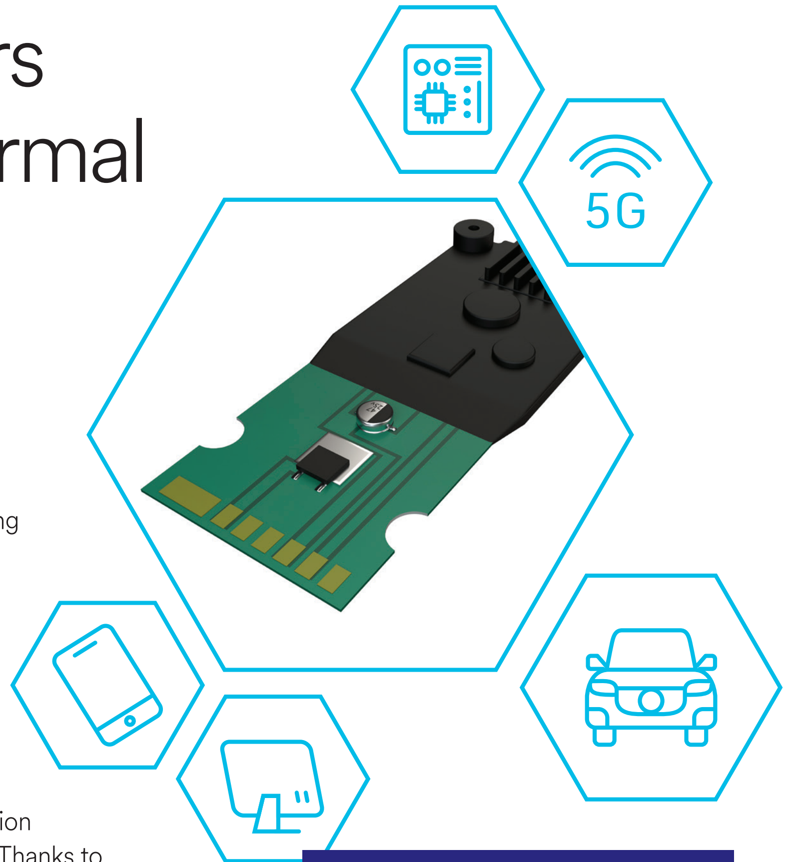
Science.
Applied to Life.™

3M™ Boron Nitride Cooling Fillers
For tailoring thermally conductive and electrically insulating polymers.

The next level of thermal management.

Designing polymers for demanding thermal management applications



Manufacturers of consumer and automotive electronics, high-capacity batteries, LED lighting, 5G applications and other electrical and electronic devices are increasingly utilizing high-performance polymers to help reduce component size and weight while simplifying assembly. Most polymers, however, have inherent limitations in their ability to conduct heat, which can greatly affect a device's long-term reliability and performance.

3M™ Boron Nitride Cooling Fillers offer a unique opportunity for designers, compounders and molders to help improve both thermal conductivity and electrical insulation in a wide range of plastics, elastomers, adhesives and more. Thanks to their enhanced thermal management capabilities, these materials are helping manufacturers enable a new generation of electrical and electronic components that may also offer improved performance, reliability and waste reduction.

Meeting the need for "smart" materials

3M Boron Nitride Cooling Fillers are a family of advanced ceramic materials used to help manufacturers improve thermal conductivity in polymers while maintaining or improving electrical insulation. They are also ideal for developing lightweight parts with complex geometries.

Using 3M Boron Nitride Cooling Fillers, thermal conductivity can be tailored to meet the thermal requirements in your system – harmonized with performance criteria such as target electric insulation, flame retardancy, mechanical properties and low dissipation factor.

For example, many modern electrical and electronics applications require materials that can effectively spread heat within a small space and transfer it to the surrounding air. Plastics are the material of choice in these kinds of applications – but plastics are generally not thermally conductive. Adding 3M Boron Nitride Cooling Fillers to the compound is an effective way to help resolve this issue.

Potential Applications

- Thermal interface materials (TIMs) for automotive, 5G and consumer electronics
- Thermally conductive adhesives and greases for bonding
- Automotive electrification, including housings for high-capacity batteries and electric motors in electric and hybrid vehicles
- Over molding of sensors and electronics by potting resins
- Injection molded thermoplastics and thermosets for motors, batteries and radome boxes
- Compounds with low dissipation factor for copper clad laminates (CCL)

Inside the Technology

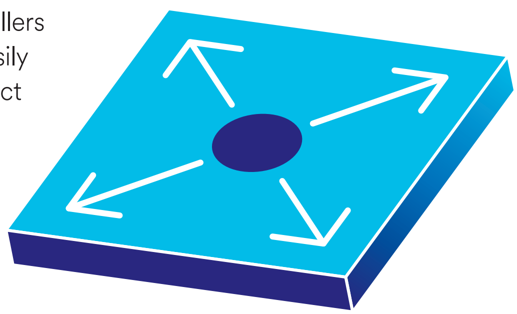
Boron nitride: the "white graphite"

Hexagonal boron nitride (hBN) is a synthetic material with a high aspect ratio (ranging from 2:1 to 30:1) and a structure similar to graphite. Unlike graphite, 3M boron nitride has a pure white color and is not electrically conductive.

The particle geometry and composition of 3M Boron Nitride Cooling Fillers have been specially engineered for better heat transfer and dissipation – both of which are affected by the orientation of the material grades (platelets, flakes, agglomerates) as shown in the illustrations below.

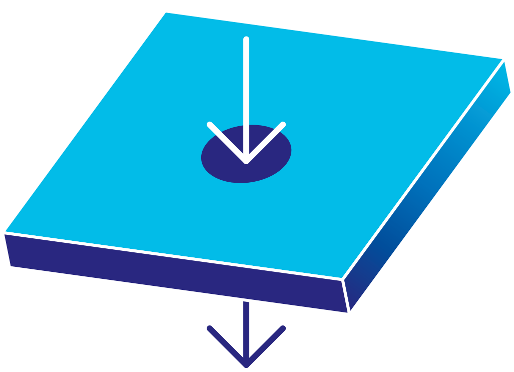
In-plane (x-y) heat dissipation

3M Boron Nitride Cooling Fillers are engineered to line up easily and form "bridges" to conduct heat in the direction of their orientation – either horizontal or vertical.



Through-plane (z) heat transfer

This general orientation is accomplished by employing various formulating and processing techniques.



Features and Benefits

Thermal conductivity
(400 w/m•K in-plane)

- Intrinsically 8–20x more thermally conductive than alumina fillers
- 2–8x more thermally conductive when mixed in polymers

Electrical insulation

- $>10^{15}$ Ohm•cm electrical resistivity with a high breakdown strength
- Ideal for materials such as thin insulation foils

Low loss factor
(0.00035 @1GHz)

- As signal transmissions and frequencies increase, so does the risk of signal loss
- Permittivity (Dk) of 4 @1 GHz

Low density
(2.25 g/cm^3)

- Allows for boosting of compound properties with final part density of 1.2–1.6 g/cm^3
- Excellent for housings or LED lamp sockets

Very good processing properties

- One of the least abrasive fillers used in plastic compounds, it can help minimize equipment wear
- Available in multiple grades for excellent viscosity control

Optical properties

- Easy to color
- Excellent optical surface quality
- >95% reflectivity

With 3M Boron Nitride Cooling Fillers, you can create polymers with excellent thermal conductivity and electrical insulation.

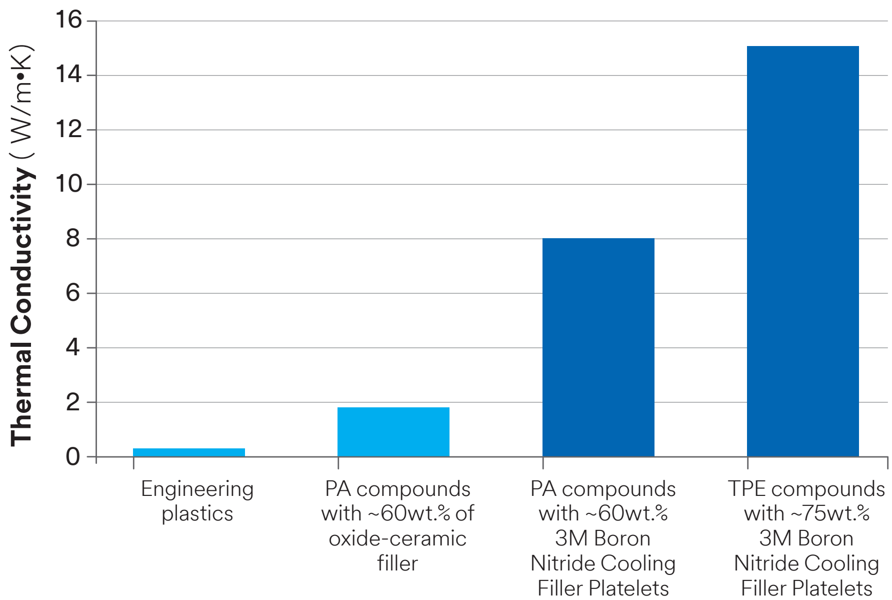
Thermal Conductivity

Thermal conductivity in plastics is limited by the amount of fillers and the natural conductivity of the base polymer matrix. For example, with spherical alumina, thermal conductivity can be increased up to 3.5 or 4 W/m•K.* Compounds filled with 3M Boron Nitride Cooling Fillers, however, can reach conductivity levels up to 15 W/m•K while maintaining good processing properties.

* Laser flash measurement according to ASTM E 1461/DIN EN 821 on 2 mm samples.

Not for specification purposes.

Comparing In-Plane Thermal Conductivity of Thermally Conductive Plastics



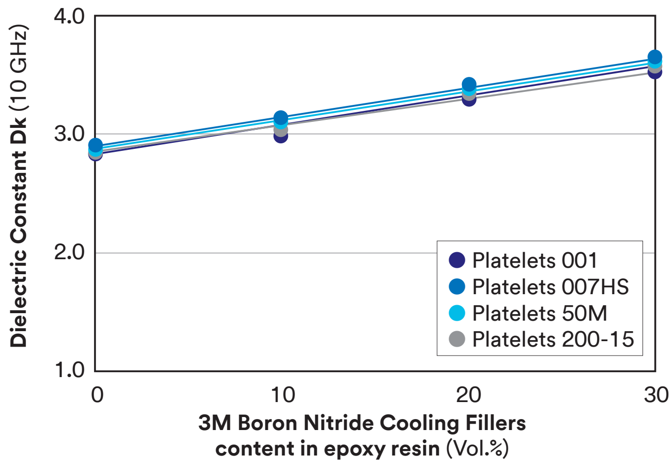
Electrical Insulation

When using electrically conductive additives, such as graphite, additional insulation layers are typically required. These layers not only add to the size and cost of the component, but also form an added barrier to efficient heat transfer. By using electrically insulating thermal fillers, these layers can be virtually eliminated. With some of the highest electrical resistivity compared to other ceramic fillers, 3M Boron Nitride Cooling Fillers will help maintain or even improve the electrical insulation values of the filled compound while achieving high thermal conductivity.

Material	Dielectric Properties Ω*Cm	Dielectric Properties KV/mm
Boron Nitride	$>10^{15}$	>67
Al_2O_3	$>10^{12}$ - 10^{15}	17-40
AlN	$>10^{12}$ - 10^{13}	16-20

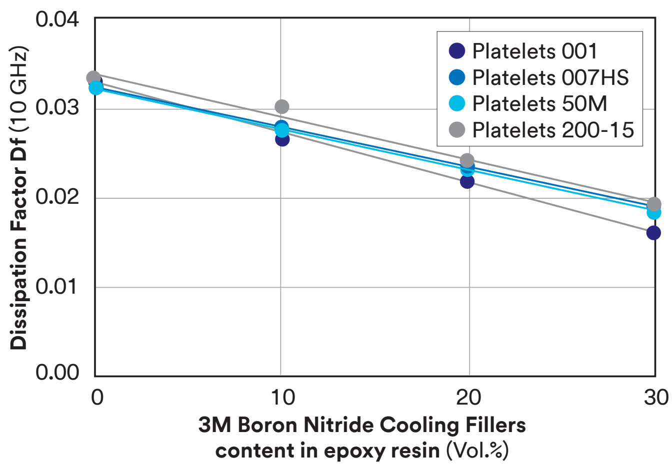
Low Loss Factor

As devices and applications for telecommunications continue to demand more data with increased signal transmission, this has a significant impact on existing devices and exacerbates design challenges. Adding 3M boron nitride as a filler to plastics and composites provides manufacturers with a solution with multiple functionalities in one material, allowing optimization of the component. 3M Boron Nitride Cooling Fillers help to provide thermal management, electrical insulation and low dielectric loss (Df). With a low intrinsic Df of 0.00051, 3M Boron Nitride Cooling Fillers help in reducing signal transmission power loss. Constant loss factor through wide frequency and temperature range helping enable high frequency data transmission.



Typical Electrical Properties
(Not for specification purposes)

Material	Dielectric Properties Dk	Dielectric Properties Df
BN	~4.3	0.00051
Al_2O_3	~9.5	0.0024
AIN	~8.4	0.0035
Minerals	~6-8	>0.005



Low Density

For equivalent thermal conductivity levels, a much lower weight percentage of boron nitride is necessary, compared to mineral- or oxide-based fillers. Consequently, a 3M boron nitride-filled compound at the same level has lower density. For example, an Al_2O_3-PA66 compound (2.3 kg/L) is 1.6X heavier than a 3M BN-PA66 compound (1.4 kg/L). The lower density of 3M Boron Nitride Cooling Fillers can help you improve processing and reduce your final part weight.

Density of Thermally Conductive Filler (Not for specification purposes)

Filler	Density (g/cm³)
Al_2O_3	3.99
AIN	3.26
Minerals (e.g. Al_2SiO_5)	3.60
3M Boron Nitride Cooling Fillers	**2.25**

Processing and optical properties

	3M Boron Nitride Cooling Filler	Aluminum Oxide (Al_2O_3)	Aluminum Nitride (AIN)
Raw Materials	• Lower filler loading level, lower material consumption • Low density, lighter weight	• Requires higher filler loading to generate desired thermal conductivity (TC) • Higher density, heavier weight	• Requires higher filler loading to generate desired thermal conductivity • Medium density, medium weight
Processing	• Faster cycle times and line speeds due to high TC • No increase in wear on process tooling	• Hard abrasive particulate cause wear on process tooling	• Hard, abrasive particles cause wear on process tooling
Viscosity at 2 W/mK	• Low compound viscosity • Agglomerates and Flakes give lower viscosities than Platelets	• Higher required loading results in medium compound viscosity • Spherical Al O_3 gives lower viscosity than bulk-shaped Al O_3	• Higher required loading results in medium compound viscosity
Reflectivity	• High reflectivity for LED applications	• Low reflectivity for LED applications	• Low reflectivity for LED applications

Powder Characteristics

(Not for specification purposes)

3M Boron Nitride Cooling Filler Grade	Filler Type	Particle Size Distribution d(0.1) µm	Particle Size Distribution d(0.5) µm	Particle Size Distribution d(0.9) µm	Particle Size Distribution d(0.97) µm	Bulk Density, Scott (g/cm³)	Bulk Density, DIN (g/cm³)	Surface Area (m²/g)
001	Platelets	n.a.	0.5**	0.8**	n.a.	<0.14	n.a.	<30
003E	Platelets	0.5-2.5	1.3-8.8	n.a.***	n.a.	n.a.	<0.3	<15
003	Platelets	1–2	2–5	8.5–22.5	n.a.	<0.15	n.a.	<18
003SF	Platelets	0.5–2	2–6	6–14	n.a.	n.a.	<0.15	<20
006	Platelets	1.5–3	4.5–8	10–20	n.a.	<0.2	n.a.	<8.5
007HS	Platelets	1.5–3	5–8	10–20	n.a.	<0.22	n.a.	<13
0075	Platelets	2–3.5	6–8.5	12–25	n.a.	<0.22	n.a.	<5.5
009	Platelets	2–3.5	6–12	14–32	n.a.	<0.22	n.a.	<5.5
012	Platelets	2–4.5	8–14	20–40	n.a.	<0.25	n.a.	<4.5
012P*	Platelets	65–120	125–190	200–300	n.a.	n.a.	0.3–0.55	<3.5
50M*	Agglomerates	5–10	15–30	35–70	n.a.	n.a.	0.1–0.4	<3.5
75*	Agglomerates	5-16	25-55	75-115	n.a.	n.a.	0.25–0.4	<3.5
100*	Agglomerates	10–35	50–80	95–145	n.a.	n.a.	0.25–0.4	<3.0
150*	Agglomerates	20–80	120–200	240–360	n.a.	n.a.	0.3–0.55	<3.0
250S*	Agglomerates	8–20	40–100	120–210	n.a.	n.a.	0.3–0.6	<4.5
500-3*	Flakes	140–260	300–530	n.a.	n.a.	n.a.	0.25–0.5	<7.5
200-3*	Flakes	5–120	140–240	n.a.	<450	n.a.	0.3–0.6	<10
500-15*	Flakes	20–150	160–400	n.a.	n.a.	n.a.	0.5–0.7	<3.0
200-15*	Flakes	5–55	65–210	n.a.	<450	n.a.	0.5–0.75	<3.0

Bulk density determined according to ASTM B329/ISO 3923-2 (Scott density) and according to ISO 23145-2 (DIN density)

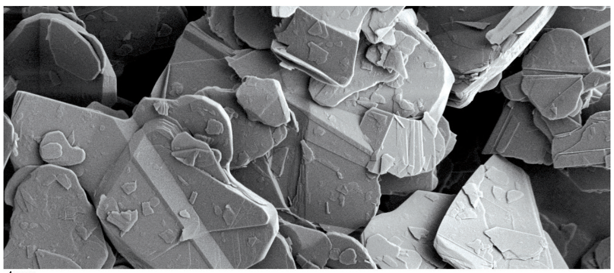
Particle size distribution measured by laser light scattering (Mastersizer 2000, dispersion in ethanol)

* Particle size distribution measured by laser light scattering (Mastersizer 2000, dry, 0.1 bar)
** Data determined by means of SEM pictures
*** Can include soft agglomerates with 50–100 µm
For calculation purpose: Density of bulk hBN 2.25 g/cm³

3M™ Boron Nitride Cooling Filler Grade Profiles

Platelets 003E, 003, 006, 0075, 009 and 012

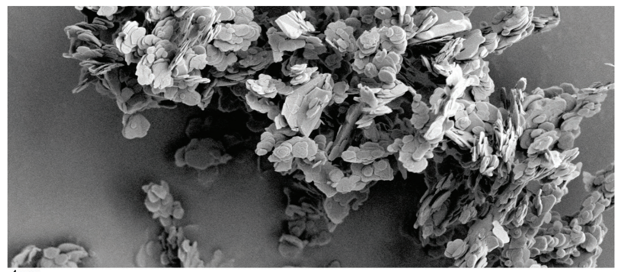
Optimal all-purpose grades for pads and injection molded parts.



1 µm SEM micrograph: Grade CFP 0075

Platelets 001 and 003SF

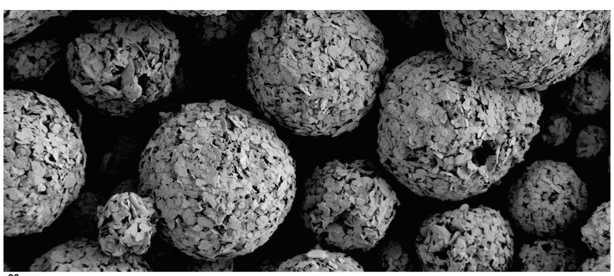
Preferred for thin films <25 µm and fibers, fine channels and windings. CFP 003SF has a controlled top size.



1 µm SEM micrograph: Grade CFP 003SF

Platelets 012P

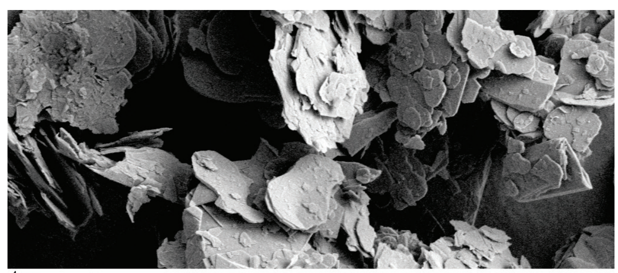
Spray-dried boron nitride platelets for excellent processability, flowability and high dosing velocities for extruded and injection molded parts.



20 µm SEM micrograph: Grade CFP 012P

Platelets 007HS

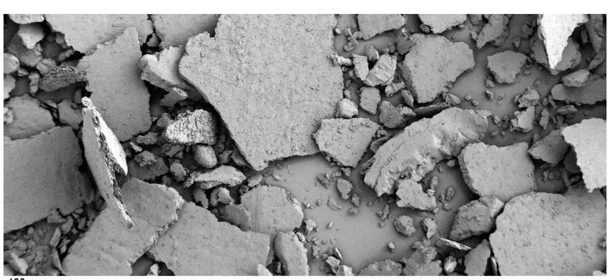
Ideal for thin films <50 µm due to its controlled top size. Highest reflectivity and increased in-plane thermal conductivity in pads.



1 µm SEM micrograph: Grade CFP 007HS

Flakes 500-3 and 200-3

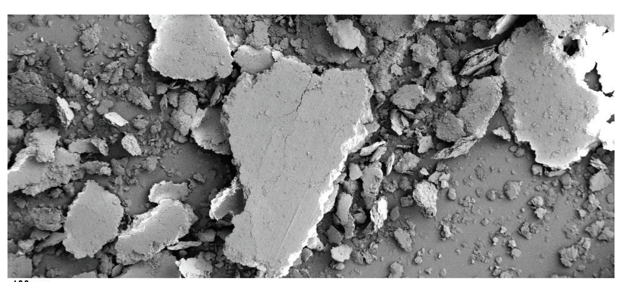
Highest through-plane thermal conductivity. Boosts thermal conductivity of compounds as secondary filler.



100 µm SEM micrograph: Grade CFF 500-3

Flakes 500-15 and 200-15

Preferred for lowest viscosity in epoxies and silicones. High thermal conductivity.



100 µm SEM micrograph: Grade CFF 500-15

3M™ Boron Nitride Cooling Filler Grade Profiles (continued)

Agglomerates 50M

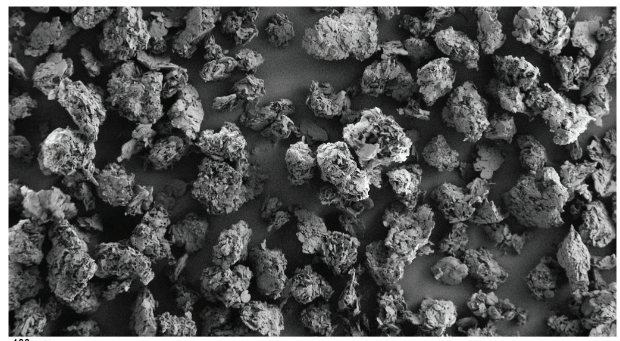
Mix (M) of agglomerates, platelets and boron nitride clusters. Excellent for potting resins and encapsulation of electronic devices.

100 µm

SEM micrograph: Grade CFA 50M

Agglomerates 100

Soft agglomerates for high filler loadings and isotropic thermal conductivities. Used for potting resins and conformable TIM foils or pads with thin bond line 150-200 µm.



100 µm

SEM micrograph: Grade CFA 100

Agglomerates 75

Soft agglomerates for high filler loadings and isotropic thermal conductivities. Used for potting resins and conformable TIM foils or pads with thin bond line 100-150 µm.

100 µm

SEM micrograph: Grade CFA 75

Agglomerates 250S

Boron nitride platelets spray-dried with inorganic binder to spherical (S) granulates for high flowability and dosing velocities during feeding. Ideal for TIM pads.

100 µm

SEM micrograph: Grade CFA 250S

Expert application support.

3M is known throughout the world as a pioneer in advanced ceramics, and has provided the industry with innovative boron nitride for over 50 years. But when it comes to making finished parts, the quality of your raw material is just one piece of the puzzle.

Factors such as melt temperature, compounding technique, injection rate and more can have a significant effect on the thermal and electrical insulative properties of parts made with 3M Boron Nitride Cooling Fillers. That's why our experienced team of materials engineers, product specialists and field application engineers will work closely with you to develop formulations and processes that can help you achieve optimal thermal conductivity and desired performance levels.

Our mission is to help you be successful in the implementation of new product ideas or in the optimization of existing designs using 3M Boron Nitride Cooling Fillers. By taking advantage of our expertise and insights, you can realize the full potential of these materials.

3M.com/thermalmanagement

3M Advanced Materials Division

3M Center
St. Paul, MN 55144 USA

Phone 1-800-367-8905
Web www.3M.com/thermalmanagement

3M Technical Ceramics

Zweigniederlassung der 3M Deutschland GmbH
Max-Schaidhauf-Str. 25, 87437 Kempten, Germany

Phone +49 (0)831 5618-0
Web www.3M.de/bncf