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Aberdeen Proving Ground, MD 21005-5055

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Change 1

4 February 1986

VEHICLE FUEL CONSUMPTION

TOP 2-2-603, 12 February 1980, is changed as follows:

1. Remove pages, and insert new pages as indicated below:

Remove pages--	Insert pages--
1	1
2	2
3	3
4	4
	C-1

2. Appendix C, page C-1, is the burette method fuel consumption test.

3. A vertical line in the left margin indicates the changed portion of the revised pages.

4. Attach this sheet to the front of the reference copy for information.

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Describes the tests to measure and evaluate wheeled and tracked vehicle fuel consumption under both controlled and typical service operating conditions. Applies to land and amphibious vehicles with internal combustion engines.

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

AMSTE-RP 702-101
*Test Operations Procedure (TOP) 2-2-603
AD No. A095967

CHANGE 1
4 February 1986

VEHICLE FUEL CONSUMPTION

			Page
Paragraph	1.	SCOPE.	1
	2.	FACILITIES AND INSTRUMENTATION	2
	3.	PREPARATION FOR TEST	2
	4.	TEST CONTROLS.	3
	5.	PERFORMANCE TESTS.	4
	5.1	Controlled Tests--Transportation Vehicles. .	4
	5.1.1	Road-load Test	4
	5.1.2	Full-load Test	5
	5.1.3	No-load Test	5
	5.1.4	Standard Course Test	5
	5.2	Controlled Tests--Engineer Type Vehicles . .	7
	5.2.1	Road-load Test	7
	5.2.2	Full-load Test	7
	5.2.3	No-load Test	7
	5.2.4	Work-function Tests.	7
	5.3	Tests Simulating Service Operations.	8
	5.4	Usable Fuel Capacity	8
	6.	PRESENTATION OF DATA	9
	6.1	Controlled Tests	9
	6.2	Tests Simulating Service Operations.	9
	6.3	Fuel Consumption Computations.	9
APPENDIX	A	RECOMMENDED OPERATING SCHEDULES.	A-1
	B	GUIDE FOR PREPARATION OF FIELD CHECKLISTS (FUEL CONSUMPTION TEST--VEHICLES).	B-1
	C	BURETTE METHOD FUEL CONSUMPTION TEST	C-1

1. SCOPE. This TOP describes the tests used to measure and evaluate wheeled- and tracked-vehicle fuel consumption under both controlled and typical service operating conditions. Tests are applicable to land and amphibious vehicles with internal combustion or turbine engines.

*This TOP supersedes TOP 2-2-603, 1 November 1977.

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2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENTS
Automotive test courses	Level paved course for road-load and full-load tests; Munson standard fuel course for standard course test--Courses required for operational tests may be selected from TOP 1-1-011.

2.2 Instrumentation.

ITEM	MAXIMUM PERMISSIBLE ERROR OF MEASUREMENT*
Fuel measuring devices (burette, flowmeter, etc.)	kg/hr (lb/hr), L/hr (gal/hr), as applicable, to ±2% of reading
Vehicle speed measuring device (calibrated fifth wheel with speed indicator)	±0.2 km/hr (mph)
Tachometer (engine speed)	rpm to ±0.5% of full scale range
Temperature measuring equipment	Fuel temperature to ±1°C (±2°F)
Meteorological equipment	Ambient air temperature to ±1°C (±2°F) Relative humidity to ±3% Atmospheric pressure to ±0.01 in. of Hg
Timing device	Fuel consumption time to ±0.1 sec
Fuel specific gravity measuring equipment	±0.1% of reading

*Values may be assumed to represent ±2 standard deviations; thus the stated tolerances should not be exceeded in more than 1 measurement of 20.

3. PREPARATION FOR TEST.

3.1 Test Vehicle.

a. Inspect and service the vehicle in accordance with TOP 2-2-505 to insure that the vehicle is in condition for optimum performance. Pay particular attention to engine adjustments, tire inflation, and track tension.

b. Record the following for each vehicle:

(1) Vehicle identification.

(2) Type, model, and serial number of each significant component (engine, transmission, etc.).

(3) Vehicle loads and weight distribution.

(4) Fuel specification/type.

(5) Fuel specific gravity.

(6) Type of fuel measuring system.

3.2 Instrumentation.

3.2.1 Controlled Tests. Instrument the vehicle to measure fuel consumed, fuel consumption time, engine speed, road speed, and fuel temperature. The instrumentation commonly used consists of a calibrated burette installed with a special tank to hold the fuel, a timer, an engine tachometer, a calibrated fifth wheel with a speed indicator, and a thermocouple to measure fuel temperature in the burette. Another method involves the use of a flowmeter in the fuel line. The procedure to follow when using the burette method is shown in Appendix C.

3.2.2 Tests Simulating Service Operations. No special instrumentation is required to measure fuel consumption during endurance tests or other tests representative of service operating conditions. To measure fuel consumed during these tests, carefully make all refills of vehicle fuel tanks to the same point. Before the tests are started, select a level that will assure no loss in fuel through spillage from vehicle movement or from thermal expansion. Determine total distance traveled and total operating time from instrumentation used for endurance tests (tachograph).

3.3 Test Planning.

a. Select the tests needed to satisfy the requirements document for the specific item to be tested.

b. Prepare a checklist to ensure that all factors essential to the precision, validity, and efficiency of the test are accomplished in an orderly manner. Use Appendix B as a guide.

4. TEST CONTROLS.

a. Do not conduct controlled tests during inclement weather. Test courses must be clear and dry.

b. Record meteorological conditions for all periods of operation.

c. Perform periodic lubrication and maintenance services throughout testing in accordance with the applicable lubrication orders and technical manuals.

d. Unless otherwise specified, use referee grade fuels to simulate the lower quality of fuel that is apt to be available in time of a national emergency. (See TOP 2-2-701, Fuels and Lubricants.)

5. PERFORMANCE TESTS.

5.1 Controlled Tests--Transportation Vehicles. Conduct the following series of controlled tests for transportation vehicles (including transport, tactical support, and combat vehicles) normally used to transport personnel, cargo, or weapon systems. Fuel consumption for these vehicles is determined on the basis of gear range, road speed, engine speed, and load carried. This category also includes some multifunctional vehicles (e.g., amphibious vehicles) requiring separate fuel consumption measurements for each function.

5.1.1 Road-load Test.

5.1.1.1 Method.

a. Load the vehicle with its rated payload or combat weight.

b. Operate the vehicle at constant speeds over a level, paved test course (unless otherwise specified) at not less than four equal increments of speed over the operating range of the vehicle in each gear.

c. Measure fuel consumed for each speed increment. Repeat each measurement a sufficient number of times to assure representative results.

5.1.1.2 Data Required.

a. Test course.

b. Vehicle weight.

c. Vehicle road and engine speeds for each measurement.

d. Fuel consumed per test condition.

e. Time to consume fuel.

f. Fuel temperature.

g. Air temperature, humidity, and pressure.

5.1.2 Full-Load Test.

5.1.2.1 Method. Conduct full-load, full-throttle fuel consumption tests simultaneously with drawbar pull tests on hard surfaces as described in TOP 2-2-604. Measure fuel consumption at several points within the engine operating range. Repeat each measurement a sufficient number of times to assure representative results.

5.1.2.2 Data Required. Collect and record data as in paragraph 5.1.1.2.

5.1.3 No-Load Test (Transmission in Neutral Gear Range).

5.1.3.1 Method.

a. With the vehicle stationary and the transmission in neutral, operate the engine at speeds ranging from rated idle speed to governed engine speed.

b. Measure fuel consumption for each engine speed. Repeat each measurement as necessary to assure reproducibility.

5.1.3.2 Data Required.

a. Fuel consumed for each engine speed.

b. Fuel temperature.

c. Air temperature, humidity and atmospheric pressure.

5.1.4 Standard Course Test.

5.1.4.1 Method.

a. Operate the test vehicle over APG's standard fuel consumption course (Figure 1) in each direction of travel using increments of speed that span the normal service speeds of the vehicle for the test conditions. Run each test at a sustained speed, controlled by the driver.

b. Measure fuel consumption for each speed and course direction traveled. Repeat each measurement a sufficient number of times to assure representative results.

Surface	Grade	Operating Distance		
		CW		CCW
		meters	(ft)	meters
Gravel	Less than 1%	828	(2718)	828
Bituminous concrete	Less than 1%	1198	(3930)	1198
	1% to 5%	158 up	(520)	158 down
	5%	148 down	(487)	148 up
	15%	61 down	(200)	61 up
Concrete	30%	45 up	(148)	45 down
Total		2439	(8003)	2439

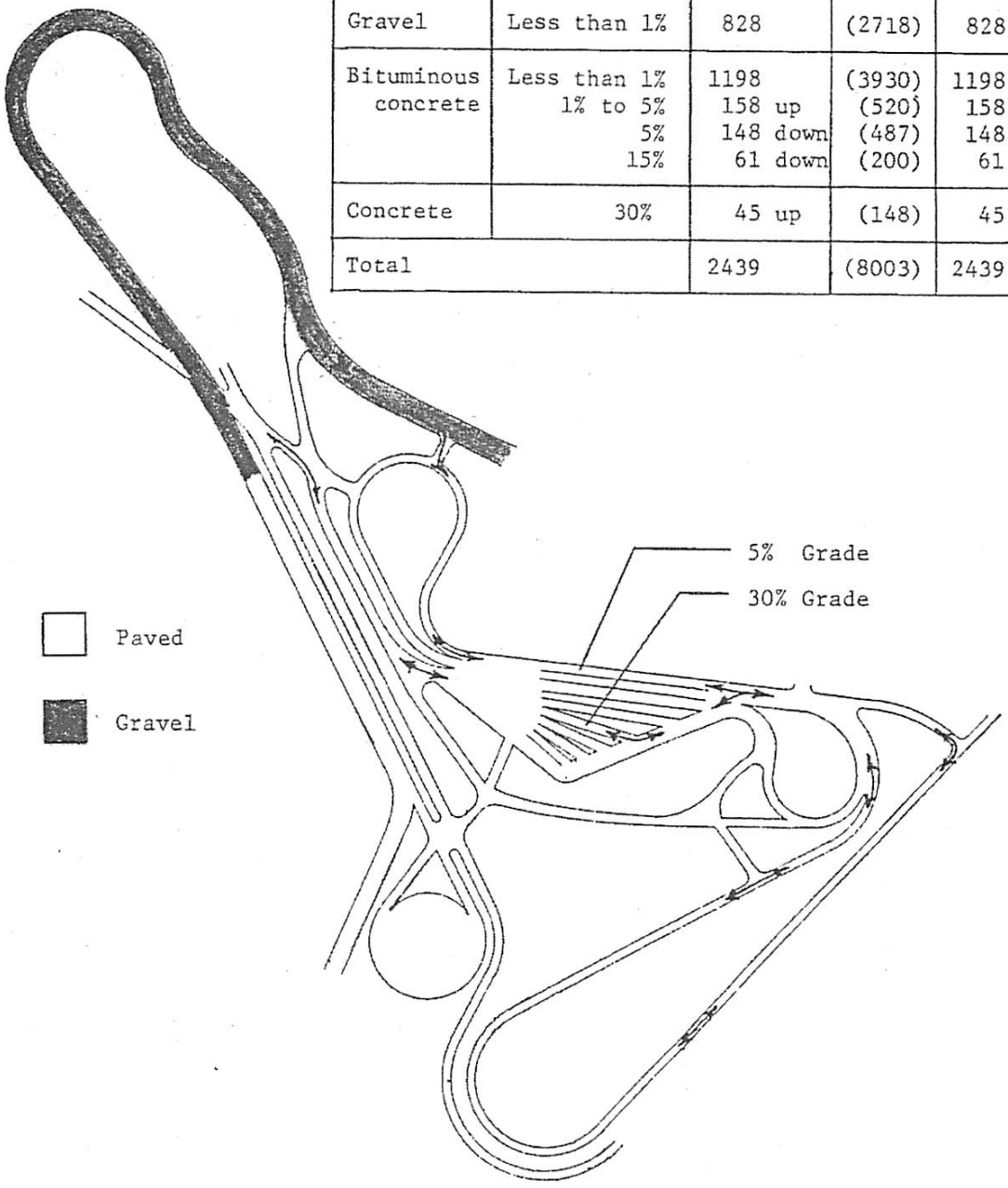


Figure 1. Fuel Consumption Course.

5.1.4.2 Data Required.

a. Vehicle weight.

b. Vehicle road speed for each test run.

c. Fuel consumed per test condition.

d. Distance traveled.

e. Time to consume fuel.

f. Fuel temperature.

g. Air temperature, humidity and atmospheric pressure.

5.2 Controlled Tests - Engineer-Type Vehicles. Conduct the following series of controlled tests for engineering equipment and other vehicles whose work cannot be rationally measured as a function of distance traveled but is usually a function of operating time. Included in this class are such items as construction machinery, earthmoving equipment, materials handling equipment, and some multifunctional equipment requiring separate fuel consumption measurements for each function.

5.2.1 Road-Load Test. Same as for transportation vehicles (Paragraph 5.1.1).

5.2.2 Full-Load Test. Same as for transportation vehicles (Paragraph 5.1.2).

5.2.3 No-Load Test. Same as for transportation vehicles (Paragraph 5.1.3).

5.2.4 Work-Function Tests.

5.2.4.1 Method. Measure fuel consumption while the vehicle is performing each work function for which it is designed.

5.2.4.2 Data Required.

a. Work function performed.

b. Time for each function.

c. Fuel consumed per work function.

d. Fuel temperature.

e. Road and engine speed, where applicable.

5.3 Tests Simulating Service Operations.

5.3.1 Method. During the vehicle endurance test or other performance tests, fill the fuel tanks at the beginning and end of test operation on each test course and record the amount of fuel consumed and mileage and hours traveled. Also fill the tanks at the start and finish of operation under each different test condition, such as with and without trailed load, change in vehicle components, change in load, etc. Clearly mark the "full" point for filling fuel tanks before each test as indicated in Paragraph 3.2.2.

5.3.2 Data Required. Record the following data, as applicable, using the data collection sheets for endurance testing shown in Appendix D, TOP 2-2-506. Fuel consumption data should also be entered into the automatic data processing (ADP) system for the specific vehicle to permit ready retrieval of overall fuel consumption data or consumption on specific types of terrain or courses.

a. Test course.

b. Fuel consumed per test course or condition.

c. Average road speed or operating time for each course condition.

d. Distance traveled.

e. Vehicle load and weight.

5.4 Usable Fuel Capacity.

5.4.1 Method.

a. Operate the vehicle until the engine stalls from lack of fuel. For diesel powered vehicles, stop the engine as soon as it begins to misfire to prevent damage to fuel metering pump or injectors.

b. Fill the fuel tank or tanks to the established full point (Paragraph 3.2.2). The amount of fuel required is the usable fuel capacity.

c. When required, determine the maximum refueling rate for each tank fill port using a calibrated flowmeter and a 5.1-cm (2-inch) fuel line with a variable-flow nozzle.

5.4.2 Data Required.

a. Usable fuel capacity.

b. Refueling rate, if required.

6. DATA REDUCTION AND PRESENTATION.

6.1 Controlled Tests.

a. Reduce fuel consumption data to liters per 100 kilometers or kilograms per hour according to the method of work measurement. (If using US customary units, reduce to mpg and ton-miles/gal or, if applicable, lb/hr.)

b. Prepare graphic presentations to show the relationship between fuel consumption characteristics under various modes of operation. Typical graphic forms are described below, some of which are illustrated in Figures 2 and 3. If SI units are used in measurements, charts should be prepared with data in SI units.

(1) No-load, road-load, and full-load fuel consumption in kilograms per hour (lb/hr) versus engine speed (rpm).

(2) Standard course fuel consumption in liters per 100 kilometers (mpg and ton-miles/gal) versus road speed in kilometers per hour (mph).

(3) Road-load and full-load fuel consumption in liters per 100 kilometers (mpg) versus road speed in kilometers per hour (mph).

6.2 Tests Simulating Service Operations.

a. For transportation-type vehicles, reduce data recorded in operational logs (or by ADP) to liters per 100 kilometers (mpg) for each course and condition. Fuel consumption for full-tracked combat vehicles should also be expressed in liters per hour (gal/hr).

b. For engineer-type vehicles, reduce data recorded in operational logs (or by ADP) to hours per liter (hr/gal) or liters per hour (gal/hr) for each course and condition.

c. Present data in tabular form and use the data as required to compute operating range or service fuel consumption (Paragraph 6.3).

6.3 Fuel Consumption Computations.

6.3.1 Operating Range. Army specifications require vehicles to have a specified operating range usually in one or both of two forms: "cruising range" or "battlefield day." Cruising range is usually specified for all vehicles, wheeled and tracked; battlefield day is generally required only for combat and tactical support vehicles.

TEST VEHICLE, XXXX, PILOT NO. X

Engine: Model VTA-903T
Track: Steel, Single Pin, 6-in. Pitch, 21-in. Width
Fuel: VV-F-800, DF-2
Transmission: Model HMPT500
Test Weight: 43,440 Lb
Date of Test: November 1979

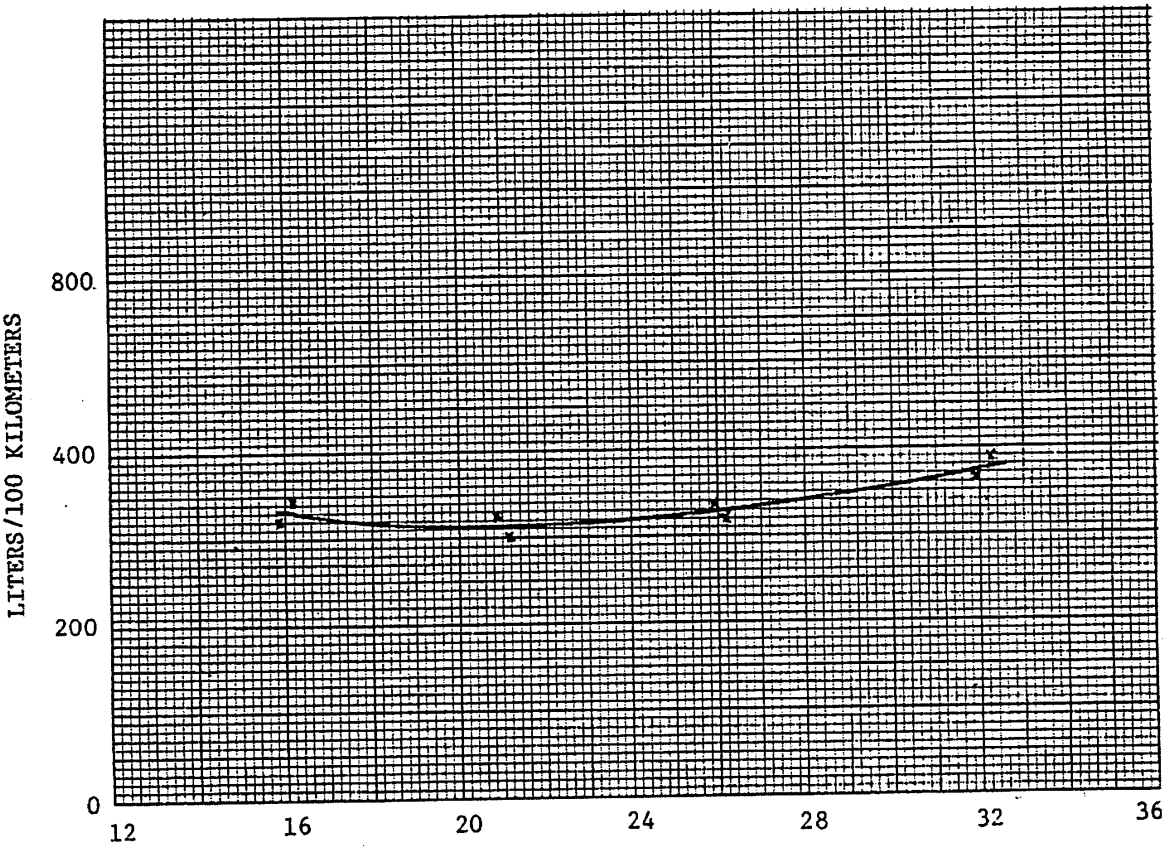


Figure 2. Sample Plot of Fuel Consumption Course Test Data.

TEST VEHICLE, XXXX, PILOT NO. X

Engine: Model VTA-903T
Track: Steel, Single Pin, 6-in. Pitch, 21-in. Width
Fuel: VV-F-800, DF-2
Transmission: Model HMPT500
Test Weight: 43,440 Lb
Dates of Test: December 1979 and January 1980

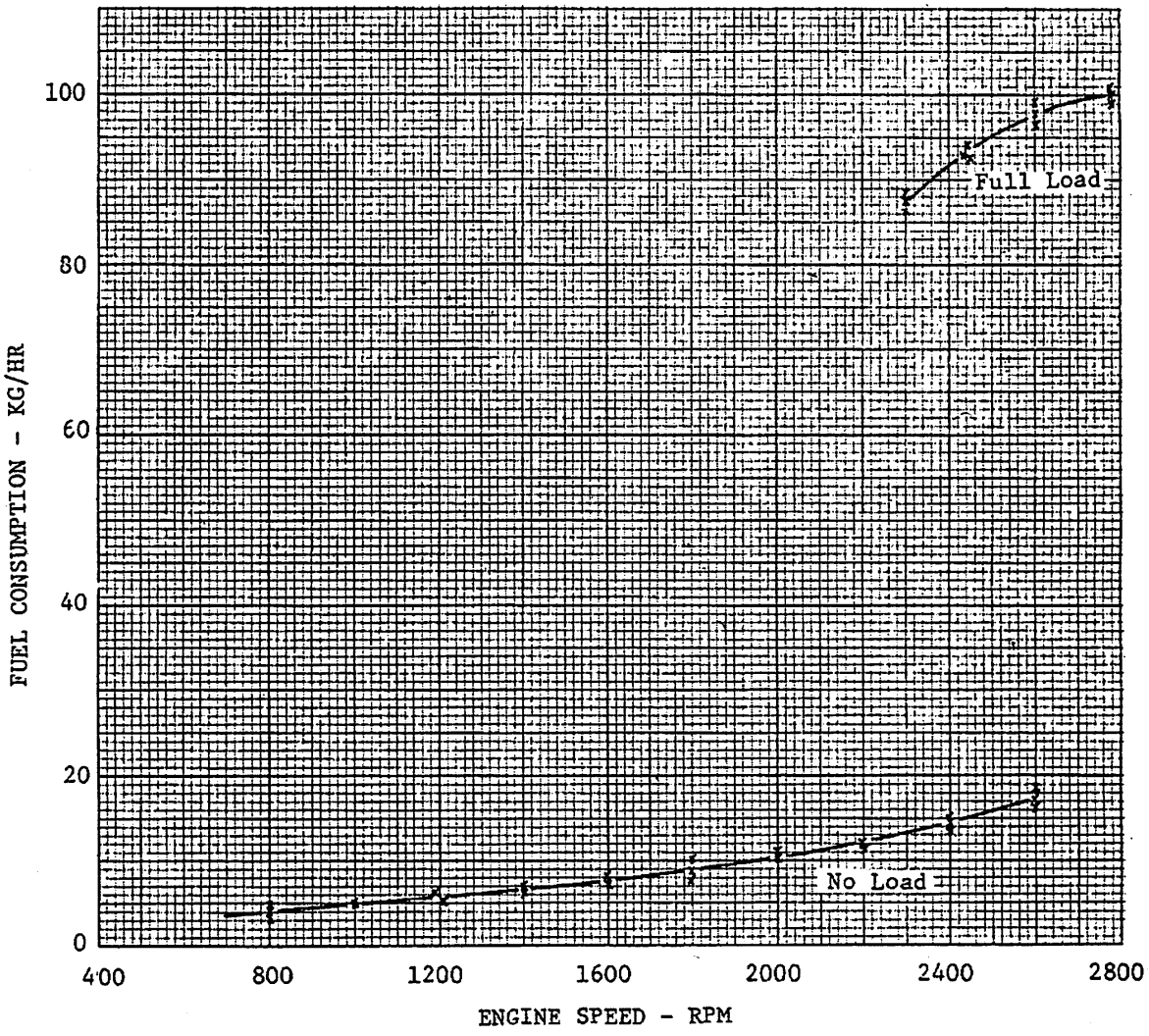


Figure 3. Sample Plot of Maximum and Minimum Fuel Consumption.

To determine operating range, apply fuel consumption rates measured for various courses and speeds during the performance tests (para 5) to a specified combination of operating conditions (speed, terrain, operating time, etc.) and compute the range for the usable fuel capacity of the vehicle. When the operating conditions are not specified, use the recommended schedules in Appendix A for comparison purposes. Computations are made using the following formula:

$$\text{Operating range, km (miles) or hours} = \frac{T}{C_1F_1 + C_2F_2 + \ldots C_nF_n}$$

where: T = usable fuel capacity in liters (gal)
C = fraction of specified operating condition
F = fuel consumption rate for the associated operation condition in liters/100 km or liters/hr (gal/mile or gal/hr)

6.3.2 Service Fuel Consumption. To determine the average rate of fuel consumption for a vehicle operating under typical service conditions, apply measured fuel consumption rates to a specified combination of operating conditions as in determining operating range (6.3.1 above) and compute the rate (FC) in kilometers (miles) or hours per liter (gal) using the following formula:

$$FC = C_1F_1 + C_2F_2 + \ldots C_nF_n$$

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APPENDIX A
RECOMMENDED OPERATING SCHEDULES

Recommended operating schedules for typical vehicle missions are provided in Tables 2 through 5 so that comparisons can be made between similar vehicles when specific requirements are not stated. Conditions indicated are for guidance and should be altered to suit test requirements at the discretion of the test director.

a. Tactical Support - role normally filled by wheeled vehicles with a high degree of off-road capability.

Table 2 - Tactical Support Schedule

Operating Condition			Cruising Range and Service Fuel Consumption (% of Test Distance)	Battlefield Day (% of Test Time)
	km/hr	mph		
Engine idling	.....	.....	0	10
Paved road	48 to 56	30 to 35	30	30
Secondary road	24 to 32	15 to 20	30	30
Cross-country	8 to 16	5 to 10	40	30

b. Logistical Support - a mission characterized by long-haul operations on identifiable roads, either paved or secondary.

Table 3 - Logistical Support Schedule

Operating Condition			Cruising Range and Service Fuel Consumption (% of Test Distance)	Battlefield Day (% of Test Time)
	km/hr	mph		
Engine idling	.....	.....	0	10
Paved road	48 to 56	30 to 35	75	50
Secondary road	24 to 32	15 to 20	20	30
Cross-country	8 to 16	5 to 10	5	10

c. Combat - characteristically, armored and armed tracked vehicles engaged in actual combat duty.

Table 4 - Combat Schedule

Operating Condition			Cruising Range and Service Fuel Consumption (% of Test Distance)	Battlefield Day (% of Test Time)
	km/hr	mph		
Engine idling	.....	.....	0	40
Paved road	32 to 40	20 to 25	18	0
Secondary road	16 to 24	10 to 15	18	20
Cross-country	3 to 13	2 to 8	64	40

d. Combat Support - characteristically, tracked vehicles supporting combat by hauling supplies within the combat zone; self-propelled artillery in the combat support role is included.

Table 5 - Combat Support Schedule

Operating Condition			Cruising Range and Service Fuel Consumption (% of Test Distance)	Battlefield Day (% of Test Time)
	km/hr	mph		
Engine idling	.....	.....	0	5
Paved road	32 to 40	20 to 25	23	0
Secondary road	16 to 24	10 to 15	23	85
Cross-country	3 to 13	2 to 8	54	10

APPENDIX B
GUIDE FOR PREPARATION OF FIELD CHECKLISTS
(FUEL CONSUMPTION TEST - VEHICLES)

Item	Yes	No	NA
I. General			
1. Preoperational inspection and services performed on vehicle.			
2. Referee grade fuels used.			
3. All required instrumentation calibrated, properly installed, and operational.			
4. Payload secured.			
5. Tire pressures checked and adjusted for proper course condition.			
6. Fuel tanks filled and quantity recorded before test operation on each course or change in test condition during simulated service operation.			
7. Required test data recorded.			
8. Problems, defects, unusual operating noises, etc., noted and described on test log.			
II. Specific			
(Add other items that are particular to the specific test item, test facility, and test scope.)			

APPENDIX C
BURETTE METHOD FUEL CONSUMPTION TEST

1. Instrumentation:

   a. Disconnect fuel line to fuel pump and return line.

   b. Connect instruments as indicated in Figure C-1.

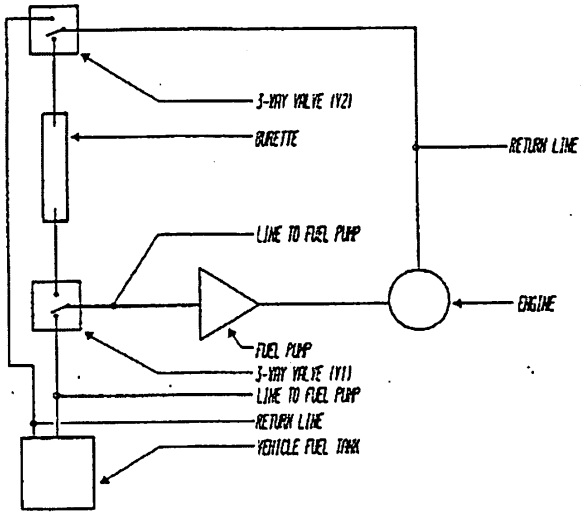


Figure C-1. Diagram of burette method fuel consumption test.

2. Operation Procedure:

   a. Set V1 so engine can feed from fuel tank.

   b. Set V2 so line fuel is sent to the burette and it starts to fill.

   c. When burette is full, turn V2 so return is sent back to fuel tank.

   d. Run vehicle to required rpm and speed.

   e. Turn V1 and V2 simultaneously so vehicle can be fed from the burette and return fuel can go into the burette.

   f. Perform test run.

   g. Before the end of the run, turn V1 and V2 simultaneously so vehicle can be fed from the fuel tank and return fuel can go back into the fuel tank. Then stop the vehicle (engine idling), and read the burette.

   h. Repeat steps a through g for each test run.