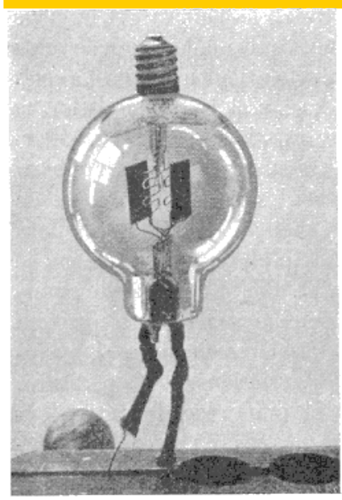
History . -- At the start of the war, the existence of 5-electrode lamps was virtually unknown in France or at least they were not used.

These devices were then presented either in the form of the German **Von Lieben** tube - a large elongated bulb, separated into two parts by a perforated metal grid like a skimmer, a filament reminiscent of that of incandescent lamps located on one side, one metal rod or anode which played the role of plate located on the other - either in the form of the American *Audion* of **De Forest** ; It is the latter that we must consider as the starting point of the current lamp (**fig.1**)



In the very first days of the war, **Colonel Ferrié** , now a general, had the good fortune to receive tube devices from America: an oscillator or heterodyne and a transformer amplifier, as well as half a dozen audions, charged **M. Abraham** , professor of physics at the Sorbonne, mobilized with Military Telegraphy, with their study .

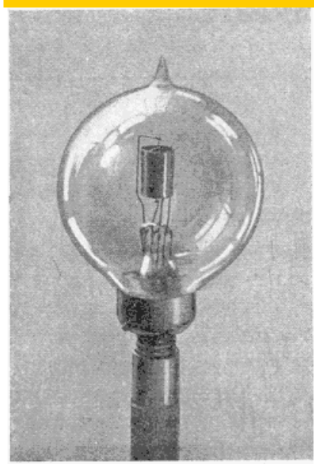
Mr. Abraham , who had been following all TSF issues for a long time and had also been charged in 1913 with a fact-finding mission on this subject to the United States, immediately took an interest in the new instruments. In a very short time, he reproduced in his laboratory at the Ecole Normale Supérieure the oscillator brought from overseas; then he endeavored to create in Paris itself, in the interest of national defense, some models of lamps, by contacting the master glassmaker **Berlemont** , known in the scientific world for his manufacture of physics devices where he enters glass frames. But at this time, Abraham's tests were interrupted momentarily by his departure for Lyon, where he was assigned to the large wireless station at the Customs, the installation of which was beginning.

Despite this move, **Mr. Abraham** , who of all the specialists had the most faith in the immense usefulness and the future of vacuum tubes, continued his tests, despite everything, with the greatest spirit of consistency.

Having inquired, he learned that there existed in Lyon itself a factory of incandescent lamps belonging to the **Grammont** establishments and with the Lampe Fotos brand ***.*** He presented himself at the door of the factory, asked to see the director, was received by a “beneficiary” (because the director was then mobilized), made himself known; and some time later (November 4, 1914), Grammont **was** able to reproduce a first audion by copying it.

But he was not immediately satisfied. The director of the factory, **Mr. Biguet** , was recalled from the armies in the first half of November, and work began in earnest, **Abraham** bringing his science and **Biguet** his technique of manufacturing incandescent lamps.

Very quickly, the device changed shape; and, on December 1 , the first type with symmetrical electrodes around a common axis was released, a type that the radios of 1915 were well known: the *filament* became rectilinear, surrounded by a helical *grid* , the whole being at the interior of a cylindrical *plate* ; the system was then placed vertically in the bulb (**fig. 2**)



In the meantime, **Abraham** and **Biguet** realized that, to have lamps comparable to each other, they had to be completely emptied, the electrodes and the glass had to be perfectly purged of gas; in a word, let the lamp be “hard”. To achieve this result, they found methods similar to those that we describe below, because these are the ones that are still broadly used today.

On December 31, **Abraham** and **Biguet** sent **Colonel Ferrié** a first shipment of 10 of these lamps, at the same time as **Abraham** sent the colonel a report giving a description of the device and its method of manufacture.

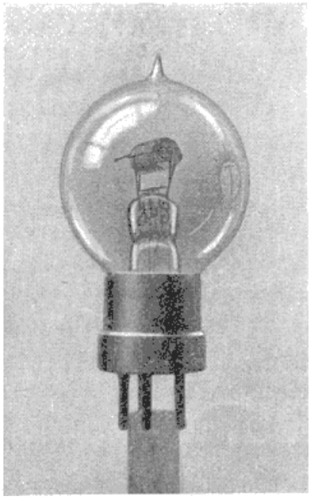
From that moment on, most officers and technicians felt violently attracted to the 5-electrode lamp; and so marvelous were its properties, so vast seemed the field that it opened up from scientific and especially industrial points of view, that interested passion got involved... Each brings a more or less new mode of assembly, while **Abraham** and **Biguet** continued and perfected the manufacture of these vacuum tubes that everyone was asking for.

This production is increasing steadily. But **Abraham** , for reasons of service, was recalled to Paris on May 1, [1915] .

As it was, the lamp had the following defects: a fairly great fragility, because the system was mounted in an overhang and the shocks deforming the assembly led to short circuits and filament ruptures; an inconvenience of use resulting from the nature of the base: it was necessary, after screwing in the lamp, to establish the grid and plate connections with flexible wires starting from the device and going to attach to the metal rods which protruded from either side and den of nerve. The manufacturers had not yet managed to use the pin base, although they had requested its establishment from specialist suppliers in December 1914; but in vain.

Colonel Ferrié having spoken to **Abraham** about the fragility of these lamps on his return, the latter immediately told him the remedy: to securely support the grid at both ends. This indication was transmitted from Paris to the appropriate person by telephone and little by little the lamp reached its current state: The filament grid plate system is made more rigid than in the previous lamp, and for this the plate was placed horizontally, supported in the middle by a thick and short wire; the grid, always formed of a helix, is fixed at both ends; finally the filament is placed symmetrically. As for the base, it has 4 pins - 2 to bring the current to the filament, 1 to the grid, 1 to the plate - and of course their arrangement is such that we can always place the lamp in the necessary position in the matrix, even groping: for this purpose, the pins are placed asymmetrically.

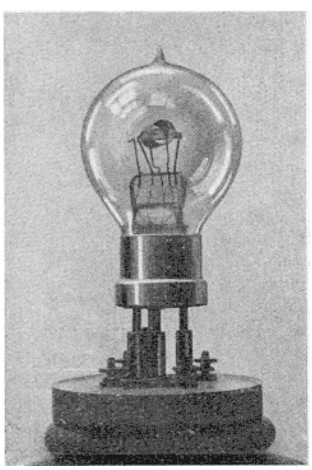
This is the type known as ***Military Telegraphy*** *(* TM), which everyone knows today (**fig .** *3*)



It was built for the needs of the army during the war, numbering hundreds of thousands, first by the Grammont establishments alone (**Fotos**), then concurrently by Grammont and by the General Electricity Company (**Métal**). At the end of the war, Grammont stopped its production. Today, we have as manufacturers: The General Company of Metal Lamps ; Radiotechnics ; The independent company of TSF (**SI F.**) . It is the latter which was kind enough to allow us to follow the manufacturing phases in its workshops.

TM Lamps -- To avoid repetitions, and to allow us to focus above all on the characteristic features of this manufacture, we ask our readers to kindly refer to the article on the Making of lighting lamps published in **La Nature** du 24 .February 1923: in broad terms, the operations of assembling the vacuum tubes, the skills are the same. We will therefore assume them to be known. However, a general remark must already be made: the production of these tubes does not need, for the present, to be intensive like that of lighting lamps, and their organs are moreover more complicated , much less automatic machinery is used, a large part of the work is done solely by hand.

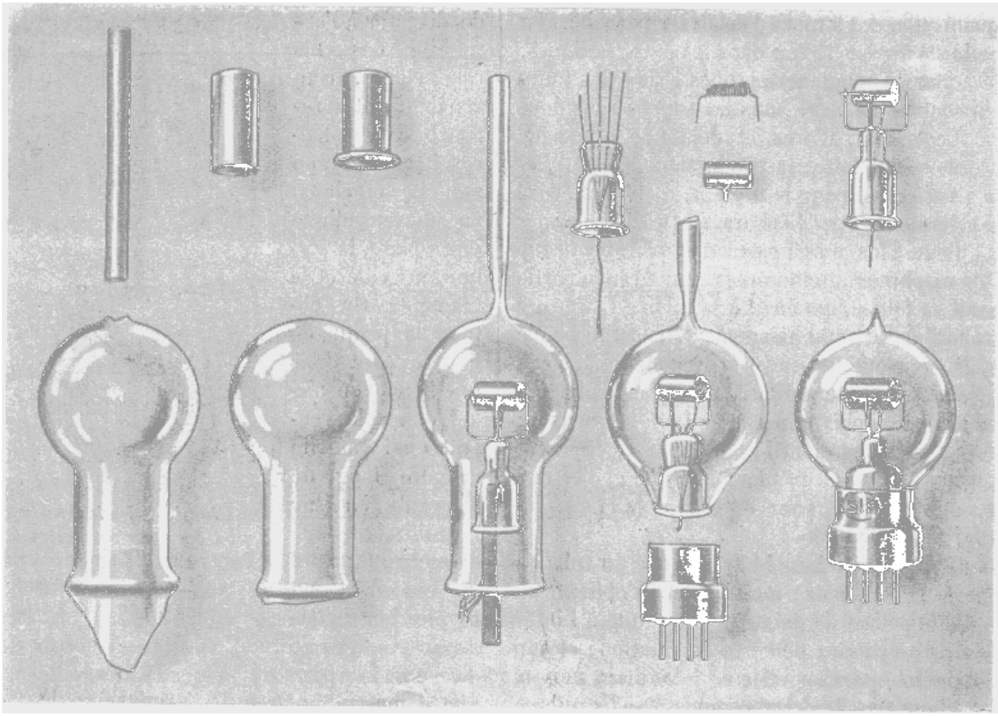
Let us first follow the establishment of the small TM type lamp, in use everywhere, and draw up a table of its elements: the crystal tube for making the base; thinner tube to make the queusot; conductive wires, the end of which will be shaped to form a frame; a filament; A grid, a plate, a bulb to enclose everything, a base (**fig. 5**).



Let's move quickly on to *cutting* the tube into sections of the desired length, which is obtained by means of a diamond point inserted inside the small rotating glass cylinder; and on its *flaring,* which is carried out by hand under the pressure of a curved iron rod, while a machine turns it on its axis and heats it with a gas torch. Much more interesting is the preparation and installation of the conductive wires.

These are made up of three metals: copper, platinum (**sheathed ferronickel**) or platinum, nickel. To bring them together, the worker arranges the ends of copper wire in a fan between the fingers of her left hand, heats the ends in the flame from a blowtorch which brings them to fusion, forming a very small ball, and inserts into this ball the ends of sections of platinite or platinum a few millimeters long; she operates the same for the pieces of nickel, and finally she obtained conductive wires which will be placed in the bulb: the nickel part inside, the platinum part embedded in the mass of the molten base with which it will become one . The copper part on the outside to bring the current. The pinching of the base of the molten glass tube trapping the five conductors - 2 for the filament, 2 for the grid, .1 for the plate - is obtained by means of the ordinary *foot-making machine* (**fig. 6**)

It is now a matter of garnishing this foot, that is to say of arranging at the end of the conductive wires, suitably curved into brackets (with or without hooks) by means of flat pliers, the plate, the grid and filament. The plate is obtained by cutting it from a strip of nickel and rolling it into the shape of a cylinder 1.5 centimeters long by 9 millimeters in diameter; the grid, by winding a molybdenum wire in the groove of a screw (**threaded rod 4 millimeters in diameter**); the filament is usually made of a tungsten wire measuring 55/1000 millimeters, but assembling these parts is a delicate operation! For the plate and the grid, electric welding is used for this purpose, carried out using a special machine. On a frame, a double copper jaw is placed, one part of which is fixed and the other movable; the worker applies the two pieces to be welded together flat on the fixed jaw and gives a pedal stroke which tightens the movable jaw, at the same time as a very high current produced by a transformer passes; a sharp click is heard: The soldering took place instantly. This machine, of American origin, bears the name of *spot-welder* (**fig. 7**) To place the filament, in the small lamps, we house the ends in the hooks of the gallows; In the big ones, we weld them "spot".



The various operations which precede the assembly of the lined foot inside the bulb - cutting it, washing, queusot age - do not differ in any way from those that we have described throughout in our article on manufacturing incandescent lamps for lighting; likewise, the fixing of the entire device in its glass prison is done using the *closing machine* (**fig. 8**), the operation of which we have previously observed in detail. But, when you reach the emptying of the lamp, you have to extend yourself further.

Pumping. It is necessary to evacuate the lamps as completely as possible, by removing not only the air which is contained in the bulb, but also by purging the electrodes of the

gases which are occluded therein, that is to say which impregnate them in the way that water impregnates a piece of wood which has been in a tub for a long time. To carry out this operation, we will use excellent pumps, the best we know; these will be either molecular pumps or mercury vapor condensation pumps, the study of which would go beyond our scope. Let's just say that these types of pumps, based on the kinetic properties of gases, can push the vacuum to a huge point, perhaps further than 1/100000 of a millimeter of mercury, i.e. further than the one hundred millionth atmosphere.

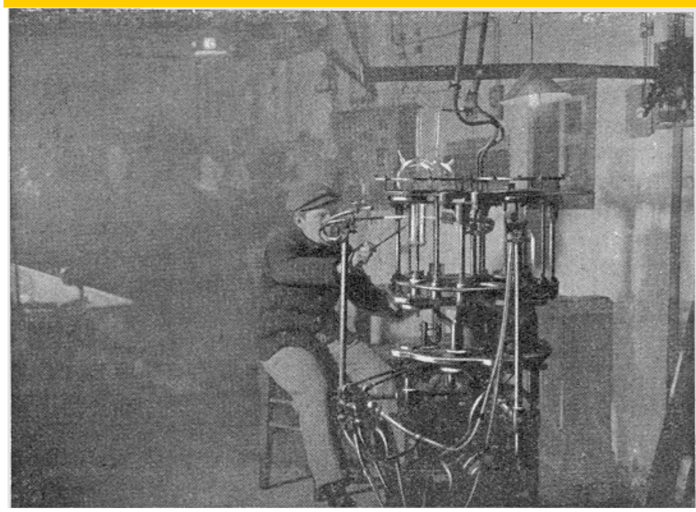
We will therefore understand that, in pumps using mercury, it will be necessary to use special devices so as not to be bothered by the mercury vapor, which, at ambient temperature, is 1/1000 of a millimeter of mercury, i.e. that is to say 100 times stronger than the pressure we talked about above; for example, we will pass the vacuum pipe into an enclosure cooled by liquid air or more simply by dissolved dry ice. in acetone.

To pump the lamps, we will mount them on a frame which includes a sort of shelf below which runs horizontally a glass pipe connected to the pump, pipe to which vertical glass tubes passing through the shelf are welded. It will be at the end of these tubes that the pump lamps will be welded, around fifteen at a time in the case of small lamps, and sometimes only one when it is a large one (**Fig. 9**)

Above the shelf is placed an asbestos oven, lowering and raising at will; its purpose is to allow the lamp to be heated while it is evacuated. Finally, the electrodes are connected to the various electrical circuits which will cause currents to pass through them, as we will explain in a moment. The role of these currents is to cause strong heating of the electrodes, just as the oven produces heating of the entire lamp. In fact, we only know one way to evacuate gases occluded in metals and glass, which is to bring these materials to a high temperature in a vacuum.

First of all, increasingly intense currents are passed through the filament, so as to gradually bring it to incandescence. Then, we try to heat the grid and the plate and, to do this, we bring these two electrodes to a strong positive voltage with respect to the filament. Under these conditions, we know that, the incandescent filament emitting electrons or particles of negative electricity, these, attracted by the grid and plate electrodes, precipitate on said electrodes; at the moment of shock, their kinetic energy will be transformed into heat, and this electronic *bombardment* will produce considerable heating of the grid and the plate to bring them to incandescence... and even to melt them on occasion!

The gases occluded in the electrodes are released and invade the bulb, where the pressure subsequently rises. In this imperfect vacuum, electrons encounter a large number of gas molecules and strongly ionize them; This results in a blue glow in the bulb, a glow that is all the more intense as the vacuum is worse.



The operation is repeated several times until the electrodes can be heated strongly without significant gas release. At this time, the pumping is finished and the lamp is separated from the pump by blowing a blowtorch on the narrowed part of the tail. The operation takes, all things considered, around an hour for small lamps and several hours for large ones.

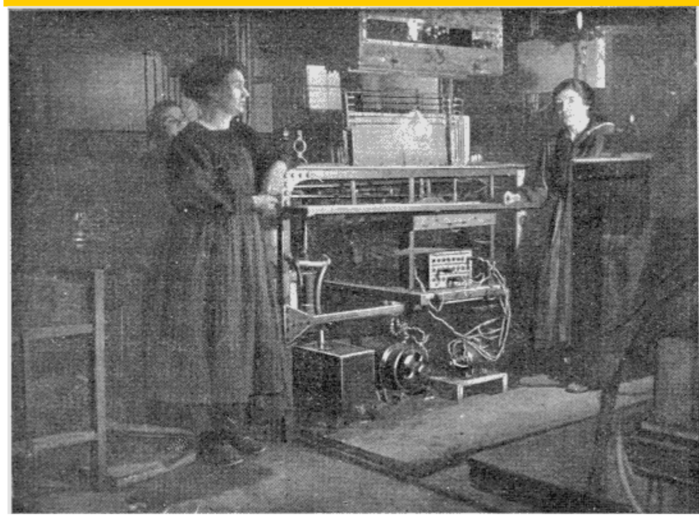
During emptying, the filament, ignited in a bad vacuum, supercharged, and subjected to the shock of the positively ionized particles that it attracts, wears out quite quickly; the lamp coming out of the pump is already “old”. One way of obviating this disadvantage consists of using, as a source of electrons to bombard the plate, no longer the filament itself, but the grid, in which we make pass an electric current; this explains why this grid is supported by two distinct wires which cross the base of the lamp (**see fig. 3**).

Various types of lamps. - As everyone knows, vacuum tubes can be used for many purposes, the main ones being: detection of TSF waves; - the amplification of currents, particularly in TSF and telephony; - the creation of alternating current from direct current (**heterodyne, TSF transmission stations**)

The same lamp can fulfill these three roles. Also, during the war, General Ferrié insisted that we have an “omnibus” lamp, which could be used for detection, amplification and small emissions at the same time: this is the current TM type. .

Since then many types have been put into service; but in France we have remained faithful to the TM type for TSF reception devices. As for the so-called “transmission” lamps, the greatest modifications have been made to them.

In lamp transmission stations, in fact, a part (50 to 50 percent) of the energy supplied by the machines, and which the lamp transforms into electric waves, remains in the device. This energy is transformed into heat which strongly heats the electrodes and consequently the entire lamp. This heating risks, if the pumping operation has been poorly carried out, of releasing gases which have remained hidden in some corner of the electrodes or the glass. The vacuum then becomes less good and; from a certain moment, goodbye to the transformation of machine energy into electrical waves!



This phenomenon will appear all the sooner the less the lamp has been emptied, but it will always occur if it manages to heat up too much.

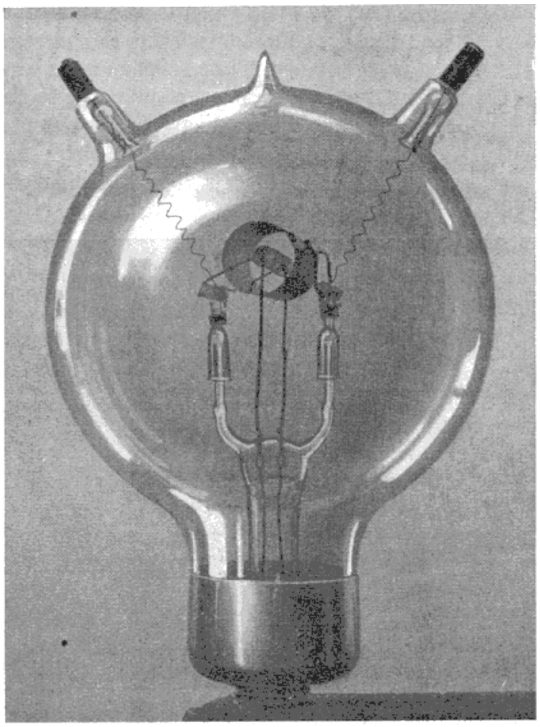
Also, to avoid this heating, we have to increase the dimensions of the lamps, at the same time as we increase the quality of the vacuum.

The types of transmission lamps are quite numerous and their devices diverse. Our figure 10 represents a model. In this device, we sought to distance the different current inputs as far as possible (which allows very high voltages to be used) while keeping the assembly by a single foot: this led to *horny bulbs,* which the This is obtained by hand welding small glass appendages, or *horns, on the top.* In other models, on the contrary, the grid-plate-filament systems will be supported on different feet on either side. Our lamp also has a much larger filament: 200/1000 millimeters. Its plate, made of molybdenum and not nickel, is relatively small and works at orange-red (**1200 degrees**) without the device deteriorating. In other lamps of the same power, the plate, which can be made of nickel; is much larger, but will only withstand a much lower temperature without accident.

Try-on . - When the lamps have been fitted with their four-pin base - the operation is carried out in exactly the same way as for lighting lamps - they are subjected to a test, a *test.* This test consists of making them undergo certain electrical measurements aimed at verifying that the characteristics are within defined limits.

To do this, each lamp will be placed successively on a table where various devices measure the various currents passing through it.

Suppose it is a TM lamp. First, a current is passed through the filament which is adjusted using a rheostat, so that there is just 4 volts across the filament. , which is observed using a voltmeter; an ammeter measures the current passing through the filament itself: it must be between 0.6 and 0.75 amperes, this condition defining the size of the filament. We then bring together the grid and the plate and bring them to a voltage of + 80 volts relative to the filament: under these conditions, all the electrons emitted by the filament are collected by the grid-plate assembly; the corresponding current is called *saturation* current . For a filament of determined length and diameter, this condition defines the filament temperature (value: 10 to 20 milliamps).



The operator then makes measurements on the plate current, as a function of the grid voltage, and, to achieve this, he brings the grid to the 0.0 potential and to the -3 volt potential relative to the negative end of the filament. The plate current must then be between 3.5 to 5.5 milliamperes and the variation of this current, going from the grid voltage of 0.0 to -2 vollS, must be at least 0.6 milliampere. Finally, we measure the grid current itself using a galvanometer. In the previous experiment, it should be smaller than a millionth of an ampere. According to a theory that we do not want to develop here, it is all the smaller as the vacuum has been pushed further. It is therefore a real measurement of the vacuum that we carry out at the same time.

Now let's move on to the transmission lamps. We heat the filament under a determined voltage, and we check that the amperage of the heating current is between determined limits, in particular that it is greater than a given value, which indicates that the filament does not have been too worn out when pumping. On the other hand, we have seen that these lamps must be able to heat without emitting gas, which would harm their operation. These gaseous releases have the effect of modifying the currents which pass through the lamp under specific conditions, we often operate in the following way when testing: we bring the plate together at a high positive voltage in relation to the filament (often several thousand volts) and the filament-plate current is adjusted by means of the gate voltage so as to expend a determined energy in the device. The lamp starts to heat up and, if it is good, it must in these conditions keep for a determined time (1/4 hour for example) the same current plate on the same grid voltage. This is a guarantee of good evacuation, because, otherwise, the presence of the gases which are released during this operation would cause the said currents to vary. Thus, in the lamp in Figure 10, we can expend energy of +250 watts without risking an accident.