THE SINTHESIS

of the research contract for 105 / 01.10.2007 financing contract,
CNCSIS 618 code, named
"INTERDISCIPLINARY RESEARCHES FOR ESTABLISHING POTENTIAL LIMITS OF SOLAR ENERGY WITHIN SOLID CORPS ON HEATING-MELTING INTERVAL"

Introduction

Many of the photovoltaic systems function independently of the wire system. These systems are made of: solar panels matrixes, control systems, storage systems and consuming like DC or AC. In first figure it is presented the scheme of a PV system:

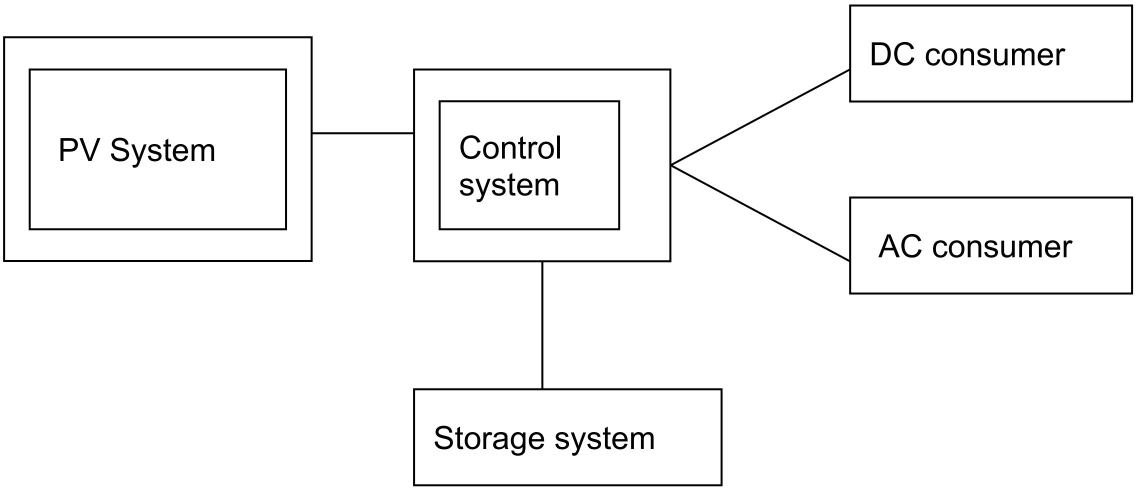


Figure 1. PV system

Panel matrixes are made of modules which consist in serially or parallel connected panels depending on requirements. The panels are generally made of 36 serially connected cells.

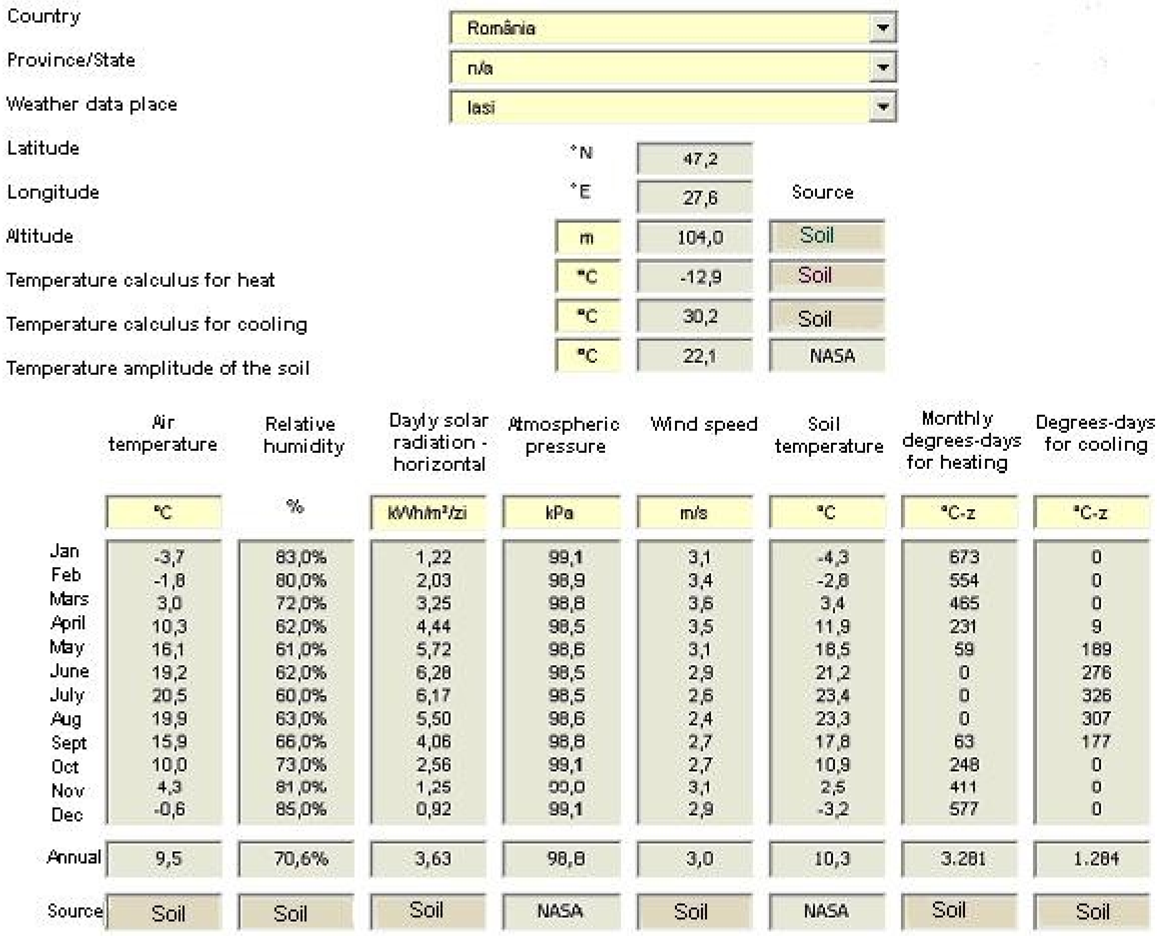
There are used specific batteries for PV systems for storage and in for a stabilized tension.

Control systems have charging regulators, converters which can be as needed DC-DC or DC-AC and blocking diodes. Control systems assure the interface between all components of the PV system protecting and controlling the system.

1. Technical-scientific fundament of using solar furnaces

1.1. Documentary study regarding solar furnaces and the importance of climatic conditions

In order to design a PV system it is going from the consuming requisite power (load resistance) which in this case is an electric furnace of 1 l capacity and a 0.55kWh power, a lab furnace, the work time and climatic conditions of the zone where the system is installed. The necessary Climatic conditions are given in figure 2.



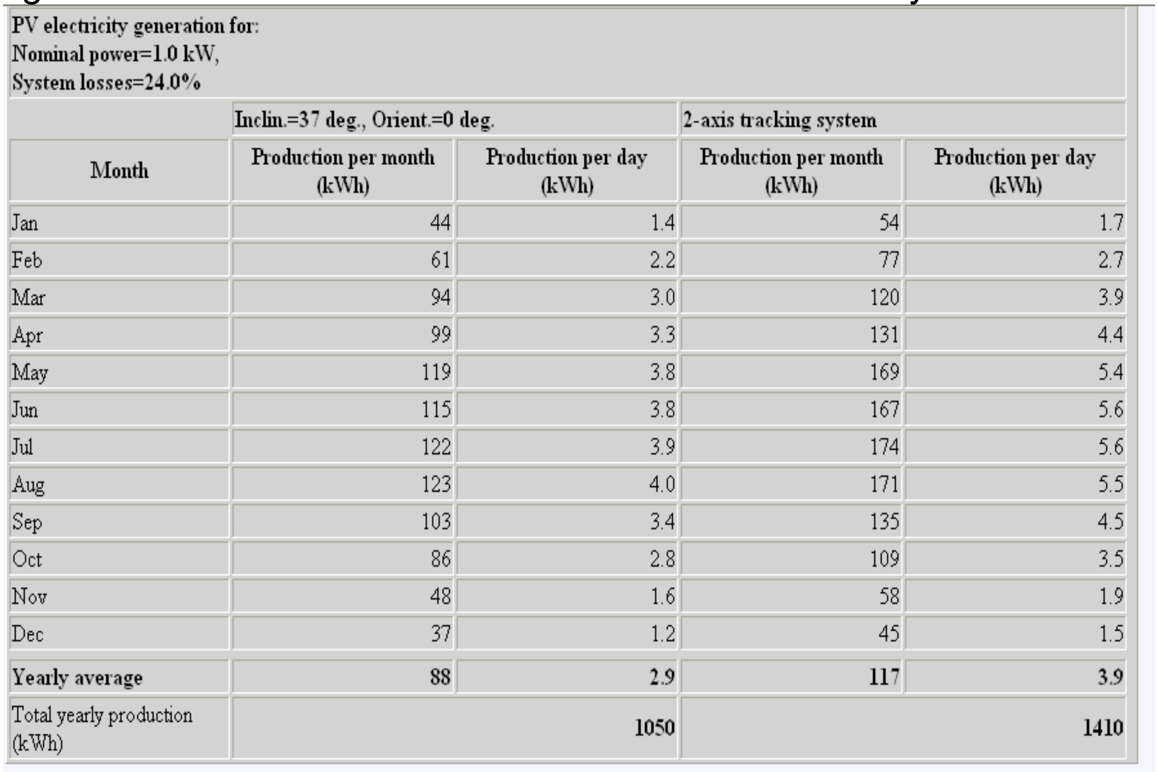
Country		România	
Province/State		n/a	
Weather data place		Iasi	
Latitude	°N	47,2	
Longitude	°E	27,6	Source
Altitude	m	104,0	Soil
Temperature calculus for heat	°C	-12,9	Soil
Temperature calculus for cooling	°C	30,2	Soil
Temperature amplitude of the soil	°C	22,1	NASA

	Air temperature	Relative humidity	Dayly solar radiation - horizontal	Atmospheric pressure	Wind speed	Soil temperature	Monthly degrees-days for heating	Degrees-days for cooling
	°C	%	kWh/m²/zi	kPa	m/s	°C	°C-z	°C-z
Jan	-3,7	83,0%	1,22	99,1	3,1	-4,3	673	0
Feb	-1,8	80,0%	2,03	98,9	3,4	-2,8	554	0
Mars	3,0	72,0%	3,25	98,8	3,6	3,4	465	0
April	10,3	62,0%	4,44	98,5	3,5	11,9	231	9
May	16,1	61,0%	5,72	98,6	3,1	16,5	59	189
June	19,2	62,0%	6,28	98,5	2,9	21,2	0	276
July	20,5	60,0%	6,17	98,5	2,6	23,4	0	326
Aug	19,9	63,0%	5,50	98,6	2,4	23,3	0	307
Sept	15,9	66,0%	4,06	98,8	2,7	17,8	63	177
Oct	10,0	73,0%	2,56	99,1	2,7	10,9	248	0
Nov	4,3	81,0%	1,25	00,0	3,1	2,5	411	0
Dec	-0,6	85,0%	0,92	99,1	2,9	-3,2	577	0
Annual	9,5	70,6%	3,63	98,8	3,0	10,3	3.281	1.284
Source	Soil	Soil	Soil	NASA	Soil	NASA	Soil	Soil

Figure 2.

As observed from the column which gives solar radiation average horizontal per days, we have the sufficient radiation quantity in order to produce consuming requisite power of 0.55 kWh.

By orienting the system to an optimum bent degree it can be obtained a significant radiation increase that can be used. If it is used a tracking type system it is obtained a higher quantity with almost 40%, see figure 3 where there are also considered system losses.



PV electricity generation for:
Nominal power=1.0 kW,
System losses=24.0%

	Inclin.=37 deg., Orient.=0 deg.		2-axis tracking system	
Month	Production per month (kWh)	Production per day (kWh)	Production per month (kWh)	Production per day (kWh)
Jan	44	1.4	54	1.7
Feb	61	2.2	77	2.7
Mar	94	3.0	120	3.9
Apr	99	3.3	131	4.4
May	119	3.8	169	5.4
Jun	115	3.8	167	5.6
Jul	122	3.9	174	5.6
Aug	123	4.0	171	5.5
Sep	103	3.4	135	4.5
Oct	86	2.8	109	3.5
Nov	48	1.6	58	1.9
Dec	37	1.2	45	1.5
Yearly average	**88**	**2.9**	**117**	**3.9**
Total yearly production (kWh)	**1050**		**1410**	

Figure 3. Comparison between a fix system with a 37^o optimum angle and a tracking system

In order for a PV system to offer in standard condition 1 kW it can use 8 modules Mitsubishi PV-MF 130 EA2LF type, polycrystalline silicium, 8 x 130Wp = 1.04 kW.
For this system there are necessary 3 batteries of 130Ah, 12V which assure a two days functioning reserve even if there is no sun. The calibration of the storage system is made based on use period and the days when the system provides power from the batteries.
Charging regulator for batteries has as a basic function the charging stop when the batteries are completely charged. There are some other functions as consuming disconnection when tension is small, temperature compensation etc.
Blockage diodes are used to avoid batteries discharge, on cells, during night period or when are cloudy days.
For some systems there can use MPPT (maximum power point trackers). The purpose of this device is to maintain operating tension of the system to a maximum tension which is independent of the load resistance changes.

1.2. The determination of the geometric arrangement and the components of a solar furnace used for processing metallic and non-metallic materials

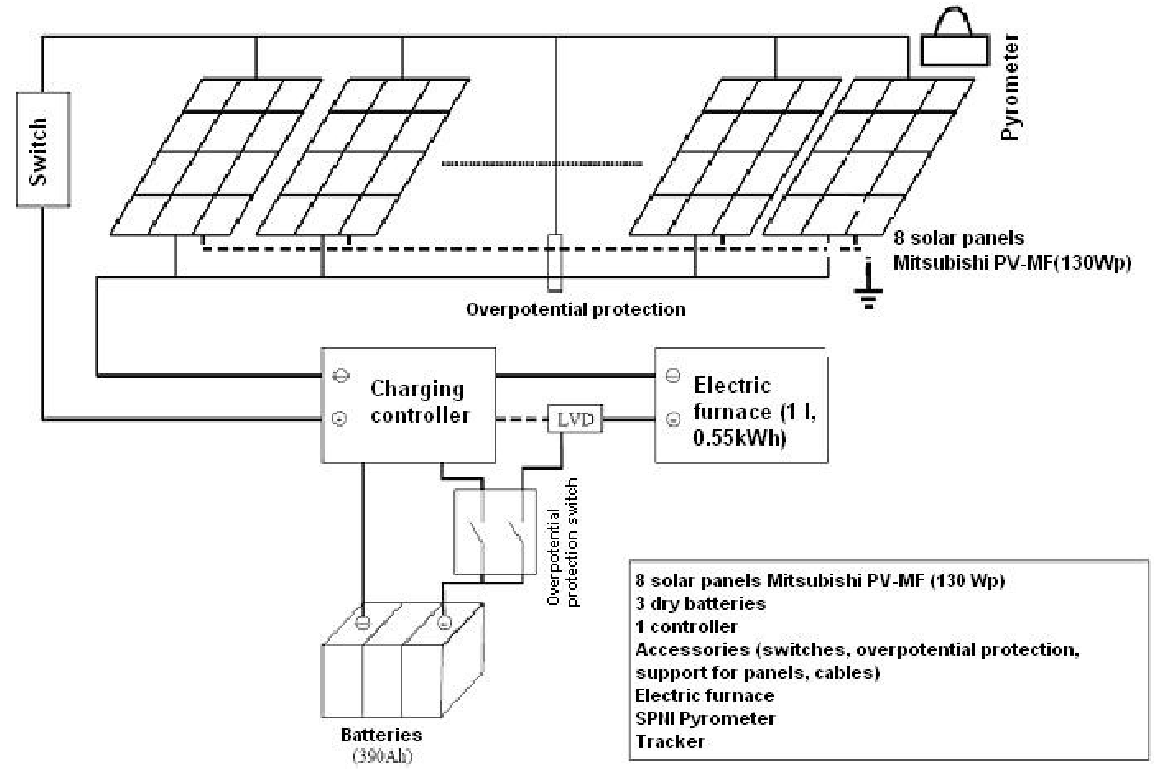


Figure 4. Scheme of an electric system with PV for direct current

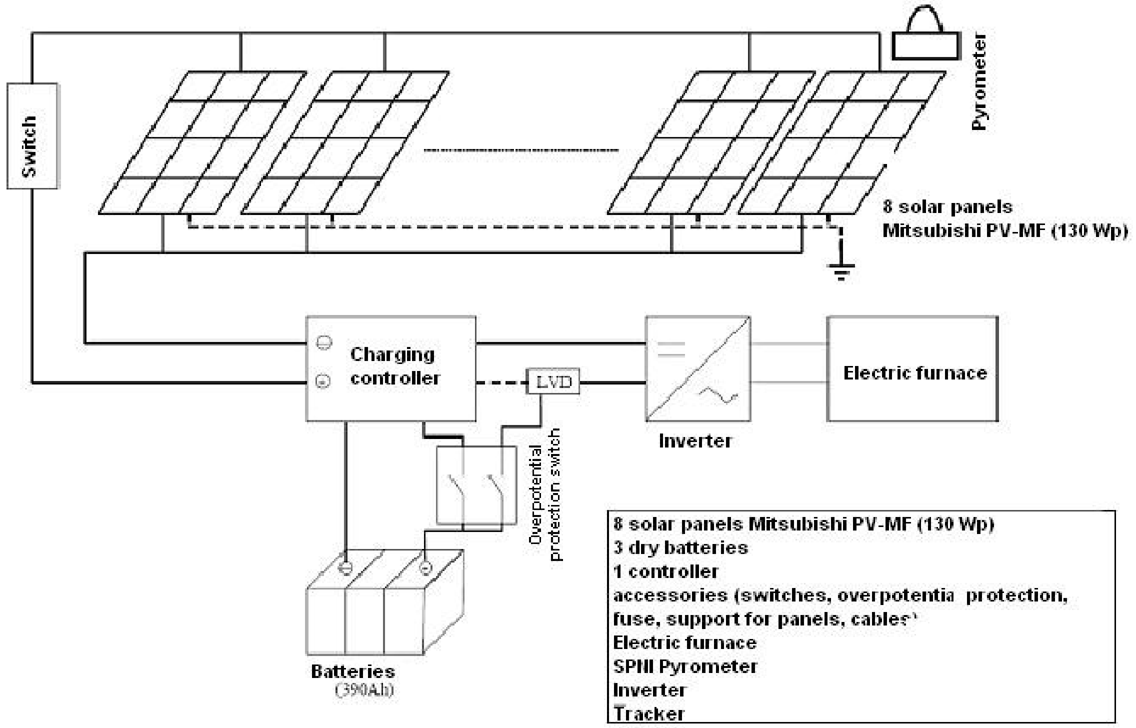


Figure 5. Scheme of an electric system with PV for alternating current

2. The analysis of heating process within solar furnaces

2.1. Mathematical model of heating regime within work chamber of a solar furnace

The factors that influence the performances of the solar furnace used in industrial applications which impose the procurement of some large densities of the radiant power and thus need a geometric perfection of the concentrator; they are divided in three categories as follows:

- the first category is pertinent to basic geometry of the parabolic concentrator defined by focal distance, f, and its opening, D. Once these were chosen, it results the dimensions of the solar image, focusing factor and the ideal maximum values of temperature and radiant power density into the image, regardless the concentrator's construction and its installation place.
- the second category consists in the factors that reduce the performances of the solar furnace due to its construction and installation place. These factors are: transmission energetic factor of the atmosphere, directional reflection energetic factor of the mirrors and index of geometric perfection of the parabolic concentrator.
- the third category includes the factors pursuant to receiver's properties : its adsorption and emission energetic factors and heat losses that take place through conduction and convection.

The available potential power P_f in Sun's image from the focal plan of a solar furnace is given by the relation:

$$P_f = \pi R_d D_a E_0 f^2 \sin^2 \theta_{max} \qquad (1)$$

where:

R_d – directional reflection energetic factor of the parabolic mirror (including heliostats, if they exist);

D_a – transmission energetic factor of the atmosphere where the furnace is installed;

$E_0 = 1353$ W/m^2 – solar constant;

f – focal distance;

θ_{max} – opening angle of the parabolic concentrator.

If it is disposed a solid corps in solar image, the available fraction of potential power effectively absorbed by the corps would be determined by absorption factor and the form of this corps-receiver. As such, maximum temperature that could be obtained into a solar furnace depends on the properties of the receiver disposed in the focal zone of the furnace:

$$T_{max} = T_S \left(R_d D_a \right)^{\frac{1}{4}} \left(\sin \theta_{max} \right)^{\frac{1}{2}} \qquad (2)$$

where $T_S = 5800$ K – temperature at Sun's surface.

2.2. The determination of the technological parameters involved in heating process in a solar furnace

The most important researches will refer to some metals and refractory materials behaviour at high temperatures, to some materials purifying and to the achievement of some chemical syntheses.

T rature which is obtained by
f be used by the furnace in
c crucible, without other
c al process.

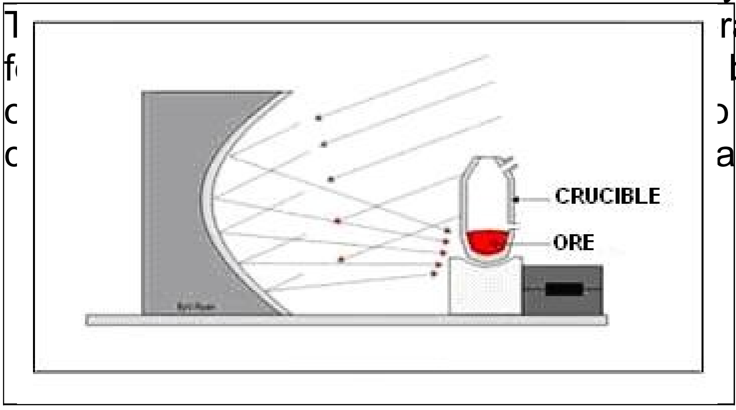


Figure 6.

Steel or aluminium production needs very high energy quantities. This is normally given by electric power, natural gases or conventional fuels. Solar furnace uses the energy given by Sun's power.

It is notices in image how sun's rays can be focused towards the crucible where the ore is. This is heated to a very high temperature until it melts and can be molten. Pollution is practically inexistent because solar energy is a clean form of energy.

One of the most important applications of the solar furnaces is that of melting materials with very high melting point.

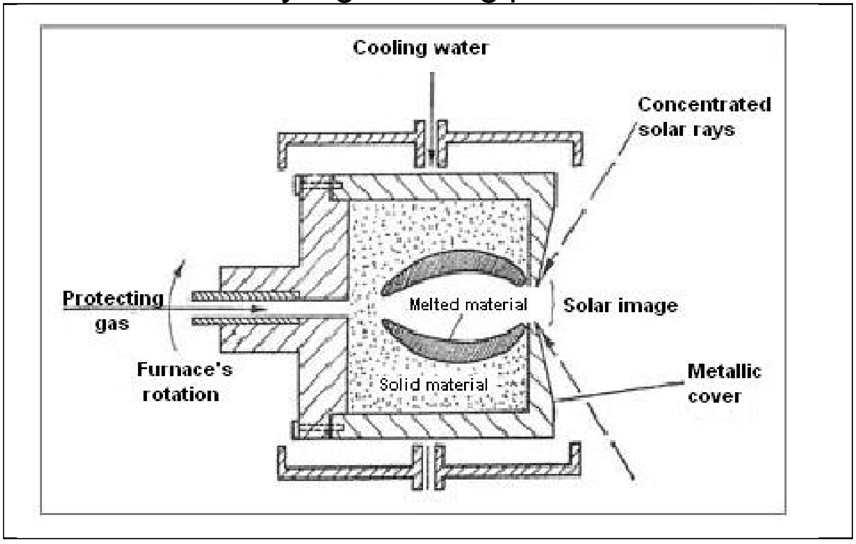


Figure 7.

If the surface of a solid material is exposed to very intense radiation from the focal zone of a solar furnace it takes place materials melting on a portion whose area is approximately equal to the area of Sun's image. As heat enters the solid the melted material quantity increases and forms a liquid cavity. Through such a process it is possible melting into a crucible made of the material which is to be melted; these happens cause to the existence of a high temperature gradient between melted material and crucible's exterior.

In conventional furnaces, the crucible is heated from exterior and thus it has always a higher temperature than the melted material. That is why in such furnaces the crucible must be made from a material more refractory than the material which is to be melted; in addition, it must be inert from chemical point of view towards the melted material. The achievement difficulties of these two conditions increase as the melting point of the studied material is higher and over 2000°C there are few chances to avoid chemical reactions. The use of solar furnaces in melting materials with high refractivity overbears these important limitations of the conventional furnace. Thus, melting can be achieved in furnaces with horizontal axis. The furnace is turned round its horizontal axis and has an inner diameter several times bigger than solar image diameter. If rotation speed is low the melted material remains at the inferior part of the furnace and the turning helps to achieve a uniform distribution of heat. For higher rotation speeds the melted material is centrifugally – forming a cavity – which does not allow its flow from the furnace. The exterior walls of the furnace – made of steel for example – can be water cooled in order to maintain (if necessary) a high temperature gradient through walls.

When melting should be made into a certain protective atmosphere it is passed an adequate gas current as indicated in the figure. Through the materials which can be studied there are: quartz, zirconium dioxide, corundum, ceramic oxides and materials like carbides, nitrides and boron for which conventional melting techniques present a series of disadvantages.

As well, it can be studied the practical possibility of using solar furnaces to steels melting. Technically the crucible can be made easily by introducing in furnace’s cavity a refractory powder (e.g. mullit) and sintering it or even melting it through furnace’s whizzing which is exposed to solar radiation. Afterwards it is introduced scrap iron, melted and then – if necessary – molten in forms. The performances of such a solar furnace must not be special because there are sufficient temperatures of 2000 – 2500 ºC.

For the future, a bigger interest presents some other metals melting, more expensive than steel, such as titanium, zirconium and molybdenum. In this case it must be assured an inert protective atmosphere and thereby it must be taken into account the complications and expenses related to these.

Some other applications of the solar furnaces are impurities evaporation, zonal melting, fractioned crystallization, the extraction of zirconium oxide from zirconium (zirconium silicate), and the material study under thermal shock conditions.

Project manager,
Associate professor dr. eng. Petrică VIZUREANU