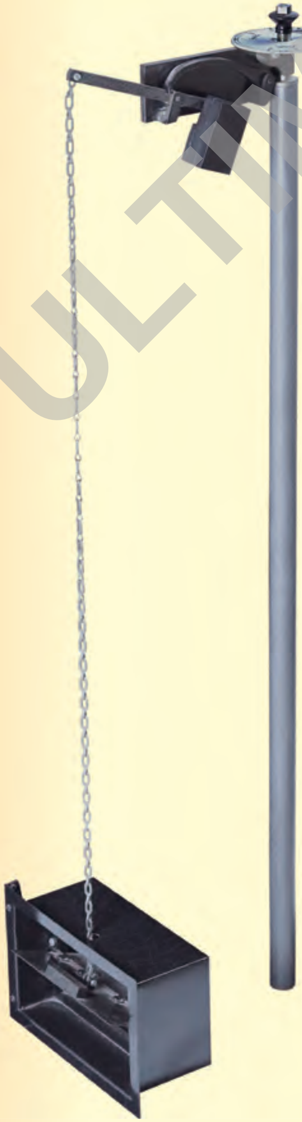
Aerostats
Air flow thermostats
Air inlet regulators
Airstats
Aquarium thermostats
Aquastats
Bimetal thermostats
Bulb and capillary thermostats
Calorstats
Capillary limiters
Combistats
Combustion regulators
Cooling regulators
Cyclic energy regulators
Disc Thermostats
Draft regulators
Duostats
Electric faucets
Energy reglators
Exostats
Fire governors
Fire protection fusible links
Frangible glass bulb limiters
Glass thermometers with contact
Hydrostats
Incubator thermostats
Infinite switches
Kiln pointers (Kiln sitters)
Leak regulators
Oven thermostats
Pneumatic thermostats
Protectostats
Pyratherms
Pyrostats
Refrigerator thermostats
Rod thermostats
Room thermostats
Sautomats
Simmerstats
TCO (non-resettable thermal cut-out)
Thermal protectors
Thermostats for vitroceramic cooktops
Vaporstats
Varioruptors
Variostats
Vitroceramic hobs limiters

Outline of thermostats history



"Fire governor" of Jean Simon Bonnemain patented in 1783.

Jacques Jumeau

Preface

Thermostats arose with the need to maintain a constant temperature in alchemist ovens and incubators, and to save fuelwood, then followed, using various techniques, the development of the use of charcoal, lighting gas, electricity, and petroleum-derived liquid fuels.

Their mechanisms were diversified according to the needs of the devices: Incubators, stoves, industrial and domestic boilers, central heating systems, water heaters, radiators and gas and electric fireplaces, electric and explosion motors, then all domestic cooking appliances.

Their operating principles and construction evolved with the emergence of new metals and alloys: Invar, Beryllium or Phosphorus Bronze, Stainless Steel, Tombac. The precision of the devices followed the evolution of metal rolling and bimetal co-lamination. Gas mixtures, essential for vapor pressure thermostats, and liquids, essential for liquid expansion thermostats, followed the development of chemistry.

The manufacture of capillary tubes in copper and then in stainless steel, in smaller and smaller diameters, allowed the expansion of devices with remote measurement.

Electrical insulation, long limited to micas and micanites, improved with the arrival of thermosets: ebonite, bakelite, and polyesters, then finally the huge family of thermoplastics that were developed following the invention of nylon. The boxes and bases followed the same evolution.

Electrical contacts, initially dependent on bulky and oxidizable mercury pots, became more effective with mercury bulbs under nitrogen atmosphere, then with dry contacts in silver and its alloys.

The invention of snap-action contact mechanisms allowed use on 220 volts circuits, while providing a very long service life to all these devices.

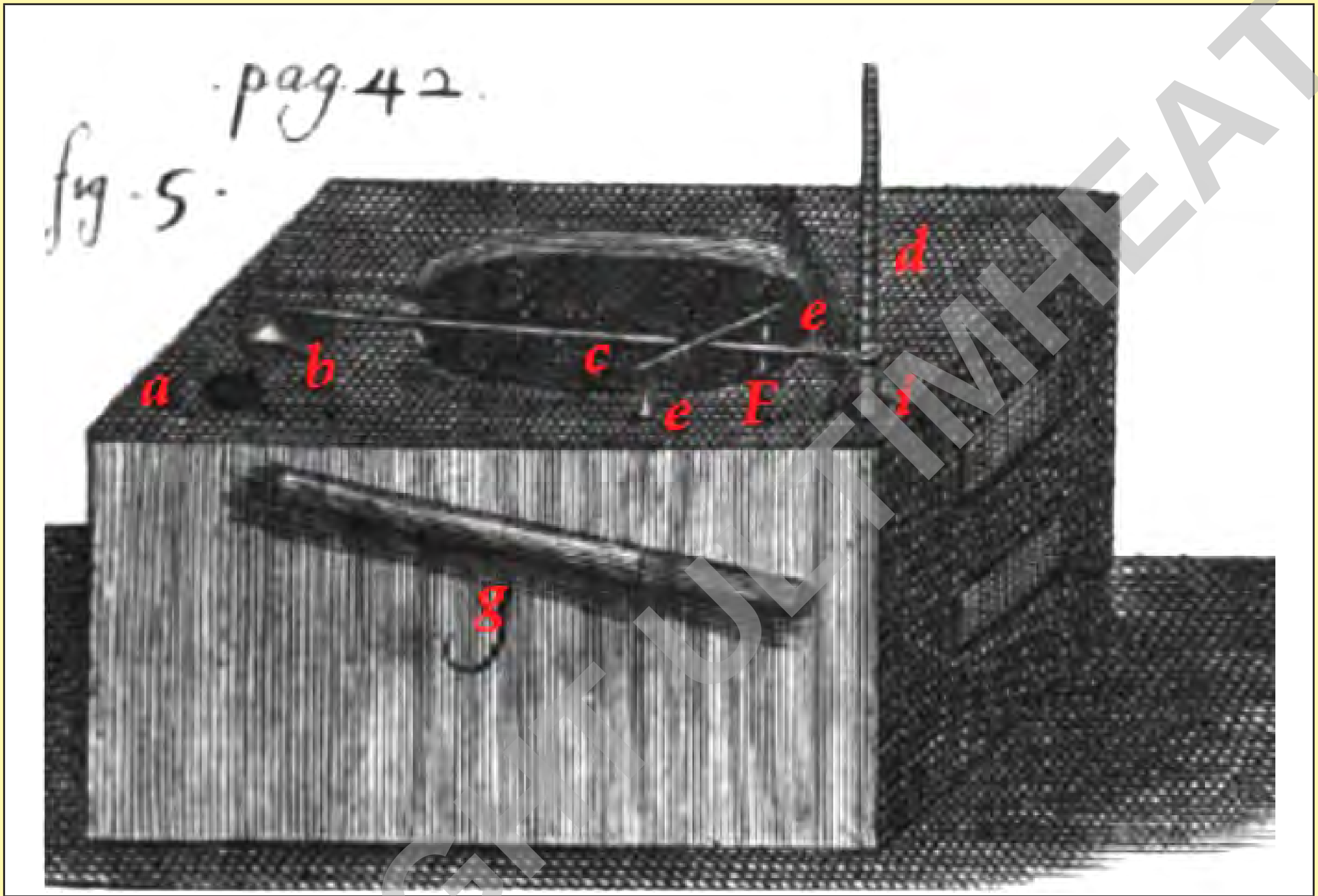
Initially bulky, the mechanisms were miniaturized by following the development of micromechanics and by borrowing watchmaking techniques.

A corollary of miniaturization, automation, especially from the years 1975-80, caused production costs to fall.

While some models have disappeared, often following the decline in their applications, thermostats have proliferated in a world where safety is a priority. They are now present, although invisible, by the dozens or even hundreds, in all homes, in household appliances, in small electric motors, in heaters as well as in vehicles.

Thanks to their proven reliability, their high electrical breaking capacity and their (apparent) simplicity, they will remain irreplaceable, even in a world where electronics are playing an increasingly important role.

Summary



*Here is roughly the figure *:*
A: Register
B: Iron platinum which clogs it
BC: Iron branch that carries the lock
EE: Iron easel on which the rod BC balances in balance
F: Opener or hourglass to put the vessels
C: End of the tip of the rod BC which is a threaded ring ["snapped" in the original document]
D: Screw-turned iron, which enters the ring C, which always balances with B, however you put it, but which must have the effect of the artifice, according to the more or less of heat that we desire, because it is deeply embedded in
I: Hole where this spiral iron enters the capacity of the furnace, the inclination of the rod BC being less, the slightest heat will bring it into equilibrium and therefore the plate will first cover the register: instead of if it is slightly depressed, the inclination of the rod BC, being less, it will take more movement to put it back parallel, a situation necessary to block the register
G: Is the glass pipe with quicksilver at the bottom and air at the top, both ends of which fit into the furnace capacity

** : extract from Monsieur de Monconys' travel diary Second part, Voyage d'Angleterre (1666). For more information on this device, see the Synthesis of Cornelius Drebbel's inventions in heating, by Jacques Jumeau, available on the Ultimheat site of the Heating Museum)*

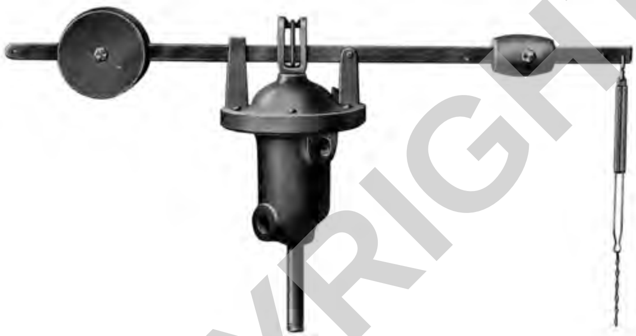
During the development of central heating boilers in the second half of the 18th century, steam models first came onto the market.

With the circuit under pressure, and the temperature of the steam always above 100°C, the easiest way to control the temperature was to control the pressure. It was therefore regulators measuring the vapor pressure, either by the deformation of a rubber membrane or by the displacement of a float (hydrostatic models) which actuated the combustion air inlet flap.

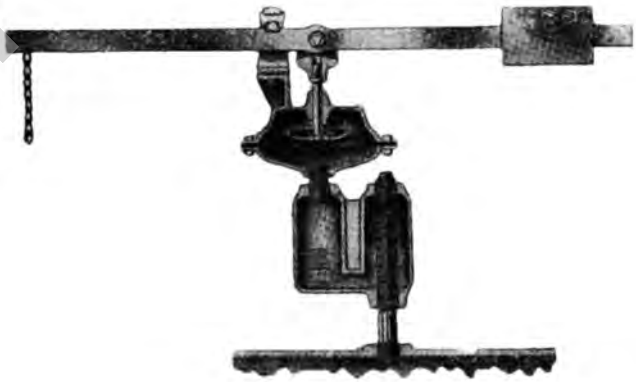
One of the first companies to make these simple regulators was the Compagnie Nationale des Radiateurs in Dôle (Jura).

This steam central heating system quickly gave way to hot water systems whose temperature did not exceed 100°C, and whose control therefore had to be done according to the temperature of the water.

Between 1880 and 1930 there were dozens of complex mechanisms to perform this temperature control, but we only present here the simplest and most common.

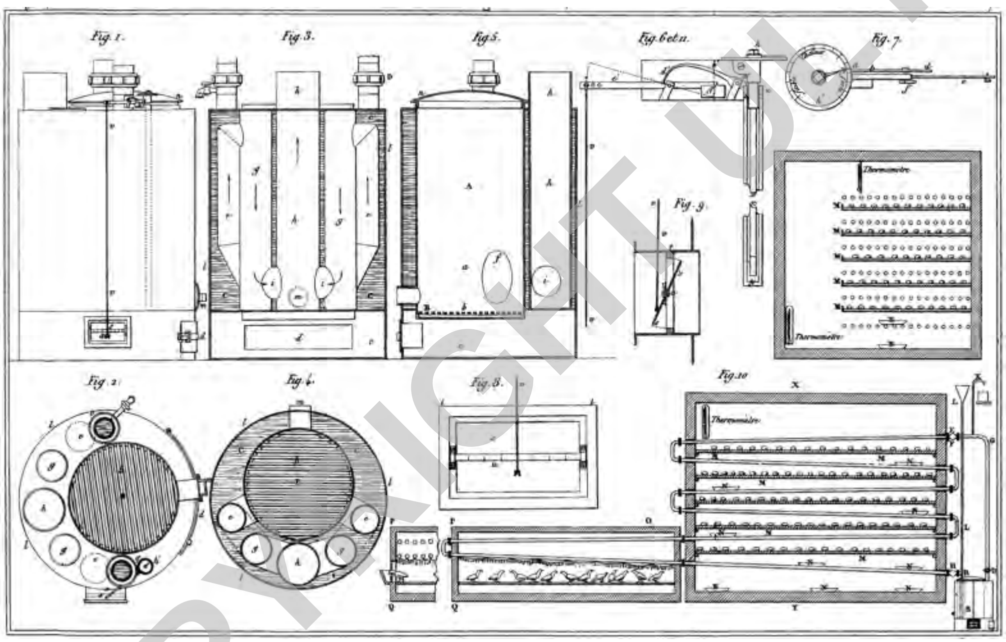


*Membrane fire governor, controlled by vapor pressure (circa 1920, Catalog des Fonderies de Brousseval *)*

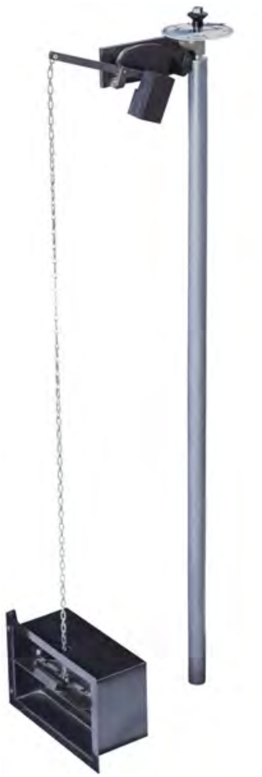


*Fire governor with pocket and membrane (1930 Chappée Catalog *)*

In the 3rd quarter of the 18th century, when physicist Boerhave and the abbot Nolet began to study the expansion of solids, a French engineer, the Parisian Jean Simon Bonnemain, imagined using the expansion of metals to regulate the temperature of what he called a hot water calorifier. After having presented in 1777 the result of his research to the Academy of Sciences, he finally obtained a 15 years Royal patent on July 28, 1783 for his "fire governor", the development of which had taken him more than 15 years. He first developed a model based on the differential expansion of two long parallel bars placed one against the other, one in iron and the other in copper. The second type was using lead tube with an iron rod inside. The difference in expansion made it possible to actuate a lever operating the air inlet door of a boiler. A knob and a graduated dial were used to adjust the temperature. Bonnemain, during its long existence, used this device in many applications: incubators, greenhouses, pharmacy stoves, domestic baths, stoves and boilers.



Bonnemain fire governor used on a water boiler (water calorifier), and its use in a large chicken incubator (1830, Encyclopédie Moderne)*



Identical reconstruction of a Bonnemain fire goveror using a long lead tube immersed in water ( )*

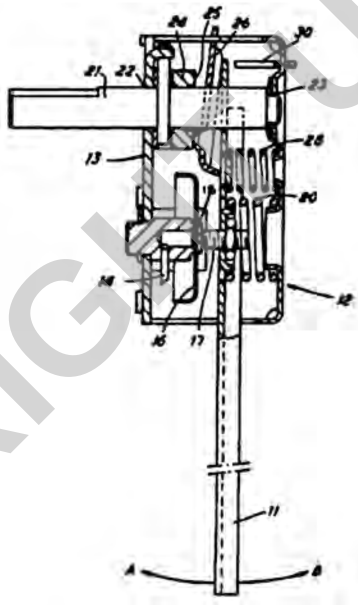
Different from the devices developed for boilers and controlling the temperature of hot water, they are intended to control the combustion of solid fuel heating devices, by measuring the temperature of the hot air or fumes. They feature a remote, liquid-filled, bulb and capillary temperature diastat. An arm, moving according to the temperature of the hot air, controls the opening or closing of the air intake or combustion air dampers. This arm must be mechanically connected to the shutter to be controlled or directly incorporate a valve.

Variants of this thermostat, but with vapor pressure, were developed to control the circulation of cold air in refrigerators.

It seems that the first model of this type was developed by the Sopac company in 1956, but it very quickly disappeared from their catalog, and 24 years later, in 1984, Teddington in England filed a patent for an identical product.

There are currently few applications for this type of thermostat.

*Damper regulator, liquid expansion mechanism (1956 Sopac Catalog *)*



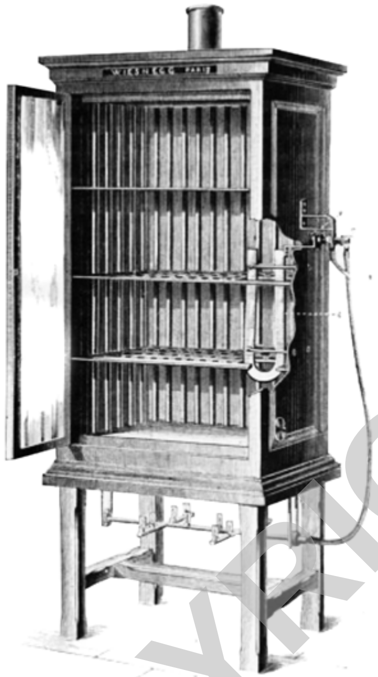
Damper regulator, liquid expansion mechanism (1984 England, Teddington patent 12157432)

*Damper regulator, liquid expansion mechanism (2015 JPC *)*

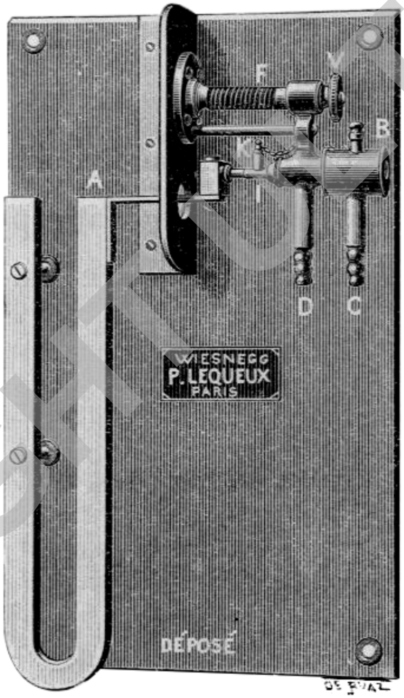
Around 1890, the first precision bimetallic temperature regulator appeared. Also produced by Victor Wiesnegg, this temperature regulator was known as that of Dr Emile Roux (1853-1933)

"We believe we are doing workers a service by making them aware of a robust regulator, simple at the same time as precise, and which has been operating for several years at the Institut Pasteur without needing repair.

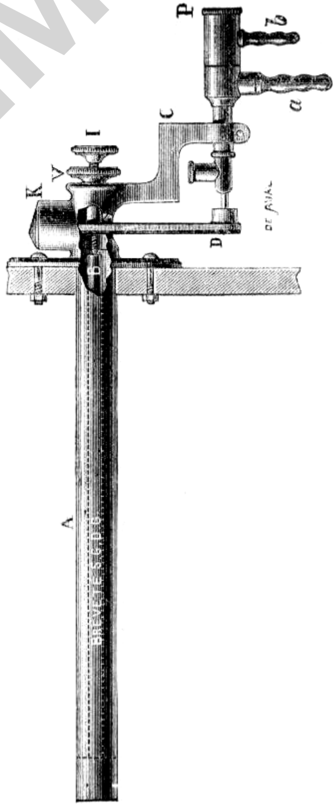
This regulator consists of two metal bars, one in steel, the other in zinc, welded together over their entire length and then bent into a U shape". Extract from Annales de l'Institut Pasteur: journal de microbiologie, N°3, March 1891.



Doctor Roux's bimetallic regulator, Wiesnegg manufacture, mounted on a medical oven (Annales de l'Institut Pasteur: journal de microbiologie, N°3, Mars 1891, p159)

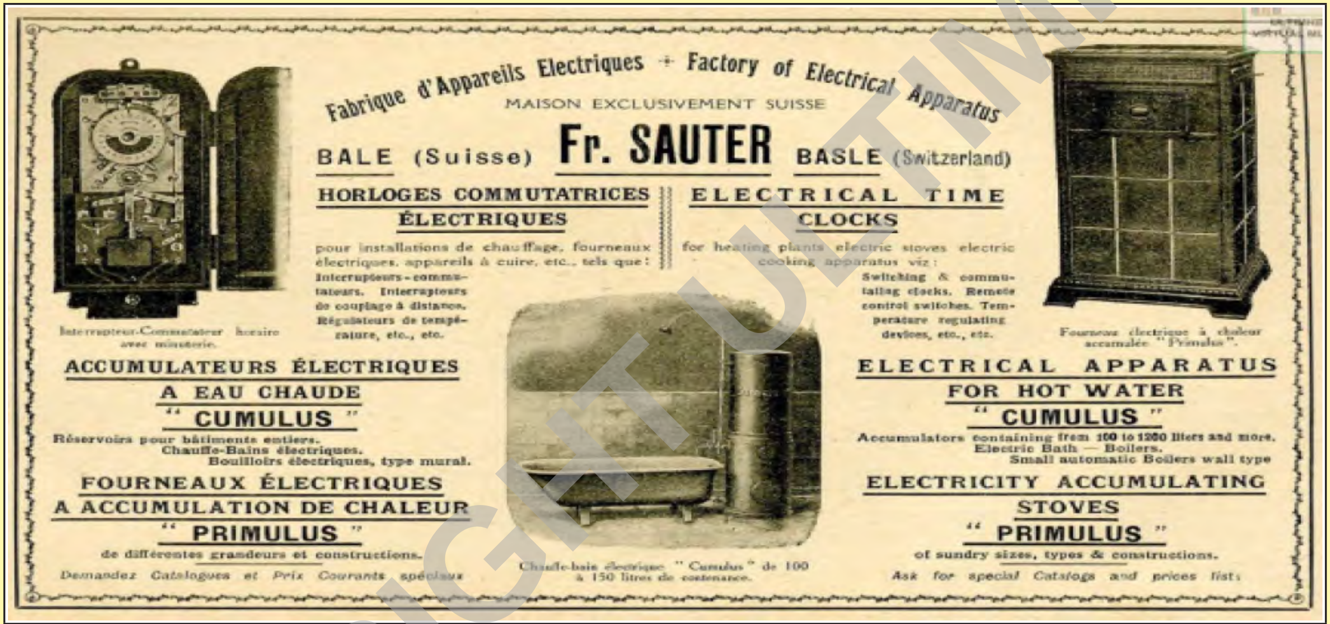


*Doctor Roux's bimetallic regulator, Lequeux manufacture, successor to Wiesnegg, (Catalog Poulenc 1905 *)*



*Bimetallic rod regulator. Lequeux manufacture. This model also existed with an electrical contact with a mercury bulb (Catalog of the French Industry of Precision Instruments 1901 and Poulenc Catalog 1905 *)*

The low cost of electricity produced by waterfalls in mountainous regions, in particular in the Swiss and French Alps, encouraged the emergence in these regions of electric storage water heaters in the years 1915-1920. In order to be able to limit the temperature of these tanks, special thermostats were born, as well as switching clocks allowing the heating of the water heater to operate during periods of economy tariff. The pioneer in this field was Swiss watchmaker Franz Sauter in Basel. He was the first to produce, around 1920, switching clocks and thermostats suitable for this application. The sensitive part of these thermostats consisted of a brass tube (very expandable) surrounding an invar rod (non-expandable metal).



1920 Franz Sauter's products range ( )*

Following Franz Sauter's installation of a factory in Alsace, in the city of Saint Louis, near the Swiss border, other builders popped in the area between 1922 and 1925, and several began building water heater thermostats.

In Switzerland, in addition to Franz Sauter, the companies Landys & Gyr and Ghielmetti were set up, which specialized in these types of thermostats.

At that time, the only existing contact system able to switch high ratings in 110 or 220V consisted of mercury bulbs in a neutral atmosphere, the tilting of which opened or closed the electrical circuit.

*Petroleum incubator thermostat with "accordion" mechanism with zinc / steel bimetal French manufacture La Nationale, (Operating instructions for La Nationale incubators, circa 1920 *)*

*Electric incubator thermostat with tilting mercury bulb and double membrane mechanism. French manufacture La Nationale, circa 1950. (**)*

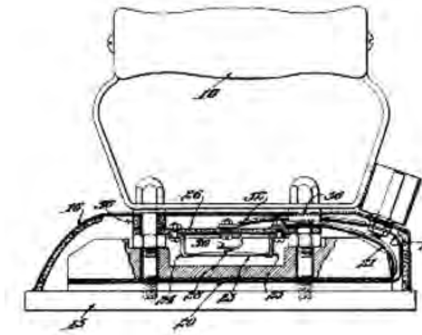
*Electric incubator thermostat with snap-action microswitch actuated by a double membrane filled with ether. Made by Burgess England, circa 1955. (**)*

*Electric incubator thermostat with bimetallic rod, with snap-action microswitch. French manufacture Lucien Lieubray circa 1960 (**)*

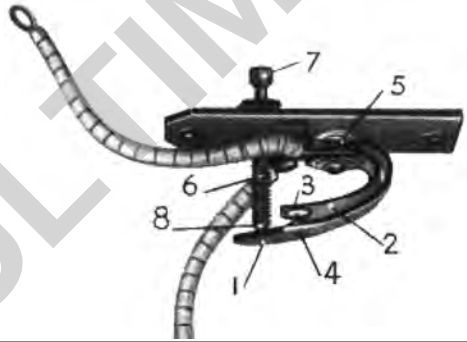
the market for electric kettles, a British specialty, specific snap action models with manual reset appeared.

In 1945 and 1946, Eric Hardman Taylor invented a particular mechanism, adapted to this market. This invention was put to use in 1951 by the company founded as Casteltown Thermostat in the Isle of Man, which later became Strix Limited.

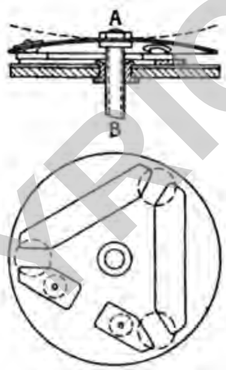
The main innovation of this thermostat was to automatically cut off the power supply when the water started to boil, and no longer just when there was insufficient water. This device is now universally used in electric kettles



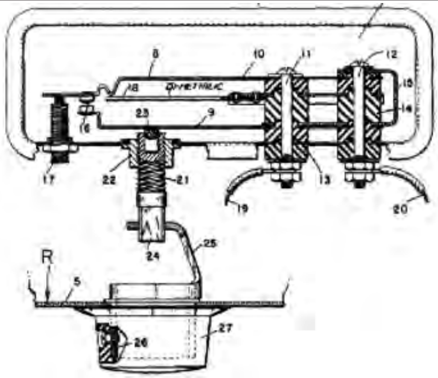
Non-adjustable, snap-action, bimetallic disc thermostat mounted in an iron, 1921 U.S. Patent No. 1,448,240 of John A. Spencer



*Alsthom slow break bimetal thermostat for 500W iron. Blades 1 and 2 are bimetallic and bend together upwards when the temperature rises (La Nature, 1934, P430 *)*



*The first Calor snap-action fixed temperature thermostat for an iron, using a Spencer's domed bimetal disc with 3 silver contacts. (La Nature, 1934, N° 2921, inventions and novelties, p 94 *)*



Slow-break bimetal strip thermostat for small household electrical equipment, adjustable, filed in September 1937 by Alva T. Smith. We see the assembly with columns in superimposed ceramic washers. (US N° 2,190,276)

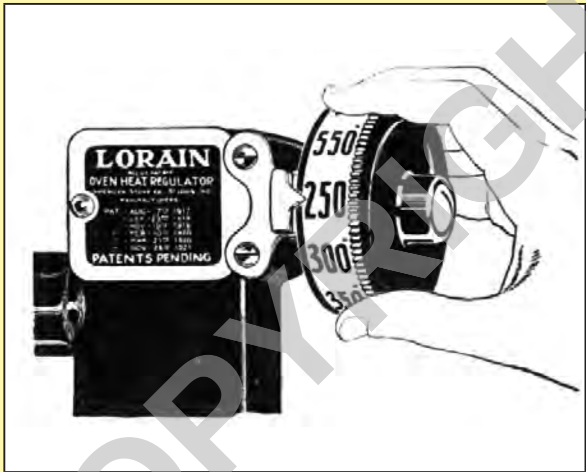
In 1924, during the centenary of the gas industry, when the state of this industry was reviewed, there was no gas cookers on the market in France with a temperature control system for their ovens. One of the reasons is probably the high temperature (300°C) reached by these ovens. However, by that date, the American Stove cooks in the USA had already included this appliance in their range under the Lorain brand. These regulators had started to be developed as early as 1917 (US Patent No. 1,236,335). They included part of the gas burner.

It was not until 1931 that Arthur Martin added this accessory to his 506 cooker, in a version where the gas burner was independent. It was followed in 1933 by the National Radiator Company, which offered this thermostat as an option on its latest model of stove. All these thermostats were devices with a bimetallic rod, activating the progressive opening of the gas supply to the oven.

At the Household Appliances fair, in January 1935 in Paris, thermostatically-controlled ovens were finally in the spotlight. The Paris gas company also promoted them. Manufacturers of cookers with gas ovens will therefore offer them on their products.

In 1950, on his BR2 model, Brachet Richard allowed adjustment by a knob on the front board and no longer on the side.

In the 1960s, when the thermostatic bulb and capillary diastats withstanding 300°C appeared, easier to mount on the front board, most of rigid rod models disappeared.



*The Lorain "Lorain Oven Heat Regulator" gas oven thermostat with the same design than patent 1,656,010 filed October 23, 1925. (1926 Catalog of New Process Stove Company, Cleveland, USA *)*

*Model 506 cooker with "Telegaz" oven thermostat. The rod thermostat and the burner are independent. (Catalog 1932 Arthur Martin *)*

The invention of bimetallic disc thermostats in 1928, descendants of John A. Spencer's snap-acting disc of 1921 was a revolution in the design of electric heating devices. This invention brought, in a small footprint, a snap-action thermostat at a fixed temperature and high breaking capacity.

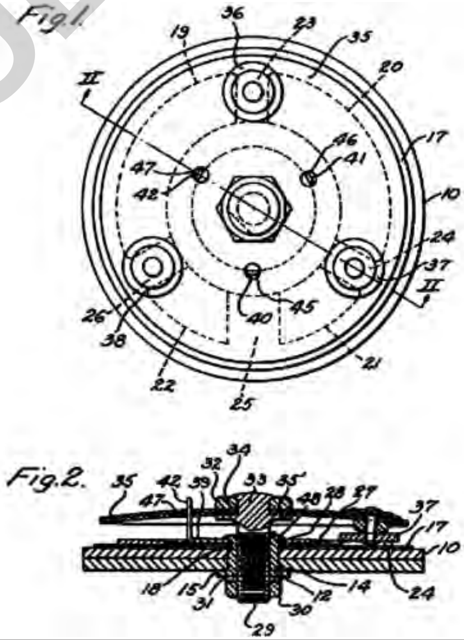
On electric heating devices they were first used primarily as safety devices to prevent overheating or destruction of heating elements or devices, for example on kettles, coffee makers and teapots.

Calor, on his electric kettles, had, like his competitors, since 1918 only the solution of replacing the heating element when it burned from lack of water. It was not until 1933, with the arrival of disc thermostats, that he was able to install a snap-action temperature limiter on the No.523 luxury kettle. This thermostat was of the same type as the one that fitted its "Automatic" irons that same year.

This thermostat was derived from the Westinghouse patent of 1928.

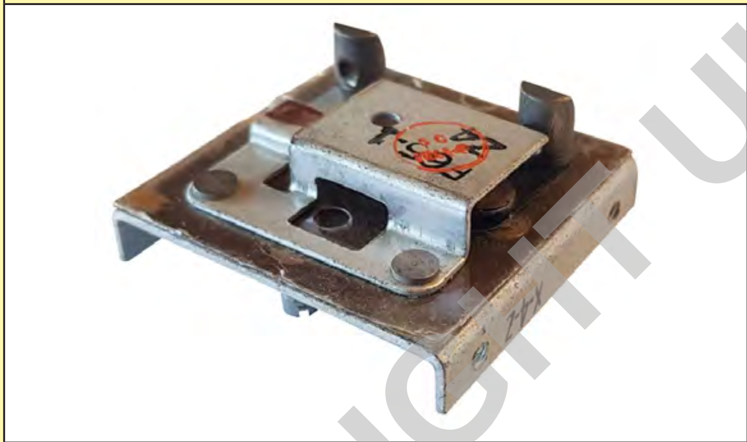
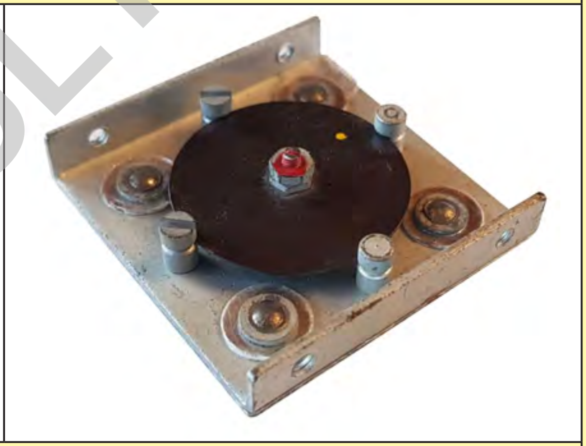
It used a 29mm bimetallic disc for a 38mm diameter body.

The first electric kettle with protection against dry run (Calor Catalog 1934)*



Westinghouse Disc Thermostat, invented by Lewis J. Greenawalt (US Patent 1,687,664) of October 16, 1928. This is the model, in a Bakelite case, that Calor will use under license from Westinghouse, until the 1960s.

*Top and bottom view, snap-action temperature limiter with 29mm disc used on Calor kettles (1952 **)*

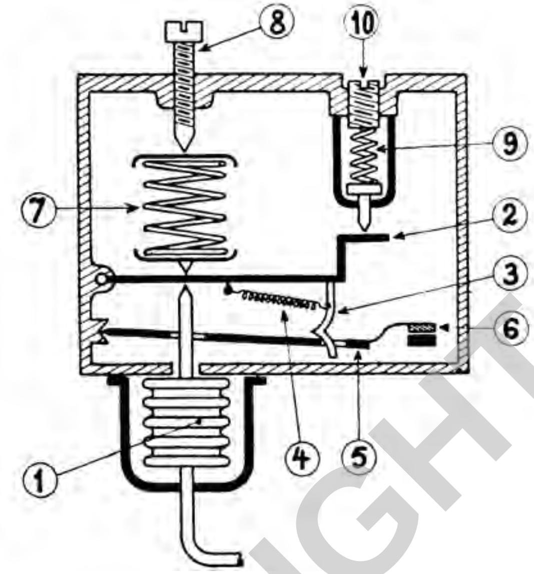



*Top and bottom view, snap-action temperature limiter with 29mm disc used on military radio equipment to turn on ventilation. Type "Blower thermostat" (Around 1935-37, **)*

Over the next several years, as the manufacture of bimetals became more and more precise and reliable, the original disc thermostat became simpler and its size was greatly reduced. Therefore it became easier and easier to incorporate into equipment. Spencer thermostat, then Texas Intrument, under the Klixon brand, became a key supplier to the market for the duration of the validity of its first patents. From the years 1950/1955 three American manufacturers: Klixon, Therm-O-Disc and Stevens manufacturing, shared the world market for models with ¾" and ½" disc. The global market for these products exploded in the 1970s and dozens of manufacturers appeared when their patents expired.

These devices, designed to operate at negative or slightly positive temperatures, were used to measure the surface temperature of evaporators: they were vapor pressure thermostats, to avoid the influence of the ambient temperature on the thermostat head. The use of vapor pressure meant limiting the vaporizable liquid charge in the thermostatic train, so that the thermostat could withstand the ambient temperatures it had to endure during transport. All the liquid then had to be vaporized in order to avoid excessive swelling of the pleated tube or membrane. In order to be able to directly control the operation of the compressor motor, they had to have a snap-action contact.

This gave rise to the invention of a snap-action contact system that was only used in this application in the 1940s-1950s and only on vapor pressure mechanisms: the ***double ramp blade.***



1: Vapor pressure bellow
2: Angled lever
3: Double ramp blade
4: Double ramp blade return spring
5: Contact carrier blade with an orifice for the passage of the double ramp blade
6: Electrical contacts
7: Set point adjustment spring
8: Spring tension adjustment screw
9: Differential adjustment spring
10: Differential adjustment screw

While moving, the angled lever 2 moves the double ramp blade in the hole, which abruptly causes the contact blade to pass to one side or the other of the ramps.

*Working principle of double ramp blade to achieve snap action (Automatic electric refrigeration, Pierre Degoix 1942 *)*

These thermostats were complicated with the addition of a defrost position, cyclic, automatic or manual, and adjustment ranges depending on the exact application (evaporator, refrigerating cabinet, household cabinet, beer or milk cooler, ice cream maker, etc...)

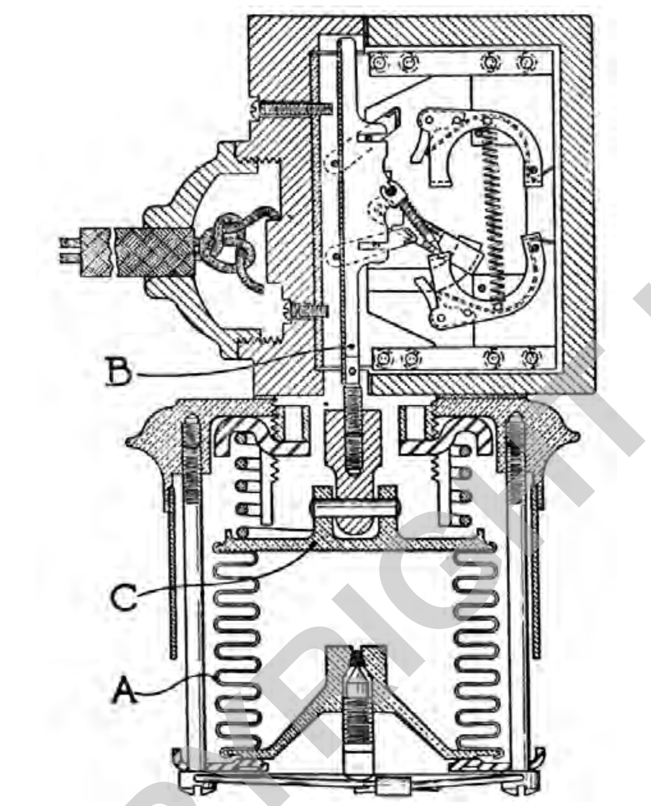
The use as a cold room room thermostat allowed for simple, less expensive bimetal mechanisms, which were also used at the beginning.

It was not until 1926 that the refrigerators built by the Delco-Light Co, subsidiary of General Motors, under the Frigidaire brand, made their entry into the European market, particularly in England, Belgium, and then France.

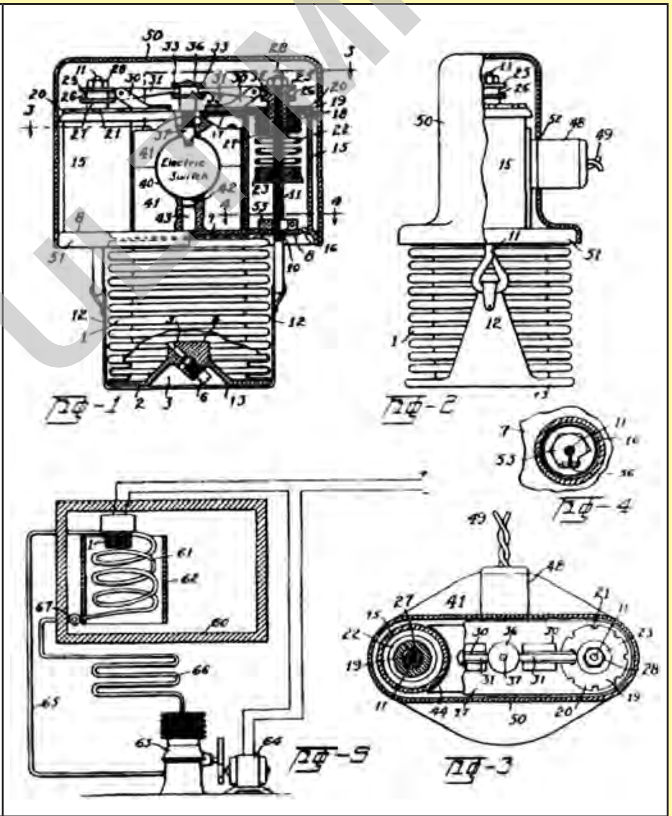
Kelvinator, who was the forerunner in the USA, arrived at the same time.

In these devices, the starting and stopping of the engine was automatic and controlled by the degree of temperature inside the cooler.

Built in the USA since 1916, these 10 years in advance had allowed the manufacturers of American thermostats to develop perfectly functional thermostats. Many thermostatic solutions relied on controlling the flow of gas or refrigerant liquid were developed, but electric contact thermostats remained widely used.

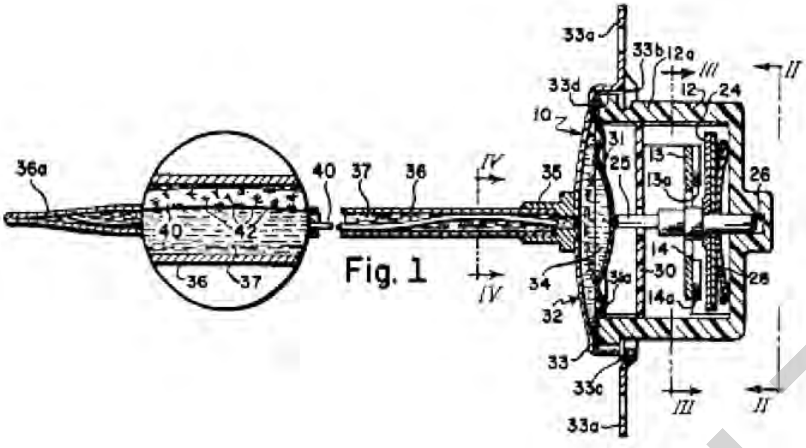


*First patent, due to Kelvinator, for a vapor pressure thermostat actuating an electrical contact for a refrigerator (Extract from The thermostat or Heat Governor, an Outline of its History by A.M.J. Ramsey, 1949 *)*



Kelvinator patent filed in 1918 (US No. 1,329,351) for a sulfur dioxide vapor pressure thermostat, range +15 to +50°F, shutting off the engine of the refrigeration compressor.

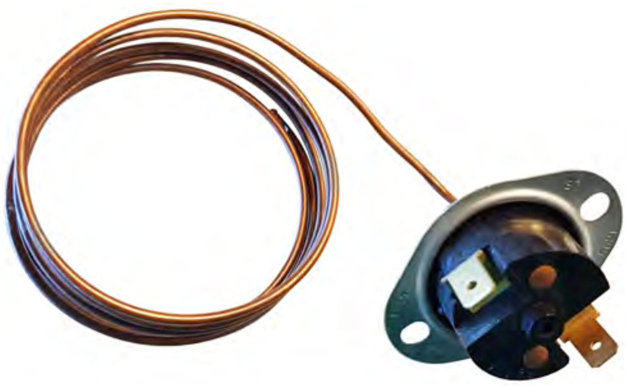
"A few years ago, it was fashionable to equip thermostats with a thermal relay ensuring the triggering of the thermostat and the stopping of the motor when the current taken by this one



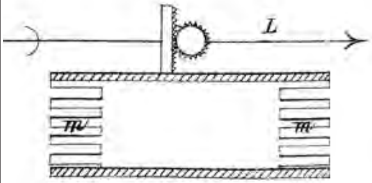
U.S. Wilcolator patent (1,374,229, filed 1962) for a fail-safe capillary thermostat using a Spencer membrane

1975, Demoly type 1062 capillary limiter ( )*

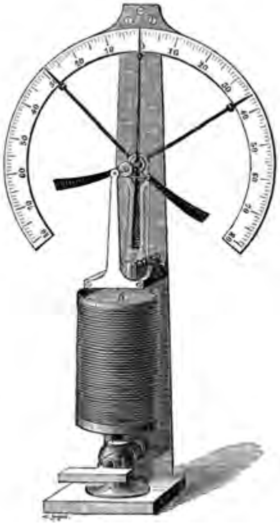
Jaeger Regulation capillary limiter (catalog 1985)*



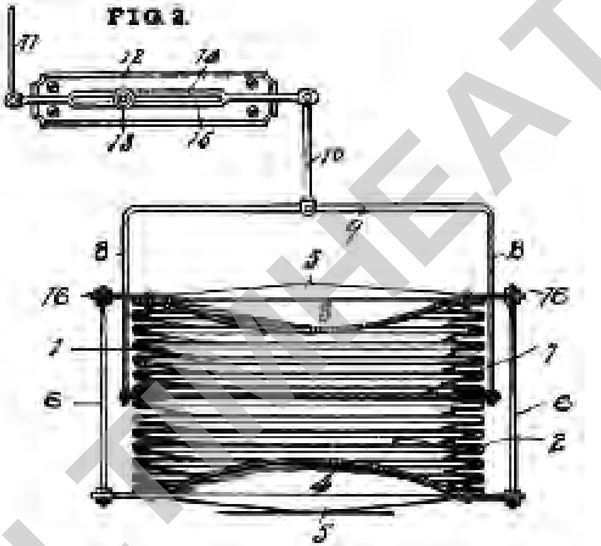
*Ranco capillary limiter circa 1985 (**)*



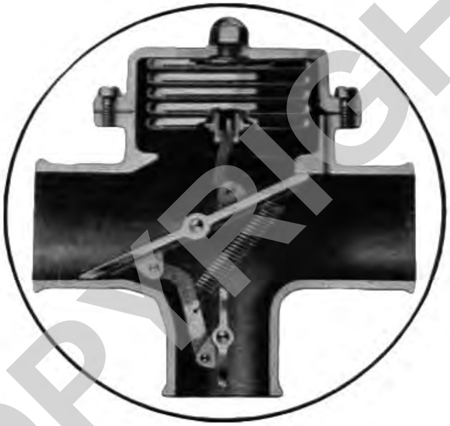
1846 Flexible corrugated tube surrounding a closed tank (English patent 4702 of August 20, 1846 from French Lucien Vidie *)



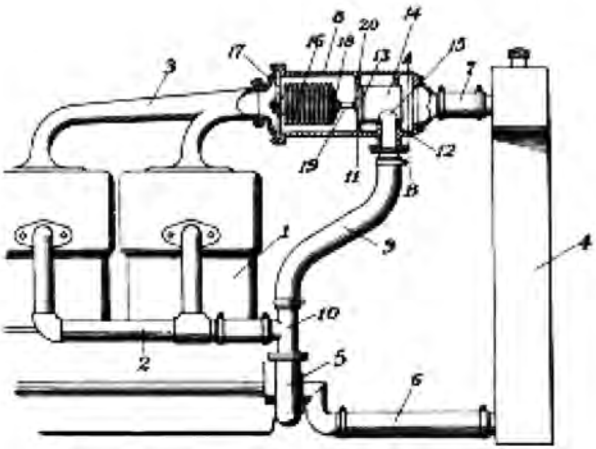
Lucien Vidie's corrugated tube pressure gauge (Biography of Lucien Vidie, by Auguste Laurent, 1867*)



1903 French patent No. 333087 of Weston Miller Fulton for a two-chamber, atmospheric pressure compensated, benzine vapor pressure corrugated tube thermoregulator. The second chamber used for atmospheric pressure compensation will be quickly abandoned.



Rayfield Motor Thermostat manufactured by Beneke and Kropf manufacturing Co (extract from Motor Age magazine, October 23, 1919)



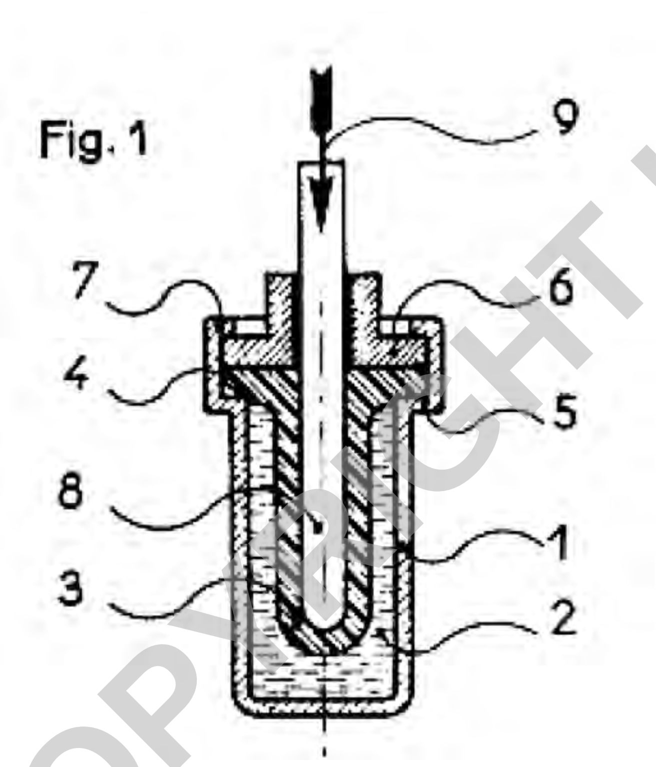
Extract from US Patent 1561153 filed in August 1916, by J.V. Giesler of the Fulton Co. company (Patent accepted in October 1925)

This was followed, as early as November 1962, by the patent for a new and efficient design of a wax expansion thermostatic element, improving the inventions of Sergius Vernet. This product would become the flagship product of the company.

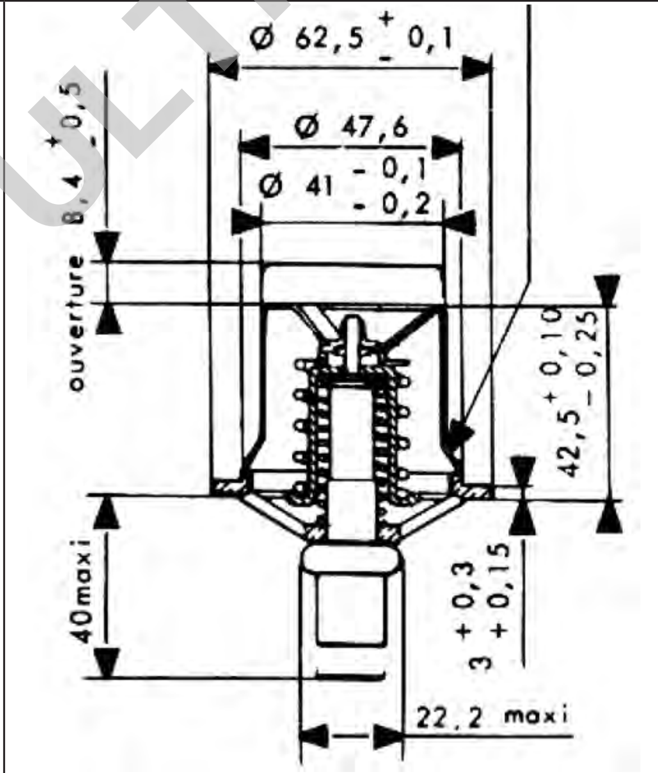
His competitor, in France, Sopac had been manufacturing similar products under American license for several years.

On January 1, 1968, the plant and offices of Vernet Processes, a Calorstat division, were transferred to rue Minard in Arpajon.

In 1972 the Paris headquarters of Calorstat, as well as the workshops and offices of the two companies were transferred to a newly built factory 21-27 route d´Arpajon in Ollainville. The activities of Calorstat and Vernet were then inseparable.



Extract from French patent 1,347,119 filed on November 12, 1962 by Calorstat S.A. for a thermostatic wax element. The innovation is that the flexible seal (N°3) envelops the plunger (N°8)

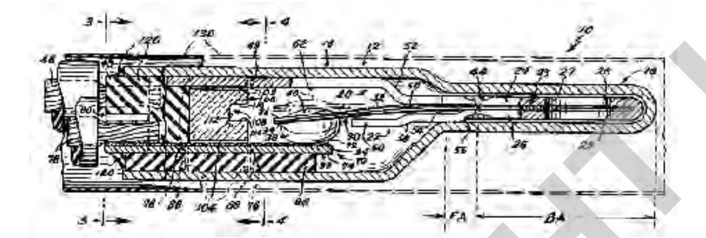


*By-pass type automotive thermostat, VD111 series. (1968 Catalog of the Vernet process exploitation company *)*

The thermal protection of electric motor windings, in particular for fractional motor, had to meet a series of particular requirements: a snap action contact with high breaking capacity, in particular in inductive current, a sealed case to be able to withstand the impregnation of the windings, a small size to allow its incorporation into or on the winding, a direct output by wires, a temperature resistance corresponding to the class of the windings, and if possible, a very fast tripping time in the event of blocked rotor causing high overcurrent.

This required detailed knowledge of bimetals, and the ability to produce them with specific characteristics. Texas Instrument, which produced its own bimetals, inherited from Metals and Controls, under the Truflex brand, was in a good position.

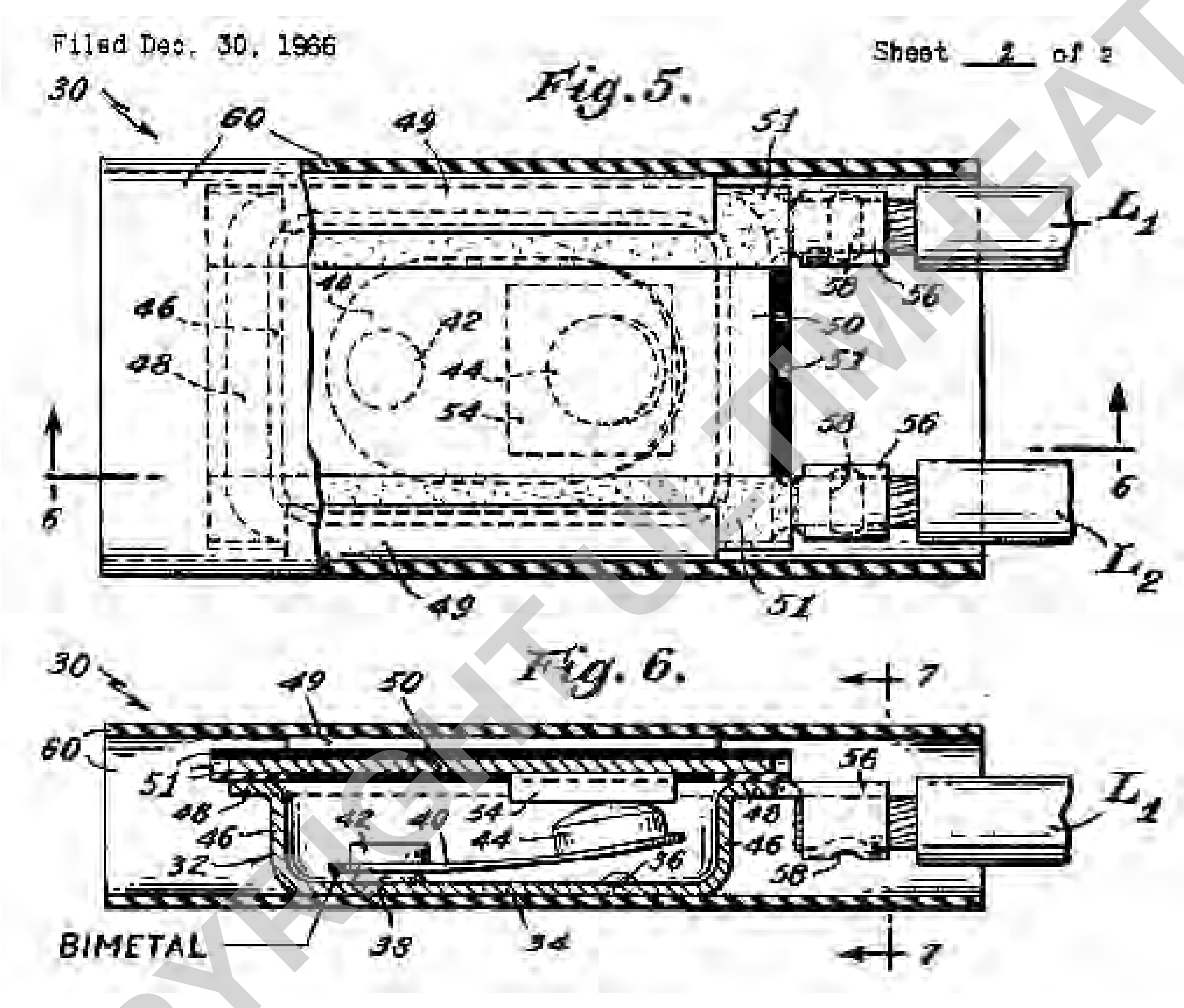
It wasn't until 1959 that engineers Walther H. Moksu and Henri David Epstein of Texas Instruments USA filed a patent (3,104,296) for a miniature snap-action thermostat. This model will be the origin of a long line of devices of this type: the SL11 series. Thanks to its small size, and its assembly, it will immediately find its market in motor windings.

	
Texas Instrument Patent 3104296	*Prototype of the SL11 series (1960 **)*

Seven years later, in 1966, engineer Richard T. Audette of Texas Instrument developed the simplest to produce snap-action temperature limiter, which was marketed as the 7AM series. This model combined both miniaturization and low differential, as well as good sensitivity to current and temperature. Although not waterproof, it suited a whole class of electric motors perfectly, and its price was particularly attractive. When the patents protecting it ended, it was manufactured by numerous companies.

In 1967 Microtherm GmbH, on a different design, began manufacturing the T10 (size 13×8.5×5mm) and T20 (17×12×6mm) sealed bimetallic disc limiters, with high inductive breaking capacities, 1.6A and 6.3A, also particularly suitable for the windings of electric motors.

In 1971 Uchiya (Japan) developed a series of limiters with an even smaller footprint, the 8×5 series, (size 22.7×4.4×6.8mm) with snap action and breaking capacity 2A, which covered the range of miniature windings.



1966 Patent of Richard T. Audette for Texas Instrument (US Patent 3,430,177)

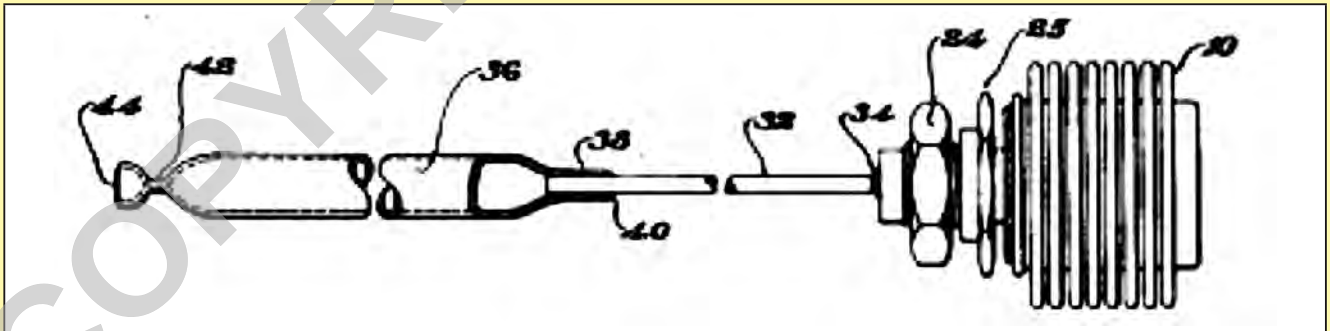
The diastat, closed assembly filled with liquid, has followed a slow evolution since the invention of the Vidie capsule and the flexible corrugated metal membrane. To achieve its current apparent simplicity, it took more than 130 years of technical evolution in the manufacture of components: capillary, tube, membrane, but also metals, heat treatments, welding methods, filling liquids and vacuum pumps so that this system becomes an essential component of thermostats. The capillary made it possible to have a measurement remote from the adjustment and contact body.

In the vapor pressure systems, which preceded it, the amount of vapor in the capillary and in the capsule (or in bellows) did not affect how the membrane responded to temperature. For models with liquid filling, it was necessary to limit as much as possible the quantity of liquid in the capsule and in the capillary, in order to limit the incidence of parasitic displacement due to the ambient temperature on them. It was also necessary to make and weld thin membranes without gap between them, and connect them to a capillary as thin as possible, letting neither air nor gas going inside.

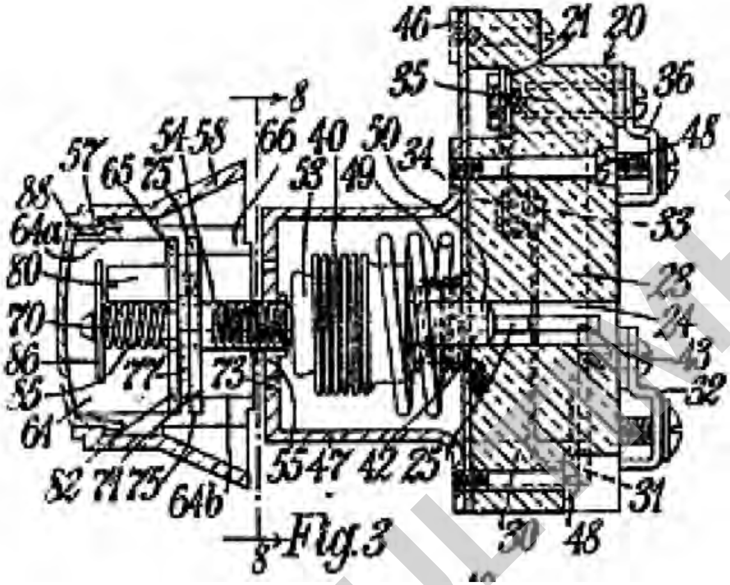
Until then, the use of bellows with a large volume of liquid required to provide in the head of the thermostat, a large bimetallic ambient temperature compensation system. The required technological level was not reached until around 1936 in St Louis, (USA) simply because this city was then the seat of many companies specialized in the measurement and the control of temperature, and that the demand for this new technology was strong in household appliances.

On June 23, 1937, Samuel G. Eskin, (1900-1977), an emigrated Russian engineer, working on thermostats for several years at Edison General Electric Appliances, filed a patent for an electric thermostat using the corrugated membrane system of the Vidie capsule, a bulb and a capillary, functioning by the expansion of liquid. He will improve it two years later.

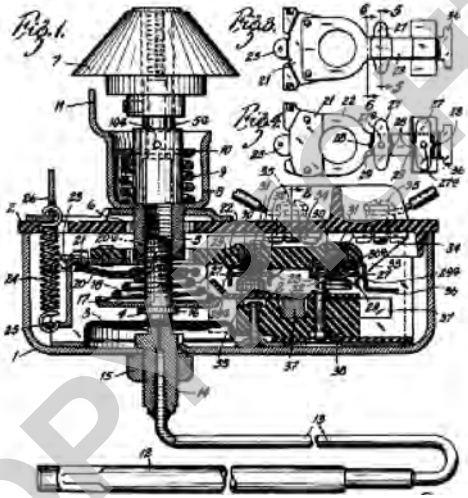
It will serve as a model for all manufacturers thanks to its compactness, its ease of manufacture and its low sensitivity to the ambient temperature around the capsule.



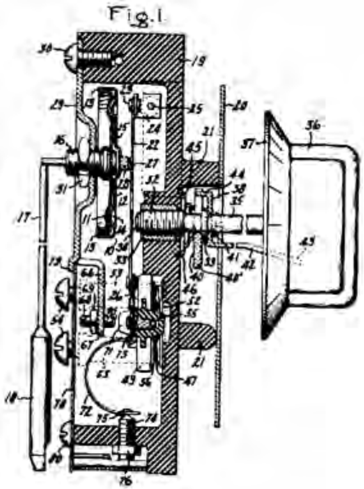
1931 Walter B. Clifford patent for a very low temperature corrugated tube thermostatic assembly (patent US2,068,626).



1936 Diamond H. Switches patent (England), for a slow-break bulb and capillary thermostat with bellow (No. 40) and ambient temperature compensation system (No. 35). Filed in 1936 in the USA, and in 1937 in France.



1937, U.S. Patent No. 2,121,079 to Samuel G. Eskin, for an electric bulb and capillary thermostat, with a liquid-filled Vidie capsule diastat. This diastat model (N°3, 12, 13, 14) has remained unchanged today.

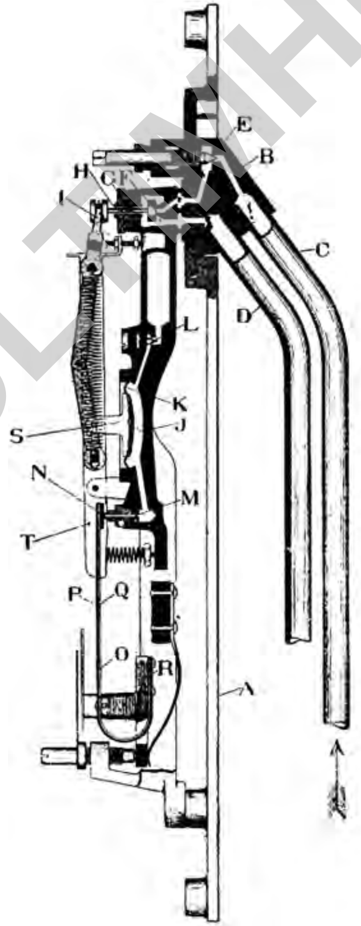


1939, U.S. Patent No. 2,260,014 to Samuel G. Eskin, for an electric bulb and capillary thermostat with liquid-filled diastat with snap-action contact.

At the end of the 19th century, when electricity was still in its infancy, a number of manufacturers tried to find a way to connect a measurement of the temperature to the actuation of a mechanical member like a valve.

A number imagined pneumatic solutions. This research gave birth to thermostatic valves, but also to some specific devices.

*Two variants of the Dorian thermo-regulator used for the regulation of the room temperature in rooms heated with stoves or gas boilers. The system uses the expansion of liquids to actuate a valve, which can actuate either directly the gas supply or a hot water circulation circuit (1902 La Nature *)*

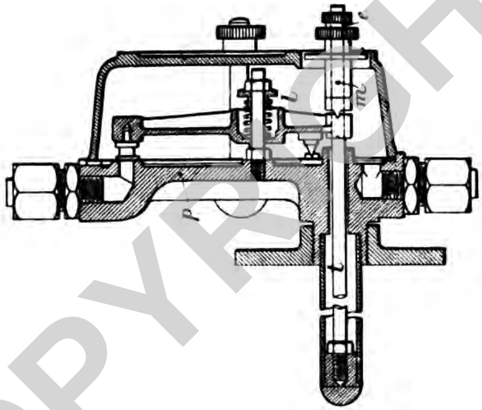


Room thermostat for compressed air circuit used to automatically operate valves, registers, steam or hot water distribution taps. The temperature measuring device is a bimetal actuating a micro-valve. Produced by the Johnson Service corporation of Milwaukee USA. Presented at the Saint Louis Exhibition in 1904.

In 1877, Henri Arquembourg, to improve the automatic temperature control of big buildings, invented the auxiliary fluid pressure operated relays. In 1908 Ragnar Carlstedt in Stockholm set up the Company of Arca regulators, using this technical solution. The innovation of these devices was to regulate from the opening or closing of a small calibrated orifice, the opening of which caused a pressure drop in a diaphragm valve named "pressure relay". The temperature control obtained by this system was very precise, and the forces available at the pressure relay made it possible to control valves or other pneumatic or hydraulic systems without the need for a power supply. This technique was particularly suitable for large building heating installations, and many industrial applications.

In 1924 the "Compagnie Française des régulateurs Arca" was set up in Paris, with an outsourced manufacturing activity in France.

In 1946 Christian Bürkert in Germany started a manufacture, originally to produce incubators thermostat. In its range, a similar device with air leakage was introduced: a rise in temperature causes a leak of air in the thermostat and thus causes the distant valve to operate. This leak is gradual and helps achieve a point of equilibrium. This system therefore controls pneumatic diaphragm valves. Manufacturing was quickly relocated to eastern France. Due to the lack of interest in the market and the evolution of electronic control systems, manufacture stopped in December 1996.



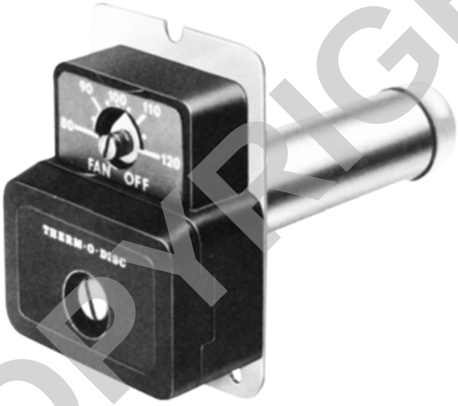
1924 Hydraulic pressure temperature regulator. The pressure variations are used to actuate a valve regulating the amount of steam used to heat the liquid. (Civil engineering of July 26, 1924)

*Temperature regulator with bimetallic rod, on air or hydraulic circuit, called Thermo-relay (Arca Catalog *)*

This type of thermostat took the name of "airstat" when it was placed on a hot air stream heater. It was mainly used on industrial gas air heaters. Its function was to control the outlet temperature of the hot air. As a result, its design allowed it to be mounted perpendicular to a metal wall, with temperature-sensitive elements: bulb or bimetal located in the air stream and designed to have the shortest thermal response. It actually looked like pyrostats, but with a lower tripping temperature and less overheating constraints. The hot air heating systems being very common in the USA, many models were developed there.

*1960 Fixed temperature airstat using disc thermostat (1960 Catalog Therm-O-Disc *)*

*1960 Airstat with adjustable temperature set point, bimetallic temperature responsive element in the air stream (1960 Catalog Therm-O-Disc *)*



*1960 Airstat with adjustable temperature set point, rod temperature responsive element in the air stream (1960 Catalog Therm-O-Disc *)*

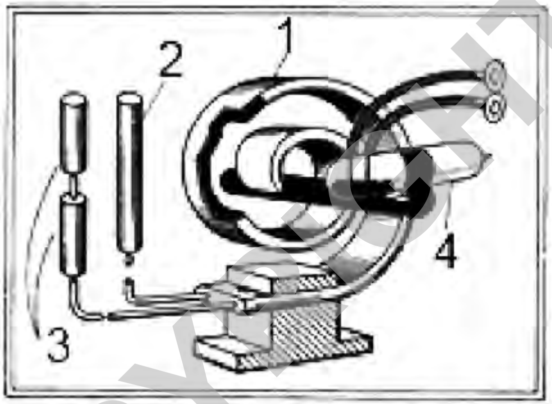
Airstat for forced air heating systems, two bulb liquid expansion mechanism for regulation and safety. Snap-action microswitch contacts. ST series (1977 Sopac Catalog)* according to the hourly rates, the nature of the walls and the heating system. The patent (No. 778,692) was issued in January 1935. This device was built by the "Société pour le Perfectionnement de la Chaufferie" (S.P.C.).

But already had started to appear electromechanical systems using a Wheastone bridge, the imbalance of which, between a resistor measuring the temperature of the water and another the outside temperature was operating a galvanometer.

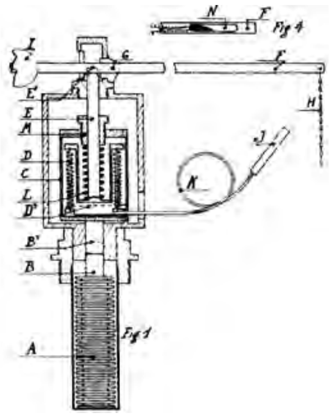
In 1956 La Thermostatique developed a thermostat system using a bimetal rod, the CR or CRX series, coupled with an external "pilot" type CP sensor, and a CC control box. This system made it possible to control a mixing valve, a motorized valve or a burner.

While Sopac remained on the range of differential thermostats with its Variostat model, in 1957, Honeywell used the term Duostat for **its electronic** Moduflow range with external sensor. The Duostat Moduflow includes an atmospheric detector and a heating water temperature detector. The central electronic station transmits the values received until a balance is established between the inside and the outside.

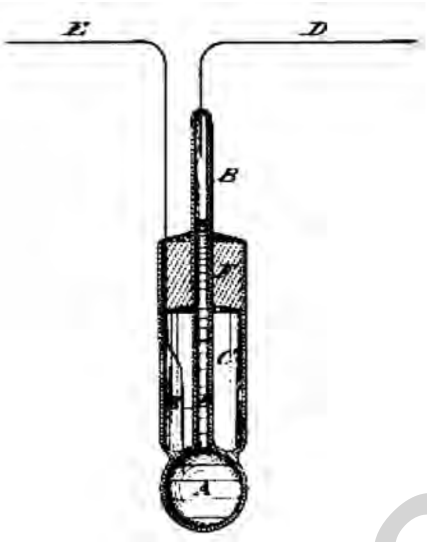
In 1978 Sopac produced two models of **fully electronic** variostats, the types VE01 and VE02, which foreshadowed the control panels of modern boilers.



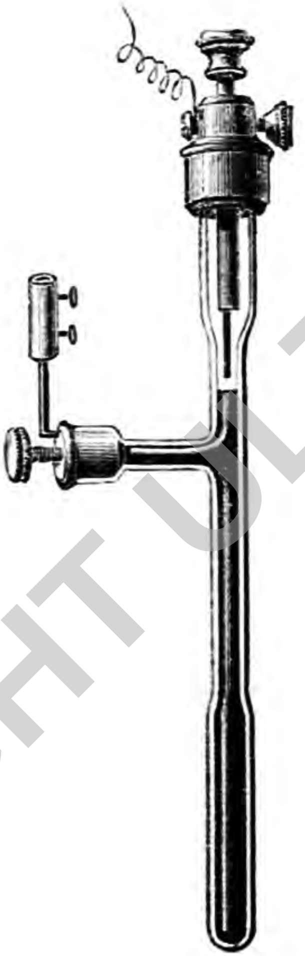
Circa 1934. Operating principle of the Duostat or differential thermostat from Jules Richard S.A.
1: Bourdon tube;
2: Outer bulb
3: Radiator bulbs;
4: Tilting mercury bulb.
(Extract from 1937, La Nature N°3000, The evolution of automaticity in central heating by Pierre Devaux *)



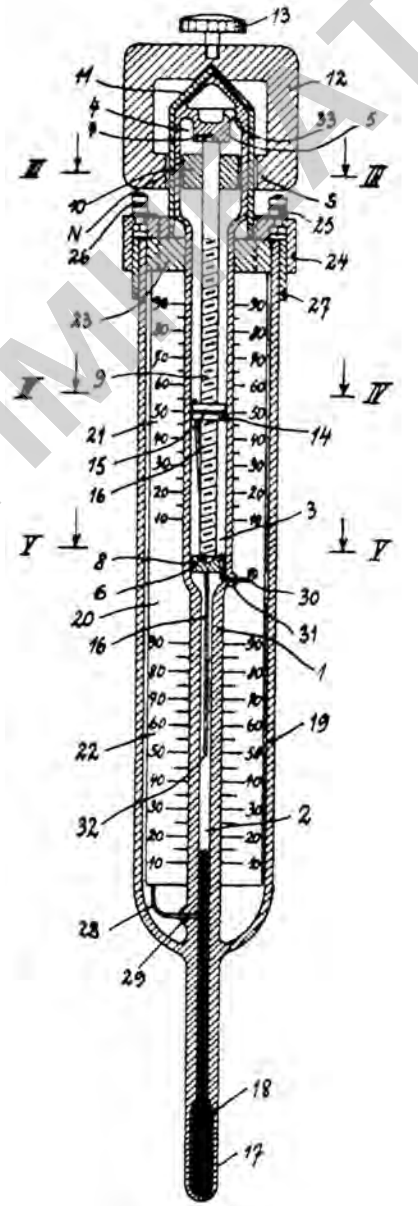
French patent 820,129 from Louis Soupire, for the Damien et Cie company, filed on July 6, 1937, for a combustion regulator comprising an auxiliary external temperature measurement system, with either mechanical or electrical action, for solid fuel boilers, gas or oil.



John H. Guest, electric fire alarm, using two platinum wires in a mercury thermometer (US patent 139,953 filed in March 1873)



*Electric alarm adjustable by electrode immersed in mercury, calibration by comparison with a thermometer. (Poulenc Catalog 1905 *)*



Patent of Erich Juchheim, filed on March 23, 1936, for thermometer adjustable under nitrogen, with double scale and magnetic adjustment knob

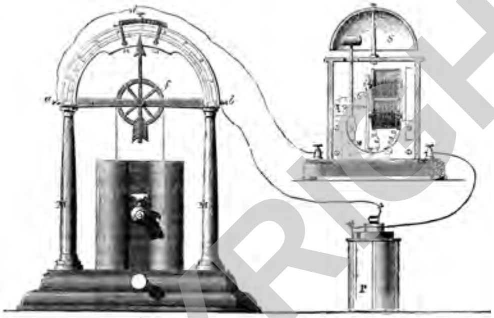
From the emergence of electric batteries, manufacturers of dial measuring devices developed so-called "warning" mechanisms to use the possibility of remotely reporting an alarm or signal.

In 1856, Bréguet, a watchmaker, developed a pointer contact switch for manometers and barometers. The insulating pieces were made in ivory.

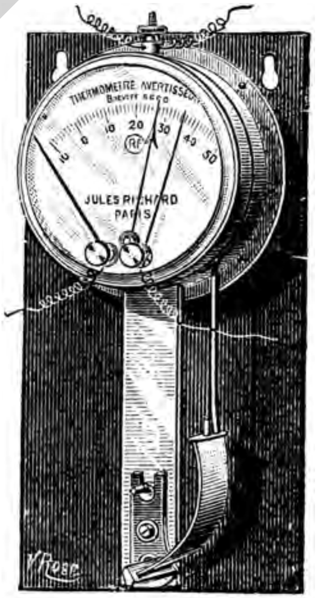
In 1889, the Richard Frères company introduced its range of electrical warning thermometers for maximum and minimum temperatures.

In 1909 Schaffer and Budenberg, offered a wide range of thermometers and manometers with pointers carrying electrical contacts. The set point can be fixed or mobile, minimum or maximum.

In 1911, Joseph Barbe Fournier, attached to the physical research laboratory of the Sorbonne in Paris, and who was the first to invent, in 1905, the theory and then the bulb and capillary vapor pressure thermometers, developed versions of these with pointer electrical contacts. In 1932, its new version with pointer actuating a tilting mercury bulb made it possible to control significantly higher powers.



*Pointer contact on Siry and Lizars manometer, produced by Bréguet (1856, L'ami des sciences N°24 *)*



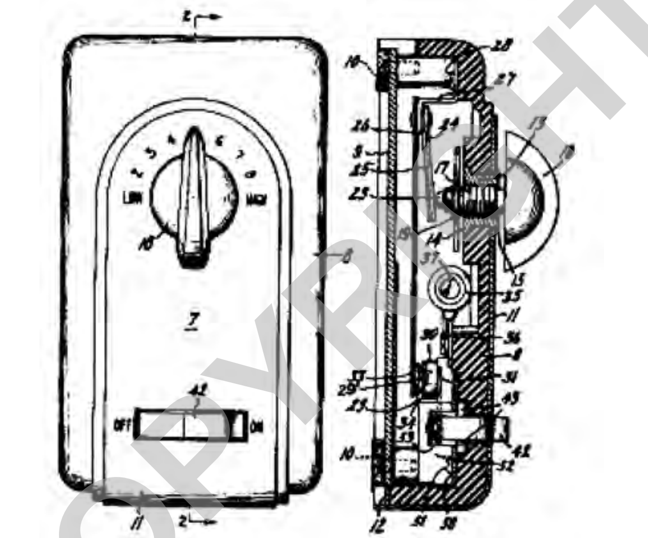
Double pointer contact on Jules Richard thermometer (1901-1902 L'industrie Française des instruments de précision)*

The bimetal energy regulator is a rotary switch which controls the power dissipated by a heating element. It is used on electric ranges, hot plates, space heaters, and many applications which call for proportionate control of a resistive load.

It was born from the development, before 1939, of electric cookers with hotplates. The makers of these household appliances were looking for a device that could continuously adjust the output of the heating element, somewhat in the same style of operation as gas burner valves, hence the name it has sometimes been given of "Electric tap".

Blanket heaters energy regulators

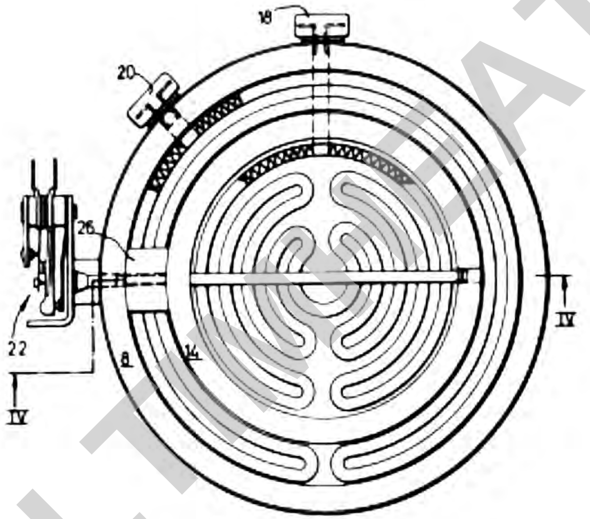
The precursor to the energy regulator was the electric blanket temperature controller. The Second World War, by scarce supplies of fuel for heating homes, strongly developed the demand for electric blankets, and some manufacturers, and in particular General Electric in the USA, devised a way to regulate the power by an adjustable bimetallic strip installed on the power cord, and heated by a small resistance with a power of the order of one watt, placed in series with that of the blanket. Therefore, by controlling the temperature of the bimetallic strip of the control box, the power of the blanket was controlled. Connecting a small resistor in series simplified wiring, and the slow-break contacts withstood the blankets low wattages, in the range of 50 to 100 watt.



System for regulating the power of heated blankets by bimetal thermostat with additional heater in the casing (1942, Cook patent for General Electric)

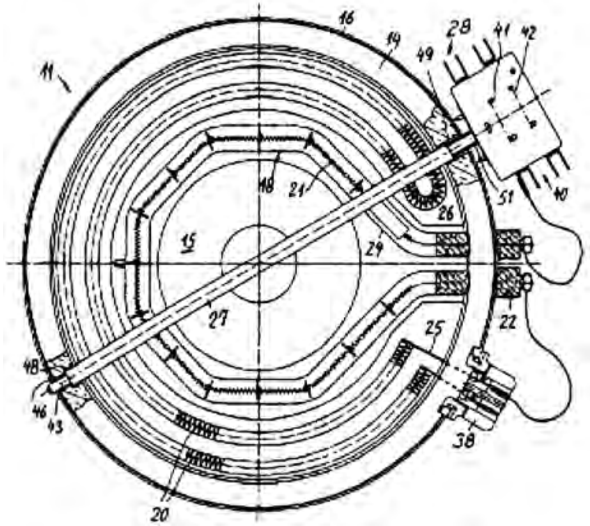
Energy regulator system for heating blankets based on the General Electric model patented in 1942 (Catalog Calor Textorève 1955)*

1972 First vitroceramic hotplates fitted to a Brandt electric cookstove (*)



Micropore plate with quartz / Inconel thermostat (English patent of Joseph Antony McWilliams filed on February 7, 1979)

Ceramaspeed radiant heating plate with quartz / Inconel limiter and EGO sensor thermostat (circa 1985 **)



Patent for mixed radiant and halogen hotplate with quartz / Inconel limiter (German patent DE3929965 filed on September 8, 1989 by EGO)

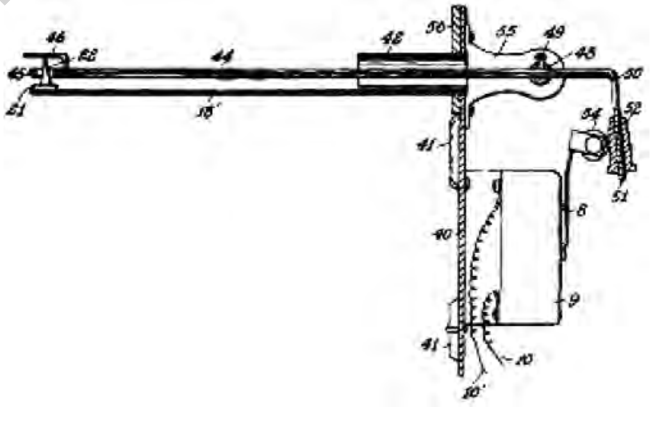
The first idea of using the deformation of cones made of different clay mixtures to measure a temperature belongs to MM. Lauth and Vogt who applied it to the Sèvres manufacture before 1882. But they did not give it all the development it required; they contented themselves with establishing a small number of pyrometric cones corresponding to the various temperatures used in the porcelain manufacture of Sèvres. (*1900 Measurement of high temperatures, H. Le Chatelier and O. Boudoux*).

In 1884, then in 1896, this system was perfected by Doctor Hermann August Seger, head of the research department at the Royal Manufacture in Charlottenburg (Germany); he developed what he called fusible watches, covering a temperature range of 600 to 1800°C, in 25°C intervals.

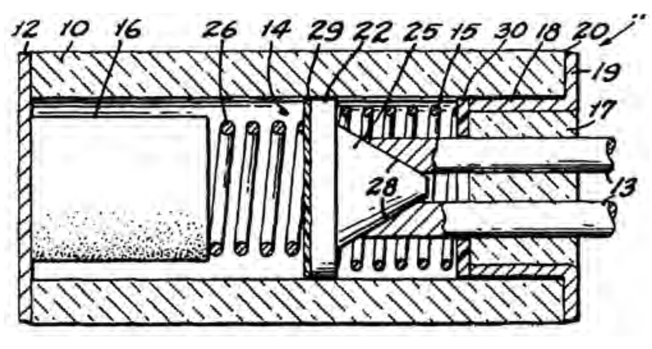
In the USA, Orton developed similar pyrometric cones.

In 1954, Wilfred W. Dawson of Detroit, USA, invented an automatic kiln firing control he named "Kiln Sitter", which automatically cut off power to a kiln when a pyrometric cone melted. During the previous decade many products of this type had been invented, including that of Charles H. Strange in 1951, based on the vertical collapse of the cone, but their operation was uncertain because these systems pushed strongly on the cone which modified their deformation temperature. In 1954, the operation of Wilfred Dawson's device, later improved by Lewis Burmeister, was reliable because it did not apply significant force to the pyrometric cone. The fusion of the horizontally placed clay pyramid released a needle placed in it, connected to a switch that cut off the power to the kiln. Dawson Inc. ceased operations in 2019. Its devices were used by most pottery kiln builders such as Duncan, Orton, or Paragon.

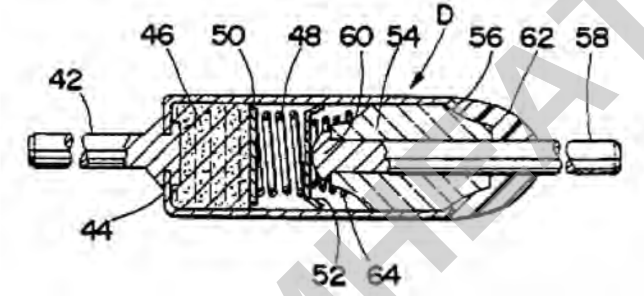
*Seger pyrometric cones in different states of softening (Poulenc Catalog, 1905 *)*



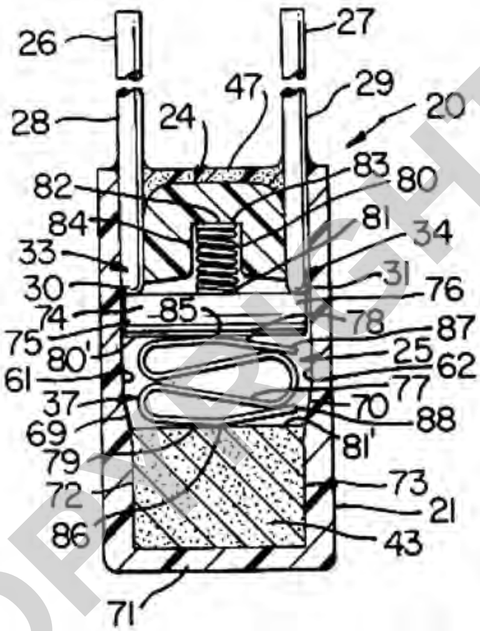
Vertical pyrometric cone mechanism (US Patent 2,555864 to Charles Strange filed in June 1948)



1958 NEC thermal cut out.
When the tripping temperature is reached, spring No. 26 plunges into fusible pellet No. 16, then the part No. 25 opens the contact between the two conductors. The two conductors come out side by side and are electrically insulated. (US Patent 2,934,628 filed August 25, 1958 by Julius C. Massar for NEC)

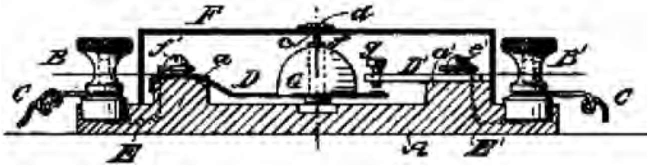


1969 Micro Devices miniature TCO, with wires coming out at both ends. One of the two wires is not electrically isolated. (US Patent No. 3,519,972 filed March 18, 1969 by Philip Edward Merrill for Micro Devices)

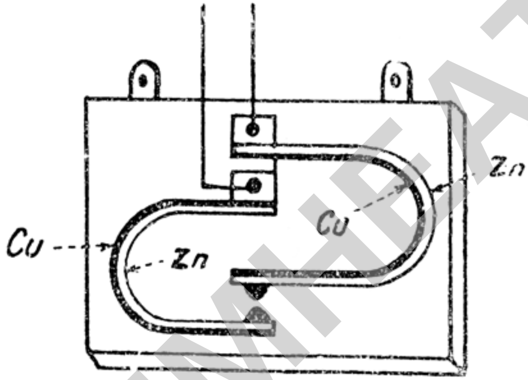


1974 miniature TCO, with 2-wire side-by-side output (US Patent US3,956,726 by Emil Robert Plasko and Philip Edward Merrill for Micro Devices)

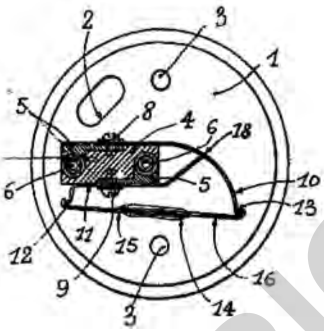
Last version of Microtemp TCO, division of Therm-O-Disc (Emerson, 1998 ** *)*



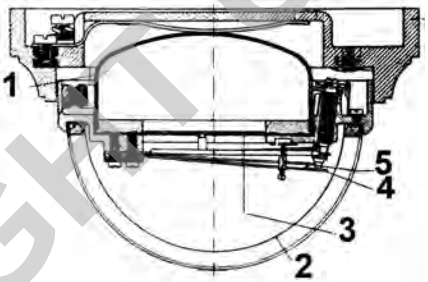
1884 Fire alarm closing an electrical contact, using fusible alloy washer shown in “d” (US Patent of Charles T. Ross, No. 298121)



Alarm system reacting only to the rate of temperature rise, made of two zinc-copper bimetals with different thermal inertia. A rapid rate of temperature rise causes the low- bimetallic strip inertia (left side) to bend slower and close the contact (1925 Applications of electricity to home life, by H. Mathis *)



Detector opening an electrical contact during the fusion of an aluminum link glued with a mixture of 1⁄3 virgin wax, 1⁄3 whale white and 1/3 paraffin (shown in 14)
(French patent 750,712, from the Société des coffres forts Bauche and Mr Pillon 1932)

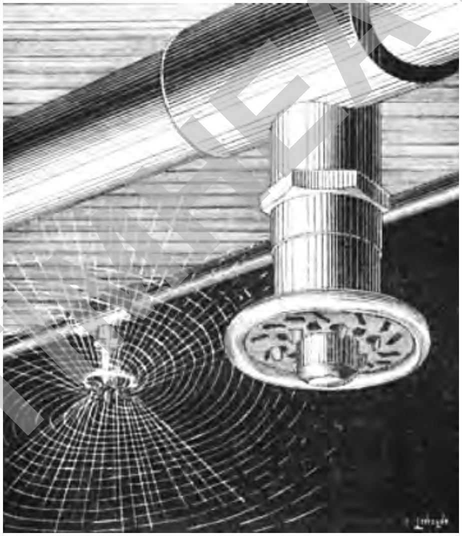


Ericsson thermo-velocimetric detector with two chambers separated by a membrane
1: Thick-walled chamber with long response time
2: Thin-walled chamber with short response time
3: Membrane
4: Rigid blade
5: Bimetallic blade used to detect a slow rise in temperature.
(1938 Electricity on Farms, by R. Borlase Matthews, and R. H. Drilhon)

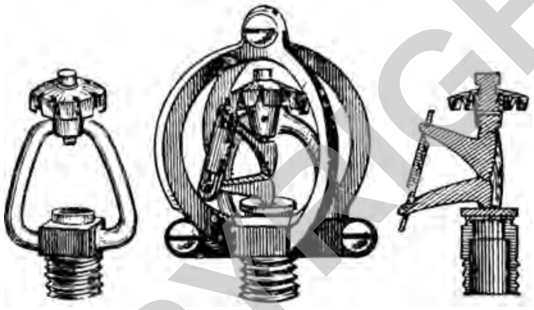
Disc thermostat for fire detection, short response time (Essex Catalog 1976 *)

But the technical development of frangible light bulbs would, from the 1980s, gradually put an end to fusible alloy systems.

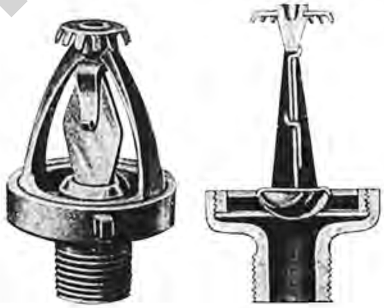
Grinnell fusible alloy sprinkler head of the first model on the market. In 1, solder with fusible alloy. (The Pantheon of Industry of February 22, 1885)



"Vulcain" fusible wax sprinkler head (Journal de la Meunerie, July 1888)



Automatic fire valve with a multiplied fusible link from the International sprinkler company in London (La Nature, supplement to N° 1697 of 2 December 1905)



*Grinnell fusible alloy sprinkler head. It then has a de-multiplicated link and a cup returning part of the water to the ceiling. (Science and Life N° 39, 1918 *)*

Fidex fusible alloy sprinkler, made by Mather and Platt in Roubaix (Informations sociales, bulletin mensuel à l'usage des services sociaux,1970)

The technical answer to these imperatives began to be solved when in 1985 Eduard J. Job of Ahrensburg, R.F.A. devised how to make elongated bulbs with reinforced ends, allowing the use of a classic borosilicate type glass. (German patent DE3532042 of September 1st registered in the US under the number US 4796710).

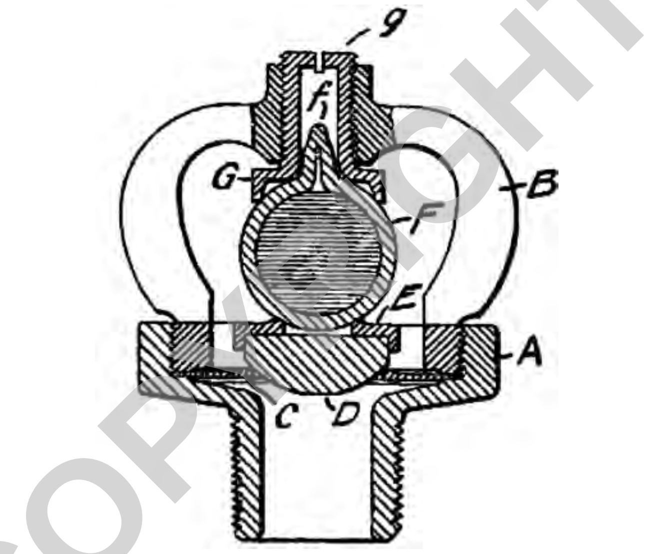
The success of these systems was immediate and helped simplify sprinkler heads, lower their price, and improve their reliability. The automatic manufacture of these bulbs also benefited then from the development of machines for the manufacture of miniature neon bulbs for pilot lights.

The German technical review of 1988, "Sprechsaal", vol. 121, no. 9 on its pages 781-787, then described the manufacturing methods and possible filling liquids. (Article by H.H. Fahrenkrog entitled "Untersuchung der Einflußgrößen beim Bersten von Sprinklerampullen": Investigation of the factors influencing the bursting of sprinkler bulbs)

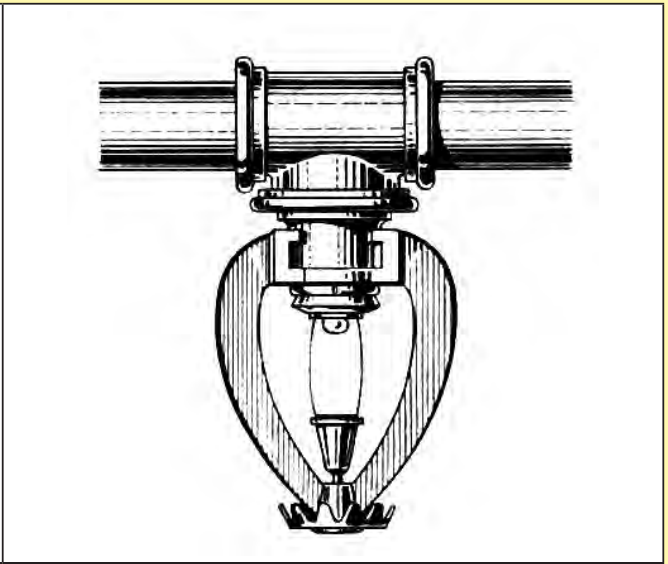
From the 1990s, development focused on reducing the opening time in the event of a fire, in particular on the production of models with a response time of less than 14 seconds, by reducing the diameters and thicknesses of the walls, by the use of different non-toxic and more reactive liquids.

The JOB company in Germany became the main producer.

Mather and Platt's fire protection activities were taken over by Tyco Fire Products.



Spherical frangible bulb sprinkler head (English patent to John Taylor, May 25, 1904 England)



Sprinker Grinnell with elongated frangible bulb type "Quartzoïd" (1970 Mather and Platt)

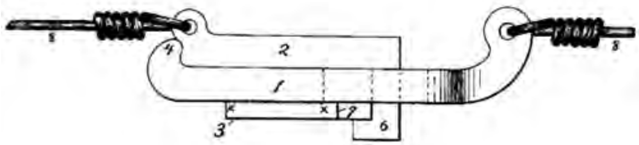
From their invention, at the end of the 19th century, the fusible links suffered from the poor mechanical strength of fusible alloys. When subjected to an excessive constant force, the solder would eventually fail after slowly creeping. Permanent exposure to temperatures close to the alloy's melting temperature was also a parameter increasing creepage. Several solutions were developed to improve this strength. The first was to increase the welding surface, the second was the reduction of the force by a system of levers, (which was the solution also adopted for the sprinklers), the third was a system of ramps or bumps separating surfaces in contact in order to prevent creep, the fourth was the use of an external force reduction mechanism. Another constraint was the requirement to have a short response time, which limited the mass. The last constraint was resistance to corrosion, in particular for systems subjected to industrial environments.

All these requirements were at the origin of the UL33 standard, the first edition of which was published in November 1968.

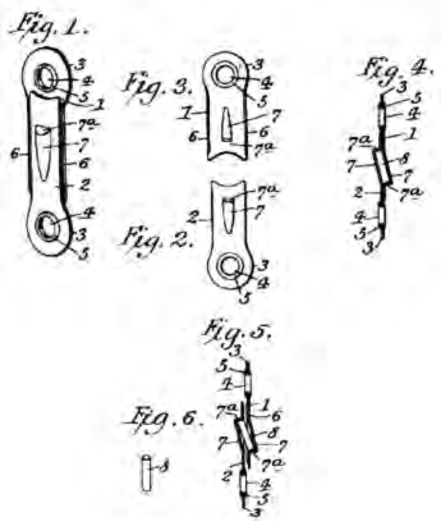
After the publication of the UL33 standard, the years 1969 to 1990 saw the development of many models with various systems to prevent creepage.

In their simple forms, these links were and still are used in kitchen hoods and in ventilation ducts. In their multiplied forms they are used to automatically operate smoke evacuation hatches and fire doors.

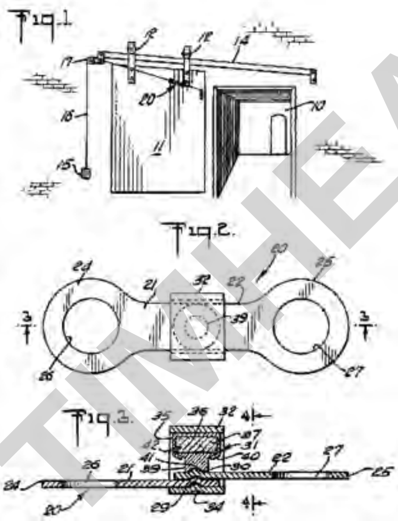
Grinnell fusible link, with double solder surface interposed in a wire to trigger the opening of a sprinkler valve (Grinnell patent US 269199 filed May 31, 1880)



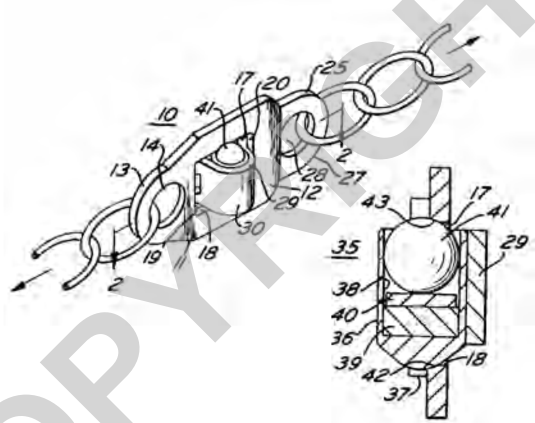
Grinnell demultiplicated fusible link inserted in a wire, for the door closing control. A solder with a fusible alloy is made on the x-x surface.



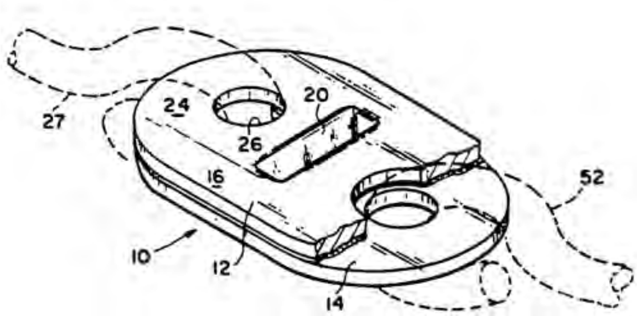
This very massive system had to have a very long response time. (Grinnell patent US432403 filed February 19, 1890) Fusible link with creep strength improved by an inclined bar represented under the N° 8. This system, made in a thin metal sheet, had to have a short response time. (Patent of John W. Yates filed in 1910 in the USA, and filed in France under the number FR472762 on August 18, 1914)



Solderless fusible link, with fusing pad operating in compression (N° 37). Use on automatic fire doors (US Patent 3,348617 filed September 13, 1965 by Bruce Macartney)



Solderless fusible link, operating by compression of a ball blocked by a fusible alloy pellet visible under No. 39 (Patent US3779004 filed on September 12, 1972 by Fred A. Gloeckler for Star Sprinkler)



Globe fusible link with central boss to improve creep resistance. (Patent US5,120152, 1992)

The use of frangible bulbs in links seems to have been invented by John Taylor for the automatic closing of fire doors, and used the quartzoid bulbs developed for sprinklers. The tensile strength was greater than for the fusible models, and no creep phenomenon was to be expected. However, the risk of these mechanisms was that they could be blocked by the fragmented parts of broken bulbs, and their design had to take care of it.

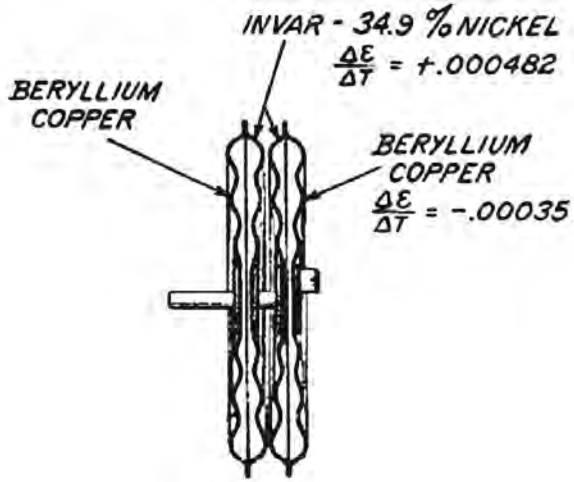
In the 1960s, the Esti company in Berlin produced a spherical bulb model with a very large mechanism. Mather and Platt proposed one in the 1970s, using his quartzoid bulbs. The cylindrical bulbs developed in the 1980s, with the reinforced ends currently allow the realization of mechanisms supporting high tensile forces, while offering a short response time.

*Spherical frangible bulb link for opening doors and valves. Maximum tensile force on the link 30kg. (Catalog Esti 1967 *)*

Mather and Platt "Quartzoïd" type elongated frangible bulb link ensuring automatic closing of doors when the temperature exceeds 68°C. Maximum tensile strength unknown. (Informations sociales, bulletin mensuel à l'usage des services sociaux 1970)

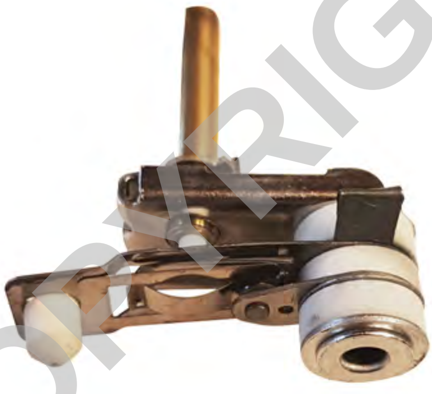
England is still an exporter of pure Beryllium, with an average production of 90 tonnes per year.

Despite many attempts by the metallurgical industry, to date there is still no material with the same properties and as important to the thermostat and switch industry as beryllium copper.



Pressure measuring device capsule, using capsules with a beryllium bronze membrane on one side and an invar membrane on the other side (US Patent No. 2,162,308 for Bendix aviation filed July 21, 1936)

*Vapor pressure thermostat with contact blades and thermostatic capsule made in beryllium copper (1957 Sopac Catalog *)*



*Iron thermostat with beryllium copper snap action contact blade (Cobra, circa 1985**)*

*Miniature beryllium copper contact blade on Cotherm water heater thermostat (1998 **)* *temperature, due to its extraordinarily high coefficient of thermal expansion. But this application did not last beyond the 1925s, due to the drift because of parasitic elongation due to humidity.*

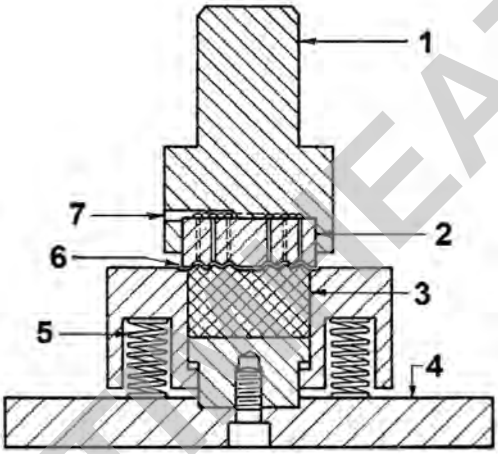
Electrical plugs were made of ebonite for a long time, and were not replaced by bakelite until around 1935.

*In 1954, the Drouet company in Paris still marketed ebonite plates and bars (1954 Catalog Drouet *)*

Under the name of hard rubber, ebonite still retains industrial applications, but is no longer used in the field of thermostats.

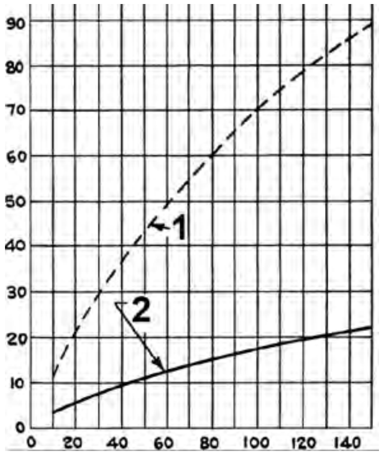
		
*Lamp base with ebonite head (Catalog Maure 1931 *)*	*1924 Arca room thermostat operating by expansion of an ebonite strip (Arca Catalog 1924 *)*	*Room thermostat with base and box in ebonite (Circa 1925 **)*

The corrugated membrane of one of Lucien Vidie's first aneroid barometers, traces of the embossing tool are visible, as well as the tin solder. (**)

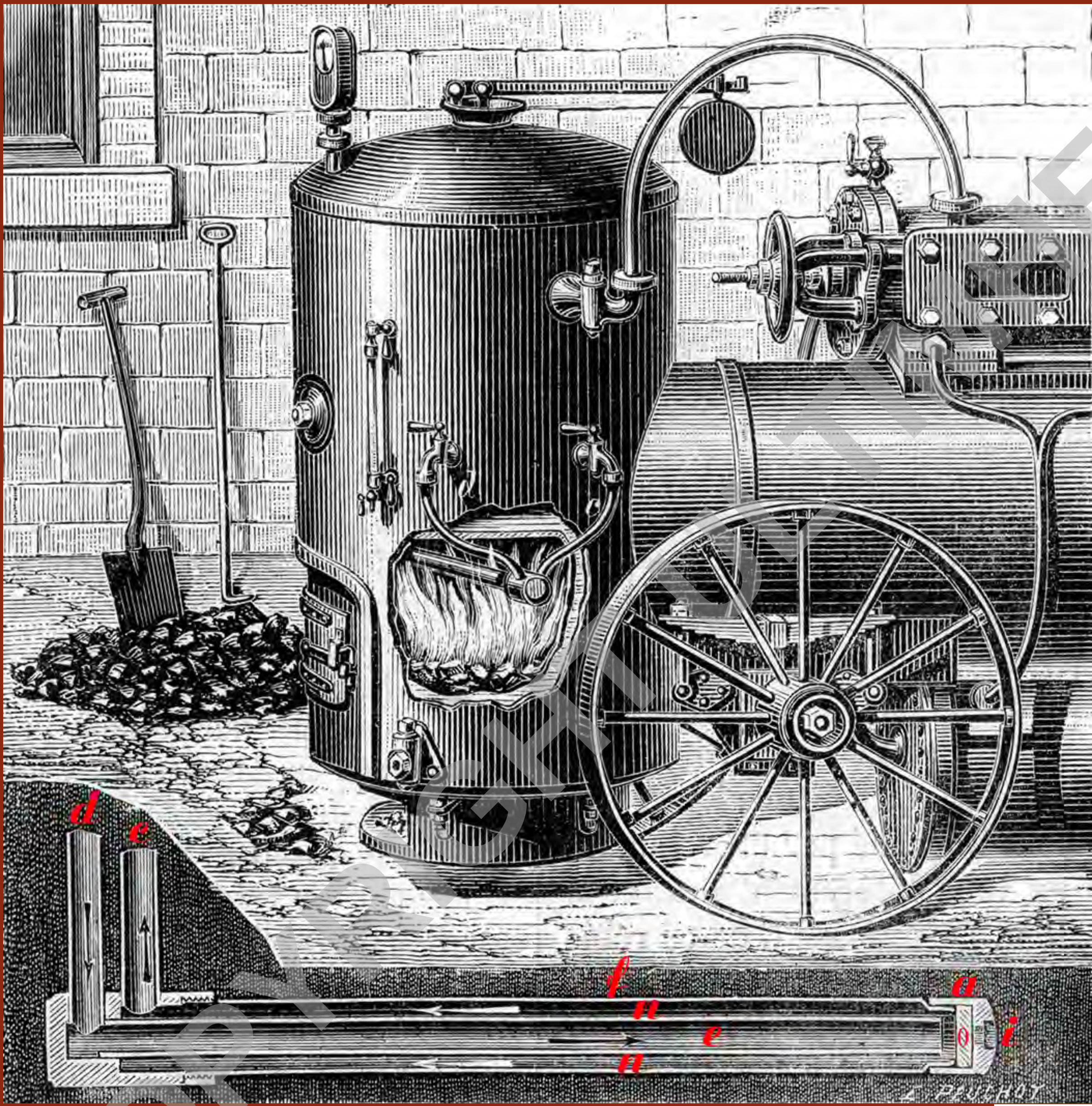


Stamping die for corrugated diaphragm using rubber nest (Copper in instrumentation, 1955 Copper development association *)
1: Shank
2: Die
3: Rubber
4: Plate
5: Die springs
6: Nest
7: Vents

Examples of corrugated membranes (Copper in instrumentation, 1955 Copper development association *)



Comparison of the displacement characteristics between a corrugated membrane and a flat membrane 1 : Corrugated diaphragm, 2 : Flat diaphragm. (Copper in instrumentation, 1955 Copper development association *)



Steam boiler equipped with the usual safety devices: pressure gauge, level indicator, safety valve. It also includes an Ubermuhlen water shortage alarm with a fusible plug. The fusible plug is in “O” and its melting, when the water is no longer circulating, causes a warning whistle inside the hearth. (La Nature, N° 785, June 2, 1888).

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