SECTION 5:
DESIGN FOR ASSEMBLY

NOVA Chemicals’ DYLARK resins are preferred by plastics designers, engineers and processors for automotive applications, such as soft instrument panels (IP’s), structural consoles, roof-mounted LCD video supports, interior trim and audio components. DYLARK resins are specified for their temperature resistance, stiffness and strength, lot-to-lot consistency, exceptional foam adhesion and low total cost.

During the past three decades, DYLARK substrates were installed in more than 200 million soft instrument panels worldwide. Beyond instrument panels, DYLARK resins are specified in other automotive segments, such as defroster panels, center stacks, radio buckets and a variety of structural brackets. NOVA Chemicals continues to develop new market opportunities in floor and overhead consoles, structural center stacks, door modules and interior grab handles.

DYLARK At-A-Glance

- Outstanding structural properties and dimensional stability
- Proven heat and long-term thermal aging resistance
- Exceptional urethane-foam adhesion
- Processing ease for injection molding and extrusion applications
- Ease of recycling
- Outstanding thin-wall capability
- Consistent property performance: -40°F (-40°C) to 185°F (85°C)
- Excellent chemical resistance to most stamping or screw oils
- Low creep – fastener torque remains high over the life of the part
- High modulus - instrument panels have a high natural frequency rating and, therefore, low NVH
- Responds well to joining technologies, such as chemical bonding, ultrasonic welding, vibration welding and heat staking
- Excellent processability – flows easily in the mold, does not require drying and achieves short cycle times with fewer drops than competitive materials

FASTENING AND JOINING METHODS

Instrument panel substrates are one or two-piece hybird designs. Substrates may serve simply as a “crash” pad with foam/skin or as structural assembly for packaging instruments, such as audio and climate controls.

Fastening and joining substrate assemblies can offer:

- Further enhance structure
- Increase occupant protection
- Improve assembly operations
- Reduce squeak and rattles (NVH)
- Improve serviceability

Common methods to fasten and join parts molded from DYLARK resins :

- Mechanical
- Screws & bosses
- Snap fit
- Stapling
- Vibration
- Chemical
- Adhesive
- Solvent
- Sonic welding
- Vibration welding
- Laser welding
- Heat stake
- Hot/cold upset
- Hot plate

Commercial applications are used in both North America and Europe for bonding air defrosters (channel) to the underside of molded Instrument panel substrates. These ducts are located beneath the windshield edge to form a “hollow beam” providing increased stiffness and stability to the assembly.

In other designs, an air distribution plenum chamber is heat staked or welded to the substrate underside beneath the windshield edge to provide airflow to the windshield and side window defoggers. These assemblies reduce part weight by increasing the stiffness of the system and minimizing steel support.

Sonic and linear vibration welding of DYLARK substrates with sub-component assemblies creates more design freedom,a higher level of integration and reduces metal reinforcement required in an assembly. The basic instrument panel substrate shell is molded with minimal rib and mounting features. A secondary molded ribbed part can be welded to the substrate to provide high stiffness to the whole assembly with a significant weight reduction compared to steel reinforced assemblies.

These separate molded parts can use technical designs free from line of draw restrictions inherent in conventional molded in reinforcements in the basic instrument panel substrate. Several separate molded parts can be welded to a substrate to provide both function and design freedom.

Ultrasonic and linear vibration welding methods are most widely used for glass-reinforced DYLARK molded parts. Advantages are relatively short cycle times and excellent bond strengths. In addition, DYLARK can be joined successfully to other amorphous thermoplastic resins such as, PC/ABS, ABS, HIPS, and PPE.

Fastening methods such as, heat stake, hot plate, hot/cold upset, adhesive and mechanical require longer cycle times. These methods produce satisfactory joints, can be limited by design and are less satisfactory for complex designs. However, they are more economical for smaller production runs. Adhesive and solvent welding are used successfully in large production runs but care must be taken with environmental considerations.

MECHANICAL FASTENING AND JOINING METHODS

Screws

The type and size of screw should match the boss design for maximum performance. For example, PT®, HiLo® or VA® type screws, as cited in SAE Paper #950810, have performed satisfactorily when the correct boss ID's were chosen. The mating of the proper screw and boss design are essential to long term performance and elimination of squeaks and rattles.

FIGURE 5:1 **Boss Design for Self Tapping Screws**

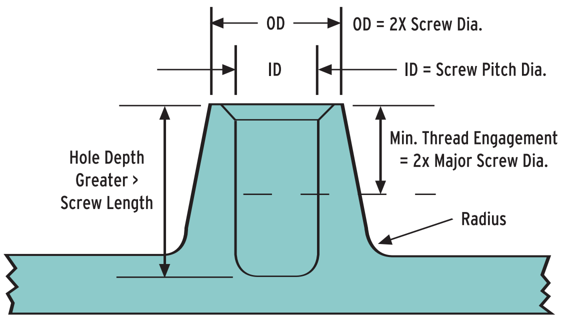


FIGURE 5:2 **Generic Boss Design**

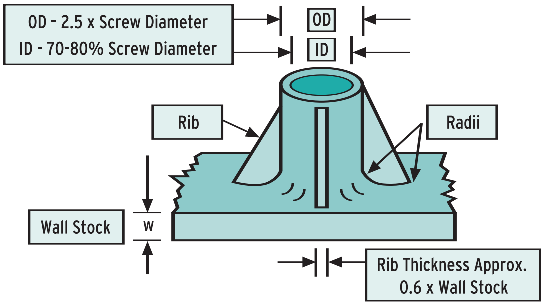
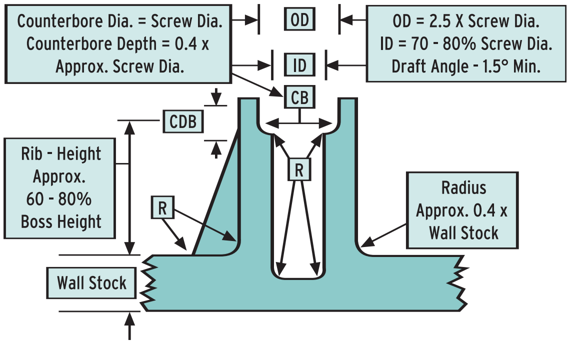


FIGURE 5:3 **Generic Boss Cutaway View**



Boss and Screw Design

Consider the load requirements when locating bosses in the initial instrument panel design phase. Standardization of the "screw type" and boss design for the instrument panel can help to eliminate assembly production issues. NOVA Chemcials' computer aided engineering group can assist with design evaluation in the engineering design phase. Figures 5:1-5:3 are visual guidelines for use with glass reinforced DYLARK resins.

Clips/Rivets

Holes and slots can be molded into a DYLARK instrument panel and console substrates for use with metal clips, push nuts and screw in plastic nut inserts. Round holes can also be drilled into instrument panel substrates. Molded-in slots or square holes should be clean and free of stress risers with adequate radii and wall stock. See figures 5:4-5:5 on next page.

FIGURE 5:4 **Clip Hole Design**

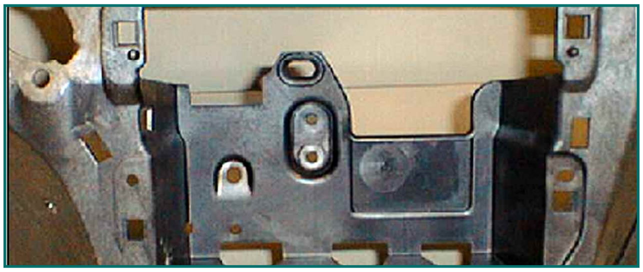
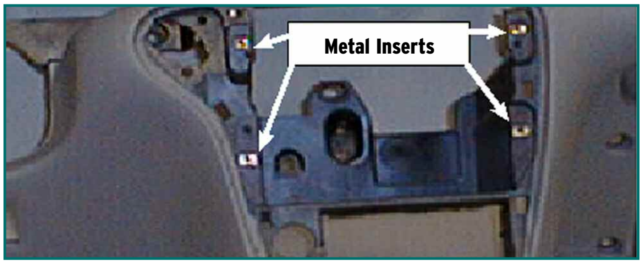


FIGURE 5:5 **Clip Hole with Inserts**



Designing for Staple Attachments

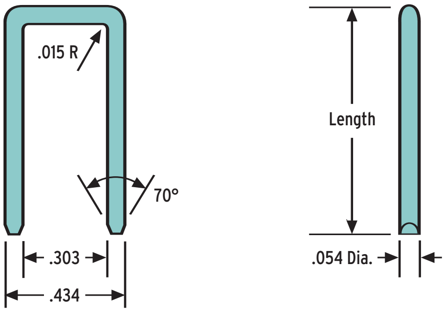
Stapling can be an alternative method for fastening various items to DYLARK that would require minimal pull strength or shear load. Common applications that utilize staples as a fastening method include attaching parts less functional or assembling carpeting to DYLARK substrates.

Recommendations for use with staples:

1. Maintain the recommended 0.50 inch or greater distance from any edge.
2. Utilize a chisel shaped design versus a wedge shaped design. This allows the plastic to be punched through the material instead of splitting the material causing fractures in the part.
3. Parts should be well supported in areas that are being stapled to minimize flexing of the parts. The use of nests or fixtures is recommended.

Figure 5:6 illustrates an example of a galvanized, 17 gage staple supplied by Stanley/Bostich utilized in attaching a meter cover to the instrument panel prior to the foam/skin process. In the manufacturing process, staples can be applied through the use of hand held staple guns or automated equipment.

FIGURE 5:6 **Staple Design**



FASTENING AND JOINING PROCESS

WELDING METHODS: THERMAL, VIBRATION AND SONIC

Optimized welding performance is achieved by selection and design of "horn" and booster together for the application.

Surfaces to be welded should be designed with "energy directors" to concentrate the welding energy in the desired zone. These directors promote early and adequate melting of the resin to maximize bond strength. Machine manufacturers can provide specific recommendations to optimize energy director design relative to weld width and length, type and power of the machine system. Typical joint designs for DYLARK resins are illustrated as follows in figures 5:7-5:12.

Butt, tongue and step joint designs are illustrated in figures 5:7-5:9. Energy directors as illustrated enhance the weld improving the weld strength and minimizing or eliminating flash at the joint.

Solid and hollow stake designs are illustrated in figures 5:10-5:12. The "stake" is energized ultrasonically and then formed as illustrated. In appearance parts, the flush weld is used as illustrated in figure 5:12.

Advantages of vibration welding:

Process requires seconds
Heat generation is localized in the joint area
External energy sources are not required
Material combinations possible
Precise repeatability
Produces an airtight seal

FIGURE 5:7
Ultrasonic Butt Joint Design with Enegry Director

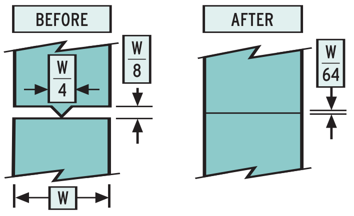


FIGURE 5:8
Ultrasonic Tongue and Groove Design with Enegry Director

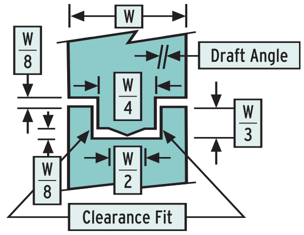


FIGURE 5:9
Ultrasonic Step Joint Design with Enegry Director

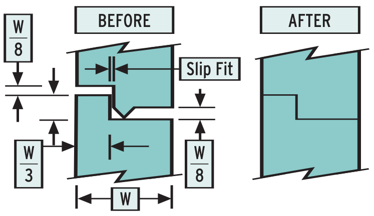


FIGURE 5:10
Ultrasonic Welding Stake and Weld

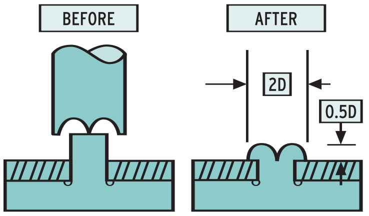


FIGURE 5:11
Ultrasonic Welding Stake and Weld

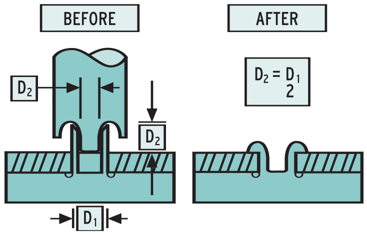
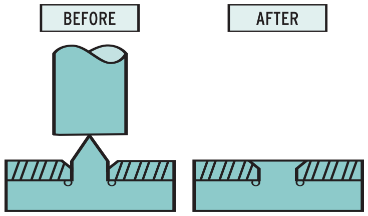


FIGURE 5:12
Ultrasonic Welding Stake and Weld



Design

It is necessary to have collaboration of the part designer, equipment manufacturer and resin supplier. Consideration must be given to end-use requirements of the finished part assembly. The design must be suitable for vibration welding to maximize cost effectiveness, part quality and performance. The "weld" and surface conditions must be considered for large volume production.

Joint designs range from simple "butt" joints to more complex designs. The joined mating surfaces generally exhibit "flash" at the weld joint. In non-appearance parts this may be acceptable. figures 5:13 and 5:14 illustrate a simple butt joint before and after welding.

To enhance appearance butt joints are designed to trap the "flash." Figures 5:15 and 5:16 are illustrations of a "simple butt joint" with a flash reservoir.

Figure 5:17 illustrates an air duct (A) and foamed/covered instrument panel (B). Mounted in a moveable fixture, the air duct has surface contact with the I.P. (B) mounted in a stationary fixture. Linear vibration of the duct at a predetermined amplitude softens the resin and bonds the mating parts (A-B) into continuous unit. Clamp force, hold/weld times and amplitude influence the ultimate bond strength.

Commercial Examples

Europe

Since 1988, DYLARK resin has been in production since in Europe utilizing linear vibration welding to bond an air duct (A) to the instrument panel (B) the manufacturer developed specialized vibration equipment and fixtures to directly bond the air channel system to the I.P. backside after the foam/cover operation (figure 5:18).

United States

Figure 5:19 is an example of linear vibration welding is used to bond a molded center stack and a driver side knee bolster to a DYLARK substrate.

PC/ABS resin is used for the knee bolster system. This part has been designed with a cross hatch of ribs to provide greater femur load distribution upon knee impact. The PC/ABS is bonded to the DYLARK substrate by vibration welding with excellent bond strength. Figure 5:20 highlights the rib and bead design.

FIGURE 5:13 Vibration Welding Common Butt Joint Design

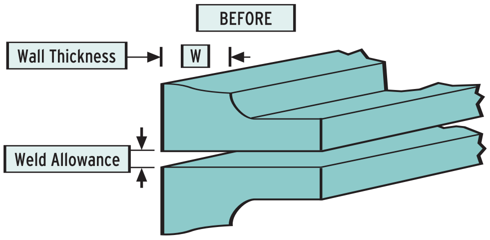


FIGURE 5:14 Vibration Welding Common Butt Joint

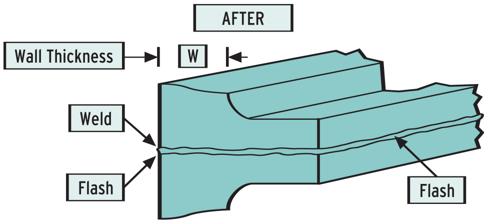


FIGURE 5:15 Vibration Welding Common Butt Joint Design with Flash Design

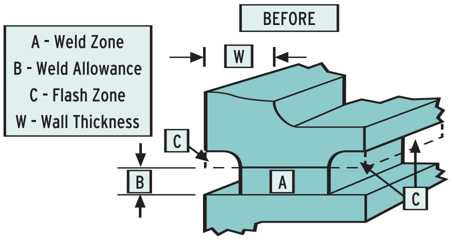


FIGURE 5:16 Vibration Welded Butt Joint

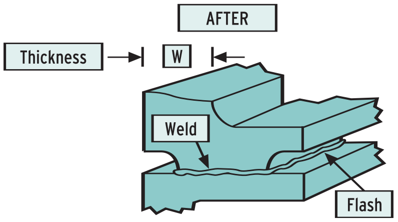
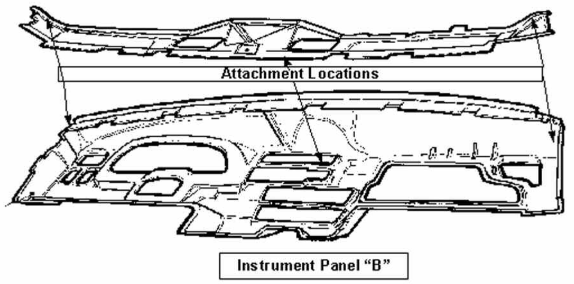


FIGURE 5:17 Vibration Welding Common Butt Joint Design



Foamed/Covered Panel "B" is fixture and fixtured Air Duct "A" placed in close proximity to "B". Linear Vibration energy is appliied and parts mated to form continuous bond.

Vibration Direction

←→

FIGURE 5:18 Linear Vibration Welded Panel IP/Duct Instrument Panel Back View

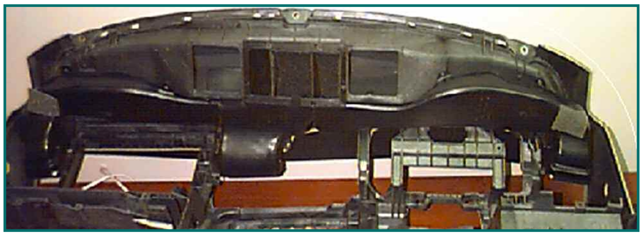
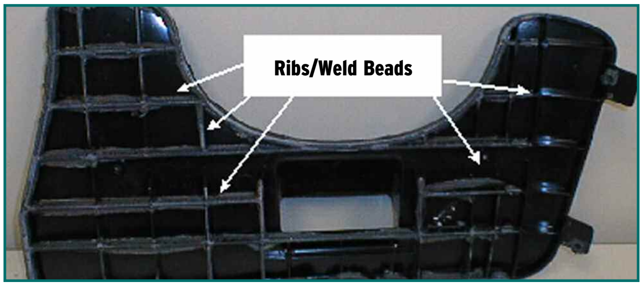


FIGURE 5:19 Instrument Panel Foamed/Covered with Linear Welded Parts

FIGURE 5:20 Knee Bolster



Adhesive and Solvent Bonding Methods

DYLARK resins may be effectively bonded using solvents and adhesives. Generally these processes require an application and joining phase and longer cycle times compared to other thermal/sonic welding methods.

There are a variety of commercial adhesives that successfully bond with DYLARK materials. When bonding DYLARK with adhesives, typically butt, lap and tongue and groove joints are used.

Adhesives

Adhesive bonding utilizes a thin layer of a bonding chemical or compound between mating parts. To achieve maximum bond strength, the adhesive must make intimate surface contact with the mating parts and have sufficient time to cure and set-up. Each adhesive has an optimum distance between mating surfaces – cycle times may range from a few minutes to an hour or more. Federal, EPA and local regulations must be observed regarding ventilation, air emissions, worker protection and solvent recovery.

Advantages of Adhesives

Adhesive bonding is one of the easiest and most convenient ways of assembling similar and dissimilar materials. Adhesives offer a number of advantages:

- Adhering Dissimilar Materials
- Ease of Application
- Cost Effectiveness
- Flexibility with Materials of Different CLTE Values
- Hermetic Seal

Adhesive use with DYLARK

Adhesive families that work best with DYLARK are those that are either acrylic, cyanoacrylate or methacrylate based. Caution should be taken in using anaerobic based adhesive in that these are typically incompatible with polystyrene type materials. One of the key factors is good wet out of the adhesive to fill any irregularities in the substrate surface. This is essential for developing strong and reliable bonds.

Application/Tips for Good Adhesive Bond

- Cleaning and surface preparation are critical in maximizing the bond strength. A lightly roughened surface may be required.
- Adhesive should be thoroughly mixed as separation can occur during storage. Avoid using the first 2ml of adhesive at initial dispensing.
- Smaller diameter mixing tips provide better mixing of adhesive.
- Maximize the width of the bond joint versus the bond length to improve strength.
- Once adhesive is applied clamp parts with uniform pressure to help ensure a uniform bond layer.
- Cycle times are dependent on the adhesive type and requirements. Full bond strength can range from 1 to 24 hours. Allow 24 hours time for best bond performance.

Adhesive Joint Design Types

- Simple Lap Joint
- Tongue and Groove Joint
- Double Lap Joint
- Joggle Lap Joint
- Wall Tongue and Groove Joint
- Wall Butt Lap Joint
- Round Lap Joint

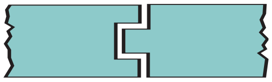
Commercial Adhesives Used With DYLARK

- Loctite Depend 330
- Loctite Prism 401
- ITW Plexus A0420FS
- Dow Betamate 73100
- Lord Acrylic 508
- Lord Fusor 320FC
- Lord Versilok AS5404
- Bostick 7119
- Bostick HM 9239
- Bostick Supergrip 9743

FIGURE 5:21
Adhesive/Solvent Weld Joint Design

Simple Lap

FIGURE 5:22
Adhesive/Solvent Weld Joint Design



Tongue and Groove

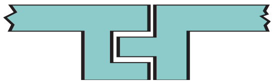
FIGURE 5:23
Adhesive/Solvent Weld Joint Design

Double Lap

FIGURE 5:24
Adhesive/Solvent Weld Joint Design

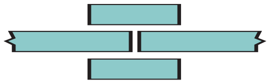
Joggle Lap

FIGURE 5:25
Adhesive/Solvent Weld Joint Design



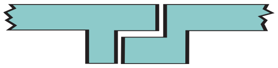
Wall Tongue and Groove

FIGURE 5:26
Adhesive/Solvent Weld Joint Design



Double Lap

FIGURE 5:27
Adhesive/Solvent Weld Joint Design



Wall Butt Lap

FIGURE 5:28
Adhesive/Solvent Weld Joint Design

Round Lap

Joint Design for Adhesive Bonding

Various joint types may be used with adhesive bonding. Typical joint designs are shown in the following illustrations, figures 5:21-5:28.

Solvent

In solvent bonding or welding, the part surface is sufficiently softened with a solvent to bond the mating parts upon evaporation. Advantages of solvent bonding or welding are:

Relatively fast set-up
Little surface preparation
Independent of chemical bonding with a separate compound

Solvent Types

Methyl-ethyl-ketone (MEK)
Methylene chloride (dichloromethane)
Xylene (xylol)
Toluene (toluol)

In general, solvents that work well with other styrenic polymers and polycarbonate can also be used.

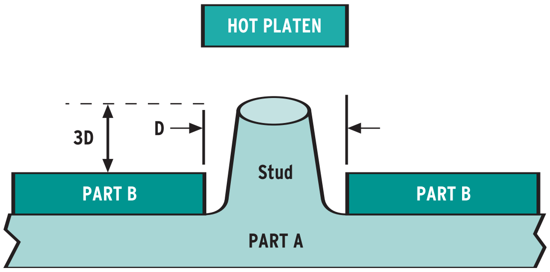
Joint Design

Joint designs such as single, double lap and butt lap may be used similar to those illustrated in figures 5:21-5:28.

Design Guidelines for Heat Staking Methods

The stakes (studs) can be designed as rounds, ovals or rectangular tabs. Both the diameter and length of studs or tabs will vary dependent upon the size of the overall part and the ultimate functionality. Typical designs for heat staking using a heated die and assemblies are illustrated in the following examples. Figure 5:29 is a generic heat stake design.

FIGURE 5:29 **Design for Heat Stake**



Design Guidelines for Hot Cold Upset

Stakes, tabs or studs should be designed with radii in the molded part (A) for increased strength to the substrate. The height should be approximately 2-3 times the diameter or tab thickness with a slight taper.

Holes and slots in part (B) should be slightly larger than the mating stake or tab (0.05 inches). After heating and flattening, the formed heads should be approximately 2D, where D is the diameter, X or tab thickness. It is important to have adequate head mass to form tight, rigid bonds.

Foam/Skin

Most soft instrument panels are a three-piece laminate construction. The outermost layer or skin is usually composed of a vinyl or vinyl/abs resin, the center layer, typically polyurethane foam, and the structural frame support, substrate, composed of a thermoplastic engineering resin.

INSTRUMENT PANEL CROSS SECTION

Substrate Design Considerations

The substrate is the structural frame that gives the instrument panel its shape and supports the gauge cluster, radio and HVAC controls. It must have high heat resistance, a high flexural modulus to resist sag and vibration, long-term heat aging properties and dimensional stability over a wide temperature range. DYLARK resins contain these characteristics in addition to being a cost-effective solution for automotive applications.

DYLARK substrate designs should maintain uniform wall thickness, preferably 2.5 mm (+/- .3mm). To increase the structural integrity of specific regions of the substrate, ribs and gussets are preferred over locally thicker wall sections.

However, at times, local variation in substrate wall thickness is required to increase or decrease local section stiffness. An increase in wall thickness, transition zone, or feathering increases the structural integrity of a section; however, a thicker section requires a longer cooling time and produces differential cooling in the part.

FIGURE 5:30 Hot/Cold Upset Stake Design

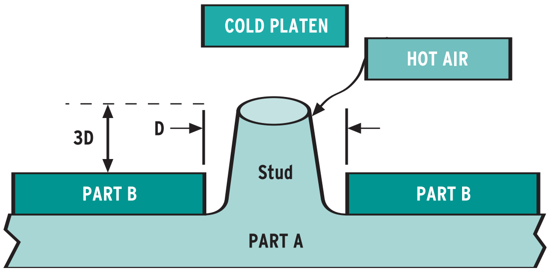


FIGURE 5:31 Hot/Cold Upset Formed

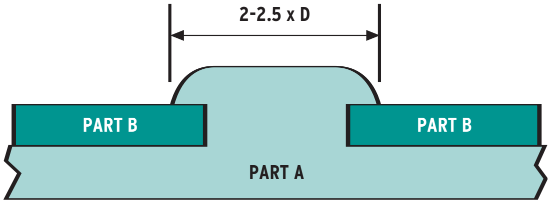
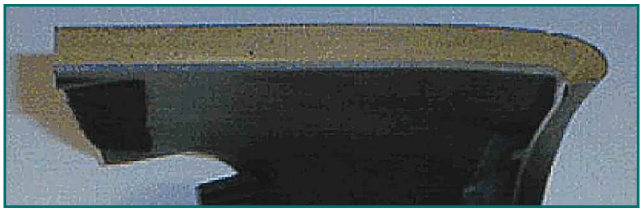


FIGURE 5:32



Differential cooling affects section density and final part stability. It is recommended to review of the impact of part cooling time as part of the design process.

Flash-overs, local regions of decrease wall thickness, are commonly used to expedite secondary die or water-jet cutting operations and should have a concentric, racetrack design. The thinner wall stock in the racetrack region permits the best cutting rate while maintaining minimal effect on the flow distribution during injection molding.

Typically, the substrates are injection molded using single cavity molds. Based on production volume, many times two to eight molds may be used. During molding, caution must be used with mold releases. If release is required, thorough tests are recommended to insure no effect is made on foam adhesion to the substrate. Teflon-type spray mold releases should be avoided.

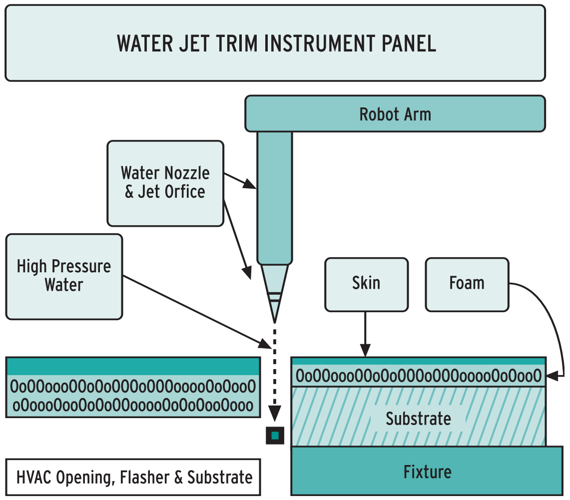
Substrates may be contaminated with grease or hydraulic oil from the molding machine, which will affect foam adhesion. Contaminated parts can be salvaged by a thorough wash with a mild detergent solution prior to the foaming operation.

After the injection molding operation, the substrates are typically placed in foam tools and urethane foam is injected between the substrate and skin. The final laminated part is then trimmed, washed and ready for assembly. Foam adhesion to both the substrate and the skin is critical. Loss of adhesion can cause delamination of the skin and potentially cause warranty issues. DYLARK substrates have excellent adhesion characteristics to urethane foams, as well as various adhesives. DYLARK substrates do not require surface treatment prior to the foaming operation.

Typically during the foaming process several foam tools are used. It is imperative that all the foam tool cavities match cavities of the injection tools to avoid process scrap due to part detail mismatch between tools.

It is also recommended to test changes to the urethane foam formulation prior to production.

FIGURE 5:33



Water-jet Trim

Water-jet cutting is used by many molders to trim foam, skin and remove flashed-over areas from instrument panels. Recommended guidelines to minimize damaging panels during this operation include:

- Fixtures that use holes in the panels as locators should have sufficient clearance to avoid forcing the panel into place. Chamfer locator pins to facilitate easy loading.
- Avoid blind areas in loading parts. Operators must have an unobstructed view of where to place the panel to avoid damage.
- Keep fixtures clean and clear of reject pieces that cause misalignment of the panel.
- Do not place clamps in areas of the panel that are not structurally adequate.
- Clearly outline operating procedures and steps and familiarize operators with all procedural details.
- When trimming vinyl and/or vinyl/skin from IP's, great care must be taken to not cut through the substrate material. The water-jet pressure must be set high enough to cut through the skin and foam, yet low enough not to cut through or score the substrate material. Scoring the substrate material can result in a weakened area subject to damage.

Die Cutting

Die punch operations are commonly used with DYLARK resins to remove flashed-over areas in the molded part. Generally the die punch process is used with high volume and lower cost IP's and can possibly eliminate slides and other mechanical actions that are costly for tooling or lead to manufacturing difficulties.

Typically punched out areas are defroster vents, glove box door openings and air bag door openings. Standard practice normally incorporates punch designs that are cutting from the "A" surface of the panel to maximize anvil support, maintaining skin surface integrity and eliminates substrate fracturing.

Complex instrument panels that require multiple cutting operations can be designed with a number of different punching angles. Operations can incorporate other operations such as "hot knife" cut for trimming the foam and skin. Depending on the operation most substrates are handled through the use of manual loading. However, robotic's can be utilized.

Punch die cutting is substrate penetration with a controlled shear break in a predictable pattern for glass filled resins. When designing for this type of operation it is recommended to use the following design criteria for part design and punch design:

Part Design:

1. Part thickness 2.5 to 4.5 mm; > 3.0 mm requires an increased "penetration" angle, i.e. 10-15% thickness for cut initiation.
2. Wall stock for "flash overs" or thin areas, 0.9 -2.0 mm, may be used for a controlled break for situations i.e. Oblique angles, inadequate anvil or clamp support
3. Corners or angles require adequate radii i.e. 2 mm; Sharp, i.e. 90º corners without radii cannot be punched
4. Minimum recommended distance between opening and substrate edge is generally 6.0 mm

A generic frontal and edge view designs for a HVAC opening is illustrated in figures 5:34 and 5:35.

FIGURE 5:34

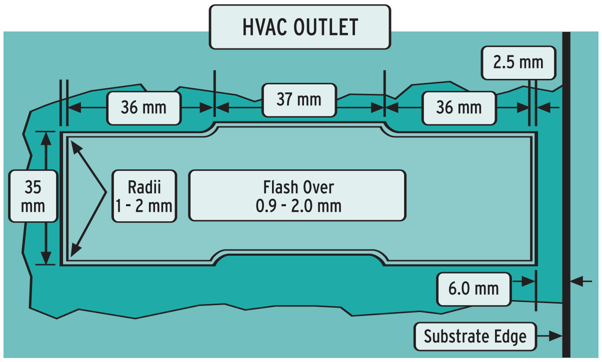
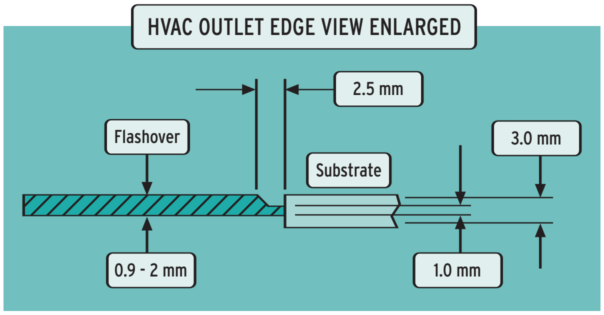


FIGURE 5:35



Punch Design:

1. Knife edge taper of approximately 60°
2. Slight point, 10-15% of wallstock thickness, on "knife edge" at either near a corner or approximately mid way along longest straight side
3. Die flat side located towards the insert or anvil
4. Die- punch clearance i.e. 0.1 mm
5. Top fixture to prevent substrate movement

Figures 5:36 and 5:37 are illustrations of a Punch-Die / Anvil set-up and Knife Edge design.

Punch-die maintenance is another key factor for a successful operation. As punches become dull instrument panel fracturing can occur which leads to unnecessary scrap. A preventative maintenance program should be established and include the following checks:

1. Keep punch and anvil edges sharp
2. Schedule die sharpening of at regular intervals
3. Have sufficient anvil support at the side/underside at the cut line
4. Prevent panel movement or flexing (bending) on the fixture
5. Restrain the part on the non-anvil surface to prevent sliding or buckling
6. Remove foam/skin residue build-up from fixture or dies
7. Clear all hold-up trimmings from fixture / die prior to loading next panel

Hot Knife Die Cutting
Hot knife die cutting is typically used to trim “skin” and foam from the plastic substrate, without cutting the substrate itself i.e. molded-in air conditioning outlets, and radio openings.

The knife-edge die is heated with cartridge heaters. The heated die is maintained at approximately 400-500°F (204-260ºC) so that the die will make a quick, clean cut of the vinyl skin and polyurethane foam. The fixtures must properly support and hold the substrate securely in place during the cutting operation. Care must be taken not allow the knife edge to cut into the substrate.

Painting

DYLARK resins can be painted. Formulas containing up to 20% glass have been successfully painted in highly visible areas of production applications. No special treatment prior to painting is necessary. Solvent based and water based paints can be used with standard painting techniques for DYLARK applications.

Use of external mold releases is not recommended for parts that are to be painted. If external mold release is required it is recommended to wash parts prior to painting.

FIGURE 5:36

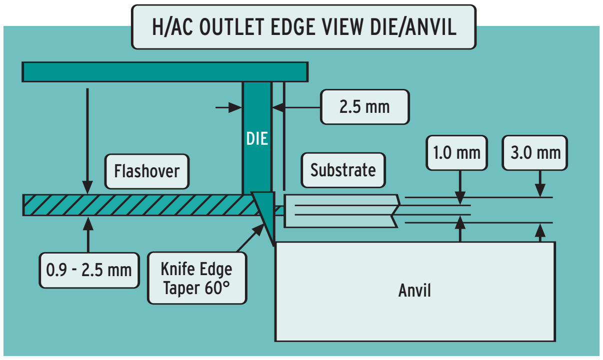
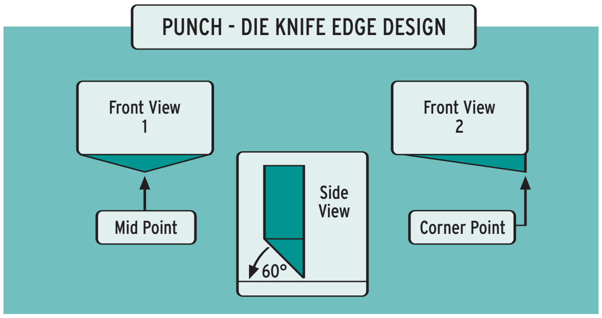


FIGURE 5:37



Following are paint formulations that have been tested and approved for use on DYLARK resins:

Water based:

Paint - Red Spot #296WLE
Solvent - Water

Paint - Bee #WB48
Solvent - Water

Paint - United #AWHP
Solvent - Water

Paint - Sherwin Williams #E67FC1
Solvent - Ready to spray

Solvent based:

Paint - Red Spot #AE261C
Solvent - Red Spot #SV-3720

Paint - Bee #R5
Solvent - Bee #T-369

Paint - Bee #R344
Solvent - Bee #T-245