Hanwha Azdel Process Guidelines
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The process is characterized as “Thermo-stamping” or “Matched-mold Thermoforming”.

- The material is supplied in a rigid form and must be made pliable or “drape-able” through preheating. Preheating also allows the material to expand or “loft” to the desired thickness for forming/shaping into the desired geometry.
- Typical forming pressures are low and rarely exceed atmospheric pressure.
- The material is typically covered with an in-mold appliqué (typically fabric) to achieve a desired appearance. This, along with mold geometry and other in-mold attachments, will influence the forming behavior of the Azdel material and the resulting molded part.
- For optimal section stiffness, lofted material should not be fully compressed during molding.
- Formed thickness from fully heated/lofted material can be variable within a single part. It is influenced both by the spacing of the two forming mold halves when in a “closed” tool position and by the extension of the material that occurs as the heated sheet is drawn into the desired part geometry. In most cases, smaller mold gaps and larger material extensions result in a thinner molded section.
• Double platen pressure forming equipment is ideal for forming SuperLite. However, traditional compression molding presses with stand-alone ovens and product transfer implements can also be used.
• Typical forming pressures are around 1-2 bar (15-30 psi) and are unlikely to exceed 3 bar (75 psi).
• Formed thickness from lofted material is inversely proportional to the depth of draw.
Product Heating – Equipment

Function
To make the SuperLite sheet pliable or “drape-able” so that it can be molded into the desired geometry.

Key Considerations
• Heat Transfer Methods
  o Conduction (contact)
  o Convection (forced air)
  o Radiation (element or bulb)
• Types of Radiant heat
  o Ultra Violet
  o Microwave
  o Radio Frequency / Induction
  o Infrared
• Material Transport System
  o 4 sided frame
  o 2 sided rail
  o Belt
  o Hybrid System

The IR spectrum (0.72μ - 1000μ)
• Near IR (short wave) = 0.72μ -1.5μ
• Middle IR (medium wave) = 1.5μ - 5.6μ
• Far IR (long wave) = 5.6μ – 1000μ
Element Selection
- Quartz panel
- Quartz Tube
- Tubular
- Ceramic
- Calrod

Power Density – Dependent on the final oven selection, a target of 15 to 25 watts/in² or 2.3 to 3.9 watts/cm²

Element Spacing – Elements spacing should be based on recommendation by oven and/or element manufacture with consideration of and additional spacing for Azdel heated sheet sag (see sheet sag reference page).

Index Trigger
- Time, temperature and sheet sag
- Combining of all 3 is a best practice with target temperature as the leading index trigger & complimentary “fail-safe” index triggers for max time & max sheet.
A minimum of one (1) IR sensor or radiometer per oven, per sheet surface should be used to control and/or monitor the actual sheet surface temperature as influenced by the oven’s process.

Use of a thermal imaging line scanner or similar device has been recognized as a best practice for identifying and correcting overall sheet temperature variability.

- A minimum of 1 should be installed at the exit side of the oven.
- The exit side of the oven should include the appropriate mounting accommodations to allow a change to evaluation surface (top/bottom) if only one thermal imaging device is installed.

Oven Zoning – Key Considerations

- Number of zones
- Layout of zones
- Element Wavelength
- Element power density
Oven zones
The oven zones (elements) should be shielded with suspended support wires, IR permeable mesh or a comparable safeguard. This will provide protection from contact between the oven elements and the heated material. Protection from damage (fire, etc) that could possibly occur via an overheated material condition or exposure to other flammable sources (debris, contaminants, etc).

Oven Enclosure
A fully enclosed oven with actuated doors for open and close action is preferred.

External Environment
Ambient temperature and humidity can have a large impact on process repeatability. If the environment is not controlled, the ambient plant temperature and humidity should be tracked and recorded to assist in anticipating process adjustments.
Product Heating – Key Temperatures

Keeping the temperature of the Azdel board uniform in temperature from front to back (machine direction) and side to side (cross machine direction) prior to molding is key in producing consistent molded part attributes. Within sheet variability should be $\leq 20^\circ C$. 

![Graph showing temperature variation](image)
SuperLite is available in 2 basic color types (black/gray and natural/white). Historic investigations indicate that these two colors have different IR absorption characteristics and may require a different oven recipe to achieve the same temperature result. The difference is dependent on the peak operating wavelength of the emitter type.

- **Medium-to-high wavelength emitters require little adjustment when changing between product colors while low –to-medium wavelength emitters are affected to a greater degree and typically require more substantial modifications to the oven recipe.**

In general, a black/grey product is likely to heat at a faster rate and with more “within sheet” temperature variation, than a white/natural product.

Please consult with an Azdel Specialist when considering a change to product color.
As SuperLite is heated, its composite structure promotes differing degrees of product expansion or “loft”. The amount of loft will correspond with the product grade, product weight and forming process heating. The expected trends for product loft are as follows:

- XLT lofts more than standard SuperLite
- Higher weight products loft more than lower weight products.
- Longer exposures to elevated temperatures result in a higher loft result.

Loft Measures can be used as a quick indication (NOT DEFINITIVE) of proper heating.
Product Heating - Expansion (Cont.)

Trends for product heating time, rate and subsequent product temperatures are illustrated below. XLT is more sensitive to these parameters than standard SuperLite.

Peak product loft occurs when a temperature $> 190^\circ$C has been obtained thru the total sheet thickness.

Product loft amount and rate are dependant on product temperature and product heating time.
Product Heating – Sheet Sag

- Additional dimensional change is expected during the heating of a SuperLite sheet. The center point of the sheet will drop or “sag” below the edges of the sheet.

- Although expected, it is important that this dimensional change be verified and controlled:
  - Too much sag can indicate an overheating condition and/or lead to molded material folds, creases, etc.
  - Too little sag can indicate an under-heating condition and lead to tears, blow-outs, creases and poor interlaminar strength.

- Key factors for sag include product grade, product temperature and clamping.

- Additional control can be established via:
  - Running with 4 sided clamping of the sheet vs. 2 sided clamping has been proven to reduce sag
  - Running lower temperature on the scrim side can reduce the amount of sag.
  - When utilizing a two sided pin-chain system, set-up a V or run-out that will continually stretch the Azdel as it indexes thru the oven and into the forming area
  - A clamping mechanism that has the ability to stretch / pull out sag prior to molding is beneficial.
  - Zero Gravity forming.
Product Forming - Tensioning

Function
To “take-up” extra sheet area, created by product heating and sheet sag.

Product Tensioning

A degree of sheet and in-mold-decoration tension control is required during part forming to ensure optimal part aesthetics.

- Various process aides can be attached to the tool geometry. Common aides used in SuperLite tooling are “tension blades”.

- Tension blades should be adjustable in height and location and should be used at part geometries that are prone to poor molded part aesthetics.

- The least amount of blade height should be used to minimize over tensioning the coverstock which can lead to warpage of a finished molded part.

- The wiper blade should be placed perpendicular to a wrinkle.

Serrated edge helps to grab and hold the SuperLite material during forming.

Adjustment slot on the wiper blade allows for easy adjustment up and down.

This picture shows the wiper blade on the fabric side of the tool. You may want to install your wiper blade on the Azdel side (bottom tool) near the location of a wrinkle.

Materials for the Future
Hanwha Azdel
Product Forming - Tooling

Function
To form the heated SuperLite sheet and join with an in-mold coating/component.

Production Materials
- Kirksite – Low cost. Durability not as good as aluminum. No known, long term production use
- Aluminum billet – Can be used as pull ahead production. “Steel” safe and able to accommodate last minute engineering changes. Cooling limited to gun-drilling limitations. (Most Common)
- Aluminum casting – Best for cooling but very little production application.

Stop Blocks (Gap Control)
- Stop blocks, occurring in the tool geometry, are possible but uncommon.
- Preferred placement is outside of tooling and material clamping areas.
- If stops are designed into the tool, the “land” area of the block should be small to minimize part sticking and tool gap error.

Temperature Control
- Tooling is plumbed for water.
- Typical tooling temperatures range from 20°C to 50°C
- Coolant plumbing and manifold should be designed for turbulent flow.
- Typically two cooling zones with a simple manifold – One zone for the core tool side and one for the cavity tool side. More zones are possible but no known production application or benefit.

“Land” area
Function
To provide platens and up-ward/down-ward action for fixing a product form tool and pressing a heated SuperLite sheet.

Key Considerations
• Double or single acting press?
  o Single acting press (only one platen - tool half moves). Not recommended, limits processing window.
  • Double acting press (both platens move independent of one another with freedom to adjust the tool pass line with the Azdel material.) This is a preferred design offering a larger process window. **PLEASE NOTE: If no double acting platen movement capability exists, a Z-axis (up/down) action needs to be added to sheet transfer design and execution.**

• Other considerations
  o Minimum shut height
  o Pressing Speed
  o Maximum daylight (distance between tie bars.)
  o Platen size
  o Quick change tool needs
  o Tonnage (typically not an issue due to the low forming pressure of SuperLite. 100 tons is sufficient for headliners and other large parts)
The CLTE of SuperLite family products is comparable to aluminum and thermo setting plastics.

Typical CTE values @ 55% glass and 2.5mm molded thickness are:

- 800 GSM: $13.5 \times 10^{-6}$ mm/mm/°C
- 2000 GSM: $18.9 \times 10^{-6}$ mm/mm/°C

Typical shrinkage values @ 55% glass and 2.5mm molded thickness are:

- machine direction: $0.11 \times 10^{-3}$ mm/mm (0.011%)
- transverse direction: $0.17 \times 10^{-3}$ mm/mm (0.017%)
- average shrinkage: $0.14 \times 10^{-3}$ mm/mm (0.014%)

In most cases, SuperLite tooling is cut with zero shrinkage allowances.
SuperLite family products are moldable at very low pressures. In most cases, the weight of a SuperLite forming tool will apply sufficient load to achieve the desired molded part geometry.

Although still low, the required molding pressures for XLT are higher than those required for SuperLite.

Higher weight products resist more compression than lower weight products.
Product Forming – Molded Thickness

- Product forming temperatures can also affect molded part thickness.
- Lower molding temperature will require more force to mold to the same thickness than a higher temperature product.
Product Trimming

Function
Cut the molded SuperLite part to the desired geometry.

Key Considerations
- Cycle Time
- Edge quality/appearance
- Edge Trim Angle
- Edge accuracy
- Capital Investment

<table>
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<tr>
<th></th>
<th>Water-Jet</th>
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</table>

Possible Executions
- Water-Jet (Most common) - Good overall process.
- Secondary bypass punch die – Good cycle time and accuracy
- Shear edge – Worst edge quality
- Laser – Poor edge quality, best edge angle opportunity.
- NC Router – Difficult to tune proper edge quality.
Different settings of a water jet process can have different affects on cut quality and Accuracy. The main affects are as follows:

- Pressure
- Head speed
- Amount of abrasive / Size of Orifice
Edge Folding

Function
Allow the elimination of additional trim pieces by re-heating and re-forming the portion of the SuperLite part so as to conceal the trim edge surface.

- Initial opening cut smaller than final size.
- Automated “pie-cut” corner patterns can help to lower fold height and reduce uneven or bumpy corners but manual cutting should be avoided due to variability.
- Both SuperLite and textile folded over and bonded in secondary operation.

Front surface

Rear surface

Edge-wrap
Edge Folding – Machine and Process

**Machine and Process Sequence:**

1. The machine is turned on and up to temperature ready for production.
2. Load the headliner A-side down onto the 2-way and 4-way locators and Sunroof support nest.
3. Clear the light curtains and activate cycle start button.
4. Clamp finger and heat ring make contact to the C-side and dwell per cycle time developed at tuning.
5. Heat ring retracts and all eight fold finger extend and lower to fold the opening, dwell to set and retract.
6. Cycle complete all item move to the home position and the headliner is ejected 8” above the nest.

**How to manage the tolerance:**

1. The edgefold height should be tuned using the Sunroof checking fixture with multiple SPC triggers for correct fold height determination.
2. Every day parts will need to be inspected using this gauge and the edgefold machine can be adjusted or tuned if required.
3. 2-way and 4-way steel datum's on the machine should be used for headliner alignment with sensors to make sure the headliner is loaded correctly before folding operation can start.
4. All of the moving or adjustable features should have mounted scales that are used for recording any adjustments made.
General Forming Information

Sheet heating, sheet transport, sheet clamping and sheet forming pressure are the most important processing factors for Azdel products. Key considerations are as follows:

- Ovens having infra-red heating elements (ceramic or quartz) are most common.
- Ovens should have several independently controllable zones for local sheet area temperature adjustment.
- Additional ovens can be added to increase throughput and reduce cycle time.
- Heating times will vary according to oven design and grade. Typical single-oven heating time is 25-100 seconds, depending on zone temperature setpoints and material grade:
  - Product weights from 600 to 1200 GSM: ~ 25 - 50 seconds
  - Product weights from 1400 to 2000 GSM: ~ 50 - 100 seconds
- Preheat Temperature: ~ 400°F-420°F (204°C-215°C).
- In-process Transfer: 4-sided frame or 2-sided rail.
- Maximum “open” time: ~ 10 seconds
- Tool Temperature: Typical mold temperature is 80°F (27°C) up to 140°F (60°C). With 80°F, being most typical.
- Sheet clamping and tension: 4-sided and adjustable
- Residence (dwell) Time for Pressing : ~ 20 - 40 seconds
**In-Mold Finishing with Fabrics/Films**

Material blank is conveyed through oven with tension on all 4 sides. Mold closed, low pressure applied during cooling.

Heated blank and fabric/film-placed mold

Mold on stops

Tension should be maintained on product edges to control aesthetics.
Infrared ovens typically use medium infra-red wavelength.

- Medium infra-red wavelength is from 3.0 to 4.0 μm.
- Generally, as the wavelength decreases the temperature increases.
- A crossover into the medium/long wavelength spectrum is permitted.
Typical SuperLite Manufacturing Cell

- Forming press
- Trim station
- Heating oven
- Clamped Super Lite
- Indexing conveyor
- Fabric shuttle system
- Fabric
- Pallet of Super Lite
Pin Chain/Clamping

Function
To hold SuperLite sheet in place during heating and forming cycles.

General characteristics
• 4-sided clamping in a pneumatically-operated clamp frame is preferred.
• Fully automated in-line systems using pin chains to hold sheet during transfer are most common.
• Tension blades/clamps on tool sides perpendicular to the chain rails are recommended to apply 4-sided sheet tension during forming.
• If using compression molding equipment, a separate “pin” frame (tenter frame) on a conveyor belt can be used to transport the sheet but this method is not preferred.
Types Of Ovens For Heating

Items for Consideration

IR (Typical)
• Element Type (Ceramic, Quartz, Resistance.)
• Profiling Heat Intensity
• Ventilation
• Spacing

Air Flow
• Hot Air - Air Flow
• RF - Power & Frequency
AZDEL SuperLite sheets are normally supplied cut to size, however, it is possible to cut the sheets to a different size utilizing a mechanical shear. The sheets will also cut easily with a utility knife.

**Part trimming can be achieved using several different options:**
- In-mold bypass-punch die (double acting press/mold.)
- Secondary bypass-punch die.
- Steel-rule die.
- Laser trimming.
- Water-jet trimming
- NC Router.
Adhesive Bonding

AZDEL SuperLite is thermoplastic-based, but the composition of films and scrim materials used in combination will affect the choice of adhesive. The use of different types of adhesives is highly dependent upon the substrates being bonded. Therefore, please refer to an adhesive supplier for recommendations of appropriate products. Examples are:

**Bostik**
Automotive & Industrial Div.
211 Boston Street
Middleton, MA 01949
Tel: (888) 333 6630
Fax: (978) 750-7319
URL: www.bostik.com

**3M**
Bonding Systems Division
3M Center, Bldg. 220-7E-01
St. Paul, MN 55144-1000
Tel: (800) 362-3550
URL: www.3M.com

**Loctite Corporation**
1001 Trout Brook Crossing
Rocky Hill, CT 06067
Tel: (860) 571-5100
Fax: (860) 571-5465
URL: www.loctite.com
Product Temperature (Oven) Considerations

Maximum peak temp suggested is 220°C (may vary/construction). Temperature decay rates will vary between 2°C/sec to 3.5°C/sec depending on surface measured and environmental conditions. Transfer time should be 15 seconds or less for optimal surface covering adhesion.

Normally suggest peak variance less than 15°C.

Tool dwell / Clamp close time and tool temperature should be sufficient to accommodate a 100°C sheet exit temp (even core).

Total time in oven is suggested to be less than 80 seconds.

<table>
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<th>Sensor Locations</th>
<th>C1 = 0</th>
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</table>
Pick and Place

Capture Types

• Vacuum pick-up systems – good range of motion, sensitive to season static “sticking” and sheet permeability.

Needle grippers – better for permeable sheet.

Combo – best system. Sequenced vacuum used to help eliminate static induced sheet sticking and needle grippers to eliminate permeability issues. Quantity of suction cups and grippers are contingent on construction and size. By default the Azdel has air permeability and any one specific quantity for each is learned through trial and error. Starting suggestions would be 12 suction cups and 8 needle grippers.

There multiple bellow cups available, Azdel would propose a double bellow for enhanced conveyance. The more bellows you have you reduce the likelihood of breaking the seal between the board and the cup.
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Managing Static Electricity through anti-static and Friction Brush Solutions:

Static discharging brushes
Static brushes are often made from metal bristles held together with a metal channel. They are made to discharge electricity created by static through a grounding wire.
The image on the next page is one example of a static discharging brush. It is manufactured by Precision Brush Company INC. There are many other companies that make this type of brush.

Friction resistance brushes
These brushes are made of synthetic bristles that are stiff and wider than a static discharge brush.
They work by causing resistance to the sheets being picked up that is stronger than the static charge causing only the top sheet to be loaded.
A common brush that is used for this purpose is the end of a push broom like the bottom picture to the lower right.

*See next page for examples*
Antistatic Materials

Antistatic Materials as defined by the EIA and the ESD Association, refers to the property of material that inhibits triboelectric generation of static charges (generally less than 200 volts). These materials would be near neutral (cotton) in the center of the triboelectric series. A material’s antistatic characteristics do not necessarily correlate with its resistivity.

Friction resistance brushes
Static Electricity Management Air Solutions:

Ionizer Fan:
Industrial ionizer fans work by blowing positively charged ions into the air to neutralize the negative charges that are causing the static. They can be mounted on the floor or the wall.

Air Curtain or Knife:
An air curtain would work by forcing an air flow between the sheet being picked up and the rest of the stack. For an air curtain or knife to be successful it needs to always be aimed just under the sheet that is being picked up.

*See next page for examples*
**Static electricity** (cont.)

**What Is The Super Ion Air Knife?**

EXAIR's Super Ion Air Knife removes static electricity from plastics, webs, sheet stock and other product surfaces where tearing, jamming or hazardous shocks are a problem. The laminar sheet of air sweeps surfaces clean of static, particulate, dust and dirt. Production speeds, product quality and surface cleanliness can improve dramatically.

**Why the Super Ion Air Knife?**

The Super Ion Air Knife floods an area or surface with static eliminating ions - up to 20 feet (6.1m) away. A uniform airflow across its length will not cause misalignments to critical surfaces such as webs. Force can be adjusted from a "blast" to a "breeze". The Super Ion Air Knife is electrically powered, is shockless and has no moving parts. It also requires only 3.7 SCFM of compressed air per foot of length at 5 PSIG (105 SLPM per 300mm of length at 0.3 BAR). Sound level is surprisingly quiet at 50 dBA for most applications.

**How the Super Ion Air Knife Works**

Compressed air flows through an inlet (1) into the plenum chamber of the Super Ion Air Knife. The flow is directed to a precise, slotted orifice. As the primary airflow exits, it creates a balanced sheet of air across the entire length that immediately pulls in surrounding room air (2). An electrically powered ionizing bar (3) fills the curtain of air with positive and negative charges. The airstream delivers these static eliminating ions to the product surface (4) where it is instantly neutralized and cleaned of dust and other particulates.

The Super Ion Air Knife eliminates static on a sheeter, so it picks up one sheet at a time.