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# LOW VOLTAGE FUSE HAVING A CASING OF CELLULOSIC MATERIAL AND AN ARC-QUENCHING FILLER OF QUARTZ SAND

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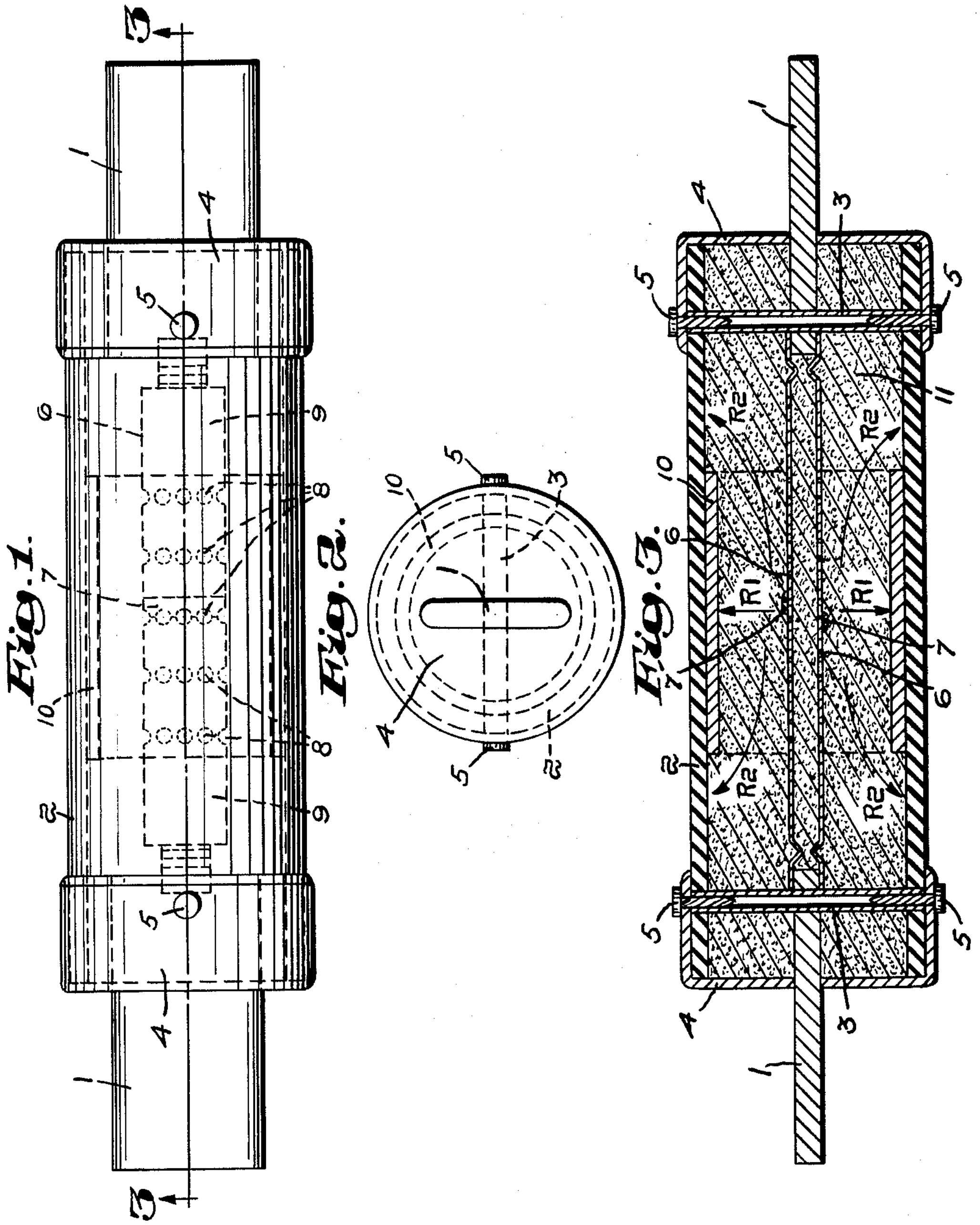


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LOW VOLTAGE FUSE HAVING A CASING OF CELLULOSIC MATERIAL AND AN ARC-QUENCHING FILLER OF QUARTZ SAND

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This invention refers to high interrupting-capacity fuses.

It is one object of this invention to provide high-interrupting capacity fuses, i.e. fuses having fuse link means of a high current-limiting action metal (silver or copper) and having a filler of quartz sand and comprising a casing of a cellulosic material.

Another object of this invention is to provide fuses of the above description in sizes specified by the Underwriters' Laboratories Standards (see Standards for Safety Fuses UL 198 Underwriters' Laboratories, Inc., reprinted July 1959) wherein the maximum casing temperatures admitted by said Standards are not exceeded when the fuses carry for protracted periods of time their minimum fusing current, or any current above their minimum fusing current.

A further object of this invention is to provide high interrupting-capacity fuses which can be manufactured at smaller cost than those involved in the manufacture of comparable prior art fuses.

The design of conventional cartridge fuses is subject to the rules and regulations set forth in the so-called Underwriters' Standards. The Underwriters' Standards specify in a general way the dimensions which the casings or cartridges of fuses of any particular voltage rating and current rating must have. These dimensions have been evolved with relatively small interrupting capacity requirements, casings of fiber or other cellulosic materials, and with arc-quenching fillers having a relatively small thermal conductivity in mind. The design of high interrupting-capacity fuses have generally sizes which differ from the sizes of fuses complying with the Underwriters' Standards.

As the magnitude of major fault currents available in industrial and commercial distribution systems increases, it has become desirable, or mandatory, to increase the interrupting capacity ratings of Underwriters' Standard fuses, i.e. to convert such fuses into high interrupting capacity fuses with a minimum of change, and with a minimum increase in manufacturing cost. This long felt want could not be satisfied heretofore for the following reasons.

In order to increase the interrupting-capacity of fuses having the dimensions specified in the Underwriters' Standards to, say 50 kilo-amps, it is necessary or desirable to substitute quartz sand for the kind of arc-quenching fillers which are normally used in such fuses. If the cost of manufacturing such fuses is not to be significantly increased, the casing thereof should preferably be made of an inexpensive cellulosic material such as fiber, or even convolutely wound paper. Heretofore these conditions could not be met, and were considered contradictory, and mutually exclusive.

It is, therefore, another object of this invention to provide electric fuses melting simultaneously and reconciling the two aforementioned conditions.

Substitution in Underwriters' Standards fuses of quartz sand for pulverulent arc-quenching fillers such as gypsum or chalk which have a substantially smaller thermal conductivity than quartz sand results in an entirely different pattern of heat flow. Heat flow in fuses is an extremely difficult and complex subject which has not been



fully investigated as yet. For an evaluation of the changes in the pattern of heat flow in fuses resulting from substitution of quartz sand for such fillers as gypsum, or chalk, reference may be had to Everett C. Elgar "Steady-State Temperature Distribution in Electric Fuse Elements," Thesis, Massachusetts Institute of Technology 1953. Without giving detailed attention to the change in the pattern of heat flow resulting from the adoption of quartz sand as arc-quenching filler, it is apparent that the adoption of quartz sand with its high thermal conductivity as arc-quenching filler results in a greatly increased cooling action and, therefore, in an increase of the minimum fusing current and in an increase of the current rating of the fuse. The substitution by quartz sand of low thermal conductivity fillers of the kind generally used in Underwriters' Standards fuses also results in a drastic decrease of the radial temperature gradient between the fuse link and the casing. Therefore the temperature at the inner and outer surfaces of the casing is increased way above the limits allowed by the Underwriters' Standards, and way above the temperature which cellulosic materials are capable of withstanding for protracted periods of time. To be more specific, in fuses of the instant description the casing is likely to be impaired thermally when the fuses carry for prolonged periods of time currents in the order of their minimum fusing current. Upon interruption of small overload currents the casing of such a fuse will tend to be charred and represent, therefore, a considerable hazard, since it invites a re-strike of the arc which had been extinguished. Engagement by incandescent fulgurites of cellulosic casings of fuses results in a thermal destruction of the latter, if such engagement lasts for a significant period of time.

These are the reasons underlying the fact that a conversion of Underwriters' Standards fuses into high interrupting-capacity fuses involving adoption of quartz sand as arc-quenching medium and retention of conventional cellulosic casing materials could not be achieved heretofore.

These difficulties can, however, be overcome by the following line of reasoning: The above referred-to thermal impairment of a casing of cellulosic material is generally limited to the center region thereof where the radial temperature gradient is smallest and the temperature highest. By providing the center region of the inner surface of the casing with a heat resistant and heat-shock resistant thermal insulating liner of limited length and sufficient thickness, the radial heat flow from the center region of the fuse link can be reduced to such an extent as to preclude any thermal impairment of a casing of cellulosic material. A casing liner limited to the peak temperature region of a fuse structure allows an increased heat flow from the fuse link in substantially axial direction, and along a longer path and through portions of the wall of the casing not juxtaposed to the peak temperature region of the fuse link structure and, therefore, less subject to thermal damage.

For a better understanding of the present invention together with other objects thereof reference may be had to the following description, taken in connection with the accompanying drawings, and its scope will be pointed out with particularity in the appended claims.

Referring now to the drawings:

FIG. 1 is a side elevation of an electric fuse embodying this invention;

FIG. 2 is an end view of the structure of FIG. 1; and

FIG. 3 is a section along 3—3 of FIG. 1.

In the drawings numeral **1** has been applied to indicate a pair of spaced knife blade contacts having axially outer ends situated outside of casing **2** and having axially inner ends situated inside of casing **2**. Casing **2** is a tube of cellulosic material. It may be made of fiber, but is preferably made of convolutely wound paper. Hollow resilient metal pins **3** project transversely through blade contacts **1** and casing **2** and thus support blade contacts **1**. Metal caps or ferrules **4** are mounted on the axially outer ends of casing **2** and drive screws **5** project transversely through caps or ferrules **4** into the ends of pins **3**, enlarging the latter and securing caps or ferrules **4** firmly to casing **2**. A pair of parallel spaced ribbon fuse links **6** connects conductively the axially inner ends of blade contacts **1**. The average spacing of fuse links **6** is equal to the thickness of blade contacts **1**. The axially outer ends of fuse links **6** sandwich the axially inner ends of blade contacts **1** and may be brazed or welded to the latter. Each fuse link **6** is made of a high current-limiting action metal such as, for instance, copper. The term high current-limiting action metal is used in this context in a generic sense, encompassing copper and silver, as more fully explained in the copending patent application of Erwin Salzer and Frederick J. Kozacka, filed March 30, 1964, Ser. No. 355,804 for Electric Cartridge Fuses. Each fuse link **6** is provided adjacent the center thereof with a link-severing low-fusing point overlay **7** as, for instance, an overlay of tin. This overlay **7** precludes fuse links **6** when performing their current-carrying duty from ever substantially exceeding the fusing point of the overlay metal. Only during the interrupting process when links **6** have been severed and arcs kindled can the temperature inside of casing **2** ever substantially exceed the fusing point of the metal of which overlays **7** are made. Fuse links **6** are provided with a plurality of transverse lines **8** of circular perforations, and fuse links **6** have non-perforated end regions **9**. Reference numeral **10** has been applied to indicate a liner of fibrous inorganic heat-resistant and heat-shock resistant material having a high degree of porosity. Liner **10** is arranged inside of casing **2** covering and hugging the inner surface thereof. Liner **10** is substantially coextensive with the perforated regions of fuse links **6**. The body of quartz sand **11** is in immediate physical engagement with the inner surface of casing **2** not covered by liner **10**. Hence liner **10** allows unimpeded heat-exchange between the body ofquartz sand **11** inside of casing **2** and the portions of casing **2** adjacent the axially outer ends thereof. The effective length of fuse links **6** is equal to the spacing of blade contacts **1**, the portions of fuse links **6** overlapping blade contacts **1** being ineffective. Liner **10** is limited to the center region of casing **2** and has a length substantially less than the active length of fuse links **6**. The length of liner **10** exceeds slightly the length of the perforated regions of fuse links **6** and the ends of liner **10** form a pair of shoulders axially spaced from the ends of casing **2**.

Liner **10** consists preferably of asbestos fibers in sheet-form defining relatively large interstices between the constituent fibers of the liner to increase the thermal insulating action of the liner. Such an asbestos liner should have a thickness substantially equal to, or at least in the order of, the thickness of the wall of casing **2** as specified by the Underwriters' Standards. The Underwriters' Standards require a minimum wall thickness of ⅛" for casings of fuses having a rated current of 400 amps. and a minimum wall thickness of $\frac{3}{16}$" for casings of fuses having a rated current of 600 amps. The aforementioned data apply to fuses having a voltage rating of 250 volts. If the rated voltage is 600 volts, the minimum wall thickness of the casings of fuses having a rated current of 400 amps. is $\frac{3}{16}$", and the minimum wall thickness of the casing of fuses having a rated current of 600 amps. is ¼".

In FIG. 3 arrows R**1** indicate diagrammatically the relatively reduced radial heat flow resulting from the presence of liner **10** and arrows $R_2$ indicate diagrammatically the relatively increased preponderantly axial heat flow resulting from the presence of quartz sand as arc-extinguishing medium and the immediate physical engagement with that medium of the portions of casing **2** juxtaposed to the non-perforated regions **9** of fuse links **6** and juxtaposed to the axially inner ends of blade contacts **1**.

On occurrence of overloads of inadmissible duration overlays **7** melt and sever fuse links **6** at the center thereof by a metallurgical reaction, i.e. metal diffusion. Short-circuit currents cause formation of series breaks each along one transverse line **8** of perforations.

Thermal damage to the casing **2** is effectively avoided by the presence of liner **8**, drastically reducing the radial heat flow $R_1$. Sufficient or more than sufficient cooling is provided by the means which establish relatively large, preponderantly axial heat flow $R_2$.

It appears from published calculations that the thermal resistance of the casing structure to heat flow is relatively small in comparison to the thermal resistance of the arc-quenching filler and it was concluded from such calculations that the temperature differential prevailing radially across the casing is relatively small in comparison to the temperature differential prevailing radially across the arc-quenching filler and that changes of the material of which the casing is made have virtually no effect upon the rating of a fuse structure. This may be true in regard to conventional casing materials including solid cellulosic materials and various synthetic resins and laminates thereof, however, the presence of a highly porous relatively thick fibrous liner as described above has a significant derating effect. Considering any fuse structure having Underwriters' Standards dimensions and comprising a pair of ribbon fuse links forming parallel current paths which fuse structure includes gypsum as pulverulent arc-quenching filler, the increase in heat dissipation and the concomitant increase of the minimum fusing current which result from the substitution of the gypsum filler by a quartz sand filler can be largely compensated by an asbestos liner limited to the center region of the casing. As far as the requirement of thermal protection for the casing is concerned such a liner must be relatively thick but does not need to extend, and should not extend, over the entire length of the casing. If the length of the liner is strictly limited as required for thermal protection of the cellulosic casing the increase in current carrying-capacity resulting from the substitution of quartz sand for gypsum may somewhat outweigh the reduction of current carrying capacity resulting from the presence of the liner **10**. This does, however, not require a re-design of the fuse link structure or a change of the rating thereof. A slight reduction of the spacing of the two ribbon fuse links is sufficient to achieve the additional amount of reduction of current carrying-capacity, or the increased derating, required if the same pair of ribbon fuse links as in a prior art Underwriters' Standards fuse having a filler of gypsum is to be used in the proposed novel high interrupting-capacity fuse.

Considering—in order to simplify the following line of thought—a cylindrical casing of infinite length housing an axial fusible element in form of a straight wire and housing a pulverulent arcquenching filler, then the following pair of simultaneous equations may be written:

$$\frac{t_f - t_i}{W_f} = \frac{t_i - t_o}{W_c} = \frac{t_o - t_a}{W_a} \qquad (1, 2)$$

In this pair of equations $t_f$ is the temperature of the fusible elemen, $t_i$ the temperature on the inside of the casing, $t_o$ the temperature at the outside of the casing, $t_a$ the ambient temperature, $W_f$ the thermal resistance of the filler, $W_c$ the thermal resistance of the casing, and $W_a$ the thermal resistance of the layer of air across which fusible element, $t_i$ the temperature on the inside of the

Solving the first pair of equations for $t_i$ and the second pair of equations for $t_o$ yields:

$$t_i = \frac{t_f W_c + t_o W_f}{W_f + W_c} \qquad (3)$$

and

$$t_o = \frac{t_i W_a + t_a W_c}{W_c + W_a} \quad (4)$$

The temperature $t_i$ depends upon the temperature $t_f$ and the latter can and must be limited by the presence of link-severing overlays of a low fusing point metal such as, for instance, tin. The temperature $t_i$ may be significantly reduced by the addition of the thermal resistance resulting from the presence of an effective thermal insulating liner to the thermal resistance of the quartz filler. The temperature $t_o$ decreases as the temperature $t_i$ decreases. I have measured differences in the temperature $t_o$ in the order of 140° C. in comparable Underwriters' Standards fuses carrying their minimum fusing current and having a quartz filler of which one fuse was provided with an asbestos liner as shown, and the other fuse was not provided with such a liner.

To achieve the desired result, i.e. to change over from a relatively high thermal resistance arc-quenching filler to a quartz sand filler without changing the fuse link structure calls for a liner **10** having a critical length and a critical thickness and density. A liner of asbestos fibers which is substantially thinner than the wall of the casing and extends along the entire length of the casing may result in substantially the same total heat flow and current rating when the change-over from one type to the other type of arc-quenching filler is effected, but does not offer sufficient thermal protection for a cellulosic casing in case of small protracted overload currents. The same applies if the asbestos fiber liner is relatively dense rather than porous. A liner of asbestos fibers having substantially the same thickness and porosity as required for thermal protection of the cellulosic casing, but having the same length as the casing and covering the entire inner surface thereof is not only conducive to excessive cost, but reduces the volume of quartz sand which can be filled into the casing to an extent adverse to the interrupting capacity requirements of the device, and results also in an insufficient cooling action.

It will be understood that I have illustrated and described herein a preferred embodiment of my invention, and that various alterations may be made therein without departing from the spirit and scope of the appended claims.

I claim as my invention:

**1.** An electric high interrupting-capacity fuse for circuit voltages from 250 to 600 volts comprising in combination:
- (a) a pair of terminal elements;
- (b) a ribbon fuse link of copper conductively interconnecting said pair of terminal elements, said fuse link having a plurality of transverse lines of perforations forming a perforated center region and having non-perforated end regions;
- (c) a link-severing low fusing point overlay on said fuse link;
- (d) a body of arc-quenching quartz sand surrounding said fuse link;
- (e) a tubular casing of convolutely wound paper supporting said pair of terminal elements at the ends thereof and housing said fuse link and said body of quartz sand; and
- (f) a liner of fibrous inorganic heat-resistant and heat-shock resistant insulating material having a high degree of porosity inside said casing covering the inner surface thereof, said liner being substantially coextensive with said perforated center region of said fuse link and being sufficiently short to allow immediate physical engagement between said body of quartz sand and the inner surface of said casing along portions thereof coextensive with said non-perforated regions of said fuse link and said liner forming a pair of shoulders spaced from the ends of said casing.

**2.** An electric high interrupting-capacity fuse for circuit voltages from 250 to 600 volts comprising in combination:
- (a) a pair of aligned blade contacts;
- (b) a ribbon fuse link of copper conductively interconnecting said pair of blade contacts, said fuse link having a plurality of transverse lines of perforations forming a perforated center region and having non-perforated end regions;
- (c) a link-severing low fusing point overlay on said fuse link;
- (d) a body of arc-quenching quartz and sand surrounding said fuse link;
- (e) a tubular casing of convolutely wound paper housing the axially inner end regions of said pair of blade contacts, said fuse link and said body of quartz sand; and
- (f) a liner of fibrous inorganic heat-resistant and heat-shock resistant insulating material having a high degree of porosity inside said casing covering the inner surface thereof and being substantially coextensive with said perforated center region of said fuse link, said liner exposing to immediate physical engagement with said body of quartz sand the regions of said casing coextensive with said axially inner end regions of said pair of blade contacts and said regions of said casing coextensive with said non-perforated end regions of said fuse link.

**3.** An electric high interrupting capacity fuse comprising in combination:
- (a) a pair of terminal elements;
- (b) fuse link means of a high current-limiting action metal having a predetermined active length conductively interconnecting said pair of terminal elements;
- (c) a link-severing low fusing point overlay on said fuse link means;
- (d) a body of arc-quenching quartz sand surrounding said fuse link means;
- (e) a tubular casing of a cellulosic material having a predetermined wall thickness supporting said pair of terminal elements at the ends thereof and housing said fuse link means and said body of quartz sand; and
- (f) a porous liner of asbestos fibers in sheet form inside said casing covering the inner surface thereof, said liner being arranged in the center region of said casing and having a length less than said predetermined active length of said fuse link means and said liner having a thickness of the same order as said predetermined wall thickness of said casing.

**4.** An electric high interrupting-capacity fuse comprising in combination:
- (a) a pair of terminal elements;
- (b) a ribbon fuse link of copper having a predetermined active length conductively interconnecting said pair of terminal elements;
- (c) a link-severing low fusing point overlay on said fuse link;
- (d) a body of arc-quenching quartz sand surrounding said fuse link;
- (e) a tubular casing of convolutely wound paper having a predetermined wall thickness supporting said pair of terminal elements at the ends thereof and housing said fuse link and said body of quartz sand; and
- (f) a porous liner of asbestos fibers in sheet form inside said casing hugging the inner surface thereof, said liner having a length less than said predetermined active length of said fuse link and being arranged in the center region of said casing, and said liner having a thickness of the same order as said predetermined wall thickness of said casing.

**5.** An electric high interrupting-capacity fuse comprising in combination:

(a) a pair of spaced blade contacts having a predetermined thickness;

(b) a pair of ribbon fuse links of copper having axially outer ends sandwiching the axially inner ends of said pair of blade contacts and having an average spacing equal to said predetermined thickness of said pair of blade contacts;

(c) a pair of link-severing low fusing point overlays each on one of said pair of fuse links;

(d) a body of arc-quenching quartz sand surrounding said pair of fuse links;

(e) a tubular casing of cellulosic material having a predetermined wall thickness housing said pair of fuse links and said body of quartz sand;

(f) a pair of caps mounted on the ends of said casing each defining a passage for one of said pair of blade contacts; and

(g) a porous liner of asbestos fibers in sheet form inside said casing hugging the inner surface thereof, sail liner being arranged in the center region of said casing having a length substantially less than spacing of said pair of blade contacts, and said liner having a thickness of the same order as said predetermined wall thickness of said casing.

**6.** An electric high interrupting capacity fuse comprising in combination:

(a) a pair of spaced blade contacts;

(b) a pair of ribbon fuse links of copper having axially outer ends sandwiching the axially inner ends of said pair of blade contacts, each of said pair of fuse links being provided with a plurality of transverse lines of perforations;



(c) a pair of link-severing low fusing point overlays each on one of said pair of fuse links;

(d) a body of arc-quenching quartz sand surrounding said pair of fuse links;

(e) a tubular casing of convolutely wound paper having a predetermined wall thickness housing said pair of fuse links and said body of quartz sand;

(f) a pair of caps mounted on the ends of said casing each defining a passage for one of said pair of blade contacts; and

(g) a porous liner of asbestos fibers in sheet form inside said casing hugging the inner surface thereof, said liner being arranged in the center region of said casing and having a length substantially less than the spacing between said pair of blade contacts but overlapping said plurality of transverse lines of preforations, and said liner having a thickness of the same order as said predetermined wall thickness of said casing.


**References Cited by the Examiner**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 964,592 | 7/1910 | Weston | 200—132 |
| 2,832,868 | 4/1958 | Kozacka | 200—131 |
| 2,866,038 | 12/1958 | Kozacka | 200—131 X |
| 2,939,934 | 7/1960 | Kozacka | 200—131 |
| 2,988,620 | 6/1961 | Kozacka | 200—135 X |
| 3,010,000 | 11/1961 | Swain et al. | 200—131 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 659,811 | 5/1938 | Germany. |


BERNARD A. GILHEANY, *Primary Examiner.*