Multi-outrigger-bow Marine Heat Flow Instrument: Mechanical Design

by

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INTRODUCTION

The multi-outrigger-bow marine heat flow instrument measures geothermal heat flow on the deep seafloor. It is lowered from the ship, penetrates in the seafloor sediments and measures the thermal gradient and the thermal conductivity. The heat flow value is calculated from the two measurements. The detailed measurement technique is described in a separate report.

The multi-outrigger-bow instrument essentially consists of two units: the weight stand and the sensor unit (Fig. 1). The weight stand accommodates the electronics pressure cases. The sensor unit consists of outrigger-bow sensor strings spirally mounted on a strength member. 4 sensor strings can be installed.

In this report, we describe each mechanical part and construction procedure of the sensor string and water temperature sensor. All the designing and manufacturing were done at the Institute for Geophysics and the Department of Geological Sciences, both at the University of Texas at Austin.

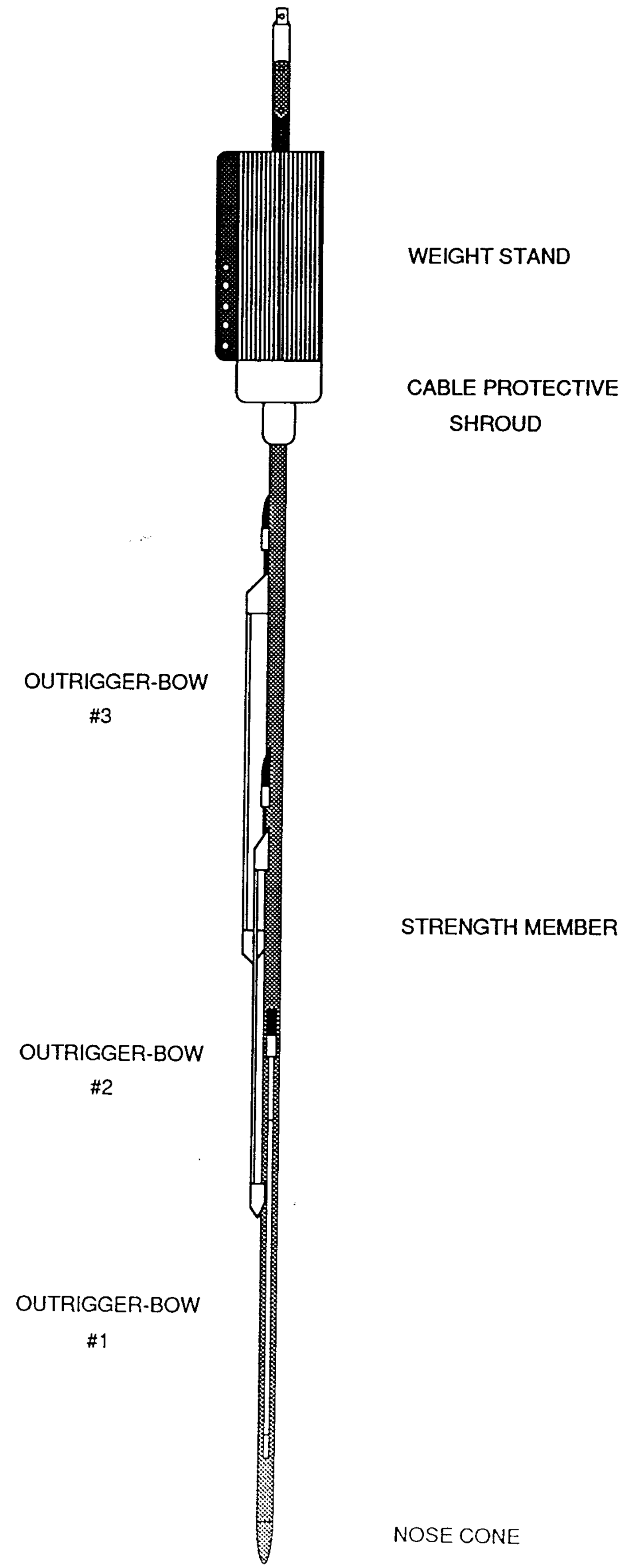

Fig. 1 Schematic diagram of the multi-outrigger-bow heat flow probe.

DESCRIPTION OF THE PARTS

I. Weight stand

The weight stand basically consists of 4 steel pipes (7" O.D., 6" I.D.) welded together (Fig. 2). Two of them accommodate the pressure cases and the other two are partially filled with lead for extra weight. A connector on the bottom of the weight stand holds the strength member. The underwater electrical cables, which connect the pressure cases and the sensor strings on the strength member, are protected by a steel cover on the bottom. The clevis on the top couples with a swivel for lifting by a wire. The system can also be lifted horizontally by the side fin for mobilization on the deck.

II. Pressure cases

Two cylindrical aluminum pressure cases are necessary for the heat flow probe, one for the data logger electronics and the other for the heater and acoustic transducer electronics (Fig. 3). The two cases are identical in size (6" O.D., 4.5" I.D., 40" tall), but they have different bulkhead connector assemblies on the end caps.

The pressure cases are constructed from 6061-T6 aluminum for the light weight to strength ratio. Both ends are threaded with 5.5"-5 ACME-2G-RH threads. The end caps are a two-piece construction so that the internal electric wires do not have to be twisted; a threaded protection ring fits over the end cap and threads onto the pressure case (Fig. 3). All the parts are built with a loose tolerance and then they are hard anodized for the protection from the sea water.

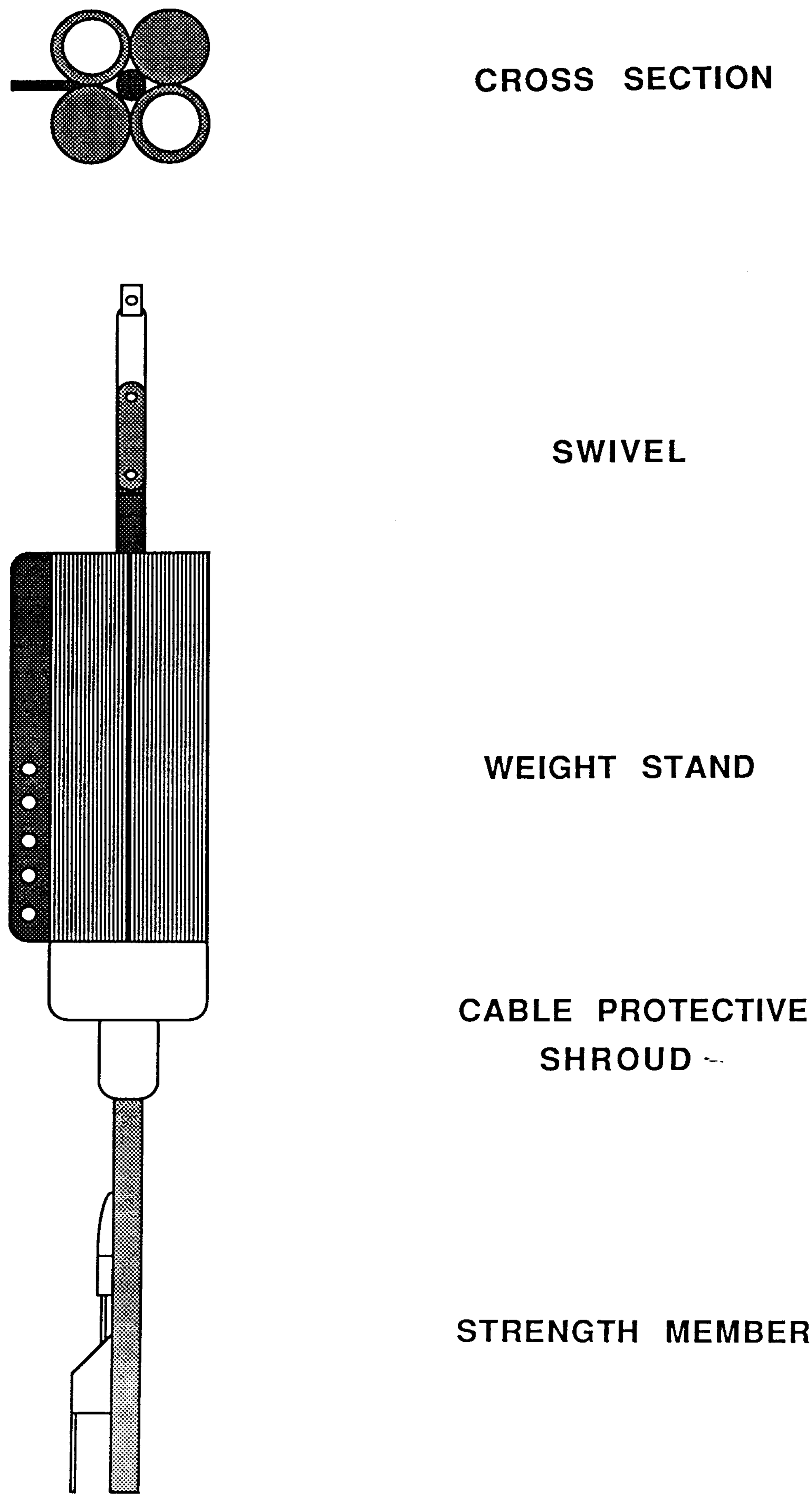

Fig. 2 Schematic diagram of the weight stand.

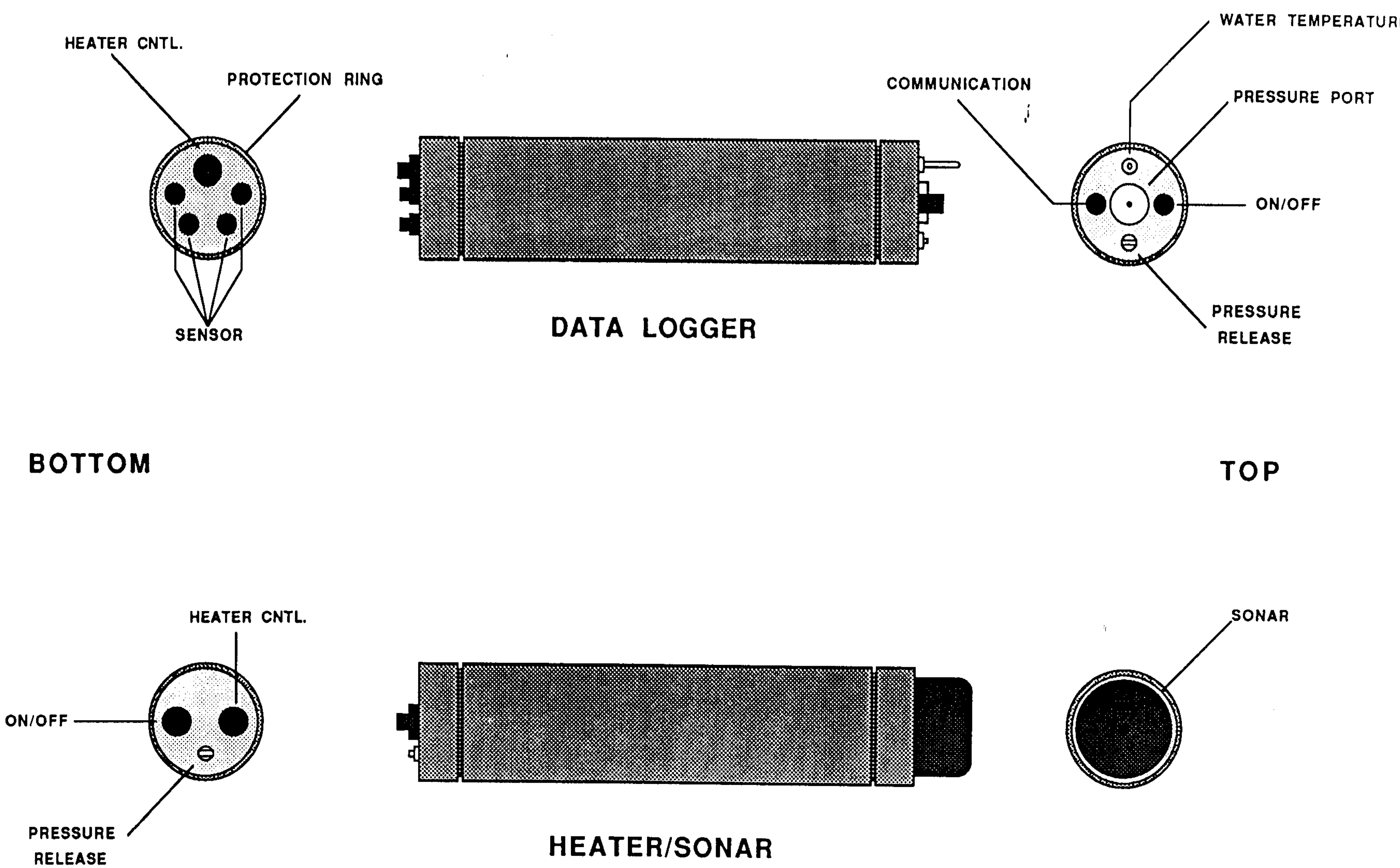

Fig. 3 Pressure cases and their accessories.

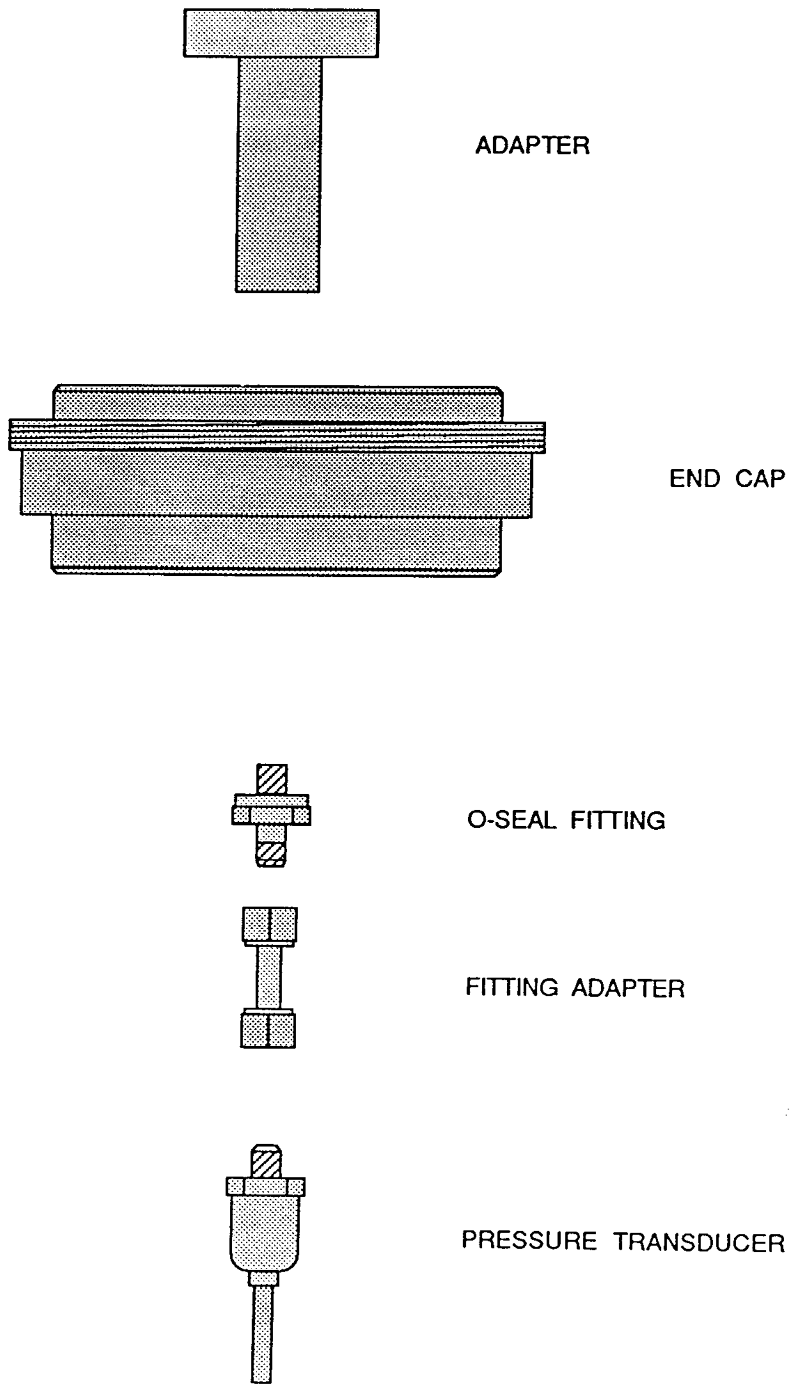

Fig. 4 Installation of the pressure transducer.

A. DATA LOGGER PRESSURE CASE

(1) Top end cap

(a) water temperature sensor

The water temperature sensor is a tubular probe with a fitting that is screwed into the pressure case. See Section 3.1 for the necessary parts and the construction procedure.

(b) Pressure transducer unit

The pressure transducer is installed inside the end cap, but the pressure port must feel the hydrostatic pressure outside the pressure case. Thus, the installation requires an adapter that goes through the end cap (Fig. 4).

parts: Pressure transducer (*Viatran* 122S20)

Pressure transducer adapter

Swagelok O-seal straight thread male connector (1/4".O.D.) (400-1-OR)

Swagelok fitting to AN adapter (1/4") (400-A-4ANF)

(c) Pressure release screw

When the batteries for the data logging system are recharged, they emit gases to be released to the atmosphere. The gases are released by loosening the pressure release screw without opening the pressure case. The screw is constructed from 316 stainless steel. It is screwed into s screw coupler, which is seated inside of the aluminum end cap, instead of the end cap itself (Fig. 5). The coupler is made of brass and screwed into the end cap. The use of coupler is because the soft aluminum end cap thread could be damaged by frequent use of the screw.

parts: Pressure release screw

Pressure release screw coupler

(d) Bulkhead under-water connectors

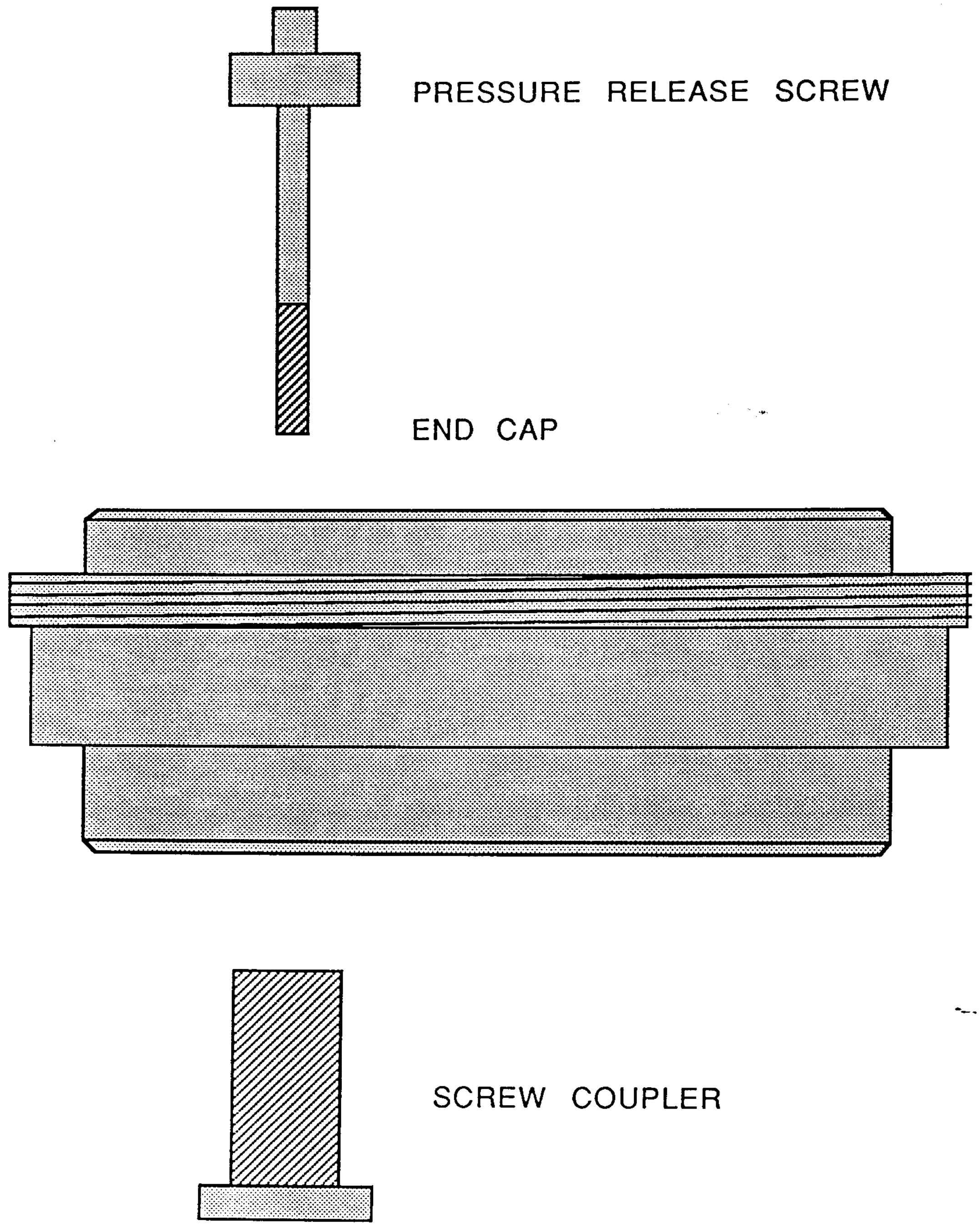

Fig. 5 Installation of the pressure release screw.

1. Connector for power switching (*SEA CON*, AWL-4P-BC)

The connector is used for switching the electric power for the data logger by closing a dummy plug (*SEA CON*, AWL-4-MPDHP) on which two pins are shorted. This connector is also used for recharging the batteries when the probe is on board.

2. Connector for data retrieval (*SEA CON*, AWL-4S-BC)

Three of the pins are used for on-board data retrieval. A dummy plug (*SEA CON*, AWL-4S-FSDHP) protects it when it is over the side.

(2) Bottom end cap

The bottom end cap has four connectors for the sensor cables (1 for each bow) (*SEA CON*, XSE-10-BCR) and 1 connector (*SEA CON*, VSK-12-BCL) for communication to the other pressure case.

B. SONAR/HEATER PRESSURE CASE

(1) Top end cap

An acoustic transducer for the data transmission (*International Transducer Corp.*, ITC-3013) is installed on the end cap. The cap has six holes to secure the bolts of the transducer and one hole for wiring.

(2) Bottom end cap

The bottom end cap has two bulkhead connectors and a pressure release screw. One connector is used to communicate with the other pressure case (*SEA CON*, VSK-12-BCL). The other connector is for power switching/recharging (VSK-6-BCL). The on/off switching is done by mating a dummy plug (VMK-6-FSDHP) with two shorted pins.

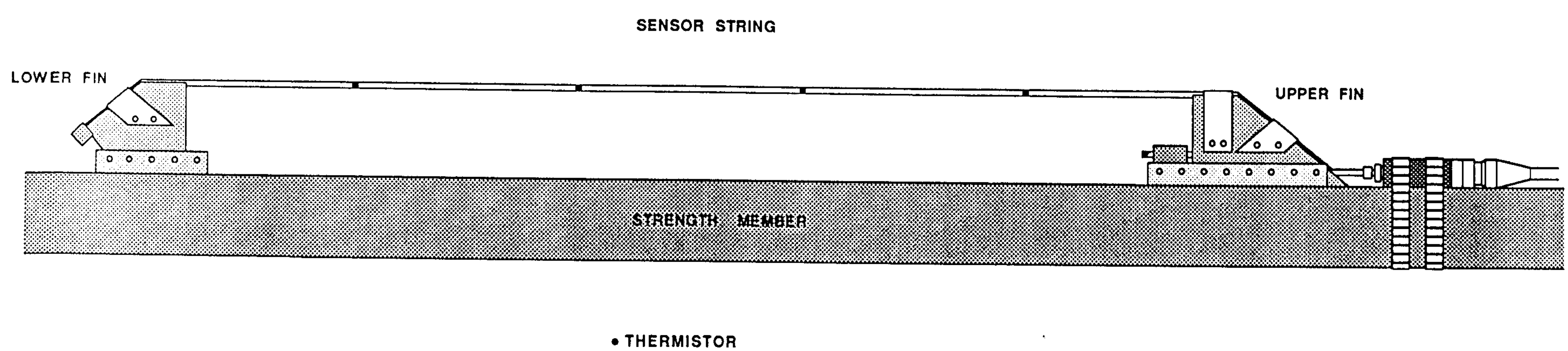

Fig. 6 Assembly of the outrigger-bow.

III. Strength member

The strength member is made of standard 8.9 cm (3.5") O.D. drill pipe. The appropriate length of pipe is chosen depending on the number of the outrigger-bows in use: 3.4 m for 2 bows, 4.4 m for 3 bows, and 5.4 m for 4 bows. The pipe has no joint to minimize the possibility of bending during the operation. The fin adapters (see section IV) and the nose cone are machined from a mild steel and are welded onto the strength member with a 7018 low hydrogen welding rod. Holes of 1.25" diameter are cut into the strength member to thread the sensor cables into the inside for protection.

IV. Outrigger-bow systems

A. SENSOR STRINGS

Each sensor string is mounted on the strength member by a fin (10 cm height) at the each end (Figs. 1 and 6). The sensor string is made of 6.35 mm (0.25") O.D., 4.60 mm (0.18") I.D., type-316 stainless steel tubing. The two fins are mounted 115 cm apart. The ends of the string are bent along the fins. Thickness of the fin is the same as the diameter of the sensor string so that the probe minimizes the disturbance of sediments at the penetration.

Each sensor string has four equally spaced (25 cm) thermistors and one heater wire. The heater wire is a polymide, varnish-coated, 90 alloy wire of 28 AWG (0.321 mm diameter). It has a very low temperature coefficient of resistance (450 ppm/^{o}C). The thermistors are YSI (*Yellow Springs Inc.*) 44032 (30 kΩ at 25 ^{o}C). The thermistor leads are soldered to teflon wires and insulated by teflon tubing. To ensure the electrical insulation, the whole thermistor and heater wire assembly is placed in a protective fiberglass sleeving. The Inside of sensor string is filled with silicone oil to obtain good thermal contact between the thermistors and the tube wall.

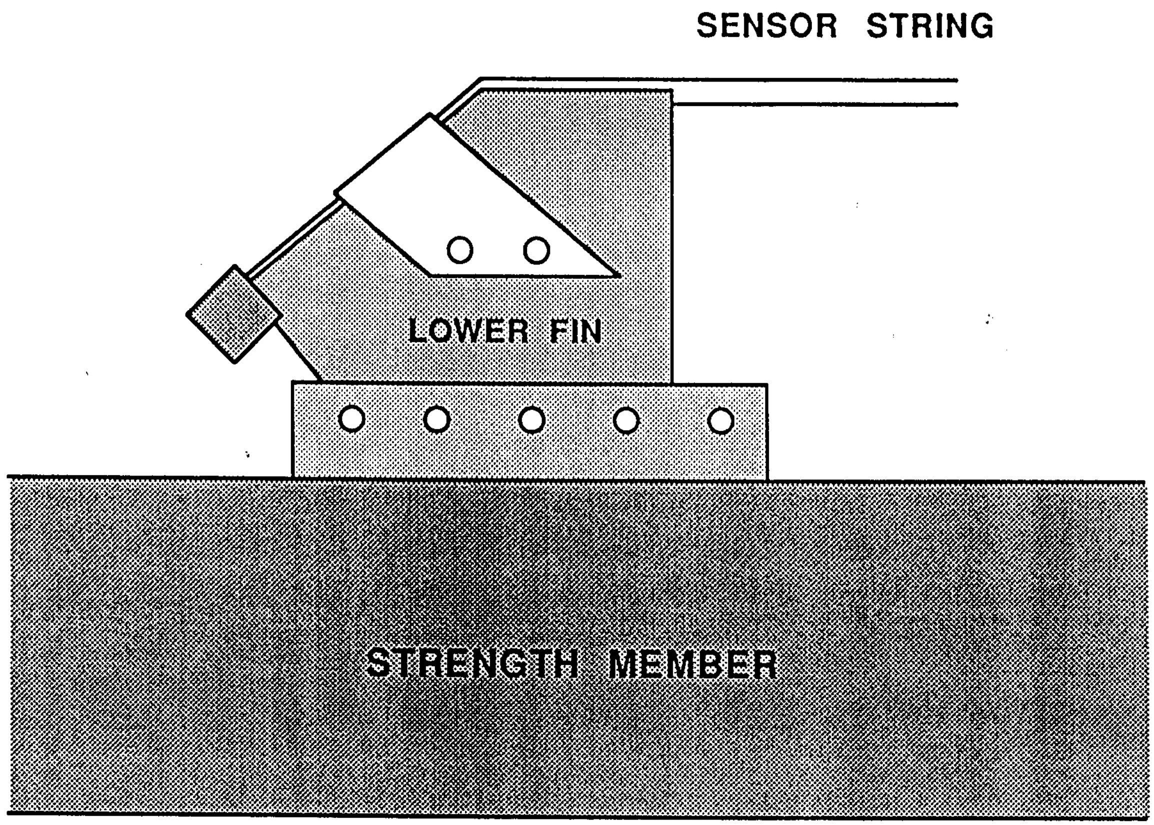

Fig. 7 Assembly of the lower fin.

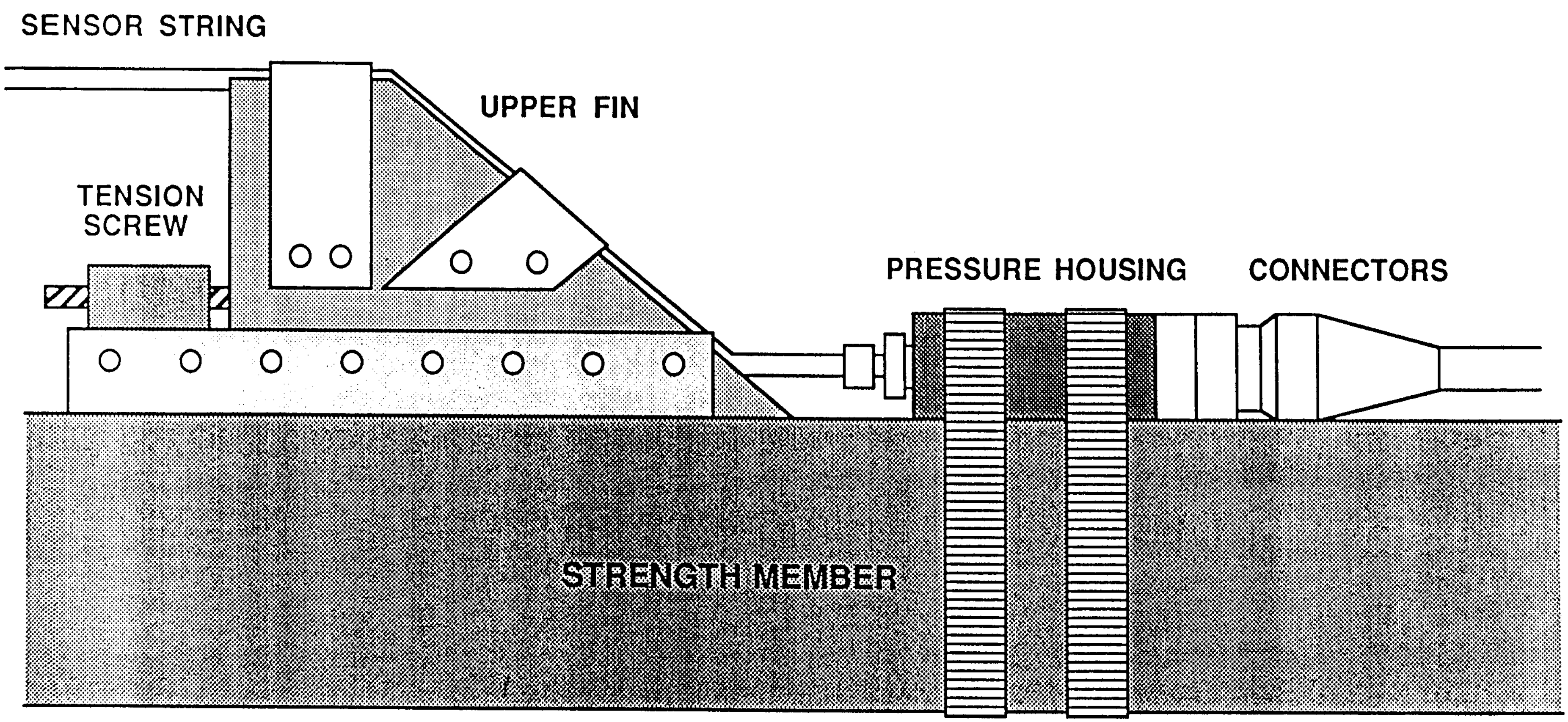

Fig. 8 Assembly of the upper fin.

B. LOWER FIN (Fig. 7)

The bottom end of the sensor string is attached to the lower fin by a stainless steel clip and bolt. It is then held to the fin adapter of strength member by bolts. A series of holes are drilled in the fin for a greater degree of freedom in the bolting. The fin is made of 304 stainless steel.

C. UPPER FIN (Fig. 8)

The upper fin is also bolted to the strength member. The bolt holes in the fin are slotted so that pressure from the tension nut can stretch the sensor string and make it tight between the fins.

D. CABLE-SENSOR JOINT PRESSURE HOUSING (Fig. 8)

The upper end of the sensor string has a *Swagelok* O-seal connector. It is screwed into this housing. The wires from the thermistors and the heater go through this and are soldered to the bulkhead connectors (*SEA CON*, XSE-10-BCR) to mate with the sensor cable (18/10 SO cable with *SEA CON*, XSE-10-CCP). The wires must be twisted by 5 to 6 turns counter clockwise before the bulkhead connector is screwed in. The pressure housing is fastened to the strength member by way of hose clamps.

CONSTRUCTION PROCEDURE OF THE SENSORS

1. WATER TEMPERATURE SENSOR

parts: Type 316 stainless steel tubing (3/16" O.D., 0.035" wall)

Swagelok O-seal straight thread male connectors (300-1-OR)

Thermistor: YSI (*Yellow Springs Inc.*) 44032 (30 kΩ at 25 °C)

Teflon wire (stranded, 28 AWG)

Teflon tubing (24 - 26 AWG)

Heat shrink tubing (1/16" O.D.)

2 Ton Epoxy

Pre-bonding etching fluid (*Fluori Etch*).

Silicone break fluid (EIS, MIL B-46176)

tools: Silver solder

Syringe with thin hose

Pipe cutter

* Only special tools are specified.

Construction procedure:

1. Cut the stainless steel tubing in 2" length.
2. Close one end of the tube with silver solder.
3. Put a Swagelok O-seal connector on the other end. The nut must be tightened by 1-1/4 turns from a finger-tight position.
4. Cut the thermistor leads to distinct lengths (1" and 1.5") and place the teflon tubing on each lead for insulation.
5. Etch the surface of the 5"-long teflon wires (for procedure 11).
6. Solder the thermistor leads to the teflon wires.

* Make sure the two soldered parts do not meet each other when the wires are straight.

7. Place 1" long heat shrink tubing over the two teflon wires. Shrink the tubing at the solder point.

8. Put the thermistor into the stainless steel tubing through the Swagelok connector. Push the thermistor wires into the tubing until the thermistor is tight against the closed end of the tube.

9. Fill the stainless steel tube with the silicone break fluid using a syringe. The whole system should be vertical with the Swagelok connector on top.

10. Leave the tubing upright for 30 minutes until all air bubbles inside the tube have come out.

11. Close the end of connector by filling with the epoxy and leave it until it dries completely.

   * If the surface of the teflon wires is not properly etched, the epoxy will not settle onto it and will cause leakage of the oil.

B. SENSOR STRING

parts: Type-316 stainless steel tubing (1/4" O.D., 0.035" wall)

Swagelok O-seal straight thread male connectors (300-1-OR)

Thermistors: YSI (*Yellow Springs Inc.*) 44032 (30 kΩ at 25 ^{o}C)

Teflon wires in four colors: brown, red, orange, and yellow (stranded, 28 AWG)

Teflon wire (stranded, 24 AWG)

Teflon tubing (24 - 26 AWG)

Heat shrink tubing (1/16" O.D.)

2 Ton Epoxy

Pre-bonding etching fluid (*Fluori Etch*)

Silicone break fluid (EIS, MIL B-46176)

Uncoated fiberglass sleeving (*alpha*, PIF-240-8)

Heater wire (polymide varnish coated Nickel alloy 90, 28AWG)

Silicone spray

Dental floss

Thin string

tools: Vacuum pump, Pipe cutter, Pipe bender, Vise, and Syringe

Construction procedure

(a). Preparing the tubing

1. Cut the stainless steel tubing in 63" (160 cm) length.
2. Trim the inner edge of both ends.
3. Put the fiberglass sleeving all the way through the tubing.

(b) Preparing the thermistors

1. Cut the two leads of each thermistor to different lengths (1" and 1.5") and place the teflon tubing over each lead for insulation.

   * The teflon tubing must be etched previously for a latter Procedure C-3.
2. Cut the 28 AWG teflon wires in proper lengths.
3. Follow Procedures 6 to 7 for the water temperature sensor for each thermistor.

(c) Assembling the wires

1. Secure two nails 1.55 m apart. Fasten one lead of the heater wire to one of the nails. Stretch the wire around the other nail so that it returns to the first nail. Cut the wire and fasten the two ends to the first nail. The total length of the stretched wire should be 3.1 m.

2. Fasten the four thermistors on the wire correctly spaced using the dental floss.

3. Glue the teflon tubes covering the thermistor leads onto the heater wire so that they cannot slide when pulled through the stainless steel tubing.

   * Do not put any glue (epoxy) on the thermistor itself so that it can be reused if the sensor string is broken.

4. Solder 24 AWG teflon wires (cut in 15 cm length) onto both ends of heater wire.

(d) Inserting the wires

1. Mark all the wires at 160 cm length from the loop side nail.
2. Etch the teflon surfaces around the marked positions.
3. Lubricate the inner wall of the stainless steel tubing with the silicone spray.
4. Thread a thin string through the tubing.
5. Fix the tube with a vise.
6. Fasten one end of the string to the bottom end of the heater wire (loop side).
7. Pull the other end of the string and lead all the wires through the tubing.

   * Be careful. The thermistor beads are easily hooked by the tubing wall at the terminal.

8. Stop pulling when the heater wire first shows up on the other end. The markers on the wires should meet the other end.
9. Unfasten the string.
10. Put the Swagelok O-seal connector on the other end. The nut must be tightened by 1-1/4 turns from finger tight position.

(e) Inserting the silicone fluid

1. To evacuate bubbles from the silicone fluid, keep the fluid container vertical with its cap open and leave it for a while before start.

2. Connect a clear vacuum hose to the upper end of the sensor string. Make sure the leads are inside the hose.
3. Connect a small hose to the other end of the sensor string and place it in the silicone container.
4. Turn on the vacuum pump and let it pull up the silicone fluid.
5. Turn off the pump as soon as you observe the silicone fluid flowing into the vacuum hose.
6. Remove the small hose on the other end. The tubing end should be lifted to prevent back flow of the silicone fluid out of the sensor string.
7. Put the Swagelok plug on the bottom end of the sensor string. The nut must be tightened by 1-1/4 turns from a finger tight position.
8. Lift the top end of the sensor string and remove the vacuum hose.
9. Keep the sensor string vertical with Swagelok O-Seal connector on top.
10. Add silicone fluid from the top using the syringe. Continue while bubbles are observed coming out of the tubing.
11. When the tubing is completely filled with silicone fluid, apply epoxy to the Swagelok connector to seal the tubing.
12. Leave the sensor string until it dries, which takes at least half a day.

(f) Bending the sensor string

The sensor string must be bent at both ends to fit with the fins before being installed to the strength member. The bending positions are 10.5 cm (for the lower fin), and 140.7 cm and 157.0 cm (for the upper fin) from the bottom end of the Swagelok plug. Minor measurement errors can be adjusted at the installation.

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