SCHOTT is an international technology group with more than 125 years of experience in the areas of specialty glasses and materials and advanced technologies. With our high-quality products and intelligent solutions, we contribute to our customers’ success and make SCHOTT part of everyone’s life.
SCHOTT Solar CSP with its high performance receivers – which comprise the core of all solar power plants using parabolic trough and linear Fresnel technologies – contributes decisively to making tomorrow’s energy production possible today. We rank as market and technology leader for receiver tubes and have supplied more than 1 Million receivers to power plants all over the world.
SCHOTT Solar CSP: the most bankable receiver supplier
Outperforming technology, excellent production and service and an unmatched track record

<table>
<thead>
<tr>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Superior product durability and lifetime</td>
</tr>
<tr>
<td>• Benchmark product performance</td>
</tr>
<tr>
<td>• Strong product development capabilities</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Excellence in production and service</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Lean manufacturing</td>
</tr>
<tr>
<td>• Reliable high volume capability</td>
</tr>
<tr>
<td>• Technical customer service on-site</td>
</tr>
<tr>
<td>• After-sales service</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Track record</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 3 GW installed base (out of 4 GW total)</td>
</tr>
<tr>
<td>• More than 50 projects supplied around the globe</td>
</tr>
<tr>
<td>• More than 1 Million receivers delivered</td>
</tr>
</tbody>
</table>
Parabolic trough technology
The first choice for large-scale solar power generation

Concentrated Solar Power – Clean and predictable electricity generation around the clock
Concentrated Solar Power (CSP) technology uses energy from the sun to generate heat, which is used in steam cycles to produce electricity. The technology is particularly efficient in regions with high direct solar irradiation, encompassing the earth’s sunbelt on both sides of the equator to 35 degrees latitude.

CSP plants are used in a similar manner like conventional steam power plants. The key difference is that CSP plants use emission-free, clean solar radiation to produce heat instead of fossil or nuclear fuels. Amongst all CSP technologies, the parabolic trough technology has the longest commercial track record of almost 30 years. Parabolic trough power plants are suitable for large-scale use in the range of 10 to 300 megawatts electrical output and can replace conventional thermal power plants without any qualitative changes in the electricity grid structure. Due to the option of thermal storage or hybridization, the turbines of CSP plants can also produce power in low solar radiation periods and at night, delivering power reliably, on a planned schedule and in a way that keeps the grids stable.
How parabolic trough power plants work

In a CSP plant, the generation of heat mostly depends on the level of solar irradiation. In order to achieve the necessary temperatures, solar radiation is concentrated in parabolic trough arrays. These troughs can be more than 600 meters in length and are made of parabolic shaped mirror segments. The troughs track the sun over the course of the day and focus the solar radiation along the focal point of the mirrors onto the “heart” of a CSP plant: specially coated, evacuated receiver tubes. The receiver tubes convert solar radiation into thermal energy, and therefore their durability and efficiency are crucial for the sustainable profitability of the entire solar plant. A heat transfer fluid, which circulates through the receiver, is heated up and then used to generate steam.

The overall power plant efficiency is determined by the maximum operating temperature of the heat transfer fluid used. The most commonly used oil-based heat transfer fluids operate at temperatures up to 400 °C. A key innovation to further improve the plant efficiency is the usage of heat transfer that allows operation up to 550 °C, such as molten salts or direct steam.

SCHOTT PTR®70 Receiver

The receiver, being the key component of a CSP plant, has a decisive influence on the overall efficiency of the plant and has to withstand drastic temperature changes and mechanical stresses throughout its lifetime. The SCHOTT PTR®70 Receiver responds to this challenge and allows SCHOTT not only to claim technology leadership, but also to be the clear market leader in solar receivers. More than 1 Million SCHOTT PTR®70 Receivers have been delivered to power plants all over the world. High solar absorptance, low thermal losses and a durable vacuum body are crucial and in all aspects, the SCHOTT PTR®70 Receiver delivers outstanding results.
The SCHOTT PTR®70 Receiver Platform
Three receiver products – one technology base

SCHOTT introduces the 4th generation of receivers which collects the experience of more than 1 Million receivers installed in over 50 CSP projects worldwide. The 4th generation receiver products are built upon a common technology platform. With the base product, the platform already provides best-in-class optical and thermal performance. The Premium receiver includes an integrated noble gas capsule and facilitates sustainable profitability far beyond 25 years of operation. The Advance receiver paves the way to the next technology leap in CSP: Molten Salts as heat transfer fluid operating at temperatures up to 550 °C.

SCHOTT PTR®70 Advance
The technology leap towards Molten Salts

SCHOTT PTR®70 Premium
The profitability booster

SCHOTT PTR®70
The receiver benchmark in CSP industry

<table>
<thead>
<tr>
<th>SCHOTT PTR®70</th>
<th>SCHOTT PTR®70 Premium</th>
<th>SCHOTT PTR®70 Advance</th>
</tr>
</thead>
<tbody>
<tr>
<td>for usage with oil-based heat-transfer fluids</td>
<td>for usage with oil-based heat-transfer fluids</td>
<td>for usage with Molten Salts heat-transfer fluids</td>
</tr>
<tr>
<td>• New bellow design, suitable for high-temperature operation</td>
<td>• SCHOTT PTR®70 plus</td>
<td>• SCHOTT PTR®70 plus</td>
</tr>
<tr>
<td>• Glass-to-metal seal with matching coefficients of thermal expansions</td>
<td>• Integrated noble gas capsule as lifetime extender</td>
<td>• New steel grade for 550 °C operation</td>
</tr>
<tr>
<td>• Protection cap for improved robustness and easy handling</td>
<td></td>
<td>• Novel absorber coating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Stress-optimized bellow configuration</td>
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</table>
SCHOTT PTR®70 Receivers
Designed for maximum profitability of the power plant

SCHOTT Solar CSP introduces the 4th generation of receivers, which benefits from the experience of more than 1 Million receivers installed in over 50 CSP projects worldwide. The new generation SCHOTT PTR®70 again sets the benchmark in product performance and provides superior product durability and lifetime.

The SCHOTT PTR®70 is designed for usage in state-of-the-art power plants operating with oil-based heat transfer fluids at temperatures up to 400°C.

<table>
<thead>
<tr>
<th>Stable performance</th>
<th>Higher efficiency through low heat loss</th>
<th>Improved handling and robustness</th>
</tr>
</thead>
<tbody>
<tr>
<td>The optical properties of the absorber coating are crucial for the performance of the collector field. SCHOTT Solar CSP has developed and patented the absorber coating with remarkable optical and thermal values for a long-term performance stability.</td>
<td>A new receiver end design includes an innovative internal heat shield that minimizes heat losses and improves the efficiency of the receiver.</td>
<td>The 4th generation receiver is significantly lighter and is equipped with a protection cap at the receiver ends. It prevents mechanical impact to sensitive parts during mounting, installation and operation, thus improving project execution.</td>
</tr>
</tbody>
</table>
**Validated best-in-class performance**

According to measurements at DLR (German Aerospace Centre) Quarz, the SCHOTT 4th generation receiver shows an optical performance 6% above the industry standard.

Heat loss measurements carried out in a round robin test performed by SCHOTT Solar CSP in cooperation with NREL (US National Renewable Energy Laboratory) and DLR confirmed a heat loss of less than 250 W/m at working temperatures (400 °C).

**Technical specification**

<table>
<thead>
<tr>
<th>Components</th>
<th>Specification</th>
</tr>
</thead>
</table>
| Dimension    | • length: 4060 mm at 20 °C ambient temperature (159.8 inches at 68 °F)  
• aperture length: > 96.7% of the bulk length at 350 °C / 662 °F working temperature |
| Absorber     | • outer diameter: 70 mm / 2.75 inches  
• steel-type: DIN 1.4541 or similar  
• solar absorptance:  
  \[ \alpha_{so} \geq 95.5 \% \]  
  \[ \alpha_{sina} \geq 96 \% \]  
• thermal emittance:  \[ \varepsilon \leq 9.5 \% \] |
| Glass envelope | • Borosilicate glass  
• outer diameter: 125 mm / 4.9 inches  
• antireflective coating  
• solar transmittance:  \[ \tau \geq 97 \% \] |
| Thermal losses | • in conjunction with SCHOTT Solar CSP patented shields  
  < 250 W/m (\@ 400 °C)  
  < 165 W/m (\@ 350 °C)  
  < 110 W/m (\@ 300 °C)  
  < 70 W/m (\@ 250 °C) |
| Vacuum       | • residual gas pressure:  \leq 10^{-1} \text{ mbar} |
| Heat transfer fluid | • non-corrosive thermal oil with an effective partial pressure of dissolved Hydrogen of  
  \[ p_{H_2} < 30 \text{ Pa} \] |
| Operating pressure |  \leq 41 \text{ bar (absolute)} |
SCHOTT PTR®70 Premium Receivers
Best performance with integrated 2nd life kit

SCHOTT PTR®70 Premium Receivers incorporate a major benefit for power plant owners and investors: a noble gas capsule. With this solution, receivers affected from the “hot tube phenomenon”, which reduces significantly the thermal efficiency of the receiver, can be recovered easily making possible to reach again thermal efficiencies close to the initial ones. This makes possible to extend the lifetime of the receivers and to minimize the O & M costs associated with replacements increasing the overall plant profitability.

**Integrated noble gas capsules**
SCHOTT PTR®70 Premium Receivers include a new conceptual design patented by SCHOTT and are equipped with a noble gas capsule to maintain excellent thermal properties over the full operation period. The heat loss of hot tubes is typically increased by a factor of ~6 compared to the vacuum. In such a case, the activation of the integrated noble gas capsule can be carried out within minutes without interrupting the operation. The result: thermal losses are immediately reduced almost to the initial value, and the temperature of the glass tube cools down accordingly.
**SCHOTT Premium Receivers with activated noble gas capsule provide 10% higher life-time output**

Simulations show that solar fields with activated noble gas capsule receivers yield 10% more electricity output over 40 years of operating lifetime, as compared with conventional receivers that remain in the solar field when turning into hot tubes. Moreover, noble gas capsule solar fields almost reach the output level of solar fields with new replacement receivers. These direct benefits of maximized output and minimized O&M costs reduce risks and increase the overall profitability of the power plant.

**Technical specification**

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| Absorber            | • outer diameter: 70 mm / 2.75 inches  
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                      • solar absorptance:  
                        $\alpha_{so} \geq 95.5\%$  
                        $\alpha_{ASTM} \geq 96\%$  
                      • thermal emittance: $\varepsilon \leq 9.5\%$                                                                                                    |
| Glass envelope      | • Borosilicate glass  
                      • outer diameter: 125 mm / 4.9 inches  
                      • antireflective coating  
                      • solar transmittance: $\tau \geq 97\%$                                                                                                        |
| Thermal losses      | • in conjunction with SCHOTT Solar CSP patented shields  
                      $< 250$ W/m (@ 400°C)  
                      $< 165$ W/m (@ 350°C)  
                      $< 110$ W/m (@ 300°C)  
                      $< 70$ W/m (@ 250°C)  
                      $<$ Residual gas pressure: $\leq 10^{-1}$ mbar                                                                                              |
| Vacuum              | • integrated noble gas capsule for extended product lifetime                                                                                   |
| Noble gas capsule   | • non-corrosive thermal oil with an effective partial pressure of dissolved Hydrogen of $p_{H_2} < 30$ Pa                                          |
| Heat transfer fluid | • ≤ 41 bar (absolute)                                                                                                                          |
| Operating pressure  |                                                                                                                                             |
Global presence

1.000.000 receivers delivered

Technical Service

Benchmark product performance

Your innovation partner

Profitability booster

Over 50 commercial plants world wide

Technology & Market leader

Bankability

Optical performance 6% above DLR reference

Pilot line for prototypes & small series

Superior durability & lifetime

600 MW annual capacity

100% delivery reliability

3GW installed

Over 50 commercial plants world wide

Technology & Market leader

Bankability