Fuel Meter Model FM 200

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The motor benefits fuel meter is an accurate, wide flow range fuel-measuring device designed for use in fuel consumption tests of large gasoline- and diesel-powered highway vehicles. The meter is virtually uneffected by normal changes in flow rates, fuel pump pressures, electrical voltage, ambient temperatures, and vehicle ride.

•VEHICLE STUDIES at the University of Washington involving measurement of fuel have resorted to use of calibrated burettes placed in the cab of the test tractor. This arrangement, although satisfactory, has the undesirable features of large space requirements, excessive installation time, and the fire hazard of liquid fuel in the cab. This fuel meter is the outcome of numerous discussions for a more simplified method of measuring the fuel consumed by the test vehicles. Commercial fuel measuring devices are not available that have the features of covering the flow rates encountered and the accuracy desired, and that can be easily installed and carried in a test truck.

THE METER

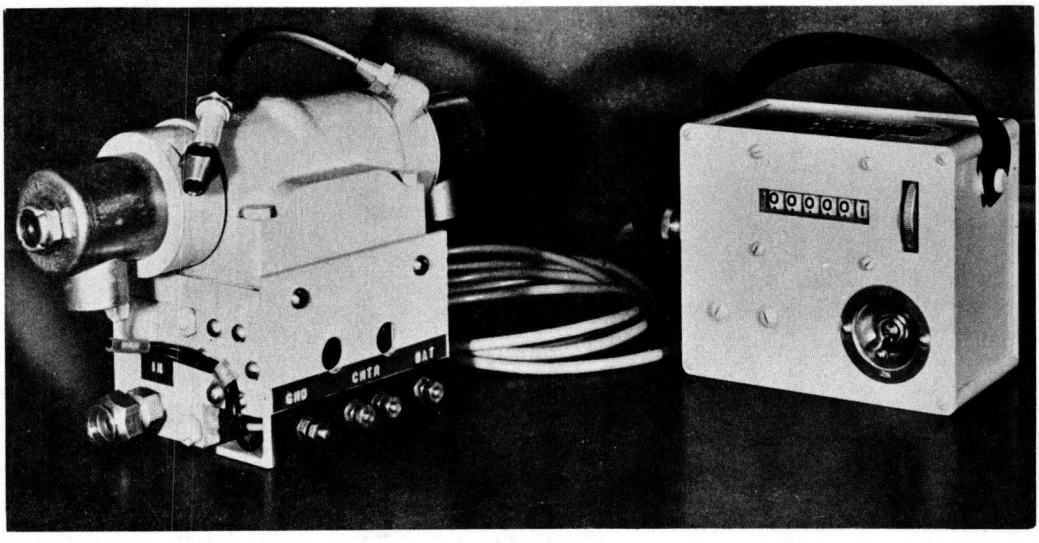

Figure 1. Fuel meter model FM 200 with counter model FM 201.

The meter (Fig. 1) is a volumetric fuel-measuring device consisting of a solenoid-actuated, air-operated valve and two measuring chambers. In operation, fuel enters a float-controlled vapor separator where liquid fuel is separated from vapor or air. The liquid fuel passes through the valve into one end of a double cylinder fitted with a

free-floating piston. On entering the chamber at one end of the cylinder, the incoming fuel moves the piston which in turn discharges fuel from the second cylinder into a surge chamber and out into the fuel line. At the end of the piston travel, an electrical switch is actuated by the piston, causing the solenoid valve to interchange inlet and outlet ports of the two chambers. The measuring chambers are alternately filled and exhausted by actuation of the valve. A magnetic digital counter in series with the solenoids of the valve will record each actuation of the valve. By having a predetermined piston travel, the cylinder volume can be established; and hence, the quantity of fuel passing through the meter is known from cylinder volume and number of times the cylinder is filled. Piston travel is limited to give a cylinder volume of approximately 2.74 ml which gives approximately 1,380 counts per gal. This can be altered to give a greater or lesser number of counts per gallon by changing spacing of the electrical switches. With an increased number of counts per gallon, the operational period of the meter between servicing will become proportionally reduced. Because the electrical switches and O-rings are subject to much use, their life will determine the length of operation between normal replacement of these items. The period between meter servicing should be the time required to meter approximately 500 to 700 gal of fuel.

A fuel pressure drop through meter ranges from 1 to $1\frac{1}{2}$ psi at flow rates corresponding to normal truck fuel use. A booster fuel pump is recommended in addition to the vehicle fuel pump to insure proper engine operation.

Installation of Meter

Reference to Figures 2 and 3 is made when making the meter installation.

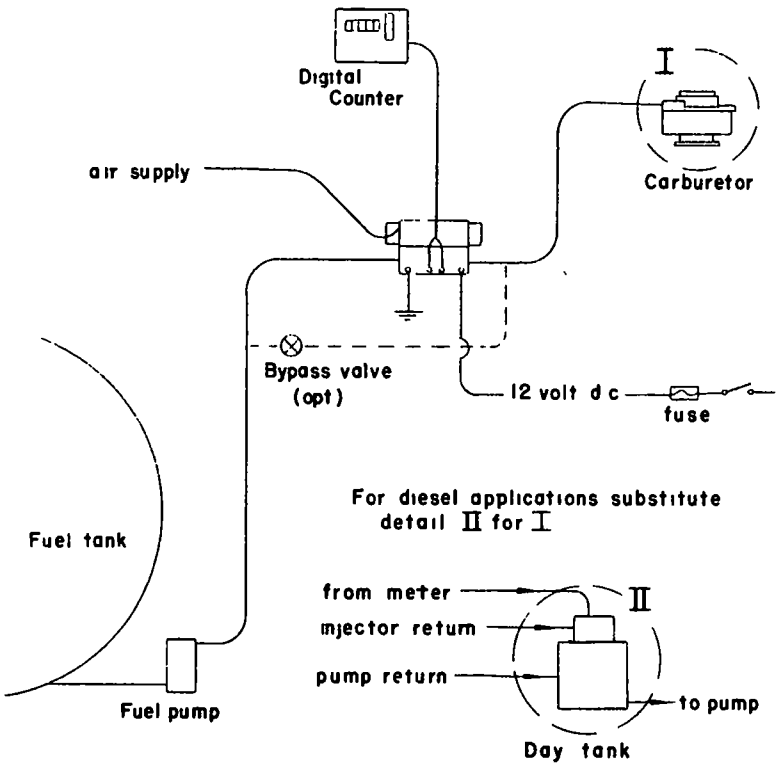

Figure 2. Installation diagram.

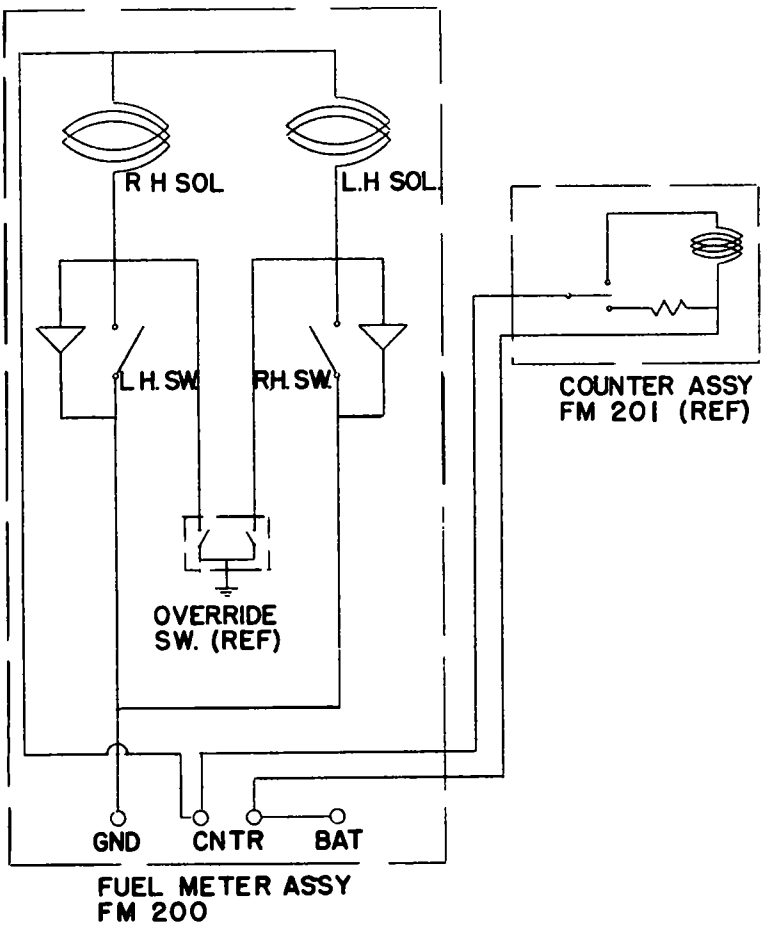

Figure 3. Wiring diagram.

The meter is installed in an upright position in the engine compartment of the vehicle being tested. The extreme temperature area of the exhaust manifold should be avoided. Mounting of the meter in other than an upright position will hinder operation of the float-controlled vapor separator and may permit fuel to pass directly from the vapor separator to the surge chamber without being measured.

Inasmuch as installations will vary so widely, no specific mounting directions are given but left to the discretion of the instrumentation mechanic. Two holes have been provided in the bottom of the cover plate for anchoring the meter to a horizontal shelf; and two holes, tapped 1/4-20 UNC, have been provided in the rear side of the base plate for attaching the meter to a vertical bracket or bulkhead. The meter may also be suspended by clamps placed around the solenoid covers. Suspension by attaching to the ¼-in. copper air line is not recommended.

Fuel lines are connected as indicated on the installation drawing. Copper fuel lines may be used in place of flexible lines if no relative movement exists between fuel pump, meter, and carburetor. Check to make sure the fuel flow is in the proper direction through the meter. A bypass valve is recommended to permit fuel to be diverted past the meter if meter failure occurs.

An air supply is connected to the ¼-in. tube tee on one solenoid. A flexible line should be used unless relative movement is small. On vehicles that normally have an air compressor (heavy trucks), the air connection is made directly to a constant pressure

line from the air tank and reduced to the required pressure. If the vehicle is not equipped with a compressor, a nitrogen or air cylinder (2,000 to 3,000 psi) can be carried in the vehicle with necessary pressure regulating equipment. Air supply pressure is adjusted to 20 to 25 psi. When new O-rings are installed, the 20 to 25 psi may not be enough for operation of the valve and a slightly higher pressure may be required. "Pound out" of the valve may occur if excessive pressure is used.

Electrical connections are made using 18-gage wire or heavier. A small automotive fuse (9 or 14 SFE) should be used to safeguard equipment in case of an electrical short circuit. For convenience the meter and any electrical fuel pumps should be connected to the ignition switch. The electrical cord supplied with the magnetic counter (FM 201) has solderless terminals at one end for connecting to the meter. Although the wires are of different color, interchanging the leads makes no difference in meter operation. If the meter is used with a negative ground, the diodes should be reversed. The meter requires approximately 1 amp at 12 volts.

Calibration

Laboratory calibration (Figs. 4 and 5) of the flow meter was accomplished by recirculating fuel from a supply tank and through a series arrangement of an electric fuel pump, the meter, a needle valve, a three-way valve, and back to the supply tank. The needle valve was used in regulating the flow to permit calibration for any flow rate that may be encountered in the field. Fuel was recirculated until a calibration was to be made, at which time the three-way valve was used to divert fuel into a graduated burette while a predetermined number of counts were registered on the digital recorder. Fuel quantity, digital counter record, and time to meter the given quantity were all recorded for use in preparing a calibration chart. Fuel quantity was usually the quan-

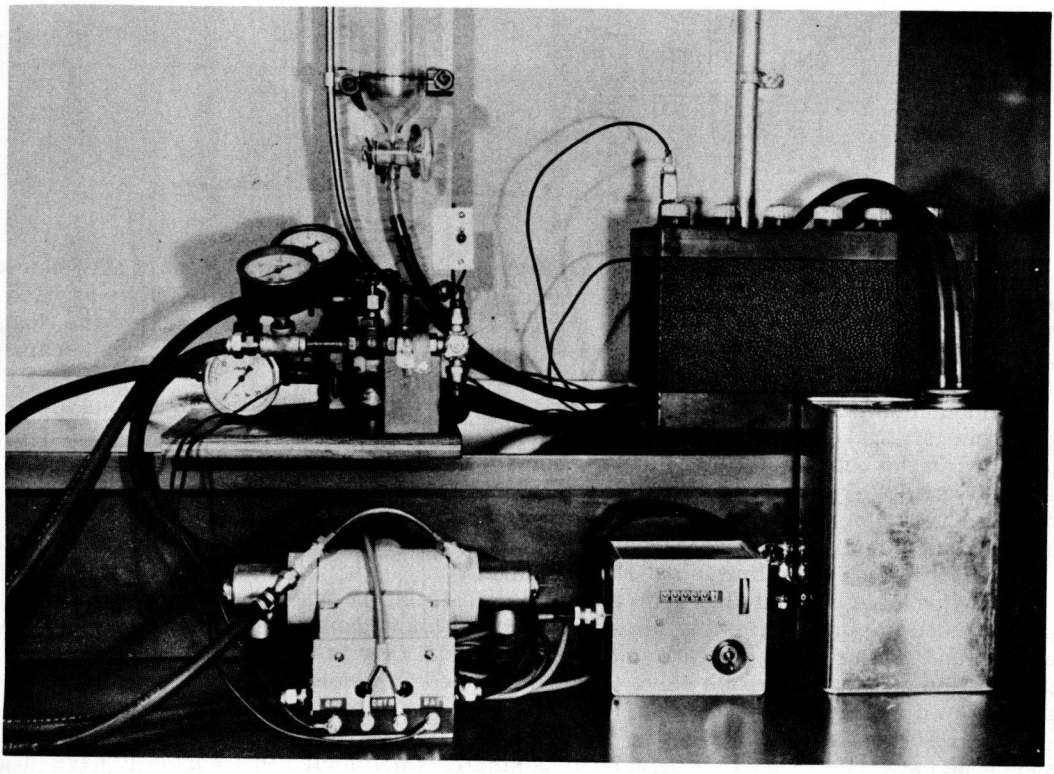

Figure 4. Laboratory calibration arrangement.

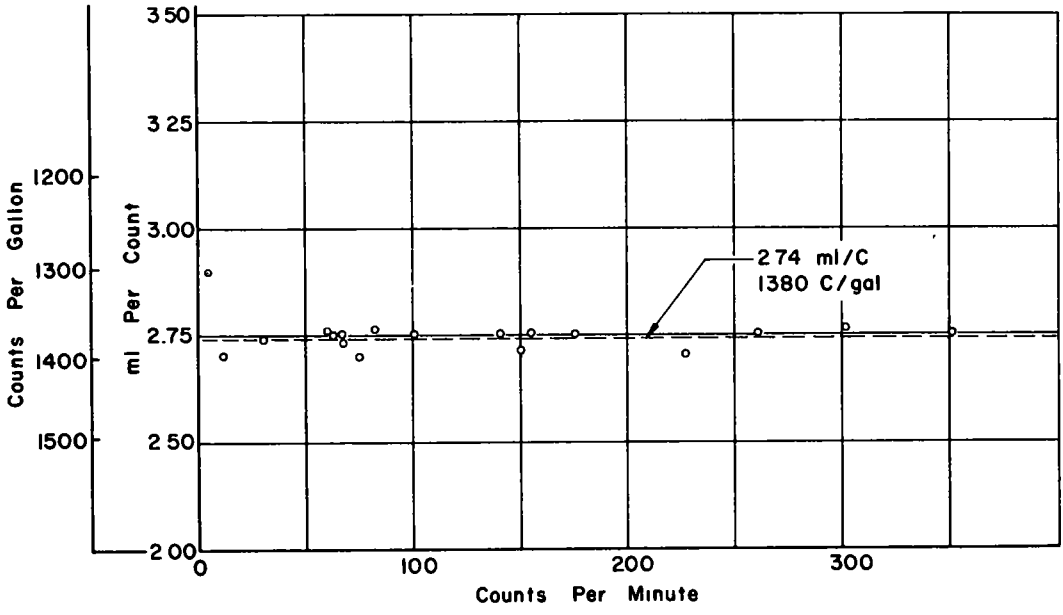

Figure 5. Calibration chart.

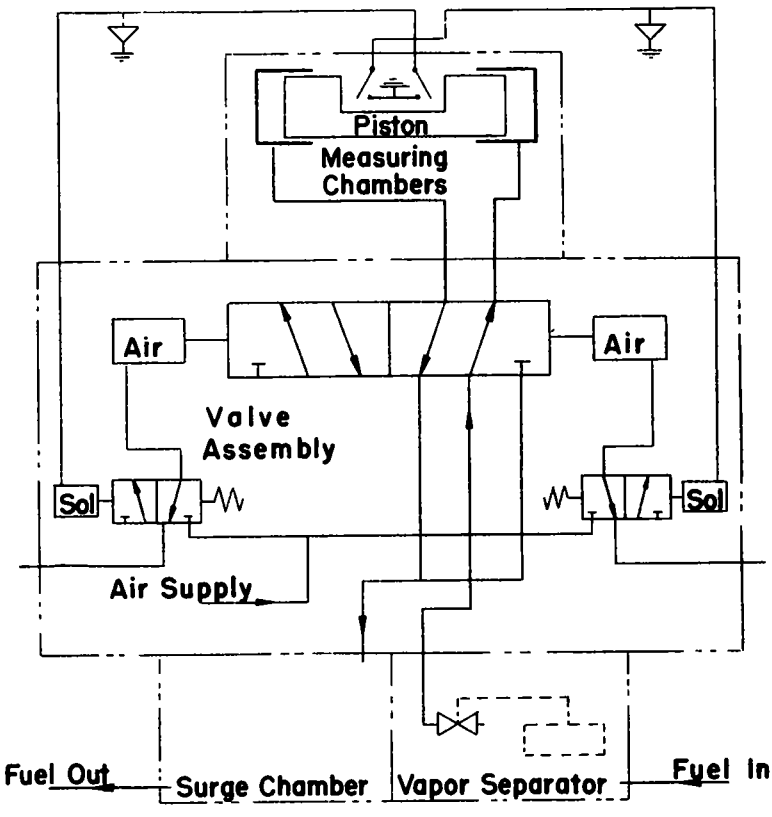

Figure 6. Schematic arrangement.

tity corresponding to 100 counts on the recorder. Fuel inlet and outlet pressures were also recorded every time a significant change was made in the flow rate.

Field calibration was also performed by installing the meter in series with the burette fuel measuring equipment in the test truck. Laboratory and field calibration were in very good agreement.

Troubleshooting

Erratic operation of the meter is probably due to air in the fuel line or a large ratio of vapor to fuel. The vapor separator will function properly with low volume of vapor in the fuel lines, but the meter will become erratic when air or vapor is admitted to the measuring chamber. Erratic operation should cease after a few minutes operation unless there is an air leak or restriction in the suction line. A restriction in the suction line will cause a portion of the fuel to vaporize because of the reduced pressure.

If meter fails to start, valve spool may not be positioned properly. With a screwdriver, one of the piston limit switches is actuated (or one of the two override switches depressed). If the meter has not started, air pressure, fuel pressure, and electrical connections should be checked. When actuating the electrical switches, there should be an audible exhaust from the solenoids. If air pressure is great enough, the spool can be heard moving in the valve when the switches are alternately actuated.

If the meter stops at low flow rates, it is probably because fuel is bypassing the O-rings. Two of the six O-rings are replaced on the valve spool, the second ring from each end of the spool. The ring and cylinder should fit snugly when the ring is properly installed on the spool. These two rings are critical items in the meter. Manufacturing tolerances for the rings are too wide to permit the use of all commercial O-rings for this application.

If the meter stops at any flow rate but can be started by actuation of override switches, then probably life expectancy of electrical switches has been shortened by permitting switch to become soaked in fuel. Both switches should be replaced.

If there is visible fuel solenoid exhaust, then end O-rings on valve spool should be replaced.

If the override switch does not actuate solenoid valve, then probably there is poor electrical connection, or electrical limit switch is in closed position due either to piston actuation or to defective switch.

If the meter is "dead", but all external electrical connections are good, poor electrical connection between meter and counter should be checked. This is a series electrical circuit and good electrical continuity must be maintained.

If meter calibration is nonlinear, fit of number 2 and 5 O-rings should be checked, and O-rings not having a sung fit in cylinder replaced.

If the meter does not recalibrate after changing electrical switches, then switches may not be tight against micarta block of switch assembly.

Applications

The fuel meter is intended to be used in vehicle testing and can adequately measure fuel at flow rates corresponding to all highway vehicles using gasoline or diesel fuels. The meter is not suitable for constant use on highway vehicles, because its initial cost and periodic servicing would make it impractical.

When using the meter to measure fuel consumption of diesel vehicles having a recirculating fuel system, a float-controlled "day tank" must also be used. Using the day tank, an equivalent volume of fuel is measured instead of the actual quantity entering the vehicles injectors.

Improvements

A direct acting solenoid valve replacement for the air-operated solenoid valve would permit a better application on test vehicles not equipped with a constant pressure air supply such as found on large trucks. Solenoid life and high current for the small electrical switches will be problems faced when redesigning for the direct acting solenoid valve.

Future fuel meters using the air-operated solenoid valves should be redesigned slightly to incorporate a valve built to tighter valve spool tolerances than the commercially available valves. This should not change the meter except in appearance.

The meter should be scaled down in future changes to provide for better operation at the extremely low flow rates. Presently the meter operates best at rates above idle fuel flow rates.

CONCLUSIONS

The Motor Benefits fuel meter will measure motor vehicle fuel consumption from idle to wide-open throttle operations with accuracies better than any commercially available meter. Although research personnel at the University of Washington have not used this meter exclusively for vehicle fuel consumption tests, they have had good correlation between laboratory tests and field tests and have used the meter to measure in excess of 700 gal of fuel between service periods without major difficulty or any meter component replacements.

ACKNOWLEDGMENT

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