

**Modular Coil Fabrication- VPI/ Autoclave Activities
D-NCSX-MCF-003-01**

Princeton Plasma Physics Laboratory Procedure			
Procedure Title: Modular Coil Fabrication-VPI/ Autoclave Activities			
Number: D-NCSX-MCF-003	Revision: 01	Effective Date: February 17, 2006 Expiration Date: <i>(2 yrs. unless otherwise stipulated)</i>	
Procedure Approvals			
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Responsible Division: NCSX Project			
Procedure Requirements Designated by RLM			
LABWIDE:			
X	Work Planning Form # WP-1188 & 1138 (ENG-032)		Lockout/Tagout (ESH-016)
	Confined Space Permit (5008,SEC.8 Chap 5)		Lift Procedure (ENG-021)
	Master Equip. List Mod (GEN-005)	X	ES&H Review (NEPA, IH, etc.) NEPA 1283
	RWP (HP-OP-20)		Independent Review
	ATI Walkdown	X	Pre-Job Brief
X	Post-job Brief *		
D-SITE SPECIFIC:			
X	D-Site Work Permit (OP-AD-09)		Door Permit (OP-G-93)
	Tritium Work Permit (OP-AD-49)		USQD (OP-AD-63)
X	Pre-Job Brief (OP-AD-79)		T-Mod (OP-AD-03)
	** DCA/DCN (OP-AD-104) # _____		

* Required for installations involving internal vacuum installations, critical lifts, and for the initial installation of repetitive work.

** OP-AD-104 was voided by procedure ENG-032. However, DCA's that were open at the time of adoption of ENG-032 are still considered valid for work approval purposes.

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Note: X indicates that comments were received and incorporated

TRAINING (designated by RLM)			
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Technicians performing task		X	
Field Supervisors		X	
Quality Control Representative		X	
Training Rep.			
RLM Larry Dudek			

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RECORD OF CHANGE

Revision	Date	Description of Change
00	1/17/05	Initial release
01	2/17/06	General description of changes 1) General reformatting and rearrangement of some sections in proper order 2) Modified Delivery system based upon TRC trials 3) Added safety notes using scaffolding 4) Added emergency autoclave entry steps section 6.11

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1 Scope

1.1 Introduction

The Modular Coil Manufacturing Facility is divided into 5 workstations. Each workstation has a specific set of tasks that will be performed as part of the overall fabrication process. This procedure addresses the manufacturing, inspection, test and QC inspection points for a specific workstation.

- Station No. 1... Winding Form Preparation & Post VPI Activities
- Station No. 2... Winding Station Molding and VPI Preparation [TRC coil prep & Winding operations]
- Delete reference to station 3
- Station No. 4... Winding Station Molding and VPI Preparation
- **Station No. 5... VPI and Autoclave Activities**
- *Deleted Reference to Station 6*

1.2 Scope

This procedure is used to impregnate the modular and Twisted Racetrack coils with epoxy. The work is all performed at Station No.5. The activities include:

- Installing the Modular Coil into the autoclave
- Preparing the modular coil for VPI
- Preparing the epoxy resin
- Vacuum impregnating the Modular coil
- Preparing the VPI'd coil for removal
- Cleanup of the autoclave

1.3 Identification of Coil being manufactured:

Station Number: _____

Winding Form Type: _____ (A, B, C or Twisted)

MC Winding Form ID No: _____

Modular ID Coil Number: _____

2 Applicable Documents

2.1 NCSX-MIT/QA-142-01:

All applicable documents associated with this procedure, are identified in the MIT/QA Plan, document number **NCSX-MIT/QA-142-01**.

2.2 NCSX-PLAN-MFOP-00:

All Modular Coil work processes are governed by the "Manufacturing Facility Operations Plan", document number **NCSX-PLAN-MFOP-00**.

2.3 D-L-NCSX-984: Lifting Modular Coil Assemblies

2.4 D-PTP-NCSX-CL-030 Modular Coil Autoclave Checkout

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3 Safety Requirements:

All work will be performed in a safe manner in accordance with PPPL safety policies **ES&H 5008** and “Integrated Safety Management” (ISM) policy.

3.1 Job Hazard Analysis:

A JHA will be generated for the winding stations, identifying existing or potential workplace hazards and to evaluate the risk of worker injury or illness associated with job tasks. (Reference document **ESH-004 “Job Hazard Analysis”**) The IH representative will review the JHA’s for accuracy as well as completeness. It will be reviewed with all activity participants at the Pre-Job briefings.

3.2 Autoclave Activities:

All entries into the autoclave regardless of whether or not the chamber lid is in place will require a **CONFINED SPACE** permit. Entry into the autoclave once the chamber has been heated shall only be permitted per written orders by the Industrial Hygienist [See section 6.11].

3.3 Removal of Autoclave Lid or Modular Coil:

The upper catwalk around the top of the autoclave will be restricted (chained) during the removal/installation of the autoclave lid, or a modular coil. An observation area on the catwalk will be provided to allow the crane operator and/or lift engineer to observe the lift. There will be no restrictions on use of the upper catwalks by personnel while the autoclave lid is in position or while the space between the lid and vessel is less than 12 inches.

4 Prerequisites & Conditions:

4.1 Pre-Job Briefing:

A pre-job briefing will be held, describing the processes and safety issues prior to starting any part of this procedure. Attendance shall be documented via training sign-in sheet.

Pre job Briefing complete: _____
MC Field Supervisor **Date**

4.2 Daily Operations Startup and Shutdown:

Each working day, it is required that the Lead Technician complete and initial the daily operations startup log to ensure that the station is ready to commence work activities for the day. The signoff log is located in the Daily Station Log. See section 6.1 and 6.2 for details.

4.3 Torque Values:

Unless a torque value is specified, the following torque values shall be used whenever the procedure requires a torquing operation. (Low carbon steel hardware)

3/8-16UNC	18 ft-lbs	3/8-24UNF	19 ft-lbs	1/2-13 UNC	38 ft-lbs
1/2 -20 UNF	40 ft-lbs	5/8-11 UNC....	83 ft-lbs	5/8-18 UNF...	95 ft-lbs
3/4-10 UNC.....	105 ft-lbs	3/4-16 UNF	102 ft-lbs	1-8 UNC ...	236 ft-lbs
1-14 UNF	212 ft-lbs	1 1/4 UNC	432 ft-lbs	1 1/2-6 UNC	732 ft-lbs

4.4 VPI Director

The VPI Director will be appointed by the Manufacturing Facility Manager, and is responsible for all activities associated with the epoxy filling of the modular coils. The VPI Director may not be the same for all modular coils.

VPI Director for this coil shall be: _____

<p>Verified by: _____ Date: _____</p> <p align="center">Manufacturing Facility Manager</p>

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4.5 AC Power Notification

Notify the AC power group **48 hours prior** to the start of VPI operations to transfer the autoclave/ VPI systems to the electrical backup circuit.

Notified [48 hours]: Verified by: _____ Date: _____ <p align="center">VPI Director</p>

4.6 ESU Notification:

Notify the Emergency Services Unit (ESU) **24 hours prior** to the start of VPI operations. Contact the ESU the morning of the VPI operation per the emergency response procedure **D-NCSX-OP-EO-41**. [A “RUN” copy of the emergency response procedure must be obtained for each VPI operation]

Notified [24 hours]: Verified by: _____ Date: _____ <p align="center">VPI Director</p>

4.7 Industrial Hygiene Notification:

Notify the PPPL IH group **24 hours prior** to the start of VPI operations.

Notified [24 hours]: Verified by: _____ Date: _____ <p align="center">VPI Director</p>

5 Materials and Parts for this station

The following materials and/or equipment will be used with this procedure.

General Description	Material	Reference Document/Product No.
Solvent	Acetone	MSDS# 00561
Vacuum Pressure Impregnation Epoxy System	Resin/ Hardener/Accelerator [3-part system]	CTD-101K (Composite Tech Dev. Corp.) [MSDS #04979]
Autoclave	Fabricated vacuum/pressure chamber	SE144-301
Vacuum leak checking equipment	Equipment	
Heat resistant Vacuum tubing	0.625 inch OD x 0.5 inch ID	FTP Chemflor tubing
Vacuum tubing	0.50 inch OD	Poly-flo
Epoxy delivery system	Manifold- valves/PVC fittings & tubing	SE144-205
Viscometer-	Equipment	
Hot Plate- for Gel [Scrambled egg] tests	Equipment	
Digital scale- for weighing epoxy components	Equipment	
Bench top oven	Equipment	
Nitrogen	Material- gas	

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Vacuum pumps	Equipment	
Personnel Protective Equipment	Face shields, goggles, gloves, etc	

6 Fabrication Process

This fabrication procedure is to be used as guide to complete the VPI activities. Deviation from this procedure for processes that DO NOT affect the design of the coil can be made during the VPI process with the concurrence of the VPI Director or MC Field Supervisor. All deviations shall be documented in the procedure and initialed by the VPI Director or MC Field Supervisor prior to implementing the deviations. Deviations that may effect the design of the coil requires a Request for Deviation “RFD” approval. The RFD must be approved prior to proceeding. Procedure changes need to be incorporated into the document via “Minor Procedure Changes” or “Revisions”.

6.1 Daily Startup Activities:

- Check all daily supplies needed:
- Verify operation of all equipment needed that day.
- Check station for cleanliness
- Check that safety guards or systems are in place.
- Check that the safety equipment needed for that day is available.
- Check that the day’s travelers and procedures are in their document holder.
- Once completed, date and Lead Technician initial the daily log at the back of the stations log book.

6.2 Daily Shutdown Activities:

- Turn off power to equipment not in use.
- Clean entire workstation area.
- Verify that all Traveler and data sheet information is complete.
- The Lead Technician shall verify that the Station’s Log Book has been completed and signed for the day.
- Once completed, date and Lead Technician initial the daily log at the back of the stations log book.

6.3 Transporting MCWF from Winding Station 2 or 4 to the Autoclave [Station 5]

A confined space permit is required for performing any work in the autoclave.

6.3.1 Winding Station preparations [Station 2 or 4]

- Ensure that the autoclave is ready to receive the coil and winding form.

Verified by: _____ Date: _____ <p align="center">Lead Technician</p>
--

- Install the upper support plates that secure the support ring to the support/lift beam. This operation must be verified prior to proceeding. See Figure 1- Upper Support Plates

Verified by: _____ Date: _____ <p align="center">Lead Technician</p>
--

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- **SAFETY NOTE:** Use scaffolding or appropriate ladders while working on upper section of turning fixture. Scaffolding must be inspected prior to use per Section 9 Chapter 5 in PPPL ES&H Manual.
- Using the lift data sheet on procedure **D-L-NCSX-984**, rig the upper support/lift beam to the overhead crane.
- Once a slight load has been taken, remove the hardware that secures the upper support/lift beam to the turning fixture frame.
- Compress the springs under the gear box (drive system) until they are bottomed.
- Disengage and remove the upper guide rollers. NOTE: Sling the rollers and raise them into position with rope. **Do not climb up ladder with roller assembly in hand.**
- Carefully raise the winding form/ring assembly from either station 2 or 4 and transport to the autoclave [Station 5]. Install the MCWF into the autoclave turning fixture via the open chamber.

Note: During the removal of the MCWF from the turning fixture, to minimize risk of potential dirt contamination, the rooms must be isolated from each other. This only applies if a coil is already in the adjacent winding station.

Verified by: _____ Date: _____
Field Supervisor

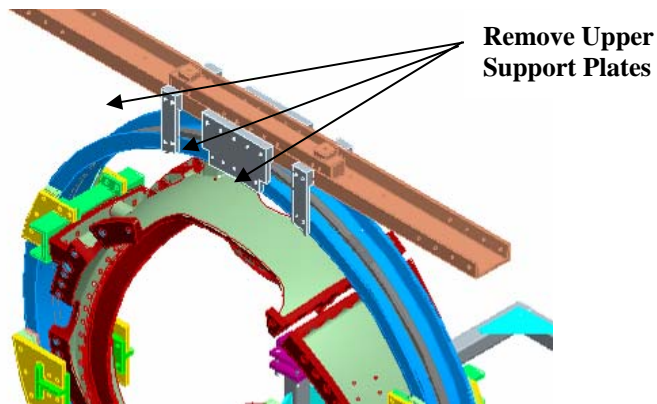


Figure 1- Upper Support Plates

6.3.2 Autoclave Turning Fixture Preparations [Station 5]:

Activities associated with receiving modular coil at the VPI station.

- Prior to installing the MCWF compress the springs under the gear box (drive system) until they are bottomed.
- Lower the MCWF and ring assembly into the turning fixture using the corner brackets for alignment.

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- **SAFETY NOTE 1:** Use scaffolding or appropriate ladders while working on upper section of turning fixture. Scaffolding must be inspected prior to use per Section 9 Chapter 5 in PPPL ES&H Manual.
- **SAFETY NOTE 2:** The upper catwalk around the top of the autoclave will be restricted (chained) during the removal/installation of the autoclave lid, or a modular coil. An observation area on the catwalk is provided to allow the crane operator and/or lift engineer to observe the lift. There will be no restrictions on use of the upper catwalks by personnel while the autoclave lid is in position or while the space between the lid and vessel is less than 12 inches.
- Install the upper guide rollers and align all of the guide rollers to the support ring. NOTE: Sling the rollers and raise them into position with rope. **Do not climb up ladder with roller assembly in hand.**
- Decompress springs under the gear box (drive unit) until gear is fully engaged with ring gear rack. This must be verified prior to proceeding.

Verified by: _____ Date: _____
Lead Technician

- Verify that the upper support/lift beam is in proper position.

Verified by: _____ Date: _____
Lead Technician

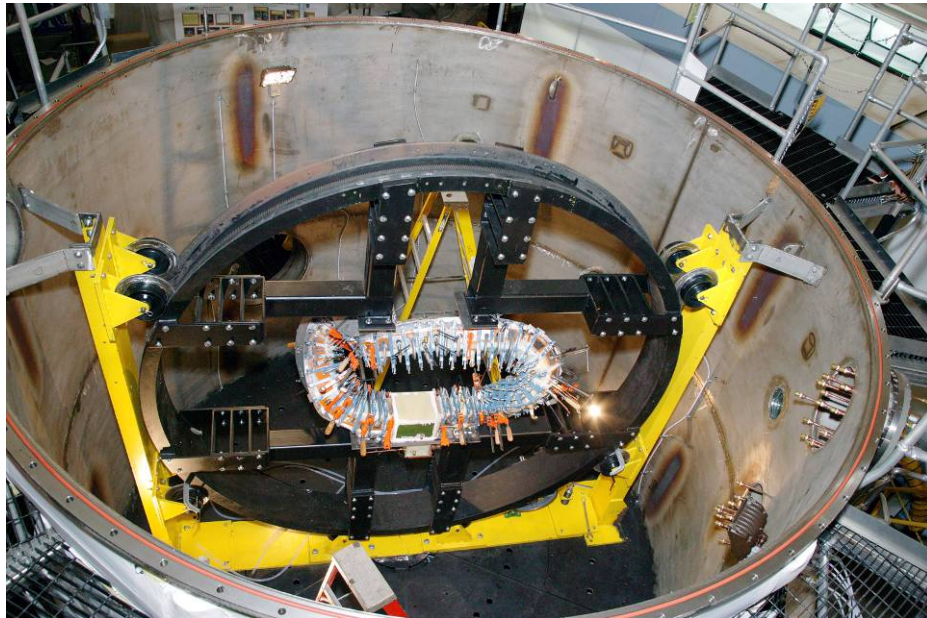


Figure 2- Coil/Ring Assy in Autoclave

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- Remove the upper support plates between the support-ring and lift beam. [Figure 1- Upper Support Plates] This operation must be verified prior to operating turning fixture. Once removed, using the crane transport the lifting beam from the autoclave and store the unit on facility floor. [Figure 2- Coil/Ring Assy in Autoclave]

Verified by: _____ Date: _____ Lead Technician
--

- Verify that the upper support/lift beam is in proper position. Using a drill motor connected to the gear box, slowly rotate the MCWF until it is in its proper orientation for VPI operations. Secure the support ring to the turning fixture uprights so that the unit cannot rotate.

Support Ring secured: Verified by: _____ Date: _____ Lead Technician _____ Date: _____ VPI Director

- 6.3.3 Autoclave Lid:
Reinstall the autoclave lid and secure in place using the 3/4-10 UNC hardware and torque to appropriate value per section 4.3.

Lid Secured: Verified by: _____ Date: _____ Lead Technician

6.4 Epoxy Delivery System Preparation

- 6.4.1 Assemble Delivery System:
Using Diagram Figure 3- VPI Delivery System, connect the modular coil to the epoxy delivery system. The number of coil connections as well as the connection details will be at the discretion of the VPI Director. CLEARLY identify sprue numbers so that they are visible from the autoclave windows. Record sprue location on appropriate figure- Figure 11-Sprue Locations for Type C Casting, Figure 10- Sprue Locations for Type B Casting, Figure 13-Sprue Location for Type "A" Casting, Figure 14- Sprue Locations for Twisted Racetrack Coil.

- 6.4.2 Pump Down and Leak Check:
Apply a vacuum to the entire delivery system [Do not include coil in test]. Pump down the system to <1 Torr.

- **Acceptance criteria:** The vacuum test level shall be maintained for one hour minimum with no greater than a 15 Torr rise. The start time begins from the time the system was isolated from the vacuum source.

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LEAK TEST RESULTS:
 Start Time: _____ Vacuum Reading: _____
 Stop Time: _____ Vacuum Reading: _____

Notes:

Table 1- VPI Valve Identification Key

Valve ID	Valve Description	Valve ID	Valve Description
D-1	Vacuum/pressure to Tank 1	A-1 thru A-9	Zone 1 epoxy Fill valves
D-2	Vacuum/pressure to Tank 2	A-10 thru A35	Zone 2 epoxy Fill valves
D-3	Tank 1 to Tank 3	B-10 thru B-35	Zone 2 epoxy Exit valves
D-4	Tank 2 to Tank 3	C-36 thru C-47	Zone 3 epoxy Exit valves
D-5	Vacuum to Tank 3	Sample	Fill valve for in vessel epoxy sample
D-6	Pressure to Tank 3	P1	Pressure to coil
D-7	Shut off valve to Tank 3	V1	Vacuum to coil
D-8	Valve to epoxy dump/waste	A-VV-1	Autoclave chamber- Vacuum pump 1
D-9	Sample valve from Tank 3	A-VV-2	Autoclave chamber- Vacuum pump 2
D-10	Valve to fill manifold	A-SV-5	Vacuum to Autoclave chamber
D-11	To Epoxy Filter- Side A	A-SV-4	Pressure to Autoclave chamber
D-12	From Epoxy Filter- Side A		
D-13	Filter bypass In- Side A		
D-14	Filter bypass Out- Side A		
D-15	To Epoxy Filter- Side B	Sprue Number	Zone & Description
D-16	From Epoxy Filter- Side B	1-6	Zone 1 Fill valves
D-17	Filter bypass In- Side B	7-30	Zone 2 Fill & Vacuum/return valves
D-18	Filter bypass Out- Side B	31-42	Zone 3 Vacuum /return valves

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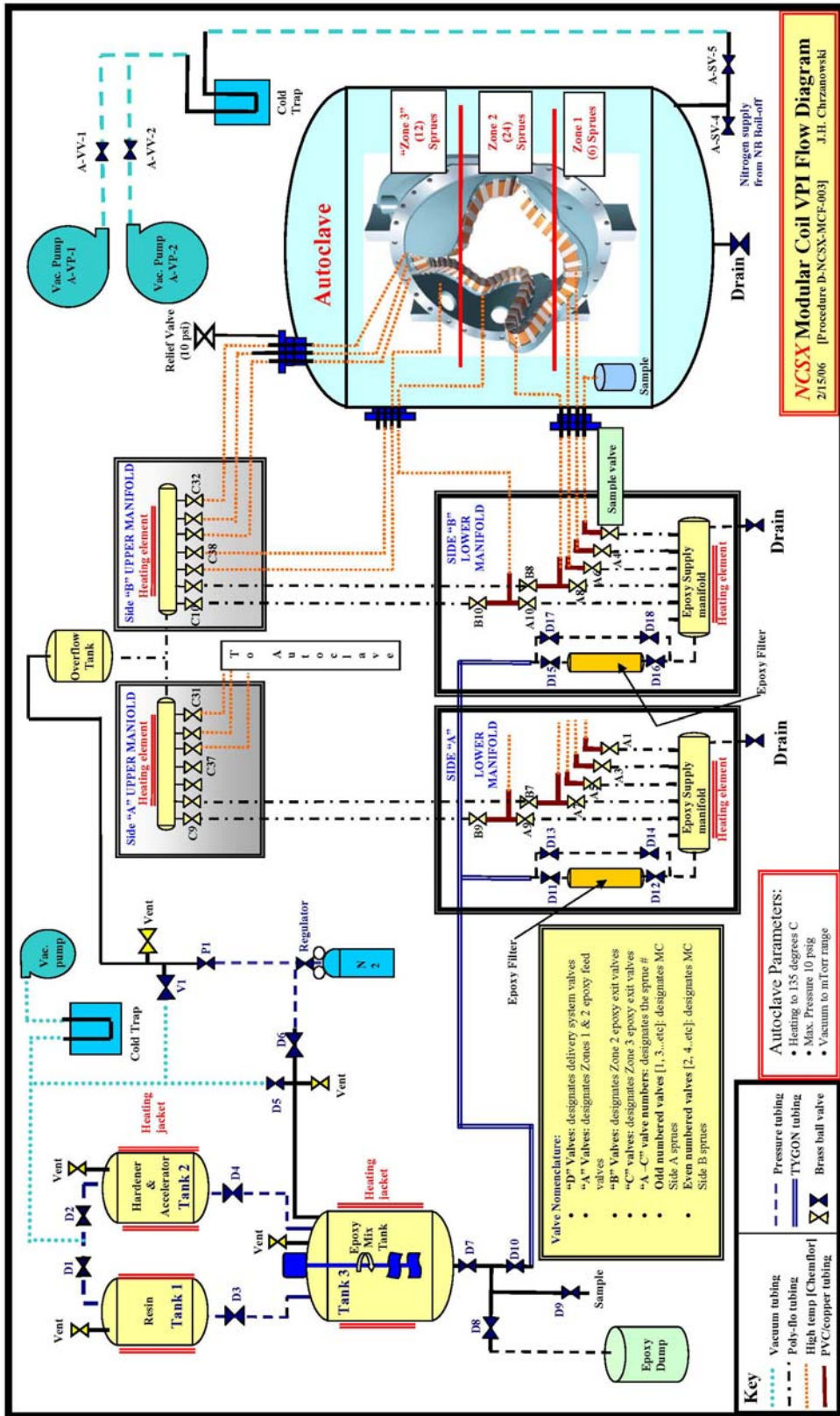


Figure 3- VPI Delivery System

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6.4.3 Thermocouples:

Install the thermocouples in the autoclave and on the coil being impregnated in the locations identified by the VPI Director. Using Table 2-Thermocouple Locations and Figure 4-Thermocouple Locations identify and show positions of each thermocouple.

Table 2-Thermocouple Locations

Thermocouple No.	Thermocouple Location	Thermocouple No.	Thermocouple Location
1		13	
2		14	
3		15	
4		16	
5		17	
6		18	
7		19	
8		20	
9		21	
10		22	
11		23	
12		24	

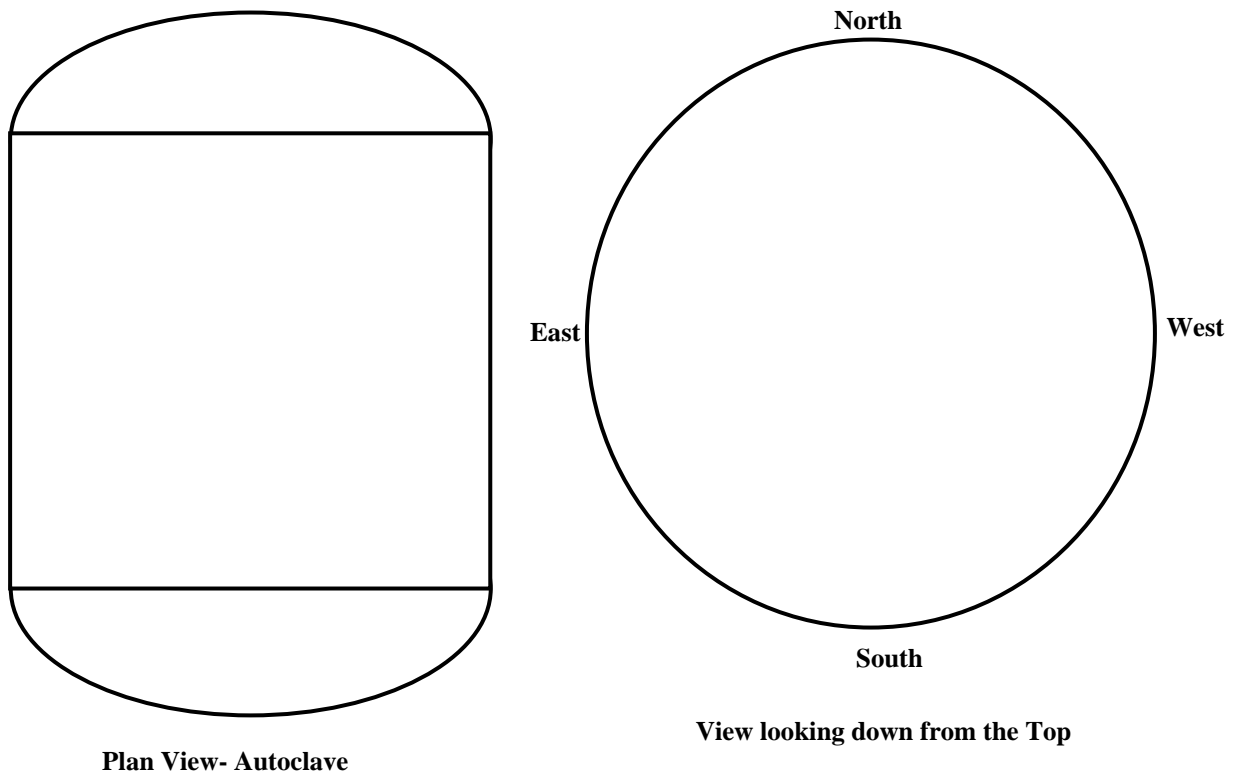


Figure 4-Thermocouple Locations

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6.4.4 Pre-VPI Inspection:

A final inspection shall be made by the VPI Director and lead technician of the entire delivery system. This inspection will include as a minimum the following:

- Verify that all epoxy connections are secure.....
- Verify that the labeling of sprues and valves is correct and that sprue numbers are visible from viewing ports.....
- Verify that the bag mold is adequately supported. [Primarily the lower section].....
- Verify that the epoxy sample container [In Autoclave] is in position.....
- Verify that all thermocouples are properly located and functioning.
- Final inspection has been completed and coil/VPI system is ready for vacuum.....

Verified by: _____ <p align="center">Lead Technician</p>	Date: _____ _____ <p align="center">VPI Director</p>
--	---

6.4.5 Applying Vacuum to Modular Coil

- **Open** all of the A, B and C valves on the manifolds, plus valves D10, D11, D12, D15 and D16. **Do not** open the sample valve.
- Apply vacuum to the bag mold and manifold by turning on vacuum pump and **opening valve V1**.

Vacuum readings: Mold: Autoclave: Notes:

Verified by: _____ <p align="center">Lead Technician</p>	Date: _____
--	-------------

- Preheat the autoclave to 50 °C using the blower system and wall heating elements.

Temperature verified: Verified by: _____ <p align="center">Lead Technician</p>	Date: _____
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- Shutdown and isolate blower system. [SC144-400]

Verified by: _____ Date: _____ <p align="center">Lead Technician</p>
--

- Apply a vacuum to the autoclave chamber by turning on the autoclave vacuum pump and opening valve A-VV-5.
- Allow the mold and autoclave vacuums to equalize.

Vacuum readings: Mold: Autoclave: Notes:

Verified by: _____ Date: _____ <p align="center">Lead Technician</p>
--

6.5 Epoxy System:

6.5.1 Epoxy Description:

- **CTD-101K:** a modified 3-part anhydride cured epoxy system with excellent performance at cryogenic temperatures. [MSDS of epoxy MUST be at Station #5]
- *Manufacturer:* Composite Technology Development Inc.
1505 Coal Creek Drive
Lafayette, Colorado 80026
Phone: (303) 664-0394

6.5.2 Epoxy Working and Cure Temperatures

- *Mixing Temperature:* 40-60 degrees C
- *Cure Cycle:* 5 hours @ 110 degrees C
- *Post Cure:* 16 hours @ 125 degrees C

6.5.3 Epoxy Mix Ratio: By weight/Gallon

Description	Ratio- Parts per weight	Calculated Weight/gallon pounds	Calculated Weight/gallon grams
Resin (part A)	100	5.0	2268
Hardener: (Part B)	90	4.5	2041.2
Accelerator: (Part C)	1.5	0.075	34.02
Total		9.575	4343.22

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6.5.4 Epoxy Mixture per Coil:

Using a digital scale carefully weigh out the three components of the VPI epoxy system and place them in clean separate containers. [Reference lbs x 453.6 = grams]

- **Total mix for Twisted Racetrack coil (TRC) VPI Operation: 14-gallons**

Description	Calculated Weight lbs	Calculated Weight grams
Resin (part A)	70	31,752
Hardener: (Part B)	63	28,577
Accelerator: (Part C)	1.05	476.3
Total	134.05	60,805.3

Epoxy breakdown for TRC: Approximate allocations

- 6 gallons for coil
 - 4 gallons for fill lines
 - 4 gallons extra (back fill and measurements)
- **Total mix per Modular coil (Type A, B and C) VPI Operation: 24-gallons**

Description	Calculated Weight lbs	Calculated Weight grams
Resin (part A)	120	54,432
Hardener: (Part B)	108	48,989
Accelerator: (Part C)	1.8	816.5
Total	229.8	104,237.5

Epoxy breakdown for Modular Coils: Approximate allocations

- 11.2 gallons for coil
- 6 gallons for fill lines
- 4 gallons extra (back fill and measurements)

6.6 Preparation of Epoxy Components

6.6.1 Weighing and Loading Components:

- Using a digital scale carefully weigh out the three components of the VPI epoxy system and place them in clean separate containers. Use the quantities as prescribed in sections 6.5.4 Record the actual weights below.

Description	Measured Weight Grams	Measured Weight Pounds
Resin (part A)		
Hardener: (Part B)		
Accelerator: (Part C)		
Total		

**Modular Coil Fabrication- VPI/ Autoclave Activities
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Verified by: _____ <p align="center">Lead Technician</p>	Date: _____ Date: _____ <p align="center">VPI Director</p>
--	---

- Pre-mix weighed components of Part B (hardener) and Part C (accelerator) together. Mix the epoxy system components in a clean container using either a paddle or air mixer.
- Pour the pre-weighed component of Part A (resin) into Tank No. 1. See Figure 5- Epoxy Mixing System.
- Close Tank No. 1 lid and secure.
- Pour pre-mixed components of Part B (hardener) and Part C (accelerator) into Tank No. 2
- Close Tank No. 2 lid and secure.
- Using heating jackets, heat and maintain the temperature of Tanks 1 and 2 at 50 degrees C (+/- 5)
- Once at temperature, apply a vacuum to the both tanks and components. Maintain a 2-3 Torr vacuum on the components until the boiling (degassing) of the components has subsided (VPI Director's discretion)

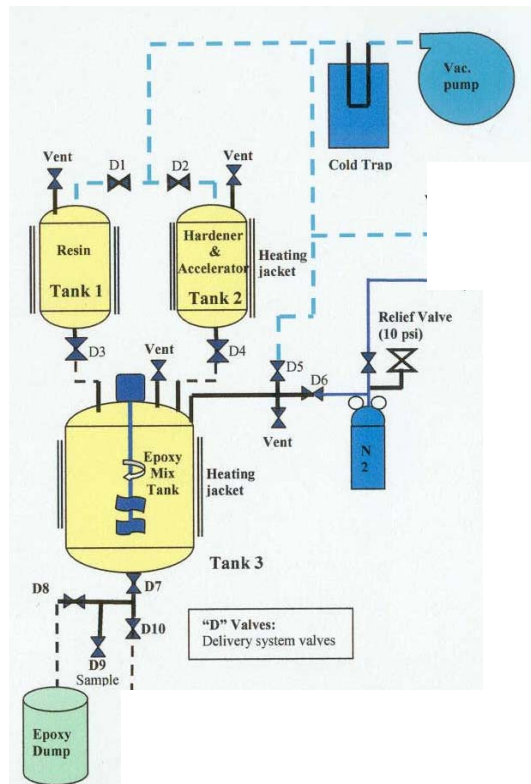


Figure 5- Epoxy Mixing System

Modular Coil Fabrication- VPI/ Autoclave Activities
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DEGASSING DATA:	
Vacuum pressure- Tank #1: _____	Vacuum pressure- Tank #2: _____
Temperature- Tank #1: _____	Temperature- Tank #2: _____
Time Start degassing- Tank #1: _____	Time Start degassing- Tank #2: _____
Time Stop degassing - Tank #1: _____	Time Stop degassing- Tank #2: _____
OBSERVATIONS:	

Verified by: _____ Date: _____
Lead Technician
_____ Date: _____
VPI Director

- Components shall be maintained at the 50-degrees C temperature per VPI Director's direction.
- Once the Modular Coil is within 4 hours of starting the VPI, the final mixing of the components will commence.

**Modular Coil Fabrication- VPI/ Autoclave Activities
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6.6.2 VPI Pre-requisite Checklist:

- The VPI Director shall verify that the VPI check list has been successfully completed and that the Modular Coil or TRC is ready for epoxy impregnation and that the mixing of the epoxy can commence.

VPI-PRE-REQUISITE CHECKLIST

• Mold and Delivery system ready:	<input type="checkbox"/>
• Epoxy Components weighed out and degassed:	<input type="checkbox"/>
• AC Power Notified:	<input type="checkbox"/>
• ESU Notified:	<input type="checkbox"/>
• Industrial Hygiene Notified:	<input type="checkbox"/>
• Autoclave readiness checklist complete: Attach copy of completed Checklist to back of procedure	<input type="checkbox"/>
• Obtain "RUN" copy of Emergency Response Procedure: [Procedure has been reviewed with team]	<input type="checkbox"/>

VPI Pre-Requisite Checklist Complete:

Verified by: _____ Date: _____
VPI Director

6.6.3 Mixing of Epoxy Components

- CLOSE** all valves on the delivery system including tanks and manifolds.

Verified by: _____ Date: _____
VPI Director

- Vent Tanks No. 1, and 2 by **closing** valves D1 and D2, and **opening** the vent valves on Tanks 1 and 2.
- Open** valves D3 and D4 and allow the epoxy components to drain into Tank No. 3 (Mixing Tank).
- Once all of the components have drained into Tank No. 3, start the mixing motor. The speed or revolutions for the mixer is approximately 72 revolutions per minute.

Modular Coil Fabrication- VPI/ Autoclave Activities
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- **Open** valve D5 and begin pulling a vacuum on the epoxy components being mixed. Maintain a 2-3 Torr vacuum on the components until the boiling (degassing) of the mixture has subsided. (VPI Director's discretion)

TANK #3 DEGASSING DATA:	
Vacuum Reading-: _____	Temperature Reading-: _____
Time Start mixing-: _____	
Time- Start degassing: _____	
Time Stop Mixing: _____	
Time Stop degassing -: _____	
Observations:	

Verified by: _____	Date: _____
Lead Technician	
_____	Date: _____
VPI Director	

6.7 Gel Test Procedure (“Scrambled Egg Test”)

The “Scrambled Egg Test” will be performed just prior to every VPI injection. The purpose of the test is to verify the cure integrity [Gel Temperature] of the epoxy mixture.

- **Close** valve D10.
- **Close** the vacuum to Tank 3 and **vent** to atmospheric pressure.
- Draw approximately 1 pint of mixed epoxy from the 30-gallon mix tank by **opening** valve D7 and D9. This epoxy will be **discarded** and not used for viscosity or test samples.
- Draw an additional 1.5 quarts of epoxy from the same valve D9. This epoxy will be used for all viscosity and gel tests related to the VPI. **Close** valve D9.
- Pour approximately 1 ounce of epoxy from the sample epoxy into a metal disk
- Place the metal disk on a pre-heated hot plate set at 110 degrees C.
- Periodically stir the mixture. The mixture should Gel in approximately 10- 20 minutes.

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SCRAMBLED EGG TEST RESULTS:

Start time for ‘Scrambled Egg’ test: _____

Time that epoxy gelled: _____

Observations:

- The VPI director must decide whether the mixture will be used for the epoxy impregnation of the coil should the Gel Time (Cure) not be within the above limits, (The rejected epoxy shall be oven cured in 1 gallon batches to minimize any exothermic reaction of the epoxy)

Verified by: _____ Date: _____
 Lead Technician

_____ Date: _____
 VPI Director

6.8 Viscosity Measurements

“Viscosity” measurements will be taken during the epoxy fill-cycle and continue until the epoxy mixture has begun to Gel or get thicker in consistency.

- Pour approximately (1) pint of the epoxy mixture into a metal container and place onto a hot plate that will be maintained at the same temperature as the epoxy in the autoclave chamber.
- Position the viscometer into the epoxy, and begin to record viscosity, time and temperature at the frequency as directed by the VPI Director. Record all data on “Viscosity Data Sheet” at back of procedure.

6.9 Emergency Dump:

- If it becomes necessary to dump the epoxy from Tank 3 for any reason, **vent** tank 3 then **open** valves D7 and D8. This allows the epoxy to flow into a 55 gallon steel drum. This can also be used for cleaning the tanks after epoxy use. Caution should be used to minimize the about of mixed waste that may be generated.

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6.10 General VPI Notes:

All valving operations as noted below are to be used as a guide. Deviation from this procedure (Field Changes) can be made during the VPI process with the concurrence of the VPI Director. All field changes must be indicated in the Run Copy of this procedure and initiated by the VPI Director.

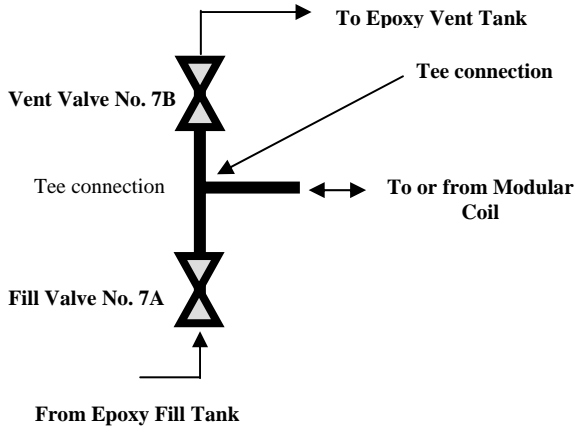


Figure 6- Typical Zone 2 Valve Assembly

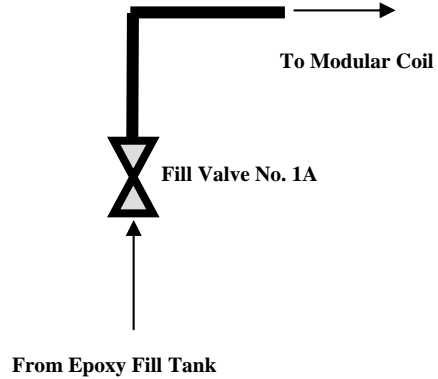


Figure 7-Typical Zone 1 Valve Assembly

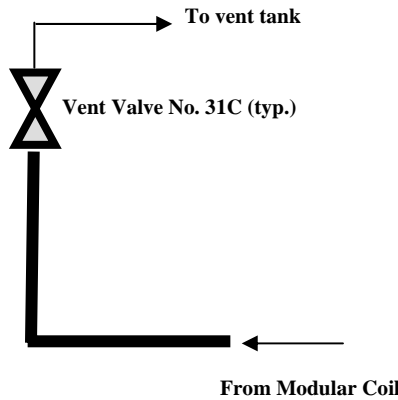


Figure 8-Typical Zone 3 Valve Assembly

- The VPI Director shall verify that all prerequisites have been completed and that the modular coil is ready to receive epoxy.
- Record all data in the appropriate table, identified below.
 - Viscosity Readings **Table 3- Viscosity Measurements**
 - Thermocouple Readings: **Table 4-Thermocouple Readings**
 - VPI Log: **Table 5- VPI Log**
- During the coil filling operation, the VPI Director may decide to modify the atmosphere in the autoclave to support the filling operations. He/she may also elect to apply a positive pressure (5 psig max) to the fill tank to enhance the filling operations. These decisions are the discretion of the VPI Director, but must be documented in the procedure.
- Turn on the manifold heating elements. Temperature is to be set to 50 degrees C.

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Verified by: _____ Date: _____
Lead Technician

6.11 Autoclave Entry during VPI Operations:

During a typical VPI operation it may become necessary to enter the autoclave to make a repair to the “bag” mold or epoxy lines after the VPI process has begun. Entry into the Autoclave can only be made if the temperature inside the autoclave is < 50° C.

- The following steps **MUST** be completed prior to entering the Autoclave.
 - Industrial Hygiene **MUST** be notified.
 - A special “HOT Entry” Confined Space Permit **MUST** be available. [Obtain prior to starting VPI process]
 - The autoclave blower **MUST** be in the purge mode.
 - A minimum of 6 air exchanges of the autoclave **MUST** be completed prior to entry [approximately 30 minutes].
 - The Nitrogen line to the Autoclave **MUST** be disconnected.
 - The autoclave heating elements **MUST** be locked out and tagged.
 - Personnel Protective Equipment such as hot gloves, heat protection blankets, etc **MUST** be available.

Entry requirements have been completed, ready for entry:

Verified by: _____ Date: _____
VPI Director

- The VPI Director and Lead Technician shall evaluate the necessary repairs needed to correct the problem and return to VPI operations.

DESCRIPTION OF NECESSARY REPAIRS;

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Repairs completed, return to VPI operations:

Verified by: _____ Date: _____
 VPI Director

6.12 Coil Fill Procedure

6.12.1 Priming Manifold with Epoxy

- **Close** vacuum valve D5 on the mixing tank, and open the vent valve to allow the mixing tank to return to atmospheric pressure.
- **Close** all valves accept for Zone 3 “C” valves numbered 36 thru 47.
- **Open** the epoxy filter valves numbered D-11, D-12, D-15 and D-16.
- **Open** valve D10 and allow the epoxy to flow through the filters and fill the manifold.
- **Open** each Zone 2 “A” valve, one at a time, to allow the epoxy to flow from the manifold and fill the poly-flo lines up to the “A” valve [valves 9 thru 35]. As the epoxy reaches the valve, **Close** that “A” valve and open the next. Continue this process until the epoxy has reached all of the “A” valves. The manifold is primed and ready to begin the VPI fill of the coil.

Ready to begin epoxy fill:

Verified by VPI Director: _____ Date: _____

- **Open** “SAMPLE” valve and fill the sample can in the autoclave with epoxy. Once the epoxy can has been filled, **close** the “SAMPLE” valve.

Epoxy Sample Obtained:

Verified by VPI Director: _____ Date: _____

- **Open** the “B” and “C” valves numbered 9 thru 35. [At the discretion of the VPI director]
- **Close** “C” valves numbered 36 to 47.

6.12.2 Starting Epoxy Fill

- **Open** all Zone 1 valves A-1 thru A-8 on the control manifold to allow the epoxy to flow into the lower portion of the modular coil.

Record start time: _____

- Record all times, as well as any VPI notes on the VPI Data sheet Table 5- VPI Log. Observe and record the time that epoxy exits each sprue on the coil.

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- Continue filling operations until the epoxy exits sprues 9 thru 35 [Zone 2] and approaches the tee connection. [Figure 6- Typical Zone 2 Valve Assembly] Once the line from the manifold “A” valve to the tee connection is filled, **open** the corresponding “A” valve and **close** the corresponding “B” valve. This allows that sprue to be used for filling the coil.

(Note: The time allowed between opening the fill and closing the vent valves is at the discretion of the VPI Director.)

- The VPI Director, at his/her discretion will begin to **open** the “C” valves for Zone 3 [sprue 36-47] valves as the epoxy level rises in the coil.
- Continue flowing epoxy into the coil via the Zone 1 and 2 valves until epoxy is observed exiting each of the Zone 3 (Exit) valves [36 thru 47]. Figure 8-Typical Zone 3 Valve Assembly. **Close** each Zone 3 exit valve once epoxy reaches the control panel.
- The VPI Director will determine when the filling operation has been completed.
- The autoclave **MUST** be at positive pressure at the conclusion of the filling operation. This pressure is used to reinforce the bag mold until the Gel temperature has been reached.

Verified by: _____ Date: _____ <p style="text-align: center;">VPI Director</p>
--

6.13 VPI Evaluation Prior to Cure:

- If there is evidence of air bubbles in the vent lines, or if the VPI director judges the necessity, the “Milking” procedure may be applied to the VPI process. Go to section 6.14 **Milk Procedure (optional)**
- If the VPI Director is satisfied with the epoxy fill of the coil. Go to section 6.15 **Cure Cycle- (GEL)**
- The coil filling operation is complete and is ready for starting the cure cycle.

Verified by: _____ Date: _____ <p style="text-align: center;">VPI Director</p>
--

6.14 Milk Procedure (optional)

This process is used for removing trapped gas pockets in the coil by flowing epoxy back and forth through the coil once the coil has been filled.

- **Close** all “A”, “B” and “C” valves.
- Remove the nitrogen pressure from the mix tank and allow the tank to return to atmospheric pressure.
- Remove the vacuum from the overflow manifold and raise the pressure to atmosphere.

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- **Open** all Zone 1 [A-1 thru A-8] and Zone 3 [C-36 thru C-47] valves as well as the Zone 2 manifold valves [B-9 thru B-35]. Note: the number and location of B valves to be opened is at the discretion of the VPI Director.

List the Zone 2 valve numbers that are being opened as part of the Milking Process:

- Raise the pressure on the overflow manifold to 5 psig and move the epoxy to within 6 inches of the coil.
- Vent the pressure on the overflow tank and apply 500 to 1000 microns vacuum.
- Apply 5 psig of nitrogen pressure to the mix tank move the epoxy no closer than 18 to 24 inches of the of the Tee connections.
- Remove the pressure on the mix tank and vacuum on the overflow manifold.
- Repeat entire milking process as required.
- If no bubbles are seen, go to section 6.15 Cure Cycle- (GEL)
- If bubbles are seen, repeat milking process.

Note: During the cure cycle, the delivery system and tanks should be cleaned.

6.15 Cure Cycle- (GEL)

During this phase the coil temperature is slowly raised to the cure [Gel] temperature of 110 degrees C and held for a period of 5 hours. [Figure 9- VPI Cure Cycle]

- **Close** all valves.

Verified by: _____ **Date:** _____
VPI Director

- Shut off all tank and manifold heating elements.
- Maintain positive pressure in the autoclave.

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Autoclave pressure at start of temperature ramp-up: _____ psi

- Begin the temperature ramp-up to **110 degrees C** @ rate of 10 degrees per hour.

Time- Begin Ramp up: _____

- During the ramp up cycle, continue to monitor the viscosity readings while increasing the temperature at the same rate as the coil. Continue to record readings in viscosity table at the frequency identified by the VPI Director. Abort viscosity readings once sample mixture begins to Gel. Clean viscometer.
- It will take approximately **6 hours** to reach Gel temperature.

Time- Gel Temperature Reached: _____

- Once the coil has reached the Gel temperature of **110 degrees C**, hold the coil at that temperature for **5 hours**.

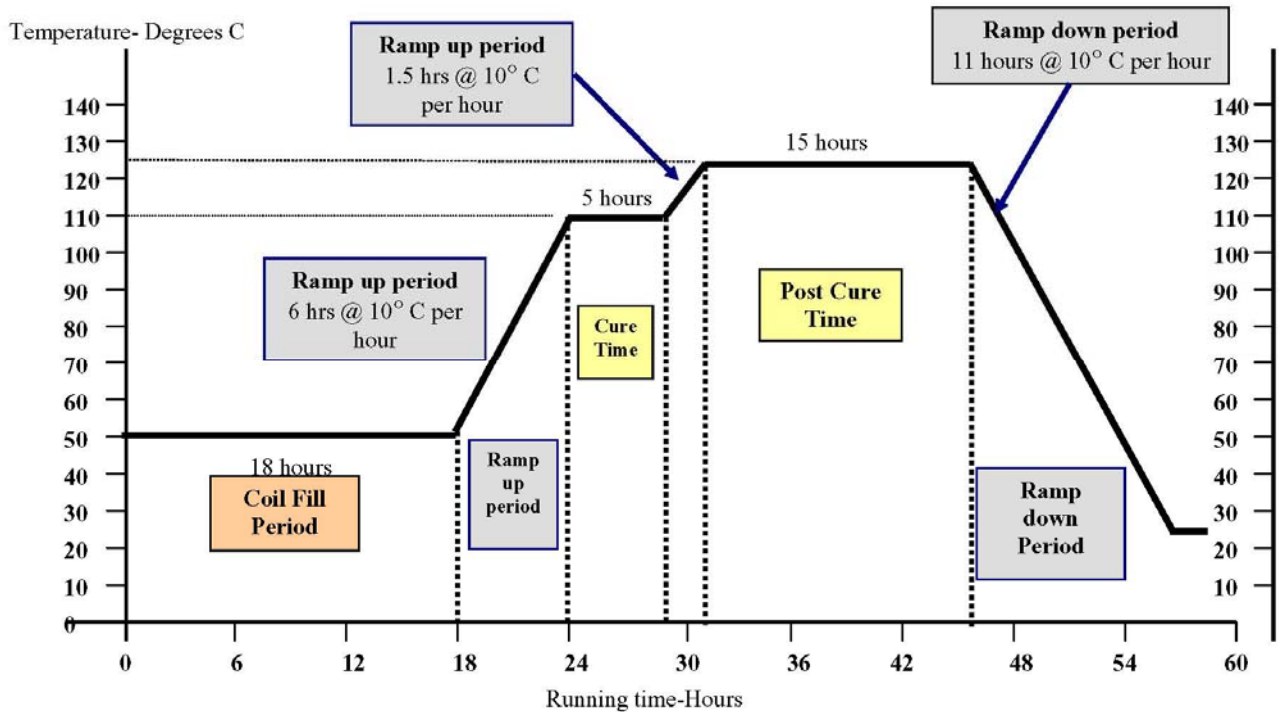


Figure 9- VPI Cure Cycle

Modular Coil Fabrication- VPI/ Autoclave Activities
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6.16 Post Cure Cycle

Temperature at time which maximum mechanical and electrical properties are reached

- After 5 hours at Cure [Gel] temperature begin ramp up to **125 degrees C** @ a rate of 10 degrees per hour.

Time- Begin Ramp up: _____ Lead Tech. _____

- Once the epoxy has gelled, slowly vent the autoclave pressure until it reaches atmospheric pressure.

Verified by: _____ Date: _____ VPI Director or Lead Tech.

- It will take approximately **1.5 hours** to reach post cure temperature.

Time- Post Cure Temperature Reached: _____ Lead Tech. _____

- Once the coil has reached **125 degrees C** hold at temperature for **15 hours**. During this operation, continue to monitor and record data at the frequency identified by the VPI Director.

6.17 Ramp-Down Period

This is the period that the coil temperature to slowly lowered to room temperature. Figure 9- VPI Cure Cycle

- After 15 hours at temperature, begin the ramp-down phase of the cure cycle.
- Shut down all heaters.

Start of Ramp-Down: _____ Lead Tech. _____
--

- Keep the autoclave chamber closed until the coil temperature reaches **45 degrees C**. A sudden change in temperature on the hot coil could cause a thermal shock resulting in possible cracks in resin rich areas.
- The coil temperature shall ramp down at a rate of approximately 10 to 15 degrees C per hour.
- Once the coil has reached a maximum temperature of 45 degrees C the autoclave door and lid may be opened.

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The epoxy impregnation and curing operations have been satisfactorily completed.	
Lead Technician: _____	Date: _____
VPI Director: _____	Date: _____
QC shall verify completion of documentation:	
Quality Control Representative: _____	Date: _____

NOTES:

6.18 Post Autoclave Activities:

A confined space permit is required for performing any work in the autoclave.

6.18.1 Removing upper epoxy feed-lines:

Carefully cut and remove all of the epoxy feed lines running between the coil and dome feed-thru port.

6.18.2 Removing Autoclave Lid:

Remove the autoclave lid to gain access to the VPI'd modular coil.

- **SAFETY NOTE:** The upper catwalk around the top of the autoclave will be restricted (chained) during the removal/installation of the autoclave lid, or a modular coil. An observation area on the catwalk is provided to allow the crane operator and/or lift engineer to observe the lift. There will be no restrictions on use of the upper catwalks by personnel while the autoclave lid is in position or while the space between the lid and vessel is less than 12 inches.
- Loosen and remove the 3/4 inch hardware that secures the lid to the autoclave chamber.
- Using the overhead crane carefully lift the lid and position it on the Manufacturing Facility Floor.

AUTOCLAVE LID REMOVED:
Verified by: _____ Date: _____
Lead Technician

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6.18.3 Post VPI Coil Preparations:

- Remove the epoxy sample from the autoclave and clearly label the specimen container with the coil number and VPI date. Store the epoxy specimen in a safe dry area for future testing.
- Carefully cut and remove all of the remaining epoxy feed lines running between the coil and feed-thru ports.
- Disconnect all thermocouple lines from the coil.
- Clean the autoclave and delivery system and prepare for the next coil.

6.18.4 Removing VPI'd Coil from Autoclave:

- Ensure that Station 1b is ready to receive the coil and winding form. [Note: the coil may be transferred to one of the winding stations 2 or 4 at the Field Supervisor's discretion]

Verified by: _____ Date: _____ Lead Technician
--

- Using the lift data sheet on procedure **D-L-NCSX-984**, rig the upper support/lift beam to the overhead crane and transport to the Autoclave [Station 5].
- **SAFETY NOTE:** Use scaffolding or appropriate ladders while working on upper section of turning fixture. Scaffolding must be inspected prior to use per Section 9 Chapter 5 in PPPL ES&H Manual.
- Install the upper support plates that secure the support ring to the support/lift beam. This operation must be verified prior to proceeding. See Figure 1- Upper Support Plates
- Verify that all hardware has been torqued and that modular coil is ready for transport from the autoclave [Station 5] to the Turning Fixture at station number 1b, 2 or 4.

Verified by: _____ Date: _____ Lead Technician
--

- Once a slight load has been taken, remove the hardware that secures the upper support/lift beam to the turning fixture frame.
- Compress the springs under the gear box (drive system) until they are bottomed.
- Disengage and remove the upper guide rollers. NOTE: Sling the rollers and raise them into position with rope. **Do not climb up ladder with roller assembly in hand.**
- The epoxy filled coil is rigged to the overhead crane and ready for transport to station 1b, 2 or 4 per procedure D-NCSX-MCF-004.

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Verified:	
Lead Technician: _____	Date: _____
Field Supervisor: _____	Date: _____

7 Completion of Activities at VPI Station:

7.1 Document Verification:

Verify that all pertinent data in the procedure and data sheets have been completed.

7.2 Field Package:

Ensure that all data sheets, photographs, QC inspection sheets, etc are included in the “Coil Field Package”.

7.3 Approval:

Prior to releasing a modular coil to the Post VPI station, it is required that the all-responsible individuals sign the release indicating that all processes at the VPI/Autoclave station have been satisfactorily completed. The release will include signatures from the Station Lead Technician, VPI Director and the QC representative.

All epoxy impregnation/cure (VPI) activities have been satisfactorily completed.	
Lead Technician: _____	Date: _____
Field Supervisor: _____	Date: _____
QC shall verify completion of documentation:	
Quality Control Representative: _____	Date: _____

The epoxy filled coil is ready for transfer to the Post VPI station:

Comments:
--

Modular Coil Fabrication- VPI/ Autoclave Activities
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8 Glossary of VPI Terms:

- **Bag Molding-** A less expensive method of building a mold where high tolerance outside dimensions are not required and can accommodate more difficult configurations. Can be made using silicone sheet or tape with a rigid strong back for support
- **Cure temperature:** Temperature at which the epoxy begins to solidify (GEL) and to reach cured properties
- **Degass:** To remove trapped air in epoxy components via 1-2 Torr vacuum
- **Gel Point:** The time at which the viscosity of the epoxy mixture rises and the mixture begins to solidify
- **Milking-** Term used for back flowing epoxy through coil once coil has been filled to remove trapped gas pockets
- **Post-Cure Temperature:** Temperature at time which maximum mechanical and electrical properties are reached
- **Pot life (*working time*)-** The life of the epoxy from the time that it is mixed until it begins to gel
- **Ramp up-** Process of raising the temperature to cure a coil during VPI
- **“Scramble Egg Test”-** Test used to verify the correct mixture of components prior to introducing the epoxy to the coil. Test verifies that the epoxy mixture will Gel at the correct temperature.
- **Soak Period:** Period of time following epoxy fill in which additional epoxy may be wicked into the coil insulation usually under slight positive pressure
- **Sprues-** Fittings located on the coil mold to allow transfer of epoxy to and from the coil.
- **Viscometer:** operates on the principle of rotating a cylinder or disc immersed in the liquid under test and measuring the torque necessary to overcome the viscous resistance to rotation. (Digital readout) Equipment is used to measure the viscosity of the epoxy components.
- **VPI [Vacuum Pressure Impregnation]:** The process of filling a coil with epoxy resin using both vacuum and pressure control.

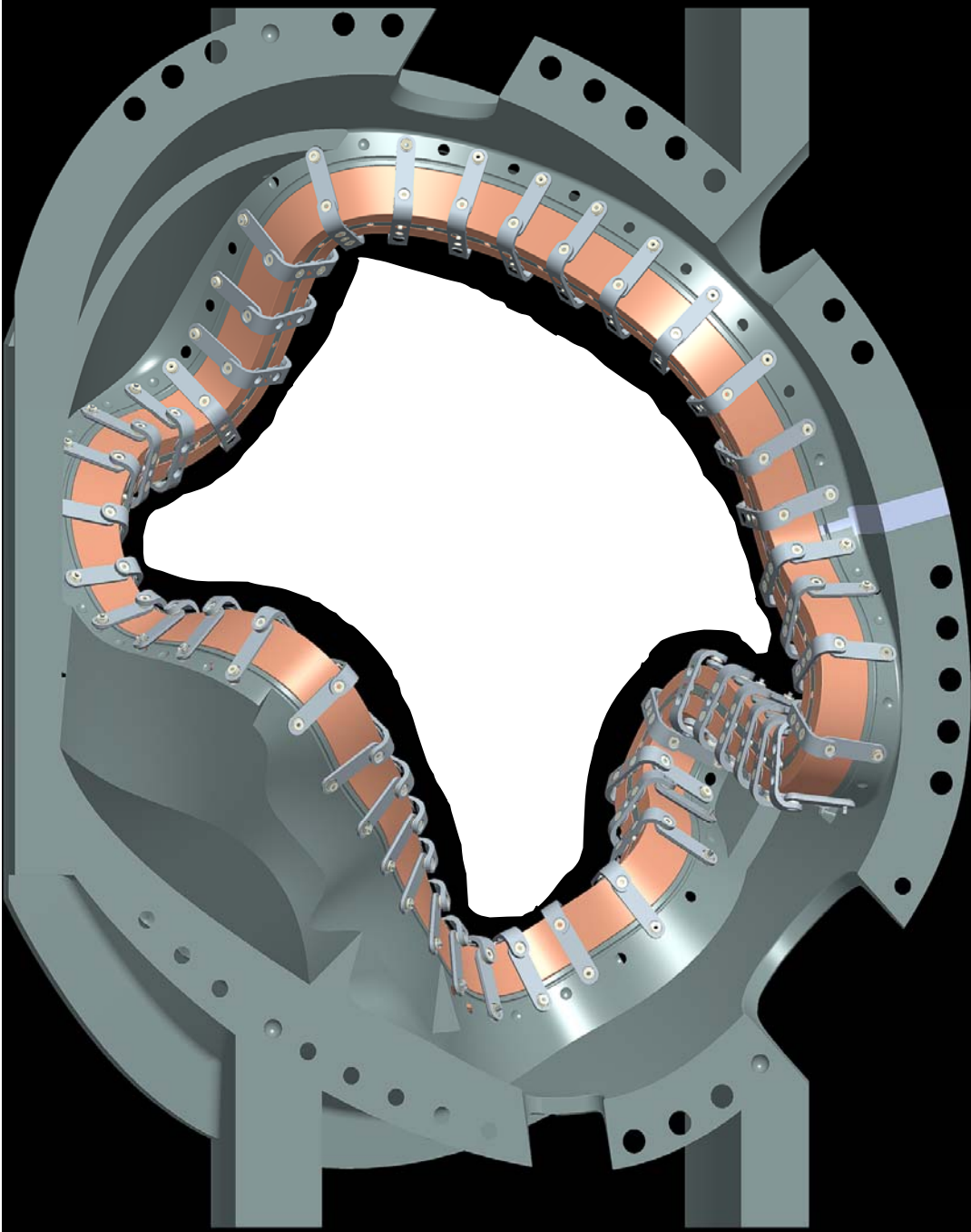


Figure 11-Sprue Locations for Type C Casting

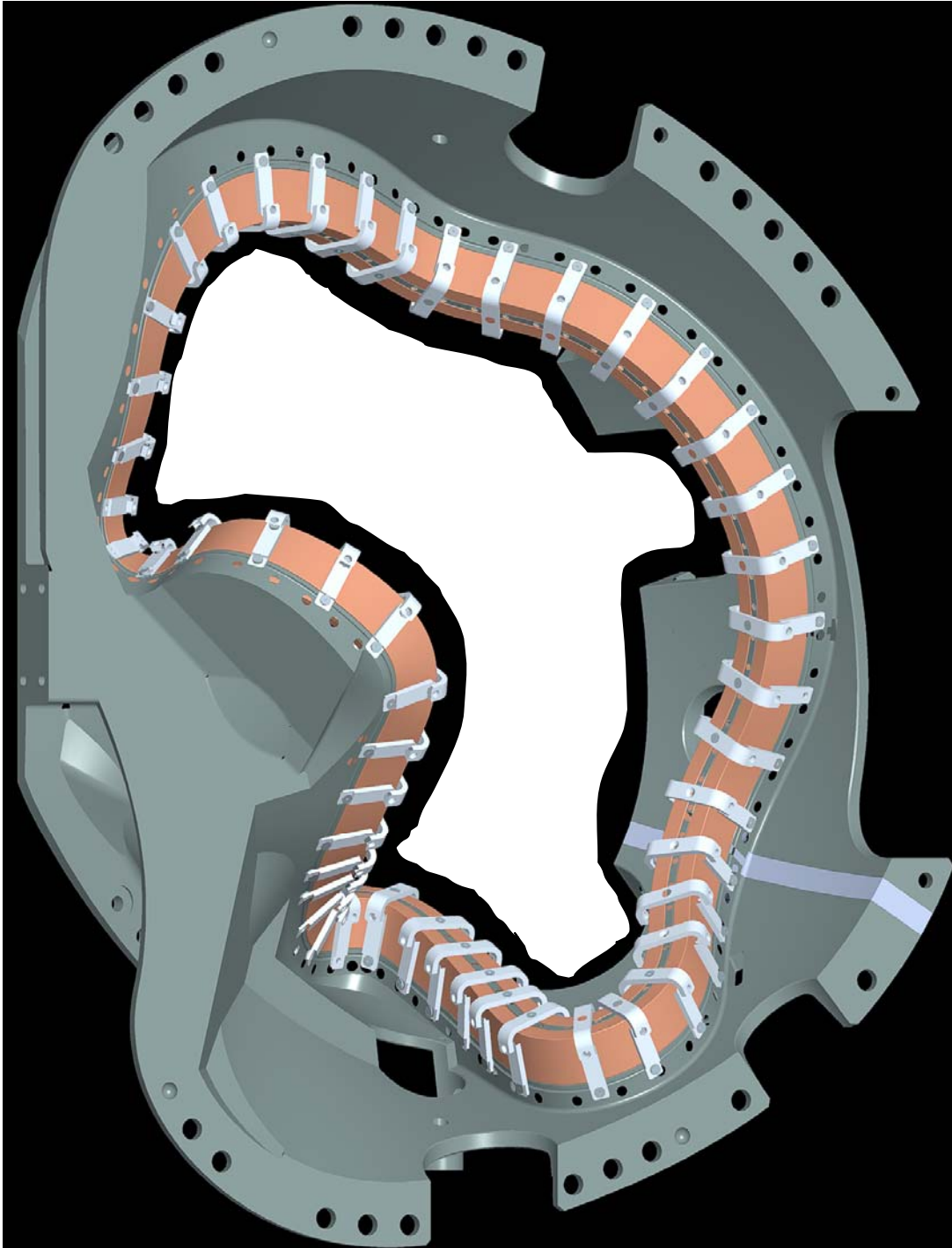


Figure 12-Sprue Location for Type “B” Casting

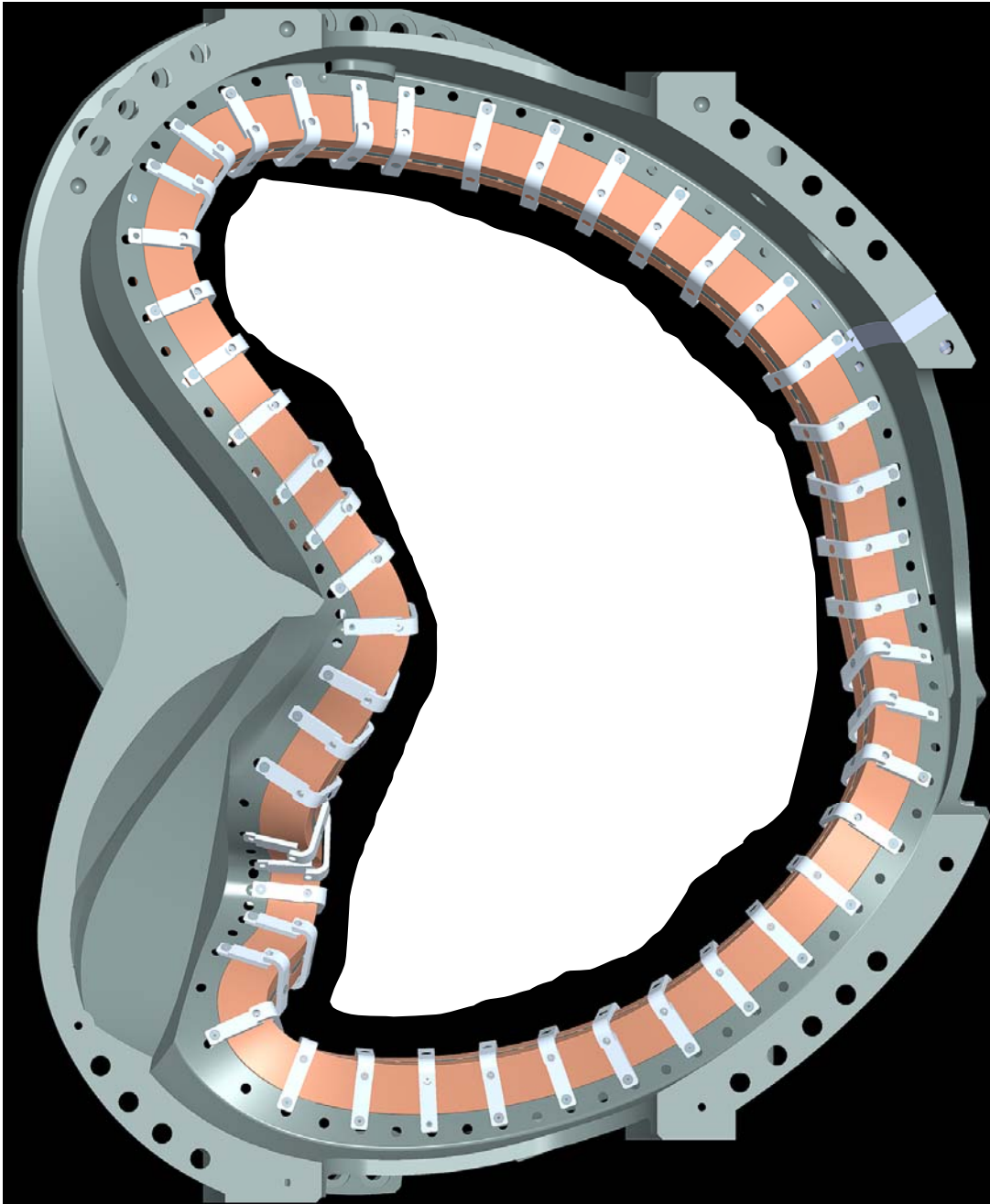


Figure 13-Sprue Location for Type "A" Casting

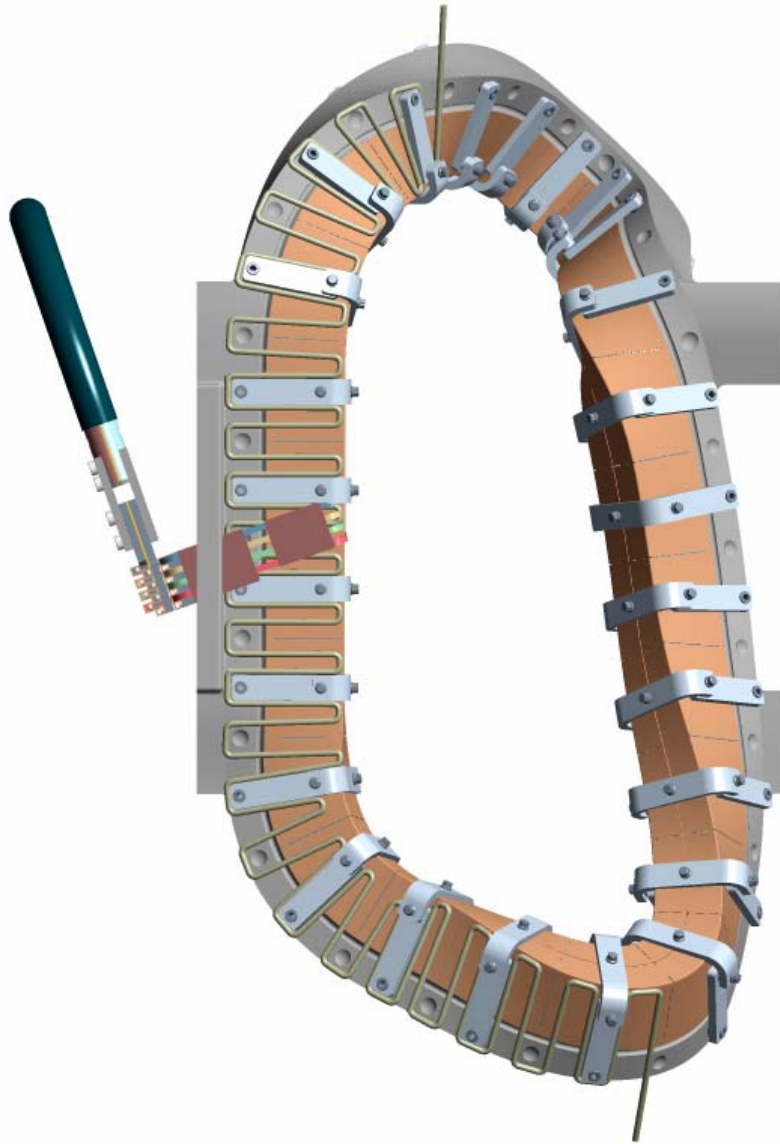


Figure 14- Sprue Locations for Twisted Racetrack Coil

**Modular Coil Fabrication- VPI/ Autoclave Activities
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Table 3- Viscosity Measurements

Sheet No. _____

VISCOSITY MEASUREMENTS	Date	Time	Sample Description	Temp- C° C°	Viscosity Cp	RPM	Spindle No.	%	

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Table 4-Thermocouple Readings

Sheet No. _____

THERMOCOUPLE MEASUREMENTS	Thermocouple ID Numbers												Blower	Oven	Coil	
	Time												Temp.	Pressure	Pressure	

**Modular Coil Fabrication- VPI/ Autoclave Activities
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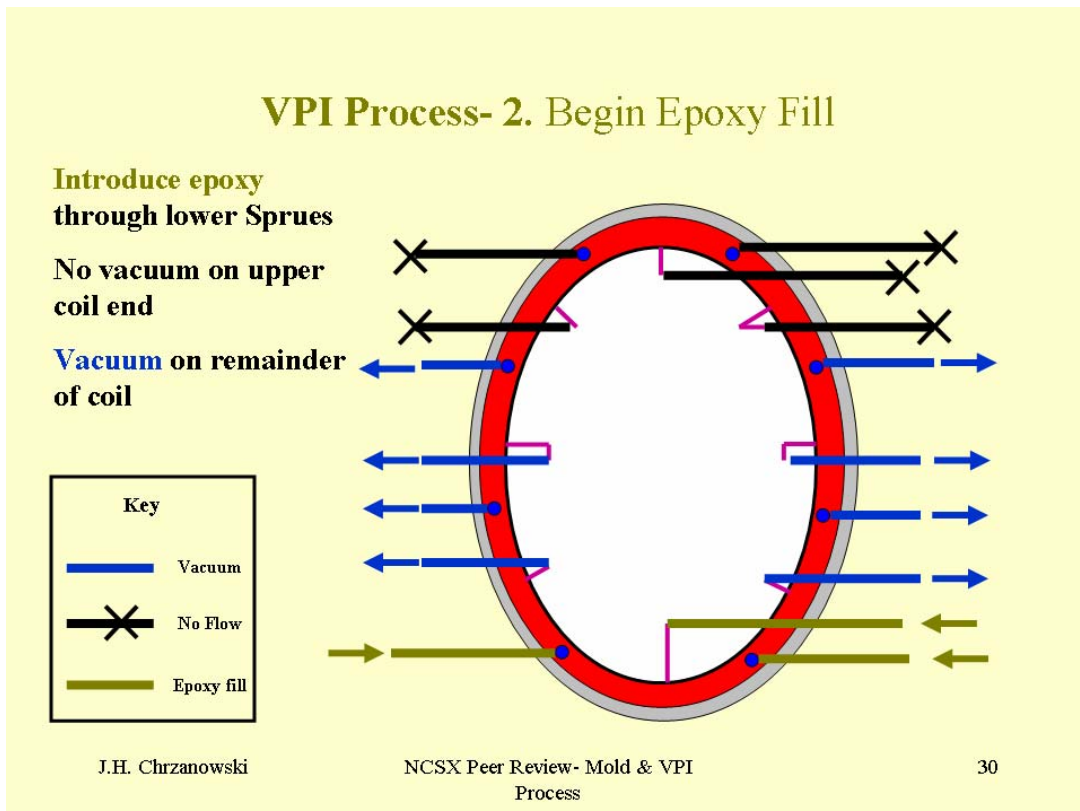
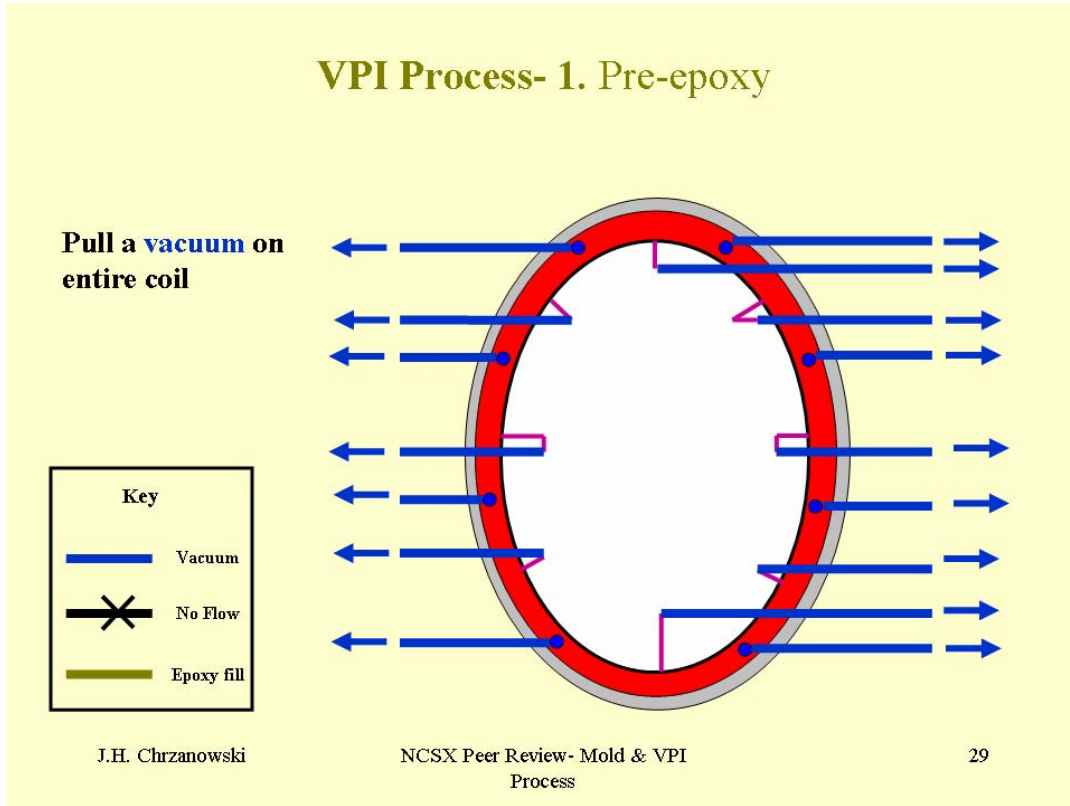
Table 5- VPI Log

Time	Sprue ID No.	Notes

Modular Coil Fabrication- VPI/ Autoclave Activities
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GENERAL VPI NOTES

Figure 15- VPI Process Diagrams- Reference

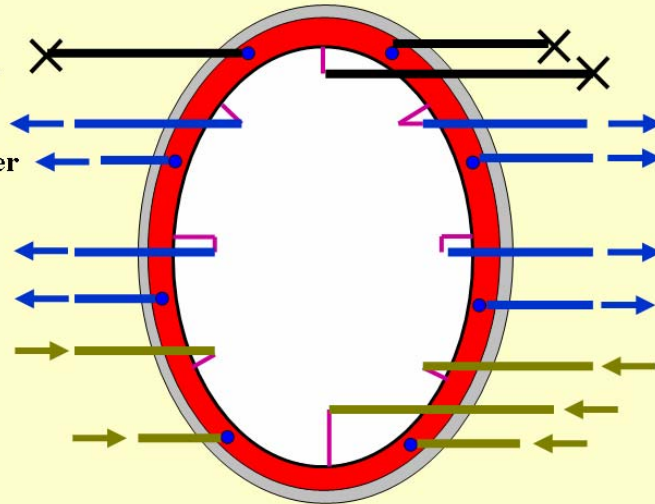
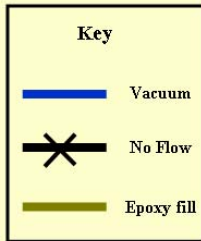


VPI Process- 3. Continue Epoxy Fill

Introduce epoxy through additional lower Sprues

No vacuum on upper coil end

Vacuum on remainder of coil- more upper Sprues added



J.H. Chrzanowski

NCSX Peer Review- Mold & VPI Process

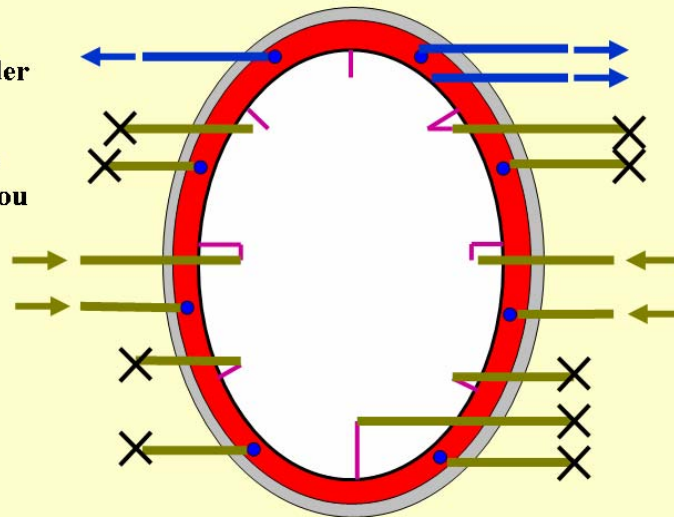
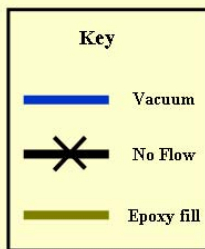
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VPI Process- 4. Continue Epoxy Fill

Introduce epoxy through mid level Sprues

Vacuum on remainder of coil

Continue to walk up the fill points until you reach the upper quarter

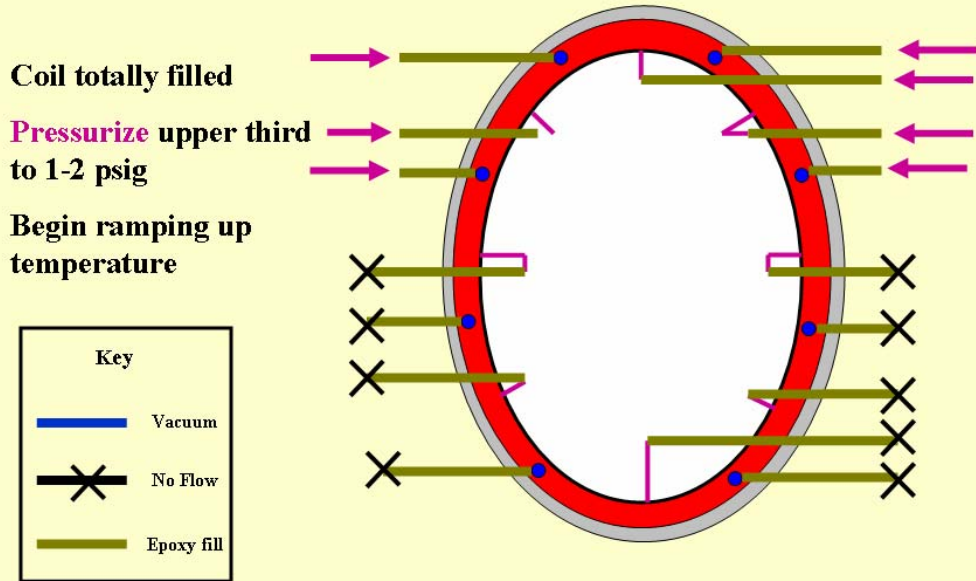


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VPI Process- 5. Coil Filled/Soak Period



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