Figure C4-34.- Final lowering of heater probe.

Figure C4-35.- Wire loop used to install heater probe retaining bolt.

Figure C4-36.- View inside tank showing heater probe upper retaining bolt.

Figure C4-37.- Pulling wires from tank.

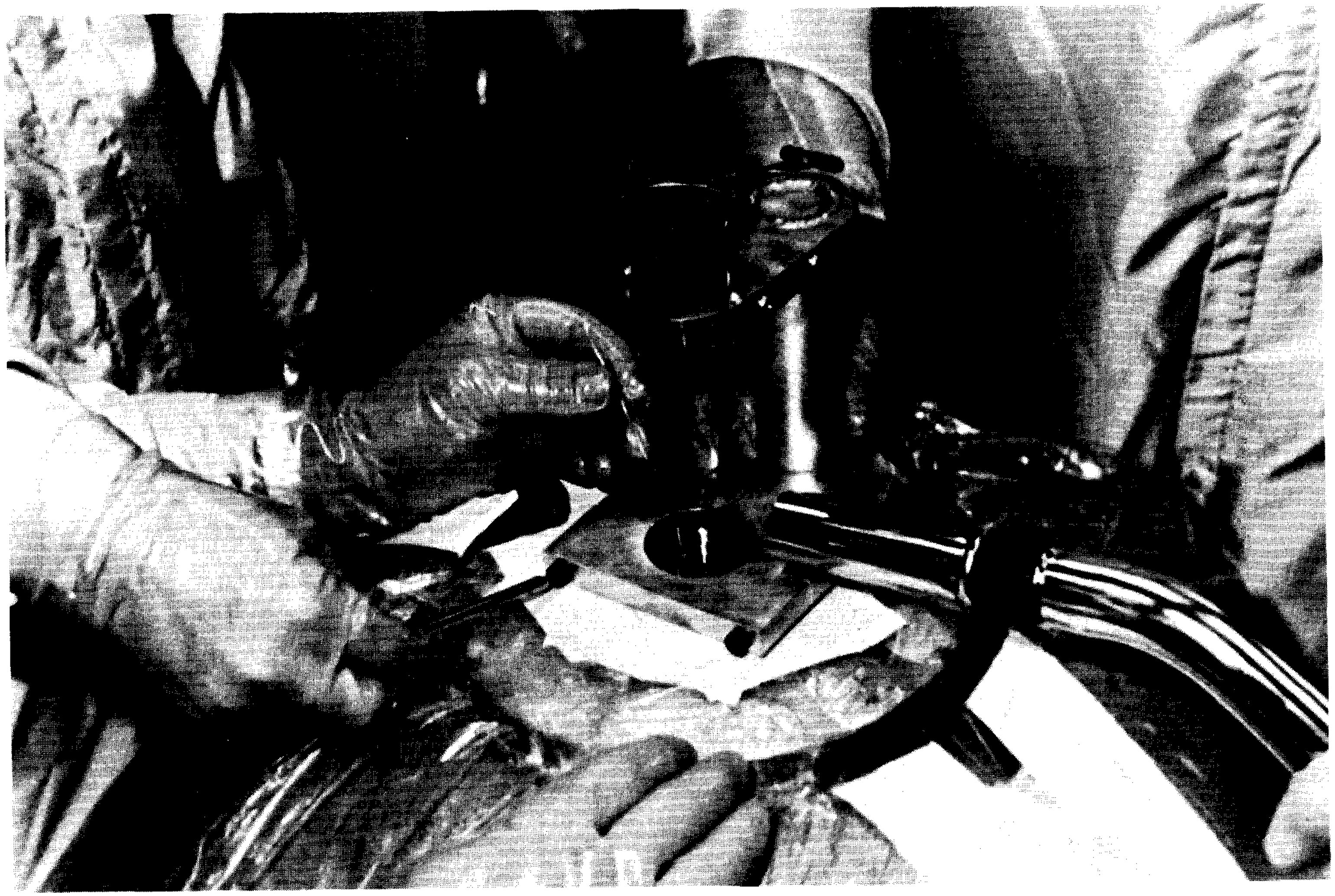

Figure C4-38.- Lowering wires into tank with fixture to hold quantity probe installed.

Figure C4-39.- Quantity probe being installed in fixture and heater probe wires being pulled from the tank.

At this point the wires are once again withdrawn from the tank. Again any possible tangles are removed. Then the pull wires previously installed in the probe are soldered to the motor and heater lead bundles. The solder joints are thoroughly cleaned and taped to made a smooth transition from each single pull wire to each bundle of six leads. These wire bundles are pulled into the conduit one bundle at a time with one man feeding the wires at the feedthrough hole in the quantity probe and the other man pulling approximately 25 to 35 pounds on the pull wire (figs. C4-40 through C4-42). The bundles are pulled through until the slack is taken out of the wire bundle with the probe in this elevated position (about 9 inches of slack when probe is lowered into into tank) (fig. C4-43). Then holding the probe assembly, the fixture is removed from the tank neck and the probe is lowered into the tank (fig. C4-44). The probe assembly is then rotated counterclockwise approximately one turn. The unit is then very carefully rotated clockwise to start the quadruple thread and pilot the lower end of the probe into the ring provided at the bottom of the tank. If the probe assembly in the tight position does not result in alignment of the supply tube, then the probe assembly is re-indexed in 90-degree increments to achieve alignment. These procedures are carried out to a specific Manufacturing Operations Procedure and in the presence of quality control inspectors. (Figures C4-45 and C4-46 show the typical routing of wires from the heater and fan probe assembly into the quantity probe.)

The electrical connector is then installed so that a complete checkout can be performed on the electrical operations. The lead wires are cut about 3 inches beyond the connector adapter flange. At this point a 3-inch length of large-diameter Teflon sleeving is installed in the neck of the conduit. About 2 inches is slid into the conduit with about 1 inch protruding into connector space. The wires are thermally stripped, tinned, and soldered into the connector. After a thorough cleaning with alcohol, the connector is inspected with black light to assure complete removal of flux. After the resistance, isolation, and functional tests are completed, the metal sleeve is slid in place and welded. The connector proper is protected during the welding process by a set of copper chills which have cooled in liquid nitrogen. Even so, the weld is made in a series of short segments to limit the heat.

The next operation is the welding of feed line connections and the tank neck adapter. A helium leak test is run on the weld joints using a mass spectrometer leak detector. After satisfactory completion of these checks, the welds are all X-rayed.

Next, insulation is installed in the vacuum dome area. Two layers of aluminized Mylar are applied over the outer shell material that extends under the dome. The tank adapter flange is covered with four layers of aluminized Mylar. All the tubes in the dome area are wrapped with 1-inch aluminized Mylar strips held in place with nylon thread.

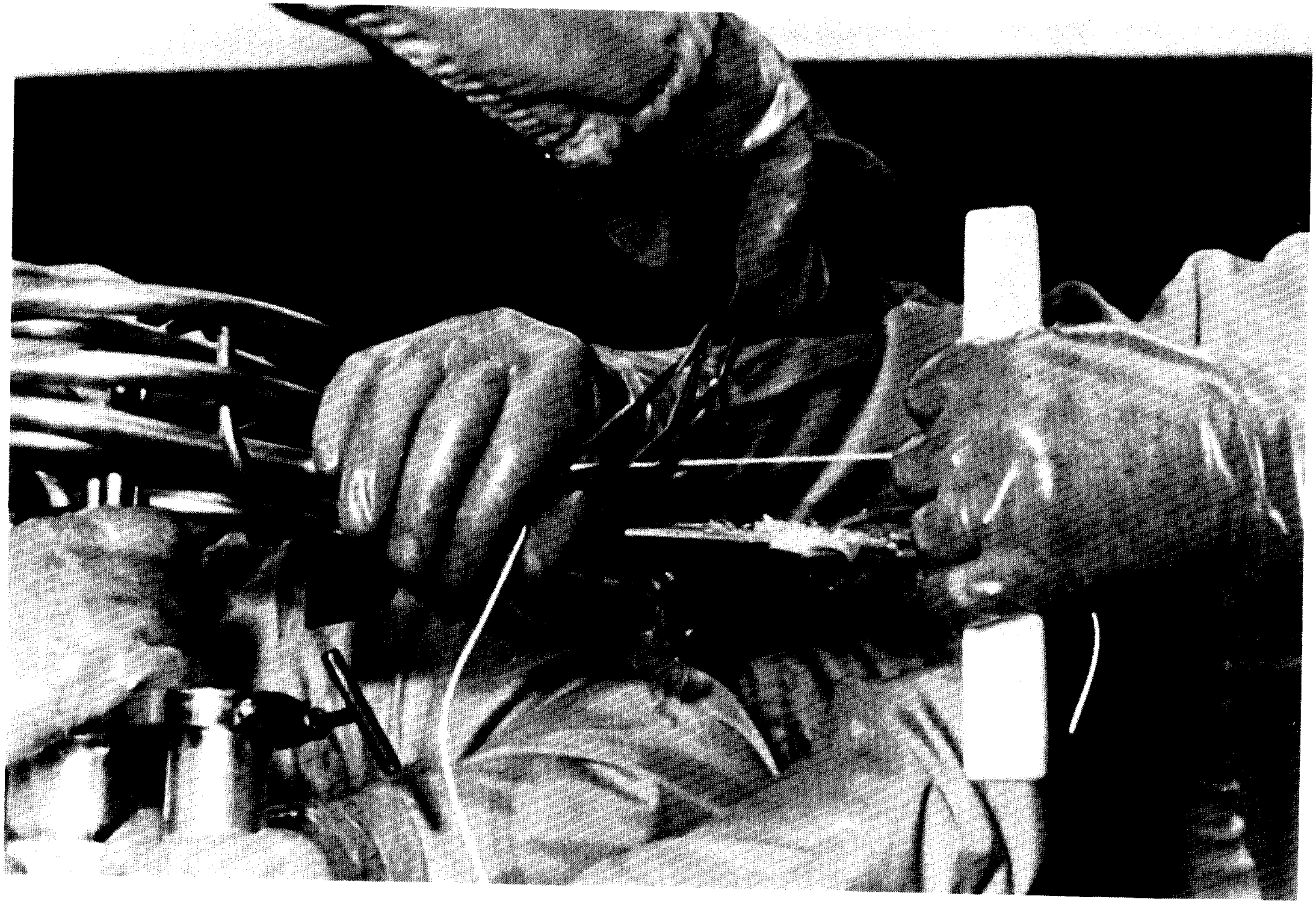

Figure C4-40.- Pulling first bundle of heater and fan motor leads into upper coil assembly.

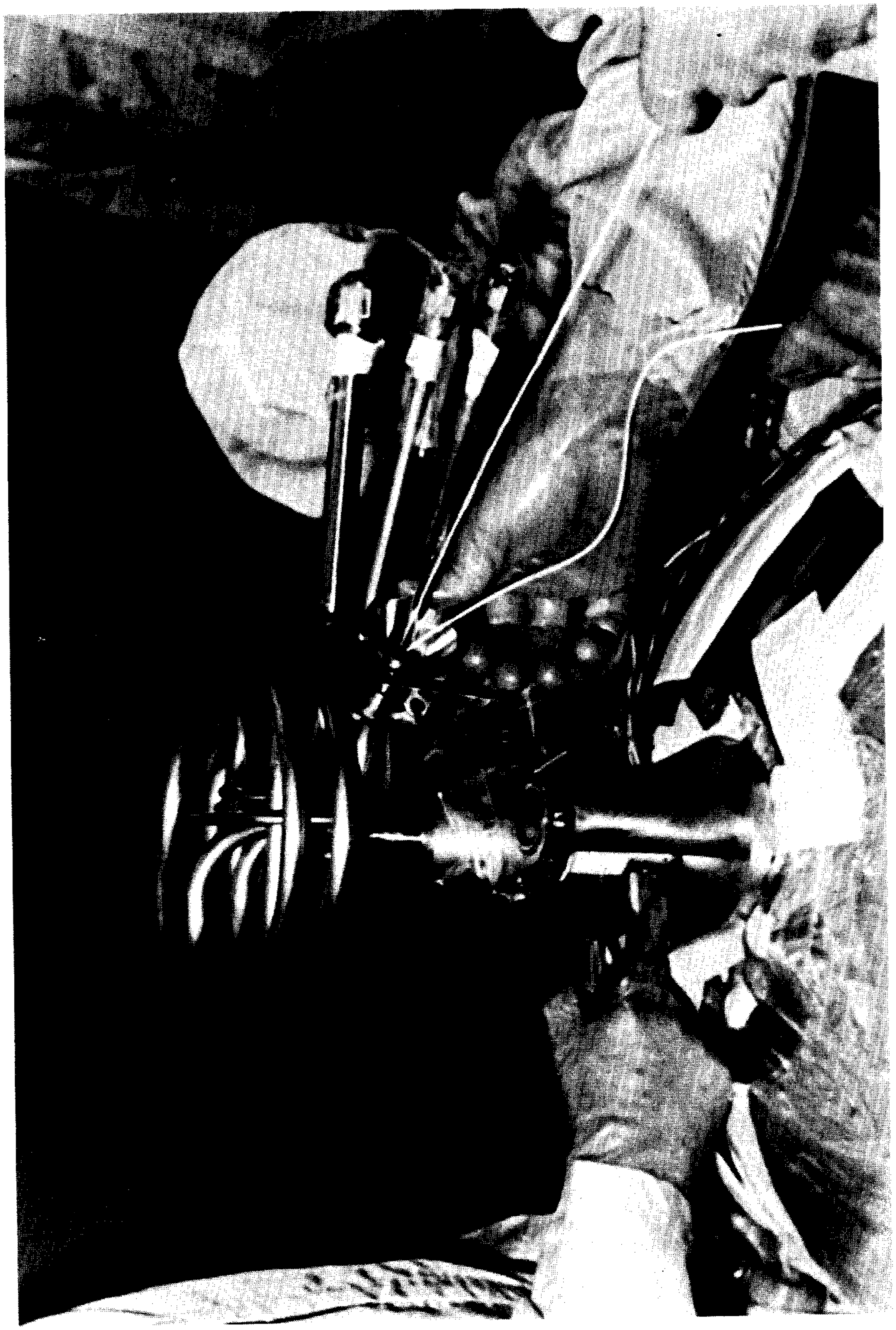

Figure C4-41.- Pull wire used to route heater and fan motor leads into upper coil assembly.

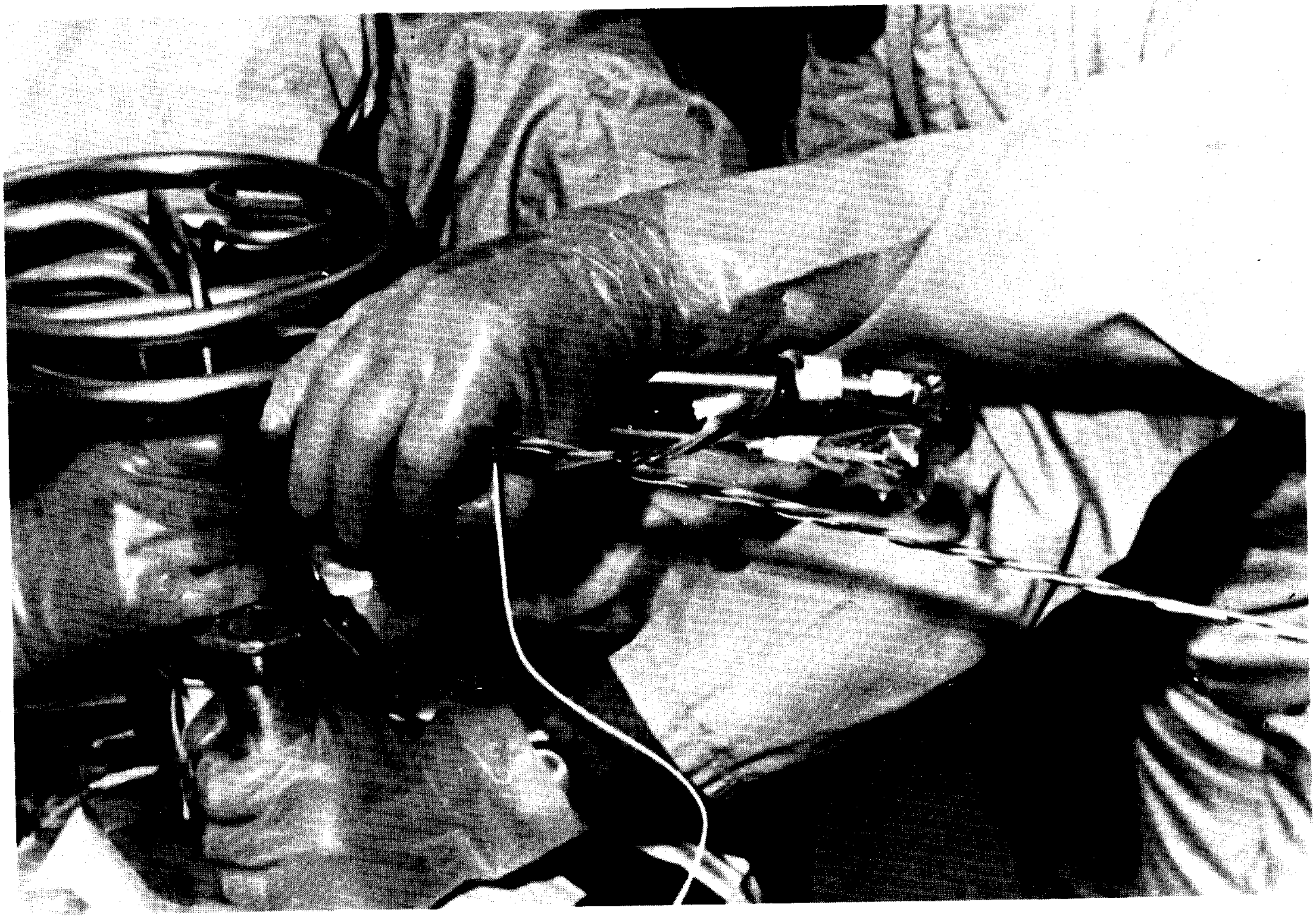

Figure C4-42.- First bundle of heater and fan motor leads pulled through upper coil assembly.

Figure C4-43.- Heater and fan motor lead routing into quantity probe.

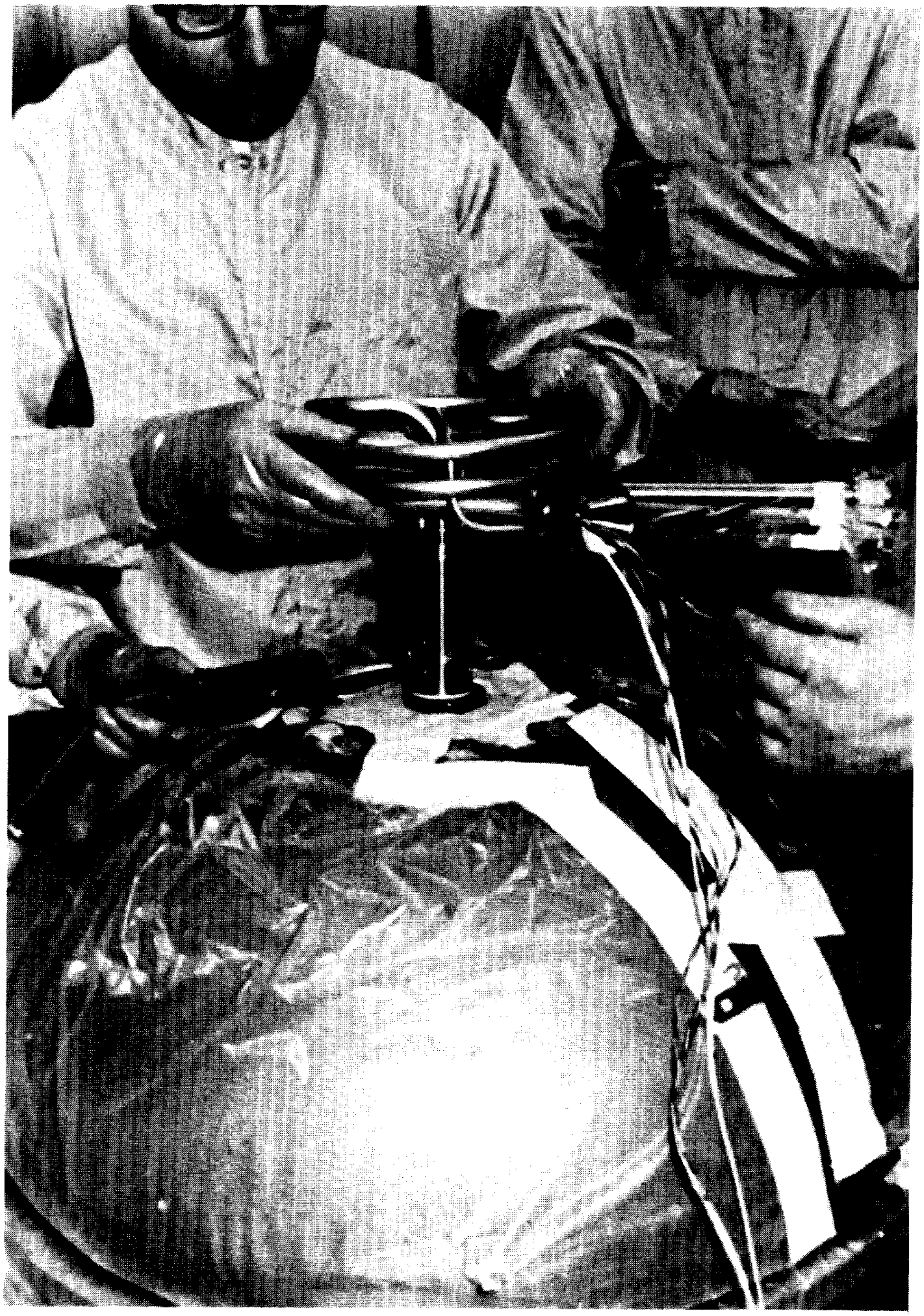

Figure C4-44.- Lowering quantity probe assembly into tank.

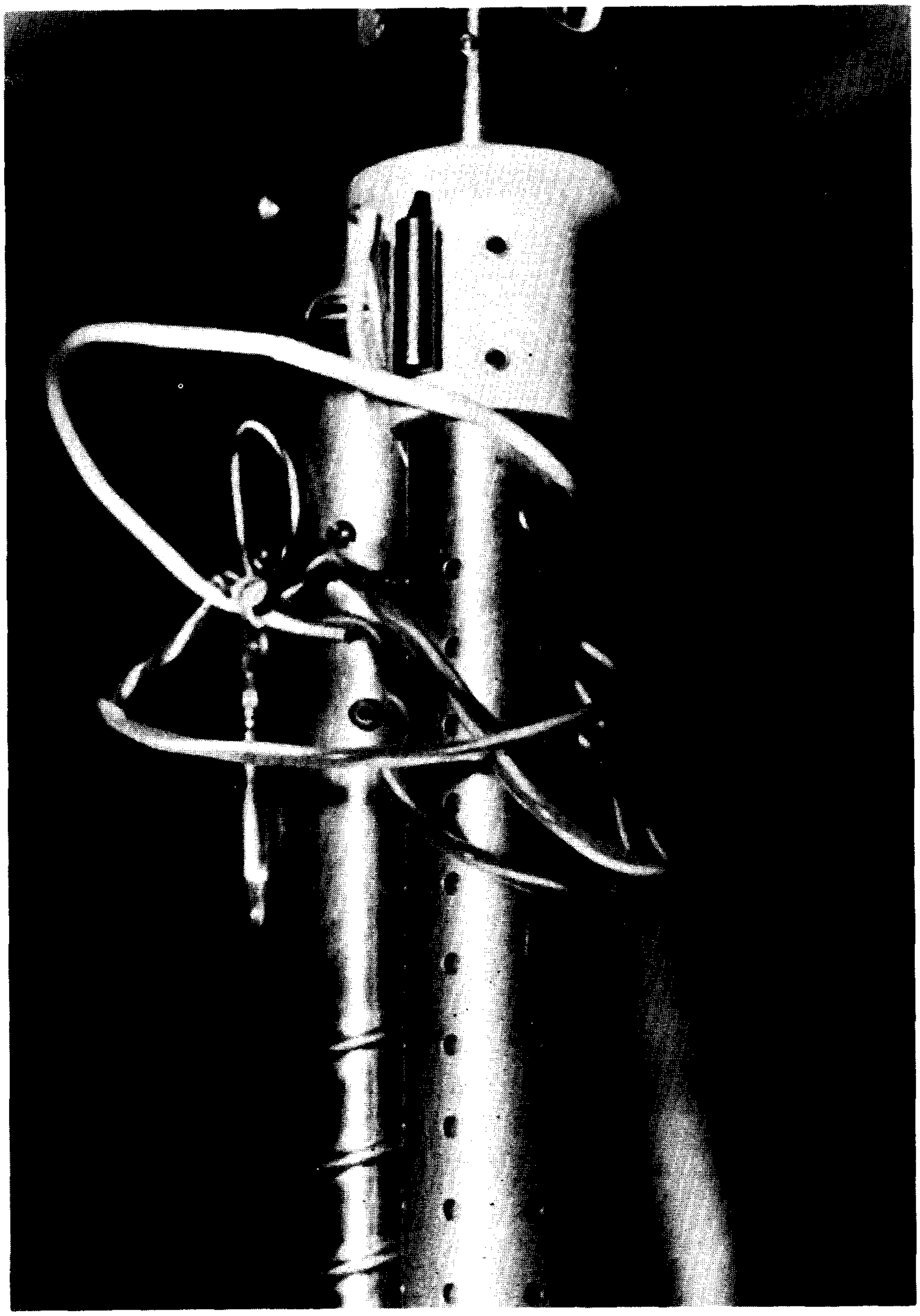

Figure C-4.45 - View inside of tank of typical wire routing from heater probe to quantity probe.

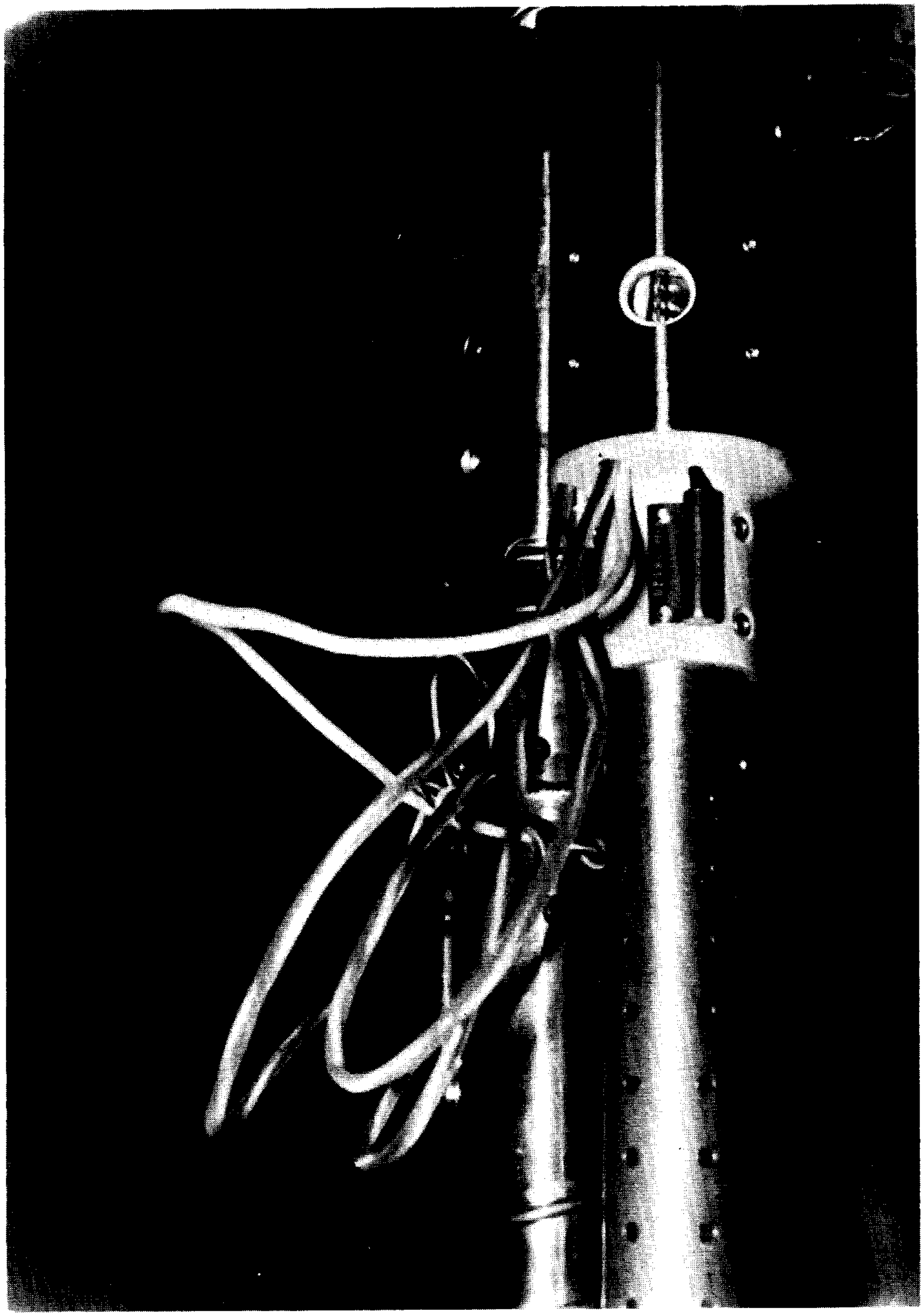

Figure C-4.46 - View inside of tank of typical wire routing of heater probe wires into quantity probe.

The coil housing (dome) cover is now welded in place. The housing contains the vacuum pumpdown tube, the blowout disc, and the vac-ion pump bracket (fig. C4-47). In addition, a pumpdown tube is welded to the lower hemisphere to speed the pumping process. After the welds are X-rayed, a preliminary pumpdown is made.

After a check is made to insure vacuum integrity, the vacuum is broken and additional insulation is stuffed into the dome area through the vacuum pumpdown tube. This insulation consists of 40 square feet of 0.0005-inch gold-coated Kapton which has been crinkled and cut into small pieces with pinking shears. (This represents about 5760 individual pieces approximately 1-inch square with pinked edges. This represents 2.3 ounces of Kapton.)

The actual pumpdown is accomplished in an oven at 190° to 220° F to speed the pumping and to assure a low final pressure. Because of the many layers of insulation, a complete pumpdown requires 20 to 28 days. At the completion of the pumpdown, the vacuum pumpdown tubes are pinched and sealed and protective caps are installed. The installation of the vac-ion pump completes the fabrication process of the tank assembly.

Acceptance Testing

End-item acceptance testing is a long and elaborate process controlled by a detailed written test procedure. The sequence consists of the following: (1) A dielectric strength test of the following wires or groups of wires shorted together. The test is run at 500 V dc and leakage current to ground (tank assembly) shall not exceed 0.25 milliamp; the four temperature sensor wires, the quantity gage outer tube lead, the quantity gage inner tube lead, the quantity gage inner tube lead shield, the eight wires from the two fan motors, the four wires from the two heaters, and the low-voltage input wires to the vac-ion pump; (2) Dielectric strength test of vac-ion converter output to ground (tank assembly) at 400 V dc. Leakage shall be no more than 0.8 milliamp; (3) Insulation resistance test to check that every wire or group of wires that should be isolated from other wires or ground shows a minimum of 2 megohms isolation at 500 V dc; (4) The isolation between the vac-ion pump electrical terminals and ground is tested at 500 V dc and must be at least 50 megohms; (5) The isolation between the vac-ion converter electrical output terminals and the tank assembly (ground) is tested at 500 V dc and must be 50 megohms or greater; (6) The vac-ion pump is functionally tested; (7) The inner vessel is pumped down for 4 hours to assure that the inner vessel is dry; (8) Helium leak test at 500 psi and a helium proof-pressure test at 1335 ± 20 psi; (9) A heater pressurization test and heat-leak test (vessel filled with liquid oxygen and 65 V ac supplied to heaters); (10) Cryogenic proof-pressure test at 1335 ± 20 psi (heaters powered by 65 V ac to raise pressure of liquid oxygen);

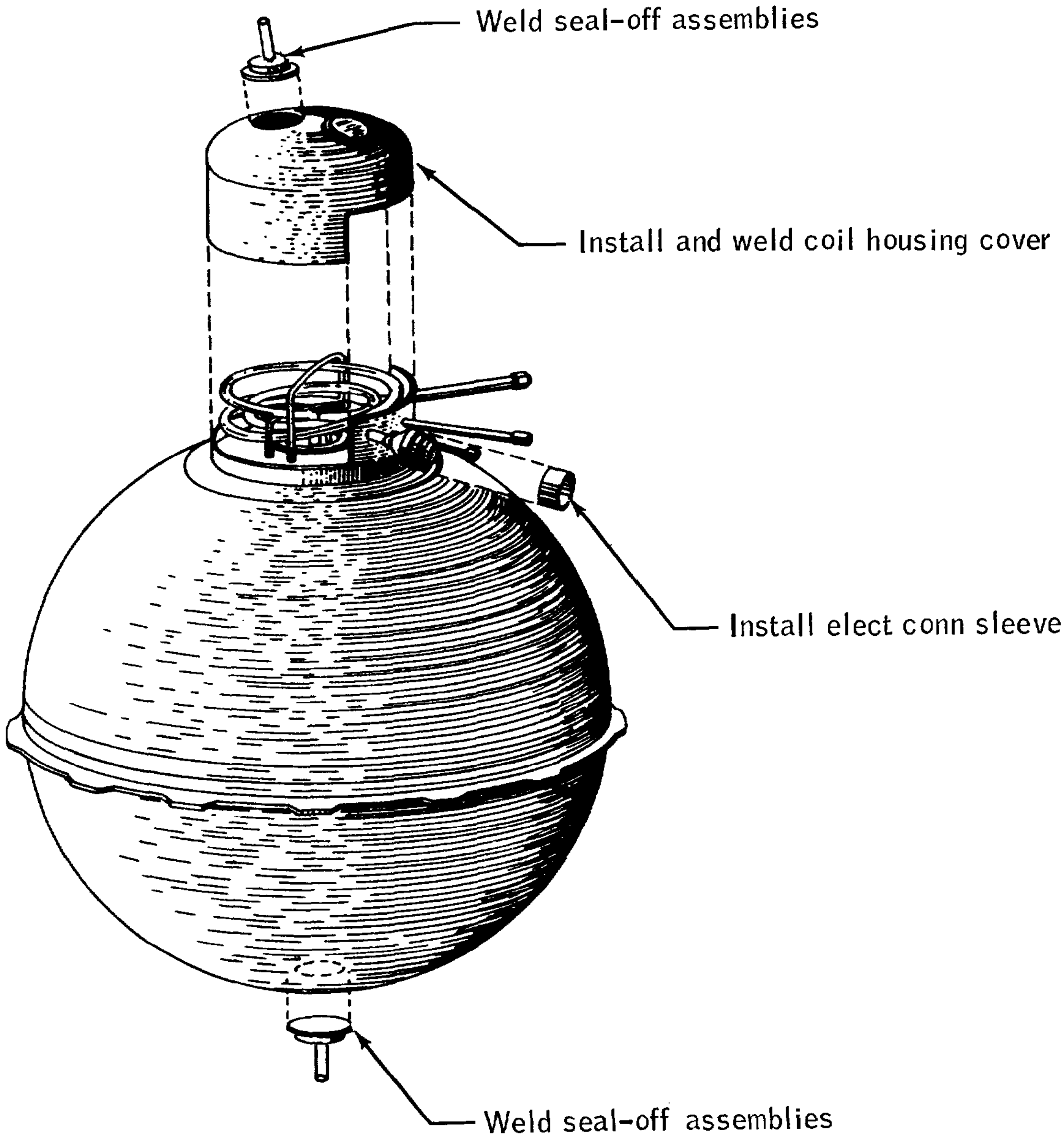

Figure C4-47.- Final vacuum closure operations.

(11) Heat-leak test; (12) Inerting of the vessel with 100° to 160° F nitrogen gas; (13) Check to see that thermostats are open when nitrogen purge temperature of 100° to 110° F flows from exit of tank (30 V ac applied momentarily to verify that thermostats are open); (14) Vac-ion pump final functional test; and (15) Final motor run verification and coastdown. The heat-leak tests consist of many runs to cover a range of ambient conditions and outflow rates. Total testing involves 40 to 60 hours with liquid or supercritical oxygen in the tank. Data sheets on cryogenic performance specified in the procedure are furnished to North American Rockwell in the end-item acceptance data package which accompanies each tank on delivery to North American Rockwell.

At the conclusion of the heat-leak test, approximately 100 pounds of oxygen remain in the tank which must be emptied and purged for delivery. Approximately three-fourths of the mass of oxygen in the tank is released from the tank through the supply line in the process of reducing tank pressure from the initial 925-935 psia to the final pressure of 25-35 psia. To complete emptying, the portion of this oxygen which remains liquid after the pressure bleeddown is expelled through the fill line. The application of warm gas at 30 psia through the vent line to accomplish this expulsion approximates the normal detanking procedure used by KSC at the completion of the CDDT. The CDDT is the next time, after delivery of the tank by Beech Aircraft to North American, that cryogenic oxygen is loaded into and expelled from each tank.

Summary of Significant Aspects of the Manufacture and Acceptance Test of Cryogenic Oxygen Storage Tank Serial No. 10024XTA0008

The manufacturing and test flow for cryogenic oxygen storage tank serial no. 10024XTA0008 is shown in figure C4-48. The item of particular significance is the recycle that was required in the manufacturing process brought on by motor failures.

The manufacturing history of the fan motors installed before or during 1966 contains many incidents of failures encountered in motor tests which resulted in design or fabrication process changes. The failure modes experienced were categorized as:

(a) Contamination failures

(b) Bridge ring (stator laminations) failures

(c) Bearing failures

(d) Phase-to-phase (stator windings) dielectric breakdown or shorts

(e) Grounds (of stator wiring)

(f) Lead wire damage (primarily at Beech)

(g) (Motor fan) speed

(h) Coastdown failures (less than 30 seconds in air or gas)

Design and manufacture process changes to minimize the effect of some of these failure modes were initiated during Block I motor manufacture. Most others were initiated before the motors used in tank 10024XTA0008 were assembled at Globe Industries. Failure mode (d) was the basis for the most recent changes affecting these particular motors. Corrective actions to employ extreme care in stator winding and to use phase-to-phase dielectric checks at 300 V rms were incorporated in the winding process. These were followed by a phase-to-phase dielectric check at 250 V rms after the winding was complete and before the terminals were soldered. Effectivity of these actions caught the lower motor in rework and the upper motor in original stator winding. After installation of the heater tube assembly, including the motor fans, Beech tested the motor wiring, shorted together, with 500 V dc to ground.

A listing of the inspection discrepancies issued against serial no. 10024XTA0008 are listed in table C4-I. In the Beech nomenclature these discrepancies are known as Withholding Forms. As stated previously, the motor problem is considered the significant item. The heat-leak problem was not considered serious because many missions required use rates above the minimum flow capability of tank 0008.

The oxygen storage tank assembly is normally handled and tested at Beech Aircraft in the upright position. Vertical motions may compact the tube set to minimum length so as to contribute to dislodgment by minimizing overlap with the upper stub tube nipple of the tank adapter.

Shortly before shipment from Beech, the tank is rotated (tumbled) while in a handling fixture, "to determine if all parts are secure." Since this is the only known source of side forces applied to the fill tube components and since the detanking was apparently normal in the Beech tests, it lends evidence to the assumption that the fill tube components were in the proper position at that time.

Investigation of Manufacturing Process and Supporting Analysis

To gain a first-hand appreciation of the manufacturing process, a visit was arranged to the Beech Aircraft Corporation, Boulder Division, to observe key assembly operations. In addition to a detailed discussion