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NCAMP Process Specification

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Polymer Additive Manufacturing Materials, Machine, Processing and Quality Requirements Specification for ULTEM™ 9085 and Stratasys Inc. Fortus 900mc Machine

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1. Scope

This process specification describes the methods of fabricating test coupons using a Free Form Fabrication (FFF) process (Fusion Deposition Modeling (FDM™)) using Stratasys Aerospace Certified ULTEM 9085™ thermoplastic resin on the Stratasys Fortus 900mc Plus printer. Specifically, this specification covers the constituent material, the configuration of the machine, operating software, machine calibration, and machine and build parameters and acceptance criteria. In addition to the instructions contained in this specification, users are advised to obtain hands-on guidance directly from the machine manufacturer for the setup of the machine, part design, establishing the build and slice files as well as determination of the correct build parameters.

This specification does not contain all the necessary information typically required for the fabrication of FDM parts, such as personnel qualification, facility requirements or any part acceptance criteria. Users should refer to their existing company process specification for such information.

1.1. Purpose

This specification establishes the requirements for the Fused Deposition Modeling (FDM™) process using Stratasys Aerospace Certified ULTEM 9085™ thermoplastic resin on the Stratasys Fortus 900mc Plus printer combination, herein referred to as “FDM System”. This specification requires qualified processors.

1.2. Classification

- a) Raw Resin – Raw material purchased to Stratasys Specifications (300000-0001).
- b) Filament – When the Raw Resin is processed and procured to NMS 085 and NMS 085/1, “Aerospace Filament Specification (ULTEM 9085)”.
- c) Fortus 900mc Plus - A machine supplied by Stratasys, identified by Serial number at a specific location where Type I material manufactured to this Process Specification, for Qualification and/or Equivalency.
An example may include a manufacturer having multiple *Stratasys Fortus 900mc Plus printers*.
- d) FDM System – Is representative of the combination of FDM equipment and software, configured, calibrated, and maintained outlined per this Process Specification.

1.3. Types

Type defines the material used in the FDM process.

Type I Material: “Material” processed to the requirements in this Process Specification, in combination with correct equipment and software configurations, have undergone appropriate calibrations, and correct maintenance to be approved for use in a production environment.

1.4. Health and Safety

While the materials, methods, hardware, applications, and processes described or referenced in this specification may involve the use of hazardous materials and hazardous environments, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials or processes and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. Applicable Documents

The following specifications, drawings, and publications, of latest issue when not specified, form a part of this document to the extent specified herein.

2.1. Stratasys/NCAMP Documents:

Document No.	Document Title
SSYS 300001-0001	Stratasys PEI Resin Specification
NMS 085	Aerospace Filament Specification (ULTEM 9085)
NMS 085/1	Aerospace Filament Specification (ULTEM 9085)
SSYS 400337-0001	Production Quality Documentation
FM93268	Certificate of Compliance
SSYS 108313-0009	Fortus 900mc Quick Reference CARD
SSYS 402737-0001	Fortus 900mc 3D Production System User Guide, SN >1000
SSYS 108314-0011	Fortus 900mc 3D Production System User Guide

2.2. Industry Standards:

Document No.	Document Title
ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D1238	Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
ASTM D695	Standard Test Method for Compressive Properties of Rigid Plastics
ASTM D790	Standard Test Methods of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D3418	Standard Test Method for Transition Temperatures and Enthalpies of Fusion and Crystallization of Polymers by Differential Scanning Calorimetry
ASTM D7191	Standard Test Method for Determination of Moisture in Plastics by Relative Humidity Sensor
ASTM D6980	Standard Test Method for Determination of Moisture in Plastics by Loss in Weight

2.3. US Government Publication:

Not Used

2.4. Abbreviations and Acronyms:

DSC	Differential Scanning Calorimetry
BOM	Bill of Material
°F	Degrees Fahrenheit
FFF	Free Form Fabrication
Hg	In. of Mercury
Hz	Hertz
OEM	Original Equipment Manufacture
PEI	Polyetherimide (Thermoplastic)
PPE	Personal Protective Equipment
QA	Quality Assurance (Department)
QMS	Quality Management System
VAC _{RMS}	Volts Alternating Current (Root Mean Square)

2.5. Terms and Definitions:

- Bead – A single line of extrudate material from an FDM liquefier tip.
- Bead Mode – Pre-programmed settings that can be used to replace default inputs within Insight™ to better tailor printing parameters to unique geometries or build styles
- Breakaway – A type of Support Material (consumable) that represents the method of removal from the final part.
- Build – The physical activities the machine takes in producing a single or set of parts within a unique start and stop of the machine
- Build Chamber – The “in-oven” portion of the FDM System hardware that includes the platen, tip wipe, tip calibration, and purge chute
- Build Envelope - The three-dimensional space within the FDM System that can be utilized to produce a part or sets of parts
- Canister – Packaging used to house filament to aid in maintaining moisture and eliminating contamination
- Control Center – A software module provided with Insight to pack several parts into a single build and allows for manipulation of location, orientation, and enable machine scheduling.
- Controller Software (SW) – Software that controls motion and extrusion during the FDM process workflow.
- Contour – The exterior bead, setting the perimeter of a given layer.
- Command Move Binary File (CMB) – Part specific toolpath file created by Insight that is sent to the printer for execution via Control Center. Contains machine and material type as well as XYZ coordinates and bead areas of all toolpaths.
- Part – Physical object produced by FDM System
- Custom Groups – Insight’s editable parameters used to modify toolpath settings

- Double Dense Fill – A type of Fill Pattern that has overlapping, 90o intersections of sparse layers.
- Fill Pattern – Preset methods of different ways or lattice structures used to complete the interior of a part.
- Filament – Feedstock of raw material in continuous rod form, used in FDM Systems
- Fortus 900mc Plus – A specific model of 3D printer, trademarked by Stratasys, denoting the build volume and grade of printer
- Fused Deposition Modeling (FDM™) - A type of extrusion based additive manufacturing technology that enables the construction of three-dimensional objects, prototypes and products through a computer-aided process
- Insight™ - Stratasys pre-processing software that converts .STL files into machine process-able file .CMB which generates and controls toolpaths
- Lattice – Re-occurring pattern of geometries used to fill the interior of a part.
- Linked Contour – Two adjacent contours are joined as one continuous toolpath.
- Lot (Filament Lot) - The quantity of Stratasys consumables manufactured at one time to a single set of defined properties using a single raw resin lot or batch
- Qualification — Demonstrates that the implementation meets the requirements and is suitable for operation
- Qualified Processor
- Raster – The internal bead, used by the fill pattern between the perimeters created by a contour.
- Raw Resin Lot or Batch - Total quantity of a unique lot or batch identifier as defined by original resin manufacturer
- Seam – The start and stop location of a contour for each perimeter for every part layers
- Shall — Expresses a binding requirement.
- Should/May — Expresses a recommended or allowed action.
- Solid Fill/Mode - In Solid, Insight™ will fill a single contour bead around the outside with rasters in a repeating, alternating pattern to fill as much space as possible.
- Sparse Fill - Sparse fill is designed to expand the gap between rasters within the confines of the part to reduce the amount of material used. Raster width for sparse fill can be controlled exactly like in solid mode but the gap between rasters is controlled with the variable cell size.
- Style/Build Style – Preset building parameters used to customize toolpaths within Insight
- System – Refers to the combination of equipment and software used to process FDM material
- Support Style - The fill pattern built underneath overhanging components are built in the exact manner as the toolpath sparse mode.
- Toolpath – A plan of predetermined xy coordinates used to drive motion and material deposition control.
- Validation — Identifies that the requirements for a product are sufficiently correct and complete.
- Verification — Identifies that the implementation has been evaluated to determine that all design requirements have been met.

- Will — Expresses a declaration of intent.

3. Environmental Control

3.1. Fabrication Facility Conditions

The FDM System is for indoor use only

- a) Operating temperature: 60°F (15.5°C) to 85°F (29°C)
- b) Humidity: 0%RH to 80%RH non-condensing

3.2. Fabrication Facility Electrical Requirements

Facility power is required to meet the following power quality and nominal voltage requirements:

- a) Rating: 13.5KVA
- b) Voltage: 230VAC nominal 3-phase service with 5% regulation
Note: 230VAC as measured phase-to-phase
- c) Frequency: 50 Hz or 60 Hz
- d) Current: 40 Amp circuit
- e) Full load current: 34 Amp full load current on all three phases
- f) Maximum inrush current ~570 Amps for 2ms
- g) Three wire plus ground electrical connection

Operation of the FDM System outside this range is not recommended and degradation of the FDM System performance and shortened component life expectancy will be experienced. The FDM System is to be operated on a 3-phase service meeting the recommendations for power quality given in IEEE Standard 141-1976. Facilities who are unsure of their power quality should contact their service provider.

3.3. Compressed Air Requirements

The FDM System has an onboard pressure regulator, onboard particle filtration, water, and oil separation. Air-lines must be used in conjunction with the following:

- a) Supply pressure at the FDM System:
 - a. 90-120 PSI with a minimum flow of 14 CFM (GEN II) and 8 CFM (GEN I)
 - b. Input Manifold Air Pressure setting 75 ± 5 PSI
 - c. Non-lubricated
 - d. Non-condensing
- b) DIN ISO 8573-1 Quality Class 5 or better is recommended to improve onboard filter life
- c) Connection: Dimensional standard A-A-59439

4. Equipment Control

- a) Once approved, unless otherwise specified, this document is the primary reference source for the operating and performance standards for all parts fabricated with the FDM System (manufactured by Stratasys Inc.).
- b) The FDM System shall be installed in accordance with all Stratasys Inc. installation manuals and guidance, including installation of line power transformers as required and recommended by Stratasys (Section 3, Setup and Installation found in SSYS 108314-0011, 402737-0001) to be performed by a qualified electrician.
- c) This document is to cover all Fortus 900mc Plus machines with serial numbers L0002 through L0589 (SN < 1000 referring to GEN I system) and serial numbers L1031 – L2000 (SN > 1000 referring to GEN II systems). Serial Numbers shall be recorded.
- d) T16A tips are required to process Type I Material.

4.1. Fused Deposition Modeling (FDM™) Equipment

- a) FDM Systems must be identified by names or numbers for setup and traceability.
- b) All FDM Systems must be calibrated in accordance with Section 5: Calibration of SSYS 108314-0011, SSYS 402737-0001.
- c) All FDM™ machines must have a maintenance plan based on the manufactures' recommended procedures.
- d) Record of calibration and machine maintenance must be retained as QA records and must comply with Section 4.2.2.

4.2. Machine Maintenance and Control

Modifications or repairs to major sub-system equipment may demonstrate significant changes in build quality and are noted in Table 1. Any changes made and communicated by Stratasys or replacement of these components must be reviewed and dispositioned by designated authority and may require requalification per Section 8, repeated Equivalency, or even full certification based on the change classification.

Table 1. Critical Sub-System Components

Sub-System	Description
Head	Critical sub-components within the head consist of drive motors, heater blocks, drive wheels, on-board electronics
Platen	Scratching of the build surface can result in lack of vacuum
X, Y, or Z Motor	Mechanism that drives belt or screw controlling gatry motion or platen location. Observed faults, shifts, and motion failures will result in replacing these motors and requiring requalification.
Gantry Rail	Structures holds the head and bridge and controls and maintains rigity during x and y motions.
Master Computer	On-board computing system
Universal Power Supply	Critical component of the electrical system to regulate incoming power to all electronics on an FDM System

4.2.1. Preventative Maintenance

- a) Preventive maintenance will be performed on each FDM System used to fabricate production parts. This maintenance will verify proper operation of the FDM System.
- b) Preventive maintenance will be performed a minimum of every three months per Stratasys' recommend maintenance procedures per Section 6: System Maintenance – Quarterly Maintenance (SSYS 108314-0011, SSYS 402737-0001).
- c) All maintenance activities will be performed in accordance with the Stratasys standard procedure using Stratasys replacement parts as needed.
- d) After maintenance has been performed on a FDM System, the FDM System shall be calibrated using the Stratasys calibration procedure outlined in Section 5, Calibration (SSYS 108314-0011, SSYS 402737-0001).
- e) Liquefier tips shall be replaced after 396.2 cubic inches of use.

4.2.2. Maintenance Record

A record of all machine maintenance activities, calibrations, and repairs will be maintained for each FDM System and stored per the user's applicable quality management system procedures.

5. Software Control

Software for additive manufacturing systems is an essential part of the process and must be defined and be under configuration control. Specific software versions utilized for the qualification of the material will be controlled for that material. Any changes to software used in this process shall be approved via ACN through NCAMP.

Type I material shall be built in accordance with the approved software version in Table 2.

Table 2: Software Revisions

Number	Revision Description
Pre-Processing Software: Insight Version 11.5	Contains T16 and T16A configurations for U9085CG material on Fortus 900mc Plus in Modeler dropdown menu.
Controller Software Version: 3.21.2922.0	Contains T16/U9085CG configuration with T16/U9085CG parameters and T16A/U9085CG configuration with T16A/U9085CG Model and Support High Quality Build Mode parameters. Model activeWipeTime returns non-4 digit number, Model inActiveWipeTime returns a value "0". Contains restrictions against building mismatched tip/material cmb and tip/CGmaterial machine configurations.

Note: The software for the Fortus 900 Plus machines are provided by Stratasys Inc.

5.1. Model Preparation

Model preparation is performed using industry standard CAD and .STL modification software. The required output of this process is a .STL file that can be imported into Stratasys’ pre-processing software. The control and verification of these software packages is at the discretion of the user.

5.2. Pre-Processing

The Insight™ software, provided by Stratasys, has a release version designation that must be recorded and maintained for any certified production. Version installed on the machine must match version listed in Table 3 of Section 5.

5.3. .CMB and Job File Creation

Pre-load CMB’s for all coupon geometries and orientations shall be used for Type I Qualification and Equivalency and should be downloaded from the NCAMP website. For a list of all Pack Files and CMBs for each test and coupon in Appendix A: NCAMP Coupon Build information.

5.4. Build Styles and System Mode

Insight™ has pre-programmed parameter sets that can be used when certain geometric features, functional results, or aesthetic effects are required. These build styles consist of Part Interior Style, Visible Surface Style, Support Styles, and System Mode.

5.4.1. Part Interior Style

Part interior styles consist of Solid (default), Sparse, and Double Dense Sparse. Type I material shall be built using Solid Part Interior Style.

NOTE: Utilizing “Sparse Fill” or “Sparse Double Dense” will disallow the use of the reported test data from solid fill samples.

5.4.2. Solid

Type I material shall be built using a single outer contour and -45/+45 raster pattern.

NOTE: The rasters and contours are controlled by multiple variables, some of which can be changed to improve build and part quality covered in Sections 5.4.13, 5.4.14, and 5.4.15.

5.4.3. Sparse

The default cell size for materials should not be expanded as the material will no longer stay in the x-y plane as it will still be molten while trying to bridge the expanded gap. The rasters alternate so as to create a lattice structure with gaps every other layer.

5.4.4. Sparse Double Dense

Sparse Double Dense mode contains a sparse pattern that no longer alternates every layer; both the original raster angle and its 90° variant are extruded on every single layer, this mode uses more material than standard sparse mode and has the potential for increased strength compared to standard sparse mode.

5.4.5. Visible Surface Style

Type 1 Material shall be built with default settings per 5.4.15. Changing the contour and raster definitions only on the visible layers is an option to increase the aesthetic appearance of parts. These settings should not be touched unless specific drawing callouts and expert Insight™ training has been approved as there is a high possibility of adversely affecting the mechanical properties.

5.4.6. Support Style

Type I material shall be built using Basic Support and is default as Sparse per Section 5.4.3.

5.4.7. Basic

Basic support style is a Sparse style without the external contour. This enables simpler breakaway of the support but the structures build are less stable and more prone to tipping over if the aspect ratio is too high.

Type I material for geometries that have more than a 45 degree overhang requires Basic Support.

5.4.8. Surround

Surround support surrounds the entire slice of the part in support up to a specified depth. It is advised to use this style with fragile structures that might not build properly; this support style should also not be removed manually and should be removed using the WaterWorks tank systems and should not be used with non-soluble support materials.

5.4.9. SMART

SMART support is an algorithm designed to reduce support material usage and reduce the amount of time the support structures take to build. The SMART support algorithm doesn't take into account the aspect ratio of support towers that support large areas. These reverse pyramid type support structures are prone to tipping over at extremely tall towers and are not recommend for use.

5.4.10. Stabilizer Walls

Stabilizer walls are a method of building tall, thin parts without the use of Support material but may still require anchoring to ensure successful build. For Type I Material that has an aspect ratio of greater than 3:1 the following settings will be used:

- Three points of contact, outer two points shall be close to the edges of the coupons, the inner point shall be within the gage section shall be used along .
- 0.5 inch separation. (applicable for all coupons with 0.5-0.75 inch tab width)
- Check flat back option on stabilizer wall settings.
- Wall penetration shall be -0.0050in

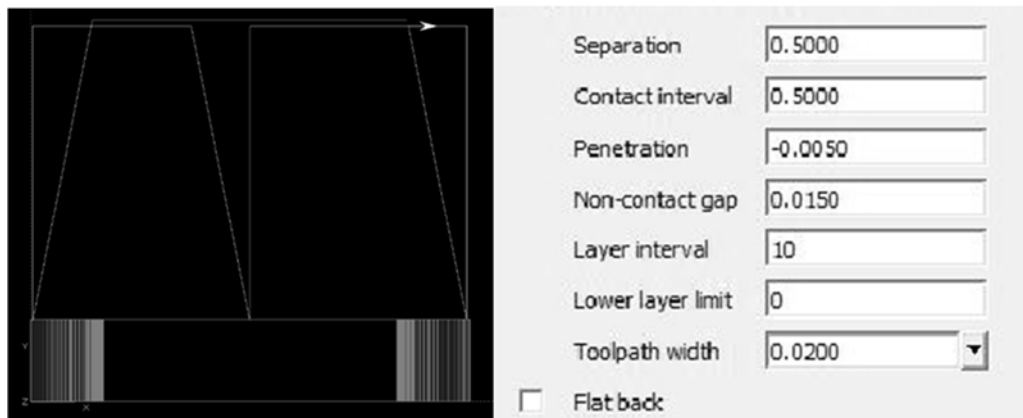


Figure 1. Example of stabilizer wall and settings used in Insight for Type 1 Material.

5.4.11. System Mode

Thin wall mode lowers the oven temperature by 10°C to minimize vertical distortion. Thin wall mode is recommended for parts with a wall thickness below 0.1” although 0.125” may also be successful.

5.4.12. Custom Groups

Type I material shall be built using default parameters found in Section 5.4.13 through 5.4.16.

NOTE: The following Insight Parameters and definitions can be used to create Structured Note Identifiers for drawing callouts

5.4.13. Low Impact Parameters

Parameters exist within Insight which are able to be changed from default which can improve build quality and print reliability and are not critical to part performance. These settings which can be customized are listed in Table 3

Table 3. Low Impact Parameter Settings

Attribute	Section	Default	Type 1	Notes
Support Style	Modeler Setup	Dropdown: Sparse	Dropdown: Sparse	
Linked Contours	Contour Controls	Unchecked	Unchecked	
Bypass Seam Placement	Contour Controls	Unchecked	Unchecked	
Start Angle	Raster Angle Controls	45.0	45.0	
Add a Contour Around Sparse	Sparse Fill Controls	Checked	Checked	Deselected when “Include in part sparse fill” is unchecked
Seam Placement Method	Toolpath Parameters	Dropdown: Automatic	Dropdown: Automatic	see appendix for coupon geometry seam placement

5.4.14. Medium Impact Parameters

Parameters that are able to be changed from default which can improve build quality and print reliability but can also impact part performance.

The default settings for Type 1 Material are provided in Table 4.

Table 4. Medium Impact Parameter Settings

Attribute	Section	Default	Type I	Notes
Part Interior Style	Modeler Setup	Dropdown: Solid	Dropdown: Solid	
Contour Style	Contour Parameters	Dropdown: Single Contour	Dropdown: Single Contour	
Contour Width	Contour Parameters	0.020"	0.020"	
Number of Contours	Contour Parameters	1	1	Deselected when "Single Contour" style is selected
Part Raster Width	Raster Fill Parameters	0.020"	0.020"	
Double Dense Raster	Raster Fill Parameters	Unchecked	Unchecked	
Part Interior Style	Sparse Fill Controls	Dropdown: Solid	Dropdown: Solid	
Sparse Raster Air Gap	Sparse Fill Controls	0.0800"	0.0800"	
Start Angle (Sparse Fill)	Sparse Fill Controls	45.0	45.0	
Visible Surface Rasters	Toolpath Parameters	0.0170	0.0170	Requires Advanced-user experience and training
Surface max contours	Toolpath Parameters	0	0	

5.4.15. High Impact Parameters

Parameters that are able to be changed from default which can improve build quality and print reliability but required advanced training and specific understanding of performance implications.

The default settings for Type 1 Material are provided in Table 5.

Table 5. High Impact Parameter Settings

Attribute	Section	Default	Type I	Notes
Slice Height	Modeler Setup	Dropdown: 0.010"	Dropdown: 0.010"	
Invert Build Materials	Modeler Setup	Dropdown: No	Dropdown: No	
Allow Increased Contour Overfill	Contour Parameters	Unchecked	Unchecked	
Outer Contour Location	Contour Controls	Dropdown: Inside	Dropdown: Inside	
Adjacent Rasters	Air Gaps	0.0000"	0.0000"	
Contours and Rasters	Air Gaps	0.0000"	0.0000"	
Contour and Contour	Air Gaps	0.0000"	0.0000"	
Align Rasters	Raster Fill Parameters	Unchecked	Unchecked	
Parallel Offset Rasters	Raster Fill Parameters	Unchecked	Unchecked	
Use Alternate Sparse Fill Pattern	Raster Fill Parameters	Unchecked	Unchecked	
Sparse Raster Width	Sparse Fill Controls	0.0200"	0.0200"	
Delta Angle	Raster Angle Controls	90	90	
Layers Between Deltas	Raster Angle Controls	1	1	
Part X shrink factor	Toolpath Parameters	1.0100	1.0100	
Part Y shrink factor	Toolpath Parameters	1.0100	1.0100	
Part Z shrink factor	Toolpath Parameters	1.0097	1.0097	
Visible surface raster air gap	Toolpath Parameters	-0.0010"	-0.0010"	Requires Advanced-user experience and training

5.4.16. Controller Software Parameters

Controller Software has a release version designation that must be recorded and maintained in accordance with the user's designated Job Tracking system for Type I material. Version installed on the machine will match the version called on in Table 2 of Section 5. Change notification documents for updates to be provided and validated by Stratasys.

6. Materials Control

6.1. Deliverable Material

- a) All parts using Type I material to be fabricated with Stratasys Fortus Plus Certified ULTEM 9085™ - Generic Aerospace, Part Number 355-23101, and ASSY, Fortus Plus, (M), ULTEM 9085 NAT, AEROSPACE, 92CI (Assembly Number 400461-0001) filament material.
- b) Filament must be converted in compliance with NMS Aerospace Filament Specification (NMS 085 and NMS 085/1) from an approved source.

NOTE: The Fortus Classic Certified ULTEM 9085™ Material ordered against Part Number 312-2000X (X can be 1 – 9) is compliant with Filament Specification (NMS 085) but must have the canister’s chips converted to Plus™ in order to be processed for Type I Material production. Contact qualified Stratasys field service technician for this conversion.

6.2. Consumable and Expendable Materials

Consumable and expendable materials are necessary for part production and shall not be part of bill of material (BOM) or will be used in the part assembly.

6.3. Support Material

- a) ULTEM Support, Part Number 355-03220 is the only approved support material to be used with ULTEM 9085 and shall be removed per Section 7.4.
- b) The support material shall not permanently adhere to the final deliverable part. Moreover, it shall not adversely affect or contaminate the finished product. The removal should be secured by a visible inspection per Section 8.4

6.4. Miscellaneous Contact Materials

- a) Build sheets - Only build sheets that do not adversely affect the material / part properties shall be used.
 - 1. Any build sheet used must have been purchased after July 2015. If origin is unknown, replace with recently purchased build sheet per Table 6. Build Sheet Specification.

Table 6. Build Sheet Specification

Feature	Polyethersulfone (PES)
Color	Light tan color
Bagging/shrink wrapped	Placed in bag
Label	6.5"x4"

- 2. Re-use of build sheets is not allowed for Type 1 Material.
- b) Gloves and other PPE for handling parts, tools for support removal, shall be utilized as required when handling the build sheets

6.5. Material Receiving Inspection

- a) Stratasys shall provide a Production Quality Documentation document (SSYS 400337-0001) for each Stratasys Filament Lot of material for pull force, moisture content, melt flow rate, average filament diameter, max filament ovality, DSC, as printed specimen thickness, and as printed Tension, Compression, and Flex in conformance with NMS 085 and NMS 085/1.
- b) Stratasys shall provide a Certificate of Compliance (FM93268) for each Raw Resin Batch or Lot in conformance with SSYS 300001-0001.
- c) Document Stratasys Filament Lot#, Raw Resin Batch#, and per user’s designated Job Tracking system.

NOTE: Additional drying must be conducted prior to loading into the printer per Section 7.1e)

6.6. Material Storage Control

Storage area conditions shall maintain a temperature between 55 – 75°F and a relative humidity of 0% - 60%. If conditions exceed requirements, materials shall be tested for moisture content per ASTM D7191 and dried per Section 7.1e) prior to use.

FDM Materials, including Type I, shall be stored unopened in the original canisters until ready for installation and use in the FDM System in accordance to Section 4.0 (SSYS 108314-0011, 402737-0001). Filament canisters shall be properly stored per manufacturer’s recommendations at 55-75 °F and 60% maximum relative humidity.

- a) First time used canisters shall be dried per Section 7.1e) drying time and conditions shall be recorded per user’s designated Job Tracking system.

NOTE: NMS 085 adheres to a moisture content reading of 0.04% as a specification limit for shipping material but still requires additional drying prior to usage in an FDM System.

Table 7. In-Process Canister Requirements

Properties	Test Method	Unit	Requirements
Pull force	-	lbs	Pull force spikes ≤ 1.75 lbs
Moisture	ASTM D7191	%	≤ 0.04%
Melt Flow	ASTM D1238	g/10 min	6.5 – 11.0 g/10 min

- b) Opened, partially used canisters shall be sealed by retracting all filament material and returning the stopper to prevent moisture absorption and can be stored with unopened canisters.

- c) Opened, partially used canisters can be stored for 36 months from date of manufacture after opening provided the factory seals and caps are returned to place after use.
- d) Opened, partially used canisters that have been stored for longer than 2 hours shall be tested for moisture content per section 6.1d) and dried per section 7.1e) if above specified moisture values.

7. Build Process

7.1. Start-up

- a) Control Center: Parts must stay in the same location as set by control center, no part relocation is acceptable. If a part is moved by the operator the job must be restarted so that the part is re-centered to the original location
NOTE: Machine User Interface part relocation may also be disabled per Section 4: Default Setting (Figure 4-7 of SSYS 108314-0011, SSYS 402737-0001)
- b) Machine heat up time and stabilization must be at minimum the time prompted by the machine for each material set, these times are also listed in Table 1-3 of SSYS 108313-0009. If minimum heat up time is not met prior to starting the job, the job must be canceled and the machine must be allowed to heat up to the minimum time for specified material combination
- c) The oven plane temperature shall be stabilized to a set point of 185°C with an acceptable range of 20°C when measured at the back left and front right location.
- d) Material shall have a moisture content less than 0.01% when tested per ASTM D7191. If material moisture content does not meet this criteria the material will be re-dried per Section 7.1e) and retested. If canister fails a second time, material shall be rejected and dispositioned by a user approved authority.
- e) Material preparation must be conducted within the following limits.
 - a. Remove the top cap from the canister
 - b. Vacuum oven temperature must be 68°C ± 5°C.
 - c. Canister shall be positioned upright in vacuum oven once oven has reached set point temperature
 - d. Material must be dried in oven for a minimum of 12hr if material does not meet the moisture requirements.
- f) Machine Readiness values fall within the following limits
 - a. A dryer check must have been performed after the most recent Quarterly PM and before fabrication and marked as completed per the user's preferred scheduled maintenance documentation.
 - i. Record manometer PSI-G reading per user's designated Job Tracking system.
 - ii. Dewpoint meter shall be less than or equal to -40°C using (Vaisala DM70 or equivalent) as measured at the head
 - iii. Record value per user's designated Job Tracking system.
 - b. A head motor test must have been performed after the most recent Stratasys Service performed PM, before fabrication and marked as completed per user's designated Job Tracking system.
 - i. Torque values for the following error test results must be within 2-5% of

- full torque (which reads as 0.2 – 0.5) with NO filament present.
- ii. Torque values for the following error test results must be within 9 to 14% of full torque (which reads as 0.9 – 1.4) with filament present.
 - iii. Record value in torque values per user's designated Job Tracking system.
- c. A tip ramp-up test must have been performed after the most recent Stratasys Service performed PM, before fabrication and marked as completed per user's designated Job Tracking system.
- i. Tip ramp-up results from 200°C to 300°C is expected to take less than 45 sec.
 - ii. Record liquefier heat up time value per user's designated Job Tracking system.
- g) Material volume must be sufficient to complete the entire build without enabling the FDM System automated "material change-over" procedure to occur. If material quantity is insufficient, the canister must be replaced with a canister that can meet this criteria, that has been dried per Section 7.1e)
- h) Tip life must be sufficient to complete the build and stay under the maximum allowed tip material volume consumption of 369.2 in³ (equivalent of 4 full canisters). If tip life is not sufficient, tip must be replaced with a tip per approved procedures (see Section 4: SSYS 108314-0011, SSYS 402737-0001) as tips cannot be replaced during a part build.
- i) Material loading must be conducted in accordance to the procedure outlined in the Changing Tips or material type per Section 4 of SSYS 108314-0011, SSYS 402737-0001. If material loading procedure is not followed material must be removed and reloaded in accordance to the procedure per Section 4: Unloading Material from the Liquefier Tips in SSYS 108314-0011, SSYS 402737-0001.
- j) Material build sheets described in Section 6.4a) shall be placed on the platen to achieve vacuum.
- k) The vacuum light must illuminate green to indicate acceptable vacuum before the job is started.
- l) The purge bucket must be emptied prior to starting the build. Failure to empty the purge bucket shall not fail a build unless an overflow of the purge bucket occurs during the build.
- m) The tip calibration procedure must be conducted per Section 5: Calibrating Liquefier Tips SSYS 108314-0011 and per the specifications listed in SYSS 402737-0001.
- a. Tip offset values must be adjusted until the support toolpath is centered between all X and Y zero indicators. Failure to achieve this calibration shall result in replacement of tips. If second set of tips fails to meet this criteria, contact Stratasys Field Service representative.
 - b. Z box support layer thickness must measure within ±0.0005 in (0.01mm). Failure to achieve this calibration shall result in replacement of tips. If second set of tips fails to meet this criteria, contact Stratasys Field Service representative.
- n) The health monitoring light pole must be green prior to starting the build. If the light pole is not green follow machine touchscreen prompts to address the issue. If issue is not resolved by touchscreen prompts, contact Stratasys Field Service representative.

- o) Perform Manual Ooze Test and record weight prior to the start of every build.

7.2. Fabrication

- a) Prior to build removal confirm the build is a 100% complete via touching the machine display screen. Builds removed prior 100% completion will be invalidated.
- b) Builds will not contain any part failures regardless of location within the build. Builds with this incident shall result disposition by user designated authority.
- c) Builds will not encounter a resume status at any point throughout the build. Builds with this incident shall result disposition by user designated authority.
- d) Builds will not encounter any errors at any point throughout the build. Builds with this incident shall result disposition by user designated authority.

7.3. Part Removal

- a) Vacuum must be shut off from the display screen prior to removing the part and build sheet from the machine. Failure to shut off Vacuum prior to part removal shall not fail build unless part is deformed or damaged during process
- b) Parts shall be removed at a minimum of 30 minutes after the platen has reached its end of the build position and can be left in the build chamber for up to 48hrs.
- c) Parts shall be removed from build sheet prior to reaching room temperature.
- d) Parts shall be removed manually from build sheet without the use of tools directly contacting the parts.

CAUTION: Care should be taken on fine feature geometries to not distort parts on removal.

NOTE: Wear heat resistant glove and proper PPE while removing parts and build sheet from platen and until parts have cooled to room temperature.

7.4. Support Removal

- a) Remove build sheet with part attached from oven prior to separating part from build sheet, if part delaminates from build sheet the build shall not be rejected.
- b) Support removal should be conducted while parts are between 90-160°C and support can be easily removed without damaging the part
- c) In the case where support removal cannot be completed prior to part cool down, reheat parts in an oven at 130-175°C until they reach oven temperature and supports can again be easily removed.
 - a. Parts may not exceed a 2 hour out of oven limit while the support removal procedure is still being conducted

NOTE: Wear heat resistant glove and eye protection while attempting to remove support from parts.

- d) As necessary, use needle nose pliers, probes, knife, or a pick to remove the support material from the part.

CAUTION: care must be taken when removing support to prevent breaking of small

features and gauging of part

NOTE: Use special care when removing support material from thin sections of the part, as to not puncture the part.

- e) Remove support using a generally flat work surface.
- f) The use of hand sanding to remove excess support material or to meet surface finish requirements is permitted.

NOTE: All rework shall be documented in the production routing prior to being started.

7.5. Fabricated Parts Identification & Storage

- a) Completed parts are compatible with all major inks and markers and can be directly labeled once cooled.
- b) Parts should be stored in a sealed bag, at temperatures between 60°F and 95°F.
- c) Sealed bags should be properly labeled according to user’s preferred part identification methods. Parts in bags with no label shall be dispositioned by user designated authority.

8. Quality Assurance & Inspection Control

8.1. General

Quality Assurance must insure that the FDM System is adequately controlled to consistently produce quality parts that meet the requirements of this specification.

8.2. Quality Testing & Control

Type I material shall be inspected in accordance with this specification.

- All requirements of the applicable Engineering Drawing shall be met.
- All non-conforming conditions shall be submitted on the appropriate rejection documentation.
- All parts shall be individually weighed and part weight should be recorded per user’s designated Job Tracking system.

8.3. Dimensional Inspection

Dimensional requirements are specified on the engineering drawing. Parts produced by the FDM process in the as built condition, would be limited to the accuracy defined below. Accuracy greater than those specified below may require additional post processing to achieve. To remove any thermal effects, dimensional inspections should occur at room temperature after the part has been removed and any support material removed:

Highest Accuracy:	± 0.005 inch or ± 0.0015 inch / inch (Whichever is greater (reference only))
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Minimum Wall Thickness: .020 (reference only)
 Profile Tolerance .030 (reference only)
 Geometric Tolerance: ANSI Y14.5M.
 Raster orientation: Must be +/-45

8.4. Visual Inspection

8.4.1. Typical Acceptable Anomalies

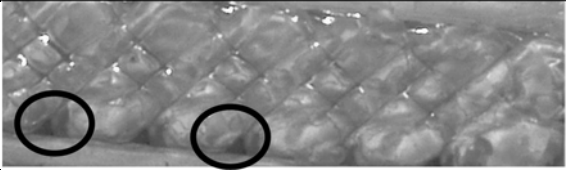
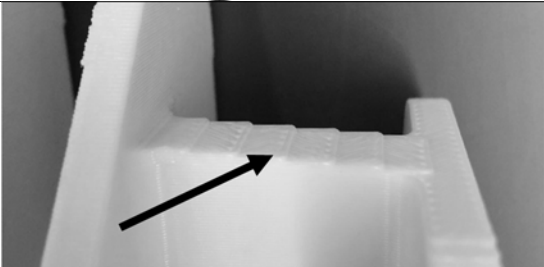
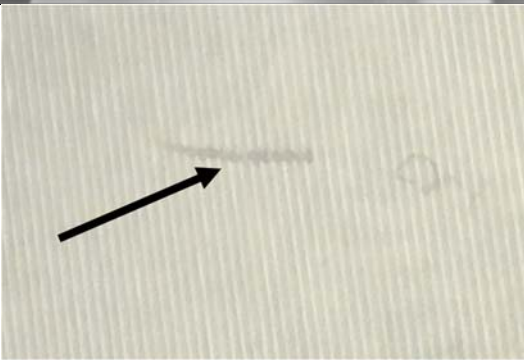
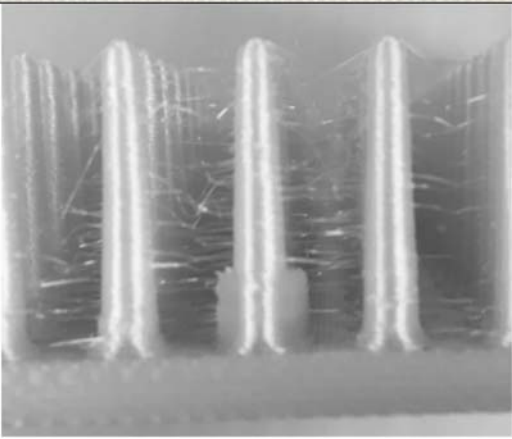
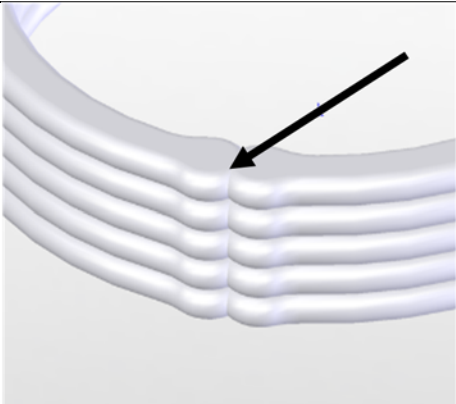
The following anomalies are inherent to the FDM process, are deemed aesthetic, and are acceptable to the extent specified herein.

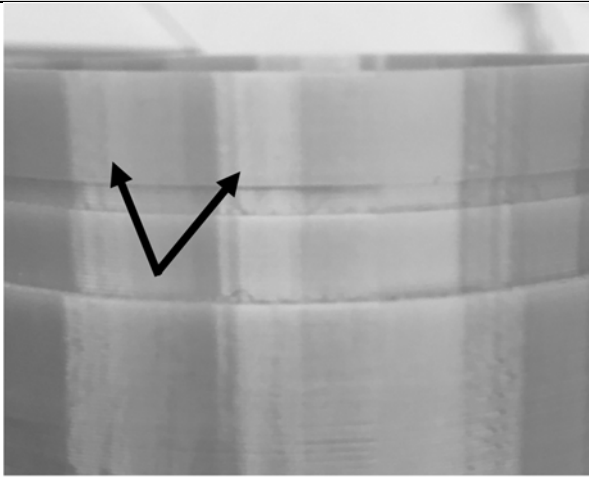
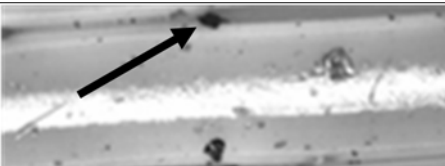

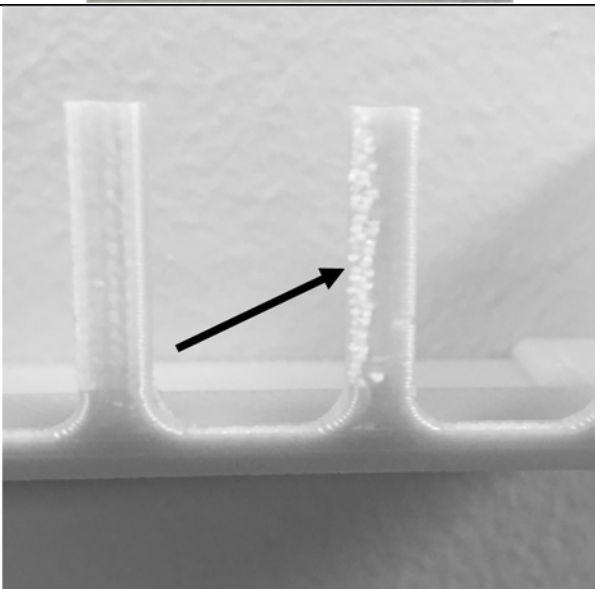
Table 8. Common Anomalies Inherent to FDM Process

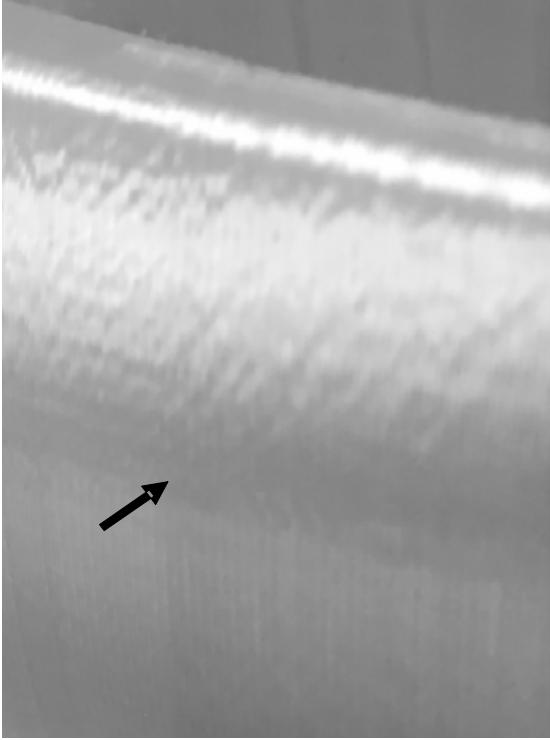
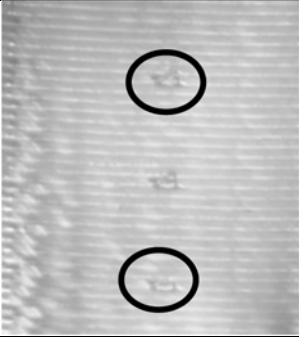
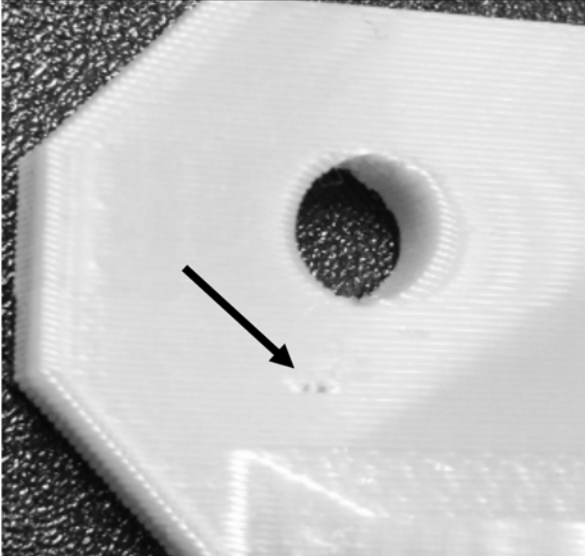
Anomalies	Definition	Allowable Limit
Porosity	Incomplete part fill inherent to the process due to FDM bead microstructure gaps.	Acceptable levels are determined by the tuning process of the material, deviations from the tuning process are captured in other defect descriptions
Stairstepping	Visible, perceptible lines or ridges between successive build layers that are typical on highly curved surfaces.	Ridges should not be greater than the height of the deposition slice for the appropriate tip
Scratches	Shallow cut or scrape on the surface of a part occurring from routine handling, such as support removal.	Scratches shall not be greater than 2mm ² in surface area or greater than one layer deep
Stringing	Short/thin lengths of filament that protrude from the part surface due to residual melted extrudate being drawn away from the part as if a string.	Hairs of 0.2mm that can be removed without damaging the surface of the part
Seams	The start/stop location of a build contour layer.	Seams are inherent to FDM builds and are acceptable, as long as the seam does not expose or extend 25% of the layer height.
Faceting	File resolution artifact that results in flat surfaces on the FDM part where curved surfaces were intended.	Minor faceting is acceptable More extreme faceting should be addressed during file/model preparation prior to part processing. Acceptable levels of faceting are defined by the tolerances imposed on the features of the part by the responsible engineering authority
Contamination	Discontinuous black flakes	Less than 10 flakes per 5 mm.
Bubbles	Small voids found throughout the entirety of the part	Voids must be contained within the thickness of a single bead

Anomalies	Definition	Allowable Limit
Ooze Dits	Small material particles common on seams and can be sanded to be removed	Ooze dits should not expose or extend beyond a single layer thickness
Color Striation	Gradual change from dark to light color	Pigmentation is allowed as long as color does not display dark brown or black which is an indication of burnt material
Stabilizer wall indentions	Repeated pattern of pox marks on the outer 1/3 rd of a contour that is in contact with a stabilizer wall	Stabilizer walls shall not penetrate through the exterior contour it is connected to at any point on the part.
Pin holes	Small divot in surface caused by removal of support structure, typically seen around vertical holes	Must be smaller than 2mm ²

Table 9. Representative Examples of Acceptable Anomalies

Anomalies	Picture / Figure
Porosity	
Stairstepping	
Scratches	
Stringing	
Seams	

Anomalies	Picture / Figure
Faceting	 A grayscale photograph of a cylindrical metal component with several horizontal rings. A black arrow points to a specific ring that exhibits a distinct faceted or stepped appearance, indicating a manufacturing defect.
Contamination	 A close-up grayscale photograph of a metal surface. A black arrow points to a dark, irregular spot on the surface, which is likely a contaminant or a defect.
Bubbles	 A grayscale photograph of a metal surface with a fine, grid-like texture. A black circle highlights a small, dark, circular feature on the surface, which is likely a bubble or a similar defect.
Ooze Dits	 A grayscale photograph of a metal component with two vertical, U-shaped channels. A black arrow points to a vertical line of small, white, irregular particles (ooze dits) that have accumulated along the inner wall of the right-hand channel.

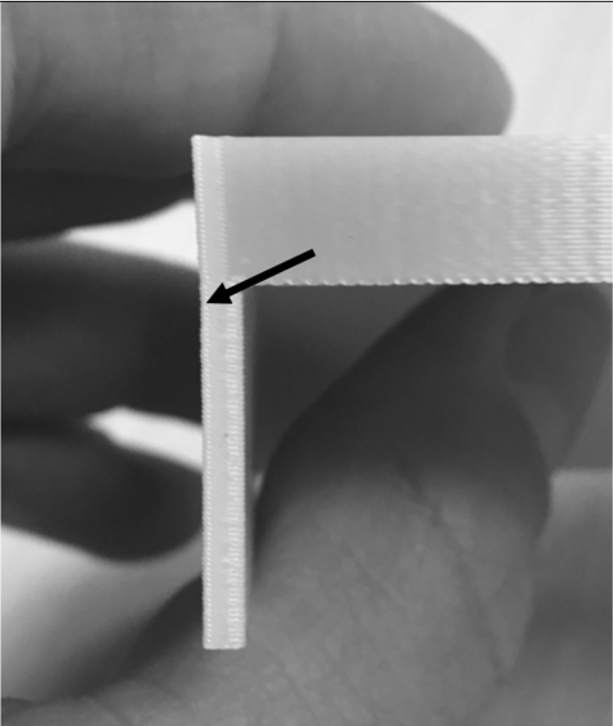
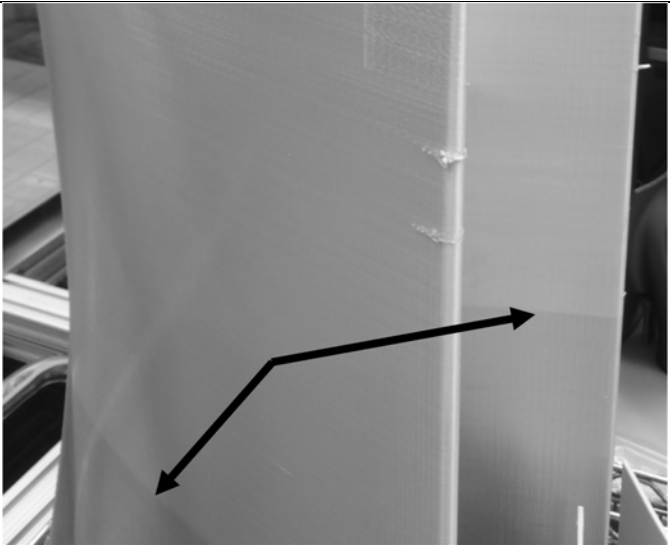

Anomalies	Picture / Figure
Color Striation	
Stabilizer wall indentions	
Pin holes	

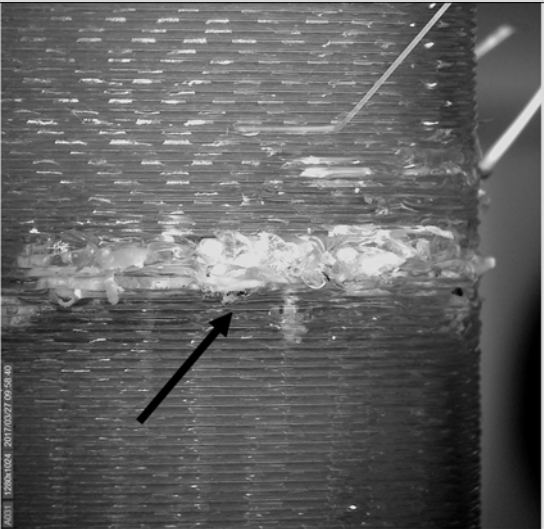
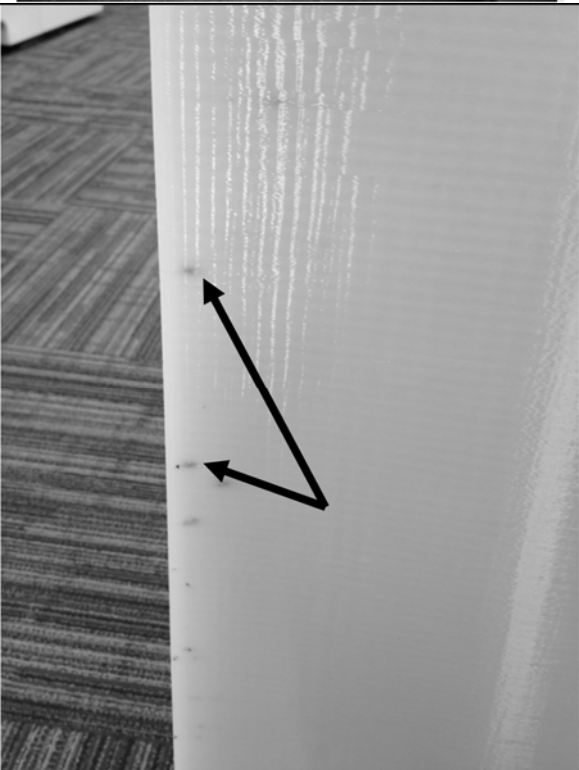
8.4.2. Unacceptable Defects

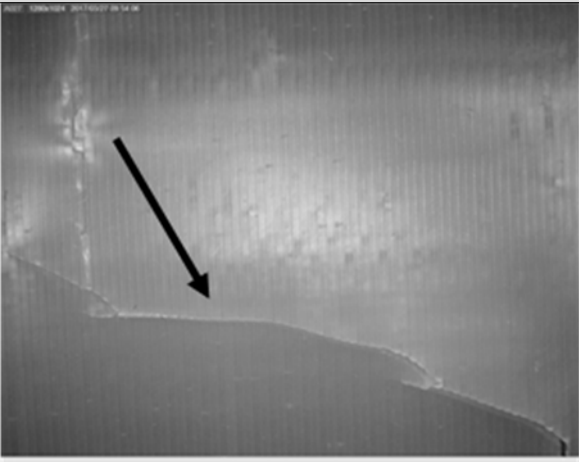
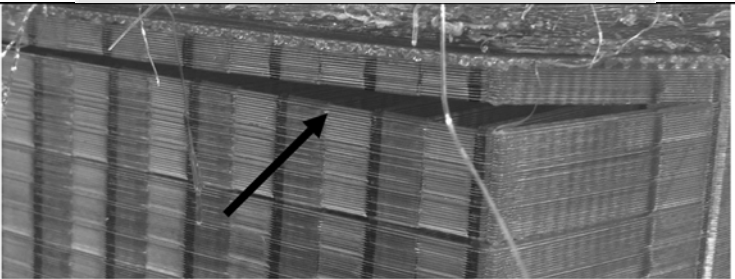
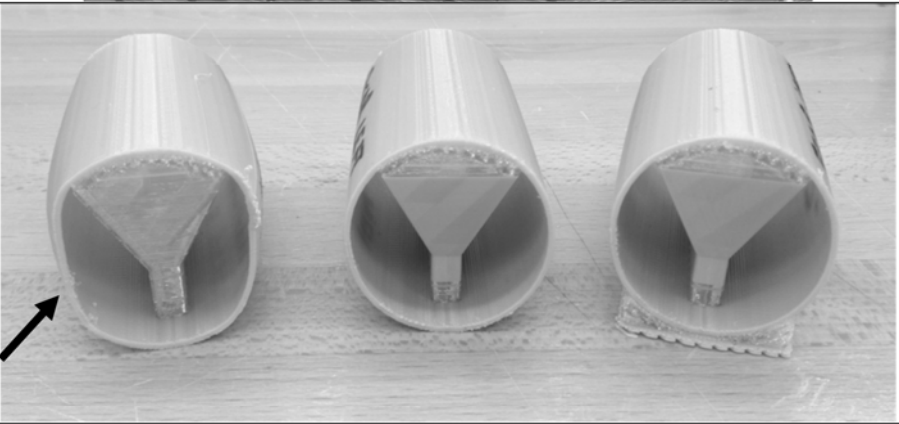
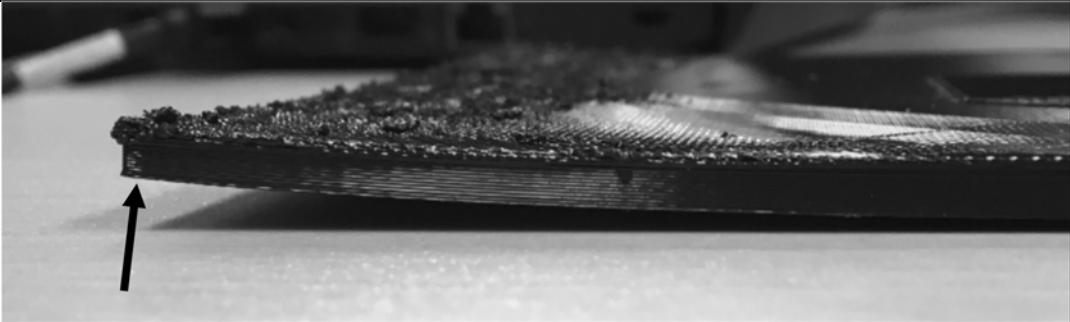
Parts with the following part defects shall be rejected and dispositioned by user designated authority.

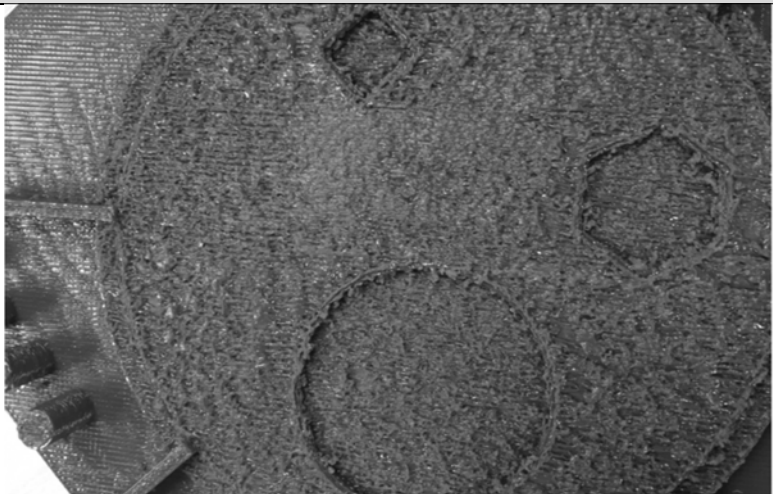
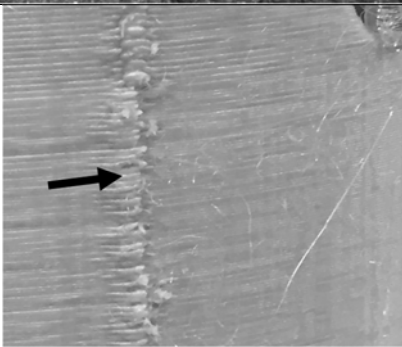
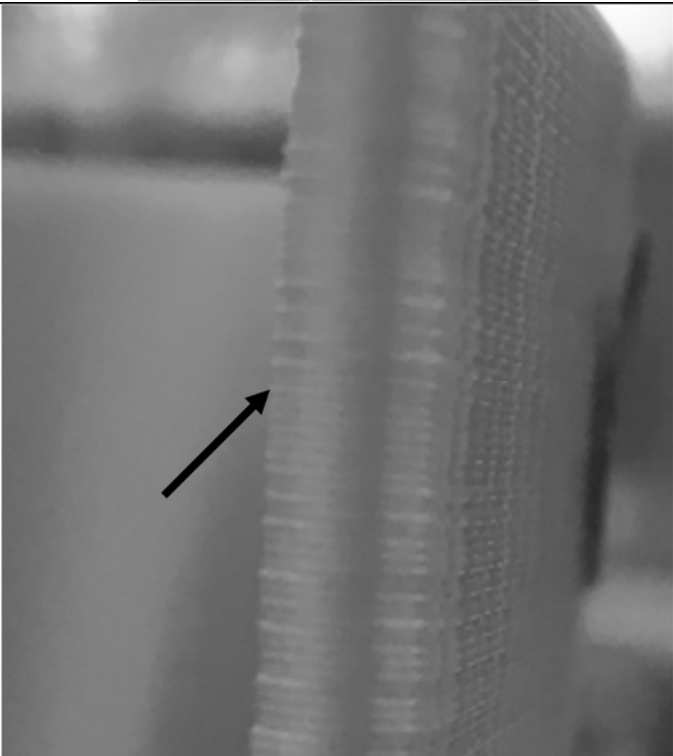
Table 10. List of Part Defects

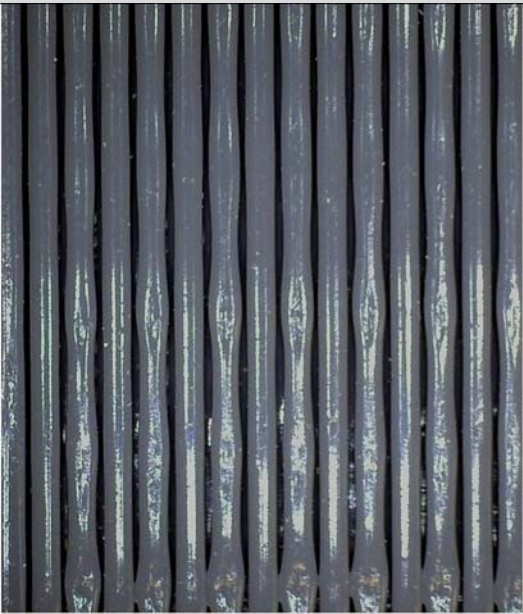
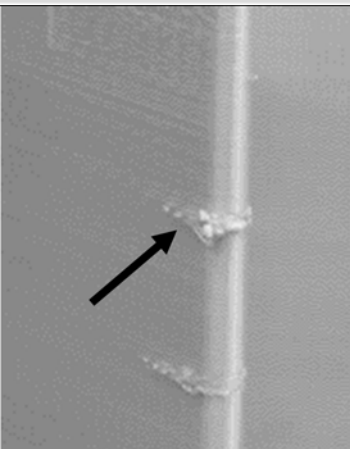
Defect	Definition
Sink	Thin vertical wall pulls in just below horizontal stiffener, causing a deviation in dimensions greater than 1% for verticality
Start/Stop Error	Machine triggers an error that causes the build to pause or stop
Burn	Discoloration seen as dark brown or black color change to the material, can be in streaks or sections of beads that are greater than 0.08mm ²
Embedded Support	Excess support in model material leaving discoloration
Contamination	Cluster of black flakes (continuous mass) greater than 5mm in any dimension, not to be confused with scattered black flakes (discontinuous flakes)
Crack	Sharp break in a feature
Delamination	Separation from two model layers
Warpage	Deformation of features due thermal mass and residual stress build up causing failures in meeting tolerances required for the part
Curl	Deformation of features and surfaces due to excessive part shrinkage (can cause delamination from support interface, greater than 0.5 mm/250 mm)
Overfill	Excessive material deposition causing bead structure disruption, visible globs of material and loss of definition to bead cross section circularity
Heavy Seams	Seams in excess of 3mm. greater than bead width
Vertical Surface Uniformity	Waviness of vertical wall over multiple layers, a function of gantry repeatability, oven temp and Z stage consistency, in which the stacking of layers are inconsistent and result in a toolpath greater than 1500 micro-in RA
Under-fill	Gaps between adjacent rasters particularly in the raster straightaways with a depth of over ½ the bead height, width be about ¼ of the bead width and length of about 12mm.
Purge Blobs	Extrusion from a purge gets redistributed and embedded into a part inclusion for the purge part

Defects	Picture / Figure	
Sink		
Start/Stop Error		
Burn		

Defects	Picture / Figure
Embedded Support	
Contamination	

Defects	Picture / Figure
Crack	
Delamination	
Warpage	
Curl	

Defects	Picture / Figure
Overfill	
Heavy Seams	
Vertical Surface Uniformity	

Defects	Picture / Figure	
Under-fill		
Purge Blobs		

9. Retention of Qualification

The Qualification of Type I material was based on the system and processes outlined within this specification. Any changes to the material, machine, software including physical location is considered to be a change to the process. All changes to the system shall be submitted to the cognizant design authority for review and disposition via Advanced Change Notice (ACN).

It is up to the manufacturer to maintain the system to the requirements outlined in the Maintenance manual. Any deviation to the prescribed maintenance shall be considered as a non-conformance and shall be dispositioned by the cognizant design authority. Repair, as defined by any action not outlined in the maintenance manual for normal maintenance, shall be considered to be a change to the system and submitted to the cognizant design authority for review and disposition.

The software utilized in the manufacture of Type I material is specified in Section 5 of this

document are the only approved versions for making Type I Material. Newer versions of the software will need to be submitted to cognizant design authority for review and disposition. Once a newer version of the software is approved, this specification will be updated to list all approved versions.

10. Quality Assurance

10.1. Process Control

In-process monitoring data should be in accordance with user's applicable company process specification or an approved shop practice. For material qualification and equivalency purposes, the in-process monitoring data should be provided to the appropriate organizations in accordance with the applicable test plan. Process control testing is not required for the fabrication of finished parts.

10.2. Visual Inspection

Verify that there are no obvious defects such as warpage, dry spots, etc. Finished products for material qualification and equivalency purposes must be labeled in accordance with the applicable test plan for identification purposes.

10.3. NDI Testing

An NDI procedure has yet to be developed for additively manufactured polymer materials that is both time and cost effective for the material qualification and part build level. At this time the industry standard is to use a rigorous visual and dimensional inspection process of the additively manufactured coupons or parts.

11. Shipping

For material qualification and equivalency purposes, it may be necessary to send the finished parts to a designated test lab as specified in the applicable test plan. The finished parts shipping instruction should also be included in the applicable test plan.

Appendix A: NCAMP Coupon Build information

The following information shall be utilized for any NCAMP material testing. Any deviation to the build definitions provided will result in non-conforming coupons which may not be acceptable. For a more complete definition of the test requirements please refer to the NCAMP test plan.

Table 11. .CMB Files for Coupon Fabrication

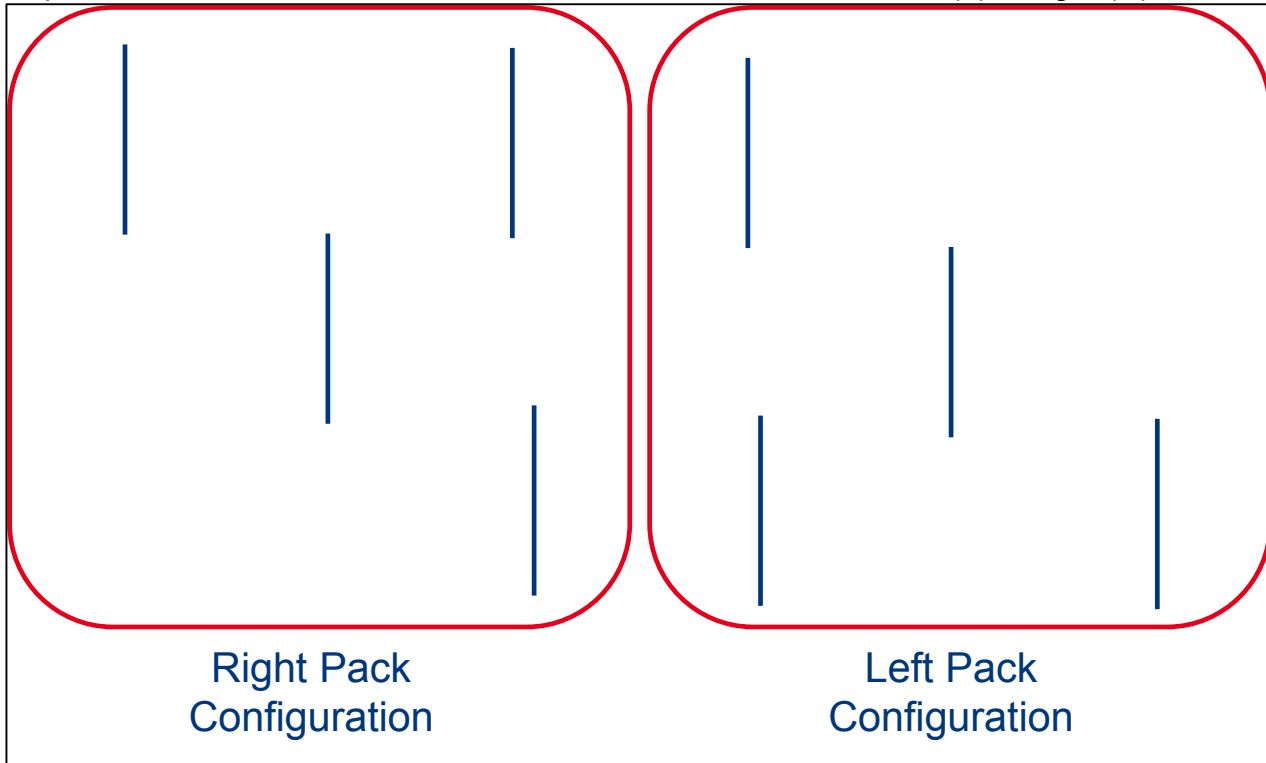
Test	Properties	Method	Type	ASTM F2921 Orientation	CMB Name
Tensile	Modulus, UTS, EAB, Poisson, Yield	ASTM D638	Type 1 T = 0.130"	XZ, XY, ZX, ZX-45	<ul style="list-style-type: none"> D638_XY_T16A.cmb D638_XZ_T16A.cmb D638_ZX_T16A.cmb D638_ZX45_T16A.cmb
Flex	Modulus, UFS	ASTM D790	NA	XZ, XY, ZX, ZX-45	<ul style="list-style-type: none"> D790_XZ_T16A.cmb D790_XY_T16A.cmb D790_ZX_T16A.cmb D790_ZX45_T16A.cmb
Compression	UCS, Yield	ASTM D695	Modified Type 6.7.2	XZ, XY, ZX, ZX-45	<ul style="list-style-type: none"> D695_ZX_T16A.cmb D695_XZ_T16A.cmb D695_XY_T16A.cmb D695_ZX45_T16A.cmb
UnNotched Izod Impact	Impact Resistance	ASTM D256	NA	XZ, XY, ZX, ZX-45	<ul style="list-style-type: none"> D256_XY_T1A.cmb D256_XZ_T16A.cmb D256_ZX_T16A.cmb D256_ZX45_T16A.cmb
V-Notched Beam In-Plane Shear	Modulus, UTS	ASTM D5379	NA	XY	<ul style="list-style-type: none"> D5379_XY_T16A.cmb
Open Hole Tension	Modulus, UTS	ASTM D5766	L = 8"	XZ, XY, ZX, ZX-45	<ul style="list-style-type: none"> D5766_XY_T16A.cmb D5766_XZ_T16A.cmb D5766_ZX_T16A.cmb D5766_ZX45_T16A.cmb
Filled Hole Tension (1)	Modulus, UTS	ASTM D6742	L = 8"	XZ, XY, ZX, ZX-45	<ul style="list-style-type: none"> D5766_XY_T16A.cmb D5766_XZ_T16A.cmb D5766_ZX_T16A.cmb D5766_ZX45_T16A.cmb
Open Hole Compression	Modulus, UCS	ASTM D6484	NA	XZ, XY, ZX, ZX-45	<ul style="list-style-type: none"> D6484_XY_T16A.cmb D6484_XZ_T16A.cmb D6484_ZX_T16A.cmb D6484_ZX4_T16A.cmb
Filled Hole Compression (2)	Modulus, UCS	ASTM D6742	NA	XZ, XY, ZX, ZX-45	<ul style="list-style-type: none"> D6484_XY_T16A.cmb D6484_XZ_T16A.cmb D6484_ZX_T16A.cmb D6484_ZX4_T16A.cmb
Single Shear Bearing	UTS, Deformation	ASTM D5961	NA	XZ, XY, ZX, ZX-45	<ul style="list-style-type: none"> D5961_XY_T16A.cmb D5961_XZ_T16A.cmb D5961_ZX45_T16A.cmb D5961_ZX_T16A.cmb

Note 1: Filled Hole Tension will be tested against ASTM D6742 but shares the same geometry and .CMB file as D5766 samples

Note 2: Filled Hole Compression will be tested against ASTM D6742 but shares the same geometry and .CMB file as D6484 samples

Appendix B: Representative Build Sheet Locations

Representative build sheet locations as denoted in table below left (L) or right (R)



Build Name	Pack File Name	.CMBs Contained	Quantity	Locations (R or L)	Orientations
Build 1_Machine 1	Pack1_T16A_L	<ul style="list-style-type: none"> D790_XZ_T16A.cbm (12) D638_XZ_T16A.cbm (12) 	<ul style="list-style-type: none"> 12 12 	Left	XZ
Build 1_Machine 2	Pack1_T16A_R	<ul style="list-style-type: none"> D790_XZ_T16A.cbm (12) D638_XZ_T16A.cbm (12) 	<ul style="list-style-type: none"> 12 12 	Right	XZ
Build 2_Machine 1	Pack2_T16A_R	<ul style="list-style-type: none"> D638_XY_T16A.cbm (12) D638_ZX_T16A.cbm (12) 	<ul style="list-style-type: none"> 12 12 	Right	XY, ZX
Build 2_Machine 2.cmb	Pack2_T16A_L	<ul style="list-style-type: none"> D638_XY_T16A.cbm (12) D638_ZX_T16A.cbm (12) 	<ul style="list-style-type: none"> 12 12 	Left	XY, ZX
Build 3_Machine 1.cmb	Pack3_T16A_R	<ul style="list-style-type: none"> D790_ZX_T16A.cbm (12) D790_XY_T16A.cbm (12) 	<ul style="list-style-type: none"> 12 12 	Right	ZX, XY
Build 3_Machine 2.cmb	Pack3_T16A_L	<ul style="list-style-type: none"> D790_ZX_T16A.cbm (12) D790_XY_T16A.cbm (12) 	<ul style="list-style-type: none"> 12 12 	Left	ZX, XY
Build 4_Machine 1.cmb	Pack4_T16A_L	<ul style="list-style-type: none"> D638_ZX45_T16A.cbm (4) D790_ZX45_T16A.cbm (12) 	<ul style="list-style-type: none"> 4 12 	Left	ZX45

Build Name	Pack File Name	.CMBs Contained	Quantity	Locations (R or L)	Orientations
Build 4_Machine 2.cmb	Pack4_T16A_R	<ul style="list-style-type: none"> D638_ZX45_T16A.cmb (4) D790_ZX45_T16A.cmb (12) 	<ul style="list-style-type: none"> 4 12 	Right	ZX45
Build 5_Machine 1.cmb	Pack5_T16A_L	<ul style="list-style-type: none"> D638_ZX45_T16A.cmb (8) 	<ul style="list-style-type: none"> 8 	Left	ZX45
Build 5_Machine 2.cmb	Pack5_T16A_R	<ul style="list-style-type: none"> D638_ZX45_T16A.cmb (8) 	<ul style="list-style-type: none"> 8 	Right	ZX45
Build 6_Machine 1.cmb	Pack6_T16A_R	<ul style="list-style-type: none"> D256_ZX_T16A.cmb (4) D5961_ZX_T16A.cmb (8) D695_XY_T16A.cmb (16) D256_ZX45_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 8 16 4 	Right	ZX, XY, Z45
Build 6_Machine 2.cmb	Pack6_T16A_L	<ul style="list-style-type: none"> D256_ZX_T16A.cmb (4) D5961_ZX_T16A.cmb (8) D695_XY_T16A.cmb (16) D256_ZX45_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 8 16 4 	Left	ZX, XY, Z45
Build 7_Machine 1.cmb	Pack7_T16A_L	<ul style="list-style-type: none"> D5961_ZX_T16A.cmb (8) D5961_XY_T16A.cmb (8) 	<ul style="list-style-type: none"> 8 8 	Left	XZ, XY
Build 7_Machine 2.cmb	Pack7_T16A_R	<ul style="list-style-type: none"> D5961_XZ_T16A.cmb (8) D5961_XY_T16A.cmb (8) 	<ul style="list-style-type: none"> 8 8 	Right	XZ, XY
Build 8_Machine 1.cmb	Pack8_T16A_R	<ul style="list-style-type: none"> D5961_ZX_T16A.cmb (8) 	<ul style="list-style-type: none"> 8 	Right	ZX
Build 8_Machine 2.cmb	Pack8_T16A_L	<ul style="list-style-type: none"> D5961_ZX_T16A.cmb (8) 	<ul style="list-style-type: none"> 8 	Left	ZX
Build 9_Machine 1.cmb	Pack9_T16A_L	<ul style="list-style-type: none"> D256_XZ_T1A.cmb (4) D256_XY_T1A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Left	XZ, XY
Build 9_Machine 2.cmb	Pack9_T16A_R	<ul style="list-style-type: none"> D256_XZ_T1A.cmb (4) D256_XY_T1A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Right	XZ, XY
Build 10_Machine 1.cmb	Pack10_T16A_R	<ul style="list-style-type: none"> D5961_XY_T16A.cmb (12) D695_ZX45_T16A.cmb (16) D695_ZX_T16A.cmb (16) 	<ul style="list-style-type: none"> 12 16 16 	Right	XY, ZX45, ZX
Build 10_Machine 2.cmb	Pack10_T16A_L	<ul style="list-style-type: none"> D5961_XY_T16A.cmb (12) D695_ZX45_T16A.cmb (16) D695_ZX_T16A.cmb (16) 	<ul style="list-style-type: none"> 12 16 16 	Left	XY, ZX45, ZX
Build 11_Machine 1.cmb	Pack11_T16A_L	<ul style="list-style-type: none"> D5766_XY_T16A.cmb (12) 	<ul style="list-style-type: none"> 12 	Left	XY
Build 11_Machine 2.cmb	Pack11_T16A_R	<ul style="list-style-type: none"> D5766_XY_T16A.cmb (12) 	<ul style="list-style-type: none"> 12 	Right	XY

Build Name	Pack File Name	.CMBs Contained	Quantity	Locations (R or L)	Orientations
Build 12_Machine 1.cmb	Pack12_T16A_R	<ul style="list-style-type: none"> D5766_ZX45_T16A.cmb (4) D5766_ZX_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Right	ZX45, ZX
Build 12_Machine 2.cmb	Pack12_T16A_L	<ul style="list-style-type: none"> D5766_ZX45_T16A.cmb (4) D5766_ZX_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Left	ZX45, ZX
Build 13_Machine 1.cmb	Pack13_T16A_L	<ul style="list-style-type: none"> D5766_XZ_T16A.cmb (8) 	<ul style="list-style-type: none"> 8 	Left	XZ
Build 13_Machine 2.cmb	Pack13_T16A_R	<ul style="list-style-type: none"> D5766_XZ_T16A.cmb (8) 	<ul style="list-style-type: none"> 8 	Right	XZ
Build 14_Machine 1.cmb	Pack12_T16A_R	<ul style="list-style-type: none"> D5766_ZX45_T16A.cmb (4) D5766_ZX_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Right	ZX45, ZX
Build 14_Machine 2.cmb	Pack12_T16A_L	<ul style="list-style-type: none"> D5766_ZX45_T16A.cmb (4) D5766_ZX_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Left	ZX45, ZX
Build 15_Machine 1.cmb	Pack15_T16A_L	<ul style="list-style-type: none"> D695_XZ_T16A.cmb (16) D5766_XZ_T16A.cmb (4) 	<ul style="list-style-type: none"> 16 4 	Left	XZ
Build 15_Machine 2.cmb	Pack15_T16A_R	<ul style="list-style-type: none"> D695_XZ_T16A.cmb (16) D5766_XZ_T16A.cmb (4) 	<ul style="list-style-type: none"> 16 4 	Right	XZ
Build 16_Machine 1.cmb	Pack12_T16A_R	<ul style="list-style-type: none"> D5766_ZX45_T16A.cmb (4) D5766_ZX_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Right	ZX45, ZX
Build 16_Machine 2.cmb	Pack12_T16A_L	<ul style="list-style-type: none"> D5766_ZX45_T16A.cmb (4) D5766_ZX_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Left	ZX45, ZX
Build 17_Machine 1.cmb	Pack17_T16A_R	<ul style="list-style-type: none"> D5766_XZ_T16A.cmb (4) D5766_XY_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Right	XZ, XY
Build 17_Machine 2.cmb	Pack17_T16A_L	<ul style="list-style-type: none"> D5766_XZ_T16A.cmb (4) D5766_XY_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Left	XZ, XY
Build 18_Machine 1.cmb	Pack12_T16A_L	<ul style="list-style-type: none"> D5766_ZX45_T16A.cmb (4) D5766_ZX_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Left	ZX45, ZX
Build 18_Machine 2.cmb	Pack12_T16A_R	<ul style="list-style-type: none"> D5766_ZX45_T16A.cmb (4) D5766_ZX_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Right	ZX45, ZX
Build 19_Machine 1.cmb	Pack17_T16A_R	<ul style="list-style-type: none"> D5766_XZ_T16A.cmb (4) D5766_XY_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Right	XZ, XY
Build 19_Machine 2.cmb	Pack17_T16A_L	<ul style="list-style-type: none"> D5766_XZ_T16A.cmb (4) D5766_XY_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Left	XZ, XY

Build Name	Pack File Name	.CMBs Contained	Quantity	Locations (R or L)	Orientations
Build 20_Machine 1.cmb	Pack12_T16A_L	<ul style="list-style-type: none"> D5766_ZX45_T16A (4) D5766_ZX_T16A (4) 	<ul style="list-style-type: none"> 4 4 	Left	ZX45, ZX
Build 20_Machine 2.cmb	Pack12_T16A_R	<ul style="list-style-type: none"> D5766_ZX45_T16A (4) D5766_ZX_T16A (4) 	<ul style="list-style-type: none"> 11 	Right	ZX45, ZX
Build 21_Machine 1.cmb	Pack17_T16A_R	<ul style="list-style-type: none"> D5766_XZ_T16A.cmb (4) D5766_XY_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Right	XZ, XY
Build 21_Machine 2.cmb	Pack17_T16A_L	<ul style="list-style-type: none"> D5766_XZ_T16A.cmb (4) D5766_XY_T16A.cmb (4) 	<ul style="list-style-type: none"> 4 4 	Left	XZ, XY
Build 22_Machine 1.cmb	Pack12_T16A_L	<ul style="list-style-type: none"> D5766_ZX45_T16A (4) D5766_ZX_T16A (4) 	<ul style="list-style-type: none"> 4 4 	Left	ZX45, ZX
Build 22_Machine 2.cmb	Pack12_T16A_R	<ul style="list-style-type: none"> D5766_ZX45_T16A (4) D5766_ZX_T16A (4) 	<ul style="list-style-type: none"> 4 4 	Right	ZX45, ZX
Build 23_Machine 1.cmb	Pack23_T16A_R	<ul style="list-style-type: none"> D6484_XY_T16A (8) 	<ul style="list-style-type: none"> 8 	Right	XY
Build 23_Machine 2.cmb	Pack23_T16A_L	<ul style="list-style-type: none"> D6484_XY_T16A (8) 	<ul style="list-style-type: none"> 8 	Left	XY
Build 24_Machine 1.cmb	Pack24_T16A_L	<ul style="list-style-type: none"> D6484_ZX45_T16 (4) 	<ul style="list-style-type: none"> 4 	Left	ZX45
Build 24_Machine 2.cmb	Pack24_T16A_R	<ul style="list-style-type: none"> D6484_ZX45_T16 (4) 	<ul style="list-style-type: none"> 4 	Right	ZX45
Build 25_Machine 1.cmb	Pack25_T16A_R	<ul style="list-style-type: none"> D6484_XZ_T16A (4) 	<ul style="list-style-type: none"> 4 	Right	XZ
Build 25_Machine 2.cmb	Pack25_T16A_L	<ul style="list-style-type: none"> D6484_XZ_T16A (4) 	<ul style="list-style-type: none"> 4 	Left	XZ
Build 26_Machine 1.cmb	Pack24_T16A_L	<ul style="list-style-type: none"> D6484_ZX45_T16 (4) 	<ul style="list-style-type: none"> 4 	Left	ZX45
Build 26_Machine 2.cmb	Pack24_T16A_R	<ul style="list-style-type: none"> D6484_ZX45_T16 (4) 	<ul style="list-style-type: none"> 4 	Right	ZX45
Build 27_Machine 1.cmb	Pack27_T16A_L	<ul style="list-style-type: none"> D6484_ZX_T16A (4) 	<ul style="list-style-type: none"> 4 	Left	ZX45
Build 27_Machine 2.cmb	Pack27_T16A_R	<ul style="list-style-type: none"> D6484_ZX_T16A (4) 	<ul style="list-style-type: none"> 4 	Right	ZX45

Build Name	Pack File Name	.CMBs Contained	Quantity	Locations (R or L)	Orientations
Build 28_Machine 1.cmb	Pack27_T16A_L	• D6484_ZX_T16A (4)	• 4	Left	ZX45
Build 28_Machine 2.cmb	Pack27_T16A_R	• D6484_ZX_T16A (4)	• 4	Right	ZX45
Build 29_Machine 1.cmb	Pack25_T16A_R	• D6484_XZ_T16A (4)	• 4	Right	XZ
Build 29_Machine 2.cmb	Pack25_T16A_L	• D6484_XZ_T16A (4)	• 4	Left	XZ
Build 30_Machine 1.cmb	Pack30_T16A_R	• D6484_ZX45_T16 (4)	• 4	Right	ZX45
Build 30_Machine 2.cmb	Pack30_T16A_L	• D6484_ZX45_T16 (4)	• 4	Left	ZX45
Build 31_Machine 1.cmb	Pack31_T16A_L	• D6484_XY_T16A (8)	• 8	Left	XY
Build 31_Machine 2.cmb	Pack31_T16A_R	• D6484_XY_T16A (8)	• 8	Right	XY
Build 32_Machine 1.cmb	Pack30_T16A_R	• D6484_ZX45_T16 (4)	• 4	Right	ZX45
Build 32_Machine 2.cmb	Pack30_T16A_L	• D6484_ZX45_T16 (4)	• 4	Left	ZX45
Build 33_Machine 1.cmb	Pack25_T16A_L	• D6484_XZ_T16A (4)	• 4	Left	XZ
Build 33_Machine 2.cmb	Pack25_T16A_R	• D6484_XZ_T16A (4)	• 4	Right	XZ
Build 34_Machine 1.cmb	Pack27_T16A_R	• D6484_ZX_T16A (4)	• 4	Right	ZX
Build 34_Machine 2.cmb	Pack27_T16A_L	• D6484_ZX_T16A (4)	• 4	Left	ZX
Build 35_Machine 1.cmb	Pack25_T16A_L	• D6484_XZ_T16A (4)	• 4	Left	XZ
Build 35_Machine 2.cmb	Pack25_T16A_R	• D6484_XZ_T16A (4)	• 4	Right	XZ

Build Name	Pack File Name	.CMBs Contained	Quantity	Locations (R or L)	Orientations
Build 36_Machine 1.cmb	Pack27_T16A_R	<ul style="list-style-type: none"> • D6484_ZX_T16A (4) 	• 4	Right	ZX
Build 36_Machine 2.cmb	Pack27_T16A_L	<ul style="list-style-type: none"> • D6484_ZX_T16A (4) 	• 4	Left	ZX

REVISION HISTORY

Rev	By	Date	Description
-	Paul Jonas, and John Tomblin	3/27/2017	Initial Release
A	Paul Jonas, and John Tomblin	11/3/2017	Updated Insight and Controller Software versions (Section 5) Added minimum time for part removal (Section 7.3) Raster orientation added to Dimensional Inspection (Section 8.3)
B	Royal Lovingfoss	3/27/2019	Formatting Added a new reference, NMS 085/1 Removed duplicated section 4.5.8 Updated section 6.5 per NMS 085/1
C	Royal Lovingfoss	4/2/2019	Updated section 7.1 e and 6.6