Next100 Pressure Vessel - User's Design Specification (DRAFT 3)

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NEXT Collaboration

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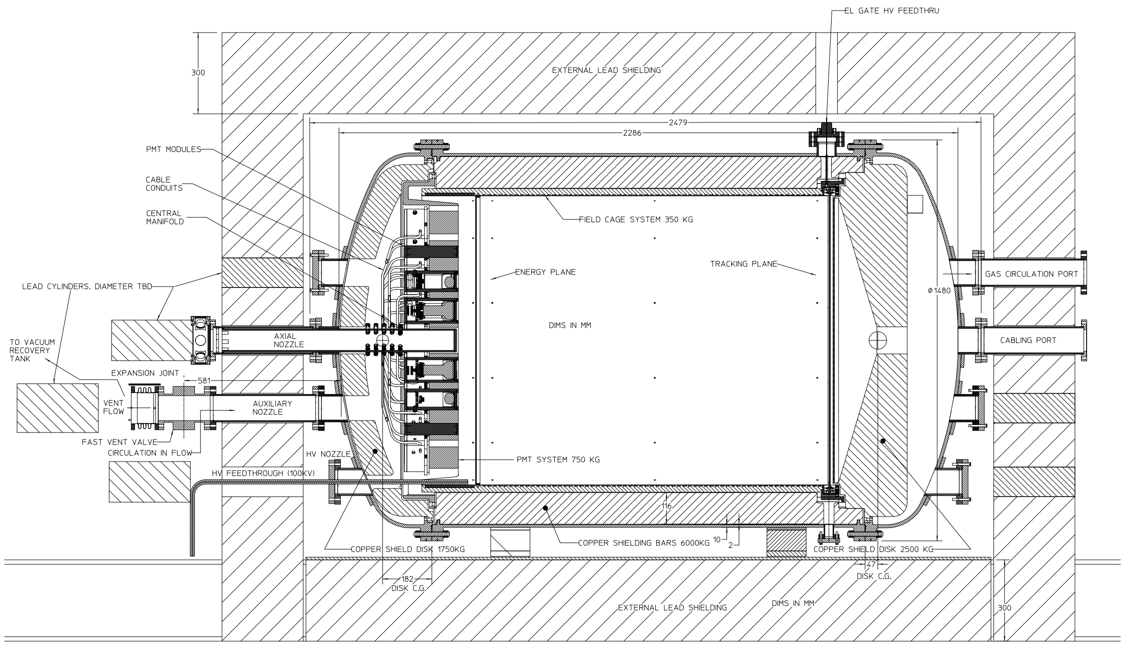

Figure 1: Detector Cross section

1 Introduction

This document is a User's Design Specification for a pressure vessel to be used in a neutrino physics experiment called NEXT-100. Drawings presented here are not to be considered final. Prospective Manufacturers are encouraged to provide feedback on the design, and details of fabrication, as well as preliminary cost and schedule estimates.

2 Purpose

The NEXT Collaboration is a group of physicists and engineers affiliated with Institute of Particle Physics/ University of Valencia, (IFIC) (principal institution), LBNL, and many others. The NEXT-100 experiment proposal is funded by this collaboration to build a detector to look for a phenomenon called neutrinoless double beta decay. The experiment requires a pressure vessel, to be used for gas containment, and additionally as the housing and support for a neutrino detector installed inside. Figure 1, below, shows a cross section of the detector inside the pressure vessel. This pressure vessel is the subject of this Specification.

3 Introductory Requirements Description

The pressure vessel has the following general requirements:

1. Size, Shape, Orientation: 1.360m inner diameter x 2.286m inside length, cylindrical main vessel section with detachable torispheric heads on each end, vessel axis horizontal, with two saddle

supports welded to main vessel shell. Welded-in nozzles on both the main vessel and the heads extend the overall size to 2.8m overall length x 1.5m high.

2. Assembly Configuration: 3 parts, a main cylindrical vessel with bolted flange connections to torispheric heads on each end. Flanges are flat faced with double O-rings or, possibly a Helicoflex C-ring/O-ring combination, to provide pressure and vacuum seal on both main flanges and on nozzle flanges.
3. Material: Main Vessel and Heads, shells, nozzles and flanges: Stainless Steel, 316Ti plate (UNS S31635, EN 1.4571) per ASME specification SA-240 or (EU) equivalent; main flange bolting: Inconel 718 ASME specification grade SB-637 (UNS N07718) or (EU) equivalent.
4. Fluid: gaseous xenon (primary), argon, neon, nitrogen, dry air, with small amounts of CF4, CH4, H2, at room temperature to 50C (negligible corrosive, flammable or toxic hazard).
5. Design Pressure Range : -1.5 atm to 15.4 barg (16.4 bara)
6. Leak Tightness: (1X10^{-6} torr*L/sec
7. Design Standard: ASME Pressure Vessel Code section VIII, division 1, using full weld efficiency (fully radiographed double and full penetration welds required). Other design standards allowable in Canfranc, Spain may be used. Note that although the requirement for a User's Design Specification is only required for Pressure Vessels designed under ASME section VIII division 2 rules, we regard this as an essential controlling document for the vessel.
8. Low residual background radioactivity; additional material and process screening, over and above that required by ASME Pressure Vessel Code, or equivalent, will be performed by the Collaboration; full cooperation of Manufacturer is required. Nominal design may be impacted by (now pending) test results.
9. Internal detector components will be supported on internal flanges on the vessel (on both main cylindrical and on torispheric heads), and nozzle flanges. Total weight of detector inside vessel does not exceed 13000 kg (13 metric tons).

These requirements and others are fully detailed in the Requirements section below. This includes requirements outlined in ASME PV code sec VIII, division 2, part 2.2.2 "User's Design Specification". We continue with the general description:

There are two unique and noteworthy aspects of this vessel; the first is a radiopurity requirement and, the second to a lesser extent, the need to mount internal components. The detector inside the vessel is highly sensitive to radiation from trace amounts of uranium (U) and thorium (Th). Austenitic stainless steel alloys contain uranium and thorium in trace amounts, from several parts per trillion (ppt) to hundreds of parts per million (ppm), only the lower levels are acceptable to us. 316Ti (1.4571) has been well characterized by others and found to typically show acceptably low levels; this is the reason we are specifying its use, even though other alloys may also be acceptable.

To assure sufficient radiopurity of materials, the Collaboration will require samples (several kg. each) from all raw material lots (bar, plate, tubing, forging ends, etc.) in order to perform background radiation counts prior to the material be accepted for fabrication, These counts take 1 month each to perform and we can only perform 2 simultaneous sample measurements at one time, so adequate material procurement scheduling is required.

Regarding manufacturing, thoriated TIG welding electrodes, and guns that have been used with such electrodes must not be used. Ceriated, lanthanated, yttriated, or plain tungsten electrodes are acceptable. Special cleaning procedures for material preparation are required, and may be subject to testing by the Collaboration and may be modified

The pressure vessel also serves to support the detector inside. The detector contains a large amount of radiation shielding, in the form of precision machined copper bars and plates, approx. 12000 kg of copper in all. The vessel to head flanges incorporate internal flanges for mounting of both this copper shielding and the detector components. As such all final machining on the must be performed only after a full stress relief anneal is performed after welding operations. Head to vessel flanges are nominally bolted; a flat faced flange design is used having 2 O-rings for seals, with a vacuum sense port in between them to detect leakage. The inner groove will be compatible, if feasible, with a Helicoflex gasket, loaded to its Y1 unit force. Manufacture must only demonstrate proper sealing performance using elastomer O-ring seals in both grooves. Manufacturer is invited offer some details as to preferred fabrication details before final specification is issued.

4 Parties to the Contract

Henceforth in this Document, the parties to the contract are listed and defined as follows:

4.1 Collaboration

The Collaboration is headed by Dr. J.J. Gomez, IFIC. The lead mechanical engineer for the pressure vessel is Derek Shuman, LBNL, with assistance from mechanical engineers: Sara Cárcel and Alberto Martínez (IFIC). Sara will be the prime contact person overseeing fabrication, as of this writing.

4.2 Manufacturer

This is the primary firm contracted with the Collaboration to perform or coordinated the design, fabrication, and testing. Subcontractors are not included, however, the rights of inspection negotiated between the Collaboration and the Manufacturer must be extended to apply to all subcontractors.

4.3 Certification Authority

This is an independent Certification Authority contracted to certify this document for completeness and correctness prior to the commencement of fabrication, and also to certify the Manufacturer's Design Report prior to the acceptance of the vessel by the Collaboration.

4.4 Inspector

This is a qualified person provided by the Certification Authority to perform inspections of all aspects of the design, fabrications and testing, in order to verify that the vessel has been designed, fabricated and tested in full compliance with the appropriate pressure vessel code.

5 Scope of Contract

Manufacturer is to supply, at a minimum, the complete vessel, in a clean condition compatible with high vacuum testing, complete with all flange bolts, nuts, washers, and all blank-off plates used for hydrostatic testing. Optionally, the Manufacturer may additionally supply the nozzle extensions, and other internal parts of the detector. Excess unused plate material shall be returned to Collaboration, if feasible. The Collaboration will supply the pressure relief devices. Here is a detailed list:

1. (1) main vessel, per LBNL drawing 26K590A
2. (2) torispheric heads per LBNL drawing 26K591A
3. (300) studs, per LBNL drawing 26K593A
4. (300) hex nuts, per LBNL drawing 26K597A
5. (600) washers, per LBNL drawing 26K598A

6. (4) O-rings, nitrile, 5mm x 1320mm ID, Trelleborg Fleximold splice-free suggested
7. (4) O-rings, nitrile, 3mm x 1460mm ID, Trelleborg Fleximold splice-free suggested
8. (16) O-rings, nitrile, 3mm x 90mm ID
9. (16) O-rings, nitrile, 3mm x 110mm ID
10. (4) O-rings, nitrile, 3mm x 65mm ID
11. (4) O-rings, nitrile, 3mm x 70mm ID
12. (12) O-rings, nitrile, 3mm x 35mm ID
13. (12) O-rings, nitrile, 2.5mm x 50mm ID
14. (2) heads per LBNL drawing 26K591A
15. (9) Nozzle Cover Plates, DN100 per LBNL drawing 26K594A
16. (3) Nozzle Cover Plates, DN75 per LBNL drawing 26K595A
17. (7) Nozzle Cover Plates, DN40 per LBNL drawing 26K596A
18. hardware (316 SS, silver plated) to attach the above 3 items to vessel flanges
19. Manufacturers Design Report, in both Spanish and English

6 Responsibilities

6.1 Manufacturer

6.1.1 Accreditation

Manufacturer, and all subcontractors, is required to be fully certified under ASME rules, or European equivalent, to design, fabricate , inspect, and test pressure vessels. Welders and NDT inspectors, in particular, shall be certified to perform all operations required.

6.1.2 Material Use Planning

Manufacturer is to use materials provided by the Collaboration to fabricate the vessel, unless other arrangement is made. Manufacturer is required to approve any materials provided by the Collaboration with regards to fitness of use. Manufacturer must request any certifications, samples needed for testing. Manufacturer is to specify the range of raw material sizes, and the amounts of each needed to fabricate the vessel All materials and equipment used, that are supplied by the Manufacturer, are subject to approval by the Collaboration, both raw materials that will be part of the vessel, and all other materials and equipment used in the manufacturing process.

6.1.3 Final Design

Manufacturer is responsible for the pressure integrity of the vessel and is required to perform all necessary calculations and analyses, as Manufacturer sees fit. Detailed preliminary calculations are provided by the Collaboration, in the Appendix, as a convenience, and to justify the dimensions of the vessel presented here in this Specification, however manufacturer is ultimately responsible for pressure integrity and sufficiency of design. Manufacturer may propose changes to the design, however these must be approved by the Collaboration. The design presented here is performed according to the rules of ASME section VIII, division 1, with full weld efficiency, which is required in the final design. This requires full penetration double welds on the major welds plus a full radiographic inspection. Other codes that are acceptable in the Jurisdiction of Canfranc, Spain are acceptable in part, or in full, as allowed by the codes themselves.

6.1.4 Fabrication Plan

Manufacturer is to submit a detailed fabrication plan to Collaboration for approval prior to commencement of fabrication, describing the sequence of operations to be used in fabricating and testing the vessel. These shall include (but not be limited to) the following:

1. Main Cylindrical Vessel: shell forming and welding sequence, all dimensions of shell sections, rolling methods, edge preparations and cleaning, welding procedures and equipment, intermediate heat treatments, and inspections.
2. Torispheric Head: shell forming, rolling methods, edge preparations, welding procedures and equipment, intermediate heat treatments, and inspections.
3. Head to Vessel Flange fabrication sequence, all dimensions of flange sections, edge preparations, welding procedures, intermediate heat treatments and inspections.
4. Flange to Shell Weld joint design

6.1.5 Collaboration Access

Manufacturer and all subcontractors are to allow visits and inspections by members of the Collaboration during any and all parts of the fabrication, upon request. This is in addition the access granted to the Inspector of the Certifying Authority.

6.2 Collaboration

Collaboration is responsible for finding and securing the required material in timely manner prior to scheduling construction. The Collaboration is responsible for timely radiopurity testing of material samples from lots. Each of these measurements can take up to one month to complete. A schedule of radiopurity measurements will be drafted once the manufacturing process is fully known.

7 ASME User Design Specification

2.2.2.1 ASME required specifications

a) Installation Site

1) Location - Installed location - Canfranc Spain, inside Canfranc Under Ground Laboratory (LSC) in Hall 1. Vessel may be staged temporarily at some other location, perhaps for pressure testing, and/or for trial assembly of detector. This location will be either at IFIC in Valencia, or perhaps at University of Zaragoza, or some other location in Spain.

2) Jurisdictional Authority All that are required for the locations listed above

3) Environmental conditions

i) Wind loads - None

ii) Seismic Design Loads - 1m/s^2 (0.1g) maximum vertical (over static gravity); 2 m/s^2 maximum horizontal acceleration. Vessel will be mounted on a shock isolating platform, and will be elevated above the hall floor by 1.2m

iii) Snow Loads - None

iv) **Lowest one day mean temperature-** 10C . Note - remote possibility exists of cryogen spill underneath pressure vessel, with temperature unknown. Cryogenic liquid is not expected to contact vessel, as the vessel will be mounted on a platform at least 1.5 m above the main hall floor, and a total cryogenic liquid spill will result in at most a few cm of liquid height on floor. Nevertheless, vessel will be immediately vented to 0 barg upon receiving a fault signal indicating a cryogen spill in the LSC hall.

b) **Vessel Identification**

1) **Vessel Number -** "NEXT100-PV1"

2) **Fluids -** gaseous xenon (primary), argon, neon, nitrogen, dry air, with small amounts of CF4, CH4, H2 (<5%), all held at room temperature to 50C (negligible corrosive, flammable or toxic hazard). No liquids will be introduced into the vessel, other than cleaning, in the disassembled condition or perhaps in an assembled condition, unpressurized. Although not presently planned, the vessel may eventually be immersed in a fluid bath, of either ultrapure water, or scintillator fluid (as yet unknown), with the vessel in either the pressurized or vacuum condition. Maximum fluid pressure of this bath will be, at the lowest point of the vessel no higher that 0.35 barg, from hydrostatic head only, the water or scintillating fluid being at atmospheric pressure. There should be no corrosion allowance made in the design for this possible future use; adjustment will be made to operating pressure if needed.

c) **Vessel Configuration and Controlling Dimensions -** The vessel will be oriented with its axis of revolution in the horizontal direction. LBNL Drawing number 26K589A shows the assembled vessel with controlling dimensions, some of which are listed below:

Inside Diameter, Vessel and Head Shells	1360 mm
Inside Length, on Centerline Axis, including Heads	2286 mm
Length, Main Cylindrical Vessel	1600 mm
Torispheric Head Inner Crown Radius (R_c=1.0D, Kloepper)	1360 mm
Torispheric Head Inner Knuckle Radius (R_k=0.1D, Kloepper)	136 mm
Center axis height above floor(including support pads)	800mm

Table 1: Required Geometric Values

d) **Design Features**

1) **Supports -** The vessel shall be designed with saddle supports welded to the main cylindrical vessel. These supports shall be sufficient to support the weight of the pressure vessel, with all internal components and fluids, for static gravity plus the maximum seismic acceleration, described below. The supports shall be designed to accommodate expansion and contraction of the vessel, from both pressure/vacuum and from temperature excursions. The vessel must return to the same position upon returning to normal operating temperature. The proposed design utilizes low friction polymer bearing pads in a 2D kinematic support arrangement (shown in the Calculations); Manufacturer may propose alternate methods or materials. The vessel may be lifted with slings while empty. It is not foreseen that the vessel will be lifted with the internal copper shielding inside, however jacking screws on the support feet are provide for leveling with the copper inside. The Appendix contains a set of illustrations detailing the proposed design.

The torispheric heads are not required to have lifting lugs welded to them, though Manufacturer may elect to add these, with prior approval. If lugs are added, they must be designed for the entire mass of the head plus its internal copper disk (2500 kg). The collaboration will be using specially designed lift fixtures to handle the heads; these attach to the head using various combinations of the flange bolt (clearance) holes. Some of these clearance holes will be threaded to accept certain lift fixture mounting bolts. See section on Loads below for further description.

2) **Flanges -** The main cylindrical vessel flanges incorporate a step of 1mm to provide a recessed gasket sealing surface for protection against damage. Simple flat covers may then be used for servicing conditions. Care must still be taken during final machining and later operations to place the flange surface on a very clean surface with no chips or debris.

   The head flanges contain 2 O-ring grooves, the inside a pressure seal and the outside a vacuum seal. Four drilled holes (vacuum ports) located between the lands allow vacuum checking for O-ring permeation or leakage. A shallow groove at this radial location is incorporated to improve gas conductance to the vacuum ports.

   A "shear lip" is incorporated in the ID of the head flange which fits inside the Vessel ID so as to prevent the head from sliding downward in case the flange studs somehow come loose or the joint opens under pressure (not likely to occur), though very little extra stud tension is needed to support the head vertically by friction. The shear lip may also reduce light leakage through the O-rings, should this be a problem.

e) Design Conditions

Internal Pressure, MPa (g)	External Pressure, MPa (g)
1.54	0.15

Table 2: Design Pressures,(gauge)

f) Operating Conditions

1) **Maximum Operating Pressure (MOP) -** 14.0 barg

2) **Maximum Allowable Working Pressure (MAWP) -** 15.4 barg

3) **Operating Temperature -** 15C-30C. Temperature may rise to 150C under a vacuum (-1.0 barg) condition, but not under pressure condition.

4) **Fluid Transients and Flow -** A typical operating cycle, following any condition requiring the vessel to be opened, is as follows:

   1. Vessel will be pulled to vacuum condition and held for several days. Vessel may be heated to 50C during this operation.
   2. Xenon gas will then be introduced at a slow fill rate, no less than 10 min. to fully pressurize.
   3. Xenon gas will then be circulated at 200 SLPM through the vessel/ purifier circuit. Detector will be operated during this time, continuously, without interruption of flow or pressure, for as long as possible.

   Should the detector need a repair which requires removing at least one of the heads or nozzle attachments, the following sequence of operations is performed:

   1. Vessel will be vented by opening a valve connecting to a cryogenic recovery cylinder, depressurization is expected to take at least 30 minutes. Pressure will be reduced to less than 1 torr.
   2. Vessel will be filled with clean dry air to 0.01-0.1 barg, then vented to atmosphere.
   3. The head assembly fixture will be assembled to the floor.
   4. Head to flange studs occupying the threaded holes in the head are be removed

5. The head assembly fixture is then aligned to closely mate with the head flange and is then bolted to the head
6. The remainder of the head to vessel flange studs are removed to allow head to be moved away from the vessel, on the fixture rails, by a distance of 1m
7. A second lift fixture is then bolted to the head using a number of holes at the top; this lift fixture provides a single lift point for attachment to a crane hook, with the lift point over the center of gravity of the head/internal copper shield disk assembly. See section on Loads below for further description.

Under a possible emergency condition defined as an abnormally high pressure drop rate occurring during normal operation, the vessel will be vented in approximately 10 sec. to the large vacuum tank, in order to minimize loss of the xenon into the LSC Hall. This will be accomplished by using at least one remote operated active vent valve that will open fully upon receiving a controller signal. Figure 1 shows the location of this valve. This valve is in parallel with the main pressure relief valve (not shown). The active vent valve will be a straight-through design, so that reaction force does not exert a force transverse to the nozzle axis. However, the possibility exists that a right angle valve might mistakenly be substituted, and so the auxiliary nozzles on each head must be designed to withstand a moment caused by the reaction force from this valve. The maximum flow rate will be 25 kg/sec (Xe). The reaction force associated with this flow (xenon) is 3500 N. The vent valve will be located on the end of a nozzle extension that is 58cm long; thus a maximum moment of 2300 N*m may be applied to the nozzle to head weld; this is the design requirement for weld and nozzle sufficiency. The relief valve for fire condition or failed regulator is much lower flow and may be a right angle valve. It may be located next to the active fast vent valve, in parallel flow, or may be located on the tracking plane head auxiliary nozzle (right side of fig. 1).

g) **Design Fatigue Life -** The vessel is estimated to undergo not more than 200 full pressure cycles, at most (including head removals) during its lifetime. Each vessel head is not expected to be removed more than 50 times. Pressure will remain static for each pressure cycle; i.e. pressure is not varied during vessel operation, only during filling and venting. Some pressure cycles will be less than full MOP. Pressure change rate under typical operating conditions will be low, less than 0.001 bar/sec. There will be a few rapid depressurization events, of maximum 2 bar/sec using a remote actuated vent valve; not more than 10 of these cycles are estimated to occur, primarily from testing.

h) **Materials of Construction**

1) **Vessel -** Stainless Steel plate, 316Ti (UNS S31635, EN 1.4571) per ASME SA-240 specification or equivalent: all vessel shells, nozzles and head-to vessel flanges shall be made from plate unless other forms are allowable, under acceptable pressure vessel codes other than ASME sec VIII, div. 1. Material will be provided by the Collaboration.

2) **Bolting -** Inconel 718 (UNS N77180) to ASME SB-637 standard or equivalent, studs, nuts and washers. Material will be provided by the Collaboration.

i) **Flange Seals**

1) **Main Head to Vessel Flanges-** O-rings: butyl, nitrile, possibly PCTFE or PTFE ((nozzle flanges only), or special low force Helicoflex (type HN200), aluminum jacket. Main head to vessel flanges will be double O-ring sealed, the larger cross section O-ring for pressure, the outer, smaller cross section for vacuum. The annulus between them will incorporate a sense port for leak checking the O-rings.

2) **Nozzle flanges** All nozzle flanges are sized to ASME standards (section VIII, div 1, Appendix Y) using standard CF knife edge flange bolt patterns. This is to allow use of pressure rated or tested

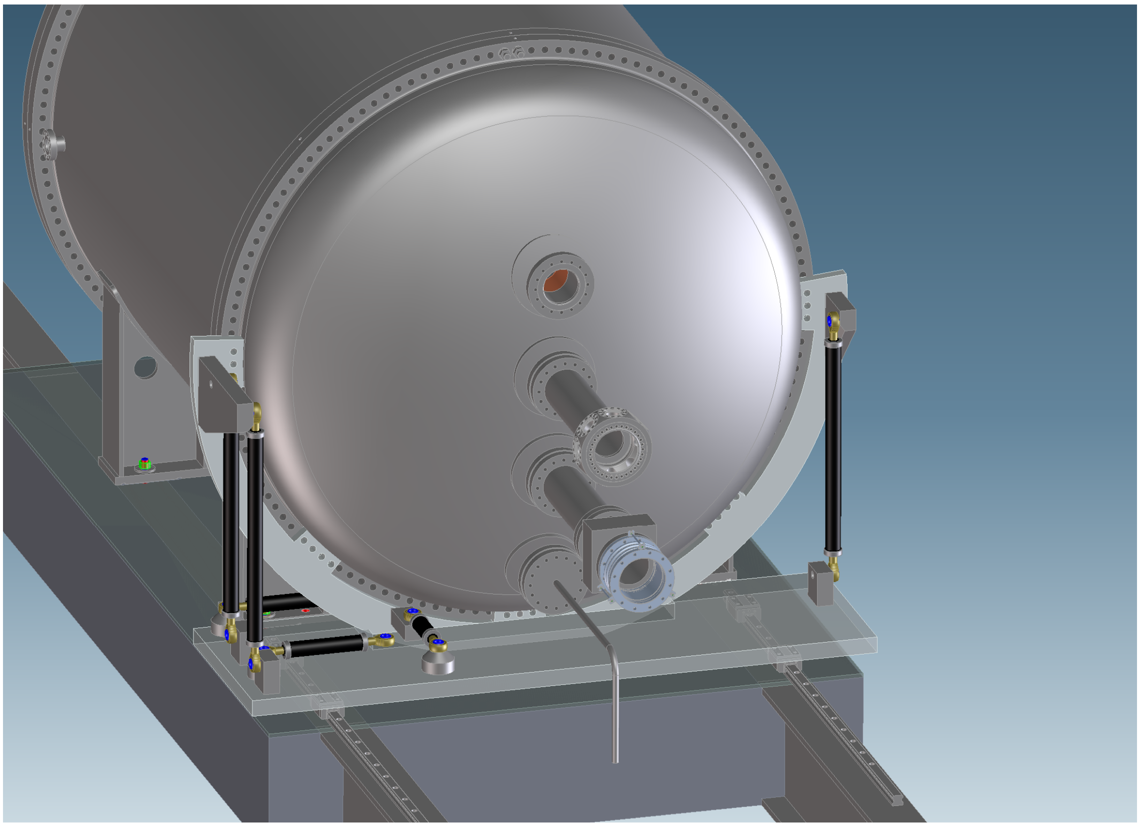

Figure 2: Head Assembly Fixture

CF components via an adapter flange, if needed. The flange sealing faces shall be plain flat faced, to be used only with special interface flange plates having double O-ring, or O-ring/Helicoflex seals. Design gasket force shall be for Helicoflex Y2 values, if feasible, but at least 3x Y1 value.

j) **Loads and Load Cases -** The vessel supports an internal detector of no more than 12000 kg. The weight is almost entirely in the form of copper bars supported by the main cylindrical vessel and copper disks supported by the heads.

A circular array of copper bars, each the full length of the main cylindrical vessel will be mounted to the internal flanges of the main cylindrical vessel; these comprise a total of 6000 kg. Up to an additional 1000 kg of detector components are attached to each end of the bar array, for a total mass of 8000 kg supported by the two internal flanges of the main cylindrical vessel, 4000 kg on each flange. These bars attach to the vessel only by the internal flanges, no contact is made with the main vessel shell.

One head will contain a copper disk of 1500 kg, the other a disk of 2500 kg. , each mounted to the internal flange of the head. Figure 1 shows the locations of the centers of gravity. The heads must support this weight in any orientation when detached from the main cylindrical vessel. Provision will be made for differential thermal expansion between head and disk, if needed, to eliminate unwanted stress. The heads are handled separately by attaching lift fixtures to the flange bolt holes, using through bolts and nuts. To perform the initial separation of the head from the vessel, some of these flange holes are threaded for a several mm size larger bolt, in order to attach the head retraction fixture which is used to bring the head up to/away the vessel (on precision rails). The resulting effective hole diameter still yields acceptable stress levels under operating pressure. These threaded holes must be sleeved when the head is bolted to the main vessel, so as to prevent interference between them and the bolt threads. Fig . 2 shows the fixture in use:

k) **Overpressure Protection -** There are no conditions, short of a fire in the LSC hall that can lead to an overpressure condition. There are no flammable gas mixtures, nor any oxidizing gases inside the vessel at any time when it is closed (dry air may be circulated through the vessel when heads are removed to allow people to work inside). There are only metals, ceramics and common plastic materials such as polyethylene, PEEK, PTFE, PMMA, epoxy, etc. inside the vessel, There are electrical components inside generating no more than 1 kW of heat dissipation, these will be actively cooled with water cooling circuits, either inside the vessel, or outside, using either the xenon gas or the vessel as a heat transfer surface (10C maximum allowable temperature rise above 20C ambient; 30C actual temp). Fast vent capability is incorporated solely for the purpose of minimizing gas loss in the case of an unexpected leak, as the xenon gas is very expensive and the LSC Hall is an enclosed space. Fast venting, in an emergency, will be done by actuating a remote operated vent valve leading directly to a large evacuated recovery cylinder of 20-30 m^3 (thus reducing pressure to <1 bara). The high cost of the xenon, and the enclosed underground cavern combined with the potentially dangerous anesthetic properties of xenon gas preclude venting directly to atmosphere. There will be two relief devices, one passive and one active:

1) Passive: Pilot operated reclosable relief valve, back pressure insensitive - set to 100%MAWP), valve sized for fire or malfunctioning regulator.

2) Pilot operated servo vent valve, 65 mm vent dia. - Set to actuate only upon emergency signal (indicating a substantial leak), at any pressure, for fast vent to vacuum tank. maximum discharge rate is, for xenon at 15 bara 25 kg/sec. This valve will be a straight through design, to eliminate torque on the nozzle from reaction (it may be located at the end of a 60 cm long nozzle extension). However the nozzle must be designed to withstand a reaction force directed at a right angle to the nozzle axis, as described above

2.2.2.2 Additional Specifications

a) **Material Supplied by Collaboration -**

As part of the radiopurity requirement below, the Collaboration will find, measure samples and purchase all consumable materials used for fabrication, including plate and welding wire. These shall be purchased and secured prior to commencement of fabrication. Manufacturer shall submit a list of materials to purchase which must include all necessary allowances for trimming and finish machining.

b) **Minimum Thickness Design -**

This requirement is driven by the radiopurity requirements below; the proposed design assumes a weld efficiency of 1.0 for any division 1 calculations and thus will require a full radiographic inspection of all pressure bearing welds. Welds in category A and B will be required to be full penetration double welds.

The use of a large number of flange bolts and the specification for using fine thread Inconel 718 bolting material follows, this minimizes flange outer diameter; bolt holes will need higher than usual dimensional accuracy and must not be rough drilled prior to final solution annealing.

c) **Use of Plate Stock for Flanges -**

The flat faced flange design used is designed to div. 1 rules, Appendix Y. Div. 1 allows flanges to be made from plate if no hub is present (which is the case in this design). Plate stock is not ideal for machining into flanges, and there is some possibility that leakage paths from laminar flaws inside the plate may compromise the vacuum tightness of the vessel. 316Ti plate is the only permissible form in Div. 1. and the Collaboration is supplying 50mm stock which precludes rolling and welding into a ring. Manufacturer is cautioned to perform any necessary tests such as X-ray, ultrasound, or helium leak checking of samples, above that which are required under ASME code, so as to assure vacuum tightness as specified in the Specification.

d) **Radiopurity Assurance -**

In order to assure that all materials used to fabricate the vessel are of high radiopurity and do not become contaminated in the fabrication process, there will be additional material checks of both raw material, and of samples from each fabrication process along the way. Every effort will be made to determine the scope of these checks. Therefore Manufacturer has a responsibility to disclose any and all fabrication processes to be used, both prior to start of fabrication, and through fabrication, inspection and testing. Each material sample test takes 3 weeks to perform, so Manufacturer must be forthcoming in disclosures. Tests may be performed on the following items:

1) Possible Tests on Materials

- **i)** ends from all raw plate used to fabricate vessel shells, flanges, attachments and supports
- **ii)** ends from all finished rollings and spinnings after welding, cylinder and both heads
- **iii)** ends from all bar, pipe and tube stock used for nozzles and nozzle flanges
- **iv)** ends or samples from all bar stock used to fabricate flange bolts and nuts, if applicable

2) Procedures -

- **i)** All welding shall be of the gas tungsten arc (GTAW) in accordance with ASME or equivalent procedures.
- **ii)** The welding will be done by ASME or equivalent qualified welders, as per ASME or equivalent requirements.
- **iii)** Filler for welding: 316Ti commercial use filler. Filler material samples shall be submitted to the Collaboration for radiopurity measurement; if unacceptably contaminated, filler metal may be made from from the supplied plate stock.
- **iv)** All parts shall be thoroughly cleaned prior to assembly and welding for welding per the following process:
  - **a.** All supplies and tools to be used are subject to approval by the Collaboration. Manufacturer shall submit a list of list of tools and machinery used for cleaning, to the Collaboration prior to use.
  - **b.** The bending rolls shall be cleaned before the bending operation with an appropriate surface with clean rags.
  - **c.** The welding should be done in a clean enclosed space specific to stainless steel, to prevent inclusion of iron or other contaminants.
  - **d.** Filler must be cleaned and dried prior to use, per ASME or equivalent standards.
  - **e.** The assembly/welding area should be isolated and clean, without contamination of other work.
  - **f.** Thoriated electrodes, as well as guns and shields previously used with thoriated electrodes must *NOT* be used. Plain tungsten (WP EN 26 848, 99.8% minimum tungsten, green), ceriated, yttriated or lanthanated electrodes are acceptable. Shielding gas is argon with a minimum purity of 99.99%, group I, IN 439)

e) Precision Tolerances - To assure that vessel is fabricated on time, and to avoid unnecessary rework, it is imperative to follow a well thought out sequence of fabrications. Manufacturer is to submit a fabrication plan to Collaboration for approval, as mentioned elsewhere. Fabrication requirements:

1) All welding to be performed with flanges in rough machined condition. No flange bolt holes must be present in head to vessel flanges before full solution anneal, below. Nozzle flanges may be prewelded to nozzles, finish machined, then welded to main vessel and heads after main vessel solution anneal below.

2) Torispheric head shells are recommended be in fully solution annealed prior to welding to head flanges.

3) Main cylindrical vessel shell is recommended to be fully solution annealed prior to welding to vessel flanges.

4) Vessel and heads shall be stress relieved to 85% minimum, or better, after welding and prior to final machining; a full solution anneal is recommended (1050C maximum) for 2 hr minimum, followed by a slow cooldown period of not less than 8 hrs (4 hrs/25mm of section); vessel and heads shall be placed with axes vertical on flat surfaces, in a free unstressed, and unconstrained condition for the duration of this this operation, with full air circulation (to avoid formation of MoO_3). If annealing is performed as a bright anneal process, argon or full vacuum must be used; hydrogen shall not be used.

5) Saddle supports are to be fabricated separately, and solution annealed as above prior to final machining and welding to main cylindrical vessel.

6) Nozzles and saddle supports may be welded to vessel and heads after final machining of main flanges, if Manufacturer is confident final tolerances on drawing can be met.

8 Drawings

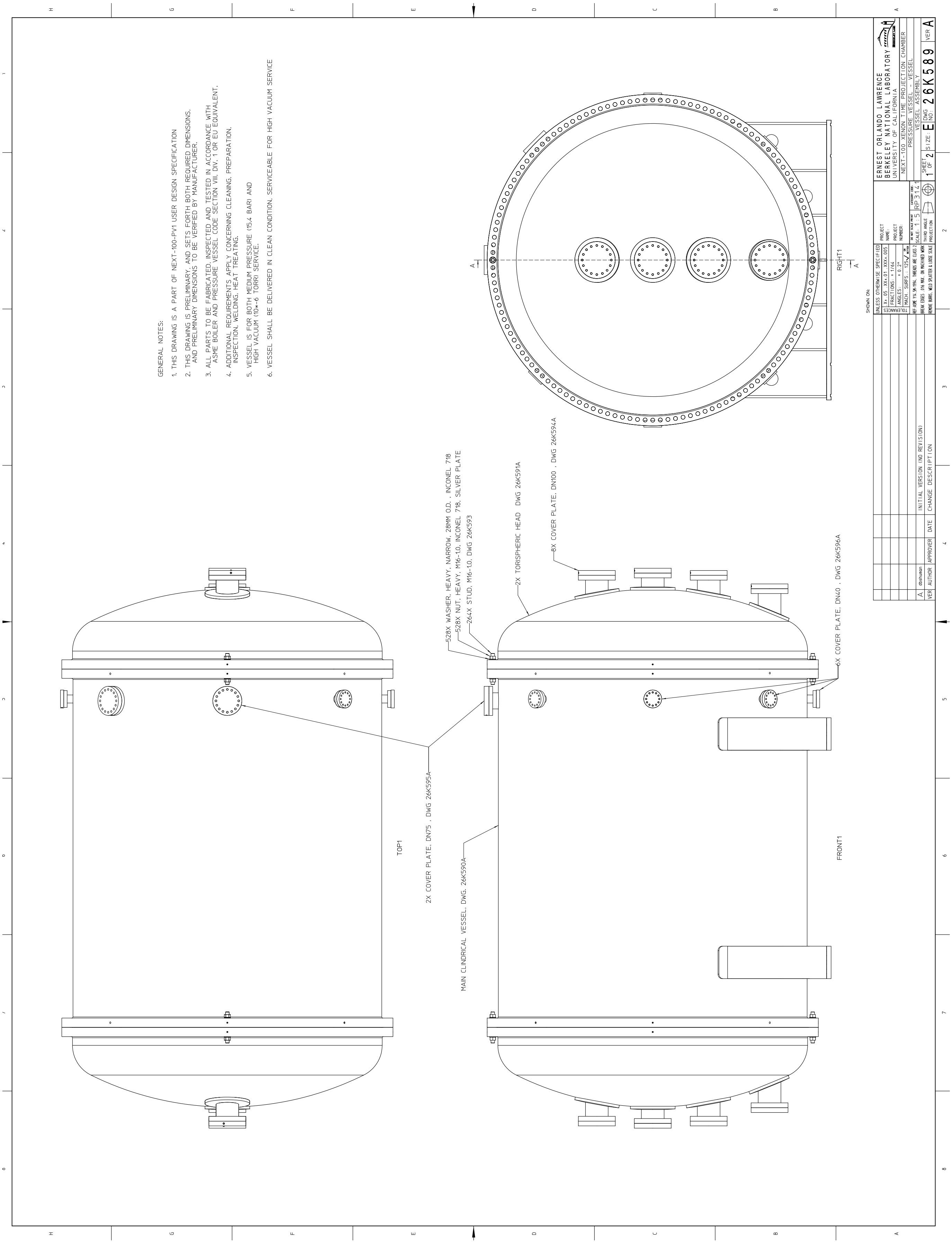

Figure 3: Vessel Assembly, as to be Delivered, sheet 1

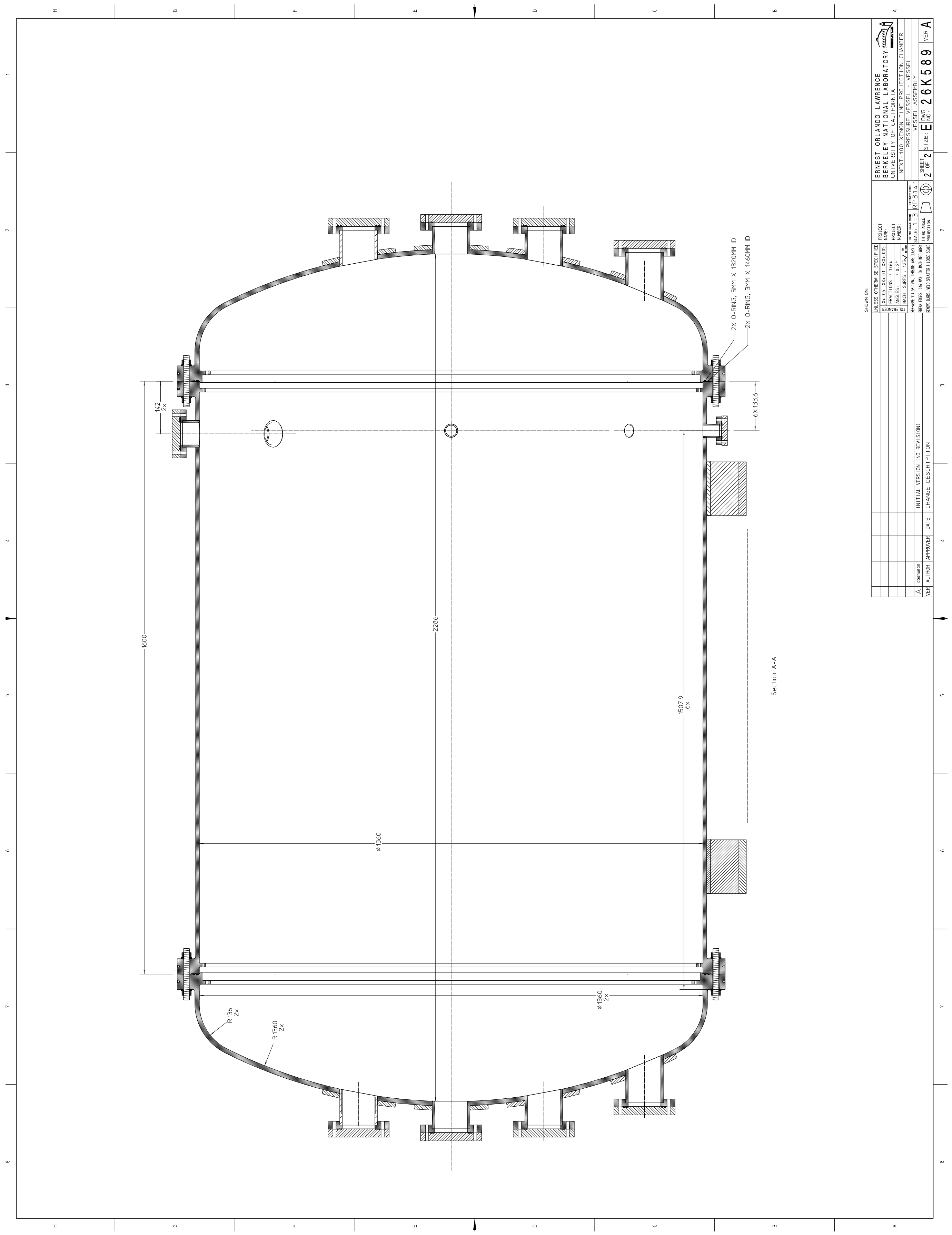

Figure 4: Vessel Assembly, as to be Delivered, sheet 2

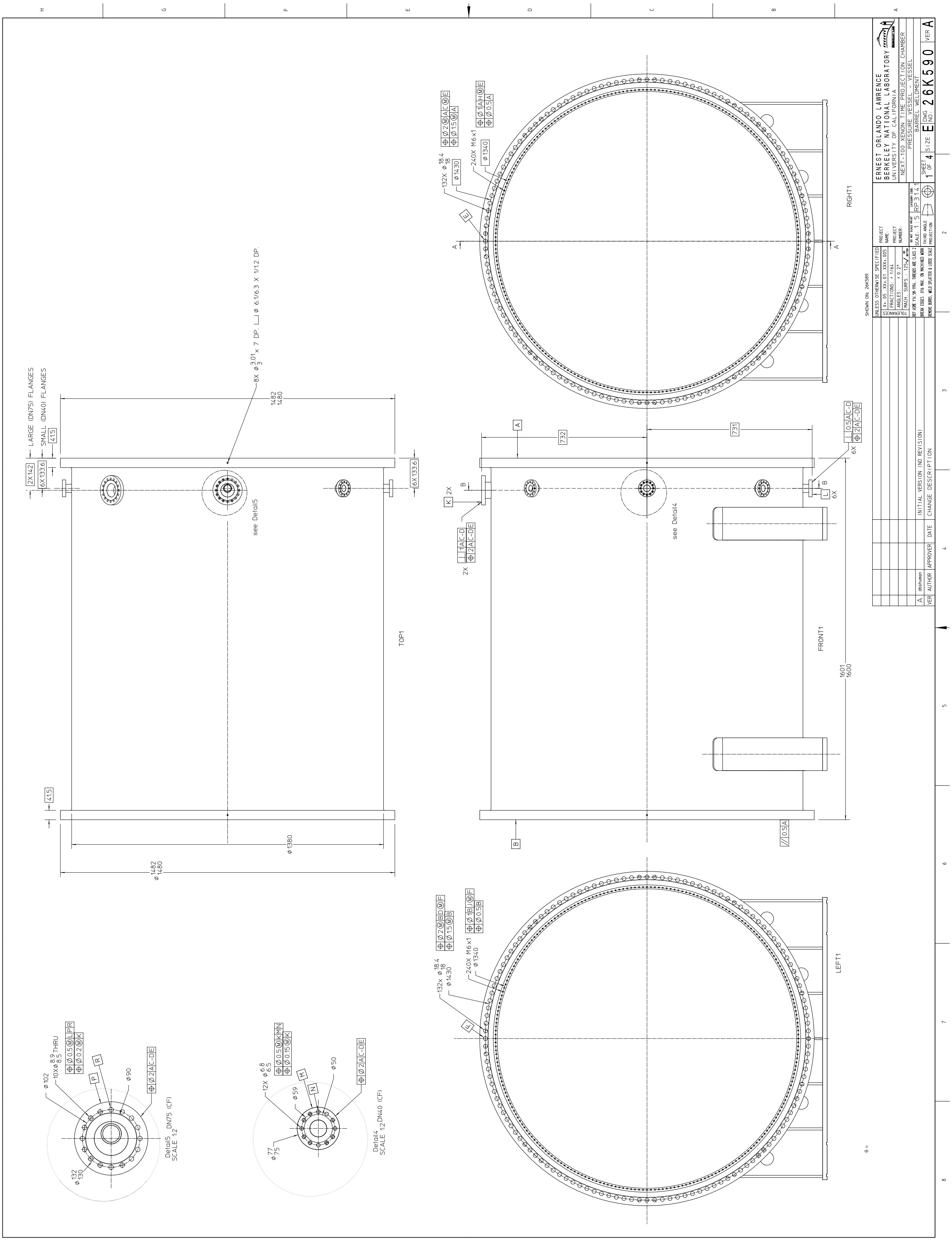

Figure 5: Main Cylindrical Vessel Weldment, sheet 1

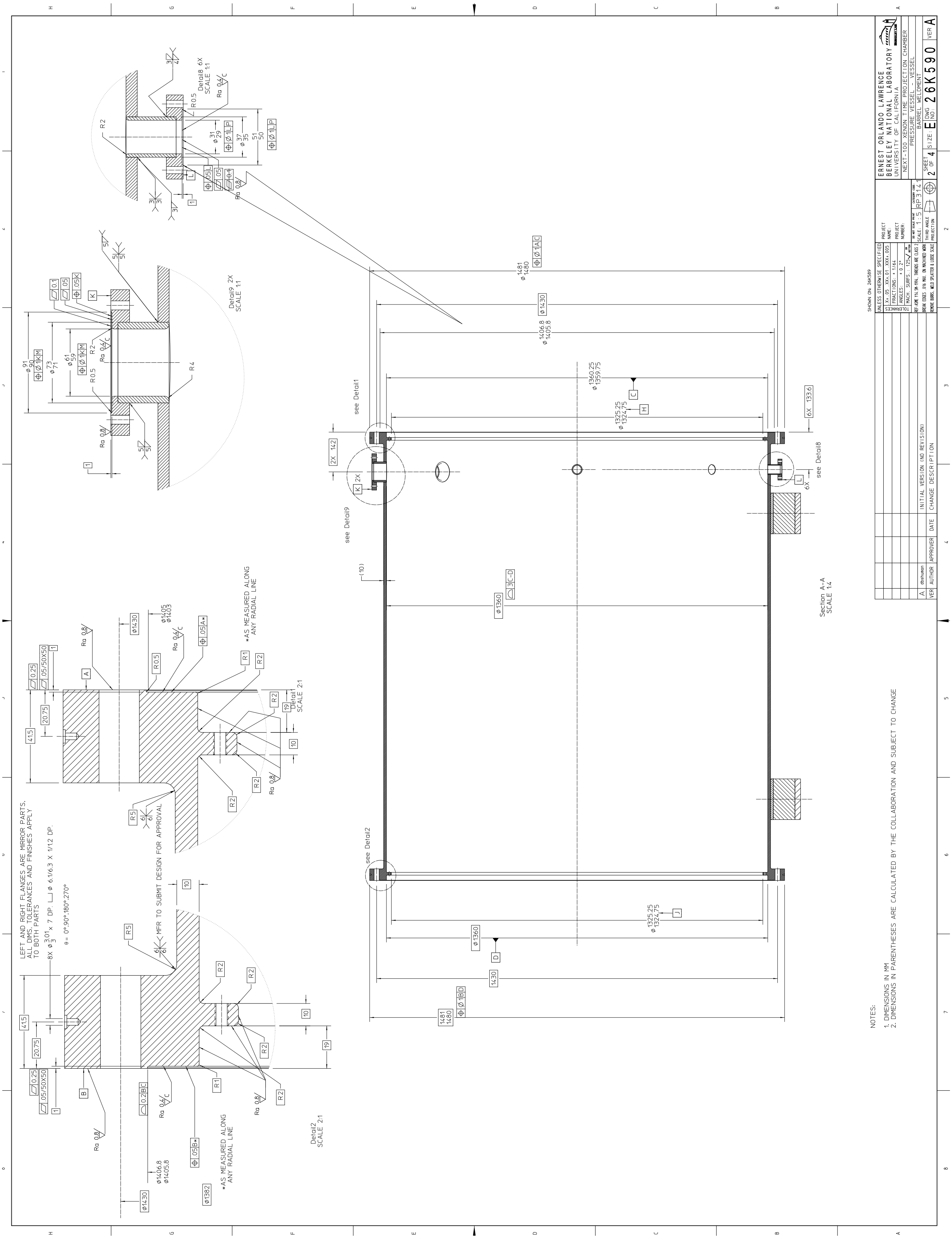

Figure 6: Main Cylindrical Vessel Weldment, sheet 2

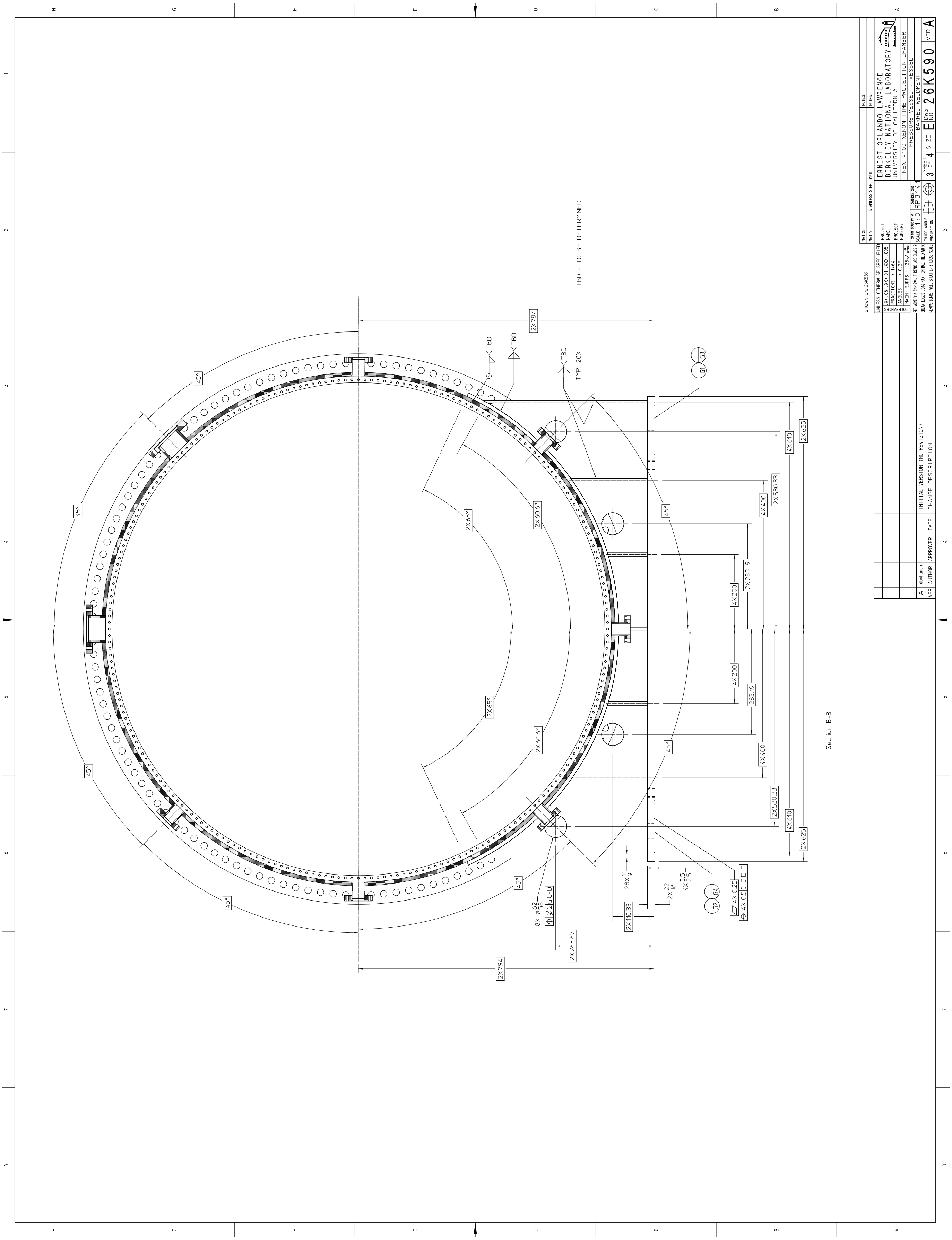

Figure 7: Main Cylindrical Vessel Weldment, sheet 3

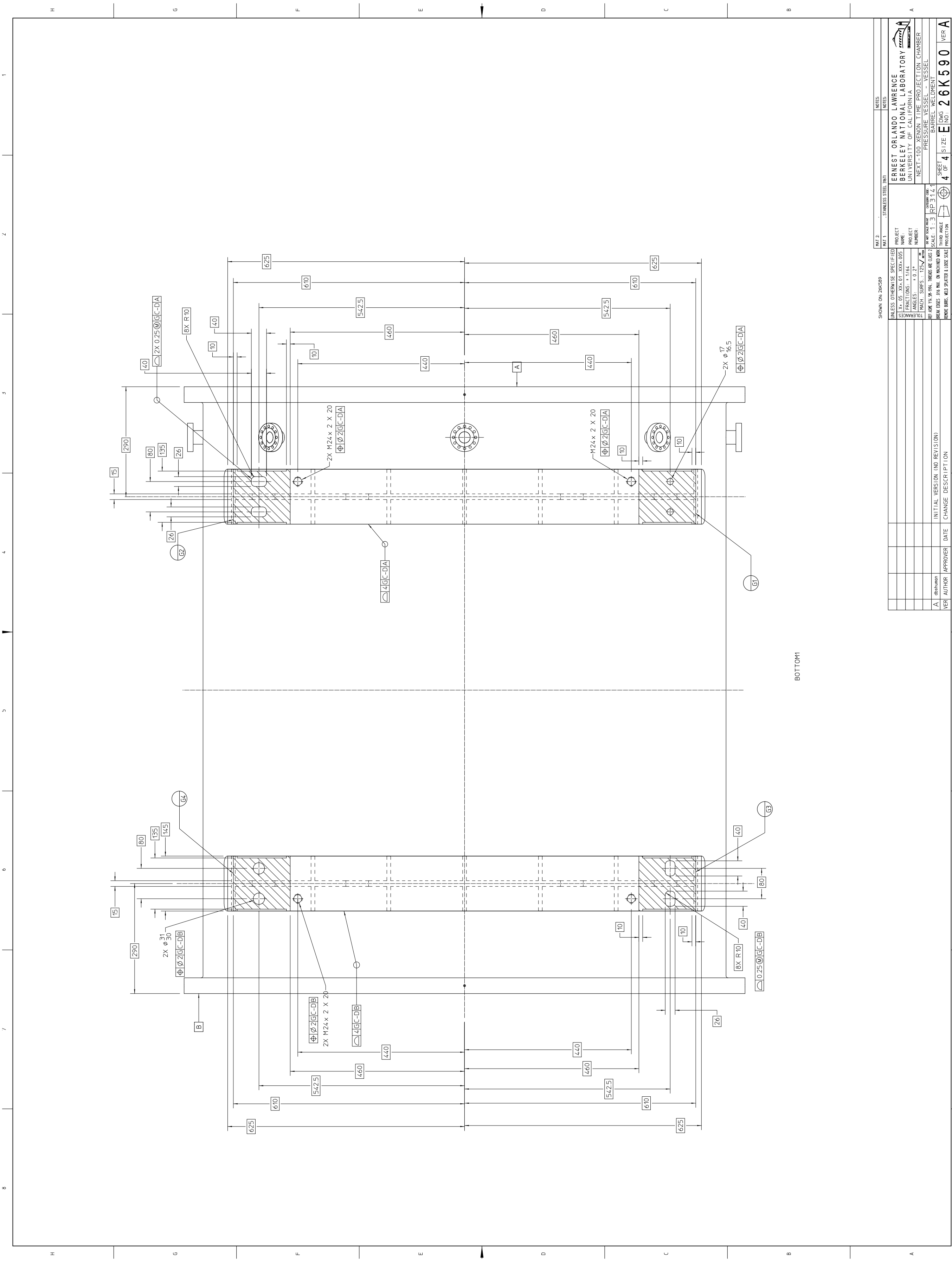

Figure 8: Main Cylindrical Vessel Weldment, sheet 4

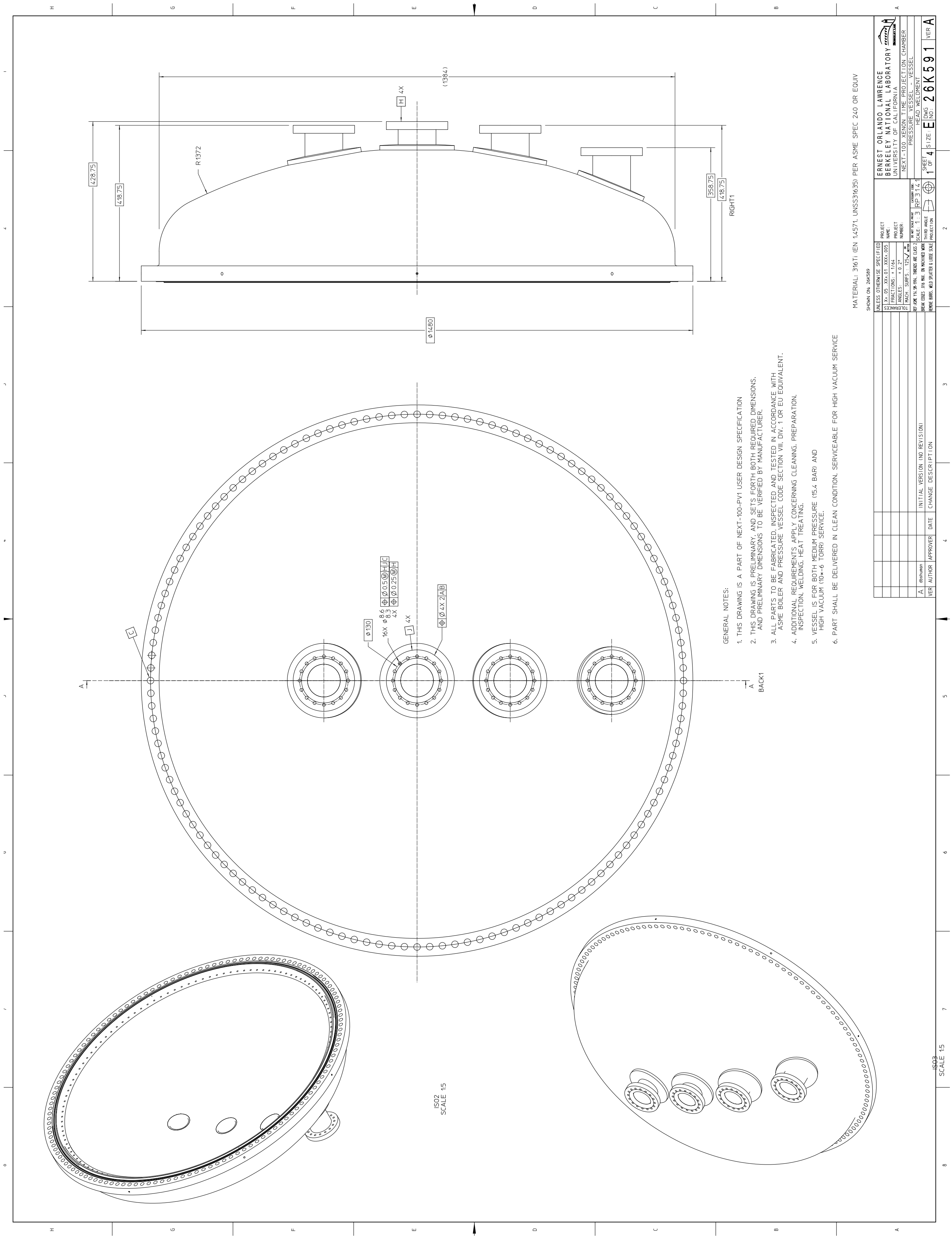

Figure 9: Torispheric Head Weldment, sheet 1

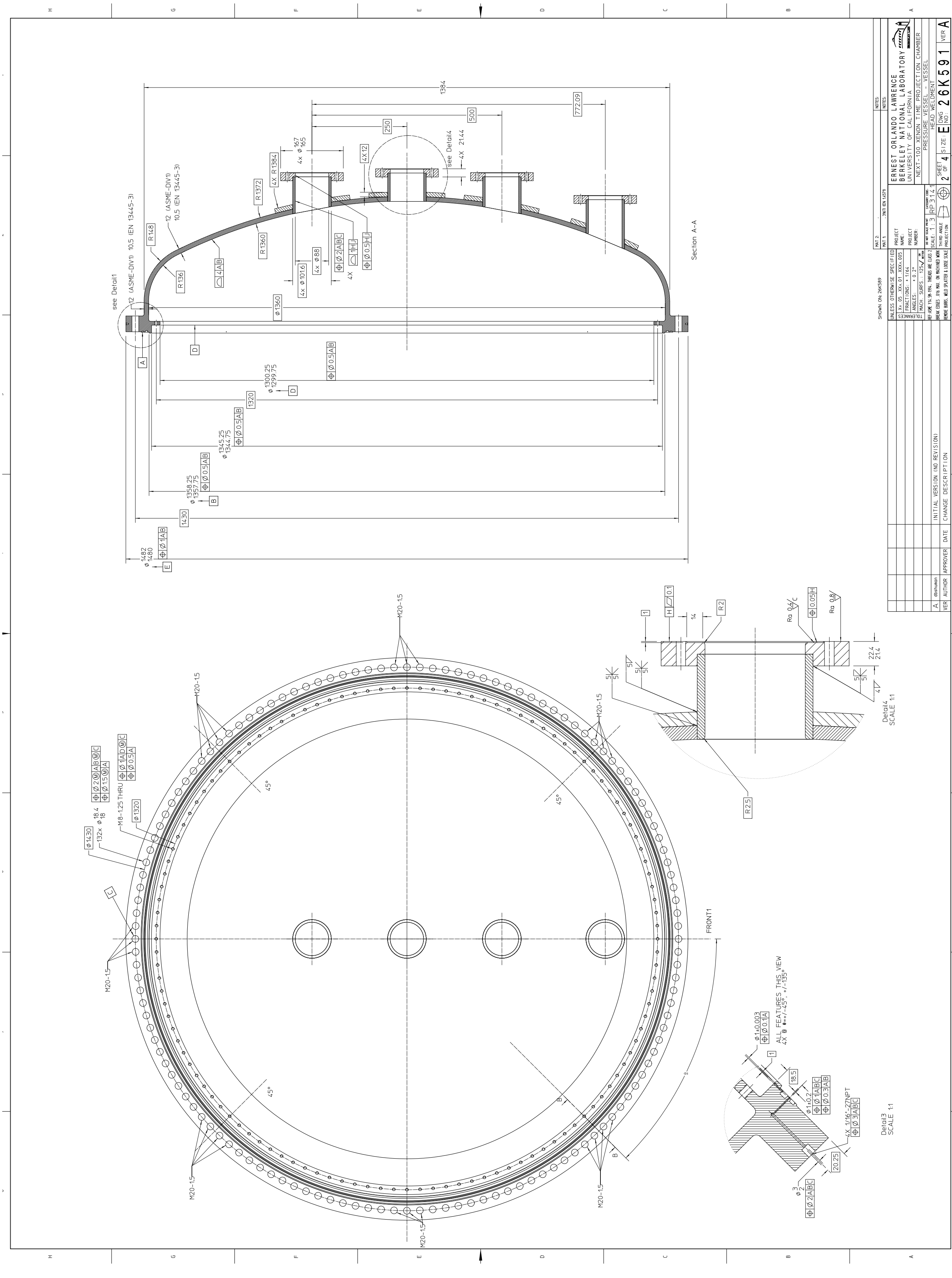

Figure 10: Torispheric Head Weldment, sheet 2

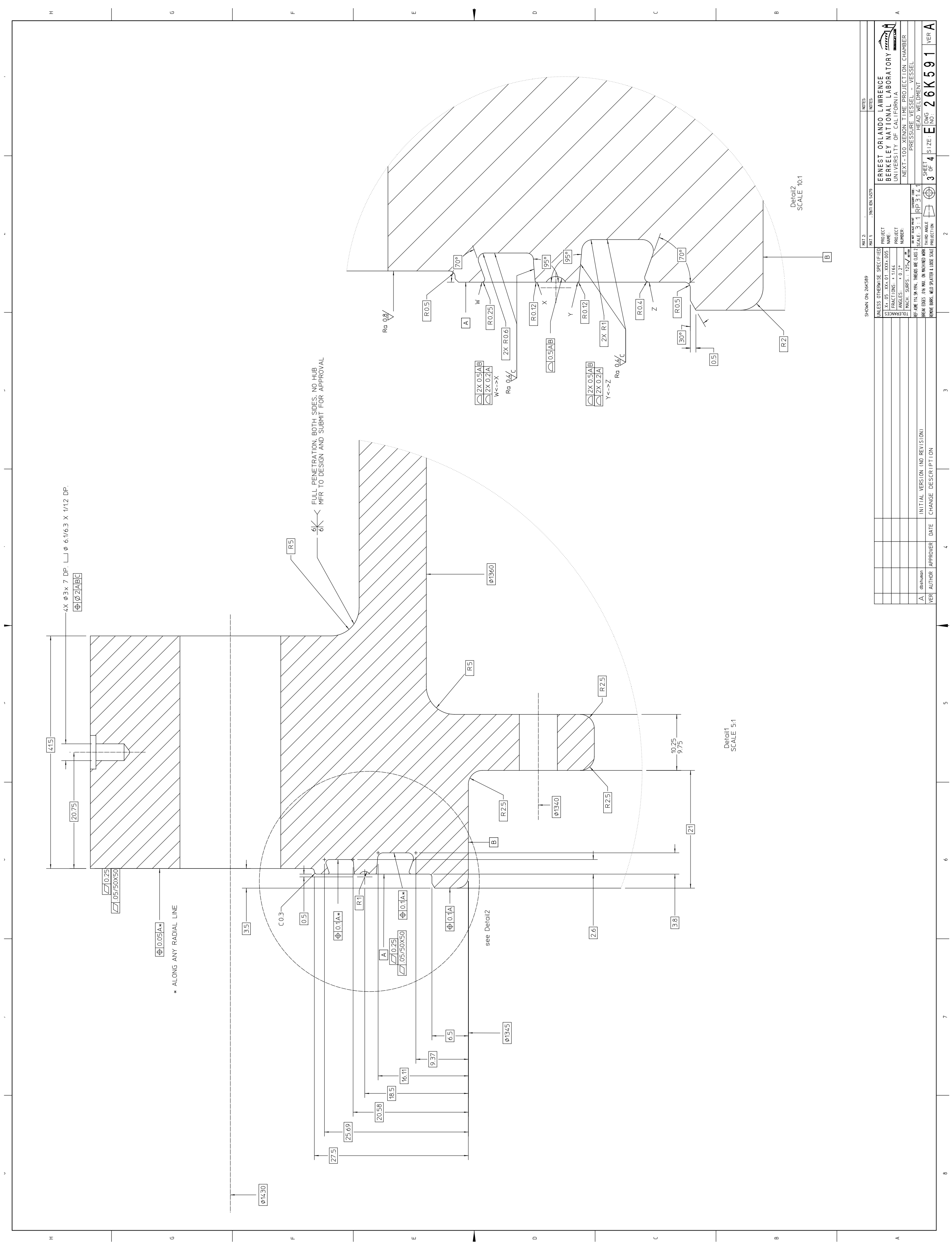

Figure 11: Torispheric Head Weldment, sheet 3

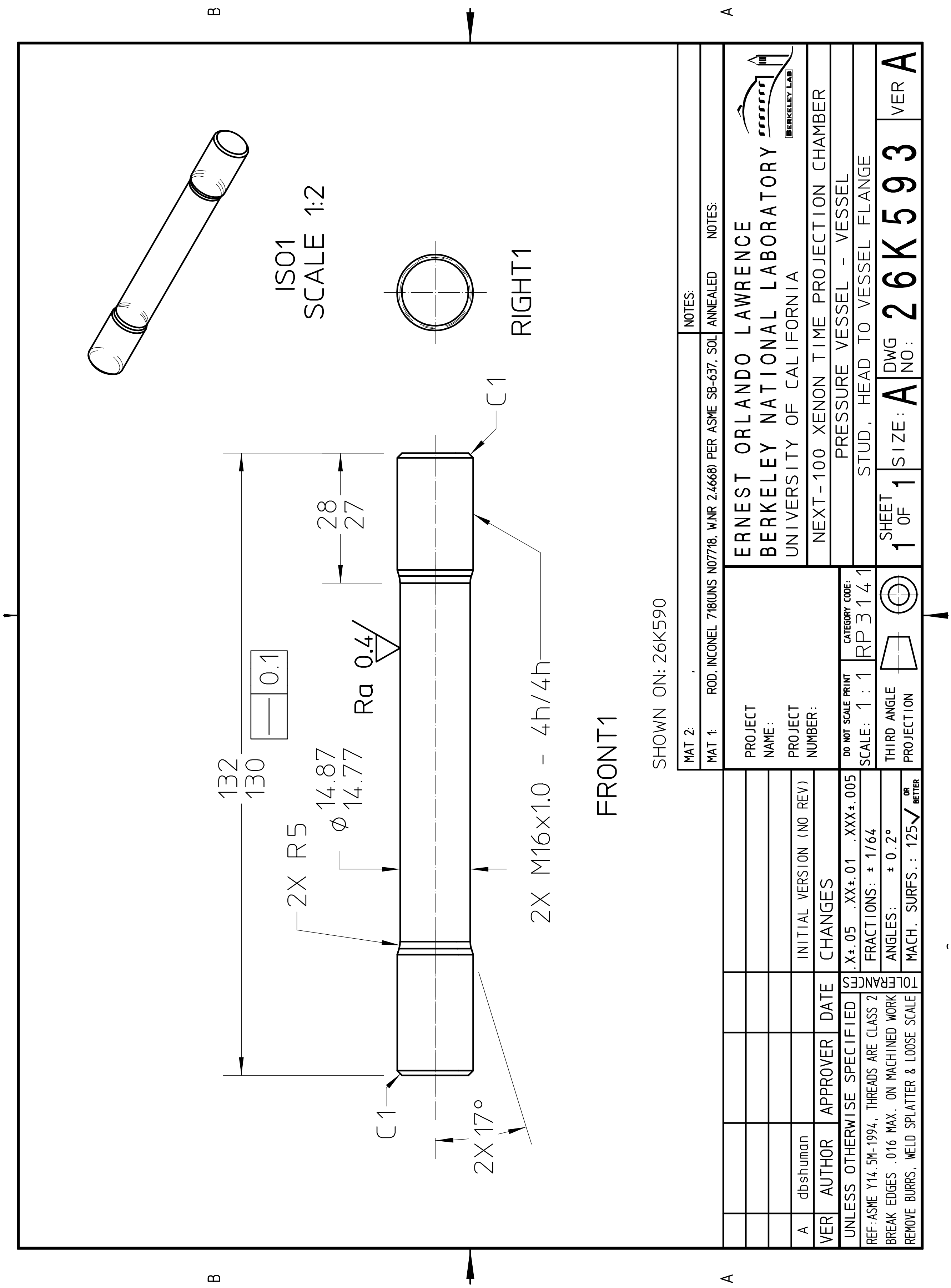

Figure 12: Main Flange Stud

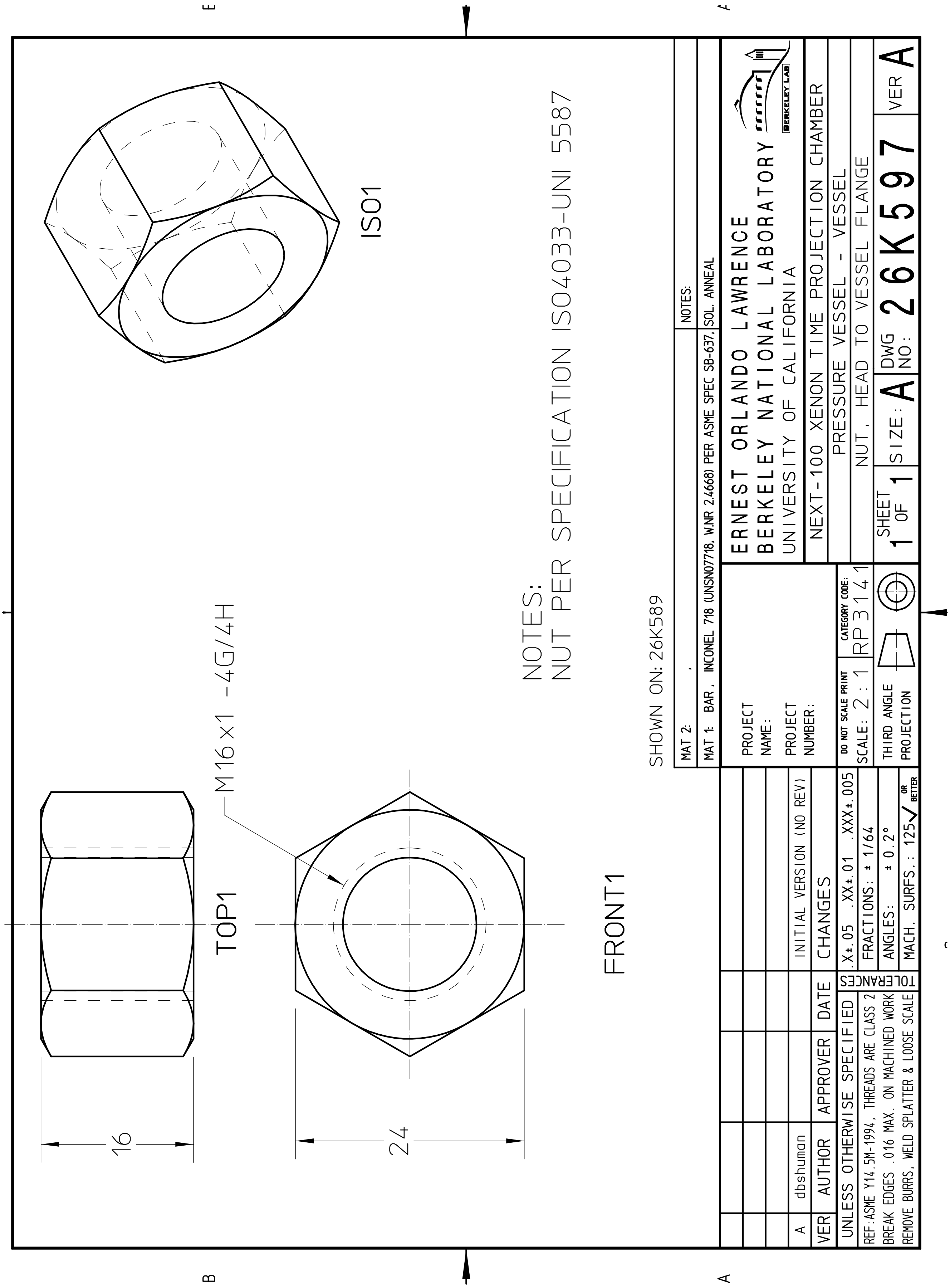

Figure 13: Main Flange Nut

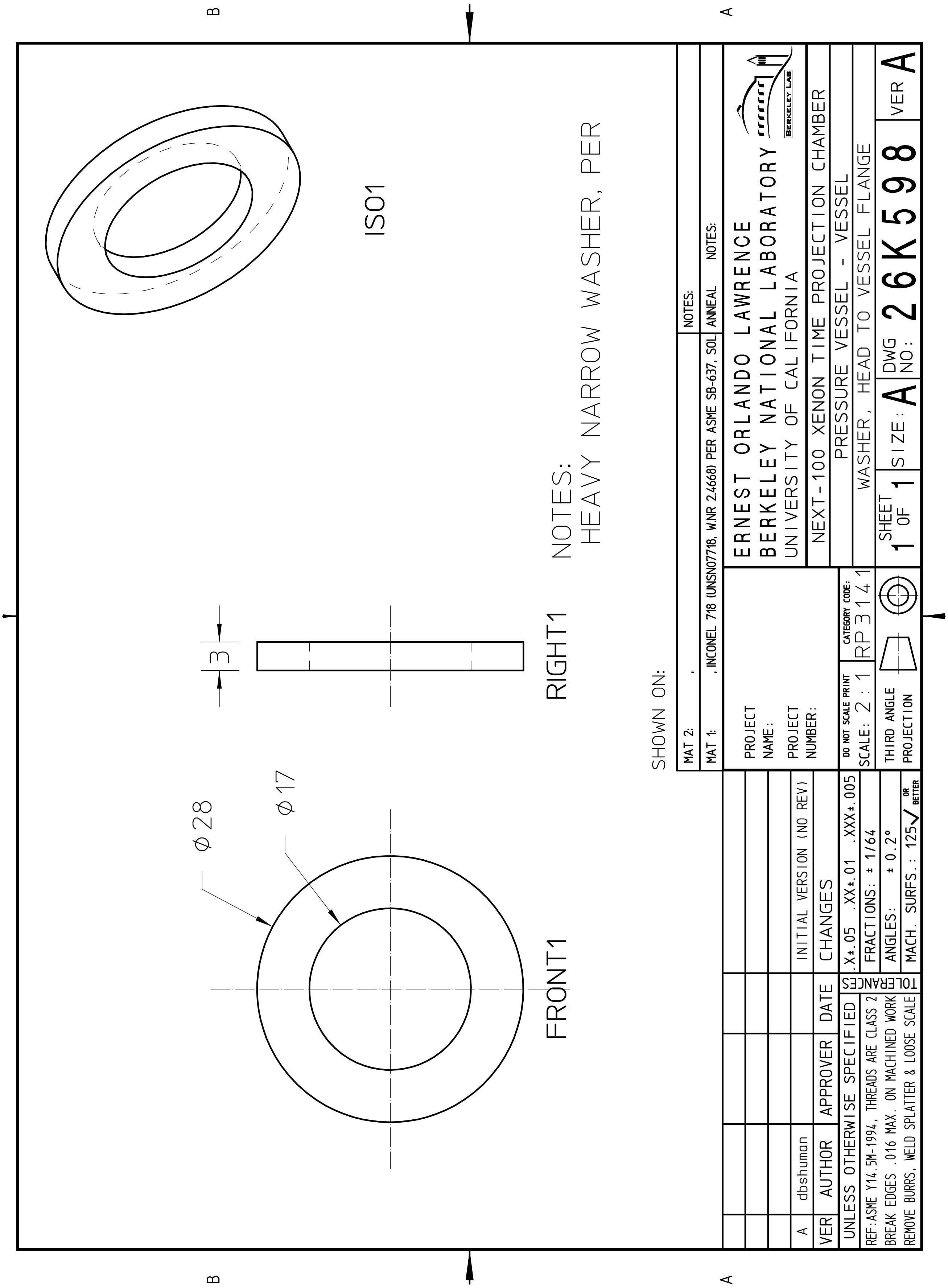

Figure 14: Washer

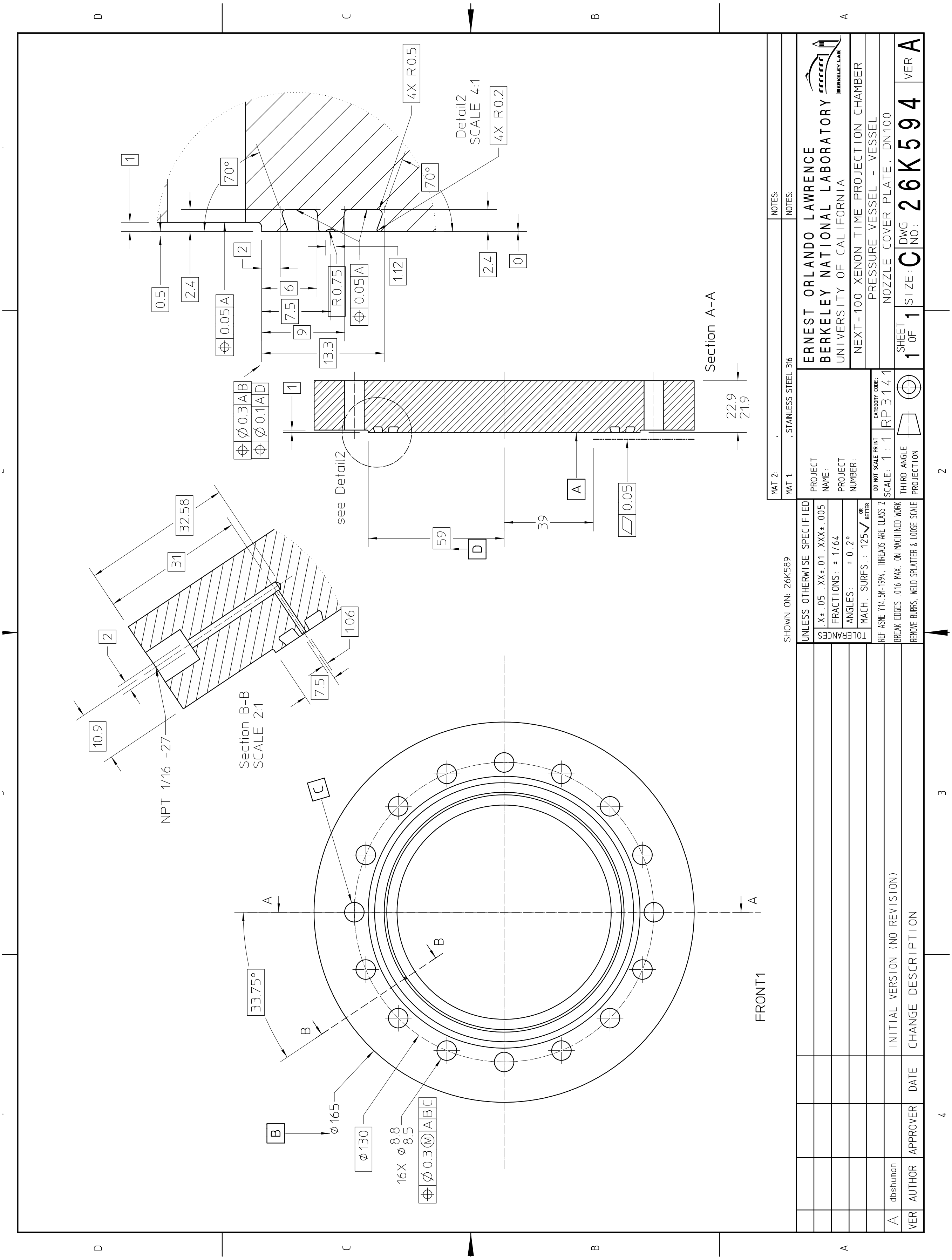

Figure 15: COVER PLATE, DN100

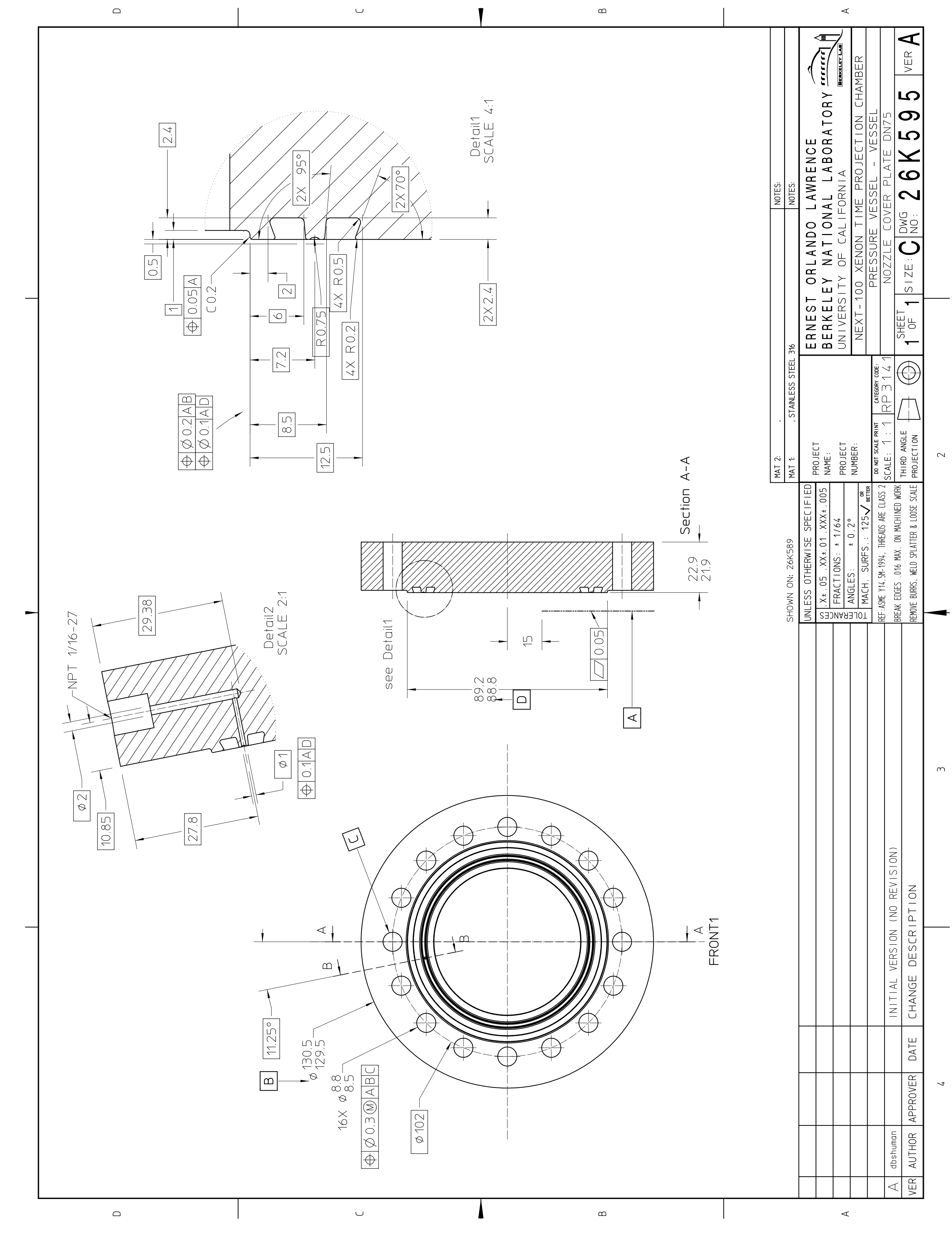

Figure 16: COVER PLATE, DN75

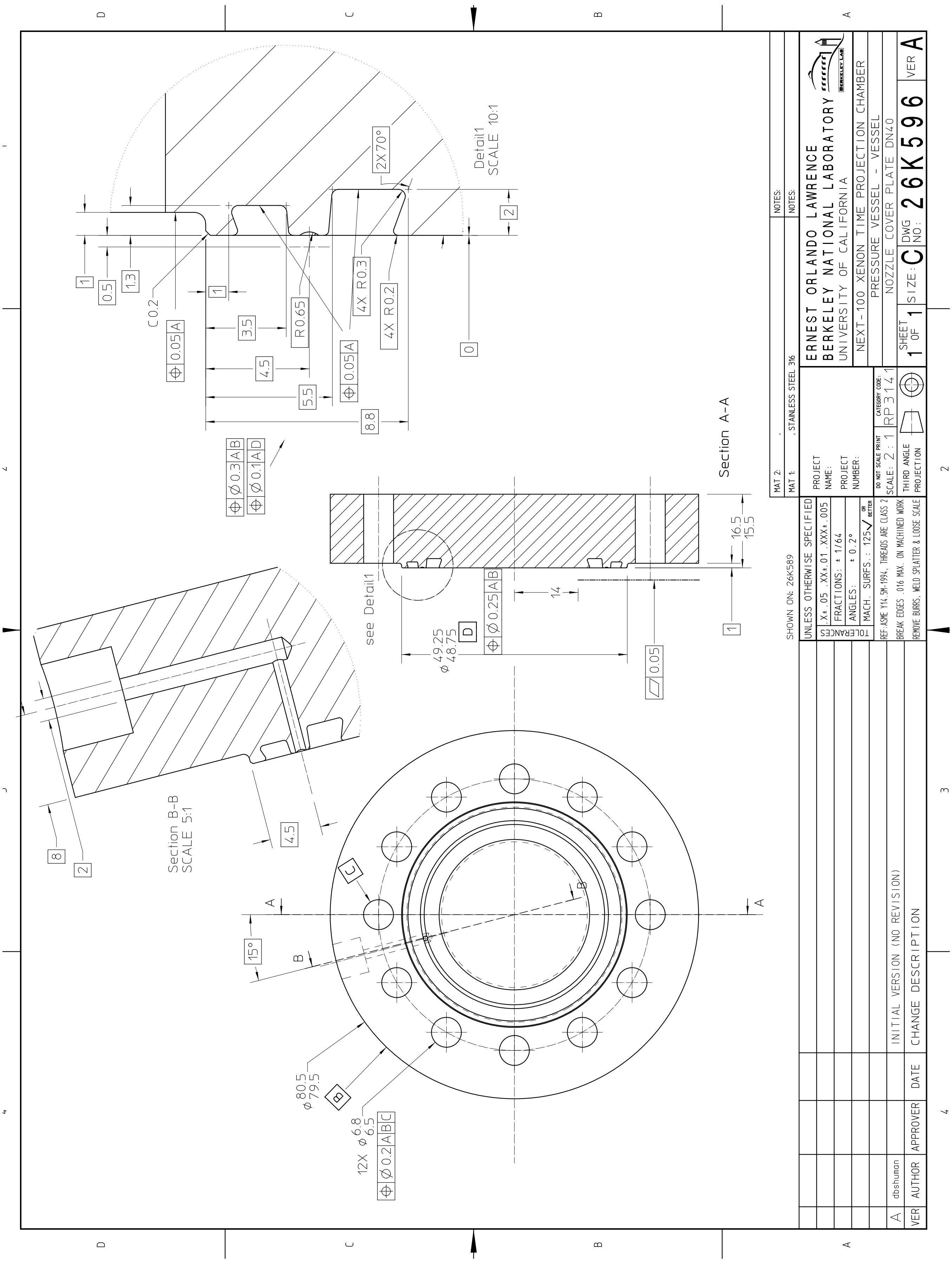

Figure 17: COVER PLATE, DN40

9 Appendix

9.1 Calculations

<u>Pressure Vessel Design Calculations</u> All calculations following by D. Shuman, except where noted.
Apr 2, 2012

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