(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 172 668**
A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: **85305265.2**

(51) Int. Cl.⁴: **G 03 G 15/20**

(22) Date of filing: **24.07.85**

(30) Priority: **01.08.84 US 636876**

(43) Date of publication of application:
26.02.86 Bulletin 86/9

(84) Designated Contracting States:
DE FR GB

(71) Applicant: **XEROX CORPORATION**
Xerox Square - 020
Rochester New York 14644(US)

(72) Inventor: **Eddy, Clifford O.**
248 Shorewood Drive
Webster New York 14580(US)

(72) Inventor: **Henry, Arnold W.**
43 Deer Creek Road
Pittsford New York 14534(US)

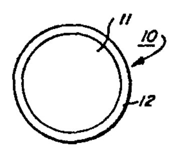
(72) Inventor: **Battat, David**
115 Towpath Lane
Rochester New York 14518(US)

(74) Representative: **Frain, Timothy John et al,**
c/o Rank Xerox Limited Patent Department Rank Xerox House 338 Euston Road
London NW1 3BH(GB)

(54) Fuser member for electrostatographic copiers.

(57) A fuser member (10) for electrostatographic reproducing apparatus has a rigid core (11) having coated thereon a thin layer (12) of a resiliently compressible material which has a significantly improved pitting resistance and fusing life. This material comprises the crosslinked product of a mixture of about 100 parts by weight alpha omega-hydroxypoly-dimethylsiloxane, about 230 to 300 parts and preferably 266 parts by weight of finely divided tabular alumina, and about 13 to 60 parts by weight of finely divided iron oxide particles, together with a crosslinking agent and a crosslinking catalyst to promote crosslinking of the siloxane. The crosslinking agent may be 6 to 20 parts by weight condensed tetraethylorthosilicate and the crosslinking catalyst may be 0.25 to 1.8 parts by weight dibutyltin diburate or bis(dibutylchlorotin)oxide.

FIG. 1



EP 0 172 668 A1

FUSER MEMBER FOR ELECTROSTATOGRAPHIC COPIERS

This invention relates to a novel fuser or fixing member for electrostatographic copiers.

As indicated in U.S. Patent 4,078,286, in a typical process for electrophotographic duplication, a light image of an original to be copied is recorded in the form of an electrostatic latent image upon a photosensitive member, and the latent image is subsequently rendered visible by the application of electroscopic particles, which are commonly referred to as toner. The visible toner image is then in a loose powdered form and it can be easily disturbed or destroyed. The toner image is usually fixed or fused upon a support which may be the photosensitive member itself or another support such as a sheet of plain paper. The present invention relates to the fusing of the toner image upon a support.

In order to fuse electroscopic toner material onto a support surface permanently by heat, it is necessary to elevate the temperature of the toner material to a point at which the constituents of the toner material coalesce and become tacky. This heating causes the toner to flow to some extent into the fibers or pores of the support member. Thereafter, as the toner material cools, solidification of the toner material causes the toner material to be firmly bonded to the support.

The use of thermal energy for fixing toner images onto a support member is well known. Several approaches to thermal fusing of electroscopic toner images have been described in the prior art. These methods include providing the application of heat and pressure substantially concurrently by various means: a roll pair maintained in pressure contact; a flat or curved plate member in pressure contact with a roll; a belt member in pressure contact with a roll; and the like. Heat may be applied by heating one or both of the rolls, plate members or belt members. The fusing of the toner particles takes place when the proper combination of heat, pressure and contact time are provided. The balancing of these parameters to bring about the fusing of the toner particles is well known in the art, and they can be adjusted to suit particular machines or process conditions.

During operation of a fusing system in which heat is applied to cause thermal fusing of the toner particles onto a support, both the toner image and the support are passed through a nip formed between the roll pair, or plate or belt members. The concurrent transfer of heat and the application of pressure in the nip effects the fusing of the toner image onto the support. It is important in the fusing process that no offset of the toner particles from the support to the fuser member takes place during normal operations. Toner particles offset onto the fuser member may subsequently transfer to other parts of the machine or onto the support in subsequent copying cycles, thus increasing the background or interfering with the materials being copied there. The so called "hot offset" occurs when the temperature of the toner is raised to a point where the toner particles liquify and a splitting of the molten toner takes place during the fusing operation. "Cold offset" may be caused, even at the temperatures below the molten point of the toner, by such factors as imperfections in the surface of the fusing members; by the toner particles being insufficiently adhering to the support; by electrostatic forces which may be present; etc.

Another problem frequently encountered in fusing with a heated member is that the substrate, e.g. a sheet of paper, on which the toner image is fused may curl and/or adhere to the heated fuser. Such adhering paper will tend to wrap itself around the fuser and thus prevent the fuser from performing its intended operations in subsequent copying cycles. Such adhering paper must be generally removed by hand, resulting in much manual labor and machine downtime.

As indicated in said U.S. Patent No. 4,078,286, it is known in the prior art to provide the heated member in a fusing system with a covering of a heat-resistant, release material on its outer surface. Coupled to such a heated member is a backup or pressure member covered with a heat-resistant, flexible material. The nip is formed by the flexible material under pressure contact with the heated member. Examples of the heat resistant release materials for the fuser members include polytetrafluoroethylene, silicone rubber, fluorocarbon elastomers and the like. A suitable offset preventing liquid may be used on the fuser member to minimize or avoid "offsetting". Silicone oils are widely used as the offset preventing or release agent. The pressure member may be made of such materials as silicone rubber and polyfluoroethylenepropylene.

In U.S. Patent 4,074,001, there is disclosed a fixing roll for electrophotography having a surface layer made of a diorganopolysiloxane having silanol groups at the molecular terminals, a diorganopolysiloxane having trialkylsilyl groups at the molecular terminals, an alkoxy-containing silane, a metal salt of an organic acid as the crosslinking catalyst, a powdery calcium carbonate, iron oxide, and titanium dioxide.

In a more recent development U.S. Patent 4,373,239 describes a fuser with a thermally conductive and resiliently compressible material having high thermomechanical strength and good release properties which is made from a composition comprising 100 parts by weight of alpha omega-hydroxypolydimethylsiloxane (PDMS) having a number average molecular weight of about 5,000 to 20,000, about 128 to 250 parts by weight of finely divided tabular alumina, about 13 to 60 parts by weight of finely divided iron oxide, about 6 to 9 parts by weight of a crosslinking agent, and about 0.25 to 1.8 parts by weight of a crosslinking catalyst. The composition may be cured and coated onto a fuser member at a thickness about 10 to 100 mils.

In optimizing the invention described in U.S. Patent 4,373,239 tests were conducted by varying the amount of tabular alumina incorporated in the formulation all other constituents being maintained constant. Based on the testing of various compositions, by cycling the fuser roll against pressure roll with no paper in between, it was discovered that optimum roll cyclic capability was obtained at about 188 parts of tabular alumina per 100 parts of PDMS. At 188 parts of tabular alumina the best resistance to cyclic fatigue, the formation of small cuts in the roll surface which rapidly become large cuts in the roll surface with material being shed from the roll in wholesale lots is achieved. In such a test, a formulation containing 188 parts of tabular alumina per 100 parts PDMS was tested on a cyclic fixture wherein the fuser roll was against a pressure roll under a normal load of 400 pounds which is approximately that which would be used in a commercial machine environment and was cammed into contact with the pressure roll 10% of the time and out of contact 90% of the time. Catastrophic failure with wholesale amounts of fuser roll surface rubber coming off the core was achieved at about 3,000 hours. The same test was conducted for the same compositions wherein the amount of alumina was 246 parts by weight all other constituents remaining constant. Failure occurred with this roll at 2,165 hours. The same test was conducted with another fuser roll containing 259 parts of tabular alumina all other constituents being the same and this roll failed at 1,258 hours. It should be noted that amounts of tabular alumina less than 188 parts per 100 parts PDMS tend to reduce the thermal conductivity of the composition.

In none of the above mentioned roll to roll tests was paper transported between the pressure roll and the fuser roll with or without unfused toner image thereon. It has now been discovered that after extensive use of such a fuser roll containing about 188 parts tabular alumina per 100 parts PDMS that a failure of the fuser roll takes place at about 250,000 copies due to pitting in the fuser roll. Pitting occurs by the formation initially of small microscopic holes in the fuser roll surface which initially do not cause any problem, but as use of the fuser roll continues the holes tend to grow in size to slightly larger than the head of a straight pin. Failure is experienced when these holes become sufficiently large that toner, in contact with the holes on the fuser roll surface, is not fused because there is no pressure between the fuser roll and the unfused image on the copy paper. Furthermore toner can get trapped in the holes and can offset in non-image areas in subsequent copies. While the holes start off very small, they rapidly get larger and even tend to overlap and blend into larger, greater voids, therefore compounding the problem. While the above described difficulty with pitting was not observed in the initial roll to roll testing between the fuser roll and the pressure roll, it was experienced when the fuser roll was used in a fuser environment fusing a toner image onto a copy sheet. It is believed that the pitting is caused by the fact that paper is more abrasive than the surface of the pressure roll used in the initial roll to roll testing. A theoretical analysis has indicated that in the fusing operation the paper initially slips relative to the fuser roll in one direction at the entrance of the paper to the nip formed between the fuser roll and the pressure roll then becomes locked in speed with the speed of the fuser roll because it is driven through the nip and then further slips in a direction opposite at the exit of the nip. It is believed that the pitting is caused by a fretting (the action of wearing away) fatigue type of failure arising from micro-slip between the surface of the rubber-covered roll and the paper.

We have now suprisingly found that if the amount of tabular alumina present in the fuser roll surface composition is between about 230 to 300 parts by weight and preferably 266 parts by weight, per 100 parts by weight PDMS that a dramatic increase in resistance to the pitting described above and fuser life is achieved. As pointed out above, prior art fuser rolls exhibited a life of about 250,000 copies. With the composition according to the present invention, a fuser life of the order of 500,000 copies and and excess thereof may be achieved.

In accordance with the present invention, a thermally conductive fuser member for use in electrostatographic reproducing apparatus is provided.

In particular, the fusing surface of the fusing member comprises a resiliently compressible material which has dramatically improved pitting resistance and fusing life. The fusing surface comprises the crosslinked product of a composition comprising 100 parts by weight of alpha omega-hydroxypolydimethylsiloxane, from about 230 to 300 parts by weight tabular alumina, about 13 to 60 parts by weight of finely divided iron oxide particles together with effective amounts of a crosslinking agent and a crosslinking catalyst.

In a specific aspect of the present invention the tabular alumina is present in an amount of about 266 parts by weight.

In a further aspect of the present invention the alpha, omega-hydroxypolydimethylsiloxane has a number average molecular weight of from about 5,000 to about 20,000.

In a further aspect of the present invention, the composition is cured and coated onto a fuser member at a thickness of from about 10 to 100 mils.

In a further aspect of the present invention, the tabular alumina is about 325 mesh in size.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 shows a cross-sectional view of a fuser roll of the present invention;

Figure 2 represents a cross-sectional view of the fuser roll of Figure 1 as a part of a roll pair, and maintained in pressure contact with a backup or pressure roll; and

Figure 3 is a schematic view of a pressure contact fuser assembly which employs the fuser member of the present invention.

Figure 4a and 4b are graphical representations of peak surface strain and input strain energy per cycle with respect to rubber modules.

Figure 5a, 5b, 5c, 5d and 5e are graphical representations of mechanical properties of pads prepared from formulations where 100, 200 and 300 parts by weight of tabular alumina per 100 parts PDMS are present.

Figure 6 is a graphical representation of total strain energy to rupture based on tabular alumina content.

Figure 7 is a graphical representation of the ratio of input strain energy per cycle to total strain energy to rupture based on tabular alumina content.

Figure 1 shows a fuser roll 10 made with an outer layer of the composition of the present invention. Although the fuser member shown in Figure 1 is in the form of a roll, it is to be understood that the present invention is applicable to fuser members of other shapes, such as plates or belts. In Figure 1, the fuser roll 10 is composed of a core 11 having coated thereon a thin layer 12 of the composition of the present invention. The core 11 may be made of various metals such as iron, aluminum, nickel, stainless steel, etc., and various synthetic resins. We prefer to use aluminum as the material for the core 11, although this is not critical. The core 11 is hollow and a heating element (not shown) is generally positioned inside the hollow core to supply the heat for the fusing operation. Heating elements suitable for this purpose are known in the prior art and may comprise a quartz heater made of a quartz envelope having a tungsten resistance heating element disposed internally thereof. The method of providing the necessary heat is not critical to the present invention, and the fusing member can be heated by internal means, external means or a combination of both. All heating means are well known in the art for providing sufficient heat to fuse the toner to the support. The composition of layer 12 will be described in detail below.

Referring to Figure 2, the fuser roll 10 is shown in a pressure contact arrangement with a backup or pressure roll 13. The pressure roll 13 comprises a metal core 14 with a layer 15 of a heat-resistant material. In this assembly, both the fuser roll 10 and the pressure roll 13 are mounted on shafts (not shown) which are biased so that the fuser roll 10 and the pressure roll 13 are pressed against each other under sufficient pressure to form a nip 16. It is in this nip that the fusing or fixing action takes place. One of the ways of obtaining high quality copies produced by the fuser assembly is when the nip is formed by a relatively hard and unyielding layer 15 with a relatively flexible layer 12. In this manner, the nip is formed by a slight deformation in the layer 12 due to the biasing of fuser roll 10 and the pressure roll 13. The layer 15 may be made of any of the well known materials such as polyfluoroethylenepropylene or silicone rubber.

Figure 3 shows a pressure contact heated fuser assembly having a sheet of a support material 17, such as a sheet of paper, bearing thereon toner image 18 passing the fuser roll 10 and pressure roll 13. On fuser roll 10 is mounted an intermediate oil-feeding member 19 from which an offset preventing fluid or release agent 20 is applied to the fuser roll 10. Such release agents are known to the art and may be, for example, a silicone oil. The intermediate oil feeding member 19 also performs the function of cleaning the fuser roll 10. The release agent 20 in sump 21 is fed to the oil feeding member 19 through another intermediate oil feeding member 22 and a feeding roll 23. The pressure roll 13 is in contact with a cleaning member 24 mounted on a supporting member 25.

While the novel fuser member of the present invention has been described with reference to heat fixing or fusing of toner images, it is to be understood that the invention may be also used in cold pressure fixing since the excellent release properties and conformability of the fuser member make it suited for the latter application as well.

In accordance with the present invention, a novel fuser member is provided which is particularly suited for use in the heat fixing of toner images in an electrostatographic copying machine. The coating on the fuser member of the present invention has improved resistance to pitting and dramatically improved useful life over prior art devices. In addition it has high thermomechanical strength, is flexible and conformable so that it can form a nip with a relatively hard pressure roll, and possesses outstanding release properties. We have found that the extent of slippage in the nip region and the intensity of a shear are a function of the input strain energy per cycle (due to loading between the fuser roll and the pressure roll) in the fuser roll rubber. We have also discovered that the input strain energy per cycle in the fuser roll is a function of the hardness of the fuser roll rubber. With increase in hardness of the fuser roll rubber, the input strain energy per cycle becomes less because the nip formed between the fuser roll and the pressure roll is smaller resulting in a reduced interaction between the two rolls causing the strain to be reduced. We have also found that if you minimize the ratio of the input strain energy per cycle to total strain energy to rupture, that the fuser roll resistance to pitting and thereby failure will be increased. We have also found that this increase in hardness in the fuser roll may be achieved with the addition of substantial quantities of additional tabular alumina to the fuser roll composition and at the same time contributes to an increase in the mechanical integrity of the rubber strength in terms of total strain energy to rupture (ultimate elongation X maximum tensile strength) and tear strength.

2

In its broadest aspect, the coating composition comprises;

(a) 100 parts of an alpha omega hydroxypolydimethylsiloxane having a number average molecular weight of between about 5,000 to about 20,000;

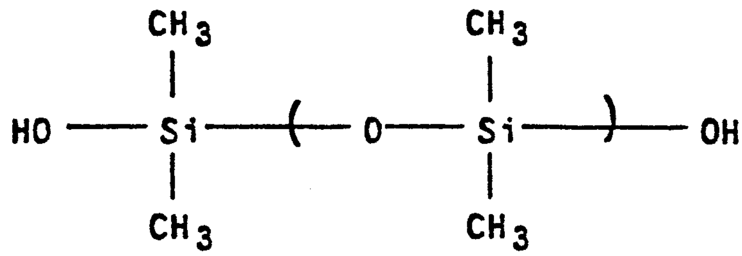
(b) from about 230 part to about 300 parts by weight of tabular alumina;

(c) about 12 to 60 parts by weight of a finely divided iron oxide;

(d) about 6 to 20 parts by weight of a crosslinking agent and;

(e) about 0.25 to about 1.8 parts by weight of a crosslinking catalyst.

We have found the alpha omega hydroxypolydimethylsiloxane to be a particularly suitable material for overcoating a thermally conductive conformable fuser roll. The alpha omega hydroxypolydimethylsiloxane, which is a disilanol, is believed to have the structural formula:



wherein n is an integer whose magnitude depends on the number average molecular weight of the disilanol. For the purpose of the present invention, we prefer to use a disilanol having a number average molecular weight between 5,000 and 20,000. In commercially available materials, this number average molecular weight corresponds roughly to materials having an average viscosity ranging from about 500 centistokes (Cstk) to about 3,500 Cstk. With a disilanol having a number average molecular weight of less than about 5,000, which roughly corresponds to an average viscosity of about less than 500 Cstk, the material is of relatively short chains and therefore contains more active sites at the end of the chains for crosslinking during the curing step. This yields a material which contains too high a crosslinking density, and which is relatively hard and brittle and not suited for the purposes of the present invention.

With the disilanol having a number average molecular weight in excess of about 20,000, which roughly corresponds to an average viscosity of about above 3,500 Cstk, the cured composition does not have sufficient crosslinking density to attain maximum strength and fatigue resistance, and therefore does not have sufficiently long operational life. The siloxane functions as a binder to hold the thermally conducting material providing overall structural integrity and elastomeric conformability. Furthermore, it preferably has a surface tension of from about 20 to 22 dynes per square centimeter to provide adequate release properties and is thermally stable up to a temperature of about 400°F with good thermal aging at elevated temperatures.

The tabular alumina is incorporated in the composition to both improve the thermal conductivity of the composition as well as provide mechanical strength to the fuser member.

Tabular alumina is a sintered alumina that has been heated to a temperature slightly below 3700°F, the fusion point of aluminum oxide. The name "tabular" comes from the fact that the material is composed predominatly of table-like crystals. As previously indicated, the material is characterized by good thermal conductivity and chemical inertness. For the purposes of the present invention the size of the tabular alumina used is important, it being finely divided and not being larger than about 100 mesh in size. At the present time the finest size tabular alumina commercially available is 325 mesh corresponding to a maximum size of about 44 micrometers. We have found this tabular alumina to be very suitable for the purposes of the present invention.

Another important aspect of the present invention resides in finely divided iron oxide. We prefer to use iron oxide which has a particle size in the range of submicron up to about 1 micrometer in its number average particle size. In particular, iron oxide is commercially available in a 0.4 micrometer size, and we have found this to be satisfactory. The amount of the iron oxide employed is an important factor. It is believed that the iron oxide serves the function of a reinforcing agent in the composition. We have found between about 13 to 60 parts by weight iron oxide per 100 parts by weight of the disilanol polymer to be suitable. Using insufficient amounts of iron oxide will result in a composition which is relatively low in mechanical strength and has poor swell characteristics under mechanical stress and in the presence of typical release agents. Excessive amounts of iron oxide in the composition yields a material which becomes relatively hard and thus requires more mechanical energy to obtain the desired constant nip size on a fuser roll, which also leads to shorter fatigue life of the fuser roll. Within this range, we particularly prefer to use about 13 to 28 parts iron oxide per 100 parts by weight of the disilanol polymer.

The crosslinking agent used in the composition for coating the fuser member of the present invention is for the purpose of obtaining a material with sufficient crosslink density to attain maximum strength and fatigue resistance. Examples of crosslinking agents which are suitable for the purposes of the present invention include: esters of orthosilicic acid; esters of polysilicic acid; and alkyltrialkoxy silanes. Specific examples of suitable crosslinking agents include: tetramethylorthosilicate; tetraethylorthosilicate; 2-methoxyethylsilicate; tetrahydrofurfurylsilicate; ethylpolysilicate; butylpolysilicate; etc. Other suitable crosslinking agents are known to the art. We particularly prefer to use condensed tetraethylorthosilicate as the crosslinking agent in the composition of the invention. The amount of the crosslinking agent employed is not critical, as long as sufficient amount is used to completely crosslink the active end groups on the disilanol polymers used. In this respect, the amount of crosslinking agent required depends on the number average molecular weight of the disilanol polymer employed. With the higher average molecular weight polymer, there are fewer active end groups present and thus a lesser amount of the crosslinking agent is required, and vice versa. When excess amounts of a crosslinking agent are used, the excess is easily removed from the cured composition. Generally, for the preferred disilanol polymer of a number average molecular weight of between about 5,000 to 20,000, we have found that between about 6 to 20 parts by weight of condensed tetraethylorthosilicate per 100 parts by weight of the disilanol polymer to be suitable. Within this range, we prefer to use about 6.6 to 8 parts by weight condensed tetraethylorthosilicate per 100 parts by weight of the disilanol polymer. Of course, if other crosslinking agents are used, the amount to be used should be adjusted stoichiometrically to provide a sufficient amount of the crosslinking agent for the reactive end groups in the disilanol polymer.

Finally, with respect to the crosslinking catalyst used in the composition of the present invention, such catalysts are well known in the art and they include: the amines and carboxylic salts of many metals, such as lead, zinc, zirconium, antimony, iron, cadmium, tin, barium, calcium, and manganese; particularly the naphthenates, octoates, hexoates, laurates and acetates. Examples of suitable catalysts include: stannous octoate; dibutyltin dilaurate; dibutyltin diacetate; and dibutyltin dicaproate. Bis(dibutylchlorotin) oxide and similar compounds can be also used. Other suitable catalysts are disclosed in U.S. Patent No. 3,664,997. The amount of the catalyst employed is not critical. However, too small an amount of catalyst used leads to a very slow reaction which is impractical. On the other hand, excessive amounts of catalyst may cause a breakdown of the crosslinked polymer network at high temperatures, to yield a less crosslinked and weaker material, thus adversely affecting the thermomechanical strength of the cured material. In general, we have found that between about 0.25 to 1.8 parts by weight of catalyst per 100 parts of the disilanol polymer to be preferred. More particularly, we prefer to use between 0.25 to 0.75 parts by weight of catalyst per 100 parts of the polymer. The specific catalysts preferred are dibutyltin dilaurate and bis(dibutylchlorotin) oxide.

We have found that if the amount of tabular alumina present in the composition is between about 230 parts by weight to about 300 parts by weight that a dramatic improvement in the fuser roll resistance to pitting is achieved and thereby the useful life is extended. This was discovered initially by a theoretical analysis of the nature of the problem, solved in a theoretical approach and confirmed with actual comparative machine test data. As indicated above fuser roll pitting occurs as the paper slips relative to the fuser roll in one direction at the entrance of the nip between the fuser roll and the pressure roll, then locks up in speed because it is being driven through the nip and finally, slips in an opposite direction at the exit of the nip. The extent of slippage region and intensity of the shear are a function of the input strain energy per cycle (loading between the two rolls in the fuser roll coating). The input strain energy per cycle is a function of hardness. Therefore by increasing the hardness the input strain energy per cycle becomes lower because the nip is smaller and therefore the interaction causing strain is reduced. The effect of changing rubber hardness in the fuser roll on peak surface strain (elongation) and input strain energy per cycle is indicated at Figure 4a and 4b. Both peak surface strain (elongation of the rubber) and input strain energy per cycle go down as rubber modulus is increased. Both peak surface strain and input strain energy per cycle also decrease as rubber thickness is increased. However the peak surface strain exhibits a relatively weak dependence on rubber thickness. On this basis by increasing the rubber overcoat hardness, it is possible to reduce the input strain energy per cycle and the peak surface strain effectively.

Another quantity of interest is the variation in the total strain energy to rupture of silicone rubber as the filler content is altered. Figures 5a, 5b, 5c, 5d and 5e indicate representative physical property measurements of fuser roll materials as a function of alumina content. The data was compiled from a pad of material comprised of the crosslinked product of a mixture of about 70 parts by weight of Rhodorsil 48V3500 which is believed to be an alpha, omega hydroxy polydimethyl siloxane having an average viscosity of 3500 centistokes available from Rhone-Paulenc Company and 30 parts by weight of Rhodorsil 48V750 which is also believed to be an alpha, omega hydroxy polydimethyl siloxane having an average viscosity of 750 centistokes available from Rhone-Paulenc Company to which was added 37.8 parts by weight of finely divided iron oxide (R2899R available from Pfizer), 15 parts by weight of tetraethyl ortho silicate and 1 part by weight of dibutyltin dilaurate. Tabular alumina (T61-325) available from Alcoa was added in amounts of 100, 200 and 300 parts per 100 parts by weight of the disilanol mixture. The plot of stress versus strain for these materials closely approximates a linear variation, therefore the product of one half the tensile strength times the maximum elongation is appropriate to use as a measure of the total strain energy to rupture of the material. The variation in total strain energy to rupture with respect to alumina is illustrated in Figure 6. It may be observed that the total strain energy to rupture increases initially as filler content increases reaching a peak at around 200 parts of alumina per 100 parts of disilanol and thereafter falls. Since at each filler level the modulus is also known, we can calculate the input strain energy per cycle and with the help of Figure 6, the ratio of input strain energy/cycle to total strain energy to rupture as alumina level is changed. This is illustrated in Figure 7 for both room temperature and fusing temperature. From Figure 7 it may be observed that the ratio of strain energies drops rapidly initially, beyond about 100 parts alumina per 100 parts disilanol it falls much slower, and between about 230 to 300 parts alumina the ratio is relatively constant. This ratio of input strain energy per cycle to total strain energy to rupture is significant because it gives an immediate visualization of the level of strain energy being imposed per cycle in relation to the total quantity of strain energy the material can absorb before breaking in any one cycle.

Thus the smaller the ratio the greater number of cycles the fuser roll will experience prior to pitting failure. Beyond a tabular alumina concentration greater than about 300 parts per 100 parts disilanol the rubber becomes very hard and brittle and the ratio will tend to increase resulting in early failure. In addition, the release properties of the fuser roll with respect to the toner may be seriously adversely affected. Furthermore with increasing alumina content in excess of 300 parts per 100 parts of disilanol the fusing latitude may be seriously reduced to the point where there is substantially no difference between the hot offset temperature and the minimum fixed temperature. As described above, hot offset temperature is the temperature at which the toner particles liquify and splitting of the molten toner takes place during the fusing operation. Minimum temperature is the lowest temperature at which the toner can be raised and still have a satisfactory fix of the toner to the copy substrate. Also as may be observed, with continued reference to Figure 6 with ratios of tabular alumina lower than about 230 parts per 100 parts of disilanol the ratio of strain energy per cycle to total strain energy to rupture tends to increase thereby reducing the number of cycles that the fuser roll may be used prior to pitting failure.

Unless otherwise indicted all parts and percentages referred to in this specification are by weight. To confirm the above analysis test pads and fuser rolls were made as follows:

EXAMPLES

To 100 parts of a thermally conductive RTV silicone supplied by Emerson & Cuming, a Dewey and Almy Chemical Division of W. R. Grace & Company, under the number EC-4952DXL 25 parts of tabular alumina, believed to be in the range of 100 to 325 mesh in size was added. The EC-4952DXL is believed to contain 100 parts of an alpha, omega, hydroxy polydimethyl siloxane having a number average molecular weight between 5000 to 20,000 plus crosslinking agent which is believed to be a trialkoxy or tetra-alkoxy or condensed tetra-alkoxy silane believed to be present in a 5 to 10 parts/100 disilanol crosslinking agent; 188 parts of a tabular alumina believed to be in the 100 to 325 mesh size range, and 25 parts of a finely divided iron oxide believed to be in the size range of 0.4 micrometers to 1.0 micrometers. The resultant mixed material is believed to have the following final composition: 100 parts of alpha, omega hydroxy polydimethyl siloxane of 5000 to 20,000 number average molecular weight plus 5 to 10 parts per 100 concentration of the crosslinking agent, 266 parts of the tabular alumina in the 100 to 325 mesh size range, and 25 parts of a finely divided iron oxide in the range of 0.4 to 1.0 micrometers. In order to make test pads and coated rolls the above formulation with extra alumina was catalyzed with a tin soap catalyst believed to be bis(dibutylchlorotin) oxide in the amount of 0.2 parts catalyst to 100 parts of the mixture. The mixture and catalyst were brought together in a continuous mixing device which metered the two streams of compound and catalyst in the above ratio before being pumped into moulds for curing in pads and onto fuser rolls.

Test pads so prepared provided the following physical property average results for ten samples.

Specific Gravity	2.27
Tensile Strength	775
Elongation (%)	60
Hardness (Shore A)	77
Trouser Tear	8.4
Crosslink Density (5 samples)	4.3×10^{-4}

These results compare favourably with the results illustrated in Figures 5a - 5d.

Fifteen of the fuser rolls so obtained were placed in 15 Xerox 1075 duplicators to be tested for pitting failure. All rolls worked satisfactorily fusing toner images on cut copy sheets and did not exhibit pitting failure until 500,000 copies or in excess thereof had been fused. By contrast fuser rolls prepared with the same formulation and in the same manner except that only 188 parts of tabular alumina were present in the formulation were tested in Xerox 1075 duplicators and exhibited a pitting failure at an average of about 250,000 copies. This result was achieved as an average failure rate for about 10,000 rolls.

It is therefore believed that a dramatic improvement in fuser roll life due to pitting failure has been demonstrated according to the specific embodiment of the present invention. Furthermore the analysis provided, clearly indicates that this dramatically improved resistance to pitting is achievable with tabular alumina contents in the range of about 230 to about 300 parts per 100 parts of disilanol. In addition to the advantages achieved with long life, it should be noted that the present invention as a result of the increased alumina content requires a reduced power input, lower surface temperature and lower temperature gradient between the surface and the core of the fuser roll. Being capable of operating at a lower core temperature provides another advantage in extending the useful fuser roll life. As indicated previously based on initial roll to roll test data with 246 parts alumina and 259 parts alumina per 100 parts disilanol, a cyclic fatigue failure was obtained substantially earlier than with rolls made containing 188 parts of alumina per 100 parts of disilanol. Accordingly the results obtained here are unexpected. It should be noted that for the roll to roll tests previously referred for 246 and 259 parts of alumina that as a result of maintaining the nip constant in those tests that with the increased hardness of the rolls as a result of increased alumina content, the load on the fuser roll had to be increased correspondingly resulting in a higher input strain energy per cycle which in turn increased the ratio of input strain energy per cycle to total strain energy to rupture and therefore earlier catastrophic failure. With the present invention the load on the fuser roll may be maintained constant without altering fusing fix. Accordingly with increased fuser roll hardness a smaller nip between the fuser roll and the pressure roll may be used resulting in reduced input strain energy per cycle and thereby reducing the ratio of the input strain energy per cycle to the total strain energy to rupture. Thus by carefully selecting the amount of tabular alumina in the formulation described in U.S. Patent 4,373,239 and increasing the amount of tabular alumina beyond the range described in said patent a dramatic improvement in fuser roll resistance to pitting failure is achieved.

While the invention has been described in detail with reference to specific and preferred embodiments, it will be appreciated that various modifications and variations will be apparent to the artisan within the scope of the appended claims.

Claims:

1.. A thermally conductive fuser member for use in an electrostatographic reproducing machine comprising a rigid base, a thin deformable layer of a composition coated thereon, characterized by said composition comprising the crosslinked product of a mixture of about 100 parts by weight of alpha omega-hydroxypolydimethylsiloxane, about 230 to 300 parts by weight of finely divided tabular alumina about 13 to 60 parts by weight of finely divided iron oxide, a crosslinking agent and a crosslinking catalyst, said crosslinking agent and catalyst being present in amounts sufficient to promote crosslinking of said siloxane.

2. A thermally conductive fuser member according to Claim 1, wherein said tabular alumina is present in an amount of about 266 parts by weight.

3. A thermally conductive fuser member according to Claim 1 or Claim 2, wherein said tabular alumina is about 325 mesh in size.

4. A thermally conductive fuser member of Claim 1, wherein said rigid base is a metallic roll and wherein said thin layer is from about 10 to about 100 mils thick.

5. A thermally conductive fuser member according to Claim 4, wherein said metallic roll is made of aluminum and said thin layer is from about 30 to about 80 mils thick.

6. A thermally conductive fuser member according to Claim 5, wherein said thin layer is from about 60 to about 70 mils thick.

7. A thermally conductive fuser member according to any preceding claim, wherein said alpha omega-hydroxypolydimethylsiloxane has a number average molecular weight between about 5,000 to about 20,000, and wherein said crosslinking agent is condensed tetraethylorthosilicate present in an amount from about 6 to about 20 parts by weight, and wherein said crosslinking catalyst is dibutyltin dilaurate or bis(dibutylchlorotin) oxide

present in an amount from about 0.25 to 1.8 parts by weight.

8.. A thermally conductive fuser member according to any preceding claim, wherein said iron oxide particles have a number average particle size of less than about 1 micrometer.

FIG. 1

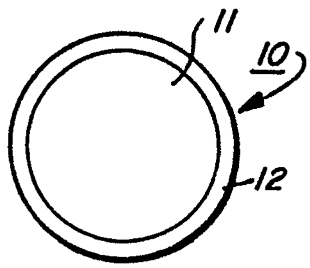


FIG. 2

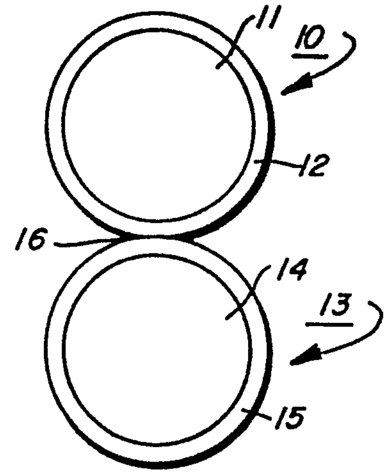


FIG. 3

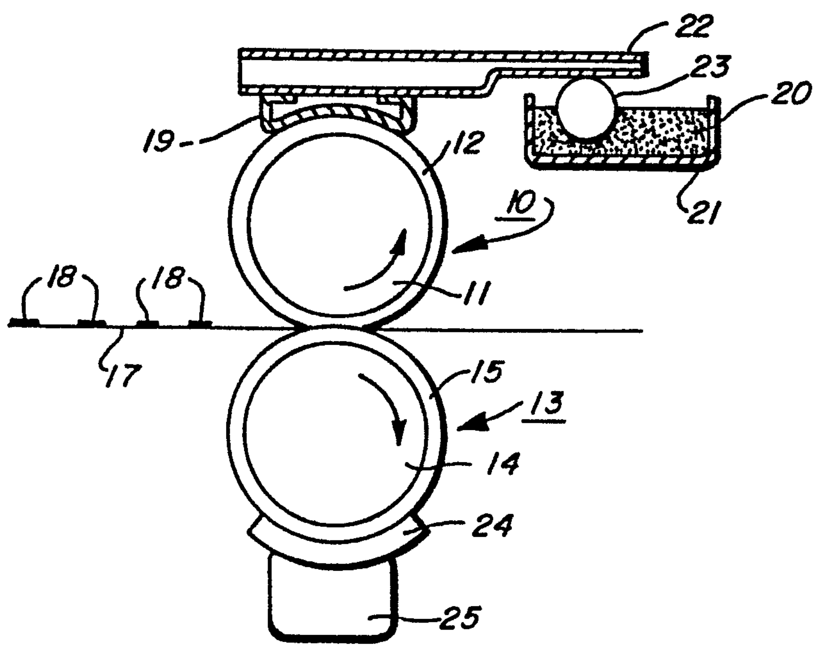


FIG. 4a

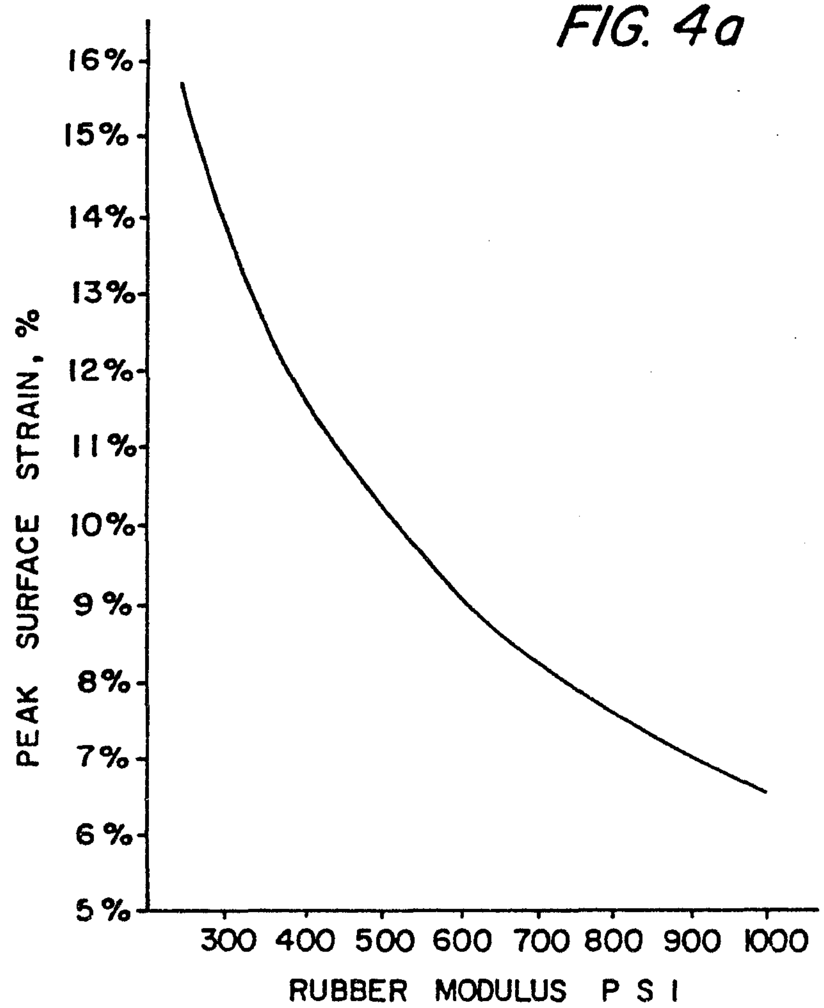

16%
15%
14%
13%
12%
11%
10%
9%
8%
7%
6%
5%
PEAK SURFACE STRAIN, %
300 400 500 600 700 800 900 1000
RUBBER MODULUS P S I

FIG. 4b

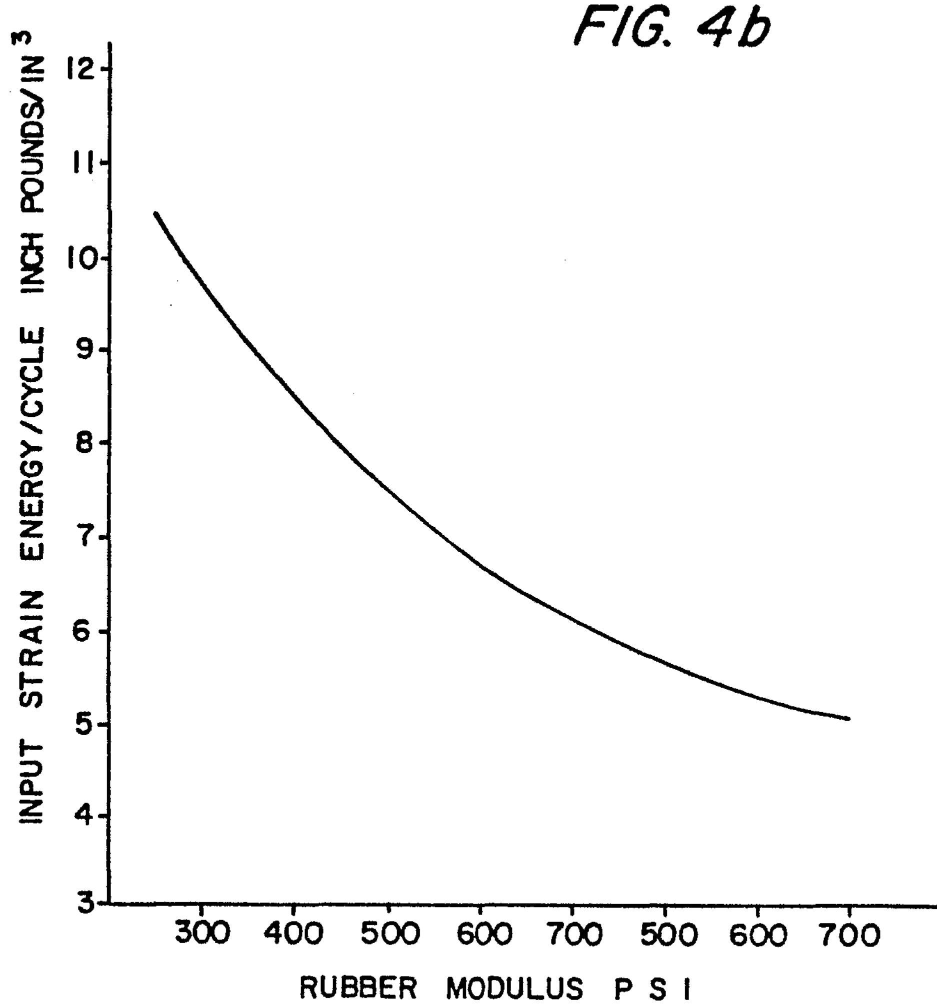

12
11
10
9
8
7
6
5
4
3
INPUT STRAIN ENERGY/CYCLE INCH POUNDS/IN 3
300 400 500 600 700 500 600 700
RUBBER MODULUS P S I

FIG. 5a

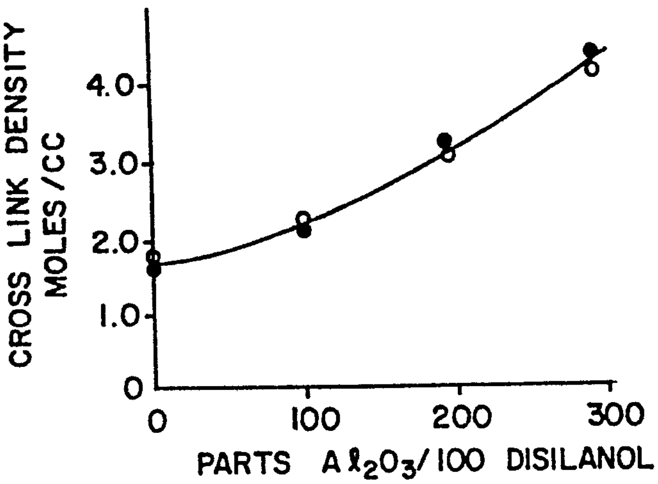


FIG. 5b

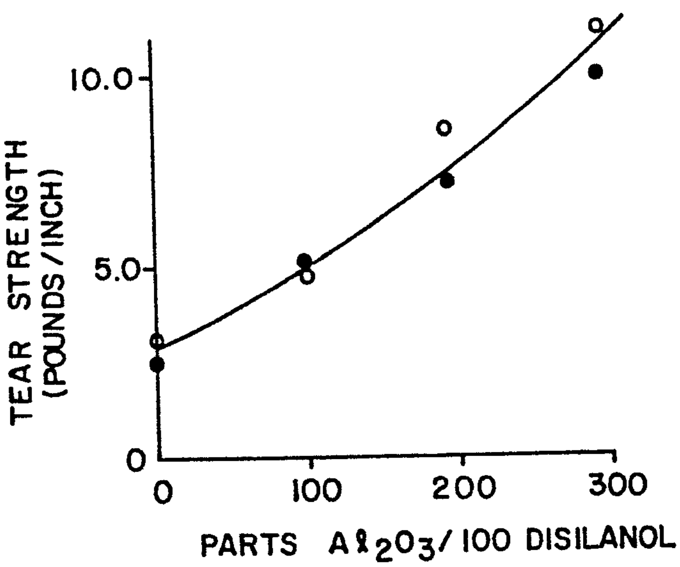


FIG. 5c

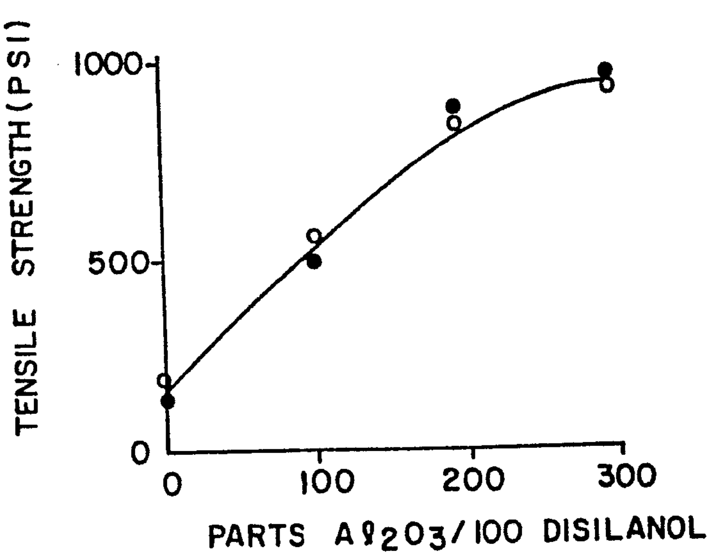


FIG. 5d

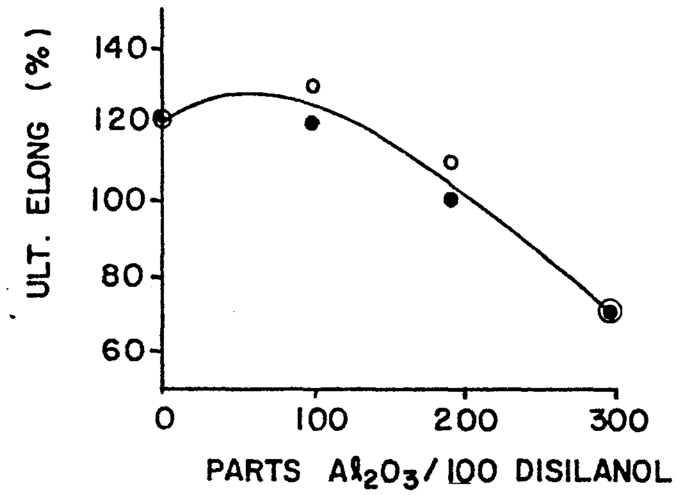

ULT. ELONG (%)
140
120
100
80
60
0
100
200
300
PARTS Al2O3/100 DISILANOL

FIG. 5e

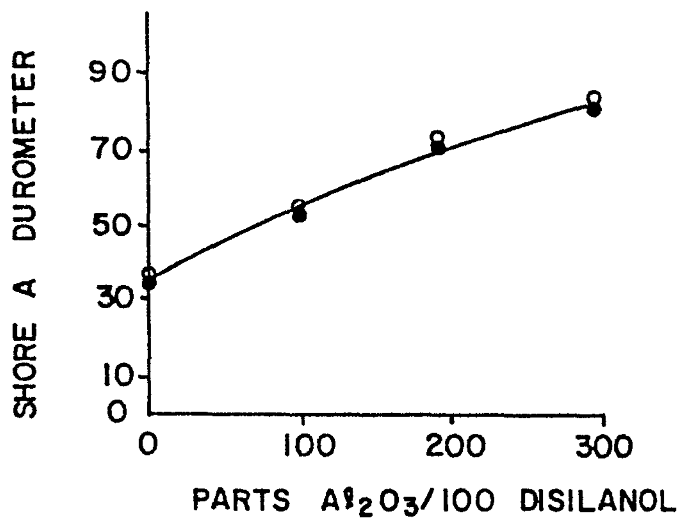

SHORE A DUROMETER
90
70
50
30
10
0
0
100
200
300
PARTS Al2O3/100 DISILANOL

FIG. 6

ENERGY OF RUPTURE
vs
FILLER CONTENT

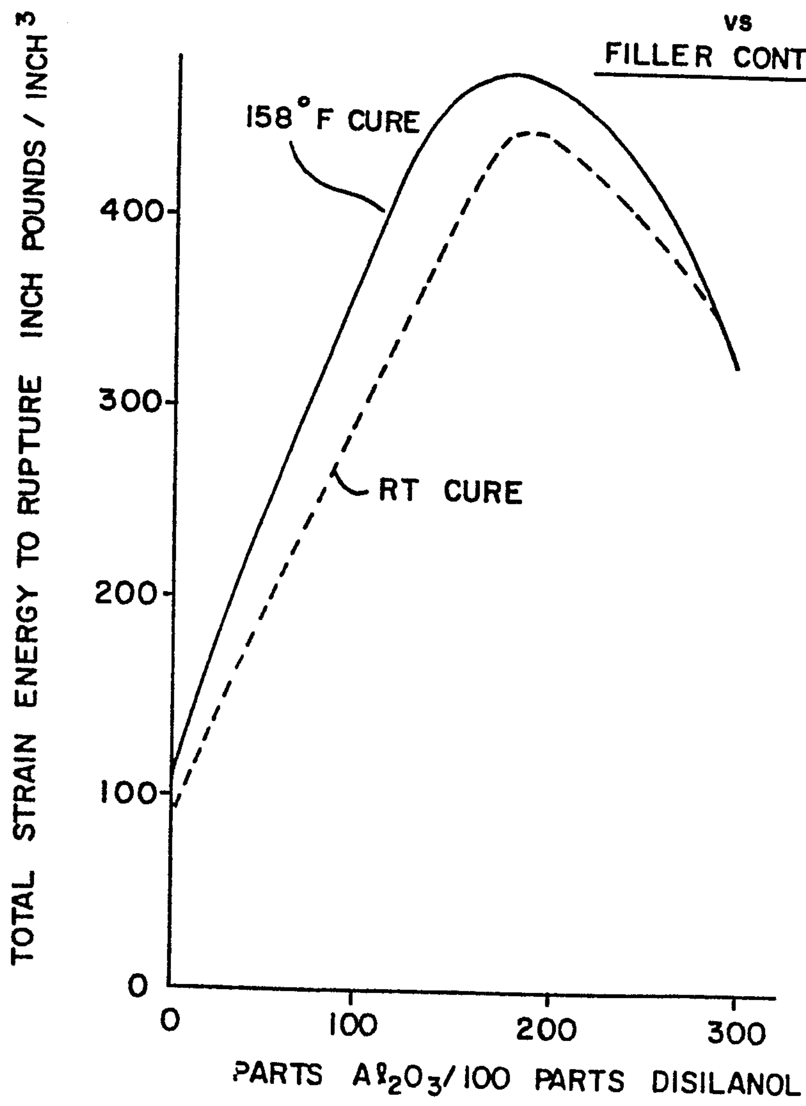
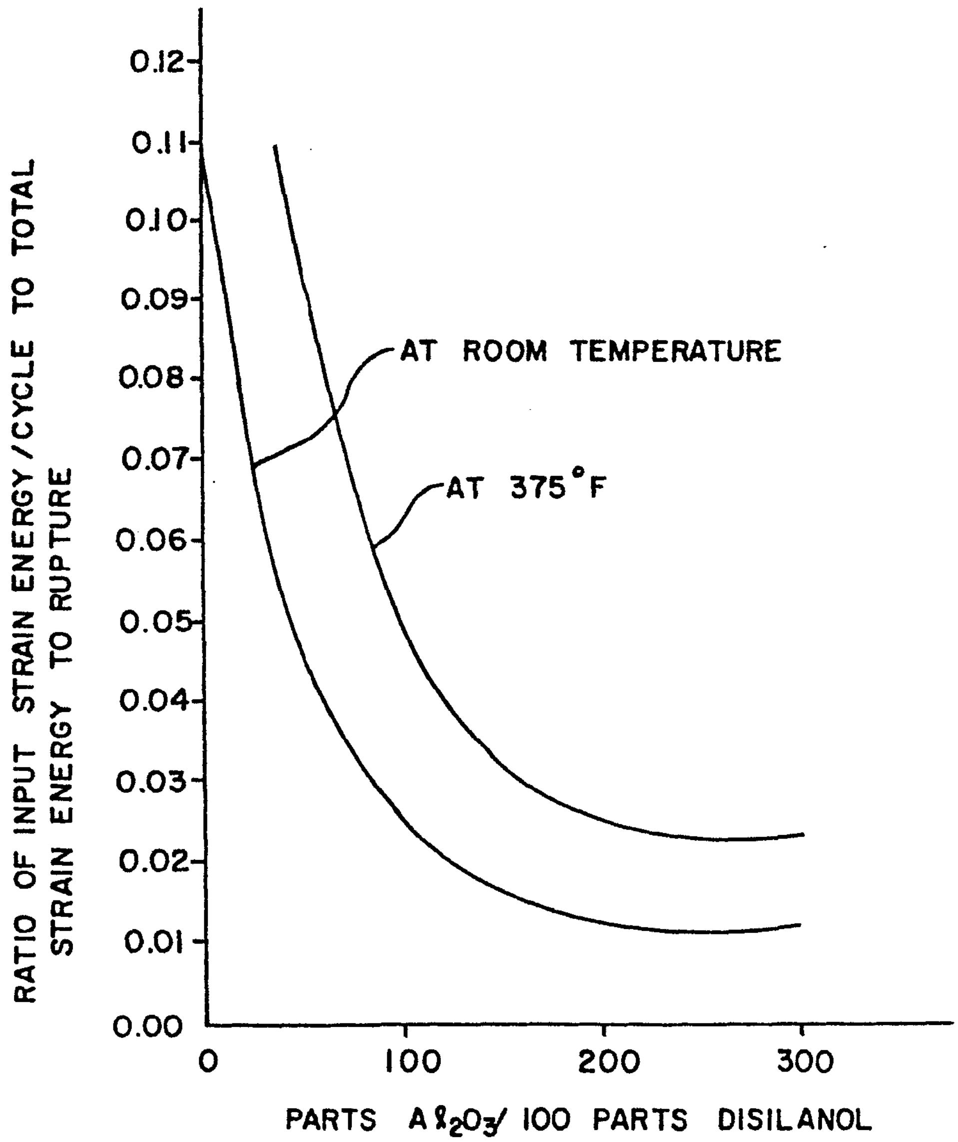


FIG. 7

VARIATION OF RATIO OF INPUT STRAIN ENERGY / CYCLE TO TOTAL STRAIN ENERGY TO RUPTURE WITH FILLER CONTENT



European Patent Office

EUROPEAN SEARCH REPORT

0172668

Application number

EP 85 30 5265

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int Cl 4)
D,X	EP-A-0 035 362 (XEROX CORP.) * Claims 1-5,8 * & US - A - 4 373 239	1,3-8	G 03 G 15/20
A	CHEMICAL ABSTRACTS, vol. 94, 18th May 1981, page 45, no. 157881b, Columbus, Ohio, US; & JP - A - 81 00 834 (SHOWA DENKO K.K.) 07-01-1981	1	
A	GB-A-2 097 725 (XEROX CORP.) * Page 3, lines 15-32 *	1,4-8	
A	PATENTS ABSTRACTS OF JAPAN, vol. 4, no. 131 (P-27) [613], 13th September 1980; & JP - A - 55 81 377 (TOKYO SHIBAURA DENKI K.K.) 19-06-1980	1	TECHNICAL FIELDS SEARCHED (Int. Cl 4)
A	US-A-3 848 305 (JACHIMIAK) * Column 2, lines 54-68 *	1	G 03 G 15

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	08-11-1985	CIGOJ P.M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO Form 1503 03.82