CARDINAL QUARTZ SENSOR IN-MOTION WEIGHING

This document provides a brief description of the quartz sensor used in Cardinal QWIM series high-speed in-motion vehicle scales. The sensor used in this scale series is manufactured by Kistler as their Type 9195 and is protected under one or more United States and foreign patents. The quartz sensor consists of an extruded metal frame supporting multiple pre-loaded quartz elements. The quartz elements are wired together and arranged such that a uniform output is produced regardless of where the force is applied along the length of the sensor. The sensor is installed perpendicular to the traffic flow by cutting a slot in the pavement and using a special epoxy / grout to hold the sensor in place.

The sensor works on a piezoelectric principle producing a voltage proportional to the force applied to it. The sensor outputs are connected to charge amplifiers used to provide the necessary drive for analog to digital conversion of the weight signal.

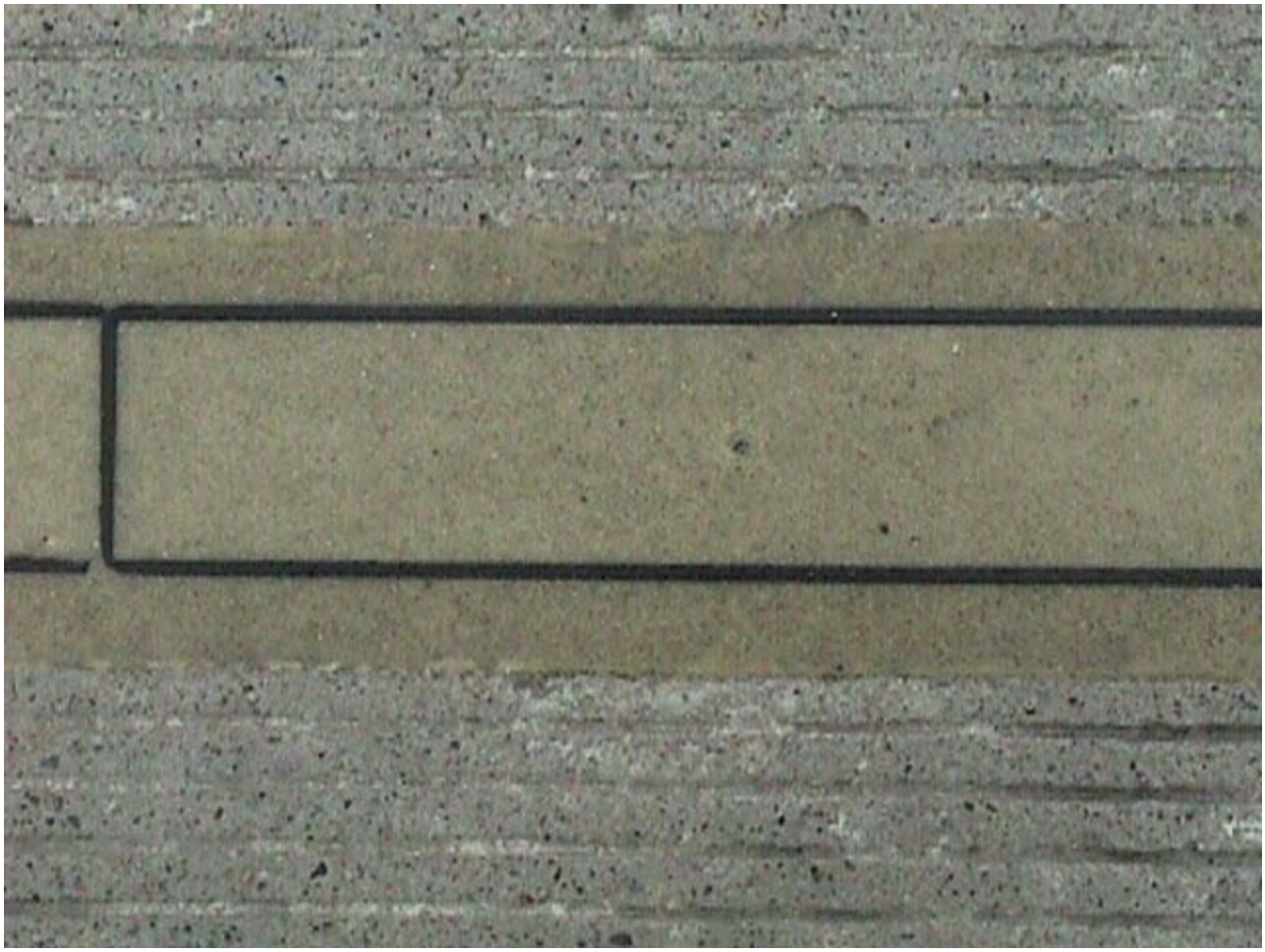

Figure 1 Quartz Sensor Installed in Roadway

Included with the quartz sensors is a loop detector positioned to detect the presence of a vehicle and to detect the beginning and end of the vehicle. All instrumentation for the in-motion scale is housed in a single roadside environmentally controlled cabinet.

Technical Data

Sensor Length	0.75 meter
Load Range	0 to 150 kN
Maximum Load (twin wheel)	250 kN
Load-bearing Capacity of Sensor Surface	> 5 N / square mm
Natural Frequency	> 5 KHz
Hysteresis	≤ 2 % FSO
Nonlinearity	≤ 2 % FSO
Operating Temperature Range	-50 to +80 degrees C
Insulation Resistance	> 100 GΩ
Capacitance	< 10 nF
Environmental Protection	IP 67 (DIN 40050)
Weight	4 kg
Cable Length	30 m

Performance

As with any in-motion vehicle scale, the performance of the QWIM series quartz sensor based in-motion scale is affected by the condition of the pavement prior to and following the sensor location. Performance can be improved by using multiple sets of sensors to average weight readings. The following data was taken from a random sampling of 35 commercial vehicles passing over a single set of sensors located in the eastbound lane of I44 milepost 2 south of Joplin, Missouri. The weight data was collected from the in-motion scale then compared with weights from multi-platform static scales located at a weigh station 2 miles east of the in-motion scale site. The single sensor set was mounted in an asphalt roadway. A comparison of the in-motion scale data with the static scale data is summarized below:

Parameter	Average Error (%)	Standard Deviation (%)
Steering Axle Weight	-0.95	3.7
Drive Axles Weight	1.30	6.6
Trailer Axles Weight	-1.26	6.4
Gross Vehicle Weight	0.03	3.0

This scale comes very close to meeting performance criteria for a Type III in-motion scale under ASTM E 1318 –00. Although this specification lists a maximum speed of 50 mph, the average speed of the vehicles in this data set was 67.9 mph. The table on the following page compares Type III specifications with the data collected from this quartz sensor site. Figures are for 95% of probability of conformity. The difference between the actual performance and ASTM specification for axle groups is likely the

result of pavement imperfections. Pavement at the site does not meet the ASTM requirements for pavement adjacent to an in-motion scale.

Parameter	ASTM E 1318 - 00	Cardinal QWIM
Single Axle	± 15%	± 7.5%
Axle Group	± 10%	± 13.3%
Gross Weight	± 6%	± 6%

Reliability

Although quartz sensors have only been available domestically for the last three years, they have exhibited a level of reliability greater than that of similar load cell based technologies. The data presented in the table below was obtained directly from Kistler, the manufacturer of the quartz sensor. The data shows a failure rate of less than 1 % per year of the installed base assuming a linear installation rate.

Location	No. Sensors Installed	No. Sensors Replaced	Time Period
USA	316	6	3 years
Switzerland	966	14	5 years
US&Switzerland	1282	20	5 years

Other characteristics of the quartz sensor which are responsible for its excellent reliability include its long-term stability resulting from the long term stability from quartz material, the ability of the sensor to be ground up to 10 mm should the road surface require grinding, and the sensor's immunity to changes in operating temperature. The minimal stresses within the structure of the quartz sensor result in an almost infinite fatigue life further improving its reliability. Sensors can be replaced within two to three hours depending on weather and road material. The use of multiple sensors can add a level of redundancy to the system allowing operation to continue should one or more individual sensors fail. The use of multiple sensors also improves the performance of the scale. The Model QWIM-1 uses a single set of sensors while the QWIM-2 employs a second set of sensors.

Figure 2 Cardinal QWIM-1 Quartz Sensor In-Motion Scale

Cardinal QWIM scales are used at a number of weigh stations as well as in main line screening operations. The QWIM series in-motion scale is a good choice for both high and moderate speed applications where reliability and consistent performance with a minimum disruption of pavement is a necessity. Cardinal maintains a staff of engineering professionals ready to assist you in the design and documentation of a weighing system for your specific requirements. And, should you ever require service, Cardinal technicians are only a phone call away. Vans equipped for in-motion scale service can be at your site in hours not days or weeks.

Cardinal Scale Manufacturing Company
203 East Daugherty Street
Webb City, Missouri 64870
417 673 4631
wim@cardet.com