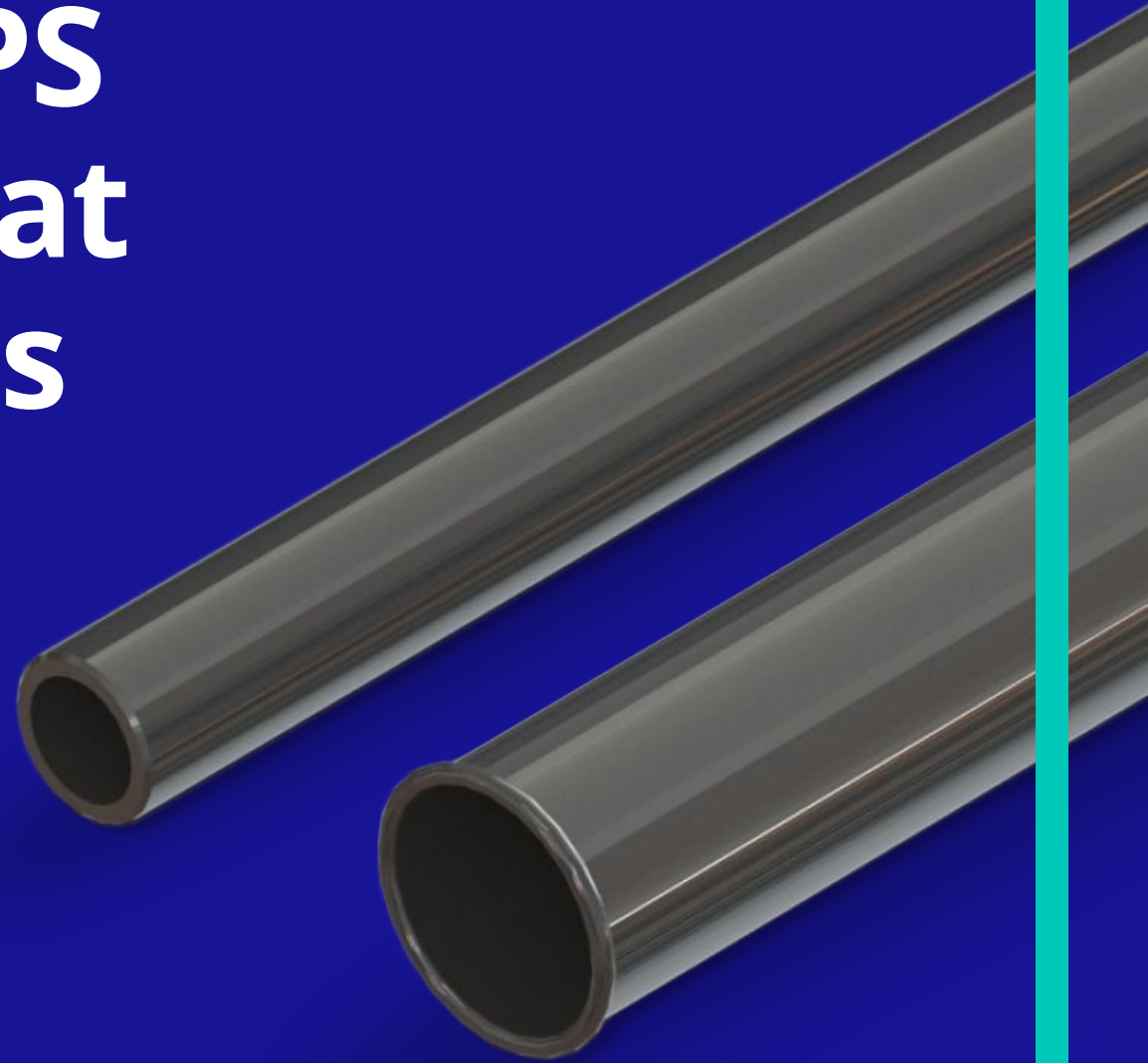


Operation manual for PPS Graphite – Heat Transfer Tubes



The information contained in this manual is provided in good faith and from sources believed to be reliable and accurate. The guidelines and procedures described herein are intended solely as recommendations designed to maximize the use and service life of PPS-GR heat transfer tubes. It is important to note that these are suggestions and should not be construed as binding instructions. Users should use their own judgment and consult additional resources or experts as needed to adapt these recommendations to specific circumstances or requirements.

| Rev. | Date | Prepare | Review | Release |
|------|------------|----------|-------------|---------|
| 02 | 02.09.2024 | Schiffer | Lenitscheck | Orth |

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1. Introduction

Welcome to the operational manual for the PPS-GR heat transfer tubes. This manual is designed to provide you with detailed guidelines for the safe handling, effective installation, and optimal use of Technoform's innovative PPS-GR heat transfer tubes. By adhering to the recommendations provided herein, you can maximize both the performance and the lifespan of these high-quality components.

1.1 About Technoform

Technoform is a global leader in precision engineering with a strong commitment to innovation and sustainability. Specializing in high-performance plastic solutions, Technoform aims to enhance efficiency and performance across a wide range of industries. Our solutions are crafted with precision and care, meeting the highest standards of quality and reliability.

1.2 PPS-GR heat transfer tubes

The PPS-GR heat transfer tubes represent a significant advancement in the field of thermal management. Constructed from a specialized polyphenylene sulfide graphite-reinforced (PPS-GR) compound, these tubes offer exceptional performance under corrosive conditions and temperatures up to 250°C. The key attributes of PPS-GR tubes include:

- **High chemical resistance:** Resilient against nearly all types of fluids, the PPS-GR compound provides reliable performance in aggressive environments.

- **Superior thermal conductivity:** Designed to facilitate efficient heat transfer, enhancing system performance.
- **Robust pressure resistance:** Engineered to withstand high pressures, ensuring durability and safety even under rigorous operating conditions.

These tubes are primarily used in applications such as heat exchangers, where their advanced properties can be fully utilized to improve energy efficiency and reduce operational costs.

1.3 Purpose of this manual

This manual serves as a comprehensive guide for handling, installing, operating, and maintaining Technoform's PPS-GR heat transfer tubes. Compiled with the utmost expertise and dedication, the recommendations herein are provided to assist you in achieving the best possible outcomes with our products. Please note that the procedures and guidelines detailed in this document are intended as recommendations based on our current knowledge and experience.

We trust that this manual will be an invaluable resource for your operations, ensuring that you benefit from the full potential of Technoform's PPS-GR heat transfer tubes.



2. Quality Management

This chapter outlines the comprehensive quality management strategies implemented by Technoform to ensure the highest standards of quality and compliance in the manufacture and delivery of PPS-GR tubes for heat exchangers. Our commitment to excellence ensures our products meet the specific needs of heat exchanger manufacturers and operators, adhering to stringent industry standards and customer expectations.

Quality assurance and compliance

Technoform maintains a rigorous quality control system, documented in our Quality Control Manual, which aligns with the ASME Boiler & Pressure Vessel Code, Section VIII, Division 1. Our facility is authorized to fabricate parts marked with the ASME Certification Mark and PRT designator, ensuring that each component meets all necessary safety and performance criteria.

Laser marking:

Each tube is laser-marked for easy and clear identification:

- **Marking format:**

TECHNOFORM CW/YEAR TRSG322001 EOXXXX XXXX

- CW - Calendar week
- YEAR – Calendar year
- TRSG322001 - Article Number
- EOXXXX - Extrusion Order / Lot Number
- XXXX - Tube serial number

Article number explanation:

- **TRSG322001** is the article number broken down as follows:
 - T - Thermal application
 - R – Profile shape
 - R Round tube shape
 - F Flat tube shape
 - S – Polymer
 - S Made of PPS (Polyphenylene Sulfide)
 - P Made of PP (Polypropylene)
 - G – Filler
 - G Graphite
 - F Glass fibers
 - 32 - Outer diameter in mm
 - 20 - Wall thickness in 2.0 mm
 - 01 - Finishing code where:
 - 00 indicates no finishing
 - 01 indicates both tube ends chamfered
 - 02 indicates one tube end hot molded and one tube end chamfered

This system ensures traceability and accountability throughout the tube's lifecycle, from production and delivery to end of life.



Documentation for quality assurance

Each delivery of PPS-GR tubes is accompanied by the following documents to ensure transparency and traceability:

- **Article Drawing:** Detailed schematics of the tubes, providing essential specifications and design parameters.
- **Test Report:** In compliance with EN10204 (types 2.2, 3.1, or 3.2), these reports outline the results of material and product testing, confirming adherence to quality and safety standards. The test report includes tests for:
 - Material Specification:
 - Hydrostatic burst pressure
 - Surface quality
 - Dimensional Specification:
 - Outer diameter
 - Wall thickness
 - Roundness
 - Deflection
 - Length
- **Declaration of Conformity:** This document certifies that the delivered PPS-GR tubes comply with all relevant EU regulations and standards, ensuring their quality and safety for use in heat exchangers.

Monitoring and Improvement

Our quality management system is designed to continuously monitor the manufacturing process and implement improvements where necessary. This proactive approach includes regular audits, both internal and by external inspectors, and comprehensive training for all staff involved in the manufacturing process.

Ensuring Material Quality and Specification

We employ strict controls over the raw materials used in our manufacturing processes, with detailed records maintained for each batch of material. These records include Certificates of Analysis (COA) that confirm the material's compliance with specified standards.

Commitment to Customer Satisfaction

Technoform is dedicated to ensuring the satisfaction of all customers by delivering products that meet both the specified technical requirements and the high standards of quality and reliability expected in the industry. Our quality management practices are integral to our mission of providing superior heat transfer solutions across global markets.



Supplementary documentation for quality assurance of pressure equipment

Important documents that accompany every PPS-GR tube delivery, with a focus on the integrity of pressure equipment.

ASME Documents: Specific documents required for customers under ASME standards, ensuring compliance and eligibility for use in pressure vessel components.

- **CMTR (Certified Material Test Report):** Specifies material properties as per ASME BPVC VIII.1 table UIG-6-1 'Compound material' and Code Case 3041. Specifications covered include
 - Compressive strength
 - Tensile strength
 - Tensile Modulus
 - Tensile strength at maximum material temperature
 - Tensile Modulus at maximum material temperature
 - Coefficient of thermal expansion
 - Coefficient of permeability
- For every new batch of compound tube material, a simplified CMTR is conducted, testing:
 - Compressive strength
 - Tensile strength at room temperature

Manufacturers Supplementary and Manufacture's Partial Data Report (MPDR form U-2a / MSDR form U-1b):

- These reports are certified by the Quality Control Manager (QCM) following final inspection and presented to the Authorized Inspector (AI) for review. Upon AI approval, the ASME Certification Mark is applied to the name plate on the container/packing unit of tubes.

Note:

ASME documents can be provided only upon request prior to the production of compound tube material. Customers must specify their need for these documents during the order process to ensure compliance and documentation readiness.



3. Transport and Storage

Transportation Guidelines:

To ensure the safe transportation of PPS-GR heat transfer tubes:

- **Avoid contact with sharp edges:** Ensure that no sharp edges come in contact with the tubes during transport.
- **Prevent tube dropping:** Dropping the shipment, applying weight directly on the tubes or walking on the tubes can cause significant damage and should be strictly avoided.
- **Use protective containers:** Technoform's shipments include containers protected from all sides, ensuring additional safety during transit.

Handling Damage:

- **Initial inspection:** Conduct a visual inspection upon delivery. If there are signs of damage, such as cracks or holes, do not proceed with installation.
- **Handling shattered or broken PPS-GR tubes:** In case a PPS-GR tube is accidentally dropped and breaks or shatters, it is important to note that the broken parts are not sharp. Therefore, these fragments can be safely touched and collected without the need for protective gloves. However, these damaged parts should not be used and must be handled according to disposal regulations.
- **Reporting damage:** Report any damage immediately to the supplier for further instructions or replacement.

Handling Instructions:

- **Single worker handling:** Tubes up to 4 meters in length can be handled by one worker.
- **Multi-worker handling:** For tubes longer than 4 meters, handling by two workers is recommended to ensure safety.
- **Careful handling:** Avoid dropping the tubes or allowing them to contact hard surfaces. Always handle with care to prevent damage.

Storage Conditions:

- **Temperature and humidity:** There are no specific temperature or humidity limitations for the storage of PPS-GR tubes.
- **Protective layering:** Store the tubes on a protective layer such as cardboard or air cushion foil to prevent damage.
- **Stacking tubes:** Tubes can be stacked up to 15 layers. Avoid stacking further as additional layers can damage the tubes at the bottom.

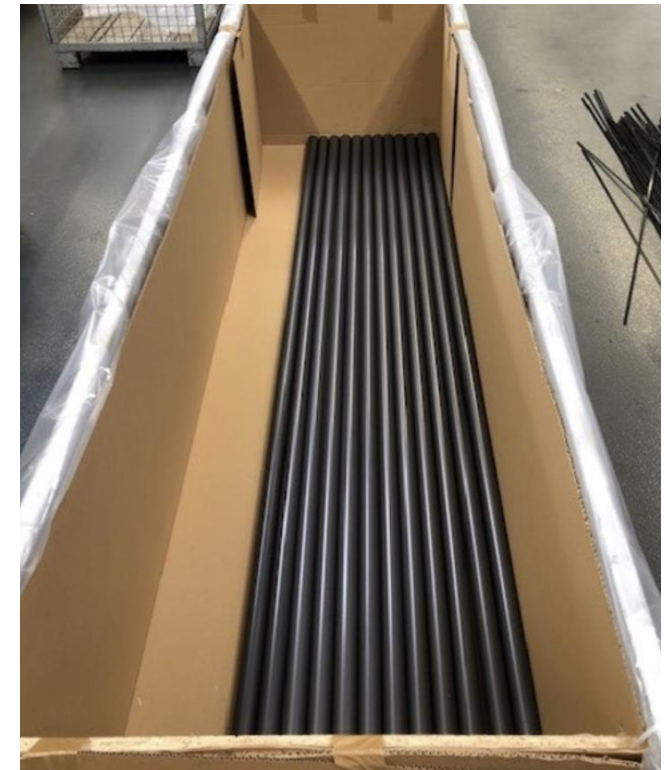
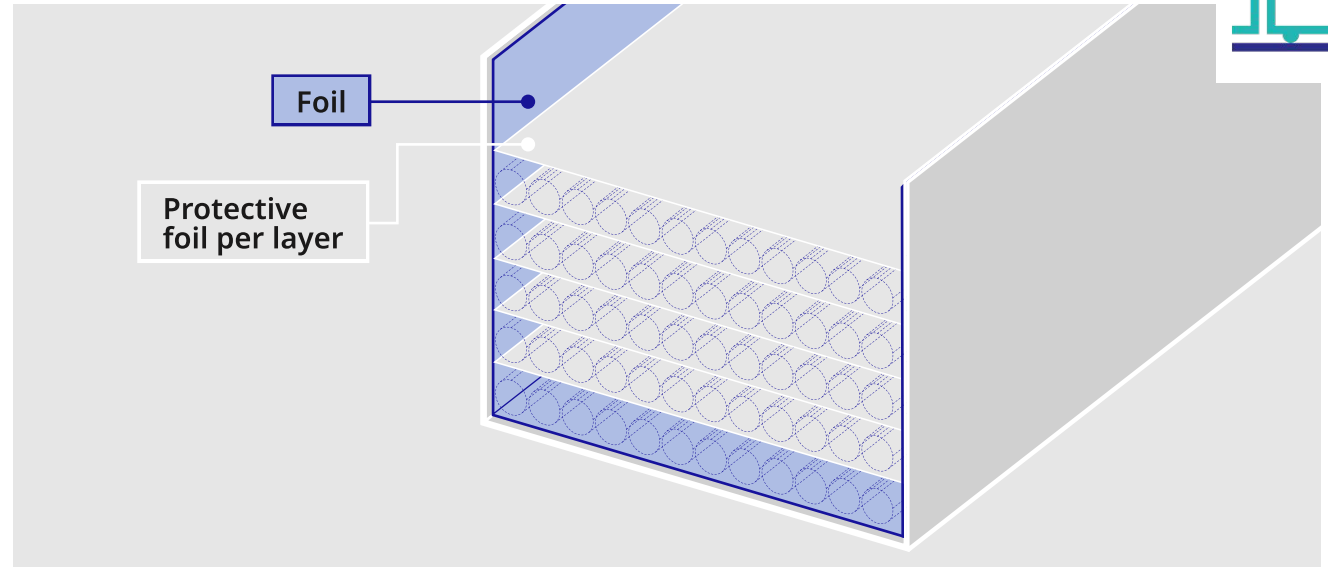
Long-Term Storage:

- **Protective foil:** While not mandatory, using a protective foil between tube layers, similar to the bottom layer, is recommended for added safety during extended storage.

Do's and Don'ts:

- ✓ **Do:** Use the protective packaging provided, handle tubes carefully, and store with protective layering.
- ✗ **Don't:** Drop the tubes, stack beyond 15 layers, or expose to sharp edges.

By following these guidelines, the integrity and usability of PPS-GR heat transfer tubes can be maintained, ensuring they are in optimal condition for installation and use. Always prioritize safety and preservation in all transportation and storage processes.





4. Installation

This section outlines the recommended procedures for the proper installation of PPS-GR tubes with O-ring and rubber grommet sealing. Ensuring correct installation is crucial for achieving optimal performance and longevity of the heat transfer system.

General Recommendations on Sealing Types and Material Selection

Sealing Pressure Limits

- **Grommets:** Recommended for applications with pressure requirements up to 16 bar.
- **O-rings:** Suitable for higher pressure applications, up to 40 bar.

Material selection based on temperature

- **EPDM:** Ideal for temperatures up to 130°C, offering excellent resistance to water and steam.
- **FKM:** Appropriate for temperatures up to 200°C, with good chemical resistance.
- **PTFE or FFKM:** Best for the highest temperature range up to 250°C, providing superior chemical and heat resistance.

These material and type choices are crucial for ensuring the integrity and functionality of the seals in various operating conditions.

Installation of Tubes with O-Ring Sealing

Preparation

1. O-Ring groove and borehole design:

Work closely with Technoform's heat transfer solutions support team to design the O-ring grooves and borehole. Take into account the tolerances of the PPS-GR tubes and O-rings and ensure chamfering of sharp edges at the entry of the borehole and groove edges to prevent damage during installation.



[Learn more](#)

Installation Steps

2. **Lubrication:** Prior to installation, immerse the O-rings in a bath of soap water and spray the PPS-GR tubes with soap water to ease the installation process. Silicon-based greases may also be used as an alternative lubricant.
3. **Inserting the tubes:** Gently insert the lubricated tubes into the designed boreholes with the O-rings in place. Avoid using excessive force or hammering, as this can cause damage to the tubes.

Post-Installation

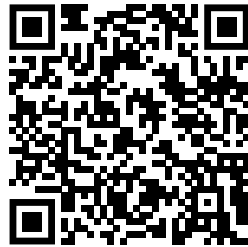
4. **Verification:** Ensure that each tube is properly sealed and positioned correctly. Follow the detailed sketches and step-by-step procedures provided in the manual and accessible via QR-code linking to an installation video on our website.



Installation of tubes with grommet sealing

Preparation

1. **Borehole design:** Similar to the O-ring setup, coordinate with Technoform to design the boreholes according to recommended specifications. No grooves or chamfering are necessary for grommet sealing, because of overall protection by the grommet.



[Learn more](#)

Installation Steps

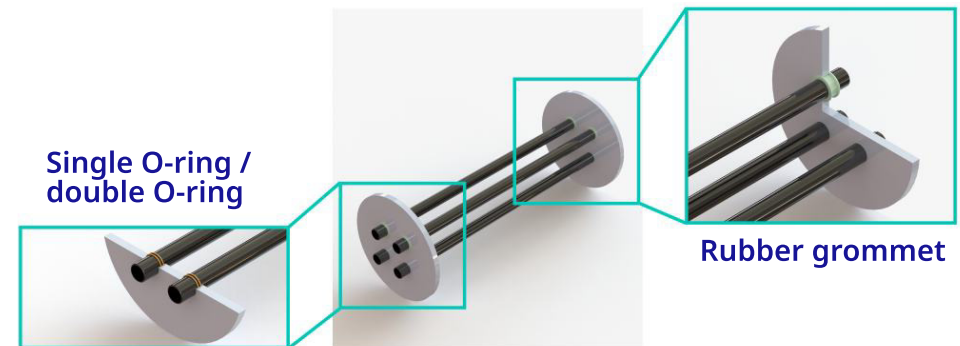
2. **Lubrication:** As with O-ring sealing, lubricate the grommets and tubes with soap water or a suitable silicone-based grease.
3. **Inserting the tubes:** Place the grommets in the boreholes and carefully insert the tubes. Ensure that there is no undue pressure that might harm the tubes.

Post-Installation

4. **Checking the seals:** Confirm that all tubes are securely sealed and positioned as per the installation guidelines. Utilize the resources provided, including visual aids on the website for additional guidance.

General Precautions

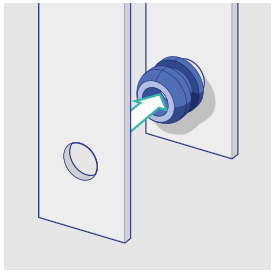
- **Handling:** Always handle the PPS-GR tubes with care during the installation process. Avoid any actions that may exert excessive force on the tubes.
- **Tools:** Do not use any tools that could impact the tubes forcefully, such as hammers or push rods.



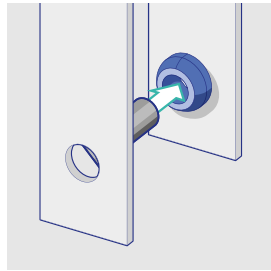
Source: Shinhan



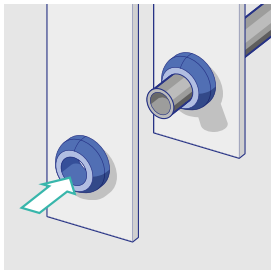
How to proceed:



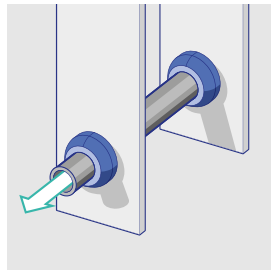
1. Plug grommet into plate.



2. Push tube through rubber grommet.



3. Insert second grommet.



4. Push tube back.
Done!

Tube finishing options:



Chamfering

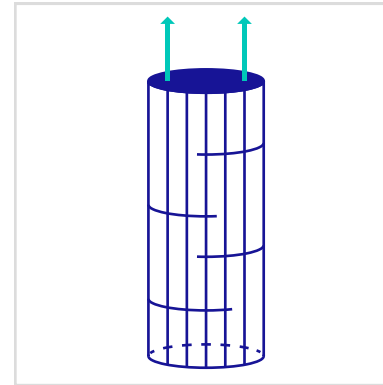


Collar

Collar for vertical installation of tubes to prevent slipping

Handling of graphite compound tube bundles

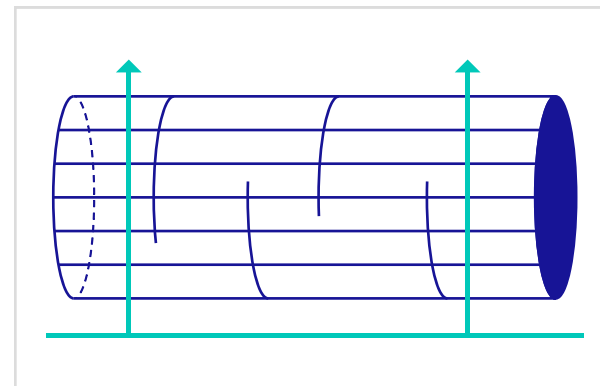
Vertical lift of tube bundle - no support is needed.



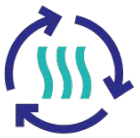
- Only use defined lifting points on tube sheet or tie rods!
- Don't apply force to tubes
- Avoid any Impact!
- If tube bundle is in shell no special handling is required
- The PPS-GR tubes are not designed for an axial load, instead the axial forces are supported via tie rods or housings.

If handled outside the shell please respect following:

Horizontal lift of tube bundle - support is needed.



- Avoid excessive bending of tube bundle/tubes!



5. Design & Operation

Maximum operating conditions (temperature and pressure) for PPS-GR63

- The maximum tube wall temperature acceptable for continuous operation is **250°C**. As an indication melting temperature of the material is around 270°C. Technoform does not warrant temperature resistance above 250°C.
- The maximum pressure depending on the profile geometry (outer diameter and wall thickness) and the operational temperature.

| Outer diameter [mm] | Wall thickness [mm] | Max. operational pressure at 23°C [bar g] | Max. operational pressure at 50° [bar g] | Max. operational pressure at 100° [bar g] | Max. operational pressure at 150° [bar g] | Max. operational pressure at 200° [bar g] | Max. operational pressure at 250° [bar g] |
|------------------------|------------------------|---|--|---|---|---|---|
| 10 | 1,25 | 33 | 33 | 33 | 29 | 21 | 13 |
| 10 | 1,5 | 48 | 48 | 47 | 42 | 30 | 18 |
| 12,7 | 1,25 | 23 | 23 | 23 | 20 | 14 | 9 |
| 12,7 | 1,5 | 33 | 33 | 33 | 29 | 21 | 13 |
| 19,05 | 1,5 | 18 | 18 | 18 | 16 | 11 | 7 |
| 24 | 1,25 | 12 | 12 | 12 | 11 | 8 | 5 |
| 24 | 1,5 | 15 | 15 | 15 | 13 | 9 | 6 |
| 24 | 2 | 18 | 18 | 18 | 16 | 11 | 7 |
| 25,4 | 1,25 | 10 | 10 | 10 | 9 | 6 | 4 |
| 25,4 | 1,5 | 15 | 15 | 15 | 13 | 9 | 6 |
| 25,4 | 2 | 24 | 24 | 24 | 21 | 15 | 9 |
| 25,4 | 2,5 | 26 | 26 | 26 | 23 | 16 | 10 |
| 30 | 1,5 | 15 | 15 | 15 | 13 | 9 | 6 |
| 32 | 2 | 13 | 13 | 13 | 12 | 8 | 5 |
| 32 | 4 | 29 | 29 | 29 | 26 | 18 | 11 |
| 32 | 4,5 | 38 | 38 | 38 | 33 | 24 | 14 |
| 40 | 2 | 10 | 10 | 10 | 9 | 6 | 4 |
| 40 | 3 | 18 | 18 | 18 | 16 | 11 | 7 |
| 40 | 4 | 23 | 23 | 23 | 20 | 14 | 9 |
| 50 | 2 | 8 | 8 | 8 | 7 | 5 | 3 |



Table of unsupported PPS-GR63 tube lengths by operational pressure at 20°C

- ASME Compliance: The unsupported tube length for PPS-GR63 tubes is calculated according to ASME BPVC VIII Sec. 1 2023 UIG-34(5) Step 9(b)(1), taking into account the maximum operational pressure specific to the tube diameter and wall thickness.
- DIN EN Compliance: In alignment with DIN EN 13480-3 C.2, the calculation of unsupported tube length for PPS-GR63 considers variations in temperature and includes the corresponding safety factor, ensuring structural integrity under various operating conditions.

| | | Operating pressure in bar | | | | | | | | | | | | | | | |
|---------------------|---------------------|-------------------------------|------|------|------|------|------|------|------|------|------|------|------|-----|-----|-----|-----|
| | | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| Outer diameter [mm] | Wall thickness [mm] | Unsupported tube length in mm | | | | | | | | | | | | | | | |
| 50 | 2 | 1500 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 4 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | - | - | - | - |
| 40 | 3 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - |
| 40 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - |
| 32 | 4,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 954 | 913 | 877 | 845 | 817 |
| 32 | 4 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 968 | 927 | 890 | 858 | - |
| 32 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - |
| 30 | 1,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - |
| 25,4 | 2,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 988 | 924 | 872 | 827 | 788 | 755 | - | - | - |
| 25,4 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 942 | 889 | 843 | 804 | - | - | - | - |
| 24 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 948 | 886 | - | - | - | - | - | - | - |
| 25,4 | 1,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - |
| 24 | 1,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 967 | - | - | - | - | - | - | - | - |
| 24 | 1,25 | 1500 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - |
| 19,05 | 1,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 894 | 816 | 756 | 707 | - | - | - | - | - | - | - |
| 12,7 | 1,5 | 1000 | 1000 | 907 | 740 | 641 | 574 | 524 | 485 | 453 | 428 | 406 | 387 | 370 | 356 | 343 | 331 |
| 10 | 1,5 | 1000 | 980 | 693 | 566 | 490 | 438 | 400 | 370 | 346 | 327 | 310 | 295 | 283 | 272 | 262 | 253 |
| 10 | 1,25 | 1000 | 1000 | 709 | 579 | 502 | 449 | 410 | 379 | 355 | 334 | 317 | 302 | 290 | 278 | 268 | 259 |



Table of unsupported PPS-GR63 tube lengths by operational pressure at 50°C

- ASME Compliance: The unsupported tube length for PPS-GR63 tubes is calculated according to ASME BPVC VIII Sec. 1 2023 UIG-34(5) Step 9(b)(1), taking into account the maximum operational pressure specific to the tube diameter and wall thickness.
- DIN EN Compliance: In alignment with DIN EN 13480-3 C.2, the calculation of unsupported tube length for PPS-GR63 considers variations in temperature and includes the corresponding safety factor, ensuring structural integrity under various operating conditions.

| | | Operating pressure in bar | | | | | | | | | | | | | | | |
|---------------------|---------------------|-------------------------------|------|------|------|------|------|------|------|------|------|------|------|-----|-----|-----|-----|
| | | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| Outer diameter [mm] | Wall thickness [mm] | Unsupported tube length in mm | | | | | | | | | | | | | | | |
| 50 | 2 | 1500 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 4 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | - | - | - | - |
| 40 | 3 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - |
| 40 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - |
| 32 | 4,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 983 | 927 | 879 | 839 | 803 | 771 | 743 | 718 |
| 32 | 4 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 998 | 941 | 893 | 851 | 815 | 783 | 754 | - |
| 32 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - |
| 30 | 1,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - |
| 25,4 | 2,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 939 | 869 | 813 | 766 | 727 | 693 | 664 | - | - | - |
| 25,4 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 957 | 886 | 829 | 781 | 741 | 707 | - | - | - | - |
| 24 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | 986 | 900 | 833 | 780 | - | - | - | - | - | - | - |
| 25,4 | 1,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 976 | 903 | - | - | - | - | - | - | - | - |
| 24 | 1,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 919 | 851 | - | - | - | - | - | - | - | - |
| 24 | 1,25 | 1500 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - |
| 19,05 | 1,5 | 1500 | 1000 | 1000 | 1000 | 879 | 786 | 718 | 664 | 622 | - | - | - | - | - | - | - |
| 12,7 | 1,5 | 1000 | 1000 | 797 | 651 | 564 | 504 | 460 | 426 | 399 | 376 | 357 | 340 | 326 | 313 | 301 | 291 |
| 10 | 1,5 | 1000 | 861 | 609 | 497 | 431 | 385 | 352 | 326 | 305 | 287 | 272 | 260 | 249 | 239 | 230 | 222 |
| 10 | 1,25 | 1000 | 882 | 624 | 509 | 441 | 395 | 360 | 333 | 312 | 294 | 279 | 266 | 255 | 245 | 236 | 228 |



Table of unsupported PPS-GR63 tube lengths by operational pressure at 100°C

- ASME Compliance: The unsupported tube length for PPS-GR63 tubes is calculated according to ASME BPVC VIII Sec. 1 2023 UIG-34(5) Step 9(b)(1), taking into account the maximum operational pressure specific to the tube diameter and wall thickness.
- DIN EN Compliance: In alignment with DIN EN 13480-3 C.2, the calculation of unsupported tube length for PPS-GR63 considers variations in temperature and includes the corresponding safety factor, ensuring structural integrity under various operating conditions.

| | | Operating pressure in bar | | | | | | | | | | | | | | | |
|---------------------|---------------------|-------------------------------|------|------|------|------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|
| | | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| Outer diameter [mm] | Wall thickness [mm] | Unsupported tube length in mm | | | | | | | | | | | | | | | |
| 50 | 2 | 1500 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 4 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 977 | 914 | 862 | 817 | 779 | - | - | - | - |
| 40 | 3 | 1500 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 937 | - | - | - | - | - | - | - |
| 40 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - |
| 32 | 4,5 | 1500 | 1000 | 1000 | 1000 | 994 | 889 | 812 | 752 | 703 | 663 | 629 | 600 | 574 | 552 | 532 | 513 |
| 32 | 4 | 1500 | 1000 | 1000 | 1000 | 1000 | 903 | 824 | 763 | 714 | 673 | 638 | 609 | 583 | 560 | 539 | - |
| 32 | 2 | 1500 | 1000 | 1000 | 1000 | 1000 | 960 | 876 | - | - | - | - | - | - | - | - | - |
| 30 | 1,5 | 1500 | 1000 | 1000 | 1000 | 1000 | 911 | 832 | 770 | - | - | - | - | - | - | - | - |
| 25,4 | 2,5 | 1500 | 1000 | 1000 | 949 | 822 | 735 | 671 | 621 | 581 | 548 | 520 | 496 | 475 | - | - | - |
| 25,4 | 2 | 1500 | 1000 | 1000 | 968 | 838 | 750 | 684 | 634 | 593 | 559 | 530 | 505 | - | - | - | - |
| 24 | 2 | 1500 | 1000 | 1000 | 910 | 788 | 705 | 644 | 596 | 557 | - | - | - | - | - | - | - |
| 25,4 | 1,5 | 1500 | 1000 | 1000 | 987 | 855 | 764 | 698 | 646 | - | - | - | - | - | - | - | - |
| 24 | 1,5 | 1500 | 1000 | 1000 | 929 | 805 | 720 | 657 | 608 | - | - | - | - | - | - | - | - |
| 24 | 1,25 | 1500 | 1000 | 1000 | 939 | 813 | - | - | - | - | - | - | - | - | - | - | - |
| 19,05 | 1,5 | 1500 | 1000 | 889 | 726 | 629 | 562 | 513 | 474 | 444 | - | - | - | - | - | - | - |
| 12,7 | 1,5 | 1000 | 806 | 570 | 466 | 403 | 361 | 329 | 305 | 285 | 269 | 255 | 243 | 233 | 224 | 216 | 208 |
| 10 | 1,5 | 1000 | 616 | 436 | 356 | 308 | 275 | 251 | 233 | 218 | 205 | 195 | 186 | 178 | 171 | 165 | 159 |
| 10 | 1,25 | 1000 | 631 | 446 | 364 | 315 | 282 | 258 | 238 | 223 | 210 | 199 | 190 | 182 | 175 | 169 | 163 |



Table of unsupported PPS-GR63 tube lengths by operational pressure at 150°C

- ASME Compliance: The unsupported tube length for PPS-GR63 tubes is calculated according to ASME BPVC VIII Sec. 1 2023 UIG-34(5) Step 9(b)(1), taking into account the maximum operational pressure specific to the tube diameter and wall thickness.
- DIN EN Compliance: In alignment with DIN EN 13480-3 C.2, the calculation of unsupported tube length for PPS-GR63 considers variations in temperature and includes the corresponding safety factor, ensuring structural integrity under various operating conditions.

| | | Operating pressure in bar | | | | | | | | | | | | | | | |
|---------------------|---------------------|-------------------------------|------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| Outer diameter [mm] | Wall thickness [mm] | Unsupported tube length in mm | | | | | | | | | | | | | | | |
| 50 | 2 | 1500 | 1000 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 4 | 1500 | 1000 | 1000 | 930 | 805 | 720 | 657 | 609 | 569 | 537 | - | - | - | - | - | - |
| 40 | 3 | 1500 | 1000 | 1000 | 953 | 825 | 738 | 674 | 624 | - | - | - | - | - | - | - | - |
| 40 | 2 | 1500 | 1000 | 1000 | 977 | 846 | - | - | - | - | - | - | - | - | - | - | - |
| 32 | 4,5 | 1500 | 1000 | 876 | 715 | 619 | 554 | 506 | 468 | 438 | 413 | 392 | 374 | 358 | 344 | 331 | 320 |
| 32 | 4 | 1500 | 1000 | 889 | 726 | 629 | 562 | 513 | 475 | 445 | 419 | 398 | 379 | 363 | - | - | - |
| 32 | 2 | 1500 | 1000 | 945 | 772 | 668 | 598 | - | - | - | - | - | - | - | - | - | - |
| 30 | 1,5 | 1500 | 1000 | 897 | 733 | 634 | 567 | 518 | - | - | - | - | - | - | - | - | - |
| 25,4 | 2,5 | 1500 | 1000 | 724 | 591 | 512 | 458 | 418 | 387 | 362 | 341 | 324 | 309 | - | - | - | - |
| 25,4 | 2 | 1500 | 1000 | 738 | 603 | 522 | 467 | 426 | 395 | 369 | 348 | 330 | - | - | - | - | - |
| 24 | 2 | 1500 | 982 | 694 | 567 | 491 | 439 | 401 | 371 | - | - | - | - | - | - | - | - |
| 25,4 | 1,5 | 1500 | 1000 | 753 | 615 | 532 | 476 | 435 | - | - | - | - | - | - | - | - | - |
| 24 | 1,5 | 1500 | 1000 | 709 | 579 | 501 | 448 | 409 | - | - | - | - | - | - | - | - | - |
| 24 | 1,25 | 1500 | 1000 | 716 | 585 | 506 | - | - | - | - | - | - | - | - | - | - | - |
| 19,05 | 1,5 | 1500 | 783 | 554 | 452 | 392 | 350 | 320 | 296 | - | - | - | - | - | - | - | - |
| 12,7 | 1,5 | 1000 | 502 | 355 | 290 | 251 | 225 | 205 | 190 | 178 | 167 | 159 | 151 | 145 | 139 | 134 | - |
| 10 | 1,5 | 1000 | 384 | 271 | 222 | 192 | 172 | 157 | 145 | 136 | 128 | 121 | 116 | 111 | 106 | 103 | 99 |
| 10 | 1,25 | 1000 | 393 | 278 | 227 | 196 | 176 | 160 | 149 | 139 | 131 | 124 | 118 | 113 | 109 | 105 | - |



Table of unsupported PPS-GR63 tube lengths by operational pressure at 200°C

- ASME Compliance: The unsupported tube length for PPS-GR63 tubes is calculated according to ASME BPVC VIII Sec. 1 2023 UIG-34(5) Step 9(b)(1), taking into account the maximum operational pressure specific to the tube diameter and wall thickness.
- DIN EN Compliance: In alignment with DIN EN 13480-3 C.2, the calculation of unsupported tube length for PPS-GR63 considers variations in temperature and includes the corresponding safety factor, ensuring structural integrity under various operating conditions.

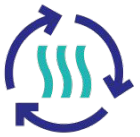
| | | Operating pressure in bar | | | | | | | | | | | | | | | |
|---------------------|---------------------|-------------------------------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|----|----|----|
| | | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| Outer diameter [mm] | Wall thickness [mm] | Unsupported tube length in mm | | | | | | | | | | | | | | | |
| 50 | 2 | 1500 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 4 | 1500 | 1000 | 979 | 799 | 692 | 619 | 565 | - | - | - | - | - | - | - | - | - |
| 40 | 3 | 1500 | 1000 | 1000 | 819 | 709 | 634 | - | - | - | - | - | - | - | - | - | - |
| 40 | 2 | 1500 | 1000 | 1000 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 32 | 4,5 | 1500 | 1000 | 753 | 615 | 532 | 476 | 435 | 402 | 376 | 355 | 337 | 321 | - | - | - | - |
| 32 | 4 | 1500 | 1000 | 764 | 624 | 540 | 483 | 441 | 408 | 382 | - | - | - | - | - | - | - |
| 32 | 2 | 1500 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 30 | 1,5 | 1500 | 1000 | 771 | 630 | 545 | - | - | - | - | - | - | - | - | - | - | - |
| 25,4 | 2,5 | 1500 | 880 | 622 | 508 | 440 | 394 | 359 | 333 | - | - | - | - | - | - | - | - |
| 25,4 | 2 | 1500 | 897 | 635 | 518 | 449 | 401 | 366 | 339 | - | - | - | - | - | - | - | - |
| 24 | 2 | 1500 | 844 | 597 | 487 | 422 | 377 | - | - | - | - | - | - | - | - | - | - |
| 25,4 | 1,5 | 1500 | 915 | 647 | 528 | 457 | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 1,5 | 1500 | 862 | 609 | 497 | 431 | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 1,25 | 1500 | 871 | 616 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 19,05 | 1,5 | 1500 | 673 | 476 | 389 | 337 | 301 | - | - | - | - | - | - | - | - | - | - |
| 12,7 | 1,5 | 1000 | 432 | 305 | 249 | 216 | 193 | 176 | 163 | 153 | 144 | 137 | - | - | - | - | - |
| 10 | 1,5 | 1000 | 330 | 233 | 190 | 165 | 147 | 135 | 125 | 117 | 110 | 104 | 99 | 95 | 91 | 88 | - |
| 10 | 1,25 | 1000 | 338 | 239 | 195 | 169 | 151 | 138 | 128 | 119 | 113 | 107 | - | - | - | - | - |



Table of unsupported PPS-GR63 tube lengths by operational pressure at 250°C

- ASME Compliance: The unsupported tube length for PPS-GR63 tubes is calculated according to ASME BPVC VIII Sec. 1 2023 UIG-34(5) Step 9(b)(1), taking into account the maximum operational pressure specific to the tube diameter and wall thickness.
- DIN EN Compliance: In alignment with DIN EN 13480-3 C.2, the calculation of unsupported tube length for PPS-GR63 considers variations in temperature and includes the corresponding safety factor, ensuring structural integrity under various operating conditions.

| | | Operating pressure in bar | | | | | | | | | | | | | | | |
|---------------------|---------------------|-------------------------------|------|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|
| | | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| Outer diameter [mm] | Wall thickness [mm] | Unsupported tube length in mm | | | | | | | | | | | | | | | |
| 50 | 2 | 1500 | 1000 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 4 | 1500 | 1000 | 787 | 642 | 556 | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 3 | 1500 | 1000 | 806 | 658 | - | - | - | - | - | - | - | - | - | - | - | - |
| 40 | 2 | 1500 | 1000 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 32 | 4,5 | 1500 | 856 | 605 | 494 | 428 | 383 | 349 | - | - | - | - | - | - | - | - | - |
| 32 | 4 | 1500 | 869 | 614 | 502 | 434 | 389 | - | - | - | - | - | - | - | - | - | - |
| 32 | 2 | 1500 | 923 | 653 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 30 | 1,5 | 1500 | 877 | 620 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 25,4 | 2,5 | 1500 | 708 | 500 | 408 | 354 | - | - | - | - | - | - | - | - | - | - | - |
| 25,4 | 2 | 1500 | 721 | 510 | 416 | 361 | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 2 | 1500 | 678 | 480 | 392 | - | - | - | - | - | - | - | - | - | - | - | - |
| 25,4 | 1,5 | 1500 | 736 | 520 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 1,5 | 1500 | 693 | 490 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 1,25 | 1500 | 700 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 19,05 | 1,5 | 1500 | 541 | 383 | 312 | - | - | - | - | - | - | - | - | - | - | - | - |
| 12,7 | 1,5 | 1000 | 347 | 245 | 200 | 174 | 155 | 142 | - | - | - | - | - | - | - | - | - |
| 10 | 1,5 | 1000 | 265 | 187 | 153 | 133 | 119 | 108 | 100 | 94 | - | - | - | - | - | - | - |
| 10 | 1,25 | 1000 | 271 | 192 | 157 | 136 | 121 | 11 | - | - | - | - | - | - | - | - | - |

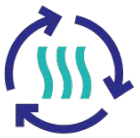


Materialproperties

Polymer-based heattransfer solutions

| Physical properties | PP-GR | PPS-GR | SI-Unit | Test Standard | Temperature |
|------------------------------|-------|--------|-------------------|--------------------|-----------------------------|
| Density | 1.58 | 1.78 | g/cm ³ | DIN EN ISO 1183-1 | 23°C |
| Specific heat capacity | 1.21 | 1.16 | J/g·K | DIN EN ISO 11357-4 | PP-GR 80 °C / PPS-GR 100 °C |
| Tensile modulus | 7751 | 17043 | MPa | DIN EN ISO 527-2 | 23 °C |
| Tensile strength | 29.1 | 47.9 | MPa | DIN EN ISO 527-2 | 23 °C |
| Tensile elongation at break | 0.46 | 0.25 | % | DIN EN ISO 527-2 | 23 °C |
| Flexural modulus | 7438 | 14864 | MPa | DIN EN ISO 178 | 23 °C |
| Flexural strength | 43.98 | 68.71 | MPa | DIN EN ISO 178 | 23 °C |
| Flexural elongation at break | 0.52 | 0.45 | % | DIN EN ISO 178 | 23 °C |

All tests performed with injection moulded standard tensile bars unless otherwise specified in respective standard.



Profile properties and design parameters

Polymer-based heattransfer solutions

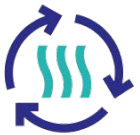
Exemplary profile properties

| Properties | | PP-GR | PPS-GR | SI-Unit | Test conditions |
|--|-------------------|-----------------------|-----------------------|---------|------------------------------|
| Heat conductivity | Through-plane | 6 | 4 | W/m·K | Laser flash analysis at 23°C |
| | In-plane | 26 | 23 | | |
| Linear thermal expansion in profile length | 0 °C ... 100 °C | 20 x 10 ⁻⁶ | 14 x 10 ⁻⁶ | 1/K | ASTM E831-14 |
| | 100 °C ... 200 °C | N/A | 26 x 10 ⁻⁶ | | |
| Surface roughness tube wall Rz | | ≤ 4 | ≤ 8 | µm | DIN EN ISO 16610 |
| Surface roughness tube wall Ra | | ≤ 0.5 | ≤ 1 | µm | DIN EN ISO 16110 |
| Burst pressure | | 20.9 | 36.6 | bar | 23 °C |

Above properties are for round tube 24 mm outer diameter, 1.5 mm wall thickness. Properties vary between different profiles, further information available upon request.

Recommended design parameters

| Design Parameter | PP-GR | PPS-GR | SI-Unit | Comment |
|---|------------|--------------|---------|--|
| Continuous operation temperature (minimum/maximum temperature in profile wall) | -30 +80 | -100 +250 | °C | Recommendation based on material properties and long-term testing in application |

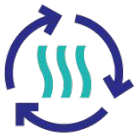



Chemical resistant of PPS-GR


- The following overview shows the chemical resistant of the PPS-GR material.
- The chemical resistance to additional acids or concentrations has to be tested.


| Medium | Concentration | Temperature | Duration | Result |
|--|--------------------------|---------------|----------|--------|
| Seawater | 6,5% | 80°C (176°F) | 180 d | ++ |
| Hydrochloric acid (HCl) | 36% | 100°C (212°F) | 30 d | ++ |
| Sulfuric acid (H ₂ SO ₄) | 60% | 120°C (248°F) | 180 d | ++ |
| | 60% | 140°C (284°F) | 180 d | ++ |
| | 70% | 150°C (302°F) | 30 d | ++ |
| | 80% | 160°C (320°F) | 30 d | + |
| | 96% | 95°C (203°F) | 14 d | + |
| Phosphoric acid (H ₃ PO ₄) | 85% | 158°C (176°F) | 180 d | ++ |
| Hydrofluoric acid (HF) | 40% | 100°C (212°F) | 14 d | ++ |
| Nitric Acid (HNO ₃) | 30% | 100°C (212°F) | 14 d | -- |
| Sodium Hydroxide (NaOH) sol. | 72% satur. | 23°C (73°F) | 69 d | ++ |
| mixed acid condensate DIN EN 14471 class 2 | | | | |
| Hydrochloric acid (HCl) Nitric Acid (HNO ₃) Sulfuric acid (H ₂ SO ₄) | 0,003% 0,02% 0,04% | 90°C (194°F) | 70 d | ++ |
| Green death test solution | | | | |
| Sulfuric acid (H ₂ SO ₄) Hydrochloric acid (HCl) Ferric chloride FeCl ₃ Cupric chloride CuCl ₂ | 23% 1,2% 1% 1% | 100°C | 7 d | ++ |


++ no influence + small change or moderate resistant - attack visible -- non resistant



 In the case of **cooling failure** in a pressurized system, Technoform recommends depressurizing the system and opening it via a safety valve so that the pressure does not rise with the temperature in the tube.

 In the case of **high dust content** or abrasive components in the fluid stream, particularly on the shell side Technoform recommends using a protective tube layer in terms of an uncooled stainless steel tube row or perforated sheet in front of first/front PPS-GR tube row.

 Resistance to **pressure shocks**: PPS-GR tubes are designed to withstand water hammering and pressure shocks up to their maximum mechanical strength, ensuring they remain undamaged under such conditions.

 Instructions for monitoring and adjusting operational parameters:

- For the long-term durability of the PPS-GR, the temperature and pressure (both inlet and outlet) must be measured and documented to ensure that the PPS-GR tubes are operating under the defined design conditions of the heat exchanger.



6. Maintenance and cleaning

Overview of maintenance intervals (short-, medium-, and long-term)

Short-term maintenance

It can be anyway considered a “short-term” maintenance maintaining the plant in operation through by-pass the complete heat exchanger.

Medium-time maintenance

Medium-time maintenance, carried out during plant shut-down (in case the tubes damaged do not affect thermal performance).

1. Visual inspection for damage to the tube, o-ring or grommet.
2. Pressurized inspection to detecting the position of leaking areas.
3. If accessibility is guaranteed, tube, o-rings or grommets can also be replaced during medium-time maintenance period.
4. Plugging individual broken or damaged tubes.

Long-term maintenance:

Requested substitution of tubes/heat exchanger:

Removing bundles and retrofit tubes.

Do's and Don'ts:

- ✗ Do not walk on the tubes during the maintenance.
- ✗ Do not drop any parts or tools on tubes during maintenance.
- ✓ In case of tube replacement, it is recommended to replace the tube sealing, too.

Cleaning instruction:

- There are no limits to the cleaning agents that can be used, even hydrochloric acid can be used to remove dirt from the surfaces.
- Do not use kettles, explosive or abrasive methods to clean PPS-GR tubes.
- Do not use hard brushes or similar hard tools to clean PPS-GR tubes.

If PPS-GR tube has collar:

- **Do not walk on tube collars**
- **Visual inspection of the collar:** Check for any breakages and verify the functionality
- **Cleaning:** Remove deposition and contamination according cleaning instruction.
- **If function is not given:** Short to medium term: Plug the tube or use sleeves if the tube is sliding through the tube sheet. Long-term solution: Replace with new tubes.





Cleaning during operation:

Specific instructions for cleaning during operation:

Cleaning of the heat transfer surfaces can be carried out by pressurized water spraying using inline cleaning lances.

The PPS-GR material has excellent thermal shock behavior - No additional stresses due to temperature differences.

Cleaning during operational interruptions:

Specific instructions for cleaning during operational interruptions:

Hydro jet cleaning may be used respecting following:

- Do not exceed pressure above 1450 psi (100 Bar)
- Keep minimum 8" (20 cm) distance to the tubes
- Do not use temperatures above 430°F (220°C)
- Avoid abrasive particles (e.g. sand) in water



Only use soft cloth or soft brushes.



Do not use hard brushes or cleaning pads (scotch brite).

Recycling information

Specific instructions for recycling

- All PPS-GR parts should be sent for material recycling
- All non-PPS-GR parts must be taken care of in agreement with local regulations

Scrapping

- At end of use, the equipment shall be recycled according to relevant, local regulations. Beside the equipment itself, any hazardous residues from the process liquid must be considered and dealt with in a proper manner. When in doubt, or in the absence of local regulations, please contact Technoform




7. Appendix

Disclaimer:

This handbook manual provides guidelines for the usage of PPS-GR heat transfer tubes, particularly in pressurized vessels. Technoform is an ASME-certified manufacturer, qualified to fabricate, test, and provide pressure parts in accordance with ASME BPVC VIII UIG "PRT" standards.

While Technoform ensures that all components are manufactured to the highest standards, users must adhere to all safety and operational guidelines provided within this manual. Improper use, installation, or maintenance of PPS-GR heat transfer tubes can result in equipment failure, personal injury, or property damage. Users should ensure that all personnel handling these components are adequately trained and familiar with relevant safety protocols.

Technoform does not assume responsibility for damages or losses resulting from the misuse of the product or failure to follow the instructions provided. Regular inspection and maintenance of the equipment are crucial to ensure safe and efficient operation. For specific applications and additional guidance, please consult with a qualified engineer or contact Technoform directly.

| | | |
|---|---|-------------------------------------|
| The American Society of Mechanical Engineers |  | CERTIFICATE OF AUTHORIZATION |
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| | COMPANY: | |
| | Technoform Tailored Solutions Holding GmbH HTS Otto-Hahn-Strasse 34 Lohfelden 34253 Germany | |
| | SCOPE: | |
| | Fabrication of parts without design responsibility for ASME Section VIII, Div. 1 at the above location only | |
| | AUTHORIZED: | January 21, 2022 |
| | EXPIRES: | January 21, 2025 |
| | CERTIFICATE NUMBER: 59943 | |
|  |  Board Chair, Conformity Assessment | |
| |  Managing Director, Conformity Assessment | |

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