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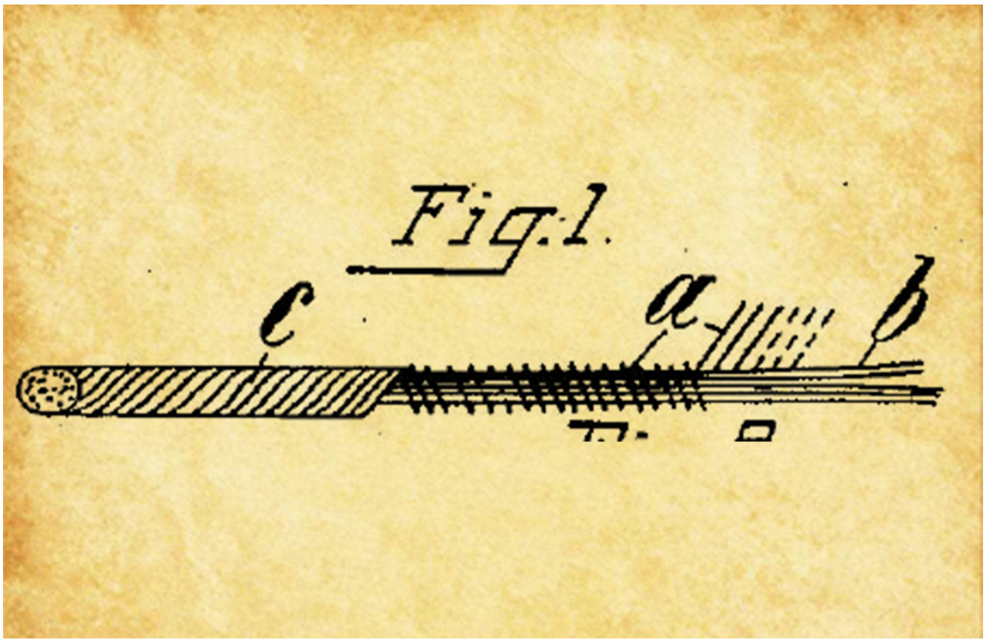
History of technologies linked to heating.

Chapitre 11

Historical introduction to flexible heaters in silicone rubber sheets



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The appearance, in the years 1960/70, of this type of heaters, now universally used, is due to the conjunction of the development of several techniques: that of the vulcanization of elastomers on textile fabrics or on electrical conductors, that of manufacturing glass fabrics, that of the manufacture of silicone, that of the coating of silicone on glass fabrics.

The first tests of vulcanized heating wires in an elastomer, in this case rubber, date back to the first years of the 19th century, and the tariff published in the official journal of 5 August 1912 states «electric heating mats made of rubberized fabric used as insulation to an electrical heating wire »

The manufacture of fiberglass fabric dates back to 1893, when two dresses were made, the first for an actress, the second, which must still be in a museum in Toledo, for a Spanish princess. These were mere curiosities: the fabric was heavy, of a difficult cut; it irritated the skin and did not support many folds; the dress could only be worn with a thick silk undergarment. At that time, the glass fibers were indeed obtained by a process which did not differ much from that which was used to obtain the glass silk in laboratories: a glass rod was stretched from its ends, first by hand, then by winding on a drum animated with a rapid rotation movement. The diameter of these fibers, quite irregular, was at least 25 microns. (1938 Le Génie Civil)

The industrial manufacture of fiberglass was born from the necessity for the Germans, from the beginning of the First World War, to find, in order to manufacture various insulators, a substitute for asbestos, a product which they had previously totally imported . As early as 1915, the Gossler factory in Dusseldorf manufactured a glass silk whose fineness and flexibility were rapidly improved and which not only was able to replace asbestos, but could also be used to manufacture thin sheets with entangled fibers, used to filter gases and rid them of the finest dust. First of all, the manufacturing process did not differ essentially from the intermittent process of drawing rods by hand and drum; but in 1931, after many attempts, it was possible to make the manufacture entirely mechanical and continuous, by using a jet of steam.

In 1937, two factories, one in Germany and the other in the United States, could commonly manufacture glass fibers of less than 5 microns. At that time, apart from furnishing fabrics, glass fiber silk threads were used only to make porous, electrical, acoustic or thermal insulators, filters, gaskets, and plastic cements.

The description of the manufacturing processes, whose development took more than 3 years was described in July 1938 in an article by MJH Plummer of Owens-Illinois Glass Co, Newark, Ohio, (published in Industrial and Engineering Chemistry), then in August of the same year in an article by M. Th. R. Olive, (published in Chemical and Metallurgical Engineering) (1938 Le Génie Civil)

This new insulating textile material that could be woven, named "Silionne", revolutionized the manufacture of flexible heating elements. Invented and first produced in the USA by Owens Corning it appeared in France in 1938. But it was only around 1952-1954 that this fiber was produced industrially under license in France. This flexible fiber, (also called glass silk because the diameter of the filaments was similar to that of silk), is formed from molten glass at 1300°C. It is then extruded and stretched into filaments (strands) with an average diameter between 5 to 9 microns combined into single threads of 100 to 600 filaments. These single wires are then grouped and "twisted" to form cords that make up the core of the flexible heating elements, or the wrapping of the electrical wires.

Among the first applications we can name its use, in the strengthening of plastics, when in 1941 began the realization of a aircraft made of plastic resin impregnated fiberglass. The fuselage was built in the first place and was found to be 50 percent stronger in static resistance tests than a conventional metal fuselage. One aircraft of this construction completed 500 flying hours, mostly in the Arctic, during the winter season. The material consisted of 50 percent fiberglass and 45 percent resin. The fiberglass fabric was impregnated with Plasko resin "911" (l'Aviation française 16 Juillet 1947)

Silionne was an excellent electrical insulator, and was non-flammable and resistant to high temperatures. It was also braided and woven and as soon as it appeared, it was used for the production of sheets and fabrics. As early as 1948, glass fabrics were used by the French company "Tentation" in the manufacture of electric blankets, just as some American manufacturers were already doing. It also rapidly replaced many asbestos applications, including the conductor core around which the conductor wires of the heating cords were spiraled.

Developed in 1940 with rubber insulation, flexible fabrics were quickly put to use for de-icing aircraft wings.

At the same time appeared the silicone rubber

Invented by Dow Corning in the US shortly before the Second World War, and made public in 1944, silicone rubber was initially reserved for military applications. Rhône Poulenc began experimentally producing silicone (Rhodorsil) in Lyon in 1948, and then opened its Saint Fons factory near Lyon in 1954. This elastomer was first used to impregnate braided fiberglass sleeving, allowing small electric motors to operate at a higher temperature. This glass silk withstood heat very well. Its silicone impregnation gave it good water ingress protection and resistance to many chemical agents. (1954 Meci, Ultimheat catalog)

In 1949, Dow Corning USA engineer Earl.L Warrick developed a silicone elastomer with a small percentage of iron oxide (less than 2%) to improve its heat stability. This low percentage stained the silicone in orange-brown. (US Patent 2,541,137). Firstly in 1952 in the USA, and secondly in 1953 in France, Dow Corning patented a calendering technique to deposit a layer of partially vulcanized rubber or silicone on a textile support. This technique made it possible to make sheets and ribbons whose adhesion on a support or on a heating wire could be realized in a simple way by a subsequent heating. This paved the way for flexible heating elements made of silicone rubber and other heat vulcanizable resins. (French patent 1,090,190)

In 1960 the Compagnie Française Thomson-Houston, filed in France the American patent of William Joseph Bobear (US Patent General Electric 3,053,687). This patent improved the coating of fiberglass fabrics with silicone elastomers to achieve better adhesion and resistance to elongation. This method also allowed the production of partially vulcanized strips that could be bonded by heat pressing.

At the beginning of 1960, following the development of PVC and silicone elastomers, appeared the first flexible heaters for industrial use in the form of ribbons and plates, the main insulation of which was produced by an elastomer resin polymerized or vulcanized around a heating wire. The elastomers used were PVC, rubber, neoprene. Silicone.

There were then woven canvases, made with a sheet whose chain was made of asbestos and the frame of Ni-Cr or constantan, embedded in a silicone gel. These flexible blocks were manufactured in a thickness of 2.5 to 5 mm, in rectangular format (max of 0.90 x 0.20 m) or square (max of 0.50 x 0.50 m), with variable power densities, from 0.4 to 1 W/cm2. Their maximum temperature was of the order of 250°C.

In 1960/1961 the final technical solution appeared: the use of non-insulated heating wires sandwiched between sheets of silicone rubber reinforced with glass fibers and then vulcanized. The fiberglass fabric provides mechanical strength; and the silicone electrical insulation and bonding at high temperature; and the vulcanization the indestructible link between these elements. The assembly then forms a waterproof heating sheet. The French manufacturer of warming blankets Méneret could then write: "all our heating blankets without exception are equipped with special heating wires isolated under totally invisible channels».

This technology had no outlet in domestic warming blankets because of the price of silicone resins. In addition, the high temperature resistance was not necessary for this application.

But this technique gave rise to the branch of high temperature flexible flat heaters for industrial applications.

Since then, various ways of producing the heating web have raised.

- Wire wound conductors: the oldest solution, but which gives the greatest flexibility;

- Thin metal sheet etched with acid, a process similar to that of the manufacture of printed circuits, but whose flexibility is limited (Invented around 1969);

- Conductive ink printed circuit, silk screen printed on flexible polymer, quite flexible and cheap, but with low temperature resistance.

High temperature-resistant adhesives (FEP, acrylic) have also emerged which allow to replace the vulcanization of elastomers, and which are particularly suitable for the use of polyester (PET), polyimide (PI) and polycarbonate (PC) sheets, allowing to laminate the various layers of the flexible elements and to realize extremely fine elements (down to 0.2mm for Kapton-type polyimide models).