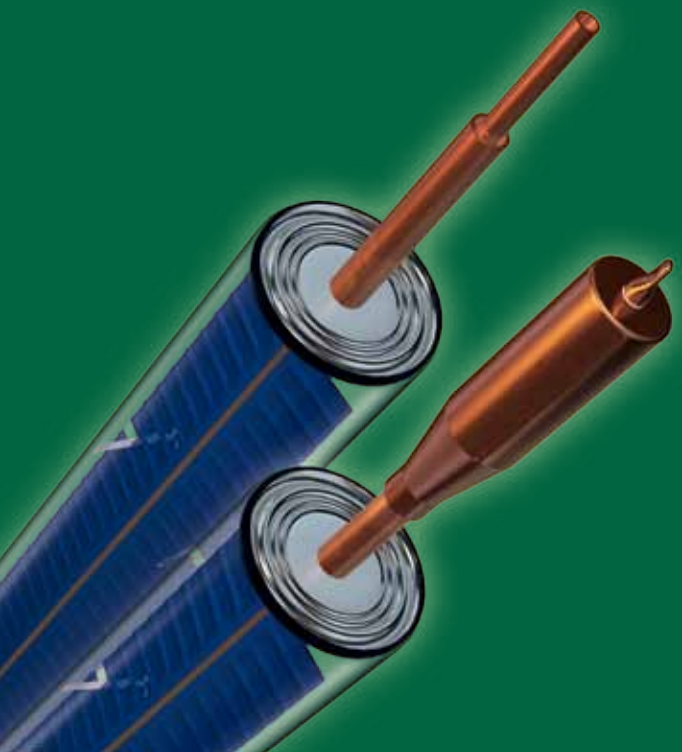
NARVA
GERMANY

SOLAR energy
natural HEAT.

Vacuum tubes
made in Germany



Innovation award for NARVA products

At the 18th Solar Thermal Energy Symposium, held in April 2008 in Kloster Banz – Bad Staffelstein, Germany, NARVA received the innovation award for our solar vacuum tubes.

Determining factors for the award included:
- Innovation
- Energetic relevance
- Market relevance
- Issued property rights

Prof. Dr. Goetzberger, chairman of the jury, pointed out in his congratulation remarks that the NARVA tubes bring to the solar industry a product which is especially suitable for the solar process heat market. This area of application usually needs higher temperatures which are best achieved with the use of collectors with vacuum tubes.

Vacuum tubes made in Germany

With the introduction of the NARVA Direct Flow vacuum tube in 2007, a new generation of highly efficient vacuum tubes was made available to the solar thermal market. Since that time, NARVA has made significant investments in both engineering resources and manufacturing equipment to support the steadily increasing demand for efficient solar thermal collectors. Today, at our modern plant in Brand-Erbisdorf, Germany, approximately one million vacuum tubes can be manufactured per shift per year.

The design and development of this new generation of high quality vacuum tubes was made possible by NARVA's 40 years of experience in the field of glass manufacturing, glass-to-metal sealing and the extensive knowledge of coating applications and vacuum processes. Especially significant in this design is the unique seal (Patent Pending) between the glass tube and the metal disk supporting the absorber assembly. This glass-to-metal seal makes the product both robust and durable. With the addition of a special nano-particle, anti-reflective coating on both internal and external surfaces of the glass, the NARVA vacuum tube achieves the highest efficiency of any vacuum tube on the market.

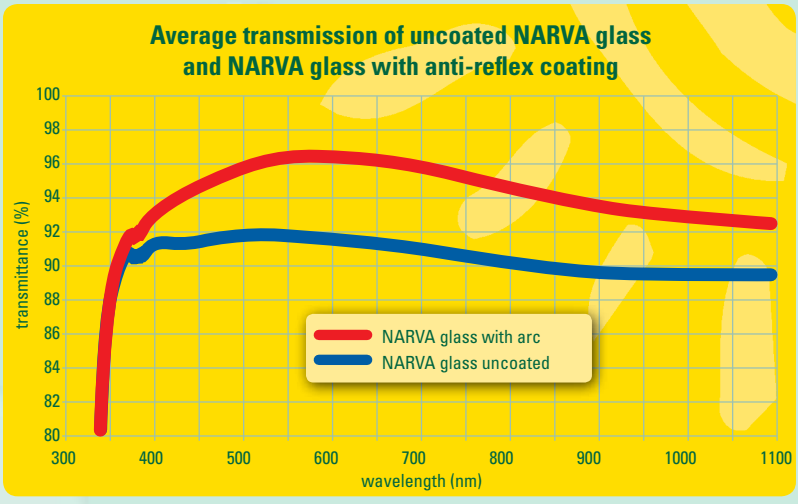
At our ISO 9001 certified production facility in Brand-Erbisdorf, Germany, all essential production steps are completed. The tube is made at the company's own glass factory. The copper and absorber plates are pre-assembled and each absorber unit is precision mounted in the glass envelope in preparation for vacuum processing. The assembly of both parts, the glass tube and the absorber unit, takes place on a new automated line which was put into production in 2007.

The NARVA Vacuum tube

The special glass used in the vacuum tube is produced at NARVA's own glassworks and is made from raw materials that are low in iron. This makes the glass highly transmissive over the full visible spectrum and continuing on into the infrared region. Hence, the tube is well suited for the collection of the full spectrum of solar radiation.

In addition, the tube is coated with nano-particles of silicon dioxide (SiO_2), both inside and out. This coating reduces the reflection of light rays striking the tube, increasing the transparency of the glass to a final transmission of approximately 96% making the tube highly efficient in the collection of solar radiation.
The SiO_2 layers are baked into the glass, making the surface highly resistant to abrasion and degradation due to environmental conditions referred to as weathering.

The comparatively thick wall of the NARVA vacuum tubes combined with the external coating gives the tubes a high level of resistance to breakage by flying debris or hail. The tubes have been tested for hail resistance (ice ball tests) by TÜV Rheinland, in accordance with the EN 12975-2.
The special glass of the vacuum tube also has a significantly lower permeability level for hydrogen and helium compared to the frequently used borosilicate glass. As a result, the vacuum properties of the tubes last for 20 years.



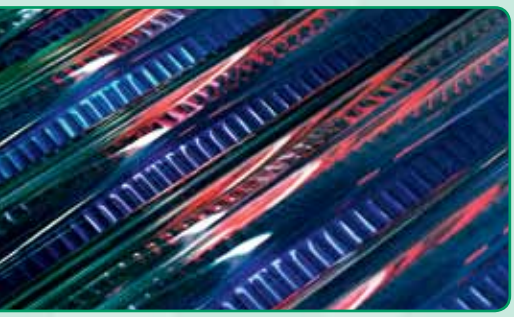
Glass-to-metal seal

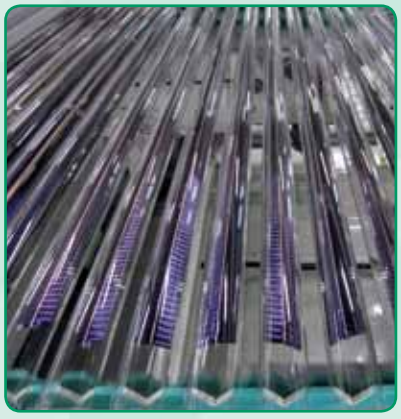
NARVA vacuum tubes use a new and highly robust glass-metal seal. The susceptibility to glass breakage is reduced because the seal design is not under tensile load and thus resists strong axial and shear forces.

The NARVA glass-to-metal seal has been assigned the following international patent numbers:
International patent: PTC/DE2006/001244
Int. publication number: WO 2007/033630

The design has been tested as a component in various solar collectors and passed all of the critical durability and reliability tests as prescribed by the Thermal Solar Systems and Components Standard EN 12975-2. Tests include:

- Internal Pressure
- Exposure
- External / Internal Thermal Shock
- High Temperature Resistance
- Mechanical Load
- Impact Resistance Absorber

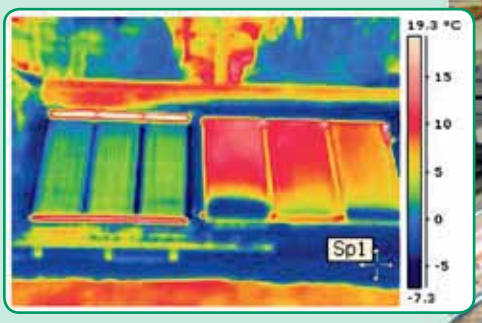




Absorber

NARVA vacuum tubes use the latest copper absorber plates on the market. The use of a multi-layer coating of titanium oxy-nitride (TiNOX®) makes the absorber highly efficient. The absorber plate is attached to the copper absorber pipe by ultrasonic welding. Through the use of highly effective vacuum pumping technologies and a barium getter, a high vacuum is achieved in the tubes of approximately 10^{-6} bar. In addition to providing exceptional insulating properties, the vacuum protects the absorber from environmental degradation. Testing indicates that the absorptive properties of the TiNOX® coating layer are maintained for a minimum of 20 years. (based on Institut fur Solartechnik SPF Qualification Report, 2008)

The absorber plates are available with either single sided (Standard) or double-sided (Power) coating. A double-sided coating is used in collectors that are designed for use with reflective surfaces where increased efficiencies can be realized by collecting reflected energy on the backside of the absorber. An increase in efficiency of up to 30% can be realized when a double-coated absorber and a reflective surface are used.



Direct flow vacuum tubes

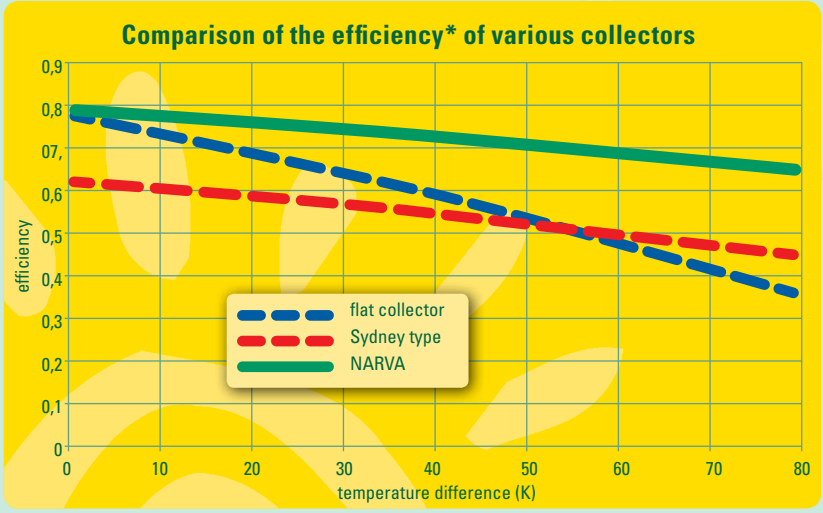
Measurements by TÜV Rheinland of the efficiency of a typical solar collector using NARVA Direct Flow vacuum tubes yielded the following performance values:

η_0: 0.781

a1: 1.12 W/m² K

a2: 0.004 W/m² K²

These values indicate very low thermal loss (a1, a2) for relatively high differentials in collector fluid to ambient temperature. Collectors designed with the NARVA vacuum tubes are well suited to providing heat for applications which require high water temperatures, such as space heating, process heat, drying processes, air conditioning etc.



*** Based upon aperture.**

Heatpipe vacuum tubes

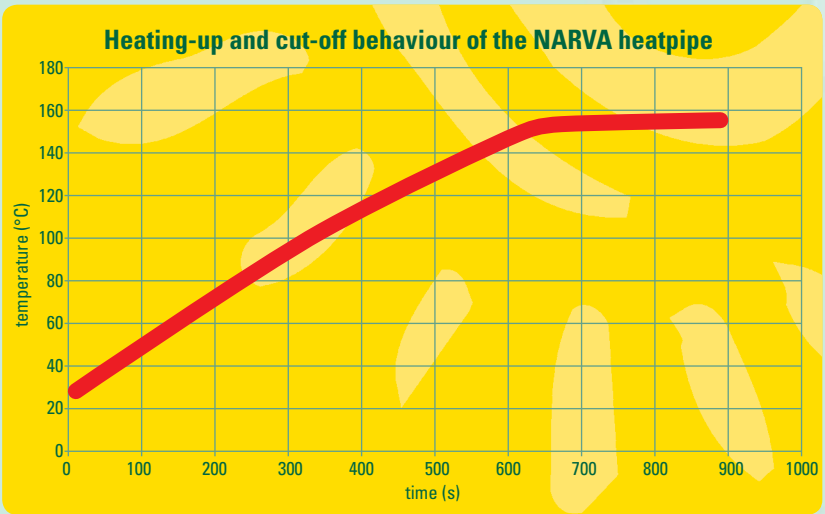
In 2009, NARVA designed a heat pipe vacuum tube with self-regulating temperature properties. The temperature of the NARVA heat pipe vacuum tube condenser will not exceed 160˚F (320˚F). Even under stagnation conditions (maximum tube temperature) the heat transfer fluid does not degrade.

The fluid contained in the NARVA heat pipe has been specially selected to ensure that no frost damage or fluid decomposition will occur over the expected 20-year product lifespan.

Inside the heat pipe the maximum pressure measured is 13 bar during stagnation (maximum tube temperature).

The condenser size and geometry has been engineered to achieve a high thermal transfer efficiency over a large range of mounting angles. A collector incorporating NARVA heat pipe vacuum tubes will still perform at its specified maximum output when positioned between the angles of 20˚ to 70˚.

The graph below shows the warm up characteristics of the NARVA heat pipe vacuum tube. Note the temperature stabilizing at approximately 160°C (320°F).



Technical Data

Coating of absorber: one side (Standard)	NARVA Vacuum tube direct flow				NARVA Vacuum tube heatpipe			
Nominal length (mm)	**800**	**1500**	**1775**	**2000**	**800**	**1500**	**1775**	**2000**
Length of glass tube (mm)	810	1510	1785	2010	810	1510	1785	2010
Diameter of glass tube (mm)	56				56			
Length of connecting pipe (mm)	57				30.5			
Aperturface of glass tube (m^2)	0.0386	0.0750	0.090	0.1010	0.0386	0.0750	0.090	0,010
Nominal tube output (W) at an irradiance of 1000 W/m^2	30	59	71	80	28	56	67	76
Absorbed heat at 1000 kWh/a*m^2 global radiation temperature difference 40 K (kWh/a)	27	53	64	72	25	50	60	68
Absorbed heat at 1000 kWh/a*m^2 global radiation temperature difference 100 K (kWh/a)	23	45	54	61	21	42	50	57
Heat transmission coefficient linear (W/m^2*K)	1.12				1.12			
Heat transmission coefficient quadratic (W/m^2*K^2)	0.004				0.004			
Efficiency factor	0.781				0.750			
Instructions for use	- As a result of the flat characteristic of the tube it may be used for continous operation at a temperature of the heat carrier up to 150 °C - The tubes fulfil the requirements according to DIN EN 12975-2 - The tubes are designated for a lifespan of 20 years - If there is a risk of frost there should be used a corresponding heat carrier - The temperature of lost motion can reach 315 °C				- The vacuum tubes are functional up to an angle of 20 degrees without any performance loss. - The tubes fulfil the requirements according to DIN EN 12975-2 - The tubes are designated for a lifespan of 20 years - The switch off temperature is 160 °C			

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