RST INSTRUMENTS LTD.

Carlson Strain Meters and other instruments for embedment in concrete structures

by
R.W. CARLSON

Edited by
Robert M. Taylor, P.Eng

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RST Instruments Ltd.
11545 Kingston St.
Maple Ridge, B.C. Canada V2X 0Z5
Tel: (604) 540-1100
Fax: (604) 540-1005
Info@rstinstruments.com
www.rstinstruments.com

Carlson Strain Meters

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PREFACE

The following pages tell how to employ embedded instruments for determination of stresses, displacements, and temperatures in mass concrete. Information is offered on how to install the meters, how to make field measurements, and how to compute stresses, strains, and temperatures from the field measurements.

CARLSON ELASTIC WIRE METERS

Carlson strain meters, stress meters and pore pressure cells all use an elastic-wire electrical resistance device as the sensing element. The device is both a strain meter and thermometer. It consists of two coils of fine steel wire, wound on ceramic spools. One of the coils increases in length and resistance with strain while the other decreases. The change in resistance is due mainly to stress and not to change in dimensions; when the length of a coil is increased by 1 percent the electrical resistance increased 3.6 percent. The ratio of electrical resistance of the two coils is directly proportional to change in gauge length, while the total resistance of the two coils is directly related to temperature. Both the ratio and the resistance can be measured accurately with a testing set of Wheatstone bridge type to 0.01 percent and 0.01 ohm, respectively.

In all Carlson elastic-wire meters the sensing element is immersed in corrosion-resistant oil, with a small amount of air to allow for expansion. Besides protecting the wire, the oil acts as a heat sink, thus reducing the effect of heating when readings are taken.

The conductor cable most commonly used with Carlson Meters is size 16 neoprene-covered, portable cord with either three or four conductors (16/3 SO or 16/4 SO). Historically, four conductors were required to compensate for leadwire desensitization, however, recent readout equipment (Carlson MA5, MA6) perform leadwire compensation on 3 wire cable. It is recommended that no longer the 600 feet of 16 AWG cable be used. Larger wire should be used with longer lengths.

When Carlson elastic wire meters are used with an automatic data acquisition system, it is customary to use a calibration constant in terms of voltage change across a full bridge instead of ratio change. The conversion equation is as follows:

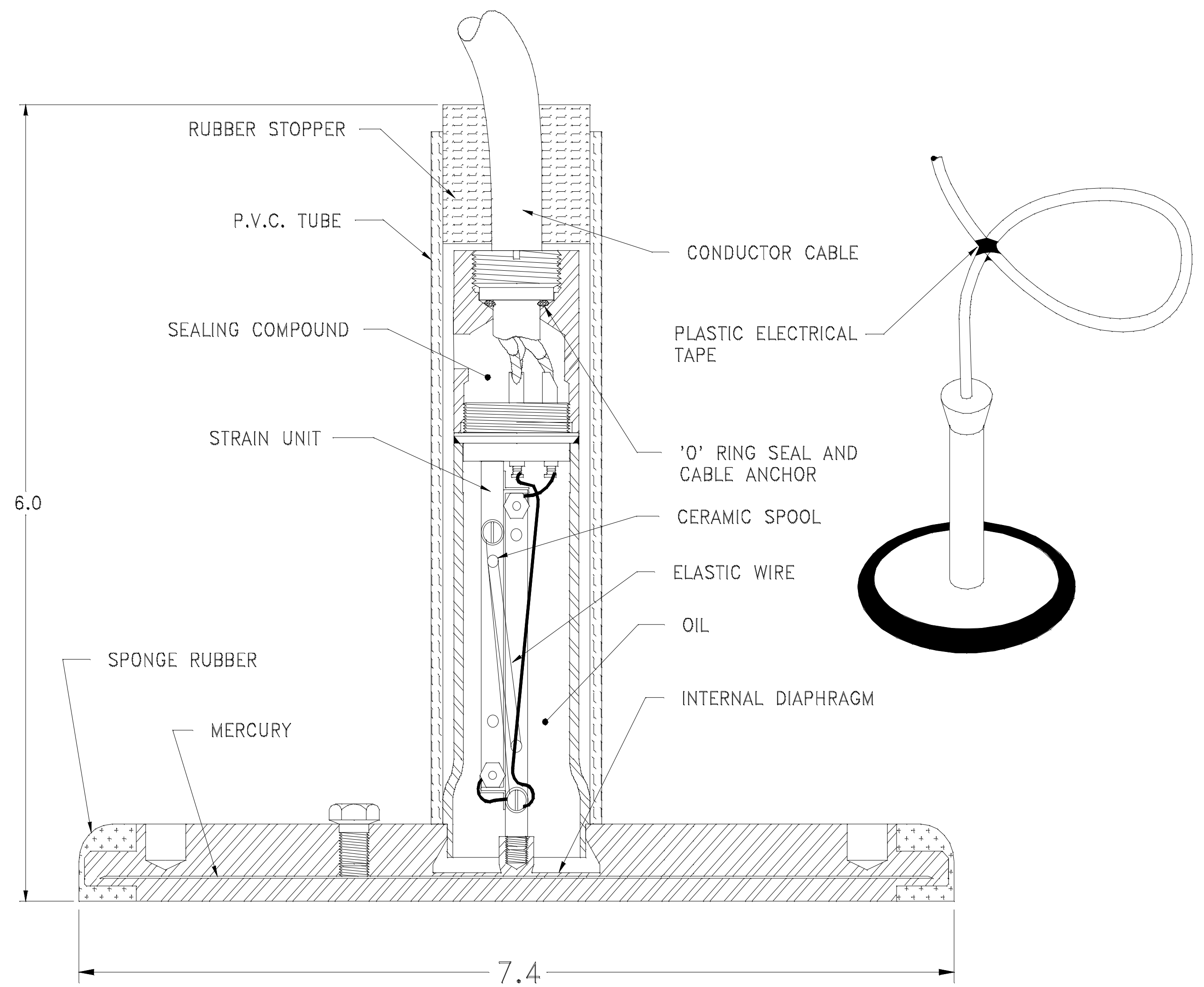
$$C'' = \frac{25}{C'}$$

Where

- C” is the new calibration constant in terms of micro-volts change per volt of excitation per micro-strain
- C’ is the ordinary calibration constant on a resistance ratio basis

A discussion of the accuracy of Carlson meters and probable sources of error may be found in the Appendix.

STRESS METER FOR CONCRETE



The concrete stress meter is a 7.3 - inch diameter plate with a strain-meter sensing element mounted on one face. The plate has a mercury film at its mid-thickness and a flexible rim with the result that any stress through the plate is applied to the mercury film. Extraneous deformations such as those due to drying shrinkage, have very little effect on stress through the plate (and the mercury) so the calibration is in terms of compressive stress per 0.01 percent reduction in the resistance ratio of the sensing element. Following a 1975 improvement, the sensing element is isolated from the concrete by having a free space around it. There was evidence that in some cases the concrete had pressed against the sensing element and caused errors, hence the isolation. A PVC plastic tube is attached to the main diaphragm in such a way that it surrounds the sensing element but does not touch it.

INSTALLATION

Since the stress meter measures the force in concrete, it is important that there be good contact between the meter and the concrete. In the manufacture of the stress meter, great precautions are taken to assure perfect contact of the mercury and the surrounding diaphragm. Similar precautions must be taken in the embedment to make good contact between the meter and the surrounding concrete. A hardened underlying concrete is essential for the placing of a stress meter for measuring **vertical** or **diagonal** stress. The meter for measuring vertical stress is usually bedded onto the top surface of the previous lift of concrete. The 45 degree meters (if used) should be bedded onto a previously prepared 45-degree surface. Placing in a deep and narrow recess should be avoided, as the new concrete would tend to shrink away for the old. The surfaces where the stress meters are placed should be reasonably plane and not too rough. Only if these surfaces are both smooth and plane can the uniformly thin bonding layer of mortar be achieved.

The following steps are recommended as a means to obtain good contact between stress meter and concrete. First, wire brush (or otherwise treat) the hardened surfaces of the underlying concrete to leave a good bonding surface. About 30 minutes before placing the stress meter, mix 80 gm. cement, 120 gm. sand passing the #30 sieve, and enough water to make a plastic consistency. Practice trials should be made to learn just how wet to make this mortar. Just before placing a stress meter, paint the concrete surface with a film of grout made by adding water to a part of the mortar until it has the consistency of cream. This is to dampen and lubricate the surface so that when the stress meter is set down on the mortar pad in the next step, the mortar will not ride over pits or depressions as it squeezes outward, thus leaving voids on the contact surface. After the surface has been painted, about 150 grams of the mortar are placed in the center of the area where the stress meter is to be seated, and this mortar is shaped roughly into a cone. Then, with a reciprocal rotary motion, the stress meter is pressed down on this mortar cone causing it to squeeze outward and appear around the rim. After the meter has been set in mortar, a metal tripod is set on the upper face of the diaphragm, such that a weight of about 20 pounds can be placed on the tripod a foot or more above the meter. After the meter is well covered with concrete, the weight and tripod can be removed. The practice insures that there is intimate contact between the stress meter and concrete below. The tripod can be made with slender vertical legs of about 1/4-inch diameter or slightly larger.

Good results in placing stress meters can be assured if preliminary trials are made with a dummy stress meter. A dummy can be made from a steel disc of about one-half inch thickness and about seven-inch diameter. A steel tube or rod can be welded to the center of one face of the disc to simulate the strain meter unit of the stress meter. A trial consists in bonding this dummy stress meter to a hardened concrete surface according the directions above. After the bonding mortar have been allowed to harden about 24 hours the dummy can be removed and the contact surface examined. The bond should be strong and the appearance of the contact surface should indicate intimate bond with no voids except perhaps a few small air bubbles, which are unimportant here. Although good placement of stress meters is difficult without practice, good placement is easy to achieve after practice.

Stress meters for measuring **horizontal** stress are placed in the fresh concrete, usually by hand. It is customary to place the fresh concrete around all except a small portion of the upper rim, and to tap the concrete well and allow it to stiffen for some minutes before covering the entire device. Leaving a small portion of the rim exposed as long as practicable helps to insure that the position and alignment are correct. Placement of meters for measuring horizontal stress is usually done at the end of a lift, after the workmen have left, but when the concrete is still plastic. Thus, the conductor cables can be carried along the top of the fresh concrete and covered so as to be protected from time on.

Instructions for taking readings are given in the appendix.

COMPUTATION OF STRESS AND TEMPERATURE

A typical work sheet for recording measurements and computing temperature and stress is presented as Fig. 1. In the upper part of this sheet are recorded the location of the stress meter and calibration data. The data supplied by the manufacturer are marked with an asterisk, thus *. For determining temperature, the calibration is given as "change in temperature per ohm", and the resistance at 0^{O} F. is provided as a reference. To obtain the temperature, it is only necessary to subtract the "resistance at 0^{O} F" from the measured resistance and multiply by the "change in temperature per ohm".

The resistance ratio at zero stress should be confirmed after embedment of the stress meter, sometime during the first day when there is a fairly uniform temperature around the meter. Thus, it will include the effect of added cable and it will not be subject to possible error due to a slight deformation, which has been known to occur in shipment.

The explanation of how the computations are made to fill the columns of Fig. 1 is given below the figure. In the sample data sheet, the temperature correction is computed for each age even though it is very small. In most cases the correction is small that rough estimation is satisfactory. For example, in Fig. 1, if the temperature correction had been omitted entirely, the error would not have exceeded 8 psi at any age listed, and this might be considered to be negligible. It is suggested, however, that the temperature correction be computed according to the equation, in order that there be provided some knowledge of whether or not it is important. Since the correction is usually small, the terms of the equation can be estimated when not available otherwise. In the equation, D is the thickness of the stress meter proper (usually about 0.5 inch); T is the thickness of the mercury film (usually not over 0.015 inch); K is the coefficient of thermal expansion of the concrete (usually about 5 millionths per degree F.); and E is the sustained modulus of elasticity of the concrete for the period of time over which the temperature change applies. Due to the fact that creep continues after the date at which any particular temperature correction is applied, there is no simple and exact method of taking account of the modulus of elasticity of the concrete. However a fairly reliable method is to compute the correction due to the change in temperature up until either maximum temperature is reached or the age of 14 days, whichever comes first. After maximum temperature has been reached, the correction can be computed from the temperature and added to the correction which has been applied up to that point. This may become clear from an examination of the sample data sheet (Fig.1).

The use of a strain meter with each stress meter offers some advantages. The stress meter is a useful device, which required more that 60 years for development to its present state. If the concrete tends to compress exactly the same, as does the thickness of the stress meter, the indicated stress is true, with no corrections. Even when the concrete tends to deform differently than does the stress meter, the current Carlson stress meter is 93 percent independent of this so-called "extraneous" deformation. Only when the deformation of is abnormally high does the indicated stress require substantial correction. To guard against the rare occurrence of errors due to abnormal deformations in the concrete, a companion strain meter is a good investment. The measurement of attendant deformation by strain meter allows a simple correction to be made for abnormal strains. In addition, the strain meter offers a means of determing tensile stress which occasionally develops in concrete.

Stress Meter No. _______________

Sheet No. ______of______

Project Sample Data

Location: Sample Data

Calibrations:

Meter resistance at O* °F	59.44*	ohms
Change in temperature per ohm change in resistance	9.44*	degrees F.
Ratio at zero stress	101.72	percent
Calibration	5.68	psi per 0.01% ratio change
Resistance of leads at 70°F.	5.48	ohms (pair)

Temperature Correction = -[(80T/D + 6.7) 10^{-6} -K] EF   80T/D = 2.0*; K = 5.5x10^{-6}; F = 0.07*

= -[2.0 +6.7 - 5.5]E (0.07) (10^{-6}) = - 0.22 E(10^{-6}) psi per 1°F. temperature rise

1	2	3	4	5	6	7	8	9	10	11	12
Date	Time	Meter Resistance, ohms	Temp, °F	Resistance Ratio, % (101.72)	Change in Ratio, %	Indicated Stress, psi	Estimated "E" million psi	Correction per 1°F., psi	Total Temp. Correction , psi	Actual Stress, psi	Notes
2-05-94	8am	67.11	72.4	101.73							conc. not
2-06-94	9am	67.82	79.1	101.70	-.02	11			0	11	set
2-07-94	8am	68.14	82.2	101.71	-.01	6	1.2	-0.3	-1	5	24 hr age
2-09-94	8am	68.50	85.5	171.68	-.04	23	1.4	-0.3	-2	21	
2-11-94	8am	68.75	88.0	101.65	-.07	40	1.5	-0.3	-3	37	max. temp
2-13-94	8am	68.70	87.4	101.63	-.09	51	2.0	-0.4	-3	48	refer to
2-15-94	8am	68.65	87.0	101.60	-.12	68	2.0	-0.4	-3	65	2-11-94
2-17-94	8am	68.61	86.6	101.55	-.17	96	2.0	-0.4	-3	93	
8-05-94	9am	67.33	74.4	101.31	-.41	233	3.0	-0.7	+3	236	
8-12-94	8am	67.10	72.3	101.21	-.51	289	3.0	-0.7	+5	294	

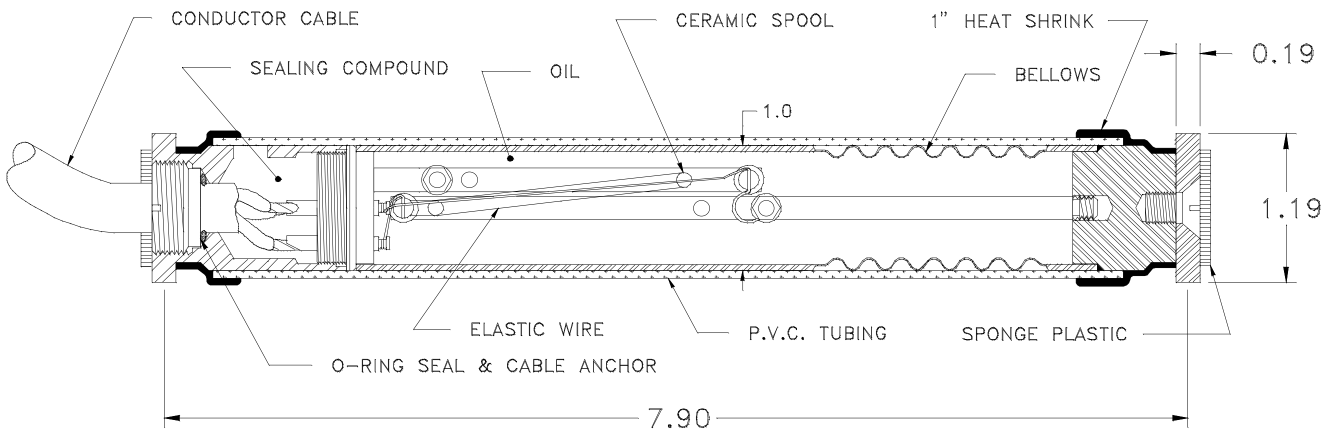
Fig. 1, Sample Data Sheet, Stress Meter

EXPLANATION:

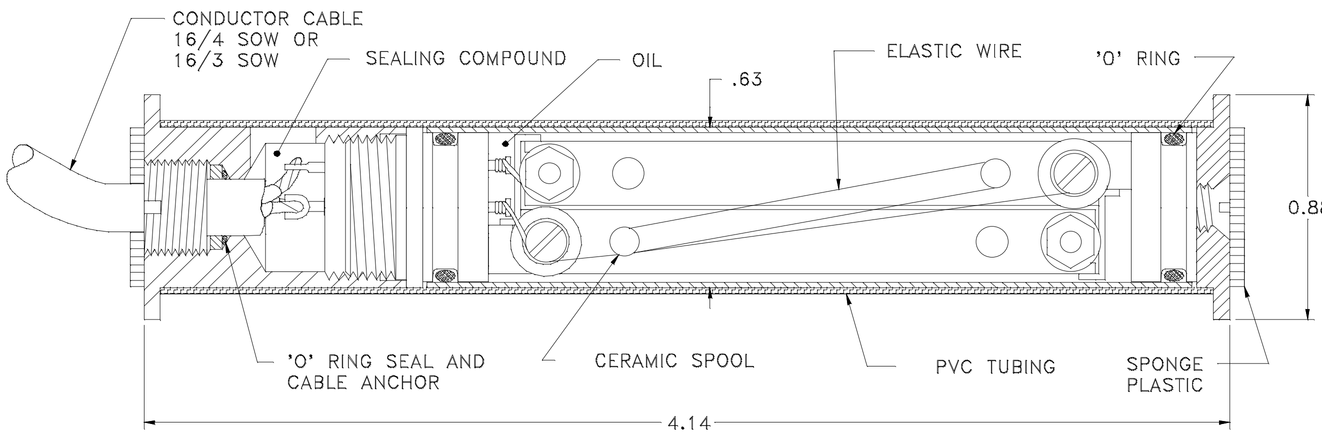
- In Col. 3 is the meter resistance exclusive of the cable.
- In Col. 4 is the temperature, computed simply by subtracting 59.44 from the meter resistance an multiplying by 9.44. These calibration constants are supplied by the manufacturer, and may vary from meter to meter.
- In Col. 5 is the resistance ratio of the stress meter as measured in the field with the MA6.
- In Col. 6 is the change in resistance ratio (in percent) as obtained by subtracting the "zero-stress" ratio from each measured ratio. In this case, the zero ratio is 101.72, determined by taking several readings a few hours after the meter is placed and choosing that which is obtained at a time when the concrete is under no stress and at a fairly uniform temperature. Actually, all of the readings during the first few hours are at or near the zero ratio.
- In Col. 7 is the indicated stress, obtained by multiplying the change in ratio from Col. 6 by the calibration constant, which is 5.68 psi. per 0.01 percent in this case.
  The next 3 columns are for making a slight temperature correction. In Col. 8 is the sustained modulus of elasticity of the concrete, as estimated from laboratory tests or from data from other sources. That is to say, it is a reduced modulus of elasticity, including the effect of creep over the duration of time for which the temperature correction is being applied. This sustained modulus will often be as low as half of the ordinary modulus of elasticity.
- In Col. 9 is the correction per degree of temperature change, as computed from the equation given in the heading of the sheet.
- In Col. 10 is the total temperature correction for the number of degrees temperature change to which it applies. Note that the reference temperature is that at 24 hours age in this case. Before that age, the concrete is too soft to support much stress and the correction is considered to be negligible. In rich concrete and especially when the curing temperature is that at 24 hours age in this case. Before that age, the concrete is too soft to support much stress and the correction is considered to be negligible. In rich concrete and especially when the curing temperature is unusually high, the reference temperature might need to be taken at 12 hours or some earlier time. This choice makes very little difference and is therefore not important.
- In Col. 11 is the actual stress, after applying the temperature correction (Col. 10) to the indicated stress (Col. 7). Care must be taken to observe the signs of the stress and the correction. A reduction in resistance ratio means a compressive stress when the temperature rises, and vice versa.

* Supplied by the manufacturer

ELASTIC WIRE STRAIN METERS



STANDARD STRAIN METER



MINIATURE STRAIN METER

The strain meter is a device which can be embedded in concrete to reveal the internal deformations. It responds to any change in dimension of the concrete, whether the change is due to stress, to the creep, to temperature change, to moisture change or to chemical growth of the concrete. The main purpose to the strain meter, however, is to determine stress, although indirectly. Quick changes in stress are revealed simply by multiplying the measured strain by the modulus of elasticity. But for stress which develops over a long period of time, account must be taken for changes in modulus of elasticity and of deformations due to creep and to all causes other than stress.

It is often desirable to measure separately the deformations due to creep and to all causes other than stress. This has been done in the past by installing "nonstress" strain meter in the structure, these being subjected to the same conditions as the surrounding concrete by protected from stress. The "nonstress" meters have not worked out as well as expected, possibly due to migration of moisture in the cavity surrounding each meter. Therefore, it is suggested that the so-called autogenous volume change be determined in the laboratory, using concrete identical to that in the structure. Since it is not practicable to duplicate the temperatures in the structure, specimens for autogenous volume change could be stored at two different temperatures so that the effect to the temperatures can be observed. These specimens can also serve to determine the coefficient of thermal expansion.

The elastic wire strain meter is in the shape of a long cylinder with anchors on the ends to engage the surrounding concrete. The cover tube of the standard strain meter is brass and has a corrugated section to give it some lengthwise flexibility. However, the cover tube is stiff enough to permit fixing the initial setting. Standard strain meters are set for about 2/3 of their range in compression and 1/3 in expansion. They may, however, be set otherwise.

The miniature strain meter differs from the standard one in being smaller in diameter and having a stainless steel cover tube riding on “O” rings to allow for movement. Initial setting of the miniature strain meter is achieved by a “C” shaped spring inserted between the end plug and the link between the bars of the frame on the right side of the figure. Normally the miniature strain meter is initially set so that between 1/3 and 1/4 of its range is in expansion. Variations in setting may be provided upon request.

All strain meters now have their cover tubes protected against bonding to the concrete by a second cover of PVC tubing. The space between the two tubes is lubricated with silicone oil.

As all strain meters are now covered with PVC tubing it becomes difficult to install the full-length cables directly to the meters in the field. It is recommended that either the meters be obtained with 30” of cable installed for later field splicing, or the full length be installed by the manufacturer. (Refer to Splicing Section of the Appendix). Cable information is detailed in the Data Sheets supplied by the manufacturer.

The standard strain meters are intended for use in service structures, and the miniature strain meters are mainly for laboratory testing. However, the miniature strain meters have been successfully used in such service structures as bridges, where less ruggedness can be tolerated.

INSTALLATION

Although strain meters and related instruments have been especially designed for embedment in concrete, nevertheless they are delicate. Special techniques have been devised for proper embedment to avoid breakage. Before beginning the lift in which the instruments are to be embedded, tour the location, check all conduits to see that they are clear, see that all advance installation such as recesses and terminal boxes have been made, check to see that extra help will be available during the installation. Go over all the survey points with plainly visible crayon, and carry the marks up so that they will be clear of the incoming concrete and visible during the night hours. It should be noted that many of these installations are made in the night.

GROUPS OF SEPARATE STRAIN METERS

One or more strain meters not in rosettes, are usually embedded near the top of a lift. In this case, let the lift be topped off and the placing crew moved away. Then:

1. Dig into the area for the full depth of the instruments.
2. Discard all cobbles over 3”.
3. Backfill to provide a bed for the instruments.
4. Use an electric laboratory vibrator to make a hole for vertical or a diagonal meter, and insert the meter in the hole. Meters to be oriented horizontally can be laid flat in the bed.
5. Check angles, direction, and depth. A protractor level is most useful.
6. Vibrate around deeply embedded meters, or hand puddle around shallow meters.
7. Continue backfilling by hand with 3” maximum concrete, and hand puddling until up to grade.

With larger groups of strain meters, up to a maximum of ten, more elaborate preparations must be made to assure correct installation in the limited time available before the concrete loses plasticity. The meters must be installed so quickly that the concrete around the meters is, in all essentials, the same as that of the rest of the lift. For this reason time is saved if the installation begins before the lift in completed.

1. Have the placing foreman level off at the elevation at which the horizontal meters are placed - not less than 6” below the top of the lift.
2. Protect this area with a frame of 2” boards and finish off the rest of the lift outside of these areas. The barrier prevents slumping the concrete.
3. Explore the bed with shovels and discard all cobbles over 3” to a depth the 4”. Vibrate lightly to consolidate without segregation.
4. Run in lines and set template.
5. Set meters in approximate position, running cable under protecting barrier and template.
6. Use electric laboratory vibrator to punch holes for vertical and inclined meters, and set to line and angle, using protractor level and vibration.
7. Line and level horizontal meters, and cover immediately with hand placed 3” concrete until a three-inch cushion is built up on top of each meter.

Continue to bring in fresh 3” concrete with shovels to bring concrete up to grade. Do not throw concrete, but place it carefully to avoid direct shocks on the meters. Allow no traffic in area. Remove protective barrier during backfiling. Finish with light shallow vibration, and protect area with a light board barrier. Mark with yellow painted metal stakes so that following crafts will not drill into meters nor set heavy skip directly over them.

STRAIN METERS ON SPIDERS

When many strain meters are to be embedded at a single location it may be desirable to mount the meters on spiders. The manufacturer can supply the spiders, which will insure that each meter is held in its intended position and direction. This is especially important for the meters to be oriented at 45 degrees with vertical. The customary procedure is to board off temporarily the location where the cluster of meters is located, and then place the concrete around the meters by hand. A fixture for holding the spider should be embedded in the previous lift of concrete.

FIELD MEASUREMENTS

Readings are taken on strain meters in the same way as for the other Carlson meters. (see section on Testing Sets, page 19).

COMPUTATION OF LENGTH CHANGE AND STRAIN

There are several steps to the procedure for converting field measurements on strain meters into stresses. The first steps are to compute the length changes and the strains from the field measurements. Fig. 2 is a sample data sheet which illustrates the steps.

The identification and location of the meter, and all calibration data are shown at the top of the data sheet. All quantities marked with an asterisk have been supplied by the manufacturer. In the columns below the headings are the measured and computed data. The procedures for making the computations are given at the base of the data sheet.

The temperature correction for the strain meter is large but definite. The strain meter is "over-compensated" for temperature. That is to say, if the strain meter is embedded in concrete which expands freely due to a temperature rise, the strain meter will indicate a **contraction**. Thus, the large but definite correction of 6.7 millionths per degree Fahrenheit must be added algebraically to the indicated length change. It is important that the analyst understand the temperature correction and apply it in the right direction.

Only **changes** in length are measured with the strain meter. Thus a single reading has no meaning, but the difference between two readings indicates the length change occurring from the time of the first reading to the time of the second reading. Thus, a reading before embedment of the strain meter has little meaning. The reference length is not fixed until the meter is embedded, because the length of the bare meter will be vary with expansion of the brass cover or with expansion of the filling oil. After embedment, the force due to expansions of the cover or filling oil is negligible.

COMPUTATIONS OF ELASTIC STRAINS FROM LENGTH CHANGES OF STRAIN METERS

There are numerous cases where the corrections for thermal expansion of the concrete need be the only correction to the length change indicated by the strain meter. The most common cases are where only approximate results are sufficient and there is known to be no appreciable alkali-aggregate expansion in the concrete. Many cases appear also where the interest is centered in quick changes of stress, and especially where this stress is mainly in one direction. Also, within many massive structures, there is no appreciable volume change due to any cause except stress and temperature. Shrinkage due to loss of moisture has never been detected (to our knowledge) in the center of a thick concrete dam. Expansion, or "growth", due to chemical action is rather common, however, and one should not assume without evidence that such growth is absent.

The actual strains derived in Fig. 2 and recorded in Col. 11 have been corrected for length change due to temperature but not for creep. The correction for autogenous length change is made simply by subtracting the length change measured on identical concrete up to the age being considered. The correction for creep of the concrete is somewhat more involved, and the complete method using a relaxation approach is explained in the Appendix.

Strain Meter No.. ______________________

Sheet No. ______of______

Project ______________Sample Data__________________

Location: ______________Sample Data__________________

Calibrations:

Meter resistance at O* °F	56.10*	ohms
Change in temperature per ohm change in resistance	8.61*	degrees F.
Useful range	97.2-103.0*	percent
Original calibration constant	3.82*	millionths (με) per 0.01% ratio change
Calibration constant corrected for leads	3.98	millionths (με) per 0.01% ratio change
Resistance of leads at 70°F.	2.61	ohms (pair)
Temperature correction	6.7	millionths (με) per degree F.
Concrete expansion	5.5	millionths (με) per degree F.

1	2	3	4	5	6	7	8	9	10	11	12
Date	Time	Meter Resistance ohms	Temp, °F	Resistance Ratio, %	Change in Ratio, %	Indicated Unit Length Change millionths (με)	Correction for Meter Expansion millionths (με)	Actual Unit Length Change millionths (με)	Correction for Meter Concrete Expansion millionths (με)	Actual Strain, millionths (με)	Notes
2-05-94	9am	64.30	70.5	100.97		0	+3	+3	-3	0	age 24hr
2-06-94	10am	64.73	74.2	100.91	-0.06	-24	+28	+4	-23	-19	
2-07-94	9am	65.30	79.1	100.83	-0.14	-56	+61	+5	-50	-45	
2-09-94	9am	65.92	84.5	100.74	-0.23	-92	+97	+5	-79	-74	
2-11-94	9am	66.33	88.1	100.68	-0.29	-116	+121	+5	-98	-93	
2-13-94	9am	66.55	89.8	100.65	-0.32	-128	+135	+5	-109	-104	
2-15-94	9am	66.75	91.5	100.63	-0.34	-136	+144	+8	-118	-110	
2-17-94	9am	66.88	92.6	100.61	-0.36	-144	+151	+7	-124	-117	
2-19-94	9am	67.02	94.1	100.59	-0.38	-152	+161	+9	-131	-123	
2-21-94	9am	67.12	94.9	100.58	-0.39	-156	+167	+11	-136	-120	
2-23-94	9am	67.24	95.9	100.56	-0.41	-163	+174	+11	-141	-130	
2-25-94	9am	67.33	96.7	100.51	-0.46	-183	+179	-4	-146	-134	doubtful
2-27-94	9am	67.41	97.4	100.54	-0.43	-171	+184	+13	-150	-131	
3-06-94	9am	67.65	99.4	100.53	-0.44	-175	+197	+22	-161	-134	
3-13-94	9am	67.77	100.5	100.53	-0.44	-175	+204	+29	-166	-131	
3-20-94	9am	67.83	101.0	100.55	-0.42	-168	+208	+40	-170	-130	

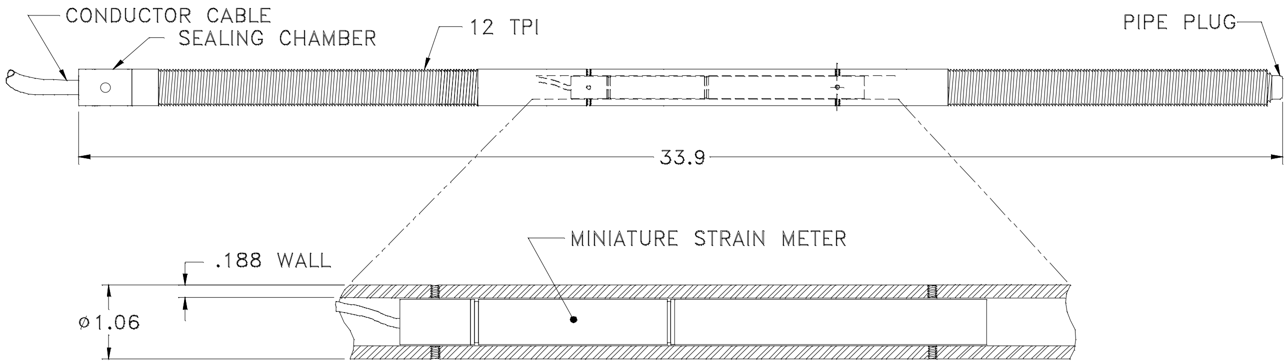
Fig. 2. Sample Data Sheet, Strain meter

EXPLANATION:

- The first 5 columns are exactly similar those for the stress meter (Fig. 1) so the explanation is not repeated here.
- In Col. 6 is the change in resistance ratio from some convenient reference. Usually, the reference is taken as the first reading after the concrete is set; here it is at age 24 hours (100.97).
- In Col. 7 is the indicated unit length change as obtained by multiplying the change in ratio (Col. 6) by the corrected calibration constant, which in this case is 3.98 millionths per 0.01 percent change in ratio.
- In Col. 8 is the temperature correction for expansion or contraction of the meter frame.
  For each degree that the temperature rises, 6.7 millionths must be added to the indicated length change to obtain the true unit length change. Care must be taken to observe the correct signs; note on the second line that the indicated length change is a negative 24 millionths, the correction due to a rise in temperature of 4.2 degrees (above 70) is a plus 28 millionths, so the true length change is 28 minus 24, 4 millionths expansion. The reference of 70 degrees is often used arbitrarily, because in the further application of results, it is only change in strain which is considered Thus, the reference is not important, and the use of 70 degrees as a base is convenient. Thus, in Col. 9 is the corrected unit length change, referred to a n arbitrary base of 70 degrees. Note that the figures in Col. 9 are the algebraic addition of the figures in Cols. 7 and 8.
- In Col. 10 is the correction for thermal expansion or contraction of the concrete. Making this correction is equivalent to subtracting from the actual length change the amount the concrete would have expanded if it were free, or 5.5 millionths per degree in this case. Thus, the figures in Col. 11 are obtained by subtracting 5.5 millionths per degree temperature rise (as listed in Col. 10) from the actual length change in Col. 9. Again, the reference temperature of 70 degrees is chosen to simplify computations and thus allow less tendency toward error.

* Supplied by the manufacturer

THE R-C (Reinforced Concrete) METER



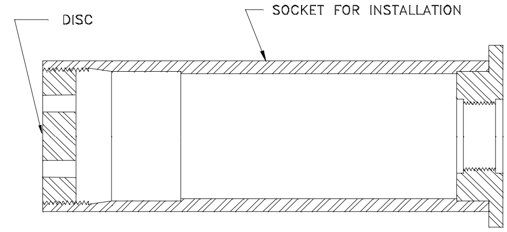
The best device for measuring the behavior of reinforced concrete is the R - C Meter. It is a rod like device which simulates a bar of reinforcing steel. The rod is hollow to accommodate a miniature strain meter within, and it is this strain meter which measures the change in length from which the stress is derived. What makes the R - C Meter unique is that it measures the change length of the steel rod regardless of the occurrence of fine cracking which is common to reinforced concrete. It measures the **average** strain over most of the rod's length, because all of the bond between the steel rod and the concrete occurs within a few inches of each end. To insure this happening, the hollow steel rod is threaded externally near each end.

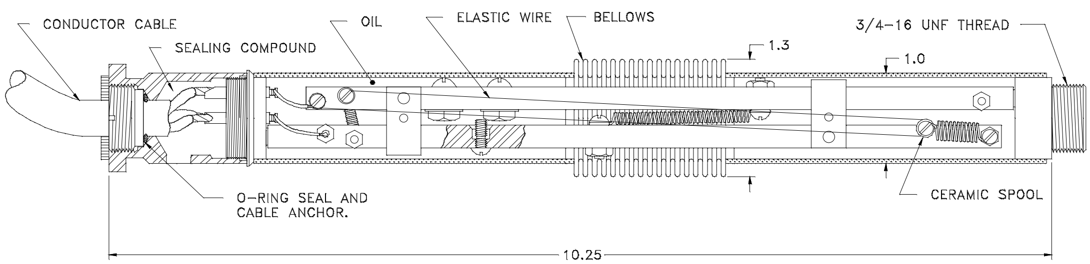
The fact that the R - C Meter measures **average** length change is important when there are tensile cracks, because the average length change determines the stress in the reinforcing. On the other hand, if conventional strain meters of limited length were to be used, they would indicate a difference result depending whether a crack is within the gauge length or just beyond it. Whenever the R - C Meter indicates a strain greater that the strain capacity of the concrete, it may be concluded that the concrete is cracked. In such a case, the R - C meter nevertheless indicates the true stress in the steel. In the case where the tensile strain is below the strain capacity of the concrete, the R - C Meter indicates both the tensile stress in the reinforcing and that in the concrete.

Another advantage of the R-C Meter is its ease of installation. Since the sensing element is surrounded by a heavy steel wall, the device is very rugged. The usual method of installation is to wire the meter to a bar of reinforcing steel and have the cable attached to the reinforcing in such a way that when the concrete is placed, movement of the concrete will not pull on the cable.

The temperature correction can be applied simply and accurately because the R-C Meter is also a thermometer, and the correction per degree is well known.

CARLSON JOINT METERS AND FOUNDATION METERS





Joint meters and foundation meters are similar to strain meters except that they have greater range. The range is increased by having a coil spring in series with each of two loops of elastic wire. The foundation meter is the same as the joint meter except that it has its range mainly in contraction. The joint meter is used mainly to measure the opening of joints and therefore it has most of its range in expansion. Both measure temperature as well as expansion or contraction in the same way that strain meters do.

The joint meter is designed to withstand a shearing movement of about 0.10 inch by reducing the frame section at the ends to serve as elastic hinges. A bellows section in the cover tube permits movement to be transmitted to the interior elastic wires. The bellows has a bursting pressure of 400 psi, but should normally not be exposed to more than 100 psi hydraulic pressure.

INSTALLATION

A steel socket and disc are provided with the joint meter to simplify the installation. The disc is intended to hold the socket onto the form on one side of the joint. Preliminary work consists of:

1. Nail the disc to the form at the joint meter location. This should not be more than 6" below the top of the lift for easiest installation.
2. Screw the socket into the disc.
3. If the forms are to be removed at an early age an additional anchor might be welded onto the socket to prevent pulling it out during form removal.
4. If the cable leads are to be run in the block in which the socket is embedded, a recess should be provided adjacent to the socket, into which not less than 3 feet of cable have been coiled.

After the low block reaches the elevation in which the joint meter itself is to be embedded, preliminary work will consist of stripping out the recess, tying up the cable stub end out of the lift, and marking the location.

1. Complete the lift.
2. Dig back at the location until the disc is uncovered, leaving a small trench about one foot square.
3. Back out the disc and screw the joint meter into the socket.
4. Tie the joint meter cable lead out of the concrete, then backfill and hand puddle.
5. Splice the meter cable to the cable extension, if required.

COMPUTATION OF THE JOINT OPENING

The procedure for computing the joint opening from the field measurements is shown in Figure 3. In this figure, it may be noted that the data in the heading of the sheet which are marked with an asterisk are supplied by the manufacturer of the joint meter. In figure 3, note that the resistance ratio and meter resistance are measured in the field. Computation of joint movement and temperature are explained at the bottom of the figure.

.

Joint Meter No. ________________

Sheet No. ______of______

Project ______________Sample Data__________________

Location: ______________Sample Data__________________

Calibrations

Meter resistance at O* °F	50.16*	ohms
Change in temperature per ohm change in resistance	11.10*	degrees F.
Ratio closed	96.79	percent
Original calibration constant	0.000046*	inches per 0.01% ratio change
Calibration constant corrected for leads	0.00051	inches per 0.01% ratio change
Resistance of leads at 70°F.	6.30	ohms (pair)

1	2	3	4	5	6	7	8
Date	Time	Meter Resistance ohms	Temp, °F	Resistance Ratio, %	Change in Ratio, %	Indicated movement inches	Remarks
5-02-94	8am	56.55	70.9	96.79	0	0	concrete ser.
5-03-94	8am	56.73	72.9	96.77	-0.02	-0.0010	joint closed
5-04-94	8am	57.14	77.5	96.77	-0.02	-0.0010	joint closed
5-05-94	8am	57.21	78.3	96.78	-0.01	-0.0005	joint closed
5-07-94	8am	57.35	79.8	96.77	-0.02	-0.0010	joint closed
5-09-94	8am	57.44	80.8	96.76	-0.03	-0.0015	joint closed
5-11-94	8am	57.45	80.9	96.76	-0.03	-0.0015	joint closed
5-13-94	8am	57.44	80.8	96.76	-0.03	-0.0015	joint closed
5-15-94	8am	57.43	80.7	96.77	-0.02	-0.0010	joint closed
5-22-94	8am	57.25	78.7	9678	-0.01	+0.0005	joint open
5-29-94	8am	56.99	75.8	97.06	-0.27	+0.0138	joint open
6-06-94	8am	56.66	72.2	97.37	-0.58	+0.0296	joint open

Fig. 3, Sample Data Sheet, Joint Meter

EXPLANATION:

- The first 5 columns are exactly similar to those in data sheets for stress meters and stain meters, and thus need no further comment.

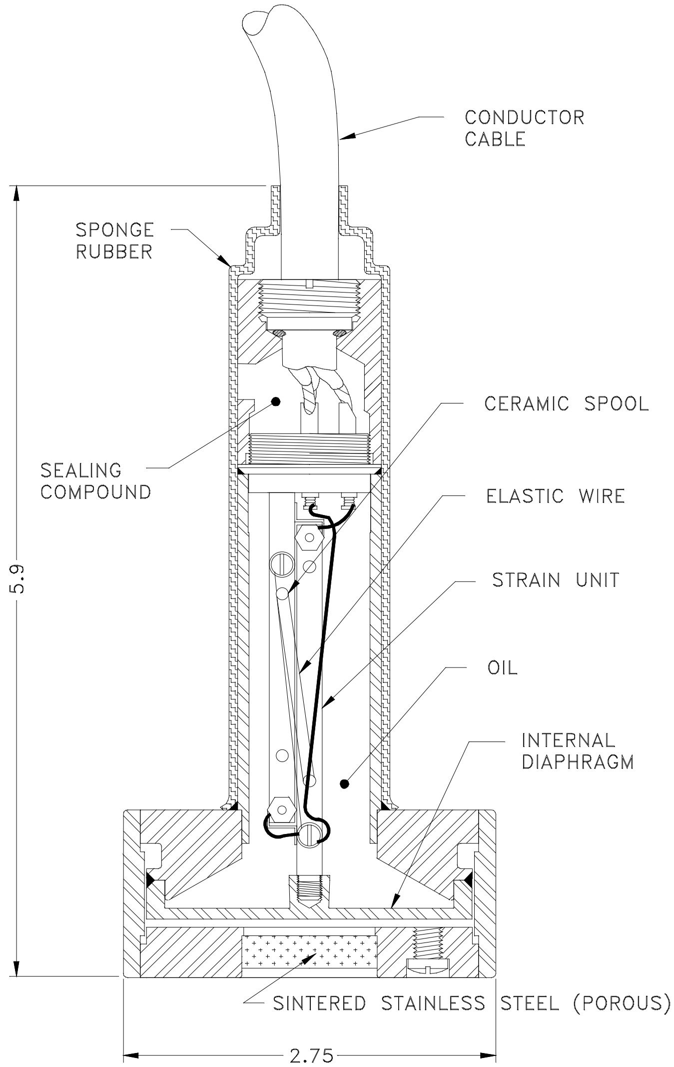
The change resistance ratio in Col. 6 is the change in ratio referred to a time when the joint is known to be closed. In this example, this reference is a few hours after the meter has been covered with concrete, when the ratio is 96.79 percent.

- In Col. 7 is the indicated movement on the joint, obtained by multiplying the change in resistance ratio (Col. 6) by the corrected calibration constant, which in this example is 0.00051 inch per 0.01 percent.

  This example is a typical one; where the joint remains closed until a temperature drop occurs Then, the joint opens quite rapidly as cooling progresses.

* Supplied by the manufacturer

CARLSON PORE PRESSURE CELL



Pore pressure in concrete or granular material like soil can be measured by a device which separates the water pressure from the intergranular pressure. In the Carlson pore pressure cell, the water pressure is admitted to an internal diaphragm through a porous disc which holds back the soil or other granular material. The deflection of the internal diaphragm is measured with the same sensing element as is used in the stress meters. For a pore pressure cell, to be fully satisfactory it must permit measurement with a minimum of water movement. Both of these requirements are met by the Carlson pore pressure cell.

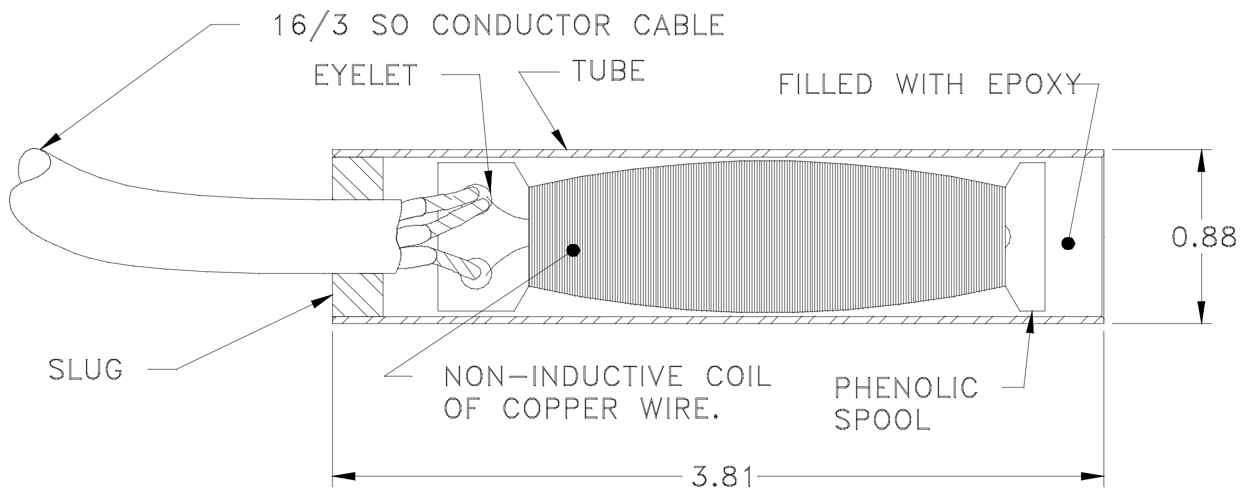
INSTALLATION

For embedment in concrete, pore pressure cells should be installed with their diaphragms facing upward. After placement of the pore pressure cell, remove the 10-32 screw from the face of the meter and fill the cavity with water until it flows out of the porous sintered metal disc. Replace the 10-32 screw, backfill and vibrate. When installing the pore pressure cell, care should be taken to tamp the concrete or soil, well around the conductor cable to prevent the conductor cable providing a leakage path and thus altering the pressure being measured.

COMPUTATION OF PORE PRESSURE

Computation of pore pressure and applying the temperature correction can be done as for the inter-face stress meter. In fact, the same computation form can be used if one changes the term “stress” to “pressure” whenever it occurs.

CARLSON RESISTANCE THERMOMETER

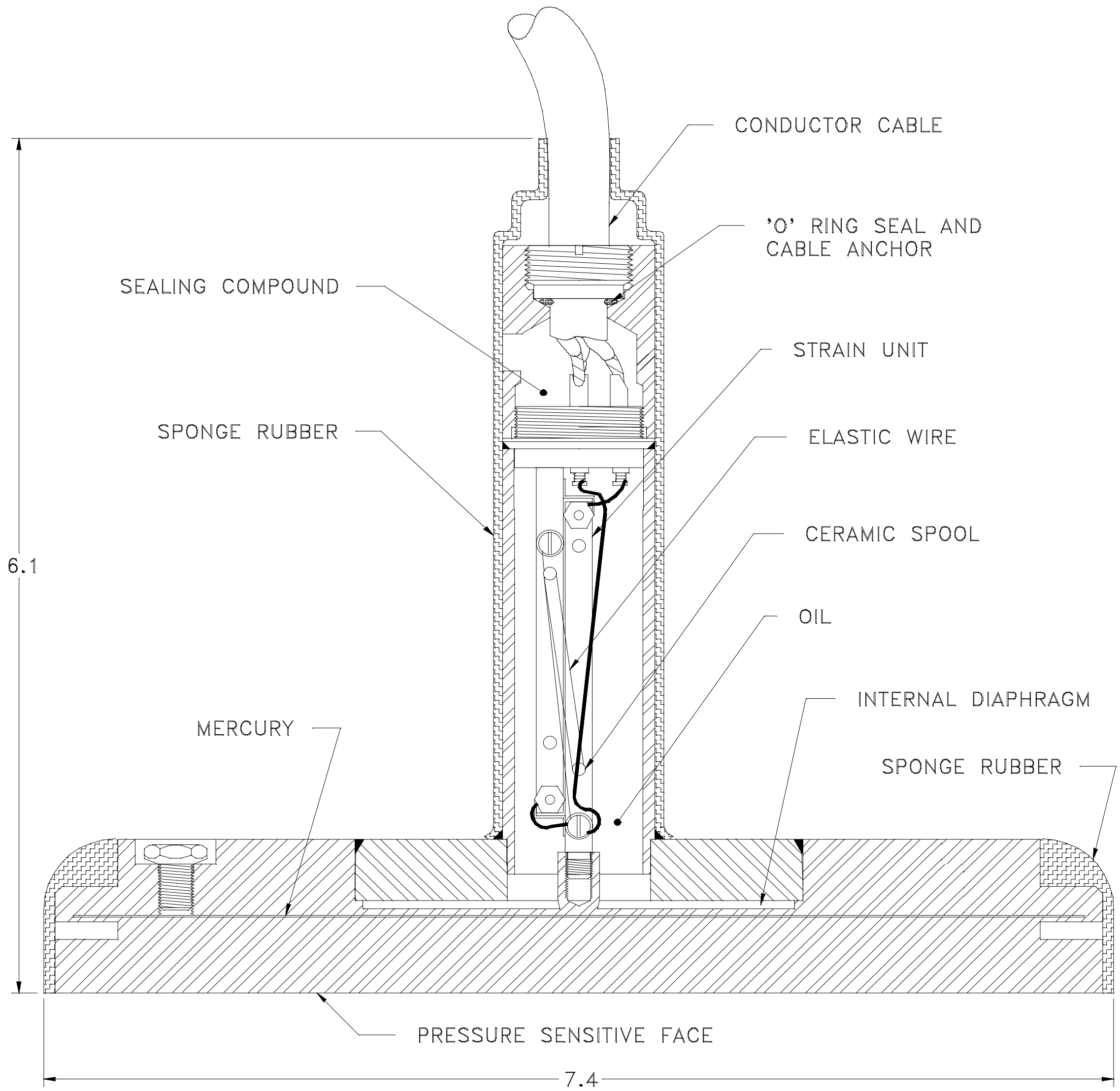


In locations where temperature alone is to be measured, the Carlson resistance thermometer may be used to advantage. This thermometer is essentially a coil of copper wire, non-inductively wound and sealed. Like other Carlson meters, it is usually provided with 3-conductor portable cord attached. Two conductors are connected to one end of the copper coil and the third to the other end. The extra conductor enables resistance to be measured exclusive of the conductors by balancing one against another, but only when all three conductors are used as directed. When only two conductors are used, the resistance indicated by the testing set will include the resistance of both conductors. In such case, the conductor resistance should be subtracted before computing temperature from resistance readings.

The thermometers are adjusted to have a resistance of 39.00 ohms at 0^0 F., and to change 0.10 ohm per degree. Thus, a resistance of 46.00 ohms means a temperature of 70.0^0 F. The thermometers are accurate within 0.5^0 F., while changes in temperature can be measured readily to 0.1^0 F.

The installation of thermometers is similar to that of strain meters. Good practice is to tie the thermometer to a wire previously embedded in the underlying concrete for this purpose. Unless the thermometer is tied to some fixed object, it is likely to be moved during concreting operations. Although less care is necessary when embedding thermometers, splicing of cables should be done with the same special care as is used for other Carlson meters.

CARLSON INTERFACE STRESS METER



The interface stress meter is so called because it is adapted to the measurement of compressive stress against a surface. It is similar to the concrete stress meter, but it has much thicker plates to make it independent of the distribution of force against it.

Flexibility of the rim is obtained through the use of grooves in such a way that there is no unloaded ring at the outer edge as in the case of the concrete stress meter. Thus, this stress meter can be mounted in a concrete wall for example, so that the flat face is flush with the surface of the concrete and then the stress meter acts as part of the wall.

The interface stress meter has 1/16 inch thick cover of sponge rubber covering its strain element housing. This cover has proven satisfactory in preventing interaction between the strain element and the concrete.

INSTALLATION

When interface stress meters are to be used to measure horizontal stress, they are embedded flush with the face of the concrete. When the installation is to be made within a foot of the top of a lift, it is simple to follow the procedure below:

1. Complete the concrete placement.
2. Hand-excavate to the position of the stress meter.
3. Holding the meter in place against the form, back fill and vibrate. Readings are made in the same manner as for the concrete stress meter.

COMPUTATION OF STRESS AND TEMPERATURE

The taking of readings and the computation of stress and temperature are the same for the interface stress meter as for the concrete stress meter, but there is an important temperature correction. When the temperature rises, the oil expands and causes a "back pressure" on the internal diaphragm which is significant in the case of the interface stress meter. The correction constant is called "increase in resistance ratio per degree temperature rise" and is supplied by the manufacturer. To make the total correction, multiply the constant by the temperature rise and subtract from the measured ratio. If the temperature falls, the correction is to be added. It may be emphasized that an increase in temperature will correct the ratio reading to a lower number. Work sheets similar to fig. 1 may be prepared with appropriate changes in headings of cols. 6 through 10. For example, col. 6 becomes "Change in ratio due to temp., per cent", col. 7: " corrected resistance ratio, per cent" col. 8: "Change in ratio, per cent" and col. 11 will remain "actual stress psi".

MA-6B READOUT INSTRUMENT

The Carlson MA-6B Readout Instrument is a dedicated computer especially for reading the output of all Carlson meters. Its special features are:

1. All meter readings are readings at the meter, eliminating the effects of cable.

2. All Carlson meters require only 3 conductor cable when used with the MA-6B Readout Instrument. (If the meters already installed have 4 conductor cable, disregard the red wire.)

3. If cable connections to the Readout Instrument are broken or connected in the wrong order, the display indicates Check Cons.

4. The MA-6B Readout Instrument automatically distinguishes between thermometers and all other Carlson meters. If the Readout Instrument senses a thermometer it displays the temperature in degrees F and C. For all other meters the display indicates ratio and resistance in percent and ohms respectively.

5. The portable MA-6B Readout Instrument is rechargeable battery (Sealed Lead Acid) operated.

The MA-6B is a precision instrument and should be treated as such. It should be protected against shock and heavy vibration. Its case is water resistant, however care should be taken to avoid getting the open unit wet as damage to internal components could occur.

For any repair the unit should be returned to the manufacturer as there are no user serviceable parts within. In the event that the unit is disassembled by the user the warrantee will be void.

CONNECTIONS OF CARLSON METERS

The thermometer is connected as follows:

Green wire to terminal 1.
White wire to terminal 2.
Black wire to terminal 3.

All other meters are connected as follows:

Black wire to terminal 1.
Green wire to terminal 2.
White wire to terminal 3.

THE CIRCUIT

The circuit resides on 3 printed circuit boards: analog, computer and display.

ANALOG CIRCUIT

The analog circuit includes the excitation to the Carlson meter, protection of the analog to digital (A-D) converter circuits from electromagnetic induction (EMI) and radio frequency induction (RFI) and the A-D converter.

The (A-D) converter is of the delta-sigma type. It is controlled by the computer circuit and software, its output is transferred via the Serial Peripheral Interface to the computer board. The delta-sigma converter includes a digital low-pass filter with zeros at 50 and 60 hertz to maximize common mode rejection (CMR) at power line frequencies. The output resolution is 16 bits, or 1 part in 65536.

The Carlson meter is excited by a current source and semiconductor current switches as required for the several readings taken. All control of the analog switches is by software.

The circuits are not connected to the case ground in the portable model except when the battery is on charge, this is through the charging connector. It is recommended that the Readout Instrument should not be operated while on charge as errors may be encountered.

COMPUTER CIRCUIT

The computer circuit is based on the Motorola 68HC11 microprocessor. It is completely CMOS and runs continuously when the unit is on, taking approximately on reading per second. Current drain from the battery is approximately 80 mA.. The battery consists of 1 12v 1.2 A-H Sealed Lead Acid battery.

The unit automatically turns off after approximately 90 seconds. The theoretical continuous operating time is nearly 15 hours continuous or 600 readings. The battery should typically be charged 1-2 hours a week depending on the amount of use, endeavoring to avoid fully discharging the unit and especially avoiding leaving it in the discharged condition.. The unit should not be left on charge for more than 8 hours, as resulting overcharging will damage the batteries. Similarly, even if the unit is not used for months, it should be occasionally charged for an hour or so to ensure best battery life.

The computer circuit provides control for the analog circuit as mentioned above, acquires and stores the digital output of the A-D converter, does the necessary arithmetic (see below), and provides output for the display including units information.

DISPLAY

The display circuit board contains a 2 X 20 multiplexed liquid crystal display (LCD) and its driver. The display has continuous electroluminescent backlight to assist in readings in underground and other poorly lit locations.

ARITHMETIC

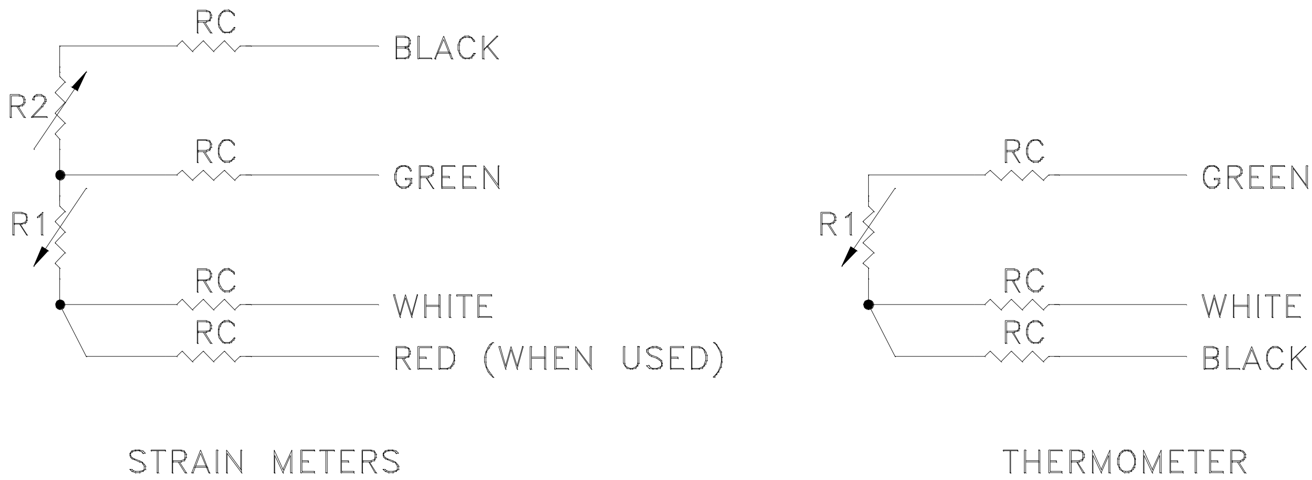


Fig. 2, Carlson Meter Electrical Diagram

Refer to Figure 2. for a schematic of the Carlson (RTD) thermometer and all other Carlson meters:

For each reading, 3 measurements of the Carlson meter are made:

The first reading	$R1+R2+2R_C$
The second reading	$R1+R_C$
The third reading	$R1+2R_C$

By adding and subtracting in various combinations, values for R_1+R_2= RESISTANCE (R) may be found.

If the value for ratio was found to be less than 50%, the Carlson meter is determined to be a thermometer (RTD) and the resistance is converted to temperature by the following equation:

$10(R-39.00 \text{ ohms}) = {}^{o}F.$

The result is processed and displayed in both F and C units.

If any one of the three connections to the Readout Instrument is broken or the ratio is greater than 199% the reading is out of range and the display will show error (Check Connections). This will occur for any case where the total resistance exceeds 120 ohms, e.g. $R1+R2+2R_C$ >=120 ohms.

If the value for ratio was found to be greater than 50%, the Carlson meter is determined to be one having the elastic wire strain meter sensing element. Display will be in ratio expressed as a percentage and resistance expressed in ohms.

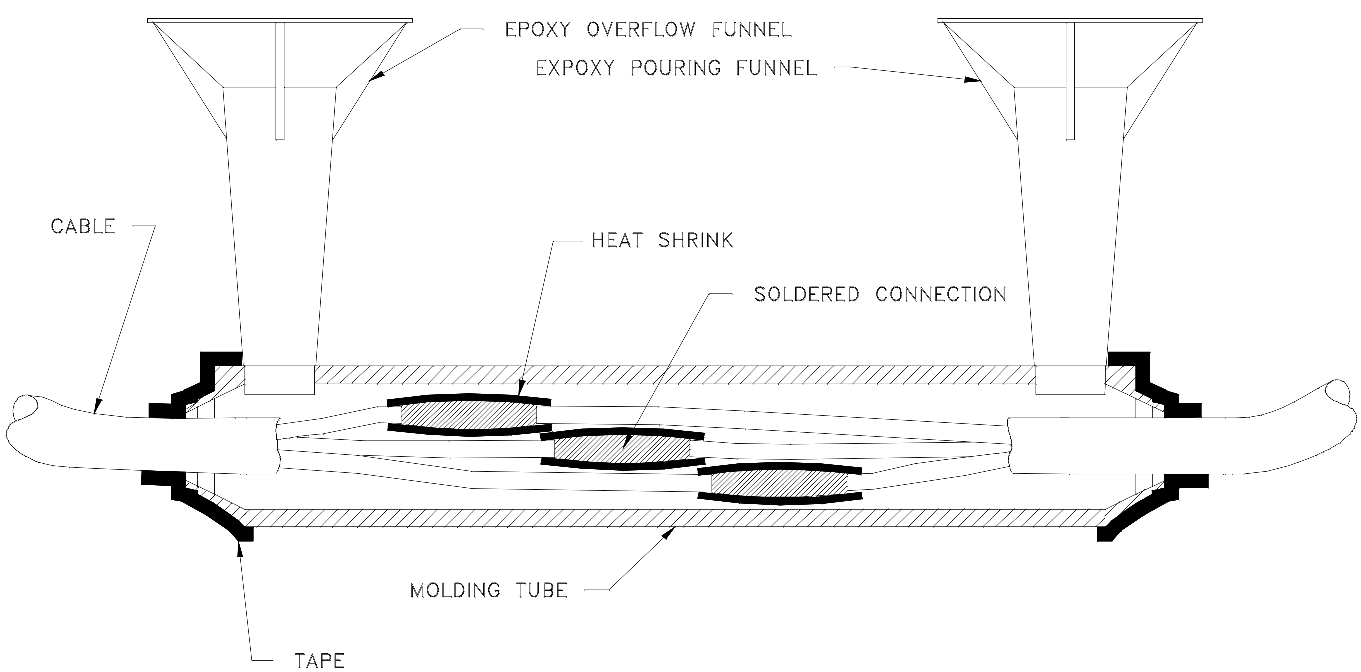
APPENDIX

SPLICING OF CABLES FOR EMBEDDED INSTRUMENTS
16/3 SO AND 16/4 SO CABLE

Recommended Splice Kit – 3M Scotchcast™ 82-A1. (Product manufactures represent that this is water proof where their products are properly applied.)

1. Strip approximately four (4) inches of the neoprene jacket from the ends to be spliced.
2. Cut conductor wires so that the solder joints will be staggered.
3. Strip approximately 3/4” of the rubber insulation form each conductor wire.
4. Slip pre-cut heat shrink tubing over conductor ends on one cable.
5. Twist the copper conductors tightly so that each spliced wire is approximately the same length. Solder connections using rosin core solder and sufficient heat to cause solder to flow around all of the strands.
6. Apply heat to shrink tubing.
7. Tape Over Connector Area - apply one layer, half-lapped, vinyl tape over connector area only.
8. Rough up approximately 1-1/2” of neoprene jacket either side of the splice using 80-100 grit emery cloth. Clean roughed area with solvent on a clean rag.
9. Install Mold Body - trim mold body ends with knife to fit cable slightly loose. Hold mold halves in place; CENTERED OVER SPLICE. Snap mold halves together firmly. check to see that both seams are completely snapped together.
10. Tape Ends of Mold - tape ends of mold to seal around cable. Use tape supplied with kit.
11. Insert Pouring Spouts in holes on each end of the mold.
12. Pour Splice - Position splice level. Mix resin thoroughly per instructions on Unipak Guard Bag. POUR RESIN IMMEDIATELY AFTER MIXING. Fill mold through one spout until both spouts are completely filled. When resin has solidified and cooled, splice may be put into service.

THE ABOVE IS SUGGESTED PROCEDURE ONLY AND IS NOT REPRESENTED AS THE ONLY OR BEST METHOD.



APPENDIX

USE OF RELAXATION DATA FOR CONVERTING STRAIN INTO STRESS

In order to avoid confusion, strain is defined in this section as that portion of any length change which is due to stress alone. Thus, if the concrete expands or contracts freely, there is length change but no strain. If there is restraint such that some of the thermal expansion or contraction is prevented, that portion of the length change which is prevented and does not occur, is called strain. When there is 100 percent restraint such that no length change occurs when the temperature would have occurred if there had been no restraint. In this case, the strain is numerically equal to the temperature change times the coefficient of expansion.

Although the measurement and determination of strain is important, it is usually only a first step, because it more often is the stress which needs to be known. When the strain is applied quickly, the immediate stress can be derived very simply. It is merely the strain multiplied by the modulus of elasticity of the concrete at the age when the strain occurred. However, this stress will then change with time, and creep or relaxation must be taken into account to obtain the stress at any later age.

The term “creep” is used to define the continued deformation when the stress is held constant. The term “relaxation”, on the other hand, refers to the reduction in stress with time when the strain is kept constant. Creep of concrete is easier to measure than relaxation, because it is simpler to apply a constant load to a specimen and measure the strain periodically, than to maintain a constant strain and measure the reducing stress. However, the determination of stress from strains occurring over a period of time is far simpler when the changes with time are treated as relaxation instead of being derived from creep data.

A new technique has been developed wherein relaxation tables are derived from measured creep data, usually with the help of the computer. That is to say, computations are made to obtain the theoretical reductions in stress which would have occurred if the strain had been kept constant. Tables 1 and 2 are the result of such computations. These tables show the percentage of the instantaneous stress which remains at various ages after the application of the strain or stress. Table 1 is for a concrete containing basalt aggregate and therefore having a very low creep rate, while Table 2 is for a more nearly average concrete. The use of such tables is described hereafter.

Strains which occur over a period of time can be converted into stress most easily if each change in strain is treated independently of each other change in strain. Let us consider the general case where there is a record of strain occurring over a period of time. Consider further that those strains are made up of a series of independent strain changes, which are hereafter called “increments”. In order that each increment be independent of each other, the strain in each increment must be kept constant thereafter. This means that instead of the strain in each increment being allowed to change or “relax”. The new relaxation table show the percentage of stress remaining at various ages after each increment has occurred.

EXAMPLES OF STRESS CONPUTATION INCLUDING RELAXATION

Begin by drawing a curve of observed or computed strains, corrected for autogenous length changes, versus age of the concrete. From the curve, enter in a table like that below listing the strains at intervals as shown. Include in the table measured or interpolated values of the modulus of elasticity of the various ages, as shown in the 4th column below. Then compute the “quick-load” stress by simply multiplying the change in strain by the modulus of elasticity, entering it in the last column of the table. In the following tables, strains are in “millionths” and modulus of elasticity are in “millions of psi.”

AGE Days	STRAIN from curve	CHANGE in Strain	MODULUS of Elasticity	QUICK-LOAD Stress, psi
1	+16	0 (ref.)		
2	+9	-7	2.20	-15
4	+12	+3	2.38	+7
6	+21	+9	2.56	+23
8	+35	+14	2.67	+37
10	+51	+16	2.75	+44
12	+66	+15	2.83	+43
14	+80	+14	2.90	+41

Suppose now that we wish to know the stress at the age of 15 days. Referring to the relaxation table (Table 1), we find the percentages of quick-load stresses remaining the corresponding incremental stresses as follows:

AGE Days	QUICK LOAD Stress, psi	% RETAINED at 15 days	INCREMENTAL Stress, psi
2	-15	85	-13
4	+7	84	+6
6	+23	83	+19
8	+37	84	+31
10	+44	84	+37
12	+43	87	+37
14	+41	93	+38

The algebraic sum of the stresses listed in the final column of the above table is the net stress, and this is found to be 155 psi. This is the stress at that stage of 15 days, taking into account that the increment of stress which was applied at the age of 2 days had relaxed for 13 days, that which was applies at the age of 4 days had relaxed for 11 days, etc. The procedure for any age other than 15 days could be found in the same way, using relaxation percentages for the age in question.

It may be of interest to note that the algebraic sum of the quick-load stresses in the table above was 180 psi. Thus, the effect of relaxation (or creep) was in this case merely to reduce the sum of the quick-load stresses from 180 to 155, or 14 percent. It should be borne in mind that the relaxation of the concrete of Table 1 is very small compared with most concrete’s, and this accounts for the unusually small effect of duration of load in this case. The modulus of elasticity of the coarse aggregate in the concrete of Table 1 was very high, approximately 11 million psi.

APPENDIX

PROCEDURE FOR DERIVING RELAXATION FROM CREEP DATA

Relaxation can be computed from creep data quite simply if the creep is considered to occur in small steps. By definition, the stress needed to offset the creep during each such step is the relaxation during that step. Consider, for example, the first day after a stress is applied. If the creep were to be prevented to meet that condition of no strain, and offsetting stress must be applied which is numerically equal to the creep strain multiplied by the modulus of elasticity at the age. The table below gives an example of how such computations are made. In general, the method is simply to multiply the creep strain for the interval by the modulus of elasticity at that age. However, it must be borne in mind that the relaxation causes a reduction in stress at each successive interval, so the creep must be reduced as the stress is reduced. Thus, for each step, there are three numbers to multiply together (1) the creep for the interval (assuming no relaxation), (2) the percentage stress remaining, so as to correct the creep to a lower value, and (3) the modulus of elasticity at the age under consideration. The procedure may become clear from an inspection of the partial example given below. This example shows the first few steps of computation for the case of stress applied at the age of 7 days.

SAMPLE COMPUTATION

(In the following tables, Strains are in "Millionths" and Modulus of Elasticity are in "Millionths of PSI")

DAYS AFTER STRESS APPLICATION	TOTAL CREEP FROM LAB TESTS	CREEP FOR INTERVAL	MODULUS OF ELASTICITY FROM CURVE	RELAXATION STRESS TO MAINTAIN ZERO STRAIN	STRESS REMAINING
0	0.00				100.0
1/2		6.00	2.54	15.2	
1	6.00				84.8
1 1/2		3.50	2.63	7.8	
2	9.50				77.0
2 1/2		2.30	2.66	4.7	
3	11.80				7.23
3 1/2		1.70	2.68	3.3	
4	13.50				69.0
4 1/2		1.50	2.70	2.8	
5	15.00				66.2

In making creep tests, specimens are usually loaded at each of only a few ages, often 3, 7 and 28 days. When the relaxation's have been computed for stress applied at these ages, values for stress applied at other ages can be found readily by interpolation. In making up a table for use in stress analysis, it is believed desirable to show "stress remaining" rather than relaxation itself. If the initial stress is assumed to be 100 psi or 100 percent, the stress remaining is obtained by subtraction the relaxation from the initial stress.

APPENDIX

METHOD FOR EMBEDDING STRESS METERS IN CONCRETE (REVISED)

Some difficulty has been encountered in installing stress meters so as to be sure they remain oriented correctly and that there is intimate contact between the faces of the meter and the surrounding concrete. A revised method employing embedded rods for tying down the horizontal and inclined meters has been found to avoid this difficulty. The new method applies only to horizontal meters (for measuring vertical stress) and inclined meters. The placing of vertical meters is relatively easy and needs no tie down help.

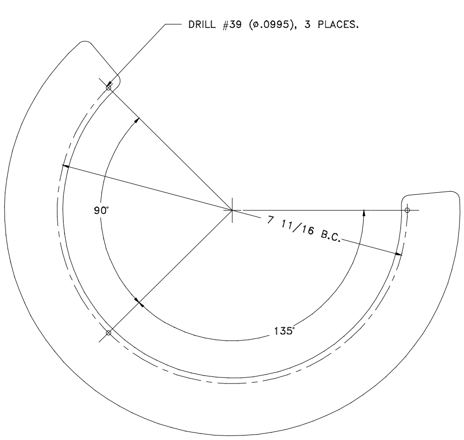
Consider first the placing of the meter to be placed with the plate horizontal for measuring vertical stress. The scheme is to embed three thin rods with anchors at the bottom as shown in the sketch. The rods are to be placed vertically so that their top ends emerge near the periphery of the meter plate. A slotted bar is provided for connecting each rod to the stress meter plate in the manner shown. While embedding the rods, a template* (semi-circular in shape) is oriented to position the rods sot that their upper ends will be in the desired positions as shown in the sketch.

The installation of stress meters in any inclined position requires a form to insure that the angle is correct and that the surface is plane and fairly smooth. The thin rods are embedded in a member like that for horizontal meters, but instead of the semi-circular shaped template, holes in the form provide the guidance for positioning the rods. (The template can also be used as a drilling jig for inclined meters.)

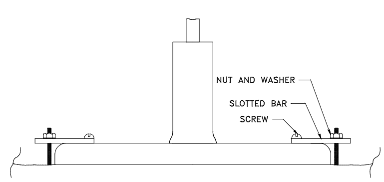
For both horizontal and inclined meters, the meter is placed only after bleeding has stopped in the underlying concrete, usually from 4 to 6 hours after casting. Before placing the meter, a cone of special mortar is placed at the center of the meter location and meter is pressed against this mortar with a twisting motion such that some of the mortar oozes out at the edges. Then the tie-down bar is secured and adjusted so that the meter shield firmly against the underlying concrete. Concrete is then placed over each meter and carefully compacted.

MORTAR FOR BEDDING STRESS METER

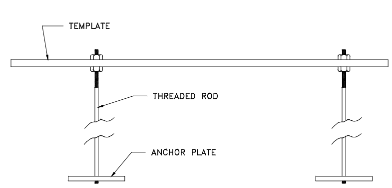
Because of the difference in compressibility of concrete and mortar, it is advisable to use a special mortar for cementing the stress meter to underlying concrete. Among the several ingredients of either mortar or concrete it is the aggregate which has the highest modulus of elasticity. Thus, that mixture which has the largest volume percentage of aggregate and the lowest percentage of cement, water and air, will have the highest modulus of elasticity. Thus, for a given water cement ratio, the mortar will necessarily have a much lower “E” of the concrete and the mortar identical. Steel shot is available in very fine sizes, between the #100 and the #16 sieves. When this is used to replace a part of the regular sand, a mortar can be made with an “E” equal to that of the concrete, or greater. This mortar is very workable due to the spherical steel particles and has been found to work well for bedding stress meters. Iron filings can be used instead of steel shot, with proper proportions to be determined by trials.



TEMPLATE



ASSEMBLY OF STRESS METER TO ANCHOR RODS



ASSEMBLY BEFORE EMBEDMENT OF ANCHOR RODS

WARRANTY

RST Instruments reserves the right to change the price or modify the specifications of its equipment without notice.

RST Instruments agrees, for a period of 12(twelve) months from the date of purchase, as evidenced by the date of the invoice, to replace any equipment which fails or malfunctions as a result of defects in materials or workmanship when that equipment has been serviced or installed by the servants or agents of RST Instruments. The agreement to replace herein contained does not apply to the compensation or any portion of installation or site preparation.

There is not warranty, representation, or condition of any kind, expressed or implied with respect to the equipment or the accuracy or longevity thereof, except that of replacement as stated above. RST Instruments and its servants or agents will not be liable for any special, indirect or consequential damages arising from the servicing or installation of the equipment, nor shall recovery of any kind against the said company be greater in amount that the purchase price of the specific equipment purchased which allegedly caused the damage. The purchasers assumes all risks and liabilities for any loss, damage or injury to persons or property of the purchasers assumes all risks and liabilities for any loss, damage or injury to persons or property of the purchasers or others, however caused, arising out to the use or possession of any equipment supplies by RST Instruments save and except the agreement to replace contained herein.