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Instruction Manual

Model 4855

Pile Tip Pressure Cell

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1. INTRODUCTION

1.1 Theory of Operation

The ability of cast-in-place piles to support a load relies on friction along the pile and on end bearing. The load distribution along the pile can be measured by embedding strain gauges at different depths along the pile and by comparing the measured strains at different depths with the strains at the top of the pile, very close to the applied load, which are assumed to be equivalent to 100% of the applied load. This ratio method does not require knowledge of the concrete modulus. Another method, to determine the actual end-bearing load taken by the pile tip is to measure it directly by installing a pressure cell between the pile tip and the ground below. Application of the load to the top of the pile causes pressure to be developed inside the pile tip pressure cell and this pressure, when multiplied by the area of the pile tip pressure cell, is directly equivalent to the end bearing load.

1.2 Pile-Tip Pressure Cell Design and Construction

The basic cell is manufactured to be close to the diameter of the pile. It is comprised of two circular stainless steel plates welded together around their periphery, leaving a thin space between the plates filled with de-aired hydraulic oil. This oil filled space is connected via a pressure tube to a vibrating wire pressure sensor. End-bearing pressure applied normal to the plate is balanced by a corresponding build-up of internal oil pressure, which is measured by the sensor. The use of de-aired hydraulic oil guaranties that the modulus of the pile tip pressure cell is equal to or greater than the modulus of the surrounding concrete. This ensures that the pressure measured by the cell is characteristic of the pressure across the entire cross-section of the borehole and that there is no error created by a certain amount of the load being transmitted directly through the concrete around the edges of the pressure cell.

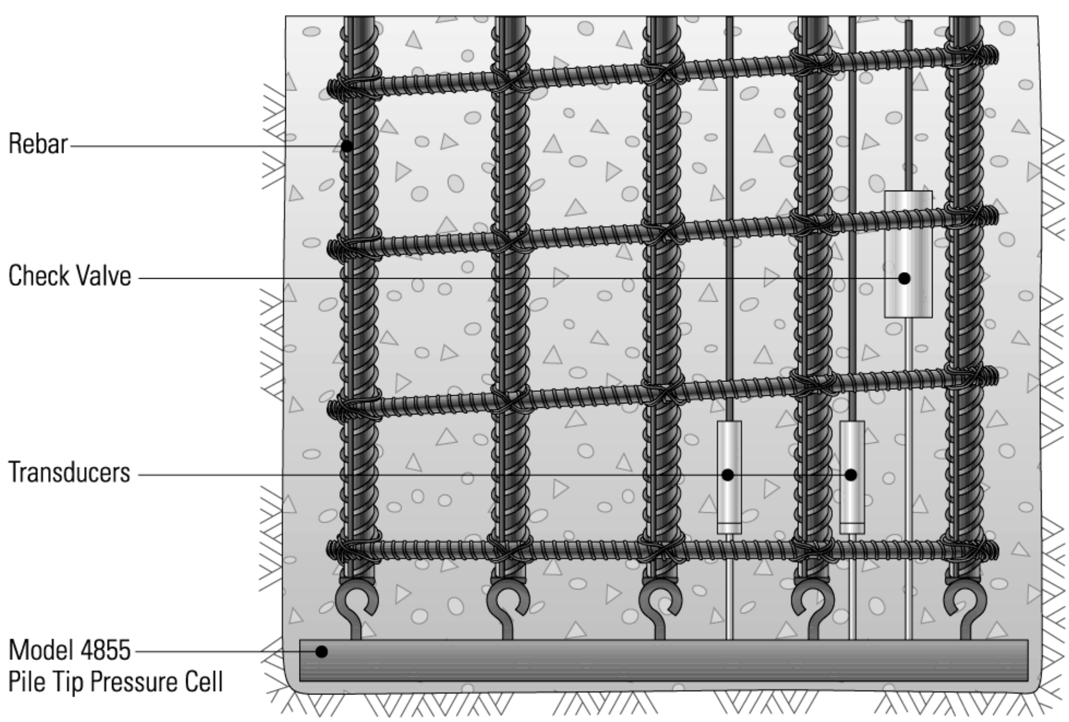

Figure 1 - Showing a Pile Tip Pressure Cell

Lugs are provided on the back of the upper plate for welding to the rebar cage as shown in Figure 1.

Lugs are also welded to the lower plate for attachment of short lengths of rebar, which are designed for pre-embedment in a concrete cone or cylinder, covering the entire lower plate. This cone, or cylinder, depending on the shape of the bottom of the excavated shaft, prevents the formation of voids beneath the pressure cell caused by the entrapment of air or water.

During concrete curing, temperatures very often rise and will cause the cell to expand in the still green concrete. On cooling, the cell contracts leaving a space between it and the surrounding concrete which, if allowed to remain, might prevent the transmission of pressures from the concrete to the cell. To overcome this, provision is made so that the cell can be inflated until it comes back into perfect contact with the concrete on both surfaces. This re-inflation is performed from the surface through a hydraulic line operating through a check valve. (An alternative method, using a pinch tube and remote crimping device, is also available).
The vibrating wire sensors are standard Geokon Model 4500H transducers inside all-welded housings. The sensors are hermetically sealed and are connected via waterproof connectors to an electrical cable leading to the surface. The sensor housings also incorporate a thermistor that permits measurement of temperature at the cell location.

2. INSTALLATION

2.1 Preliminary Tests

It is always wise, before installation commences, to check the cells for proper functioning. Each cell is supplied with a calibration sheet, which shows the relationship between readout digits and pressure and shows the initial no load zero reading. The transducer's electrical leads (usually the red and black leads) are connected to a readout box and the zero readings given on the sheet is now compared to the current zero readings. (See Section 3 for readout instructions.) The reading should not differ by more than ≈50 digits, after due regard to corrections made for different temperatures, barometric pressures and height above sea level and actual cell position (whether standing up or laying down).

Take Initial No-Load Reading of pressure and temperature with the cell laying flat on the ground. These are important readings and will be used in future calculations of pile-tip load.

By standing on the cell it should be possible to change the readout digits, causing them to fall as the pressure is increased.

Checks of electrical continuity can also be made using an ohmmeter. Resistance between the gauge leads should be approximately 180 ohms, ±10 ohms. Remember to add cable resistance when checking (22 AWG stranded copper leads are approximately 14.7Ω/1000' or 48.5Ω/km, multiply by two for both directions). Between the green and white should be approximately 3000Ω at 25 °C (see Table 4 in Appendix B), and between any conductor and the shield should exceed 20 megohm.

2.2 Pressure Cell Installation

The short pieces of threaded re-bar are screwed into the lugs welded to the bottom plate of the pressures cell. A depression is excavated in the ground and lined with sand. The shape of the depression should match the profile of the bottom of the pile shaft, whether conical or cylindrical. This depression is now filled with concrete of the same type as the rest of the pile and is heaped in the middle so that when the pile tip pressure cell is lowered into it the concrete extrudes out to the side carrying any voids with it. The concrete is left to harden.

The lugs protruding from the upper plate of the pressure cell are welded to the rebar of the rebar cage as shown in Figure 1. (More details of this operation will be found in Appendix C) The cables from the sensors and the hydraulic pressure line to the check valve are fixed firmly to the rebar using nylon zip ties every meter or so. The cables and hydraulic line should be positioned so that they are protected from the concrete tremie pipe and from being scraped as the rebar cage is lowered into the hole.

Preparation of the bottom of the hole should ensure that the surface below the pressure cell is clean of debris and is pre-filled with wet concrete to a depth of 30 cm. It is important that there be no voids below the cell.

One technique to ensure that there are no voids below the pile tip load cell is shown in Figure 2.

Figure 2 - Concrete Cone

A concrete cone is constructed and attached to the under-surface of the load cell in the following manner: The load cell is manufactured at Geokon so that it has threaded lugs welded to the underside. Pieces of rebar, supplied with the load cell, are threaded at one end and are threaded into the lugs so that they form two circles of rebars; short rebars on the outside circle and longer ones nearer the center. A hole is excavated in the ground in the shape of the desired cone and then it is filled with concrete. The pile tip load cell is then placed over the top of the hole so that the rebars poke down into the concrete. After the concrete has set up then the load cell with the concrete cone attached is welded to the bottom of the rebar cage.

Take readings of pressure and temperature at regular intervals throughout the installation process. It should be possible to monitor the pressure of the wet concrete as it is poured. Allow the concrete set up and cool to a temperature close to ambient. It may be observed that there is a drop-in cell pressure from the value observed with the wet cement when the hole was filled. Connect the cell re-inflation line to a hydraulic hand pump filled with de-aired oil and pump oil into the cell while observing the pressure reading. The cracking pressure of the check valve is set so that it will open at a higher pressure than the static head of oil in the re-pressurization tube plus any suction that will be generated by the weight of the concrete attached to the lower plate. As soon as the pressure begins to rise sharply above this value and reaches the wet cement value then stop pumping. Disconnect the pump from the hydraulic line and cap the end of the re-pressuring tube.

2.3 Cable Installation and Splicing

The cable should be routed to minimize the possibility of damage due to moving equipment, debris or other causes. The cable can be protected using flexible conduit, which can be supplied by Geokon.

Terminal boxes with sealed cable entries are available from Geokon for all types of applications. These allow many gauges to be terminated at one location with complete protection of the lead wires. The interior panel of the terminal box can have built-in jacks or a single connection with a rotary position selector switch. Contact Geokon for specific application information.

Because the vibrating wire output signal is a frequency rather than a current or voltage, variations in cable resistance have little effect on gauge readings; therefore, splicing of cables has no ill effects, and in some cases may in fact be beneficial. The cable used for making splices should be a high-quality twisted pair type, with 100% shielding and an integral shield drain wire. **When splicing, it is very important that the shield drain wires be spliced together.** Always maintain polarity by connecting color to color.

Splice kits recommended by Geokon incorporate casts which are placed around the splice and are then filled with epoxy to waterproof the connections. When properly made, this type of splice is equal or superior to the cable itself in strength and electrical properties. Contact Geokon for splicing materials and additional cable splicing instructions.

Cables may be terminated by stripping and tinning the individual conductors and then connecting them to the patch cord of a readout box. Alternatively, a connector may be used which will plug directly into the readout box or to a receptacle on a special patch cord.

3. TAKING READINGS

3.1 GK-404 Readout Box

he Model GK-404 Vibrating Wire Readout is a portable, low-power, handheld unit that can run continuously for more than 20 hours on two AA batteries. It is designed for the readout of all Geokon vibrating wire gauges and transducers; and is capable of displaying the reading in either digits, frequency (Hz), period (μs), or microstrain (με). The GK-404 also displays the temperature of the load cell (embedded thermistor) with a resolution of 0.1 °C.

3.1.1 Operating the GK-404

Before use, attach the flying leads to the GK-404 by aligning the red circle on the silver "Lemo" connector of the flying leads with the red line on the top of the GK-404 (Figure 3). Insert the Lemo connector into the GK-404 until it locks into place.

Figure 3 - Lemo Connector to GK-404

Connect each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

To turn the GK-404 on, press the "ON/OFF" button on the front panel of the unit. The initial startup screen will be displayed. After approximately one second, the GK-404 will start taking readings and display them based on the settings of the POS and MODE buttons.

The unit display (from left to right) is as follows:

- The current Position: Set by the **POS** button. Displayed as a letter A through F.
- The current Reading: Set by the **MODE** button. Displayed as a numeric value followed by the unit of measure.
- Temperature reading of the attached gauge in degrees Celsius.

Use the **POS** button to select position **B** and the **MODE** button to select **Dg** (digits). (Other functions can be selected as described in the GK-404 Manual.)

The GK-404 will continue to take measurements and display readings until the unit is turned off, either manually, or if enabled, by the Auto-Off timer. If the no reading displays or the reading is unstable see Section 5 for troubleshooting suggestions.

For further information consult the GK-404 manual.

3.2 GK-405 Readout Box

The GK-405 Vibrating Wire Readout is made up of two components: The Readout Unit, consisting of a Windows Mobile handheld PC running the GK-405 Vibrating Wire Readout Application; and the GK-405 Remote Module, which is housed in a weatherproof enclosure and connects to the vibrating wire gauge to be measured. The two components communicate wirelessly. The Readout Unit can operate from the cradle of the Remote Module, or, if more convenient, can be removed and operated up to 20 meters from the Remote Module.

3.2.1 Connecting Sensors

Connecting Sensors with 10-pin Bulkhead Connectors Attached:

Align the grooves on the sensor connector (male), with the appropriate connector on the readout (female connector labeled senor or load cell). Push the connector into place, and then twist the outer ring of the male connector until it locks into place.

Connecting Sensors with Bare Leads:

Attach the GK-403-2 flying leads to the bare leads of a Geokon vibrating wire sensor by connecting each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

3.2.2 Operating the GK-405

Press the button labeled "POWER ON". A blue light will begin blinking, signifying that the Remote Module is waiting to connect to the handheld unit. Launch the GK-405 VWRA program by tapping on "Start" from the handheld PC's main window, then "Programs" then the GK-405 VWRA icon. After a few seconds, the blue light on the Remote Module should stop flashing and remain lit. The Live Readings Window will be displayed on the handheld PC. Figure 4 shows a typical vibrating wire output in digits and thermistor output in degrees Celsius. If the no reading displays or the reading is unstable see Section 5 for troubleshooting suggestions.

For further information consult the GK-405 Instruction Manual.

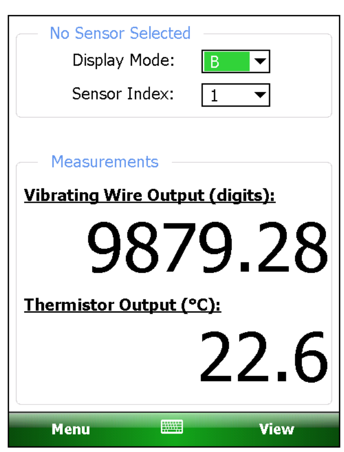

Figure 4 - Live Readings – Raw Readings

3.3 GK-403 Readout Box (Obsolete Model)

The GK-403 can store gauge readings and apply calibration factors to convert readings to engineering units. The following instructions explain taking gauge measurements using Mode “B”. Consult the GK-403 Instruction Manual for additional information.

3.3.1 Connecting Sensors

Connecting Sensors with 10-pin Bulkhead Connectors Attached:
Align the grooves on the sensor connector (male), with the appropriate connector on the readout (female connector labeled senor or load cell). Push the connector into place, and then twist the outer ring of the male connector until it locks into place.

Connecting Sensors with Bare Leads:
Attach the GK-403-2 flying leads to the bare leads of a Geokon vibrating wire sensor by connecting each of the clips on the leads to the matching colors of the sensor conductors, with blue representing the shield (bare).

3.3.2 Operating the GK-403

1) Turn the display selector to position “B”.

2) Turn the unit on.

3) The readout will display the vibrating wire output in digits. The last digit may change one or two digits while reading.

   The thermistor reading will be displayed above the gauge reading in degrees centigrade.

4) Press the “Store” button to record the value displayed.

If the no reading displays or the reading is unstable see Section 5 for troubleshooting suggestions. The unit will automatically turn itself off after approximately two minutes to conserve power.

3.4 Measuring Temperatures

All vibrating wire pressure cells are equipped with a thermistor which gives a varying resistance output as the temperature changes. The white and green leads of the instrument cable are normally connected to the internal thermistor. Readout boxes will read the thermistor and display the temperature in degrees C. To read temperatures using an ohmmeter complete the following:

1. Connect an ohmmeter to the green and white thermistor leads coming from the pressure cell. (Since the resistance changes with temperature are large, the effect of cable resistance is usually insignificant. For long cables a correction can be applied, equal to approximately 14.7Ω for every 1000 ft (48.5Ω per km) at 20 °C. Multiply these factors by two to account for both directions.)
2. Look up the temperature for the measured resistance in Appendix B, Table 4.

4. DATA REDUCTION

4.1 Pressure Calculation

The basic units utilized by Geokon, and displayed on the readout box Channel B, for measurement and reduction of data from a Pile Tip Pressure Cell are "digits". Calculation of digits is based on the following equation:

$$\text{Digits} = \left(\frac{1}{\text{Period}}\right)^2 \text{ x } 10^{-3} \text{ or Digits} = \frac{\text{Hz}^2}{1000}$$

Equation 1 - Digits Calculation

To convert digits to pressure the following equation applies;

$$\text{Pressure} = (\text{Initial Reading - Current Reading}) \times \text{Calibration Factor}$$

Or

$$P = (R_0 - R_1) \times C$$

Equation 2 - Convert Digits to Pressure

The Initial Reading is obtained as described in Section 2.1. The Calibration Factor (usually in terms of PSI or MPa per digit) comes from the supplied Calibration Sheet.

4.2 Temperature Correction

The vibrating wire sensor is relatively insensitive to temperature fluctuations and usually the effect of temperature is insignificant and can be ignored. But, if desired, correction for temperature effects on the sensor can be made using the factors supplied on the calibration sheet and Equation 3. Also, there are spurious temperature effects caused by the mismatch between temperature coefficients of the cell and surrounding concrete. This effect is not quantifiable in the laboratory and, hence, no correction factor for this effect can be supplied.

$$\text{Temperature Correction} = (\text{Current Temperature - Initial Temperature}) \times \text{Thermal Factor}$$

Or

$$P_T = (T_1 - T_0) \text{ x } K$$

Equation 3 - Temperature Correction

4.3 Barometric Correction

Barometric pressure fluctuations will be sensed by the cells. However, the magnitudes (±0.5 psi) are usually insignificant.

5. TROUBLESHOOTING

Maintenance and troubleshooting of pressure cells is confined to periodic checks of cable connections and maintenance of terminals. Once installed, these instruments are usually inaccessible and remedial action is limited. **Gauges should not be opened in the field.** Should difficulties arise, consult the following list of problems and possible solutions. Return any faulty gauges to the factory. For additional troubleshooting and support contact Geokon.

Symptom: Pressure Cell Readings are Unstable

- ✓ Is the readout box position set correctly? If using a datalogger to record readings automatically are the swept frequency excitation settings correct?
- ✓ Is there a source of electrical noise nearby? Likely candidates are generators, motors, arc welding equipment, high voltage lines, etc. If possible, move the instrument cable away from power lines and electrical equipment or install electronic filtering.
- ✓ Make sure the shield drain wire is connected to ground whether using a portable readout or datalogger. Connect the shield drain wire to the readout using the blue clip. (Green for the GK-401.)
- ✓ Does the readout work with another pressure cell? If not, it may have a low battery or possibly be malfunctioning.

Symptom: Pressure Cell Fails to Read

- ✓ Is the cable cut or crushed? Check the resistance of the cable by connecting an ohmmeter to the gauge leads. Table 1 shows the expected resistance for the various wire combinations. Table 2 is provided for the user to enter the actual resistance found.

  Cable resistance is approximately 14.74Ω per 1000' of 22 AWG wire. If the resistance is very high or infinite (megohms) the cable is probably broken or cut. If the resistance is very low (<20Ω) the gauge conductors may be shorted. If a cut or a short is located in the cable, splice according to the instructions in Section 2.3.

- ✓ Does the readout or datalogger work with another gauge? If not, it may have a low battery or possibly be malfunctioning.

Symptom: Thermistor resistance is too high

- ✓ Likely there is an open circuit. Check all connections, terminals, and plugs. If a cut is located in the cable, splice according to instructions in Section 2.3.

Symptom: Thermistor resistance is too low

- ✓ Likely there is a short. Check all connections, terminals, and plugs. If a short is located in the cable, splice according to instructions in Section 2.3.
- ✓ Water may have penetrated the interior of the transducer. There is no remedial action.

Vibrating Wire Sensor Lead Grid - SAMPLE VALUES					
	Red	**Black**	**White**	**Green**	**Shield**
Red	N/A	**≅180Ω**	infinite	infinite	infinite
Black	**≅180Ω**	N/A	infinite	infinite	infinite
White	infinite	infinite	N/A	**3000Ω at 25°C**	infinite
Green	infinite	infinite	**3000Ω at 25°C**	N/A	infinite
Shield	infinite	infinite	infinite	infinite	N/A

Table 1 - Sample Resistance

Vibrating Wire Sensor Lead Grid - SENSOR NAME/## :					
	Red	**Black**	**White**	**Green**	**Shield**
Red					
Black					
White					
Green					
Shield					

Table 2 - Resistance Work Sheet

APPENDIX A. SPECIFICATIONS

A.1 Pressure Cells

Model:	4855
Ranges:	2 MPa (300 psi), 3. MPa (450 psi), 5 MPa (750 psi), 7.5 MPa (1100 psi), 10 MPa (1500 psi), 20 MPa (3000 psi)
Sensitivity:	0.025% FSR
Accuracy:	0.10% FSR
Linearity:	0.25% FSR (standard) 0.1% FSR (optional)
Operating Temperature:	-30 to +70° C
Frequency range	1400-3500 Hz
Dimensions:	Diameter to suit the pile. Thickness approximately 50 mm
Material:	303 & 304 Stainless Steel
Electrical Cable:	Two twisted pair (four conductor) 22 AWG Foil shield, PVC jacket, nominal OD=6.3 mm (0.250")

Table 3 - Specifications

Consult the factory for other sizes or options available.

A.2 Thermistor (see Appendix B also)

Range: -80 to +150° C
Accuracy: ±0.5° C

APPENDIX B. THERMISTOR TEMPERATURE DERIVATION

Thermistor Type: YSI 44005, Dale #1C3001-B3, Alpha #13A3001-B3
Resistance to Temperature Equation:

$$T = \frac{1}{A + B(\mathrm{LnR}) + C(\mathrm{LnR})^3} - 273.15\ ^\circ\mathrm{C}$$

Equation 4 - Resistance to Temperature

Where;
T = Temperature in °C.
LnR = Natural Log of Thermistor Resistance.
$A = 1.4051 \times 10^{-3}$
$B = 2.369 \times 10^{-4}$
$C = 1.019 \times 10^{-7}$
Note: Coefficients calculated over the −50 to +150° C. span.

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.1	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342.2	83	107.9	123
77.66K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-34	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	292.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	5692	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.0	53	250.9	93	83.6	133
41.56K	-26	4939	14	929.6	54	243.4	94	81.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	**3000**	**25**	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

Table 4 - Thermistor Resistance versus Temperature

APPENDIX C. ATTACHING THE PRESSURE CELL TO THE REBAR CAGE

The eyebolts are threaded into the three lugs welded to the top plate. The three hooks and chains supplied with the cell are then hooked to the eyebolts and used to lift the cell and position it close to the bottom of the rebar cage, (within two meters). The cables and hydraulic lines are then routed along the rebars leaving an extra two meters of slack between the cell and the bottom of the cage. A steel rope of approximately one-meter length is tied to one of the eyebolts and to the bottom of the cage. The purpose of the steel rope is to make sure that the cables and hydraulic lines cannot be ripped off when the rebar cage is lifted from the horizontal to the vertical.

The bottom of the rebar cage should have some standard form of support for the pressure cell. These standard designs include a steel cross at the bottom and a steel belt around the periphery, adjacent to the bottom. These features require that tapped lugs be welded on the upper plate of the cell at specific locations to match corresponding holes drilled in the cross-piece.
When the cage has been lifted to a vertical position it is lowered onto the cell. The bottom of the cage should be guide by at least two people to prevent it from twisting and swinging. The holes in the crosspiece are lined up with the threaded lugs on the pressures cell and then the bolts supplied with the cell are used to bolt the cell to the crosspiece. The chains can now be removed from the eyebolts.

Three pieces of rebar, approx. 1.5 m long are bent into a hook shape at one end. The hooked ends are hooked into the three eyebolts and the other ends are welded to the rebar cage. The assembly is now ready to be lowered into the shaft. While lowering the cage into the shaft the cables and the hydraulic line are tensioned step by step and fastened to the longitudinal rebars of the cage with cable ties at intervals of approximately one meter.