RST INSTRUMENTS LTD.

Tension Measuring Gauge Tensmeg Instruction Manual

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Tension Measuring Gauge – Tensmeg Manual

Product: RST Tension Measuring Gauge - Tensmeg

Document number: EXM0040F Tension Measuring Gauge.doc
Date: December 4, 2017

TABLE OF CONTENTS

LIST OF FIGURES

1 INSTALLATION OF TENSMEG GAUGES ALONG A CABLE BOLT (7-WIRE STRAND), WATERPROOFING AND CONNECTION OF LEAD WIRE

1.1 INSTALLATION OF GAUGES

1. Measure and cut the cable bolt the desired length using a buffer tool.
2. Install the cable bolt on strands or trestles.
3. Use a felt marker to mark the center of each gauge to be installed on the cable-bolt.
4. Clean the marked areas of the cable to be instrumented by using a steel brush and acetone or a similar solvent.

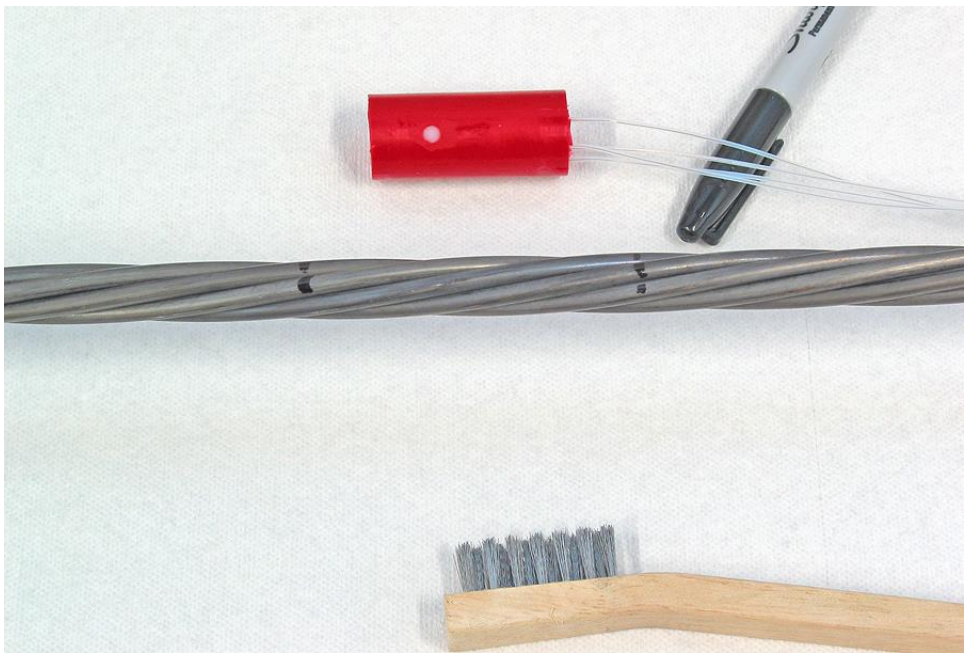


Figure 1 – Clean marked areas of cable

5. Stretch the gauge to be installed along the cable in order to locate the position of the head anchor of the gauge (anchor with the three wires). The head anchor should be towards the collar of the hole.

6. Spread a layer of Loctite 495 Instant Adhesive glue, using a cotton swab, on the cable over a length equivalent to the length of the head anchor.

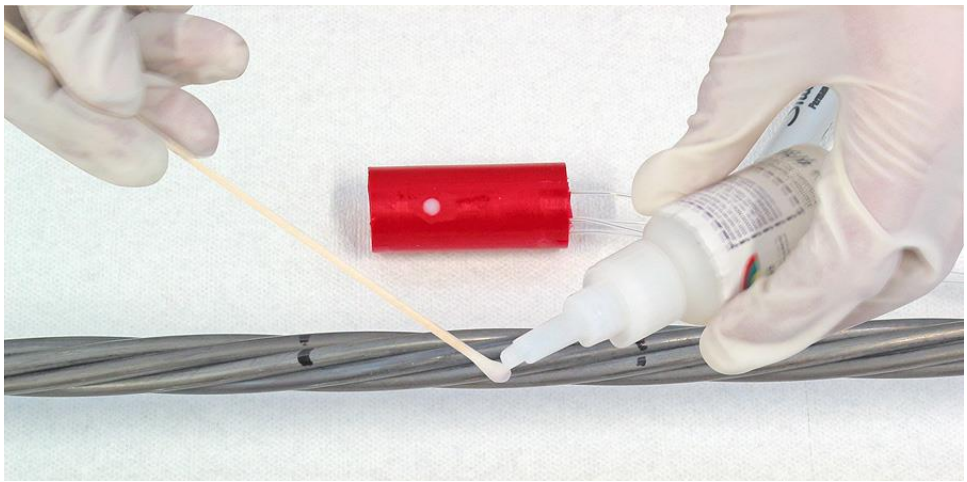


Figure 2 – Apply glue

7. Insert the opening tool over the cable, and then insert it in the longitudinal slot of the head anchor. While the anchor is opened to a width equivalent to that of the cable, pull it on to the cable while making sure that the wires of the gauge are vis-à-vis grooves of the cable.

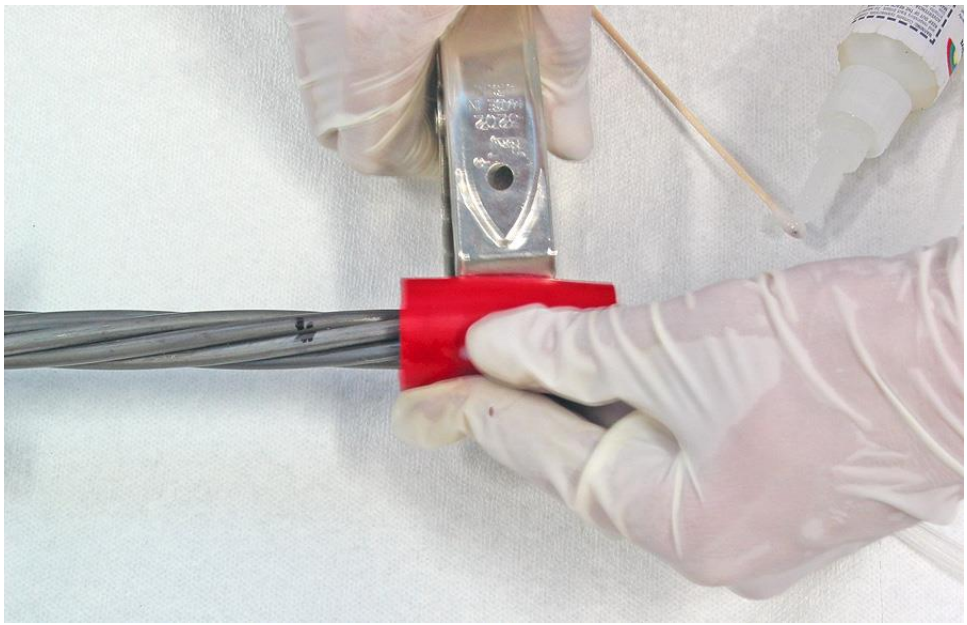


Figure 3 – Apply anchor with opening tool

8. Remove the opening tool and immediately clamp the anchor with a clamping tool, while making sure that the slot of the anchor coincides with one of the slots of the clamping tool. Steps 6 to 8 must be performed in less than a minute. Let the glue harden for at least ten minutes.

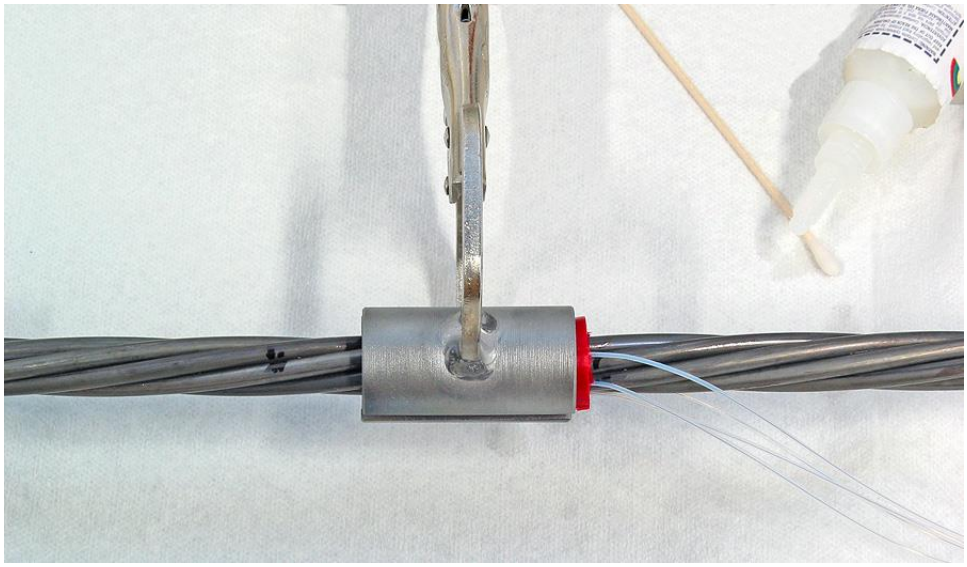


Figure 4 – Clamp the anchor

9. Wind the wires of the gauge around the cable by positioning them along the grooves of the cable. Five centimetres before the tail anchor, use tape around the cable to keep the wire in the grooves in place while performing the subsequent steps.

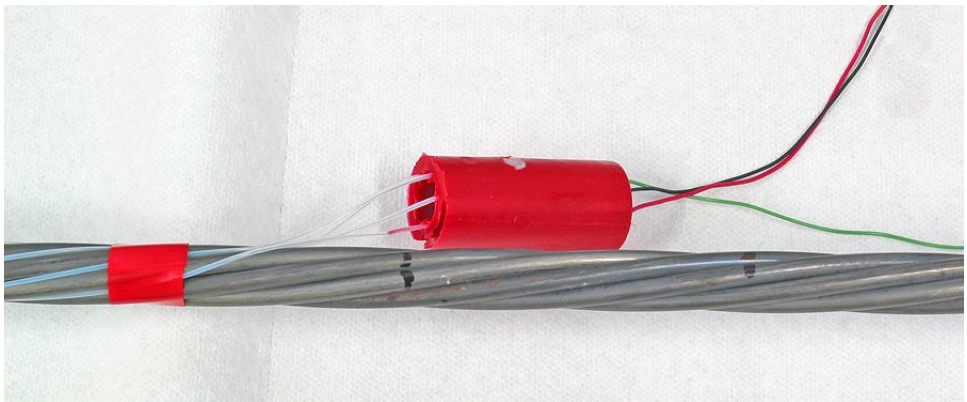


Figure 5 – Align gauge wires along cable grooves

10. Connect an ohm-meter to the two connectors of the gauge and read its electrical resistance which should be in the vicinity of 120 ohms. The ohm-meter should be provided with alligator clips to conduct this step.

11. Repeat steps 6, 7 and 8 to insert the tail anchor with the exception that the anchor must first be inserted ONLY PARTIALLY AND AT ANGLE and then pulled manually so that the ohm-meter shows an increase of electrical resistance of 0.1 ohm, prior to closing it completely and to clamping it with the clamping tool. This procedure will ensure that the gauge is adequately pre-tensioned. (THIS IS THE MOST DELICATE STEP OF ALL THE INSTALLATION PROCEDURE.)

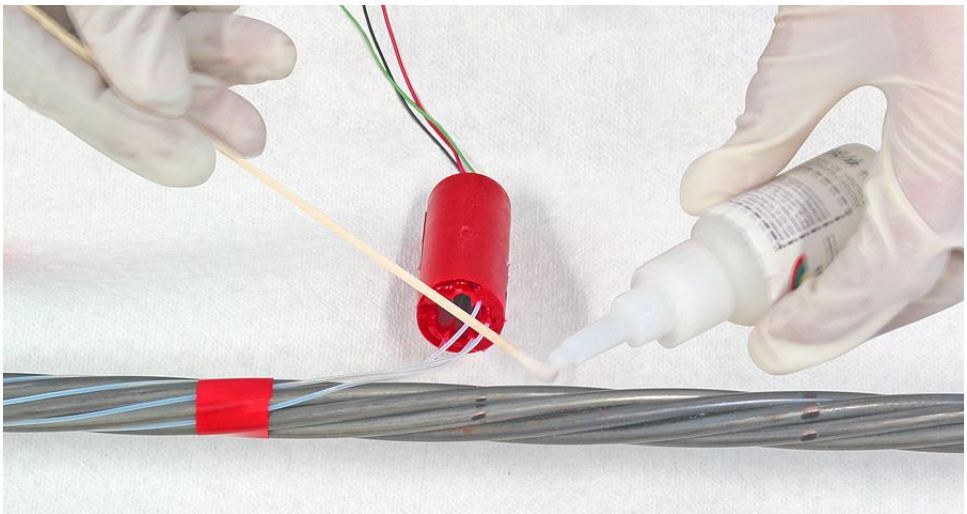


Figure 6 – Apply glue

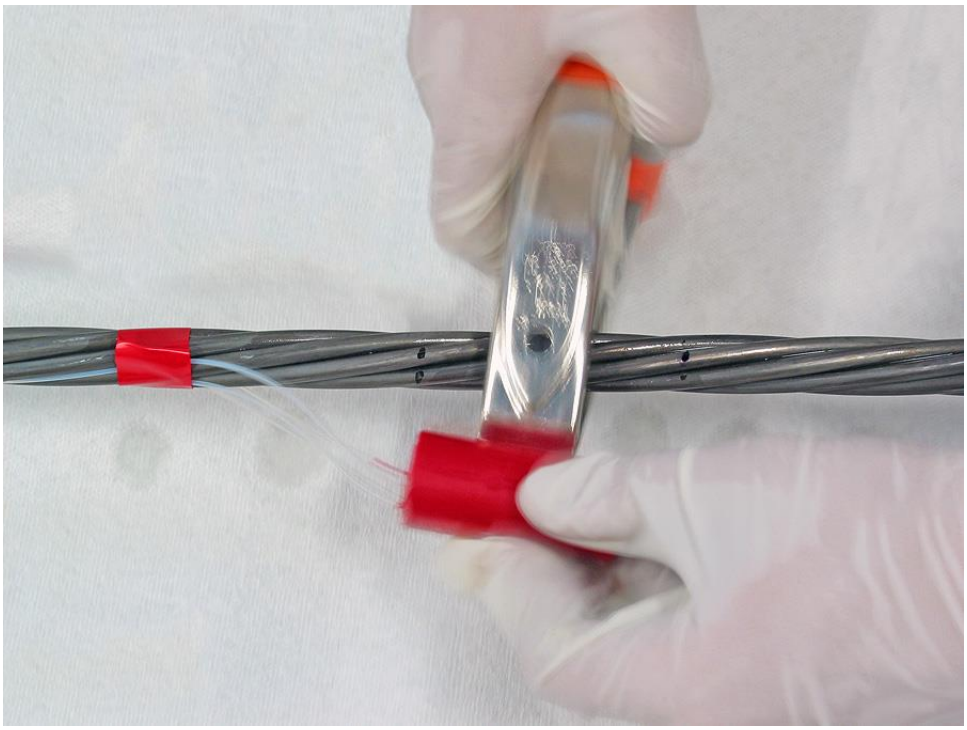


Figure 7 – Apply anchor with opening tool on angle

Figure 8 – Manually pull the anchor to achieve proper tension

12. Leave the two clamping tools on anchors for at least 30 minutes to allow the glue to cure.

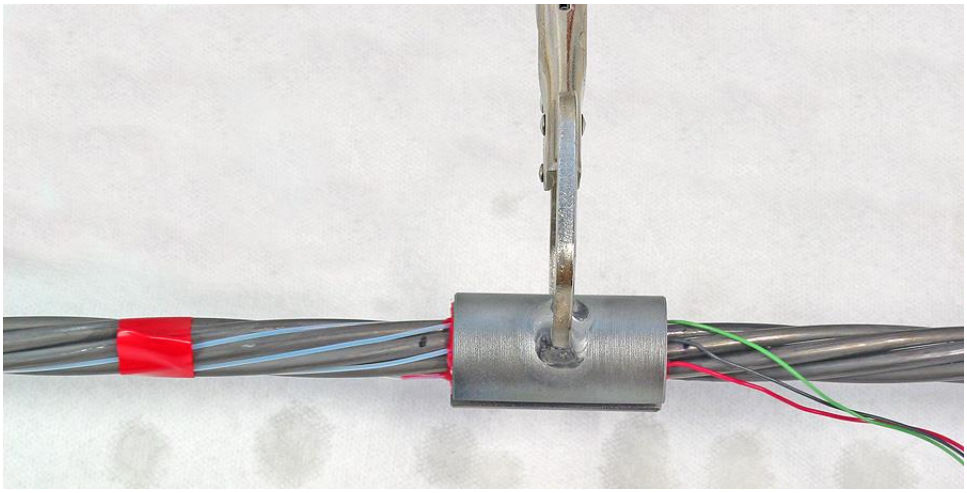


Figure 9 – Clamp the anchor

13. Repeat steps 5 to 12 for all other gauges to be installed on the cable bolt.

1.2 CONNECTION OF GAUGES TO LEAD WIRE

14. Position the lead wire along the cable bolt, starting from the head anchor of the last gauge at the bottom of the hole to the desired length beyond the collar of the hole.

15. Strip the three wires over a 1 inch length and refer to the colour code given in FIGURE 27, or to your own colour code. Insert a 2 cm length of shrink tube along the conductors.

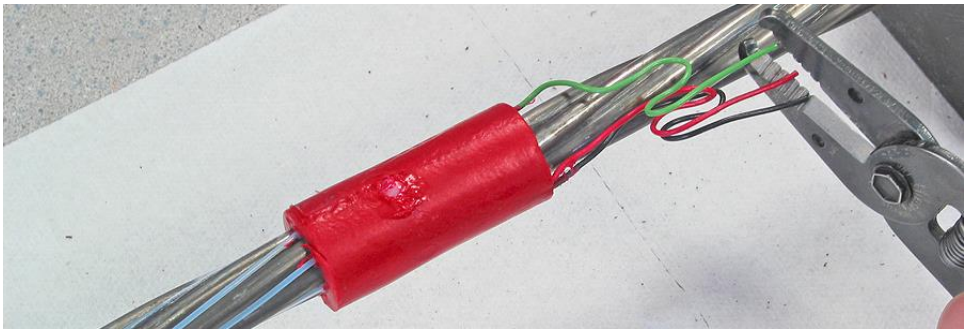


Figure 10 – Strip wires

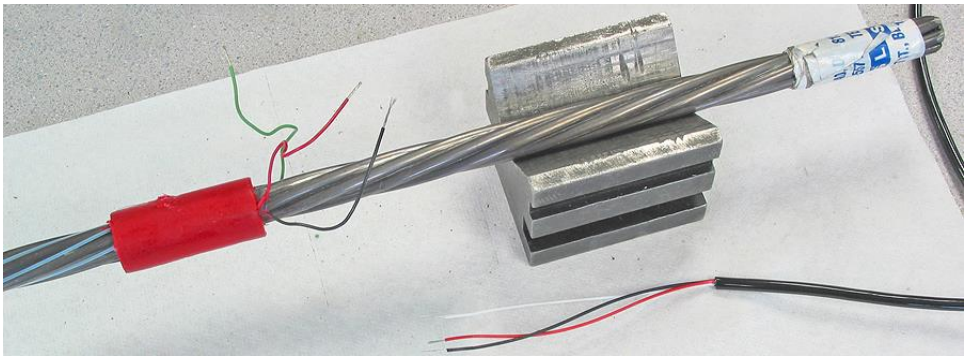


Figure 11 – Prepare to splice wires together

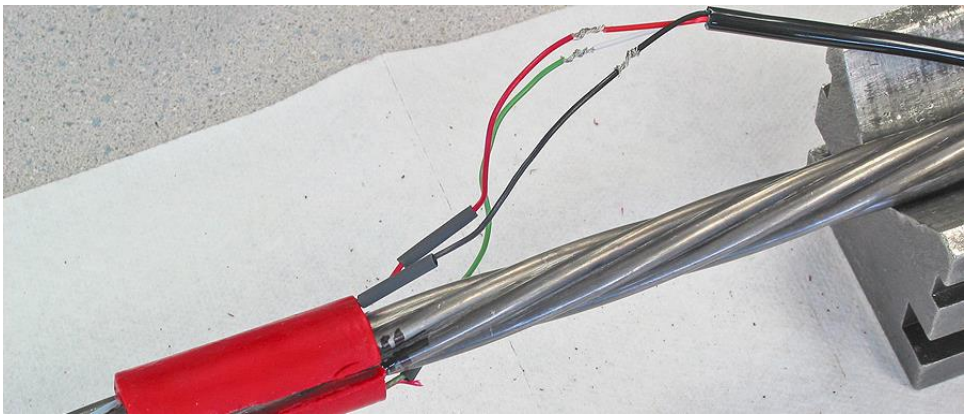


Figure 12 – Spliced together with shrink tubes along conductors

16. Apply a thin tin solder layer on the connectors and the conductors.
17. Solder the conductors while ensuring that the tin solder does not touch the cable bolt.

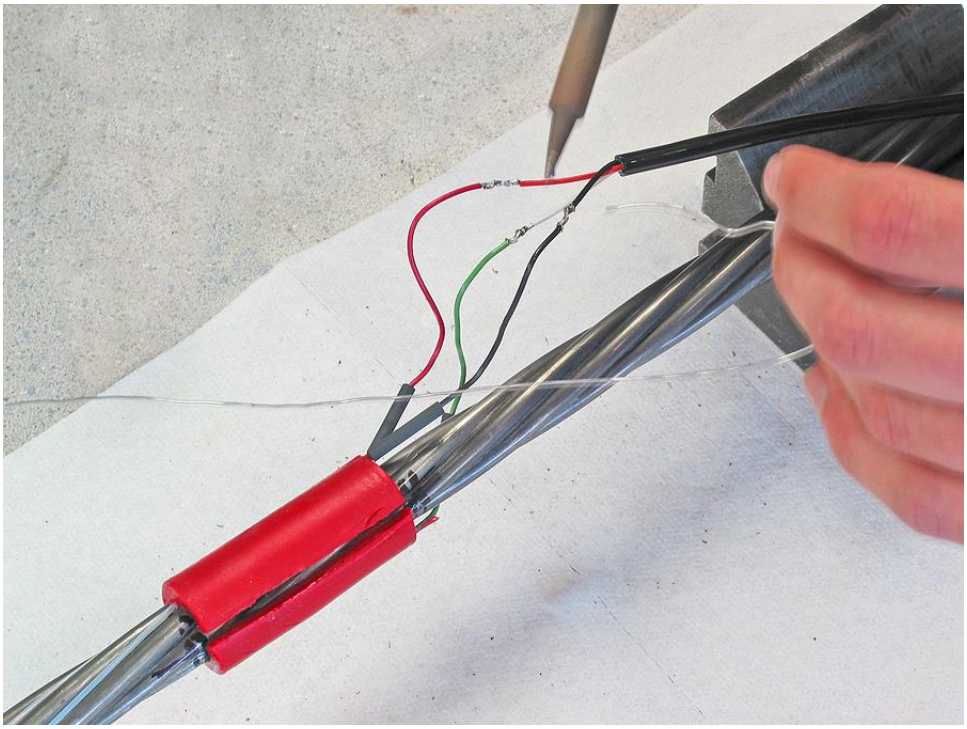


Figure 13 – Solder the conductors

18. In order to verify the connections, measure the electrical resistances at the end of the lead wire. Measurements P+ / S-, P+ / 120, and S- / 120 in ohms should be respectively 120 + x, 120 + x and x; x being twice the electrical resistance of a conductor of the length of the lead wire.

    Colour codes: P+: White (standard) / Green (right hand spiral)
    S- : Red
    120: Black

19. Apply layers of electrical isolation coating M-Coat A on the soldered connections and let them dry for a few minutes.

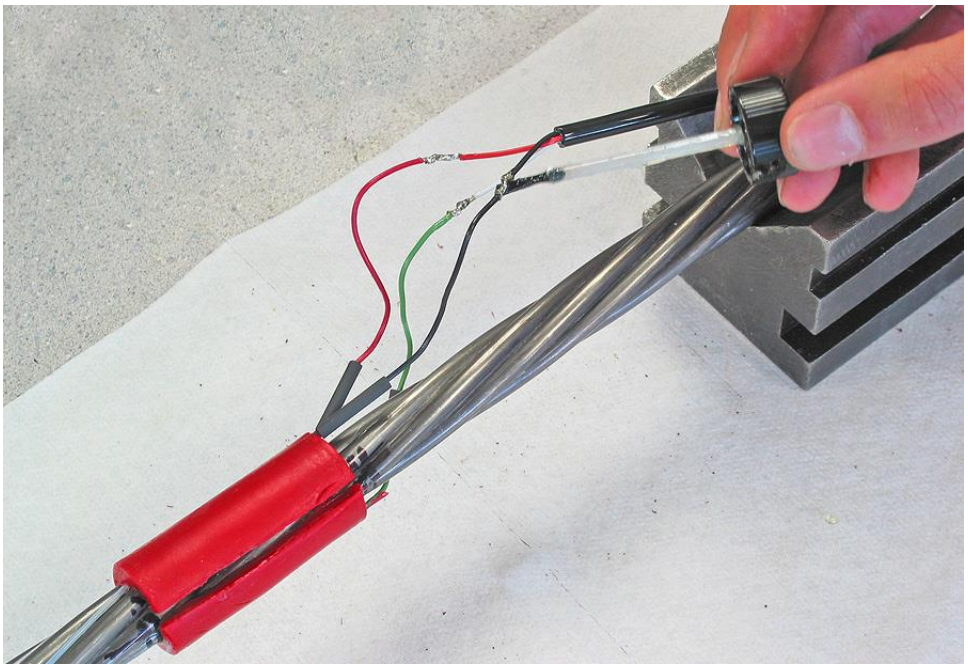


Figure 14 – Apply electrical isolation coating

20. Pull back the shrink tubing over the connections and shrink them, using a heat gun.

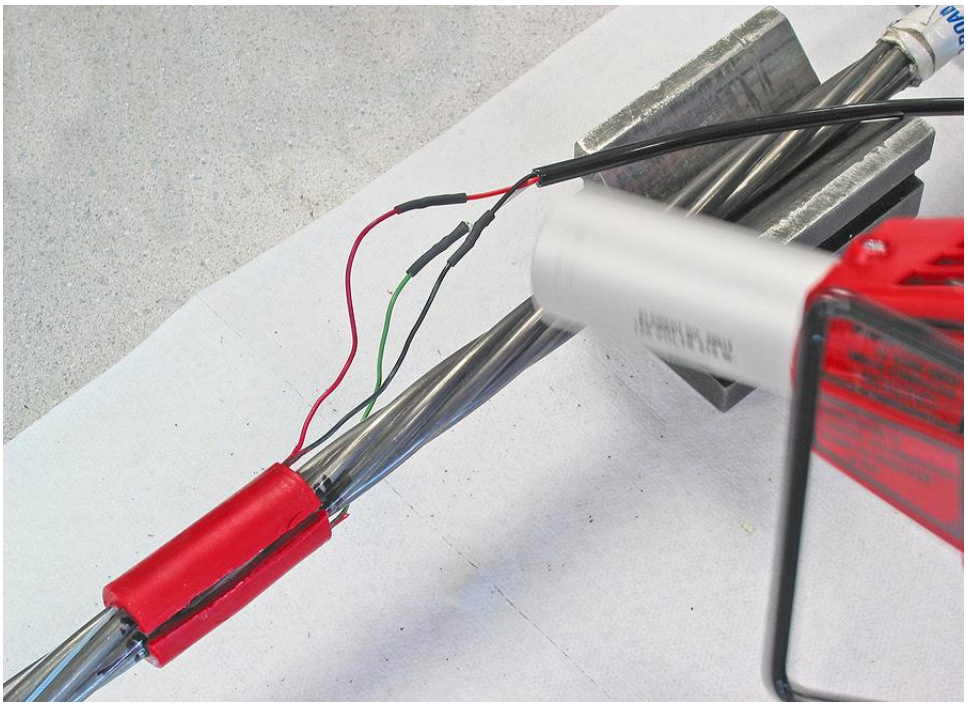


Figure 15 – Shrink the shrink tubing with a heat gun

21. Apply another layer of electrical isolation coating on the shrink tubings and let dry for a few minutes.

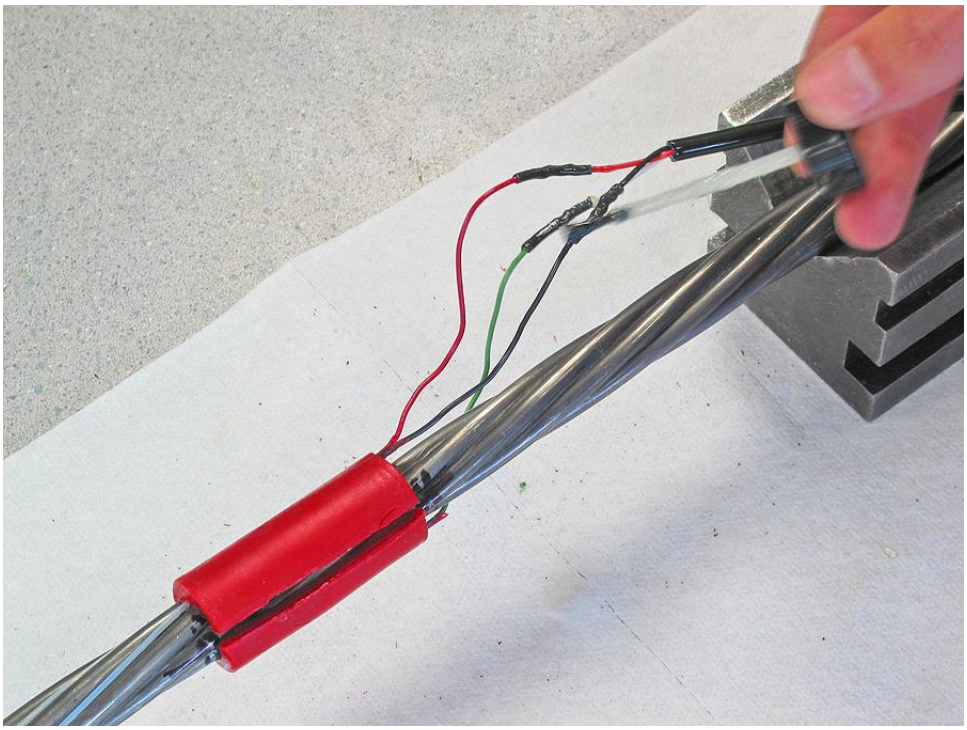


Figure 16 – Apply electrical isolation coating over shrink tubings

22. Repeat steps 15 to 24 for all other gauges along the cable bolt.

1.3 INSTALLATION OF WATERPROOFING TAPE (AQUASEAL)

23. In order to safeguard the electrical connections during elongation of the cable bolt in service, make a loop of approximately 5 cm in diameter with the conductors connected to the head anchor (one single loop only).

Figure 17 – Tensmeg gauge ready for Aquaseal

24. Cut a length of Aquaseal tape slightly longer (6 cm longer) than that of the rubber anchor to be waterproofed. Both head and tail anchors should be waterproofed. Apply this length longitudinally along the rubber anchor and close it around. In the case of the head anchor, be sure to surround the electrical connectors completely with Aquaseal. Add some extra Aquaseal. The Aquaseal should also generously protect the 5 cm diameter conductor loop.

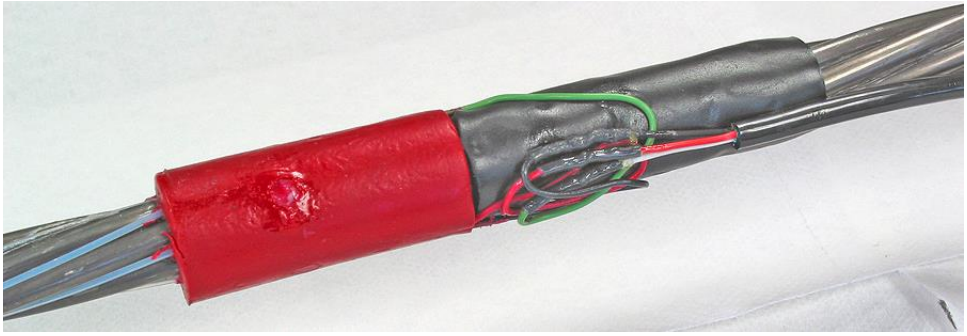


Figure 18 – Aquaseal applied under conductor loop at head anchor

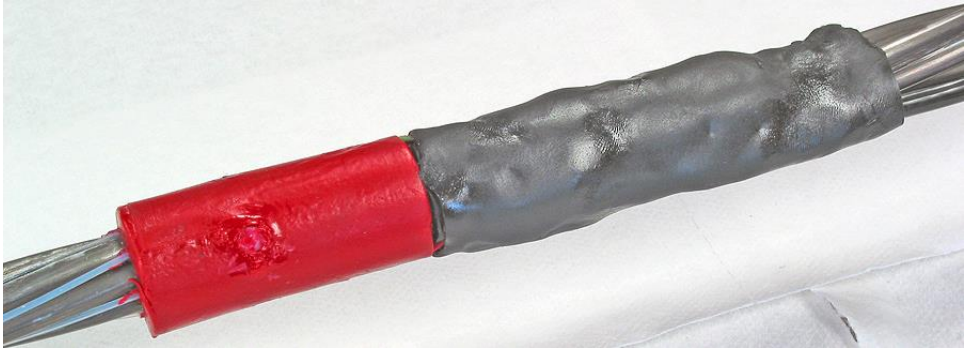


Figure 19 – Aquaseal applied over conductor loop at head anchor

Figure 20 – Aquaseal applied at tail anchor

Figure 21 – Aquaseal applied between tail and head anchors

Figure 22 – Aquaseal applied to entire gauge

25. Tape the Aquaseal-protected anchor completely, while following these instructions:
    - Pull firmly on the tape to compress the Aquaseal.
    - At each roll-around of the tape, cover the preceding band by 1/3 of its width.
    - Keep the same roll-around angle.
    - Proceed two times back and forth along the protective tubing while taping a few centimetres beyond its two ends.

Figure 23 – Second application of tape over Aquaseal

Figure 24 – Taping completed over Aquaseal

26. Attach the lead wire to the cable bolt using tape or tie wraps at the top side of the head anchors. Attach the cable, along the cable bolt, to the top after all the gauges have been installed. DO NOT TIE THE LOWER GAUGE CABLES TO UPPER GAUGED AREAS.
27. Repeat steps 27 to 28 for all other gauges along the cable bolt.

1.4 FINAL STEPS BEFORE INSTALLATION IN BOREHOLE

28. Measure all electrical resistances, using an ohm-meter with alligator clips, according to the colour code.
29. Measure the initial micro-strain readings of the gauges by connecting the connector to the readout.
30. If shipping to site, coil the instrumented cable bolt to a coil of approximately 1.5 m in diameter, while being careful not to rub the gauges excessively on the ground floor.
31. Measure the micro-strain readings of the gauges using the readout to compare them to the readings of the flat-lying cable.

1.5 ADDITIONAL REMARKS ON THE BEHAVIOUR OF THE TENSMEG GAUGE

32. The Tensmeg gauge is subject to a certain amount of drift in readings immediately after installation on the cable. The drift will be in the range of -80 micro-strains after 48 hours to -250 micro-strains after 6 months, and it will be completely stabilized after that period of time. The drift is intrinsic to the gauge; it is not possible to cycle it in factory prior to its first installation on a strand. However, traction tests of short duration can be made on the instrumented strand prior to 6 months (namely a few hours after installation of the gauge), since the drift will not affect the measurement results over the short duration of the test. It should be noted that the total drift of 250 micro-strains is small, when compared to the total strain of 8,000 micro-strains at yield limit of usual 7-wire strands.
33. In order to be able to compensate for the drift of the readings which will be taken over time, it is important to record the date of installation of the gauges so that the future readings can be modified according to the estimated amount of drift incurred.
34. Measurement results: the gauge has a very linear behaviour, including beyond yield limit of the resistance wire from which the gauge is made (approximately 5,000 to 7,000 micro-strains, depending on the actual initial pre-tension applied to the gauge). The gauge can actually read strains in excess of 50,000 micro-strains, possibly 100,000 to 200,000 micro-strains. It should be noted that beyond yield limit of the resistance wire, the gauge cannot return to zero when the strand is unloaded. Rather, it will indicate a strain value reflecting the amount of micro-strains by which it has exceeded yield during the test.
35. Once the final installation of the instrumented cable in a borehole is completed, the gauge must be read every day during one complete week to ensure that readings have stabilized and the correct value is selected for the initial reading which will serve as reference for all subsequent readings. <u>IF AN INITIAL READING IS NOT TAKEN IMMEDIATELY AFTER INSTALLATION OF THE INSTRUMENTED CABLE IN THE BOREHOLE, IT WILL NOT BE POSSIBLE TO ADEQUATELY INTERPRET THE SUBSEQUENT READINGS</u>. Very small fluctuations of readings in the first few days are possible and they can be explained by the curing of the grout.

Figure 25 – Drift after installation of a Tensmeg gauge – Data Table

(48 cm long, 120 ohm electrical resistance)

		Gauge 1		Gauge 2	
Date	Days	Reading (με)	Difference (με)	Reading (με)	Difference (με)
96/07/09	0	-4674	0	-2282	0
96/07/09	0.5	-4681	-7	-2280	2
96/07/10	1	-4681	-7	-2283	-1
96/07/11	2	-4685	-11	-2287	-5
96/07/12	3	-4688	-14	-2290	-8
96/07/15	6	-4684	-10	-2287	-5
96/07/16	7	-4683	-9	-2286	-4
96/07/17	8	-4682	-8	-2292	-10
96/07/18	9	-4689	-15	-2295	-13
96/07/19	10	-4690	-16	-2294	-12
96/07/22	13	-4692	-18	-2295	-13
96/07/23	14	-4691	-17	-2297	-15
96/07/24	15	-4694	-20	-2297	-15
96/07/25	16	-4693	-19	-2298	-16
96/07/26	17	-4693	-19	-2298	-16
96/07/30	21	-4690	-16	-2298	-16
96/08/02	24	-4692	-18	-2299	-17
96/08/05	27	-4695	-21	-2303	-21
96/08/06	28	-4693	-19	-2302	-20
96/08/07	29	-4693	-19	-2303	-21
96/08/08	30	-4691	-17	-2300	-18
96/08/09	31	-4691	-17	-2300	-18
96/08/12	34	-4693	-19	-2302	-20
96/08/13	35	-4693	-19	-2303	-21
96/08/14	36	-4693	-19	-2303	-21
96/08/16	38	-4698	-24	-2308	-26
96/08/19	41	-4697	-23	-2308	-26
96/08/21	43	-4696	-22	-2307	-25
96/08/28	50	-4696	-22	-2308	-26
96/09/03	56	-4698	-24	-2311	-29
96/09/05	58	-4699	-25	-2312	-30
96/09/10	63	-4695	-21	-2308	-26
96/09/12	65	-4694	-20	-2308	-26
96/09/13	66	-4696	-22	-2308	-26
96/09/17	70	-4698	-24	-2314	-32
96/09/23	76	-4696	-22	-2311	-29
96/09/27	80	-4697	-23	-2313	-31
96/10/01	84	-4697	-23	-2314	-32

Figure 26 – Graph of drift data

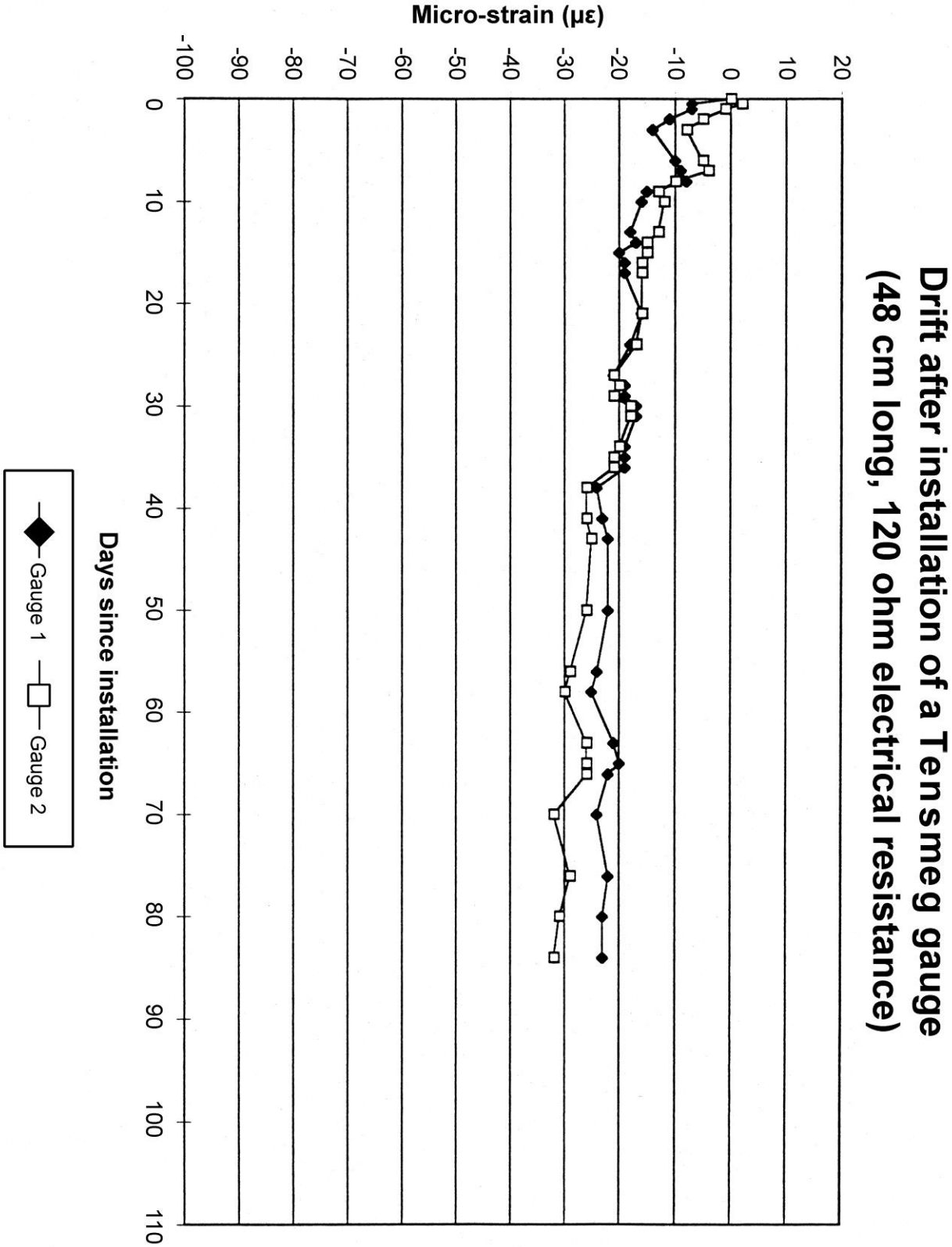
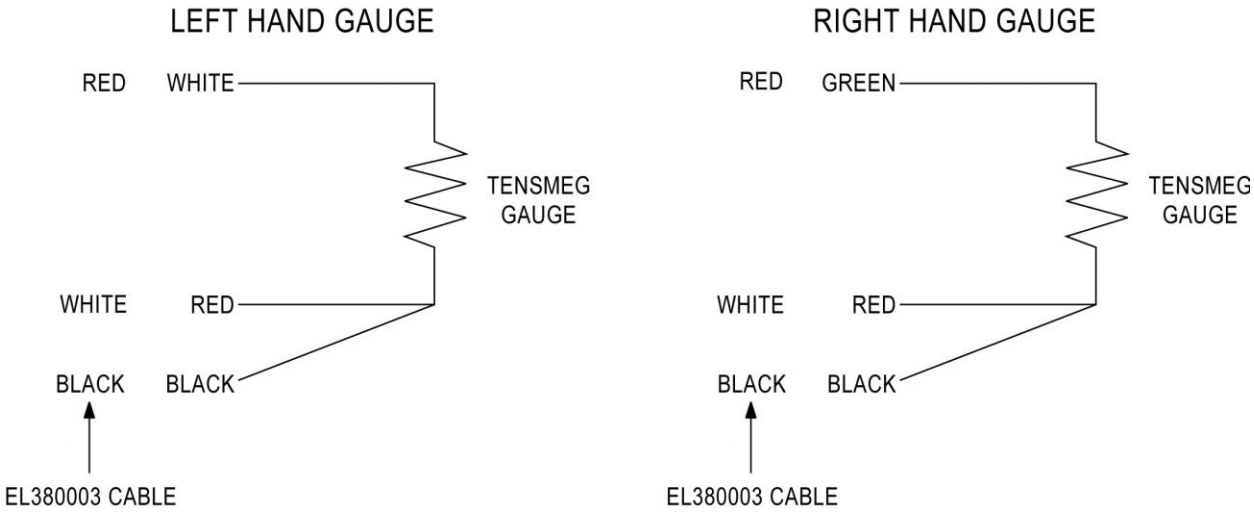


Figure 27 – Colour code for the lead wire and connector (one gauge connected to a single lead wire)



2 ACCESSORIES REQUIRED FOR INSTALLATION OF A TENSMEG GAUGE AND CONNECTION LEAD WIRE

2.1 TOOLS

- Measuring tape
- Opening tool
- Clamping tools (2)
- Metallic brush
- Ohm-meter with alligator clips (precision 0.01 ohm)
- Long-nose pliers
- Pliers for stripping wires
- Soldering iron
- Buffer tool to cut cables
- Cutter tool (paper type)

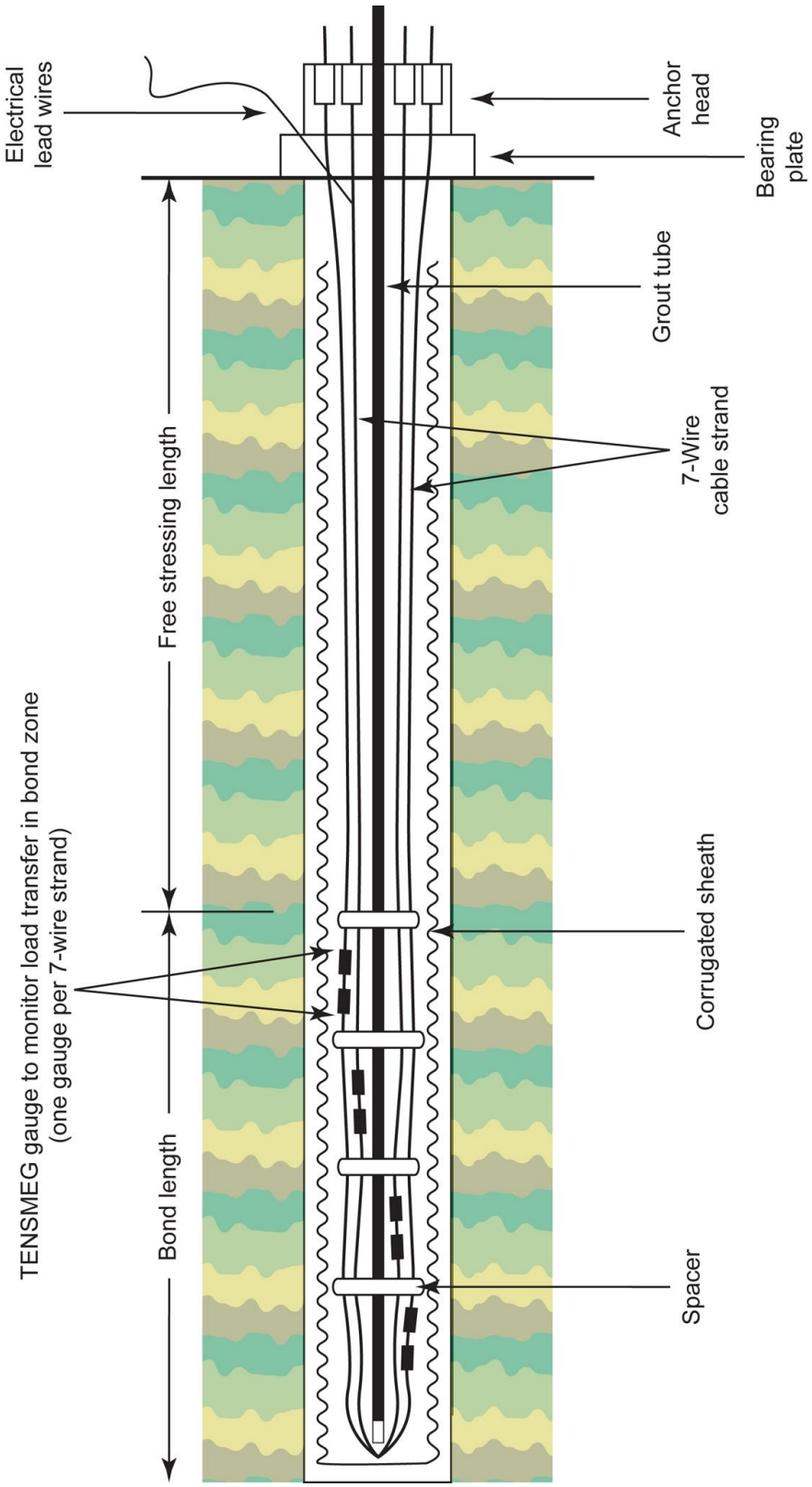
2.2 SUPPLIES (REQUIRED IN SMALL QUANTITIES)

- Loctite 495 Instant Adhesive glue (one bottle per 10 gauges)
- Acetone
- Cotton swabs (2 per gauge)
- Electrical isolation coating M-Coat A (one bottle per 50 gauges)
- Shrink tubing (3.2 mm diameter, 8 cm per gauge)
- Thin soldering tin
- Rubber gloves (surgeon type)

2.3 MAIN SUPPLIES (WITH QUANTITIES REQUIRED TO INSTRUMENT A 30-METER LONG CABLE BOLT WITH 5 GAUGES)

- 30-meter long steel cable, 7 wires, 15.2mm diameter (or other cable models). Be sure to verify if cable is left-hand lay (most common) or right-hand lay and if Tensmeg gauges supplied are the same mode.
- 5 Tensmeg gauges
- 5 x 35 meters (or more) lead wire, shielded, 3 conductors, 22 gauge EL380003 (22 gauge)
- Aquaseal tape (3.3 m length, e.g. 1 box)
- Vulcanizing electrician’s tape 3 meter type (10 rolls)
- P3 readout with patch cord (to use with Cannon connectors 3 pins)

Figure 28 – Tie-back anchor instrumented with Tensmeg gauges



3 READING TENSMEG GAUGES ON A P3 STRAIN INDICATOR

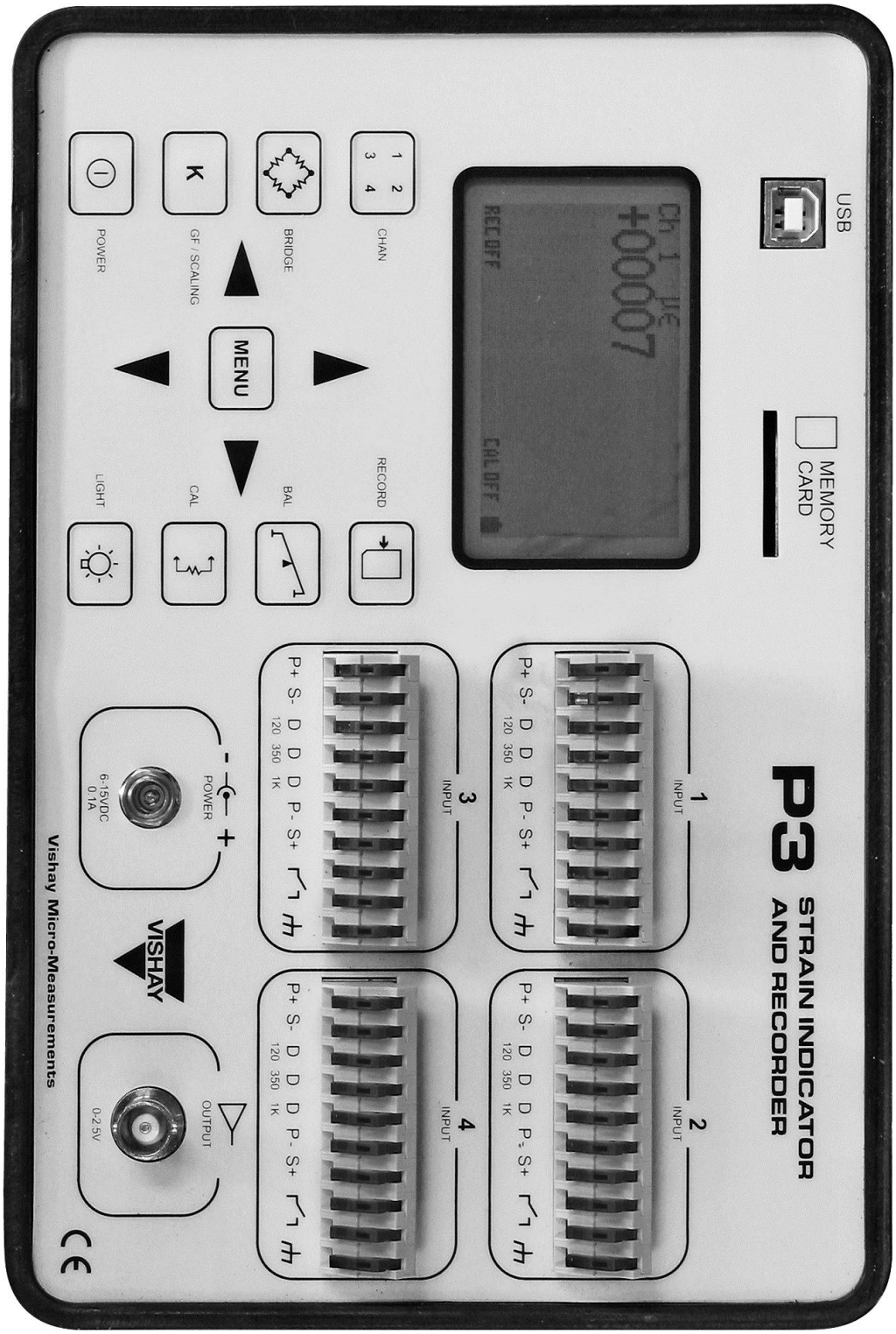
STEP 1: **Strain Indicator Setup**

- Select Channels to enable (CH1 – Ch4)
- Select Bridge Type to ¼ bridge for all active channels
- Set Gauge Factor and Display Units (uE) to appropriate value for all active channels
- **Gauge factor**
  = 2.0 for 48 cm long gauges (electrical resistance: 120 ohms)
- Set Balance Mode to off for all active channels
- Exit to Run Mode
- See the P3 instruction manual for more details.

STEP 2: **Reading Tensmeg gauges**

- Connect the Tensmeg gauge(s) to P3 readout - P+ (wht), S- (blk) and D120 (red) (120 **Ω** dummy gauge).
- Record the initial reading and sign (+ or -) for each gauge. Readings are in micro-strain.

Figure 29 – P3 Strain Indicator and Recorder



4 INTERPRETATION OF READINGS OF TENSMEG GAUGES

In order to interpret readings, it is necessary to subtract the final readings from the initial readings, and then account for desensitization due to the lead wire length:

$$Strain(\%) = \frac{[Finalreading - Initialreading]}{Desensitization * 10^4}$$

WORKED EXAMPLE WITH 50 FEET (15 M) LONG LEAD WIRE:

The desensitization due to the length of 50 feet (15 m) of the lead wire is:

$$\frac{120}{120 + 15 * 0.05\Omega / meter} = 0.994$$

assuming individual conductors of lead wire have an electrical resistance for 0.05 ohm/meter (EL380003 cable, 22 gauge).

Initial reading	=	+1128 micro-strains
Final reading	=	+4310 micro-strains
Desensitization	=	0.994

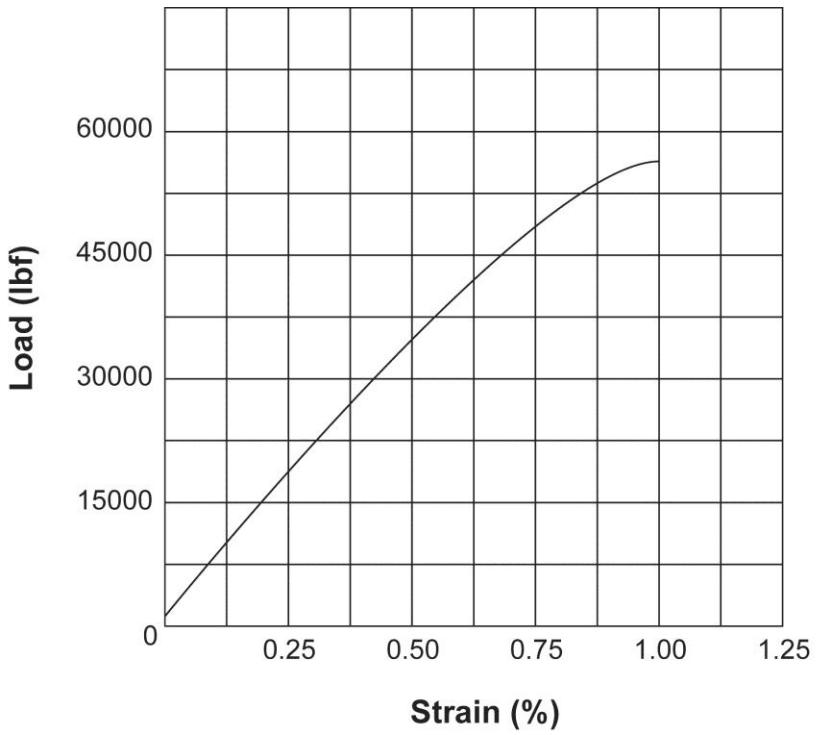
$$Strain(\%) = \frac{(4310 - 1128)}{0.994 * 10^4} = 0.3201$$

The values of cable strain can be plotted directly as a function of elapsed time or they can be converted in cable load using the load-strain curve attached.

Note: - From 0 to 50,000 lb, the conversion factor for a 0.600, 270 ksi LOLAX cable is: 0.01% = 620.6 lb or 0.01% = 2.76 kN.

- In the preceding example, the load in the cable is: 0.3201/0.01 x 620.6 = 19,867 lb, or 0.3201/0.01 x 2.76 = 88.35 kN.

Figure 30 – Typical Load Elongation Curve



TEST RESULTS

Area:	0.2240 in^2
Elastic Modulus:	28.15 Msi
Yield Point:	56516 lbf

5 CONTACT US

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