CHAPTER 3
THE SURVEY VEHICLE

3.1 INTRODUCTION

Two survey vehicles were constructed by the Measurement Instrument Group to measure rapidly, from a moving vehicle, roadway grade, horizontal curvature, distance and roughness. The general configuration of the instruments is depicted in Figure 3.1 and the instrument panel in Figure 3.2. Fabrication details for the survey vehicles are presented in a Project Instrumentation Memo (Linder *et al.*, "Design and Operation of the Instrumented Survey Vehicles"). The general specifications are shown in Table 3.1.

3.2 GRADE METER

The grade meter is a specially constructed instrument that uses a linear accelerometer shown in Figure 3.3 as a grade sensing device. Other types of grade sensing devices were evaluated. These included: an aircraft "artificial horizon" gyro dive/climb instrument, a spirit level, a ball level, a U-tube level, and several configurations of pendulums. None of these devices proved as accurate, easy to read, easy to construct, or as durable as the accelerometer. The "artificial horizon" showed promise at the outset, but due to fluctuations (which are normal for gyro instruments), it was finally rejected.

The ball level consisted of a one-meter radius section of glass tube with a steel ball suspended in a damping fluid. It was in use for a period but showed that even the slightest amount of impurity in the damping fluid would cause the ball to stick in its glass tube. The glass tube proved extremely difficult to construct. Of the twenty tubes built for the PICR by a professional glass worker, only two were usable . Even these two were not bent to a perfectly smooth curve, which caused the ball to move in a non-uniform manner at the deviant points in the tube. The ball level is a feasible, low cost, grade-measurement device if suitable construction facilities are at hand. This instrument is being successfully employed in Australia.

The pendulum, while a serviceable method, would have been too large and costly to construct. The accelerometer is also a type of pendulum, but its two cubic inch volume and ready-made mechanical and electrical features made it very easy to implement. All that was needed

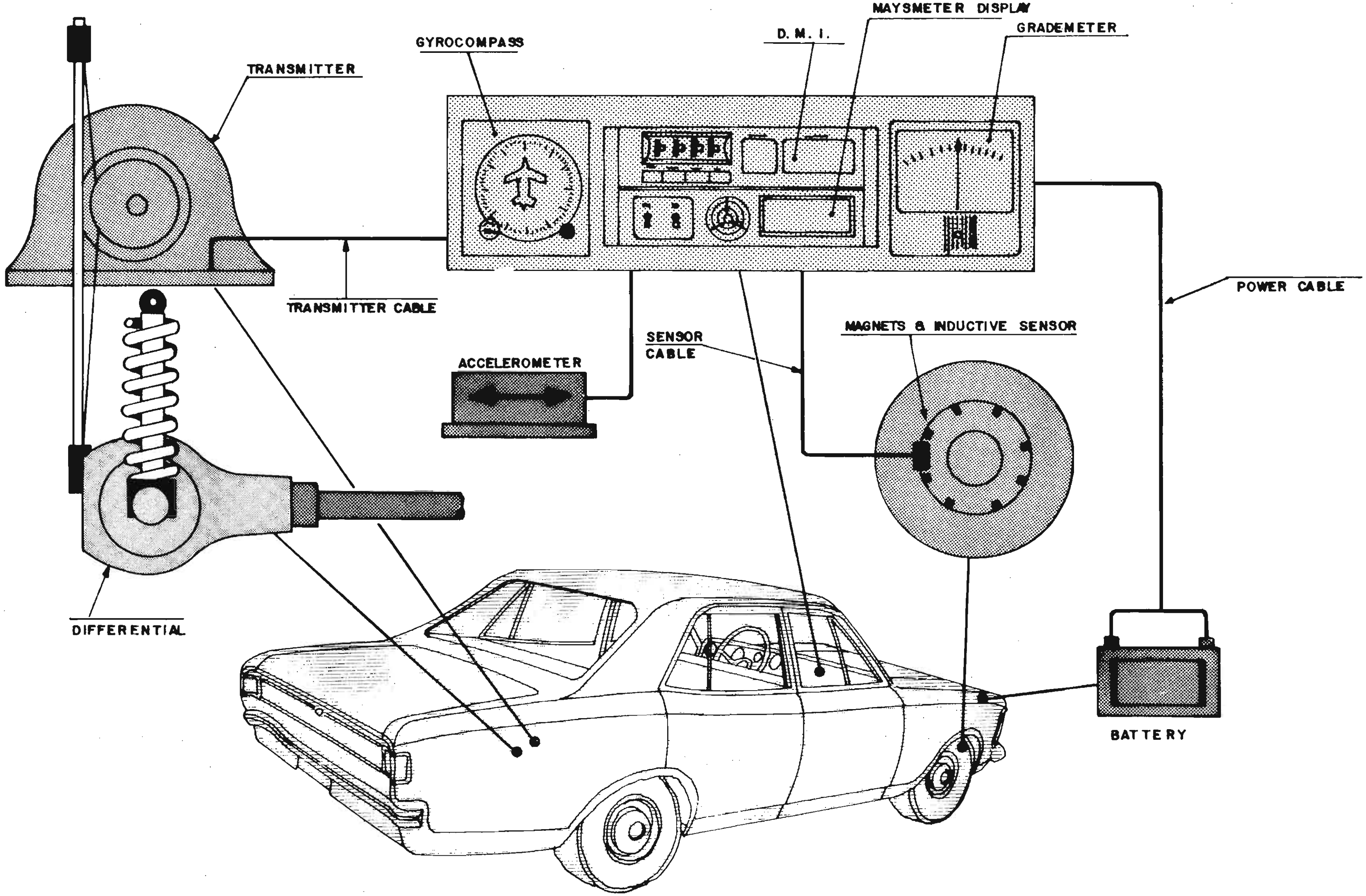

FIGURE 3.1 - SURVEY VEHICLE

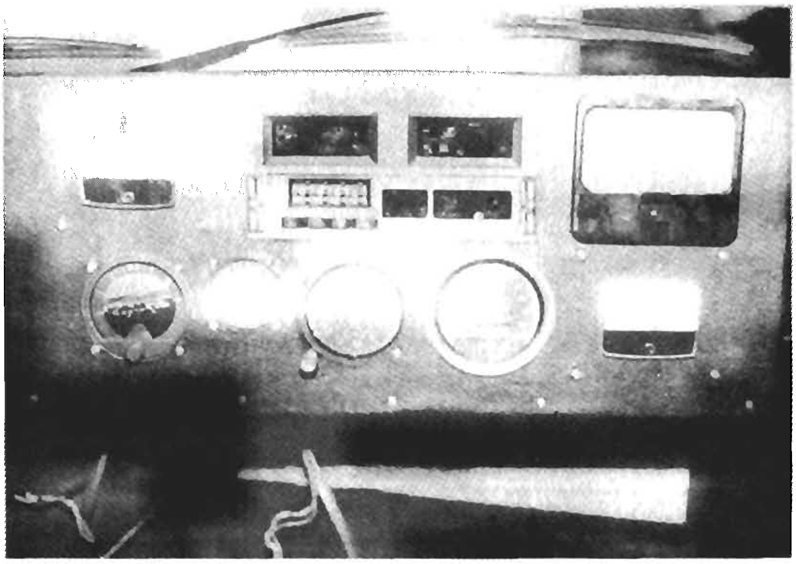

FIGURE 3.2 - SURVEY VEHICLE PANEL SHOWING DMI, MAYSMETER, GYROCOMPASS AND GRADE METER DISPLAY

TABLE 3.1 - SPECIFICATIONS FOR THE SURVEY VEHICLES

GRADE METER	
Resolution	± .25% grade units
Repeatability	± 10%
Power	7 VDC to 37 VDC
Damping	Infinitely adjustable
Output	± 12% grade panel meter
GYRO COMPASS	
Resolution	5° curvature
Repeatability	100% for practical purposes
Power: Pneumatic	1 7/8 cubic feet of air per minute 14 VDC
electric	14 VDC
Output	Rotating dial on instrument face
D M I	
Resolution	± 10 centimeters (depending on the number of magnets on wheel)
Repeatability	± 1 meter
Power	7 VDC to 37 VDC
Output	6 digit incandescent display
MAYSMETER	See Table 2.1, Chapter 2

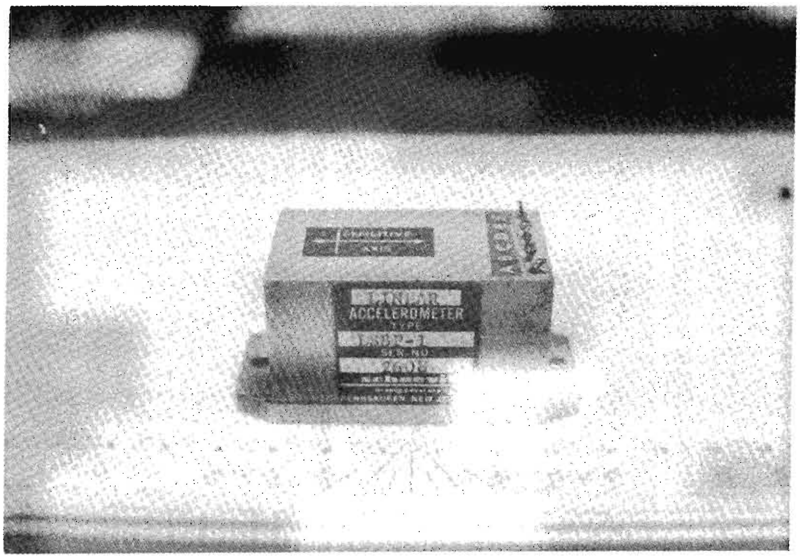

FIGURE 3.3 - ACCELEROMETER USED TO DETECT GRADE

to convert its output to a grade representation was a power source, a simple signal conditioning circuit and a panel meter. Figure 3.4 shows a block diagram of the survey vehicle. Figure 3.5 illustrates the panel meter. Vehicle construction details are presented in a Project Instrumentation Memo (Linder, "Accelerometer-Based Grade Meter").

The accelerometer grade meter is sensitive to vehicle speed changes. These accelerations act on the grade meter in the same manner as a change in grade. Electrical damping (infinitely adjustable) was added to the grade meter to eliminate short duration accelerations from road surface roughness. The long-term accelerations, due to vehicle speed drift, affect the grade meter output. This error depends on the magnitude of the vehicle speed drift and also on the road grade itself. The smaller the road grade, the greater the influence of the vehicle speed drifts. As an example, if the grade meter is operating on a 7% grade and the vehicle's speed changes uniformly by 5 kilometers per hour in 20 seconds, a 10% error will be introduced into the reading. Such a rapid speed change is not considered careful driving. Unlike purely mechanical instruments, the accelerometer grade meter does lend itself to error correction techniques.

A problem common to all vehicle mounted grade detection devices is "when to read the grade". If the vehicle is operating on a road with an extremely uneven surface, the vehicle will frequently be at a grade angle which is not representative of the average grade of the road. In such cases it must be left to the observer's judgement to determine points on the road which are suitable for measurement. The alternative is to take an enormous number of readings and average them. This method is not practical for high-speed survey techniques where the data is taken manually and reduced the same way. The accelerometer grade meter does lend itself to automatic data taking and reduction which could solve this problem.

3.3 *HORIZONTAL CURVATURE METER*

The horizontal curvature meter depends on an aircraft directional gyro compass. Two types were used, one pneumatically-driven and the other electrically-driven. The pneumatic model is less expensive and lasted through two and one-half years of use under severe environmental conditions. The electrical model should outlast the pneumatic

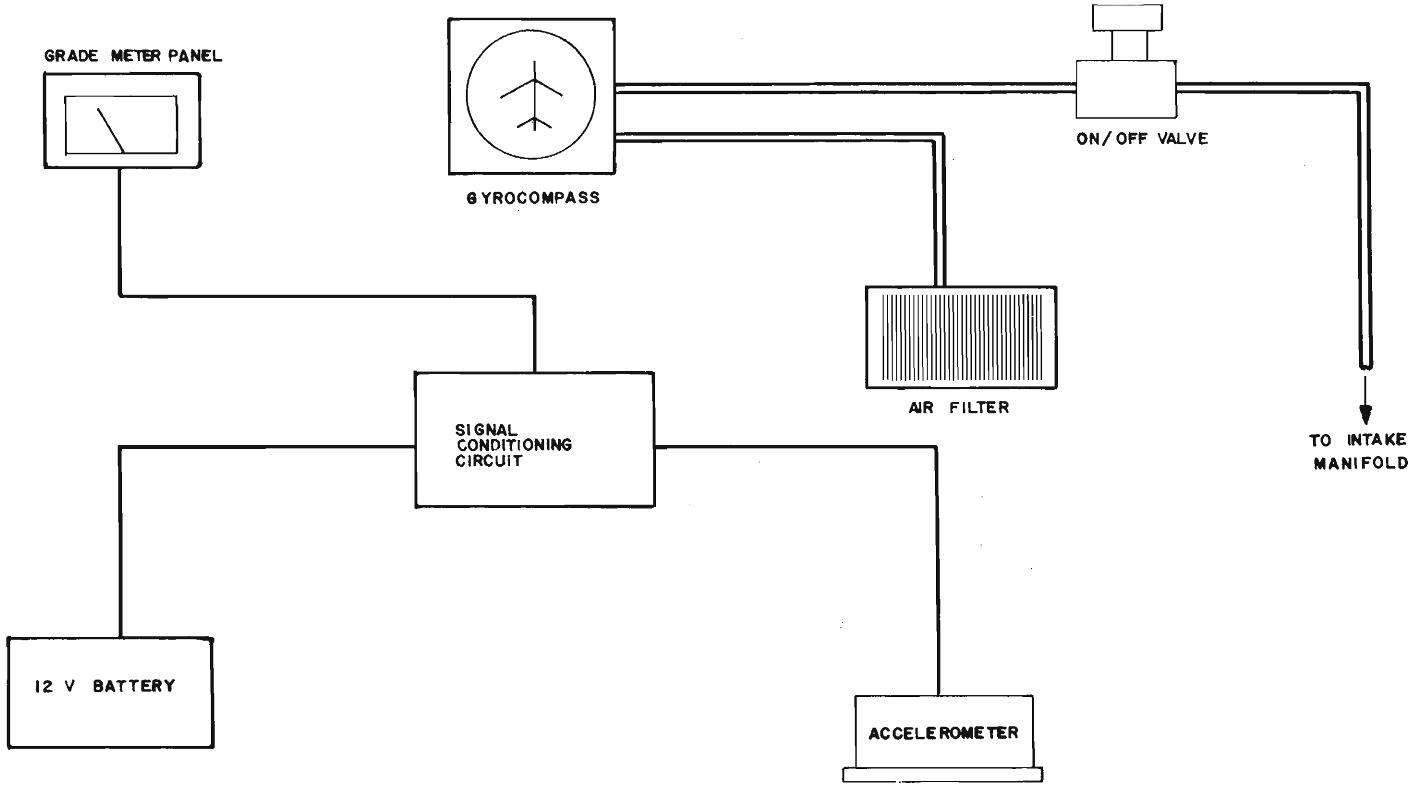

FIGURE 3.4 - BLOCK DIAGRAM - GRADE METER AND GYROCOMPASS IN THE SURVEY VEHICLE

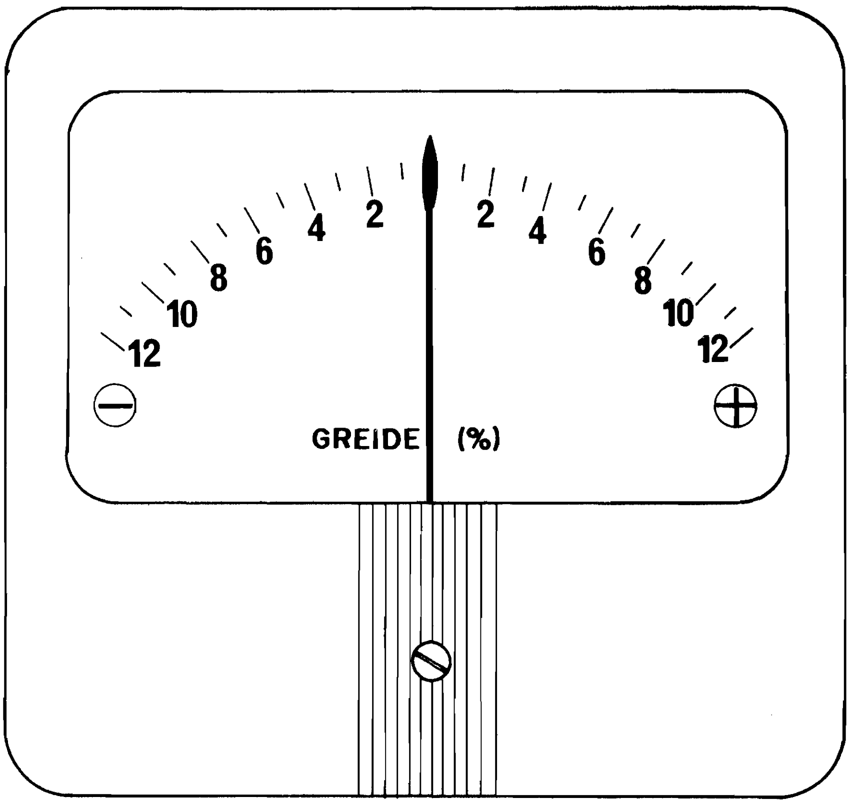

FIGURE 3.5 - GRADE METER DISPLAY

model several times over because it is sealed against dirt which is the major cause of the pneumatic's motor wear. However, the lower cost model is recommended based on project experience. Both units take about 15 minutes to reach operating speed after initial turn-on and exhibit the same long and short-term stability. The gyro compass was chosen because of successful use in Australia. No other direction detection devices were considered. The display of the gyro used in the project is shown in Figure 3.6. Further details on this device are presented in a Project Instrumentation Memo (Linder, "Directional Gyro").

3.4 DISTANCE METER

Road distance measurements were obtained using the DMI, a precise, low cost, electronic odometer. This device measures distance by converting revolutions of the front wheel of the vehicle into a digital display of distance travelled. Instrument reliability is primarily limited by the vulnerability of the wheel revolution sensing device. The front vehicle wheel is fitted with eight magnets. A magnetic sensor is mounted near the magnets, on the steering arm. These may be damaged by stones, road debris or by careless tire replacement. Some electrical problems did occur with the DMI's signal conditioning and display unit. The problems were easy to repair for a qualified electronics technician. The switches of the DMI wore quickly at the beginning of the project. This was caused by excessive use of the switches and by dirt in the dry season. The DMI is a part of the Maysmeter system. A detailed description of the DMI is presented in a Project Instrumentation Memo (Linder, "Distance Measuring Instrument - DMI"). The DMI panel is shown in Figure 3.7.

A mechanical odometer was tried and rejected because of mechanical lash-up problems, i.e., namely, the vehicle's speedometer drive cable is required to drive both the observer's odometer and the driver's speedometer. To gain accuracy, an adjustable ratio gear box is needed to correct the odometer drive speed. This additional strain, caused by the gear box and extra odometer, resulted in early failures of the drive cable. Although the mechanical odometer is cheaper, its resolution is much lower than the DMI's and it is more trouble-prone.

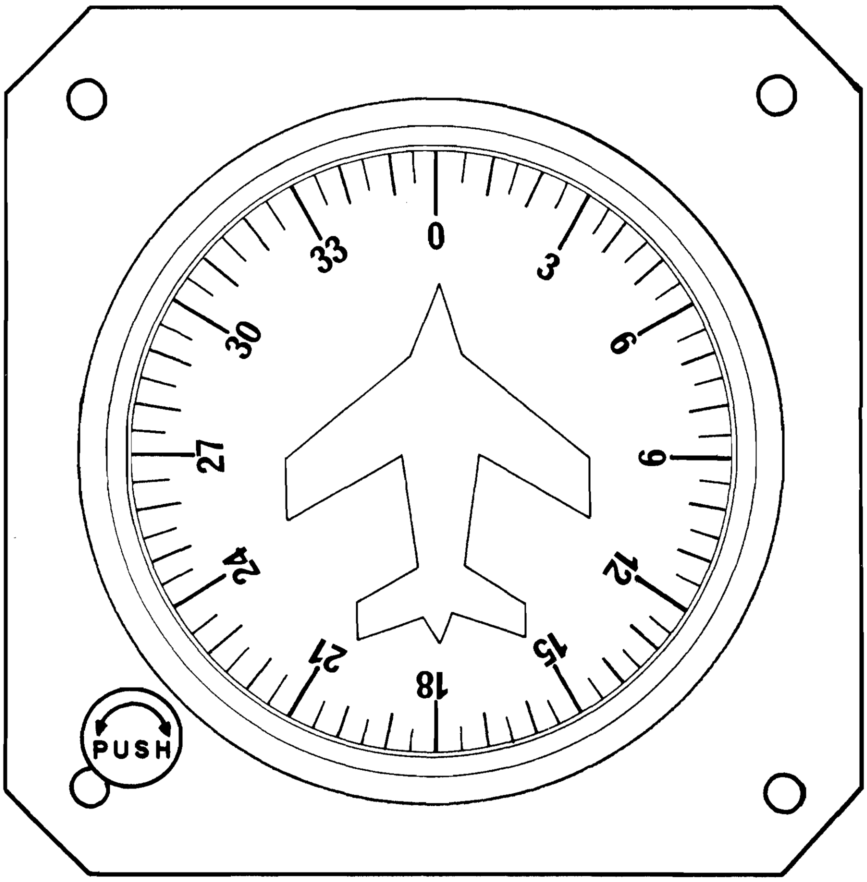

FIGURE 3.6 - GYROCOMPASS DISPLAY

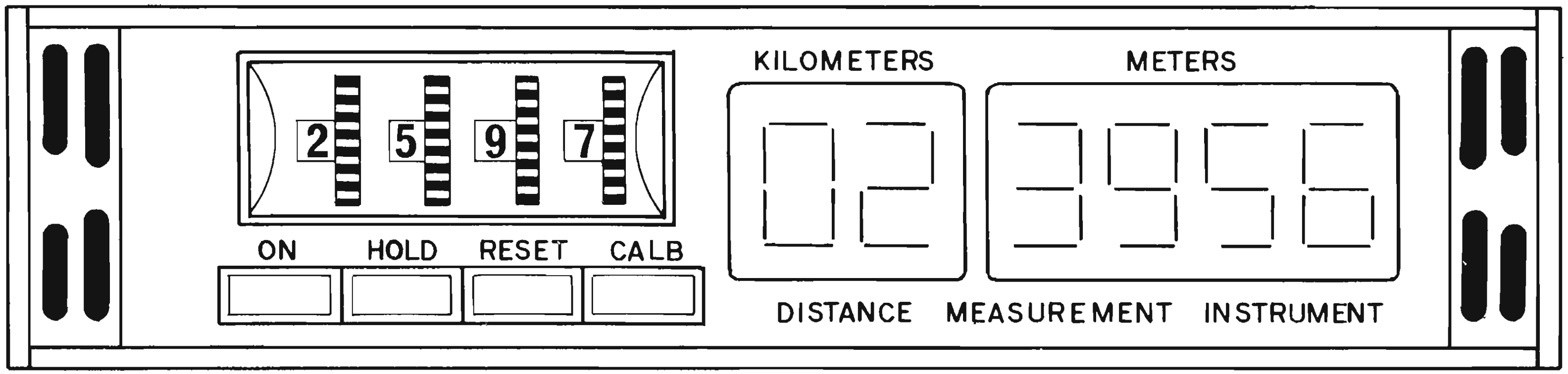

FIGURE 3.7 - DIGITAL ODOMETER (DMI)

3.5 *ROUGHNESS METER*

The road roughness measuring equipment is the Maysmeter system which was described in Chapter 2.

3.6 *FIELD OPERATION*

Good grade and roughness measurements require that the vehicle be operated at a constant speed. On grades, the actual speed is not important as long as it is kept constant. For the roughness measurements, the speed must be kept both constant and at a preselected standard speed. Constant speed is not required for horizontal curvature measure and distance measure, but in the case of curvature the speed must be slow enough to allow the observer time for his notations.

Accurate control of the vehicle is the responsibility of the driver. The skill necessary to drive in such a manner is not possessed by all individuals, so care is needed in selecting a driver who can perform satisfactorily. The observer requires no special skills. He should be a mature individual capable of assuming responsibility for the equipment and measurements. He must take the measurements and write them on the recording forms. His judgement concerning measurement conditions has a great impact on the quality of the recorded data. Ideally, the two crew members should be interchangeable to allow each a break from the routine.

Extracting data from instruments requires reading the display of the individual instrument and recording the numbers on a form. This task proved difficult on very rough surfaces because the grade meter pointer of the panel meter moved continuously. For roughness extremes, sections were run at a lower speed. The observer could not record all of the instruments in the survey vehicle simultaneously, so separate runs were required for geometry and roughness measurements.

3.7 *OPERATING PROCEDURES*

The grade meter is read and recorded as a grade is approached.

It is read and recorded again once the vehicle is well into the grade, and again at points on the grade. The horizontal curvature meter is read (it may be set right on a division mark if desired) just before the start of a curve, as is the DMI distance measure. Both are read again just after the end of the curve. The readings are recorded on the form shown in Table 3.2. Further description of the field use of the survey vehicle is outlined in a Project Technical Memo (Linder *et al.*, "Design and Operation of the Instrumented Vehicle").

3.8 MAINTENANCE

The horizontal curvature meters required no repairs, although the air filter on the pneumatic model needed changing at six-month intervals.

One grade meter required a new power supply unit. The other grade meter was fitted with a new panel meter after the original developed stiffness in its pivot bearing. This was very good service considering the harsh treatment that the equipment received.

Both vehicles were originally lightweight Chevrolet "Caravan" station-wagons. Both were eventually replaced with lightweight Chevrolet Opala passenger cars because of fractures in both station-wagon chassis.

3.9 RECOMMENDED REPAIR FACILITIES

One qualified electronics technician
One mechanic
Volt-ohm meter
Normal electronic hand tools
Normal mechanical hand tools

FICHA DE CAMPO - GEOMETRIA DOS LINKS

FOLHA ______ DE ______

FICHA Nº		LINK Nº						SEÇÃO DE CONTROLE		LEITURA DE ODÔMETRO				INFLEXÃO	DEFLEXÃO			SINAL + OU –	GREIDE			USO DA TERRA	PAVIMENTO	LARGURA DA PISTA			ACOSTAMENTO	LARGURA E ACOSTAMENTO		LARGURA TERRAPLA-NAGEM			ENTRONCA-MENTO
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
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DATA : ____ / ____ / ____
DIA MES ANO

OBSERVAÇÃO : ____________

CÓDIGO

INFLEXÃO : D-À DIREITA E-À ESQUERDA F-EM FRENTE
SINAL DO GREIDE : + , OU –
USO DA TERRA : R-RURAL U-URBANA
ENTRONCAMENTO : D-DIREITA E-ESQUERDA

X-CRUZAMENTO B-BULBO OU BALÃO
R-ROTA DESVIADA
PAVIMENTO / ACOSTAMENTO { P-PAVIMENTADO N-NÃO PAVIMENTADO S-S/ACOSTAMENTO

TABLE 3.2 - HIGHWAY SURVEY FIELD RECORD FORM