

A highly innovative, high temperature, high concentration, solar optical system at the turn of the nineteenth century .The Pyrheliophoro,

by

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I-Introduction

The ISES initiative of recovering the recent and not so recent history of solar energy and its pioneers has prompted several investigations into the past. Several gems of ingenuity, scientific and technical capacity, way ahead of their time, have been uncovered. The one to be described in this paper is one of those, having produced quite a stir in its own time. It was soon to be forgotten given that the World in transition from the nineteenth to the twentieth century, was about to embark in the "oil race", and solar energy was not even given half a chance to be "in the race" at that time.

The man behind the work described here was a truly remarkable personality, a self made scientist, a catholic priest, without a proper (academic) scientific training. Through life he tried to compensate for it by his constant travels, in particular to France (mainly Paris), but also to many other scientific relevant European Countries, in particular England and Germany and to the U.S., interacting and even studying with top notch people of his day, like Berthelot, Moissan, Violle, among others.



Father Himalaya 1902

His name was Manuel António Gomes, soon nicknamed by a friend as Himalaya, because he was taller than his colleagues. He added this nickname to his name and was (and still only is) known by it. He was born in 1868, in Cendufe, a small village in the North of Portugal. He was one in a large family with little economical resources. As usual in those days and in such circumstances, he entered the Seminary, as a way to study and to succeed in life. He was ordained priest, and a practicing priest he was until his last day (in 1933), in spite of his very controversial life style, unorthodox views of the Church and its dogmas, the very critical position he had on items like the forced celibacy of priests and its constant fight for a more socially responsible and committed Church, embracing as he did the truly liberal, republican, socialistic and idealistic ideas of the day.

He was quite famous in his lifetime and respected for his achievements. He became member of the Portuguese Science Academy and had at least an attentive audience amidst the politicians of that day.

This paper is dedicated to his crown achievement in the field of optics and solar thermal, but he is also known for many other original contributions, for which he got

a truly large number of patents, in Europe and in the U.S.. and, most notably, the Grand Prix at the St. Louis World Exhibition of 1904.

He really lacked a proper high level training in Physics and other basic sciences, which would have been very good to shape his enormous qualities as an experimentalist and as a mechanical genius. His training in chemistry was probably deeper (his interaction with Berthelot and other important chemists certainly had a crucial part in that). Among other things he invented and developed an explosive (a chlorine based, smokeless-powder, the himalayite - said to be more powerful, easier and safer to use than dynamite) which he put to many pacific usages, in particular in agriculture and in quarries¹. His explosive was sought after by several armies of the World (U.S., German, Portuguese, etc.) and his involvement with some of those is still more or less shrouded in mystery. Another one of his inventions, deserving a mention in this brief account, is the one of a rotary steam engine, looking very much like the rotary engines first proposed-and developed- many years after².

He was also a Nature lover, a self trained biologist, a practitioner of natural medicine, but, most remarkably, he was an ecologist "avant la lettre", an explicit and stout advocate of sustainable development, through a proper balance of Humanity, its needs and Nature, regarded by him not just as a provider but also as an important part of the whole scheme of things. He constantly called for Renewable Energies (solar, hydro, tidal, wave,...) as the means for long term and balanced solutions for the many problems caused by poverty and starvation facing the World of his time and in particular of his own country. He had, in this regard, a truly modern view of the World and of the place of Man in Nature, a view which is taking another hundred years to affirm itself.

This note and comments are largely based on the remarkable book [1] written by Prof. Jacinto Rodrigues, which is now about to be translated in several languages and being used as the basis for a movie on the extraordinary life of this towering man and personality.

II-The Pyrheliophoro

II.1- The first steps: the metallic lens

Father Himalaya, from his early days, saw solar energy as means to provide energy not just for the production of hot water or steam, but as a direct means to provide energy for industrial processes, in particular to those associated with materials production or processing, if high enough temperatures could be achieved. Among other objectives, he wanted to produce nitrogen based agricultural fertilizers by extracting the nitrogen directly from the air! He could never achieve that with his devices, as we can today well understand, but he managed to achieve perhaps the highest controlled temperatures of the day, about 3800°C, in the solar furnace of his pyheliophoro, a truly remarkable achievement.

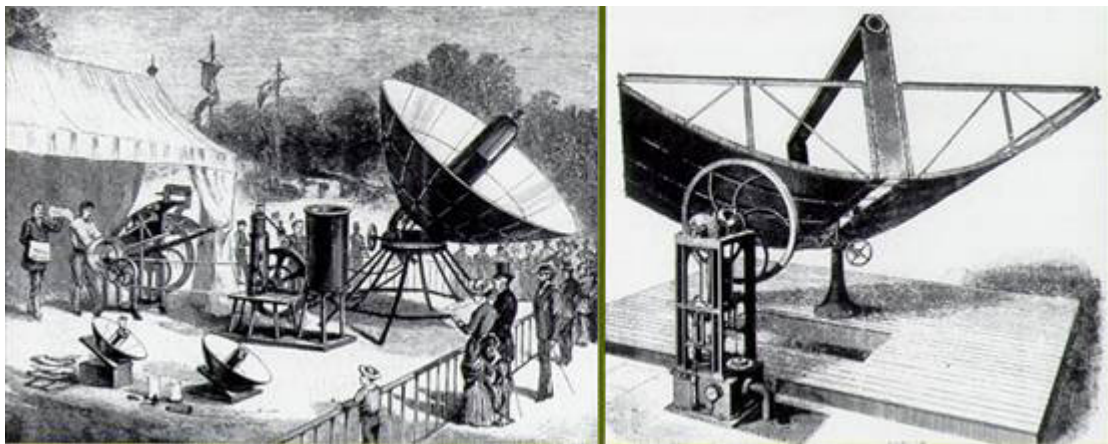
¹ Portuguese patents 8544-1912, 8932-1913, which were preceded by several U.S. French and British patents: U.S. patents 301524 (1906) 853085 (1907) 869158 (1907) French patents 374 656(1907) 374932 (1907), British patents 3179 (1907) 3199, 4439 (1908), 20931 (1908)

² (Portuguese patent-9719, March 1917.

If not before, at least in Paris, at the end of the turn of century, he became quite likely familiar with the works of A. Mouchot [2], Louis de Royaumont [3], Charles Metelier [4]. Also, mainly from his correspondence and from documents found among his belongings, it is fair to assume that he must have had some degree of familiarity with the works of John Ericson [1,8] W. Adams [1,8], Calver [1,8,5], Aubrey Eneas [1,6,7,8], among others.

He was critical of the devices produced by Mouchot-Piffre, and soon understood that he needed to modify them in order to obtain higher temperatures and also in order to break the mechanical coupling between the solar furnace (placed in the "focal zone") from the structure supporting the mirrors. If possible he also wanted a stationary solar furnace, while only the optics would do the necessary tracking of the sun's apparent motion in the sky.

In Fig1.(a) the device developed by Mouchot-Piffre is shown, a paraboloid like shaped structure with reflecting inner walls, and a furnace place along its optical axis.



(a)

(b)

Fig.1.- (a) Solar device of Mouchot-Piffre (b) parabolic trough of Ericson

Truncated cone like shaped mirrors (Eneas Fig.1. (c)[6,7], Pasadena, California, 1901) and large flat ones (Calver, [5]Tucson, 1901) were among some of the solar optics of the day. John Ericson [1,8] proposed a parabolic shaped mirror in 1880 (Fig.1(b)), but Himalaya's ideas went in rather different directions.

References [5,6,7] are explicit instances of Portuguese magazines dedicating space, in those days, to those and other inventions and F. Himalaya likely read them. It was not possible to consult the referred magazines and therefore their level of technical detail is not known to the author. However these were publications for a general audience and little should be expected beyond some photos or drawings and a reference to the purpose of the inventions. .

To the interested reader the author recommends the first section of a modern book [8] containing an interesting introductory chapter on the history of solar energy. This book makes an explicit mention of Father Himalaya and his crown solar achievement – the Pyrheliophoro- at the St. Louis Fair of 1904.

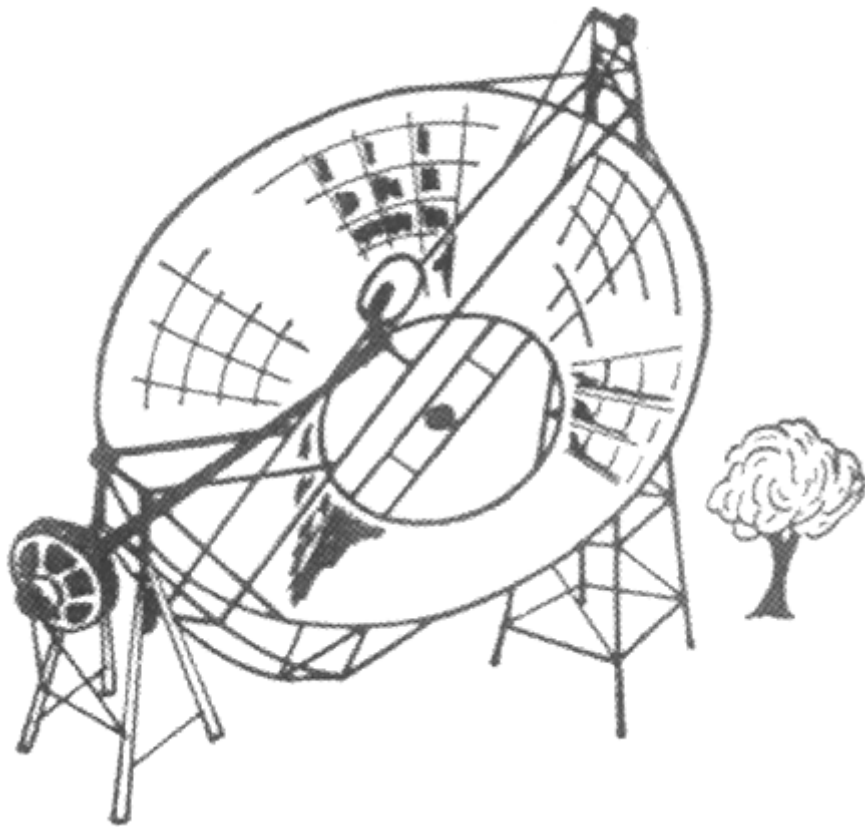


Fig.1. (c) - solar experimental apparatus of Eneas

He soon understood that the very high concentration factor he needed required two axis type tracking. With materials processing in mind, he needed solutions that would not have, in his own words, "the furnace between the reflector and the sun". He thus first thought of lenses to do the job, since these could send the concentrated light down and out, towards the target. However the required dielectric (glass!) lenses were not a practical idea in those days and his first remarkable attempt can be seen in Fig.2 and 3. It is a metallic Fresnel lens type, done with flat-strip- mirrors, ring shaped, the whole ingeniously tracking the sun in elevation and compensating for the earth's rotation, by moving together on circular rails.

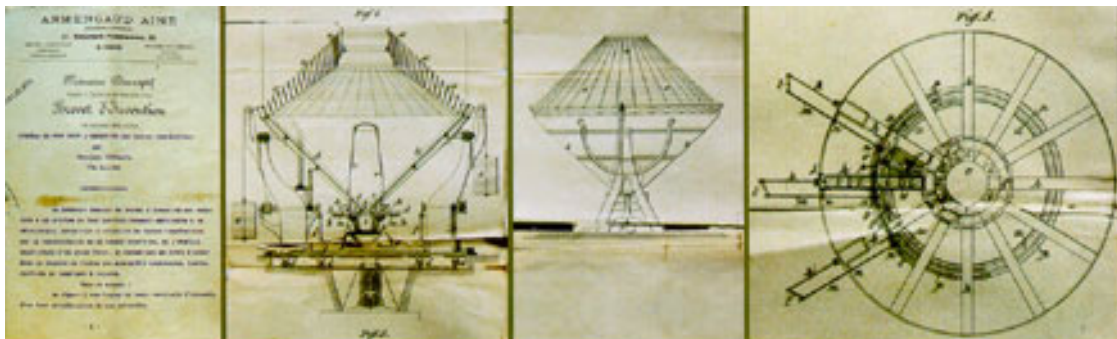


Fig2.- Figures from Patent [10]

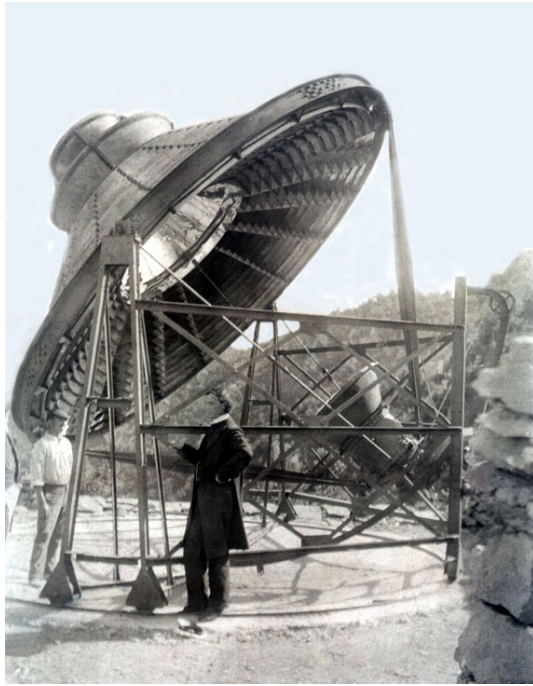


Fig.3(a)- the device and Himalaya standing in front of it , in Paris



Fig.3(b) - the device at Castel d'Ultrera

His experiments were carried out in the French Pyrenees, (Castel d'Ultrera) not far from Odeillo and Font-Romeu (of later day fame, for very similar solar reasons!)

The results he obtained were not as good as he expected, but it seems that he was able to achieve temperatures in excess of 1500°C (melting iron), a remarkable achievement, given the choice he had of materials for the mirrors, and a good measure of the mechanical precision with which he was able to produce his device. It should be noted that the solar furnace itself was object of careful developments, to be able to contain the materials he was melting/processing with it. His temperature measurements were crucially dependent on what he was able to melt.

In fact the furnace itself was the object of patents, perhaps the most important of which being Patent [9].

Fig.4 is taken from that patent, showing a radiative type furnace, where the side walls c, c' were to be heated with the burning of fuel and the heat radiated into the triangular shaped cavity was to be concentrated (focussed) down onto the hot cavity F , by a paraboloid shaped upper wall d . This furnace was later very easily (and much better) adapted to the solar focussing optics to be described next, with solar radiation coming trough an aperture placed in d and the side walls c, c' now serving as a second stage concentrator.

drawings show different solutions to track the sun in azimuth and elevation. Use is made of rotation around centre poles to compensate for the Earth's rotation, with the furnace sometimes moving in a separate fashion, on rails, or as one with the mirror, but always with the possibility of adjusting to the sun's elevation. But none of these movements could be made in fully automatic way in a modern sense, i.e, in unattended operation, since that would require modern day combinations of tracking motors and sun sensors.

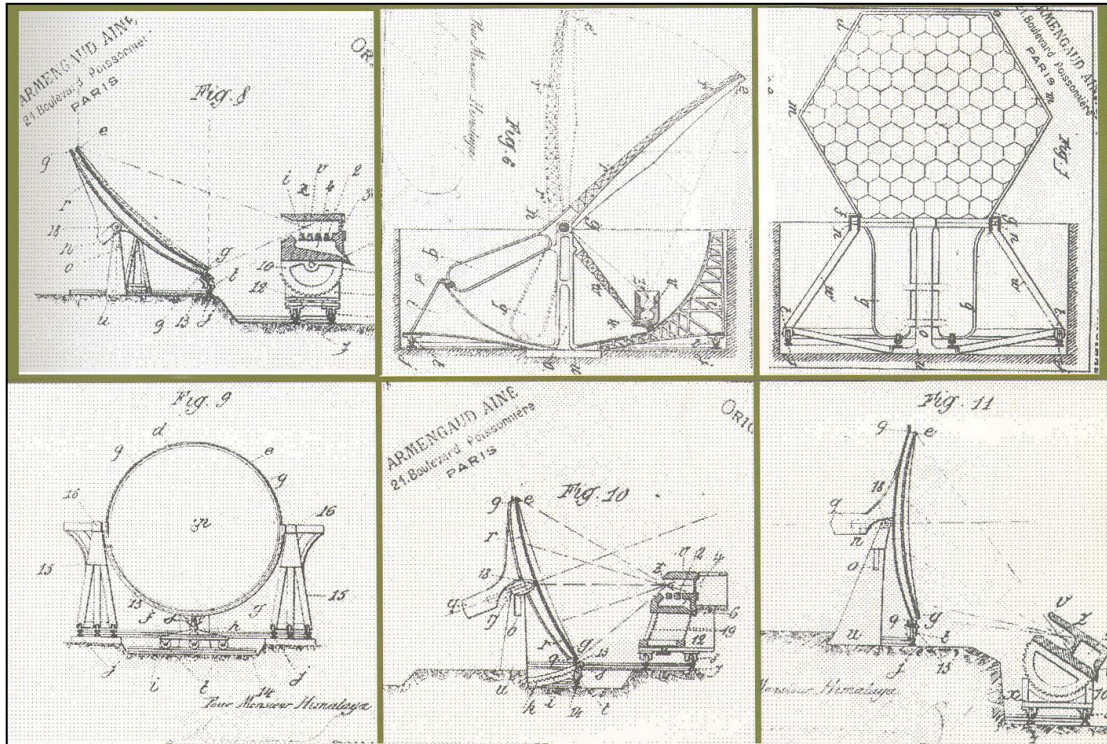


Fig.5: Excerpts from Patents [11,12,13]

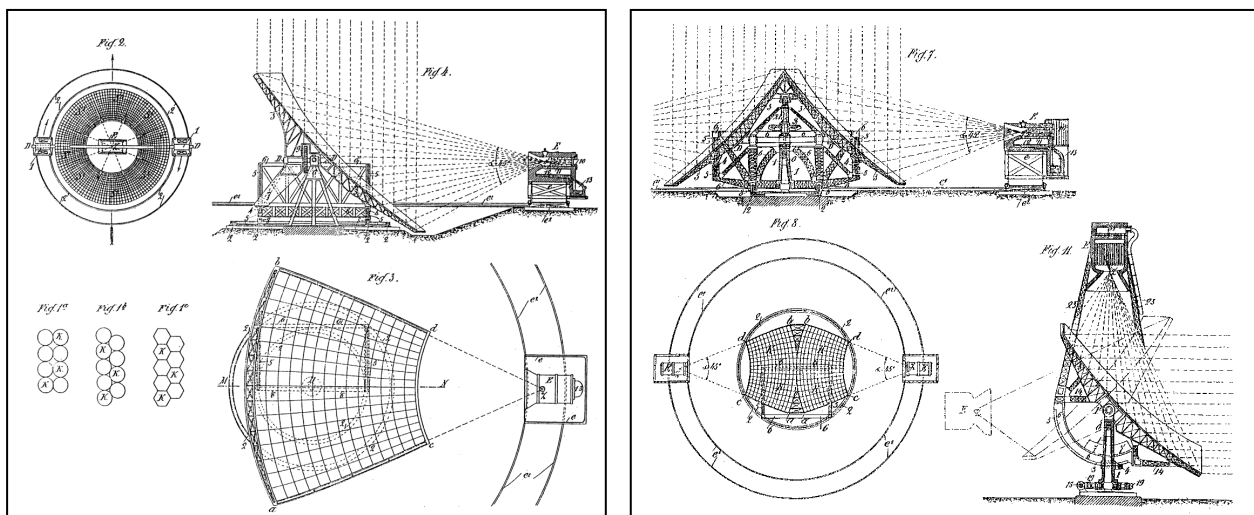


Fig.6 Excerpts from Patents [11,12,13]

Experiments with one of the possible configurations described in these patents (presumably one with the furnace going on a circular rail) were carried out in Lisbon (March/April 1902). Inaccuracies in the design and mechanical problems, plagued the

prototype. The day of the public demonstration the concentrated radiation destroyed the supporting structure and it was a fiasco!

It must be then that Father Himalaya sought about, quite beyond the fact that he needed to correct the faults with this prototype, that he needed a new idea for a truly practical system able to track the sun, unattended, at maximum concentration. A simple clock mechanism would do the trick, but that required a radically new design. That became the Pyreheliophero, to be described next.

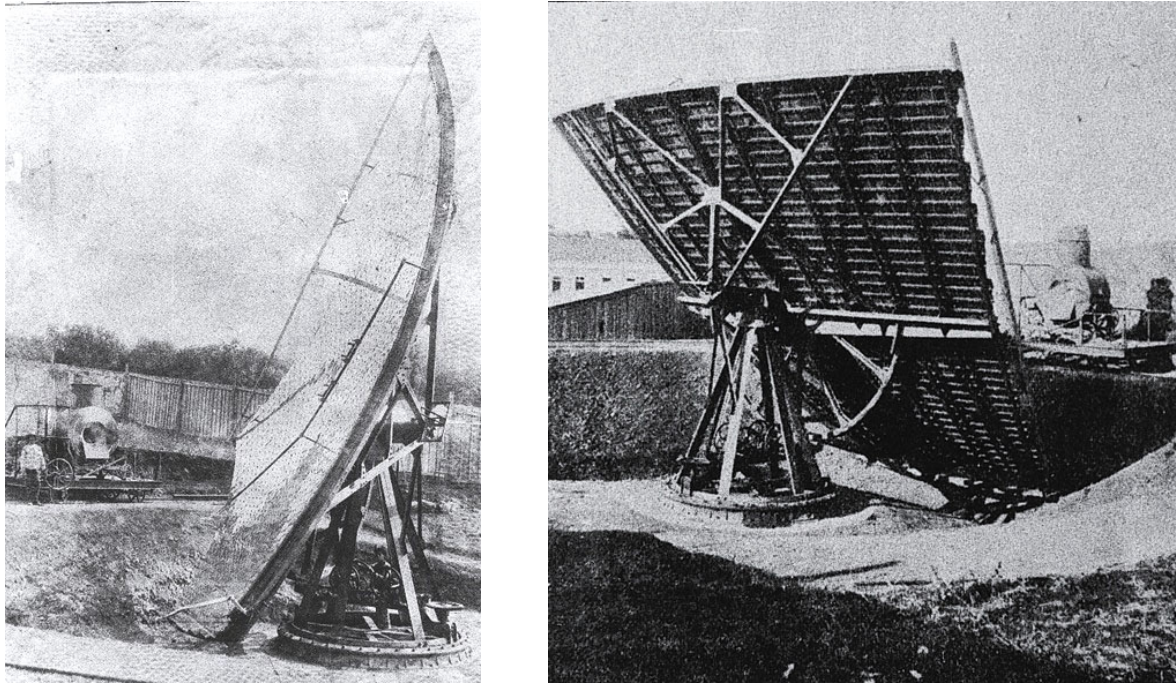


Fig7: The prototype built for the Lisbon tests with what looks like the furnace in the background

2.2- The Pyreheliophoro

Father Himalaya worked hard developing his new ideas and in a short time he was ready to show his new concept, directly at the World Fair in St. Louis.

As before, the explanations that follow result from a careful examination of the photographs below and from the educated guesses they allow. This is due to the fact that the writings of Father Himalaya available today, are even more scant about the Pyreheliophero than about the previous inventions. A particular reference should be made to the drawing, Fig.9(b), of Prof. João Gabriel da Silva [1,14].

The final configuration as it was assembled in St. Louis is shown in Figs.8,9. This solution integrates the two distinct motions necessary for the optics to track the sun, at each operating latitude, but with the required simplicity, as explained below.

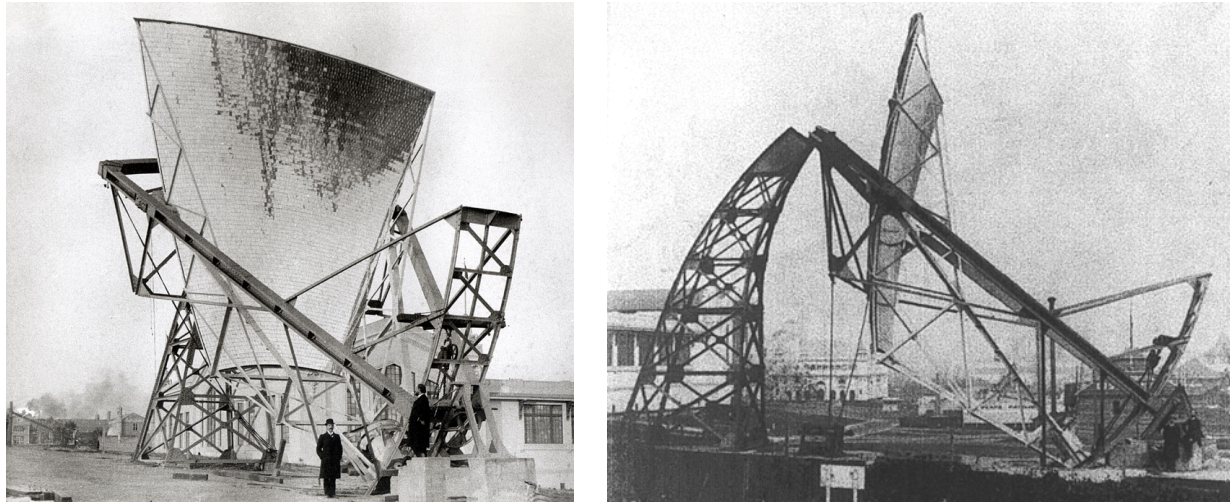


Fig. 9 : Two views of the Pyreheliophoro as assembled in St. Louis

It was 13 m tall. The total reflector area- a sector of a paraboloid- was 80m² for a mean focal distance of 10 m. There were 6117 small (123mmx98mm) silvered glass mirrors painstakingly fixed to the underlying structure. The focal area was designed to be no larger than a circle with 150mm diameter. This resulted in a total geometric concentration factor of ~4500 X. Father Himalaya claimed a final concentration factor of 6117 X, hinting at a smaller focal spot, approximately with the same area as each individual mirror. In truth, as already noted, the conic entrance to the furnace (even though it is not an ideal optics [23] for that purpose, as we know today) would have been instrumental in recovering tracking inaccuracies and the resulting radiation spillage that might have occurred and even effectively enhance the final concentration.

The way it operated is the following: (see Fig.8,9)

The system could be set with its axis AA' parallel to the Earth's rotation axis (an equatorial mount type arrangement- presumably with each model would come the possibility of slight tilt adjustment of the equatorial mount axis to the exact value of the local latitude). Simple tracking around this axis was achieved with ropes pulling on rings C and C', powered by a clock type mechanism, fixed to the ground immediately below. This would ensure that the sun would always be on a plane perpendicular to the plane of the equatorial mount structure. To concentrate its radiation on the furnace entrance, the system would now move the mirror assembly itself together with the furnace around axis BB', making the furnace describe an arc of a circle on some sort of a "rail", with centre on the line BB'. On bar D there was a pulley-chain mechanism to accomplish this movement. This adjustment, done on a daily basis, would ensure that the axis of the paraboloid would point to the sun at all time, during each day, since this whole system also moved as one with the equatorial mount! In short this corresponds to the present day complex 2 axis tracking with step or variable speed electrical motors, with sun sensors and/or computer assistance used in high concentration solar optics, substituted by a simple clock- constant speed- and potentially very accurate tracking system!. Indeed a very clever and practical solution, essential for the very high concentration Father Himalaya set out to achieve and otherwise outright impossible in a practical way, without the devices we have today.

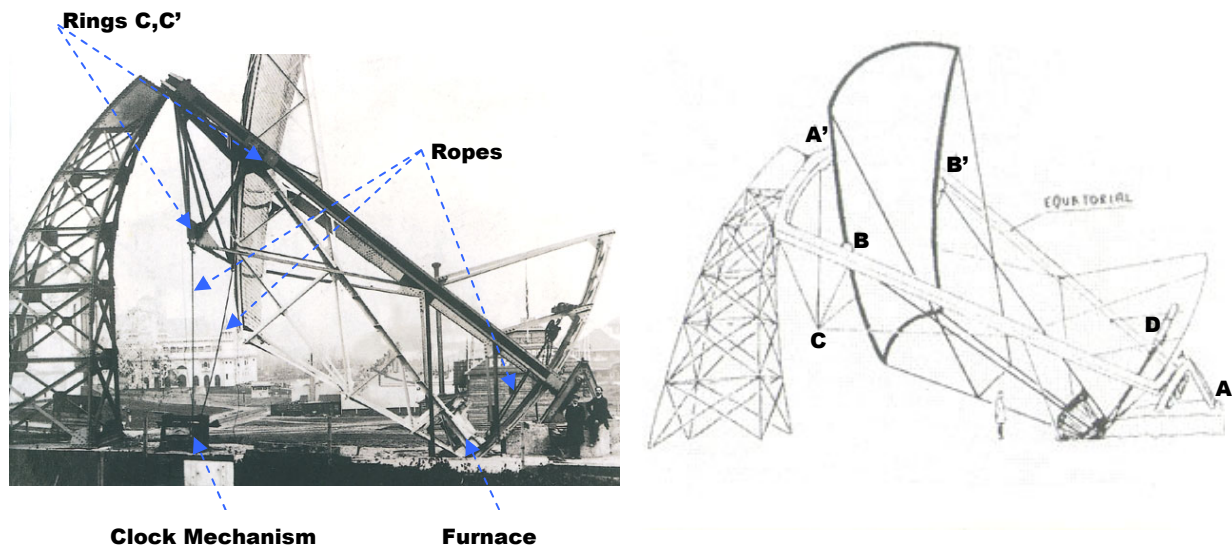


Fig.9(a) view of the Pyrehliophoro (b) Schematic drawing of the Pyreheliophoro [14]

The device was operated during the fair, to the amazement of its countless visitors. The best measure of its success is the fact that it got the **Grand Prize**.

Several books [15,16,17] and newspapers of the day[18, 19,20,21]referred to this event, reporting specifically about the Pyrehliophoro. There was even a mention of it in Scientific American [22]. In Portugal there were countless references in the press [1].

Father Himalaya only got three very clear days during which he claims to have obtained at least 3800°C, a very impressive achievement for the day.

U.S. Entrepreneurs wanted to take it (or make copies of it) to display its capabilities for the public in other fairs. The fact that iron was so easily melted or that it could turn into smoke, almost instantaneously, a piece of wood placed in the furnace was true source of wonderment for everybody.

Father Himalaya would have none of it. He wanted his system to be used in more noble applications, as he put it, namely in industries like those requiring higher temperatures than the ones obtainable at that time through combustion or electric arcs (<3500°C).

He got nowhere in his fights over what to do with the system, its potential buyers and the U.S. patent office which never granted him the classification of industrial interest that he so desperately wanted. Perhaps this is why so little was written by him directly about it.

The Pyrehliophoro was dismantled, not before Father Himalaya tried – and did not succeed- to give it to the local University. He tried also other institutions, like the Carnegie Institute, but to no avail. It could also not stay on the fair grounds. The decision came from a Mr. Skinker, invoking two major flaws he had found in the system's design. He didn't write about which ones.

It vanished after a while. Robbed, to be destroyed, as some claim? Dismantled and simply carried away, piece by piece and lost in time and place? It certainly enjoyed a very bright, but very short career, right at the dawn of the oil era.

III- In conclusion

In conclusion it is fair to say that the Pyrehliophoro and all the work leading up to it were remarkable achievements for Father Himalaya's time, truly deserving their dissemination among the solar energy scientists of today and even among the general public interested in the History of Science and Technology.

Very high concentration of solar radiation on a continuous basis was achieved by a play of clever optics and simple mechanisms, in particular in the case of the Pirheliophoro. Quite

likely it produced in a sustainable manner the highest temperature ever with a solar device, a World Record for the day. Even today it is not easy to obtain higher temperatures and the limitations in terms of the knowledge of optics, materials, sensors, etc. are quite different from those at the turn of the 19th century.

For the record it is important to point out that Father Himalaya was not always correct in his interpretations or in his stated goals. That is quite understandable when only later day science could prove him wrong. However in other instances, when even scientists of his day might have been able to correct him, he did not know better. In that case a possible excuse is that he had no way to encompass in depth the very wide range of knowledge that he needed in order not to make those specific wrong statements or claims, in particular given his lack of a high level formal training in the basic sciences, as referred . That should not prevent us from admiring his powerful and creative mind, brilliantly complemented by his cunning practical eye, to translate ideas into useful devices.

For instance, after his forays into Solar Energy, Father Himalaya moved on to other topics which, as commented upon in the Introduction, included among many other remarkable things, explosives and rotary engines.

After St. Louis he continued to work and travel all over the World, and got wide recognition, especially from his fellow country men and in particular in the region he came from, Minho, in the North of Portugal. Throughout the rest of his life he kept right on a collision course with many of the established views of the day, in such diverse areas as religion, politics, agriculture, medicine, industry, social development, ecology, etc., to a degree which would make him feel quite at home in today's World. Perhaps that really constitutes the best summary of his persona: a man 100 years ahead of its time. He died in December, 21st, 1933.

Final note: an extended version of this paper is being published in 2004 in Annals of Solar Energy, chapter XX.

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