We Stand Below Our Work
Partnering with DOTs, design firms & researchers since 1989.

Quarter Arm Strain Gage Completion Module Operations Manual

CE

(Doc Rev 2.1, 04/13)

1995 57th Court North #100
Boulder, CO 80301, USA
Tel: +1.303.494.3230
Fax: +1.303.494.5027

We Stand Below Our Work!

Email:stssupport@bridgetest.com

http://www.bridgetest.com

Warranty Information

Bridge Diagnostics, Inc. warrants its products to be free from defects in materials and workmanship under normal use and service for thirty-six (36) months from date of shipment. This warranty shall be void if any products have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. Batteries have no warranty.

All equipment manufactured by Bridge Diagnostics, Inc. is intended for use by a qualified professional only. Under this warranty Bridge Diagnostics, Inc.'s obligation is limited to repairing or replacing (at Bridge Diagnostics, Inc.'s option) of defective products. In no event shall Bridge Diagnostics, Inc. be liable for punitive, exemplary, special, indirect, incidental, or consequential damages and the customer shall assume all costs of removing, reinstalling, and shipping of defective products. EXCEPT AS STATED HEREIN, BRIDGE DIAGNOSTICS, INC. MAKES NO WARRANTIES, EXPRESSED OR IMPLIED, AND SPECIFICALLY DISCLAIMS ANY IMPLIED WARRANTY OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTABILITY.

Before returning any product, Bridge Diagnostics, Inc. technical support must be contacted at 303-494-3230 or by visiting www.bridgetest.com/contact/ and submitting a request. A technician will help determine the nature of the problem and if it cannot be resolved, authorization will be given to return the item. A return merchandise authorization (RMA) will be sent to the customer to be filled out and shipped back with the equipment. Bridge Diagnostics, Inc. will not accept shipment of any product without prior authorization as provided herein.

Ship all equipment to:

Bridge Diagnostics, Inc.

Attn: Technical Support

1995 57th Court North, Suite 100

Boulder, CO 80301-2810

(303) 494-3230

Bridge Diagnostics, Inc. has taken every precaution to ensure accuracy of its manuals, documentation, and software. Bridge Diagnostics, Inc. assumes no responsibility for any errors or omissions that may appear in any manual, documentation or software and in no event shall Bridge Diagnostics, Inc. be liable for any damages or losses that result from the use of its products in accordance with any manuals, documentation, or software.

Table of Contents

1. PRODUCT DESCRIPTION

The Quarter Arm Strain Gage Completion Module (QACM) has been designed for completing the Wheatstone bridge circuit for individual ¼-Arm foil strain gages. The QACM's are suitable for use with many different varieties of ¼-Arm foil strain gages, BDI recommend that Vishay Micro-Measurements foil gages be used with the QACM's.

The QACM employ metal-foil resistance elements, bonded to a dense ceramic substrate. The resistance elements are specially processed to "match" the thermal expansion coefficient of the ceramic, resulting in a very low resistance temperature coefficient equivalent to ±0.15με/°F [±0.27με/°C] for the half-bridge circuits, and ±0.35με/°F [±0.63με/°C] for the dummy gages, over a temperature range from 0° to +200°F [–18° to +95°C].

Completing the bridge circuit at the strain gage site provides for a symmetrical, balanced lead wire system between the strain gage circuit and the instrumentation. This can reduce effects of noise pickup in the lead wire system in some environments. Where switch contacts, slip rings, or other mechanical connections are employed between the strain gages and measuring instrumentation, or when lead wires will be periodically disconnected from the measuring instrument, accuracy can be improved by completing the bridge at the measurement site.

Each unit is fully sealed, water resistant to an IP67 rating, and incorporates a single mounting hole for efficient mounting. Based on the structure's material and length of time the QACM is to be installed, various mounting techniques can be used and are outlined below.

2. SPECIFICATIONS

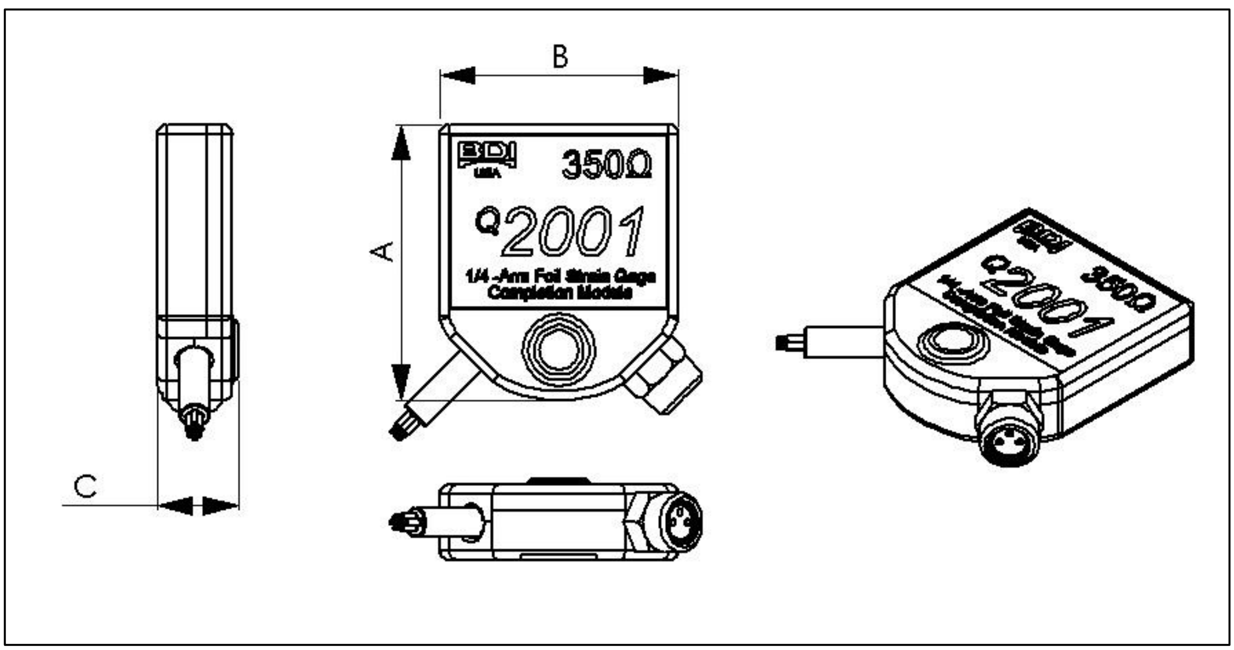

Figure 2-1 Quarter Arm Drawing

Table 2-1 General Specifications

Model	QA120	QA350	QA1000
Range (Resistance)	120Ω	350Ω	1000Ω
Circuit	Full Wheatstone bridge with 3-wire hookup to foil gage		
Foil Gage Hookup	36 inch (914mm) three-wire 30 awg assembly with waterproof M8 connector (Other lengths available upon request)		
Excitation Voltage	+1.0 to +10.0 Vdc		
Power Rating			
Max:	840 mW	300 mW	100 mW
Typical:	210 mW @ +5.0 Vdc	72 mW @ +5.0 Vdc	25 mW @ +5.0 Vdc
Intelliducer:	13 mW @ +5.0 Vdc*	13 mW @ +5.0 Vdc*	13 mW @ +5.0 Vdc*
Damping	Nitrogen Gas Damped		
Cable	IC-02-187 (22awg, 2 pair, shielded with drain wire, red PVC cable)		
Housing	6061-Aluminum		
Weather Proofing	IP67 Rated (with connector plugged in)		
Operating Temperature	-58°F to +185°F (-50°C to +85°C)		
Size (A x B x C)	0.80 in x 1.95 in x 0.49 in (20.3 mm x 49.5 mm x 12.4 mm)		
Weight	0.12 lbs. (54 grams)		
Mounting	BDI mounting Tab and adhesive, mechanical connection		

* Intelliducer connectors operate at +5.0 Vdc only.

3. Theory of Operation

The internal components of the QACM contain a Wheatstone bridge completion circuit with integral “dummy” gage. The QACM is used to connect one active foil strain gage by completing the Wheatstone bridge circuit that is needed for most standard data acquisition system.

4. Typical Applications

Typical applications for QACM include:

- Standard foil strain gage measurements
- Strain rosette measurements
- Residual Stress measurements
- Stress Vibration Monitoring

5. Connecting to Data Acquisition Systems

This section outlines how to connect and test the QACM for most standard data acquisition systems that are designed to handle either a differential or single-ended voltage signal.

5.1 Electrical Connections

The QACM is a typical 4-wire hook up for Wheatstone bridge sensors. See Table 5-1 for a description of the wiring, this table also includes the pin assignment for the BDI Structural Testing System Intelliducer connector. This is a ratiometric sensor so the output will change relative to the supplied excitation voltage, which should be between +1 to +18VDC.

Note: When using the QACM with STS data acquisition equipment, the connection has already been pre-wired with an Intelliducer plug.

Table 5-1 QACM input/output wiring scheme

QACM Wire	Signal	Intelliducer Pin Assignment
Red	+ Excitation	G
Black	- Excitation (Ground)	K
Green	+ Signal	C
White	- Signal	J
Bare	Shield/Drain	Integrated into pin K

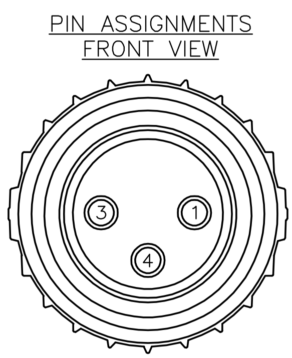

Figure 5-1 M8 connector pin assignment for three-wire connector

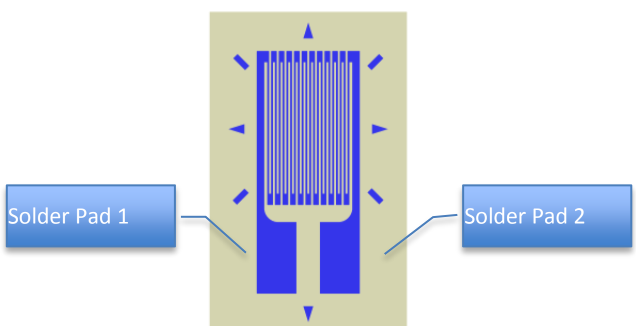

Figure 5-2 Typical 1/4-Arm foil gage

Table 5-2 ¼-Arm foil gage connection

Foil Gage	Foil Gage Wire	M8 Connector
Solder Pad 1	Red Wire	4
Solder Pad 2	Black Wire*	1
	White Wire*	3

* The Black and White wires should be twisted together and both soldered on to Solder Pad 2.

5.2 Applying Calibration Factors

BDI does not supply calibration factors for the QACM; the calibration factors will be based on the individual foil gage that is being used with the QACM. A typical gage factor (GF) for a 350Ω foil strain gage can be seen in Figure 5-3.

Figure 5-3 Typical micro-measurements foil gage calibration document

The typical metallic foil strain gage consists of a very fine wire arranged in a grid pattern. The grid pattern is oriented so that the wire is subjected to the maximum amount of strain in the in the parallel direction (see Figure 5-4). The cross-sectional area of the grid is minimized to reduce the effects of shear strain and Poisson Strain. The grid is bonded to a thin backing, which is attached directly to the test specimen. Therefore, the strain experienced by the test specimen is transferred directly to the strain gage, which responds with a linear change in resistance of the active grid.

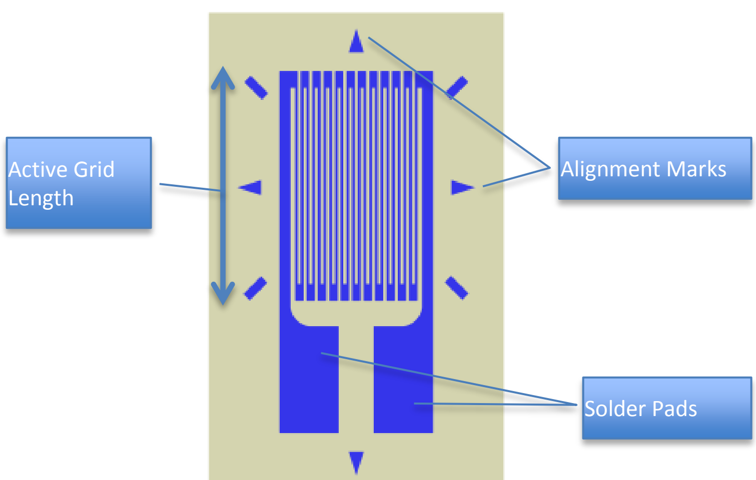

Figure 5-4 Standard Foil Strain Gage

It is very important that the strain gage be properly mounted onto the test specimen so that the strain is accurately transferred from the test specimen, through the adhesive and strain gage backing, to the active grid itself. A fundamental parameter of the strain gage is its sensitivity to strain, expressed as the Gage factor (GF). The Gage Factor is defined as the ratio of fractional change in the resistance to the fractional change in length (strain), see Equation 5-1.

$$GF = \frac{\Delta R/_{R}}{\Delta L/_{L}} - \frac{\Delta R/_{R}}{\varepsilon}$$

Equation 5-1

To calculate strain from the change in voltage output (V_o in Figure 5-5) from the QACM, the output must be entered into the into the ¼-Arm gage formula with the supplied gage factor (Figure 5-3). If the QACM is used with the any BDI Structural Testing System, the foil gage calculation is integrated into the data acquisition software (WinSTS). Otherwise, follow these procedures for calculating strain from a change in voltage.

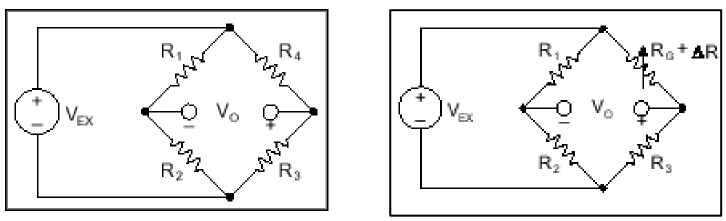

Figure 5-5 Wheatstone bridge configuration

The formula that can be developed from Figure 5-5 is:

$$\boldsymbol{V_o = \left[\frac{R_3}{R_3 - R_4} - \frac{R_2}{R_1 - R_2}\right] \times V_{ex}}$$

Equation 5-2

From Equation 5-2, it is apparent that when $R_1/R_2 = R_3/R_4$, the output voltage V_o equals zero. In this condition the Wheatstone bridge circuit is balanced. Any change in resistance to any of the four resistors will result in a non-balanced condition and will result in a measurable voltage at V_o. Using the QACM, three of the resistors are fixed resistance and the 4^{th} (R_4) is the foil gage that will be used to measure strain (change in resistance). If the nominal resistance of the foil strain gage is designated as R_G, then the strain –induced change in resistance, ΔR, can be expressed as $\Delta R = R_G \times GF \times \varepsilon$ (from Equation 5-1) Assuming that $R_1 = R_2$ and $R_3 = R_G$, the bridge equation above can be rewritten to express V_o/V_{ex} as a function of strain (see Equation 5-3). Note the presence of the $1/(1+GF \times \varepsilon/2)$ term that indicates the nonlinearity of the bridge output with respect to strain.

$$\frac{V_o}{V_{ex}} = -\frac{GF \cdot \varepsilon}{4} \cdot \left(\frac{1}{1 + GF \cdot \frac{\varepsilon}{2}}\right)$$

Equation 5-3

5.3 VERIFYING FOIL GAGE OUTPUT

Once the QACM has been connected to the data acquisition system as outlined above, the user should perform the following tests. These tests should also be conducted on a regular basis to verify proper continued operation of these sensitive instruments.

The QACM has been designed to minimize the amount of maintenance required to it operational. Before each use it is recommended that every sensor be visually inspected for damage and powered on to ensure it is working properly. This should be done two to three weeks before any scheduled testing in case any repairs are required.

5.3.1 Noise and Output Test

Once the foil strain gage has been attached to the QACM it is a good idea to test the functionality. This can be done very simply using the following steps:

1. Start a test and ensure the resolution of the foil gage is as expected for the data acquisition system that is being used (BDI generally uses a 24-bit data acquisition system and the resolution of a single foil gage with the QACM is less then ± 1με). See Figure 5-6 to see an example of the typical noise level from a 24-bit data acquisition system.

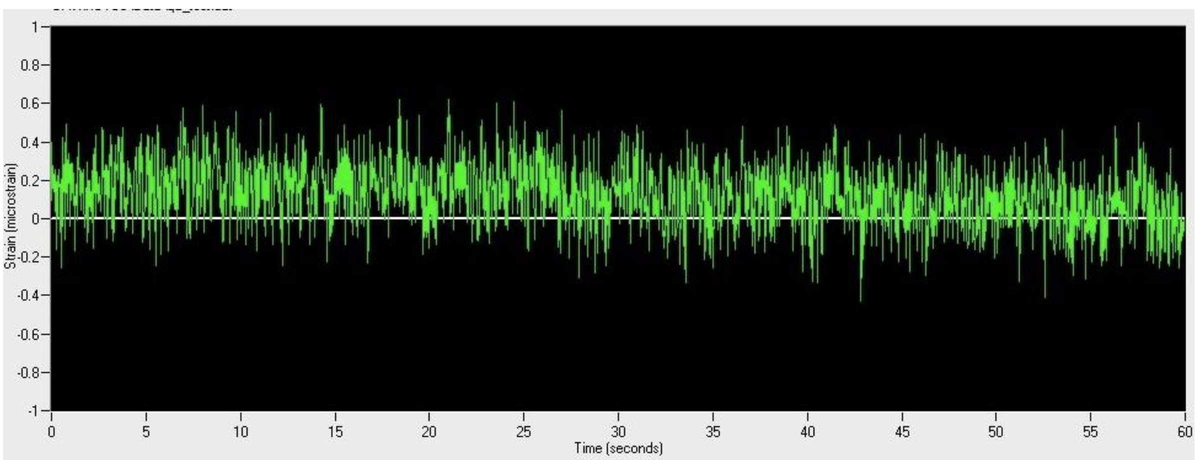

Figure 5-6 Typical noise level from a 24-bit data acquisition system

2. Using the eraser of a wooden pencil rub the element of the foil gage with approximately 2-3psi (20-30kPa) as seen below. The data acquisition equipment that is being used should display some change in voltage or strain.

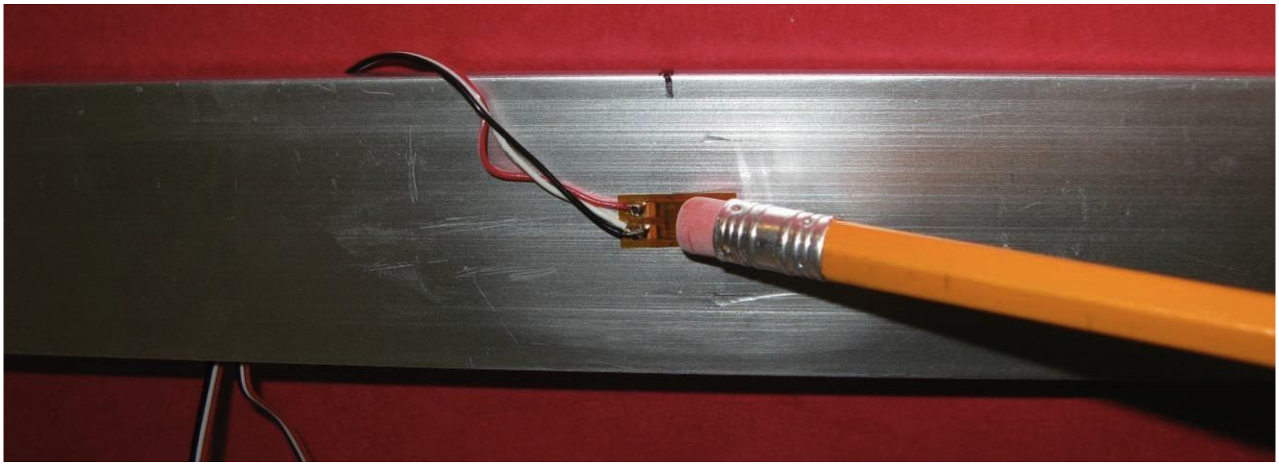

Figure 5-7 Testing the output with a rubber eraser.

5.4 LEAD WIRE EFFECTS

Strain gages are sometimes mounted at a distance from the measuring equipment. This increases the possibility of errors due to temperature variations, lead desensitization, and lead-wire resistance changes.

5.4.1 Effects of the Three-Wire Foil Gage Cable

The resistance of lead wires in series with an active strain gage attenuates the bridge output (or "desensitizes" the gage) by the factor:

$$D = \frac{R_G}{R_G + R_L}$$

where:

R_L = total resistance of lead wires in series with the gage (two lengths of lead wire for a two-wire-circuit, and on length for a three-wire circuit).

R_G = gage resistance.

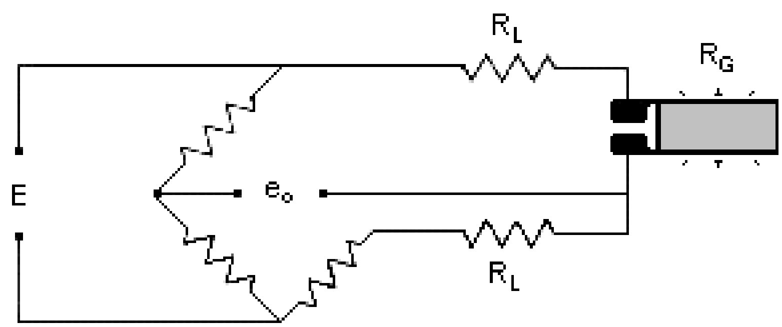

Figure 5-8 Three-wire hookup

The error, *e*, caused by lead wire resistance can be expressed as:

$$e = \frac{R_L/R_G}{1 + R_L/R_G} \times 100$$

When the lead wire resistance is known, indicated strains could be corrected for lead wire effects by multiplying the strains by:

$$1/D = \frac{(R_G + R_L)}{R_G}$$

As an alternative to correcting the data numerically, the gage factor of the strain indicator can be adjusted from its original value, F_G, to a new, compensating value, F'_G, where;

$$F' = F_G \left[\frac{R_G}{(R_G + R_L)}\right]$$

6. SENSOR INSTALLATION

This section will focus on the installation and proper connection and installation of the QACM. It is assumed that the user is familiar with the proper attachment techniques for foil strain gage installation.

6.1 LEAD WIRE CONNECTION TO FOIL GAGE

Each QACM is supplied with one three-wire foil gage connection cable. Once the foil strain gage has been installed the three-wire sensor leads can be attached using the following instructions:

1. If applicable, split the three wires; strip approximately 1/8" of the sheathing from each wire. Twist the black and white leads together and tin both this pair and the red lead. An example of this can be seen below.

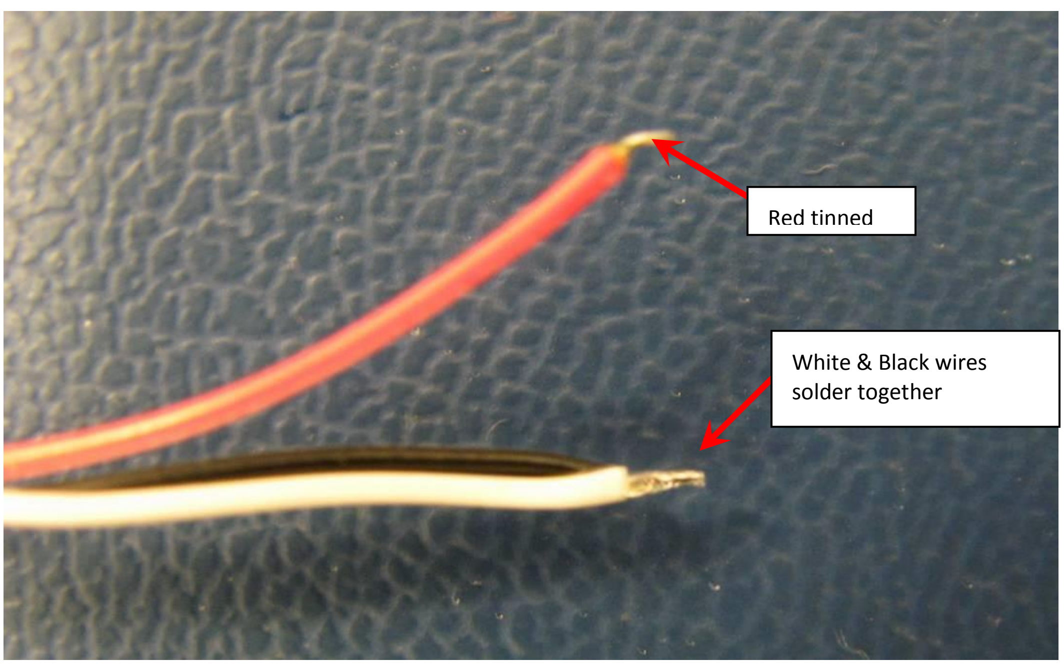

Figure 6-1Foil gage soldered lead wires.

2. Place a small bead of solder on the pads of the foil strain gage as seen below.

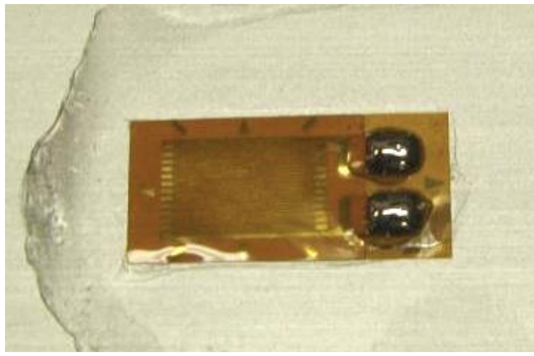

Figure 6-2: Solder bead on the two foil gage pads.

3. Solder the white/black pair to one solder pad and the red to the other as seen below.

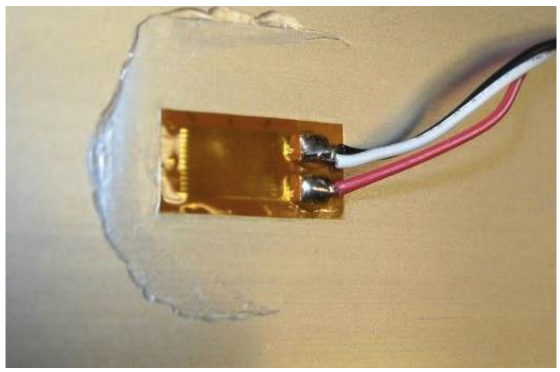

Figure 6-3: Foil gage with solder lead wires attached.

4. Securely attach the QACM to the structure within 3 ft (0.9m) of the foil gage. There is an integrated through hole on the QACM module that will fit a standard ¼-20 (or M6) mounting tab. Please see Sections 6.2 through 6.3 for further mounting information.
5. Connect the foil gage lead wire to the QACM using the M8 connector provided with the lead wire assembly.
6. Lastly, connect the QACM instrumentation cable to the data acquisition system using a typical four-wire connection and shield.

6.2 Installation on Steel Members

In most situations, the most efficient method of mounting a QACM is using the tab/glue method as it the least invasive and is truly a "non-destructive testing" technique. The following section outlines an installation for a flat a steel plate. Note that there are several alternate mounting methods that can be used depending on the material being mounting to (steel, concrete, timber) and the length of test (hours, weeks, months, years). These variations will be discussed in later sections.

Note:

Scribe line indicates a metric (M6) Tab.

BDI manufactures both Imperial (1/4-20) and metric (M6) tabs. To easily distinguish metric Tabs from imperial, BDI has scribed all metric items as seen in the above picture

- Place a tab through the integrated mounting hole from the bottom and tighten the ¼-20 (or M6) nut to approximately 40 in-lbs. Note that the bottom of the sensor has a machined slot to capture the mounting tab, so there should be no need to hold the mounting tab in-place while tightening the nut.

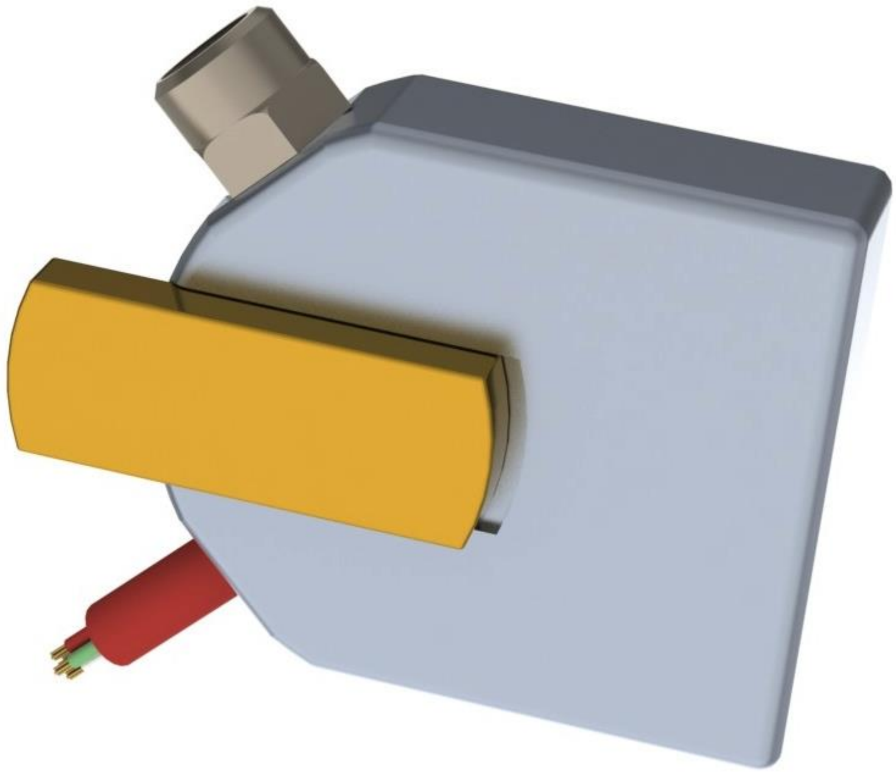

Figure 6-4 Machined slot for ¼-20 (or M6) mounting tab

- Since the location of the QACM is not vital to the measurement, simply remember that the QACM needs to be fixed to the structure within 3 feet (0.9m) of the foil gage.
- For a more secure bond, the paint and/or rust should be grinded from the surface of the steel. This may not be necessary if the surface is in relatively good condition, simply wiping the dirt and dust away may be good enough for a temporary installation.
- Next, very lightly grind the bottom of the tab that has already been mounted to the QACM to remove any oxidation and/or other contaminants. Before mounting, set the sensor in the location it is to be attached, and ensure that the unit is flush to the surface as this is important for achieving a good bond.
- Apply a thin line of adhesive to the bottom of the tab **(Loctite 410 Black Toughened Adhesive, Part # 41045 in 20 gram containers)** about ¼ inch (6.4mm) wide. Mount the QACM in the marked location, and then pull it away. This action will apply adhesive to the structural member at tab location.

- Spray the adhesive spot on the structural member with a “light shot” of the adhesive accelerator **(Loctite Tak Pak 7452, Part # 18637 in 0.7oz aerosol spray container).**
- Very quickly, mount sensor in its proper location and apply a light force to the top of the tab for approximately 15-20 seconds.

Note: To find the closest Loctite Distributor please call 1 (800) 243-4874 or visit www.loctite.com

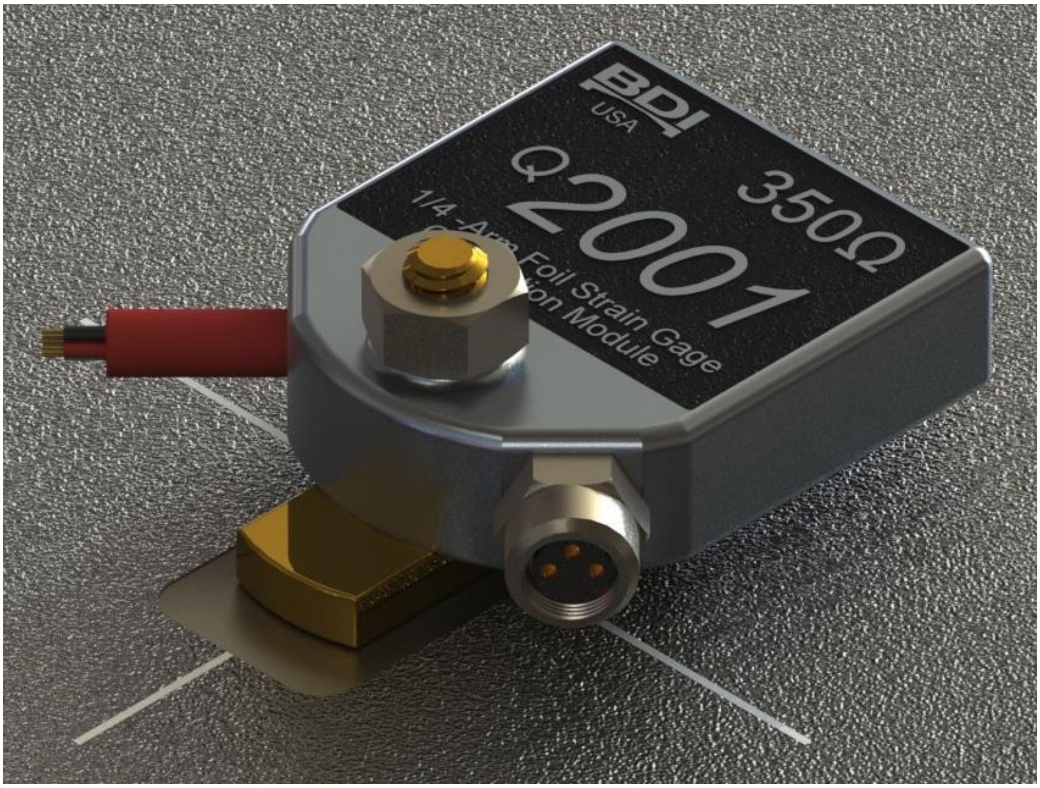

Figure 6-5 QACM glued to a steel surface

If the above steps are followed, it should be possible to mount each sensor in approximately five minutes.

Often, the above approach will make removing the tabs very difficult from steel members due to the strength of the glue. Therefore, BDI has developed a Tab Removal Tool (TRT) to help reduce the possibility of damaging BDI sensors and tabs (see Figure 6-6). Each TRT has a hex head machined into bottom face for tightening and/or loosening the designated nut size, and the small hole in the face of the hex head has been threaded to capture the threaded stud.

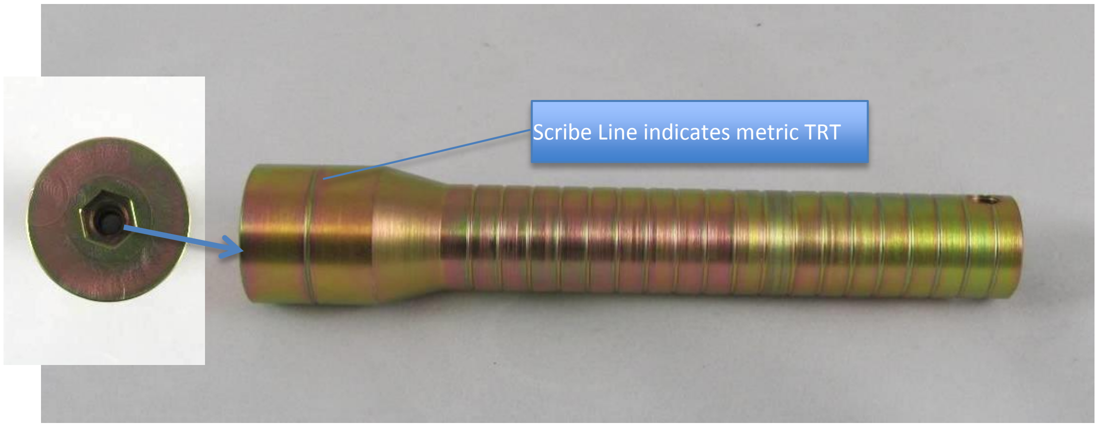

Figure 6-6 Tab Removal Tool (TRT)

Note: Please remember that BDI manufactures both imperial (1/4-20) and metric (M6) tabs. Ensure that the matching TRT threads are used with the tabs.

The following instructions describe the method used to remove a sensor that has been mounted to a steel surface. If a TRT is not available, a pair of vise grips can be used to remove the tabs, but there is a greater chance of damaging the tabs using a vise grip.

1. Use the cutout in the TRT or an end wrench; remove the nut from the tab. Carefully slide the QACM from the tab stud.
2. Thread the TRT on to the tab until the face is flush with the foot of the tab as seen below. If a gap remains between the TRT and the tab foot there is a high likelihood that the stud will be bent in the next step. Also, do not over tighten the tab into the TRT or it will be hard to remove the tab from the TRT. After a few tries this process will become a simple procedure.

Figure 6-7 TRT with a Tab inserted

3. In the direction of "thin" axis of the tab, give the TRT a quick tug or tap and the tab should pop off the member surface. Depending on how well the tab is fixed, particularly on a steel surface, more force may be required. In this case, simply hit the handle of the tool with a small rubber mallet. Note that holes in the top of the tool have been supplied so that a lanyard can be added if necessary.

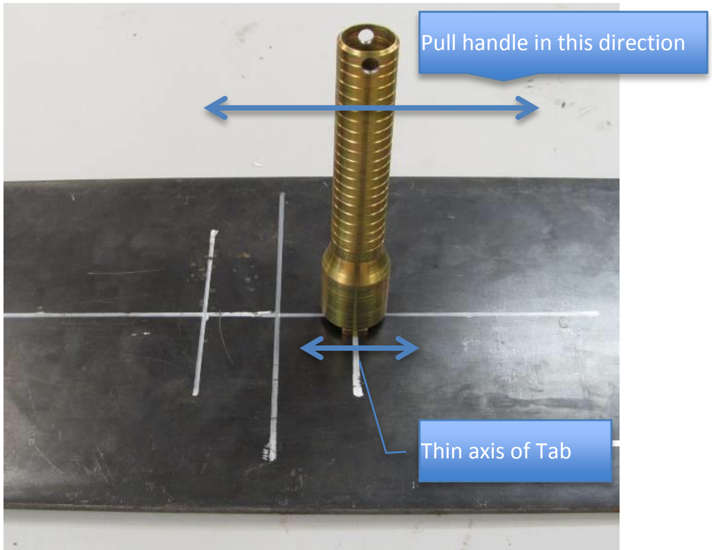

Figure 6-8 Removing a Tab with the TRT

4. Unthread the tab from the TRT and continue with the other sensors. If the tab remained with the sensor during removal, use vice grips to hold the foot of the tab while loosening the nut.
5. The tabs can be re-used by soaking them in acetone for 30-40 minutes to remove the hardened adhesive. Be sure to cover the container since the acetone will evaporate quickly and is very flammable! The mounting tabs have been designed to be reusable by simply dissolving the glue with acetone. Acetone can be reused multiple times, but if it becomes too saturated with glue it will start leaving a thin layer of glue in the threads of the mounting tabs. Also, sometimes when the mounting tabs are removed from a structure, the top threads can be chipped. If it becomes hard to thread nuts onto the mounting tab stud, run a 1/4-20 (M6) die down the threads to remove these chips and glue from the threaded stud.

6.3 Installation on Other Structures

The QACM can be installed on many structure types and in all types of applications, so it is impossible to outline all the details for each installation. However, with practice and experience, the user can select from a combination of the mounting techniques that BDI has developed over the years depending on the application.

6.3.1 Tab and Glue System on Concrete

In general, the basic “tab and glue” technique described above is suitable for most concrete member applications, however, if any of the following parameters exist; BDI recommends using mechanical anchors rather than glue:

- If concrete is moist or wet
- If the sensor must remain in place for more than a day or two
- If the instrumented areas are directly over automobile or train traffic where if the sensor came loose, it could create a hazard.

- If the instrumented area is difficult to re-access during the testing period in case sensor comes loose.

If it is judged that the tab/glue system is sufficient, some extra steps should be followed when using this method for concrete members. The primary concern when mounting sensors on either reinforced or pre-stressed concrete is that the surface must be clean, dry, and dust-free in order for the glue to adhere to. Therefore, it is highly recommended that compressed air (either in cans or from a compressor) be used to remove the dust after grinding has been completed. Follow the above steps as outlined for steel, except just prior to applying the glue to the tabs, use the compressed air to clean any surface dust away from the mounting point.

6.3.2 Concrete Mounting Studs

If it is judged that the conditions warrant are more secure mounting system, then threaded mounting studs can be used. These will require a hole to be accurately drilled in the concrete with a hammer drill as described below.

- Locate the drilling point on the structure and using a concrete drill, drill a 1/4” hole approximately 1.0” deep. If mounting to pre-stressed concrete, ensure to avoid drilling into the pre-stressing tendons.
- Drop in a 1/4"-20 x 1-1/2” Power Fasteners Power-Stud or similar and lightly tap in with a hammer to set.
- Slide the sensor over the stud.
- While holding the sensor in place, screw a nut on the stud and tighten with an open-end wrench.

6.3.3 C-Clamp

The integrated through hole should be used to align a typical C-Clamp. A C-clamp should be centered over this area and tightened until snug, DO NOT OVERTIGHTEN!

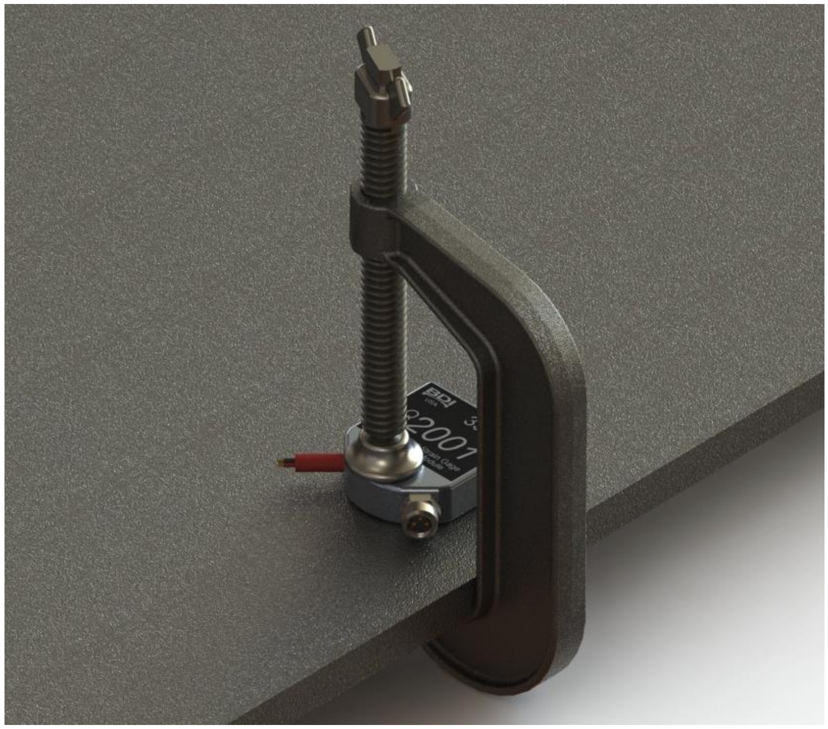

Figure 6-9 QACM mounted with a C-Clamp

6.3.4 Self-Tapping Wood Screws

If the QACM is to be mounted to a timber member or other relatively soft materials, use a 1-1/2" self-tapping screw and a power screwdriver. If the wood has any sort of glue laminated section or it has been chemically treated, it is recommended that a pilot hole be drilled.

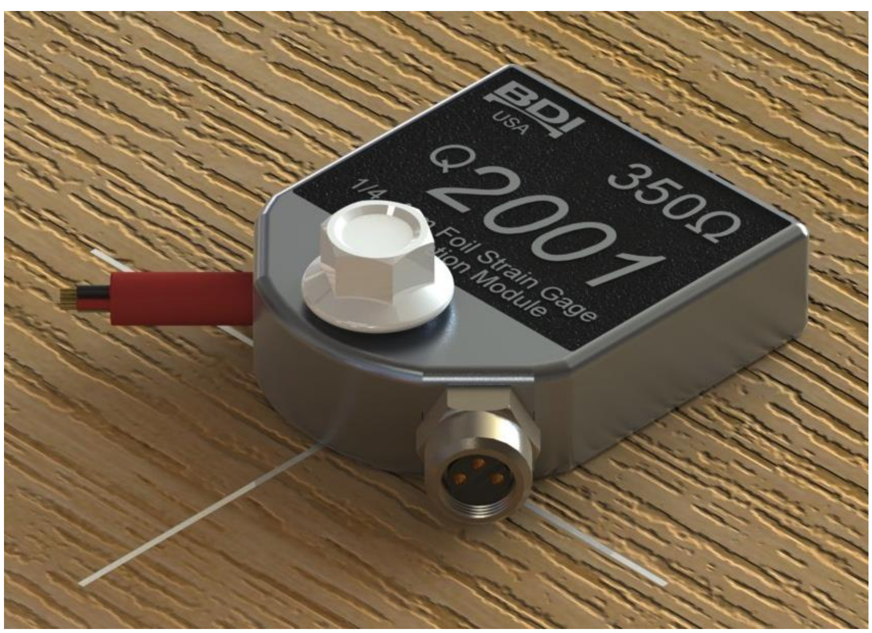

Figure 6-10 QACM mounted to a wood surface with self-tapping screw

7. Recalibration & Replacement

7.1.1 Recalibration

The QACM does not come with an individual calibration certificate. There is no need to calibrate these modules.

7.1.2 Replacement

In order to meet an IP67 rating the sensor has been potted with a non re-enterable encapsulant. Due to this design, the only replacement part available for the sensor is the cable. For the cable to be replaced, the sensor should have at least twelve inches of cable exiting the sensor body. This cable can be spliced to a new cable of the proper length.

Note: If a sensor is damaged beyond repair, the sensor may be replaced at a discounted price to the original purchaser. Please contact Bridge Diagnostics, Inc. or the local distributor to obtain authorization for return.

Bridge Diagnostics, Inc.
1995 57th Court North STE. 100
Boulder, CO 80301-2810, USA
Tel: +1.303.494.3230
Fax: +1.303.494.5027
www.bridgetest.com

We Stand Below Our Work!