A WIRELINE-POWERED INFLATABLE PACKER FOR BOREHOLE APPLICATIONS

By A.E. Hess

U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 93-485

Denver, Colorado
1993

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Robert M. Hirsch, Acting Director

Copies of this report can be purchased from:

Books and Open-File Report Section
U.S. Geological Survey
Box 25046, Mail Stop 419
Federal Center
Denver, CO 80225

For additional information write to:

U.S. Geological Survey
Chief, Branch of Regional Research
Box 25425, Mail Stop 517
Federal Center
Denver, CO 80225

CONTENTS

Page

Abstract-- 1
Introduction-- 1
Description of the packer system------------------------------ 2
    Packer pump and valve box---------------------------------- 4
    Packer power supply and control panel---------------------- 9
    Inflatable packer(s)--------------------------------------- 9
Packer operation-- 15
Packer maintenance-- 18
Summary and conclusions--------------------------------------- 19
References cited-- 19

FIGURES

Figure 1. Wireline-powered inflatable packer used with a borehole flowmeter-- 3
Figure 2. Wireline-powered inflatable straddle packers used with pressure transducers-- 5
Figure 3. Cross section of the pump and valve box---------------- 6
Figure 4. Cross section of magnetically-coupled pump which eliminates the motor to pump-shaft seal--------------------- 8
Figure 5. Packer pump power and control system------------------ 10
Figure 6. Cross-section view of a deflated and inflated slip-over packer-- 11
Figure 7. Side views of deflated and inflated woven, diamond-pattern, expansion-limiting reinforcing layer-------- 13
Figure 8. Side and bottom views of inflated quasi-spherical, fabric reinforcing layer to limit packer expansion----------- 14
Figure 9. Construction detail of a quasi-spherical reinforcing layer for an 8-inch diameter packer------------------------- 16

CONVERSION FACTORS

Multiply	By	To Obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter

Other units abbreviations used in this report:

ampere (A)
pound-force per square inch (lbf/in^2)
volt (V)
direct current (dc)

A WIRELINE-POWERED INFLATABLE PACKER FOR BOREHOLE APPLICATIONS

By Alfred E. Hess

ABSTRACT

The U.S. Geological Survey has developed a lightweight wireline-powered packer system suitable for shallow and deep borehole applications below water level. The packer is used for controlling the movement of water in boreholes and wells. It was developed as a flow concentrator for a slow-velocity thermal flowmeter, but it may be used with any borehole flowmeter or other geophysical instrument where a packer or packer string could be applied.

The packer system consists of a bidirectional pump powered by a reversible electric motor that is housed in a pressure-equalized water-tight container. The pump inflates and deflates one or more inflatable packers with borehole fluid upon command from a surface module through a conventional logging cable.

This report describes the construction of a wireline-powered packer system and some possible applications. Included are drawings and schematics to assist in the construction and application of the packer system. The U.S. Department of Interior has applied for a patent on this packer system.

INTRODUCTION

Inflatable borehole wall-conforming packers (Hsieh and others, 1987) are commonly used in geohydrologic studies to control and concentrate flow for borehole-flow measurements, and to isolate fractures and formation zones for determining shut-in pressure, hydraulic conductivity, and other applications. Borehole packers typically are inflated with gas pressure from the surface (Shuter and Pemberton, 1978). This inflation requires one or more pipes or tubes from the surface to the packers and very precise pressure control to ensure adequate inflation pressure without over-pressure that would burst the bladder, or under pressure that may not provide adequate sealing against the borehole walls.

The USGS (U.S. Geological Survey) has developed a lightweight wireline-powered inflatable packer system suitable for use in both shallow and deep boreholes (Hess, 1990). The system includes one or more packers that may be inflated and deflated by power supplied through a geophysical logging cable. The packer is inflated with resident borehole liquid by a small submersible electric pump that is part of the packer assembly. The packer assembly is lightweight, totally supported by the logging cable, and is easy to use and reconfigure for varied applications. The packer assembly normally would be used in conjunction with other borehole geophysical instruments such as flowmeters or pressure transducers. Depth of use is limited only by the length and resistance of the available interconnecting cable, which may be a conventional logging cable. A wireline-powered inflatable packer has been successfully used with a thermal flowmeter to depths in excess of 15,000 feet (Morin and others, 1992).

The packer pump described in this report is less than 2 inches in diameter and may be used in 2-inch diameter test holes. The size of the inflatable packers may be scaled up or down to suit the application. Two or more packers may be combined to form a packer string that may be simultaneously inflated and deflated by a single pump. Because the packers are inflated with borehole fluid, the relative pressure in each packer is the same irrespective of their depth so long as all packers are under water. Therefore, the operator does not need to know the exact water level in a borehole or the packer depth to determine proper inflation pressure, or need accurate high-resolution pressure gages to provide the proper pressure to the packer. Multiple pumps may be used to control multiple packer inflation individually if that is desired.

Relative packer pressure is determined by pump pressure which is dependent primarily upon pump-motor current and is independent of the depth to which the packers are set. A bidirectional gear pump powered by a reversible direct current motor is used to inflate and deflate the packers. Because relative packer pressure is low, less than 50 lbf/in^2, and is easily controlled, there is no need to use stiff packers that are designed for high pressures because of the difficulty of knowing and setting the required absolute pressure. Thus, soft, flexible wall-conforming packers may be used.

The pump and packer system described in this report has been designed to operate at any pressure depth and to produce differential pressures in the range of 15 to 30 lbf/in^2, which is adequate for flowmeter concentrators, as well as for some packer-pressure logging applications. The packer system requires only one geophysical logging cable conductor in addition to the cable armor that may be used in common with other logging instruments. Thus, if a 4-conductor logging cable is used 3-conductors of the cable will be available for other functions. The cable conductor used for the packer pump also may be shared with other functions since the pump is used only intermittently. The purpose of this report is to provide information to other government agencies and to the public about the design, construction, and use of the wireline-powered packer which the USGS has developed. While the packer was developed as a flow concentrator for the slow-velocity thermal flowmeter, it may be used with any borehole flowmeter, or with other geophysical instruments where a packer or packer string could be applied.

DESCRIPTION OF THE PACKER SYSTEM

An inflatable packer system may be used as a flow concentrator for a flowmeter (fig. 1). The system consists of a bidirectional pump powered by a reversible electric motor that inflates and deflates the packer with filtered borehole fluid upon command from a surface module through a conventional logging cable. A valve chamber between the pump and packer operates in conjunction with the pump to control the inflation and deflation of the packer. The surface module supplies the current required to operate the pump motor. The pump is reversed by reversing the current to the motor. Pump pressure, and thus packer pressure, is controlled by the amount of current provided to the pump.

The electric pump motor is housed in a pressure-equalized water-tight housing. A variable-volume reservoir equalizes the pressure between the borehole fluid and the liquid in the motor chamber. This equalization of pressure permits the use of a simple low-pressure seal on the shaft between the motor and the pump. In addition to pressure equalization, the liquid in the motor chamber also provides electrical insulation for the motor and lubrication for the bearings.

Pumping direction and pressure is controlled from the surface by the amount and polarity of the electric current supplied to the electric motor. A filter is used to keep potentially damaging particulate material, which may be present in the borehole fluid, from entering the pump and valve chamber. The valve chamber between the pump and the inflatable packer controls inflation and deflation of the packers. Valve function is controlled by pump pressure.

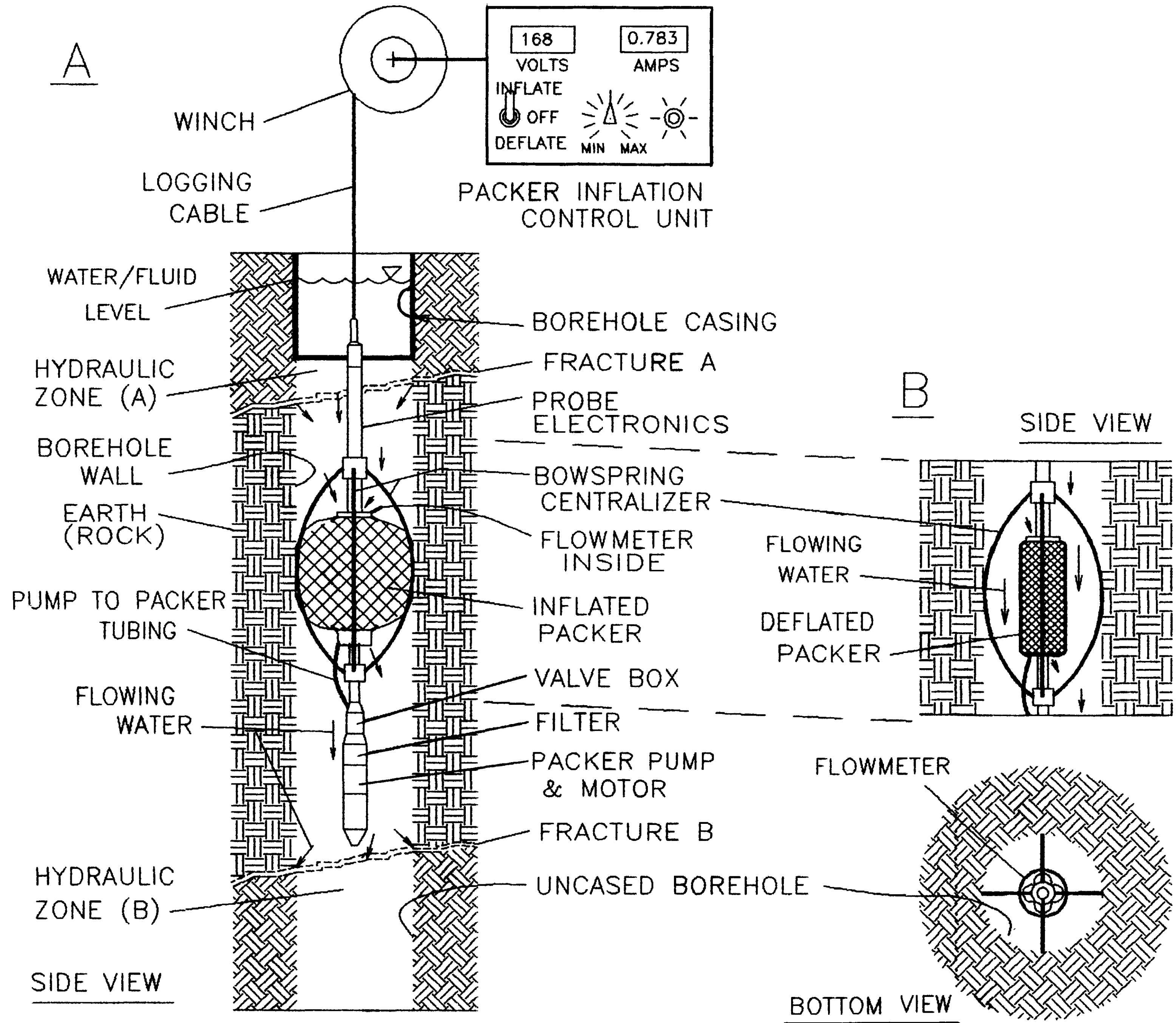

Figure 1. Wireline-powered inflatable packer used with a borehole flowmeter.

Packer bladders have been made of rubber automotive-innertubes that can expand to several times their uninflated diameter. The expansion of the packer bladder is constrained to a safe, maximum, working diameter by a strong, flexible, fabric layer.

During operation, the packer is inflated or deflated by energizing the pump motor by sending the proper polarity of electric current through the cable to the packer motor. Packer inflation pressure is controlled by the amount of current supplied to the motor. When the motor power is switched OFF, a check valve in the valve chamber closes, keeping the packers inflated.

The packer remains inflated while geophysical measurements such as fluid flow or shut-in pressure are made. The packer is deflated for removal or moving to a different depth by reversing the pump. Deflation is accomplished by reversing the polarity of the current supplied to the pump motor from the control panel.

The borehole packer should be in the deflated condition to be moved to a different depth (fig. 1B). A bowspring centralizer is used to guide the packer string in the borehole to minimize abrasive wear on the packers while they are being moved.

The ratio of inflated to deflated packer diameter is limited by the elastic bladder material. Materials presently used in this application have a useful working diameter ratio greater than 2.5 to 1.

The wireline-powered packer system is modularly constructed, which permits the packer system to be reconfigured easily. Thus, a range of inflatable packer sizes may be kept in supply and installed to suit the particular hole diameters and borehole conditions encountered.

An inflatable packer system, consisting of two or more packers and an inflating pump, may be used with a borehole fluid pressure probe to make measurements of the shut-in pressures of a fracture or formation as is illustrated in figure 2. The pressure probe illustrated has 3-pressure transducers that enable it to simultaneously measure the pressure in hydraulic zone (A) above the probe, the shut-in pressure of hydraulic zone (B), an the shut-in pressure of hydraulic zone (C) below the probe.

Packer Pump and Valve Box

A cross-sectional view of the electric motor, pump and controlling valve box used to inflate and deflate the packers is shown in figure 3. The pump is a bi-directional gear pump that is driven by a reversible electric motor. The electric motor is in a sealed motor chamber that is filled with a suitable liquid such as kerosene or Isopar-M (Exxon Company). The liquid-filled motor chamber is equalized to borehole pressure at any depth by a variable volume bellows. Electrical power from the packer inflation control unit (fig. 1) is supplied to the electric motor through the waterproof pump power cable.

The packer (fig. 1) is inflated with filtered borehole liquid pumped by the pump through the valve box containing the check valve, and through the connecting tubing to the inflatable packer. Inflation pressure is monitored indirectly with the ammeter on the packer inflation control unit. When the measured pump current reaches the desired level, indicating that the packer is inflated to the desired pressure, the power to the pump is turned off. The check valve in the valve box (fig. 3) closes retaining the fluid in the fully inflated packer.

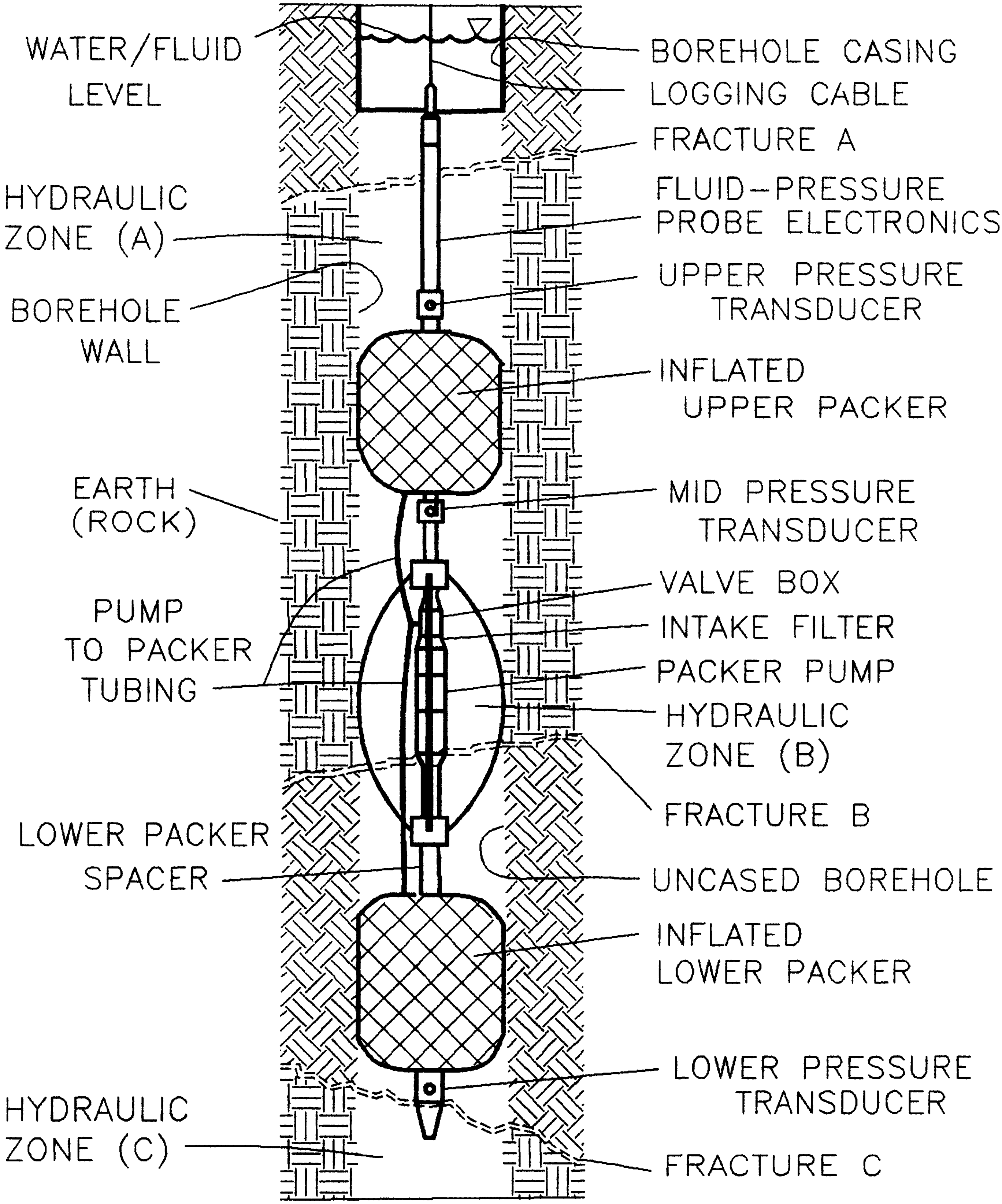

Figure 2. Wireline-powered inflatable straddle packers used with pressure transducers.

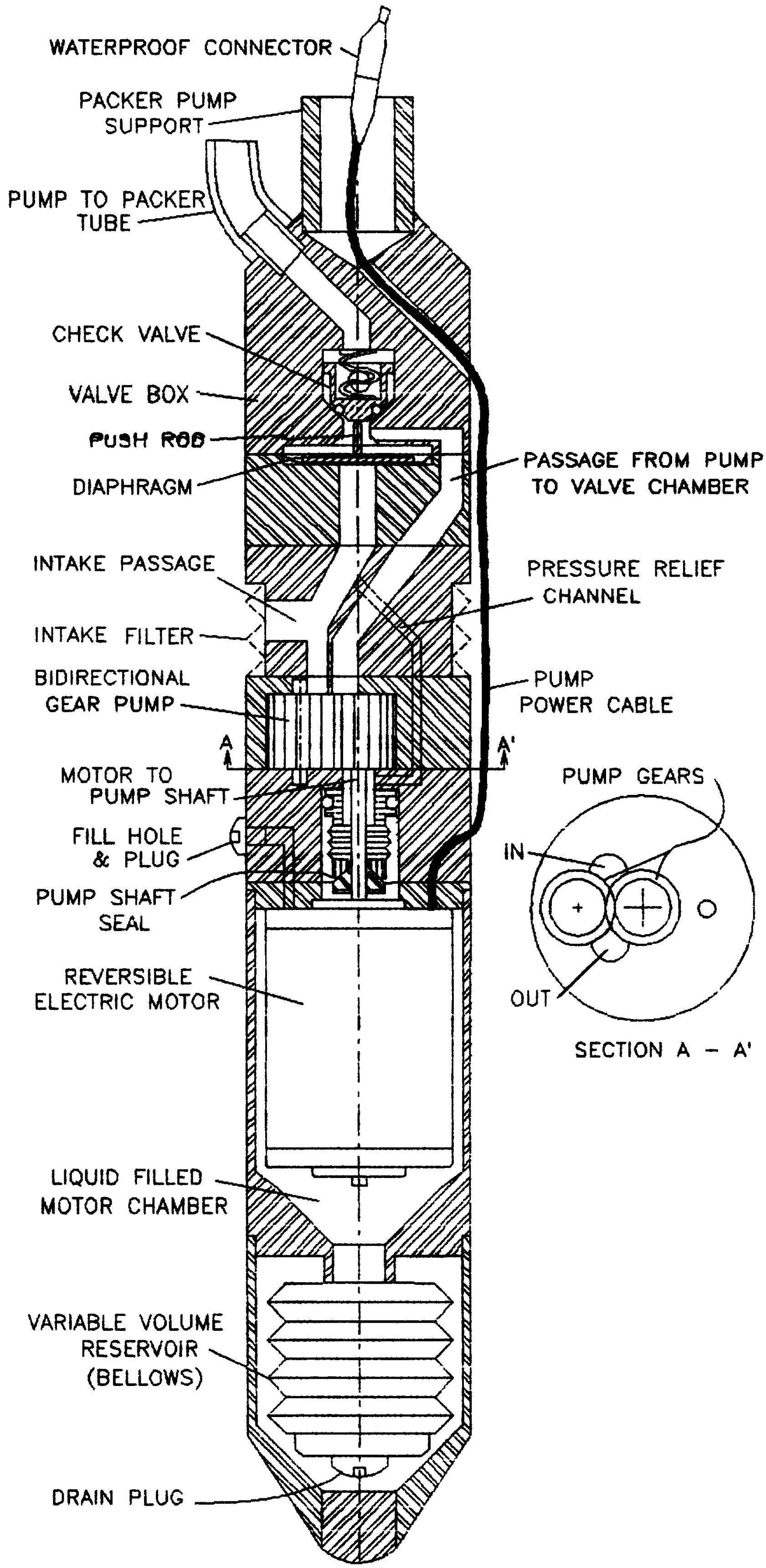

Figure 3. Cross section of the pump and valve box.

To deflate the packer, the pump is operated in the reverse direction by supplying current of reversed polarity to the pump motor. The reversed pump reduces the pressure within the valve box relative to ambient borehole pressure (fig. 3). This reduced pressure causes the opposing diaphragm in the valve box to move up causing the push rod to open the check valve, thus permitting the reduced pressure from the pump to deflate the packer.

The position of the diaphragm is determined by the pressure difference between the ambient borehole pressure and the pump-induced pressure within the valve box. During inflation, pressure within the valve box holds the diaphragm in the down position where it does not affect the normal operation of the check valve. When the pump is stopped, the diaphragm remains in the down position, and the pressure in the packer and the check valve spring causes the check valve to close.

The pressure-equalized electric motor powered gear pump and valve box shown in figure 3 are the heart of the wireline-powered packer system. The USGS modified a 1.75 inch diameter, shallow-well sampling pump, model SP-202 obtained from Fultz Enterprises. Fultz Enterprises has since replaced the model SP-202 pump with a model SP-300 pump that is reported to be more powerful. However, the SP-300 requires greater starting current, and for this application the pump must reliably start and run with as little as 0.6 amperes of direct current through 200 ohms of series resistance. The SP-300 the USGS tested did not meet this requirement.

The following modifications were made to the Fultz model SP-202 pump housing (fig. 3):

1. A variable volume reservoir (bellows) and a protective cover were added below the pump motor to provide pressure equalization to the motor chamber.
2. A fill hole and plug was added to the top of the motor chamber, and a drain hole and plug was added to the bottom of the reservoir.
3. A pressure relief channel was added to connect the area between the pump shaft seal and the driven pump gear to the intake port inside the intake filter to reduce the differential pressure across the pump shaft seal caused by leakage past the pump gears.
4. The motor chamber and reservoir were filled with clear, clean kerosene or Isopar-M.
5. A high-pressure water-proof connector was added to the motor power cable between the motor and the logging line. Only one wire to the motor was required since the metal frame of the pump and the cable armor provided the return path for motor current.

A magnetic motor-to-pump coupling may be used to completely eliminate the shaft seal and any potential seal leakage. The USGS has modified a Tuthill model B9862MC-B6729 magnetically coupled pump (fig. 4), in a manner similar to that described for the Fultz pump, to permit its use as a deep well packer pump. The modified Tuthill pump is 2.5 inches in diameter and is useable in boreholes with diameters of 3 inches or larger.

The operation of the pump and valve box is as follows. When positive current is supplied to the pump, the pump pressurizes the valve box. This pressure opens the check valve permitting fluid to flow through the tubing to the packer(s) inflating them. When the pump is turned off, the pump stops, pump pressure drops to zero, and the pressure of the fluid in the packer closes the check valve (which is lightly spring loaded) which maintains the packer in the inflated condition. The final inflated pressure in the packer is determined by the final current supplied to the pump motor.

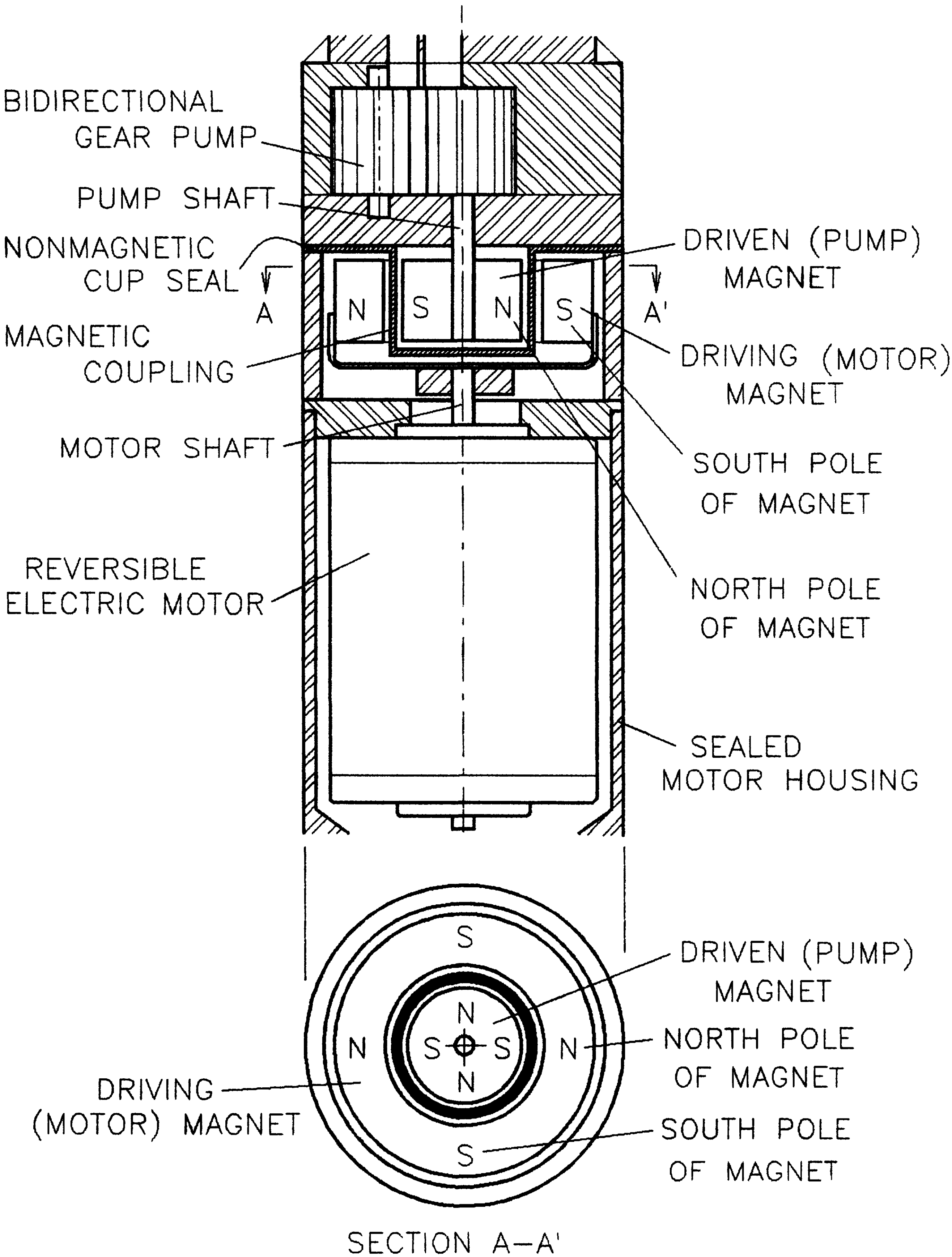

Figure 4. Cross section of magnetically-coupled pump which eliminates the motor to pump-shaft seal.

To deflate the packer, negative current is supplied to the pump which causes it to rotate and pump in the reverse direction and reduces the pressure in the valve box to below ambient (fig. 3). This reduced pressure causes the check valve to seal even tighter, but the reduced pressure also affects the diaphragm in the valve box. The diaphragm is actuated by the difference between the ambient pressure in the borehole and the pressure in the valve box, so the below-ambient pressure causes the diaphragm to move upward. The diaphragm has a much larger effective area than the check valve, so the reduced pressure causes the diaphragm to overcome the force holding the check valve closed and forces it open through a rod attached to the top-center of the diaphragm.

Packer Power Supply and Control Panel

The operation of the packer pump is powered and controlled by the Packer Inflation Control Unit shown in figure 1A. The pump requires a voltage-regulated adjustable power supply that can provide up to 1 ampere of current at up to 200 volts dc. The output of the power supply must be electrically "floating" so that either the (+) or (-) output may be grounded.

More detail of the packer power control unit may be seen in figure 5 where it is shown as a separate unit with an INFLATE/OFF/DEFLATE switch, a digital voltmeter and a digital ammeter. Operation of the packer pump is controlled by the INFLATE/OFF/DEFLATE switch on the Packer Inflation Control unit and the voltage control knob on the Power Supply. However, the control circuit could be part of the power supply or built into the control unit of another geophysical logging system. For operating convenience the USGS has incorporated its packer inflation control into its slow-velocity, thermal flowmeter control unit (Hess, 1990). Only one waterproof wire plus the grounded motor case is required to power and control the packer pump, and one pump can be used to inflate and deflate several packers. The digital voltmeter indicates the voltage available from the power supply, and the digital ammeter indicates the pump-motor current during inflation or deflation. A positive current (+) indicates inflation and a negative current (-) deflation. Both meters should have a resolution of at least 1 percent, which is one reason digital meters are used.

Inflatable Packer(s)

The inflatable packers shown in figures 1 and 2 are on a hollow mandrel that has been slipped over and clamped to the borehole probe with which it is used, a flowmeter in figure 1A and a pressure probe in figure 2. The packer mandrel shown in figure 6 is a hollow brass or stainless-steel cylinder upon which the inflatable part of the packer is assembled. The size of the mandrel is chosen to suit the application. A hollow mandrel is the most versatile because it can be slipped over and clamped to existing borehole probes.

The inflatable part of the packer is made in three layers (fig. 6). The innermost layer is an elastic watertight bladder. The expansion of the bladder is constrained to a safe, maximum working diameter by a strong, flexible, fabric reinforcing layer that permits packer inflation to much greater pressures than the bladder alone could withstand. The reinforcing layer is designed to prevent the packer from rupturing even if it should be inflated to maximum pump pressure in a large-diameter hole where the packer is not constrained by the borehole wall. The reinforcing layer is covered by a soft, elastic outer layer. The elastic nature of the inflatable packer enables it to conform to rough and irregularly shaped borehole walls and form a watertight seal.

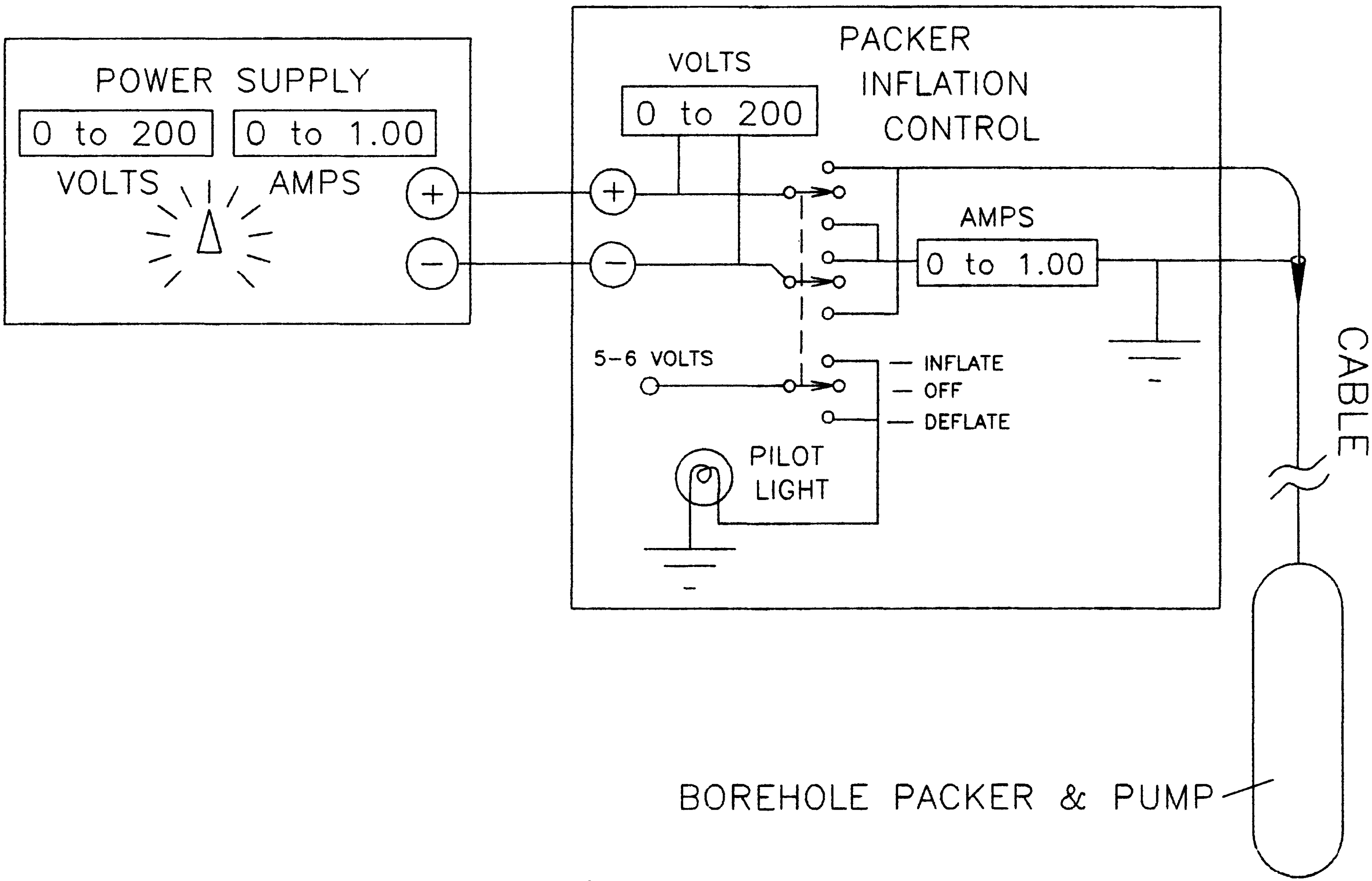

Figure 5. Packer pump power and control system.

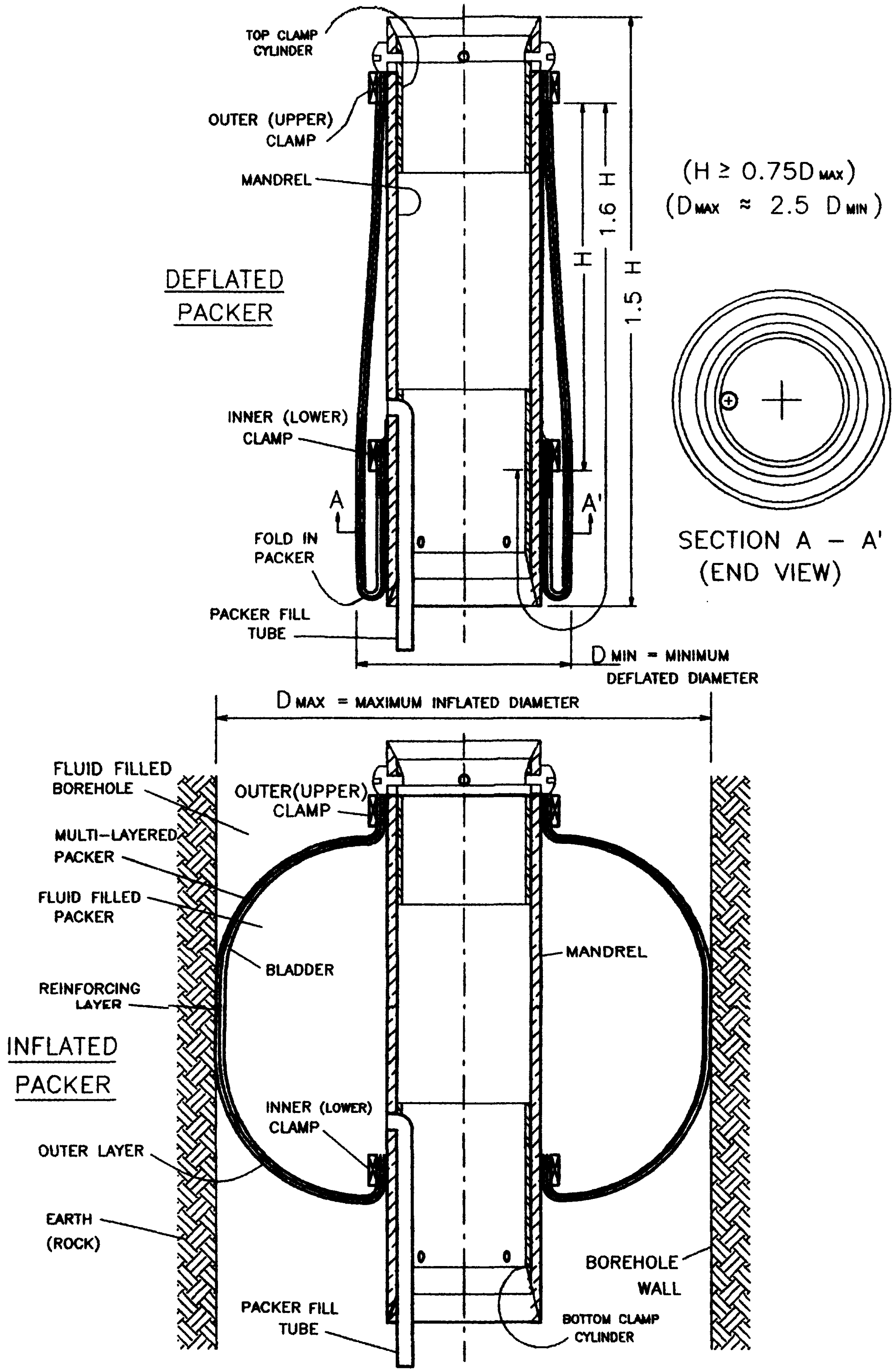

Figure 6. Cross-section view of a deflated and inflated slip-over packer.

Ideally, the bladder and outer elastic layer should be made of soft, tubular, rubber material that has a large expansion ratio. The material should be resistant to the deteriorating effects of sun, air, water, and petroleum products. The USGS has successfully used sections cut from innertubes (automotive, bicycle, motorcycle, truck, and tractor) which are readily available and relatively inexpensive. The donut shape of innertubes is not ideal but is useable. The innertubes used had an expansion ratio of more than 3 to 1, from which packers were made that had a useable expansion ratio of more than 2.5 to 1.

The lower or inner end of the inflatable packer is securely fastened to the cylindrical supporting mandrel by an inner bladder clamp (fig. 6). The free end of the packer then is folded back over itself and the inner clamp, and is brought to the opposite or upper end of the mandrel where it is clamped by the outer clamp. The technique of folding the packer back on itself eliminates the need for a sliding packer seal, which is subject to wear and leakage. To allow the packer to inflate fully the distance between the effective inner and outer clamping points, H, should be a minimum of 75 percent of the maximum inflated diameter, Dmax, of the packer, (H => 0.75 Dmax). The length of the inflatable packer material should be at least 1.6 times H.

The supporting mandrel should be long enough so the folded end of the deflated packer will not extend beyond the end of the mandrel, plus room above the top or outer clamp for the screws that hold the top cylinder clamp in place. The screws holding the bottom cylinder clamp may be located under the fold of the deflated packer and does not add to the length of the mandrel. Thus, the mandrel should be at least 1.5 times H. The top- and bottom-cylinder clamps are of such a diameter and length as to hold the packer securely over the flowmeter basket while allowing for ease of placement or removal. The rigid packer fill tube provides a fluid path from inside the packer chamber just above the lower clamp, to a little below the bottom of the mandrel to allow easy connection of the tubing that runs between the packer and the packer pump.

Construction details for two designs of packer reinforcing layers used by the USGS are as follows. (1), a fabric cylinder is woven with the warp and woof at an acute angle (about 14 degrees, which allows for a diametric expansion ratio of about 2.5 to 1); and (2), a quasi-spherical fabric bag made from flat material.

The reinforcing layer produced using the first design shown in figure 7 collapses tightly on the mandrel when deflated but is somewhat difficult and time-consuming to make, especially for the larger diameters. The second design for the reinforcing layer shown in figure 8 is easier to make but is a bit baggy and depends on the outer elastic layer to collapse it tightly on the mandrel when deflated. The packers in figures 7 and 8 are shown without the outer elastic covering to better indicate the lay of the reinforcing layer. The attachment of the packers to the mandrel by clamps is shown in figure 6.

The details for the second design that uses the quasi-spherical-shaped reinforcing will be described. As an example, assume that the packer is to fit over a flowmeter sensor with a outer diameter of 2.5 inches and a length of 4 inches. The mandrel may be made from a stainless steel or brass tube that has an inside diameter of 2.515 inches, an outside diameter of about 2.7 inches, and a length of about 10 inches, (fig. 6). The packer is to have a maximum inflated diameter of about 8.0 inches and a minimum collapsed diameter of about 3.5 inches.

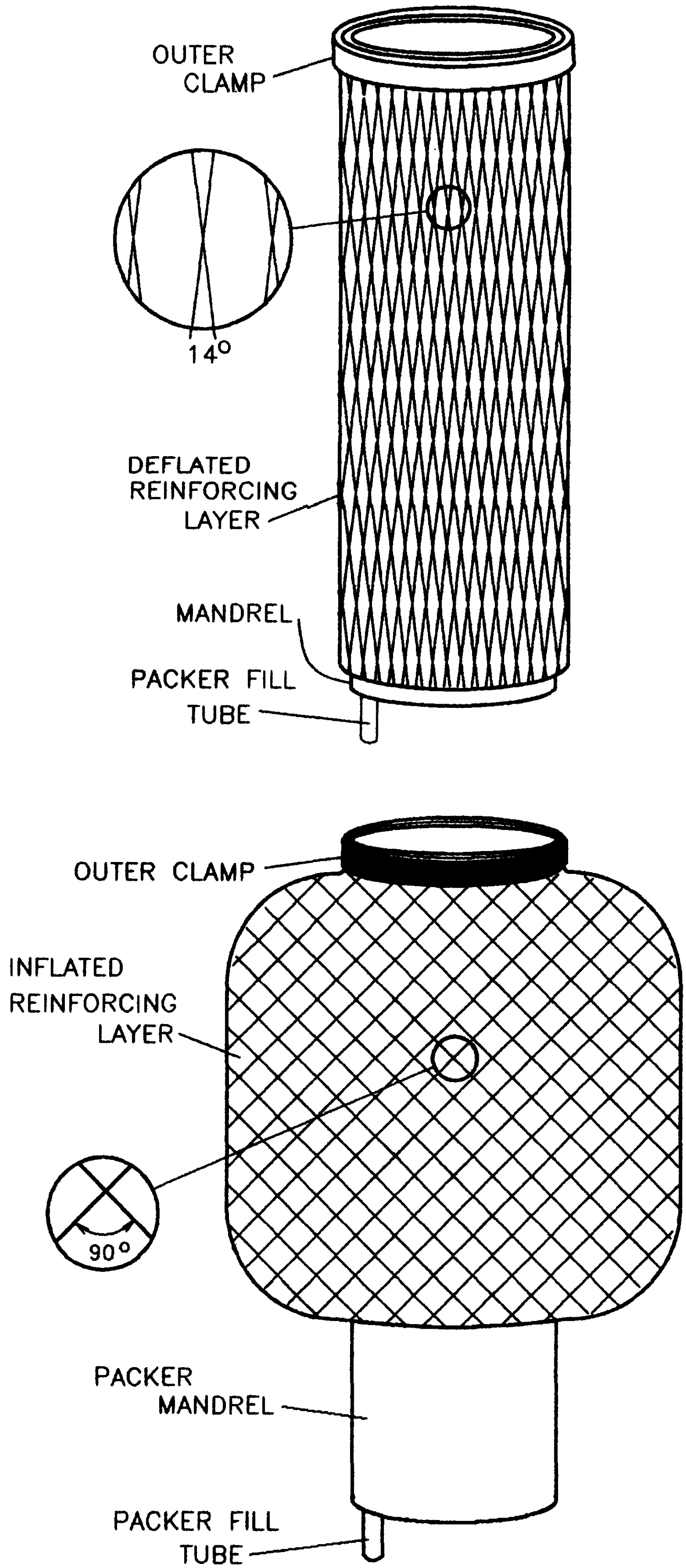

Figure 7. Side views of deflated and inflated woven, diamond-pattern, expansion-limiting reinforcing layer.

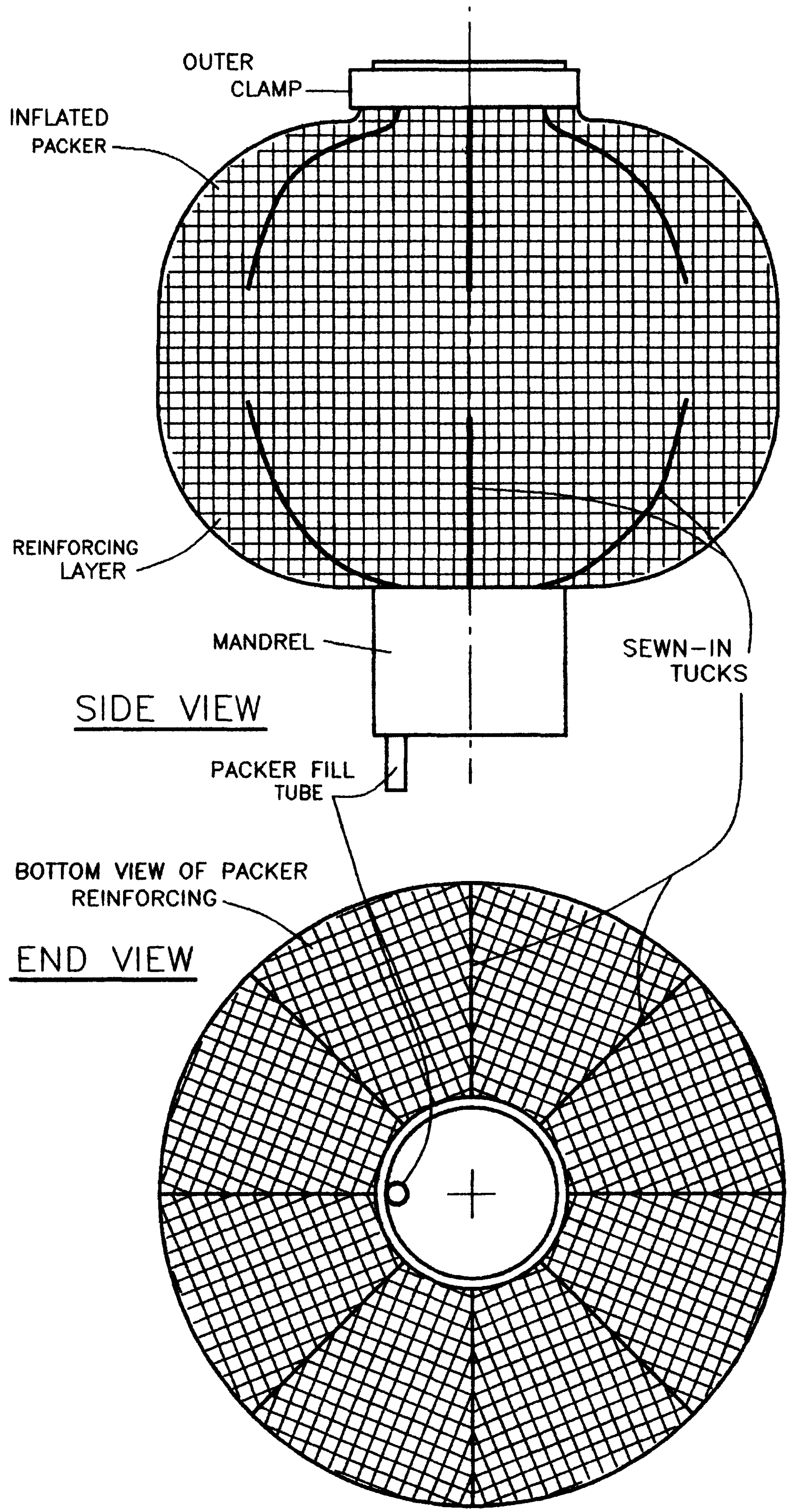

Figure 8. Side and bottom views of inflated quasi-spherical, fabric reinforcing layer to limit packer expansion.

Strong, flexible material made of Kevlar, polyester, or Nylon is used to make the quasi-spherical reinforcing. The material must have sufficient wet strength to hold at least 50 lbf/in^2, although actual pressures usually will be in the 15 to 30 lbf/in^2 range. For the 8-inch diameter packer mentioned above, a 10.5 by 25.6 inch piece of material is required for the reinforcing layer (fig. 9). The reinforcing layer is formed by first sewing together the 10.5-inch ends of the material with a 0.5-inch lap, making a tube that is about 8 inches in diameter by 10.5 inches long. Next, eight tucks or pleats are sewed into each end of the flattened fabric tube. The finished quasi-spherical reinforcing should slide easily over the 2.7-inch-diameter mandrel.

The inner bladder tube and outer elastic tube may be cut from a motorcycle inner tube that has a flattened width of about 4.3 inches, (2.7 inches * pi / 2 = 4.3 inches). The bladder tube should be about 10.5 inches long and the outer tube about 11 inches long.

Packer assembly is started at the packer fill-tube end of the mandrel. All layers of the packer are started inside-out, hanging below the fill tube. First, the outer layer is slid up to about 0.3 inch below the fill-tube hole where it is glued and temporarily clamped while the glue sets. The glue, which must adhere to metal, rubber, and fabric, and be waterproof and petroleum resistant, the USGS has used is "THE WELDER" by DIY Products Division of Rhodes American, and "GOOP" by Eclectic Products, Inc.

Next, the inside-out reinforcing layer is glued and temporarily clamped over the previously glued outer layer. This is followed by the inner bladder, which is lapped onto the mandrel a little beyond the fabric layer (just below the fill-tube hole) to ensure a pressure-proof seal, and is securely glued and clamped. Make certain that the fill-tube inlet is not obstructed. Screw-type automotive clamps make convenient temporary clamps but are too bulky to leave permanently. For permanent clamps the USGS has used four to six turns of stainless-steel wire, or stainless steel packing straps that use very small clamps. Care must be taken that the wire or clamps do not cut into the soft bladder material, especially when the packer is fully inflated and under maximum stress. It may be well to place a layer of cloth tape such as friction tape under the clamps to prevent the clamps from cutting the soft rubber.

After the lower end is securely glued and clamped, the free end of each layer is turned back over itself and slid up to the upper camp position where it is glued and clamped. The USGS uses talcum powder sprinkled liberally between layers to aid in sliding the layers into place. The finished packer should resemble that shown in the cross-sectional diagram in figure 6.

Even though the construction only one size of packer has been described, any size of packer may be made by scaling the dimensions up or down to suit the application. Packers of several sizes may be made to meet all expected needs and to have as spares. Using the design outlined above the USGS has made and used packers that have expanded outer diameters ranging from 5 to 16 inches for use in boreholes that have nominal diameters ranging from 3 to 14 inches, and to depths of 15,000 feet.

PACKER OPERATION

The packer pump requires a voltage-regulated adjustable power supply that can provide 1 ampere of current up to at least 200 volts dc. The output must be electrically "floating" so that either the plus or minus output may be grounded. The output of this power supply is

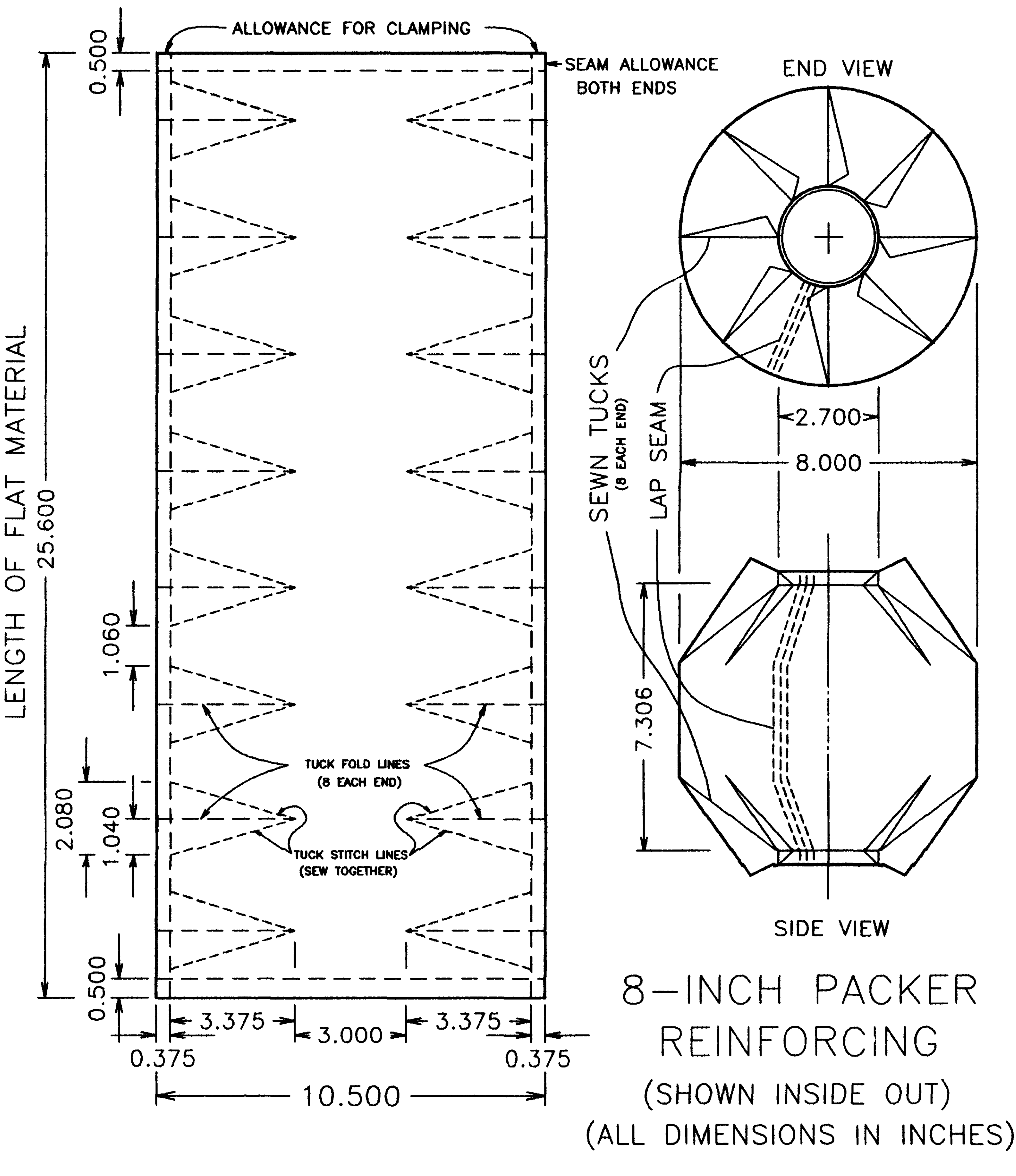

Figure 9. Construction detail of a quasi-spherical reinforcing layer for an 8-inch diameter packer.

connected to the Packer Inflation Control unit (fig. 5), making sure the polarity is correct.

The packer pump is controlled with the INFLATE/OFF/DEFLATE switch on the Packer Inflation Control unit. The ammeter indicates the pump current, which is positive when this switch is in the INFLATE position or negative when in the DEFLATE position.

The following instructions pertain specifically to the USGS packer system as used with the USGS thermal flowmeter and may need to be modified to suit other system requirements; they are given here as a general guideline.

1. Position the flowmeter with inflatable packer to the desired depth in the borehole, well below the water level. It is very important that the packer pump be under water whenever it is run. The pump will be damaged if it is run "dry".

2. Adjust the power supply voltage to about 50 volts (adjust the current limiter to 1.0 ampere maximum if such is available on the power supply).

3. Switch to INFLATE and quickly adjust the motor current to 0.75 ampere as indicated by the digital ammeter, (or to 0.05 ampere less than the current that represents the packer pressure desired), by adjusting the power supply voltage.

4. As the packer fills, the motor current may increase slightly, but when the packer is full the current will increase quickly. Switch the power to OFF when the current reaches 0.80 ampere, (or whatever current that represents the packer pressure desired). Do not readjust the power-supply voltage after the initial adjustment made during the first few seconds after switching to INFLATE.

A packer motor current of 0.80 ampere should not be exceeded for packers in boreholes having diameters larger than 8 inches, or the pressure may burst the packer. A current of 1.0 ampere should not be exceeded for smaller packers. Packer inflation time ranges from only a few seconds to more than 5 minutes depending on the size of the borehole and volume of the packer.

A packer-motor current versus packer-pressure chart should be made and used to determine packer pressure for any measured pump-motor current.

5. The packer is deflated by switching to DEFLATE. The motor current during deflation may be less than the 0.75 A set during inflation. Do not change the power supply voltage. When the packer is fully deflated, the current will usually change noticeably; turn the power OFF when this change is noted. Normally, the packer will take less time to DEFLATE than to INFLATE.

6. The first time the flowmeter is lowered into a borehole, INFLATE and DEFLATE the packer several times as indicated in steps 3 through 5 to expel all of the air from the packer (only while under water). Then with the packer completely deflated lower the flowmeter rapidly for several feet to remove any trapped air from the flowmeter sensor. Air in the sensor will cause uncertainties and errors in the measurement of flow. The above procedure should be repeated when noisy non-repeating measurements indicate that air may have collected in the sensor. Air is most likely to be trapped in the sensor just below water level.

7. The thermal flowmeter now may be positioned at the desired depth, and after inflating the packer, flow measurements may be made following the normal flow-measuring procedures.

8. Always deflate the packer before moving the flowmeter. Failure to do so will damage the packer.

9. If during a series of flow measurements there are indications that the packer has lost pressure, it may be checked for tightness by switching to INFLATE and noting now long it takes for the pump current to again reach 0.80 ampere, or whatever current is required. If it takes more than a second or two to reach the required

current the packer has leaked down. However, running the pump disturbs the flowmeter and the water near it, so the flowmeter and borehole fluid will need to stabilize for a few minutes before repeatable flow measurements can be obtained.

The packer also may be checked for tightness in shallow holes by manually pulling lightly on the logging cable to see if the packer is gripping the borehole wall (Do not use the logging winch to pull on the flowmeter). However, this procedure also disturbs the water near the flowmeter and several minutes may elapse before repeatable measurements may be obtained.

10. If the packer will not remain inflated, there are two possible problems;

1) The packer or connecting hose is leaking; or
2) The packer check valve is leaking.

If the packer or connecting hose is leaking, there will be no appreciable increase in pump-motor current during inflation, and the packer will have to be repaired or replaced. If the packer check valve is leaking, the packer will fill to the maximum desired pressure as confirmed by an increase in pump-motor current, but the pressure will not hold when the pump is turned off. This could be due to a particle caught under the check valve seat, allowing it to leak. This leakage can sometimes be stopped by inflating and deflating the packer for a few seconds several times while it is still under water in the borehole. Otherwise, the packer will have to be removed from the borehole and the valve box opened, inspected, and cleaned. Replace any damaged O-rings. Coat all O-rings and seats with silicone grease when reassembling the valve box to minimize the chances of damaging the O-rings during assembly. Inspect and clean the packer-pump intake filter and screen, or replace if damaged.

PACKER MAINTENANCE

The packer-pump motor chamber must be kept filled with kerosene or Isopar-M. The chamber should be checked occasionally to ensure that it is full. At the end of each day of use and more frequently if necessary, the fluid in the motor chamber should be drained and checked for water. More than a few milliliters (about a half teaspoon) of water indicates a serious leak or seal failure that must be repaired before further use. Refill the motor chamber with clean fluid. If clean fluid is not available, the old fluid may be reused after filtering through filter paper or several layers of Kimwipes. Be sure that all water is filtered out.

Isopar-M is less toxic than kerosene and should be used in the pump-motor chamber if the leakage of a small amount of kerosene into a borehole might cause significant contamination problems. However, Isopar-M is expensive and may be difficult to obtain and therefore should be used spartanly.

A filter should always be used over the packer-pump intake. Clean the filter if it becomes clogged or replace it if damaged. The Teflon pump gears should be replaced if the pump does not produce at least 15 lbf/in^2 pressure with a pump-motor current of 0.8 ampere. New Teflon pump gears must be run-in <u>under water</u> while the pump case cover is being tightened. The pump should <u>never</u> be run in air.

The rubber covering on the packers will last longer if they are kept clean, dry, and protected from sunlight and air with an opaque plastic covering when not in use. Insofar as possible, avoid getting kerosene on or in the packers because it causes rapid deterioration of the rubber.

SUMMARY AND CONCLUSIONS

The U.S. Geological has developed a lightweight wireline-powered packer system suitable for shallow and deep borehole applications. The packer system may be used with any borehole flowmeter or other geophysical instrument. Drawings, schematics, and information are included to assist in the construction and use of the packer system.

REFERENCES CITED

Hess, A.E., 1990, Characterizing fracture hydrology using a sensitive borehole flowmeter with a wireline-powered packer, 1988, Proceedings, Atlanta, GA,: International Conference on Fluid Flow in Fractured Rock, p. 328-345.

Hsieh, P.A., Neuman, S. P., Stiles, G.K., and Simpson, E.S., 1987, Field determination of the three-dimensional hydraulic conductivity tensor of anisotropic media -- 2. Methodology and application to fractured rocks: Water Resources Research, v. 21, no. 11, p. 1667-1676.

Morin, R.H., Hess, A.E., and Becker, Keir, 1992; In situ measurements of fluid flow in DSDP holes 395A and 534A -- Results from the Dianaut program: Geophysical Research Letters, v. 19, no. 5, p. 509-512.

Shuter, Eugene, and Pemberton, R.R., 1978, Inflatable straddlepackers and associated equipment for hydraulic fracturing and hydrologic testing; Water-Resources Investigations 78-55, July, 20 p. [Available from National Technical Information Service, Springfield, VA 22161 as NTIS Report PB-288 403.]

PRODUCT REFERENCES

ISOPAR-M; an Exxon Corp. product from Ashland Chemical Inc., 3350 So. Zuni St., Englewood, CO 80110; Phone (303)789-1888

PUMP, Fultz Enterprises, R.D.2, Box 381-M, Lewistown, PA 17044 Phone (717)248-2300

PUMP, Tuthill Pump Co. of Calif., 5143 Port Chicago Hwy, Concord, CA 94520; Phone: (510)676-8000

POWER SUPPLY; Systron-Donner Instrument Div., 2727 Systron Dr., Concord, CA 94518; Phone (415)676-5600

☆ U.S. GOVERNMENT PRINTING OFFICE: 1993—573-191 / 80010 REGION NO. 8