Verification Plan and Results

ME186 / EE188 / BME 188 – Capstone II

Team 16 – Zen of the Art and Glitter Deposition
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Date	Revision	Release Notes
1/24/2022	01	Preliminary Draft
2/14/2022	02	Resolved formatting errors, clarifying steps and processes
4/24/2022	03	Final Draft

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1 Verification Plan Introduction

The Glitter Box is a module intended as a proof of concept for additive manufacturing. The module is designed to have a substrate with an adhesive pattern enter via a conveyor belt and be completely coated with a powder dependent on the user's needs. This is done by dropping a dusting of powder onto the adhesive as it enters and using an air blade to remove any excess that has not been adhered at the exit of the module.

This document contains the results of testing all engineering specifications based on the Client's (Integrity Industrial Inkjet Integration) expressed requirements for a successful product. Passing each ID listed in the document below should indicate a finished and fully functional product.

2 ID # 10 - Demonstration

2.1 Specification

The hopper shall deposit 1 tsp +/- 1/6 tsp of glitter per coating to prevent material waste.

2.2 Verification Approach

This specification will verify that material use remains efficient. This will be done by comparing the volume of glitter deposited for a single cycle to the volume of a teaspoon.

2.3 Equipment Needed (if any)

- 1 Teaspoon measurement
- Glitter
- Deposition Assembly
    - Hopper
    - Deposition roller

2.4 Procedure

2.4.1 Safety Considerations

- Potential hazard from airborne glitter
    - Wear safety goggles during setup and demonstration
    - Utilize an enclosed testing area

2.4.2 Setup

- Clean hopper of any residual glitter from past testing
- Place hopper assembly inside of enclosed testing area
- Deposit 1 Teaspoon of glitter into the hopper

2.4.3 Demonstration Procedure

- Deposit 1 cycles worth of glitter from the hopper by spinning the deposition cylinder ½ revolution
- Inspect glitter remaining in hopper to verify if any remains

2.5 Pass Criteria

The specification will pass If any amount of glitter remains in the hopper after deposition. This indicates that less than 1 tsp was deposited.

2.6 Results – 4/4/22 - Pass

This tested showed that an amount of glitter remains in the hopper after the half revolution. This indicates a pass.

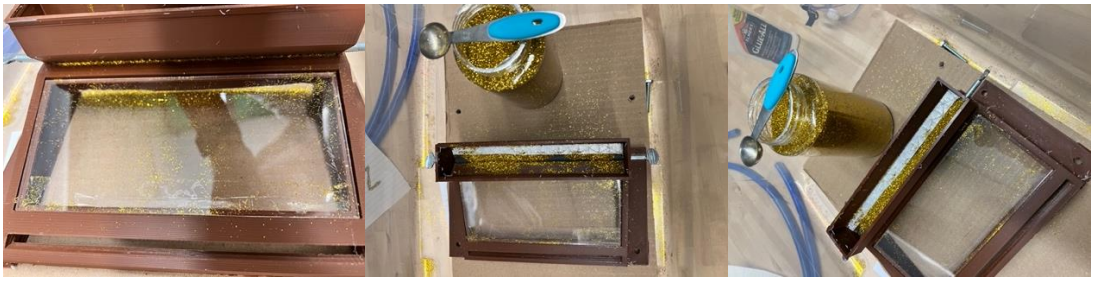

Figure 1 – Results showing glitter remaining in hopper.

3 ID # 20 - Test

3.1 Specification

The quantity of adhesive removed from the substrate shall not be below a 4 on the designated adhesive visual scale.

3.2 Verification Approach

This test will verify that the method for removing glitter does not also remove/distort the adhesive. This will be done by running the system with only adhesive and comparing the amount of displaced adhesive to the pre-determined visual scale. Passing this verification ensures high image quality and resolution for the print after exiting the module.

3.3 Equipment Needed

- Air Pump
- Air Blade Adaptor
- AC Power Socket
- Glitter Module
- Elmer's Glue
- Small brush
- Substrate (for the results given here, a sheet of paper was used)
- ¼ 20" thumbscrews
- string

3.4 Procedure

3.4.1 Safety Considerations

- Safety goggles should be always worn during testing
- Testing should be performed inside of an isolated testing container

- Long hair should be tied up and loose jewelry should be removed and kept clear of the air pump inlet

3.4.2 Setup

- Secure the module inside of the isolated testing container on a flat surface using the thumbscrews
- Plug in the air pump and attach the air blade adaptor to the end of the tubing
- Affix the free side of the adaptor to the air blade inlet on the glitter module
- Using the small brush and the Elmer's Glue, paint a design onto the substrate (Note: this design should remain constant for all testing to maintain a consistent reference)
- Attach the string to one end of substrate
- Place the substrate with the glue design slightly outside the entrance of module
- Feed the loose end of the string through the module so that the substrate may be pulled through
- Prepare video recording from above the module for future reference

3.4.3 Test Procedure

1. Take a picture of the Glue design on the substrate
2. Start recording from above the module
3. Turn on the air pump
4. Draw the substrate through the module at a constant speed by pulling on the loose end of the string
5. Once the glue has cleared the module, turn off the air pump
6. Take a final picture of the glue design
7. Compare the two photos of the glue design from before and after going through the module
8. Score the test from 0-5 on the adhesive visual scale, 0 being complete removal/distortion of all adhesive from the substrate and 5 being no adhesive removal/distortion.

3.5 Pass Criteria

To pass this specification the system must score a 4 or higher on the scale provided.

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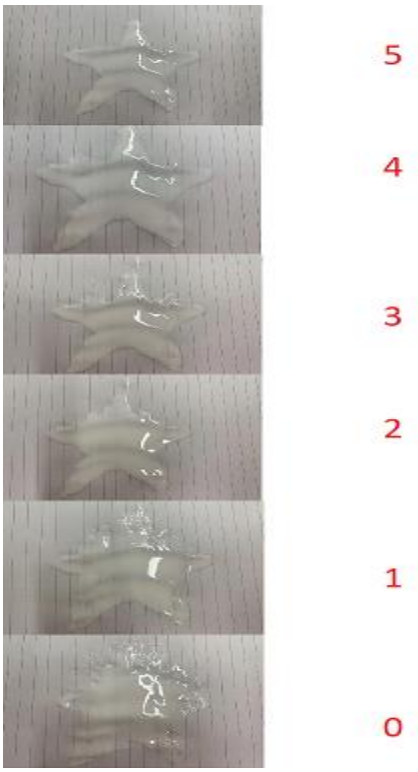

Figure 2 – Adhesive visual scale showing different levels of adhesive being disturbed on the substrate

3.6 Results – 4/18/22 - Pass

The demonstration resulted in a pass, where no adhesive was disturbed when air flow was applied within the system. A visual of the adhesive before and after shows no disruption to the substrate.

Figure 3: Before applied air flow

Figure 4: After applied air flow

4 ID # 30 - Demonstration

4.1 Specification

Box shall be compatible with ¼ 20-inch mounting threaded bolt holes on Integrity's conveyor system.

4.2 Verification Approach

This analysis will verify that ¼ 20-inch bolts will fit into the mounting holes on the box, along with verifying that the mounting holes on the box line up with the mounting bolt holes on Integrity's conveyor. To confirm this, ¼ 20-inch bolts will be used to test the size of the mounting holes while mounting the box onto a simulated conveyor with correct hole spacing based on CAD files provided by the client to test fitment.

4.3 Equipment Needed

- 4 ¼ 20-inch bolts and nuts
- Simulated conveyor with two rows 8.5 inches apart of mounting holes linearly spaced 1.5 inches apart.
- Coating box with mounting holes

4.4 Procedure

4.4.1 Safety Considerations

- Potential hazards from mechanical fastening
    - Keep hands clear from pinch points
    - Tie back or remove, necklaces, long hair, strings, sleeves, ETC.

4.4.2 Setup

- Align Mounting holes on box with mounting holes on simulated conveyor
- Prepare ¼ 20-inch bolts nearby for mounting

4.4.3 Demonstration Procedure

- Begin to screw in the ¼ 20-inch bolts into the box mounting holes through the simulated conveyor mounting holes
- Secure bolts using wing-nuts until box is firmly positioned on simulated conveyor
- Inspect the bolt/box/conveyor assembly to ensure the box is locked in place and fits properly

4.5 Pass Criteria

The specification will pass if the mounting holes on the box line up with the holes on the simulated conveyor allowing all the bolts to screw in and lock the box in place on top of the conveyor.

4.6 Results – 4/4/22 - Pass

These results show that the ¼ 20-inch bolts fit directly into the mounting holes designed to fit these ¼ 20-inch bolts. These results also show that the mounting holes on the box line up with the mounting holes on Integrity's conveyor. Once the bolts are in place, the box is securely

mounted and will not move even if accidentally nudged. This means that ID 70 passes the verification check.

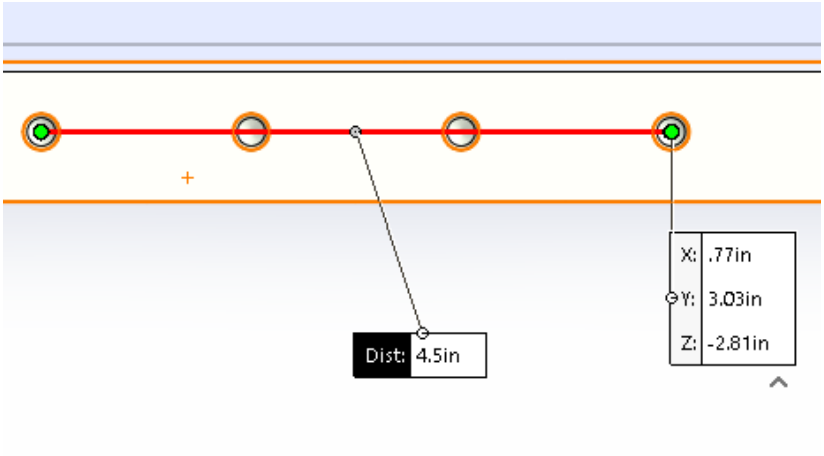

Figure 5 – Solidwork file showing exact dimentions of Integrity's conveyor

Figure 6 – Coating chamber mounted onto makeshift conveyor with ¼ 20 inch bolts.

Figure 7 – Clear view of all the bolts fastened down, holding in the coating chamber.

5 ID # 40 - Demonstration

5.1 Specification

Glitter coating process shall be haltable within 3 seconds after command is initiated.

5.2 Verification Approach

The purpose of this verification is to show that, in an emergency, the coating process may be rapidly halted to prevent the aerosolization of powder. This will be done by timing how long it takes to completely halt air flow into the module.

5.3 Equipment Needed

- 3D printed prototype
- Particles/Glitter
- Air pump
- Air blade adaptor
- Timer/stopwatch
- Substrate (Paper was used for results shown below)
- Testing container
- ¼ - 20 in screws
- string

5.4 Procedure

5.4.1 Safety Considerations

- Remove or isolate the battery before or after working to prevent shock hazards.
- Air Pump
    - High pressure system, release air slowly to not create a mess of airborne particles
- Wear safety goggles during testing to prevent glitter flying into eyes.
- Use testing container to control glitter escape

5.4.2 Setup

- Ensure the bottom of the testing area is glitter-free and clean
- Place adhesive (Elmer's glue) onto the substrate
- Attach one end of the string to the substrate and pull the loose end through the box so that it may be drawn through the module
- Position the glitter box above the substrate
- Fill hopper with glitter
- Attach air blade adaptor to air pump tubing and affix the loose end to the air blade inlet in the glitter module

- Plug in air pump

5.4.3 Demonstration Procedure

- Turn on the air inflator.
- Deposit the 1 tsp of glitter into the glitter box using the hopper by rotating the roller.
- Begin drawing the substrate through the module at a constant speed by pulling on the loose end of the string
- Start timer and turn off the inflator by using the pressure control valve on the air pump tubing simultaneously.
- Once glitter is motionless within system, stop the timer
- Record time to stop
- Unplug the inflator

5.5 Pass Criteria

To pass the test, the glitter must halt dispersion within 3 seconds of issue the command to stop the inflator from distributing air. If the timer results in more than 3 seconds, then the verification has failed. To verify the time it takes to halt the air flow, a video is taken as well to record the exact length of the process.

5.6 Results – 4/4/22 – 1:00PM – Pass

The demonstration passed the criteria of halting air flow within 3 seconds of initiating the action. Below in Figure 8 is a frame of the video displaying our prototype in action, as well as the user halting the air flow. The time it took to stop was 2 seconds, less than the 3 seconds required to pass this verification.

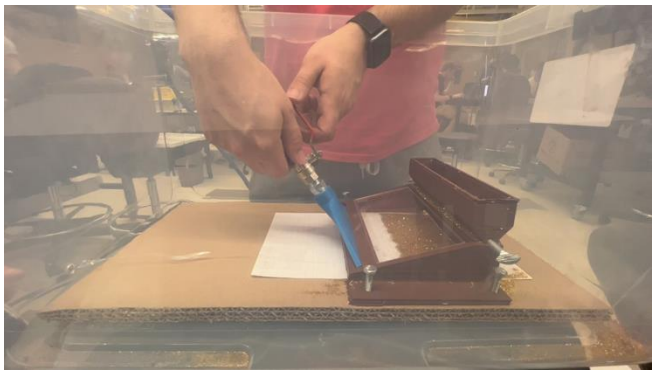

Figure 8 – User Halting Air Flow: 2.21 seconds

6 ID # 50 - Test

6.1 Specification

Box shall be able to continuously displace glitter for 1 minute.

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6.2 Verification Approach

The purpose of this verification is to show that the module can function continuously for multiple coatings over a longer period. This will be done by running the system continuously for 1 minute and documenting any failures.

6.3 Equipment Needed

- Air pump
- Air blade adapter
- AC power socket
- Glitter Module
- Glitter
- Isolated testing container
- Substrate (for the results given here, a sheet of paper was used)
- ¼ 20” thumbscrews
- String

6.4 Procedure

6.4.1 Safety Considerations

- Safety goggles should be always worn during testing
- Testing should be performed inside of an isolated testing container
- Long hair should be tied up and loose jewelry should be removed and kept clear of the air pump inlet

6.4.2 Setup

- Secure the module inside of the isolated testing container on a flat surface using the thumbscrews
- Plug in the air pump and attach the air blade adaptor to the end of the tubing
- Affix the free side of the adaptor to the air blade inlet on the glitter module
- Attach the string to one end of the substrate
- Place the substrate slightly outside the entrance of module
- Feed the loose end of the string through the module so that the substrate may be pulled through
- Load the hopper with glitter
- Prepare video recording from above the module for future reference

6.4.3 Test Procedure

- Start recording from above the module
- Turn on air pump
- Slowly draw the substrate through the module at a constant speed by pulling on the loose end of the string
- Take note of any errors that occur during the minute (glitter escape, hopper jamming, etc.)
- After 1 minute has elapsed turn of the pump and halt the substrate

6.5 Pass Criteria

To pass this verification, the module should be able to function continuously for 1 minute with no errors arising.

6.6 Results – 4/6/22 - Pass

The result from the test showed that the glitter box surpassed the 1 minute timer test, with the inflator running continuously. No fractures occurred and minimal glitter escaped, allowing the specification to pass.

Figure 9 – Coating machine will run for over one minute

7 ID # 60 - Demonstration

7.1 Specification

The chamber length shall be less than 7 inches

7.2 Verification Approach

The purpose of this verification is to show that the module does not take up too much space on the testing conveyor belt in the client's lab. This will be done by measuring the chamber length of the design using a ruler and comparing to the client's prescribed length in inches.

7.3 Equipment Needed

- Metric ruler
- Glitter module

7.4 Procedure

This verification procedure is relatively simple. The length of the chamber shall be measured by a metric ruler.

7.4.1 Safety Considerations

- Take note of pinch points between the edge of the module and the ruler

7.4.2 Setup

- Place the module on a clean flat surface
- Prepare a ruler with inch measurements

7.4.3 Demonstration Procedure

- Place the ruler along the side edge of the module and record the length in inches

7.5 Pass Criteria

If the measurement of module length is less than 7 inches, than it passes the verification.

7.6 Results – 4/6/22 - Pass

The final box design is 5.5 inches long after measurements, so the testing results pass the criteria.

Figure 10 - Chamber Size Measurement: 5.5 inches

8 ID # 70 - Demonstration

8.1 Specification

The box shall have at least 1 side that can be seen through to visualize glitter flow/adhesion.

8.2 Verification Approach

This inspection will verify that the 3D printed prototype has a specific area that is transparent, so the user is able to view what is occurring inside the chamber. This will be verified in the

SolidWorks model as well as the printing specifications to ensure the material that is being printed is transparent.

8.3 Equipment Needed

- 3D printed prototype
- Laser cut 8mm thick acrylic piece for 3.5 x 7.5inch

8.4 Procedure

8.4.1 Safety Considerations

- When installing the transparent wall, be mindful of pinch points

8.4.2 Setup

- Prepare the glitter module on a flat surface
- Have the laser cut transparent piece ready

8.4.3 Demonstration Procedure

- Place the laser cut piece in the indented portion on the top side of the box
- Verify that there are no gaps, and the interior of the module may be seen through the sheet

8.5 Pass Criteria

To pass inspection, at least one side of the exterior of the prototype is transparent enough to clearly showcase the coating of the adhesive inside which will be visually apparent.

8.6 Results – 3/1/2022- Pass

The results from the inspection conclude that one side of the exterior is transparent and showcases the particle flow/particle adhesion, passing the specification. See figure below to view the results of transparent wall.

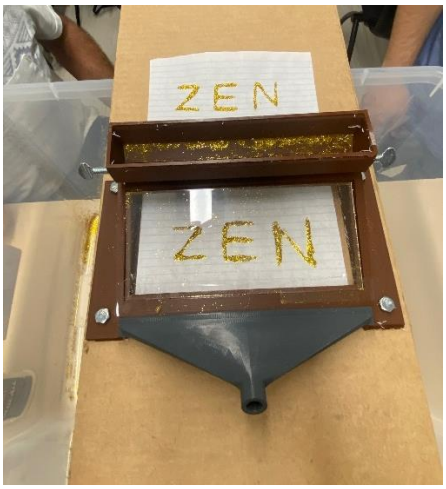

Figure 11 – View of box interior through transparent top

9 ID # 80 - Test

9.1 Specification

The quantity of escaped glitter shall not exceed a 2 on the designated glitter density visual scale.

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9.2 Verification Approach

This test will verify that glitter entering the system is not blown out of the module into the surrounding area. This will be done by running the system as intended and using a visual scale to score the amount of escaped glitter based on an acceptable range.

9.3 Equipment Needed

- Air Pump
- Air Blade Adaptor
- AC Power Socket
- Glitter Module
- Elmer's Glue
- Glitter
- Small brush
- Substrate (for the results given here, a sheet of paper was used)
- ¼ 20" thumbscrews
- String

9.4 Procedure

9.4.1 Safety Considerations

- Safety goggles should be always worn during testing
- Testing should be performed inside of an isolated testing container
- Long hair should be tied up and loose jewelry should be removed and kept clear of the air pump inlet

9.4.2 Setup

- Secure the module inside of the isolated testing container on a flat surface using the thumbscrews
- Plug in the air pump and attach the air blade adaptor to the end of the tubing
- Affix the free side of the adaptor to the air blade inlet on the glitter module
- Using the small brush and the Elmer's Glue, paint a design onto the substrate (Note: this design should remain constant for all testing to maintain a consistent reference)
- Attach the string to one end of substrate
- Place the substrate with the glue design slightly outside the entrance of module
- Feed the loose end of the string through the module so that the substrate may be pulled through
- Deposit 1 tsp of glitter into the hopper
- Clean any glitter remaining in testing container from previous trials
- Prepare video recording from above the module for future reference

9.4.3 Test Procedure

1. Start recording from above the module
2. Turn on the air pump

3. Begin drawing the substrate through the chamber
4. As the substrate is about to reach the glitter entrance, slowly rotate the deposition cylinder ½ revolution
5. Continue drawing the substrate through the chamber until the glue design has cleared the module
6. Turn of the air pump
7. Take a picture of the testing container and take note of any escaped glitter
8. Score the test from 0-5 using the glitter density visual scale, 0 being no escaped glitter and 5 being complete glitter escape.

9.5 Pass Criteria

To pass this specification the system must score a 2 or lower, as seen in Figure 12.

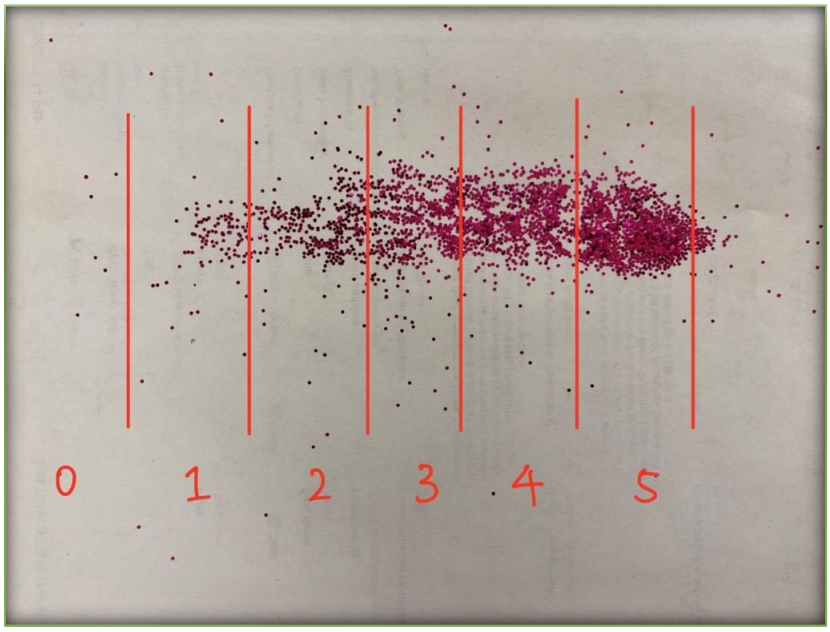

Figure 12 – Visual scale for the amount of glitter left behind by the air knife pass.

9.6 Results – 4/18/22 - Fail

After following procedure for this ID specification, the test resulted in a fail due to glitter escaping the rear of the device. The air flow was too strongly applied and forced glitter out of the back inlet.

10 ID # 90 - Demonstration

10.1 Specification

Shall not have any contact between any pieces of metal or electrical wires within the module that can create heat, sparks, or shavings.

10.2 Verification Approach

This Demonstration will verify that there is not any contact between any pieces of metal or electrical wires within the module that can create heat, sparks, or shaving. To demonstrate that there will be no risk of creating heat, sparks, or shavings within the box, the unit will be disassembled to show that there are no electrical wires on the inside of the chamber and that there are no metal pieces that will be touching each other or capable of causing any of the previously listed problems within the chamber.

10.3 Equipment Needed

- Coating chamber assembly

10.4 Procedure

Disassemble the coating chamber assembly to show that there are no risks of electrical wires or metal on metal contact that can cause heat, sparks, or shavings within the chamber.

10.5 Pass Criteria

In order to pass this demonstration, it should be clear that no contact between any pieces of metal or electrical wires within the module that would create heat, sparks, or shavings are present within the module.

10.6 Results – 4/4/2022 - Pass

There are currently no contact points between metal that touch one another or could create shavings and no wires present in the design, so the result passes the criteria.

Figure 13 – Visual of no wires or metal contact within the chamber

11 ID # 100 - Test

11.1 Specification

The quantity of adhered glitter coating the substrate shall not be below a 4 on the designated glitter density visual scale.

11.2 Verification Approach

This test will verify that the method for removing glitter does not also remove the glitter that has landed on the adhesive. This will be done by running the system with wet glue that has been pre-coated with glitter and comparing the number of displaced particles to the pre-determined visual scale. Passing this verification ensures high image quality and resolution for the product after exiting the module.

11.3 Equipment Needed

- Air Pump
- Air blade adaptor
- AC power plug and socket
- Glitter module
- Elmer's glue
- Glitter

11.4 Procedure

11.4.1 Safety Considerations

- Wear safety goggles during testing
- Testing should take place inside of an isolated testing container
- Glitter particles may be airborne if the flow settings are too high.

11.4.2 Setup

- Secure the module inside of the isolated testing container on a flat surface
- Plug in the air pump and attach the air blade adaptor to the end of the tubing
- Affix the free side of the adaptor to the air blade inlet on the glitter module
- Place a design with wet glue fully coated with glitter at conveyor inlet
- Prepare video recording from above the module for future reference

11.4.3 Test Procedure

- Line up wet glue with glitter onto conveyor inlet and start recording
- Turn on air pump and begin to pull through the conveyor without depositing glitter
- As pulling through the conveyor, examine for glitter particles falling off the adhesive
- Compare images of before and after running through the system with the designated glitter density visual scale

11.5 Pass Criteria

To pass the test, the glitter shall not be below a 4 on the designated glitter visual scale after passing through the system.

Figure 14 – Glitter visual scale

11.6 Pass – 4/19/2022

This test scored a 4 on the coating scale above, while there is still a miniscule amount of visual adhesive, the design is essentially entirely coated. This specification passes the verification check.

Figure 15 – Test Results for ID 100