CHAPTER 6
FUEL CONSUMPTION
MEASUREMENT EQUIPMENT

6.1 INTRODUCTION

Two types of fuel meters were used to make measurements of fuel consumed over a specified distance to provide data for the various fuel consumption experiments conducted by the Road User Costs and Traffic Experiments Groups (GEIPOT, "Report II: Midterm Report - Preliminary Results and Analysis"). The two types are called the "Reservoir", used over a short distance (one kilometer) and the "Volumetric", used over a long distance (ten kilometers). The "Reservoir" type could not be used over long distances since its capacity was too small, and a calibrated refill system, although feasible, was considered too cumbersome for some project vehicles.

A means of recording time and distance simultaneously was needed to determine fuel consumption during acceleration. A Camera Box was developed for this purpose (See section 4.6.1). It includes a movie camera, used to film the digital displays of an electronic distance measuring instrument, and an electronic stopwatch. Subsequently a Recorder Box was developed to fulfill this function (See section 4.6.2), the important difference being that data reduction is much easier from magnetic tape than from film.

A split-second hand mechanical stopwatch was used in conjunction with a distance measuring instrument and a reservoir fuel meter, to obtain average vehicle speed during the fuel consumption measurements.

Data acquired with these instruments were entered on the appropriate data collection form, shown in Table 6.1. The particular form shown was used with a "Reservoir" type fuel meter.

6.2 RESERVOIR FUEL METER

This fuel meter is a modified version of the ones used in the Kenya research (Zaniewski, "Fuel Meters") and was chosen for use in Brazil because of its simplicity and accuracy. It was not, however, as easily constructed as anticipated. Several models were tried, including one designed by a consultant, before the final manifold version was chosen.

OBSERVAÇÕES DE CONSUMO DE COMBUSTÍVEL

PICR

FOLHA _______ DE _______

FICHA DE IDENTIFICAÇÃO	1 [0 | 4]	SECÃO Nº	3 [| |]
		DATA (DIA / MÊS / ANO)	6 [| | | | |]
VEÍCULO-TESTE Nº	12 [| |]	CARGA (KG)	15 [| | | |]
Nº DO MOTORISTA	20 [|]	REGULADO: SIM (1) NÃO (2)	22 [ ]
INÍCIO DA CORRIDA - POSTO Nº	23 [ ]	TÉRMINO DA CORRIDA - POSTO Nº	24 [ ]

	LEITURA DO MEDIDOR DE COMBUSTÍVEL (ml)	VELOCIDADE ADOTADA (KM/H)	MARCHA USADA	TEMPOS DE PERCURSO AOS 50 % MIN	AOS 50 % SEG	AOS 50 %	TEMPOS DE PERCURSO AOS 100 % MIN	AOS 100 % SEG	AOS 100 %	CÓD. CILINDRO / EXT. TRECHO	
25											
43											
61											80
25											
43											
61											80
25											
43											
61											80
25											
43											
61											80
25											
43											
61											80

OBSERVADOR _______________

TABLE 6.1 - FUEL CONSUMPTION DATA RECORDING FORM

Any gasoline resistant material may be used as a cylinder. Glass was rejected for safety reasons. Nalgene laboratory graduated cylinders were finally selected as fuel reservoirs. Nalgene behaves well for about two years of constant exposure to gasoline and strong sunlight. Then the cylinder warps and becomes discolored, making the cylinder scale useless. Because Nalgene is nearly chemically inert, no type of adhesive or sealant could be found to seal connections to the cylinders. This caused a major problem with leaks from fuel line connections and in twin-cylinder models at the level-equalizing tube connections. The problem was eventually resolved by constructing threaded aluminum manifolds that the cylinders could be screwed into.

This type of fuel meter consists of a reservoir cylinder or pair of cylinders, sealed top and bottom with a manifold, a scale for reading the fuel level in the cylinders, an exact means of filling the cylinders with fuel, and a means of selecting the engine fuel supply, from either the vehicle fuel tank or the reservoir cylinder. In the case of a diesel vehicle, the return fuel line is switched on simultaneously with the fuel supply line, by means of a pair of conjugated valves, so the unburned fuel is returned to the source, as shown schematically in Figure 6.1. The engine block includes the vehicle fuel components such as the fuel pump, filter and carburetor. The gasoline system is shown by the solid lines while the dashed lines show the additional connections to convert to diesel.

A typical diesel system panel layout is shown in Figure 6.2. Full information concerning its development and constructional details, including the method used to conjugate two valves and machining required for the twin-cylinder manifolds is covered in two earlier Project Documents (Zaniewski, "Fuel Meters"; Buller, "Reservoir Fuel Meters").

Cylinders of individual fuel meters were scaled to the vehicle type, so each vehicle would have the smallest possible diameter cylinder to maximize the resolution. Fuel meters were built to study consumption over a range of vehicles from a 1300 cc Volkswagen up to a 285 HP Scania truck. At typical fuel meter used in test vehicles is shown in Figure 6.3.

The cylinder's scale was used for the single cylinder instruments. It was difficult to read the fuel level of two cylinder meters when the vehicle was transversely inclined. To overcome this, a small diameter sight-tube was fitted between the two cylinders and an accurate scale made and set against the sight-tube. Detailed information

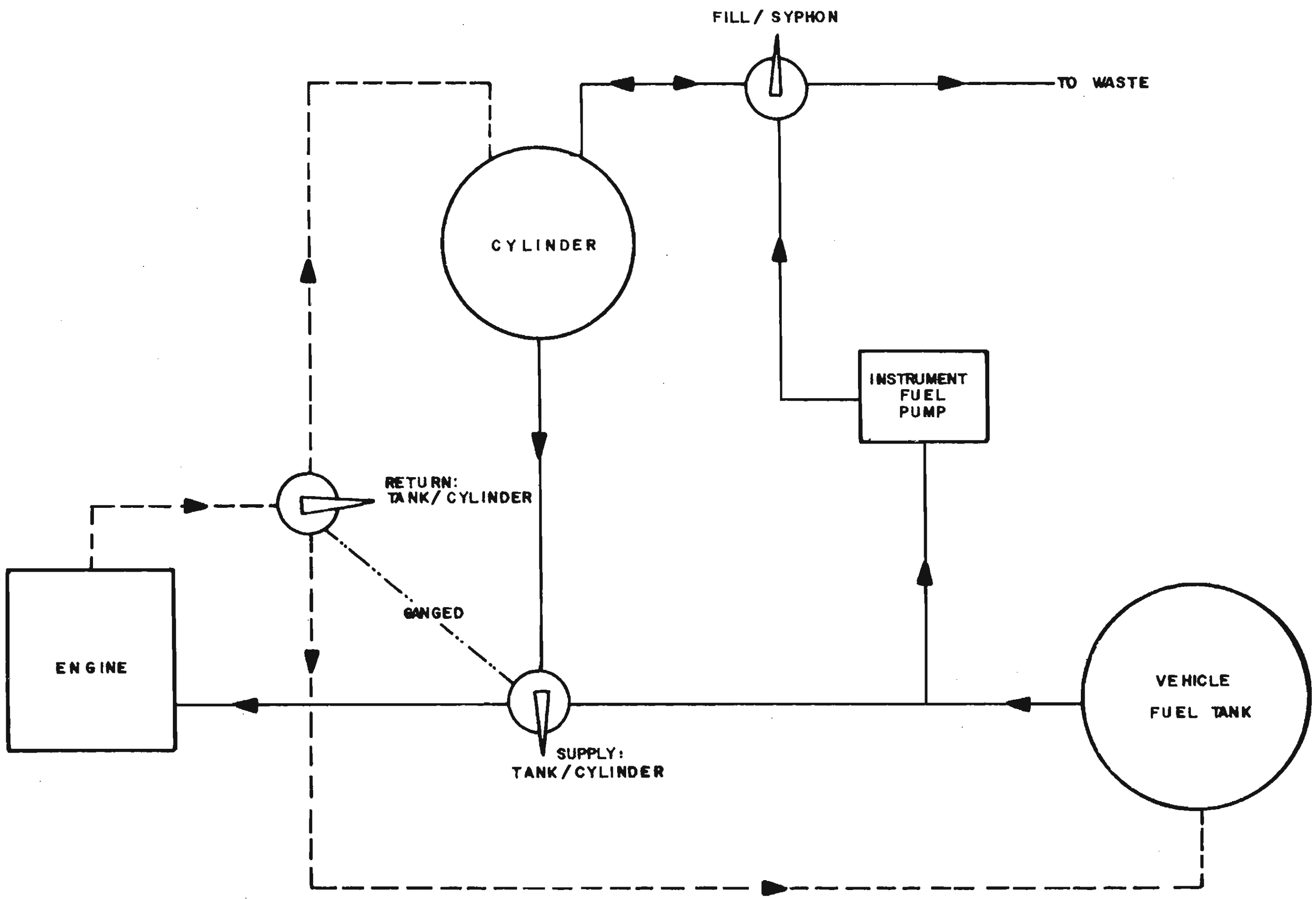

FIGURE 6.1 - SYSTEM SCHEMATIC

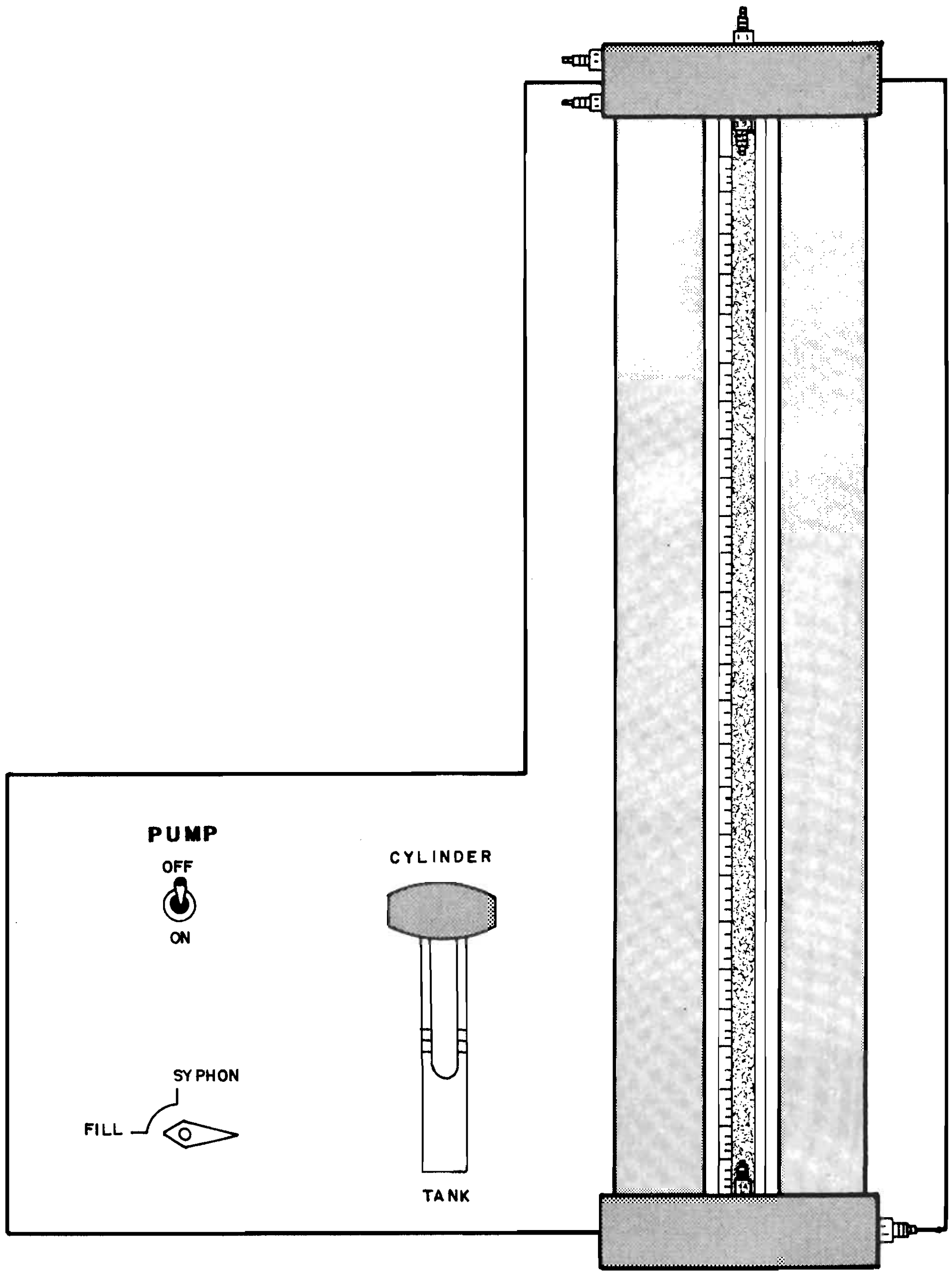

FIGURE 6.2 - DIESEL SYSTEM PANEL LAYOUT

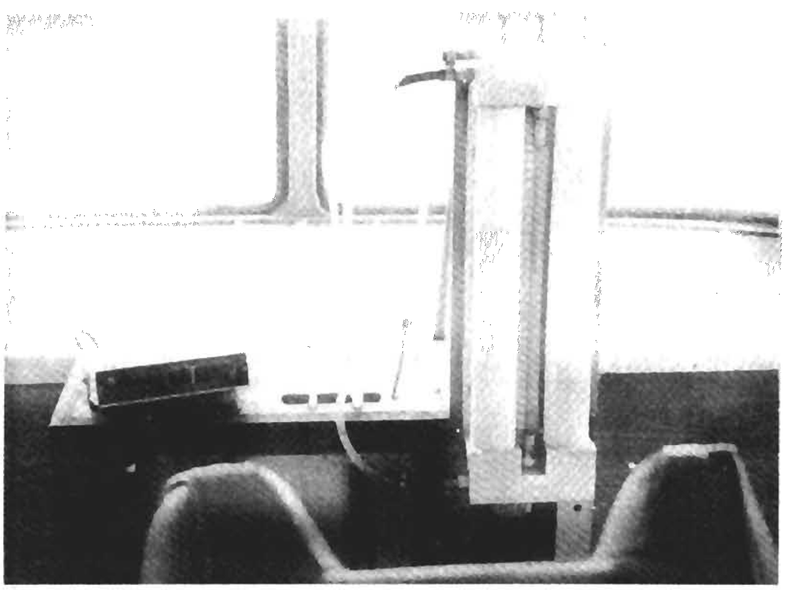

FIGURE 6.3 - RESERVOIR FUEL METER INSTALLED IN A VEHICLE

on the method used to make an accurate scale is covered in a Project Instrumentation Memo (Buller, "Reservoir Fuel Meters").

Two companion instruments were used with the fuel meter to determine speed and distance. They were the DMI, described in Chapter 3, and the split-second hand stopwatch shown in Figure 6.4. The DMI is an electronic, precision, digital odometer used to measure the distance travelled during a measurement run. The stopwatch was used to measure the time of the run. Together the data were used to calculate the average speed.

6.2.1 *Accuracy of the Measurements*

In this system, the accuracy of the reservoir fuel system depends on the accuracy and resolution of the instrument scale; the accuracy with which the reading is taken; the accuracy in operating the supply tank/cylinder valve with regard to distance; the accuracy of measured travel distance and having a leak-free system.

If a plastic measuring cylinder with its own scale is used as shown in Figure 6.5, the resolution depends upon the size of the cylinders used. The 250 ml cylinder scale has a resolution of 2 ml; the 500 ml cylinder scale, 5 ml; and the 1000 ml cylinder scale, a resolution of 10 ml.

If better resolution is required, the user's own scale can be employed as depicted in the diesel system panel layout diagram (Figure 6.2).

6.2.2 *Field Operation*

The field crew consisted of two people, a driver and an observer. The driver was trained to drive in a standard manner to minimize the effects of driver behavior on fuel consumption. The observer operated the equipment and recorded the various data on the field form shown in Table 6.1. Normally, the entire fuel consumption fleet travelled and worked together. The team was headed by a field supervisor who handled logistical problems and directed the activities of the fuel consumption team.

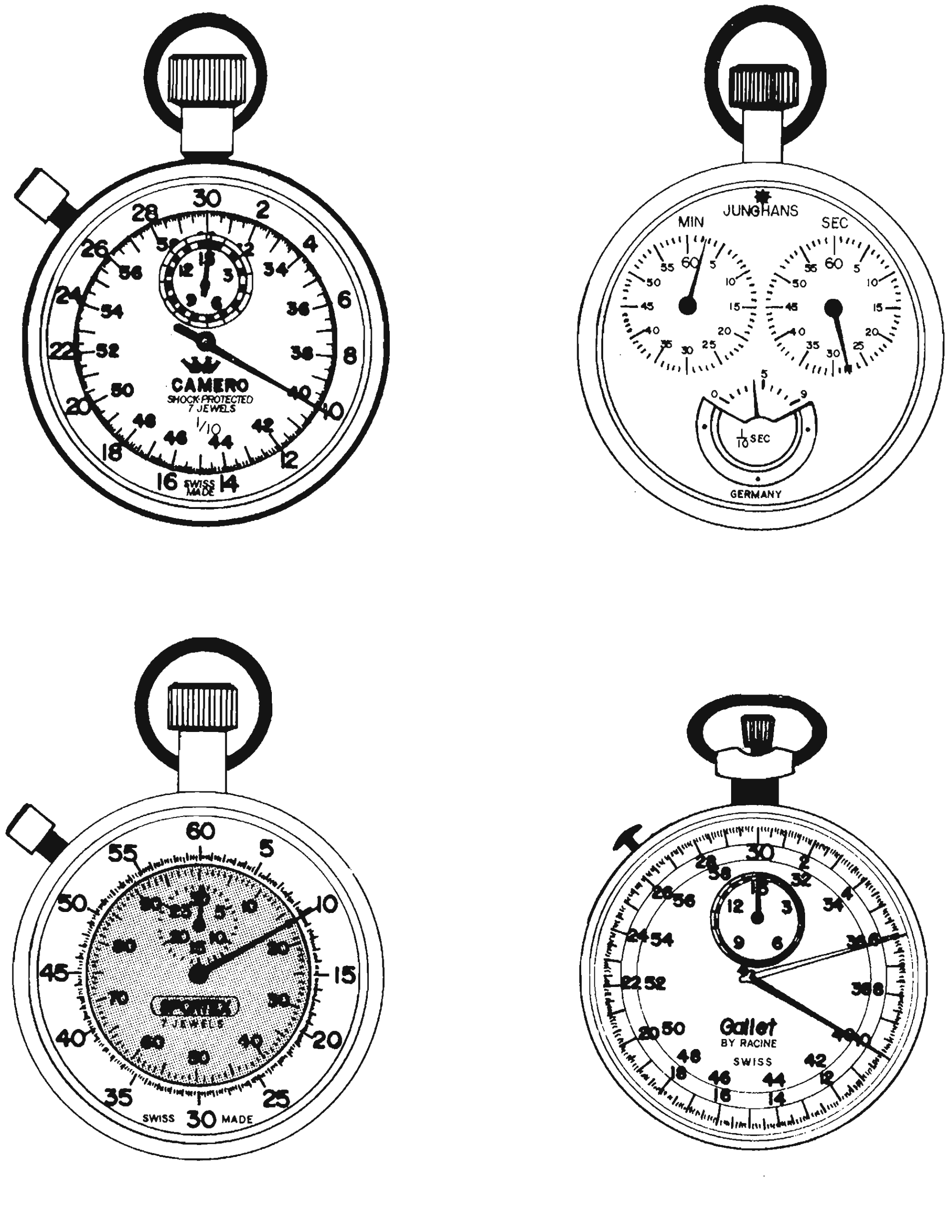

FIGURE 6.4 - MECHANICAL STOPWATCHES

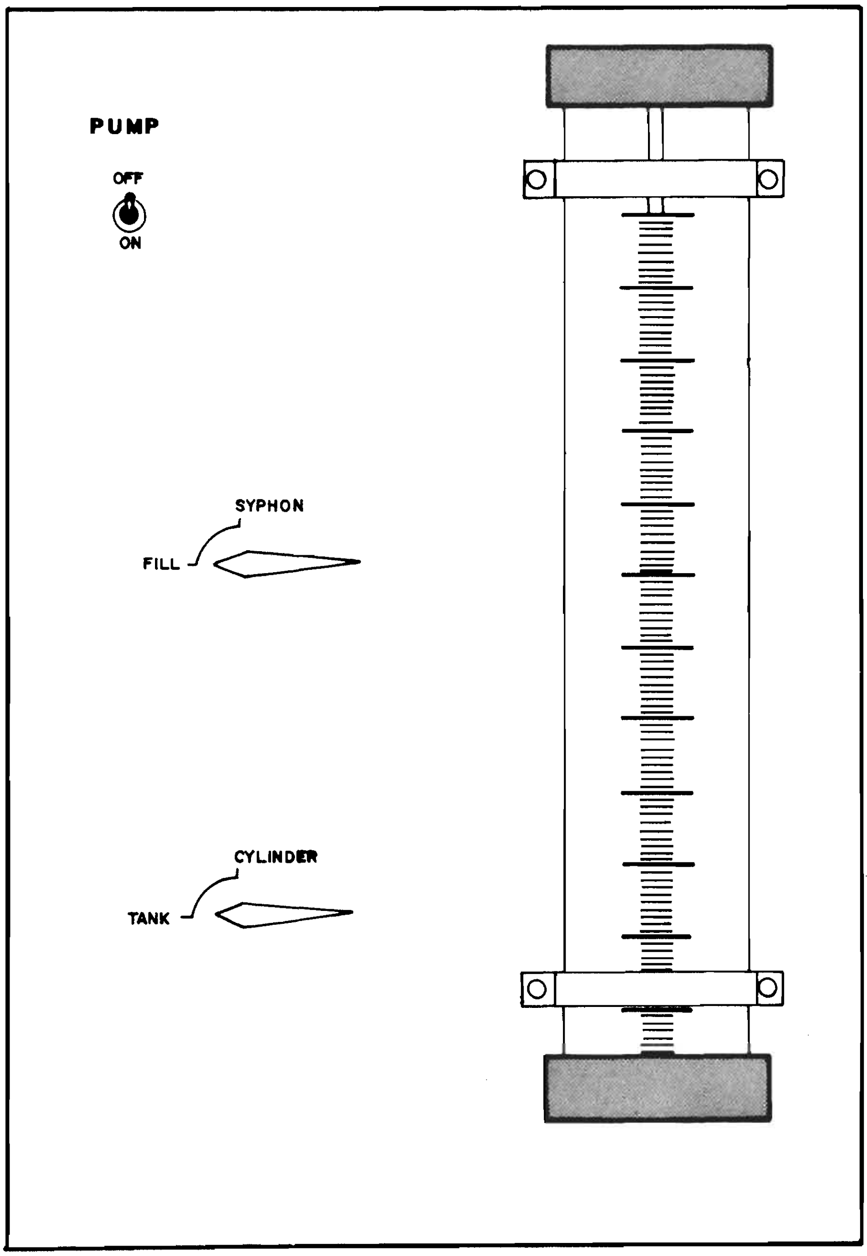

FIGURE 6.5 - GASOLINE SYSTEM PANEL

The vehicle was driven to the test site and the tire pressure measured on arrival. This ensured that the tires were warmed up. The vehicle was then loaded with the weight required for the test.

The driver made a trial run in the appropriate gear and designated speed for the first test. During this run the observer checked the DMI calibration. If the DMI was out of calibration, the vehicle DMI was calibrated on a measured road course.

At the test site, the vehicle was stopped before the test section to allow it to accelerate to the desired speed. The observer filled the fuel meter to a level slightly above the top mark on the scale and syphoned off the excess, leaving the fuel level at the correct starting point level. He then turned on the DMI and pressed the RESET and HOLD switches.

The driver accelerated to the desired speed and as the vehicle passed the starting mark, the observer released the HOLD switch on the DMI and it started measuring travel distance. When the DMI indicated 500 meters, the observer simultaneously started the fuel meter and stopwatch. At 1000 meters, he stopped one hand of the split second hand stopwatch. At the 1500 meter mark, stopwatch and fuel meter were simultaneously switched off. The vehicle stopped and the data recorded on the form shown in Table 6.1. Detailed descriptions of the field operation are covered in Project Technical Memos (Kaesehagen and Zaniewski, No. 5/76; Buller and Linder, No. 005/78).

6.2.3 *Recommended Maintenance Facilities (Fuel Meters Only)*

Electronics Technician
Mechanic
Volt-ohm meter
Hand tools

6.3 *THE VOLUMETRIC FUEL METERS*

These were commercial fuel meters and they were used to measure fuel consumption over distances greater than permitted by the capacity of the reservoir fuel meters. Two models of this type were used, the Fluidyne and the Columbia.

The Fluidyne is a very accurate, precision-machined, expensive instrument, which was quickly removed from service because it was damaged by contaminants normally found in the local fuel. It was not suitable for use in rugged environments.

The Columbia systems model was better suited for the project and the operational environment, but its resolution was much less than the Fluidyne. However, its cost was about one quarter of that of the Fluidyne and its lower precision construction allowed repairs to be made by the PICR team, rather than the manufacturer. The Columbia system consisted of a fuel filter, flowmeter, electro-mechanical digital readout unit and a diesel return-fuel tank. The major components are shown in Figure 6.6. A schematic diagram of the Columbia system is shown in Figure 6.7.

6.3.1 *Field Operation*

This is basically the same for both systems and consists of setting the display to zero or noting the reading displayed at the start of the measurement distance, driving the vehicle to the termination point and noting the final reading. The difference between these two readings is the amount of fuel consumed over the distance indicated on the Distance Measuring Instrument or the vehicle odometer.

The only difference between the two makes is that the Fluidyne readout unit must be reset whenever the engine is started and read before it is switched off. This can require that a series of readings be summed to obtain the total amount of fuel consumed over a long distance. The Columbia readout is unaffected by engine starts and stops.

6.3.2 *Accuracy*

Since this system has a digital readout, reading errors are eliminated and accuracy depends solely on the accuracy and resolution of the instruments used.

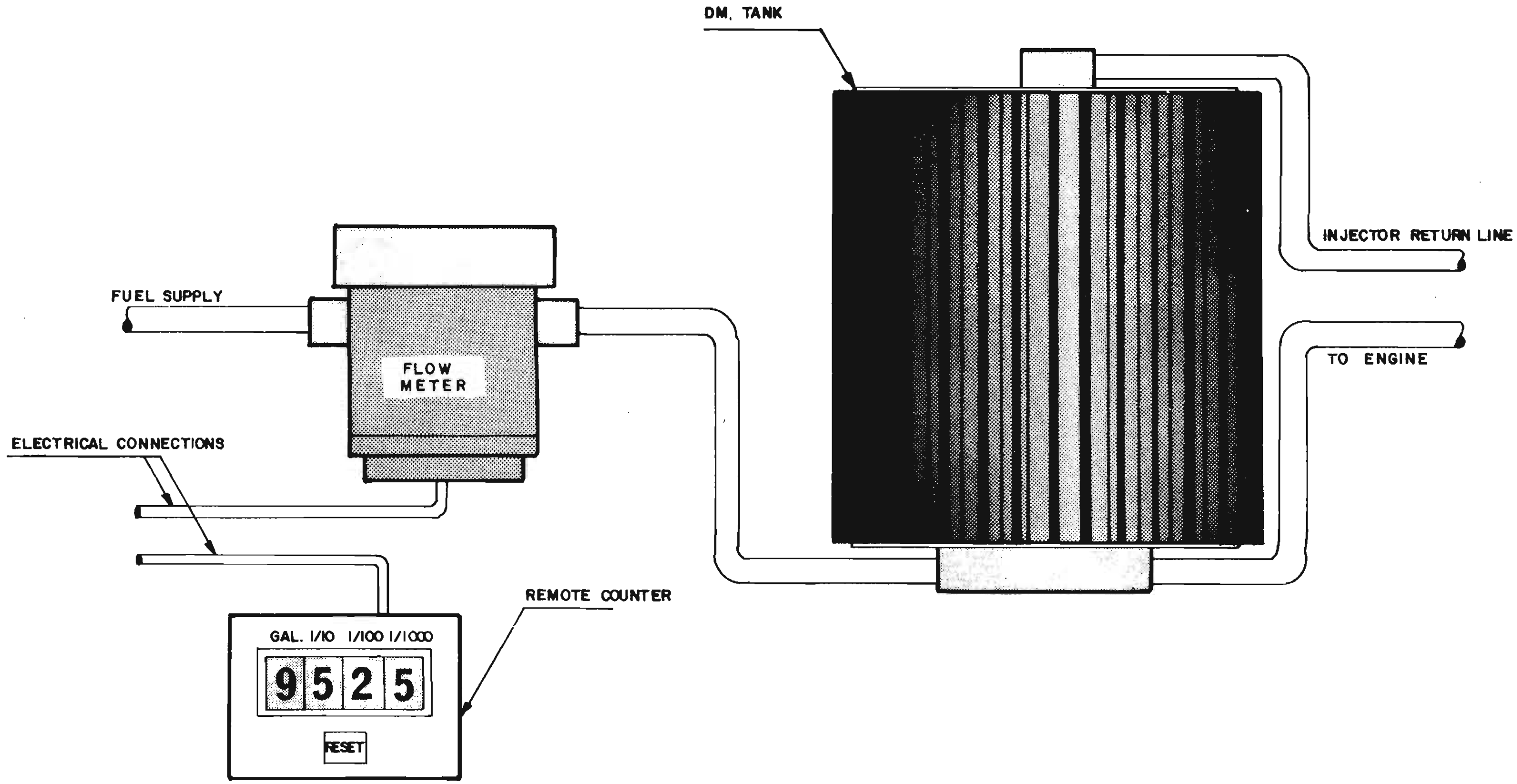

FIGURE 6.6 - COLUMBIA SYSTEM

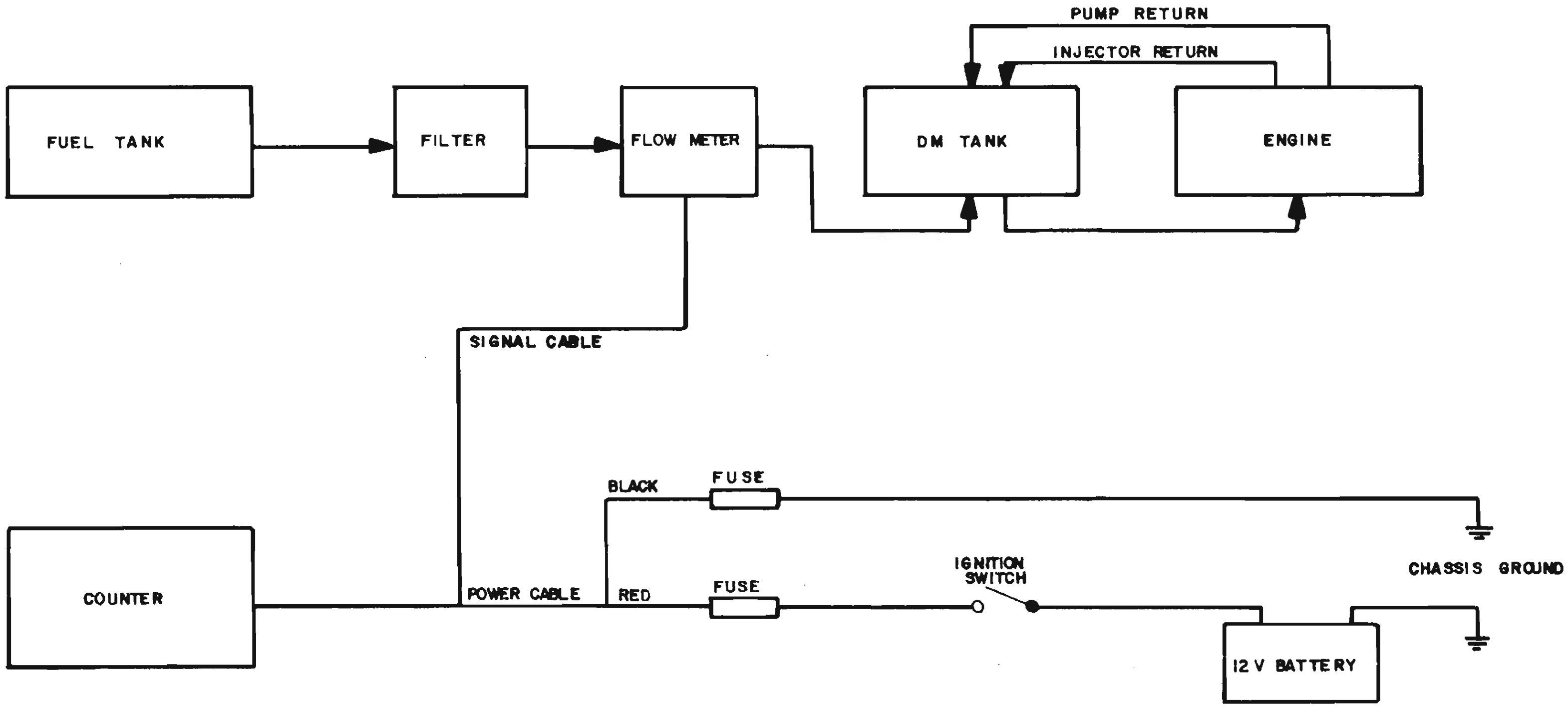

FIGURE 6.7 - COLUMBIA INSTALLATION DIAGRAM

The resolution of the Columbia fuel meter is 1/100 of a U.S. gallon for one model and 1/1000 of a U.S. gallon for a second model.

The resolution of the Fluidyne fuel meter is to a milliliter, the distance measuring instrument to 1/10 meter, and a vehicle odometer to 1/10 kilometer.

6.3.3 *Sources of Problems*

Initially, fuel pressure problems were encountered on some of the larger vehicles requiring a larger fuel pump to be fitted in place of the vehicle's existing pump. The 1300 cc Volkswagen never was able to use either fuel meter due to insufficient fuel flow. Every type of pump available was tried but none worked. Finally, a reservoir type fuel cylinder was installed on the VWs for long-range fuel measurement.

Air leaks at connection points occurred during installation causing inaccurate readings. These could have occurred again due to vibration, but did not during the short time the instruments were in service.