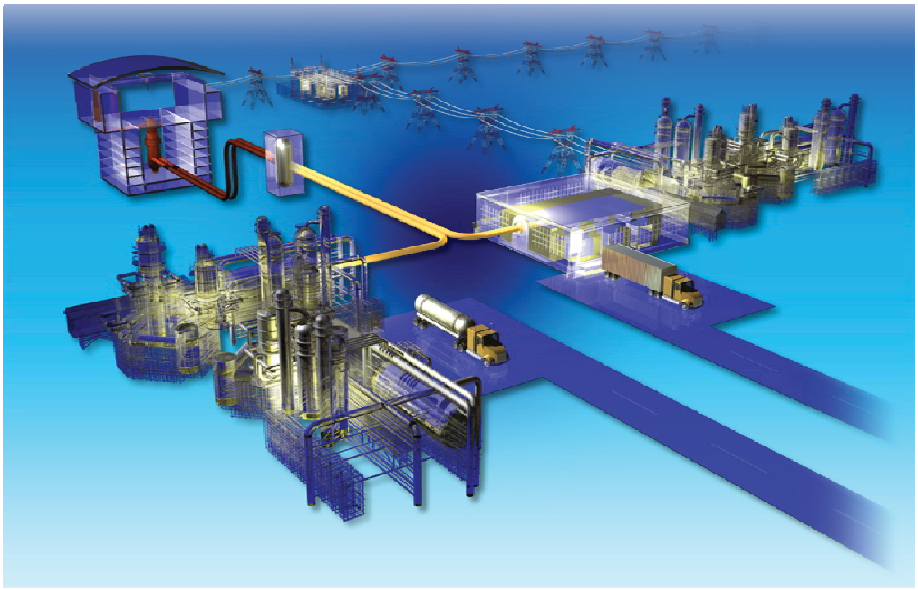
INL/EXT-10-18039

Laboratory for Characterization of Irradiated Graphite

William Windes

March 2010



The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance.

The INL is a
U.S. Department of Energy
National Laboratory
operated by
Battelle Energy Alliance

Idaho National Laboratory

INL/EXT-10-18039

Laboratory for Characterization of Irradiated Graphite

William Windes

March 2010

Idaho National Laboratory
Next Generation Nuclear Plant Project
Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

Next Generation Nuclear Plant Project

Laboratory for Characterization of Irradiated Graphite

INL/EXT-10-18039

March 2010

Approved by:

FOR WILL WINDES 3-23-10

William Windes
VHTR TDO Graphite R&D Lead
Date

3/25/2010

Gary Roberts
VHTR TDO Graphite R&D QA
Date

3/25/2010

Travis Mitchell
VHTR TDO Graphite R&D Project Management
Date

ABSTRACT

The newly completed Carbon Characterization Laboratory (CCL) is located in Labs C19 and C20 of the Idaho National Laboratory Research Center. The CCL was established under the Next Generation Nuclear Plant Project to support graphite and ceramic composite research and development activities. The research conducted in this laboratory will support the Advanced Graphite Creep experiments—a major series of material irradiation experiments within the Next Generation Nuclear Plant Graphite program.

The CCL is designed to characterize and test low activated irradiated materials such as high purity graphite, carbon-carbon composites, silicon-carbide composite, and ceramic materials. The laboratory is fully capable of characterizing material properties for both irradiated and nonirradiated materials. This report summarizes the major infrastructural modifications undertaken to support this new radiological facility at Idaho National Laboratory.

CONTENTS

FIGURES

TABLES

Laboratory for Characterization of Irradiated Graphite

INTRODUCTION

The newly completed Carbon Characterization Laboratory (CCL) is located in Labs C19 and C20 of the Idaho National Laboratory (INL) Research Center (IRC). The CCL was established under the Next Generation Nuclear Plant (NGNP) Project to support graphite and ceramic composite research and development activities. The research supports the Advanced Graphite Creep (AGC) experiments—a series of major material irradiation experiments within the NGNP Graphite program.

The CCL is designed to characterize and test low activated irradiated materials such as high purity graphite, carbon-carbon composites, and silicon-carbide composite materials. The laboratory is fully capable of characterizing material properties for both irradiated and nonirradiated materials.

The combined CCL uses Lab C20 as a standard laboratory where testing and characterization of nonirradiated samples are performed. Currently, thermal, physical, and some nondestructive examination techniques are used to characterize the AGC samples before irradiation. Lab C20 also serves as the entrance to Lab C19, which is the radiological laboratory. Lab C19 will have similar characterization capability as Lab C20 but with the added ability for mechanical testing. Figure 1 shows the lab layout.

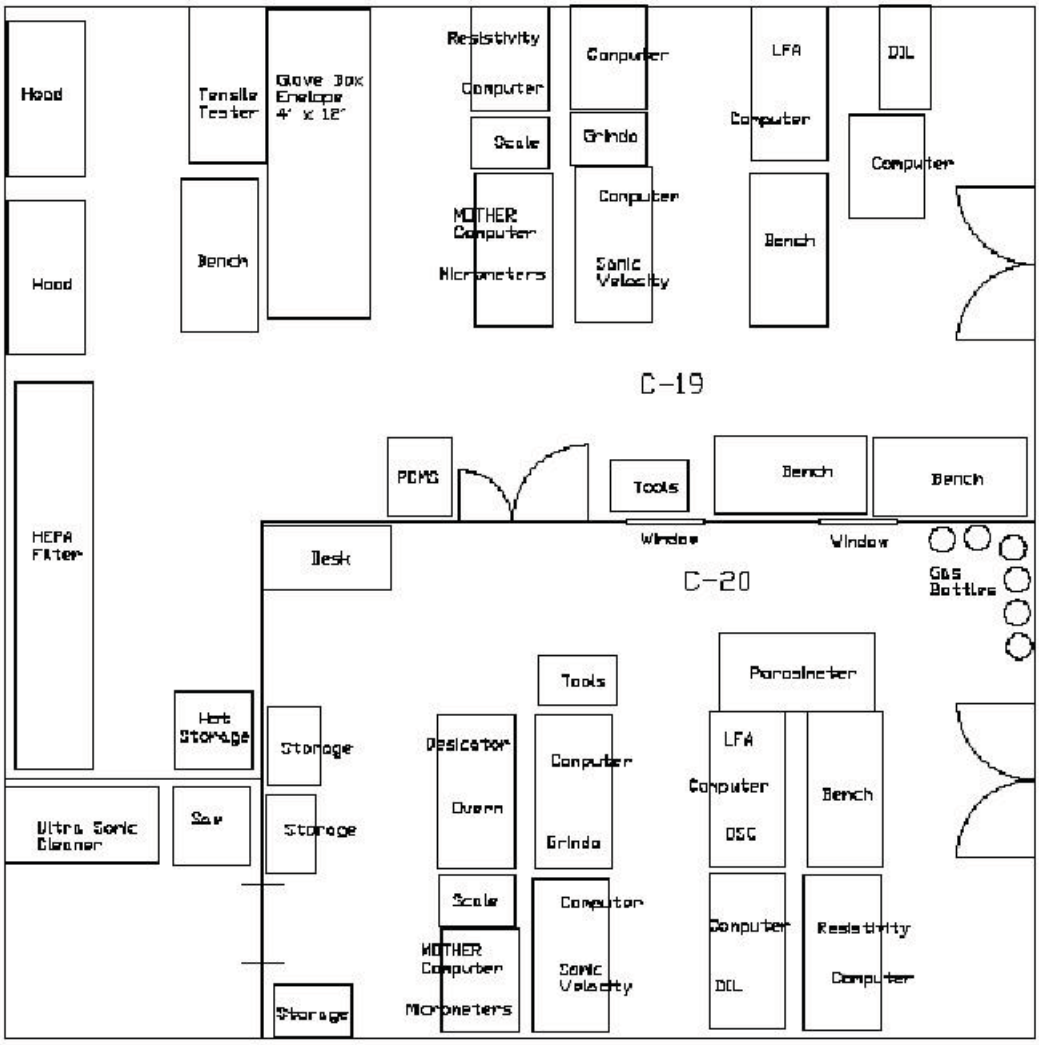


Figure 1. Layout of Lab C19 and Lab C20.

DESCRIPTION

Lab C19 has been modified to characterize irradiated material specimens. Currently, this facility is being prepared for a large graphite characterization campaign in support of the NGNP Project. Graphite characterization involves the handling of nonsealed irradiated graphite, so the lab was given a Radiological Hazard facility categorization and a National Emission Standards for Hazardous Air Pollutants (NESHAPS) inventory evaluation. It was verified that the total radioactive inventory will remain under the criteria for a less than Hazard Category 3 (non-nuclear) facility and remains below 40 CFR 61, Appendix E values for NESHAPS consideration. The engineering controls for radiological contamination in the workplace environment were evaluated in ECAR-469, “Radiological Control Recommendations for Post Irradiation Examination of Activated Graphite Performed at IRC.”

Irradiated materials to be tested and characterized in the CCL are assumed to have low activation levels. To further reduce personnel exposure only a limited number of specimens will be out of controlled, shielded storage at any one time for testing. For the handling of samples from current NGNP activities in the CCL, Table 1 gives the expected radiological dose from a single graphite specimen that is 1.0 in. long and 0.5 in. in diameter. When a sample is not being actively tested, it will be stored in

shielded storage to reduce personnel exposure. The current shielded storage facility stationed inside Lab C19 is designed to provide shielding for the total number of samples anticipated in an AGC capsule (approximately 500 samples). The anticipated radiation level at the outer surface of a fully loaded storage system is calculated to be 5 mR. Appendix A gives details on the AGC sample storage system.

Table 1. Dose from a 1 in. long graphite specimen.

mR/hr	Distance to specimen (in.)
3.68 × 103	0.8
441	2.3
15.5	13
1.44	39.6

Figure 2. Roof top exhaust blower

The air in Lab C19 will have a negative pressure to contain any contamination that may be released during testing. The additional air flow will be maintained by a make-up air supply from the IRC. A new independent exhaust system was installed in Lab C19 to ensure that all gases and air born particles are exhausted separate from the rest of the IRC building. The new welded stainless steel HEPA filtered ducting system inside Lab C19 directs air flow from the radiological fume hood through HEPA filters to a roof mounted continuously running exhaust fan. This new fan is designed to replace the need for a tall exhaust stack because the high velocity fan adds dilution air then pushes the exhaust many feet straight up before it dissipates. Figure 2 is a photograph of the exhaust blower.

The new HEPA filter housing is a 2 × 1 bag-in/bag-out, side access design as shown in Figure 3. Phoenix™ variable air volume valves and balancing dampers were installed for the air distribution system. Ducts and diffusers were removed from the ceiling to cap off the existing HVAC system and replaced with new ductwork to connect to the independent exhaust system. The new exhaust control system is integrated with the existing IRC Carrier Control System to assist with the additional air flow required for the make-up air.

Figure 3. HEPA filter housing.

An exhaust fume hood (Figure 4) has been installed for tasks that may generate contamination, such as cutting and mechanical testing. Two large windows were installed in the wall separating Lab C19 and C20 to allow personnel to view work being performed in Lab C19, as shown in Figure 5. A portal monitor used to detect contamination on personnel will control egress from the radiological facility. The arrangement of work tables, equipment, storage cabinets and desks within the radiological facility was devised to ensure the maximum contamination control for the facility and personnel protection. Table 2 lists the specific modifications that occurred in Lab C19.

Similar material property tests will be performed in both labs for the current graphite characterization campaign in support of the AGC program. The thermal and physical properties of the nonirradiated graphite samples will be characterized in Lab C20 before the samples are irradiated in the reactor. After irradiation, the same samples will be recharacterized in Lab C19 using identical material property testing procedures. Testing details are described in INL/EXT-09-15515 "Carbon Characterization Laboratory Report."

Figure 4. Radiological fume hood.

Figure 5. Windows looking into Lab C19 from Lab C20.

Table 2. Detailed modifications to Lab C19 radiological facility.

Demolition	Installation
Removal of existing walls	New walls between Labs C19 and C20
Removal of electrical power conduits, receptacles and switches from the walls	A door between Labs C19 and C20, 5 ft wide
Removal of gas lines and utilities from the walls	Two windows in wall between Labs C19 and C20
Ducts and diffusers were removed from the ceiling to cap off the existing HVAC system	New electrical panels, power conduit poles and internet cabling
Original flooring was removed	New epoxy floor surface
	Independent exhaust system, HEPA filtered with new ductwork
	New radiological fume hood
	New portal monitor to control egress
	New tables and characterization equipment
	New radiological glove box

Similar to how work is performed in Lab C20, separate stations are set up within the radiological facility. Lab C19 will allow full thermal, physical, and mechanical testing capability for low activated irradiated material specimens. Following the facility modifications described, the radiological laboratory will be outfitted with the necessary characterization equipment, recorded in Table 3.

Table 3. CCL measurement and test equipment.

Measurement	Standard	Instrumentation	Calibration	Result
Physical dimensions	ASTM C559	Mitutoyo Micrometer 121-155 Mitutoyo Caliper CD-6" CSX	INL	Bulk Density
Mass	ASTM C559	Sartorius Scale ME235P	INL	Bulk Density
Sonic Resonance	ASTM C747	J. W. Lemmens Grindosonic	None required	Elastic Modulus
Sonic Velocity	ASTM C769	Olympus NDT Square Wave Pulser/Receiver 5077PR National Instruments Digitizer USB 5133	INL	Young's modulus, Shear modulus, Poisson ratio
4-point resistivity	ASTM C611	Kiethly 6220 Precision Current Source	INL	Electrical resistivity
Laser flash diffusivity	ASTM E1461	Netzsch LFA 457	Calibration by user	Thermal diffusivity
Push rod dilatometry	ASTM E228	Netzsch DIL 402C	Calibration by user	Coefficient of Thermal Expansion
Tensile testing	ASTM C749 ASTM C781	Instron 5582 Epsilon 3560 Extensometer	INL Calibration by user	Tensile strength, elongation to failure, elastic modulus
Flexural testing	ASTM C651	Instron 5582 Epsilon 3540 Deflectometer	INL Calibration by user	Flexural strength
Compressive testing	ASTM C695	Instron 5582 Epsilon 3540 Deflectometer	INL Calibration by user	Compressive strength, compressive modulus

Since mechanical testing is destructive and will likely produce some level of contamination during failure, all mechanical testing specimens will be attached to the testing fixtures in the fume hood and placed in a transfer bag. The transfer bag will be placed inside an enclosure on the testing machine and attached to the appropriate test fixtures.

As the specimen is broken, fracture remnants will be captured in the transfer bag. Any particulate outside of the transfer bag will be exhausted from the enclosure to the exhaust system.

Finally, while not part of the actual facility modification activities, a glove box is being procured and installed for those occasional samples that have higher than anticipated radiation levels. This glove box will be vented to the exhaust system servicing the radiological facility. The glove box will be used for all activities where measured levels of contamination or activity exceed the normal range (i.e., sample repackaging, sample cutting, general handling of high activity samples, etc.). It will be designed to accommodate most of the characterization equipment so that testing can be conducted on higher radiation level samples if needed (see Figure 6 for a drawing of glove box).

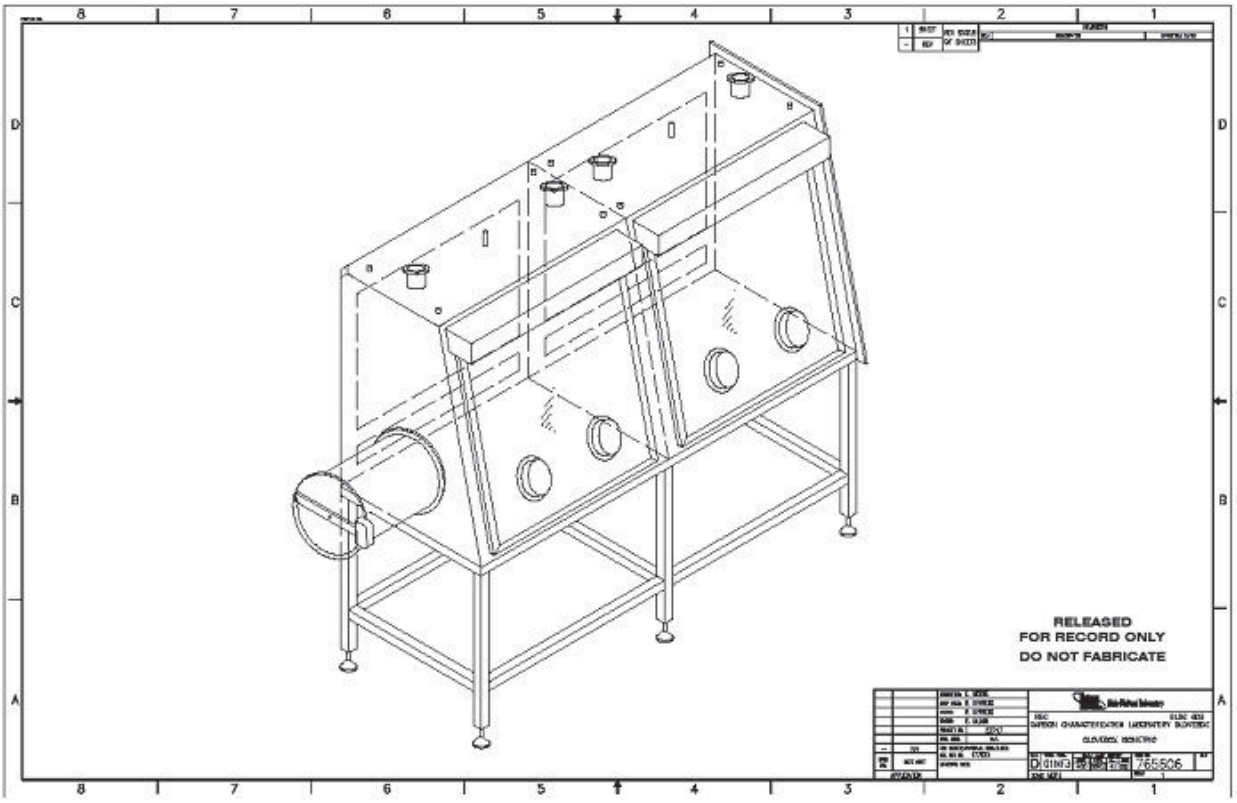
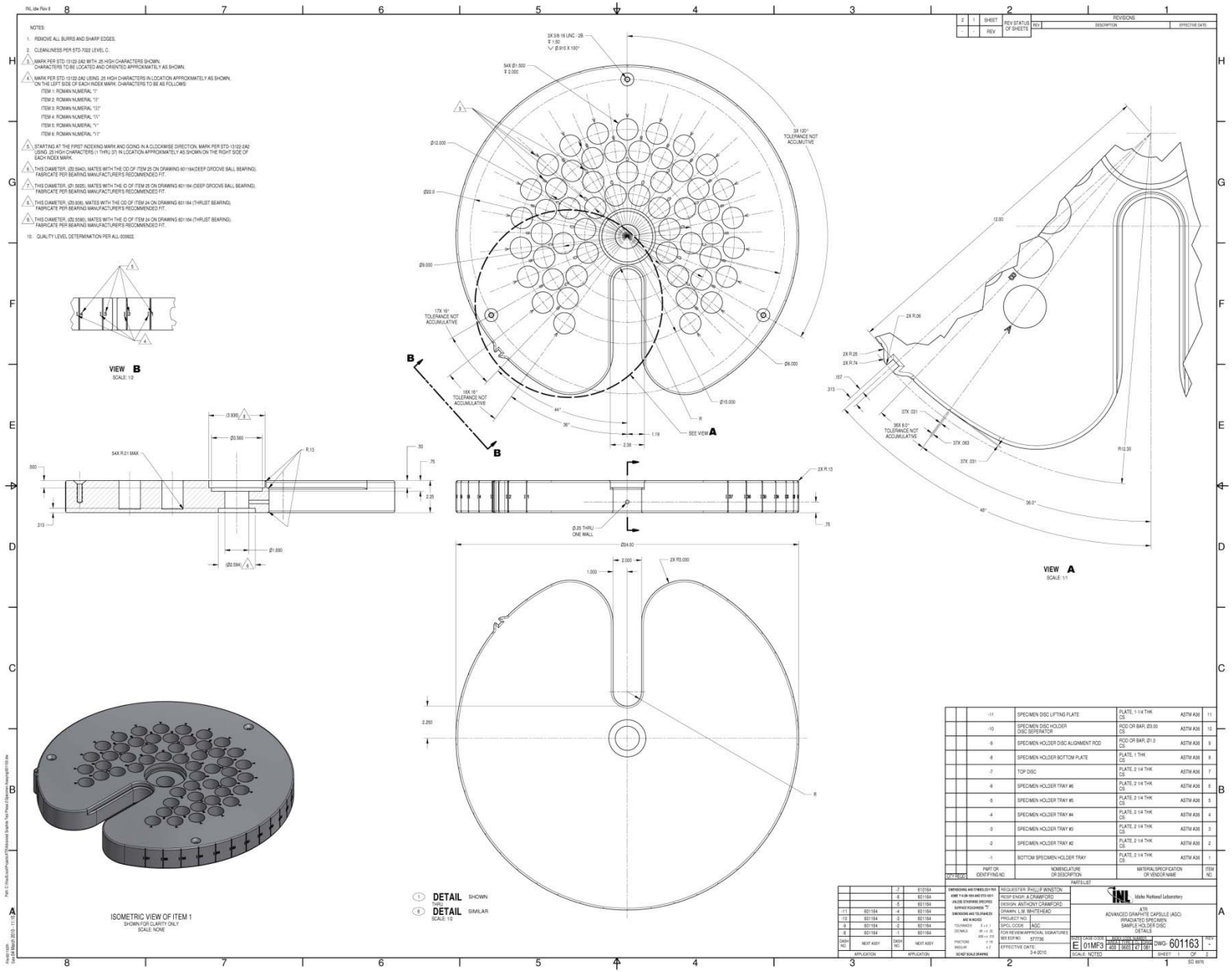


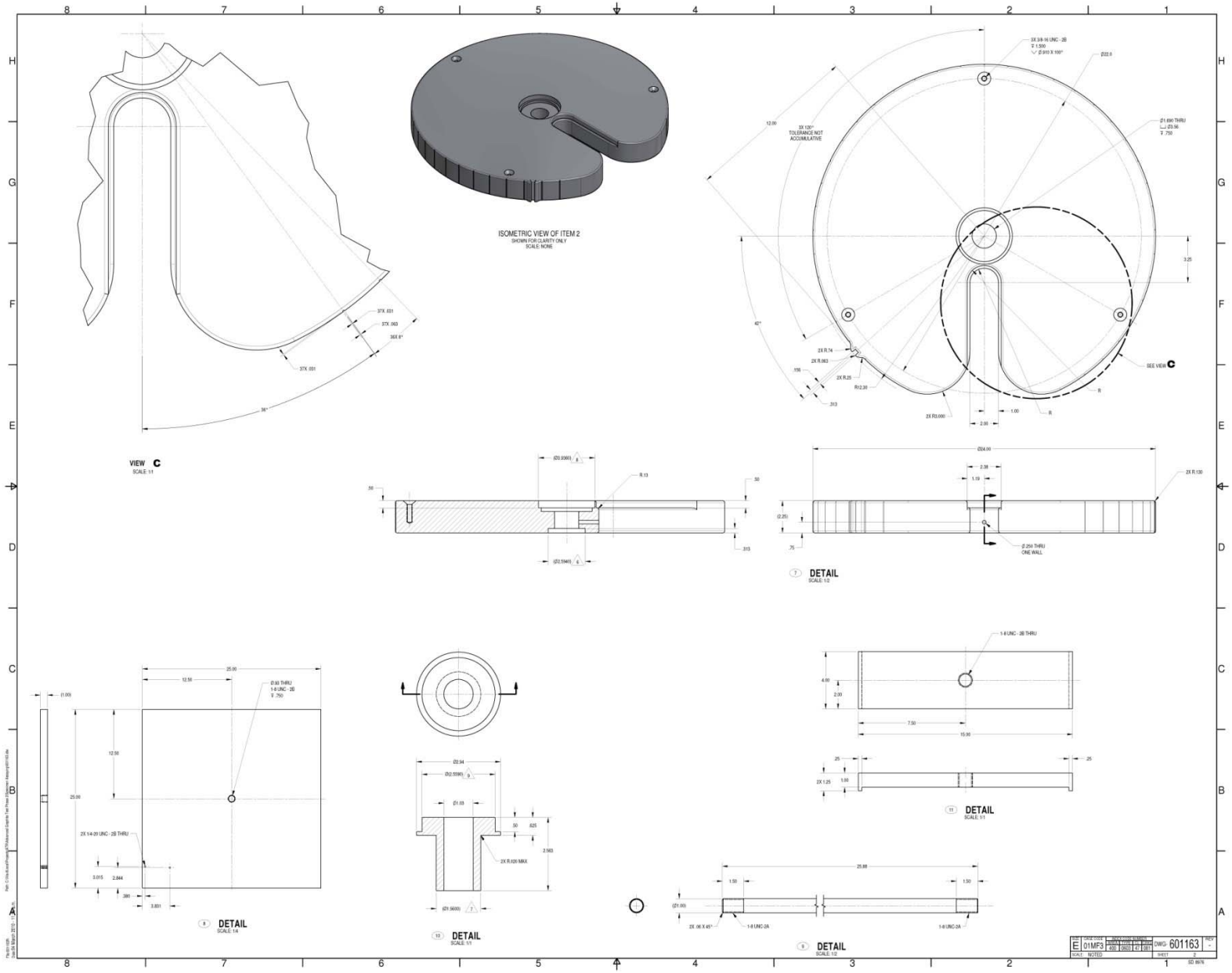
Figure 6. CCL glove box.

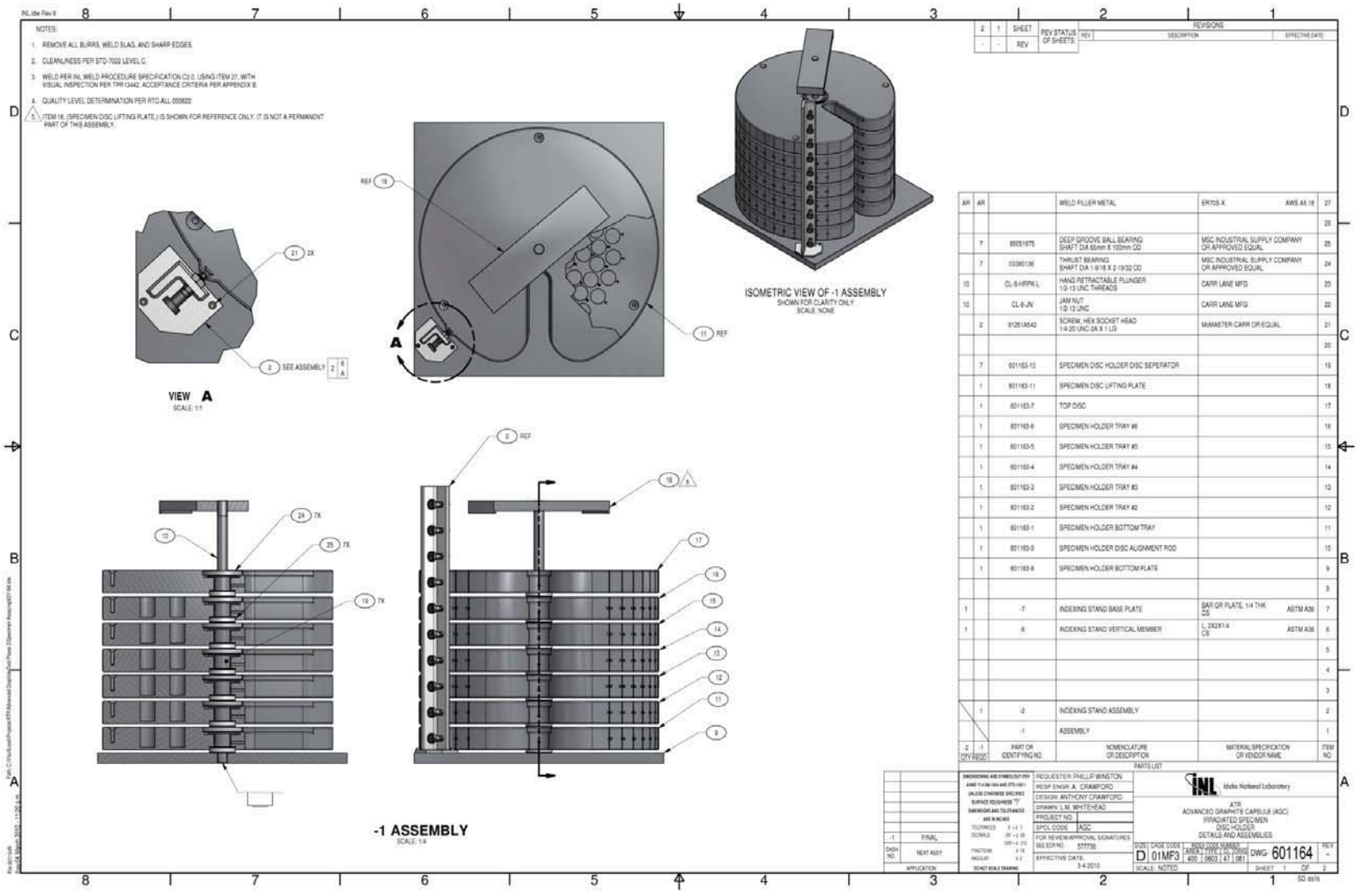
The characterization equipment (including the glovebox discussed previously) will be installed in Lab C19 over the next 6 to 12 months. A Radiological Work Permit will be created and a dry run performed to ensure that all training and monitoring systems are in place. Work in Lab C19 will require RadWorker II certification and work in the CCL glove box will require glove box training as stated in Lab Instructions LI-1577-09-IRC.

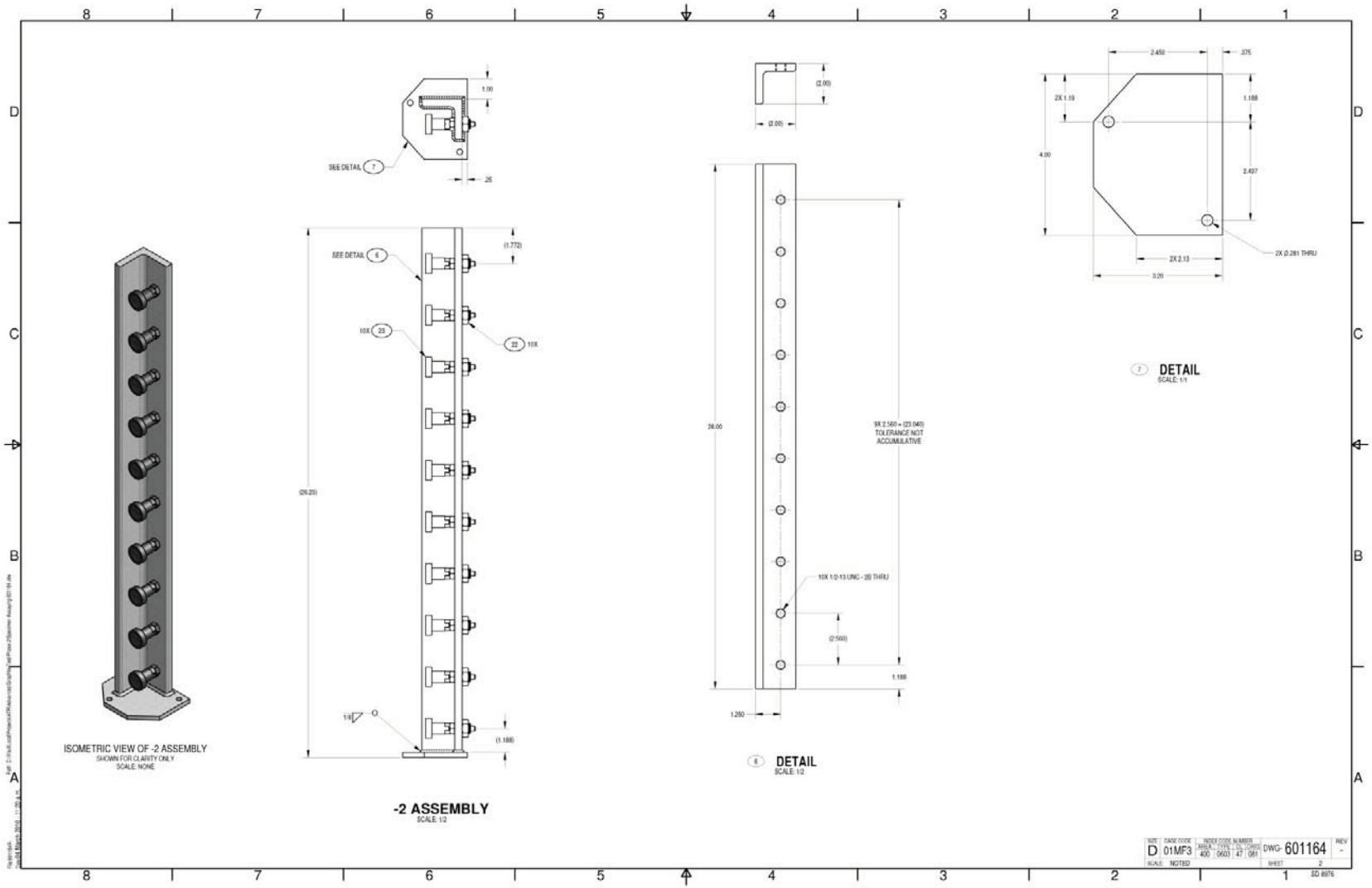
Appendix A

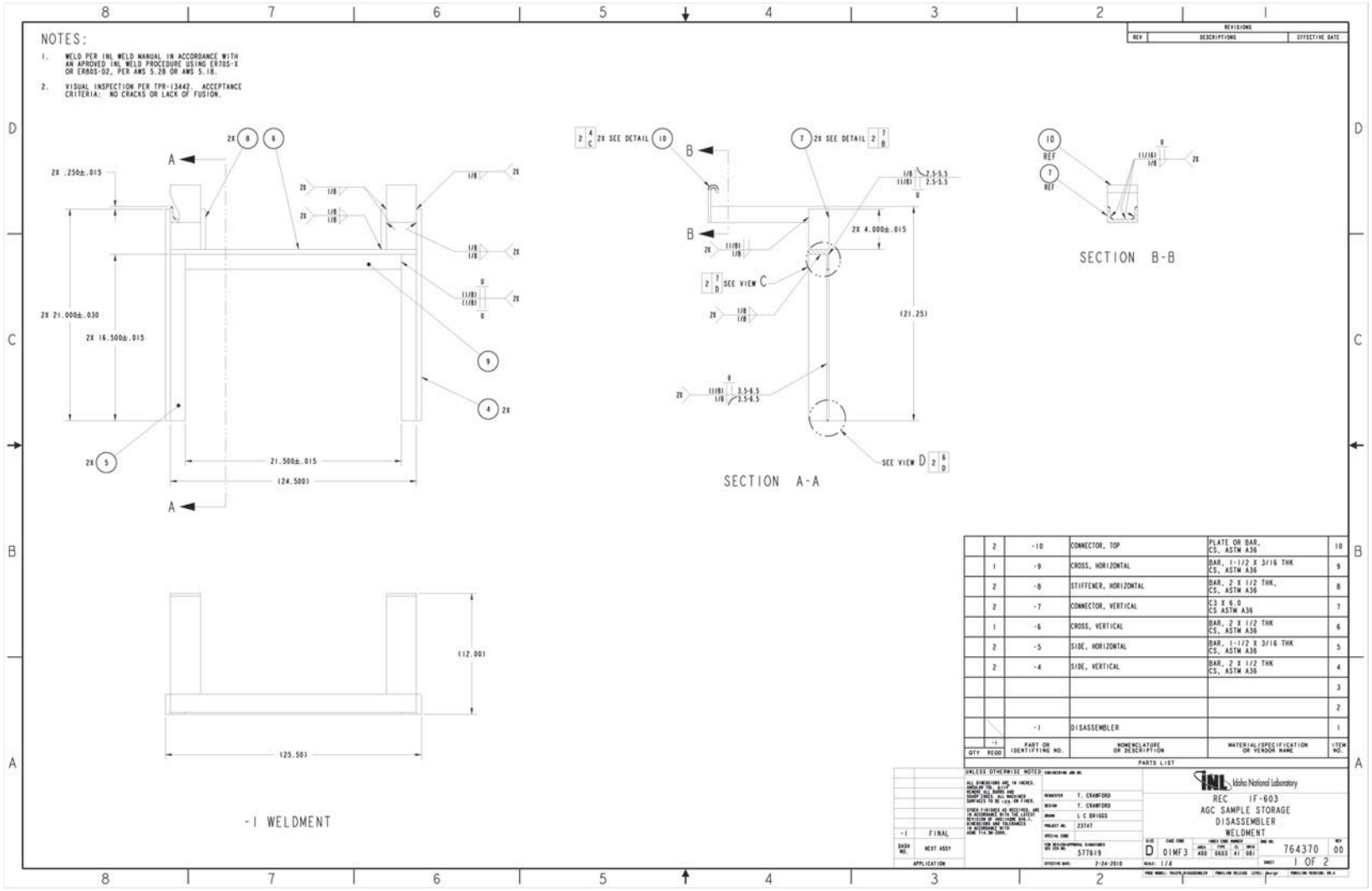
Drawings 601163, 601164 and 764370 Illustrating CCL Irradiated Sample Storage Cabinet

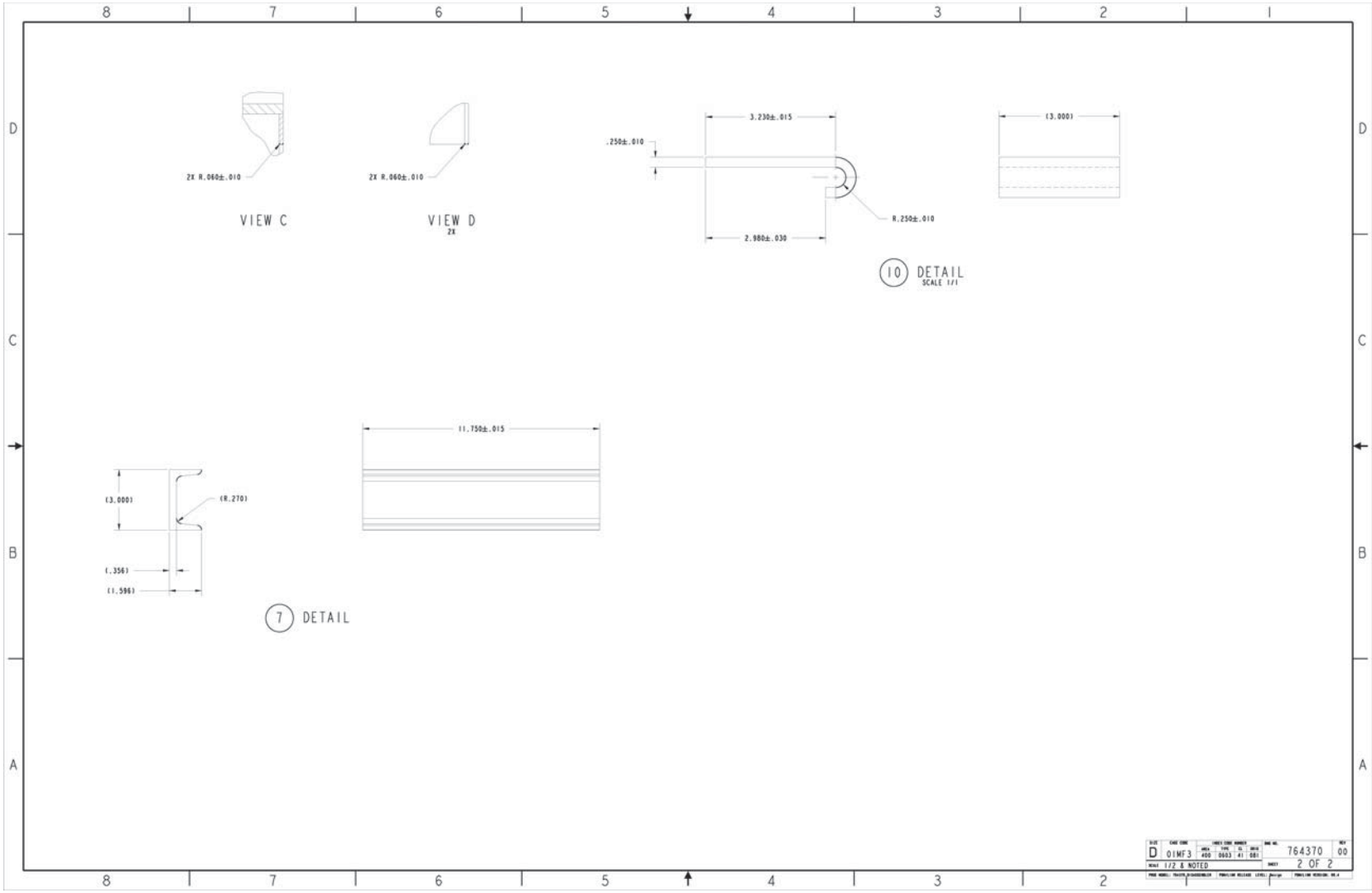

NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES.
2. CLEANLINESS PER STD-7022 LEVEL C.
3. MARK PER STD-13122-2A2 WITH .25 HIGH CHARACTERS SHOWN. CHARACTERS TO BE LOCATED AND ORIENTED APPROXIMATELY AS SHOWN.
4. MARK PER STD-13122-2A2 USING .25 HIGH CHARACTERS IN LOCATION APPROXIMATELY AS SHOWN, ON THE LEFT SIDE OF EACH INDEX MARK. CHARACTERS TO BE AS FOLLOWS:
ITEM 1: ROMAN NUMERAL "I".
ITEM 2: ROMAN NUMERAL "II"
ITEM 3: ROMAN NUMERAL "III"
ITEM 4: ROMAN NUMERAL "IV"
ITEM 5: ROMAN NUMERAL "V"
ITEM 6: ROMAN NUMERAL "VI"
5. STARTING AT THE FIRST INDEXING MARK AND GOING IN A CLOCKWISE DIRECTION, MARK PER STD-13122-2A2 USING .25 HIGH CHARACTERS (I THRU 37) IN LOCATION APPROXIMATELY AS SHOWN ON THE RIGHT SIDE OF EACH INDEX MARK.
6. THIS DIAMETER, (Ø2.5940), MATES WITH THE OD OF ITEM 25 ON DRAWING 601164(DEEP GROOVE BALL BEARING). FABRICATE PER BEARING MANUFACTURER'S RECOMMENDED FIT.
7. THIS DIAMETER, (Ø1.5925), MATES WITH THE ID OF ITEM 25 ON DRAWING 601164 (DEEP GROOVE BALL BEARING). FABRICATE PER BEARING MANUFACTURER'S RECOMMENDED FIT.
8. THIS DIAMETER, (Ø3.9356), MATES WITH THE OD OF ITEM 24 ON DRAWING 601164 (THRUST BEARING). FABRICATE PER BEARING MANUFACTURER'S RECOMMENDED FIT.
9. THIS DIAMETER, (Ø2.5590), MATES WITH THE ID OF ITEM 24 ON DRAWING 601164 (THRUST BEARING). FABRICATE PER BEARING MANUFACTURER'S RECOMMENDED FIT.
10. QUALITY LEVEL DETERMINATION PER ALL-000602.
VIEW B
SCALE: 1/2
3X 3/8-16 UNC - 2B
↧ 1.50
↘ Ø.910 X 100°
54X Ø1.500
↧ 2.000
3X 120° TOLERANCE NOT ACCUMULATIVE
Ø12.000
Ø22.0
Ø9.000
17X 10° TOLERANCE NOT ACCUMULATIVE
15X 10° TOLERANCE NOT ACCUMULATIVE
Ø6.000
Ø18.000
SEE VIEW A
44°
36°
1.19
2.38
R
B
B
2X R.06
2X R.25
2X R.74
.157
.313
12.00
37X .031
36X 6.0° TOLERANCE NOT ACCUMULATIVE
37X .063
37X .031
R12.00
36.0°
40°
VIEW A
SCALE: 1/1
(3.936)
(Ø3.560)
54X R.01 MAX
R.13
.500
.50
.75
2.25
.313
Ø1.690
(Ø2.594)
2X R.13
(Ø.25 THRU) ONE WALL
.75
Ø24.00
2.000
2X R3.000
1.000
2.250
R
ISOMETRIC VIEW OF ITEM 1
SHOWN FOR CLARITY ONLY
SCALE: NONE
1 DETAIL SHOWN
6 DETAIL SIMILAR
SCALE: 1/2
SHEET 2 1
REV
REV STATUS OF SHEETS
REVISIONS
REV | DESCRIPTION | EFFECTIVE DATE
-11 | SPECIMEN DISC LIFTING PLATE | PLATE, 1-1/4 THK CS | ASTM A36 | 11
-10 | SPECIMEN DISC HOLDER DISC SEPERATOR | ROD OR BAR, Ø3.00 CS | ASTM A36 | 10
-9 | SPECIMEN HOLDER DISC ALIGNMENT ROD | ROD OR BAR, Ø1.0 CS | ASTM A36 | 9
-8 | SPECIMEN HOLDER BOTTOM PLATE | PLATE, 1 THK CS | ASTM A36 | 8
-7 | TOP DISC | PLATE, 2 1/4 THK CS | ASTM A36 | 7
-6 | SPECIMEN HOLDER TRAY #6 | PLATE, 2 1/4 THK CS | ASTM A36 | 6
-5 | SPECIMEN HOLDER TRAY #5 | PLATE, 2 1/4 THK CS | ASTM A36 | 5
-4 | SPECIMEN HOLDER TRAY #4 | PLATE, 2 1/4 THK CS | ASTM A36 | 4
-3 | SPECIMEN HOLDER TRAY #3 | PLATE, 2 1/4 THK CS | ASTM A36 | 3
-2 | SPECIMEN HOLDER TRAY #2 | PLATE, 2 1/4 THK CS | ASTM A36 | 2
-1 | BOTTOM SPECIMEN HOLDER TRAY | PLATE, 2 1/4 THK CS | ASTM A36 | 1
QTY/ASSY | PART OR IDENTIFYING NO. | NOMENCLATURE OR DESCRIPTION | MATERIAL/SPECIFICATION OR VENDOR NAME | ITEM NO.
PARTS LIST
-7 | 601164
-6 | 601164
-5 | 601164
-11 | 601164 | -4 | 601164
-10 | 601164 | -3 | 601164
-9 | 601164 | -2 | 601164
-8 | 601164 | -1 | 601164
NEXT ASSY
APPLICATION
DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994 EXCEPT AS NOTED
UNLESS OTHERWISE SPECIFIED SURFACE ROUGHNESS IN MICRO-INCHES
DIMENSIONS ARE TO BE APPLIED AT 68°F
TOLERANCES: DECIMALS .X ±0.1 .XX ±0.05 .XXX ±0.025 FRACTIONS ±1/16 ANGULAR ±2°
REQUESTER: PHILLIP WINSTON
RESP ENGR: A CRAWFORD
DESIGN: ANTHONY CRAWFORD
DRAWN: L.M. WHITEHEAD
PROJECT NO.
SPCL CODE: AGC
FOR REVIEW/APPROVAL SIGNATURES SEE ECP NO: 577736
EFFECTIVE DATE: 3-4-2010
DO NOT SCALE DRAWING
Idaho National Laboratory
ATR
ADVANCED GRAPHITE CAPSULE (AGC) IRRADIATED SPECIMEN SAMPLE HOLDER DISC DETAILS
SIZE: E | CAGE CODE: 01MF3 | DOE CODE NUMBER: ANES / GEN IV / NGNP | DWG: 601163 | REV: -
SCALE: NOTED | SHEET 1 OF 2
SD 8976


ISOMETRIC VIEW OF ITEM 2
SHOWN FOR CLARITY ONLY
SCALE: NONE
VIEW C
SCALE: 1:1
SEE VIEW C
DETAIL
SCALE: 1:2
DETAIL
SCALE: 1:4
DETAIL
SCALE: 1:1
DETAIL
SCALE: 1:2
DETAIL
SCALE: 1:1
SIZE: E
CAGE CODE: 01MP3
DWG: 601163
REV: -
SCALE: NOTED
SHEET: 2
SD 8676


NOTES:
1. REMOVE ALL BURRS, WELD SLAG, AND SHARP EDGES.
2. CLEANLINESS PER STD-7022 LEVEL C.
3. WELD PER INL WELD PROCEDURE SPECIFICATION C2-3, USING ITEM 27, WITH VISUAL INSPECTION PER TPR 13442. ACCEPTANCE CRITERIA PER APPENDIX B.
4. QUALITY LEVEL DETERMINATION PER RTC ALL-000622.
5. ITEM 18, (SPECIMEN DISC LIFTING PLATE,) IS SHOWN FOR REFERENCE ONLY. IT IS NOT A PERMANENT PART OF THIS ASSEMBLY.
REVISIONS
REV STATUS OF SHEETS
SHEET
REV
DESCRIPTION
EFFECTIVE DATE
ISOMETRIC VIEW OF -1 ASSEMBLY
SHOWN FOR CLARITY ONLY
SCALE: NONE
VIEW A
SCALE: 1/1
-1 ASSEMBLY
SCALE: 1/4
PARTS LIST
PART OR IDENTIFYING NO
NOMENCLATURE OR DESCRIPTION
MATERIAL/SPECIFICATION OR VENDOR NAME
ITEM NO
WELD FILLER METAL
ER70S-X
AWS A5.18
DEEP GROOVE BALL BEARING SHAFT DIA 65mm X 100mm OD
MSC INDUSTRIAL SUPPLY COMPANY OR APPROVED EQUAL
THRUST BEARING SHAFT DIA 1-9/16 X 2-19/32 OD
HAND RETRACTABLE PLUNGER 1/2-13 UNC THREADS
CARR LANE MFG
JAM NUT 1/2-13 UNC
SCREW, HEX SOCKET HEAD 1/4-20 UNC-2A X 1 LG
McMASTER-CARR OR EQUAL
SPECIMEN DISC HOLDER DISC SEPERATOR
SPECIMEN DISC LIFTING PLATE
TOP DISC
SPECIMEN HOLDER TRAY #6
SPECIMEN HOLDER TRAY #5
SPECIMEN HOLDER TRAY #4
SPECIMEN HOLDER TRAY #3
SPECIMEN HOLDER TRAY #2
SPECIMEN HOLDER BOTTOM TRAY
SPECIMEN HOLDER DISC ALIGNMENT ROD
SPECIMEN HOLDER BOTTOM PLATE
INDEXING STAND BASE PLATE
BAR OR PLATE, 1/4 THK CS
ASTM A36
INDEXING STAND VERTICAL MEMBER
L, 2X2X1/4 CS
INDEXING STAND ASSEMBLY
ASSEMBLY
REQUESTER: PHILLIP WINSTON
RESP ENGR: A. CRAWFORD
DESIGN: ANTHONY CRAWFORD
DRAWN: L.M. WHITEHEAD
PROJECT NO:
SPOL CODE: AGC
FOR REVIEW/APPROVAL SIGNATURES
SEE ECR NO: 577736
EFFECTIVE DATE: 3-4-2010
FINAL
NEXT ASSY
Idaho National Laboratory
ATR
ADVANCED GRAPHITE CAPSULE (AGC)
IRRADIATED SPECIMEN
DISC HOLDER
DETAILS AND ASSEMBLIES
SIZE D
CAGE CODE 01MF3
DWG: 601164
SCALE: NOTED
SHEET 1 OF 2
SD 8976


ISOMETRIC VIEW OF -2 ASSEMBLY
SHOWN FOR CLARITY ONLY
SCALE: NONE
-2 ASSEMBLY
SCALE: 1/2
SEE DETAIL 7
SEE DETAIL 6
10X 23
22 10X
(29.25)
(1.772)
(1.188)
1.00
.25
(2.00)
(2.00)
26.00
9X 2.560 = (23.040)
TOLERANCE NOT
ACCUMULATIVE
10X 1/2-13 UNC - 2B THRU
(2.560)
1.188
1.250
DETAIL
SCALE: 1/2
2.450
.375
2X 1.19
1.188
4.00
2.437
2X 2.13
3.20
2X Ø.281 THRU
DETAIL
SCALE: 1/1
SIZE D
CAGE CODE 01MF3
INDEX CODE NUMBER AREA 400 TYPE 0603 CL 47 CHG 061
DWG- 601164
REV -
SCALE NOTED
SHEET 2
SD 8976


NOTES:
1. WELD PER INL WELD MANUAL IN ACCORDANCE WITH AN APPROVED INL WELD PROCEDURE USING ER70S-X OR ER80S-D2, PER AWS 5.28 OR AWS 5.18.
2. VISUAL INSPECTION PER TPR-13442. ACCEPTANCE CRITERIA: NO CRACKS OR LACK OF FUSION.
REVISIONS
REV
DESCRIPTIONS
EFFECTIVE DATE
2X .250±.015
2X 21.000±.030
2X 16.500±.015
21.500±.015
(24.500)
SECTION A-A
SECTION B-B
2X 4.000±.015
(21.25)
SEE VIEW C
SEE VIEW D
(12.00)
(25.50)
-1 WELDMENT
QTY REQD
PART OR IDENTIFYING NO.
NOMENCLATURE OR DESCRIPTION
MATERIAL/SPECIFICATION OR VENDOR NAME
ITEM NO.
PARTS LIST
2 -10 CONNECTOR, TOP PLATE OR BAR, CS, ASTM A36 10
1 -9 CROSS, HORIZONTAL BAR, 1-1/2 X 3/16 THK CS, ASTM A36 9
2 -8 STIFFENER, HORIZONTAL BAR, 2 X 1/2 THK, CS, ASTM A36 8
2 -7 CONNECTOR, VERTICAL C3 X 6.0 CS ASTM A36 7
1 -6 CROSS, VERTICAL BAR, 2 X 1/2 THK CS, ASTM A36 6
2 -5 SIDE, HORIZONTAL BAR, 1-1/2 X 3/16 THK CS, ASTM A36 5
2 -4 SIDE, VERTICAL BAR, 2 X 1/2 THK CS, ASTM A36 4
3
2
-1 DISASSEMBLER 1
UNLESS OTHERWISE NOTED:
T. CRAWFORD
T. CRAWFORD
L C BRIGGS
23747
577619
2-24-2010
-1 FINAL
DASH NO.
NEXT ASSY
APPLICATION
Idaho National Laboratory
REC IF-603
AGC SAMPLE STORAGE
DISASSEMBLER
WELDMENT
D
01MF3
764370
00
1 OF 2


2X R.060±.010
VIEW C
2X R.060±.010
VIEW D
2X
3.230±.015
.250±.010
R.250±.010
2.980±.030
(3.000)
10 DETAIL
SCALE 1/1
11.750±.015
(3.000)
(R.270)
(.356)
(1.596)
7 DETAIL
D
01MF3
764370
00
2 OF 2
1/2 & NOTED