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69

The Mechanical Design of Dewars

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ABSTRACT

This is everything I can remember at this time, for my own use and for all who follow. Some of this is based on our experience; some on other people's advice and experience; and some on the folklore of detector development. Some of this document is anecdotal but there are some real numbers and tabulated values. The drawings are both pencil and AutoCAD.

1. INTRODUCTION

The mechanical design of cooled detectors went from "cold boxes" using waxed balsa wood and dry ice (1960's) to the image tube dissecting scanner (IDS) with alcohol/dry ice slurry with polyurethane foam insulation (1970's) to the present liquid nitrogen-cooled CCD in a vacuum chamber (starting 1980's). In between we have used liquid helium to cool IR detectors for Dave Rank and used thermo-electric cooling for six TV guide and acquisition cameras.

2. DESIGN OF THE VACUUM CHAMBER

2.1 Why have a vacuum at all?

The CCD's don't work well at room temperature and so to isolate the cooled CCD from the warm surroundings found on a telescope, we use stainless steel thin-wall tubing structures in a vacuum. The vacuum lowers convection and conduction heat losses. To lower radiation heat loss we keep everything shiny and use low emissivity materials wherever possible.

2.2 Why use an ion pump?

The liquid nitrogen inner can does a certain amount of cryo-pumping with just the metal surface of the container. We have used zeolite in the past and found the stuff turns to powder and eventually the powder gets to the CCD surface. This is from turning the dewars to dump liquid nitrogen. We have also used activated charcoal. This pumps well and bakes out at room temperature (unlike the zeolite at 220°C). As an alternative, we tried the small 2 liter/second Varian pumps. They operate at less than 1 micro-amp (this is 10^{-8} torr). The turn-on point is about 10^{-6} torr. A torr is 1 mm of mercury.

The Varian ion pump power supply has to be modified so that after a power loss, the pump must be re-started manually. This has been done to each of about 17 Varian power supplies. A small relay circuit is added, with a push-button switch on the front panel. The reason this is needed is that if the vacuum comes up higher than 10^{-4} torr or so, the ion pump will not "come on" but rather, draws a large amount of current and the pump heats up. We worried about a fire or at best, a melted O-ring seal.

There was a story out of Kitt Peak many years ago that an ion pump was involved with the death of a CCD. Based on this hearsay, we installed wire screens on the inlet port to our ion pumps. This seemed like it would keep ions from hitting the CCD. We also tucked the pump around the corner so there was no line-of-sight path to the CCD chamber. Finally, we followed the story to a technician who, while removing a dewar from a telescope pulled the high voltage cable off the ion pump without turning off the power supply. An arc was heard between the cable and the dewar body. The CCD was still working but while the dewar was turned during removal from the telescope, the CCD ceased to exist. What happened was a loose screw inside the dewar fell against the output amplifier pin, shorting it to ground. This story is thanks to Bill Ditler at KPNO (1984). The ion pumps do not use wire screens any more. Some of the early dewars still have them because they are impossible to remove now. There are reports that faint glows can be seen during long exposures. The ion pump controllers can be turned off for many hours and then switched back on for 5 to 10 minutes to recover the vacuum.

The ion pumps eventually wear out and need replacing. We have changed to flanged pumps instead of welding the tube directly to the dewar body. Some of the knife-edge mini con-flat flanges use a copper seal and some use the viton ring provided by Varian. Most applications cannot tolerate a rotatable ion pump because the magnet will run into something and so we prefer the copper seal which will not rotate. We have also seen some of these joints leak while cold. The Varian controller #921–0015 costs $1500. We tried the smaller controller #921–2001 costing $750, but wouldn't work for cool-down use. For maintenance of a well-behaved, stable dewar, this unit might be considered, otherwise, the –0015 is preferred. See Figure 5.

2.3 Dewar windows:

We had contamination during testing (suspected to be caused from leaks): The closest thing to the CCD was the glass window sealed with a viton O-ring and so it was decided to use Apiezon sealing wax (type W, hard) to permanently seal the window into the dewar lid. This was done on some dewars but not all. The wax can be removed by soaking in xylene and then cleaning with tri-chlorethylene (111 VG-TCE). This is done to prepare for anti-reflection coating.

The windows are polished UV 1000. The first one was 1.5" in diameter by 0.164" thick. The UV transmission was important for the atmospheric cutoff of 3100 angstroms but also for the UV-flood which used a strong UV light source (e-prom burner) to shine into the dewar during cooling. This is 2500 angstroms. A zinc source has also been used with UV light at nearly 2000 angstroms. Some of the very first dewars had windows of unknown quartz and so did not flood well. The UV 1000 from Dynasil Corp. of America works very well.

To make dewars with larger windows for the big CCD's, we bought a large, thin sapphire window to test. This is a material with a yield strength of 50,000 psi (stronger than structural steel). The piece we bought was about $1000 and was 4" in diameter and 1/8" thick. We got it from Crystal Systems in Salem, Mass (617) 745–0088. There was some discussion about whether bi-refringence and fluorescence could be seen. No conclusions. We have not used sapphire in any but the test dewar.

The HIRES dewars use a large (6.5" diameter) fused silica field flattener as the dewar vacuum window. This solves problems and causes problems. First, it is thick enough (about 2.5" thick) to resist breaking under vacuum loading and it eliminates two air-glass interfaces (one is vacuum-glass). But, testing is a problem in that you cannot form an image on the CCD during lab testing; the entire Super-Duper Camera must be in place to form an image.

The optical design pushes the CCD closer to the front of the dewar window. This limits the window thickness. The maximum bending stress in a 2" diameter by 0.164" thick window is 450 psi. The maximum stress in the sapphire window above, is 4700 psi. This gives a safety factor of 10 for the sapphire, and 15 for the fused silica (Harshaw Chemical). With very large detectors or mosaics of detectors, dewar windows will approach or exceed 7" in diameter and thus need to get thicker.

2.3.1 Allowable Stresses and Reasonable Safety Factors:

Marks handbook gives the stress in a circular plane/parallel disk as:

$$\sigma = \frac{KD^2}{4t^2}P$$

For the case of a vacuum window, P is 14.7 psi. The edge support factor, K ranges from 0.75 for a clamped case and 1.125 for un-clamped. We assume that either an O-ring seal or a waxed seal gives the un-clamped case. The formula then becomes:

$$\sigma = 4.1\left(\frac{D}{t}\right)^2$$

This is independent of material. The safety factor relates material to stress. The maximum allowable stress in fused silica is 6944 psi according to Harshaw. This assumes both sides are polished and there are no stress-raisers like fine scratches. We try to keep the actual stress level below 500 psi to 600 psi. UV 1000 has a published tensile stress limit of 8534 psi; Corning 7940 has a listed yield stress limit of 6944 psi. When we are dealing with steel, the tensile stress, which can be measured and is published, should never be used. Yield stress should only be used. Once a tension test gets to a maximum load, the material begins to "neck down". The reduced area means that the stress level gets higher although the load does not increase. This gives the manufacturer a 25% bigger number to advertise and so the term 'tensile' stress was invented. Not knowing how the 8534 psi for UV 1000 was measured, we are suspicious and ignore the "tensile stress limit" from the literature. Therefore, the lower value of 6944 psi has been used for all window yield stress calculations.

After all the discussion, the final questions will be: How big a safety factor do you want? Are you happy with 10 to 1 or do you feel you need 15 to 1? Crystal Systems is the company who supplied the Sapphire window and their formula for stress in vacuum windows has a built-in safety factor of 4.

Jerry Nelson has gone as high as 1000 psi doing stress-mirror-polishing on Zerodur. Zerodur has a "burst" stress limit of 3000 psi. This is a different but related area. His process actually disrupts the polished surface and puts big stress-raisers into the glass in the grinding and polishing phases, so far, without failure. We will typically not scratch vacuum windows by this much.

2.4 Electrical Connectors:

We tried hermetic BNC's and they leak (King 79–108). Our main connector is the 41–pin Bendix pygmy connector. We solder these connectors into a pocket in the dewar housing or dewar end plate. We use low temperature (430°F) silver solder. The flux is "Stay-Clean" (cadmium free) from Central Welders Supply in Salinas. Before soldering, however, fill up the solder pockets with solder. Do this slowly to avoid heat build-up. One of the connectors developed a very small leak around the pins and we think it was thermally induced since it leak-tested ok until the wires were soldered into the connector. Before electro-polishing, seal the outside of this connector with RTV and a thin plastic disk. The solutions of phosphoric acid and sulfuric acid used in the polishing process will erode the coating on the pins. This is all right on the inside, if the solder pockets are filled, but on the outside, there will be intermittent noise problems. One dewar has this flaw and we electroless gold coated the pins and then burnished them with an electric eraser (in June 1984).

The signal wire connects to a pin in the outer row of pins in the 41–pin connector. A wall of pins is used to shield this pin. They are tied to each other and grounded. It there are more than 1 amplifier, then more signal wire pins are needed. If 4 amplifiers are used, then a lot of shield pins will be needed (11). The largest Bendix connector available is 61–pins and grounding gets tricky to save pins. See Figure 4. We have resisted using more than 1 connector because it uses up a lot of room on the vacuum chamber wall.

2.5 Dewar Housing:

We use stainless steel now. Only dewar number 1 had an aluminum body. Once we decided to eliminate O-rings, we had to change to stainless. All fittings are welded or soldered to the stainless steel: the vacuum valve is stainless steel, the ion pump connector is stainless steel, the electrical connector is silver soldered, the connector pipe to the liquid nitrogen reservoir is heli-arc welded and the stainless steel bellows fill pipe is heli-arc welded also. Initially, we used available stainless steel tubing for the vacuum housing and liquid nitrogen inner can. This is available only in 4", 5", 6" and 8" diameters. Now, we roll 1/16" thick stainless steel sheet into sizes that are more useful to us. The caps for the vacuum and pressure vessels are pressed with a 50 ton hydraulic press. We tried shear spinning stainless sheet and it work-hardens so quickly that this became too difficult. The newest dewars (for HIRES) use copper for the inner can bottom. This is made with the same press and mold plates. The copper-to-stainless steel welds have worked fine so far. They have been thermally cycled and are still leak tight. The reason for this change is that we measured a 16°F temperature drop across the stainless side wall in the liquid nitrogen inner can. This large drop impacts the copper braid: it gets shorter and the cross-section gets bigger. Finally, the end plate which has a flange for mounting is made from round stock. This is recommended by Varian and others. The reason is that in the plate-forming process, inclusions and voids are made. Then, when a flat plate is turned into a round plate, there are voids which will extend into the vacuum chamber. Round stock doesn't have this problem, but it costs much more. Most vendors will charge almost as much for the cut as the material. The largest dewars have required a plate made from 11" diameter stock cut to 1/2" long. We usually order 3 at one time, reducing costs.

The change from aluminum to stainless raised the emissivity of the housing. This drives the radiation heat transfer since polished aluminum has 3% and polished stainless steel has 7% emissivity. We have the stainless parts electro-polished. All but the final welds and so there is a dark ring of weld inside the cryogen chamber. Dewar #3 was the first stainless steel dewar and we installed aluminum liners so that we could reduce the emissivity of the walls. We have no quantitative data about whether this worked, but we know that it was very expensive to manufacture and assemble. Since then, we do not use liners. The hold time is reduced due to the radiation increase but this penalty is usually not severe.

2.6 Valves, bellows and others:

We use 5/8" Cryolab valves and valve operators. These are cheaper than regular vacuum valves and take up much less room. They are stainless and welded to the vacuum housing. They can be bought in aluminum too. The valve is about $12 and the operator is about $75. We keep valve operators at all the vacuum pumping stations. The plug in the valve has 2 viton O-rings (011 and 012). This is a special order part and takes 12–13 weeks. We usually order 10 at a time to reduce the tooling cost.

The bellows provide motion during cool-down and also a longer heat conduction path (than a thin wall tube). They also provide torsional rigidity to the inner can. They are typically 0.006" wall thickness. They are hydro-formed bellows (as opposed to welded or electro-formed). There are several manufacturers. Initially, we used small diameter bellows, but now we use 1/2" diameter bellows. It makes filling easier. All dewars up to HIRES had only 1 fill hole. HIRES has 2 so that remote filling and venting could be done.

The Braycote #3L-38RP oil from the Bray Oil Company, Los Angeles, was used in many dewars but it tends to migrate with removing and replacing CCD's. We have discontinued its use in HIRES. The oil is excellent for decreasing thermal joint resistance. It costs $154 for a 2 ounce syringe. We use indium gaskets at bolted joints between copper and stainless steel where thermal cycling could cause the joint to loosen up.

Some of the early dewars used activated charcoal on the cold surface as a cryo-pump. The nice feature here is that it bakes out at room temperature, where the zeolite must be baked at oven temperatures and so is not practical to re-condition. The charcoal is held to a cold surface with either Bray Oil or Torr Seal.

The thin wire inside the dewar is teflon coated copper stranded wire. The individual wires are 0.0015" diameter in a bundle of 7 wires. The bundle diameter is 0.005". The teflon sheathing is 0.018" diameter. We had success with a small, foot-operated wire stripper. Figure 6 shows a cross section of this wire. Teflon is not recommended inside a vacuum because it absorbs water. Also, the space inside the stranded wire out-gasses very slowly. The very best thing to do here is to use bare wire with "fish-spine." This is Coors porcelain beading from Golding, Colorado. We have lived with the out-gassing so far.

The thermal resistance, kA/l is 0.046 mw/°C for all 7 wires. The teflon sheath is 0.0005 mw/°C. This is for a 3" long piece of wire. Electrical resistance is 1.1 ohm per 35". 41 wires 3" long in a typical dewar would represent a 210 mw heat load. This is sometimes dominated by the large cross section grounding wire which runs from the CCD socket to the (warm) body of the dewar.

3. DESIGN OF THE CCD SUPPORT

3.1 Stainless Steel Spiders:

During the design of the liquid helium dewar for Dave Rank, we first used thin-walled stainless steel tubing for a support system. Two pairs of 3–legged spiders were used to support the 25 lbs inner cryogen can. We found some tubing which was 0.15" diameter and 0.0035" wall thickness. This is hard to find today. We also use other sizes but nothing comes close to the small A/L for this tubing. The mechanical failure mode is buckling and the smaller (1/8" diameter with 0.006" wall tube) is inferior and the larger (0.20" x 0.006" wall) has an A/L which is 15 times bigger.

We initially used silver solder to join the tube to the mounting flanges, but found that heli-arcing works much better. The flux used during soldering often has cadmium in it which is not good for a vacuum (it out-gasses). Also, the silver solder runs up the tube. This makes the spider effectively shorter since the silver solder conducts heat much better than the stainless steel (conductivity is 30 times higher).

3.2 Torr Seal Sockets:

We were warned that the ZIF (zero insertion force) or ZIP (zero insertion pressure) sockets out-gas badly. They are made from glass-filled poly-sulfone and the socket makers cannot say what the vapor pressure is. From early tests we estimate that the gas-evolution rate is on the order of 20 trillion molecules per second. We learned to replicate them using cast-able RTV, a good PVA mold release agent and Varian Torr Seal vacuum epoxy. We even replicated the #0–80 internal threads! There is shrinkage during both steps in this 2–step process, so the mounting holes need to allow for this. An advantage to this technique was discovered when we needed a 24 pin connector and they didn't make one. We simply cut up two 20–pin sockets, mounted 4 more pin holes and 24–pin molds were made. The ZIF sockets for HIRES were not replicated and we have seen no ill effects. These sockets are made by Amp, are blue (an unknown material) and have no mounting holes. We cut out the middle to contact the rear of the Tektronics CCD with a cooling pad. We attach the sockets by the slide rod on each side.

An alternative to ZIF sockets exists: the mechanical engineers bring it up every time we begin a new dewar, but no one is willing to solder wires directly to the CCD. Dewar 8 was converted to a chip mounted in a square header with legs pointing up. There was no way to get ZIF sockets into the dewar and so the 4 rows of pins were carefully bent 90° to each side and push-on connectors were made from Torr Seal strips with circuit board pin sockets imbedded in holes drilled in the epoxy.

To allow for different CCD geometries and hence ZIF sockets, a second set of sockets is used in some dewars. This allows a changeout from one spider/socket/CCD to another very easily. Sockets are custom made to match the required number of pins needed.

Always store Torr Seal in a refrigerator and discard after one year. The Varian p/n is 953–0001. Torr seal is only rated (presumably by Varian) from –45°C to 150°C and it cracks at LN_2 temperatures. Conductivity is 4 mw/°C-cm, expansion coefficient is 50 x 10^{-6} and allowable stress is 2000 psi. Solvent: "Vis Strip" by Oakite or "DeSolv" 292 RAM Chemical, Gardena, CA.

3.3 Spider Stiffness:

We have never measured the natural frequency of the spiders but have calculated numbers above 60 Hz. We have never seen image blur due to support vibration and the static deflection of CCD support hardware is smaller than image motion caused by flexure of other parts (like gratings). We calculated 0.02 micron flexure for 90° rotation for Dewar 1. The chip and socket and radiation shield were estimated to weigh 0.1 lb.

4. NUMBERING THE DEWARS

In the beginning of the liquid nitrogen cooled-dewars, we referred to the dewars by the name of the CCD manufacturer: there was the TI (for Texas Instruments) and then a second TI was used and so then there were the TI 500 squared and TI 800 squared. Then the RCA CCD, the GEC CCD and TI made a virtual phase CCD for TV work and then people started to change CCD's from one dewar to another. It was hopeless. The following numbering system was set up:

4.1 Dewar 1

This is the first dewar. It began as a joule-thompson cooled TI 500 x 500 (thinned) CCD for the 120" Telescope Cassegrain Spectrograph. This was in 1983 when the spectrograph became convertible to a lens/grism instrument. A photo and drawing can be seen in Reference 1, by Lauer, et al. A description of the j-t coolers can be found in Reference 5, by Wolfe. This dewar was converted to liquid nitrogen cooling. Good drawings can be seen in Reference 2, by Robinson, et al. This CCD has 15 micron pixels. It is used at the 40" Telescope at Mt Hamilton now.

4.2 Dewar 2

This was the RCA dewar we built for Lloyd Robinson. The RCA chip had 30 micron pixels. It is 320 x 572 with a mask over half the chip. Later, this dewar became the Tektronics 512 x 512.

4.3 Dewar 3

This dewar was built to go at the 120" Cass Grism camera and used the TI (round) 800 x 800 CCD. This chip has 15 micron pixels. This dewar got a lot of use. It was the first of the all-stainless steel dewars.

4.4 Dewar 4

This is the "Lab Dewar." It started out supporting an 800 x 800 TI CCD. It has no provision for mounting to a telescope and was not electro-polished. The hold time was not expected to be very long.

4.5 Dewar 5

This is the GEC dewar for Richard Stover. The GEC chip is 576 x 385 with 22 micron pixels. This also had a mask.

4.6 Dewar 6

This was the Cassegrain UV Schmidt Camera dewar. It has a built-in fill hole at 65° to the optical axis to allow easy filling at the Zenith and to increase the sky coverage and TUB rotation. Dewar3 (which Dewar6 replaced) dumped all the liquid nitrogen at certain combinations of TUB angle and telescope position. This dewar had the round TI 800 x 800 CCD initially. Later, the square header TI CCD was installed.

4.7 Dewar 7

This is the "Test Dewar." It was intended for lab use only, but has been adapted to the 40" Telescope. It has used the TI, Tektronics 512 x 512 and Reticon 400 x 1200 chips.

4.8 Dewar 8

This is a copy of Dewar 6.

4.9 Dewar 9

This began as a single dewar for Richard Stover for 40" use. It became 5 dewars — all the same. They are similar, but not interchangeable. These are 9, 10, 11, 12 and 13. Dewar 9 has a Reticon 400 x 1200 thinned chip. This chip uses two 24–pin ZIF sockets (stretched 20–pin sockets).

4.10 Dewar 10

This dewar was built for Jean Brodie for use at the 120" Prime Focus Multi-Object Spectrograph in conjunction with Lawrence Livermore National Lab.

4.11 Dewar 11

This dewar is attached to the Blue side of the KAST Spectrograph at the 120" Telescope Cassegrain focus: Reticon 400 by 1200 CCD with 27 micron pixels.

4.12 Dewar 12

This dewar is attached to the Red side of the KAST Spectrograph. Reticon 400 by 1200 CCD with 27 micron pixels.

4.13 Dewar 13

This dewar is mounted at the Hamilton Spectrograph in the 120" Telescope Coude room.

4.14 HIRES dewars

The first dewar is for the Tektronics 2048 x 2048 CCD with 24 micron pixels. The chip we ended up with had a convex radius of 65", and is very nearly spherical. The shape was measured in a vacuum at –100°C. This chip has been thinned. It has been treated so that no UV-flooding is necessary. This dewar uses the field flattener lens as a dewar vacuum window. This element is 6.45" diameter by 2.54" overall thickness. The front (or top) of the dewar body has been machined to a 6.7° half angle (13.3° included angle) with an O-ring groove in the angled surface. The O-ring supports and locates the lens on its concave side (25" radius). An aluminum ring was later installed to better define the lens since the O-ring didn't always compress completely (0.005" to 0.008" sticking up).

The second dewar is for a flat focal plane CCD; either a flat Tektronics or a mosaic of 2x2 Ford CCD's. A different field flattener lens will be designed and built. This dewar is resting at UCSC.

4.15 Dewar 16

This dewar is at the MOS red side. CCD is a Ford 2048 x 2048 with 15 micron pixels.

4.16 Dewar 17

This dewar is at the MOS blue side. CCD is a Ford 2048 x 2048 with 15 micron pixels.

5. DEWAR GEOMETRIES AND COOLING:

5.0 Universal Dewars:

The dewars we develop are not universal, in the sense that they are up-looking, side-looking or (rarely) down-looking. We have never done the research to develop a design which is completely rotatable. There are several universal designs in use by people in the astronomical community.

5.1 MMR: Micro-Miniature Refrigerators:

In 1982, we used a pair of these small coolers. They used compressed nitrogen from size 1A cylinders at 2500 psi (1.54 cubic feet). At 1500 psi, the gas looses cooling capacity and so the cylinders must be replaced. We used 7 cylinders per night. The plumbing was complex and the servicing was brutal, but these coolers worked fine when they were clean. We kept limping along with this cooling system hoping the closed cycle pump would soon be available. Then, in principle, no more gas cylinders would be needed. Also, a "cocktail" using a blend of methane, ethane and nitrogen could be used to get more heat capacity, but at a slightly higher temperature. (15% ethane, 40% methane and 40% nitrogen) The devices we used were 350 milliwatt coolers (each). During our testing with a cold trap to try to clean up the gas before it entered the coolers, an explosion happened and broken glass was seen churning around inside a test dewar. Luckily no CCD was damaged and the pumping system was un-harmed. After that experience, and with no closed cycle pump in sight, we "jumped ship" as Joe Miller said at the time, and built a liquid nitrogen 'can' to attach in place of one of the MMR coolers. This modification created the "cold finger" and the dual cylinder look for future dewars. Reference 5 discusses these coolers in detail. In our application, we used flow meters on the open exhaust ports to monitor flow restrictions and blockages.

While discussing the use of pure methane once, an engineer at MMR was told that we often keep equipment operating even though the dome was closed and that we might get to an explosive mix in the enormous telescope dome (about 15%). He suggested that we just light the exhaust and have a pilot going all the time. Of course, it needs to be dark, we reminded him.

See Reference 5 for a good description of these devices.

5.2 Liquid Helium:

Our first cryogenic design was with liquid helium. It was a 5 liter IR grating spectrometer for Dave Rank. Hold time was 40 hours. There was no liquid nitrogen inside. One of the advantages of liquid helium is that it cryopumps all of the gas which liquid nitrogen does not (like air). This means that one must close the pumping system if it is connected or the spectrograph will become as dirty as the pumping system. We pre-cooled with liquid nitrogen for 24 hours. Then, all the LN must be blown out. One time we didn't and the liquid helium froze the LN and the detectors stayed warm (77°K).

5.3 Copper plating, copper conductors and copper can:

Dewars 6 and 8 have been copper plated. The inner can has 0.010" of copper. This is then gold coated to lower the emissivity. (See source listing at the end.) Some of the gold plating is done without electricity, and some has been done with. The copper helps carry the heat from the cold finger around the can to the far side when the can is tipped away from the cold finger and there is not much liquid nitrogen left. Dewar 3 had a copper plug silver soldered into the wall of the inner stainless steel can. The inner face of the plug had a copper ring which was on the liquid side of the vacuum can and had a threaded hole for the cold finger to attach to. This worked fine thermally, but after about 50 cooling cycles, a vacuum leak developed. It was very messy to saw the dewar apart to fix the leak. During the milling to remove the copper plug, it was possible to see the porosity in the (failed) solder joint. After removing the copper plug a stainless steel plug was heli-arc welded in its place. The thermal performance did not change much. For the two HIRES dewars, we have used stainless steel cylinders for the inner can, but copper plates for the bottom caps. These were formed in the hydraulic press, like the stainless steel caps. The joint between stainless and copper is a fusion joint with no filler rod. This joint has worked very well. A copper block is heli-arc welded to the copper end plate for the cold finger to attach to. In this case, it is a long (20") copper bar (1/4" x 3"). The vacuum pipe collapsed so we split the cold finger and inserted a support web in the pipe.

Copper bands were heli-arced onto the OD of the LN_2 can in dewars 9, 10, 11, 12 and 13 for better conduction when the liquid level is low and on the opposite side from the cold finger attachment, that is when tipped over.

5.4 Electro-polishing and polishing:

Pullbrite in Freemont does our electro-polishing of stainless steel parts. See section on electrical connector protection before polishing. Use 'Brilliant Shine' on aluminum surfaces.

5.5 Liquid Nitrogen Auto-Fill System

We borrowed the technology from Lawrence Berkeley Lab. Reference 8 details how they did it (Landis, et al, 1985). See Figure 10: HIRES' auto-fill system layout and Figure 11: HIRES' tri-axial capacitor level sensors.

6. THE TV CAMERAS

...though not really "dewars," we often call them this.

6.1 Six copies were built:

The 120" Telescope uses 1 at Cass, 1 at Coude and 1 spare. The 40" Telescope uses 1 at Cass and 1 for instrumentation. The 120" spare also works at the 24" Telescope for seeing tests. Some use Texas Instrument type 4849 virtual phase, un-thinned CCD's with 22 micron pixels. Some use GEC type 8601 CCD's.

6.2 The Marlow cooler:

The cooler is a 12 Watt Peltier device which runs on 5 volts DC (2 amps, +/-) and is 95% efficient. The top of the 3 stage cooler runs at –50°C with 600 mw of cooling. The CCD and cooler are in a compact enclosure. The vacuum holds at below 1 Torr for many months. The cooler is soldered to the nickel-plated copper body with low temperature (-97°C) solder. This is done in a boiling water bath. Care must be taken so that the cooler itself does not melt or come apart. The factory specified limit is 117°C.

A test was made before soldering: the joint was bolted together using two brass #8–32 screws. The cold side was –37°C and hot side 83°C, running at 6 volts and 3.1 amps (19 Watts). After soldering (the screws remained) the cold side was –60°C and hot side 30°C with the same power consumption. In both cases, the copper base was sitting on the bed of a milling machine. This heat sink is similar to a telescope mounting.

6.3 References 6 and 7

The photos in this reference show the TV camera with the electronics package. See also Figure 13 for a line drawing.

7. OTHER COMMENTS

Frank Lowe type dewars (IR Labs in Tucson): Early use at Lick Observatory.

We had limited success adapting and testing these dewars. There were about 4 different dewars which we used for different projects. The lack of documentation created problems when holes were tapped into the copper cold surface and leaks developed. Making them into up-looking geometries caused problems. One had a thin film of clear paint of some sort inside the aluminum housing to seal porosities in the metal. This became gummy during routine cleaning with acetone. Finally, one of the copper-to-stainless steel solder joints developed a leak after a cooling cycle.

UV flood problems: The UV flood and Nitric oxide soak seemed to fix some of the CCD response problems but as soon as the CCD warmed up, even a little, the response changed. This meant that the CCD could never warm up, even during power outages. This means the dewars have to work very reliably, they must always be kept filled with liquid nitrogen or liquid air even when not in use, and after even momentary power glitches, the ion pumps must be manually re-started.

Molecular drag pumping has replaced diffusion pumping. A pumping station with an MDP backed by a KNF dual stage diaphragm pump was shipped to Hawaii with HIRES. It is oil free. A nice feature of these pumps is that the HIRES dewar can be pumped out while still mounted inside the clean enclosure of HIRES.

Since the HIRES dewars, we are no longer limited to round O-ring grooves. To hide the 20" long copper cold finger (at 1/4" x 3") in the middle of a Schmidt-type camera, required a long and skinny vacuum flange at the dewar body joint (See Figure 8). The O-ring groove is about 4.4" by 0.8". The circular groove would have been 5" in diameter and the flange on the dewar body to connect to this would have cast a very large shadow. This was possible because of the purchase of a used NC (numerically controlled) mill and the work of Jeff Lewis to get the software up and running.

Rules of Thumb:

1. Mean Free Path (MFP): John Richter from EIMAC division of Varian (thanks to Jeff Lewis) reports that your vacuum should be low enough so that the MFP is on the order of the distance inside the dewar from the hot surface (housing) to the cold surface (CCD). e.g. 10^{-3} mm is 1.8" MFP. The rule of thumb says that this is the worst allowable vacuum.

mm Hg	10^{-8}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	760
M.F.P.	1.8×10^5 in.	1800 in.	180 in.	18 in.	1.8 in.	0.18 in.	2.3×10^{-6} in.

2. Do not use Cratex polishing tools. The plastic binder gets imbedded in the metal. This appears black in the infrared and so creates big radiation heat loads. The burned-in plastic material is impossible to remove.

3. Do not put circuit boards or fiberglass material inside a vacuum chamber.

8. FIGURES AND PHOTOS

Photo 1: Dewar 1: 500 x 500 TI CCD cooled with compressed nitrogen gas in Joule/Thompson refrigerators by MMR Technologies in Mountain View, CA.

Photo 2: Same dewar: electronics package is opened showing pre-amp, and voltage and clock board.

Photo 3: Dewar 1 open: Shows a CCD mounted in Torr Seal sockets. Two MMR coolers can be seen. Ion pump has been bent 90° and has a protective screen on its opening. The BNC hermetic connectors leak and are not used after this. Note the high pressure nitrogen gas filters. The valve operator is to be removed before mounting onto the telescope.

Figure 1: Dewar 1: An ink isometric drawing by Roy Bennett.

Figure 2: Dewar 1: An ink sectional drawing by R.B.

Figure 3: Dewar 1: An ink sectional drawing showing liquid nitrogen modification.

Figure 4: Wiring Bendix 61–pin connector for 4 amplifiers.

Figure 5: Ion Pump line drawing. Varian 913–0032 with magnet 913–0011. (Controller 921–0015 and cable 924–0750) See also H7121.A

Figure 6: Teflon-coated wire.

Figure 7: HIRES dewar (H7110): Vacuum Housing Assembly.

Figure 8: HIRES dewar (H7120): Cold Finger Assembly.

Figure 9: HIRES dewar (H7122): LN_2 Can Assembly.

Figure 10: HIRES dewar (H7130): Dewar and Support Frame.

Figure 11: HIRES LN_2 autofill (H7600): System.

Figure 12: HIRES LN_2 autofill (H7601): Sensors.

Figure 13: Lick TV camera assembly (33CAS150)

Figure 14: Dewar 2: Tektronics chip shown

Figure 15: Dewar 6: Texas Instruments 500^2 chip

Figure 16: Dewar 7: Tektronics 512^2 chip

Figure 17: Dewar 7: Tektronics 2048^2 chip

Figure 18: Dewar 7: Reticon 400 x 1200 chip

Figure 19: Dewar 8: TI 500^2 chip

Figure 20: Dewar 9: Reticon 400 x 1200 chip

Figure 21: Dewar 10: Reticon 400 x 1200 chip

Figure 22: Dewar 11: KAST Spectrograph, Blue side, Reticon 400 x 1200 chip

Figure 23: Dewar 12: KAST Spectrograph, Red side, Reticon 400 x 1200 chip

Figure 24: Dewar 13: Hamilton Spectrograph, Ford 2048^2 chip

Figure 25: Dewar 16: MOS Red, Ford 2048^2 chip

Figure 26: Dewar 17: MOS Blue, Ford 2048^2 chip

Not shown: Dewars 3, 4 and 5 were drawn on 25" by 41" vellums and are not included here.

9. REFERENCES

1. T.R. Lauer, et al, "CCD Use at Lick Observatory," 1984. Lick Observatory Bulletin No. 970. SPIE Vol. 445–Instrumentation in Astronomy V.

2. L.B. Robinson, et al, "Lick Observatory Charge-Coupled-Device Data Acquisition System," August 1987, Optical Engineering, Vol. 26, No. 8, pp 795–805. SPIE Invited Paper #CC-113.

3. J.P. Holman, Heat Transfer, 2nd ed, 1963, 1968 by McGraw-Hill Inc, USA.

4. Buil, Christian, CCD Astronomy, 1991, Willmann-Bell, Inc., Richmond, Virginia.

5. Wolfe, Robert and Robert M. Duboc Jr., "Small Wonders," Photonics Spectra, July 1983, pp 52.

6. L.B. Robinson and Jack Osborne, "CCD's at Lick Observatory," 1986, SPIE Vol. 627–Instrumentation in Astronomy VI.

7. L.B. Robinson and Jack Osborne, "A CCD TV Camera for Telescope Guiding," Lick Observatory Bulletin No. 1057, 1987. Reprinted from Publications of the Astronomical Society of the Pacific (Vol 99, No. 613, March 1987)

8. D.A. Landis, N.W. Madden, and F.S. Goulding, "A Reliable Automatic Liquid Nitrogen Filling System, UC Berkeley, LBL, Engineering Division, May 1985.

9. Marks, L.S. ed., "Mechanical Engineer's Handbook," 4th Ed., McGraw-Hill Book Co., Inc., 1941, p. 477–480.

10. SOURCES

ZIF sockets: Textool #22–2600–0602–00, Glass-filled Polysulfone.

from DC Electronics, Santa Clara (408) 980–1199 (or Irving, TX

214 259–2676)

Activated charcoal: 12–20 mesh Eastman Darco Carbon De-colorizing. 500 g jar $13: P/N 15428

American Scientific Products

255 Caspian Drive

Sunnyvale, CA 94086

(408) 743–3100

Stainless Steel vacuum half nipple with 2.75" rotatable flange to make dewars 9 thru 13 connector pipe:

TLI #HN-150 SP w/275–150–RT $35 (Varian shows one in their catalog but they were not too helpful)

Thermionics Lab Inc

22815 Sutro St

Hayward, CA 94540

(415) 538–3304

SS formed bellows #6505 (1/2" I.D. x 2.6" long)

Huntington Labs

Mountain View, CA

(415) 964–3323

304 SS sheet, 1/32" thick:

Reliance Steel

Santa Clara, CA

800 672–3455

304 SS round stock, 6" diameter:

Castle Metal

San Francisco, CA

800 522–7853

Viton O-rings from Bay Seal in Hayward, CA

(415) 732–7000

41 pin Bendix connector: PTIH-20–41P (-61P, also)

Powell Electronics

San Jose, CA

(408) 943–9020

*expect 12–15 weeks delivery time.

Linde Zeolite, 5A (angstrom) from several sources

Cryolab valves: Cryolab Co.

4175 Santa Fe Road

San Louis Obispo, CA 93401

(805) 541–2796

#SV8–084–5W1–DO (buy 10 at a time to pay for setup fee)

5/8" plug w/ #8–32 thread. (Use valve operator for 1/2" plug for HIRES Photometrics TV Camera valve)

Wax: Apiezon type W, hard

Fischer #14–638–25C

Softens at 85°C, vapor pressure = 10^{-9} torr at room temperature

UV 1000 blanks from:

Dynasil Corp. of America

Berlin, NJ 08009

(609) 767–4600

$30 each if you buy 30 at a time.

In the past, we have bought rough blanks of 2", 1.5" and 1–7/8" diameters by 0.18" thick. They polished out to 0.164" thick.

Electro-polishing: Pullbrite Co.

45473 Warm Springs Blvd

Freemont, CA 94539

(408) 262–1919

Be sure to specify no bead-blasting. This will distort the little parts. (Hand clean and prep only if necessary)

Electro-less nickel plating:

Industrial Platers

San Carlos, CA

(415) 593–1046

Gold solution, 1/2 ounce bottle Atomex Gold Plate Solution:

Depends on the gold market. 1992: $380/bottle

Engelhard Industies

5510 E. La Palma

Anaheim, CA 92807

(800) 244–3282

Transition coupling: aluminum to stainless steel (6061 to 304)

Bi-Braze Corp.

2191 Ward Ave.

La Crosse, WI 54601

(608) 787–3079

11. THERMAL CONDUCTIVITY VALUES

k has units of either Watts/cm-°C or Btu/hour/ft-°F

1 Btu/hr/ft-°F = 1.73 Watts/m-°C

1 Watt = 3.41 Btu/hr

304 Stainless Steel = 163 mw/cm-°C (room temperature)

304 Stainless Steel = 123 mw/cm-°C (from 77°K to 300°K)

Aluminum (6061) = 1700 mw/cm-°C

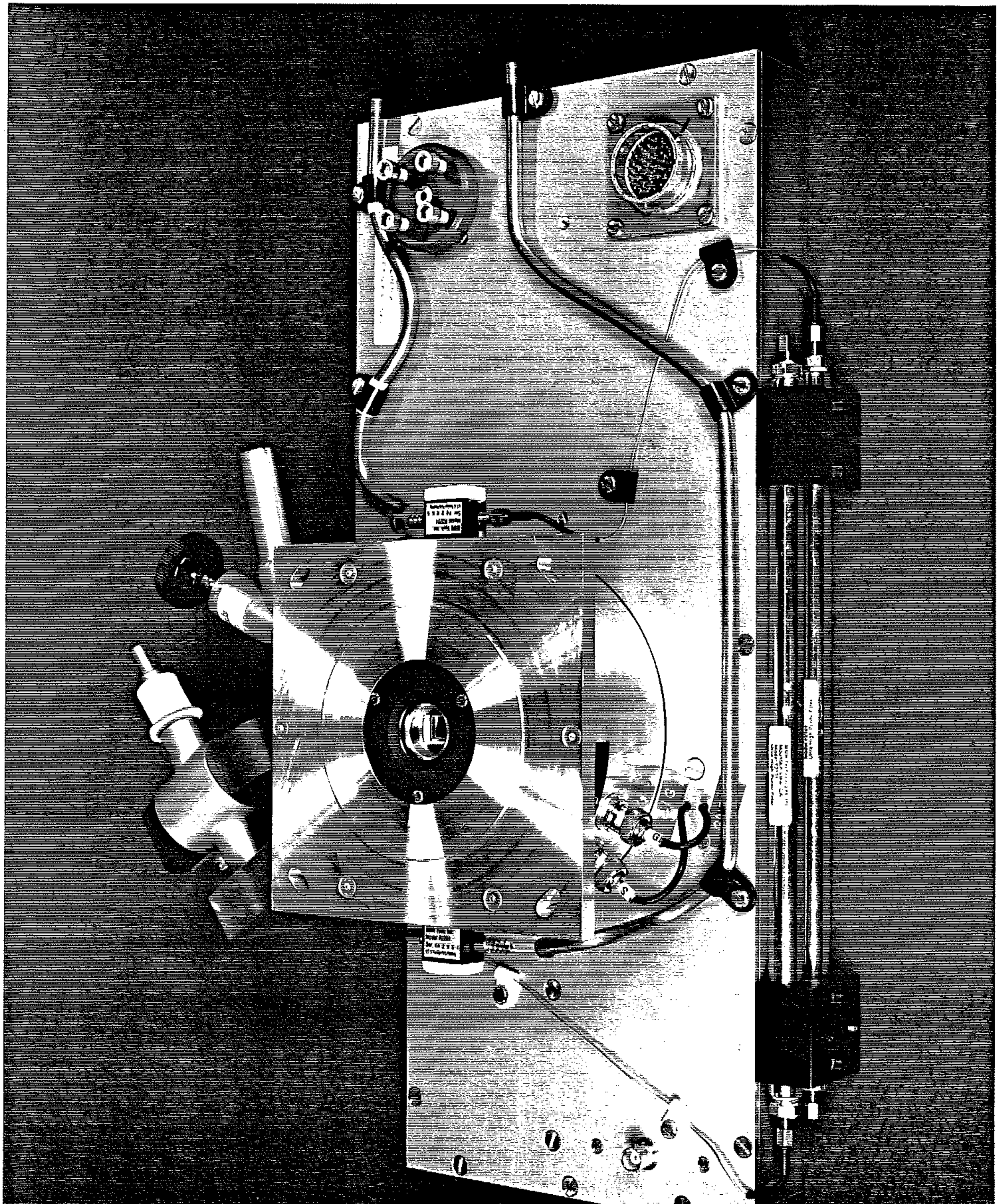
Copper (OFHC) = 3900 mw/cm-°C

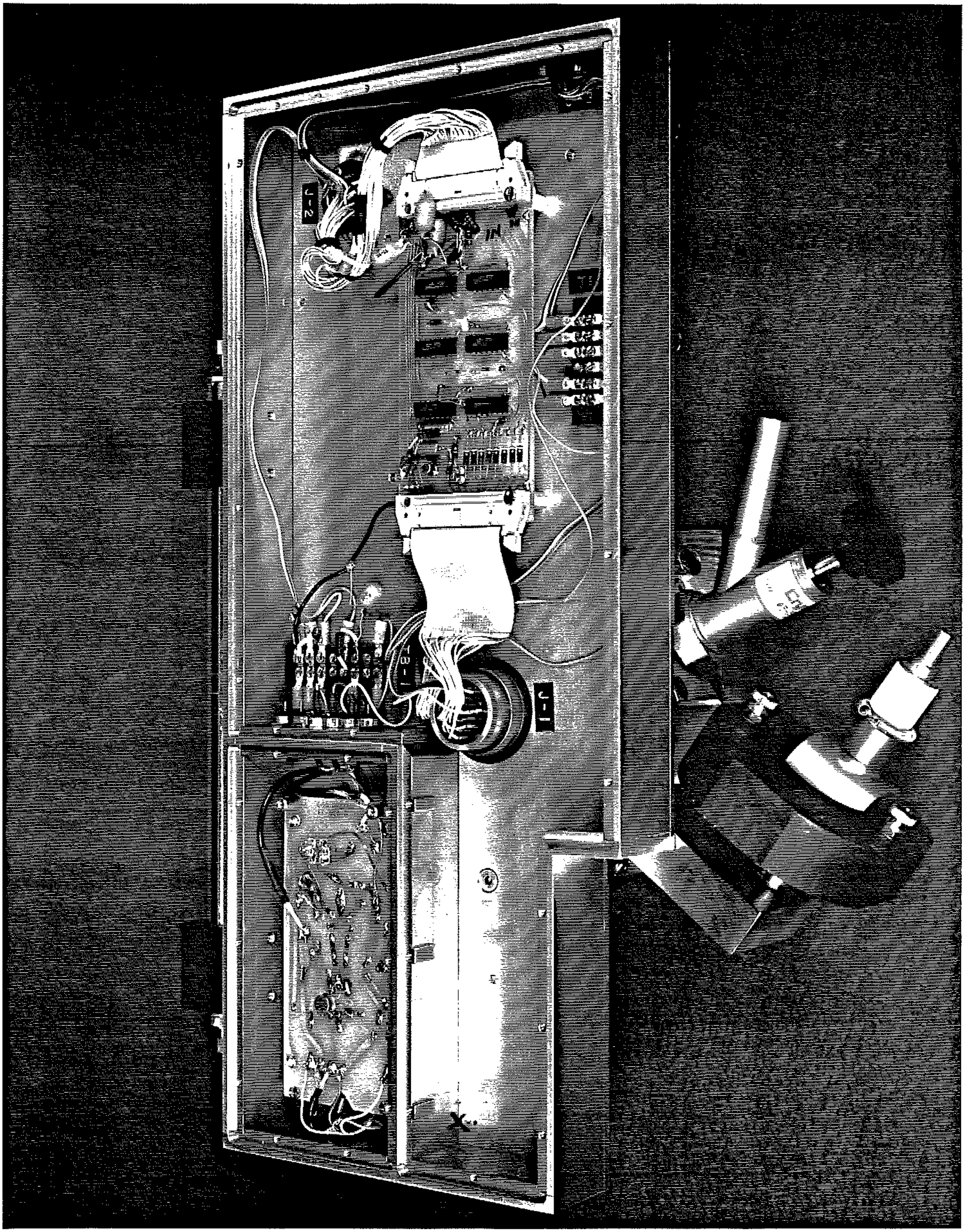
Copper (not OFHC) = 1910 mw/cm-°C

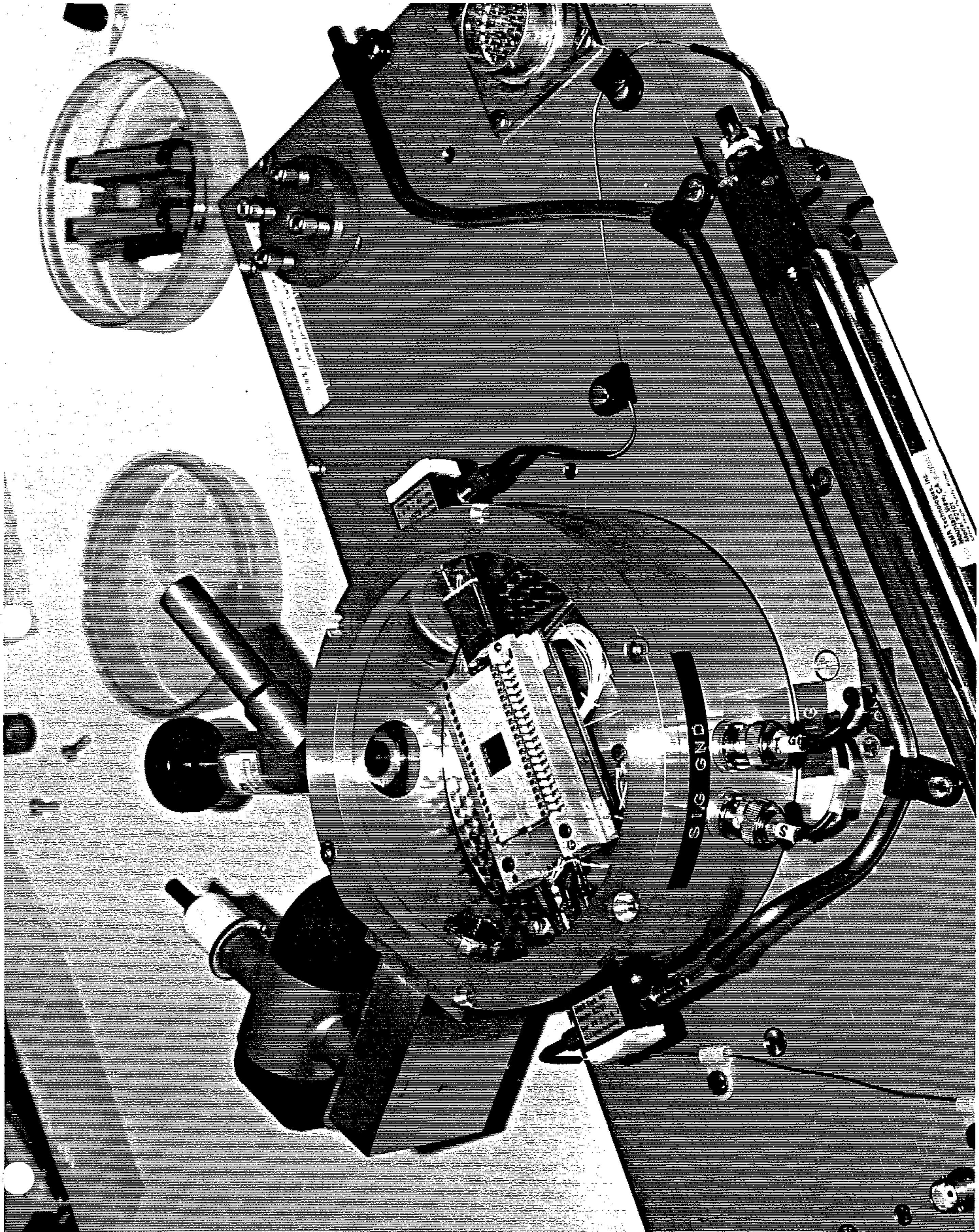
Silver = 3900 mw/cm-°C

Torr-Seal epoxy = 4 mw/cm-°C (Varian)

Quartz = 13.8 mw/cm-°C




J-2
TB-1
J-1


SIG GND

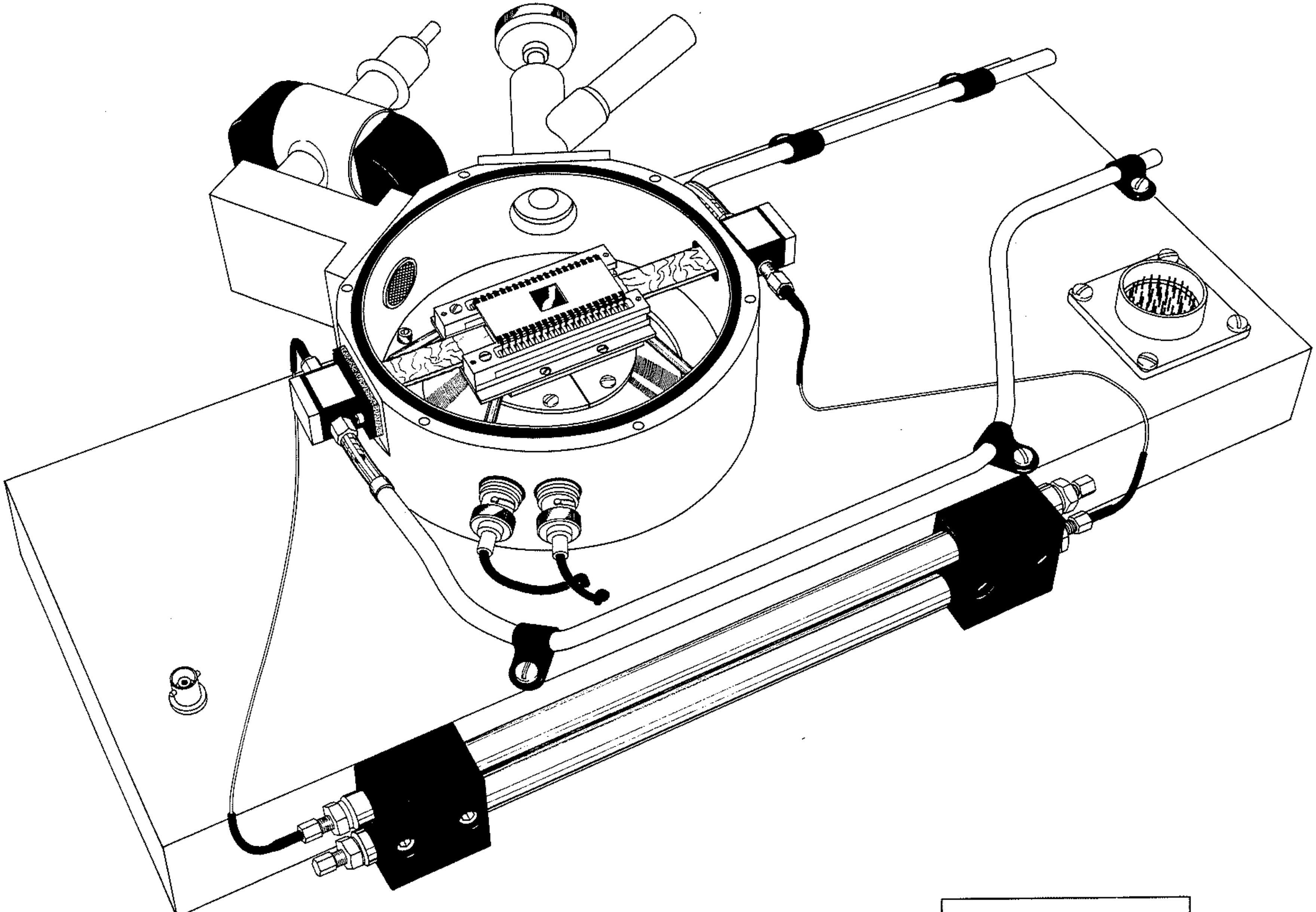


FIGURE 1

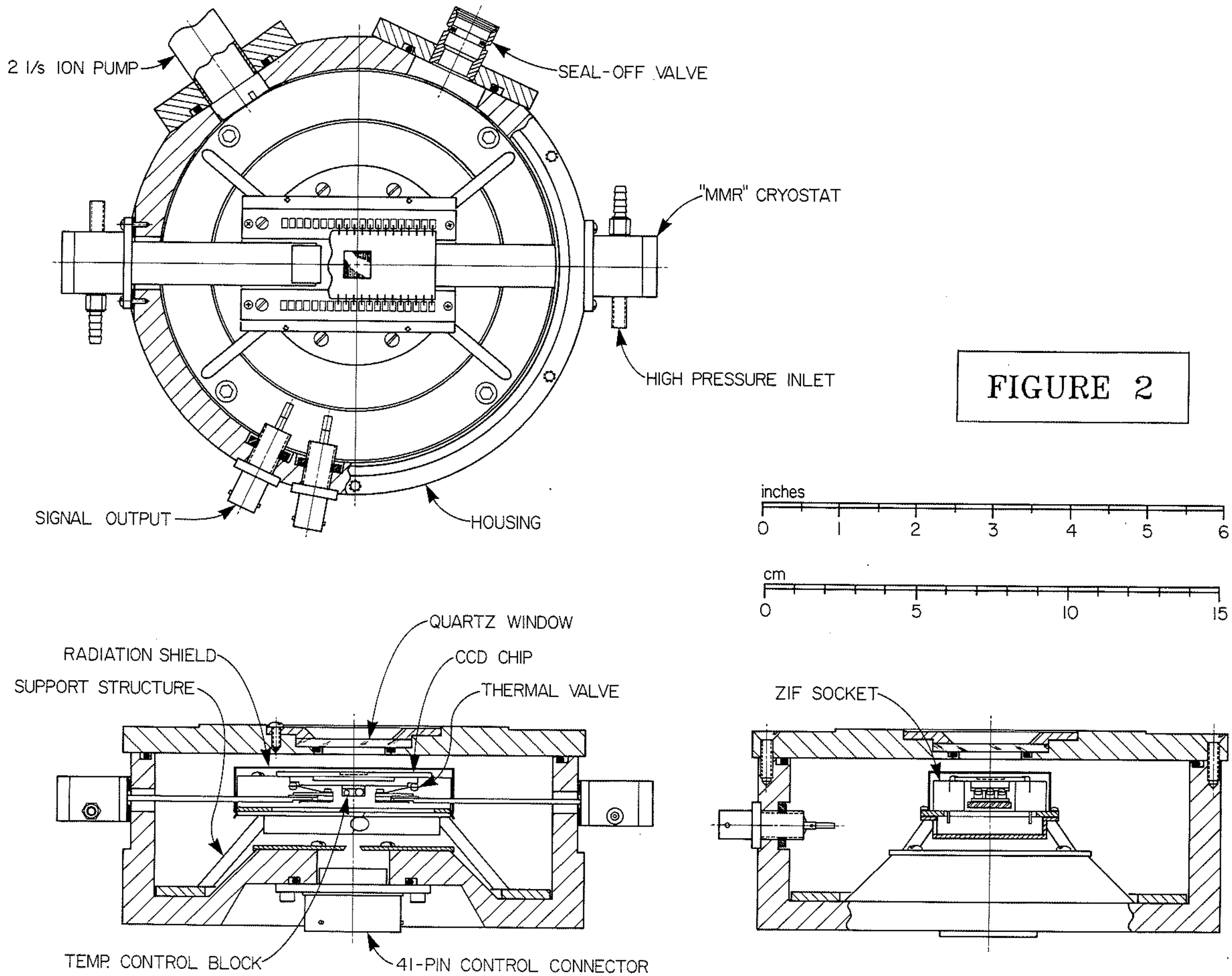

2 l/s ION PUMP
SEAL-OFF VALVE
"MMR" CRYOSTAT
HIGH PRESSURE INLET
SIGNAL OUTPUT
HOUSING
inches
0
1
2
3
4
5
6
cm
0
5
10
15
QUARTZ WINDOW
RADIATION SHIELD
CCD CHIP
SUPPORT STRUCTURE
THERMAL VALVE
ZIF SOCKET
TEMP. CONTROL BLOCK
41-PIN CONTROL CONNECTOR

FIGURE 2

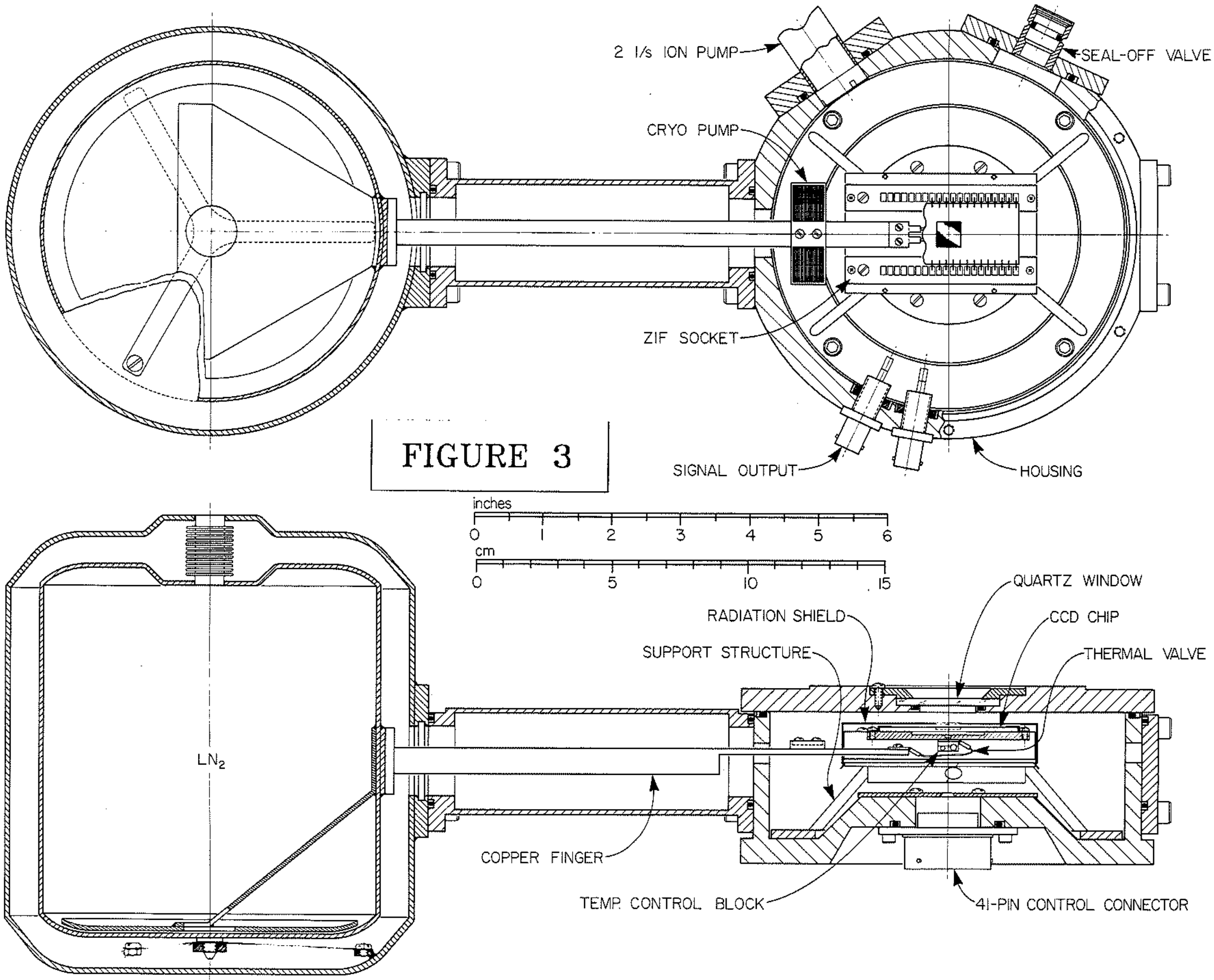
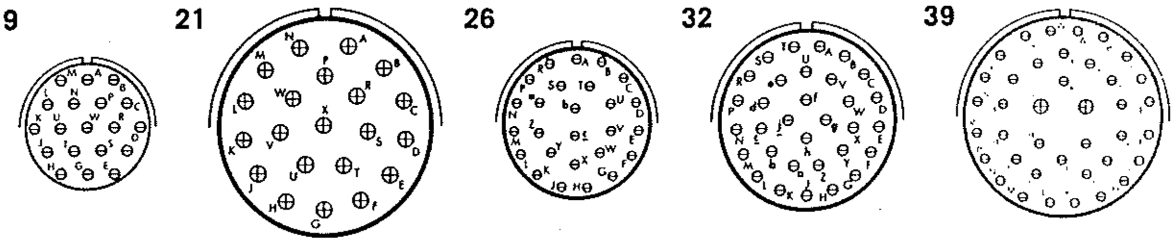
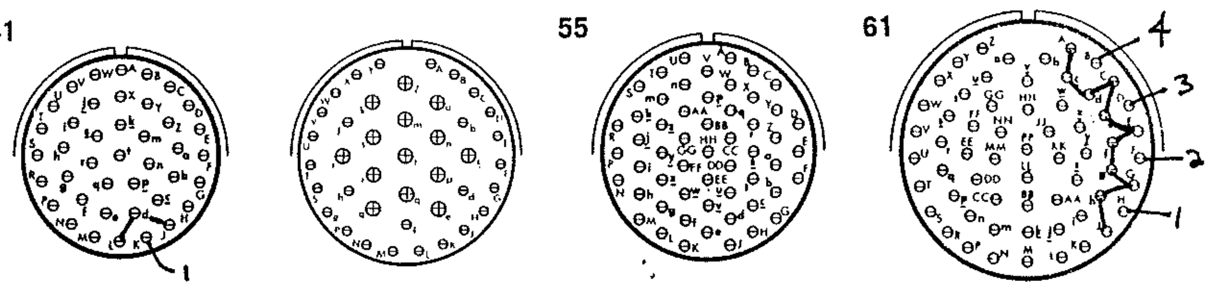

2 l/s ION PUMP
SEAL-OFF VALVE
CRYO PUMP
ZIF SOCKET
SIGNAL OUTPUT
HOUSING
inches
0
1
2
3
4
5
6
cm
0
5
10
15
QUARTZ WINDOW
RADIATION SHIELD
CCD CHIP
SUPPORT STRUCTURE
THERMAL VALVE
LN_2
COPPER FINGER
TEMP. CONTROL BLOCK
41-PIN CONTROL CONNECTOR

FIGURE 3



	19	21	26	32	39
insert arrangement	14-19	22-21	16-26	18-32	20-39
number of contacts	19	21	26	32	39
size of contacts	19 #20	21 #16	26 #20	32 #20	37 #20, 2 #16
service rating	I	II	I	I	I



	41		55	61
insert arrangement	20-41	22-41	22-55	24-61
number of contacts	41	41	55	61
size of contacts	41 #20	27 #20, 14 #16	55 #20	61 #20
service rating	I	I	I	I

contact legend	⊖	⊕
	20	16

FIGURE 4

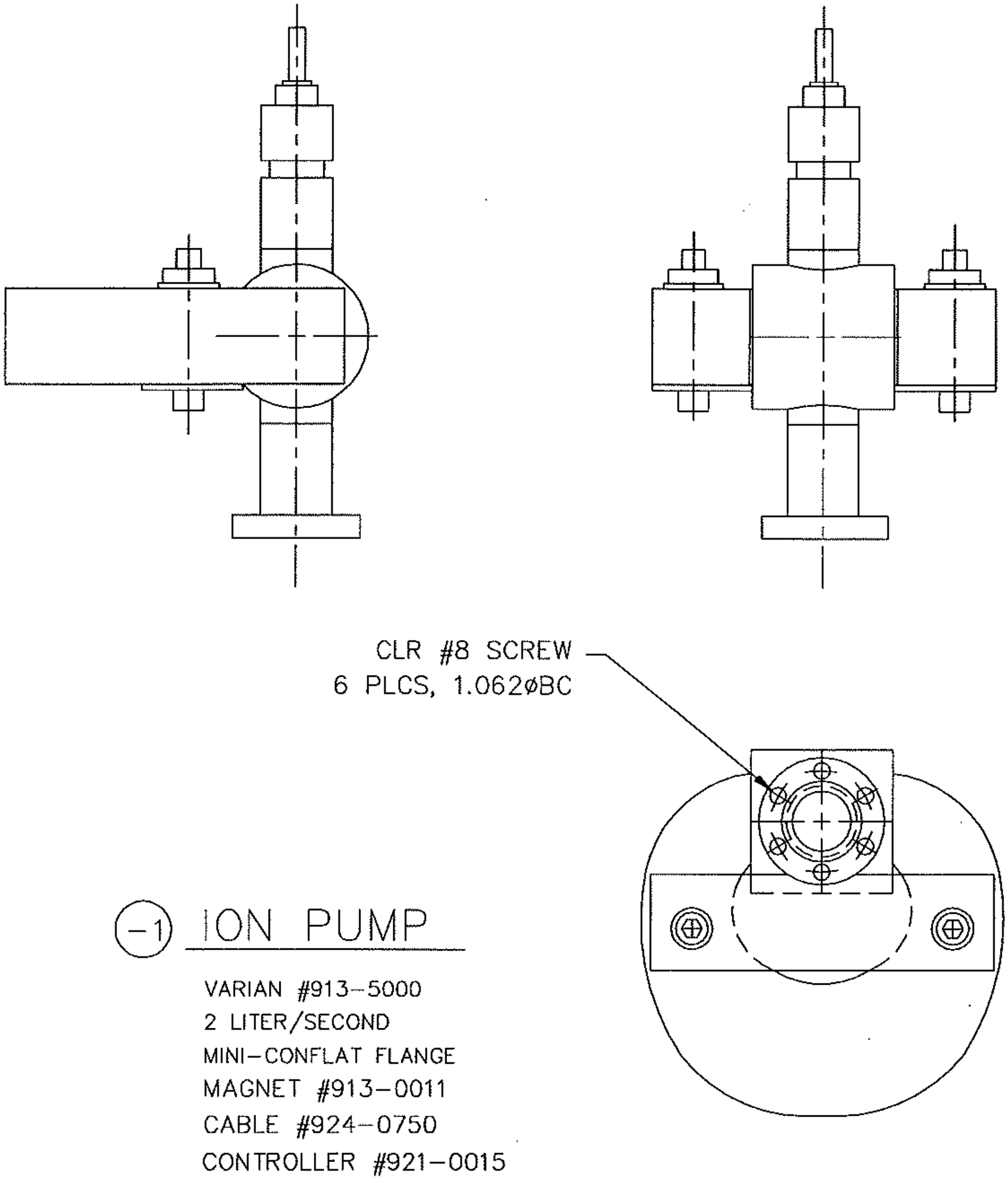


FIGURE 5: ION PUMP

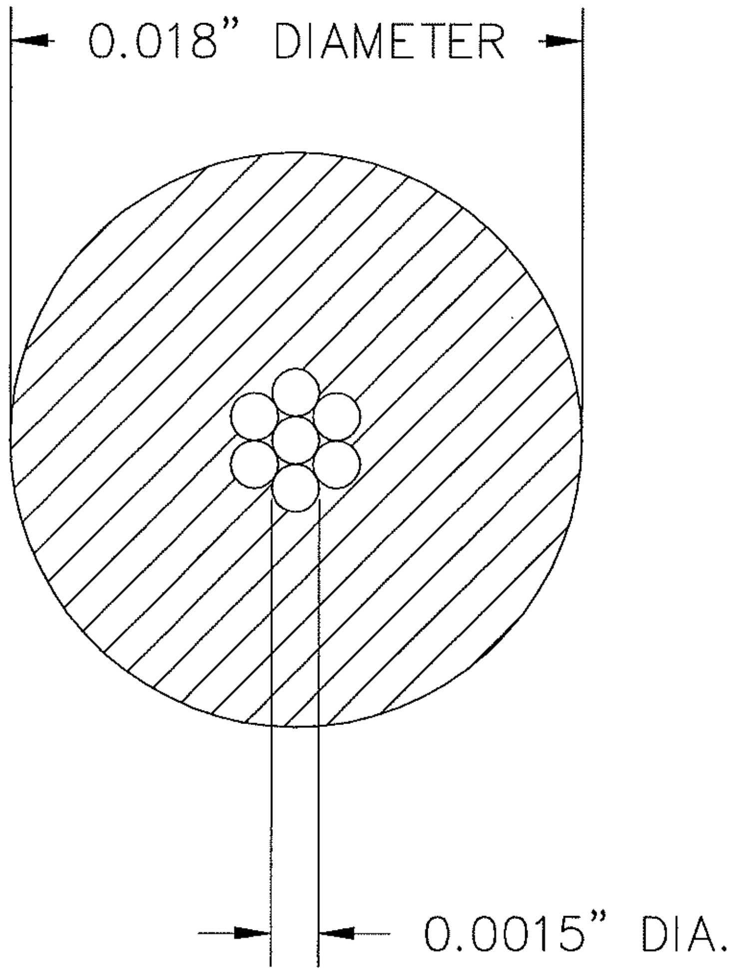


Figure 6, TFE-coated wire

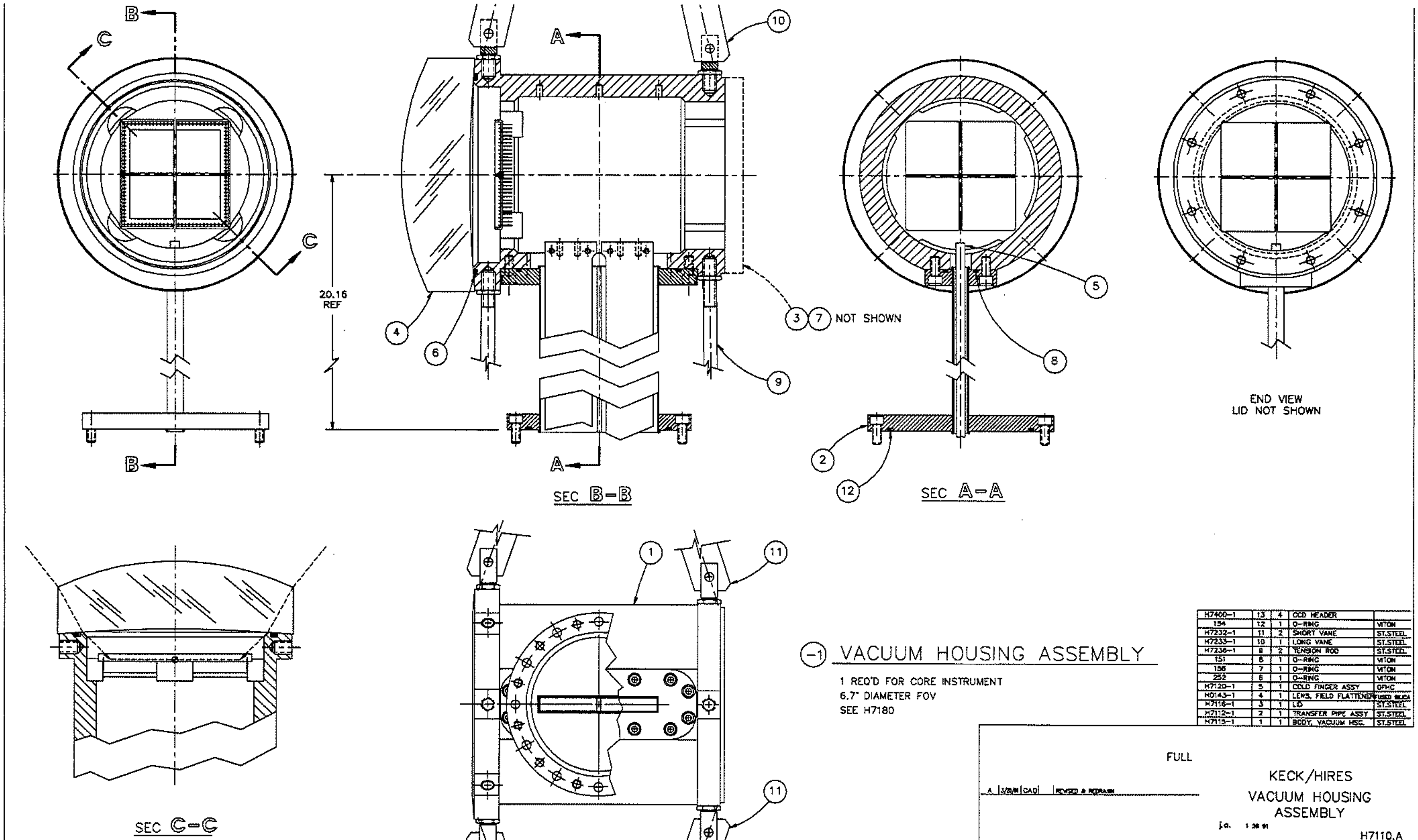
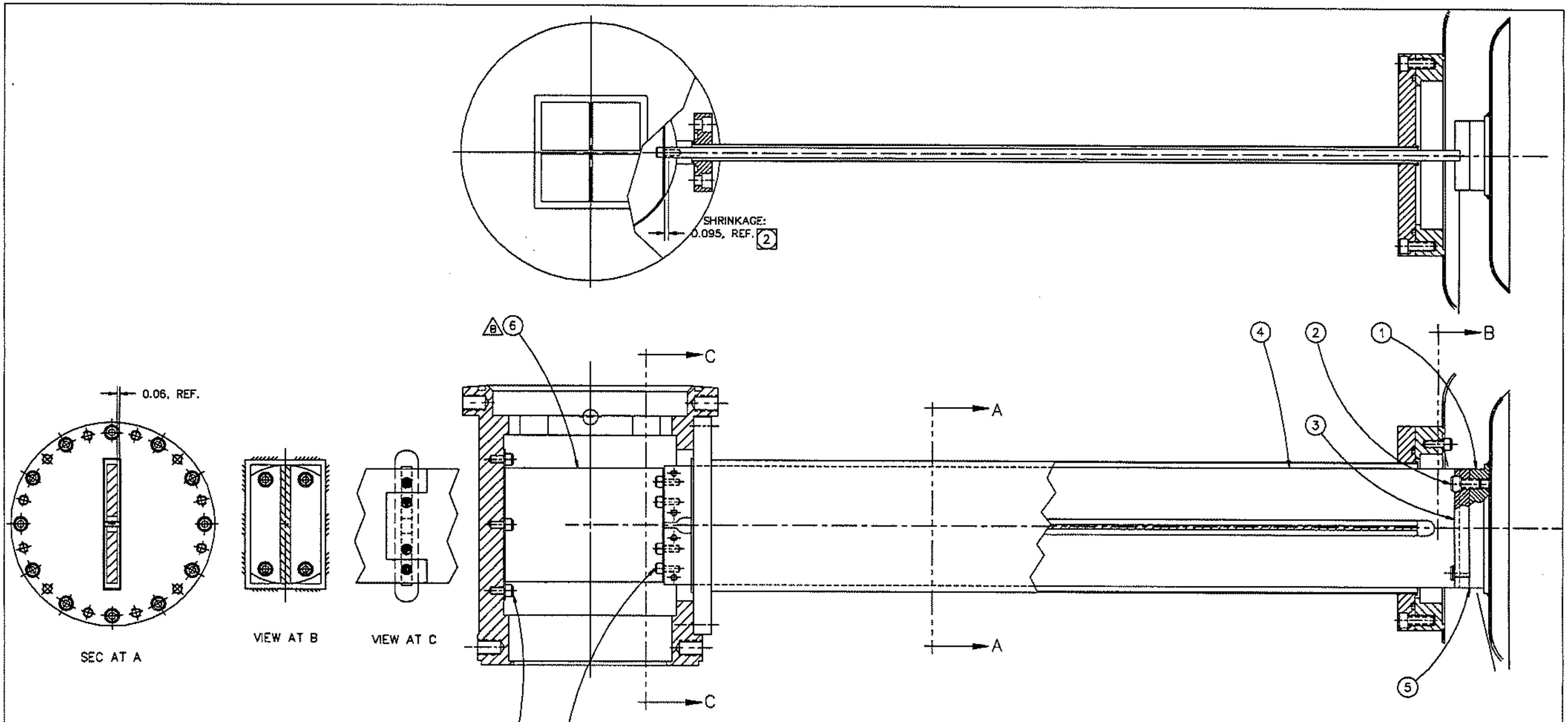

SEC B–B
SEC A–A
SEC C–C
END VIEW
LID NOT SHOWN
20.16
REF
3 7 NOT SHOWN
-1 VACUUM HOUSING ASSEMBLY
1 REQ'D FOR CORE INSTRUMENT
6.7" DIAMETER FOV
SEE H7180
H7400-1 | 13 | 4 | CCD HEADER |
154 | 12 | 1 | O-RING | VITON
H7232-1 | 11 | 2 | SHORT VANE | ST.STEEL
H7233-1 | 10 | 1 | LONG VANE | ST.STEEL
H7236-1 | 9 | 2 | TENSION ROD | ST.STEEL
151 | 8 | 1 | O-RING | VITON
156 | 7 | 1 | O-RING | VITON
252 | 6 | 1 | O-RING | VITON
H7120-1 | 5 | 1 | COLD FINGER ASSY | OFHC
H0143-1 | 4 | 1 | LENS, FIELD FLATTENER | FUSED SILICA
H7116-1 | 3 | 1 | LID | ST.STEEL
H7112-1 | 2 | 1 | TRANSFER PIPE ASSY | ST.STEEL
H7115-1 | 1 | 1 | BODY, VACUUM HSG. | ST.STEEL
FULL
KECK/HIRES
VACUUM HOUSING
ASSEMBLY
H7110.A

FIGURE 7



(−1) COLD FINGER ASSEMBLY

2 REQ'D
USE OFHC COPPER ONLY

NOTES:
1. VENT ALL VACUUM SCREWS WHICH ARE USED IN BLIND THREADED HOLES.
2. $19.86''\times(293^{\circ}-77^{\circ})\times17\times10^{-6} + 6''\times(293^{\circ}-100^{\circ})\times19\times10^{-6}$ IS COPPER + STAINLESS STEEL SHRINKAGE = 0.095"
0.073 + 0.022

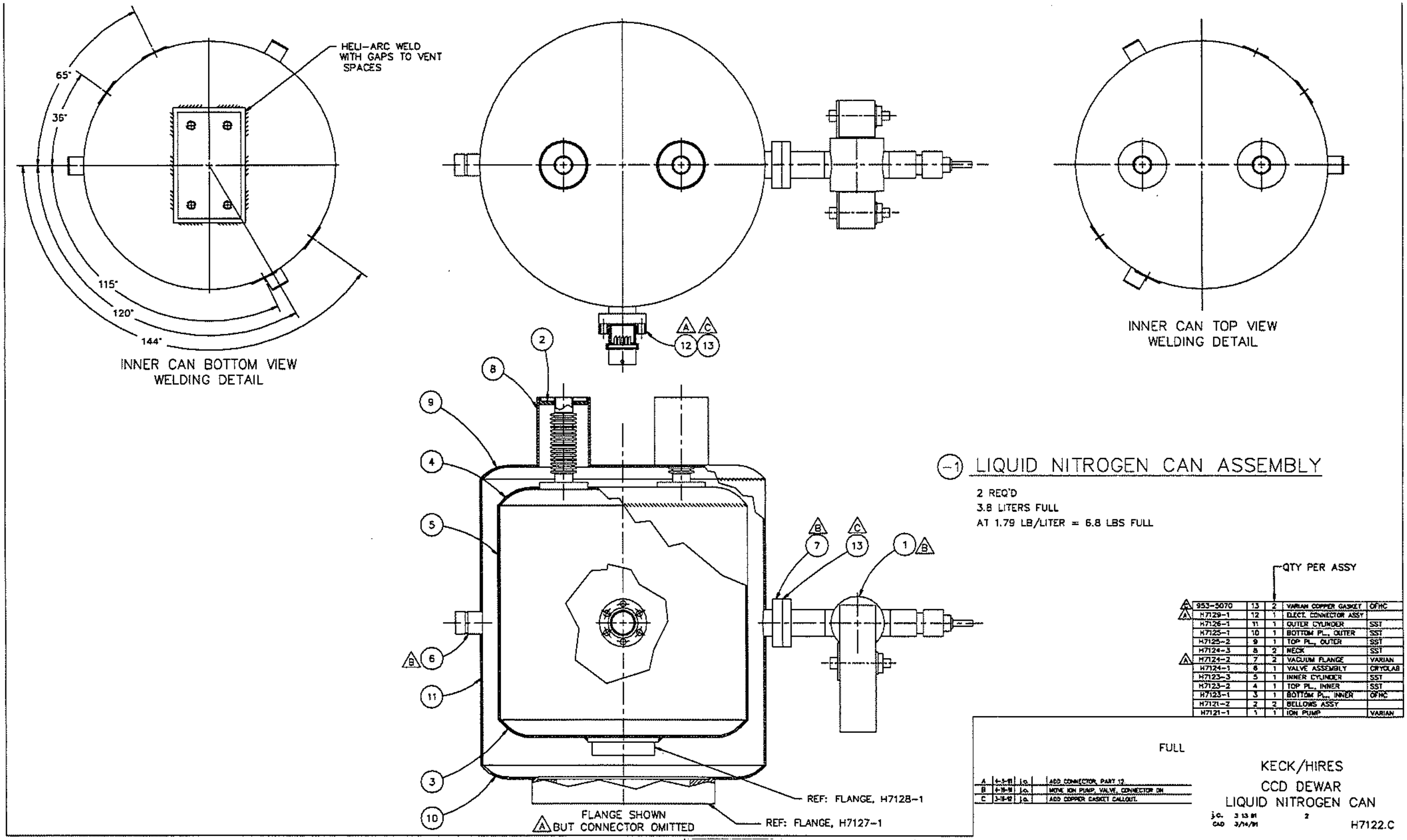
–	8	4	#8–32 AHCS X 3/8 LNG.	ST.STL
–	7	3	#10–32 AHCS X 3/8 LNG.	ST.STL
H7138–1	6	1	INTERNAL FINGER SUPPORT	ST.STL
–	5	1	INDIUM GASKET	
H7135–3	4	1	COPPER FINGER	OFHC
H7135–2	3	1	MOUNTING FLANGE	OFHC
–	2	4	#1/4–20 A.H.C.S.	ST.STL
H7135–1	1	1	WELD FLANGE	OFHC

FULL

A	4-1-91	j.o.	ADD STIFFENER, MODIFY COLD FINGER
B	4-26-91	j.o.	ADD PART 6, INTERNAL FINGER SUPT.

KECK/HIRES
CCD DEWAR
COLD FINGER ASSEMBLY
j.o. 3-91
H7120.B

FIGURE 8



C	953-5070	13	2	VARIAN COPPER GASKET	OFHC
A	H7129-1	12	1	ELECT. CONNECTOR ASSY	
	H7126-1	11	1	OUTER CYLINDER	SST
	H7125-1	10	1	BOTTOM PL., OUTER	SST
	H7125-2	9	1	TOP PL., OUTER	SST
	H7124-3	8	2	NECK	SST
A	H7124-2	7	2	VACUUM FLANGE	VARIAN
	H7124-1	6	1	VALVE ASSEMBLY	CRYOLAB
	H7123-3	5	1	INNER CYLINDER	SST
	H7123-2	4	1	TOP PL., INNER	SST
	H7123-1	3	1	BOTTOM PL., INNER	OFHC
	H7121-2	2	2	BELLOWS ASSY	
	H7121-1	1	1	ION PUMP	VARIAN

FIGURE 9

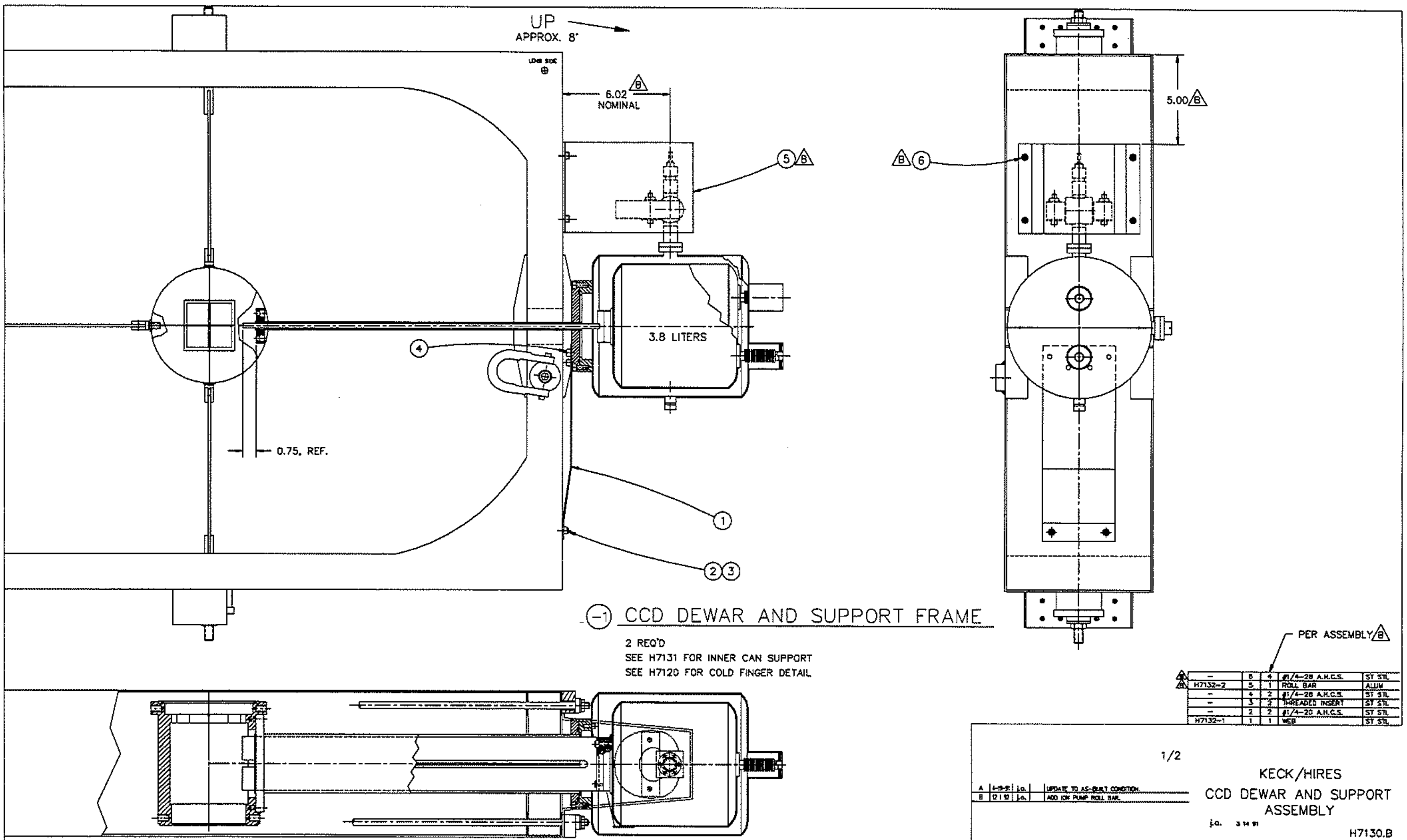

UP
APPROX. 8°
6.02
NOMINAL
5.00
3.8 LITERS
0.75. REF.
CCD DEWAR AND SUPPORT FRAME
2 REQ'D
SEE H7131 FOR INNER CAN SUPPORT
SEE H7120 FOR COLD FINGER DETAIL
PER ASSEMBLY
— | 6 | 4 | #1/4-28 A.H.C.S. | ST STL
H7132-2 | 5 | 1 | ROLL BAR | ALUM
— | 4 | 2 | #1/4-28 A.H.C.S. | ST STL
— | 3 | 2 | THREADED INSERT | ST STL
— | 2 | 2 | #1/4-20 A.H.C.S. | ST STL
H7132-1 | 1 | 1 | WEB | ST STL
1/2
KECK/HIRES
CCD DEWAR AND SUPPORT
ASSEMBLY
H7130.B

FIGURE 10

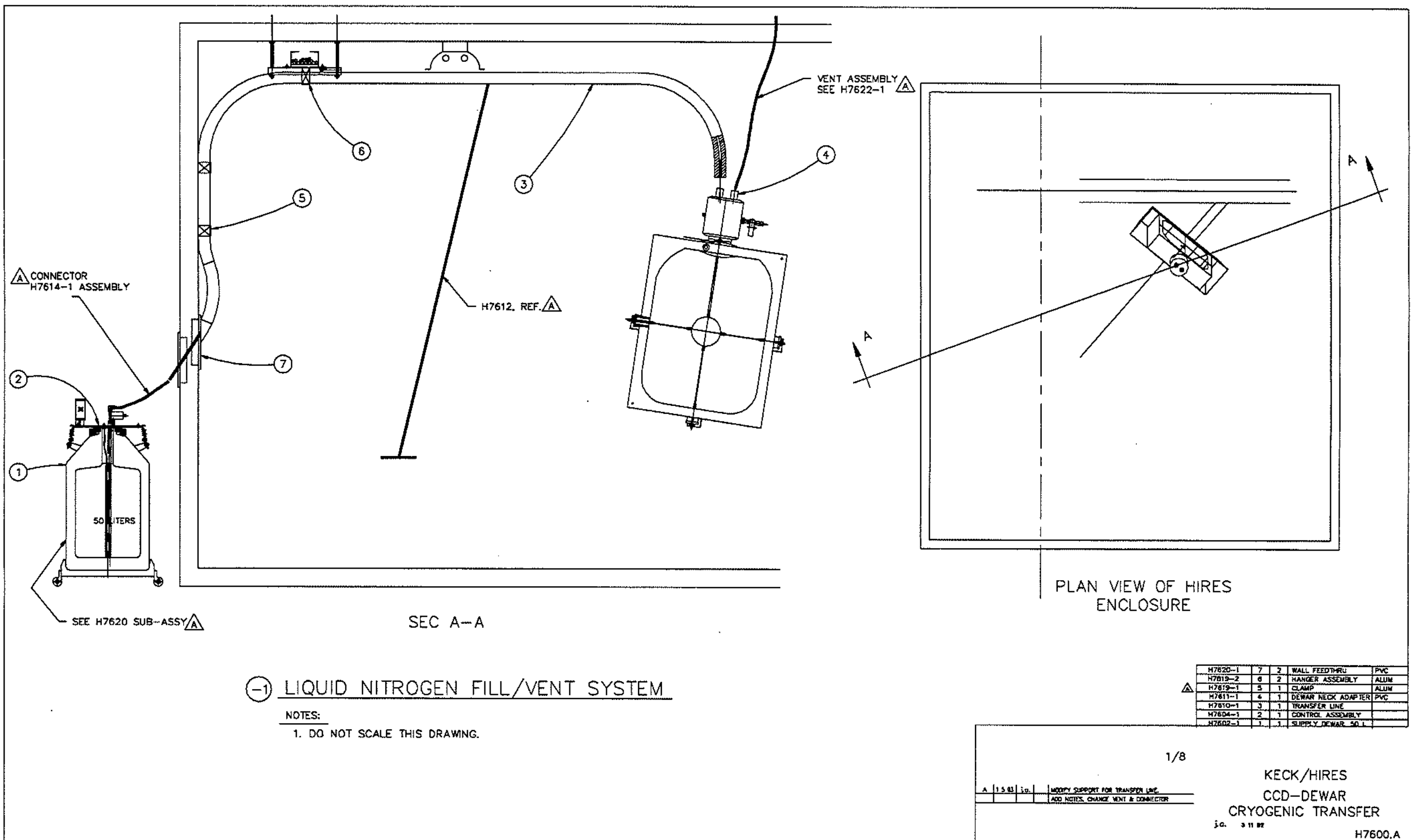
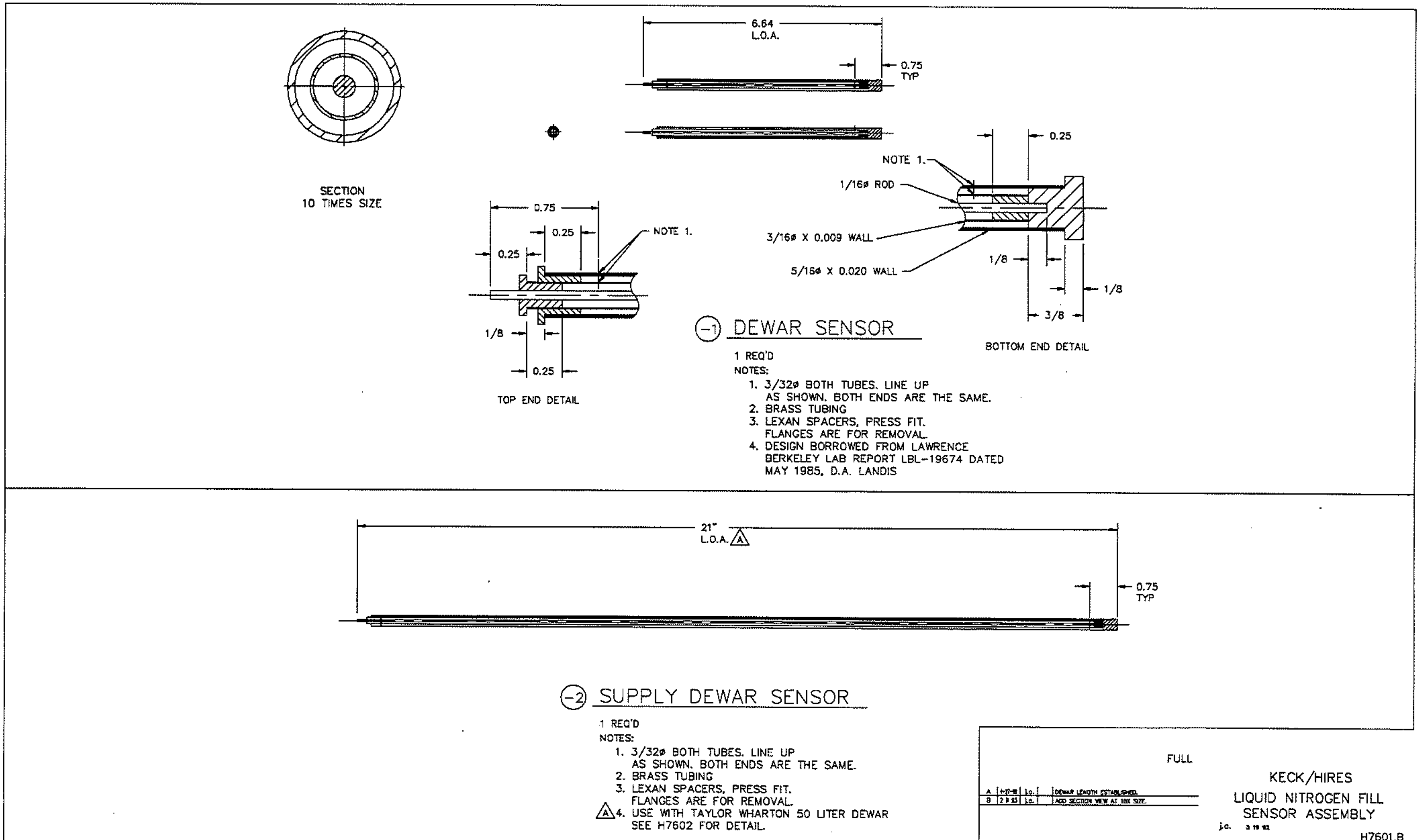
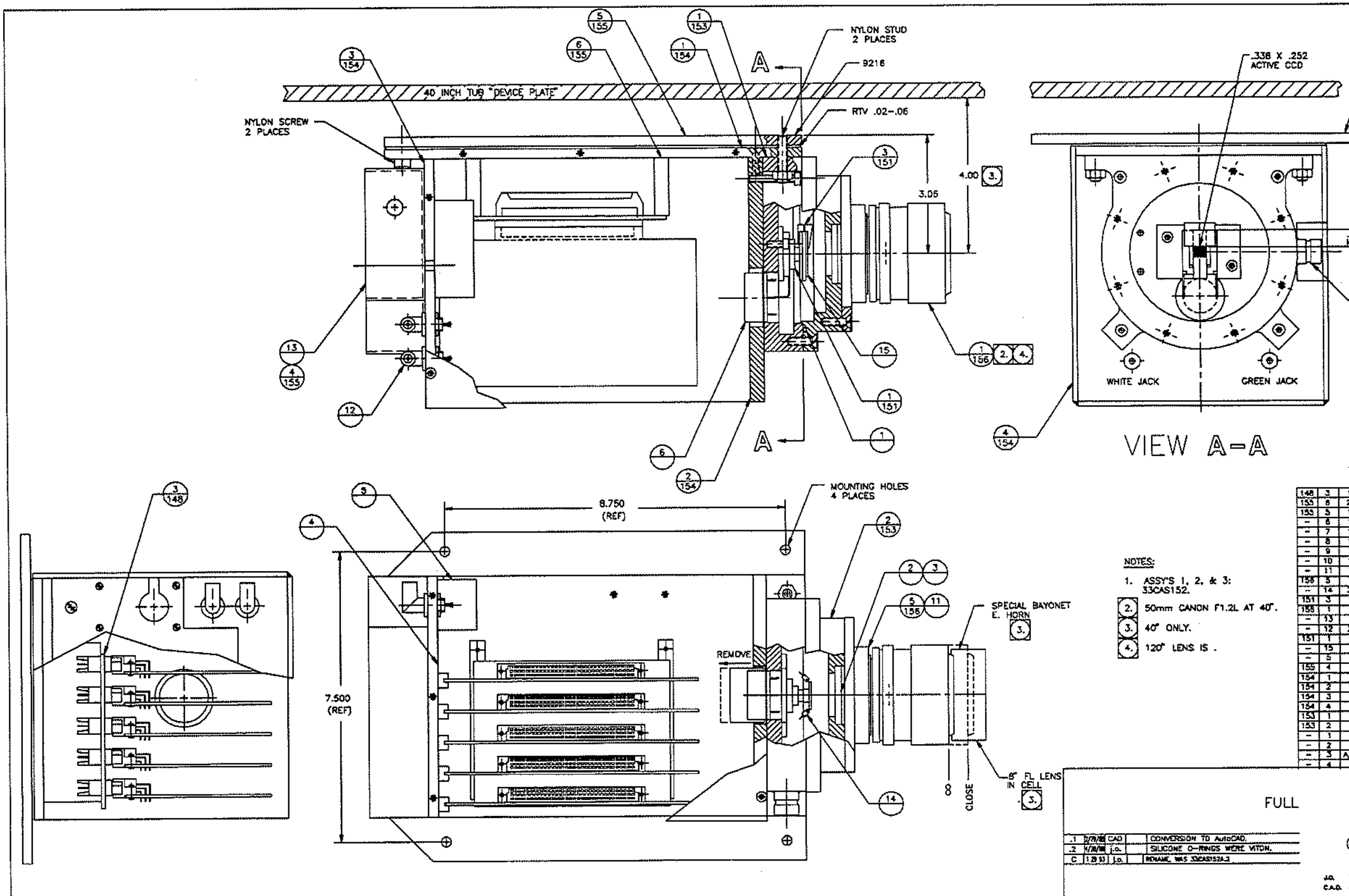

VENT ASSEMBLY SEE H7622-1 A
A CONNECTOR H7614-1 ASSEMBLY
H7612, REF. A
50 LITERS
SEE H7620 SUB-ASSY A
SEC A-A
PLAN VIEW OF HIRES ENCLOSURE
A
A
1
2
3
4
5
6
7
-1 LIQUID NITROGEN FILL/VENT SYSTEM
NOTES:
1. DO NOT SCALE THIS DRAWING.
H7620-1 7 2 WALL FEEDTHRU PVC
H7619-2 6 2 HANGER ASSEMBLY ALUM
H7619-1 5 1 CLAMP ALUM
H7611-1 4 1 DEWAR NECK ADAPTER PVC
H7610-1 3 1 TRANSFER LINE
H7604-1 2 1 CONTROL ASSEMBLY
H7602-1 1 1 SUPPLY DEWAR 50 L
1/8
A 1 5 83 j.a. MODIFY SUPPORT FOR TRANSFER LINE.
ADD NOTES, CHANGE VENT & CONNECTOR
KECK/HIRES
CCD-DEWAR
CRYOGENIC TRANSFER
j.a. 3 11 82
H7600.A

FIGURE 11



SECTION
10 TIMES SIZE
6.64
L.O.A.
0.75
TYP
0.25
NOTE 1.
1/16ø ROD
3/16ø X 0.009 WALL
5/16ø X 0.020 WALL
1/8
3/8
BOTTOM END DETAIL
0.75
0.25
TOP END DETAIL
(-1) DEWAR SENSOR
1 REQ'D
NOTES:
1. 3/32ø BOTH TUBES. LINE UP AS SHOWN. BOTH ENDS ARE THE SAME.
2. BRASS TUBING
3. LEXAN SPACERS, PRESS FIT. FLANGES ARE FOR REMOVAL.
4. DESIGN BORROWED FROM LAWRENCE BERKELEY LAB REPORT LBL-19674 DATED MAY 1985, D.A. LANDIS
21"
L.O.A. A
(-2) SUPPLY DEWAR SENSOR
1 REQ'D
NOTES:
1. 3/32ø BOTH TUBES. LINE UP AS SHOWN. BOTH ENDS ARE THE SAME.
2. BRASS TUBING
3. LEXAN SPACERS, PRESS FIT. FLANGES ARE FOR REMOVAL.
A 4. USE WITH TAYLOR WHARTON 50 LITER DEWAR SEE H7602 FOR DETAIL.
FULL
KECK/HIRES
LIQUID NITROGEN FILL
SENSOR ASSEMBLY
H7601.B

FIGURE 12



NOTES:

1. ASSY'S 1, 2, & 3: 33CAS152.

2. 50mm CANON F1.2L AT 40".

3. 40" ONLY.

4. 120" LENS IS .

148	3	1	MICROBUS 38-39104K 5 SLOT	
155	8	2	SUPPORT	ALUMINUM
155	5	1	SANDWICH PLATE	ALUMINUM
–	6	1	CONNECTOR 41P/33CAS121	BENDIX
–	7	1	VALVE 33CAS121	CRYOLAB
–	8	1	O-RING #011	SILICONE A
–	9	1	O-RING #012	SILICONE A
–	10	1	OPERATOR	CRYOLAB
–	11	1	LENS MOUNT #14-2308-000	CANON AE-1
156	5	1	LENS ADAPTOR	ALUMINUM
–	14	2	CARRY CONNECTOR #2002-40-CC-8	
151	3	1	MASK/CLIP	ALUMINUM
156	1	1	LENS	CANON
–	13	1	POWER SUP. 326 ACM	POWER GEN'L
–	12	2	BNC #KC-79-110	KING
151	1	1	COOLER SP1656	MARLOWE
–	15	1	GEC CCD (BRITISH GENERAL ELECTRIC)	
–	5	1	ITT POMONA 2417-1-163C	
155	4	1	SHIELDED BOX & LID	ALUMINUM
154	1	1	BOTTOM PLATE	ALUMINUM
154	2	1	FRONT PLATE	ALUMINUM
154	3	1	REAR PLATE	ALUMINUM
154	4	1	COVER	ALUMINUM
153	1	1	BODY	OFHC
153	2	1	LID	ALUMINUM
–	1	1	O-RING #154	SILICONE A
–	2	1	WINDOW 1.50 UV1000	QUARTZ
–	3	A/R	WAX, APIEZON	
–	4	5	H.P. GUIDE	PLASTIC

FULL

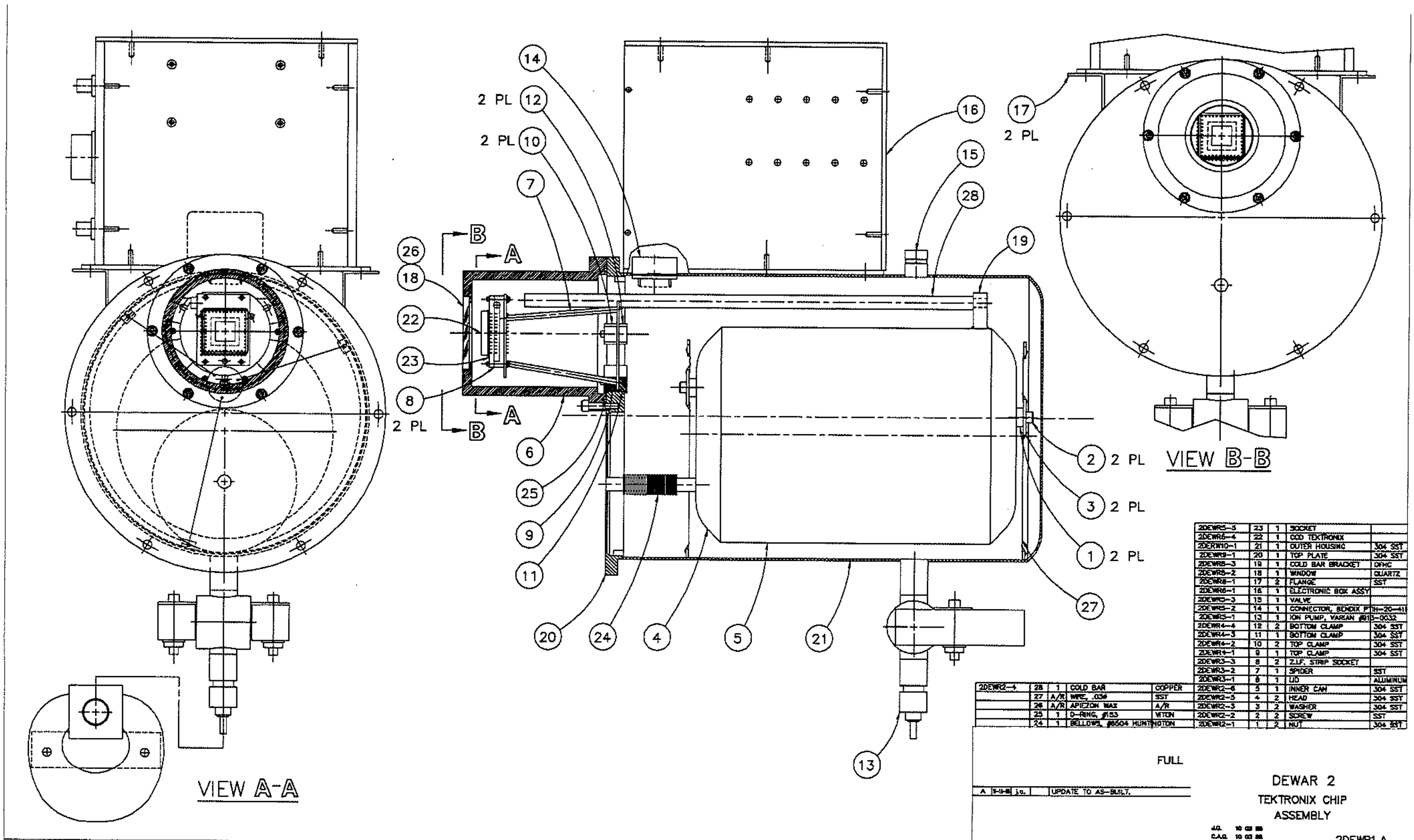
.1	[illegible]	CAD	CONVERSION TO AutoCAD.
.2	[illegible]	J.O.	SILICONE O-RINGS WERE VITON.
C	1 29 93	J.O.	RENAME, WAS 33CAS152A.3

CCD – TV MARK III
CAMERAS 4, 5, & 6
G96

J.O. 1 29 87
C.A.D. 3 4 88

C 33CAS150.C

FIGURE 13



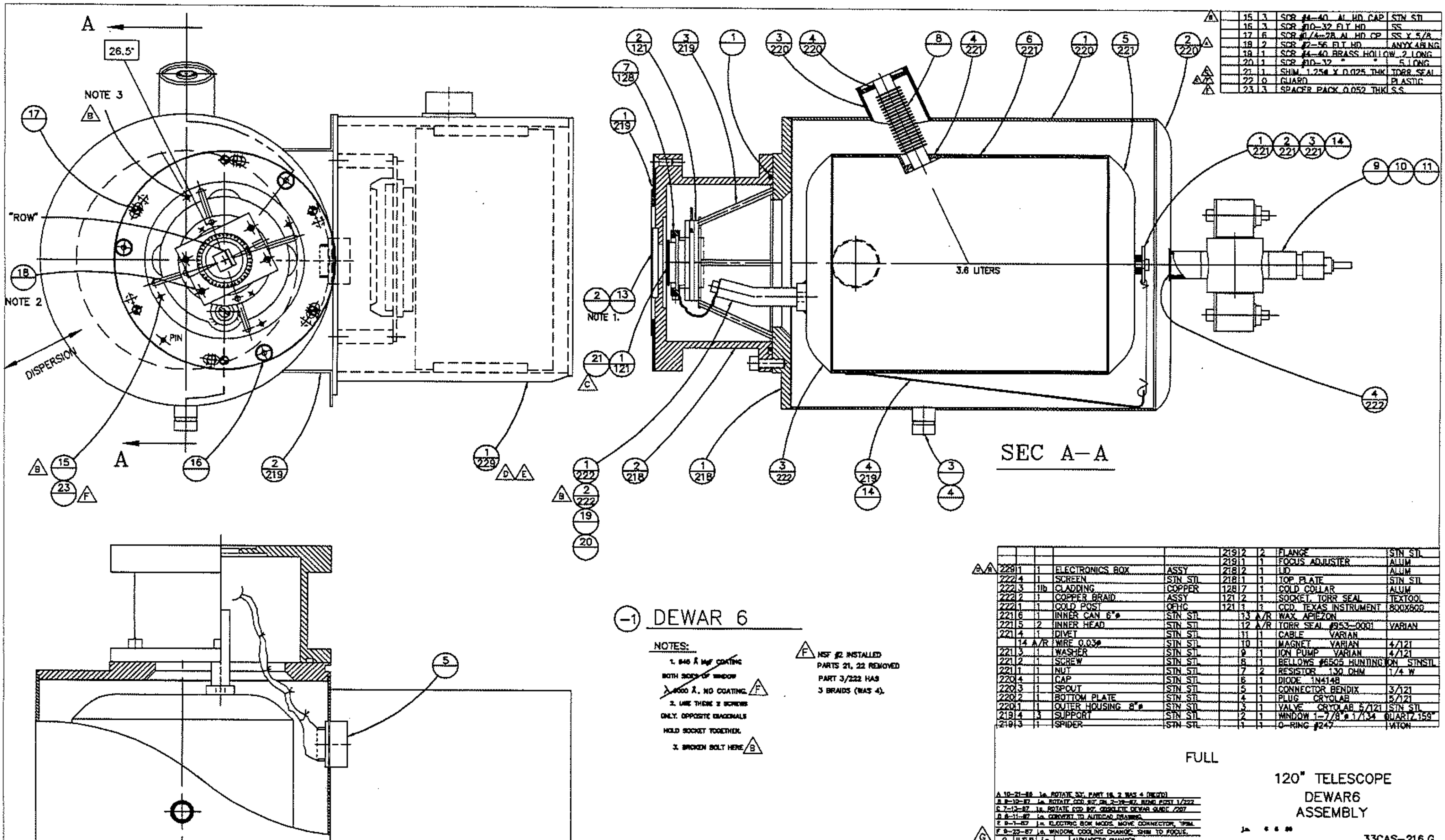
2DEWR5-3	23	1	SOCKET	
2DEWR6-4	22	1	CCD TEKTRONIX	
2DERW10-1	21	1	OUTER HOUSING	304 SST
2DEWR9-1	20	1	TOP PLATE	304 SST
2DEWR8-3	19	1	COLD BAR BRACKET	OFHC
2DEWR8-2	18	1	WINDOW	QUARTZ
2DEWR8-1	17	2	FLANGE	SST
2DEWR6-1	16	1	ELECTRONIC BOX ASSY	
2DEWR5-3	15	1	VALVE	
2DEWR5-2	14	1	CONNECTOR, BENDIX PTH-20-41	
2DEWR5-1	13	1	ION PUMP, VARIAN #913-0032	
2DEWR4-4	12	2	BOTTOM CLAMP	304 SST
2DEWR4-3	11	1	BOTTOM CLAMP	304 SST
2DEWR4-2	10	2	TOP CLAMP	304 SST
2DEWR4-1	9	1	TOP CLAMP	304 SST
2DEWR3-3	8	2	Z.I.F. STRIP SOCKET	
2DEWR3-2	7	1	SPIDER	SST
2DEWR3-1	6	1	LID	ALUMINUM
2DEWR2-6	5	1	INNER CAN	304 SST
2DEWR2-5	4	2	HEAD	304 SST
2DEWR2-3	3	2	WASHER	304 SST
2DEWR2-2	2	2	SCREW	SST
2DEWR2-1	1	2	NUT	304 SST
2DEWR2-4	28	1	COLD BAR	COPPER
	27	A/R	WIRE, .034	SST
	26	A/R	APIEZON WAX	A/R
	25	1	O-RING, #153	VITON
	24	1	BELLOWS, #8604 HUNTINGTON	

A [illegible] UPDATE TO AS-BUILT.

DEWAR 2
TEKTRONIX CHIP
ASSEMBLY

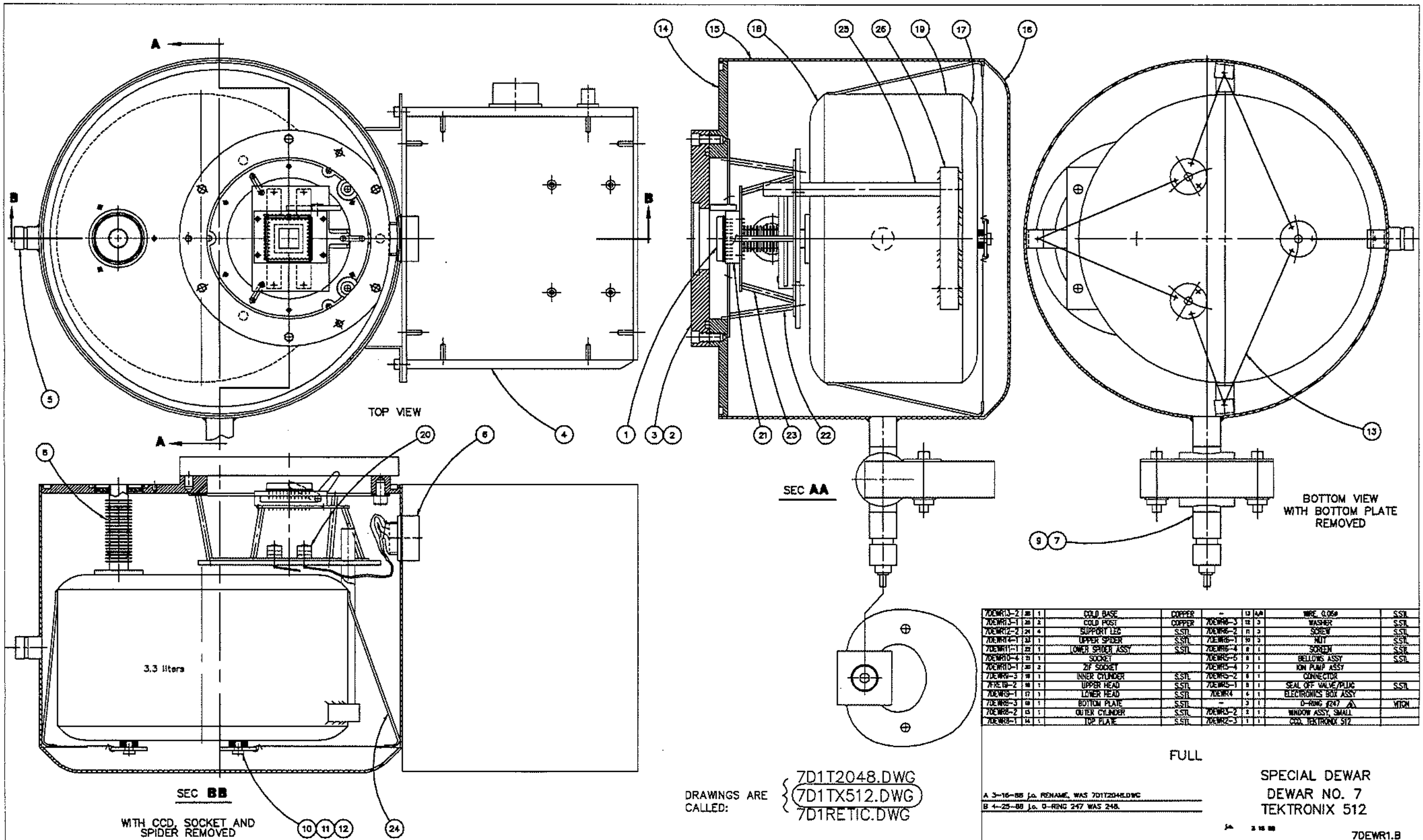
2DEWR1.A

FIGURE 14



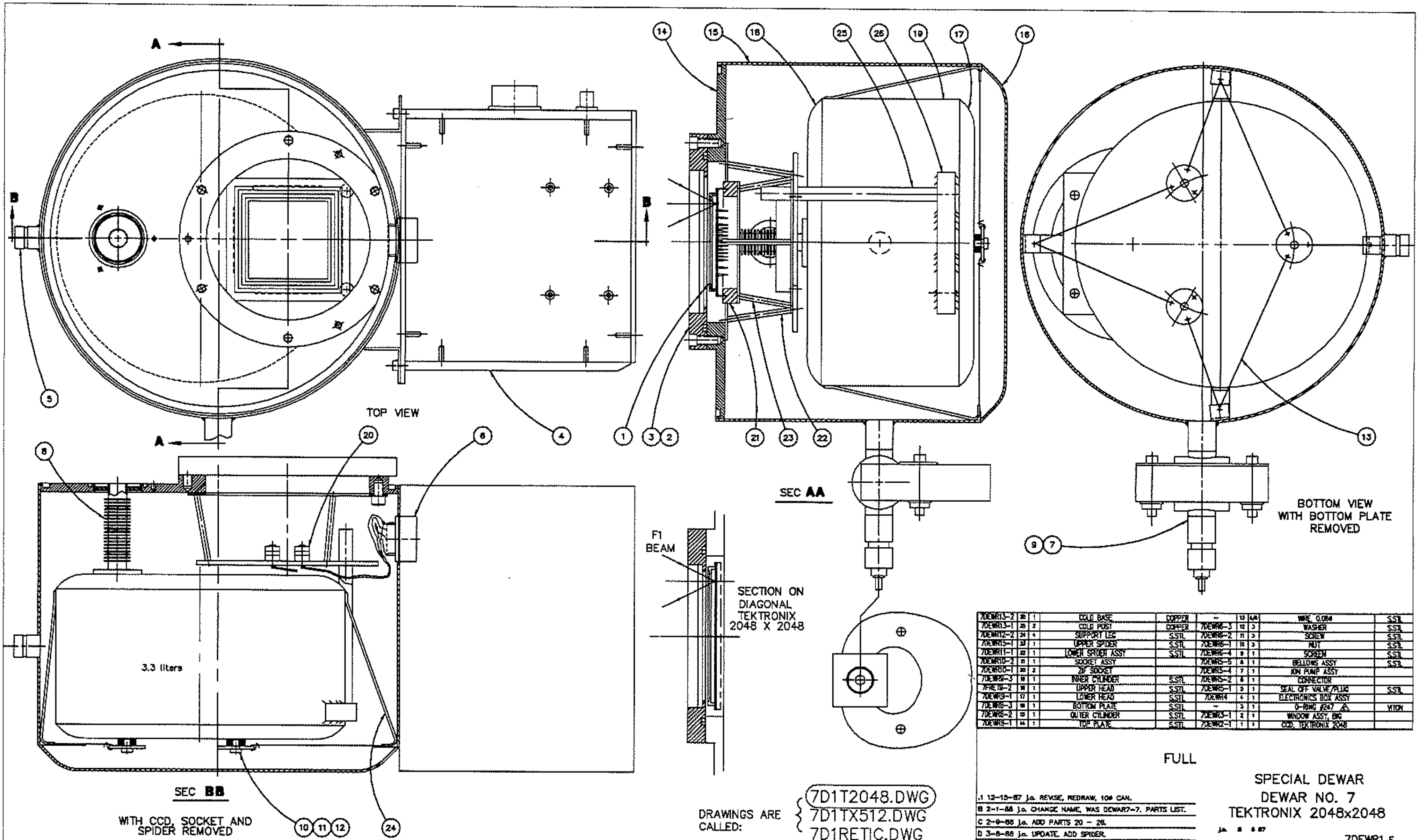
A
26.5°
NOTE 3
"ROW"
NOTE 2
PIN
DISPERSION
SEC A-A
3.6 LITERS
NOTE 1.
DEWAR 6
NOTES:
1. 846 Å MgF COATING BOTH SIDES OF WINDOW
6000 Å. NO COATING.
2. USE THESE 2 SCREWS ONLY. OPPOSITE DIAGONALS HOLD SOCKET TOGETHER.
3. BROKEN BOLT HERE.
NSF #2 INSTALLED PARTS 21, 22 REMOVED PART 3/222 HAS 3 BRAIDS (WAS 4).
15 3 SCR #4-40 AL HD CAP STN STL
16 3 SCR #10-32 FLT HD SS
17 6 SCR #1/4-28 AL HD CP SS X 5/8
18 2 SCR #2-56 FLT HD ANYX 48 LNG
19 1 SCR #4-40 BRASS HOLLOW .2 LONG
20 1 SCR #10-32 " " .5 LONG
21 1 SHIM 1.25ø X 0.025 THK TORR SEAL
22 0 GUARD PLASTIC
23 3 SPACER PACK 0.052 THK S.S.
219 2 2 FLANGE STN STL
219 1 1 FOCUS ADJUSTER ALUM
229 1 1 ELECTRONICS BOX ASSY
218 2 1 LID ALUM
222 4 1 SCREEN STN STL
218 1 1 TOP PLATE STN STL
222 3 1lb CLADDING COPPER
128 7 1 COLD COLLAR ALUM
222 2 1 COPPER BRAID ASSY
121 2 1 SOCKET, TORR SEAL TEXTOOL
222 1 1 COLD POST OFHC
121 1 1 CCD, TEXAS INSTRUMENT 800X800
221 6 1 INNER CAN 6"ø STN STL
13 A/R WAX APIEZON
221 5 2 INNER HEAD STN STL
12 A/R TORR SEAL #953-0001 VARIAN
221 4 1 DIVET STN STL
11 1 CABLE VARIAN
14 A/R WIRE 0.03ø STN STL
10 1 MAGNET VARIAN 4/121
221 3 1 WASHER STN STL
9 1 ION PUMP VARIAN 4/121
221 2 1 SCREW STN STL
8 1 BELLOWS #6505 HUNTINGTON STNSTL
221 1 1 NUT STN STL
7 2 RESISTOR 130 OHM 1/4 W
220 4 1 CAP STN STL
6 1 DIODE 1N4148
220 3 1 SPOUT STN STL
5 1 CONNECTOR BENDIX 3/121
220 2 1 BOTTOM PLATE STN STL
4 1 PLUG CRYOLAB 5/121
220 1 1 OUTER HOUSING 8"ø STN STL
3 1 VALVE CRYOLAB 5/121 STN STL
219 4 3 SUPPORT STN STL
2 1 WINDOW 1-7/8"ø 1/134 QUARTZ.159"
219 3 1 SPIDER STN STL
1 1 O-RING #247 VITON
FULL
120" TELESCOPE
DEWAR6
ASSEMBLY
33CAS-216.G

FIGURE 15



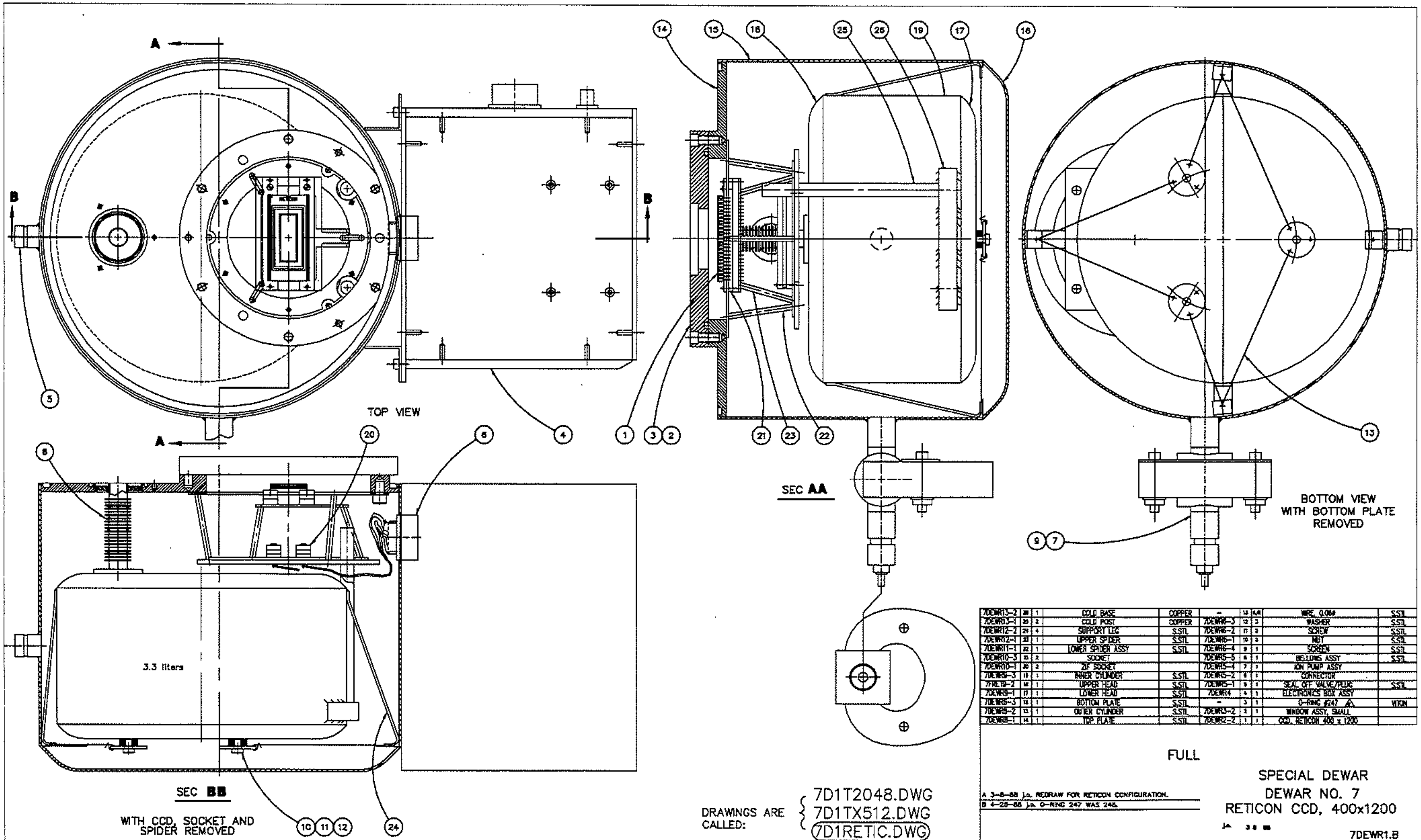
TOP VIEW
A
B
SEC AA
SEC BB
WITH CCD, SOCKET AND SPIDER REMOVED
BOTTOM VIEW WITH BOTTOM PLATE REMOVED
3.3 liters
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26
DRAWINGS ARE CALLED:
7D1T2048.DWG
7D1TX512.DWG
7D1RETIC.DWG
7DEWR13-2 26 1 COLD BASE COPPER — 13 A/R WIRE, 0.05Ø S.STL
7DEWR13-1 25 2 COLD POST COPPER 7DEWR6-3 12 3 WASHER S.STL
7DEWR12-2 24 4 SUPPORT LEG S.STL 7DEWR6-2 11 3 SCREW S.STL
7DEWR14-1 23 1 UPPER SPIDER S.STL 7DEWR6-1 10 3 NUT S.STL
7DEWR11-1 22 1 LOWER SPIDER ASSY S.STL 7DEWR6-4 9 1 SCREEN S.STL
7DEWR10-4 21 1 SOCKET 7DEWR5-5 8 1 BELLOWS ASSY S.STL
7DEWR10-1 20 2 ZIF SOCKET 7DEWR5-4 7 1 ION PUMP ASSY
7DEWR9-3 19 1 INNER CYLINDER S.STL 7DEWR5-2 6 1 CONNECTOR
7FRET9-2 18 1 UPPER HEAD S.STL 7DEWR5-1 5 1 SEAL OFF VALVE/PLUG S.STL
7DEWR9-1 17 1 LOWER HEAD S.STL 7DEWR4 4 1 ELECTRONICS BOX ASSY
7DEWR8-3 16 1 BOTTOM PLATE S.STL — 3 1 O-RING #247 A VITON
7DEWR8-2 15 1 OUTER CYLINDER S.STL 7DEWR3-2 2 1 WINDOW ASSY, SMALL
7DEWR8-1 14 1 TOP PLATE S.STL 7DEWR2-3 1 1 CCD, TEKTRONIX 512
FULL
A 3-16-88 j.o. RENAME, WAS 7D1T2048.DWG
B 4-25-88 j.o. O-RING 247 WAS 248.
SPECIAL DEWAR
DEWAR NO. 7
TEKTRONIX 512
7DEWR1.B

FIGURE 16



7DEWR13-2	26	1	COLD BASE	COPPER	–	13	A/R	WIRE, 0.054	S.STL
7DEWR13-1	25	2	COLD POST	COPPER	7DEWR6-3	12	3	WASHER	S.STL
7DEWR12-2	24	4	SUPPORT LEG	S.STL	7DEWR6-2	11	3	SCREW	S.STL
7DEWR15-1	23	1	UPPER SPIDER	S.STL	7DEWR6-1	10	3	NUT	S.STL
7DEWR11-1	22	1	LOWER SPIDER ASSY	S.STL	7DEWR6-4	9	1	SCREEN	S.STL
7DEWR10-2	21	1	SOCKET ASSY		7DEWR5-5	8	1	BELLOWS ASSY	S.STL
7DEWR10-1	20	2	ZIF SOCKET		7DEWR5-4	7	1	ION PUMP ASSY	
7DEWR9-3	19	1	INNER CYLINDER	S.STL	7DEWR5-2	6	1	CONNECTOR	
7FRE19-2	18	1	UPPER HEAD	S.STL	7DEWR5-1	5	1	SEAL OFF VALVE/PLUG	S.STL
7DEWR9-1	17	1	LOWER HEAD	S.STL	7DEWR4	4	1	ELECTRONICS BOX ASSY	
7DEWR8-3	16	1	BOTTOM PLATE	S.STL	–	3	1	O-RING #247	VITON
7DEWR8-2	15	1	OUTER CYLINDER	S.STL	7DEWR3-1	2	1	WINDOW ASSY, BIG	
7DEWR8-1	14	1	TOP PLATE	S.STL	7DEWR2-1	1	1	CCD, TEKTRONIX 2048	

FIGURE 17



7DEWR13-2	26	1	COLD BASE	COPPER	–	13	4.4'	WIRE, 0.064	S.STL
7DEWR13-1	25	2	COLD POST	COPPER	7DEWR6-3	12	3	WASHER	S.STL
7DEWR12-2	24	4	SUPPORT LEG	S.STL	7DEWR6-2	11	3	SCREW	S.STL
7DEWR12-1	23	1	UPPER SPIDER	S.STL	7DEWR6-1	10	3	NUT	S.STL
7DEWR11-1	22	1	LOWER SPIDER ASSY	S.STL	7DEWR6-4	9	1	SCREEN	S.STL
7DEWR10-3	21	2	SOCKET		7DEWR5-5	8	1	BELLOWS ASSY	S.STL
7DEWR10-1	20	2	ZIF SOCKET		7DEWR5-4	7	1	ION PUMP ASSY	
7DEWR9-3	19	1	INNER CYLINDER	S.STL	7DEWR5-2	6	1	CONNECTOR	
7FRET9-2	18	1	UPPER HEAD	S.STL	7DEWR5-1	5	1	SEAL OFF VALVE/PLUG	S.STL
7DEWR9-1	17	1	LOWER HEAD	S.STL	7DEWR4	4	1	ELECTRONICS BOX ASSY	
7DEWR8-3	16	1	BOTTOM PLATE	S.STL	–	3	1	O-RING #247 ⚠A	VITON
7DEWR8-2	15	1	OUTER CYLINDER	S.STL	7DEWR3-2	2	1	WINDOW ASSY, SMALL	
7DEWR8-1	14	1	TOP PLATE	S.STL	7DEWR2-2	1	1	CCD, RETICON 400 x 1200	

FULL

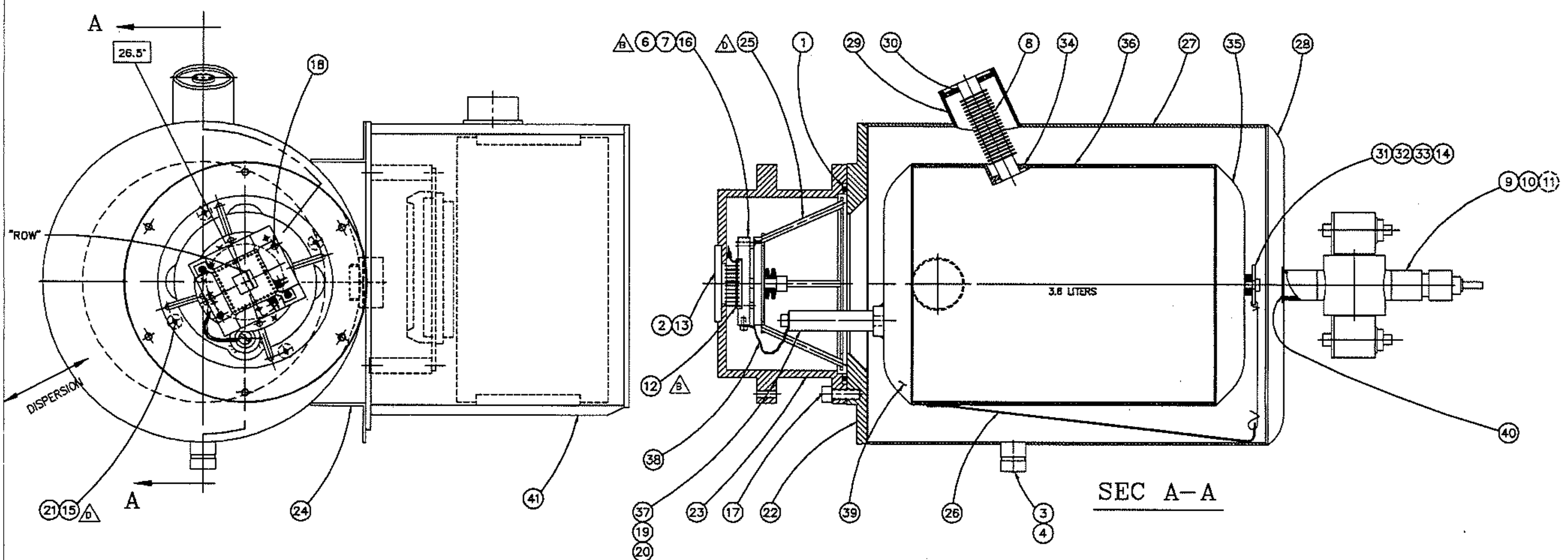
A 3-8-88 j.o. REDRAW FOR RETICON CONFIGURATION.
B 4-25-88 j.o. O-RING 247 WAS 248.

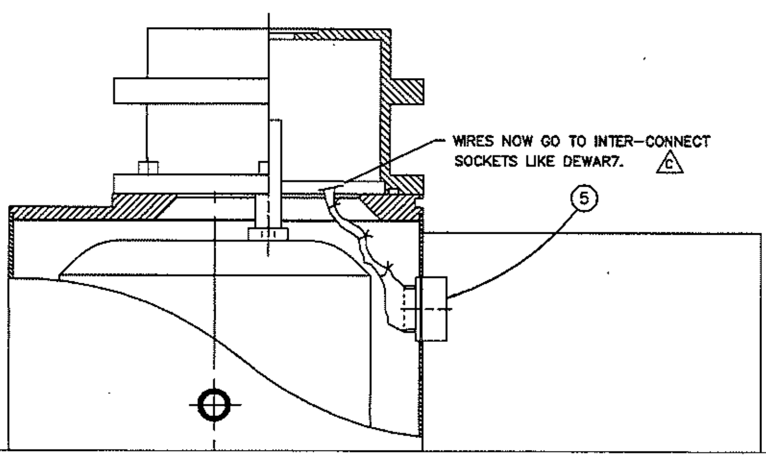
SPECIAL DEWAR
DEWAR NO. 7
RETICON CCD, 400x1200

7DEWR1.B

DRAWINGS ARE CALLED: 7D1T2048.DWG, 7D1TX512.DWG, 7D1RETIC.DWG

FIGURE 18





					– D	21	4	SPACER, 3/8ø1/8ø0.10	NYLON
33CAS229–1	41	1	ELECTRONICS BOX	ASSY	–	20	1	SCR, HOLLOW, #10–32	BRASS
33CAS222–4	40	1	SCREEN	ST STL	–	19	1	SCR, HOLLOW, #4–40	BRASS
–	39	1lb	PLATING	COPPER	–	18	2	FLT HD SCR, #2–56	ST STL
33CAS222–2	38	1	COPPER BRAID	ASSY	–	17	8	CAP SCR, #1/4–28 x 5/8	ST STL
33CAS222–1	37	1	COLD POST	COPPER	8DEWR7–1	16	1	SOCKET ASSY	
8DEWR5–6	36	1	INNER CAN	ST STL	–	15	4	CAP SCR, #4–40	ST STL
8DEWR5–5	35	2	INNER HEAD	ST STL	–	14	A/R	WIRE, 1/32ø	ST STL
8DEWR5–4	34	1	DIVET	ST STL	–	13	A/R	APIEZON WAX	
8DEWR5–3	33	1	WASHER	ST STL	–	12	1	TEXAS INST CCD 800x800	
8DEWR5–2	32	1	SCREW	ST STL	–	11	1	HIGH VOLTAGE CABLE	VARIAN
8DEWR5–1	31	1	NUT	ST STL	–	10	1	MAGNET	VARIAN
8DEWR4–4	30	1	CAP	ST STL	–	9	1	ION PUMP, 2 l/sec	VARIAN
8DEWR4–3	29	1	SPOUT	ST STL	–	8	1	BELLOWS, HUNTINGTON	ST STL
8DEWR4–2	28	1	BOTTOM PLATE	ST STL	–	7	2	130 OHM RESISTOR	
8DEWR4–1	27	1	OUTER HOUSING	ST STL	–	6	1	1N4148 DIODE	
8DEWR3–3	26	3	SUPPORT	ST STL	–	5	1	CONNECTOR	BENDIX
8DEWR3–1	25	1	SPIDER	ST STL	–	4	1	CRYOLAB PLUG	ST STL
8DEWR3–2	24	2	FLANGE	ST STL	–	3	1	CRYOLAB VALVE	ST STL
8DEWR2–2	23	1	LID	ALUM	–	2	1	QUARTZ WINDOW, 1.875ø	UV–1000
8DEWR2–1	22	1	TOP PLATE	ST STL	–	1	1	O–RING #247	VITON

FULL

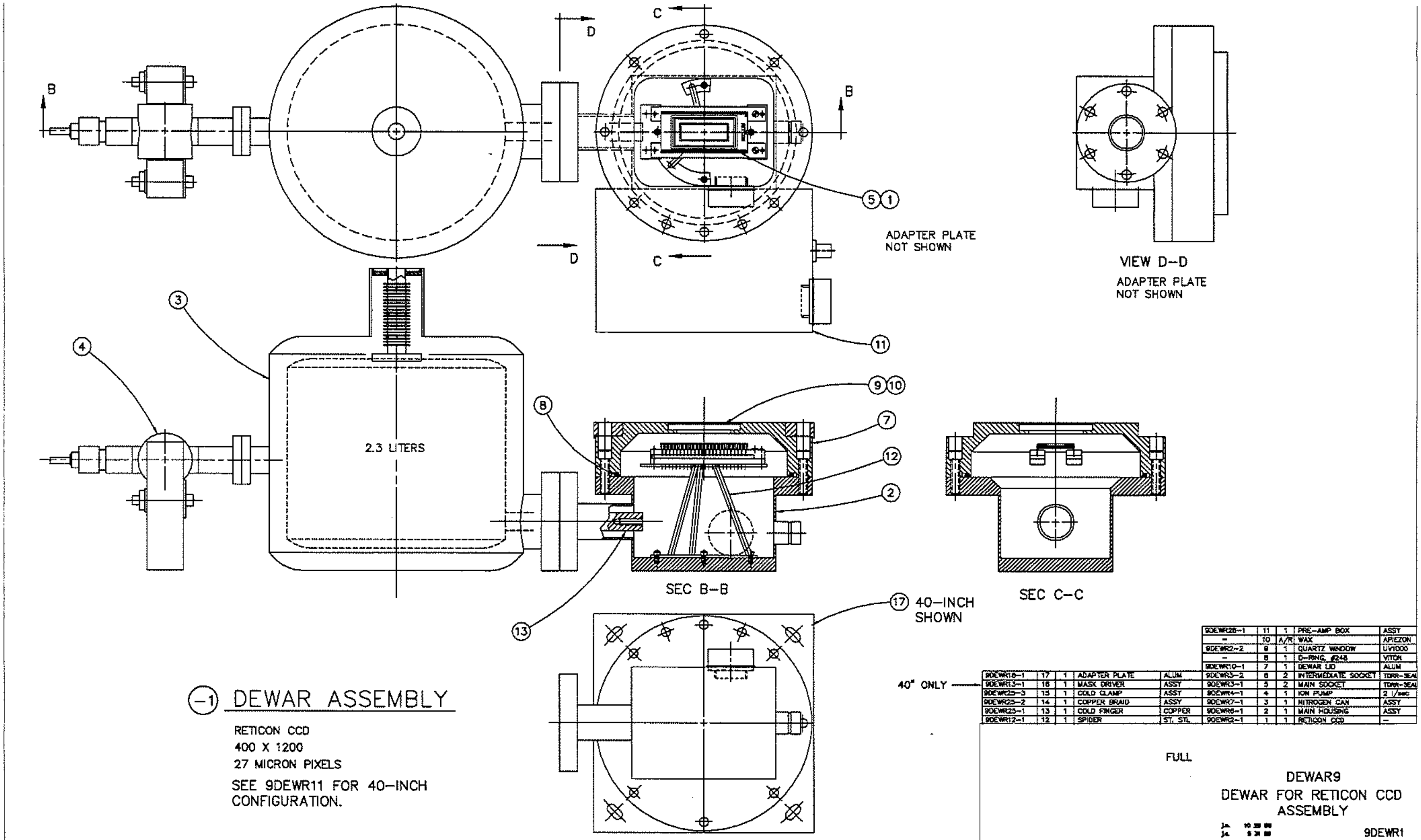
A	[illegible]	J.a.		UPDATE, LID PATTERN, TRIM BOX.
B	[illegible]	J.a.		SQUARE HEADER CCD MODS.
C	[illegible]	J.a.		MODIFY LID TO CLEAR SQUARE CCD
D	[illegible]	J.a.		RENAME, WAS DEWAR6–1.3. UPDATE.
				RAISE SPIDER 0.10" WITH PARTS 21.

J.a. 12 [illegible]

DEWAR8
ASSEMBLY

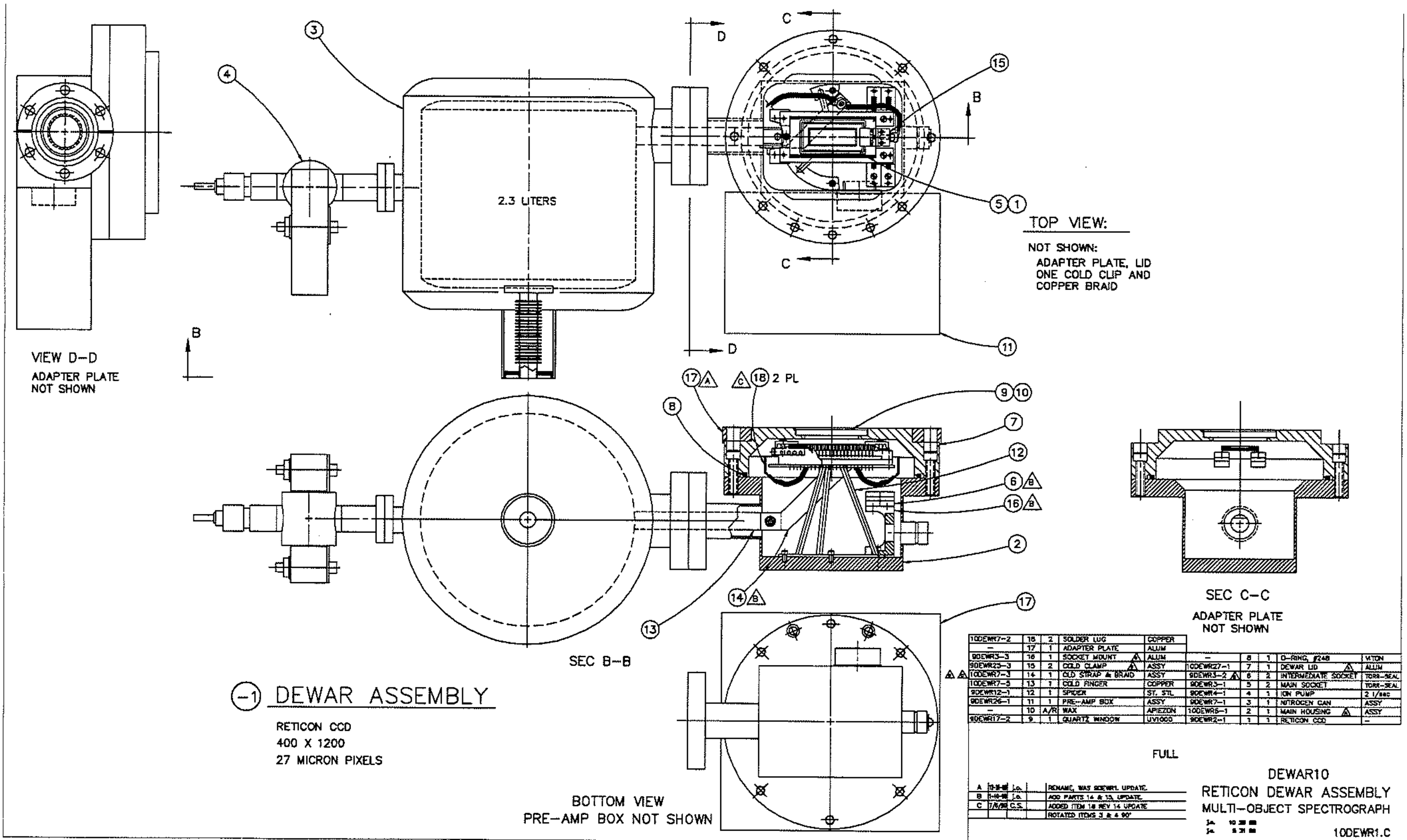
8DEWR1.D

FIGURE 19



9DEWR26–1	11	1	PRE–AMP BOX	ASSY
–	10	A/R	WAX	APIEZON
9DEWR2–2	9	1	QUARTZ WINDOW	UV1000
–	8	1	O–RING, #248	VITON
9DEWR10–1	7	1	DEWAR LID	ALUM
9DEWR3–2	6	2	INTERMEDIATE SOCKET	TORR–SEAL
9DEWR3–1	5	2	MAIN SOCKET	TORR–SEAL
9DEWR4–1	4	1	ION PUMP	2 l/sec
9DEWR7–1	3	1	NITROGEN CAN	ASSY
9DEWR6–1	2	1	MAIN HOUSING	ASSY
9DEWR2–1	1	1	RETICON CCD	–
9DEWR16–1	17	1	ADAPTER PLATE	ALUM
9DEWR13–1	16	1	MASK DRIVER	ASSY
9DEWR25–3	15	1	COLD CLAMP	ASSY
9DEWR25–2	14	1	COPPER BRAID	ASSY
9DEWR25–1	13	1	COLD FINGER	COPPER
9DEWR12–1	12	1	SPIDER	ST. STL.

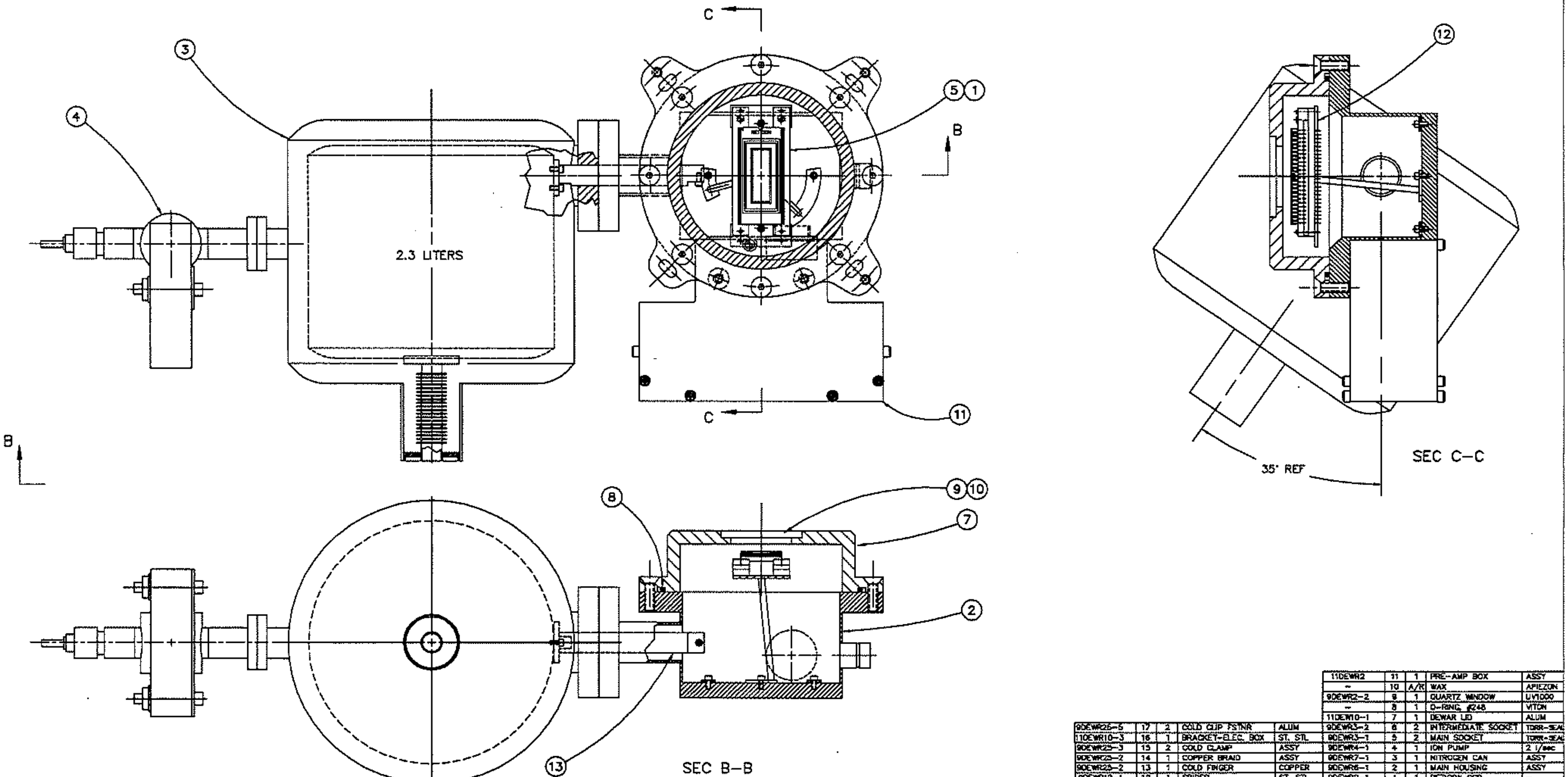
FIGURE 20



10DEWR7–2	18	2	SOLDER LUG	COPPER					
–	17	1	ADAPTER PLATE	ALUM					
9DEWR3–3	16	1	SOCKET MOUNT	ALUM	–	8	1	O–RING, #248	VITON
9DEWR25–3	15	2	COLD CLAMP	ASSY	10DEWR27–1	7	1	DEWAR LID	ALUM
10DEWR7–3	14	1	CLD STRAP & BRAID	ASSY	9DEWR3–2	6	2	INTERMEDIATE SOCKET	TORR–SEAL
10DEWR7–5	13	1	COLD FINGER	COPPER	9DEWR3–1	5	2	MAIN SOCKET	TORR–SEAL
9DEWR12–1	12	1	SPIDER	ST. STL	9DEWR4–1	4	1	ION PUMP	2 l/sec
9DEWR26–1	11	1	PRE–AMP BOX	ASSY	9DEWR7–1	3	1	NITROGEN CAN	ASSY
–	10	A/R	WAX	APIEZON	10DEWR6–1	2	1	MAIN HOUSING	ASSY
9DEWR17–2	9	1	QUARTZ WINDOW	UV1000	9DEWR2–1	1	1	RETICON CCD	–

A	[illegible]	J.o.	RENAME, WAS 9DEWR1. UPDATE.
B	[illegible]	J.o.	ADD PARTS 14 & 15, UPDATE.
C	7/6/[illegible]	C.S.	ADDED ITEM 18 REV 14 UPDATE
			ROTATED ITEMS 3 & 4 90°

FIGURE 21



					11DEWR2	11	1	PRE-AMP BOX	ASSY
					–	10	A/R	WAX	APIEZON
					9DEWR2–2	9	1	QUARTZ WINDOW	UV1000
					–	8	1	O-RING, #248	VITON
					11DEWR10–1	7	1	DEWAR LID	ALUM
9DEWR26–5	17	2	COLD CLIP FSTNR	ALUM	9DEWR3–2	6	2	INTERMEDIATE SOCKET	TORR-SEAL
11DEWR10–3	16	1	BRACKET-ELEC. BOX	ST. STL	9DEWR3–1	5	2	MAIN SOCKET	TORR-SEAL
9DEWR25–3	15	2	COLD CLAMP	ASSY	9DEWR4–1	4	1	ION PUMP	2 l/sec
9DEWR25–2	14	1	COPPER BRAID	ASSY	9DEWR7–1	3	1	NITROGEN CAN	ASSY
9DEWR25–2	13	1	COLD FINGER	COPPER	9DEWR6–1	2	1	MAIN HOUSING	ASSY
9DEWR12–1	12	1	SPIDER	ST. STL	9DEWR2–1	1	1	RETICON CCD	–

(–1) DEWAR ASSEMBLY

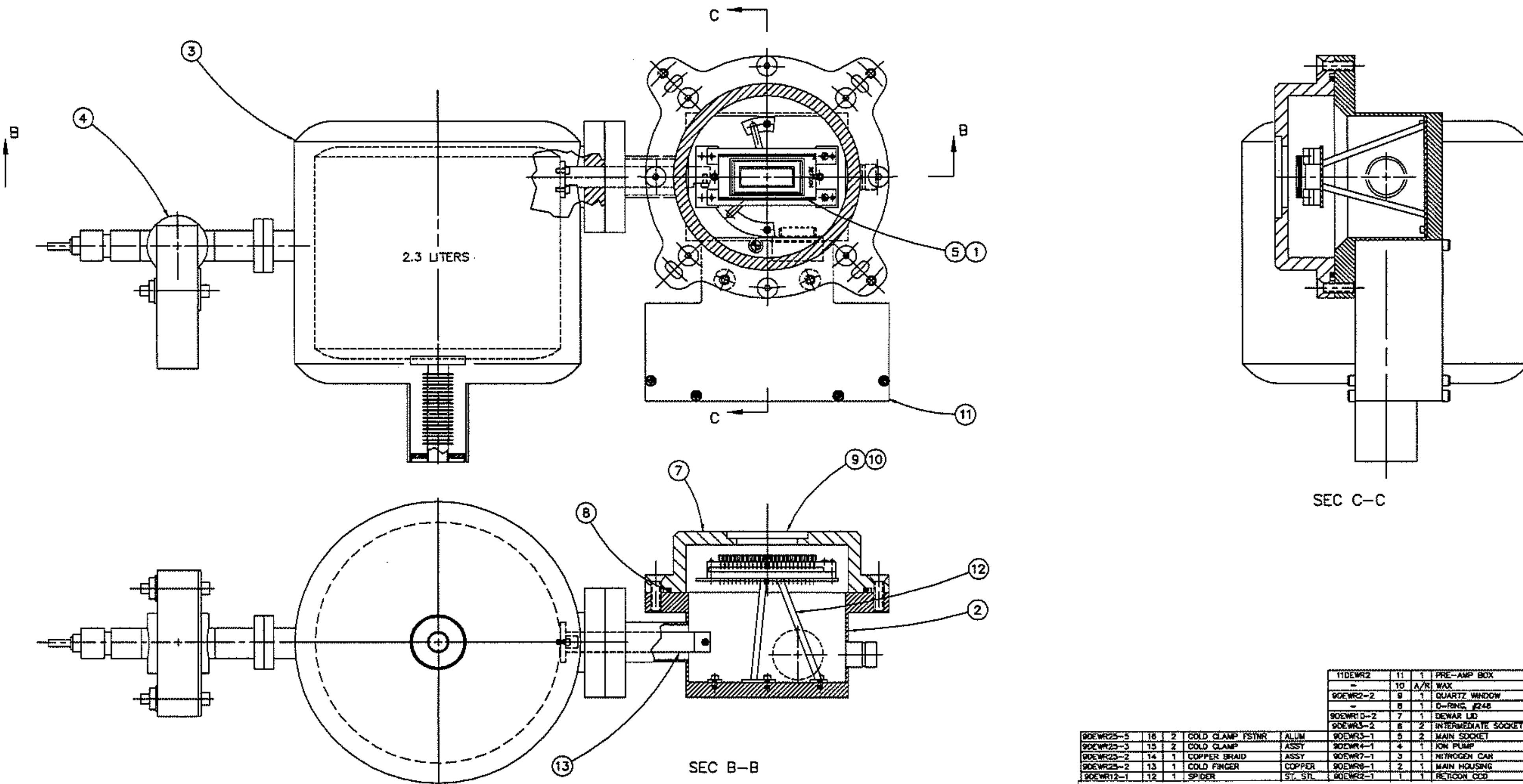
KAST SPECTROGRAPH BLUE CAMERA
120" TELESCOPE
400 X 1200 – RETICON
27 MICRON PIXELS

FULL

DEWAR11
DEWAR FOR RETICON CCD
ASSEMBLY

11DEWR1

FIGURE 22



					11DEWR2	11	1	PRE-AMP BOX	ASSY
					–	10	A/R	WAX	APIEZON
					9DEWR2–2	9	1	QUARTZ WINDOW	UV1000
					–	8	1	O-RING, #248	VITON
					9DEWR10–2	7	1	DEWAR LID	ALUM
					9DEWR3–2	6	2	INTERMEDIATE SOCKET	TORR-SEAL
9DEWR25–5	16	2	COLD CLAMP FSTNR	ALUM	9DEWR3–1	5	2	MAIN SOCKET	TORR-SEAL
9DEWR25–3	15	2	COLD CLAMP	ASSY	9DEWR4–1	4	1	ION PUMP	2 l/sec
9DEWR25–2	14	1	COPPER BRAID	ASSY	9DEWR7–1	3	1	NITROGEN CAN	ASSY
9DEWR25–2	13	1	COLD FINGER	COPPER	9DEWR6–1	2	1	MAIN HOUSING	ASSY
9DEWR12–1	12	1	SPIDER	ST. STL	9DEWR2–1	1	1	RETICON CCD	–

(–1) DEWAR ASSEMBLY

KAST SPECTROGRAPH RED-CAMERA
120" TELESCOPE
400 X 1200 – RETICON
27 MICRON PIXELS

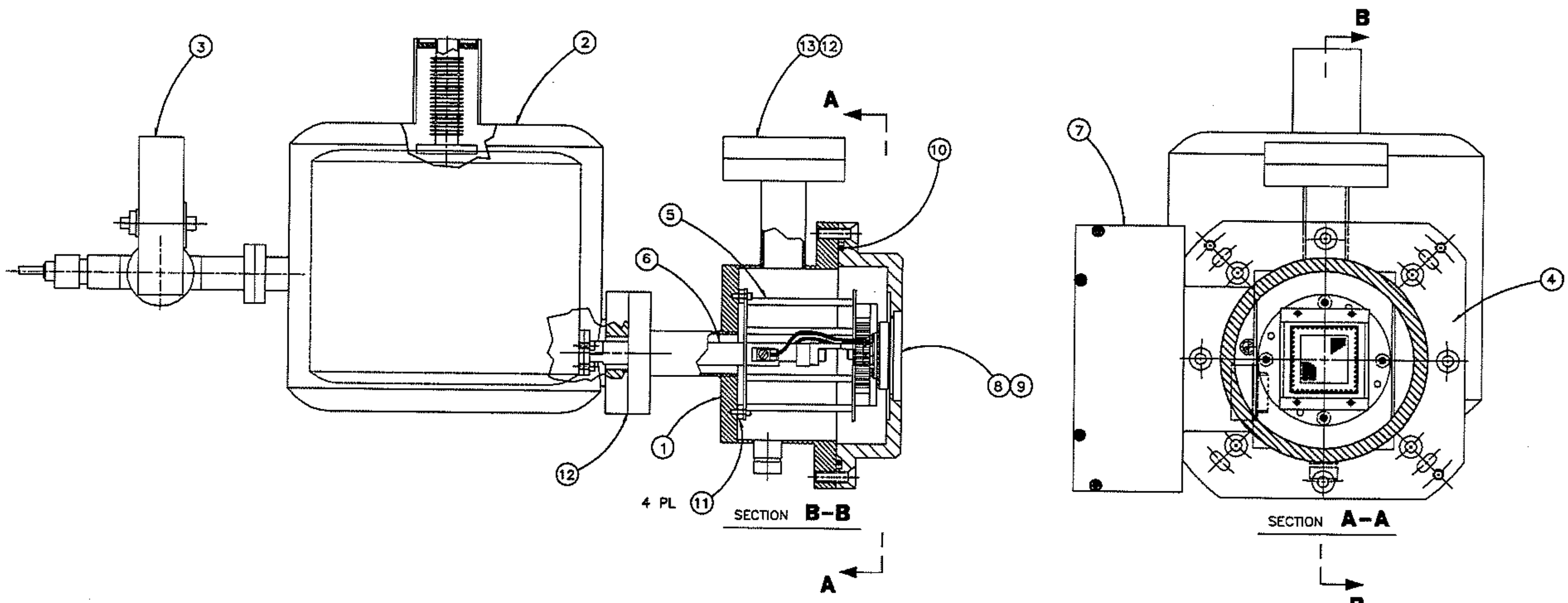
FULL

DEWAR12
DEWAR FOR RETICON CCD
ASSEMBLY

FN 1/26/90
CB 1/24/90

12DEWR1

FIGURE 23



(-1) DEWAR 13 ASSEMBLY

HAMILTON SPECTROGRAPH
120 IN TELESCOPE
COUD'E FOCUS
FORD CCD #22
2048 X 2048
15 MICRON PIXELS

–	13	1	2-3/4 BLANKET FLANGE (VARIAN)	
–	12	2	O-RING (VARIAN #01265301)	
13DEWR5-1	11	4	SPIDER STAND-OFF	ALUM
–	10	1	O-RING #248	VITON
–	9	A/R	WAX	APIEZON
9DEWR2-2	8	1	QUARTZ WINDOW	UV1000
11DEWR2	7	1	PRE-AMP BOX	ASSY
13DEWR3-2	6	1	COLD FINGER	ASSY
13DEWR3-1	5	1	SPIDER	ASSY
13DEWR4-1	4	1	LID DEWAR 13	ALUM
9DEWR4-1	3	1	ION PUMP	2 1/SEC
9DEWR7-1	2	1	NITROGEN CAN	ASSY
13DEWR6-1	1	1	MAIN HSG	ASSY

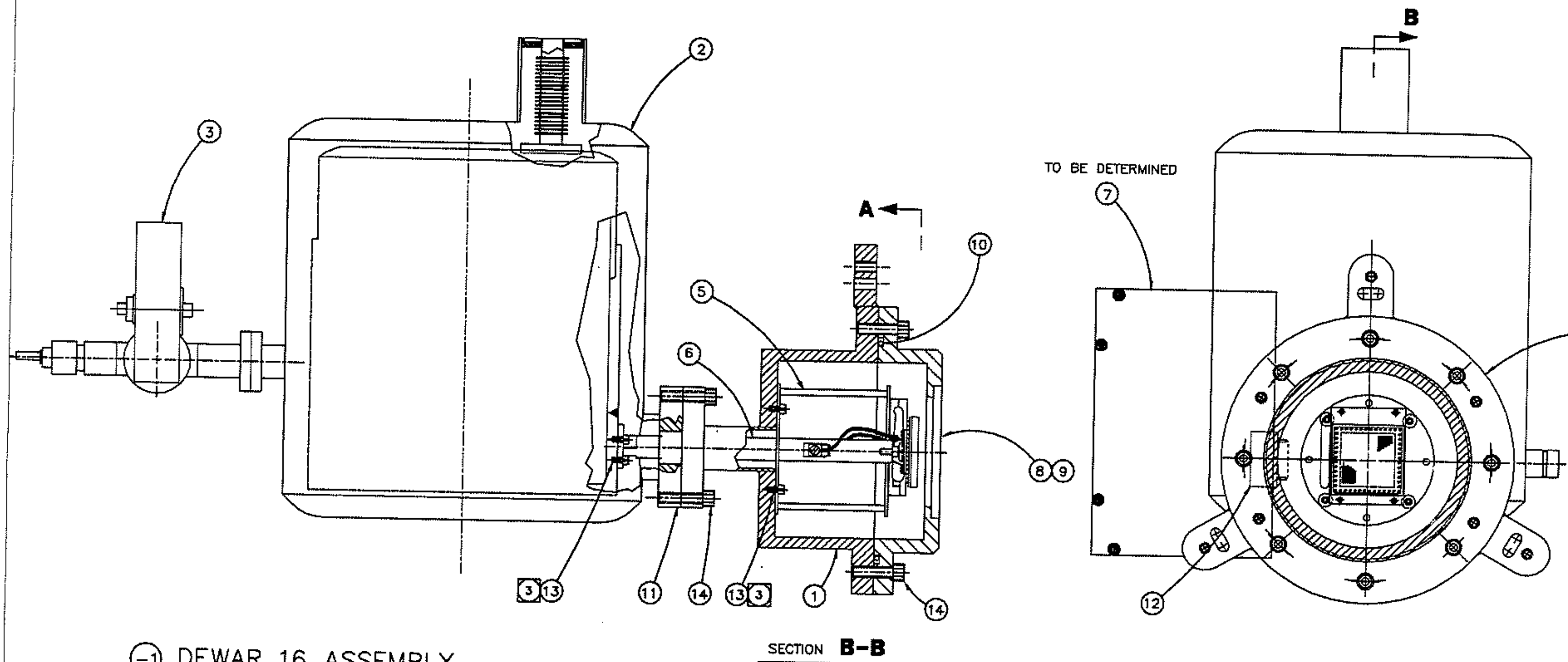
FULL

DEWAR 13
ASSEMBLY

F.M. 5/16/90
C.S. 5/16/90

13DEWR2

FIGURE 24



(-1) DEWAR 16 ASSEMBLY

MOS SPECTROGRAPH
120 IN TELESCOPE

NOTES:

1. FORD CCD
   2048 X 2048
   15 MICRON PIXELS

2. QUARTZ WINDOW
   UV1000
   3"ø X .180 THK
   COMMERCIAL POLISH
   80/50 SCRATCH
   3 WAVEOUT
   >90% CLEAR APERTURE

[3] SCREW TO BE VENTED WITH 0.050ø THRU HOLE

–	14	14	[illegible]	
–	13	7	[illegible]	
16DEWR13–1	12	1	CONNECTOR	
–	11	1	O–RING (VARIAN #01263301)	
–	10	1	O–RING #248	VITON
–	9	A/R	WAX	APIEZON
–	8	1	QUARTZ WINDOW	NOTE 2
T.B.D.	7	1	PRE–AMP BOX ASSY	
16DEWR05–1	6	1	COLD FINGER ASSY	
16DEWR04–1	5	1	SPIDER ASSY	
16DEWR05–1	4	1	COVER DEWAR 16	ALUM
16DEWR11–1	3	1	ION PUMP	2 1/SEC
16DEWR10–1	2	1	NITROGEN CAN	ASSY
16DEWR02–1	1	1	MAIN NSC ASSY	

FULL

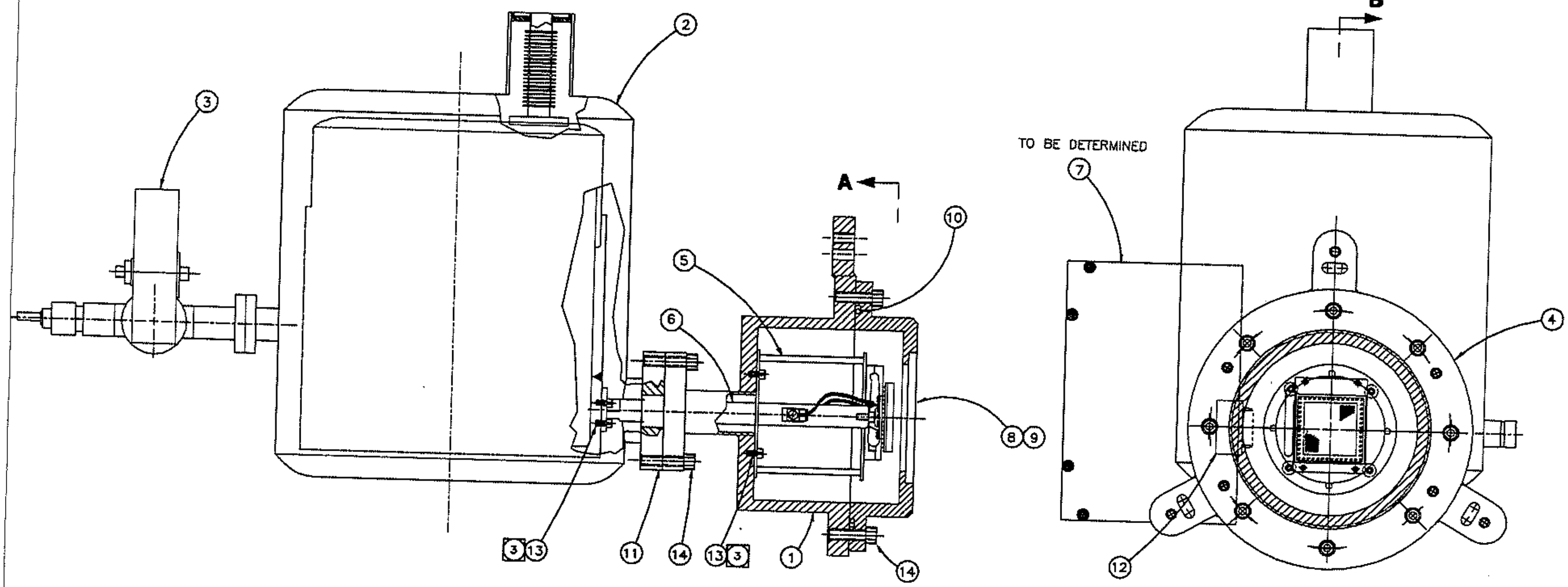
	[illegible]	MVR	MVR	EXTEND 2 3/4 CONFLAT FROM CAN
C	1/28/94	CAO		ADDED MOUNTING HOLES

DEWAR 16
DEWAR 16 – RED
ASSEMBLY

MVR
CAO

16DEWR01.C

FIGURE 25



① DEWAR 17 ASSEMBLY

MOS SPECTROGRAPH
120 IN TELESCOPE

NOTES:

1. FORD CCD
   2048 X 2048
   15 MICRON PIXELS

2. QUARTZ WINDOW
   UV1000
   3"ø X .180 THK
   COMMERCIAL POLISH
   80/50 SCRATCH
   3 WAVEOUT
   >90% CLEAR APERTURE

③ SCREW TO BE VENTED WITH 0.050ø THRU HOLE

–	14	14	1/4-[illegible] BOLT	
–	13	7	[illegible]	
17DEWR13–1	12	1	CONNECTOR	
–	11	1	O-RING (VARIAN #01263301)	
–	10	1	O-RING #248	VITON
–	9	A/R	WAX	APIEZON
–	8	1	QUARTZ WINDOW	NOTE 2
T.B.D.	7	1	PRE-AMP BOX ASSY	
17DEWR06–1	6	1	COLD FINGER ASSY	
17DEWR04–1	5	1	SPIDER ASSY	
17DEWR03–1	4	1	COVER DEWAR 16	ALUM
17DEWR11–1	3	1	ION PUMP	2 1/SEC
17DEWR10–1	2	1	NITROGEN CAN	ASSY
17DEWR02–1	1	1	MAIN HSG ASSY	

FULL

	[illegible]	MVR	MVR	EXTEND 2 3/4 CONFLAT FROM CAN
C	1/2/[illegible]	CAO		ADDED MOUNTING HOLES

DEWAR 17 – BLUE
DEWAR 17
ASSEMBLY

MVR 06 17 93
CAO 06 08 93

17DEWR01.C

FIGURE 26