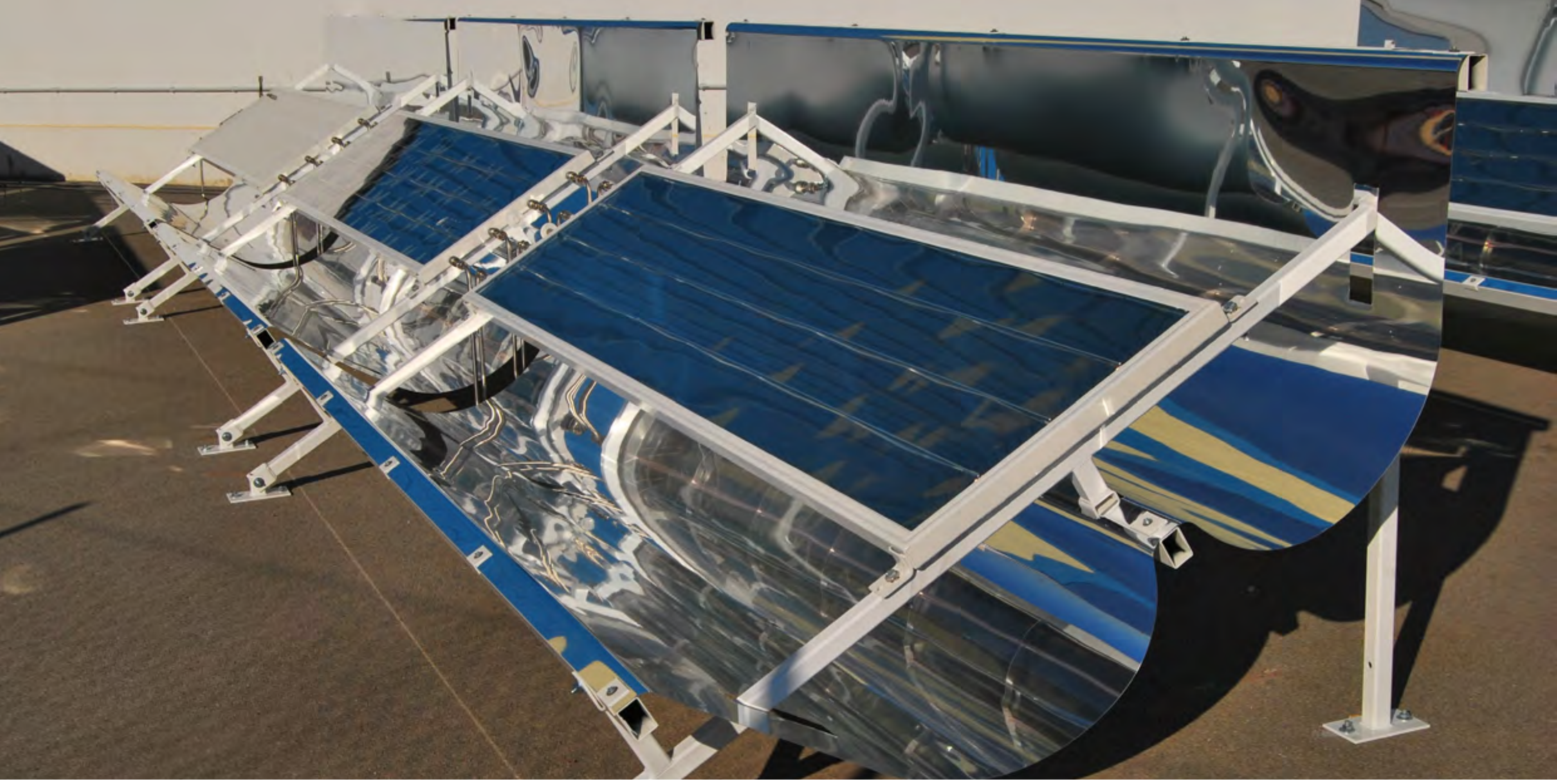


THE SRB SOLAR THERMAL PANEL

▮ C. Benvenuti – SRB Energy, c/o CERN – 1211 Genève 23, Switzerland – DOI: 10.1051/epn/2013301

Can one build a solar thermal collector which reaches 400 °C even without using focusing mirrors? Yes we can, says SRB Energy, a company aiming at industrially producing a flat panel solar collector patented at CERN in 2003. The distinctive feature of this collector is the high efficiency achieved thanks to the vacuum maintained by a getter pump powered by the sun.

▲ View of the SRB solar thermal panel with cylindrical mirrors

The mechanical design of the panel [1] is shown schematically in Fig. 1. It consists of a metal frame sealed on both sides by glass windows, allowing solar radiation to enter at either side. The resulting box contains blackened copper heat absorbers which capture the solar energy. The absorbers are laser welded to stainless steel pipes which allow the heat to be extracted by circulating a fluid. These features are common to any flat solar thermal panel. The distinctive feature of the SRB panel is that it is under vacuum.

Evacuated flat-plate panels were not produced so far because a vacuum-tight connection between large glass windows and the metal structure of the panel presents an (almost) insurmountable difficulty. The SRB solution to this problem consists of a plasma-sprayed metal coating on the glass perimeter, on which a metal joint may then be fixed by soft soldering.

When the panel is under vacuum, the atmospheric pressure applies a force of 10 N/cm^{-2} on the panel windows, resulting in a weight of many tons for a medium-size panel. This force would lead to implosion of the panel if not properly supported. The spacing between the supports depends on the glass type and thickness. The SRB panel makes use of tempered glass 5 mm thick and longitudinal supports spaced by 14 cm, resulting in an implosion pressure of 2.5 bar.

The absorbers are coated with a selective coating, to efficiently absorb the incident sunlight while providing low emission in the infrared range (*see optical characteristics*). High vacuum is maintained throughout the panel life of 30 years by a getter pump driven by solar energy (*see vacuum considerations*).

Optical characteristics

Both the pump and the absorbers are blackened electrolytically with a layer of Cr oxide which provides an absorption coefficient of about 0.9 and an infrared emissivity at 300°C below 0.07. This coating is stable when

Article available at http://www.europhysicsnews.org or http://dx.doi.org/10.1051/epn/2013301

heated under vacuum at 450°C for months or in case of an accidental air inlet during operation.
Although mirrors are not needed to reach high temperatures, the SRB panel can be equipped with cylindrical mirrors which reflect diffuse and direct light equally well onto the back of the panel, and do not require sun tracking. Parabolic mirrors – which do need sun tracking – are not suitable for diffuse light, which may exceed 50% of the total in regions like Central Europe. Use of the cylindrical mirror almost doubles the absorbed power, while the panel cost is only marginally increased.

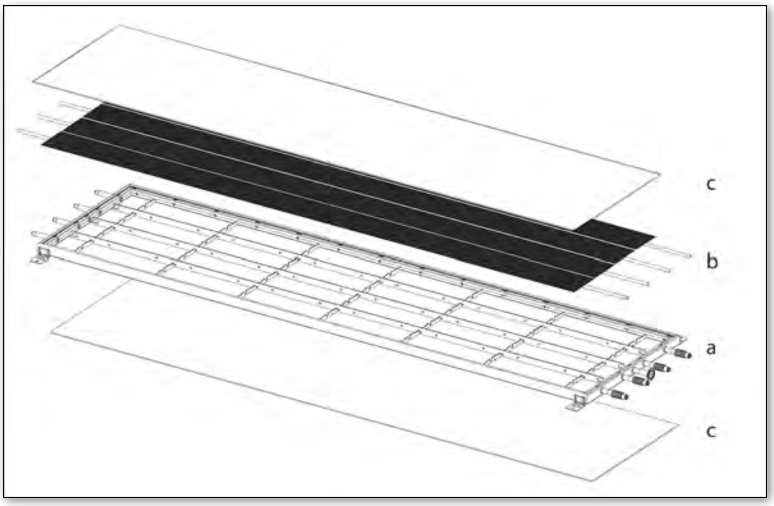
Vacuum considerations

Vacuum is the best thermal insulator provided by nature. In a traditional thermal solar panel, conduction and convection through the ambient air results in large thermal losses, which limits the panel temperature and the range of applications. By evacuating the panel, thermal losses are reduced dramatically, thus increasing the panel efficiency. When an SRB panel is exposed to sun light while being in vacuum, its temperature is limited only by emission losses through infrared radiation. If the pressure is progressively increased, the temperature does not change until about 10^{-4} mbar, and then it drops quickly due to molecular conduction and becomes constant after reaching 10^{-1} mbar. Therefore, the pressure inside the solar panel must be kept below about 10^{-4} mbar during the lifetime of the panel to keep the molecular conduction losses negligible with respect to the radiation losses.
In any sealed device, after initial evacuation of the atmospheric air, vacuum must be maintained by pumping the gases desorbing from the device components. Since about a century this is done by getters, which are materials able to chemically adsorb reactive molecules in the form of stable compounds. In this process the gas molecules are removed from the vacuum chamber, and the getter surface is progressively covered until its pumping capacity vanishes. The attractive property of Non Evaporable Getters (NEG) is the possibility of restoring the lost pumping capacity by heating. Heating provides the energy required for the gases adsorbed on the surface to diffuse into the getter bulk. The surface is then available for further pumping. However, when most of the NEG atoms have reacted with gas molecules, the pumping action gets finally lost. For this reason the quantity of NEG inserted in the solar panel must be tailored to the total quantity of gas to be pumped during the panel life (30 years). This requires the panel to be constructed with the usual precautions for ultrahigh vacuum (UHV) applications, although the vacuum required does not need to meet UHV standards. Outgassing rates of materials may vary by more than 10 orders of magnitude, but the pumping capacity cannot be increased in the same proportion. Therefore, organic materials cannot be used, and the surfaces of the vacuum system components must be carefully cleaned.
As a by-product of the constraint of maintaining the required vacuum over the panel life, the pressure is initially lower than strictly needed (*see Panel performance*).
Apparently these considerations are not always taken into account sufficiently by the manufacturers of cylindrical evacuated solar panels, whose performance is often spoiled by vacuum deterioration [2].
NEGs were used for the first time to provide the large and linear pumping required for accelerators in the Large Electron Positron collider at CERN [3]. To cope with the requirements of the subsequent CERN accelerator (the Large Hadron Collider), NEG thin film coatings were developed [4], a technology covered by CERN patents and widely used in other projects since.
The getter used for the panel consists of a thin film deposited on both sides of an aluminium foil by means of a dedicated sputtering system, which may produce about 150 m^2 of coated foil per week. The coated foil is inserted in a box coated by the same chromium black used for the panel absorbers. The absorbed sun light provides the heating of the box needed to regenerate the NEG.
Vacuum leaks were not mentioned so far. Leaks are an intrinsic danger for any vacuum system, and a correct design may at best reduce this risk to an acceptable level. Since the size of a leak cannot be predicted, the risk of leaks cannot be taken into account when dimensioning the pumps. However, an upper limit of the tolerable leak size may be obtained by comparing the quantity of gas entering from a leak with that resulting from degassing. In the present case a leak of the order of 10^{-8} mbar.l.s^{-1} would not appreciably affect the panel performance during 30 years.

Panel performance

The thermal efficiencies of the bare panel and of the panel equipped with cylindrical mirrors are shown in Figs. 2 and 3. The low-temperature performance of the bare panels is slightly higher than those equipped with mirrors, due to the non-ideal mirror reflectivity. At high temperatures, however, the mirrors provide higher efficiencies thanks to the increased power absorbed.

▼ **FIG. 1:** Schematic view of the SRB solar panel. a: frame with spacers; b: absorbers with cooling pipes; c: glass windows. The panel is 3 m long and 70 cm wide. The panel thickness is 45 mm.



When mirrors are used, an efficiency of about 45% is reached at 200°C for maximum solar power, and over 40% at 100°C for a solar power of only 200 W/m^2.
The pressure inside the panel is in the 10^{-7} mbar range just after panel sealing, and is later strongly dependent on the temperature of the absorbers. The higher this temperature, the larger the degassing and the pressure. At 350°C the pressure reaches the 10^{-6} mbar range, while during cold winter nights it may even go down below 10^{-9} mbar. These vacuum conditions did not change in some panels during the 3 years following their production.

"Cylindrical mirrors reflect diffuse and direct light equally well onto the back of the panel"

Applications

The SRB panel is very versatile: it may be used to produce heat at temperatures up to 250°C, and the heat may be used also for refrigeration by means of a cooling-cycle machine. Obviously, in sunny, hot countries also less sophisticated solar panels could be used for low-temperature applications. In cold countries, however, the SRB panel provides much higher efficiencies, plus the important benefit of being insensitive to the external temperature, thanks to its vacuum barrier.
More generally, the SRB panel represents the best choice to produce heat for industrial processes up to 250°C (particularly in countries characterized by an important percentage of diffuse light), or to drive a cooling-cycle machine in hot countries.
These panels were already used, for instance: by a pharmaceutical industry in Spain for production cooling; to keep bitumen at 180°C in the Geneva area; to provide heating and air conditioning for the Geneva Airport. This last project, with a solar field covering an area of about 1200 m^2, is described in detail on the WEB [5].
When equipped with Fresnel mirrors, the panel could also produce electricity. This application, however, faces competition of the photovoltaic technology, the cost of which is steadily decreasing. ■

Acknowledgments

SRB Energy belongs to the Grupo Segura, a Spanish company active in the automotive sector and employing about 500 people, with production factories in Spain and Hungary. The SRB panels are produced at Almussafes, close to Valencia (Spain) while the development laboratories are located on the CERN site close to Geneva (Switzerland). The SRB panel is an industrial reality thanks to the competence and the commitment of the Geneva and Valencia SRB staff.

About the author

Cristoforo Benvenuti was born in Milano in 1940. After graduating in physics in 1963 and a fellowship at the Ispra Research Center, he joined CERN in 1966, to work initially in Vacuum technology, later in Materials technology and finally as head of the Accelerators Engineering Service. He received various awards for technological achievements: the 1998 European Prize for Achievement and Innovation in the Accelerator field, and the 2002 Gaede Langmuir Award of the American Vacuum Society.
After retiring from CERN in 2005 he created SRB Energy with private investors. SRB is a company aimed at producing and commercializing an evacuated thermal solar panel which he had patented while being at CERN in 2003.

References

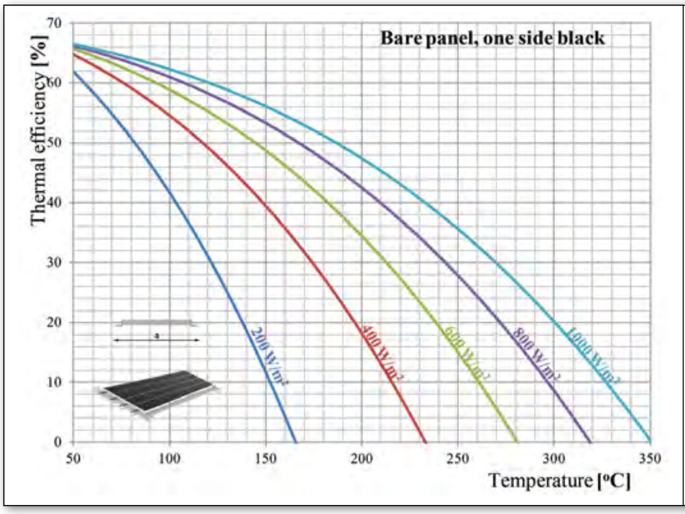
[1] C. Benvenuti and V. Ruzinov, *Proc. ECOS* 2010, June 14-17, Lausanne, Switzerland 2010, 2, p. 429

[2] A.W. Badar, R. Buchholz, F. Ziegler, *Solar Energy* **85**, 1447 (2011)

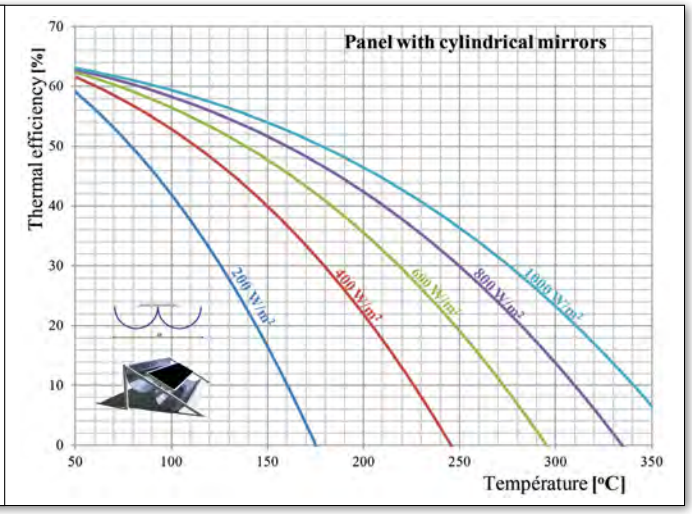
[3] C. Benvenuti, *Nuclear Instruments and Methods* **205**, 391 (1983)

[4] C. Benvenuti et al, *Vacuum* **60**, 57 (2001)

[5] www.youtube.com/watch?v=qyFZv1gWh4c&feature=youtu.be



▼ **FIG. 2:** Bare-panel efficiency as a function of operating temperature for different incident solar powers. In this case the panel absorbers are blackened only on the side exposed to sun.



▶ **FIG. 3:** Same as for Fig. 2, now for panels equipped with cylindrical mirrors. These mirrors are equally efficient for the direct and diffuse sun light reflected onto the back side of the panel. The absorbers are blackened on both sides in this case.