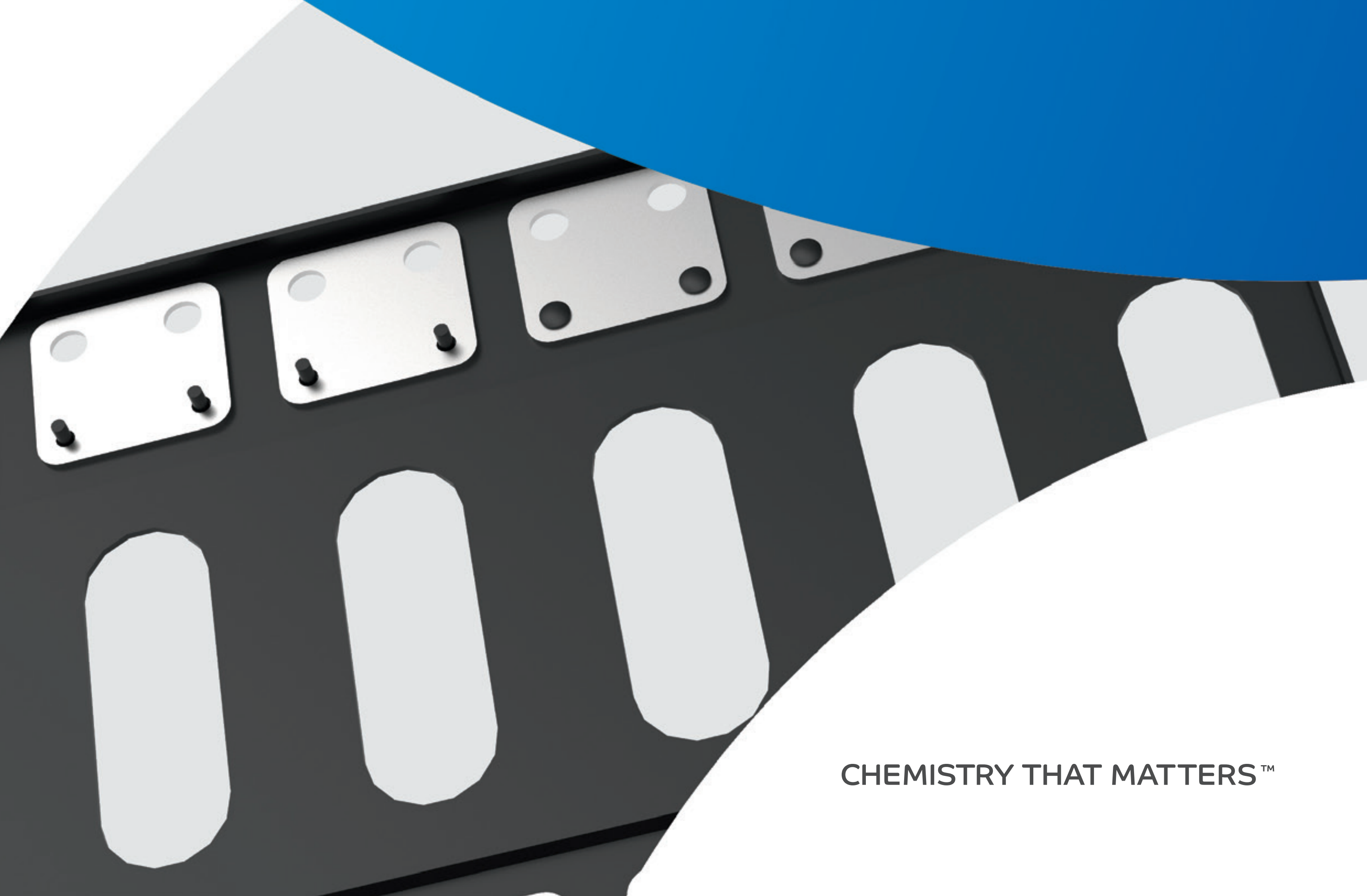
EXPERT SERIES

HEAT STAKING OF FLAME RETARDANT PP COMPOUNDS FOR EV BATTERY PACK APPLICATIONS

bdtronic



CHEMISTRY THAT MATTERS™

HEAT STAKING OF FLAME RETARDANT PP COMPOUNDS FOR EV BATTERY PACK APPLICATIONS

To accelerate time to market, the first generation of electric vehicle (EV) battery packs relied on established materials such as steel, aluminum and, to a lesser extent, thermosets. In creating next-generation designs, automakers seek improvements in overall battery performance in terms of energy density, CO_2 footprint, weight and system cost. Thermoplastic materials offer potential to address these goals. However, greater use of thermoplastics in EV battery packs poses technical challenges, particularly when joining different materials in a hybrid construction, such as a battery management control unit, cell contacting system or junction box.

AUTOMOTIVE EXPERT SERIES

This series offers education, guidance and insights from our global team of automotive experts. We cover industry pain points, a diverse range of technical topics and frequently asked questions on the use of thermoplastics for automotive applications. SABIC collaborated with bdtronic on this content.

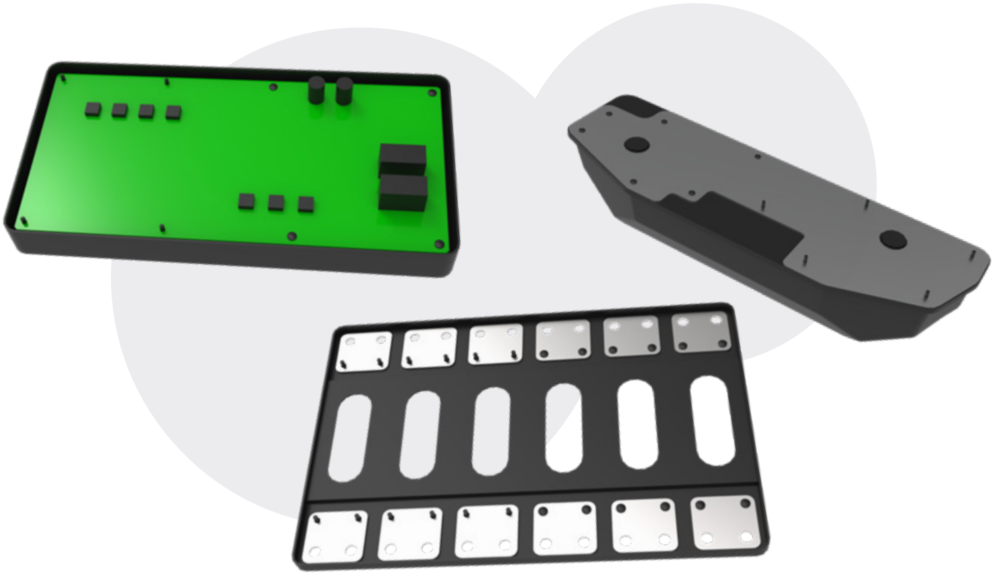


Figure 1. Example heat staking applications:
- LEFT— control unit for battery management system (plastic joined to PCB)
- MIDDLE—cell contacting system (plastic carrier joined to PCB/ FPC)
- RIGHT—junction box (cover is plastic joined with aluminum, and reverse is plastic joined to plastic)

Heat staking is a preferred method for joining metal to plastic, joining two similar or dissimilar plastics or joining plastic with a printed circuit board (PCB) without the use of adhesives or fasteners.

A study was conducted to determine the effectiveness of using bdtronic's convection and conduction heat staking technologies with SABIC® PP compound H1030.

BLUEHERO™

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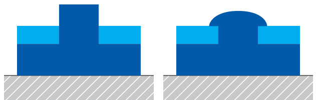
This flame-retardant (FR) polypropylene (PP) compound, reinforced with short glass fibers, was selected for evaluation because of its increasing use in battery pack applications such as top covers and module housings.

HEAT STAKING TECHNOLOGY



Heat staking is a form-fitting, point-to-point, non-detachable joining process.

Heat staking is a form-fitting, point-to-point, non-detachable joining process. A plastic stud or pin on one of the mated parts is inserted into a hole in the other part. Using special equipment, this pin is heated and reshaped into a stake (also called a cap or rivet), which mechanically holds the two parts together.

The pins are incorporated in the injection mold tool, and can have different diameters, depending on the pull force requirements of the joint.

Heat can be generated and applied by conduction or convection. bdtronic offers both: the company's BHS HOT STAMP® process uses conduction and its BHS HOT AIR® uses convection. The choice of method and production equipment depends on the materials and application requirements. Both methods create a connection between the mated parts that can only be undone by destroying the component. Fully and semi-automatic systems from bdtronic feature numerous sensors that continuously measure and regulate all relevant settings.

Heat staking technology avoids the need for additives such as bonding agents, which typically require priming and curing that increase processing times. It also eliminates the use of fastening hardware, which can raise costs and requires secondary operations. The results are very clean, with no residues or byproducts, and provide maximum pull strength. Heat staking is gentle on components and is suitable for use with various thermoplastics that must be joined with other plastics, metals or PCBs.

FLAME-RETARDANT GLASS FIBER-REINFORCED PP COMPOUNDS

SABIC has developed a new range of PP compounds reinforced with short or long glass fibers under the SABIC® PP compound and STAMAX™ resin brands, respectively. These compounds feature non–halogenated FR technology, good processability, and excellent electrical and mechanical performance. They are low-density materials that can help reduce weight in automotive, electrical/electronic, building & construction and appliance applications.

SABIC PP compound H1030 is reinforced with 30 percent short glass fibers. It offers good flammability resistance, meeting the UL94 V0 standard at 1.5mm. Key advantages of SABIC PP compound H1030 are good mechanical performance thanks to glass fiber reinforcement, excellent electrical performance with a GWIT >800°C at 0.8mm and a high CTI up to 600V, and ease of processing and recycling. Polypropylene resin has one of the lowest levels of global warming potential (<2kg CO_2 eq) among polymers, making it well suited for sustainable battery components.

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SABIC® PP compound H1030 was selected for this heat staking study due to its growing adoption in the market.

FR SABIC® PP Compounds	UNFILLED	PP Copolymer	0%	Tensile Modulus 960MPa UL 94 V0 @2mm	**H1200**
			0%	Tensile Modulus 1.7 GPa UL 94 V0 @0.8mm	**H1300**
	SHORT GLASS	PP Homopolymer	15%	Tensile Modulus 4.7 GPa UL 94 V0 @3mm	**H1015**
			20%	Tensile Modulus 6.4 GPa UL 94 V0 @1.5mm	**H1020**
			25%	Tensile Modulus 7.6 GPa UL 94 V0 @1.5mm	**H1025**
			30%	Tensile Modulus 8.7 GPa UL 94 V0 @1.5mm	**H1030**
				Tensile Modulus 8.3 GPa UL 94 V0 @1.5mm	**H1090***
		PP Copolymer	30%	Tensile Modulus 7.5 GPa UL 94 V0 @1.5mm	**H1130**

Figure 2. SABIC PP compound unfilled and short glass fiber-reinforced product portfolio

FR STAMAX™ Resins	PP Copolymer	20%	Tensile Modulus 6.0 GPa UL 94 V0 @1mm	**20YH510**
		30%	Tensile Modulus 7.2 GPa UL 94 V0 @3mm	**30YH530**
		30%	Tensile Modulus 7.6 GPa UL 94 V0 @1.5mm	**30YH515**
		30%	Tensile Modulus 7.6 GPa UL 94 V0 @1.5mm	**30YH570****
		30%	Tensile Modulus 8.1 GPa UL 94 V0 @1.5mm	**30YH611***

Figure 3. Flame retardant STAMAX™ long glass fiber-reinforced product portfolio

DEFINING PROCESSING CONDITIONS FOR TWO HEAT STAKING METHODS

Through a collaboration, SABIC and bdtronic designed and carried out a series of tests using SABIC PP compound H1030 and bdtronic's BHS HOT AIR® (convection) and BHS HOT STAMP® (conduction) heat staking technologies. The goal of this testing was to define processing conditions for the SABIC material with these two methods, and to measure the pull force from the joined parts. Because heat staking had not previously been used with SABIC PP compound, the two companies aimed to generate data for customer guidelines.

* Extrusion grade
** Better behavior towards high energy flame test compared to 30YH515

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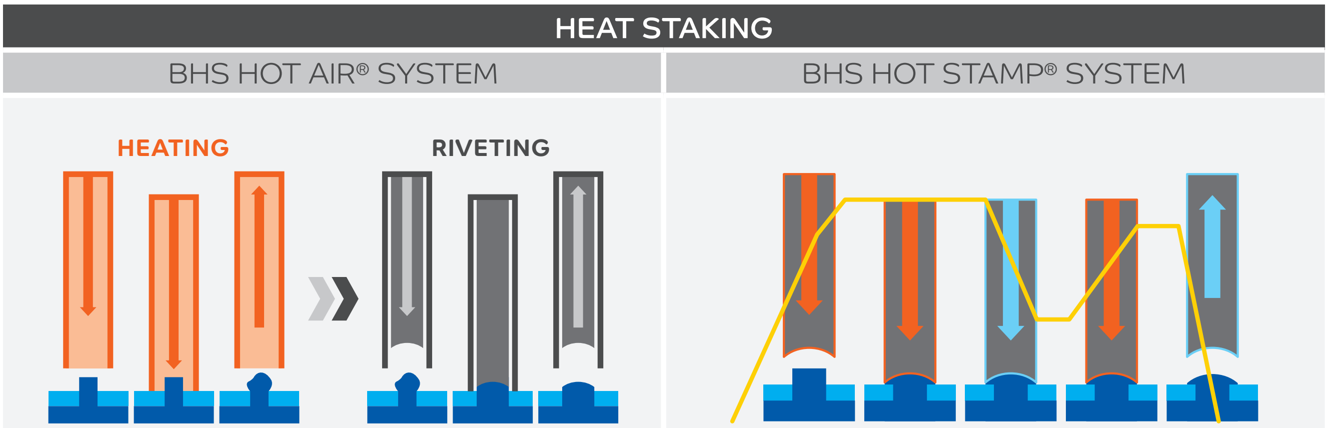

BHS HOT AIR® SYSTEM

- Convection riveting process
- Two-step process
- Maximum pull strength
- No melt flash
- Closure of gap between pin and borehole of joining partner for added stability and fixed position
- Suitable for semi-crystalline polymers with high glass fiber content

BHS HOT STAMP® SYSTEM

- Conduction (contact) riveting process
- Single-step process
- Suitable for very small and temperature-sensitive parts, such as sensors and small pins
- Small clearance area around the rivet pin
- Rivet direction can deviate from direction of gravity

Figure 4. Comparison of BHS HOT AIR® with BHS HOT STAMP® heat staking methods

SABIC provided the material in pellet form for production of test specimens (flat sheets) with a commonly used pin diameter of 3.0 mm, according to the bdtronic design guideline. bdtronic processed the test specimens with BHS HOT STAMP® and BHS HOT AIR® systems at a range of temperatures from 190°C to 220°C to form rivets (Figures 4 and 6). The rivets joined the substrate sheet with either an aluminum sheet or another sheet of SABIC® PP compound H1030.

Pull force for each rivet was measured at a temperature of 210°C, which provided the best results.

PULL FORCE RESULTS BASED ON HEATING TIME FOR BHS HOT AIR® SYSTEM

Figure 5. Rivet head before pull force test with BHS HOT AIR® System

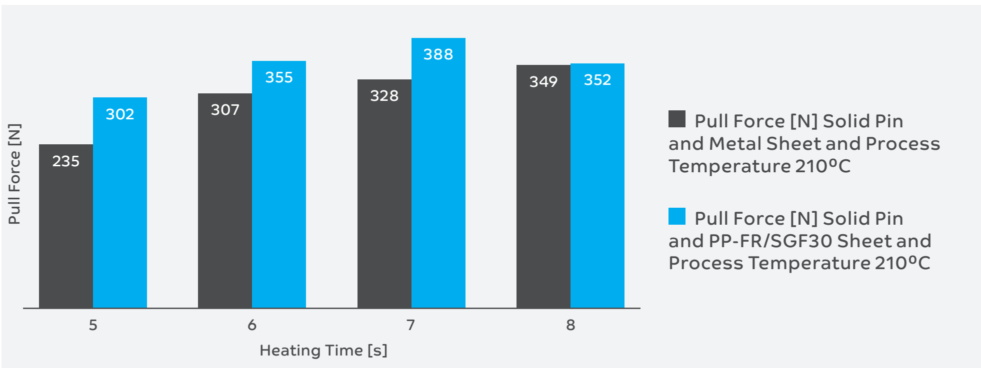

Figure 6. Test results for BHS HOT AIR® System

The bar chart (Fig. 6) shows that pull force increased with heating duration, reaching the highest pull force for a plastic-metal joint at 7 seconds, and for a plastic-plastic joint at 8 seconds.

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PULL FORCE RESULTS BASED ON HEATING TIME FOR BHS HOT STAMP® SYSTEM

Figure 7. Rivet head before pull force test with BHS HOT STAMP® System

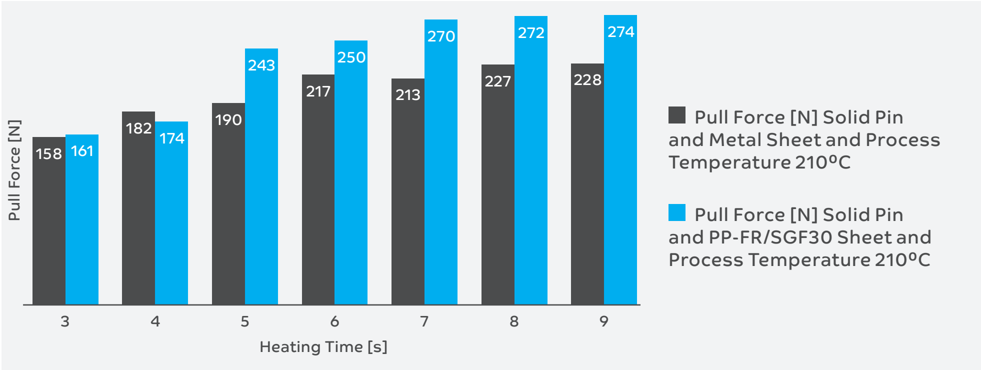

Figure 8. Test results for BHS HOT STAMP® system

The bar chart (Fig. 8) shows that pull force increased with heating time, reaching the highest level at 8-9 seconds. This result was the same for both metal-plastic and plastic-plastic joints.

These laboratory tests demonstrated that SABIC PP compound H1030 can be processed very well with both bdtronic heat staking methods, achieving the highest pull force levels at a processing temperature of 210°C, +/-5°C. The BHS HOT AIR® system achieved higher pull strength than the BHS HOT STAMP® system. Heat staking a sheet of SABIC® PP compound H1030 with another sheet of the same material achieved even higher strength due to a "welding" effect between the two plastic parts.

ONE MATERIAL: TWO HEAT STAKING OPTIONS

SABIC PP compound H1030 is being adopted in several EV battery pack applications. The test results from two different technologies demonstrated that SABIC PP compound H1030 exhibits high pull forces after heat staking using either convection (BHS HOT AIR® System) or conduction (BHS HOT STAMP® System), with heating times below 10 seconds, resulting in machine cycle times of 10-15 seconds. This data can help battery producers define the right conditions for joining FR glass fiber-reinforced SABIC PP compound to sheets made of the same material or aluminum.

BATTERY COVERS

BENEFITS OF THERMOPLASTIC-BASED SOLUTIONS

- Weight reduction
- Thermal blanket elimination
- Potential to integrate array barriers

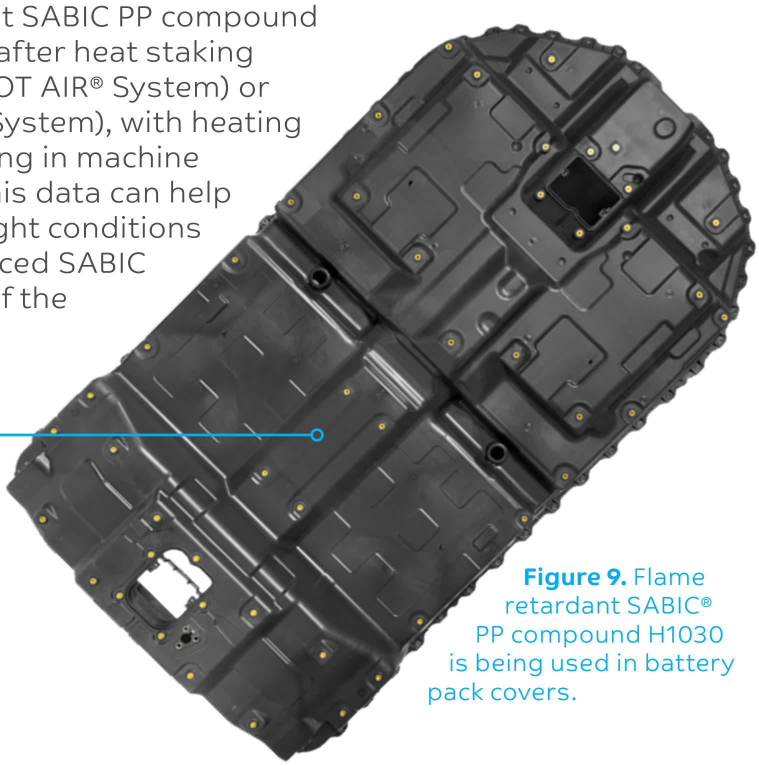

Figure 9. Flame retardant SABIC® PP compound H1030 is being used in battery pack covers.

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RECAP

- As plastic increasingly replaces or is paired with metal in EV battery components, heat staking provides an advantageous joining option.
- Heat staking technology (convection or conduction) from bdtronic, which can be used successfully with SABIC® PP compound H1030, helps to streamline processing by avoiding mechanical fasteners, gluing or other methods.
- When processed with the right conditions, SABIC PP compound H1030 yields rivets with good surface quality, despite its high glass fiber content.
- When optimal processing conditions are followed, SABIC PP compound H1030 can be used in heat staking without affecting its FR properties, which are required for battery applications.
- Testing revealed additional pull force resistance in plastic-plastic heat staking constructions due to a bonding effect between the two parts.

SABIC

SABIC, a global leader in chemicals and thermoplastics headquartered in the Kingdom of Saudi Arabia with operations and R&D centers in Europe, the Americas and Asia Pacific, is a key material supplier for automotive and electrical/electronics applications. Leveraging this expertise and its broad thermoplastic portfolio ranging from engineering resins to polyolefins, SABIC is collaborating with the EV value chain on innovative material solutions for battery packs and modules. The company has also launched a focused initiative known as BLUEHERO™, under which it is developing the materials, solutions and expertise to help industry make the transition to electrification and a lower carbon future.

BDTRONIC

bdtronic is a globally operating process-oriented machine building company in the field of 1-component and 2-component dispensing technology, plasma pretreatment, heat staking for e-mobility and driver assistance and impregnation technology for electric drives. bdtronic provides complete solutions and offers personal project support and individual customer care, amongst others with a worldwide team and 15 technology centers for process development and sample production for customers.

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