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WHITE PAPER

PROCESSING ADVANCED MATERIALS:
VACUUM CURING AND DEBULKING

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PROCESSING ADVANCED MATERIALS: VACUUM CURING AND DEBULKING



Using a vacuum table with ramp/soak heating can save time, improve quality and reduce processing costs.

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Advanced materials such as liquid resins, fiber cloths impregnated with resin (prepreg), and bonding adhesives are replacing sheet metal parts or fasteners to decrease product weight and increase performance. In many instances, resins and adhesives will harden at room temperature. However, heat may be required to complete or speed the chemical reactions necessary to cure the materials.

BriskHeat Corporation's Vacuum Curing and Debulking tables are unique pieces of equipment that allow companies to process composite materials as well as cure adhesives when joining components. This "out-of-autoclave" (OOA) solution is an alternative to the traditional high-pressure autoclave curing process commonly used by manufacturers for curing parts made from composite materials. Electrical heating elements incorporated into the table design provide heat to one or more sides of the component for curing while using vacuum pressure to debulk. These features can be used separately, but more often, part processing requires both. Here we explain various design features and advantages of this equipment, provide examples of materials that can be processed, and discuss applications for a variety of industries. ¶

DESIGN FEATURES



Figure 1 - VT4000 vacuum table features 52" x 56" usable area and designed with top and bottom heat.

Processing of composite materials requires use of the correct material for the application, precise placement of that material within a mold or as a patch, correct time at temperature as recommended by the manufacturer, and typically a pressure for debulking. This is the same whether the material will be heated in an autoclave, with a silicone rubber heating blanket controlled by a hot bonder, or molded with a heated hydraulic press.

Temperature uniformity for composite curing is an important consideration. Under the aluminum platens are heating elements arranged in a pattern to maximize temperature transfer and uniformity. Heating blankets can be incorporated under or on top of the sealing membrane for heating on two or more sides (See Figure 1). Cloth insulators are an option to minimize heat loss during cures.

Due to the size and heat density requirements, 3-phase power is required with current draws of 30 amps or more. The standard design is for 3 watts per square inch; however, heating elements can be customized to provide higher or lower watt densities,

which impact temperature ramp rates and maximum temperatures. Many autoclave systems use natural gas burners to produce the heat needed for curing. Use of electrical heating eliminates the cost of fuel gas delivery systems required by some autoclave systems and contributes to decarbonization.

The VT4000 vacuum table features one heating zone under the platen, while the VT8000 and VT10000 feature separate zones on the left and right sides of the table. The number of zones is doubled when top heat is added. Each zone has a separate sensor and temperature controllers to provide heat as required for the part. Temperature controllers are programmable allowing for specific temperature ramps, soaks, and cool-downs as required by the material used. Controllers have memory to store up to four (4) ramp/soak recipes for curing a variety of materials. Additionally, the inclusion of monitoring thermocouples can provide temperature measurements at different locations on the part being cured. The 16-channel data recorder has an easily accessible data port for downloading sensor readings.

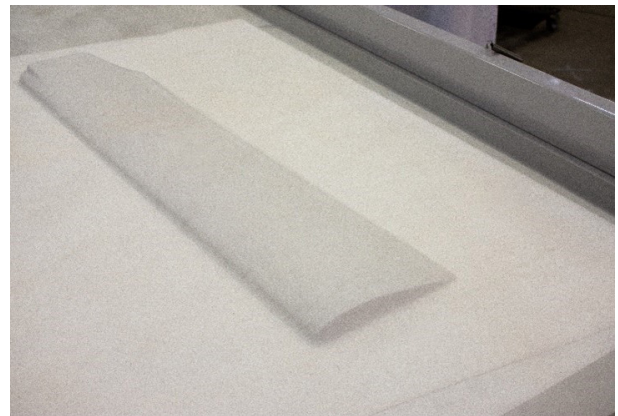


Figure 2 - Airplane wing section under vacuum.

Vacuum bagging is a skill unto itself. Knowing how or where to pleat, but also to ensure there are no leaks in the seal. Vacuum tables have the advantage of using a highly flexible silicone rubber membrane capable of 800% elongation which will seal itself to the contour of the part. Curing of thermoplastic materials at temperatures above 204°C (400°F) require high-temperature film to be used and sealed to the base of the table as it exceeds the use temperature of most silicone rubber materials. Tables include an integrated vacuum pump to draw air out from under the membrane or film at atmospheric pressure of up to 29 inches of mercury (inHG) or 14 psi at sea level (See Figure 2). Tables can be adapted to use external pumps or venturis. The self-sealing membrane has the advantage of sealing in about a minute rather than an estimated 20 minutes, to hours, to properly bag and form a seal. This reduces set up time, increases throughput, and provides for consistent quality. Cost of operation is reduced through labor costs but also with consumables such as film and sealing tape. ¶

PROCESS MATERIALS

Advanced materials are engineered to have specific curing regimes required to maximize strength and durability. Thermoset (polymer) resins are used when products require high-structural strength which is created by molecular cross-linking of the material. They will typically withstand higher temperatures than thermoplastic materials, because once cured they will not melt or flow. Examples of thermoset resins are polyester, epoxies, bismaleimides, and phenolics. Thermoplastics, such as polyether ether ketone, require consolidation temperatures in excess of 350°C (662°F), making processing on vacuum table prohibitive.

Several customers specifically mentioned processing of phenolic resins as part of a prepreg, wet layup, or molded piece. Nanocomposite materials have multiphase structures that can be engineered to have specific physical properties. Vacuum tables can be used by material manufacturers to create prepreg sheets using specific fibers, resins, and nanoparticles. Simplifying the process, the same table can be used to mold and cure. A custom design vertical lift vacuum table with 4-side access is ideal for quick loading and unloading of custom manufactured prepreg sheets or low-profile cured production parts (See Figure 3) .

Using adhesives to bond structures will transfer loads more efficiently compared to traditional fasteners. This exposes more surface area for bonding, as opposed to traditional fasteners with unbonded surfaces. Adhesives may include a thermoset resin material, which often requires heat for complete curing. Release film should be used between parts, and the membrane, to prevent issues with chemical compatibility or contamination of materials. ¶

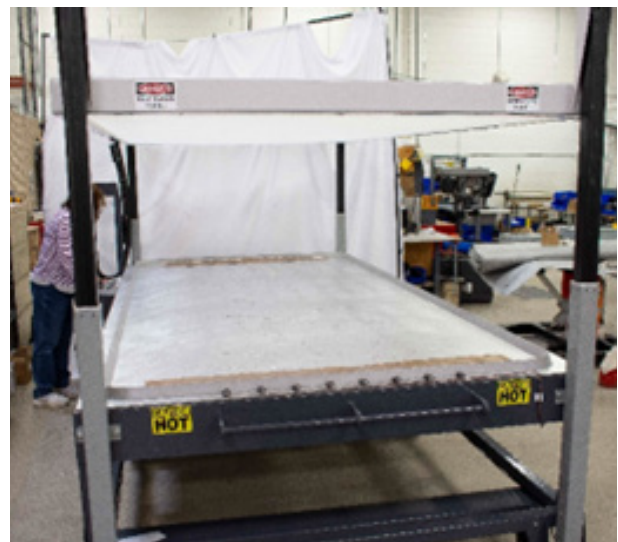


Figure 3 - Vertical-lift option for production of large panels.

VACUUM TABLE DATA SET

BriskHeat Corporation offers vacuum heating and debulking tables for composite processing. The application information below is based on our extensive sales history, spanning more than 10 years. Table are available with the following surface areas:

- VT2000 42" x 56" (1.1 m x 1.4 m)
- VT4000 60" x 66" (1.5 m x 1.7 m)
- VT8000 60" x 132" (1.5 m x 3.4 m)
- VT10000 72" x 144" (1.8 m x 3.7 m)



VT10000 Vacuum Table with top heat.

BY THE NUMBERS

56%

Approximately 56% of tables sales measured 60" x 66" (1.5 m x 1.7 m) or smaller.

35%

At 35% of all tables included a data recorder to accomodate additional temperature sensors and download recorded data.

42%

Top heat is used on 42% of large VT8000/VT10000 vacuum tables.

36%

Of non-academic customers, 36% have purchased more than one vacuum table.

APPLICATION INFORMATION

To look at the range of applications where vacuum tables are used, each customer's industry was determined by their NAICS code. Customers were contacted and asked to supply specific information as to application, materials processed, end-product, and end user (See Table 1). A customer may have more than one distinctively different industry listed, such as material research and composite part production. Corporations identified as providing either aircraft, vehicles, or weaponry for military use were 52% of total sales. For security reasons, minimal detail about applications or the materials processed were provided. The names of these companies cannot be disclosed.

The use of a table for composite part repair can be anything from large patches on structural parts, to curing adhesives when repairing rotor blades.

- Only 14% of non-academic industry vacuum tables are used for repairing composite parts; however, this is the application for 70% of those owned by the military.
- Those companies identified as defense contractors supplying only to the military accounted for 48% of all non-academic applications, of which the vast majority manufacture aircraft components.

Industry	Total %	Application	Segment %
Academic	13%	Aircraft Repair	9%
		Composite Part Manufacturing	1%
		General Composite Repair	1%
		Wind Blade Repair	1%
Aerospace	47%	Composite Repair, non-military	3%
		Manufacturing, mixed military/non-military	11%
		Manufacturing, military (defense; laminate)	33%
Composite End User	12%	Manufacturing, construction	3%
		Manufacturing, R&D, consumer products	3%
		Manufacturing, mixed parts	1%
		Manufacturing, composite panels	1%
		Manufacturing, composite parts (custom laminate)	4%
Defense	8%	Manufacturing, mixed parts including aircraft, land/sea vehicles, weapons	8%
Government (National Lab)	3%	Mixed Use R&D	3%
Industrial OEM, non-composite	4%	Manufacturing, non-composite material	4%
Military	13%	Aircraft/Composite Repair	9%
		Mixed Use R&D	4%

Table 1 - Industry and application overview (2012 - 6/30/2023)

APPLICATIONS

Research, Development & Customization of Ultra-Light Weight Bicycles

Specialized Bicycle has been making high performance bicycles since 1974. They came to BriskHeat to optimize their product development process and to provide a quick curing solution for customization. Top riders on their racing teams practice in Specialized's wind facility to test the aerodynamics of the bike and rider. Standard bicycles can be cut and reformed to match each rider's physical profile to decrease wind resistance. With BriskHeat's VT4000 with top heat, composite materials can be quickly cured and retested by the rider. Fixtures or tools to hold the modified parts heat right on the table. A data-logger with 16 additional thermocouples is used to monitor the temperature at multiple locations on the tool and bike. Not only is the table used for customization of bikes, but it is also used to develop helmets, pads, and other accessories.

Aircraft Composite Repair

TeamAerospace, Inc. is a Federal Aviation Administration (FAA) and European Union Aviation Safety Agency (EASA) approved repair station that specializes in MRO operations on commercial aircraft. Examples of parts repaired on their vacuum table include:

- Wing Panels
- Fillet Fairings
- Flight Control Surfaces
- Floorboards and other Composite Panels
- Thrust Reverser Sleeves

The owner of Team Aerospace credits the self-sealing membrane with saving time and reducing costs (See Figure 4).



Figure 4 - Composite repair of aircraft panel. Image courtesy of Team Aerospace, Inc.

Custom Laminate Panels for Aircraft

A defense contractor produces a laminate panels comprised of several thin sheets of aluminum foil bonded with PR1829 sealant for use on its manufactured aircraft parts. Breather cloth and release film are used during the processing, which requires a four (4) minute debulk and cure cycle between each layer of aluminum. The completed laminate is less than 0.010" (0.254 mm) thick and built up on a piece of carboard. The ease of operation allows one employee to operate two tables.

Armor Panels for Military Use

A defense contractor uses carbon-fiber prepreg material and layers it with steel reinforcements and adhesive. These are laid into a fixture and placed on the vacuum table. Once the lid is closed, the vacuum pump draws the membrane around the shape. The vehicles these panels are designed for have irregular shapes which the membrane conforms to. Prior to using a vacuum table, panels were vacuum bagged and then cured in an oven. The total time to build-up the panel, then bag and cure the parts, averaged 18 hours. Productivity more than doubled as total time was reduced to only six (6) hours. This improvement decreased production shifts from two, down to one.

Custom Laminate Panels for Military and Industrial Applications

A US composite company manufactures a lightweight fiber-reinforced composite material that can replace sheet metal parts in many applications, while weighing a third the weight. These composite laminate panels are sold to other companies or used for manufacturing of their own products. The composite is made by using proprietary resin along with Aramid fiber to produce a composite material that is highly flame and abrasion resistant, as well as antimicrobial. The durability, at a reduced weight, provides for energy savings when shipping containers are manufactured from this material. The material is used for EV battery enclosures, and other products where high durability is required. A modified version is sold to defense contractors for military armor integrated into aircraft.

Molded Composite Panels for Transportation

Another popular application for composite materials is transportation vehicles. This includes flooring, doors, interior and exterior walls, and storage compartments. Vehicles include everything from buses and mass transit vehicles to aircraft. Milwaukee Composites is a leading manufacturer of phenolic resin composite products that has supplied over 8.5 million square feet of floors, ceilings, and doors for such vehicles. Using their VT10000 in production molding for more than 10 years, they state many of their parts made could not be molded without the use of their vacuum table.

"If it wasn't for our ability to place material and tooling on the table for curing and debulking, we would not be supplying this product."

- Milwaukee Composites

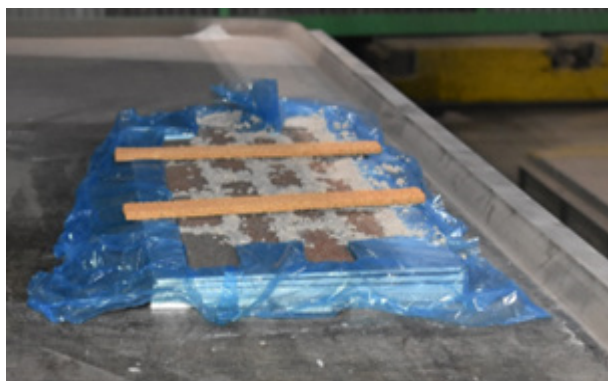


Figure 5 - Lightweight brick panel. Image Courtesy of Arcitell and Belden Brick.

Composite Panels for Home Construction

Arcitell, LLC developed Qora® Cladding as a durable, lightweight, and fire-resistant panel to use on the exterior of homes. Arcitell manufactures their own composite prepreg using a fiber matrix and phenolic resin. To manufacture Qora®, a foam core is placed between two composite sheets. This material is placed in a silicone mold that can be placed on their vacuum table or in a hydraulic press, depending on the number and shape of the pieces. The processing temperature of 190°C (375°F) and cycle time are the same regardless of method. A 72" x 144" table with top heat was a \$50,000 investment in 2017, whereas their platen press cost \$250,000. Cost of operation is approximately 25% less for the table based on utility costs. The silicone forms used by both tools is the same, however, the lower pressure of the table extends the life of the form.

A sister company uses the same phenolic resin sheets to manufacture real brick panels using their vacuum table to form and cure the panels (See Figures 5). BriskHeat has worked closely with Arcitell as they required heaters for molds used to make foam cores, as well as heaters used for reducing the viscosity of the phenolic resin.

Academic Applications

BriskHeat Corporation has supplied vacuum tables to educational institutions such as community colleges and vocational schools throughout the United States. They have also been purchased by universities in Canada and Australia. Abaris Training Resources, Inc. provides training for those interested in certification as a composite technician through several organizations. Use of a BriskHeat vacuum table is included in some of their classes. Other academic institutions use VTs for not only aircraft component repair, but also repair of wind blades, and manufacturing of composite parts.

CONCLUSION

In many applications, using a vacuum table with ramp/soak heating capabilities can save time, improve quality, and reduce processing costs. Additionally, the initial capital investment is lower than an autoclave or hydraulic press, deliveries are typically shorter, less space is required, and it's more environmentally sustainable. BriskHeat sales personnel have the composite processing application knowledge to assist you in selecting the best solution.

CUSTOMER REFERENCES

Examples of customers using vacuum heating and debulking tables, for manufacturing or repair of composite parts, includes:

- Albany Engineered Composites
- Arcitell, LLC
- Belden Brick Company
- General Dynamics Land Systems
- ITT Controls Technology
- Langley AFB
- Lockheed Martin
- Macro Industries, Inc.
- Milwaukee Composites
- Naval Surface Warfare Center
- Northrop Grumman
- Sandia National Laboratory
- Specialized Bicycle
- Team Aerospace, Inc.

ABOUT US



The Background

For over seven decades, BriskHeat has been a trailblazer in manufacturing flexible surface heating elements and controls, catering to a wide array of industries. With a rich history spanning 70 years, BriskHeat has solidified its position as a global leader in innovative heating solutions. Specializing in surface heating, our patented multi-stranded resistance wire sets us apart with unmatched durability and flexibility.

Our versatile heating elements are adaptable to various environments, making them suitable for industries such as Aerospace/Aviation, Food & Beverage Processing, Chemical Processing, Power Generation, Semiconductor, and more. With a commitment to quality and innovation, BriskHeat stands as a trusted partner in delivering tailored heating solutions worldwide.

The Solutions

- Heating Cable & Wire
- Heating Tapes & Cords
- Silicone Rubber Heating Blankets
- Silicone Rubber Drum & Pail Heaters
- Full Coverage Drum & Tote Heaters & Insulators
- Temperature Controllers
- Composite Curing Solutions & More



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