May 23, 1950 W. R. MARSHALL 2,508,462

METHOD AND APPARATUS FOR THE MANUFACTURE OF SYNTHETIC STAPLE FIBERS

Filed March 17, 1945

Fig. 1.

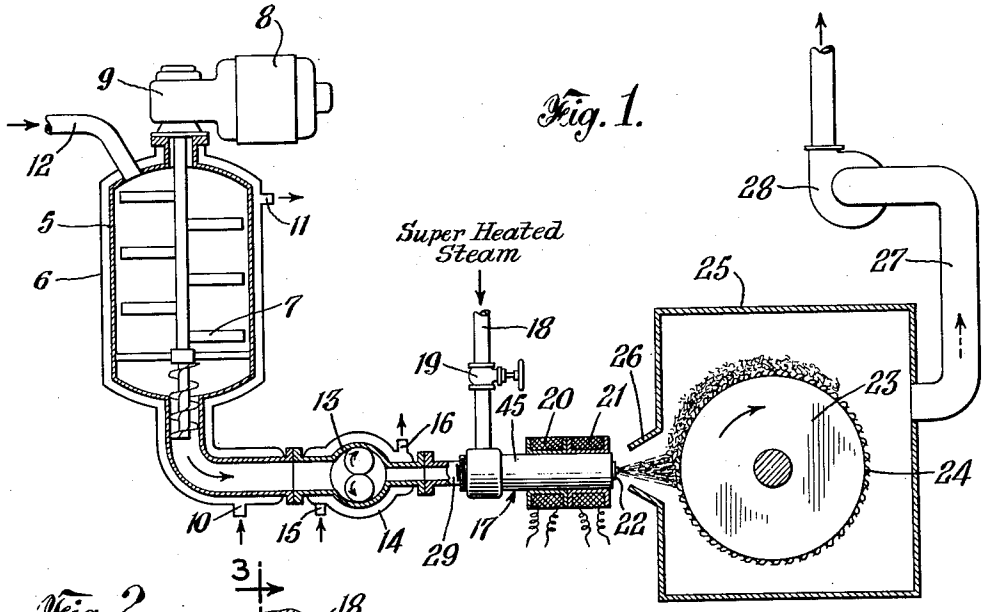


Fig. 2.

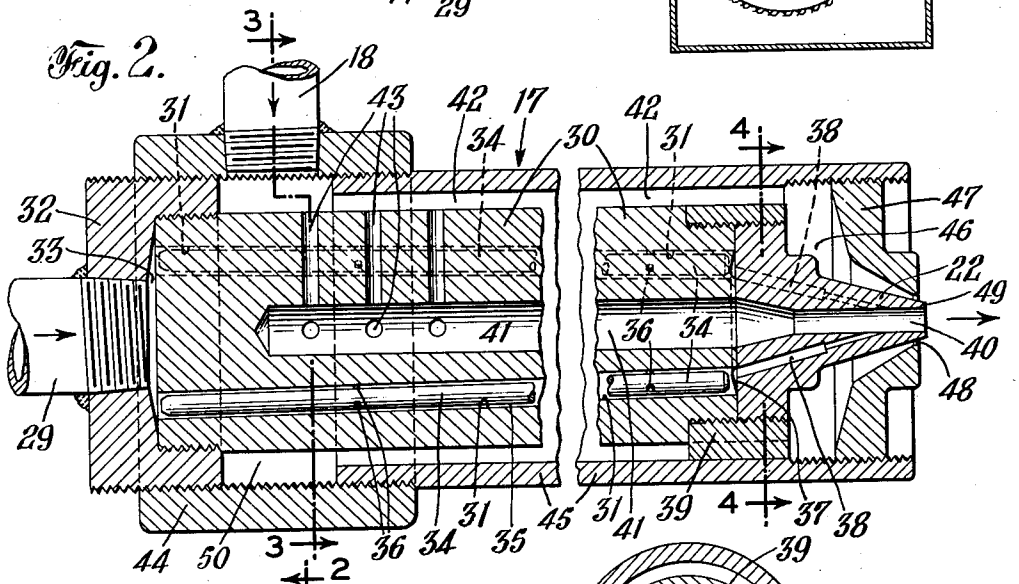


Fig. 3.

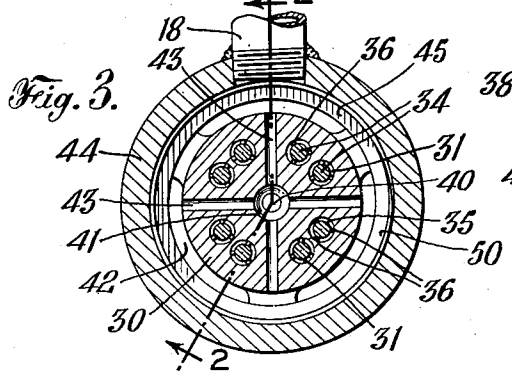
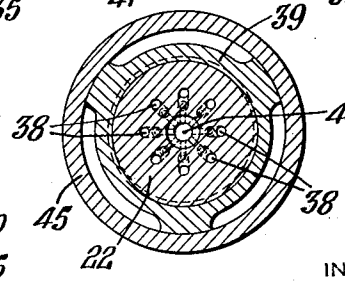


Fig. 4.



INVENTOR

WALTER R. MARSHALL

BY C. C. Scheffler

ATTORNEY

Patented May 23, 1950

2,508,462

UNITED STATES PATENT OFFICE

2,508,462

METHOD AND APPARATUS FOR THE MANUFACTURE OF SYNTHETIC STAPLE FIBERS

Walter R. Marshall, Bloomfield, N. J., assignor, by mesne assignments, to Union Carbide and Carbon Corporation, a corporation of New York

Application March 17, 1945, Serial No. 583,258

12 Claims. (Cl. 18—8)

1

This invention relates to a method and apparatus for the manufacture of fibrous products made from fiber-forming thermoplastic organic polymers, more particularly elongated or oriented staple fibers.

Heretofore synthetic organic fibers have usually been made in the form of continuous filaments by the extrusion and drawing of liquefied fiber-forming polymer through minute orifices. By subsequent treating operations the continuous fiber can be stretched to improve its strength by molecular orientation, mechanically or otherwise treated to impart a kink or curl to the fibers to improve felting and spinning characteristics, and then cut into desired staple lengths.

The present invention is directed to a method and apparatus for rapidly and economically producing feltable oriented staple fibers from fiber-forming organic polymers in a single operation. The invention is based upon the discovery that momentarily heating such a polymer to decomposition temperatures under non-oxidizing conditions whereby the polymer is brought into a highly fluid condition, and then immediately subjecting a film of the fluid polymer to a velocity and temperature controlled blast of inert hot vapor or gas discharging as a jet into the atmosphere causes filaments to be pulled off the film surface which are at once attenuated by the blast until they break into staple length fibers and at the same time are so rapidly cooled to a non-plastic state while suspended in the blast that elastic deformation or "cold drawing" occurs under conditions promoting a random angular curl, twist or kink in each fiber.

The invention is more fully disclosed in the following description taken in conjunction with the drawing in which:

Fig. 1 is a sectional elevation view, partly diagrammatic, of an apparatus for making and collecting synthetic staple fibers;

Fig. 2 is a longitudinal sectional elevation view (along the line 2—2 of Fig. 3) of a combined heating and blowing means for forming the staple fibers;

Fig. 3 is a cross-sectional elevation view along the line 3—3 of Fig. 2;

Fig. 4 is a cross-sectional elevation view along the line 4—4 of Fig. 2.

Referring to Fig. 1 there is shown a cylindrical

2

vessel 5 enclosed by a heating jacket 6 and equipped with a combination agitator and pumping screw means 7 driven by an electric motor 8 through a gear reducer 9. Heating fluid or vapor, such as hot oil or diphenyl oxide, is supplied to the jacket 6 of the cylindrical vessel 5 at an inlet connection 10 and is exhausted at an outlet connection 11. Viscous or granular fiber-forming polymer is introduced into the cylindrical vessel 5 through a loading opening 12 to be heated until it is fluid enough to be pumped. The polymer is then forced out of the cylindrical vessel 5 by the agitator screw means 7 and is picked up by a constant delivery gear pump 13, also enclosed in a heating jacket 14 fitted with an inlet connection 15 for hot vapor or fluid and an exhaust connection 16 for removal of the used heating fluid. The gear pump 13 delivers molten polymer to a fiber-forming metal nozzle assembly 17 which in turn is also connected to a supply line 18 of superheated steam or other inert hot vapor or gas whose pressure is regulated by a valve 19, preferably of a type capable of maintaining a constant desired pressure. Superheated steam is preferably used as the inert vapor since it has favorable temperature-pressure relations and furthermore aids in dissipating electrostatic charges that may form on the fibers. Encircling the fiber-forming nozzle assembly 17 about midpoint in its length is an electric induction heater 20 and another induction heater 21 is positioned close to the exit end of nozzle assembly 17. Expanding steam or other inert vapor or gas and synthetic fibers emerge from the nozzle assembly 17 through a nozzle tip 22 and strike a rotating drum 23 having a foraminous collecting surface 24 such as cotton cloth to which the fiber adheres. The fiber collecting drum 23 is mounted within a partly enclosed chamber 25 having a venturi type diverging throat opening 26 large enough to permit free induction of atmospheric gases by the jet action of the expanding steam coming out of the nozzle tip 22. The synthetic fibers collect and felt together on the foraminous surface 24 of the rotating drum 23 while the expanded steam and atmospheric gases are removed from the enclosed chamber 25 through a vent 27 connected to a ventilating fan 28.

Referring to Fig. 2, the internal construction of the fiber-forming nozzle assembly 17 shows

that the molten polymer and the superheated steam are separately ported through the major part of the nozzle assembly 17 until mutual contact is finally made within the nozzle tip 22. The individual porting is obtained by means of a cylindrical metal member 30 internally positioned within an outer tubular metal casing 45 by its attachment to a plug bushing 32 at one end and by a spider bushing 39 at the other end. Longitudinally-extending through cylindrical member 30 in a circumferentially arranged pattern tending to taper together in a direction towards the nozzle tip 22 are eight passageways 31 for the polymer. A tapered metal rod 34 (the degree of taper being too small to satisfactorily illustrate in the drawing) is positioned in each passageway 31 by means of protruding pins 36 to provide a decreasing annular clearance space 35 within each passageway 31, in a direction towards the nozzle tip 22. The plug bushing 32 is centrally tapped for connection with the polymer inlet pipe 29 and by means of internal threads is engaged to a threaded end portion of cylindrical member 30. A relieved area in the internal face of the plug bushing 32 forms a manifold space 33 for fluid polymer to flow at substantially equal pressure into the annular spaces 35 of each passageway 31. At the opposite end of cylindrical member 30, the fluid polymer flows out of the annular spaces 35 into another manifold area 37 formed by an annular depression at this end of the cylindrical member 30. Directly communicating with this manifold area 37 and registering with passageways 31 are eight circumferentially arranged counterbored orifices 38 in the nozzle tip 22. These orifices 38 converge together within the nozzle tip 22 and enter at an angle of about 15 degrees a reduced common orifice 40 centrally located in the nozzle tip 32. The spider bushing 39 connects the rear face of the nozzle tip 22 to the end of cylindrical member 30 in fluidtight relationship.

A central pasageway 41 and an annular passageway 42 are provided for the steam that enters the nozzle assembly 17 from supply pipe 18. The central steam passageway 41 is a longitudinally bored hole in the center of the cylindrical member 30 and extends from the common orifice 40 in the nozzle tip 22 to almost the opposite terminus of the cylindrical member 30. At right angles to the central steam passage 41 and in communication therewith as more particularly shown in Fig. 3, are several inlet ports 43 which extend to the exterior surface of cylindrical member 30, but which are so spaced in radial extension as not to communicate with the fluid polymer passageways 31. The annular steam passageway 42 is created by the enclosure of cylindrical member 30 by the casing 45 which is connected at one end by means of a coupling 44 to inlet cap 32 and partly plugged at the other end by the spider ring bushing 39 and a nozzle cap 47. Steam supplied by pipe 18 enters an enlarged annular chamber 50 formed by the unengaged internal threads of coupling 44 and then flows along annular passageway 42, but with a considerable part being diverted into the ports 43 and thence through the central steam passageway 41. Flow of steam along annular steam passageway 42 is to the spider bushing 39, where the steam escapes through the relieved sections of the spider bushing 39 to enter into an auxiliary nozzle chamber 46 formed by auxiliary nozzle bushing 47 that is threaded into the end of casing 45 in such manner as to have the orifice of the auxiliary nozzle bushing 47 concentrically superimposed on the exterior surface of nozzle tip 22. An annular jet space 48 is thereby provided through which steam escapes to the atmosphere to continually blow into fibers any accumulation of excess molten polymer at the external end 49 of the nozzle tip 22 which excess would otherwise tend to break loose periodically in the form of shot or pellets.

The phenomenon of directly forming feltable oriented staple fibers from organic fiber-forming polymers is dependent upon several factors, which unless mutually coordinated result in the polymer being atomized into small beads, pellets or shot rather than formed into filaments. Foremost among these factors is the fluidity of the polymer as it emerges from the nozzle orifices 38 and comes into violent contact with the steam jet in the main orifice 40. The desirable fluidity value cannot be stated with numerical precision since reliable rheological data on fiber-forming polymers at extremely elevated temperatures are not readily obtainable, but by extrapolation of known viscosity-temperature curves on these polymers, the viscosity component of these polymers at such decomposing temperatures can be estimated as being less than 100 poises but probably more than 10 poises, since with lower viscosities it is extremely doubtful that the polymers are sufficiently viscous to overcome surface tension forces tending to form drops rather than threads. It is generally agreed, however, that all fiber-forming polymers when heated above their softening temperature exhibit both plastic flow and viscous flow and with increasing temperature viscous flow becomes the predominant component and in the practice of the present invention it has been found necessary to heat the fiber-forming polymers to temperatures favoring maximum fiber-forming fluidity and minimum plastic flow. Fiber-forming fluidity as herein defined is approximately comparable with the stringy tackiness that is observed when such substances as bodied drying oils, varnishes and rubber solutions are spread out as a film and then momentarily contacted by a finger which in withdrawing pulls off a portion of the film in the form of strings or threads. In the present invention a jet of steam or other inert gas is in effect substituted for the finger and the application of sufficient heat to a fiber-forming polymer that is normally solid at room temperature converts it into fluid stringy liquid.

To avoid substantial decomposition of the polymers in the process of blowing them into fiber form but at the same time realizing the necessary fiber-forming fluidity it has been found that the heating rate must be extremely rapid and the polymer exposed to such decomposing temperatures for the least possible time. To accomplish this rapid heating with minimum exposure of the polymer to decomposing temperature, the polymer is heated in two stages; the first stage comprising a melting operation conducted in the tank 5 or alternatively in a jacketed extruder where the polymer is heated only to a temperature imparting sufficient fluidity to enable it to be delivered at predetermined flow rates by the gear pump 13 or other constant delivery means to the fiber-forming nozzle 17; and the second stage comprising a rapid heating to a decomposing temperature of only the relatively small quantity of polymer required to fill the thin tapered annular spaces provided by the filler pins 34 in the cylindrical member 30. The

heating of the polymer in the second stage is effected primarily by conduction of heat generated in the filler rods 34 and cylindrical member 30 by eddy currents and/or hysteresis losses (depending upon the electrical and magnetic characteristics of the metals used in the construction of the nozzle) induced by induction coils 20 and 21. Preferably these coils are of a multi-turn type operating with low frequency alternating current, e. g. 60 cycles, to obtain a considerable depth and uniformity of heating throughout the metallic mass comprising the fiber-forming nozzle 17. Uniform heating of the entire metal mass of the nozzle assembly 17 is also promoted by suitable choice of metals used in its construction. As for example by using stainless steel or other non-magnetic metal for the casing 45 and a highly magnetic material such as cast iron or carbon steel for the cylindrical member 30 and the filler rods 34, the casing 45 is then primarily heated by eddy currents and the cylindrical member 30 and its filler rods 34 both by eddy currents and magnetic hysteresis effects. Control of the heating energy developed by each induction coil is obtained by varying the voltage of the alternating current supply by means of transformers (not shown in the drawing) in accordance with the heat requirements of the particular fiber-forming polymer being processed. The first induction coil 20 may be controlled to produce a somewhat lower temperature in the mass of metal immediately within its effective range than the second induction coil 21 superimposed immediately around the orifices of the nozzle 22 in order to reduce the exposure time of the polymer to decomposing temperatures.

Alternatively the nozzle assembly 17 may be heated by other means than by induction coils as for example by electric resistance heaters in bayonet form to substitute for the filler rods 34, or by suitable channeling within the nozzle assembly and filler rods a separate supply of hot gas or vapor (other than that employed to pick up the fiber) may be supplied to the nozzle assembly solely for heating purposes. Such alternative heating means involve a more complicated construction and require additional control means for precisely regulating their heat input.

In addition to the factor of bringing the polymer to a fiber-forming temperature there is an additional factor comprising the coordinated effect of the temperature, pressure and velocity of the inert gas or vapor in the picking up of the polymer and forming it into a fiber. In explanation of this coordinated effect, attention is directed to the fact that the polymer as it emerges from the polymer orifices 38 into the central nozzle orifice 40 flows as a continuous liquid film along the walls of the nozzle orifice 40 to the outer edge of the nozzle tip 22, being propelled in this direction by the frictional contact of the escaping steam in the central passageway 41. Fibers are picked up by the escaping steam all along the moving film of polymer beginning at the junction point of the polymer orifices 38 and the central nozzle orifice 40 and continuing out to the extreme end 49 of nozzle tip 22 where any remaining excess polymer collects in an annular shaped mound to be also drawn into fibers by the joint action of steam escaping through the annular nozzle orifice 48 and through the central orifice 40.

Depending upon the velocity and temperature of the escaping steam the bundle of individual fibers that have been forming all along the central orifice 40 can be propelled out into the atmosphere under conditions favoring production of practically continuous attenuated fiber having little or no molecular orientation, or as staple fibers having considerable orientation such that the fiber is elastically stretched 300 to 500 per cent or even more, or as extremely short staple fibers with only a minor amount of orientation.

To produce long attenuated fibers having little or no orientation, the steam pressure is controlled so that the steam escapes at a low velocity such as a few hundred feet per minute and at a temperature substantially the same as the polymer. Under such conditions the fibers are actually floated out into the atmosphere as continuous filaments since the velocity is insufficient to break the fiber away from its originating point in the film and therefore the fiber continues to grow in length as long as the polymer film in the nozzle orifice 40 is continuously replenished by a fresh supply of liquid polymer. The fiber as it issues out of the nozzle orifice 40 is almost instantly cooled to a temperature below its softening point by the joint cooling effect of the adiabatically expanding steam, and cool atmospheric gases drawn into the jet of steam. Fibers produced in this manner are substantially straight, have diameters in the range of 2 to 15 microns and show only slight contraction when reheated to their softening temperature. They must be further treated by a cold drawing operation to improve their molecular orientation and then a crimp or curl must be imparted to them before they are cut into staple lengths.

When the steam velocity is substantially increased, approaching theoretical speeds of the order of about 20,000 to 80,000 feet per second and the temperature of the steam as it contacts the film of polymer in the nozzle orifice 40 is substantially the same as the polymer, total fiber production is not only enormously increased but also the fibers are considerably oriented, and crimped and are automatically severed into random staple lengths of 1 to 15 inches. The several results accomplished under these conditions are presumably due to the fact that each fiber from the moment it begins to be formed out of the liquid film in the nozzle orifice 40 and ejected out into the atmosphere is traveling at an accelerating speed, but at the same time the fiber is being so rapidly cooled by the adiabatically expanding steam and the atmospheric gases drawn and mixed into the steam outside the nozzle tip 22, that the fiber is cooled to a cold drawing temperature within a few inches away from the nozzle tip 22. This extremely rapid cooling effect within the expanding jet of steam and fibers is so pronounced, that one's hand can be held therein without discomfort at a distance as close as 15 inches to the nozzle tip 22 from which superheated steam at 15 to 50 p. s. i. and fibers issue at a temperature of 300 to 400° C. Accompanying the rapid chilling of the fibers to a cold drawing temperature is their accelerated motion in a direction generally parallel to the jet so that the part of the fiber furthest away from the nozzle exerts a sufficient pulling force on that part closest to the nozzle tip to cause cold drawing or orientation of the length intermediate between each part. Since the jet of steam expands in a turbulent manner the fibers are evidently caught in cross currents subjecting them to twisting and curling motions while they are still in a fluid plastic state and these twists and curls are practically instantaneously frozen into the fiber,

Probably to a minor extent some of the total crimping effect is due to differential orientation between the surface and the inner core of the fiber since cooling of the core would tend to lag behind the cooling of the surface and therefore it can be presumed that with the surface having a greater amount of frozen elastic strain than the interior, the fiber by curling or twisting on itself partially equalizes the unequal strains. Severance of the fiber into staple lengths probably occurs within or just at the nozzle tip **22** due to the fiber being formed and drawn out from its originating point in the film at a faster rate than the film is replenished at this point by polymer issuing out of the nozzle orifices **38**. It is the irregular curliness or kinkiness of these staple fibers that makes them eminently suitable for spinning into yarns for textile purposes, or for forming highly integrated felted masses suitable for thermal and acoustic insulation purposes, or as coherent preforms for molding articles of almost any desired final molded density between the apparent density of the felt up to the full molded density of the solid polymer.

In continuance of the effect of steam velocity on the fiber production, it was observed that as the steam velocity is further increased to theoretical speeds of the order of 80,000 feet per minute, but being maintained substantially at the same temperature as the polymer as it emerges from the orifices **38**, the total fiber production is increased slightly but is accompanied by the formation of increasingly shorter staple length fibers and a lower amount of orientation. Under these circumstances the fiber is picked up from the film so rapidly that only short lengths can be formed and the cooling of the fibers being less rapid due to the proportionally higher total heat content in the higher velocity steam, the propulsive forces exerted on the fibers by the steam are almost completely expended at about the moment the fibers have been cooled to a cold drawing temperature and therefore only a minimum of cold drawing is accomplished.

Temperature regulation of the steam or other inert gas or vapor is the additional important factor to be taken into consideration with the velocity of the gas as it escapes from the nozzle, since if the temperature of the steam is substantially lower than the polymer at fiber-forming fluidity only atomization of the polymer into beads occurs. As the temperature of the steam approaches that of the polymer more fibers and less beads intermixed therewith are formed. In some instances a small proportion of beads in admixture with the fibers is of advantage when the fibers as they are formed are to be collected as a felted mass, the beads increasing the density of the felted mass and by their retention of heat for a longer period than the fibers are sufficiently plastic to weld together fibers intersecting in their vicinity. As the temperature of the steam or inert vapor exceeds the temperature of the polymer at fiber-forming fluidity, fibers of decreasing orientation and staple lengths are formed and with still higher temperatures the polymer is depolymerized or decomposed.

Where emphasis is on the production of highly oriented and crimped staple fibers of an average staple length suitable for twisting or felting purposes, e. g. to 15 inches, the elastic fluid is supplied to the nozzle assembly **17** at a high enough temperature such that despite temperature losses caused by adiabatic expansions within the nozzle passageways and conduction of heat to the metal surfaces of the nozzle body, the elastic fluid arrives at the junction of the polymer feed orifices **38** with the central orifice **40** at substantially the same temperature as the fiber-forming fluidity temperature of the polymer. Superheated steam is a desirable inert gas for forming fibers from most polymers since together with its inertness to most polymers, adequate high temperatures are available when it is supplied at moderate pressures such as 5 to 60 p. s. i. to a fiber-forming nozzle as illustrated in the drawing having a central common orifice **40** with a bore of about $\frac{3}{16}$ inch diameter and an auxiliary annular nozzle port **43** of about 0.015 inch radial width.

In the following examples operational details are given with respect to various fiber forming organic polymers for the purpose of further illustrating the invention, but not in limitation of the invention except as defined in the appended claims.

Example 1.—Polystyrene of about 50,000 average molecular weight was heated to 200°–260° C. in a closed container and then pumped into a fiber-forming nozzle as depicted in the drawing. The annular film of molten styrene in each passageway **31** of the fiber-forming nozzle was about 0.010 inch radial thickness at the exit end of the passageway **31**. Two multi-turn induction coils producing about 15,000 ampere turns of 60 cycle alternating electric current with about 160 to 200 volts imposed on the coils produced a nozzle tip **22** temperature of about 380° C. as determined by a pyrometer. Saturated steam at 100 p. s. i. was superheated in a gas fired superheater to between 315° to 400° C. and then fed into the steam passages **41** and **42** of the fiber forming nozzle at about 35 p. s. i. The combined heating effect of the steam and induction heaters caused the polystyrene to attain a maximum temperature of about 370° C. as it left the nozzle. Adjusting the pumping means to feed molten polystyrene at a 5 lb. per hour rate to the nozzle polymer orifices **38** of about 0.040 inch diameter and a common central orifice **40** of about 0.1875 inch diameter resulted in a continuous production of a stream or tow of kinky oriented staple fibers having an average diameter of about 4 microns and a length estimated at about 4 to 10 inches and which were elastically deformed or cold drawn to the extent of 300 to 400 per cent as evidenced by contraction of the fibers when subsequently reheated to their softening temperature. When superheated steam at 50 p. s. i. was supplied to the nozzle, the mass of fibers ejecting from the nozzle tended to fuse together when collected due to the excess heat contained in the steam at higher pressure, and the fibers were oriented or "cold drawn" to lesser degree, although attenuated into finer and shorter filaments. When the nozzle tip temperature was reduced to about 300° C. and lower by reducing or completely cutting off the current to the induction coils and depending solely upon the superheated steam for heating of the polymer mostly beads or atomized particles of polystyrene were obtained out of the nozzle tip and very little fiber.

Although a nozzle tip **22** temperature of about 350° to 400° C. is satisfactory for forming feltable oriented staple fibers from polystyrene of about 50,000 average molecular weight, a somewhat higher nozzle temperature is required for polystyrene of higher molecular weight for instance 375° to 425° C. for polystyrene having an average molecular weight of about 80,000. Conversely with styrene polymers of lower average

molecular weight, lower nozzle tip temperatures are required, e. g. about 330° to 370° C. for polystyrene of 30,000 molecular weight. This is in accordance with the understanding of the art that polymer fluidity is dependent upon the average molecular weight of the polymer. Under normal operating conditions as herein described less than 5 to 15 per cent of the polymer is lost by decomposition into monomeric or other volatile products, although in most instances the fibers are characterized by a lower average molecular weight than the original polymer.

It is surprising, however, that the presence of minor amounts, 10 per cent and less, of plasticizer or up to 40 per cent of unreacted monomer, high boiling solvents in the fiber-forming polymer as supplied to the nozzle assembly does not appreciably lower the nozzle tip temperatures otherwise required for substantially pure polymer of the same average molecular weight or appreciably affect the properties of the fiber. Apparently these volatile substances are almost instantly vaporized as soon as they contact the hot vapor or gas jet in the central common orifice 40. Even the high boiling and substantially non-volatile compatible plasticizers are to a considerable extent removed from the polymer at these high temperatures. Accordingly although pure polymers are generally desirable, polymers contaminated with solvent or monomer may also be satisfactorily used in the production of fibers.

Example 2.—Polydichlorostyrene having an average molecular weight of about 90,000 was formed into kinky oriented staple fibers using the same apparatus and technic as described in Example 1. A somewhat lower nozzle tip 22 temperature than that required for the polystyrene was found to be feasible, for fibers of an estimated average staple length of about 1 to 20 inches were readily obtained when the polydichlorostyrene came out of the nozzle tip at a temperature between 330° to 350° C.

Example 3.—Highly polymerized polyvinyl carbazole containing 10 per cent of a plasticizer to reduce its melting point to less than 200° C. was formed into kinky oriented staple fibers in the same manner as described in the previous example, although it was found necessary to heat the polyvinyl carbazole in the nozzle to issue therefrom at a considerably higher temperature such as between 400° to 430° C.

Example 4.—Polyethylene of about 20,000 average molecular weight formed short kinky oriented staple fibers when heated to about 400° C. and ejected from the same fiber-forming nozzle by superheated steam at 45 p. s. i. and similarly a polyethylene polymer of about 28,000 average molecular weight was processed into short kinky oriented staple fibers when heated to about 430° C. Although polyethylene is ordinarily sensitive to oxidation at elevated temperatures, no perceptible oxidation occurred during the fiber-forming operation. Presumably the steam employed in forming and ejecting the fiber being itself inert to the polymer together with the rapid cooling sufficiently protected the fiber against oxidation.

The staple fibers produced in accordance with the present invention find many uses. They may be employed as textile fibers in the production of water and chemically resistant fabrics. When collected in the form of bats by deposition of the fibers on a suitable foraminous surface, they can be employed as extremely light weight

thermal insulation product, for use at low to moderate temperatures depending upon the softening point of the polymers. The density of the bats can be varied according to the methods employed for collecting the fibers and any subsequent pressing operation. The fibers when deposited in a random and heterogeneous manner yield bats having in many instances apparent specific gravities less than 0.05 especially when precautions are taken to form fibers having a minimum quantity of attached beads.

The fibers can also be used as molding materials and by varying the molding pressure and temperature molded articles of any desired low density and up to the full molded density of the solid polymer can be readily obtained. In practically all instances considerably lower molding temperatures and pressures than is normally necessary for the polymer in a granular condition can be employed thus permitting the use of such low temperature and pressure molding procedures as the various bag molding operations.

Molding operations can also be facilitated by the use of preforms to which technic the present invention contributes advantages that were lacking in fibers formed by spinneret extrusion of synthetic fiber-forming polymers. The spinneret fibers lack sufficient twist or curl for forming interfelted bats and while preform bats can be formed from them, the fibers are normally deposited in parallel laminar fashion within the bats. Accordingly these bats are limited to planar shapes and must be carefully handled to avoid injury or self-destruction before insertion in the mold.

In contrast thereto self-coherent preform bats of any desired configuration can be readily formed from fibers produced according to the present invention. By ejecting the fibers as they are formed against rotating foraminous collecting surfaces, having a surface configuration conforming to the preform shape, a coherent felted bat of any desired thickness can be efficiently prepared thereon and stripped therefrom when of the desired size and shape. Oscillatory and/or other changes in rotative movements imparted to the foraminous collecting surfaces can be employed to suitably regulate the thickness of the bat at various parts as for instance in dome-shaped preforms where a rim portion of considerable thickness is required and thin walls in the remainder of the shell. Interfelting of the fibers deposited on collecting surfaces can be promoted by maintaining the interior of the fiber collecting surface at lower atmospheric pressures than normal, thereby drawing the fibers together. Alternatively the fiber-forming nozzle may be controlled in the manner previously described so that a certain proportion of beads are formed together with the fibers. The beads because of their greater mass cool at a slower rate than the fibers and therefore act as local hot spots to cause welding of intersecting fibers in their proximity. Bats containing beads are somewhat higher in apparent density, but are more resistant to fiber segregation and can be elongated by applied tension to as much as 30% before disintegrating.

In illustration of the molding properties of the fibers, reference is particularly made to the polystyrene fiber prepared in accordance with Example 1. These fibers were collected as a bat on the rotating drum 23 and were compression molded at various temperatures and pressures into bars and other flat shapes suitable for physical test-

ing by conventional methods. The test results are given in the table.

Table

Mold Temperature, °F.	Molding Pressure, p. s. i.	Curing Cycle in Minutes	Density of of Molded Piece
210	34	25	0.802
210	34	20	0.722
210	34	10	0.647
230	34	10	0.915
230	14	10	0.740
230	7	5–7	0.630–0.700
200	5	5	0.500

Tensile and flexural strength of the molded articles increases as the density increases; tensile strength being from 600 to 2000 p. s. i. for test bars having densities in the range between 0.630 and 0.910 and similarly the flexural strengths range from 1700 to 3200 p. s. i.

The power factor for the above molded samples as measured at 15 megacycles ranges from 0.00010 to 0.0003; dielectric constant is generally a direct function of the density of the molded article ranging from 1.6 to 2.3.

Softening temperatures of the molded articles are practically identical with molded articles of full molded density prepared from conventional polymer in granular form, since panels molded from the fibers withstood a temperature of 190° F. for two hours without any measurable distortion due to unmolding.

In the appended claims, the expression "fiber-forming organic polymer" is intended to define those fusible organic polymers which in the absence of oxygen or air can be heated rapidly to a fiber-forming fluidity without being substantially decomposed or depolymerized. These polymers, in addition to the polymers described in the examples include the polymers resulting from the polymerization of ethylenically unsaturated monomers such as the vinyl polymers and copolymers, acrylates, and acrylonitrile polymers and copolymers, natural and synthetic rubber, and the fusible condensation polymers such as the alkyd resins and polyamides. The expression "inert compressed elastic fluid" is intended to define those vapors or gases such as steam and nitrogen that are substantially chemically and physically inert with respect to the polymer at the temperatures and time intervals employed in forming fibers therefrom in accordance with the invention as herein described and claimed.

What is claimed is:

1. Method for forming fibers from a fusible fiber-forming organic polymer which comprises liquefying the polymer by rapidly heating it to its decomposition temperature under non-oxidizing conditions, forming a liquid film of the heated polymer on a solid surface from which oxygen is excluded and which is substantially at the same temperature as the heated polymer, acting upon the film of the liquid polymer by a stream of inert elastic fluid substantially at the same temperature as the liquid polymer to draw out fibers from the film, and ejecting the elastic fluid and the fibers into the atmosphere to cool and solidify the fibers.

2. Method for forming staple fibers from a fusible fiber-forming organic polymer which comprises liquefying the polymer by rapidly heating it to its decomposition temperature under non-oxidizing conditions, forming a liquid film of the heated polymer on a solid surface from which oxygen is excluded and which is substantially at the same temperature as the heated polymer, acting upon the film of the liquid polymer by a blast of inert elastic fluid substantially at the same temperature as the liquid polymer and moving at a velocity sufficient to draw out fibers from the film and to sever the fibers into staple lengths, and ejecting the elastic fluid and the fibers into the atmosphere to cool and solidify the fibers.

3. Method for forming feltable oriented staple fibers from a fusible fiber-forming organic polymer liquefying the polymer by rapidly heating it to its decomposition temperature under non-oxidizing conditions, forming a liquid film of the heated polymer on a solid surface from which oxygen is excluded and which is substantially at the same temperature as the heated polymer, acting upon the film of the liquid polymer by a blast of inert elastic fluid substantially at the same temperature as the liquid polymer and moving at a velocity sufficient to draw out fibers from the film and to sever the fibers into staple lengths, discharging the elastic fluid and the fibers into the atmosphere, cooling the fibers to a cold-drawing temperature while being propelled by the elastic fluid, and cold-drawing the cooled fibers by action thereon of the propelling elastic fluid.

4. Method of forming an integral felted bat from a fusible fiber-forming organic polymer which comprises liquefying the polymer by rapidly heating it to its decomposition temperature under non-oxidizing conditions, forming a liquid film of the heated polymer on a solid surface from which oxygen is excluded and which is substantially at the same temperature as the heated polymer, acting upon the film of the liquid polymer by a blast of inert elastic fluid substantially at the same temperature as the liquid polymer and moving at a velocity sufficient to draw out fibers from the film and to sever the fibers into staple lengths, discharging the elastic fluid and the fibers into the atmosphere to cool and solidify the fibers and collecting the cooled fibers on a foraminous surface.

5. Method of forming an integral felted bat from a fusible fiber-forming organic polymer which comprises liquefying the polymer by rapidly heating it to its decomposition temperature under non-oxidizing conditions, forming a liquid film of the heated polymer on a solid surface from which oxygen is excluded and which is substantially at the same temperature as the heated polymer, acting upon the film of the liquid polymer by a blast of inert elastic fluid at a lower temperature than the liquid polymer to cause fibers and a small proportion of beads to be withdrawn from the film, discharging the elastic fluid, fibers and beads into the atmosphere, so as to cool and solidify the fibers while maintaining the beads in a sufficiently plastic state to cause welding together of fibers intersecting in their proximity.

6. Method of forming staple fibers from a fusible vinyl polymer which comprises liquefying the polymer by rapidly heating it to its decomposition temperature under non-oxidizing conditions, forming a liquid film of the heated polymer on a solid surface from which oxygen is excluded and which is substantially at the same temperature as the heated polymer, acting upon the film of the polymer by a blast of superheated steam substantially at the same temperature as the liquid polymer and moving at a velocity sufficient to draw out fibers from the film and to sever the drawn fibers into staple lengths, and discharging

the fibers and the steam into the atmosphere to cool and solidify the fibers.

7. Apparatus for forming fibers under non-oxidizing conditions from a fusible organic polymer comprising a container having two entrance ports and a tubular nozzle having an interior lateral wall, a passageway for said polymer extending through the container from one of said ports and terminating in an opening through said lateral wall enabling liquid polymer to flow from said passageway onto the lateral wall as a continuous film, a filler-rod positioned in said passageway ahead of said opening to form therewith a narrow annular passage, means associated with the container for heating to fiber-forming fluidity the polymer being forced through the annular passage on its way to the tubular nozzle and another passageway through the container from the second port to the tubular nozzle for conducting elastic fluid from said port to the nozzle for drawing the fluid polymer into fibers.

8. Apparatus for forming fibers under non-oxidizing conditions from a fusible organic polymer comprising a metal container having two entrance ports and a tubular nozzle having an interior lateral wall, passageways for liquefied polymer extending through the container from one of said ports and terminating in openings through the lateral wall enabling liquefied polymer to flow out of said passageways and directly onto said lateral wall as a continuous film, a metal filler-rod positioned in each passageway to form therewith a narrow annular passage, electric induction heating means associated with the container for heating to fiber-forming fluidity the polymer being forced through the annular passages to the tubular nozzle, and other passageways through the container from the second port to the tubular nozzle for conducting elastic fluid from said port to the nozzle for drawing the fluid polymer into fibers.

9. Apparatus for forming fibers under non-oxidizing conditions from a fusible organic polymer comprising a metal container having two entrance ports, a tubular nozzle having an interior lateral surface, an annular nozzle encircling the end of the tubular nozzle, passageways for liquefied polymer extending through the container from one of said ports and terminating in openings in said interior lateral surface enabling liquid polymer to be discharged from said passageway and directly flow onto said surface as a liquid film, a metal filler-rod positioned in each passageway to form therewith a narrow annular passage, heating means associated with the container for heating to fiber-forming fluidity polymer being forced through the annular passages to the tubular nozzle, other passageways through the container from the second port to the tubular nozzle for conducting elastic fluid from said port to the nozzle for drawing the fluid polymer into fibers, and still other passageways through the container from the second port to the annular nozzle for conducting elastic fluid to draw fluid polymer collecting at the end of the tubular nozzle into fibers.

10. Apparatus for forming fibers under non-oxidizing conditions from a fusible organic polymer comprising a metal container having two entrance ports, a tubular nozzle having a perforated lateral wall, an annular nozzle encircling the end of the tubular nozzle, passageways for liquefied polymer extending through the container from one of said ports and terminating in the perforations of the tubular nozzle at an acute angle thereto enabling liquid polymer to discharge from said passageways directly onto said perforated lateral wall as a film thereon, a metal filler-rod in each of the passageways to form a narrow annular passage, a low-frequency electric induction heating means encircling the container for heating to fiber-forming fluidity polymer forced through the annular passages to the tubular nozzle, other passageways through the container from the second port to the tubular nozzle for conducting elastic fluid from said port to the tubular nozzle for drawing said film of fluid polymer into fibers, and still other passageways through the container from the second port to the annular nozzle for conducting elastic fluid to draw fluid polymer collecting at the end of the tubular nozzle into fibers.

11. A method for preparing fibers from a fiber-forming polymer by the action thereon of an inert elastic fluid in a structure having an annular passage for the polymer, a tubular nozzle and an opening from the passage into the interior lateral wall of the nozzle which comprises imparting fiber-forming fluidity to the polymer by heating the polymer in the passage and in the absence of oxygen to its decomposition temperature under non-oxidizing conditions, continuously forcing the heated polymer through the opening and depositing it as a liquid film on the interior wall of the tubular nozzle, forming fibers by acting upon the film with inert elastic fluid substantially at the same temperature as the liquid film and moving through the nozzle at a velocity sufficient to draw fibers off said film, ejecting the fibers from the nozzle and cooling the ejected fibers below their softening temperature.

12. A method for preparing fibers from a fiber-forming polymer by the action thereon of an inert elastic fluid which comprises imparting fiber-forming fluidity to the polymer by rapidly heating a thin layer of the polymer in the absence of oxygen to its decomposition temperature under non-oxidizing conditions, forming a liquid film of the heated polymer on a solid surface from which oxygen is excluded and which is substantially at the same temperature as the heated polymer, forming fibers by acting upon the liquid polymer film with an inert elastic fluid substantially at the same temperature as the film and moving at a velocity sufficient to draw fibers from the liquid film and cooling the fibers below their softening temperature.

WALTER R. MARSHALL.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
Re. 21,814	Albertson	June 3, 1941
Re. 22,494	Ferguson	June 13, 1944
1,769,181	Jackson	July 1, 1930
1,916,402	Allen	July 4, 1933
2,126,411	Powell	Aug. 9, 1938
2,130,948	Carothers	Sept. 20, 1938
2,133,235	Slayter	Oct. 11, 1938
2,156,316	Slayter et al.	May 2, 1939
2,190,153	Holmes	Feb. 13, 1940
2,219,346	Thomas et al.	Oct. 29, 1940
2,226,447	Smith et al.	Dec. 24, 1940
2,338,473	Von Pozsiczky	Jan. 4, 1944
2,411,660	Manning	Nov. 26, 1946

Certificate of Correction

Patent No. 2,508,462 May 23, 1950

WALTER R. MARSHALL

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 12, line 12, before the word "liquefying" insert *which comprises*;

and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 26th day of September, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.