Heat Shrink Comparison & Recovery Guide

Whether insulating critical components or manufacturing medical devices, Zeus' diverse portfolio of heat shrink products helps engineers overcome complex design challenges.

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Need Heat Shrink?
No Problem.

From aerospace and automotive applications to catheter manufacturing and more, Zeus offers a wide range of heat shrink solutions designed to meet a variety of demanding challenges. Our heat shrink tubing is available in multiple resins, sizes, dimensions, and shrink ratios to ensure optimal coverage and protection from extreme heat, corrosion, shock, moisture, and other demanding conditions.

Heat Shrink Products

FluoroPEELZ™: This optically clear, peelable heat shrink is designed to improve the reflow of the catheter jacket – the final step in the catheter construction process. With a simple linear tear, FluoroPEELZ™ peelable heat shrink helps increase yield, improve safety, and simplify catheter construction. FluoroPEELZ™ is available in sizes from neurological builds to AAA profiles.

FEP Heat Shrink: FEP heat shrink is an excellent choice for electrical insulation and can be used as a more efficient replacement for films and tapes in composite manufacturing. Available in 1.3:1, 1.6:1, 2:1, and Lay-Flat™ versions.

PTFE Heat Shrink: PTFE's excellent temperature tolerance up to 500 °F (260 °C), along with its low coefficient of friction and exceptional chemical resistance, make it an ideal choice for a variety of applications. Available in 2:1, 4:1, and Sub-Lite-Wall™ versions. Sub-Lite-Wall™ versions have recovered wall of 0.004" (0.102 mm) and below.

Heat Shrink Products

PEEKshrink™: PEEKshrink™ provides a "shrink-to-fit" layer of protection for sensitive and critical components used in a variety of applications ranging from medical devices to oil exploration equipment. This product is ideal for difficult environments where abrasion, chemicals, or dielectric interference pose a threat to wires and electrical components.

Dual-Shrink™: Dual-Shrink™ heat shrinks are specialized bilayer products designed to fully encapsulate components to lock out moisture and other chemicals. Zeus offers three types of heat shrink in this type of format: Dual-Shrink™ consists of a PTFE outer layer / FEP inner layer. Low Temperature Dual-Shrink™ (LTDS) consists of FEP outer / EFEP inner. High Temperature Dual-Shrink™ (HTDS) consists of PTFE outer / PFA inner.

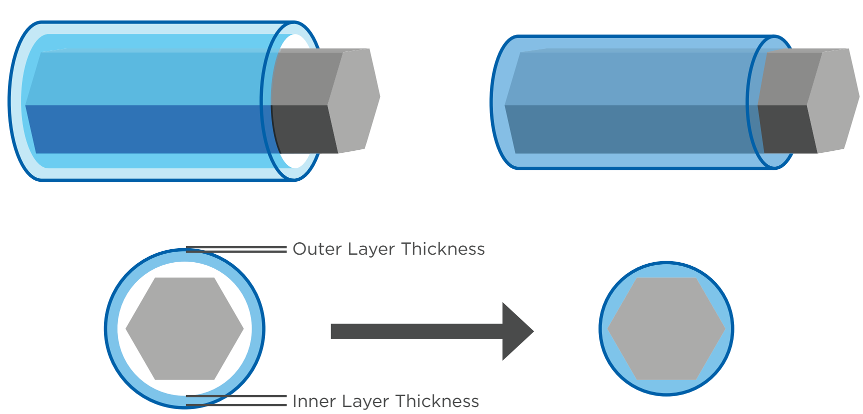
PFA Heat Shrink: PFA combines many attributes of both PTFE and FEP. With a working temperature up to 500 °F (260 °C), low coefficient of friction, and excellent chemical resistance and clarity, PFA is a suitable choice for a multitude of challenging environments.

Heat Shrink Capabilities

Typical heat shrink capabilities are listed below. Contact us to discuss custom sizes, lengths, and shrink ratios.

Material	Operating Temp	Shrink Ratios	Expanded ID Range	Recovery ID Range	Recovered Wall Thickness	Longitudinal Change Range	Recovery Temperature	Dielectric Strength (V/Mil)
PTFE	500 °F (260 °C)	Up to 4:1	0.034"-4.00" (0.863 mm - 101.6 mm)	0.015" - 1.025" (0.381 mm - 26.035 mm)	0.006" - 0.025" (0.152 mm - 0.635 mm)	± 20%	650 °F ± 50 °F (343 °C ± 10 °C)	600V/Mil
PTFE Sub-Lite-Wall™	500 °F (260 °C)	Up to 2:1	0.012" - 0.375" (0.305 mm - 9.525 mm)	0.005" - 0.187" (0.127 mm - 4.750 mm)	0.002" - 0.005" (0.051 mm - 0.127 mm)	± 20%	650 °F ± 50 °F (343 °C ± 10 °C)	600V/Mil
FEP	400 °F (205 °C)	Up to 2:1	0.025" - 2.000" (0.635 mm - 50.8 mm) *≥ 1.8:1 ratio: 0.034" - 0.385"* *≥ 1.8:1 ratio: 0.864 mm - 9.779 mm*	0.020" - 1.250" (0.508 mm - 31.75 mm) *≥ 1.8:1 ratio: 0.017" - 0.192"* *≥ 1.8:1 ratio: 0.432 mm - 4.877 mm*	0.003" - 0.030" (0.076 mm - 0.762 mm) *≥ 1.8:1 ratio: 0.010" - 0.013"* *≥ 1.8:1 ratio: 0.254 mm- 0.330 mm*	± 15%	420 °F ± 50 °F (216 ° ± 10 °C)	2000V/Mil
FEP Lay-Flat™	400 °F (205 °C)	Up to 1.6:1	0.400" - 5.000" (10.16 mm - 127 mm)	0.250" - 3.180" (6.35 mm - 80.772 mm)	0.002" - 0.020" (0.051 mm - 0.508 mm)	±15%	420 °F ± 50 °F (216 ° ± 10 °C)	2000V/Mil
FluoroPEELZ™	400 °F (205 °C)	Up to 2:1	0.015" - 0.500" (0.381 mm - 12.7 mm)	0.010" - 0.385" (0.254 mm - 9.779 mm)	0.008" - 0.018" (0.203 mm - 0.457 mm)	± 15%	420 °F ± 50 °F (216 ° ± 10 °C)	2000V/Mil
PFA	500 °F (260 °C)	Up to 1.6:1	0.025" - 2.000" (0.635 mm - 50.8 mm)	0.020" - 1.250" (0.508 mm - 31.75 mm)	0.004" - 0.020" (0.102 mm - 0.508 mm)	± 15%	410 °F ± 50 °F (210 °C ± 10 °C)	2000V/Mil
PEEKShrink™	500 °F (260 °C)	Up to 1.4:1	0.038" - 0.392" (0.965 mm - 9.957 mm)	0.027" - 0.280" (0.686 mm - 7.112 mm)	0.005" - 0.009" (0.127 mm - 0.229 mm)	TBD	650 °F - 725 °F (343 °C - 385 °C)	3500V/Mil
Dual-Shrink™ (PTFE/FEP)	400 °F (205 °C)	1.3:1 to 1.4:1	0.036" - 1.000" (0.914 mm - 25.4 mm)	0.000" - 0.700"* (0.000 mm - 17.78 mm)	N/A - 0.065"* (N/A - 1.651 mm*)	± 20%	650 °F ± 50 °F (343 °C ± 10 °C)	2000V/Mil
LTDS (FEP/EFEP)	302 °F (150°C)	1.3:1 to 1.4:1	0.046" - 0.413" (1.168 mm - 10.490 mm)	0.000" - 0.250"* (0.000 mm - 6.35 mm)	N/A - 0.059"* (N/A - 1.499 mm*)	± 20%	410 °F ± 50 °F (210 °C ± 10 °C)	N/A
HTDS (PTFE/PFA)	500 °F (260 °C)	1.3:1 to 1.4:1	0.036" - 0.875" (0.914 mm - 22.225 mm)	0.000" - 0.250"* (0.000 mm - 6.35 mm)	N/A - 0.065"* (N/A - 1.651 mm*)	± 20%	650 °F ± 50 °F (343 °C ± 10 °C)	N/A

** When heated, Dual-Shrink™'s outer layer shrinks tightly while the inner layer melts and flows into a solid or near-solid encapsulation, as seen in the illustration below. The recovered ID and recovered wall are dependent on the reflowed material and geometry of the substrate.*

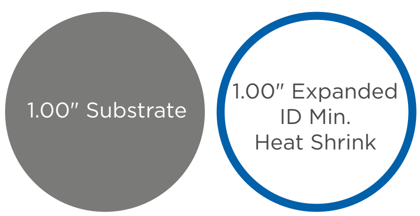


Understanding Expanded and Recovered IDs

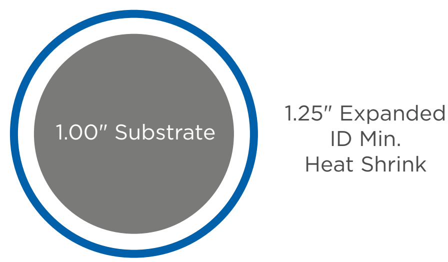
All heat shrink products are supplied in their expanded (non-recovered) state. As heat is applied, the product shrinks down to what is known as its recovered state. When sizing heat shrink, it is critical to understand the differences between these two states (expanded vs. recovered), and how the inside diameter of heat shrink is specified accordingly.

The **"Expanded ID Min."** specification is the starting point for all heat shrink sizing considerations. The Expanded ID Min. describes what the minimum inside diameter of the heat shrink will be in its expanded (pre-shrunk) state. If the Expanded ID Min. is not chosen correctly, the heat shrink will not fit over the substrate you wish to cover.

As an example, if you wish to recover heat shrink over a 1.00" diameter substrate, then the Expanded ID Min. must be **GREATER** than 1.00". For a heat shrink with a 1.3:1 ratio, an Expanded ID Min. of 1.25" would be suitable.



The ID of the heat shrink is the same as the OD of the substrate. The Heat Shrink will not fit over the substrate.



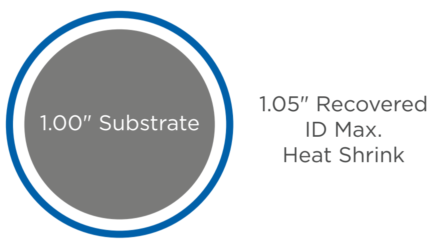
The ID of the heat shrink is larger than the OD of the substrate. The heat shrink fits comfortably over the substrate.

Note: When receiving heat shrink, it is not uncommon for the actual measured ID of the heat shrink to slightly exceed the Expanded ID Min specified. For instance, you may order heat shrink with an Expanded ID Min. of 1.25", and upon inspection, you may find the expanded ID measures 1.27". This product would be considered in-spec as it is above the minimum specified value of 1.25".

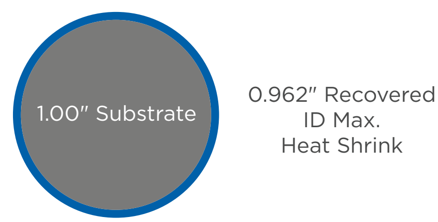
Understanding Expanded and Recovered IDs

After ensuring the unrecovered heat shrink will fit over the substrate, the next consideration is the **“Recovered ID Max.”** The Recovered ID Max. describes what the maximum inside diameter of the heat shrink will be in its recovered (shrunk) state. If the Recovered ID Max. is not chosen correctly, the material may not shrink down completely, leaving a gap between the inner diameter of the heat shrink and the outer diameter of the substrate.

As an example, if you wish to recover heat shrink over a 1.00” diameter substrate, the Recovered ID Max. specification must be **LESS** than the diameter of the substrate. In this example, the Recovered ID Max should be less than 1.00” to ensure that the heat shrink product will recover down to the underlying substrate and offer a tight fit. For a heat shrink with a 1.3:1 ratio, the desired Recovered ID Max. will be around 0.962”.



The fully recovered heat shrink has an ID that exceeds the OD of the substrate, leaving a gap.



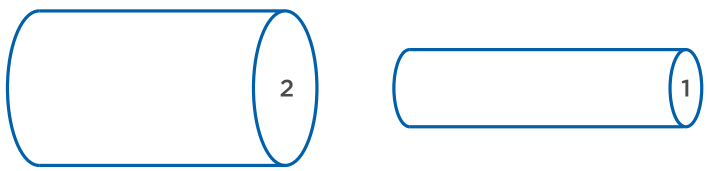
The fully recovered heat shrink has an ID that is less than the OD of the substrate, ensuring it recovers tightly with no gap.

Note: When receiving heat shrink, it is not uncommon for the actual measured recovered ID of the heat shrink to be lower than the Recovered ID Max specified. For instance, you may order heat shrink with a Recovered ID Max. of 0.962”, and after unconstrained recovery, you may find the recovered ID measures 0.950”. This product would be considered in-spec as this recovered ID is below the maximum specified value of 0.962”.

Understanding Heat Shrink Ratios

Beyond Expanded ID Min. and Recovered ID Max., the **"Shrink Ratio"** of the product is another important consideration when sizing heat shrink. The shrink ratio refers to the final inner diameter of the heat shrink, after being allowed to shrink fully unrestrained, compared to its original pre-shrunk diameter. After shrinking is complete, the material is considered to be in its "recovered" or "recovery" state.

As an example, for a heat shrinkable product with a 2:1 ("2-to-1") shrink ratio, the final diameter of the fully shrunk product will be reduced to 1/2 that of the pre-shrunk diameter. Or, put another way, the diameter of the pre-shrunk product will be 2× the diameter of the fully shrunk product. The ratio of their diameters, *pre-shrunk:fully shrunk*, will be 2:1.

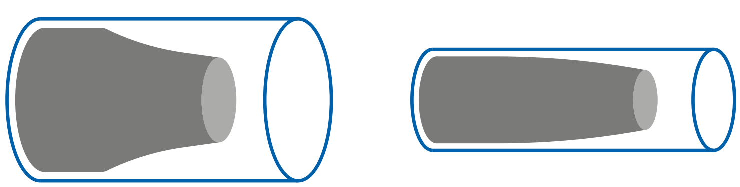


Pre-shrunk (un-recovered) Fully shrunk (fully recovered)

Note that in practical application, heat shrink is applied over a component to encapsulate it. In doing so, the heat shrink is somewhat restricted from being shrunk completely due to the underlying substrate.

When recovered over a component, the substrate prevents (restricts) the heat shrink from shrinking completely.

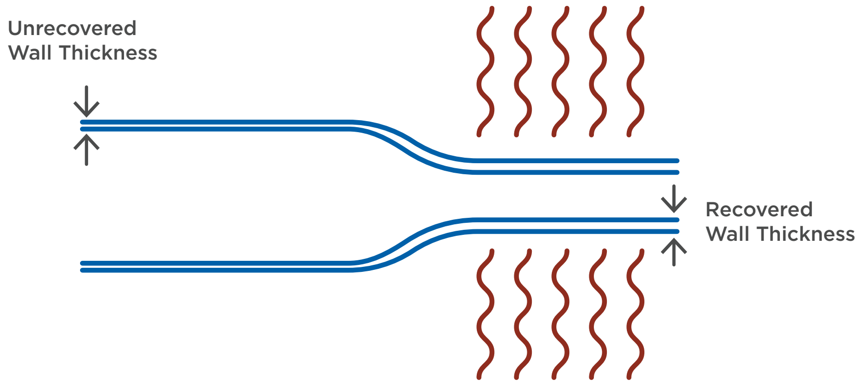
Heat shrink ratio is a fundamental consideration for every application based on the degree of non-uniformity of the items or components to be covered. The more irregular the shape, the greater the heat shrink ratio needed to adequately cover the shape. For more uniform parts such as cylinders or wires, smaller heat shrink ratios are generally sufficient to achieve proper coverage. Consideration should also be given to tapered parts. While appearing generally uniform in shape, the degree of taper should be taken into account when selecting heat shrink and its shrink ratio.



Irregular shapes and agressive tapers require a higher shrink ratio. More gradual tapers may not need as high of a shrink ratio.

Understanding Wall Thickness

Since heat shrink is provided in its unrecovered state, the wall thickness of the tube is subject to change throughout the recovery process. As such, wall thickness is specified as **"Recovered Wall Thickness."** Recovered Wall Thickness describes the thickness of the walls after complete unconstrained recovery of the heat shrink.

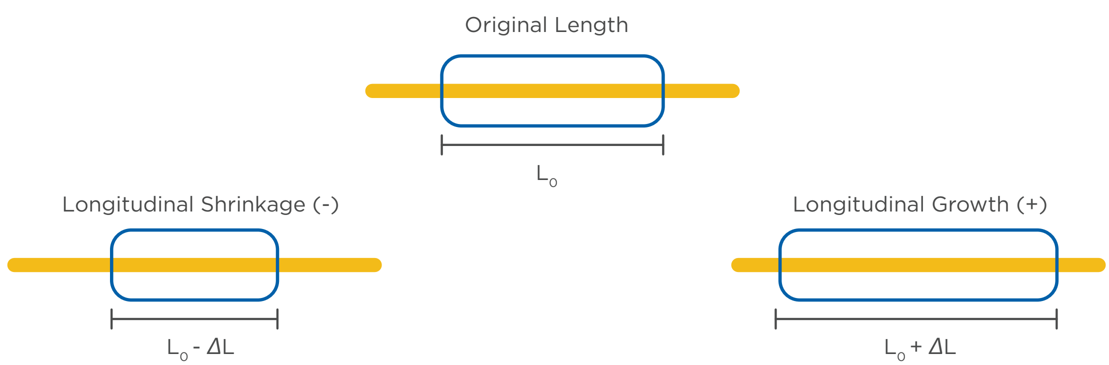


As heat is applied and the tube begins to shrink, the wall thickness of the heat shrink tubing will increase.

Understanding Longitudinal Change

Longitudinal change is an inherent characteristic of all heat shrinks during the recovery process. The change in length of the heat shrink can be either positive (growth) or negative (shrinkage). In most cases, the longitudinal change is minimal and presents as shrinkage rather than elongation.

Longitudinal Change, % = ΔL *(length change) /* L_o *(original heat shrink tubing length) x 100*



There are many factors that may help mitigate longitudinal change, such as the substrate OD, the polymer used, the recovery process, and application. Please contact your Zeus team for more detailed information on minimizing longitudinal change.

Understanding Heat Shrink Recovery Methods

There are many methods in which heat shrink can be recovered, and depending on your specific application, one method may work better for you than another.

Typically, recovery methods include:

- Heat Gun
- Hot Box
- Forced Air (Vertical Laminator)
- Radiant Heating
- Convection Oven
- Laser

Ovens and vertical laminators are typically regarded as some of the most reliable and consistent ways to recover heat shrink products due to their ability to ensure even heating while reducing the risk of overheating the material, which can lead to brittleness and cracking, as well as the destruction of the underlying part or component.

Heat guns, on the other hand, may be less consistent due to the rapid dissipation of heat at the nozzle. It is often required for a heat gun fitted with a reflector baffle to be set to a temperature significantly higher than the reflow temperature (or even melting temperature) of the material to account for this rapid heat dissipation.

PEEK, for instance, melts at 650 °F (343 °C) and its heat shrink recovery temperature is very near this same temperature. In tests performed by Zeus using a Steinel HG 2310 LCD heat gun fitted with a reflector baffle, it was required to set the temperature to 850 °F (454 °C) – well above PEEK's melting point – in order to achieve airflow temperatures ranging from 640 °F (338 °) to 700 °F (371 °C) at the reflector baffle where the heat shrink recovery would occur. At these temperatures, it is a fine line between complete heat shrink recovery and melting the product.

Recovery Method	Heat Source	Typical Usage	Heat Focus	Consistency/ Repeatability	Must Control	Benefits
Heat Gun	Hot Air Stream	R&D	●○○○○	●○○○○	Temperature Location Within Air Stream	Cost Effective
Hot Box	Hot Air Stream	R&D	●●○○○	●○○○○	Temperature Air Flow Rate Position Within Heat Zone	Cost Effective
Forced Air (Vertical Laminator)	Controlled Heated Air	Production	●●●●●	●●●●●	Temperature Air Flow Rate Position Within Chamber Traverse Speed	Consitent Batch Processing
Radiant Heating	Controlled Heated Air	Production	●●●●●	●●●●●	Temperature Air Flow Rate Position Within Chamber Traverse Speed	Consitent Batch Processing
Convection Oven	Radiant Heat/ Convection	Production	●●●○○	●●●●○	Temperature Time	Supports Volume
Laser	Laser Radiation	Production	●●●●●	●●●●●	Requires pigment (e.g. black)	Precision

Understanding How Zeus Inspects Outgoing Heat Shrink

Zeus performs routine testing on heat shrink products to ensure that outgoing product meets the correct recovery dimensions requested by the customer.

Unless otherwise specified, oven temperatures for **unrestricted shrinkage** are as seen in the table below. The heat shrink is recovered for 10 minutes after the defined oven temperature is achieved. Dimensions are recorded and measured pre-recovery (Expanded ID min), and post-recovery (Recovered ID and Recovered Wall Thickness)

Material	OD*	Oven Temp °F	Oven Temp °C
FEP or PFA	≤ 1 inch	400 - 420°F	204.4 - 215.6°C
FEP or PFA	>1 inch	420 - 440°F	215.6 - 226.7°C
PTFE	All	654 – 670°F	345.6 – 354.4°C
Dual-Shrink™	All	654 - 670° F	345.6 - 354.4°C
Low-Temp Dual-Shrink™	All	420 - 440°F	215.6 - 226.7°C

**Pre-recovered OD is calculated as pre-recovered ID + 2x pre-recovered wall.*

Unless otherwise specified, oven temperatures for **restricted shrinkage** are as seen in the table below. The heat shrink is recovered for 10 minutes after the defined oven temperature is achieved. When a restricted recovered wall is specified, the recovered wall thickness is determined by measuring the OD of the recovered sample, subtracting the OD of the pin gauge or mandrel used for the restricted recovery, and dividing by two. This is because, in general, it is very difficult to remove the restricted recovery sample in a way as to measure the walls directly. For example, a heat shrink may be specified with a recovered ID of 0.210” maximum and 0.025” nominal wall. If the heat shrink is recovered on a 0.210” pin gauge, and the OD is measured to be 0.260”, then the recovered wall is reported as (0.260” - 0.210” = 0.50”)/2 = 0.025”.

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**Pre-recovered OD is calculated as pre-recovered ID + 2x pre-recovered wall.*

General Heat Shrink Recovery Guidelines

Caution: Fumes may cause nausea and dizziness. Always ensure you have good ventilation in the immediate working area prior to beginning the heat shrink recovery process.

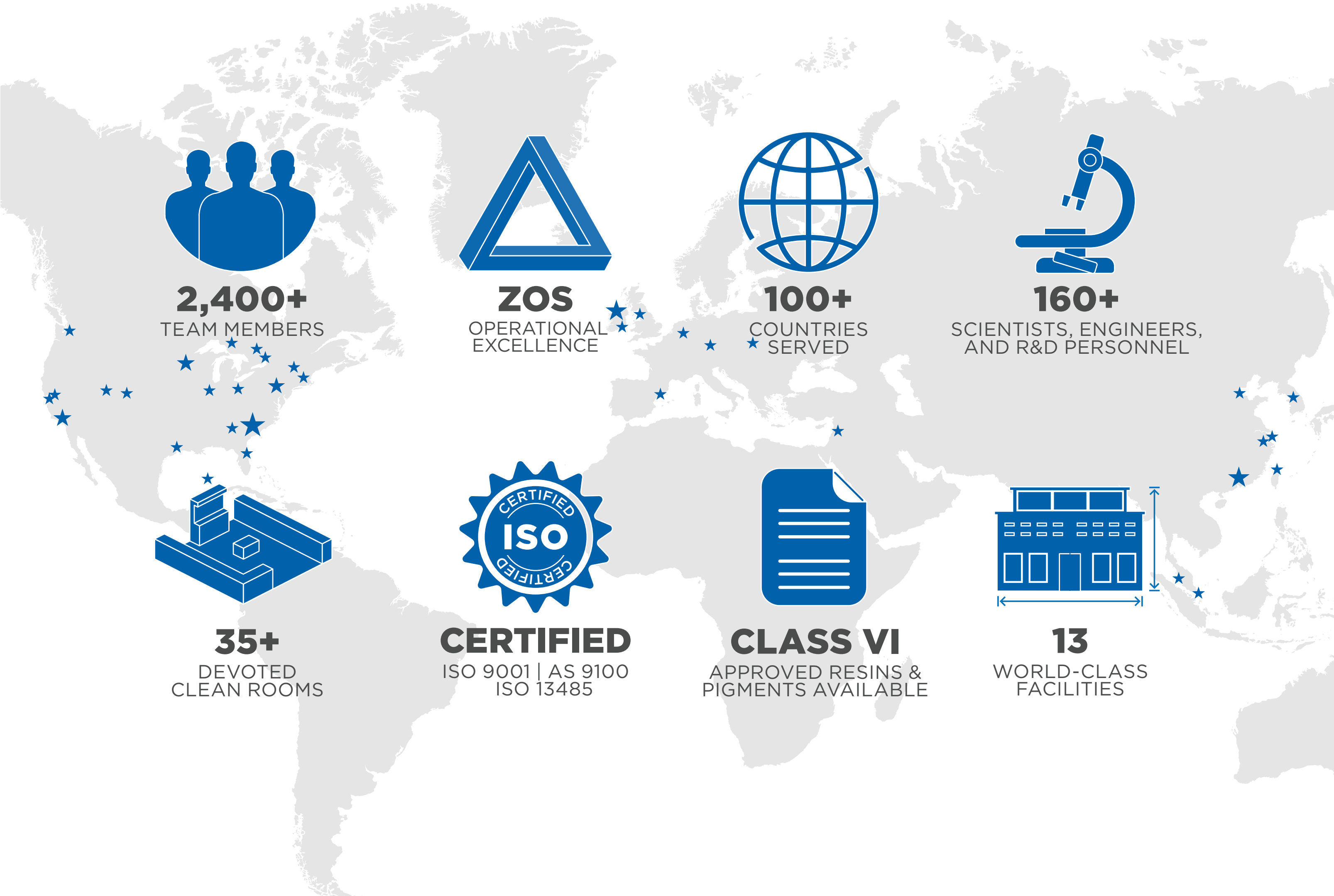
- Refer to the Heat Shrink Capabilities table on page 3 of this guide to determine the approximate recovery temperature of your specific heat shrink material.
    - o **Note:** Actual shrink temperatures may vary based on dimensions and wall thickness of the tubing, methods of application, traverse speed, and other factors.
- The mandrel (part/component) to be covered by the heat shrink must be able to tolerate the range of heat shrink temperature.
- The mandrel (part/component) may act as a heat sink, which may cool the heat shrink prematurely or require more time to reach the necessary temperature. Preheating larger diameter mandrels (parts/ components) may help.
- Generally, heat shrink should be allowed to recover to a minimum of 20%. You may experience some slight longitudinal change depending on the amount of recovery. Highly restrictive radial recovery may enhance the tendency to split
- Even heating and cooling of all sides provides the best results. Uneven heating or cooling tends to wrinkle or split the heat shrink if not uniformly heated.

Troubleshooting

When dialing in your heat shrink recovery process, you may experience one or more of the following issues. Refer to the table below for some troubleshooting tips.

ISSUE	POTENTIAL CAUSES
Bubbles after reflow	- Expanded ID too large – clearance between the heat shrink and underlying component is trapping air - Moisture in the underlying component
Braid read-through	- Heat shrink provides too much compression - Reflow temperature too high - Jacket extrusion too thin
Heat shrink splits	- Reflow temperature too high - Heating uneven - Recovered ID too small - Flaw in the heat shrink wall - Poor sizing
ID is undersized	- Heat shrink may have partially recovered – check package temperature indicators
Slow to recover	- Larger Expanded IDs (such as FEP >1"), or thicker walls may require additional heat/time to begin recovery. - Option to increase dwell time - Increase in increments of 10° C until preferred recovery is reached

Get to know Zeus.



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PROVIDE SOLUTIONS · ENABLE INNOVATION · ENHANCE LIVES

Zeus, headquartered in Orangeburg, South Carolina, is the world's leading polymer extrusion and catheter design manufacturer. With over 55 years of experience in medical, aerospace, energy, automotive, fiber optics, and other leading industries, Zeus's mission is to provide solutions, enable innovation, and enhance lives. The company employs over 2,400 people worldwide with facilities in Aiken, Columbia, Gaston, Orangeburg, and St. Matthews, South Carolina; Branchburg, New Jersey; Chattanooga, Tennessee; San Jose, California; Arden Hills, Minnesota; Guangzhou, China; and Letterkenny, Ireland. For more information, visit *www.zeusinc.com.*

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