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1989 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

October 1989

COORDINATING RESEARCH COUNCIL, INC.
219 PERIMETER CENTER PARKWAY, ATLANTA, GEORGIA 30346

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1989 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

(CRC PROJECT NO. CM-124-89)

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Prepared by the

CRC Octane Technology and Test Procedures Group

October 1989

Automotive Vehicle Fuel, Lubricant, and Equipment Research Committee

of the

Coordinating Research Council, Inc.

I. INTRODUCTION

An octane number requirement rating workshop was sponsored by the Coordinating Research Council, Inc. (CRC) April 10-14, 1989, in D'Hanis, Texas. The workshop was conducted in response to interest expressed by members of the Octane Technology and Test Procedures Group. Fifty-eight raters, technicians and engineers attended all or part of the workshop. Attendees are listed in Appendix A. Training was accomplished through seminars, extensive discussions and actual track testing.

II. OBJECTIVE

The main objective of the workshop was to improve the application of the CRC E-15 Technique for Determination of Octane Number Requirements of Light-Duty Vehicles among people familiar with the Technique so as to provide consistent results for vehicles equipped with modern automotive technology. This objective was pursued for both the set-up portion of the technique and the actual octane rating of the vehicle. An additional objective was to gather comments from the raters on the E-15 Technique as preparation for a proposed rewrite of the Technique.

Since the workshop was to be an educational experience rather than a source of octane requirement data, emphasis was placed upon exchange of information as opposed to data collection and analysis. The intent of the workshop was not to "rate the raters," but to reduce the laboratory-to-laboratory variations in the application of the E-15 Technique.

III. TEST VEHICLES

Thirteen 1989 model vehicles were available for track testing. As indicated below, five of the vehicles were set-up with auxiliary fuel systems so the full E-15 octane rating technique could be performed. The other eight vehicles were equipped with tachometer and vacuum gauge for determination of transmission characteristics.

Make/Model	Displacement liters	Fuel System	Knock Sensor	Transmission	Aux. Fuel System
Dodge Dynasty	3.0	Port-Injected	No	Automatic 4 speed lock-up	No
Ford Probe	2.2	Port-Injected	No	Automatic 4 speed lock-up	Yes
Toyota Corolla	1.6	Port-Injected	No	Automatic 3 speed	No
Ford Taurus	3.0	Port-Injected	Yes	Automatic 4 speed lock-up	Yes
Chrysler Voyager	2.5	Turbo Port-Injected	Yes	Automatic 3 speed	Yes
Dodge Van LE	5.9	Throttle Body Injected	No	Automatic 3 speed	No
Buick Regal	2.8	Port-Injected	Yes	Automatic 4 speed lock-up	No
Olds Ciera	2.5	Throttle Body Injected	No	Automatic 3 speed lock -up	Yes
Ford Aerostar	3.0	Port-Injected	No	Automatic 4 speed lock-up	No
Subaru Justy	1.2	Carb.	No	CVT	No
Cadillac De Ville	4.5	Throttle Body Injected	No	Automatic 4 speed lock-up	No
Pontiac Grand Am	2.3	Port-Injected	Yes	Automatic 3 speed lock-up	Yes
Ford Mustang	2.3	Port-Injected	Yes	Automatic 4 speed lock-up	No

IV. TEST FUELS

The test fuels used during the workshop were the 1987/1988 CRC Full-Boiling Range Unleaded (FBRU) fuels. The fuels were prepared from three base blends (RMFD-362-87/88, RMFD-363-87/88 and RMFD-364-87/88) in two octane increments from 80 to 102 RON.

The base blends were prepared from normal refinery components. Inspection data furnished by the supplier are given in Table 1. The composition and average laboratory octane data for the 1987/1988 FBRU reference fuel series are presented in Table 2.

V. TEST PROGRAM

The workshop was conducted April 10-14, 1989, at the EG&G Automotive Research Proving Grounds located near D'Hanis, Texas. The timing of the workshop was such that the results and benefits would be available for the 1989 CRC Octane Requirement Survey.

In recognition of the increasing complexity of vehicle preparation, the first day of the workshop was spent preparing the test vehicles for octane rating. The hands-on experience and discussions during vehicle set-up provided training with a minimum of formal discussion.

The remainder of the workshop used formal discussion with the entire group and vehicle testing on the track by small groups to improve consistency among the raters. In order to maximize the exchange of information, raters from different companies were assigned to work together and were encouraged to discuss informally the different ways they interpret and run the E-15 procedure. These groups were changed at the beginning of each of the three days of track work and during the day participants were free to form additional groups. This type of information exchange has proven successful in past workshops and again worked well in this workshop. Representatives from several of the automobile manufacturers were available to answer questions about their vehicles.

One half-day discussion period was devoted to problems with the current E-15 technique and ways in which the technique and its write-up could be improved. This discussion was attended by a group of experienced raters and recorded for use by the E-15 Rewrite Panel.

The program proposal and an agenda of the workshop may be found in Appendix B. The E-15 Technique used as basis of discussion is in Appendix C.

VI. ANALYSIS OF DATA

This report contains no analysis of the octane requirement data obtained during the workshop, because the data do not offer any information about the operation or success of the workshop. The workshop was designed to improve the application of the E-15 Technique, and its success was the clarification of the technique to the participants and the increased consistency of E-15 results expected in the future.

The individual data sheets from the first day of track work were reviewed on-site shortly after their completion. This review was concerned with the proper completion of the form, and served as the basis for a discussion of the Octane Number Requirement Survey Form on the second day of the track work.

In the past it has been found that the data from a workshop such as this are of little value for evaluating raters. This is not surprising, since these workshops are not designed for this purpose and are not expected to provide this type of information. The major difficulty in making any evaluation of individual raters is that operational conditions change over the course of the workshop and these changes would be expected to cause changes in the octane requirement of the test vehicles. The vehicles are also being continuously rated, which is expected to cause a decrease in octane requirement due to severe service. As these effects cannot be separated from rater effects, evaluation of the raters or of the vehicles is not possible.

VII. RECOMMENDATIONS FOR IMPROVING THE E-15 TECHNIQUE

The Octane Technology and Test Procedures Group has organized a Panel to rewrite the E-15 Technique, both to make the written description of the technique easier to use and to resolve any technical issues related to new automotive technology. One of the objectives of this workshop was to obtain suggestions from the trained octane raters concerning the improvements that the technique needs. A detailed listing of suggestions has been passed on to the Rewrite Panel. Some of the suggestions are minor and will be addressed by the Steering Panel of the Octane Number Requirement Survey Group. The listing below is a brief summary of the suggestions from the Workshop.

1. Write-up should be brief and simple.

2. The definition of knock, particularly the requirement that knock must occur as three pings over a range of 50 rpm, gives problems for knock sensor equipped vehicles. It was suggested that more stress be placed on the repeatable and sensitive nature of the engine noise.

3. The need and advisability of checking for knock at high engine speeds was questioned.

4. The usefulness of fanning for locating part-throttle knock was questioned.

5. Many raters do not start accelerations from the minimum obtainable road speed in a transmission condition, as is now required by the technique. They recommended going back to starting accelerations from the minimum speed to get into a transmission condition.

6. The section on setting up the vehicle should be made more generic. The emphasis should be on making the vehicle operate the same way under test conditions as it does for the customer.

7. Consideration should be given to the order of test fuels within a series. If possible, the octane requirement should be approached from the high octane side. This will become more important as the number of adaptive learning vehicles grows.

VIII. RECOMMENDATIONS FOR FUTURE RATING WORKSHOPS

The consensus of the participants was that a rating workshop should be held every two years unless automotive technology changes at a faster pace than has been true recently. A duration of five days, with one day devoted to set-up procedures, was successful. Many participants requested a structured lecture on the E-15 technique, followed by discussion in small groups before practice on the track. This is in contrast to the less structured large group discussion held at this workshop. Mixing raters from different companies for the track work was a success. However, several participants commented that pairing an experienced rater with an inexperienced rater would be a better learning environment for the inexperienced person. The discussion among the small group of experienced raters was very well received. It was suggested that this should be done before the workshop, both to identify important issues and to use available resources more effectively.

Although the set-up day was well received, it needs to be better organized. It was suggested that participating companies be assigned responsibility for setting up one or two test vehicles. They could then give an explanation of how they set up the vehicle to the larger group.

One area which was evidently not well covered was the distinction between above-borderline ("A") and borderline ("B") knock. Several participants suggested having one vehicle which would be previously established as giving good examples of "A" and "B" knock. Then everyone would either drive or be an observer in that vehicle to establish consistency in the recognition of these levels of knock.

TABLE 1

SUPPLIERS' FUEL INSPECTIONS

1987/1988 FBRU FUELS

	Low-Octane Base Blend RMFD 362-87/88	Intermediate-Octane Base Blend RMFD 363-87/88	High-Octane Base Blend RMFD 364-87/88
Laboratory Inspection			
Distillation, °F			
IBP	98	90	92
10% Evap.	137	124	122
30% Evap.	166	163	185
50% Evap.	192	214	237
70% Evap.	230	272	259
90% Evap.	333	353	294
End Point	413	421	388
RVP, psi	7.2	8.4	8.1
Lead, g/gal.	0.000	0.000	0.000
Oxidation Stab., min.	1440+	1440+	1440+
Hydrocarbon Type, Vol. %			
Aromatics	19.8	27.5	51.3
Olefins	13.8	9.6	0.0
Saturates	66.4	62.7	48.7
Research Octane Number	79.2	90.8	103.5
Motor Octane Number	74.7	82.6	91.8
Sensitivity	4.5	8.2	11.7

TABLE 2

OCTANE NUMBERS AND COMPOSITIONS FOR 1987/1988 FBRU FUELS

Research Octane Number	Volume Percent RMFD 356-87/88	Volume Percent RMFD 357-87/88	Volume Percent RMFD 358-87/88	Motor Octane Number	Sensitivity
80	95.0	5.0	---	74.9	5.1
82	77.5	22.5	---	76.3	5.7
84	60.5	39.5	---	77.7	6.3
85	51.5	48.5	---	78.4	6.6
86	42.5	57.5	---	79.0	7.0
87	34.0	66.0	---	79.7	7.3
88	25.0	75.0	---	80.4	7.6
89	16.5	83.5	---	81.1	7.9
90	7.5	92.5	---	81.7	8.3
91	---	99.5	0.5	82.3	8.7
92	---	92.5	7.5	82.9	9.1
93	---	85.5	14.5	83.6	9.4
94	---	78.0	22.0	84.2	9.8
95	---	70.0	30.0	84.9	10.1
96	---	62.5	37.5	85.6	10.4
97	---	54.5	45.5	86.3	10.7
98	---	46.5	53.5	86.9	11.1
99	---	37.5	62.5	87.8	11.2
100	---	28.5	71.5	88.8	11.2
101	---	19.0	81.0	89.8	11.2
102	---	10.0	90.0	90.8	11.2
103	---	1.5	98.5	91.7	11.3

APPENDIX A

ATTENDEES OF THE

1989 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

PARTICIPANTS IN THE 1989 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

NAME	COMPANY AFFILIATION
Paul Baca	Southwest Research Institute
John Baker	Shell Development Company
Bill Biller	Consultant
Carl Bones	Sun Refining & Marketing Company
Ed Bobola	Ford Motor Company
Les Bostick	Ashland Petroleum Company
Tom Breen	Mobil Oil Corporation
Greg Brooks	Unocal Corporation
Kevin Brunner	Southwest Research Institute
Craig Carlson	Texaco Inc.
David Coleman	GM Research Laboratories
Pat Costello	Mobil Research & Development
Murray Dent	Shell Canada Limited
Tom Depaulo	BP Oil Company
Jean Doyon	Shell Canada Limited
Leo Ensz	Shell Development Company
Dale Esper	Ford Motor Company
Beth Evans	Coordinating Research Council, Inc.
Bob Fields	Ford Motor Company
John Fowlks	Exxon Research & Engineering Company
Peter Furman	Texaco Inc.
Don Gibbs	Mobil Research & Development Corp.
John Graham	Chevron Research Company
Kurt Groll	Texaco Inc.
Bill Grund	Southwest Research Institute
Bruce Henderson	Amoco Oil Company
Donna Hoel	Exxon Research & Engineering Co.
Bill Honchar	Petro-Canada Products Company
Victor Kersey	Ashland Petroleum Company
John Krylowski	Exxon Research & Engineering Company
Vance McCabe	GM Research Laboratories
Art Montenegro	Chevron Research Company
Mike Noorman	Mobil Oil Corporation
Tom Orto	Ford Motor Company
Gary Parker	Exxon Research & Engineering Company
Ed Polski	Mobil Oil Corporation
Ron Reese	Chrysler Motor Corporation
James Reid	Petro-Canada Products Company
Rick Riley	Phillips Petroleum Company
Val Rodrigues	Chevron Research Company

PARTICIPANTS IN THE 1989 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

(Continued)

NAME	COMPANY AFFILIATION
Otto Rojas Ojeda	Intevep, SA
Charlie Sherwood	Ford Motor Company
Jack Sidor	BP Oil Company
Steve Simms	Amoco Oil Company
Bill Steckle	Petro-Canada Products Company
Don Swaynos	Exxon Research & Engineering Company
Jim Uihlein	BP Oil Company
Greg Van Meveren	AutoResearch Laboratories, Inc.
Scott Whitehouse	Shell Canada Limited
Ed Willis	Sun Refining & Marketing Company
Bud Wise	Sun Refining & Marketing Company
Jim Wooten	Phillips Petroleum Company
Tim Wusz	Unocal Corporation

APPENDIX B

PROGRAM FOR THE 1989 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

AND

1989 CRC OCTANE RATING WORKSHOP AGENDA

PROGRAM FOR THE 1989 CRC OCTANE NUMBER REQUIREMENT RATING WORKSHOP

I. FOREWORD

It has been the goal of participants in CRC-sponsored fuel road rating and vehicle octane number requirement programs to reduce the laboratory-to-laboratory differences in the application of rating techniques. To this end, a CRC Octane Number Requirement Rating Workshop was held in 1987 to encourage the uniform application of the CRC E-15 Technique (Octane Number Requirement). It was generally felt that the workshop was quite beneficial and should be repeated every two years.

At the October 13, 1988, meeting of the CRC Octane Technology and Test Procedures Group, interest was shown in having another rating symposium with an emphasis in three areas: vehicle preparation, the evaluation of vehicles equipped with knock sensors, and preparations for a complete rewrite of the E-15 Procedure. The preferred time for the workshop is the spring of 1989, so that the results could be used for the 1989 CRC Octane Number Requirement Survey.

II. OBJECTIVE

The objective of this workshop is to improve the application of the E-15 Procedure.

III. SCOPE AND TIMING

Training will be accomplished through seminars, discussions and demonstrations, and verified with actual track testing using rating techniques and equipment. The workshop will be held April 10 - 14, 1989.

IV. FACILITIES

Ideally, the workshop should include both track testing and dynamometer testing. Unfortunately, such a facility could not be located. The workshop will be held at EG&G Proving Grounds near San Antonio, Texas. This facility has a 5-mile oval track which is suitable for road octane testing. Garage space is available for vehicle preparation and meeting facilities can be provided in a convenient location.

V. CARS

Approximately eight to ten 1988 or 1989 model year cars with a minimum of 6,000 deposit miles will be rented. The group should include vehicles with one or more of the following features: spark adjustment by a knock sensor system, direct fire ignition, transmissions which experience indicates are difficult to rate, supercharger, electronically controlled transmissions, and continuously variable automatic transmission. Approximately three of the cars with knock sensors will be set up with auxiliary fuel systems for full octane ratings. The other vehicles will be equipped with a vacuum gauge and tachometer and will be used to sharpen skills used in determining vehicle transmission characteristics.

VI. FUELS

The fuel used will be drawn from the 1987-1988 FBRU rating series. It will be available in two octane number increments. Since the ONR Surveys which require these fuels are complete, the fuels can be made available by workshop participants form their excess stock.

VII. WORKSHOP SCHEDULE

The workshop will run from Monday through Friday.

The simplified, proposed schedule follows:

Day 1	Vehicle set-up, discussion and practice.
Day 2,3	Discussion and demonstration of E-15 Procedure mixing experienced and inexperienced raters.
Day 4	Experienced raters discuss E-15.
Day 5	Wrap-up.

One purpose of the workshop is to generate suggestions for the ONRS Program Panel concerning a complete rewrite of the E-15 Procedure in order to increase its usefulness as a teaching tool and reference. This will be done informally throughout the workshop, and especially, on Day 4.

VIII. PARTICIPATION

The workshop has been planned on the basis of the following participation by each company: (1) an engineer responsible for E-15 activities; (2) a rating crew, preferably experienced; and (3) if the rating crew does not prepare vehicles, one mechanic familiar with vehicle preparation. If multiple crews are sent, one engineer should be sufficient.

The engineering personnel will be expected to participate in the discussions, monitor test procedures in the cars and help with the E-15 Technique, and handle the logistics of the operation. Time permitting, they may also participate in the demonstrations and testing.

A significant amount of planning, preparation, and coordination will be required to assure success of the workshop. Major activities needing attention are listed below:

- Overall coordination during workshop.
- Group sessions: planning and conduct.
- Track preparations and operations.
- Test equipment.
- Test vehicles: procurement.
- Test fuels: procurement of fuels and cans and coordination of on-site handling.
- Data handling and analysis.

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1989 CRC OCTANE RATING WORKSHOP

Agenda

MONDAY, APRIL 10

8:00	Leave Alsatian Inn
8:30	Arrive at EG&G
9:00	Review Workshop agenda Brief discussion of vehicle set-up
9:30	Vehicle set-up
12:00	Lunch
1:30	Continue vehicle set-up
4:00	Discussion
5:00	Adjourn
6:15	Meet at Alsatian Inn for barbecue

TUESDAY, APRIL 11

8:30	Arrive at EG&G
8:45	Track Orientation - EG&G personnel
10:30	Review E-15 rating procedure - Tim Wusz Review completion of data forms - Bill Biller
12:00	Lunch
1:30	E-15 practice
4:00	Discussion. Turn in data forms.
5:00	Adjourn

WEDNESDAY, APRIL 12

8:30	Arrive at EG&G
8:45	Discussion of data forms filled out on Tuesday - Bill Biller
9:15	E-15 practice
12:00	Lunch
1:30	Continue E-15 practice
4:00	Discussion
5:00	Adjourn

1989 CRC OCTANE RATING WORKSHOP - (Continued)

THURSDAY, APRIL 13

8:30	Arrive at EG&G
9:00	Continue E-15 practice
	Discussion of E-15 procedure and suggestions for improvement by experienced personnel - Rick Riley
12:00	Lunch
1:30	Continue
4:00	Group discussion of E-15 procedure and suggested improvements
5:00	Adjourn

FRIDAY, APRIL 14

8:30	Arrive at EG&G
8:45	Final wrap-up
	E-15 Procedure
	Data Forms
	Suggestions for change to E-15
12:00	End

APPENDIX C

REVISED TECHNIQUE FOR DETERMINATION

OF OCTANE NUMBER REQUIREMENTS

(CRC E-15-89 TECHNIQUE)

TECHNIQUE FOR DETERMINATION
OF OCTANE NUMBER REQUIREMENTS
OF LIGHT-DUTY VEHICLES

(CRC Designation E-15-89)

April 1988

TECHNIQUE FOR DETERMINATION OF OCTANE NUMBER REQUIREMENTS OF LIGHT-DUTY VEHICLES

(CRC Designation E-15-89 - Including Attachment A)

A. GENERAL

The technique provides for the determination of maximum octane number requirements (and minimum octane number requirements for vehicles equipped with knock sensors), whether at maximum-throttle or part-throttle, of a vehicle in terms of borderline spark knock on two series of full-boiling range reference fuels as well as on primary reference fuels. If the maximum requirement is at maximum-throttle, then part-throttle requirements are investigated with only FBRU fuels of up to, and including, four octane numbers lower than the maximum requirement.

Knock intensity on tank fuel will be measured.

B. DEFINITION OF TERMS

The following definitions of knock, approved by the CLR and CFR Committees on June 8, 1954, have been rephrased for clarification and adaptability to current technology by the Survey Steering Panel.

1. **Spark Knock:**

   Spark knock is the noise associated with the autoignition* of a portion of the fuel-air mixture ahead of the advancing flame front. It is recurrent and repeatable in terms of audibility and fuel octane quality. This includes knock occurring when going from road load to other operating conditions (e.g., tip-in, etc.).

2. **Knock Intensity**

   a. **Borderline Knock**

   This means spark knock of lowest audible intensity of at least three (3) pings, and over a range of engine speed of at least 50 rpm, all being repeatable during subsequent accelerations.

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* Autoignition: The spontaneous ignition and the resulting very rapid reaction of a portion or all of the fuel-air mixture. The flame speed is many, many times greater than that which follows normal spark ignition. There is no time reference for autoignition.

b. No Knock

This means either no audible knock or knock less than borderline intensity.

c. Above Borderline Knock

This means spark knock of greater than borderline intensity.

3. Octane Number Requirements

a. Maximum Requirement

This is equivalent to the octane number of the highest reference fuel giving borderline knock as previously defined (the next higher fuel gives no knock). If the knock intensity with the highest fuel giving knock is above borderline, the maximum requirement shall be equivalent to the mid-point between the octane number of the fuel giving knock and that of the next higher fuel which gives no knock.

b. Minimum Requirement (for vehicles with knock sensors)

This is equivalent to the octane number of the lowest reference fuel giving borderline knock (the next lower fuel will give above borderline knock). If the knock intensity with the lowest fuel giving knock is above borderline and the next highest fuel is no knock, then the minimum requirement is the mid-point between the two.

4. Definition of Accelerations

Accelerations are made at maximum-throttle and part-throttle conditions which are defined below:

a. Maximum-Throttle

The throttle is depressed and held at either full-throttle or the widest throttle position that does not cause the transmission to downshift (detent) throughout the acceleration in each of the required test gears listed in D.3.d.(1)(a). The detent manifold vacuum/pressure obtainable on a given model is determined by the transmission characteristics. For manual transmissions, the throttle is depressed fully throughout the acceleration.

b. Part-Throttle

The throttle is depressed and regulated throughout the acceleration to maintain a desired, constant critical manifold vacuum/pressure as defined in D.3.d.(1)(d).

C. VEHICLE PREPARATION

The following vehicle preparation steps should be completed before any octane tests are run. Detailed procedures for each adjustment can be found in the manufacturers' shop manuals.

1. Record vehicle identification number and emission control type, Federal, Altitude, California, or Fifty-State. Fill in headings on both sheets of data form DFMF-11-89. Ford emission calibration numbers are to be recorded.

2. Inspect all vacuum lines and air pump hoses for appropriate connections. Also, check to see if PCV valve, spark advance vacuum delay controls, EGR valve, knock sensors, and heated inlet air mechanism are functioning. Engine must be warmed up for these checks.

3. Check engine idle speed and observe anti-dieseling solenoid operation. Adjust to within manufacturers' recommended specifications as specified on the underhood decal.

4. Observe and record basic spark timing at recommended engine speed. Adjust to within manufacturers' recommended setting as specified on the underhood decal.

5. Crankcase oil, radiator coolant, automatic transmission fluid, and battery fluid levels shall be maintained as recommended by the manufacturer.

6. A calibrated tachometer graduated in 100 rpm (or smaller) increments and capable of indicating engine speed from 0-5000 rpm shall be installed on the vehicle.

7. One calibrated vacuum gage, graduated in one-half inch of mercury (or smaller) increments and capable of indicating vacuum from 0-24 inches of mercury (0-81 kPa) shall be connected to the intake manifold. For vehicles with turbochargers, a compound vacuum/pressure gage should be used; the pressure side of the gage should be capable of indicating pressures up to 15 psig (103 kPa).

8. An auxiliary fuel system shall be provided to supply test fuels to the engine. Caution shall be taken to avoid placing auxiliary fuel lines in locations which promote vapor lock. If vehicles with carbureted engines have tank return fuel lines, this return line should be blocked off. Disconnect fuel tank vent line at evaporation control system canister. Instructions for the auxiliary fuel system used with fuel injection are given in Attachment A.

9. For vehicles with owner questionnaire completed, a sample of the tank gasoline shall be withdrawn for determination of Research and Motor method octane number ratings. If insufficient fuel is available, omit this step and obtain tank fuel observations as described in Item D.3.d.(2).

D. TEST PROCEDURE

1. Engine Warm-Up

a. To stabilize engine temperatures, a minimum of ten miles of warm-up is required. The test vehicle should be operated at 55-70 mph (88-113 kph) in top gear with a minimum of full-throttle operation.

b. During the warm-up period, the general mechanical condition of the vehicle should be checked to insure satisfactory and safe operation during test work.

2. Fuel Changeover

To eliminate contamination of the new fuel with residual amounts of the previous fuel, fuel-injected systems should be flushed once with new fuel and carburetted systems should be flushed twice. Fuel handling procedures for vehicles equipped with fuel injection systems are explained in Attachment A.

After fuel changeover, make one maximum-throttle acceleration before beginning Vehicle Rating Procedure.

3. Details of Observations

a. Operating Conditions

All octane number requirements will be determined under level road acceleration conditions.

Tests will be conducted on moderately dry days, preferably at ambient temperatures between 60°F (15.5°C) and 90°F (32.2°C). Tests should not be conducted during periods of high humidity such as prevail when rain is threatening or during or immediately after a rain storm. Laboratories with control capabilities should target for 70°F (21°C) air temperature and 50 grains of water per pound (7.14 gm/kg) of dry air whenever possible.

Air-conditioned vehicles will be tested with air conditioner turned ON. (Normal setting, minimum temperature, low fan.) Air conditioner will be ON at all times.

b. <u>Order of Fuel Testing</u>

1) Tank
2) FBRSU
3) FBRU
4) Primary

c. <u>Determination of Knock Intensity</u>

Maximum octane requirements will be established by evaluating the occurrence of knock in terms of knock intensity: "N" for none, "B" for borderline, and "A" for above borderline. Establishment of representative knock intensity for a given fuel will be accomplished with a maximum of three (3) rated accelerations. Coastdown time between the end of one acceleration and the beginning of the next should be approximately twenty (20) seconds. As defined below, the first two duplicating accelerations are sufficient with "N" and "B" intensity.

Acceleration Number			Representative Rating
1	2	3	
N	N	-	N
N	B	N	N
N	B	B	B
B	N	B	B
B	B	-	B
B	A	-	A
A	-	-	A

All subsequent accelerations will normally be discontinued when "A" knock intensity is experienced, and testing continued with a higher octane number fuel in that series. <u>An exception will be made if "A" knock is experienced on the highest octane fuel which knocks in the engine.</u> In this case, it may be necessary to run additional accelerations to determine the speed of maximum knock intensity. If "A" knock is experienced at initiation of acceleration, as limited by transmission characteristics, this speed will be considered the speed of maximum knock. Otherwise, the midpoint between knock-in and knock-out will be considered the speed of maximum knock. When establishing knock-in and knock-out, back off on the throttle between points to eliminate "A" knock.

Minimum octane number requirements for vehicles equipped with knock sensors will be established in a similar manner except that when "A" knock intensity is encountered, subsequent accelerations will be made with a given fuel until duplicate "A" ratings are obtained over a measurable range of engine speeds as indicated below:

Acceleration Number			Representative Rating
1	2	3	
B	A	B	B
B	A	A	A
A	A	-	A
A	B	B	B

d. Determination of Octane Requirements

Tests should be run to 70 mph (113 kph). If required to terminate at lower speed, termination speed should be noted on data sheet.

(1) Vehicle Operating Procedure

(a) Establishment of Automatic Transmission Characteristics

Determine the minimum attainable road speed, and obtain the transmission downshift characteristics of engine rpm and manifold vacuum/pressure from minimum speed at 25, 35, 45, 55, and 65 mph (40, 56, 72, 88 and 104 kph) as applicable (as obtainable in each gear), by movement of the throttle through the detent, i.e., downshift, throttle position. These characteristics are to be determined for each of the gears specified in the table below. For transmissions with converter clutches, determine the minimum road speed for clutch application. At this initial speed and at 10 mph (16 kph), increments up to about 60 mph (97 kph) determine minimum vacuums (pressures) for application. Record all road speed/engine rpm/vacuum or pressure measurements from above on data sheet.

Do not use brakes, turn signals or hazard flashers during accelerations as these may affect electronic engine controls.

The selection of required test gears, and test gear/converter clutch combinations (if applicable) for various types of transmissions are shown in Table T-I. Transmissions not explicitly described should be tested in a manner as similar as possible to those listed. Automatic transmission vehicles should be tested with the gear selector in D or O; top gear should not be locked out. Transmissions equipped with electronic overdrive should be operated in overdrive. Transmissions equipped with power/normal selection should be operated in the normal position.

TABLE T-I

TRANSMISSION GEAR SELECTION

NOTE: **TO BE UPDATED WITH NEW INFORMATION FROM AUTOMOBILE MANUFACTURERS**

AUTOMATICS

Place the selector in "D" or "O" and check for critical condition.

Type	Gears to be Tested
GM 4-speed	4th gear, converter clutch engaged 3rd gear, converter clutch engaged 3rd gear, converter clutch disengaged 2nd gear, converter clutch disengaged
GM 3-speed/ Chrysler 3-speed with converter clutch	3rd gear, converter clutch engaged 3rd gear, converter clutch disengaged 2nd gear, converter clutch disengaged
Ford Front-Wheel Drive: 4-speed overdrive	4th gear, converter clutch engaged 4th gear, converter clutch disengaged 3rd gear, converter clutch engaged, if applicable 3rd gear, converter clutch disengaged 2nd gear
Ford Rear-Wheel Drive: 4-speed overdrive	4th gear, converter clutch engaged, if applicable 4th gear, converter clutch disengaged 3rd gear, converter clutch engaged, if applicable 3rd gear, converter clutch disengaged 2nd gear
Other 3-speed	3rd gear 2nd gear

MANUALS

5-speed	4th and 3rd gears
4-speed	4th and 3rd gears
3-speed	3rd and 2nd gears

(b) Maximum-Throttle Accelerations - Automatic Transmissions

For maximum-throttle accelerations in each of the gears and gear/converter clutch combinations specified above, accelerate at the detent/application condition according to the speed versus vacuum/pressure profiles determined in (a) from the minimum obtainable speed up to 70 mph (113 kph). If the transmission downshifts, abort and start the acceleration again. Start with the highest gear or gear/clutch combination and proceed in descending order.

(c) Maximum-Throttle Accelerations - Manual Transmissions

Select the highest gear as specified in the table above. Start at the lowest speed from which the vehicle will accelerate smoothly or 25 mph (40 kph), whichever is higher, and depress the throttle fully throughout the acceleration up to 70 mph (113 kph).

Select the next lower gear specified in the table above and accelerate at full throttle from the minimum speed from which the vehicle will accelerate smoothly up to 70 mph (113 kph).

(d) Part-Throttle Accelerations for Both Automatic and Manual Transmissions

Select the highest gear as specified in Table T-I for manual transmissions. Select the two highest gears as specified in Table T-I for automatic transmissions. For example, on a four-speed automatic transmission, check both fourth locked and unlocked and third locked and unlocked; on a three-speed automatic transmission, check third locked and unlocked and second. For automatic transmissions with converter clutches use the highest gear up to the minimum vehicle speed at which the converter clutch will engage, and the highest gear/converter clutch combination above this minimum speed, to obtain the critical part-throttle vacuum or pressure. To obtain the critical part-throttle vacuum/pressure, first operate at constant speed road load, at 25, 35, 45, 55, and 65 mph (40, 56, 72, 88, and 105 kph) incremental speeds if obtainable in the specified gear. At each speed, move the throttle in approximately 3 seconds from the road-load vacuum to the positions described below for naturally aspirated and turbocharged engines:

1. for naturally aspirated vehicles, one inch Hg (3.4 kPa) above:

   a. full-throttle vacuum for manual transmissions;

   b. detent vacuum for automatic transmissions without converter clutches;

   c. the minimum vacuum at which the converter clutch disengages for so-equipped automatic transmissions.

2. for turbocharged vehicles, one psi (3.4 kPa) below:

   a. full-throttle maximum boost for manual transmissions;

   b. maximum boost at detent for automatic transmissions without converter clutches;

   c. maximum boost or 0.5 psig (1.7 kPa) above the minimum vacuum at which the converter clutch disengages for so-equipped automatic transmissions.

Use of vehicle brakes should be avoided.

If knocking occurs within any of the vacuum/pressure ranges, establish the manifold vacuum/pressure which gives maximum knock intensity on each fuel series. This is the critical vacuum/pressure to be used for all subsequent constant-vacuum/pressure part-throttle accelerations from the minimum obtainable speed in the test gear to 70 mph (113 kph), or until the vehicle ceases to accelerate. This critical vacuum/pressure should be determined for each reference fuel series.

(2) <u>Tank Fuel Observations</u>

Investigate for maximum-throttle and part-throttle knock as detailed in Item 3d(1). Define maximum knock intensity as per Item 3c. Record maximum knock intensity, speed of maximum knock intensity, and manifold vacuum/pressure at each operating condition.

(3) <u>Vehicle Rating Procedure</u>

All initial accelerations should be started from minimum obtainable gear/converter clutch combination at constant level road-load conditions. Knock rating should be performed while in a normal upright seated position with floor mats in place.

Step 1 - After Tank Fuel Observations, use a fuel estimated to give borderline knock in a given fuel series and investigate for incidence of knock under conditions as described in D.3.d.(1)(b) above, and D.3.d.(1)(c) above, whichever is applicable.

Step 2 - If no knock occurs, go to a lower octane number blend in that series and repeat Step 1.

Step 3 - If knock occurs at one or more of the operating conditions in Step 1, continue investigation at the critical condition(s) with higher octane blends until highest octane fuel giving knock is determined within one octane number or one blend (the next higher fuel giving no knock). Record maximum knock intensity on all fuels. Record speed of maximum knock intensity and manifold vacuum/pressure on highest octane fuel that knocks.

Step 4 - Using the lowest octane blend that did not knock in Step 3, investigate for incidence of part-throttle knock as described in D.3.d.(1)(d). If knock occurs, continue investigation at critical vacuum/pressure until requirement is defined. Record maximum knock intensity and critical manifold vacuum/pressure on all fuels, and speed of maximum knock intensity on highest octane fuel that knocks.

Step 5 - With FBRU fuel only, if no knock occurs in Step 4, go to a lower octane number blend and repeat Step 4. Discontinue part-throttle investigation if knock is not observed with a fuel four octane numbers lower than determined in Step 3.

Step 6 - For knock-sensor equipped vehicles after determination of maximum requirement, continue with lower octane blends until the lowest octane fuel giving borderline knock is determined (the next lowest fuel giving above borderline knock).

The rating procedure is given in arrow diagram form on page C-12 for maximum requirement, and on page C-13 for minimum requirement, for knock sensor-equipped cars.

E. INTERPRETATION OF DATA

The data will be recorded on data sheets DFMF-11-89 and DFMF-19-89. Data Form DFMF-11-89 has provisions for recording both the maximum and minimum requirements of knock-sensor equipped vehicles on the same sheet. Additional data sheets for recording run data may be appended to DFMF-11-89 as needed. Octane requirements for all reference fuels shall be determined as follows:

1. If the knock intensity of the highest reference fuel giving knock is borderline, the requirement shall be reported as the octane number of that fuel.

2. If the knock intensity of the highest fuel giving knock is above borderline, the requirement shall be reported as the mid-point between the octane number of the fuel giving knock and that of the next higher fuel.

3. If the octane requirement in high gear is equal to the requirement in a lower gear, report the highest gear data.

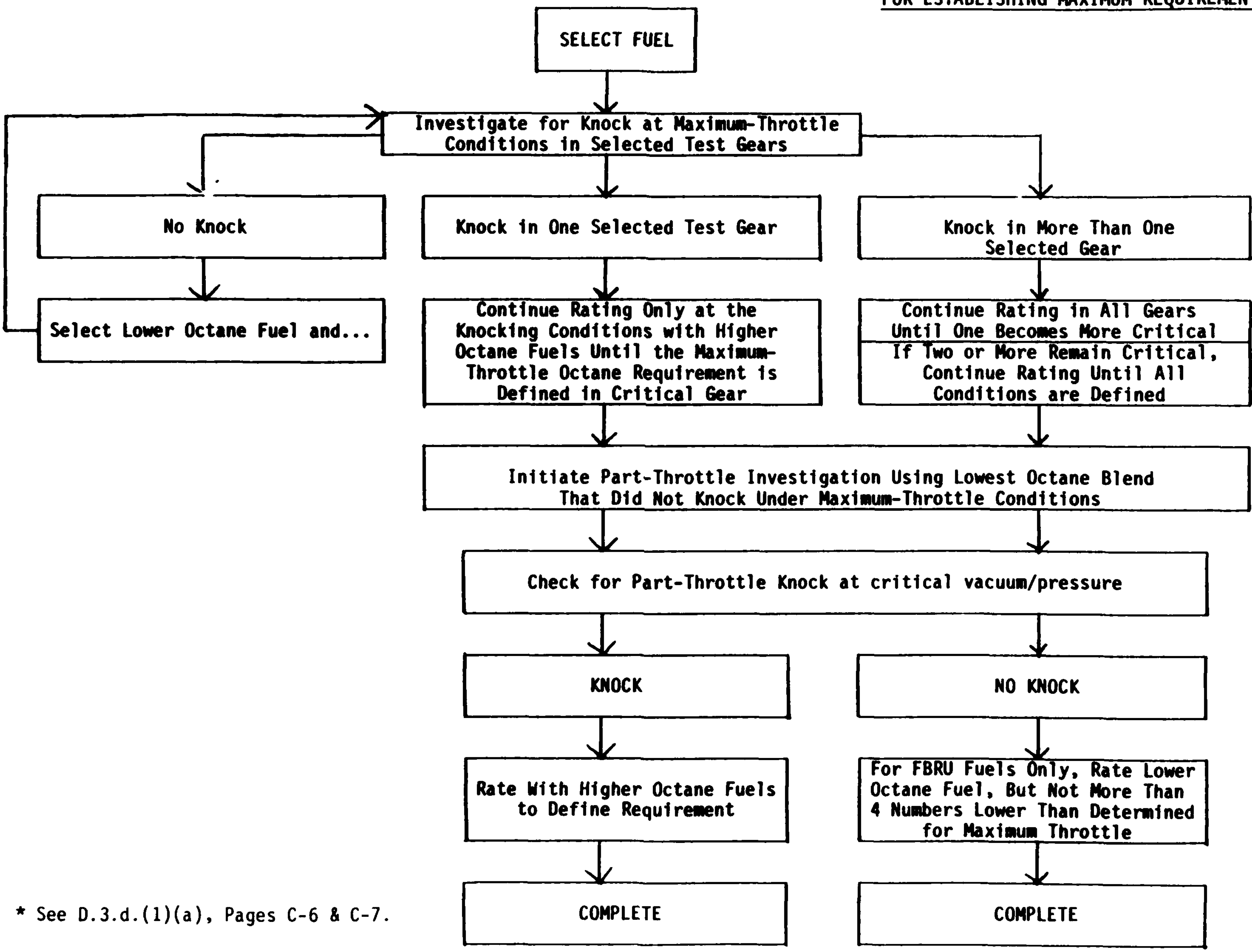
4. For part-throttle requirements, report the data from the critical manifold vacuum/pressure observations.

5. For knock-sensor equipped vehicles, report the highest and lowest fuel giving borderline knock. If the knock intensity with the lowest fuel giving knock is above borderline and the next highest fuel is no knock, then the minimum requirement is the mid-point between the two.

Record data on all fuels tested, even though knock was not encountered. The octane number requirement summary block on the first sheet of DFMF-11-89 provides space for both the maximum and the minimum requirements of knock-sensor equipped vehicles. When transferring data to the summary block, record maximum-throttle and part-throttle octane number requirements in the appropriate blocks. The higher of the two will be selected by the computer as the maximum octane number requirement. If both maximum-throttle and part-throttle requirements are equal, then the computer will select the part-throttle requirement as the maximum octane number requirement. Use proper letter designation (see footnotes on data sheet) to designate: (1) requirements outside of the reference fuel limits; (2) FBRU part-throttle requirement more than four numbers below maximum; and (3) all other cases for which the octane number requirement has not been determined. Note that in the case of a converter-clutch equipped vehicle, test gear numbers should indicate whether the converter clutch was locked or unlocked. Note also that in the case of turbo-equipped vehicles, a manifold pressure above atmospheric is indicated as a <u>negative</u> number in units of psig.

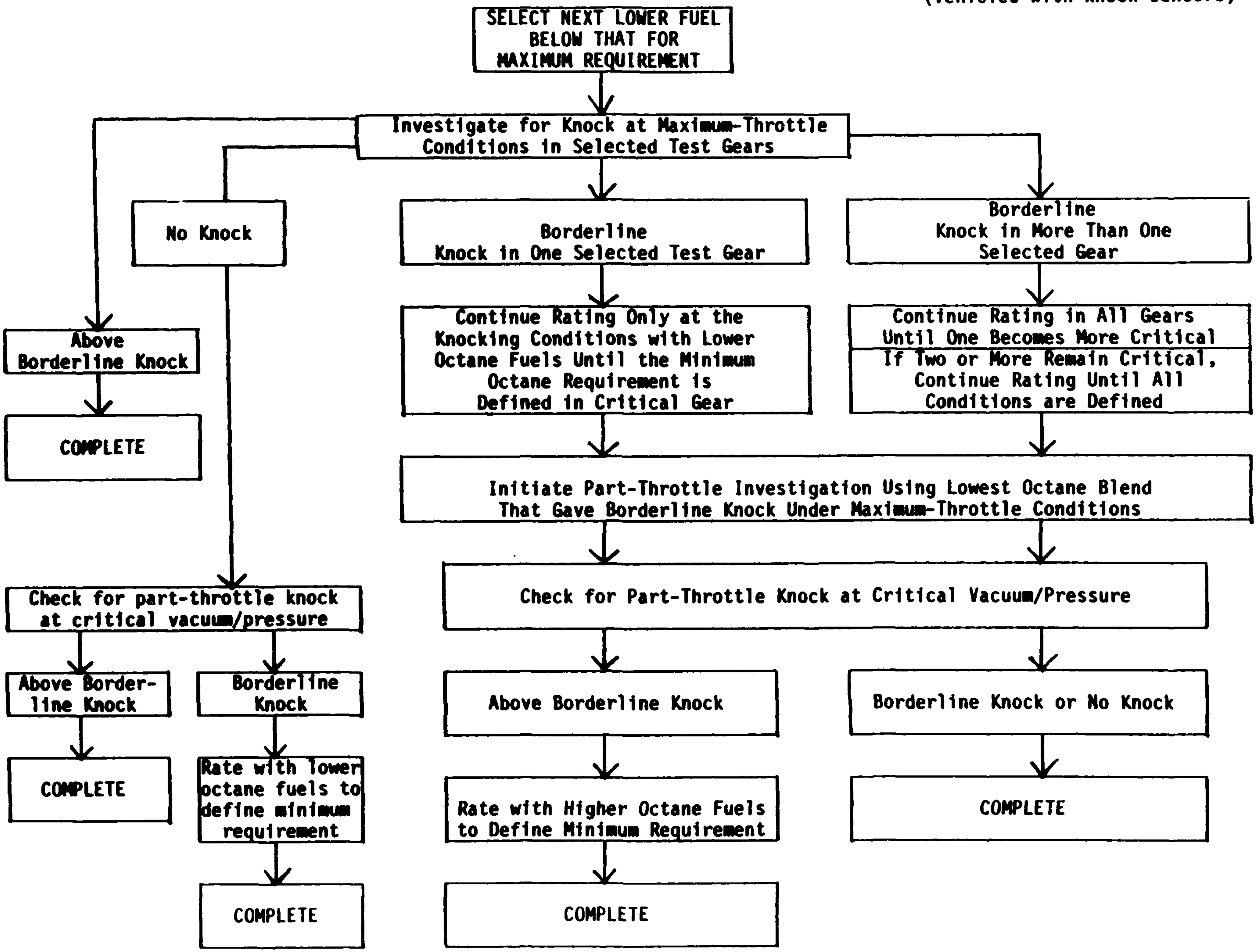
It is important that the vehicle identification number (VIN) of each vehicle tested be recorded on all data sheets to provide a means of cross-indexing.

FOR ESTABLISHING MAXIMUM REQUIREMENTS



* See D.3.d.(1)(a), Pages C-6 & C-7.

FOR ESTABLISHING MINIMUM REQUIREMENTS
(Vehicles with knock sensors)



* See D.3.d.(1)(a), Pages C-6 & C-7.

ATTACHMENT A

to the

CRC E-15-89 TECHNIQUE

PROCEDURE FOR SETTING UP VEHICLES

WITH FUEL INJECTION

ATTACHMENT A

PROCEDURE FOR SETTING UP VEHICLES AND HANDLING REFERENCE FUELS: VEHICLES EQUIPPED WITH FUEL INJECTION

1. To run octane requirements on fuel-injected vehicles, it is necessary to install an external fuel supply line with auxiliary electric fuel pump from the reference fuel can to the vehicle fuel system and an external return line back to the reference fuel can.

2. There are two types of fuel injection systems: throttle-body injection, and multi-port injection. As a general description, the systems will contain the following parts:

   Fuel Tank
   High- or Low-Pressure In-Tank Fuel Pump
   Fuel Supply Line(s)
   In-Line Filter(s)
   High-Pressure Chassis-Mounted Pump (not required for all vehicles)
   Fuel Rail (to supply multiple injectors on port fuel injection)
   Fuel-Pressure Regulator (integral on throttle-body, on fuel rail with multi-port injection; controls pressure at the injectors).

   Depending upon the vehicle's specific fuel system and/or tester's preference, installation of the required auxiliary equipment can be accomplished in a variety of ways.

3. The auxiliary fuel supply line may be installed anywhere between the fuel tank and the inlet at the throttle-body or fuel rail. The auxiliary fuel return line may be installed anywhere between the fuel-pressure regulator outlet and the tank.

4. After connections have been broken, the fuel lines on the fuel tank side should be capped and the vehicle's pump(s) disconnected or disarmed. Alternately, an additional fuel line can be looped between the supply and return lines and the vehicle pump(s) allowed to circulate fuel directly back to the fuel tank. Caution should be exercised if this alternate technique is used. A high pressure will build up in the tank due to the large amount of vapors generated.

   The auxiliary fuel supply system must be capable of supplying fuel at a pressure slightly higher than the maximum fuel pressure required (at wide-open-throttle on normally aspirated engines or at maximum manifold boost pressure on turbocharged or supercharged engines) by the particular vehicle being tested. This is to overcome any line losses and thus insure accurate results. This may be accomplished by using an adjustable high-pressure pump, or by using a low-pressure pump to supply fuel to the chassis-mounted high-pressure pump if the testing lab chooses to keep it in the system. A fuel filter may be required between the auxiliary pump and the reference fuel can to protect the pump. The fuel return line should be connected to a tee at the auxiliary pump inlet. The reference fuel can should be vented to outside the vehicle.

It is possible to use three-way valves in the fuel line between the fuel pump and the fuel tank and between the return line and the fuel tank. When used, the operator must change the return line valve to the auxiliary fuel system while the engine is shut down, to avoid building up excessive pressure in the return line which could damage both the fuel-pressure regulator and injection pump.

5. When changing from one reference fuel can to another, the following steps should be followed:

   a. Disconnect fuel inlet line from reference fuel can and run engine a short time; do not run out of fuel since this will introduce air into the fuel injection system and excessive cranking will be required to restart the engine.

   b. With the engine shut off, disconnect the fuel return line from the auxiliary pump inlet and connect it to a slop can. Connect the fuel supply line to the new reference fuel can and run the engine long enough to purge the old reference fuel from the system. The time required will be dependent upon length of added fuel lines, but it will be approximately 30-60 seconds; approximately 1-2 quarts of fuel will be discarded to slop.(1)

   c. With the engine off, connect the fuel return line to the auxiliary pump inlet. The vehicle is then ready to be tested.

   d. When changing to the next reference fuel, it is necessary to repeat Steps a, b, and c.

CAUTION

Fuel supply lines remain pressurized long after the engine is shut off; be sure to relieve the pressure before disconnecting fuel lines.

Use fuel lines designed for high pressure. They should be rated for at least 250 psi working pressure and for 1000 psi burst pressure.

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(1) It is critical to circulate an adequate amount of fuel to the slop can to prevent reference fuel contamination.

CAUTION - (Continued)

The engine and auxiliary fuel pumps should be shut off while changing from auxiliary to tank fuels.

Purging procedures should be followed strictly to preclude reference fuel contamination or discarding more fuel than is required.

Vehicle pump(s) may be disarmed by use of the inertia switch if so equipped. The voltage supplied to the inertia switch may then be used to power the auxiliary pump. When making these electrical connections, do not "splice" into the wire; instead, connect the wire lead to the connector.

Do not disarm the vehicle fuel pump by removing the fuse, since other accessories may be connected to the same circuit; instead, disconnect the fuel pump electrical lead.

Auxiliary fuel return lines should be of a size large enough to prevent a build-up of back pressure which could prevent the proper operation of the pressure regulator.

Use of the "rolled edge" style hose clamps, such as those made by Chrysler, is recommended to prevent damage to fuel lines.

Note: Diagnostic scanners should not be used while knock testing.