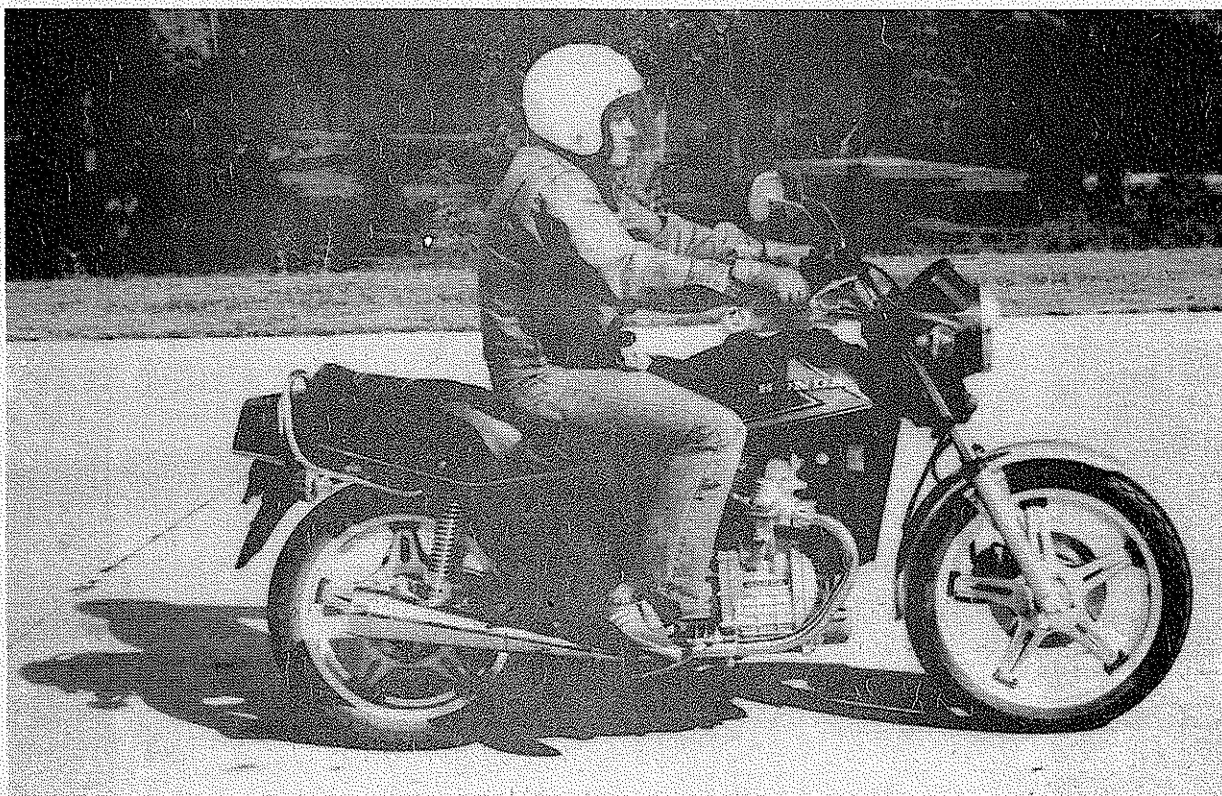
IOWA MOTORCYCLE RIDE METER



FINAL REPORT
PROJECT HR-1019

DEPARTMENT OF TRANSPORTATION
IOWA

Highway Division
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Disclaimer

FINAL REPORT

FOR

PROJECT HR-1019

IOWA MOTORCYCLE RIDE METER

BY

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TABLE OF CONTENTS

IOWA MOTORCYCLE RIDE METER

INTRODUCTION

The Iowa Department of Transportation (Iowa DOT) through the Highway Division is responsible for the design, construction and maintenance of roadways that will provide a high level of serviceability to the motorist. First, the motorist expects to be able to get where he wants to go, but now he also demands a minimum level of comfort. In the construction of new roadways, the public is quick to express dissatisfaction with rough pavements.

The Highway Division of the Iowa DOT (formerly Iowa State Highway Commission) has a specification which requires a "smooth-riding surface". For over 40 years, new portland cement concrete (pcc) pavement has been checked with a 10-foot rolling straightedge. The contractor is required to grind, saw or mill off all high spots that deviate more than 1/8" from the 10-foot straight line. Unfortunately, there are instances where a roadway that will meet the above criteria does not provide a "smooth-riding surface". The roadway may have longer undulations (swales) that result in an undesirable ride.

EARLY RIDING QUALITY TEST UNITS

The Iowa DOT built a BPR Roughometer in 1953 to evaluate the riding quality of pavement. It demonstrates relatively good repeatability and resolution and is still being used today. The mechanical parts, 20 MPH testing speed and need for external calibration are definite disadvantages.

A CHLOE profilometer, developed at the AASHO Road Test, was purchased in 1964. It is repeatable, has a high degree of resolution and is not dependent on an external calibration. The 3 MPH test speed is a major limitation. The CHLOE has been accepted as the standard for riding quality test units in Iowa.

ROAD METER DEVELOPMENT

The Portland Cement Association (PCA) Road Meter was developed by Max Brokaw in April, 1965.[1] The Road Meter is a rapid, simple and inexpensive method of determining the riding quality of a roadway. The Iowa DOT built three PCA Road Meters in 1967[2] and conducted a statewide inventory of 10,000 miles (20,000 lane-miles) of primary roadway. Several modifications were made[3] to improve the Road Meter, including a transistorized circuit to protect the segmented contact board from counter coil breakdown.

The Iowa Road Meters were outfitted with a null-seeking device developed by Max Brokaw[4] to alleviate the adverse effect of wind. Even the null-seeking device did not adequately compensate for the wind.

In 1970, after three years of road metering experience, the program was reviewed for possible improvements. Most problems seemed to relate to the wind effect on the car body.

The Iowa-Johannsen-Kirk (IJK) Ride Indicator,[5] a mechanical accelerometer, (Figure 1) developed in the Iowa State Highway Commission Materials Laboratory in 1971, is attached to the rear differential of a standard automobile. After demonstrating a higher correlation with the CHLOE and less wind effect, the IJK Ride Indicator was adopted for the highway inventory program in 1974 and has been used through 1979.

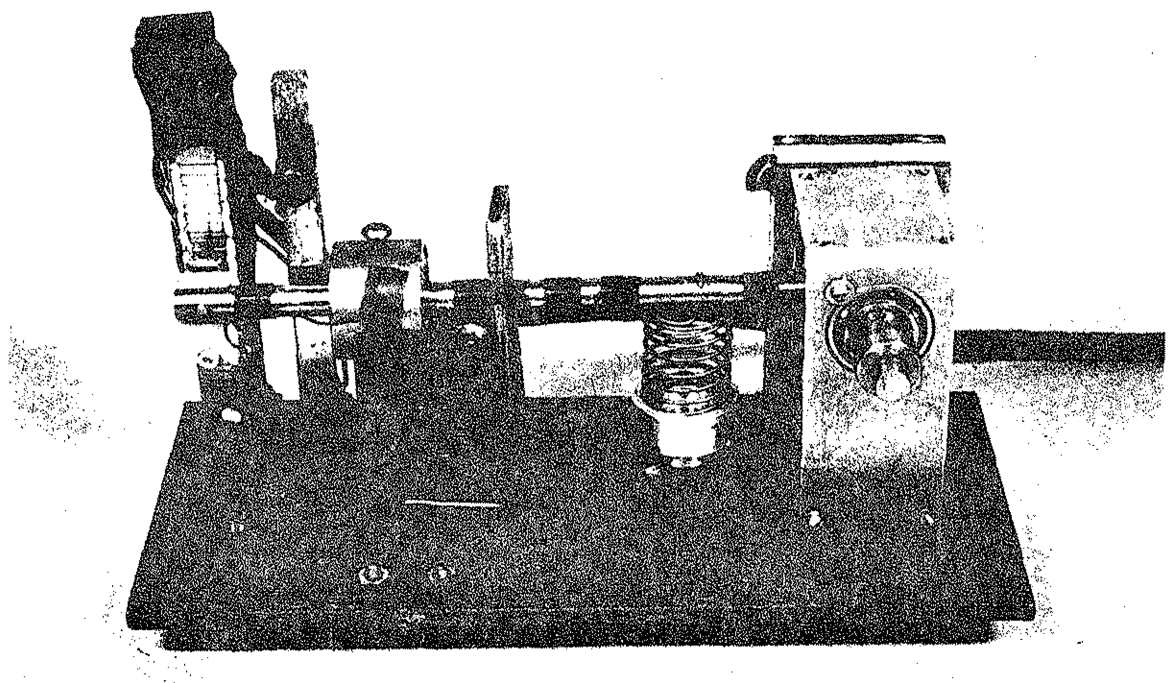

Figure 1: Overall View from Segment Board Side of IJK Ride Indicator Unit

OBJECTIVE

The objective of this project was to develop a repeatable, reliable time stable, lightweight test unit to measure the riding quality of pcc pavement at normal highway speed the day after construction.

ACCELEROMETER CONCEPT

The IJK Ride Indicator is essentially a mechanical accelerometer with electrical contacts for data collection. It has proven the accelerometer concept for evaluating riding quality. A desirable goal is to eliminate mechanical parts and reduce maintenance.

There have been tremendous advances in the electronics of both data reduction (microprocessors) and accelerometers. The accelerometers are more precise, more durable and much smaller making them more versatile.

All previous road meter units were to operate at a constant speed while obtaining riding quality data. In theory, if the output from a commercially available accelerometer is properly processed, the resulting value would be independent of testing speed. A microprocessor would double integrate the analog signal to change the output from vertical acceleration to vertical displacement (Figure 2). This resultant displacement would then be summed (both positive and negative) and divided by the distance traveled by the test vehicle.

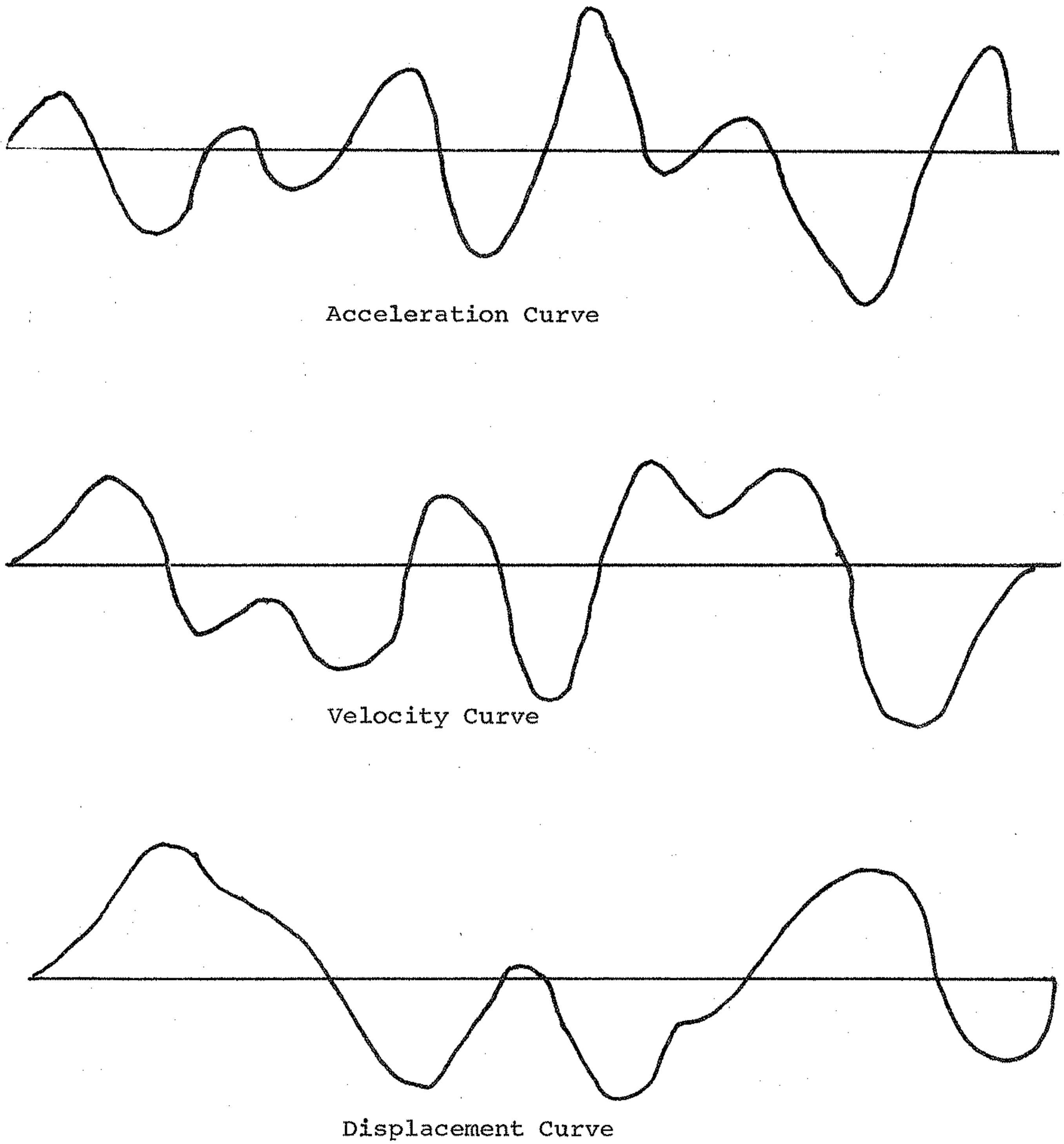

Figure 2. Graphic Example of Signal Processing

RIDE METER DEVICE

Accelerometer

A very important step was the selection of the commercial accelerometer. There was apparently no one in the Iowa DOT who had previous experience with accelerometers. A number of manufacturers and university personnel were contacted to gain information on which to base our selection. The suggested criteria were:

1. A frequency range between 2 and 30 Hertz
2. High sensitivity
3. Durability to withstand high levels of shock

The accelerometer selected was a piezontronic Quartz accelerometer (Appendix A) with a sensitivity of 50 mV/g, a frequency range of 1 - 3000 Hertz and a maximum shock of 10,000 g. The accelerometer is very small, measuring only .75 inch by 1.07 inch. A magnetic mounting base was purchased for our application.

Electronics

After the accelerometer had been selected, the next step was to determine the method of data reduction. A simple block diagram of the ride meter is given in Figure 3. There are a number of methods that may be used to double integrate an analog signal. In the method for our use, the analog signal is first amplified, then integrated and frequencies above 50 Hertz are filtered out. In the next electronic operation, it is converted

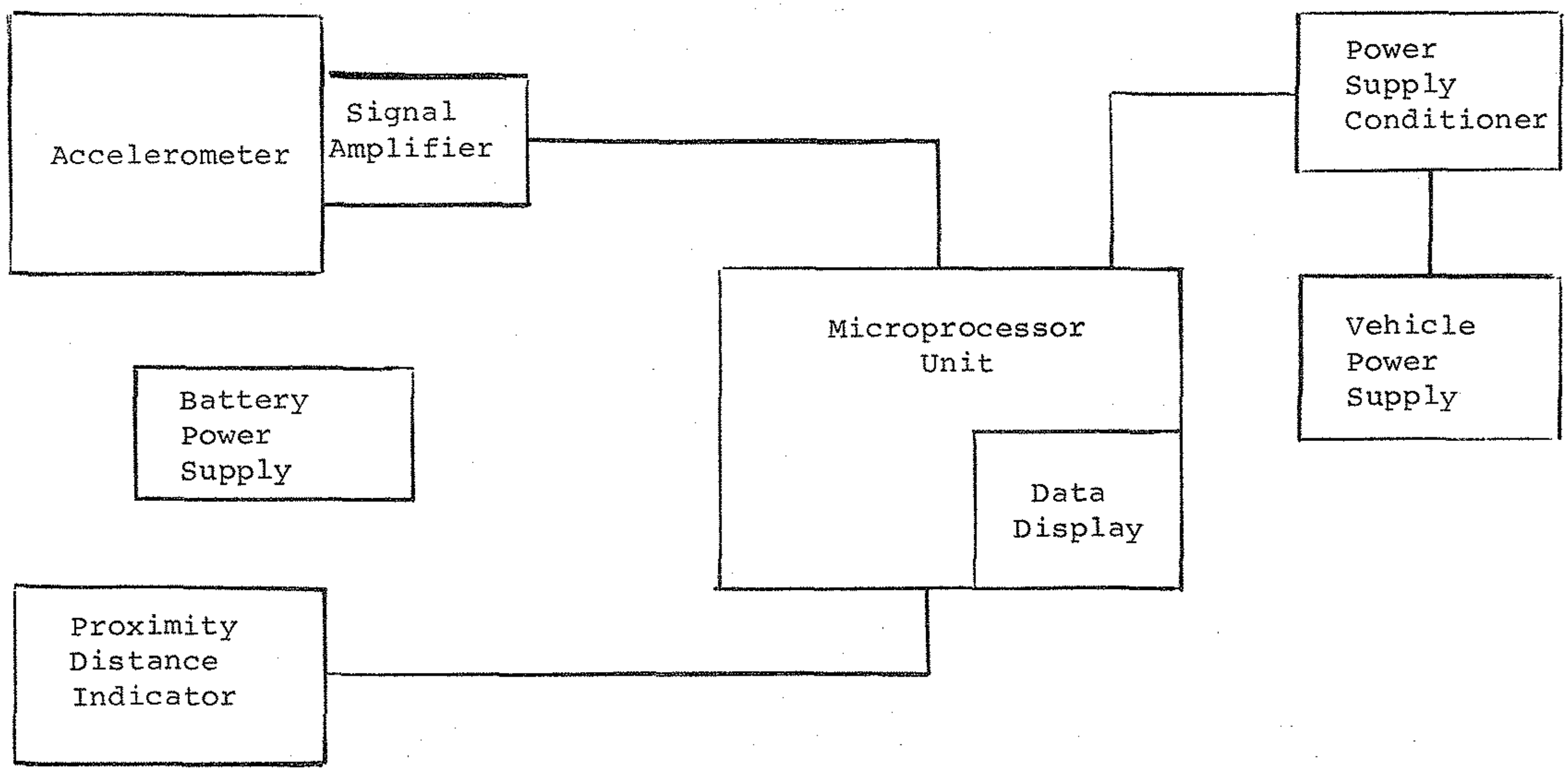

Figure 3: Block Diagram of Iowa Ride Meter Device

to direct current and rectified to yield an entirely positive output and a digital output relative to the D.C. voltage level is generated. The electrical schematic is given in Appendix B.

Distance Counter

A magnetic proximity switch was used to generate an electrical signal to an electromechanical counter. The magnet was fastened to the hub of the rear motorcycle wheel with the switch mounted on a special bracket.

MOTORCYCLE RIDE METER

Motorcycle Selection

The first trials of the ride meter unit were conducted on an employee owned 1972 model 450 CL Honda motorcycle. The signal amplification was altered to yield digital outputs per mile of about 100 for very smooth test section to 5000 for very rough sections. The repeatability was very good with count variations generally in the range of ±5%.

The operator conducting the research had access to a shaft driven motorcycle that, in his opinion, was a much "smoother" riding machine with fewer vibrations than the chain drive model. In an effort to give the ride meter every opportunity to be successful, a 1979 Honda CX 500 shaft driven motorcycle (Figure 4) was leased from a local dealer. Subsequent testing showed very little change in the output due to the change in motorcycles.

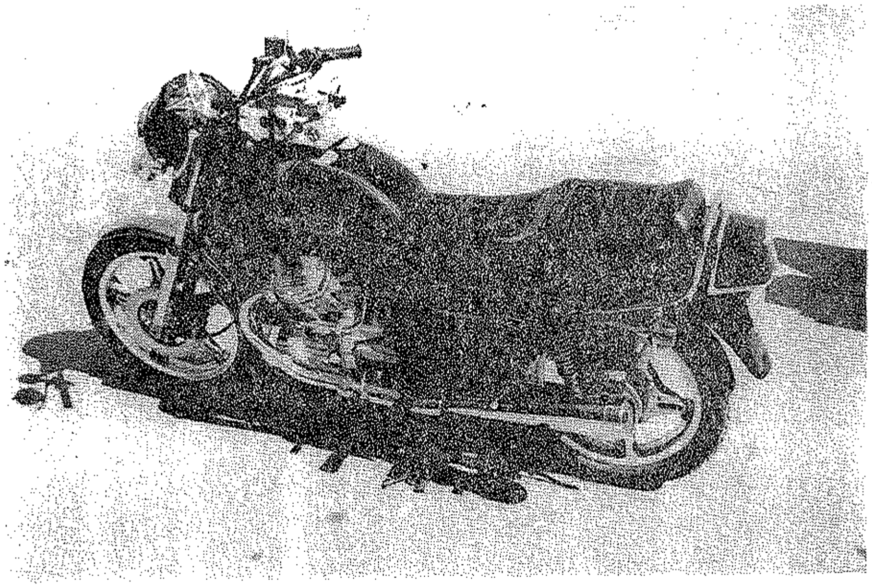

Figure 4: Honda CX 500 Test Vehicle

Mounting of Equipment

The accelerometer was magnetically mounted on a bracket attached to the rear axle (Figure 5). This mounting position was selected to prevent the pick up of other vibrations and to obtain the vertical displacement prior to dampening by a spring-shock absorber system. The mounting was relatively close to the exhaust pipe, but there seemed to be very little heating of the accelerometer. No adverse effects were noted.

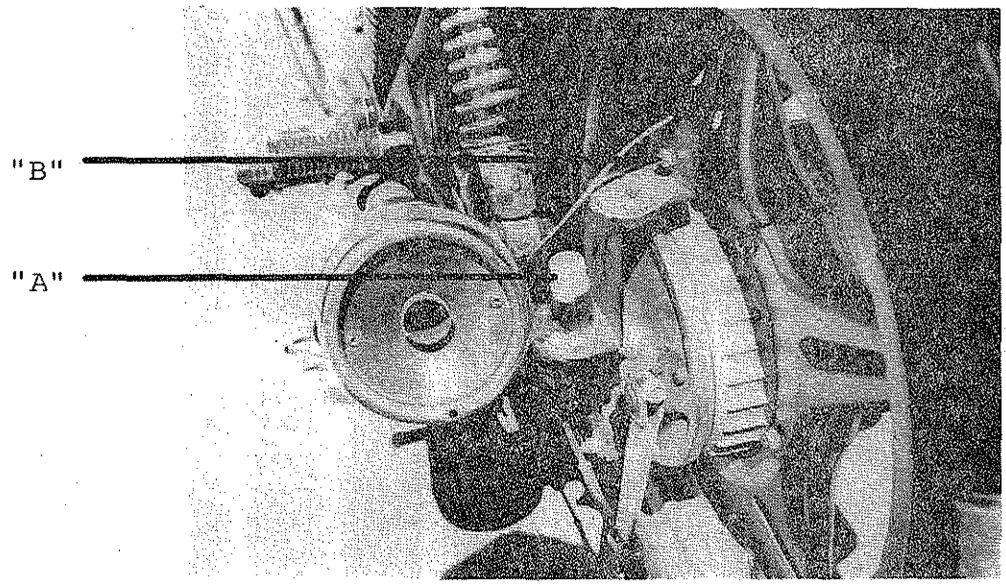

Figure 5: Mounting positions of "A"-Accelerometer and "B" Proximity Switch for measuring distance

The electronic package was mounted on the gas tank and supported on rubber suction cups (Figures 6 & 7). An elastic rubber strap was used to secure the console.

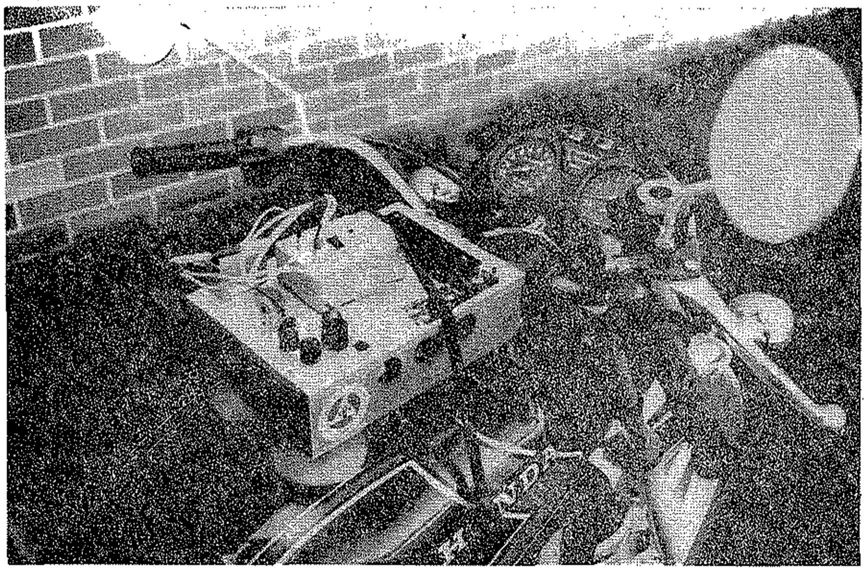

Figure 6: Electronic Console Strapped to the Fuel Tank

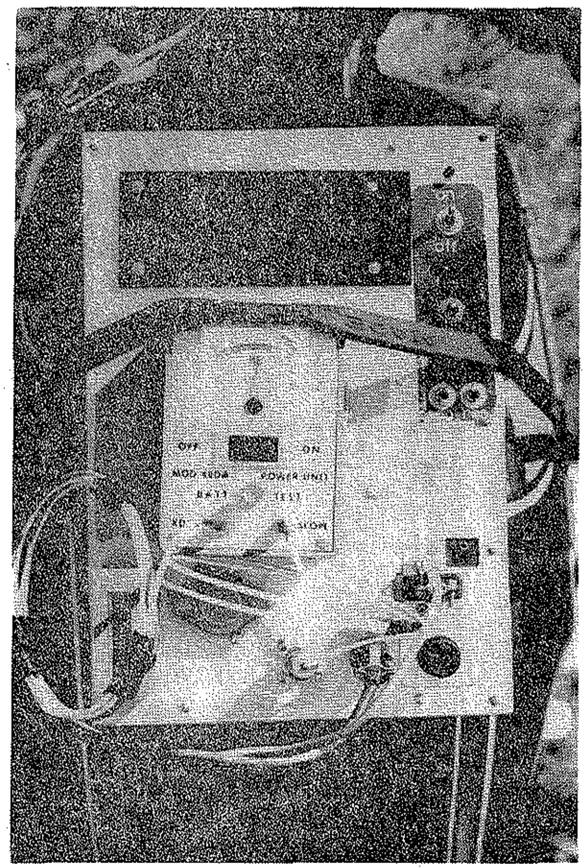

Figure 7: Close up of Electronic Console

General Operation

Prior to testing, the electronic operation was checked by means of an internal electric impulse for 30 seconds. A 30 second count of 2260 ± 10 would verify that the device was functioning properly.

The motorcycle was normally operated at a testing speed of 50 MPH. After turning "on" both the accelerometer amplifier and the electronic console, the unit was operated with a "run-stop" and a "reset" switch.

CORRELATION OF THE RIDE METER

The motorcycle ride meter was correlated with the CHLOE Profilometer on 47 pcc pavement test sections (Appendix C) with Present Serviceability Indexes ranging from 2.4 to 5.0. At 50 MPH, the correlation coefficient was 0.944. At 20 MPH, a correlation coefficient of 0.973 was obtained.

EVALUATION OF RIDE METER

Warm Up

The electronics personnel recommended a five-minute warm up period for the D.C. output to stabilize. From previous road meter experience, a vehicle warm up period is needed to bring the tires and suspension system to a stable condition. There were two specific instances in repeatability testing where an insufficient warm up period was used and some of the first readings were much too high. This may have been due to insufficient tire warm up. From these instances, it appears that a minimum of 15 miles at normal highway speeds are required for warm up.

Repeatability

Much of the time when testing an exact longitudinal line, resultant values would repeat within a ±1% range. Even during an effort to test an exact line, there would be a few erractic results and some variations in the range of ±5%.

Tire Pressure Variation

Testing was conducted to determine the effect of variation in the the tire pressure of the rear wheel. Numeric outputs were determined on six different test sections of varying levels of roughness at standard tire pressure (25 psi), 19 psi, 22 psi,, 28 psi and 31 psi. The variation in numeric output is dependent on the roughness characterisitic of the roadway, but in general, numberic output is directly related to change in tire pressure. An increase or decrease of 3 psi results in approximately a 5% change in output. A change of 6 psi results in an output variation of approximately 10%.

Motorcycle Load Variation

A limited number of tests were made to determine the effect of motorcycle load on numeric output. This was accomplished by the addition of a second rider (180 lbs) for the second series on six test sections. This additional weight reduced the output by 23%. Further evaluation will be needed in this area because of the surprisingly large influence of additional weight.

Speed Variation

Testing at 50 MPH and 20 MPH for the correlation with the CHLOE (Appendix C) exhibited substantial decrease in output at 20 MPH. The present design is therefore very speed dependent. This is very disappointing as there would be a number of advantages if the design could be altered to more closely duplicate the theory that double integration of acceleration results in vertical displacement.

RECOMMENDATION FOR FURTHER DEVELOPMENT

At least one additional accelerometer should be purchased to determine if a different sensitivity or frequency range would reduce the influence of variables and improve the relationship of actual results and theory on resultant vertical displacement.

CONCLUSIONS

Based on the correlation with the CHLOE Profilometer, the motorcycle ride meter has demonstrated a potential for being used to measure the riding quality of pcc pavement at normal highway speed the day after construction. The results have shown that additional developments are necessary to resolve the influence of variables.

ACKNOWLEDGEMENT

We wish to express our appreciation to Robert Pink, Richard Rahto and David Fenske of the Iowa DOT for the design and assembly of the electronics. We would further like to thank Jim Adams of Ames Honda for his cooperation in leasing of the motorcycle.

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2. Bunnag, Anuphan, "Iowa State Highway Commission's PCA Type Road Meter," 1967.

3. Pradubjew, Derek and Marks, Vernon, "Road Meter Modifications and Improvements" 1970.

4. Brokaw, M.P., "Developed of an Automatic Electromechanical Null-Seeking Device for the PCA Road Meter," Highway Research Board Special Report 133, 1973.

5. Marks, Vernon J. "The IJK Ride Indicator" 1976.

SPECIFICATIONS

MODELS 308B and 308B03

QUARTZ ACCELEROMETERS WITH BUILT-IN AMPLIFIERS

MODEL NO.		308B	308B03
SENSITIVITY	mV/g	100	50
RESOLUTION	g	.002	.004
RESONANT FREQUENCY, MOUNTED	kHz	25	25
FREQUENCY RANGE, ±5%	Hz	1-3000	1-3000
OVERLOAD RECOVERY	uSec	10	10
DISCHARGE TIME CONSTANT	Sec	.5	.5
AMPLITUDE LINEARITY	%FS	1	1
RANGE FOR ±5V OUT	±g	50	100
OUTPUT IMPEDANCE	Ohms	100	100
OUTPUT BIAS	Volts	11	11
TRANSVERSE SENSITIVITY	%	7	7
STRAIN SENSITIVITY	g/u in/in	.05	.05
TEMPERATURE SENSITIVITY	%/°F	.03	.03
TEMPERATURE RANGE	°F	-100 to +250	-100 to +250
VIBRATION, MAX.	g Peak	5000	10000
SHOCK, MAX.	g	5000	10000
SIZE (HEX X HEIGHT)	in.	.75 x 1.32	.75 x 1.07
WEIGHT	gm	87	55

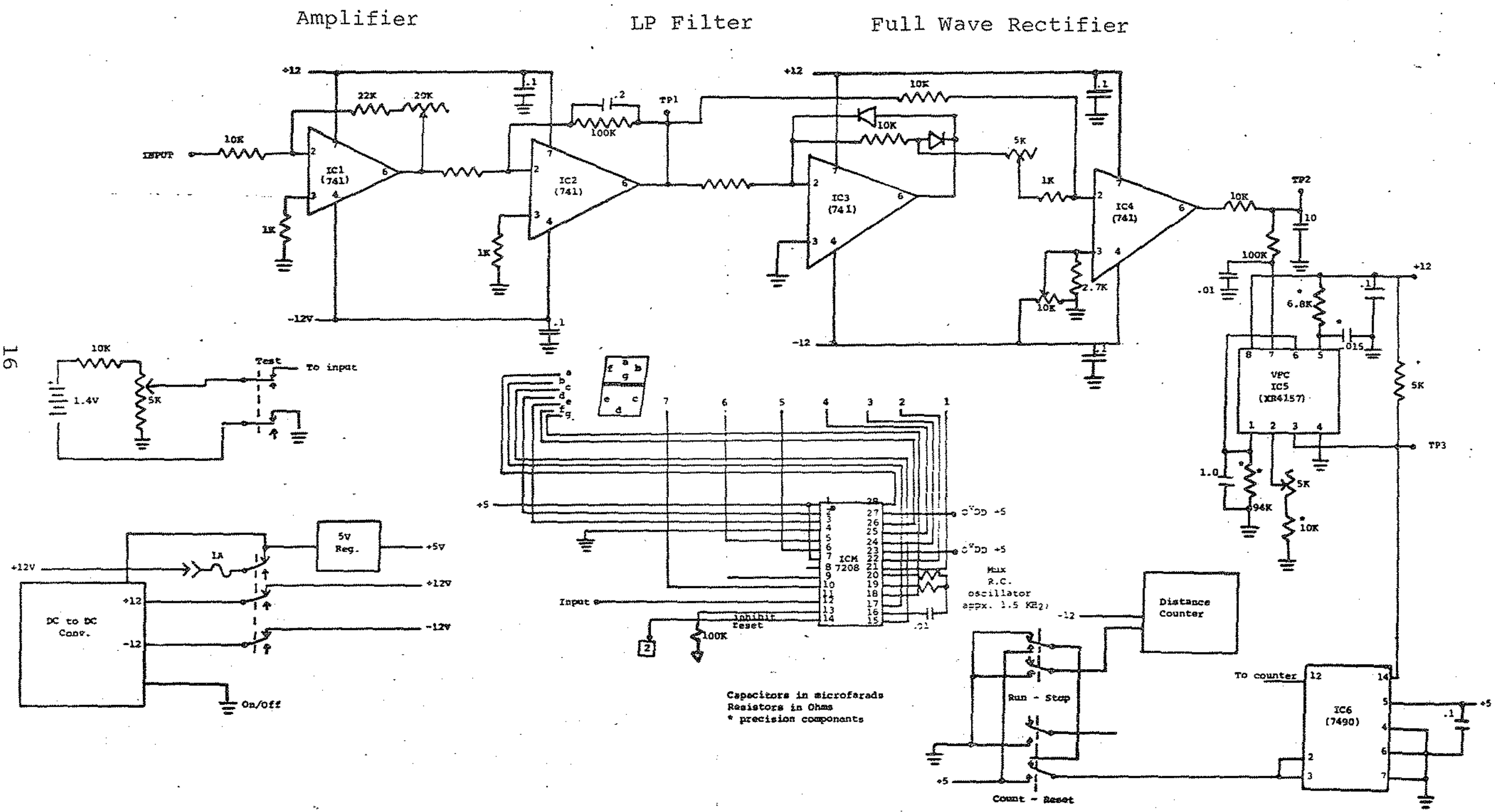
		These specifications common to both models.
STRUCTURE		Iso-compression, upright
CONNECTOR		10-32 Microdot, coaxial
CASE MATERIAL		SS/Al Alloy
SEAL		EPOXY
POWER SUPPLY VOLTAGE	Volts DC	+18 to +24
POWER SUPPLY CURRENT	mA	2-20 mA thru current regulating diode

ELECTRICAL SCHEMATIC

For

RIDE INDICATOR

Appendix B



Appendix C - CORRELATION WITH CHLOE

Section	CHLOE	Honda 50 MPH	Honda 20 MPH
1	4.84	232	47
2	5.60	141	93
6	47.02	5405	5108
9	42.18	5318	5263
11	9.56	1092	-
12	10.02	759	-
13	8.36	885	-
14	9.31	869	-
21	10.79	641	234
22	11.50	572	181
23	9.78	564	140
24	9.36	638	217
26	10.47	1054	462
27	12.33	1035	277
28	9.55	836	283
29	12.56	1256	309
38	21.48	4101	921
39	26.92	4463	1748
40	21.41	3380	1464
41	27.24	5517	1860
44	3.68	195	28
45	5.07	161	-
46	5.08	160	6

Section	CHLOE	Honda 50 MPH	Honda 20 MPH
47	4.16	156	18
48	8.69	446	117
49	6.11	156	122
51	7.37	361	68
52	7.08	368	121
53	5.16	284	22
54	4.81	213	44
55	6.22	222	26
56	13.75	1097	389
57	11.84	817	429
58	12.38	894	220
59	12.33	895	171
60	11.08	875	398
61	13.84	962	326
62	11.60	770	259
63	13.10	1129	401
64	4.57	49	38
65	4.28	114	48
66	4.92	98	-
67	4.07	100	32
68	21.52	2201	653
69	22.00	2341	1070
70	22.78	2794	1031
71	25.31	3013	1123