Monitor
with
Confidence

Vibrating Wire Crack Meter

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RST INSTRUMENTS LTD.
11545 Kingston St.,
Maple Ridge, BC
CANADA V2X 0Z5

SALES + SERVICE + MANUFACTURING:
604 540 1100 | info@rstinstruments.com
TOLL FREE (USA & Canada) | 1-800-665-5599

www.rstinstruments.com

REVISION HISTORY

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L	Updated temperature correction calculation, reformatted, removed instructions for 3D models, added troubleshooting section.	2019-May-13	QR	CB
M	Rc and Ri changed to Lc and Li to match calibration sheets, units of linear calibration factor changed to [mm/B-unit],typo in corrected linear displacement example removed.	2019-Sep-16	MP	QR
N	Addition of the description of the 3D VW crack meter diagram, photos and installation instructions in Appendix C. Typos corrected in the demo temperature correction calculation.	2020-Oct-09	CA	CB, QR

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1 INTRODUCTION

The Vibrating Wire Crack Meter measures movement between two points, as shown in Figure 1-1. Commonly, the two points are placed across construction joints or cracks.

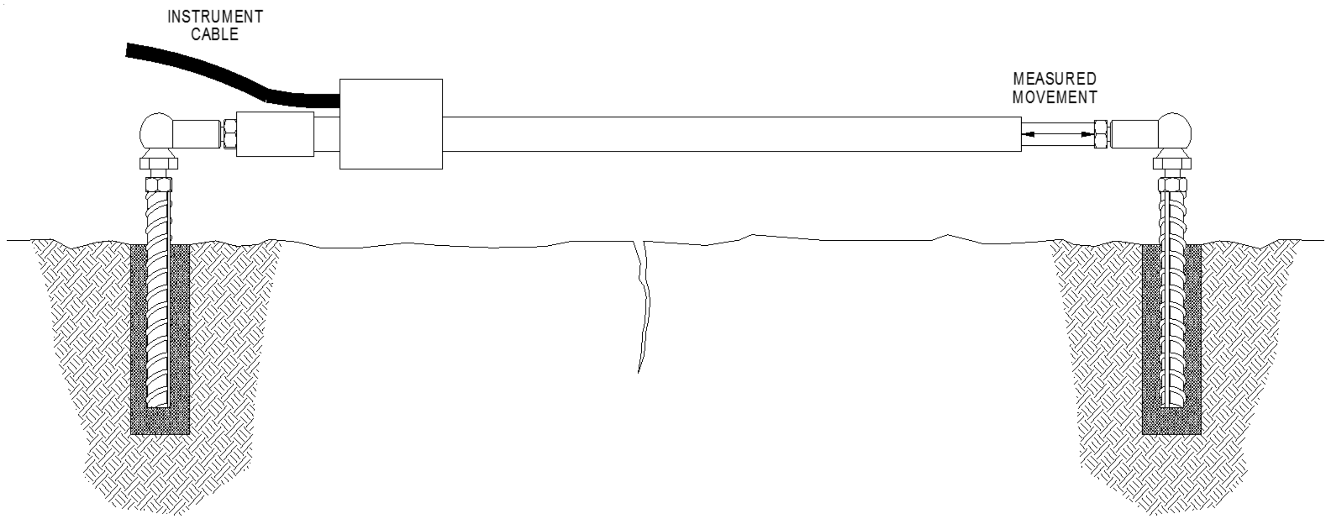

FIGURE 1-1 CRACK METER PRINCIPLE OF OPERATION

The instrument consists of an extendable shaft connected to a spring, which is further connected to a vibrating wire sensing element. As the shaft moves, the spring is stretched, which proportionally stretches the vibrating wire sensing element. The vibrating wire is very sensitive to strain changes. Upon excitation, it emits different frequencies at different strains.

The installation of the crack meter consists of drilling two holes at desired locations and grouting the two anchors in place. The crack meter cable should be installed away from electrical noise, and additional lightning protection may be installed if deemed necessary. The movement of the joint or crack may then be easily monitored by connecting the cable to an RST Readout unit. The crack meter also has a built-in thermistor, thus the temperature may also be measured and monitored.

If the installation site is prone to falling rocks or other debris, installing a guard to protect the crack meter is recommended. Contact RST for more information.

For the 3D Vibrating Wire Crack Meter installation procedure, see Appendix C.

2 INSTALLATION

2.1 PREPARATION

CAUTION: DO NOT ROTATE THE SHAFT OF THE CRACK METER RELATIVE TO ITS BODY, BECAUSE THE CONNECTED SPRING AND VIBRATING WIRE ELEMENTS CANNOT BE TWISTED. THE PIN IN THE SHAFT AND THE SLOT ON THE BODY SHOULD REMAIN ALIGNED, AS ILLUSTRATED IN FIGURE 2-1.

CAUTION: DO NOT EXTEND THE SHAFT BEYOND ITS SPECIFIED RANGE TO AVOID DAMAGING THE INSTRUMENT.

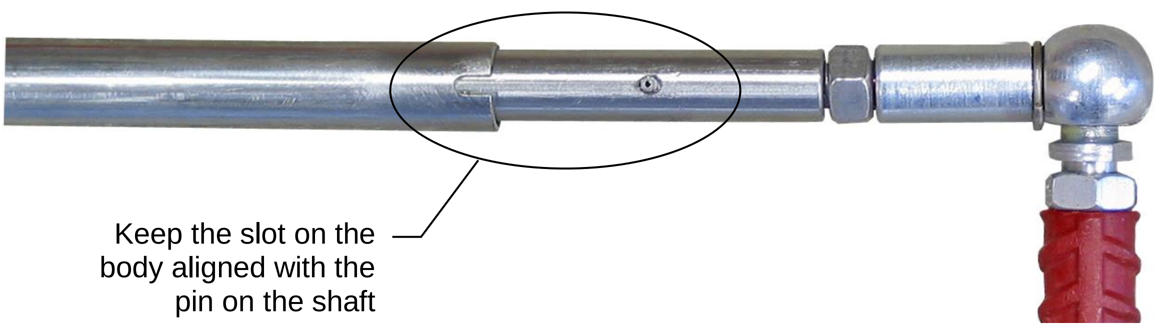

FIGURE 2-1 INSTRUMENT SHAFT ALIGNMENT

Before the site installation, the instrument should be checked for proper operation. Connecting the instrument to a readout unit should show a stable reading between 2500 and 3500 Digits ($Hz^2 \times 10^{-3}$) at zero shaft displacement.

A quick continuity check should also be performed. The resistance between the gauge leads (red and black wires) should be approximately 180Ω. The resistance between the thermistor leads (green and white wires) should be approximately 3kΩ at room temperature and should decrease with increasing temperature. Finally, there should be infinite resistance between the shield and the other leads.

2.2 PROCEDURE

The following instructions detail the steps necessary for successful installation of the crack meter.

1 Determine the anchor locations using the template provided by RST Instruments. It is important to estimate how the instrument will move in the future. For example, if the crack meter will be measuring the opening of a tension crack, then it may be expected for the crack to continue to open and the crack meter should be installed

pre-stroked to 10% of its full range. However, if the crack meter is to be installed across a joint that can either open or close, then the crack meter will likely be installed in the midrange (50% of full range).

CAUTION: DO NOT SCORE THE SHAFT, AS IT IS PART OF AN O-RING SEAL.

2 Drill a 12mm hole using a hammer drill approximately 75mm deep at the location of each anchor, determined in Step 1.

3 Fill the holes with grout or epoxy.

4 Push the crack meter anchors into the holes until they are secure in the ground, as shown in Figure 2-2. Leave enough clearance to allow the crack meter to extend or contract.

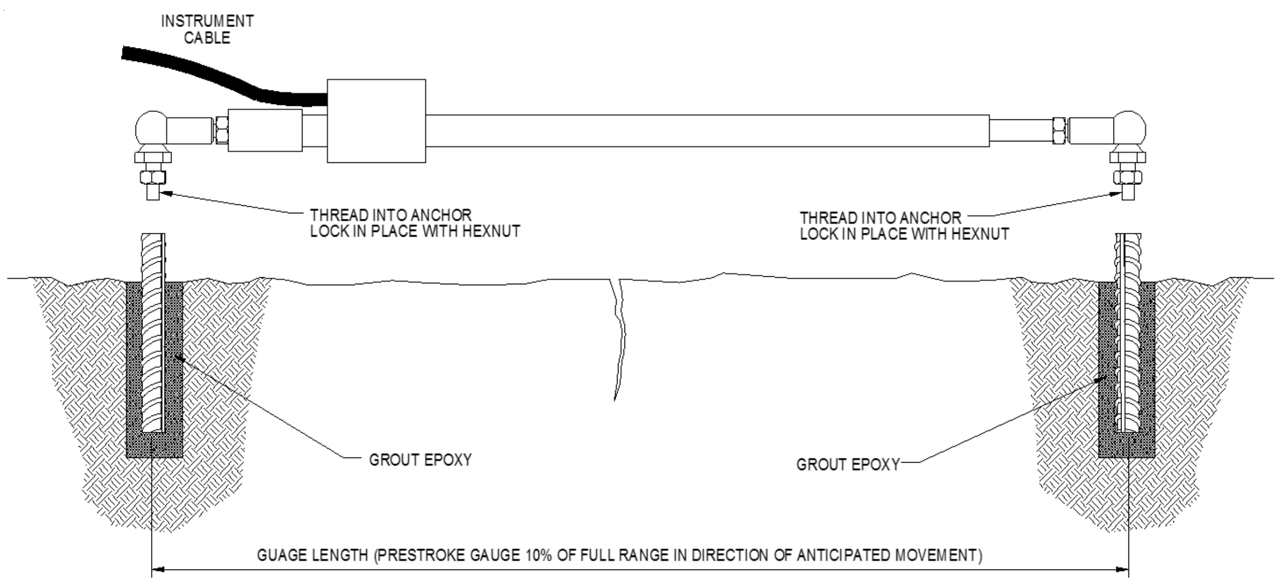

FIGURE 2-2 INSTALLING THE CRACK METER

NOTE: IT MAY BE HELPFUL TO USE A SPACER, CLAMP, OR MAKE A BRACE THAT CAN HOLD THE CRACK METER IN PLACE WHILE THE GROUT OR EPOXY CURES.

5 Check the crack meter output with a portable readout and make sure it is within the range specified on the calibration sheet. Take note of this output as the installation reference output. It may be used to find the movement changes that subsequently occur.

6 The crack meter cable should be routed away from sources of electrical interference such as power lines, motors, transformers, etc. The cable cannot run with AC power lines because it will pick up the 50 or 60 Hz noise. The cable may be lengthened to avoid sources of electrical interference and the frequency of the signals will not be affected.

The crack meter does not have built-in lightning protection. If required, a lightning protection system may be ordered from RST.

3 OPERATION

After the installation is complete, initial readings can be recorded by using an RST Vibrating Wire Readout or Data Logger. Make the electrical connections according to the instructions supplied with the readout and be sure to record relative site information to provide a unique identifier for the data. When referenced with the instrument's initial readings, subsequent readings will provide actual deformation, according to Equation 1:

$$Subsequent\ reading - Initial\ reading = Deformation$$

EQUATION 1 ACTUAL DEFORMATION

The readouts will output the displacement in B-units (Hz^2x10^{-3}) and the calibration factor, supplied with each calibration sheet, may be used to convert to linear displacement units. The readouts also output the temperature in °C. If an Ohmmeter is used directly on the green and white wires, then Appendix B may be used to convert to °C.

3.1 TEMPERATURE CORRECTION

Temperature correction may not be necessary in many cases as the Vibrating Wire crack meter has a small coefficient of thermal expansion. Temperature corrections may be applied for maximum accuracy or when temperature fluctuations are greater than 10°C.

$$Corrected\ Linear\ Displacement = CF(L_c - L_i) + K(T_c - T_i)$$

EQUATION 2 LINEAR DISPLACEMENT

Enter the appropriate values into Equation 2 to calculate the displacement and convert the readings into linear units. All subsequent readings should be subtracted from the initial reading to calculate the distance the crack has opened, where:

L_c	Current reading	[B-unit]
L_i	Initial reading	[B-unit]
CF	Linear Calibration Factor, provided on the calibration sheet	[mm/B-unit]
T_c	Current temperature	[°C]
T_i	Initial temperature	[°C]
K	Temperature Factor, see Equation 3	[mm/°C]

Use Equation 3 to calculate K, the temperature correction factor:

$$K = CF[(L_c * M) + B]$$

EQUATION 3 TEMPERATURE CORRECTION FACTOR

L_c	Current reading	[B-unit]
M	Slope, see Table 3-1	[1/°C]
B	Constant, see Table 3-1	[B-unit/°C]
CF	Linear Calibration Factor, provided on the calibration sheet	[mm/B-unit]

TABLE 3-1 TEMPERATURE CORRECTION FACTOR

Stroke (mm)	25	50	100	150	200	300
Slope (M)	0.000310	0.000311	0.000399	0.000359	0.000306	0.000277
Constant (B)	-0.3186	-0.2758	-0.8128	-0.5579	-0.4498	-0.2495

Sample calculation:

Assuming the following measurements from a 150mm sensor:

L_c	3762	[B-unit]
L_i	4791	[B-unit]
CF	0.0291788	[mm/B-unit]
T_c	22.5	[°C]
T_i	13.3	[°C]
M	0.000359	[1/°C]
B	-0.5579	[B-unit/°C]

First, calculate the Temperature Correction Factor (Equation 3):

$$K = CF[(L_c * M) + B]$$

$$K = (0.0291788) * [(3762 * 0.000359) + (-0.5579)]$$

$$K = (0.0291788) * (0.792658)$$

$$K = 0.023129$$

Next, apply the Temperature Correction Factor to Equation 2 to find the Linear Displacement:

$$Corrected\ Linear\ Displacement = CF(L_c - L_i) + K(T_c - T_i)$$

$$Corrected\ Linear\ Displacement = [(0.291788) * (3762 - 4791)] + [(0.023129) * (22.5 - 13.3)]$$

$$Corrected\ Linear\ Displacement = (-1029 * 0.291788) + (0.023129 * 9.2)$$

$$Corrected\ Linear\ Displacement = (-30.02499) + (0.212785)$$

$$Corrected\ Linear\ Displacment = -29.8122mm$$

4 MAINTENANCE

Most of the intricate components of the crack meter are sealed and do not require maintenance. However, it is important to check that the cable connections remain intact. Furthermore, it is important to ensure that the shaft does not extend outside the permissible range, does not become fully retracted, remains free to move, and does not twist.

5 TROUBLESHOOTING

Maintenance and troubleshooting of the Vibrating Wire Crack Meter is confined to periodic checks of cable connections and maintenance of terminals. The transducers themselves are sealed and are not user serviceable. The following are typical problems with suggested remedial actions.

5.1 THE CRACK METER FAILS TO GIVE A READING

1. Check the resistance of the vibrating wire coils by connecting an ohmmeter across the gauge terminals (red and black wires). Nominal resistance is approximately 180Ω (±5%), plus cable resistance at approximately 15Ω per 300 m of 22 AWG wire. If the resistance is very high or infinite, the cable is possibly broken or cut. If the resistance is very low, the gauge conductors may be shorted.

2. Check the readout unit or data logger with another vibrating wire crack meter to confirm that the readout unit or data logger is working.

3. The crack meter may have been over-ranged or physically damaged. Inspect the unit for any obvious damage. Contact RST Instruments if necessary.

5.2 THE CRACK METER READINGS ARE UNSTABLE

1. Connect the blue shield drain wire on the readout or data logger to the shield wire of the crack meter. In the absence of a shield wire on the vibrating wire crack meter, the blue shield drain wire can be connected to the black or green wires from the vibrating wire crack meter. If this does not result in more stable readings, proceed to Step 2 below.

2 Isolate the readout unit or data logger from ground sources by placing it on a piece of wood or similar non-conductive material. If this does not result in more stable readings, proceed to Step 3 below.

3 Check for sources of nearby electrical noise such as motors, generators, antennas, or electrical cables. Move the vibrating wire crack meter cables as far as possible away from any sources of electrical noise. Filtering and shielding equipment is likely required if the noise cannot be eliminated. Contact RST for technical advice.

4 The vibrating wire crack meter housing may be shorted to the shield. Check the resistance between the shield drain wire and crack meter housing. The resistance should very high.

5 The vibrating wire crack meter may have been over-ranged or physically damaged. Inspect the unit for any obvious damage. Contact RST Instruments if necessary.

5.3 Thermistor Reading is Too Low

1 If the calculated temperature from the thermistor resistance reading is unrealistically low, it is very likely that there is an open circuit or poor connection in the thermistor wiring which is resulting in excessive resistance.

2 Check all connections, terminals, and plugs for any damage or corrosion that could cause excessive in-line resistance.

3 If cable damage or a cut is located, a splice must be performed to return the function of the wire connection to normal. It is recommended that an RST ELSPLICE4 Electrical Cable Splice Kit for Vibrating Wire Cables be used to ensure a strong and waterproof splice.

5.4 Thermistor Reading is Too High

1 If the calculated temperature from the thermistor resistance reading is unrealistically high, it is very likely that there is a short circuit in the thermistor wiring which is resulting in a lower resistance reading.

2 Check all connections, terminals and plugs for any damage or current leakage that could explain a partial short that could result in a reduced circuit resistance. If a short or partial short is in the cable, the cable must be repaired with a splice. It is recommended that an RST ELSPLICE4 Electrical Cable Splice Kit for Vibrating Wire Cables be used to ensure a strong and waterproof splice.

3 If no obvious sources of shorting are found, it is possible that water may have penetrated into the interior of the crack meter. There are no remedial actions available if this is concluded to be the case

6 Service and Repair

The product contains no user-serviceable parts. Contact RST for product service or repair not covered in this manual.

Appendix A Sensor Specifications

Table A-1 Sensor specifications

Specification	Value						
Range	12.5mm	25mm	50mm	100mm	150mm	200mm	300mm
Resolution	<0.01%FS						
Accuracy	<0.1%FS						
Non-Linearity	<0.5%FS						
Zero Stability	0.02%FS/year						
Length (Mid-range, end to end)	205mm	227mm	304mm	467mm	559mm	790mm	1100mm
Frequency Range	1200-3550Hz						
Coil Resistance	180Ω						
Temperature Range	-20 to 80°C						
Over Range	105%FS						
Rated Pressure	2MPa						

Appendix B THERMISTOR TEMPERATURE DERIVATION

Equation 4 may be used to convert the measured thermistor resistance R (Ω) to temperature T (°C) to compensate for temperature.

$$T = \frac{1}{(1.4051 \times 10^{-3}) + [(2.369 \times 10^{-4}) * \ln(R)] + [(1.019 \times 10^{-7}) * (\ln(R))^3]} - 273.2$$

EQUATION 4 THERMISTOR TEMPERATURE DERIVATION

TABLE B-2 THERMISTOR RESISTANCE (Ω) VERSUS TEMPERATURE (°C)

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.11	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342..2	83	107.9	123
77.99K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-35	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	282.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	56.92	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.	53	250.9	93	83.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Appendix C 3D VW CRACK METER ASSEMBLY INSTRUCTIONS

For the 3D Vibrating Wire Crack Meter, the 3D installation template is generated by RST Instruments and sent with the equipment to aid in the correct orientation of the X-, Y- and Z-axis. Please read the Installation section of the VW Crack meter above to ensure that you have a complete understanding of the installation procedure before proceeding with the installation of the 3D VW Crack Meter.

NOTE: THE 3D CRACK METER MUST BE FULLY ASSEMBLED BEFORE INSTALLING THE ANCHORS IN THE EPOXY-FILLED HOLES. CONNECT EACH OF THE LABELLED SENSORS TO THE APPROPRIATE POSITION ON THE FRAME, AS ILLUSTRATED IN FIGURE C-1 BELOW, MAKING SURE THEY ARE PROPERLY SECURED. DO NOT PRE-TENSION THE SENSORS UNTIL THE HOLES ARE DRILLED FOLOWING THE TEMPLATE PATTERN. MAKE SURE THE SHAFT ALIGNMENT IS MAINTAINED WHEN PRE-TENSIONING THE SENSORS.

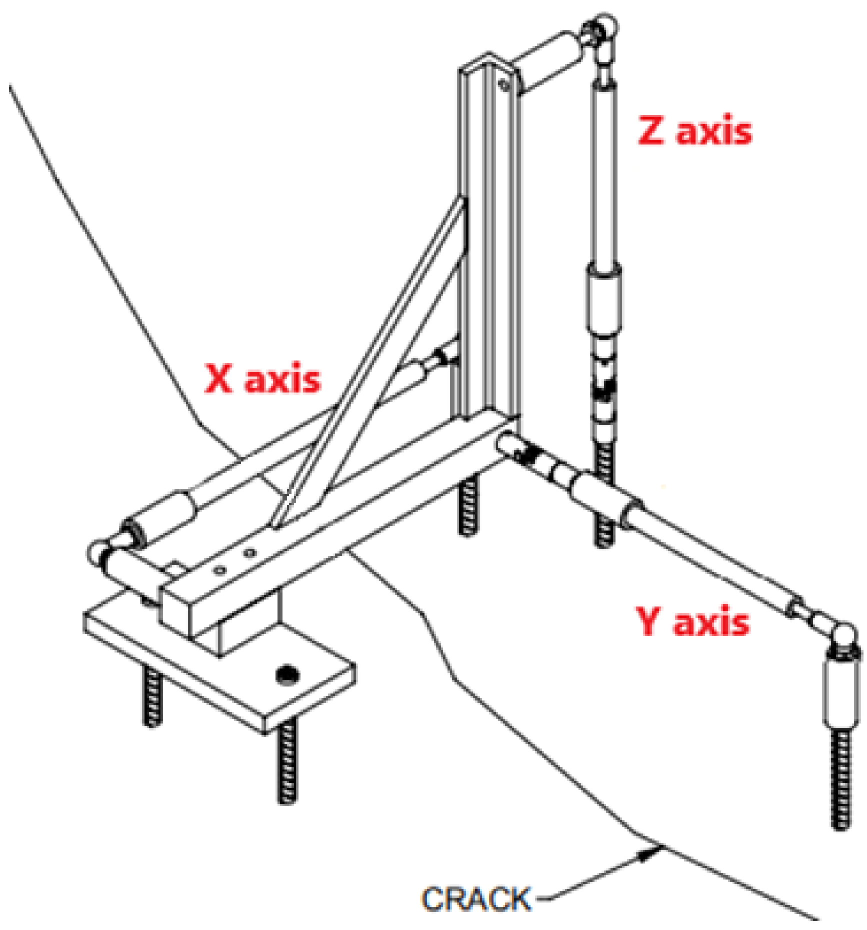

FIGURE C-1 3D VW CRACK METER DIAGRAM

1. Make sure the holes are drilled accurately using the template in Figure C-2. The template has been manufactured to allow the sensors to be connected with the sensors in the pre-tensioned position.

2. Use the photos in Figure C-3 through Figure C-5 as a guide to connect the X, Y and Z sensors to the frame. Follow the installation procedure and fill the holes with the epoxy, the frame can be positioned with the crack meters in their pre-tensioned positions and installed in the holes.

CAUTION: DO NOT EXTEND THE SHAFT BEYOND ITS SPECIFIED RANGE TO AVOID DAMAGING THE INSTRUMENT.

CAUTION: DO NOT ROTATE THE SHAFT OF THE CRACK METER RELATIVE TO ITS BODY, BECAUSE THE CONNECTED SPRING AND VIBRATING WIRE ELEMENTS CANNOT BE TWISTED. THE PIN IN THE SHAFT AND THE SLOT ON THE BODY SHOULD REMAIN ALIGNED, AS ILLUSTRATED IN FIGURE 2-1.

FIGURE C-2 VW CRACK METER INSTALLATION TEMPLATE

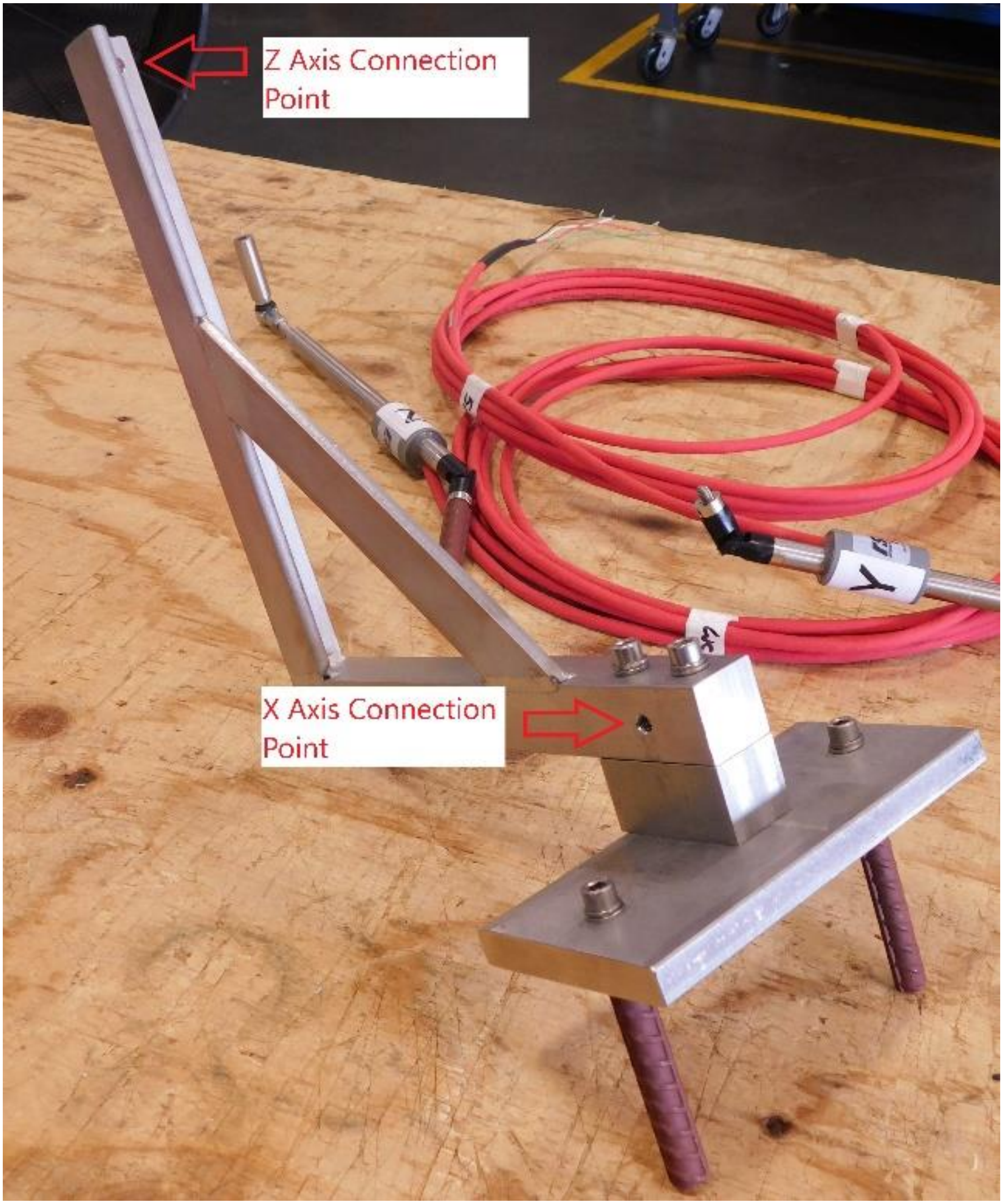

FIGURE C-3 X AND Z CONNECTION POINTS

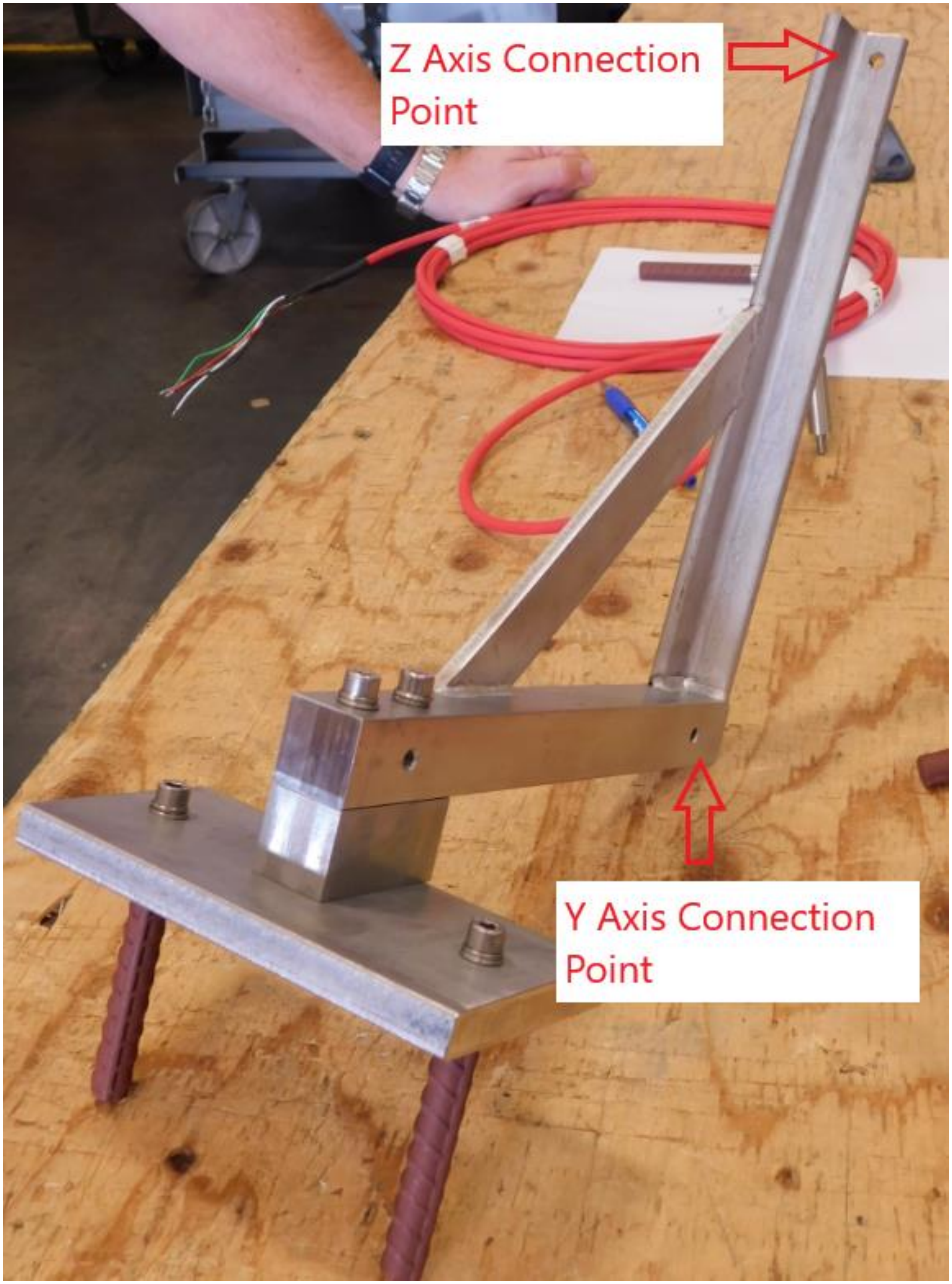

FIGURE C-4 Y AND Z CONNECTION POINTS

FIGURE C-5 X-AXIS CONNECTION

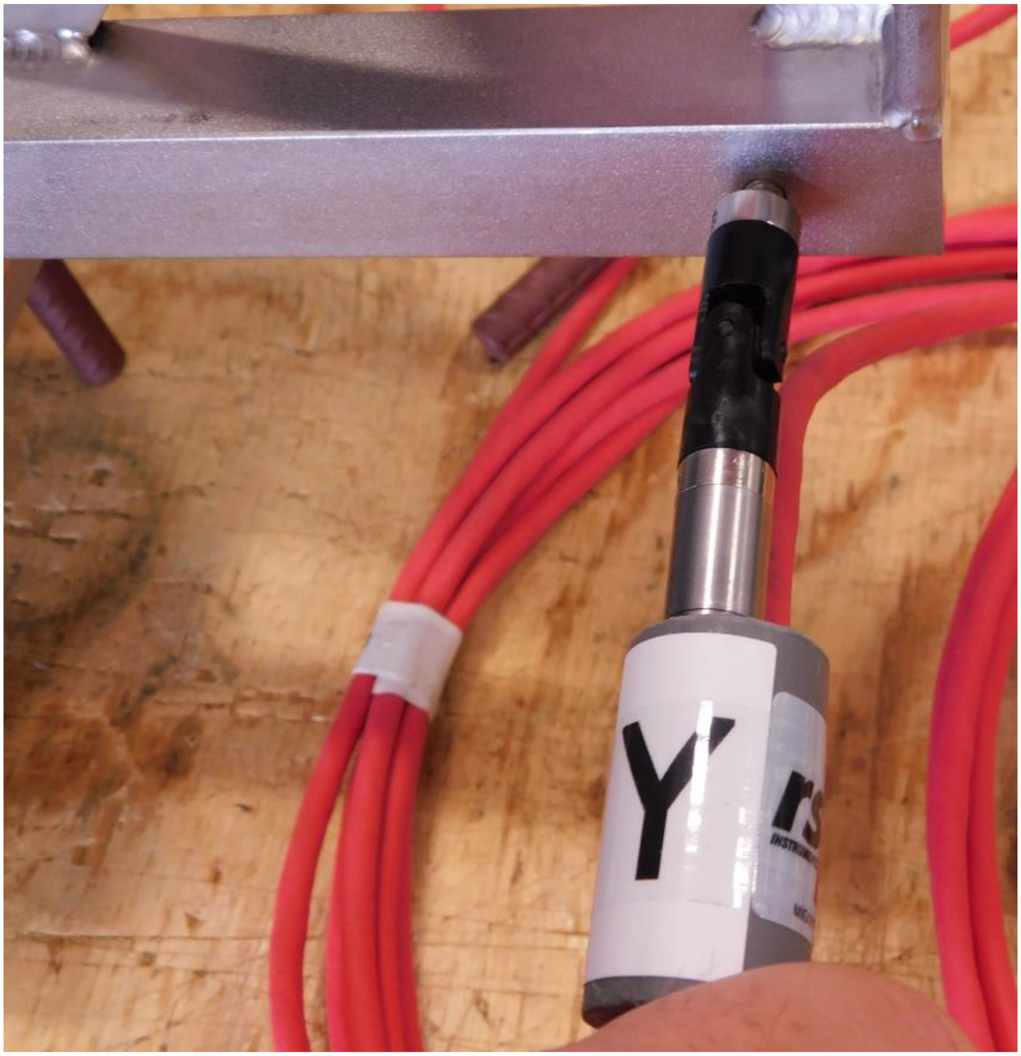

FIGURE C-6 Y-AXIS CONNECTION

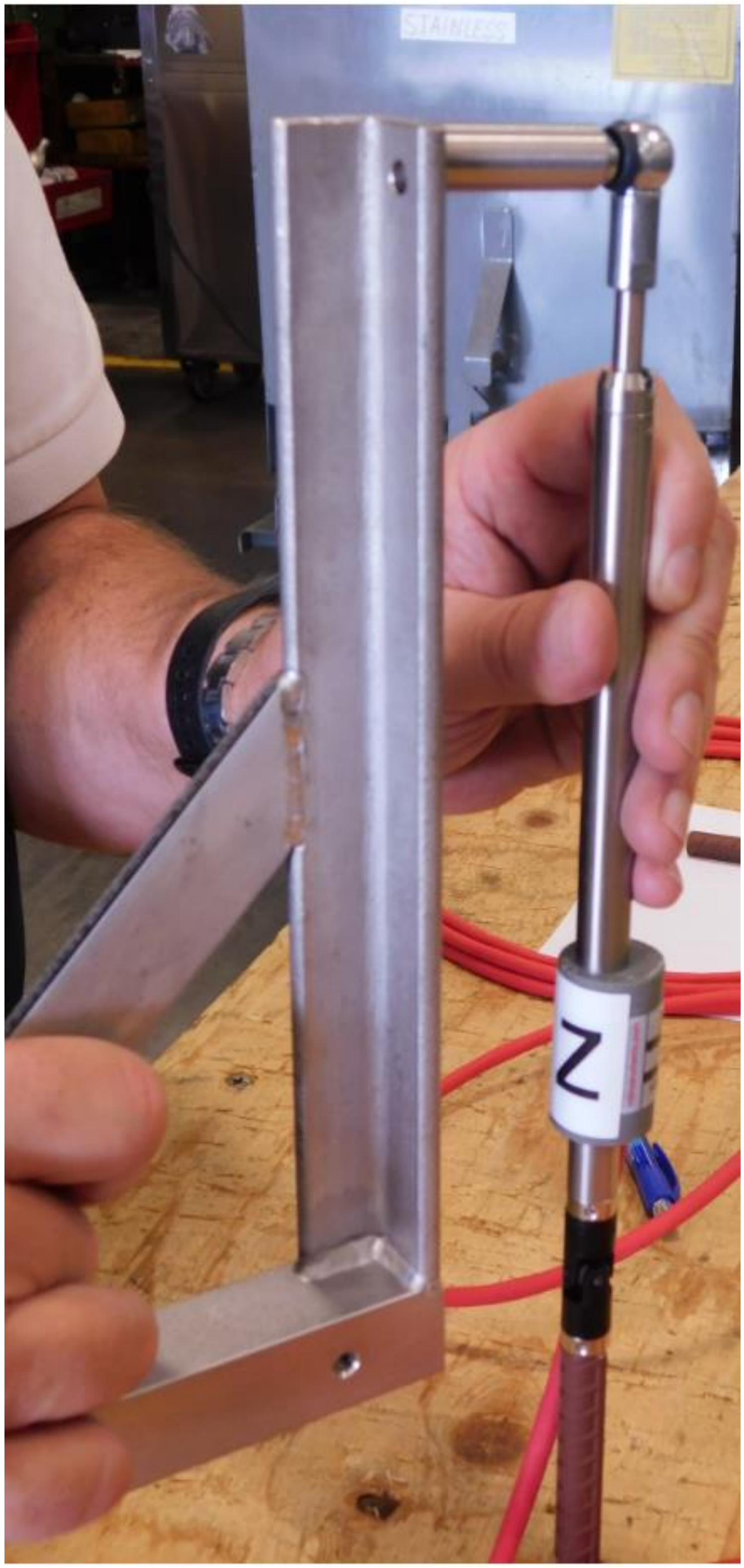

FIGURE C-7 Z-AXIS CONNECTION