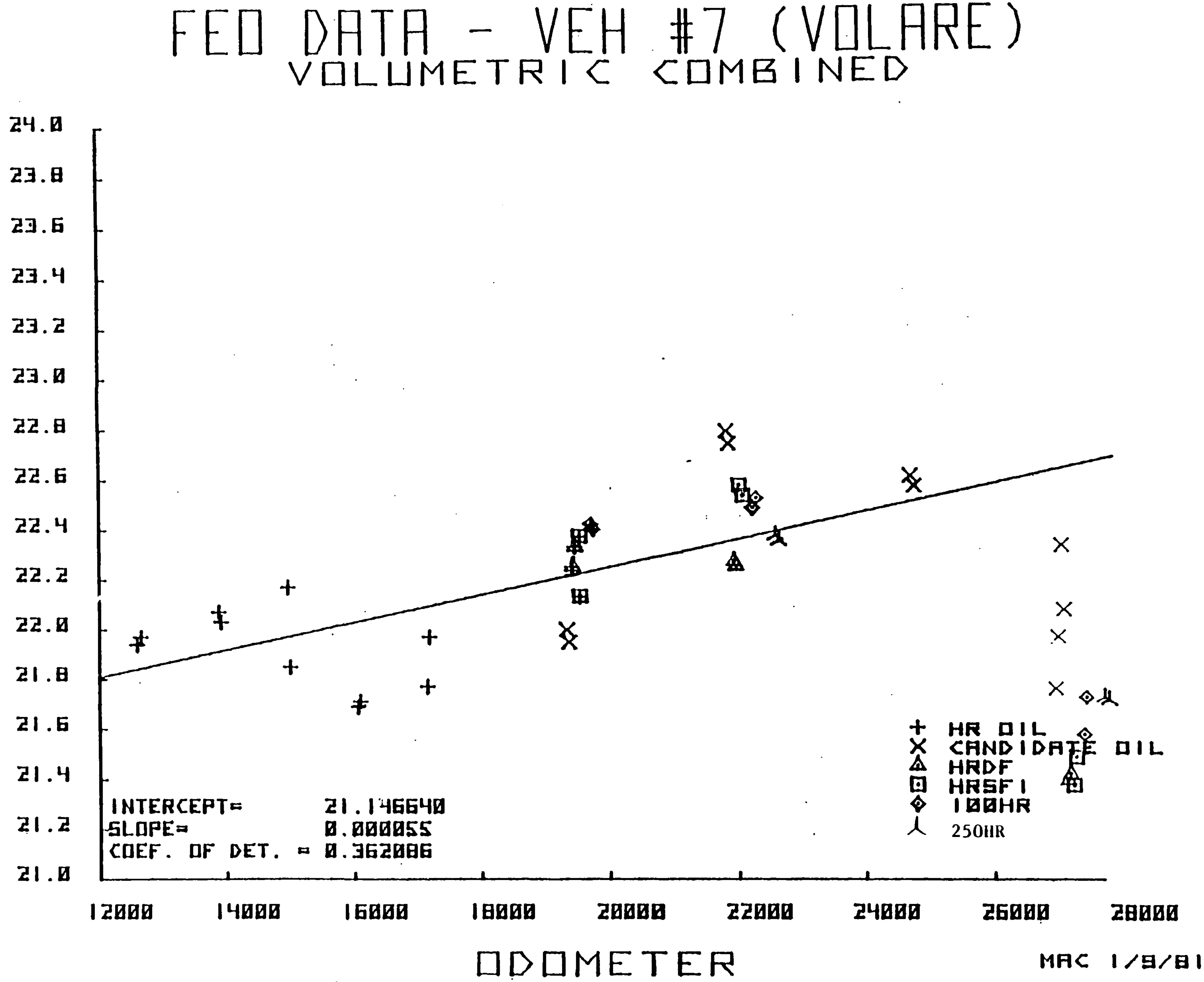
FEO DATA - VEH #5 ((CITATION)
VOLUMETRIC COMBINED MPG



FEO DATA - VEH #7 (VOLARE)
VOLUMETRIC FTP MPG




FED DATA - VEH #7 (VOLARE)
VOLUMETRIC HIGHWAY MPG
29.0
28.8
28.6
28.4
28.2
28.0
27.8
27.6
27.4
27.2
27.0
26.8
26.6
26.4
26.2
26.0
INTERCEPT= 25.841601
SLOPE= 0.000105
COEF. OF DET. = 0.377022
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
12000
14000
16000
18000
20000
22000
24000
26000
28000
ODOMETER
MAC 1/81



FED DATA - VEH #7 (VOLARE)
VOLUMETRIC COMBINED
24.0
23.8
23.6
23.4
23.2
23.0
22.8
22.6
22.4
22.2
22.0
21.8
21.6
21.4
21.2
21.0
INTERCEPT= 21.146640
SLOPE= 0.000055
COEF. OF DET. = 0.362086
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
12000
14000
16000
18000
20000
22000
24000
26000
28000
ODOMETER
MAC 1/9/81

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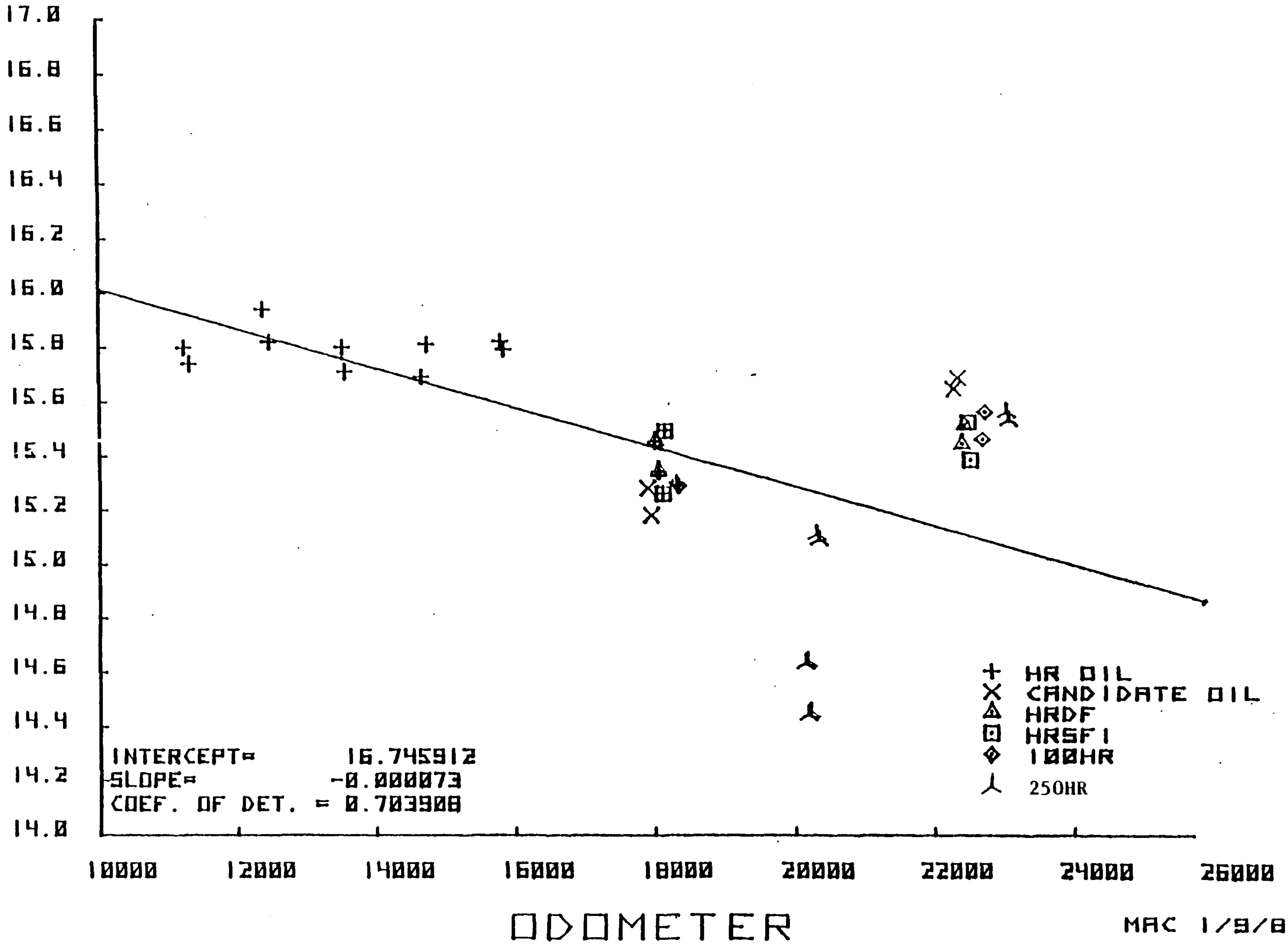
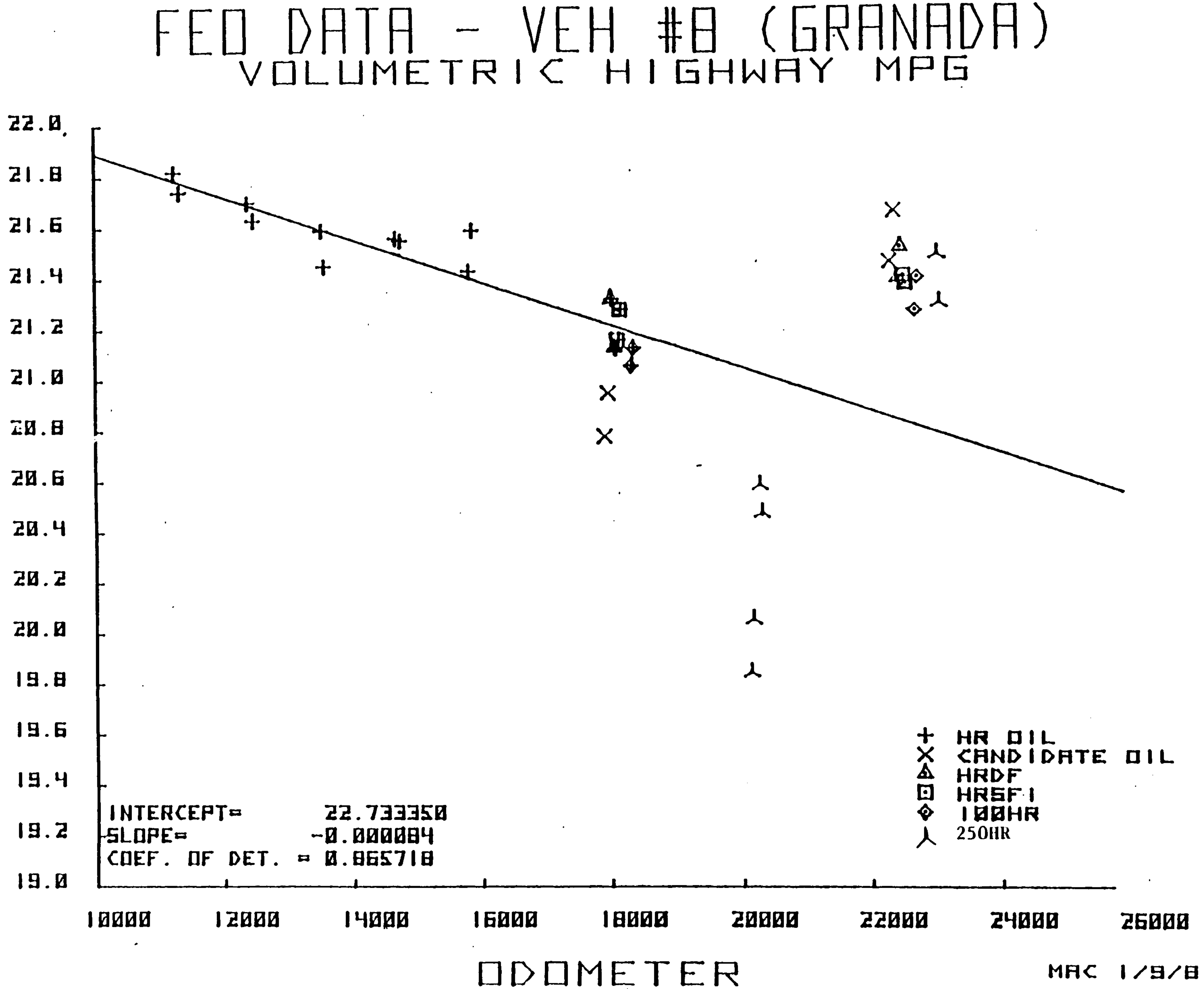
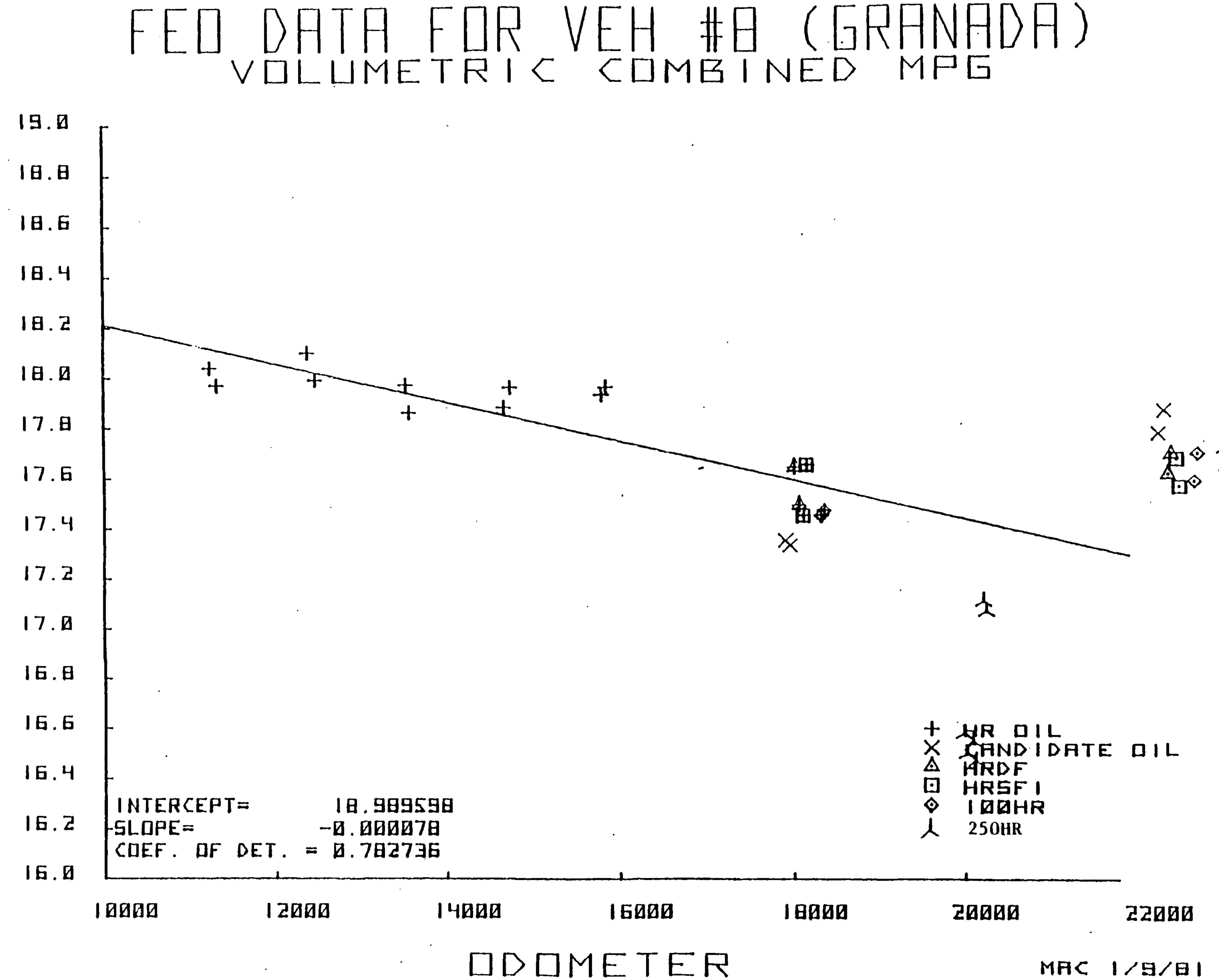
FEO DATA - VEH #8 (GRANADA)
VOLUMETRIC FTP MPG



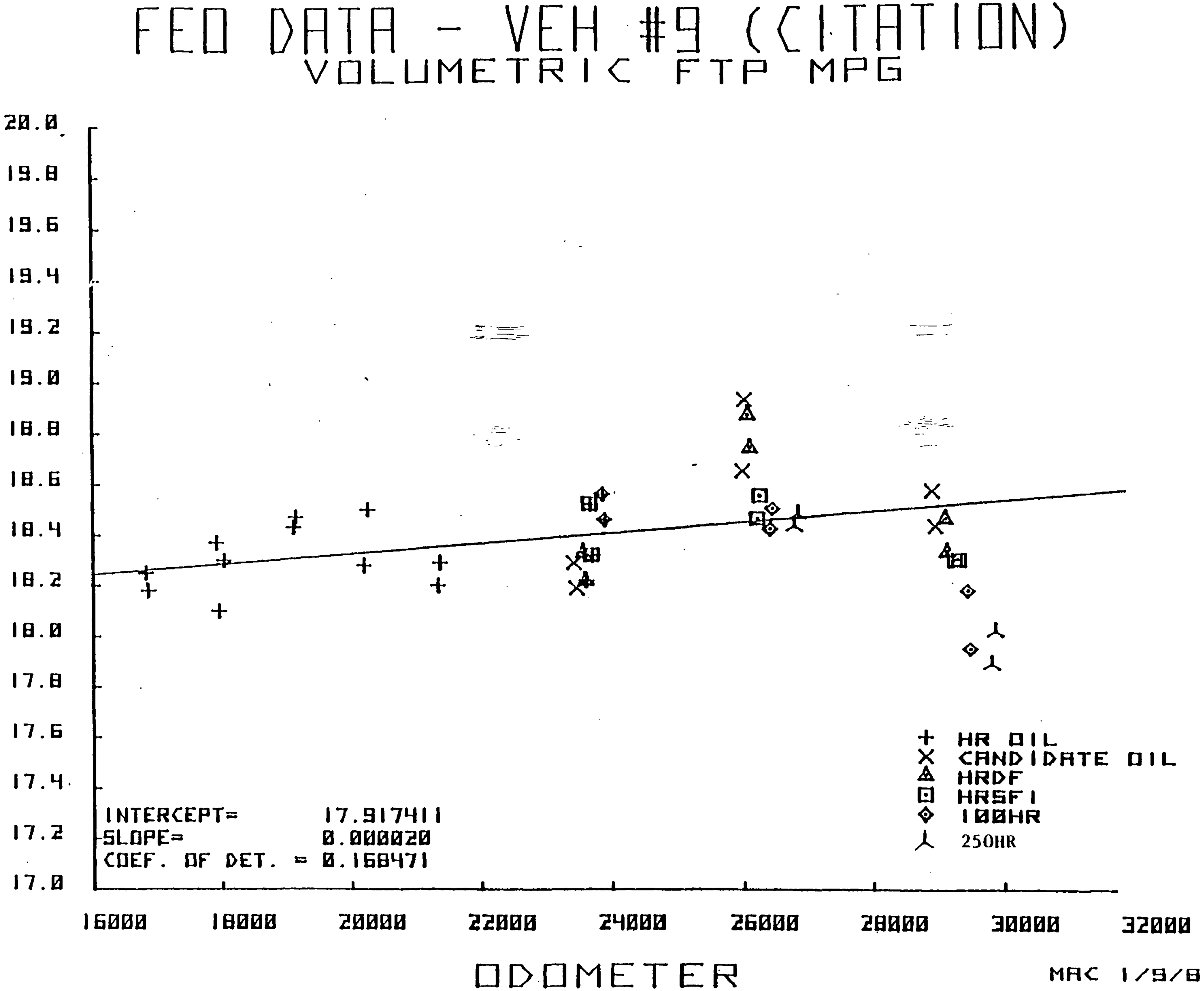


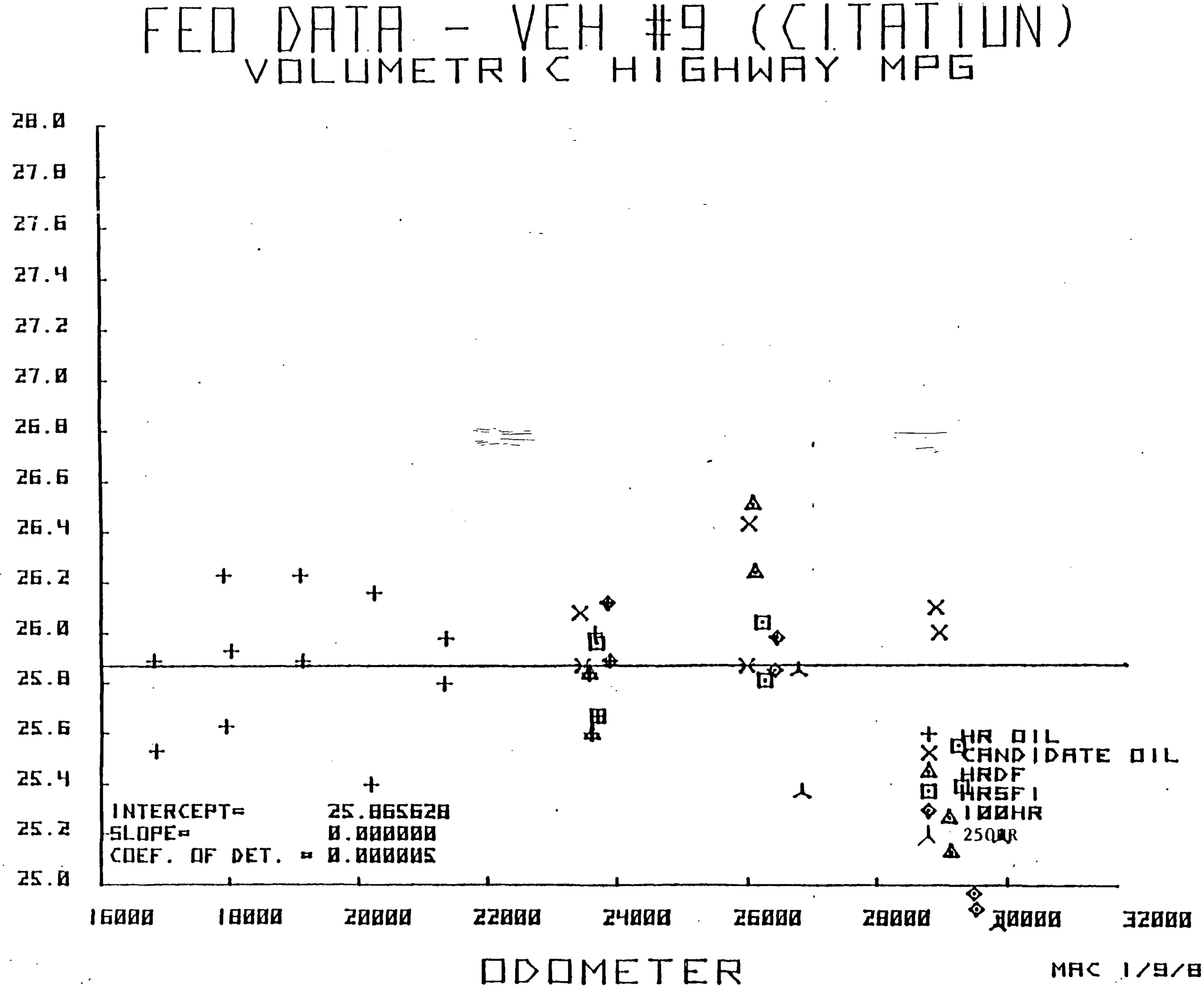
FEO DATA - VEH #8 (GRANADA)
VOLUMETRIC HIGHWAY MPG
22.0
21.8
21.6
21.4
21.2
21.0
20.8
20.6
20.4
20.2
20.0
19.8
19.6
19.4
19.2
19.0
INTERCEPT= 22.733350
SLOPE= -0.000084
COEF. OF DET. = 0.865718
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
10000
12000
14000
16000
18000
20000
22000
24000
26000
ODOMETER
MAC 1/9/81



FEO DATA FOR VEH #8 (GRANADA)
VOLUMETRIC COMBINED MPG
19.0
18.8
18.6
18.4
18.2
18.0
17.8
17.6
17.4
17.2
17.0
16.8
16.6
16.4
16.2
16.0
10000
12000
14000
16000
18000
20000
22000
ODOMETER
INTERCEPT= 18.989598
SLOPE= -0.000078
COEF. OF DET. = 0.782736
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
MRC 1/9/81

Figure 26

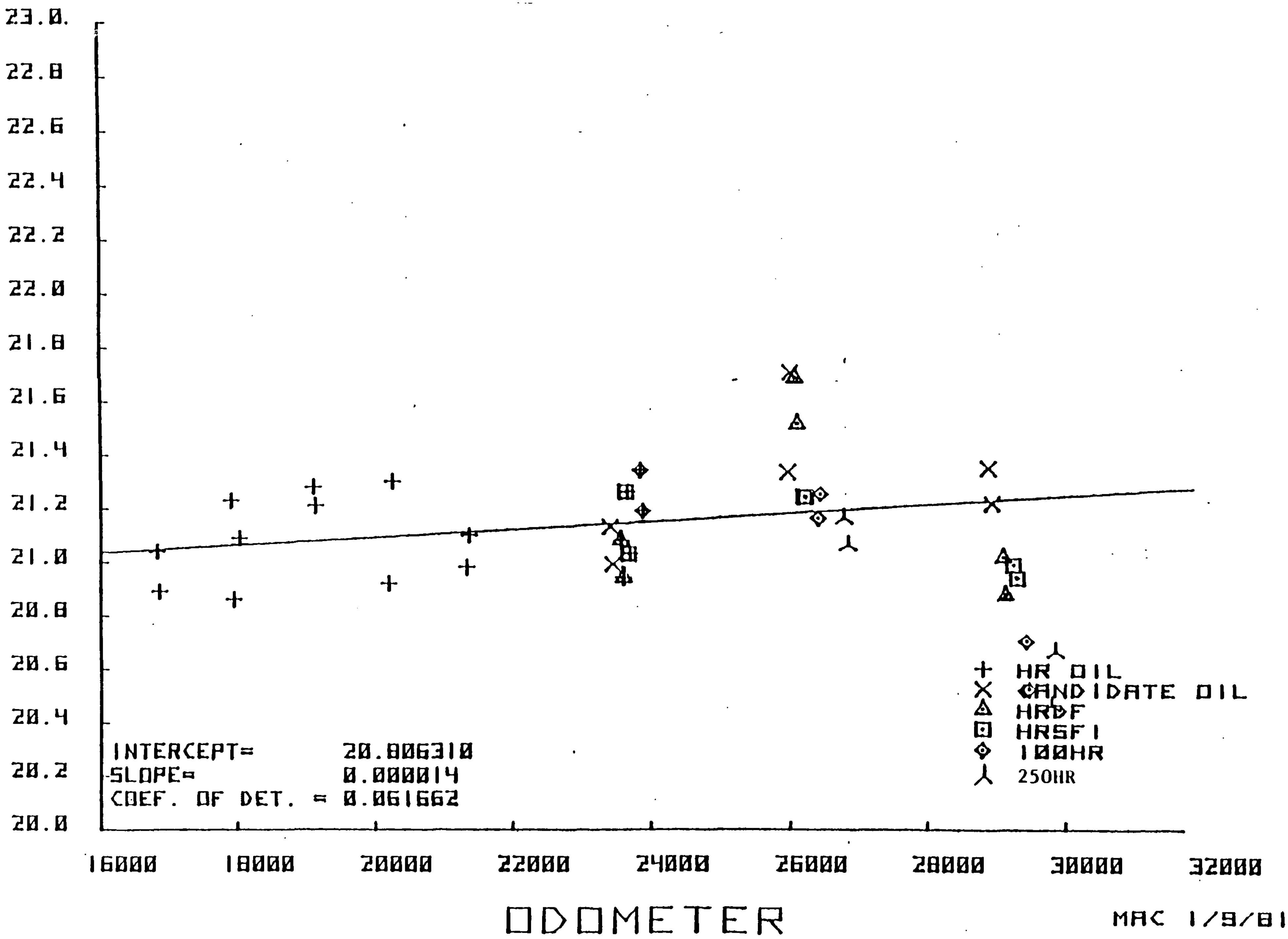

FEO DATA - VEH #9 (CITATION)
VOLUMETRIC FTP MPG
20.0
19.8
19.6
19.4
19.2
19.0
18.8
18.6
18.4
18.2
18.0
17.8
17.6
17.4
17.2
17.0
16000
18000
20000
22000
24000
26000
28000
30000
32000
ODOMETER
INTERCEPT= 17.917411
SLOPE= 0.000020
COEF. OF DET. = 0.168471
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
MAC 1/9/81

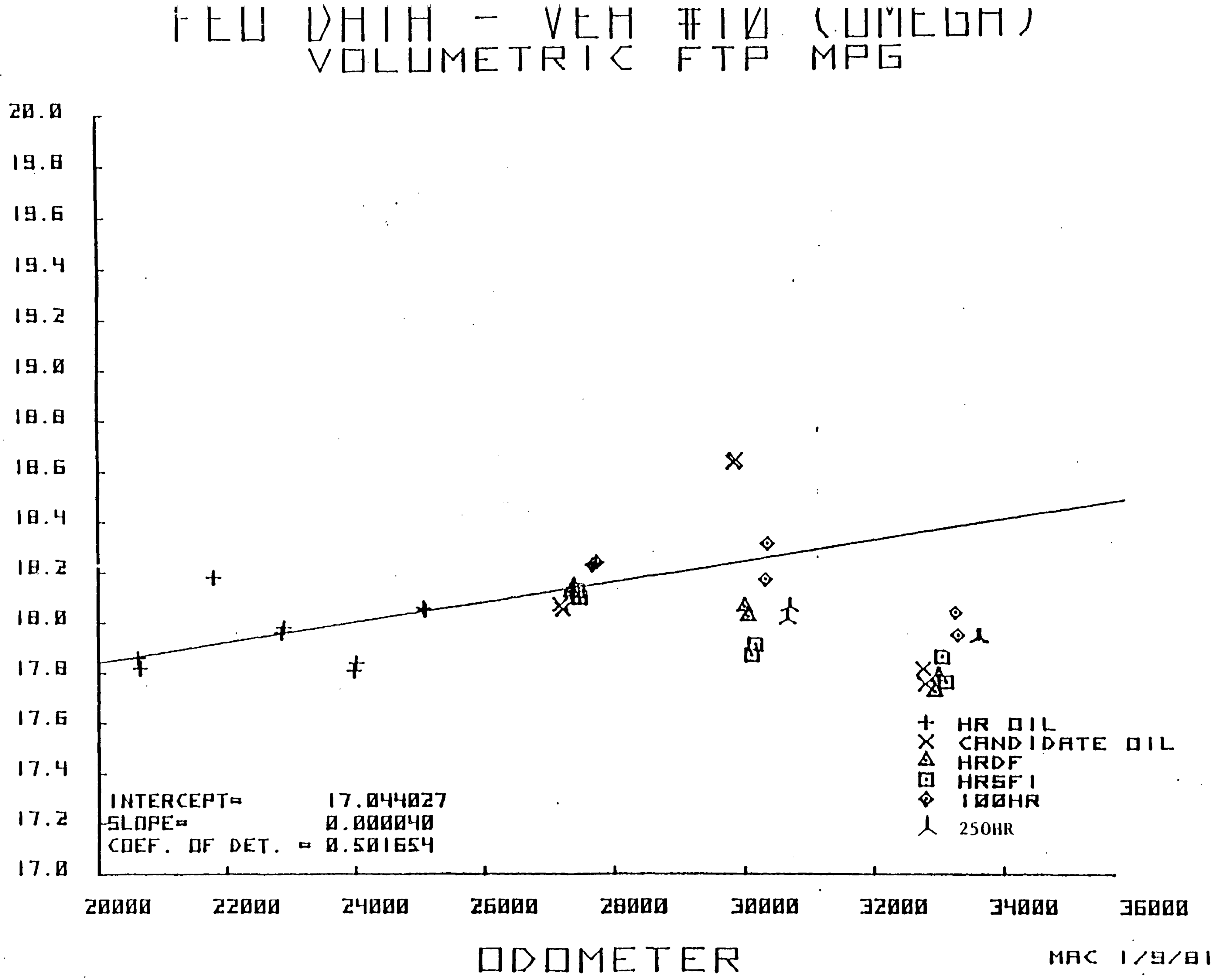


FED DATA - VEH #9 (CITATION)
VOLUMETRIC HIGHWAY MPG
28.0
27.8
27.6
27.4
27.2
27.0
26.8
26.6
26.4
26.2
26.0
25.8
25.6
25.4
25.2
25.0
INTERCEPT= 25.865628
SLOPE= 0.000000
COEF. OF DET. = 0.000005
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
16000
18000
20000
22000
24000
26000
28000
30000
32000
ODOMETER
MAC 1/9/81

FEO DATA - VEH #9 (CITATION)

VOLUMETRIC COMBINED MPG

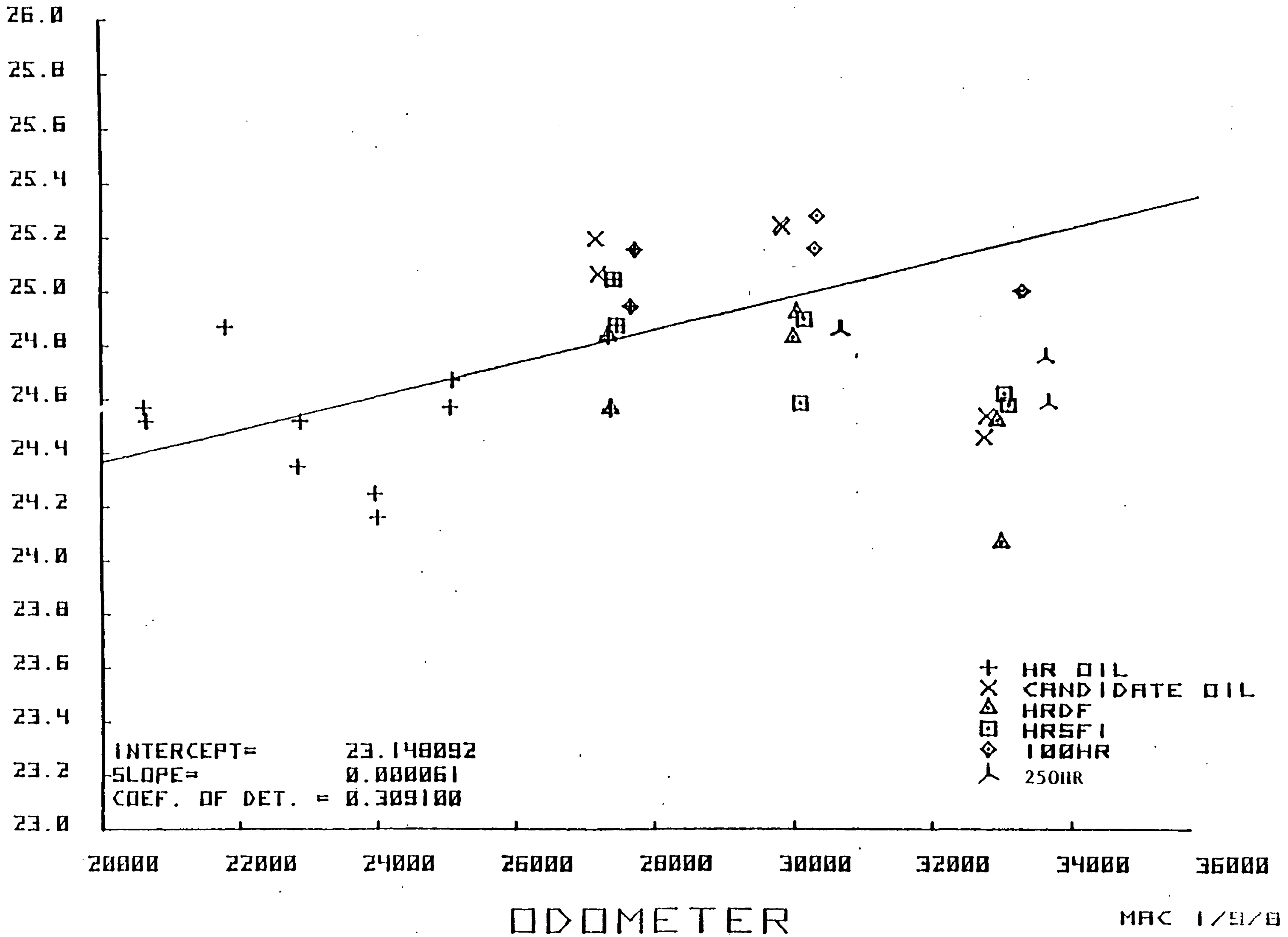




VOLUMETRIC FTP MPG
20.0
19.8
19.6
19.4
19.2
19.0
18.8
18.6
18.4
18.2
18.0
17.8
17.6
17.4
17.2
17.0
INTERCEPT= 17.044027
SLOPE= 0.000040
COEF. OF DET. = 0.501654
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
20000
22000
24000
26000
28000
30000
32000
34000
36000
ODOMETER
MAC 1/9/81

Figure 30

FEO DATA - VEH #10 (OMEGH)
VOLUMETRIC HIGHWAY MPG



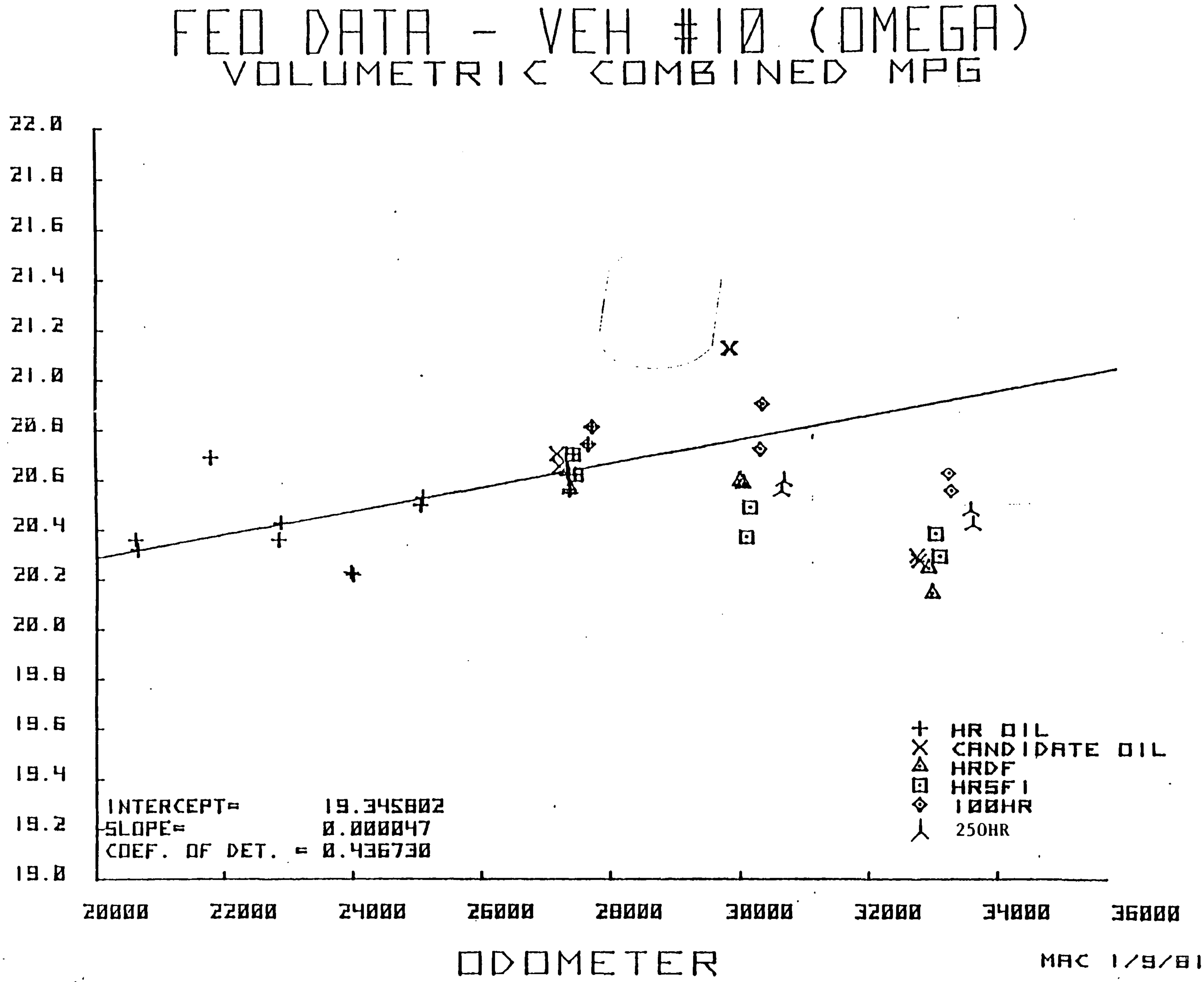
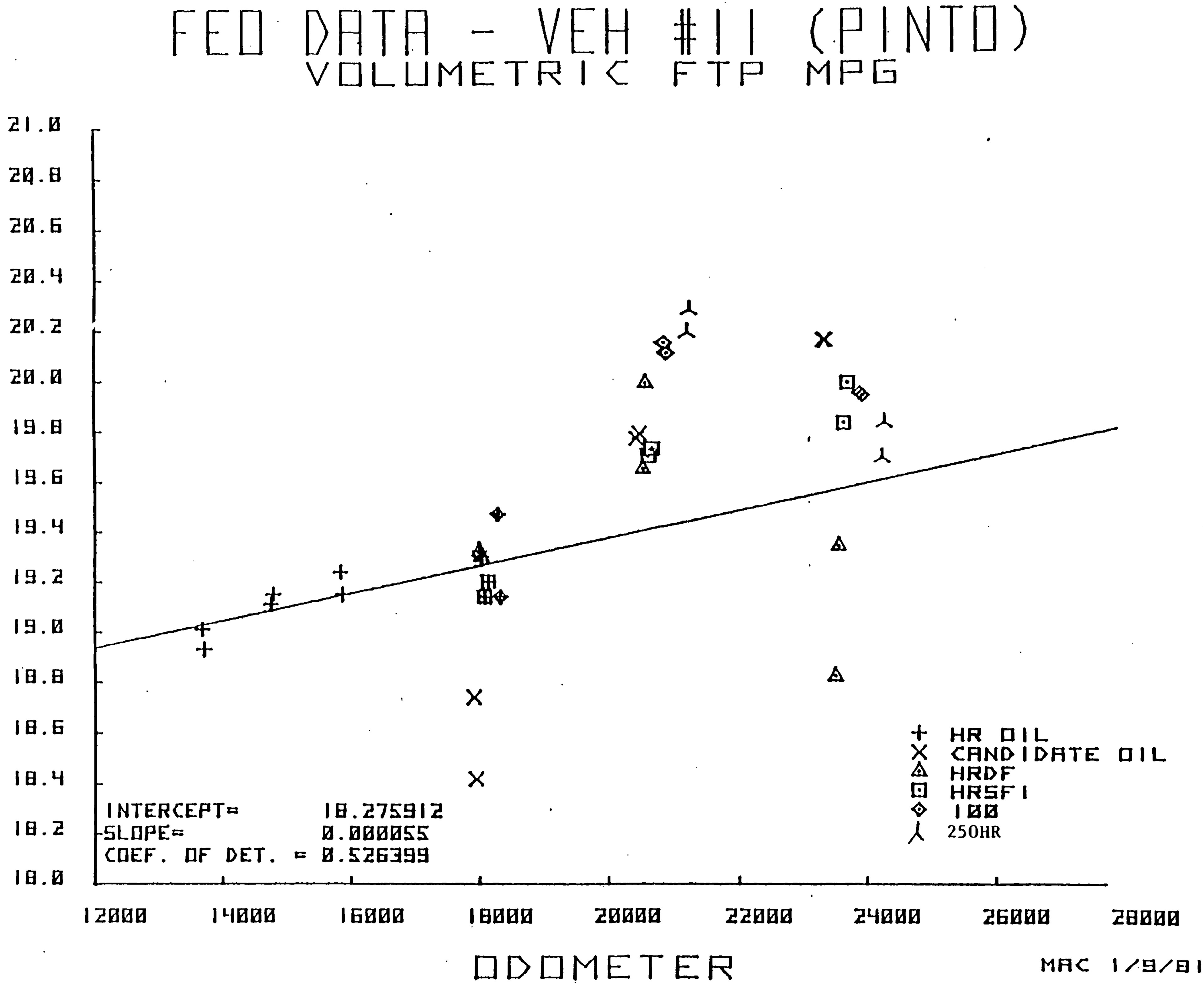
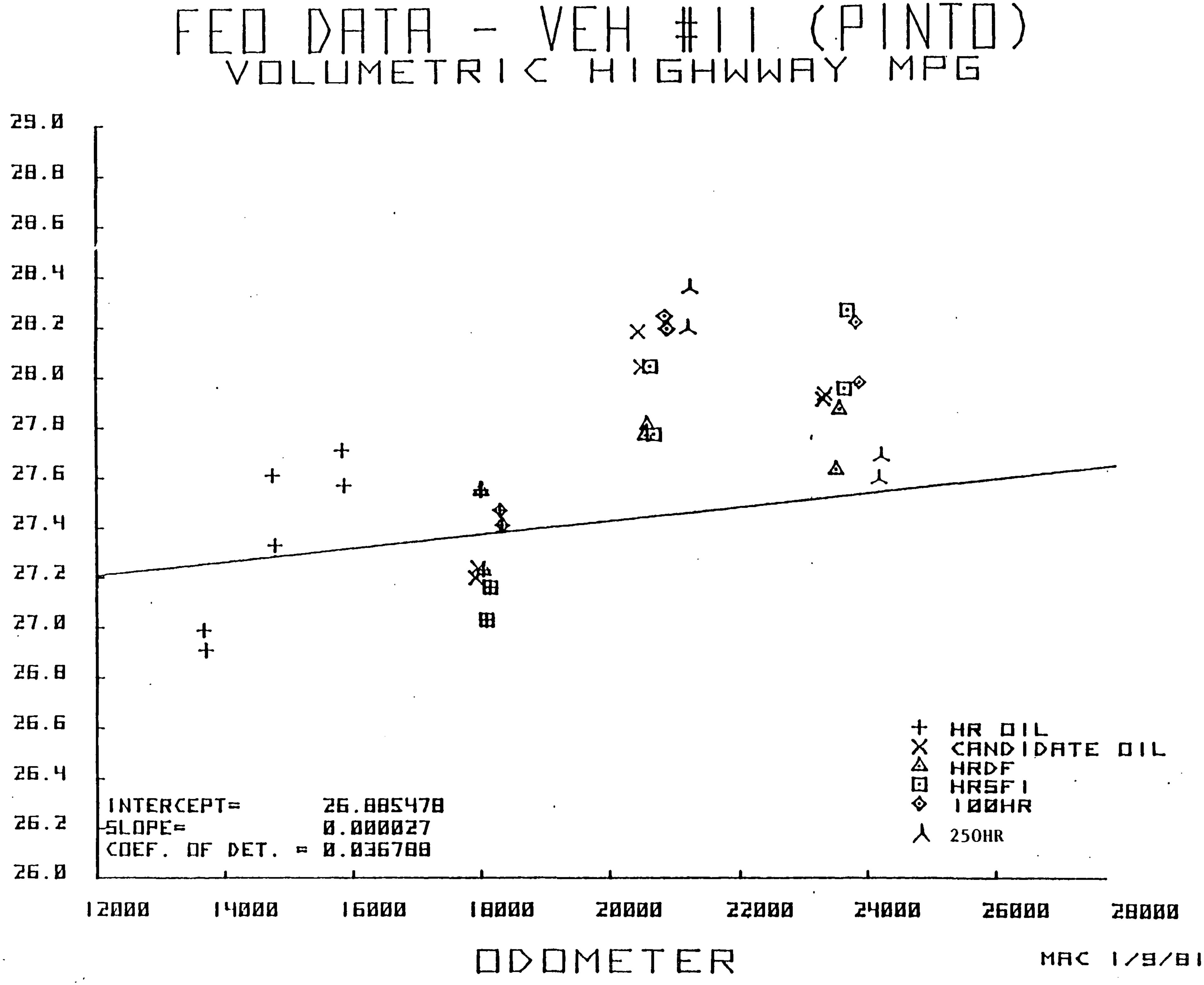

FEO DATA - VEH #10 (OMEGA)
VOLUMETRIC COMBINED MPG
22.0
21.8
21.6
21.4
21.2
21.0
20.8
20.6
20.4
20.2
20.0
19.8
19.6
19.4
19.2
19.0
INTERCEPT= 19.345802
SLOPE= 0.000047
COEF. OF DET. = 0.436730
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
20000
22000
24000
26000
28000
30000
32000
34000
36000
ODOMETER
MAC 1/9/81

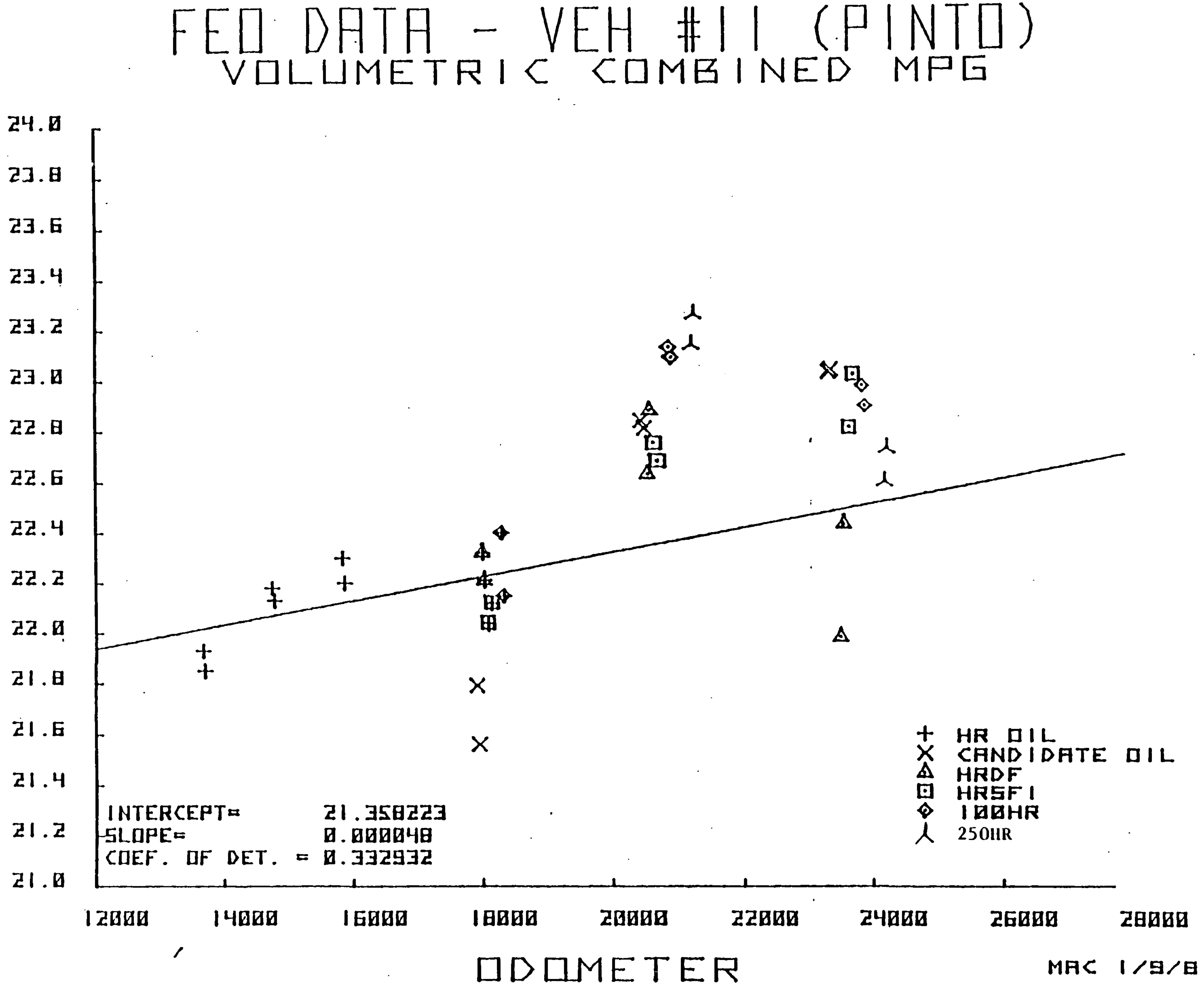
Figure 32



FEO DATA - VEH #11 (PINTO)
VOLUMETRIC FTP MPG
21.0
20.8
20.6
20.4
20.2
20.0
19.8
19.6
19.4
19.2
19.0
18.8
18.6
18.4
18.2
18.0
12000
14000
16000
18000
20000
22000
24000
26000
28000
ODOMETER
INTERCEPT= 18.275912
SLOPE= 0.000055
COEF. OF DET. = 0.526399
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100
250HR
MAC 1/9/81

Figure 33


FEO DATA - VEH #11 (PINTO)
VOLUMETRIC HIGHWWAY MPG
29.0
28.8
28.6
28.4
28.2
28.0
27.8
27.6
27.4
27.2
27.0
26.8
26.6
26.4
26.2
26.0
12000
14000
16000
18000
20000
22000
24000
26000
28000
ODOMETER
INTERCEPT= 26.885478
SLOPE= 0.000027
COEF. OF DET. = 0.036788
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
MAC 1/9/81



FEO DATA - VEH #11 (PINTO)
VOLUMETRIC COMBINED MPG
24.0
23.8
23.6
23.4
23.2
23.0
22.8
22.6
22.4
22.2
22.0
21.8
21.6
21.4
21.2
21.0
INTERCEPT= 21.358223
SLOPE= 0.000048
COEF. OF DET. = 0.332932
HR OIL
CANDIDATE OIL
HRDF
HRSFI
100HR
250HR
12000
14000
16000
18000
20000
22000
24000
26000
28000
ODOMETER
MAC 1/9/81

Figure 35

Appendix 1

EPA RECOMMENDED PRACTICE FOR EVALUATING, GRADING, LABELING THE FUEL EFFICIENCY OF MOTOR VEHICLE ENGINE OILS

DRAFT

A. PURPOSE:

The purpose of this procedure is to present a standardized method for evaluating, grading, and labeling the fuel efficiency of motor vehicle engine oils.

B. BACKGROUND:

Approximately two years ago, vehicle manufacturers requested EPA approval for the use of fuel efficient engine oils in their fuel economy determination vehicles. The EPA response to these requests was that while we encourage the development of such oils, we could not allow their use in fuel economy test vehicles until we had assurances that such oils would be representative of oils used in the national vehicle fleet*. The stated requirements for acceptance of these oils in fuel economy test vehicles were:

a. The existance of a generic specification of the oils.
b. That the oils would be readily available in the market-place.
c. That the costs of these oils would not discourage their use.
d. That vehicle manufacturers would encourage the use of the oils; e.g. tie their use to the vehicle warranty.

This EPA recommended practice will provide oil classification based on the fuel efficiency characteristies of the engine oils. The classification is one of the requirements to be met before final efficient oils will be permitted for use in the fuel economy test vehicles, and its adoption will enhance the likelihood that such oils will find representative use in the field.

---

* Stork, E.O., EPA letter to Charles M. Heinen of Chrysler Corporation, January 16, 1978; Hawkins, D.G., EPA letter to Joan Claybrook, the Administrator of the National Highway Traffic Safety Administration, February 13, 1978.

C. DISCUSSION:

This procedure determines the fuel efficiency characteristics of motor vehicle engine oils. This procedure basically conforms to the ASTM "Fuel Saving Engine Oil Test Procedure" which has been drafted but not published as of February 20, 1980. The ASTM procedure may be consulted for additional information. This procedure also draws from the EPA Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HFET). Both FTP and HFET tests are run on a chassis dynamometer. The objective is to compare the fuel economy characteristics of a test or candidate oil with respect to a reference oil in each test vehicle. Uniformity of vehicle, dynamometer, ambient conditions, and fuel measurement techniques is stressed to minimize test to test variability. The procedure allows certain options, but it is emphasized that the options selected for the reference oil shall also prevail for the candidate oil(s) in any given vehicle. The data obtained from the use of this test method provides a comparative index of the fuel economy impact of automotive engine lubricants under repeatable laboratory conditions in a complete vehicle.

Under this procedure there will be four grades of engine oils based on fuel efficiency characteristics. These four grades, labeled A, B, C, and D, are separated as follows:

Grade "A" Classification specifies that $(CO - TE) > (1.030)(HR)$

Grade "B" Classification specifies that $1.030(HR) \geq (CO-TE) > 1.010(HR)$

Grade "C" Classification specifies that $1.010(HR) \geq (CO-TE) > 0.980(HR)$

Grade "D" Classification specifies that $0.980(HR) \geq (CO-TE)$

Where:

TE = Testing Error (described below) = LSD_{95}

HR = Fuel economy using High Reference oil (MPG)

CO = Fuel economy using Candidate Oil (MPG)

The tests must be run on five specific engines/vehicles (see Section 2.1) in order to represent a significant cross section of high volume production cars. These classification criteria have been established requiring specific percentage level differences from that of the HR oil to meet specific EPA classification catagories. The required method of statistically analyzing the data is described in Section 5.

D. TEST PROCEDURE:

1. Reference Oil

A "High Reference" (HR) oil has been established by ASTM for their proposed test procedure. This same oil will be used in the EPA recommended procedure. The HR oil is a 20W-30 grade, fully formulated lubricant which meets API SE requirements. This oil has fuel economy characteristics very close to median values for 1978 production commercial 10W-30 and 10W-40 SE engine oils.

The HR oil is available from EG&G Automotive Research, 5404 Bandera Road, San Antinio, Texas 78238. Atten: Reference Oil Sales.

2. Testing Apparatus

2.1 Test Vehicles

The fuel economy tests are run on vehicles which have accumulated between 10000 and 80000 miles of normal consumer-type operation. Every effort should be made to obtain vehicles representative of similar vehicles in use in the field. Each test vehicle should be examined for (1) evidence that it has not been maintained to manufacturers specifications (especially oil changes), (2) evidence of atypical driving such as racing, mis-fire testing, endurance testing, etc., (3) evidence of tampering, and (4) evidence of use of non-OEM parts. If such evidence is noted the vehicle should not be used in this test procedure. All test vehicles will have automatic transmissions. When running this procedure, a minimum of one of each of the following engines must be used within the car models specified:

Engine	Vehicle	Dynamometer	
		Inertia Weight, lbs.	Power Absorber Load, H.P.
2.3L, I-4	Pinto/Bobcat/Mustang (Capri if 1979 Model or later)	3000	10.3
302CID, V-8	Full Size Ford (LTD, etc.) or Monarch/Granada/Fairmont/Zephyr	3500	11.2
2.8L, V-6	GM "X" Body (Citation, etc.) or GM "J" Body (Monza, etc.)	3000	10.3
3.8L, V-6	GM "A" Body (Cutlass, etc.)	4000	12.0
225CID, I-6	Volare/Aspen	3500	11.2

Some flexibility is allowed in both the choice of car models and the body styles to increase the availability of cars with these engines. Every two years these vehicles will be reviewed and if appropriate, the test vehicles/engines will be altered to insure fleet representativeness. These particular cars will be run with the chassis dynamameter inertia weights and horsepower loadings tabulated above, regardless of variations which exist in the gross weight and aerodynamic drag of the actual vehicles used. The same number of engines/vehicles must be used from each of the five groups listed above.

2.2 Chassis dynamometer

The procedure allows use of a chassis dynamometer capable of running the Federal emissions test driving cycles. To avoid variability in testing, any given car must run all dynamometer tests on the same dynamometer, and insofar as possible, operation with the same driver is recommended. Specifications, guidelines for use, and calibration of dynamometers information may be found in 40 CFR Part 86. 118-78.

2.3 Laboratory and Environmental Requirements

The tests are run on an indoor chassis dynamometer where ambient air temperatures can be closely controlled. Prior to each test sequence of FTP-HFET the test vehicle must soak with the engine off and hood fully opened in an area adjacent to the dynamometer for a minimum of 12 hours. The soak area and dynamometer must be maintained at 68° to 74°F. A narrower spread of ± 2°F is preferred to reduce the test to test variability. During testing, large variations in the humidity of the engine inlet air must be avoided. All tests on a test vehicle shall be run at a humidity within 20 grains H_2O/lb. dry air of the first test on the vehicle. Comparative tests between the candidate and the reference oil are not accurate under widely different humidity conditions. The engine oil and coolant temperatures must be within 2.5°F of the value recorded prior to the first test of the vehicle before every subsequent test on that vehicle. Narrowing this range helps minimize the test-to-test variability.

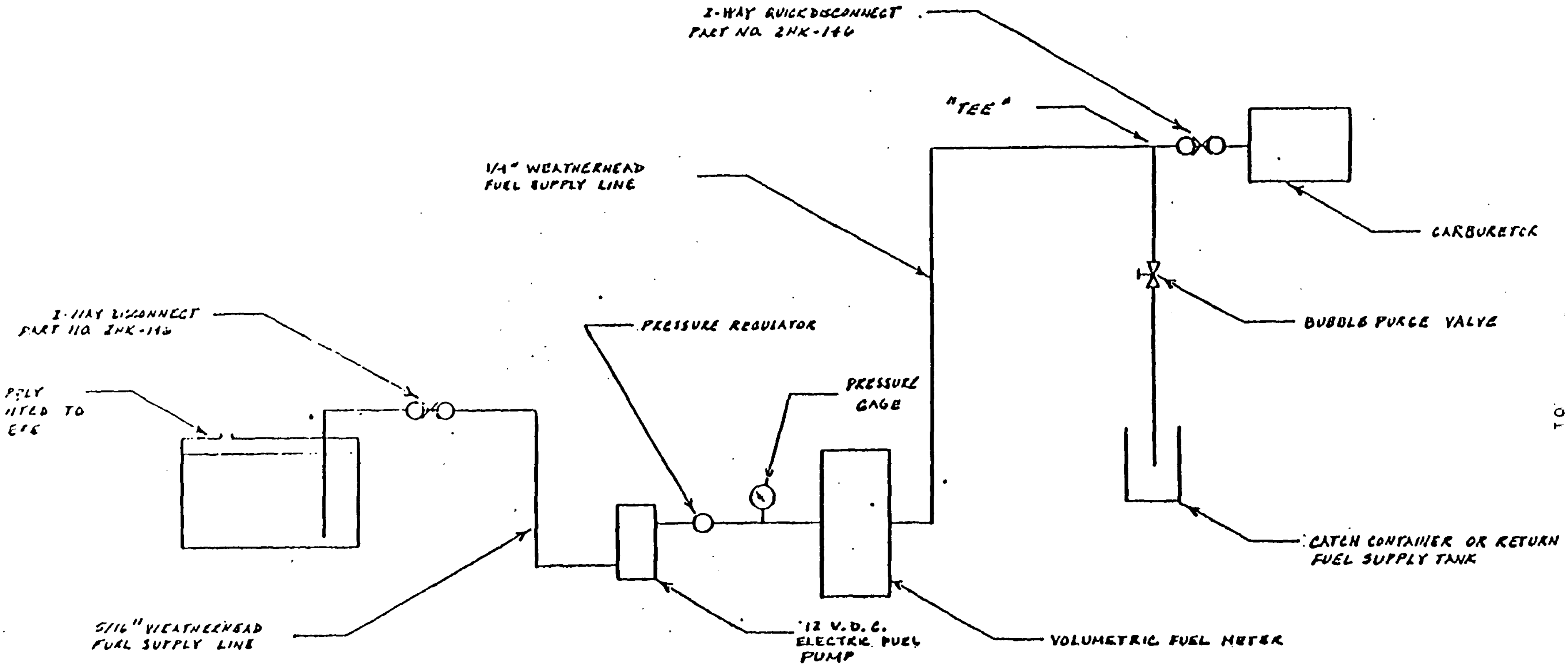
2.4 Fuel Measurement Systems

During the dynamometer fuel economy tests, fuel will be supplied to the vehicle from an auxiliary container directly to the inlet of the carburetor (or to an equivalant point in the case of a fuel injected engine). Either carbon balance or volumetric (or both) fuel measurements may be used. The carbon balance method is described in 40 CFR Part 86 for 1979 model year vehicles. Exceptions to the Federal Register procedure are designated in this Recommended Practice (i.e. assigned inertia weights and AHP settings). The volumetric fuel flow measurements will be made using a metering system capable of resolving increments no larger than one cubic centimeter with a measurement coeffieient of variation of no more than 0.2%. As an example, Fluidyne Model 1250A and Model 1240A are two units, among others, which meet this specification*. A number of precautions, as described below, should be observed in the details and use of the fuel measurement systems.

*The manufacturer of this product is identified to clarify the example and does not imply endorsement of the product.

It is recommended that the fuel supply tanks and fuel measurement system (if volumetric) be located adjacent to the dynamometer in a position where heat from operation of the vehicle will have minimal effect on fuel temperature. Rectangular marine fuel tanks of about 6 to 12 gallon capacity, placed to the side and toward the front of the cars, work satisfactorily. The fuel and tank, or tanks, should be soaked in the dynamometer area for a period long enough to insure ambient temperature before use. The objective is to meter the fuel at as nearly constant temperature as possible during the dynamometer tests to insure that the fuel temperature noted periodically during the tests are true values which prevailed for each period and are not simply transient values. Some fuel flow meters (if volumetric) are subject to error in the presence of excessive vibration of certain frequencies. To avoid this and perhaps extend the life of the meter, it is preferrable to place the meter on a suitable stationary mounting.

The following figure illustrates the recommended volumetric fuel metering and delivery systems. With the carbon balance method, the same fuel tanks, temperature measurements and electric fuel pump are required. The tee connection should be close to the carburetor inlet to purge the fuel lines of bubbles and to fill the carburetor float bowl before the engine is started for test. When making these connections, the fuel line between the car's fuel pump and the carburetor is blocked off. The original equipment lines between the car's fuel pump and the gas tank can remain connected as long as no interconnection exists with the metered fuel system. The small, cylindrical type, 12 volt, electric pumps available from auto supply stores, are recommended for this application. They are made explicitly for gasoline, they are self limiting on pressure, have adequate delivery rates and minimize fuel heating when the vehicle engine is off and the fuel pump is left on to avoid bubble formation in the fuel lines. Larger pumps may need a pressure regulator and a thermostatic cooler to maintain the fuel at a constant pressure and temperature. If a pressure regulator is included in the system, it should be permanently set at an appropriate value


2-WAY QUICKDISCONNECT
PART NO. 2HK-146
"TEE"
1/4" WEATHERHEAD
FUEL SUPPLY LINE
CARBURETOR
BUBBLE PURGE VALVE
2-WAY DISCONNECT
PART NO. 2HK-146
PRESSURE REGULATOR
PRESSURE
GAGE
CATCH CONTAINER OR RETURN
FUEL SUPPLY TANK
5/16" WEATHERHEAD
FUEL SUPPLY LINE
12 V.D.C.
ELECTRIC FUEL
PUMP
VOLUMETRIC FUEL METER

between 3 and 5 psi. Several commercially available meters are compatible with pulsating flows. If other types of volume meters are used, this factor should be investigated. Fuel hoses used under the hoods of vehicles should be standard (heat resistant) fuel line, carefully routed to avoid the fan, fan belts, pulleys, the exhaust manifolds, carburetor linkage, etc. Other precautions dictated by fire safety considerations should be observed in the construction and use of the fuel system in the indoor location.

2.5 Cooling Fans

A fan with a nominal 24" diameter propeller delivering from 5200 to 5600 CFM is required at the front of the car for the dynamometer tests. For any given car, the same fan, or an identical one from the same manufacturer must be used for every dynamometer test. After the car is chocked and secured on the rollers, the fan must be placed in the same relative position with the fan grille touching the front bumper for every test. A second, 24" diameter fan will be directed under the test vehicle during the HFET cycles. The radiator cooling fan will remain on and the hood open during the 10 minute soak in the FPT. Two small high velocity squirrel cage fans directed at the contact between the front dynamometer roller and the driving tires are recommended to reduce the possibility of tire problems. All fans should be in the same relative position for each test.

2.6 Instrumentation

The following instrumentation is required for the dynamometer tests:

2.6.1 The majority of the equipment requirements for the dynamometer and the carbon balance equipment are given in 40 CFR Part 86. Note that a digital indication of actual rear roll revolutions is used in the milage calculations. A dynamometer coastdown timer is suggested for regular dynamometer calibration checks.

A driver's aid having a trace of the Federal FTP and HFET driving cycles is required. The pointer indicating actual car speed on a continuous basis is driven by the tachometer generator on the rear roll of dual roll dynamometers. Provisions must be made for two HFET cycle traces with a period between the first and the second of exactly 13 seconds. Fuel measurements should begin 13 seconds after completion of the first HFET cycle.

2.6.2 Thermocouples installed in the engine oil pan drain plug and in the upper radiator hose are required, with plug connectors to facilitate connection to a temperature recorder accurate to 1°F when the vehicle is on the chassis dynamometer.

2.6.3 Notation of ambient conditions for each test must be made including wet and dry bulb temperatures (taken with a psychrometer at the 24" cooling fan in front of the car on the dynamometer), barometric pressure, and several thermocouples which should be positioned in the test cell to observe test cell temperatures.

2.6.4 For both carbon balance and volumetric fuel metering systems, the observed gravity and temperature of the fuel used for that particular test must be measured with an API petroleum hydrometer and recorded. It is preferable to take this measurement in proximity to the fuel container near the dynamometer since the fuel and the hydrometer will have soaked to a stable temperature making it easier to obtain an accurate reading. The hydrometer should be of a type with a narrow gravity range to improve resolution.

2.6.5 Instrument and equipment calibrations should be checked daily, or at scheduled intervals, for error in accordance with the manufacturer's recommended procedure against standards traceable to the U.S. National Bureau of Standards, and according to the 40 CFR Part 86 where applicable. While the dynamometer is being warmed up at the start of a day of testing, the speed calibration of the driver's aid should be checked against the dynamometer speed indicator or by means of a strobe light or a digital tachometer on the roller which measures speed and distance (the rear roller on dual roller units). At the same time, volumetric fuel flow meters can be checked by placing a second meter in series with the first one and flowing a quantity of gasoline through both for comparison of the readings. This will serve as a quality control check since it is unlikely that both meters would simultaneously develop directionally similar errors of the same magnitude. Weekly speed and AHP checks should be run on the dynamometer as described in 40 CFR Part 86. Coastdowns should be run at 3000, 3500, and 4000 lb. Inertia Weight settings. An absolute calibration should be run on volumetric fuel meters as recommended by the manufacturer.

3. Preparation for Test

3.1 Vehicle Preparation

3.1.1 Forms are included on the following pages enumerating the general information to be reported for each car used in conducting these tests and detailing the tune up procedure required before fuel economy testing is initiated. All adjustments must be in accordance with the vehicle manufacturer's specifications as shown on the underhood label and in their respective shop manuals. Any replacement parts must be of the original equipment brand and be of the same type, specification or part number. Once a vehicle is adjusted and tuned prior to test, subsequent adjustments or changes in the operational characteristics of any part of the vehicles should be avoided. Repairs may be handled in accordance with Paragraph 3.1.2.

VEHICLE AND TEST SPECIFICATIONS

DATE ______________________ LABORATORY ______________________

YEAR/MAKE/MODEL ______________________

ASSIGNED VEHICLE GROUP NUMBER: ______________________

VEHICLE IDENTIFICATION NO. ______________________

ODOMETER ______________________

ENGINE TYPE AND NO. OF CYLINDERS ______________________

ENGINE DISPLACEMENT ______________________

CARB TYPE AND PART NO. ______________________

DISTRIBUTOR PART NO. ______________________

EXHAUST SYSTEM TYPE ______________________

TRANSMISSION ______________________

DIFFERENTIAL RATIO ______________________

TIRES(1)

MAKE, TYPE, LINE ______________________

SIZE ______________________

EQUIPMENT

TYPE BRAKES, FRONT ______________________ REAR ______________________

POWER BRAKES ______________________ POWER STEERING ______________________

AIR CONDITIONING ______________________

CALIFORNIA OR 49 STATE EMISSION CONTROLS ______________________

DYNAMOMETER TOTAL INERTIA WEIGHT USED IN TESTS(2) ______________________

50 MPH DYNAMOMETER HORSEPOWER LOAD INDICATED ____________ ACTUAL ____________(2)

IDENT. DYNO INSTALLATION USED IN TESTS (3) ______________________

(1) Tires must have a minimum of 100 miles of service before starting test.

(2) Use inertia weight and AHP assigned in 2.1.

(3) The same dynamometer must be used, and it is recommended that the same driver conduct all of the tests on any given car.

Vehicle Inspection and Tune-Up

_____1. Road test car for satisfactory automatic transmission and proper tire balance operation.

_____2. Check belts and hoses and replace and adjust as necessary.

_____3. Check fan clutch (if applicable).

_____4. Compression check - if any cylinder is below 70% relative compression reject or repair the vehicle.

_____5. Install new spark plugs. Gap to vehicle manufacturer's specifications.

_____6. Perform oscilloscope or comparable ignition system checkout. Repair any problems noted.

_____7. Check that distributor vacuum and mechanical advance are correct.

_____8. Replace points and condenser (if applicable).

_____9. Check dwell and dwell variation. Adjust if necessary.

_____10. Check basic timing at recommended RPM. Adjust if necessary to manufacturer's specification.

_____11. Replace fuel filter.

_____12. Check idle enrichment RPM gain and record (or other idle jet enrichment). Adjust/replace as necessary.

_____13. Check high and low idle RPM - Adjust as necessary.

_____14. Check accelerator pump operation. Replace and/or adjust as necessary.

_____15. Check choke operation and setting. Adjust if necessary.

_____16. Replace air cleaner element.

_____17. Check operation of manifold heat valve (if applicable).

_____18. Check movement of stem of EGR valve when engine is warm. Repair if necessary.

_____19. Check for vacuum at EGR when engine is warm. Repair if necessary.

_____20. Replace PCV. Check for vacuum at PCV. Repair if necessary.

_____21. Check air cleaner thermostatic control. Repair if necessary.

_____22. Check air pump control operation. Repair if necessary.

____23. Fluid levels. Bring to full mark.

____Coolant - record freeze point _______ (maintain during testing)

____Brakes

____Power steering

____Battery

____Transmission
- No additions or changes during the testing
____Differential

____24. Install J type thermocouples in the upper radiator hose and in the engine oil drain plug. Allow for safe road clearance.

____25. Disconnect electic lead to air conditioner compressor clutch.

____26. Change engine oil to reference lubricant _ HR.

Drain used oil hot, install a new filter.

Flush crankcase twice with HR Oil. A flush consists of charging with new oil, operating 10 minutes at idle and draining while hot. A new filter or a filter bypass must be used for every flush.

After flushes, install a new oil filter and fill with new HR Oil.

Fill crankcase exactly to the full mark on the dipstick.

____27. Check for any brake drag on driving axle.

____28. Inflate driving tires to 45 psig (use manufacturer's specifications for road/track mileage accumulation). If any tires fail during tests, replace with a used tire of the same make, model, and size from the non-driving axle and subject to the same preconditioning prior to test. A separate pair of tires may be used for dynamometer operation only, providing they are used for every test on the car(s) involved.

____29. Install the on-board fuel flow measuring system components to allow operation of the car from the laboratory fuel system, feeding directly into the carburetor inlet (use appropriate alternatives for fuel injected vehicles) or the vehicle fuel tank using quick disconnect couplings. When the vehicle is run on the dynamometer using the laboratory fuel system the fuel line from the vehicle fuel pump to the carburetor must be blocked off. Block or delete any fuel return line that may exist. Check entire system for leaks.

____30. Prior to the preconditioning run, the carbon canister vent lines must be disconnected. The line from the canister to the carburetor must be disconnected. Reconnect the canister for mileage accumulation.

____31. Measure HC and CO at idle and 2500 rpm (adjust as necessary).

____32. Routine inspection of the vehicle should be done prior to each set of tests. An Auto Sense sequence 908 or equivalent should be run. No adjustments should be made during a test sequence.

3.1.2 The foregoing inspection and tuneup will prepare vehicles for their initial fuel economy tests. It is anticipated that vehicles used in these tests will be subject to reference runs with the HR oil to the extent that each will have a statistically reliable trend established graphically. Examination of this data and periodic inspections of the vehicles will indicate the need for maintenance. Any maintenance will be at the discretion of the test laboratory. After a series of tests is in progress, replacement of failed parts, certain adjustments and corrections of other faults is permissible if certainty exists that this re-establishes characteristics which prevailed during previously acceptable operation of the vehicle. Any maintenance which could possibly influence the fuel economy characteristics of the vehicle must be followed by HR oil reference tests to establish whether the trend still follows the previously established trend or to define the new trend.

4. Procedure

4.1 Preconditioning

Prior to the dynamometer fuel economy tests, the vehicles must undergo a preconditioning run, followed by a soak period. The preconditioning operation will be comprised of two consecutive HFET cycles on a chassis dynamometer. Prior to this schedule, the vent line between the gas tank and the vapor canister must be disconnected and both ends left open. Prior to the preconditioning run fill the vehicle's fuel tank with the same fuel that will be used for the dynamometer tests. Upon completion of the preconditioning run, the vehicle is to be parked immediately in the soak area and the hood opened. When duplicate fuel economy tests are conducted on a given car on consecutive days, the test run will also constitute a preconditioning run and the car may be immediately parked again in the soak area. The duration of the soak period will be between 12 and 24 hours.

4.2 Soak Procedure

Vehicles must be soaked for a minimum of 12 hours with the engines off and the hoods open in an area with an ambient temperature range of 68° to 74°F. Narrowing this range to, for example, 68° to 70°F significantly reduces the variation in test to test results. Vehicles should be sequenced to start the soak period and start the dynamometer test on a fixed schedule to insure similar soak times.

4.3 Dynamometer Warm-Up

Prior to starting fuel economy tests on dual roll dynamometers, the dynamometer must be warmed-up with a non-test vehicle. If the dynamometer has been out of service over night or for an extended period, operate a non-test vehicle on the rolls for 20 minutes at 50 mph with an appropriate power absorption unit loading. Any time the dynamometer has been out of service between tests for more than one hour or when different inertia weights are selected, a 10 minute, 50 mph warm-up with appropriate loading will be performed. These warm-up periods also afford opportunity to check the calibration of the driver's aid. Large single roll dynamometers may require additional warm-up time to establish thermal equilibrium in the lubricants and bearings which support the rollers and flywheels.

4.4 Dynamometer Fuel Economy Measurements

4.4.1 At completion of the soak period, the vehicle must be pushed onto the dynamometer and made ready for test without starting the engine. After positioning the car on the dynamometer, chock the non-driving wheels and attach the rear safety chain or cable or other restraints in a uniform way from test to test. Variations from test to test in the amount of forward movement of the car on the rolls during accelerations should be minimized. Check and adjust the air pressure in the driving tires to 45 psi. Position the optional squirrel cage blowers in a uniform position to cool the contact area between the driving tires and the power absorbing roller and turn these blowers on. Be certain the car's gas tank is at the usual, nearly full level (tanks are filled prior to the preconditioning run), the spare tire is in place and that no additional equipment is in the car which would change the gross weight or, especially, the weight on the driving axle.

4.4.2 Battery condition and the resulting amount of current supplied by the alternator during repetitive tests in the same car has been found to be a significant variable. To avoid this variable horsepower loading imposed by the alternator and reduce the coefficient of variation between tests, the option of disconnecting the charging system during the dynamometer tests is permissible, providing this arrangement prevails at all times for both the reference and the candidate oils in any given car. No compensating adjustment is made in the dynamometer power absorption unit horsepower loading. Care must be exercised in disconnecting the charging systems and the following directions should be followed:

(1) Make all disconnections and reconnections with the ignition system turned off to avoid arcs.

(2) In the Ford 2.3L and 302 cubic inch engine cars, disconnect the multipin plug on the voltage regulator to disable the charging system. Connect a conventional garage type battery charger while the car is on the chassis dynamometer. Cut the wire between the alternator center tap and the electric choke at about the middle point (for accessibility) and place a push-together fully insulated connector in this wire. For the dynamometer test, this connection is broken and a 6½ to 7 volt D.C. power supply is connected with the positive lead to the electric choke and the negative lead to ground on the car. Turn this power supply on immediately after starting the engine for test (do not turn it on beforehand) and leave it on through the entire test, including the shut-downs between cycles.

(3) In the Chrysler products with the 225 cubic inch engines, disconnect the plug on the voltage regulator mounted high on the right side of the firewall and connect a battery charger to the battery. The electric choke will continue to function in the usual way.

(4) In General Motors cars, disconnect the two prong white plastic connector at the back of the alternator and connect a battery charger to the battery. Models equipped with an electric choke receive current from the oil pressure switch and continue to function in the usual way with the alternator disconnected.

In further preparations for the dynamometer test, connect the cooling system and oil pan thermocouples to the laboratory temperature recorder and record these starting temperatures. The engine oil and coolant temperatures must be within ±2.5°F of the value recorded prior to the first test in the vehicle, before every subsequent test in that vehicle. Narrowing this range helps minimize test to test variability. Connect the fuel supply system and turn on the electric fuel pump. Open the valve at the tee near the carburetor inlet and flow fuel through the lines to purge them of all bubbles between the fuel measurement equipment and the carburetor. This will also fill the carburetor float bowl, replenishing any fuel lost to evaporation during the soak period. Turn the valve at the tee off so no further fuel can by-pass, and leave the fuel pump on for the entire duration of the dynamometer test, including periods when the engine is off. Check the fuel lines for any leakage and be certain the valve at the tee does not leak fuel to either the catch container or the fuel supply reservoir. Evacuate CVS bags for carbon balance method and perform other pretest calibrations as specified in Federal Register 36.

4.4.3. Position the 24" fan in front of the car in a uniform position for every test on any given car. The screen at the outlet of this fan must touch the front bumper. Turn the fan on and leave it on, with the hood fully open for the entire duration of the test, including periods when the engine is off. Record the wet and dry bulb temperatures at this fan and the barometric pressure before starting the engine.

4.4.4 The dynamometer test cycles must be run in accordance with the following sequence to derive one point on the fuel economy versus mileage curve which will be developed for each car tested.

Time In Seconds	
-20	Line purging completed and fuel pump on
-5	Read fuel meter and distance measurements (zero if necessary)
0	Start the engine and run EPA cold start cycle (bag 1), start CVS sampling bag 1
505	Read fuel meter and distance measurement, then run EPA cycle corresponding to bag 2 (start sampling bag 2)
1371	Turn ignition off
1376	Read fuel meter and distance measurement (stop sampling bag 2)
	10 minute soak. Read wet and dry bulb temperatures
-5	Read fuel meter (zero fuel meter and distance counter)
0	Start the engine and run 505 sec. cycle (bag 3)
505	Turn ignition off

Soak for 10 minutes

Run 50 mph for 3 minutes

Read oil and coolant temperatures after 2 minutes

Come to an idle

0 Read fuel meter and distance measurement (zero if necessary)

Drive HFET cycle

765 Read fuel meter and distance measurement

13 second idle

0 Read fuel meter and distance measurement

Drive second HFET cycle

765 Read fuel meter and distance plus wet and dry bulb temperatures

Remove vehicle from dynamometer

4.5 Fuel Economy Calculations

4.5.1 With volumetric metering systems, the fuel economies will be calculated on a true miles per pound basis. These values will be converted to miles per gallon for comparison. Since denser fuels deliver more miles per gallon, any differences in fuel density must be accounted for in any MPG comparisons.

4.5.2 With volumetric systems, determine the net volumes and distances for each cycle as above. Measure the API gravity and convert this to the equivalent gravity at 60°F by reference to the "Reduction of Observed API Gravity to API at 60°F" table on the following pages. Then, referring to the "Pounds per US Gallon at 60°F" table, determine the density of the fuel in pounds per gallon at 60°F. Since the fuel was probably metered at some temperature other than 60°F, the exact weight of the volume metered is determined by multiplying:

Vol. Metered x Fuel Density @ 60°F x Vol. Reduction Factor.

The volume Reduction Factor is from the "Reduction of Volume to 60°F Against API Gravity at 60°F (Abridged)" table. Use the factor for the temperature at which the gasoline was actually metered. Most gasolines are expected to be in Group 3 (51.0° to 63.9° API) in this table. The true miles per pound is then calculated and converted to miles per gallon by multiplying by the fuel density calculated in lbs/gal. The concept of starting with a volume measurement, calculating on a true weight basis and then converting back to familiar MPG terms accounts for any variations in the density of the fuel used as well as the temperature at which it was metered and then puts all results on an equal basis for direct comparisons. It is important that repetitive calculations always be done in the same sequence, carrying the same number of significant figures and where figures are rounded off, this must always be done the same way.

4.5.3 With the carbon balance method, obtain the HC, CO, and CO_2 grams per test phase as described in 40 CFR Part 86.

a. Determine the Hydrogen/Carbon ratio for the test fuel used by laboratory analysis. Calculate the Weight Fraction Carbon as follows:

$$WF_c = \frac{12.01115}{12.01115 + 1.00797(\text{H/C Ratio})}$$

Where WF_c = Weight Fraction Carbon

H/C Ratio = Hydrogen/Carbon Ratio

b. Calculate the fuel density as described in Paragraph 4.5.2 in lbs/gallon.

c. Calculate the grams carbon per gallon of fuel.

$$gmc/gal = (WF_c)\ (\text{fuel density})\ (453.5924)$$

d. Calculate the gallon per mile per test phase:

$$GPM = \frac{WF_c(\text{HC grams}) + .428808(\text{CO grams}) + .27299(CO_2\ \text{grams})}{(gmc/gal)(\text{MILES PER TEST PHASE})}$$

4.5.4 After determining the fuel economy for each of the 5 cycles in the test (which correspond to the 5 bags run in the emissions tests), calculate a 55/45 harmonic mean value to reduce the results of the approximately 2 hour long test to a single number as follows:

Table 8

Pounds per U. S. Gallon and U. S. Gallons per Pound

API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound	API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound	API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound
	6.675	0.14982	50.0	6.491	0.15407	55.0	6.316	0.15832
	6.671	0.14990	50.1	6.487	0.15416	55.1	6.313	0.15841
	6.667	0.14999	50.2	6.483	0.15424	55.2	6.310	0.15849
	6.663	0.15007	50.3	6.480	0.15432	55.3	6.306	0.15858
	6.660	0.15016	50.4	6.476	0.15441	55.4	6.303	0.15866
	6.656	0.15024	50.5	6.473	0.15449	55.5	6.299	0.15875
	6.652	0.15033	50.6	6.469	0.15458	55.6	6.296	0.15883
	6.648	0.15041	50.7	6.466	0.15466	55.7	6.293	0.15892
	6.645	0.15050	50.8	6.462	0.15475	55.8	6.289	0.15900
	6.641	0.15058	50.9	6.459	0.15483	55.9	6.286	0.15909
	6.637	0.15067	51.0	6.455	0.15492	56.0	6.283	0.15917
	6.633	0.15075	51.1	6.451	0.15500	56.1	6.279	0.15926
	6.630	0.15084	51.2	6.448	0.15509	56.2	6.276	0.15934
	6.626	0.15092	51.3	6.444	0.15517	56.3	6.273	0.15943
	6.622	0.15101	51.4	6.441	0.15526	56.4	6.269	0.15951
	6.618	0.15109	51.5	6.437	0.15534	56.5	6.266	0.15960
	6.615	0.15118	51.6	6.434	0.15543	56.6	6.263	0.15968
	6.611	0.15126	51.7	6.430	0.15551	56.7	6.259	0.15977
	6.607	0.15135	51.8	6.427	0.15560	56.8	6.256	0.15985
	6.604	0.15143	51.9	6.423	0.15568	56.9	6.253	0.15994
	6.600	0.15152	52.0	6.420	0.15577	57.0	6.249	0.16002
	6.596	0.15160	52.1	6.416	0.15585	57.1	6.246	0.16011
	6.592	0.15169	52.2	6.413	0.15594	57.2	6.243	0.16019
	6.589	0.15177	52.3	6.409	0.15603	57.3	6.239	0.16028
	6.585	0.15186	52.4	6.406	0.15611	57.4	6.236	0.16036
	6.581	0.15194	52.5	6.402	0.15619	57.5	6.233	0.16045
	6.578	0.15203	52.6	6.399	0.15628	57.6	6.229	0.16053
	6.574	0.15211	52.7	6.395	0.15637	57.7	6.226	0.16062
	6.570	0.15220	52.8	6.392	0.15645	57.8	6.223	0.16070
	6.567	0.15228	52.9	6.388	0.15654	57.9	6.219	0.16079
	6.563	0.15237	53.0	6.385	0.15662	58.0	6.216	0.16087
1	6.559	0.15245	53.1	6.381	0.15671	58.1	6.213	0.16096
2	6.556	0.15254	53.2	6.378	0.15679	58.2	6.210	0.16104
3	6.552	0.15262	53.3	6.375	0.15688	58.3	6.206	0.16113
4	6.548	0.15271	53.4	6.371	0.15696	58.4	6.203	0.16121
5	6.545	0.15279	53.5	6.368	0.15705	58.5	6.200	0.16130
6	6.541	0.15288	53.6	6.364	0.15713	58.6	6.197	0.16138
7	6.538	0.15296	53.7	6.361	0.15722	58.7	6.193	0.16147
8	6.534	0.15305	53.8	6.357	0.15730	58.8	6.190	0.16155
9	6.530	0.15313	53.9	6.354	0.15739	58.9	6.187	0.16164
0	6.527	0.15322	54.0	6.350	0.15747	59.0	6.183	0.16172
1	6.523	0.15330	54.1	6.347	0.15756	59.1	6.180	0.16181
2	6.519	0.15339	54.2	6.344	0.15764	59.2	6.177	0.16189
3	6.516	0.15347	54.3	6.340	0.15773	59.3	6.174	0.16198
4	6.512	0.15356	54.4	6.337	0.15781	59.4	6.171	0.16206
5	6.509	0.15364	54.5	6.333	0.15790	59.5	6.167	0.16215
6	6.505	0.15373	54.6	6.330	0.15798	59.6	6.164	0.16223
7	6.501	0.15381	54.7	6.327	0.15807	59.7	6.161	0.16232
8	6.498	0.15390	54.8	6.323	0.15815	59.8	6.158	0.16240
9	6.494	0.15398	54.9	6.320	0.15824	59.9	6.154	0.16249
0	6.491	0.15407	55.0	6.316	0.15832	60.0	6.151	0.16257

Pounds per U. S. Gallon and U. S. Gallons per Pound

API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound	API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound	API Gravity 60° F.	Pounds per U. S. Gallon at 60° F.	U. S. Gallons at 60° F. per Pound
60.0	6.151	0.16257	65.0	5.994	0.16682	70.0	5.845	0.17108
60.1	6.148	0.16266	65.1	5.991	0.16691	70.1	5.842	0.17116
60.2	6.145	0.16274	65.2	5.988	0.16699	70.2	5.840	0.17125
60.3	6.141	0.16283	65.3	5.985	0.16708	70.3	5.837	0.17133
60.4	6.138	0.16291	65.4	5.982	0.16716	70.4	5.834	0.17142
60.5	6.135	0.16300	65.5	5.979	0.16725	70.5	5.831	0.17150
60.6	6.132	0.16308	65.6	5.976	0.16733	70.6	5.828	0.17159
60.7	6.129	0.16317	65.7	5.973	0.16742	70.7	5.825	0.17167
60.8	6.126	0.16325	65.8	5.970	0.16750	70.8	5.822	0.17176
60.9	6.122	0.16334	65.9	5.967	0.16759	70.9	5.819	0.17184
61.0	6.119	0.16342	66.0	5.964	0.16767	71.0	5.816	0.17193
61.1	6.116	0.16351	66.1	5.961	0.16776	71.1	5.814	0.17201
61.2	6.113	0.16359	66.2	5.958	0.16784	71.2	5.811	0.17210
61.3	6.110	0.16368	66.3	5.955	0.16793	71.3	5.808	0.17218
61.4	6.106	0.16376	66.4	5.952	0.16801	71.4	5.805	0.17227
61.5	6.103	0.16385	66.5	5.949	0.16810	71.5	5.802	0.17235
61.6	6.100	0.16393	66.6	5.946	0.16818	71.6	5.799	0.17244
61.7	6.097	0.16402	66.7	5.943	0.16827	71.7	5.796	0.17252
61.8	6.094	0.16410	66.8	5.940	0.16835	71.8	5.794	0.17261
61.9	6.091	0.16419	66.9	5.937	0.16844	71.9	5.791	0.17269
62.0	6.087	0.16427	67.0	5.934	0.16853	72.0	5.788	0.17278
62.1	6.084	0.16436	67.1	5.931	0.16861	72.1	5.785	0.17286
62.2	6.081	0.16444	67.2	5.928	0.16870	72.2	5.782	0.17295
62.3	6.078	0.16453	67.3	5.925	0.16878	72.3	5.779	0.17303
62.4	6.075	0.16461	67.4	5.922	0.16887	72.4	5.776	0.17312
62.5	6.072	0.16470	67.5	5.919	0.16895	72.5	5.774	0.17320
62.6	6.069	0.16478	67.6	5.916	0.16904	72.6	5.771	0.17329
62.7	6.065	0.16487	67.7	5.913	0.16912	72.7	5.768	0.17337
62.8	6.062	0.16495	67.8	5.910	0.16921	72.8	5.765	0.17346
62.9	6.059	0.16504	67.9	5.907	0.16929	72.9	5.762	0.17354
63.0	6.056	0.16512	68.0	5.904	0.16938	73.0	5.759	0.17363
63.1	6.053	0.16521	68.1	5.901	0.16946	73.1	5.757	0.17371
63.2	6.050	0.16529	68.2	5.898	0.16955	73.2	5.754	0.17380
63.3	6.047	0.16538	68.3	5.895	0.16963	73.3	5.751	0.17388
63.4	6.044	0.16546	68.4	5.892	0.16972	73.4	5.748	0.17397
63.5	6.041	0.16555	68.5	5.889	0.16980	73.5	5.745	0.17405
63.6	6.037	0.16563	68.6	5.886	0.16989	73.6	5.743	0.17414
63.7	6.034	0.16572	68.7	5.883	0.16997	73.7	5.740	0.17422
63.8	6.031	0.16580	68.8	5.880	0.17006	73.8	5.737	0.17431
63.9	6.028	0.16589	68.9	5.878	0.17014	73.9	5.734	0.17439
64.0	6.025	0.16597	69.0	5.875	0.17023	74.0	5.731	0.17448
64.1	6.022	0.16606	69.1	5.872	0.17031	74.1	5.729	0.17456
64.2	6.019	0.16614	69.2	5.869	0.17040	74.2	5.726	0.17465
64.3	6.016	0.16623	69.3	5.866	0.17048	74.3	5.723	0.17473
64.4	6.013	0.16631	69.4	5.863	0.17057	74.4	5.720	0.17482
64.5	6.010	0.16640	69.5	5.860	0.17065	74.5	5.717	0.17490
64.6	6.007	0.16648	69.6	5.857	0.17074	74.6	5.715	0.17499
64.7	6.004	0.16657	69.7	5.854	0.17082	74.7	5.712	0.17507
64.8	6.000	0.16665	69.8	5.851	0.17091	74.8	5.709	0.17516
64.9	5.997	0.16674	69.9	5.848	0.17099	74.9	5.706	0.17524
65.0	5.994	0.16682	70.0	5.845	0.17108	75.0	5.704	0.17533

Observed Temperature, °F.	50	51	52	53	54	55	56	57	58	59
	Corresponding API Gravity at 60° F.									
50	51.0	52.0	53.0	54.0	55.1	56.1	57.1	58.1	59.1	60.2
51	50.9	51.9	52.9	53.9	54.9	56.0	57.0	58.0	59.0	60.0
52	50.8	51.8	52.8	53.8	54.8	55.9	56.9	57.9	58.9	59.9
53	50.7	51.7	52.7	53.7	54.7	55.8	56.8	57.8	58.8	59.8
54	50.6	51.6	52.6	53.6	54.6	55.6	56.7	57.7	58.7	59.7
55	50.5	51.5	52.5	53.5	54.5	55.5	56.5	57.6	58.6	59.6
56	50.4	51.4	52.4	53.4	54.4	55.4	56.4	57.4	58.5	59.5
57	50.3	51.3	52.3	53.3	54.3	55.3	56.3	57.3	58.3	59.3
58	50.2	51.2	52.2	53.2	54.2	55.2	56.2	57.2	58.2	59.2
59	50.1	51.1	52.1	53.1	54.1	55.1	56.1	57.1	58.1	59.1
60	50.0	51.0	52.0	53.0	54.0	55.0	56.0	57.0	58.0	59.0
61	49.9	50.9	51.9	52.9	53.9	54.9	55.9	56.9	57.9	58.9
62	49.8	50.8	51.8	52.8	53.8	54.8	55.8	56.8	57.8	58.8
63	49.7	50.7	51.7	52.7	53.7	54.7	55.7	56.7	57.7	58.7
64	49.6	50.6	51.6	52.6	53.6	54.6	55.6	56.6	57.6	58.5
65	49.5	50.5	51.5	52.5	53.5	54.5	55.5	56.5	57.4	58.4
66	49.4	50.4	51.4	52.4	53.4	54.4	55.4	56.3	57.3	58.3
67	49.3	50.3	51.3	52.3	53.3	54.3	55.3	56.2	57.2	58.2
68	49.2	50.2	51.2	52.2	53.2	54.2	55.1	56.1	57.1	58.1
69	49.1	50.1	51.1	52.1	53.1	54.1	55.0	56.0	57.0	58.0
70	49.1	50.0	51.0	52.0	53.0	54.0	54.9	55.9	56.9	57.9
71	49.0	49.9	50.9	51.9	52.9	53.9	54.8	55.8	56.8	57.8
72	48.9	49.8	50.8	51.8	52.8	53.8	54.7	55.7	56.7	57.6
73	48.8	[illegible]	50.7	51.7	52.7	53.6	54.6	55.6	56.6	57.5
74	48.7	49.7	50.6	51.6	52.6	53.5	54.5	55.5	56.5	57.4
75	48.6	49.6	50.5	51.5	52.5	53.4	54.4	55.4	56.3	57.3
76	48.5	49.5	50.4	51.4	52.4	53.3	54.3	55.3	56.2	57.2
77	48.4	49.4	50.3	51.3	52.3	53.2	54.2	55.2	56.1	57.1
78	48.3	49.3	50.3	51.2	52.2	53.1	54.1	55.1	56.0	57.0
79	48.2	49.2	50.2	51.1	52.1	53.0	54.0	55.0	55.9	56.9
80	48.1	49.1	50.1	51.0	52.0	52.9	53.9	54.9	55.8	56.8
81	48.0	49.0	50.0	50.9	51.9	52.8	53.8	54.8	55.7	56.7
82	48.0	48.9	49.9	50.8	51.8	52.7	53.7	54.7	55.6	56.6
83	47.9	48.8	49.8	50.7	51.7	52.6	53.6	54.5	55.5	56.4
84	47.8	48.7	49.7	50.6	51.6	52.5	53.5	54.4	55.4	56.3
85	47.7	48.6	49.6	50.5	51.5	52.4	53.4	54.3	55.3	56.2
86	47.6	48.5	49.5	50.5	51.4	52.4	53.3	54.2	55.2	56.1
87	47.5	48.5	49.4	50.4	51.3	52.3	53.2	54.1	55.1	56.0
88	47.4	48.4	49.3	50.3	51.2	52.2	53.1	54.0	55.0	55.9
89	47.3	48.3	49.2	50.2	51.1	52.1	53.0	53.9	54.9	55.8
90	47.2	48.2	49.1	50.1	51.0	52.0	52.9	53.8	54.8	55.7
91	47.2	48.1	49.0	50.0	50.9	51.9	52.8	53.7	54.7	55.6
92	47.1	48.0	48.9	49.9	50.8	51.8	52.7	53.6	54.6	55.5
93	47.0	47.9	48.9	49.8	50.7	51.7	52.6	53.5	54.5	55.4
94	46.9	47.8	48.8	49.7	50.6	51.6	52.5	53.4	54.4	55.3
95	46.8	47.7	48.7	49.6	50.5	51.5	52.4	53.3	54.3	55.2
96	46.7	47.7	48.6	49.5	50.5	51.4	52.3	53.2	54.2	55.1
97	46.6	47.6	48.5	49.4	50.4	51.3	52.2	53.1	54.1	55.0
98	46.5	47.5	48.4	49.3	50.3	51.2	52.1	53.0	54.0	54.9
99	46.5	47.4	48.3	49.2	50.2	51.1	52.0	52.9	53.9	54.8
100	46.4	47.3	48.2	49.2	50.1	51.0	51.9	52.8	53.8	54.7

Observed Temperature, °F.	60	61	62	63	64	65	66	67	68	69
	Corresponding API Gravity at 60° F.									
50	61.2	62.2	63.2	64.2	65.3	66.3	67.3	68.3	69.3	70.4
51	61.1	62.1	63.1	64.1	65.1	66.2	67.2	68.2	69.2	70.2
52	60.9	62.0	63.0	64.0	65.0	66.0	67.0	68.1	69.1	70.1
53	60.8	61.8	62.8	63.9	64.9	65.9	66.9	67.9	68.9	70.0
54	60.7	61.7	62.7	63.7	64.8	65.8	66.8	67.8	68.8	69.8
55	60.6	61.6	62.6	63.6	64.6	65.6	66.6	67.7	68.7	69.7
56	60.5	61.5	62.5	63.5	64.5	65.5	66.5	67.5	68.5	69.5
57	60.4	61.4	62.4	63.4	64.4	65.4	66.4	67.4	68.4	69.4
58	60.2	61.2	62.2	63.2	64.2	65.3	66.3	67.3	68.3	69.3
59	60.1	61.1	62.1	63.1	64.1	65.1	66.1	67.1	68.1	69.1
60	60.0	61.0	62.0	63.0	64.0	65.0	66.0	67.0	68.0	69.0
61	59.9	60.9	61.9	62.9	63.9	64.9	65.9	66.9	67.9	68.9
62	59.8	60.8	61.8	62.8	63.8	64.7	65.7	66.7	67.7	68.7
63	59.7	60.6	61.6	62.6	63.6	64.6	65.6	66.6	67.6	68.6
64	59.5	60.5	61.5	62.5	63.5	64.5	65.5	66.5	67.5	68.5
65	59.4	60.4	61.4	62.4	63.4	64.4	65.4	66.4	67.3	68.3
66	59.3	60.3	61.3	62.3	63.3	64.2	65.2	66.2	67.2	68.2
67	59.2	60.2	61.2	62.2	63.1	64.1	65.1	66.1	67.1	68.1
68	59.1	60.1	61.0	62.0	63.0	64.0	65.0	66.0	67.0	67.9
69	59.0	59.9	60.9	61.9	62.9	63.9	64.8	65.8	66.8	67.8
70	58.9	59.8	60.8	61.8	62.8	63.8	64.7	65.7	66.7	67.7
71	58.7	59.7	60.7	61.7	62.7	63.6	64.6	65.6	66.6	67.5
72	58.6	59.6	60.6	61.6	62.5	63.5	64.5	65.5	66.4	67.4
73	58.5	59.5	60.5	61.4	62.4	63.4	64.4	65.3	66.3	67.3
74	58.4	59.4	60.3	61.3	62.3	63.3	64.2	65.2	66.2	67.1
75	58.3	59.3	60.2	61.2	62.2	63.1	64.1	65.1	66.1	67.0
76	58.2	59.1	60.1	61.1	62.1	63.0	64.0	65.0	65.9	66.9
77	58.1	59.0	60.0	61.0	61.9	62.9	63.9	64.8	65.8	66.8
78	58.0	58.9	59.9	60.8	61.8	62.8	63.7	64.7	65.7	66.6
79	57.8	58.8	59.8	60.7	61.7	62.7	63.6	64.6	65.5	66.5
80	57.7	58.7	59.7	60.6	61.6	62.5	63.5	64.5	65.4	66.4
81	57.6	58.6	59.5	60.5	61.5	62.4	63.4	64.3	65.3	66.2
82	57.5	58.5	59.4	60.4	61.3	62.3	63.3	64.2	65.2	66.1
83	57.4	58.4	59.3	60.3	61.2	62.2	63.1	64.1	65.0	66.0
84	57.3	58.2	59.2	60.2	61.1	62.1	63.0	64.0	64.9	65.9
85	57.2	58.1	59.1	60.0	61.0	61.9	62.9	63.8	64.8	65.7
86	57.1	58.0	59.0	59.9	60.9	61.8	62.8	63.7	64.7	65.6
87	57.0	57.9	58.9	59.8	60.8	61.7	62.7	63.6	64.5	65.5
88	56.9	57.8	58.8	59.7	60.6	61.6	62.5	63.5	64.4	65.4
89	56.8	57.7	58.6	59.6	60.5	61.5	62.4	63.4	64.3	65.2
90	56.6	57.6	58.5	59.5	60.4	61.4	62.3	63.2	64.2	65.1
91	56.5	57.5	58.4	59.4	60.3	61.2	62.2	63.1	64.1	65.0
92	56.4	57.4	58.3	59.2	60.2	61.1	62.1	63.0	63.9	64.9
93	56.3	57.3	58.2	59.1	60.1	61.0	61.9	62.9	63.8	64.7
94	56.2	57.1	58.1	59.0	60.0	60.9	61.8	62.8	63.7	64.6
95	56.1	57.0	58.0	58.9	59.8	60.8	61.7	62.6	63.6	64.5
96	56.0	56.9	57.9	58.8	59.7	60.7	61.6	62.5	63.4	64.4
97	55.9	56.8	57.8	58.7	59.6	60.5	61.5	62.4	63.3	64.3
98	55.8	56.7	57.6	58.6	59.5	60.4	61.4	62.3	63.2	64.1
99	55.7	56.6	57.5	58.5	59.4	60.3	61.2	62.2	63.1	64.0
100	55.6	56.5	57.4	58.4	59.3	60.2	61.1	62.0	63.0	[illegible]

Table 6

60-69° API Volume Reduction to 60° F.

50-100° F.

Observed Temperature, °F.	API Gravity at 60° F.									
	60	61	62	63	64	65	66	67	68	69
	Factor for Reducing Volume to 60° F.									
50	1.0062	1.0063	1.0063	1.0064	1.0065	1.0065	1.0060	1.0007	1.0068	1.0068
51	1.0056	1.0056	1.0057	1.0058	1.0058	1.0059	1.0060	1.0060	1.0061	1.0061
52	1.0050	1.0050	1.0051	1.0051	1.0052	1.0052	1.0053	1.0054	1.0054	1.0055
53	1.0043	1.0044	1.0044	1.0045	1.0045	1.0046	1.0046	1.0047	1.0047	1.0048
54	1.0037	1.0038	1.0038	1.0038	1.0039	1.0039	1.0040	1.0040	1.0041	1.0041
55	1.0031	1.0031	1.0032	1.0032	1.0032	1.0033	1.0033	1.0033	1.0034	1.0034
56	1.0025	1.0025	1.0025	1.0026	1.0026	1.0026	1.0026	1.0027	1.0027	1.0027
57	1.0019	1.0019	1.0019	1.0019	1.0019	1.0020	1.0020	1.0020	1.0020	1.0021
58	1.0012	1.0013	1.0013	1.0013	1.0013	1.0013	1.0013	1.0013	1.0014	1.0014
59	1.0006	1.0006	1.0006	1.0006	1.0006	1.0007	1.0007	1.0007	1.0007	1.0007
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
61	0.9994	0.9994	0.9994	0.9994	0.9994	0.9993	0.9993	0.9993	0.9993	0.9093
62	0.9988	0.9987	0.9987	0.9987	0.9987	0.9987	0.9987	0.9987	0.9986	0.9986
63	0.9981	0.9981	0.9981	0.9981	0.9981	0.9980	0.9980	0.9980	0.9980	0.9979
64	0.9975	0.9975	0.9975	0.9974	0.9974	0.9974	0.9973	0.9973	0.9973	0.9973
65	0.9969	0.9969	0.9968	0.9968	0.9968	0.9967	0.9967	0.9966	0.9966	0.9966
66	0.9963	0.9962	0.9962	0.9961	0.9961	0.9961	0.9960	0.9960	0.9959	0.9959
67	0.9957	0.9956	0.9956	0.9955	0.9955	0.9954	0.9954	0.9953	0.9953	0.9952
68	0.9950	0.9950	0.9949	0.9949	0.9948	0.9948	0.9947	0.9946	0.9946	0.9945
69	0.9944	0.9943	0.9943	0.9942	0.9942	0.9941	0.9940	0.9940	0.9939	0.9938
70	0.9938	0.9937	0.9937	0.9936	0.9935	0.9934	0.9934	0.9933	0.9932	0.9932
71	0.9932	0.9931	0.9930	0.9929	0.9929	0.9928	0.9927	0.9926	0.9925	0.9925
72	0.9925	0.9925	0.9924	0.9923	0.9922	0.9921	0.9920	0.9919	0.9919	0.9918
73	0.9919	0.9918	0.9017	0.9916	0.9916	0.9915	0.9914	0.9913	0.9912	0.9911
74	0.9913	0.9912	0.9911	0.9910	0.9909	0.9908	0.9907	0.9906	0.9905	0.9904
75	0.9907	0.9906	0.9905	0.9904	0.9903	0.9901	0.9900	0.9899	0.9898	0.9897
76	0.9901	0.9899	0.9898	0.9897	0.9896	0.9895	0.9894	0.9893	0.9891	0.9890
77	0.9894	0.9803	0.9892	0.9801	0.9890	0.9888	0.9887	0.9886	0.9885	0.9883
78	0.9888	0.9887	0.9886	0.9884	0.9883	0.9882	0.9880	0.9879	0.9878	0.9877
79	0.9882	0.9881	0.9879	0.9878	0.9877	0.9875	0.9874	0.9872	0.9871	0.9870
80	0.9876	0.9874	0.9873	0.9871	0.9870	0.9869	0.9867	0.9866	0.9864	0.9863
81	0.9870	0.9868	0.9866	0.9865	0.9863	0.9862	0.9860	0.9859	0.9857	0.9856
82	0.9863	0.9862	0.9860	0.9859	0.9857	0.9855	0.9854	0.9852	0.9851	0.9849
83	0.9857	0.9855	0.9854	0.9852	0.9850	0.9849	0.9847	0.9845	0.9844	0.9842
84	0.9851	0.9849	0.9847	0.9846	0.9844	0.9842	0.9840	0.9839	0.9837	0.9835
85	0.9845	0.9843	0.9841	0.9839	0.9837	0.9836	0.9834	0.9832	0.9830	0.9828
86	0.9838	0.9836	0.9835	0.9833	0.9831	0.9829	0.9827	0.9825	0.9823	0.9822
87	0.9832	0.9830	0.9828	0.9826	0.9824	0.9822	0.9820	0.9819	0.9817	0.9815
88	0.9826	0.9824	0.9822	0.9820	0.9818	0.9816	0.9814	0.9812	0.9810	0.9808
89	0.9820	0.9818	0.9815	0.9813	0.9811	0.9809	0.9807	0.9805	0.9803	0.9801
90	0.9813	0.9811	0.9809	0.9807	0.9805	0.9803	0.9800	0.9798	0.9796	0.9794
91	0.9807	0.9805	0.9803	0.9800	0.9798	0.9796	0.9794	0.9792	0.9789	0.9787
92	0.9801	0.9799	0.9796	0.9794	0.9702	0.9789	0.9787	0.9785	0.9782	0.9780
93	0.9795	0.9792	0.9790	0.9788	0.9785	0.9783	0.9780	0.9778	0.9776	0.9773
94	0.9788	0.9786	0.9784	0.9781	0.9779	0.9776	0.9774	0.9771	0.9769	0.9766
95	0.9782	0.9780	0.9777	0.9775	0.9772	0.9770	0.9767	0.9765	0.9762	0.9759
96	0.9776	0.9773	0.9771	0.9768	0.9766	0.9763	0.9760	0.9758	0.9755	0.9753
97	0.9770	0.9767	0.9764	0.9762	0.9759	0.9756	0.9754	0.9751	0.9748	0.9746
98	0.9763	0.9761	0.9758	0.9755	0.9752	0.9750	0.9747	0.9744	0.9741	0.9739
99	0.9757	0.9754	0.9752	0.9749	0.9746	0.9743	0.9740	0.9737	0.9735	0.9732
100	0.9751	0.9748	0.9745	0.9742	0.9739	0.9736	0.9734	0.9731	0.9728	0.9725

$$\text{CITY} = \frac{1}{.43\left(\dfrac{gal_1 + gal_2}{mi_1 + mi_2}\right) + .57\left(\dfrac{gal_2 + gal_3}{mi_2 + mi_3}\right)}$$

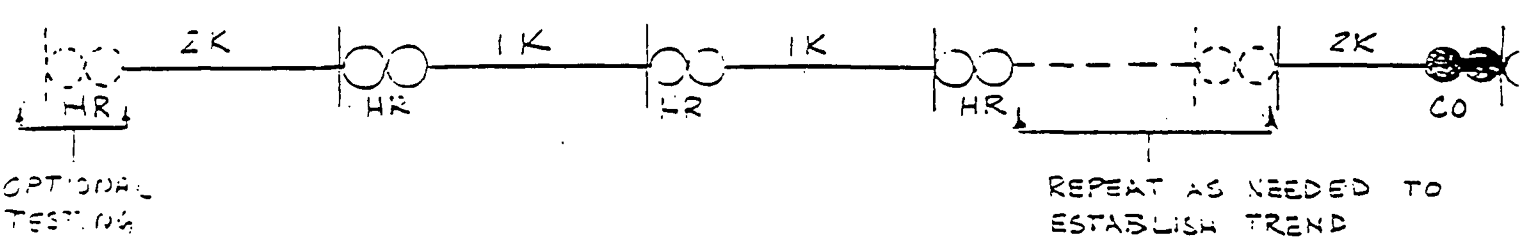
$$\text{COMBINED} = \frac{1}{\left(\dfrac{.55}{\text{CITY}}\right) + \left(\dfrac{.45}{\text{HWY.}}\right)}$$

The subscripts refer to the cycle (or bag) numbers and the highway miles per gallon figure used in the second equation is taken only from the 5th cycle (the second highway cycle).

4.6 Summary of the Overall Test Procedure

The EPA procedure for testing fuel efficient oils does not differentiate between those oils with carryover characteristics and those without such characteristics. Oils with carryover characteristics are those whose effects are residual after oil replacement. This procedure tests all oils as if they were carryover oils. All valid test data must be used in the candidate oil analysis. Therefore if an oil is retested on five new vehicles, the calculations must be made on ten vehicles, not just the five new vehicles.

4.6.1 The relative performance of candidate oils (CO) is ascertained from the delta between the fuel economy measured with the used candidate oil and an extrapolation of a trend line developed during repetitive tests with the HR oil in each vehicle. A schematic describing the test sequencing is given below:



where 2K, 1K = 2000 miles, 1000 miles respectively of 55 mph steady state mileage accumulation on the road, track, or mileage accumulation dynamometer.

HR = High reference oil

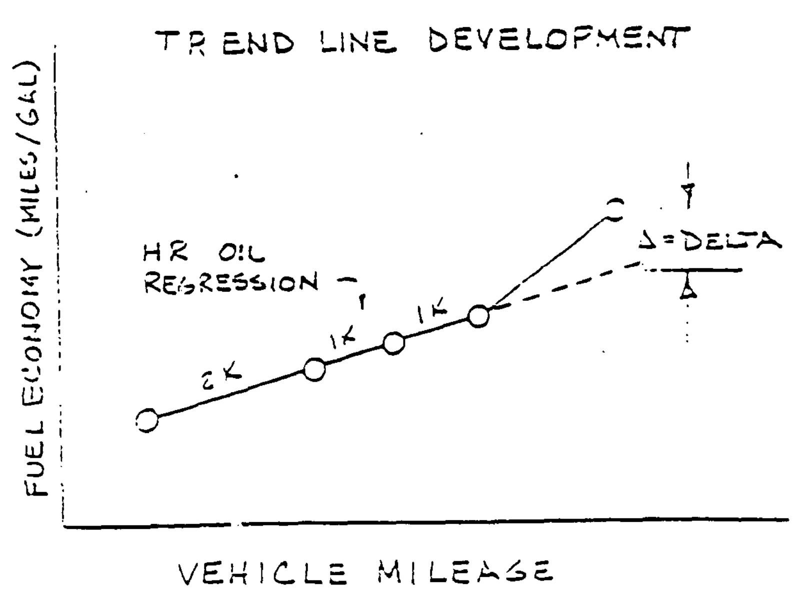
CO = Candidate oil

| = Double flush as described in Section 3.1.1

○ = FTP/HFET test sequence with fresh oil

● = FTP/HFET test sequence with used oil

Operate the vehicles for a minimum of 2000 miles at a nominal 55 mile per hour using HR oil. As indicated, double flush the engine and run duplicate test sequences as described above on HR. A minimum of 3 sets of mileage accumulation/duplicate test sequences are required. The first FTP/HFET sequences are optional and are not used in the trend line analysis. The objective is to establish a trend prediction from a linear regression of the averages of each set of FTP/HFET tests with minimum scatter in the data. Graphically, a plot of the data from each vehicle will have the general appearance shown below:



In order to minimize the scatter in the data, the following data tests are suggested:

1) Test to test repeatability:

Let the FTP/HFET fuel economy number from the first test = x_1

Let the FTP/HFET fuel economy number from the 2nd test = x_2

$$\text{LET } A_{1,2} = \frac{|X_1 - X_2|}{\frac{1}{2}(X_1 + X_2)}$$

If $A_{1,2} \leq .021$, then the repeatability test has been passed.

If $A_{1,2} > .021$, then another test sequence, x_3, is required.

In words this reads; if the absolute difference between the two measurements is less than or equal to 2.1% of their mean (average) value, the repeatability criteria has been satisfied. Should the repeatability test not be met by x_1, and x_2, x_3 is measured for repeatability with x_1, and with x_2. If x_3, x_1, or x_3, x_2 pass the 2.1% criteria use their average value in further calculations. If both x_3, x_1, and x_3, x_2 fail the 2.1% criteria, obtain x_4. If x_1, x_4, or x_2, x_4, or x_3, x_4 pass the 2.1% criteria, use their average value in further calculations. If all three sets fail the test use the average of the pair such that their difference is minimized.

After at most 4 FTP/HFET sequences, the two fuel economy measurements which are most repeatable will be used in the trend line analysis.

2) Trend Line Analysis - By the completion of the third set of test sequences the following data has been collected:

Measurements

1st mileage point:	$HRF_{i,1,1}$	$HRF_{i,2,1}$	$HRM_{i,1,1}$	$HRM_{i,2,1}$
2nd mileage point:	$HRF_{i,1,2}$	$HRF_{i,2,2}$	$HRM_{i,1,2}$	$HRM_{i,2,2}$
3rd mileage point:	$HRF_{i,1,3}$	$HRF_{i,2,3}$	$HRM_{i,1,3}$	$HRM_{i,2,3}$

where for $HRF_{i,j,k}$

HR = High Reference Oil

F = Fuel Economy Measurement

M = Mileage at Test j

i = Vehicle Number

j = Test number at a test point

k = test point

The trend line is established using the following definitions of (x_1, y_1), (y_2, y_2), (x_3, y_3) for the three pairs of points to be used in the regression:

$y_1 = \frac{1}{2}(HRF_{i,1,1} + HRF_{i,2,1})$
$x_1 = \frac{1}{2}(HRM_{i,1,1} + HRM_{i,2,1})$
$y_2 = \frac{1}{2}(HRF_{i,1,2} + HRF_{i,2,2})$
$x_2 = \frac{1}{2}(HRM_{i,1,2} + HRM_{i,2,2})$
$y_3 = \frac{1}{2}(HRF_{i,1,3} + HRF_{i,2,3})$
$x_3 = \frac{1}{2}(HRM_{i,1,3} + HRM_{i,2,3})$

To obtain y = mx + b:

$$m = \frac{\frac{\Sigma x_i \Sigma y_i}{3} - \Sigma x_i y_i}{\frac{(\Sigma x_i)^2}{3} - \Sigma x_i^2}, \quad b = \bar{y} - m\bar{x}, \quad \bar{x} = \frac{1}{3}\Sigma x_i, \quad \bar{y} = \frac{1}{3}\Sigma y_i$$

In words this means fuel economy = m * (mileage) + b;

The line y = m x (mileage) + b will be used to extrapolate to x_o miles which is the mileage at which the candidate oil (CO) measurements are to be taken. To determine if the line y = m x (mileage) + b fits the data points well, a measurement of fit, r, is calculated:

$$r = m\, S_x / S_y$$

WHERE : $S_x = \sqrt{\frac{1}{3}\Sigma x_i^2 - \bar{x}^2}$

$$S_y = \sqrt{\frac{1}{3}\Sigma y_i^2 - \bar{y}^2}$$

A very good fit can be defined by $r > 0.85$. If r is lower than 0.85 the testing indicates considerable fuel economy variability.

3) Trend Line Slope Analysis and Coefficient of Fit.

The slope of the trend line (m) must be positive. If the slope (m) is negative, additional series of mileage accumulation and tests to yield x_4, y_4 are required. If x_4, y_4 are developed, the trend line can be taken either through all four points or any three points whichever gives the <u>highest</u> r value. If the slope of the developed trend line remains negative with test point x_4, y_4, continued mileage accumulation and testing is required until a positive sloped trend line is developed. All combinations of data points yielding positive sloped lines should be calculated and the line with the <u>highest</u> r value selected. Proceeding to the candidate oil testing with a poorly defined trend line will cause a large error term in the final calculations.

4) Trend Line Last Point Criteria.

The highest mileage data point used in the trend line analysis must be within 1.0% of the calculated trend line. This data point is the average of the two fuel economy test points at the average mileage.

Only trend lines meeting the criteria described above may be used in the fuel economy calculations. Further data points at 1000 mile intervals can be taken until a satisfactory trend line is established.

Further data points at 1000 mile intervals can be taken until a satisfactory trend line is established. An example is given below:

Measurements for Trend Line

	Fuel Economy	Mileage
1st mileage point	18.29, 18.39	9996, 10017
2nd mileage point	18.83, 18.74	11011, 11032
3rd mileage point	18.78, 19.15	12021, 12042

These values give:

i	x_i (Average Mileage)	y_i (Average MPG)
1	10007	18.340
2	11015	18.785
3	12032	18.965

Then $y = .0003084(x) + 15.298$

$r = .9707$

Last Point Calculation: $y = .0003084\ (12032) + 15.298 = 19.0087$

Then: $[(19.0087 - 18.965)/18.965] \times 100 = .23\%$

This is one trend line for one vehicle to test a given candidate oil. It passes the tests for positive slope, lastpoint, and highest r value. If the candidate oil measurements are taken at 14078 miles, the HR extrapolation would be:

$$y = (.3084)(14078) + 15.298 = 19.64 \text{ mpg}$$

The closer that r is to 1.0000, the better will be the accuracy of the extrapolation.

Once a reliable trend line has been developed for each vehicle, double flush, and start operation with candidate oil. It is optional to determine the fuel economy of the candidate oil, fresh, in duplicate tests at this point. Operate the vehicle for 2000 miles at 55 mph as before, and then determine the fuel economy with the used candidate oil during duplicate dynamometer tests. Determine the repeatability of the used candidate oil tests using the same procedure as described above for the trend line data points in Section 4.6.1 - test to test repeatability. If the two candidate oil tests do not meet the less than 2.1 percent criteria, a third test should be run. Using the same procedure, if the third test does not yield two points within 2.1 percent, a fourth test should be run. After at most 4 FTP/HFET sequences, the two fuel economy measurements which are most repeatable will be used. Determine the percentage improvement in economy for each vehicle with the used candidate oil as compared with an extrapolation of the HR oil trend line at the same odometer mileage. An average of these values for all of the vehicles in the test is the average delta for the oil.

Test vehicles used in the procedure may be used to evaluate a second candidate oil if the first candidate oils effects' are eliminated and a new trend line is established. Upon completion of the after CO oil testing, a vehicle should be double flushed, and put on mileage accumulation for 1000 miles. After the 1000 miles of accumulation, FTP/HFET sequences are run using the previously described repeatability criteria. After an acceptable average (less than 2.1% difference) of two tests is arrived at, the data point may be compared to the former extrapolated trend line. If the 1000 mile point is within .5% of the former trend line, a new trend line using the 1000 mile point as a data point may be developed. If the new trend line meets the positive slope, highest r, and last point specifications, the trend line is accepted as representing the vehicle and the next candidate oil can be run. If the 1000 mile point is not within .5% of the former trend line, another 1000 miles of accumulation and testing sequences is required. If the second 1000 mile point is within .5% of the former trend line, it may be used in a new trend line analysis. Mileage accumulation and testing should continue in 1000 mile increments until either (1) an acceptable average of two tests is within .5% of the former trend line and the trend line developed using that data point meets the positive slope, highest r, and last point requirements or (2) enough points are run to develop a completely new trend line for the vehicle which meets the same requirements. Any vehicle maintenance required should be performed prior to the first 1000 mile increment.

5. Analysis of Results

This analysis assumes that each car exhibits a linear mileage trend of fuel economy. It requires that the the oil effect be estimated as the average difference between the observed candidate MPG's (average of two repeat tests on 2000-mile aged oil) and a linear extrapolation of the fresh HR values to the odometer reading at which the candidate oil is tested.

5.1 The analysis proceeds as follows:

a. Calculate a difference between the observed candidate oil (CO) MPG (average of two tests) and the extrapolated HR MPG trend line for each test vehicles.

$\Delta_{i'k}$ = Candidate oil MPG - HR MPG (extrapolated)

where k = number of vehicle of the ith model; k = 1 to K

where i = number of model i = 1, 2, 3, 4, or 5

b. Calculate the mean and the pooled standard error s_Δ of the $\Delta_{i'k}$.

$$\bar{\Delta} = \sum_i \sum_k \Delta_{ik}/5K = \sum_i \left(\sum_k \Delta_{ik}/K \right)/5$$

$$S_\Delta = \sqrt{\sum_i \sum_k \left[\Delta_{ik}^2 - \left(\sum_k \Delta_{ik} \right)^2 / K \right] / 5(K-1)}$$

$$\text{IF } K = 1, \quad S_\Delta = \sqrt{\frac{\sum_i \Delta_i^2 - 5\bar{\Delta}^2}{5-1}}$$

c. Calculate the one-sided significant difference at the 95% confidence level.

$$LSD_{95} = t_{.95 \text{ d.f.}} \left(S_\Delta / \sqrt{5K} \right)$$

where $t_{.95}$ is obtained from the student distribution (see below) for df = 5 (K-1) degrees of freedom. If K = 1 then df = 4.

ONE-SIDED CRITICAL VALUES FOR STUDENT'S t-DISTRIBUTION

Pr {Student's t ≤ tabled value} = 0.95

df	$t_{.95, df}$
1	6.3138
2	2.9200
3	2.3534
4	2.1318
5	2.0150
6	1.9432
7	1.8946
8	1.8595
9	1.8331
10	1.8125
11	1.7959
12	1.7823
13	1.7709
14	1.7613
15	1.7531
16	1.7459
17	1.7396
18	1.7341
19	1.7291
20	1.7247
21	1.7207
22	1.7171
23	1.7139
24	1.7109
25	1.7081
26	1.7056
27	1.7033
28	1.7011
29	1.6991
30	1.6973
31	1.6955
32	1.6939
33	1.6924
34	1.6909
35	1.6896
36	1.6883
37	1.6871
38	1.6860
39	1.6849
40	1.6839

With data to two decimal places, use three decimal places for means and mean differences and four decimal places for standard error.

d. Calculate the average CO MPG and average extrapolated HR-MPH:

$$C = \sum_i \left(\left(\sum_k COF_{ik} \right) / K \right), \quad H = \sum_i \left(\left(\sum_k HRF_{ik} \right) / K \right)$$

where COF_{ik} = average candidate oil fuel economy for ith vehicle group

where HRF_{ik} = extrapolated fuel economy of HR trend line to mileage = CO tests for ith vehicle group.

e. Calculate the fuel economy improvement as follows:

$$\epsilon = \left(\frac{C - LSD_{95}}{H} \right)$$

f. Fuel efficient oil rating:

D	C	B	A
$\epsilon \leq .98$	$.98 < \epsilon \leq 1.01$	$1.01 < \epsilon \leq 1.03$	$1.03 < \epsilon$

6. Determination of Carry Over Effects

To determine whether or not a candidate oil has a carry over effect, one might use the following criteria:

a. Calculate -

$$\bar{C} = \frac{\left| \left(\sum_i \sum_k HRFF_i \right) - \left(\sum_i \sum_k HRF_{ext} \right) \right|}{\sum_i \sum_k HRF_{ext}}$$

Where $HRFF_{i,k}$ = the high reference final fuel economy for the $_i$th group for k vehicles.

$HRFext_{i,k}$ = the extrapolated fuel economy trend line to the mean mileage of the two $HRFF_i$ tests for the $_i$th group for k vehicles.

b. If $\Phi > 1.005$ then the candidate oil has carry over characteristics.

E. Report:

All data obtained in the conduct of a test program should be retained. Rejected test results should be properly noted.

As a minimum, the report should contain the average HR and candidate MPG's for each model of car, plus the grand averages, the observed test differences, the standard error and its degrees of freedom, and the LSD_{95}. The average candidate-HR difference for each model car can be listed additionally, if desired.

F. Final Grade:

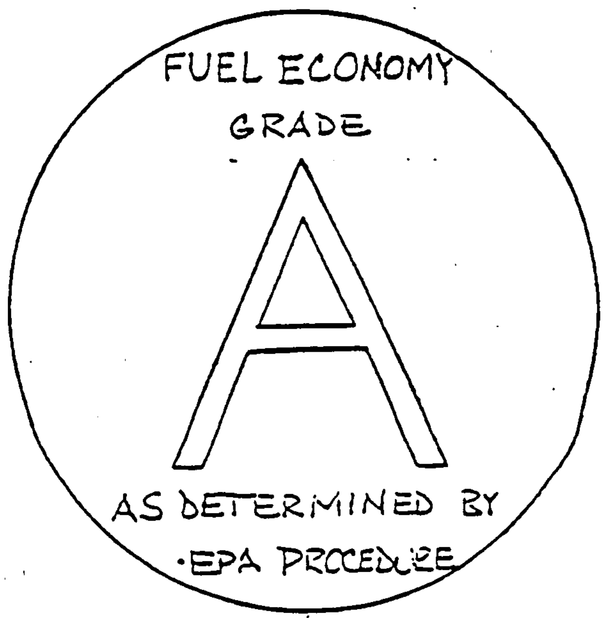
Section 5.1.f will grade an engine oil as to its fuel economy characteristics. (Grade A, B, C, or D). A label which specifies the grade of the candidate oil is described in the next section. This label will represent a generic specification and allow easy customer comparison as to which engine oil to purchase. Advertising which uses the designated label without proper EPA procedural documentation is prohibited and will be referred to the Federal Trade Commission (FTC) as appropriate.

G. Labeling:

The label for designation of the engine oil's fuel economy grade must meet the following specifications:

1. The label shall be permanently affixed to the top (or to the side if the top is not large enough) of each oil sale container in such a manner that it is contrasting with the other container colors and easily readable.

2. The label shall be configured (as shown in the attached sketch) in a 2½ inch diameter circle. No other information may be included in the label. Information outside the circle is not affected. The lettering should be clear upper case Roman type no less than 1/8 inch tall. The main grading letter (A, B, C, or D) should be a minimum of 1½ inch tall.


FUEL ECONOMY
GRADE
A
AS DETERMINED BY
EPA PROCEDURE

H. Fuel Specification:

Commercial unleaded gasoline meeting the ASTM D-439 specification, exclusive of any supplementary additives is acceptable for mileage accumulation. Preconditioning and dynamometer fuel economy tests must be run with unleaded gasoline conforming with the following specifications:

Octane, research minimum	93
Pb (organic), grams/u.s. gallon	00.0 to 0.05
Distillation range	
IBP, °F	75 to 95
10% point, °F	120 to 135
50% point, °F	200 to 230
90% point, °F	300 to 325
E.P., °F (maximum)	415
Sulfur, weight percent, maximum	0.10
Phosphorus, grams/U.S. gallon, maximum	0.005
RVP, pounds	8.0 to 9.2
Hydrocarbon composition	
Olefins, percent maximum	10
Aromatics, percent maximum	35
Saturates	Remainder