Aug. 29, 1961 K. VATTERODT 2,998,469

ELECTRIC FURNACE FOR MELTING QUARTZ

Filed Sept. 11, 1959 2 Sheets-Sheet 1

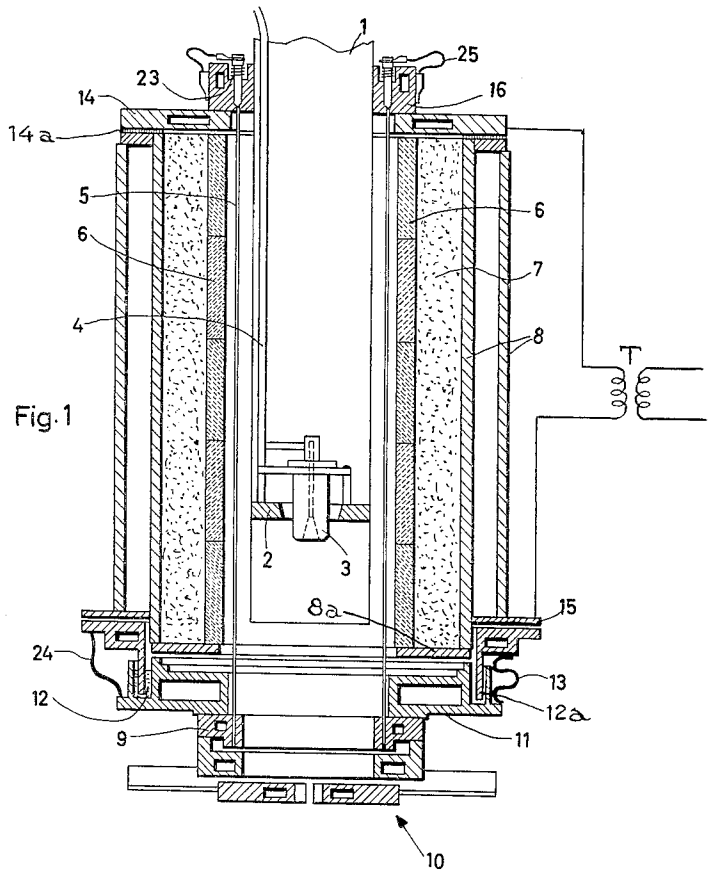


Fig. 1

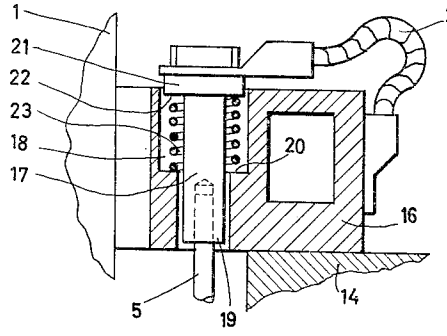


Fig. 2

INVENTOR
KARL VATTERODT
BY
Howard P. King
ATTORNEY

Aug. 29, 1961 K. VATTERODT 2,998,469

ELECTRIC FURNACE FOR MELTING QUARTZ

Filed Sept. 11, 1959 2 Sheets-Sheet 2

Fig. 3

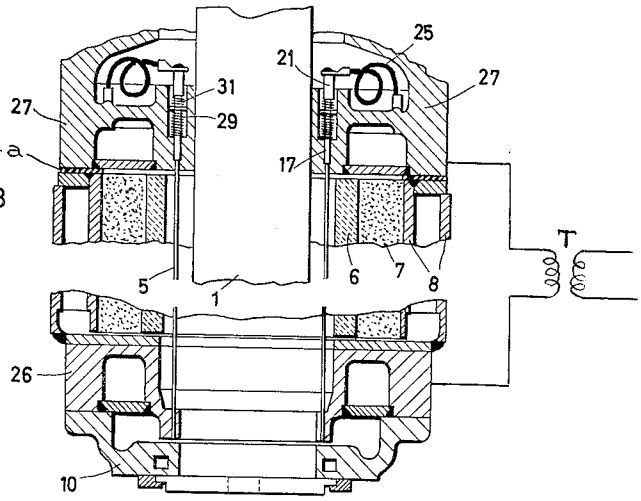


Fig. 4

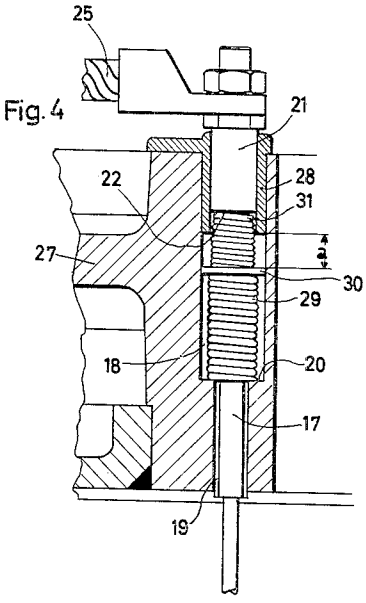
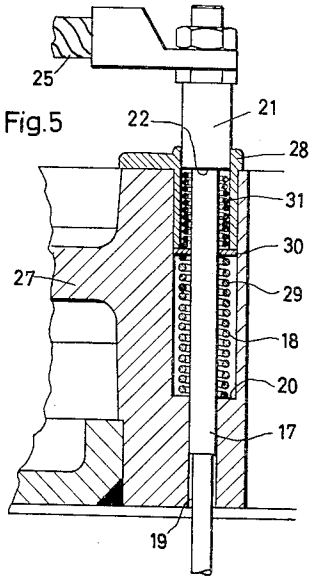


Fig. 5



INVENTOR
KARL VATTERODT
BY
Howard P. King
ATTORNEY

United States Patent Office 2,998,469
Patented Aug. 29, 1961

2,998,469

ELECTRIC FURNACE FOR MELTING QUARTZ

Karl Vatterodt, Berlin-Spandau, Germany, assignor to Patent-Treuhand-Gesellschaft für Elektrische Glühlampen m.b.H., Munich, Germany

Filed Sept. 11, 1959, Ser. No. 839,339
Claims priority, application Germany Sept. 17, 1958
7 Claims. (Cl. 13—22)

This invention relates to furnaces for melting quartz or quartz-like glasses having a high content in silicic acid, and is of the type wherein the melting crucible is heated electrically.

In one of the well known constructions of such a furnace, heating wires are arranged in the form of a winding or of a grid on the inner side of a fireproof jacket surrounding the cylindrical melting crucible, which jacket is also enclosed by an outer water-cooled covering. The heating wires consist of a refractory metal, as molybdenum or tungsten, around which a protective gas, as for instance hydrogen or a mixture of hydrogen-nitrogen, is flowing during operation. Changes in length of the heating wires occurring in operation of the above-mentioned construction effects dislocations in the heating-wire arrangement whereby the wires come into contact with one another or with the crucible. Nonuniform current loads which occur thereby cause a premature destruction of the heated wires.

The above drawback was intended to be overcome by another well known furnace construction, viz. by means of arranging a greater number of wires as uniformly as possible in parallel to the melting crucible axis so that the wires form a jacket surface of a coaxial cylinder. The heating wires are fastened on both ends respectively to upper and lower clamping rings. The upper clamping ring is connected firmly with the furnace whereas the lower clamping ring is connected firmly with the lower furnace parts only, so that said lower clamping ring and lower furnace parts are held suspended by said heating wires. By virtue of the weight of the lower furnace parts a pull is exerted on the heating wires, in consequence of which, as said heating wires elongate from thermal expansion, said lower ring sinks correspondingly and maintains the wires always in taut condition. It was to be expected that by this means any dislocations caused by the thermal longitudinal extension and any touching of the wires with one another and with the melting crucible would be prevented.

It came, however, as a surprise that the heating wires are, during operation, exposed to different longitudinal extensions and that in the course of operation permanent extensions or shrinkings of different extent are brought about. The shortest heating wires have to bear alone the load of the lower furnace parts while the other heating wires develop slack and become more or less curved. The extended shorter wires begin, therefore, to break after a proportionately short time whereas the very much curved wires come into touch with one another or with the crucible whereby they are also damaged. Life of such a heating device only amounts to 100 to 350 operation hours. Thereupon, operation has to be stopped and new parts have to be built into the furnace. Such frequent interruptions of the continuity of production requires great expense in material and time which has a bad effect on the price of the finished object of quartz or of glass.

Consequently, it is an object of the present invention to disclose a furnace construction which does not show the above-mentioned drawbacks and guarantees a satisfactory continuous operation of the melting furnace for a time which amounts to a multiple of the usual life of prior art furnaces. In order to explain the unexpected different behavior of the heating wires extensive examinations were made with respect to the longitudinal extension of tungsten heating wires. It was found that the thermal expansion according to certain well-known laws is not decisive therefor. In an axial symmetrical arrangement in which like temperatures are at all places, similar heating wires must have similar thermal expansions. The aforesaid experiments have shown that the observed differences are due to recrystallization processes in the tungsten wires. Tungsten wires are, as is known, manufactured from tungsten powder by subsequent pressing, sintering, hammering and drawing. The finished tungsten wire has a fiber structure which transforms again under strong heating. This transformation in structure, the recrystallization, takes place in a non-uniform manner, corresponding to the microscopic heterogeneous structure of the tungsten wire. Recrystallization has, therefore, quite a different effect on each of the tungsten wires and brings about the observed permanent different extensions or shrinkings of the individual heating wires.

At first, during heating up of the wires merely thermal expansion occurs and that as a comparatively great variation in length which is alike to all heating wires. The transformation in structure in the tungsten wires from the fiber structure of the new wire to the crystal structure does not ensue until strong heating prevails. During continuous operation of the furnace the heating wires are subjected to but trifling changes in temperature. The variations in length resulting therefrom and from recrystallization are small in comparison to the variation in length during heating up. But the comparatively small variations in length lead also to a rapid destruction of the heating wires as was apparent from the aforementioned furnace structure wherein the heating wires are fixed between upper and lower clamping rings.

The present invention proceeds from these observations and arrives at two types of furnaces for melting quartz or quartz-like glasses having a high content of silicic acid with a cylindrical melting crucible surrounded by electrically heated wires arranged in parallel to the axis of the crucible and being under tensile stress, these heating wires being rigidly connected at one end to the end parts of the furnace whilst the other end of each heating wire, together with a guide member or stud mounted thereon, is individually led through a bore therefor in an annular end part of the furnace, wherein each heating wire is movably supported in order to compensate for its variation in length. In both furnace constructions of the present invention two systems of different strength are provided for every single heating wire, exerting tensile stress and the change from the greater tensile stress of the stronger system to the smaller tensile stress of the weaker system is effected automatically.

For the greater tensile stress in the first type of construction the weight of the lower furnace parts suspended on the heating wires serves for neutralizing the variations in length common to all heating wires and mainly occurring during heating up. For the smaller tensile stress there is mounted in each bore a compression spring surrounding the heating wire with its guide member and being arranged between a supporting area in the bore and a guide member end section or head of larger diameter for neutralizing the differences of extension of length of the individual heating wires occurring during operation.

In the second type of furnace construction the two systems of different strength exerting tensile stress and being provided for each heating wire, are in the form of two compression springs of different strengths surrounding the heating wire with its guide member in the bore. They are arranged in such a manner that the weaker spring between one guide member end section of larger diameter and a disc being axially displaceable on the guide member cannot be released until the stronger spring between the

disk and a supporting area in the bore corresponding to the extension in length of a heating wire during heating up, is released to such an extent that the disc bears against a fixed stop within the bore, thereby preventing a further relaxation of the strong spring.

This invention guarantees that all heating wires, independent from more or less variations in length of each single wire, are in expanded condition in every moment of heating up and of operation whereby they heat the crucible in uniform manner. The invention also guarantees that there does not occur any non-uniform current or tensile stress overloadings which may cause a too early destruction of some or all of the heating wires.

The accompanying drawings show two embodiments of the invention and like numerals of reference indicate similar parts throughout the several views.

FIG. 1 shows a side view, partly in section, of a melting furnace for the manufacture of quartz tubing according to one of the embodiments of the invention.

FIG. 2 shows a cut-out from FIG. 1 in larger scale, viz. the holding device of the upper end of the heating wire.

FIG. 3 shows, similar to FIG. 1, a side view, partly in section, of a melting furnace for the manufacture of quartz tubing according to another embodiment of the invention, in which a large part of the heating zone is omitted.

FIG. 4 shows a cut-out from FIG. 3 in enlarged scale, viz. the holding device of the upper end of a heating wire in cold condition.

FIG. 5 shows the same heating wire end as FIG. 4, as in operation under heated condition.

The melting furnaces for the manufacture of quartz tubing shown in FIGURES 1 and 3 are operated in connection with a drawing machine which is not here shown. Such drawing machine is arranged below the furnace and continuously draws the quartz tubing which leaves the furnace, whereby the tubing is formed by appropriate tapering down to desired diameter and wall thickness. The furnaces shown in the drawing have an input of 60 kw. and are operated on a low-voltage heavy current transformer.

A hollow melting crucible 1, open at its upper end, is shown in FIG. 1, into which raw material, namely, rock crystal for example, is fed. The bottom of the crucible 1 is formed by an annular drawing nozzle 2 with a coaxial mandrel 3. The raw material is melted in the crucible and flows from said nozzle and accordingly emerges therefrom formed in tubular shape in plastic condition and passes immediately to the aforementioned drawing machine. The mandrel is hollow and connected therewith is a pipe 4 for feeding an inert gas, or reducing gas, such as hydrogen and nitrogen respectively or a mixture thereof, to the interior of the quartz tubing as it is formed, thereby prevening surrounding atmosphere from penetrating into the nozzle through the quartz tubing.

As shown in this embodiment, the crucible 1 is surrounded with heating wires 5 arranged in parallel to the crucible axis and spaced at equal distances from each other, forming a coaxial cylindrical cage or jacket. The heating wires 5 are composed of tungsten, and during operation, just as with the inner surface of the mandrel, are scavenged with a reducing gas of which a mixture of hydrogen and nitrogen is again an example. As in operation these heating wires carry a current of about 150 amps. each, the diameter thereof may well be 2.8 mm.

The outer lateral closure of the heated zone of the furnace is formed by a metallic water-cooled furnace jacket 8. A cylindrical muffle 6 of zirconium oxide is arranged outside of the crucible and inside the water jacket in spaced coaxial relation to both. The cage of heating wires 5 is enclosed by the muffle. Under the bottom ends of the muffle 6 and furnace jacket 8 there is a bottom closure ring 8*a* the central opening of which is large enough to permit the heating wires to pass therethrough to depend therebelow. In the space above said closure ring and between said muffle and furnace jacket is a pressed-in layer 7 of zirconium oxide powder for heat-insulating purposes.

At the lower ends of the heating wires 5 is a horizontally disposed clamping ring 9 to which all of said wires are securely attached. Below said clamping ring is a cover cap 10 and above said clamping ring is a cooling plate 11 with a central opening similar to that of the closure ring 8*a* admitting free passage of the heating wires therethrough. The cover cap 10 and lower cooling plate 11 are secured to and supported by said clamping ring 9 and together constitute the lower furnace end which is suspended by the heating wires for its entire support. The distance between the crucible and said lower furnace end increases with longitudinal extension of the wires 5 due to thermal expansion, as a result of which there will be variable spacing between the closure ring 8*a* and the proximate cooling plate 11. In order to prevent the protective gas scavenging the heating wires 5 from escape out of this intermediate space, there is provided thereabout an oil immersion seal constituted by annular trough 12 at the periphery of the cooling plate 11, into which depends a cylindrical apron 12*a* secured to the bottom of the water jacket 8. If preferred, the seal may be effected by means of a flexible folding surrounding sheath or bellows 13 of copper or other suitable material may be employed to supplement or in place of the oil seal.

At the top of the muffle 6 and jacket 8 is an upper transverse cooling plate 14, which is electrically insulated from the metal of the water jacket by the interposition of an insulation gasket 14*a* therebetween. In addition to the transverse cooling plate 14, there is superposed thereon and around the crucible, a cooling ring 16 which is secured to said plate and is electrically conductive. Both the said cooling plate and cooling ring are appropriately constructed for water cooling thereof. It also is to be noted that the transverse cooling plate 14 has a central opening through which the crucible and the cage of heating wires may depend from the superposed cooling ring.

Mounting of the heating wires for suspension from said cooling ring 16, is shown with respect to one of said wires in FIG. 2, and description of the one will suffice for all. On the upper end of the tungsten heating wire 5, secured thereon in any suitable manner, as by sweating or pinching, is a cylindrical guide member or floating stud 17 slidably located in a socket therefor which is constituted as a hole of relatively large diameter at its upper portion 18, large enough to freely receive the stud head 21, and a relatively smaller diameter lower portion 19 for receiving and guiding the shank of said stud 17. Between the larger and smaller hole portions is a transverse shoulder or supporting area 20 for the lower end of a helical spring 23 the upper end of which bears against the under stop surface 22 of said stud head 21. The surface areas of the smaller diameter hole portion 19 and the stud surface proximate thereto are considerably greater than a corresponding length of heating wire and therefore sufficiently extensive to lead off considerable heat transferred thereto by the respective heating wire and consequently will keep the headed end of the stud at a temperature not over 200° C. The spring 23 is of appropriate strength so as to be substantially fully compressed by the weight of the lower furnace end hereinabove identified as comprising clamping ring 9, cover cap 10 and cooling plate 11.

At the top end of each guide member or stud 17 is attached a stranded flexible lead connection 25 the other end of which is attached to the upper cooling ring 16, there of course being as many of said flexible lead connections as there are heating wires. As all of the bottom ends of the heating wires 5 are secured to clamping ring 9, it will be readily appreciated that by applying a source of voltage to the upper cooling ring 16 and to the bottom clamping ring 9 current will flow in parallel through all of said heating wires 5. For illustrative purposes the output from a transformer T is shown having wired con-

nections with the top cooling plate **14** and to the fixed bottom plate **15** of cooling jacket **8**, it being remembered that the cooling jacket and the top plate are electrically separated by insulating gasket **14***a*. A flexible cable **24** to carry the current across the oil seal to the lower suspended furnace end is provided. When current is applied and the wires **5** heated thereby, they all expand more or less in their longitudinal direction. The alteration in length common to all of the heating wires is compensated for by gravitational downward pull of the lower furnace parts. There will be some of the wires, however, that elongate more than the said common alteration or lengthwise expansion, and this difference is balanced by and the wire kept taut by upward pull exerted by the particular spring **23** associated with that particular wire. Owing to the fact that the difference in elongation is small compared to the alteration in length common to all of the wires, the tensile stress of the heating wires having greater elongation only decreases a little, so that the heating wires which remained shorter are not overloaded in consequence of the tensile force of their somewhat more compressed springs. Thus constructed, furnaces have proven to be highly successful with life duration up to 2000 operating hours.

Referring now to the embodiment of the invention illustrated in FIG. 3, observation is made at the outset that whereas in FIG. 1 the lower furnace parts are movable and suspended on the heating wires, this modification shows the lower furnace parts fixed with respect to the main body of the furnace. The required tensile stress and the compensation for the differential in elongation is here supplied by springs only.

Shape and arrangement of the melting crucible **1**, the heating wires **5**, the muffle **6**, the insulating layer **7** and the cooling jacket **8**, are like those shown in FIG. 1. The heating wires **5** are clamped firmly by a water-cooled lower contact ring **26** which is connected in a rigid manner with the water-cooled closing cap **10** as well as with the rest of the furnace. On the furnace there is located in electrically insulated manner the upper contact ring **27** which is provided with sockets or borings for the several heating wires **5**.

Because of the fact that the tungsten wires **5** while initially heating up have a considerable longitudinal thermal expansion, but during operation some may elongate beyond the common-to-all initial expansion a further small amount, there are provided for each heating wire **5** two springs of different strength. The stronger spring for each wire balances the longitudinal extension thereof during the heating-up period and is without any greater effect thereafter during operation. Only the weaker spring has an effect on the heating wire **5** in operation for elongation occurring beyond the extension common to all of the heating wires.

As is shown in FIGS. 4 and 5, more clearly than in FIG. 3 by use of larger scale, each socket or boring consists, just as in FIGS. 1 and 2, of a main section **18** of larger diameter than and adjacent a smaller section **19** coaxially therebelow. Into the upper end of the main section **18** of said socket there fits a shell **28** of such a wall thickness that the end section or head **21** of the stud or guide member **17** may be inserted into shell **28** with sufficient play for axial movement. The main section **18** of the socket contains what is herein termed a stronger spring **29** which rests on the supporting area **20**. Above said spring and in said socket there is a sliding disc **30** which may be shifted axially upwardly to the shell lower rim. Above and seating against said disc **30** is what is herein termed a weaker spring **31** located in said shell **28** and abuts at its upper end against the stop shoulder **22** and on the under side of head or end section **21** of the stud or guide member **17**. The sizes of surfaces of the adjacent section **19** of the socket or boring and of the lower section of the guide member or stud **17** sliding within the aforesaid section **19**, are chosen in such a manner that a

sufficient deduction takes place by the upper contact ring **27** of heat transferred during operation out of the interior of the furnace by heating wire **5** through heat conduction that the temperature in end section or head **21** of the stud **17** does not rise above 200° C.

As shown in FIG. 4, both of the springs **29** and **31** are completely pressed together, which is the condition before the wires are heated. Between the disc **30** and the lower rim of shell **28** there exists, in that condition, a distance *a* which corresponds nearly to the longitudinal extension of the heating wire **5**, common to all of the wires, when heated up. During the heating up period of the wire its thermal expansion is compensated for and the wire kept taut by the stronger spring **29** which pushes upward until the disc **30** abuts from below against the shell **28** as shown in FIG. 5. After this proportionately considerable extension has taken place only smaller differences in extension occur in several heating wires **5** which the weaker spring **31** then compensates for, taking up the slack and keeping the wire taut. The several weaker springs **31** therefore take care of the slightly different variations of wire lengths and have adequate tensile force which will suffice to keep any one or more of the wires taut that may have, during operation, an expansion greater than that which is common to all of the wires.

It will of course be understood that a coaxial mandrel such as that shown in FIG. 1 is also used in the furnace of FIG. 3 and in conjunction therewith an appropriate gas such as the hydrogen-nitrogen mixture is also used. A like gas is also present around the heating wires. Mention may be made of the fact that since in FIG. 3 the lower furnace end is fixed to the water jacket, there will be direct electrical connection thereby and thus current from the transformer, example of which is shown in FIG. 1, will be conducted to the lower end of the heating wires. To guarantee good electrical contact between the upper contact ring **27** and each heating wire **5**, there is provided for each single heating wire, just as in FIGS. 1 and 2, a flexible current in-lead **25**.

With this furnace construction of FIGS. 3–5, there was obtained also a life duration of about 2000 operating hours.

I claim:

1. An electric furnace of the character described, comprising upper and lower end parts for the furnace, a cooling jacket between said ends parts, a crucible longitudinal of and within said cooling jacket, an annular series of heating wires parallel to said crucible and between said crucible and cooling jacket, said wires being subject to elongation, by thermal expansion when heating up and during operation, each said wire having two systems of different strength applied thereto exerting tensile stress longitudinally thereof, the stronger system being effective to maintain tension in the heating wire during heating up thereof and the weaker system being effective for maintaining tension in the heating wire in event of greater elongation during operation, and means for compensating for differences in elongation of said heating wires from each other, said means effecting an automatic change from the greater tensile stress of the stronger system effective on said wires to the smaller tensile stress of the weaker system effective on said wires.

2. An electric furnace in accordance with claim 1, wherein said stronger system comprises gravitational suspension of the said lower end parts of the furnace at the lower ends of said heating wires and the weaker system comprises individual springs for each said wire for neutralizing the differences of extension in length of the respective heating wire.

3. An electric furnace in accordance with claim 1, wherein said upper end part of the furnace provides a plurality of sockets, one for each heating wire, and wherein a stud is slidable in said socket for each wire and secured to said wire, and a spring in each said socket in en-

gagement with said stud for sliding the same and tension said wire.

4. An electric furnace in accordance with claim 1, wherein two springs of different strength are provided in each socket for constituting said two systems exerting tensile stress on the respective heating wires.

5. An electric furnace in accordance with claim 3, wherein two springs are provided in each socket constituting said two systems, and wherein a disc is interposed between said springs and a fixed shell provided above the lower one of said springs and above said disc and receiving the upper one of said springs therein.

6. An electric furnace in accordance with claim 3, wherein said socket and stud have lower end portions proximate one to the other for heat transfer to thereby lessen the heat passing to the upper end of said stud.

7. An electric furnace in accordance with claim 5, wherein both of said springs are substantially fully compressed in cold condition of said heating wire and the lower spring is the stronger one and expands until the said disc thereabove is stopped by engagement with said shell after which the upper and weaker spring may expand upon further thermal elongation of said wire.

References Cited in the file of this patent

UNITED STATES PATENTS

269,760	Weston	Dec. 26, 1882
853,492	Beck	May 14, 1907
1,234,499	Smalley	July 24, 1917
2,445,120	Levinson et al.	July 13, 1948
2,445,457	Roth	July 20, 1948
2,577,745	Foster	Dec. 11, 1951
2,650,254	Kremers	Aug. 25, 1953