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[54] **ELECTROSTATIC COATINGS**
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164/60, 48, 82, 67, 86, 99, 107, 122, 89, 49;
18/8(A,C,U,E,QA)

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ABSTRACT: This invention provides a process for forming filaments from molten material which comprises the continuous casting of a molten jetstream of the material, rapidly cooling and stabilizing the stream to prevent droplet formation by contacting the stream with a coolant medium comprising finely dispersed coolant particles. Then, an electric charge is imposed on the particles and a charge is imposed on the stream of opposite polarity to that on the particles, the difference in the charges being sufficient to attract the coolant particles to the molten jetstream, attracting the particles to the jet, thereby cooling and solidifying the jet, and recovering a composite case filament.

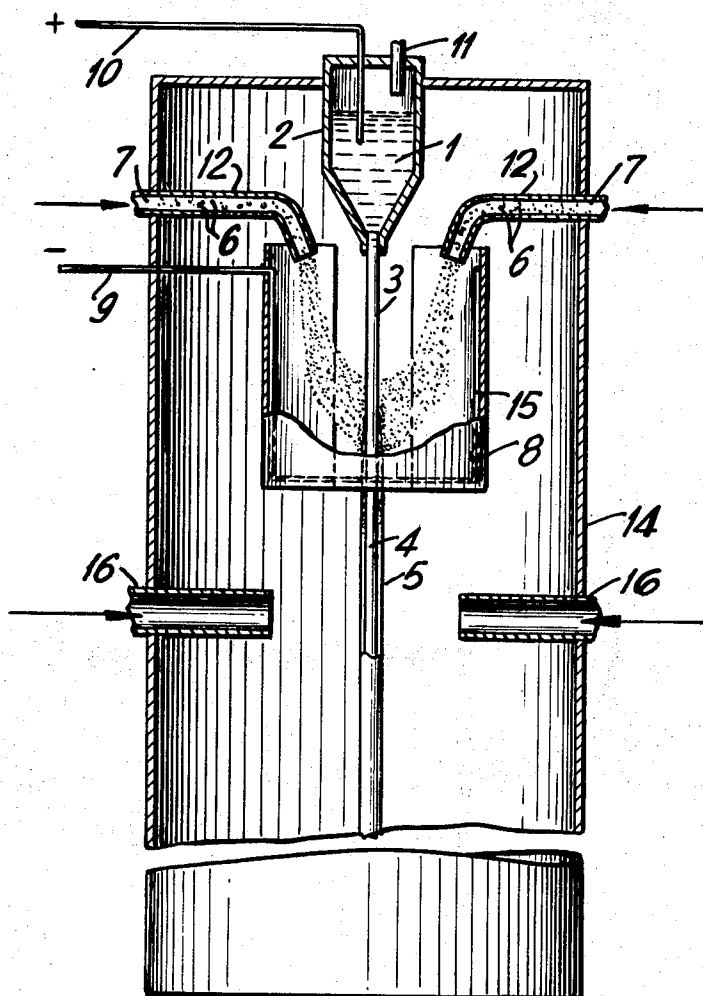


FIG. 1

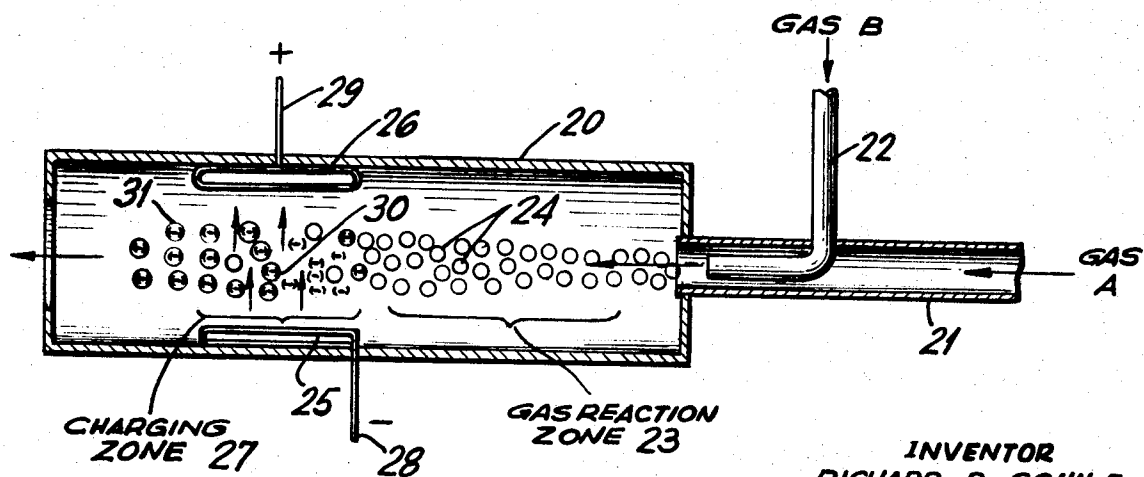


FIG. 2

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ELECTROSTATIC COATINGS

A process for cooling and stabilizing a continuous cast molten filament comprising electrostatic contacting of said filament with finely dispersed coolant particles and articles produced thereby as described hereinbelow.

The process of the present invention relates to novel filaments and to a method of producing filaments from refractory and nonrefractory materials. The present invention relates to the production of wires, filaments or fibers from molten material by passing the molten material through an orifice and cooling, stabilizing and solidifying the resultant molten material jet by controlled contact with finely divided coolant particles.

This invention particularly relates to process of forming metal wires, fibers and filaments by melting a metal and passing it as a continuous stream of molten metal through an orifice.

The jet will remain in the form of a circular cylinder for a certain length of time after passing through the orifice, depending on the physical properties of the molten material, after which the jet normally degenerates into droplets. Molten streams become unstable due to wave motions set up on the surface of the jet which become amplified, making the jet unstable and causing it to break into droplets.

The process of this invention provides for the formation of a layer of material on the surface of the molten metal jet, thereby preventing its breakup into droplets and also provides for rapid cooling of the jet by absorbing the heat of fusion of the molten metal. The heat of fusion is absorbed by finely divided particles which are contacted with the jet.

The molten material jet can be stabilized by cooling the molten material to form the stabilizing layer of the molten material, cooling and stabilizing the jet by deposition on the surface of said molten material of a stabilizing layer of coolant particles. The stabilizing of the molten material jet prevents the degeneration of the jet into droplets for a sufficient period of time to allow the jet to solidify in the form of a continuous filament.

In accordance with the present invention, the molten metal jet is made to pass through a zone containing dispersed therein finely divided particles which are provided with an electric charge. The particles can be charged by passing them through a corona discharge zone during which they acquire an electric charge. The molten metal is arranged to have a polarity opposite to that of the charged particles, thereby causing an electrostatic force of attraction to exist which draws the particles to the jet, thereby rapidly cooling and solidifying the jet.

By providing an electrostatic force of attraction between the coolant particles and the molten jetstream, a large number of particles are attracted to the jet in a very short period of time, thereby providing sufficiently rapid cooling to absorb the heat of fusion and allow the jet to harden. The particles also provide a protective stabilizing sheath of solid material on the molten jet which stabilizes the jet and prevents droplet formation, thereby allowing the jet sufficient time to give up its heat of fusion and to harden without breaking up into droplets.

The present invention relates to a casting process for molten metal, which metal is not confined by a mold on any surface nor cooled by contact with any surface.

More specifically, the present invention is directed to a process of forming continuous metal filaments from refractory materials and high melting reactive materials, which materials have not heretofore been able to be formed into metal filaments by conventional means.

The conventionally used methods of filament production are not applicable to certain hard, refractory, and reactive metals. In the conventional processes of forming molten metal jets of refractory metals and/or reactive metals, wave motions are set up on the surface of the molten metal jet which makes the jet unstable and causes the jet to break up into droplets, which effectively prevents the formation of a continuous filament of the metal.

The problem has been how to effectively remove the heat of fusion at a sufficiently high rate so that the jetstream becomes stabilized and droplet formation prevented until sufficient time has passed for the jet stream to solidify into a solid filament.

In order to increase the cooling rate of a molten jetstream, it has been proposed to direct a cold stream of air at the jet but this proved to be ineffective because it created additional turbulence on the surface of the jetstream, thereby aggravating the wave motion and enhancing the breakup of the stream and droplet formation. Another procedure attempted was to contact the jet with a spray of water droplets, but this also tended to cause breakup of the jet into droplets.

The problem therefore has been how to effectively cool and stabilize the molten metal jetstream, particularly where the jet consists of refractory materials or highly reactive materials, before the jet becomes unstable and breaks up into droplets.

In accordance with the present invention, molten metal is extruded through an orifice into a vessel containing a cooling medium comprising finely divided particles. The molten stream of metal is solidified into a continuous filament in the cooling vessel by bringing it into contact with the finely divided coolant particles. The cooling particles used will be determined by the type of metal filament to be formed, the temperature of the molten metal, and the chemical reactivity of the molten metal. The molten metal jet flows under the force of gravity through the dispersion of particles for a sufficient distance to effect solidification of the jet.

The molten jet is cooled by bringing it into contact with the suspension of finely dispersed coolant particles which, on contact with the molten jet, absorb the heat of fusion thereby cooling at least the surface of the jet and hardening the surface to stabilize it for a sufficient period of time for the remainder of the metal jet to form into a solid filament.

In accordance with the present invention, in order to substantially increase the number of hits or contacts for any given period of time, that is, the number of coolant particles in the suspension which come into contact with the jet, the coolant particles are provided with an electric charge. The molten jet itself acts as an anode and is of opposite charge to that of the particle and attracts the coolant particles to the jet. The jet, as it passes through the coolant particles, strongly attracts the coolant particles to the jet thereby effecting rapid cooling and stabilization of the jet.

The rate at which the cooling and stabilizing particles are deposited on the jet is critical and determines whether or not filament formation will be successful. If the deposition rate is too low, the jet will break up into droplets before it can be solidified in the form of a filament. In order to obtain high deposition rates, the particle flow rate must be sufficiently high, the particles must be rapidly charged, and the time of transit of each particle from the charging device to the jet must be low. The transit time of an individual particle depends on the ratio of the electric charge on the particle to the mass of the particle. The electric charge is proportional to the surface area of the particle and the mass is proportional to the volume of the particle. Therefore, in order to obtain a short transit time, the particles must be very small. Particles in the submicron size range are preferred.

The coolant particles can comprise solid particles or liquid particles. The solid particles may be chemically reactive or nonreactive with the molten jet. Similarly the liquid particles can be chemically reactive or nonreactive. The solid particles provide both stabilization and cooling of the molten metal jet. The liquid particles can be used for stabilizing as well as cooling the jet. The liquid particles can be used to provide cooling by themselves or can be used subsequent to a solid particle deposition step to obtain additional cooling of the jet. Generally the liquid particles are used in a subsequent cooling step.

The particular type of coolant particles selected will depend on the particular molten metal jet being cast into a filament and the desired physical characteristics of the end product

filament. Also depending on the filament being cast and the desired end results to be obtained, any of the above cooling means may be used alone or in combination.

The electrostatic charge is imposed on the finely divided dispersed coolant particles by causing the particles to pass through a corona discharge, during which they acquire an electric charge.

The coolant particles can be selected so that they do not react with the molten metal but melt or sinter on contact with the jet and form a protective sheath on the surface of the jet. The presence of the sheath stabilizes the jet and prevents the jet from breaking up into droplets.

The molten metal to be cast into a filament can be a high melting refractory metal and/or a highly reactive metal.

The coolant particles can consist of finely dispersed liquid particles, which liquid particles can be reactive or nonreactive. The liquid particles can react with the metal filament and form a solid reaction product on the surface of the filament and/or can form an alloy with the filament or they can be inert and be used for cooling, e.g. they can vaporize on contact with the hot filament.

A coolant medium of solid finely dispersed particles can be used. The solid particles can be reactive or nonreactive, i.e. with reference to the molten jet. They may be a fine dispersion of metal particles or a fine dispersion of chemical particles. Depending on the mutual solubility of the solid particles and molten metal jet, e.g. where metal particles are selected as the coolant medium, they may dissolve partially or totally in the jetstream to form an alloy having the same alloy composition throughout the cross section of the diameter of the filament. They may, on the other hand, form an outer layer of the metal particles with an intermediate layer containing a diffused layer of a metal particle and molten metal and a core of the filament metal.

The cooling and particle deposition steps can be carried out at the same time as the particle charging step is carried out and/or the charging step and particle deposition can be carried out separately. The charging step in each case is carried out in an atmosphere capable of being charged and capable of transferring the charge to the coolant particle.

The process is carried out by heating the metal to be cast to its melting temperature or somewhat above its melting temperature. The metal is heated to a temperature at which it can be easily handled and passed through a small orifice. The coolant medium is usually at about ambient temperature and contains the finely dispersed coolant particles.

One of the primary advantages of the present process is in obtaining a high rate of contact of the finely dispersed coolant particles with the molten metal jet to be cooled. This high contact rate is obtained by imposing a high electrostatic field voltage gradient between the particles and the molten metal jet, thereby causing attraction of the coolant particles to the jet and rapid cooling and stabilizing of the jet.

The invention may be better understood by referring to the FIGS. of the drawing which are illustrative of the procedures and of the apparatus that can be used in the process of the invention. The FIGS. of the drawing schematically show procedures for contacting the molten metal jet with the finely dispersed coolant particles.

The invention has particular application to making filaments from metals such as nickel, chrome, titanium, beryllium and various nickel and chrome alloys. The process can also be used with relatively nonrefractory metals such as copper and aluminum. Other metals that can be cast into continuous metal filaments, by using the process of this invention, are silicon, boron, vanadium, manganese, zirconium, etc. and many alloys.

The coolants that can be used in accordance with this invention are finely dispersed coolant particles. Such particles can comprise liquids which are nonreactive, such as water, and liquids which are reactive, such as hydrocarbons, and organic liquids in general. The coolant particles used have a resistivity of less than 10^8 ohm cm.

The coolant liquids can be pure liquids or can contain dissolved salts, such as boric acid, sodium chloride and other inorganic mineral salts or organic salts. The salts can be used to increase the rate of absorption of the heat of fusion of the metal filament or can chemically react to carry out a particular desired chemical reaction with the metal filament being cast.

The preferred coolants of the present invention are finely divided solid particles. Finely divided particles can be reactive or nonreactive and can be metals or can be chemicals and/or chemical compounds. Metals can be selected which are mutually soluble with the metal material being cast.

The temperature to which the molten metal is heated and the temperature of the coolant particles and the rate of deposition of the coolant particles on the metal filament will determine whether or not an alloy having a uniform composition in cross section of the diameter of the filament is obtained or a filament consisting of a core of the metal and a sheath of the coolant material.

Metal particles, such as aluminum, copper, zinc, and tin, can be used. Chemicals or chemical compounds can also be used as coolant particles which are selected to either melt or sinter to form a protective sheath on the metal filament being cast or can be selected to react with the metal filament to form and obtain a protective sheath of the reaction product of the metal and the chemical particles on the surface of the molten metal jet. A suitable chemical particle can be graphite and a suitable metal particle can be tungsten. The graphite reacts to form metal carbides and the tungsten will form metal-tungsten alloys. Nonreactive coolant particles can be used which form a protective sheath of the coolant, such as boron nitride and silicon dioxide.

In order to put an electric charge on the particles, the coolant and stabilizing particles are dispersed in a gas which is capable of generating a sufficient number of negative ions under an impressed electric field gradient to support a corona discharge. A suitable gas medium is helium containing a small amount, e.g. 1—5 percent by volume, of boron trichloride. A combination of an inert gas and a gaseous chemical compound containing e.g. chlorine or fluorine is also generally suitable and can be used to support a corona discharge.

The metal filaments formed in accordance with this invention can be either high melting or low melting. The high melting metals are generally those that melt above about $1,500^\circ\text{C}$. and low melting metals are those that generally melt below about $1,500^\circ\text{C}$. Iron is considered to be more or less in the middle and melts at about $1,535^\circ\text{C}$.

Coolant particles can be selected so as to affect the characteristics of at least the surface layer of the metal filament being cast. Thus coolant materials can, by diffusion into a surface layer of the filament, influence the chemical and/or physical properties of the surface layer. The coolant particles or liquids on contact with molten metal filament absorb at least a portion of the heat of fusion of the filament, stabilizing the surface, and preventing droplet formation.

In addition to the above named coolant particles, finely divided particles of glass or silicon dioxide can be used. Also, the solid particles can be selected so that they do not react with the molten metal but rather merely melt or sinter on contact with the jetstream and form a protective sheath on the surface of the jet. Liquid particles can be selected so that they do not chemically react with the jet but vaporize on the surface of the jet, thereby rapidly absorbing the heat of fusion of the jet, cooling and solidifying the jet.

In accordance with the present invention, the metals to be cast into continuous filaments are heated to a temperature at which they melt and are passed through an orifice which provides an outside diameter of molten metal jet of 0.0001—0.050 inch; the outside diameter of the metal being cast will generally be nearly the same as the inside diameter of the orifice through which it is passed. Preferably the molten metal jets are cast having diameters of 0.001—0.005 inch. Depending on the particular coolant medium being used, the finished

diameter of the cast jet can be about the same as the diameter at which it was cast. Where a reaction takes place on the surface or merely a surface coating is applied as a protective sheath, the thickness of the coating or protective sheath can vary between extremely thin, e.g. about 10 percent, up to about 100 percent of the diameter of the molten metal jet.

The metal to be cast can be heated to a temperature at which it melts and can, when required, be superheated so that the molten metal is sufficiently fluid and has a viscosity which permits it to be cast at the rate desired. Normally the amount of superheat will be about 0 to 10 percent of the absolute melting point temperature of the metal. The cooling medium, that is the temperature of the coolant particles, plus the inert gas in which it is dispersed, will be about ambient temperature. Cooling medium temperatures of 20° to 30° C. are satisfactory. Sufficient pressure is applied to the container containing the molten metal to provide a smooth flow of molten metal. The amount of pressure required to cast the molten metal will vary with the viscosity, surface tension and density of the metal being cast and the size of the orifice. The jet velocity of the molten metal can be between 500 to 2,000 ft. per minute, e.g. 600—1,000. The pressure at which the metal is cast will usually be between 10 and 100 pounds per sq. inch gauge above the pressure in the cooling medium, depending on the orifice size.

The coolant particles, be they liquid or solid, can be of a particle size of a fraction of a micron to several microns in diameter. Suitable particles can be 0.1 micron to 50 microns in size. Particles of submicron size are preferred.

The coolant particles are charged by passing them through a corona discharge which is occurring between two electrodes. An adjustable d.c. voltage is applied across the two electrodes. As the voltage is increased, a voltage is reached at which negative ions appear about the cathode. The negative ions drift across the gas space and reach the anode where they are neutralized. When the gas space contains very small particles, the ions collide with the particles and become attached to them, giving the particles a negative charge. If the voltage is increased further, a voltage is reached at which positive ions are generated at the anode, in addition to negative ions at the cathode. No particle charging occurs under these conditions and the voltage must be set below this point.

When the negatively charged particles come near a positively charged surface, they are attracted to the surface and are deposited on it. When a particle makes contact with the positively charged surface, it must give up its charge or the accumulation of negatively charged particles will cause negative ionization and expulsion of the particles. This is called reverse ionization and does not occur if the electrical resistivity of the particles is less than about 10^8 ohm cm.

The anode of the charging circuit may be made the surface on which deposition is desired or the particles may be charged with one set of electrodes and then collected on the anode of a second set of electrodes. Where a second set of electrodes is used to collect the charged particles, the electrodes are maintained at a lower potential than the charging electrodes in order to minimize the possibility of accidental reverse ionization at sharp points on the particles.

The molten jet can be made the collecting anode by connecting the jet to the charging circuit through the melt in the crucible.

Where the same electrodes are used to charge the particles and to deposit the charged particles, the voltages used can be between 2,000 and 20,000 volts depending on the particles charged, the spacing between the electrodes and the gas used to generate the negative ions.

Voltages of 5,000 to 20,000 volts can be used in the charging step on the particle charging electrodes when the charging and depositing are each done in separate steps, in which case voltages between 500 to 5,000 volts can be used on the collecting electrodes. The voltages used also depend on the gas used, the coolant particles, and the size, i.e. diameter, of the collecting surface, i.e. jet.

The coolant particles may be dispersed in the gas stream by mechanical means or they may be produced by a gaseous chemical reaction prior to entering the ionizing or charging unit. The latter means is particularly desirable because the particles produced are extremely small in size. For example, carbon particles may be produced by decomposition of a gaseous hydrocarbon. Extremely small particles of boron nitride may be produced simply by mixing and reacting ammonia with boron trichloride vapor before the gases enter the ionizing unit. Other coolant particles, such as silicon dioxide particles, can be produced in a similar manner by reacting silicon tetrachloride and steam.

The heat of fusion of the molten metal jet can be absorbed in many ways. For example, with reference to dispersed water droplets having an electric charge and containing dissolved salts, the heat of fusion can be absorbed by vaporization of the water, removal of heat of solution of the dissolved salts, removal of combined water of the dissolved salts, melting of the salts and/or vaporization of the dissolved salts.

Where solid particles are used as a coolant medium, the heat of fusion of the solid particles in contact with the metal jet can absorb the heat of fusion and where the solid particles chemically react with the molten metal jet, if the reaction is endothermic the heat of reaction can absorb part or all of the heat of fusion. If the reaction is exothermic, an additional cooling step may be necessary, using, for example, a nonreacting coolant.

Where the solid particle vaporizes on contact with the molten metal jet, the heat of vaporization can absorb all or part of the heat of fusion.

The protective stabilizing layer can have a melting point below the melting point of the molten jet material and good stabilization is obtained when the coolant is selected to form such a coating.

The invention may be better understood with reference to the FIGS. of the accompanying drawing. FIG. 1 of the drawing is a schematic illustration of apparatus that can be used to carry out one embodiment of the process of the present invention.

With reference to the drawing, there is vertically disposed elongated cylindrical vessel 14 in which the filaments are cast. Inside of vessel 14 there is a cylindrical cathode member 8, supported by means not shown. The cylindrical cathode 8 can be made of one-half of a cylinder, i.e. a semicircle, when viewed at its end, or two semicircles, each connected to a high voltage source of a negative polarity. One or more very fine wires 15 are fastened to the inside surface of the cylindrical cathode to provide a sharply-curved surface for generating the negative ions for charging the coolant particles. The wires have the same polarity as the cylindrical cathode. The molten jet stream 3 is directed to the center of curvature of the cathode member 8. By applying a high negative voltage to cathode member 8 an electrostatic gradient of high potential is established in an area surrounding the molten jet 3. The finely dispersed coolant particles are fed into the cylindrical cathode 8 by conduits 12. The conduits 12 can be provided in one position or in two or more positions so as to surround the molten jetstream 3 with a dispersed phase of charged coolant particles. By introducing the finely divided coolant medium into the region of the electrostatic field, the coolant particles can be given the desired electric charge. The coolant particles are charged by collision with the negative ions in the electric field and are attracted to and deposited on the molten jetstream.

The molten jet is provided with a polarity opposite that of the charged particles by connecting the molten metal 1 with a positively charged electric lead 10. Electric lead 10 is connected directly to the molten metal 1 in the crucible 2 containing the molten metal. Pressure is applied, e.g. using an inert gas, to the crucible through a conduit 11 which communicates with a pressure source to develop a positive pressure in the crucible. Sufficient pressure is applied to the molten metal through conduit 11 to provide a continuous even flow of the

molten metal jetstream 3. Finely divided coolant particles 6 of micron and submicron size are provided through conduits 12 using an inert carrier gas 7, capable of generating ions in an electric field.

The suspension of finely divided particles passes downward and there is imposed thereon a negative charge by their passing through the electric field and the particles are attracted to the molten metal jet 3 and rapidly contact, deposit thereon, and cool and stabilize the jet.

In this embodiment a stabilizing sheath 5 is formed on the outer surface of the rapidly hardening metal jet 4. Electric lead 10 and electric lead 9 are connected to a suitable power source which generates potential voltages 2,000 to 20,000 volts. The cathode 8 and anode 3 are not shown to scale and the distance between the cathode and anode can be, for example, $\frac{1}{2}$ to 2 inches.

The process is carried out in an inert gas atmosphere. Oxygen is not permitted in the container since it would cause an adverse reaction with the molten metal jet, particularly where highly reactive materials are being cast. A cooled and partially solidified metal jet 4 which has protective sheath 5 continues downward in vessel 14 until the filament is completely cooled and solidified. The cooled and hardened metal filament can be collected on a suitable rotating drum, not shown, at the bottom of vessel 14.

Additional cooling of the filament can be provided by introducing coolant particles into vessel 14 through conduits 16 situated at a point below the electrostatic charging and contacting zone. The secondary cooling step can be by simple contact and/or by an electrostatic cooling procedure similar to the one discussed above.

In the above described embodiment, the heat of fusion can be removed principally by contact of the molten metal jet with the finely divided charged coolant particles.

An alternate means of providing electrically charged particles will be described with reference to the embodiment of the invention disclosed in FIG. 2 of the drawing. In this embodiment the electrostatic field of FIG. 1 can be used to collect the charged particles on the molten metal jet 3. The particles, however, are generated and provided with an electric charge in the apparatus of FIG. 2. In this manner the particles can be provided with an electric charge at a high voltage, e.g. 5,000 to 20,000 volts, and collected on the molten metal jet at a lower voltage, e.g. 500 to 5,000 volts. This scheme can be used to advantage when back ionization becomes a problem.

In this embodiment the charging wires 15, FIG. 1, are removed from the inside surface of the cylindrical cathode 8 so that no ionization takes place in this region.

The electrostatic charge is applied to particles 24 in charging zone 27 by applying a voltage of 5,000 to 20,000 volts across electrodes 25 and 26, FIG. 2.

The charging apparatus comprises an insulating cylinder 20 having gas inlet conduits 21 and 22. The gases A and B are injected into the gas reaction zone 23 through conduits 21 and 22 respectively and immediately react to form extremely small dispersed coolant particles in a gas.

Suitable reactant gases that can be used to form the coolant particles can be ammonia gas introduced through conduit 21 and boron trichloride introduced through conduit 22. The two gases react in reaction zone 23 to form extremely fine dispersion of boron nitride and boron oxide particles in a carrier gas which is capable of supporting a corona discharge. A gas capable of supporting a corona discharge can be added to either of the reactant gases. In this case, however, HCl is a byproduct of the reaction and is capable of supporting a corona discharge.

The charging zone 27 is provided with a positive electrode 26 having the shape of an elongated cylinder with smoothly rounded contours and a negative electrode 25 in the form of one or more fine wires. A power supply, not shown, which generates voltages of 5,000 to 20,000 volts, is connected to the electrodes by leads 28 and 29, respectively. The voltage is adjusted so that negative gas ions 30 are generated at the

cathode 25 and flow across the charging zone 27 toward the anode 26 and charge particles 24 by collision. The flow rate of particles 24 is adjusted so that it is sufficiently fast, and the anode 26 is made sufficiently short so that no deposition of charged particles takes place on the anode 26.

The negatively charged coolant particles 31 exit the charging zone 27 and can be suitably fed, e.g. through conduits 12, FIG. 1, into cathode 8 where they are attracted to and collect on molten metal jet 3.

The coolant particles, however, of course, do not have to be formed by reacting two gases as described above. Any cooling particles of suitable size and type can be used in the apparatus of FIG. 2 and introduced through either or both of conduits 21 and 22. The above description is given merely as illustrative of one means of providing finely divided coolant particles.

This embodiment can be used as an alternate means of generating charged coolant particles and/or can be used as a supplementary means of providing charged coolant particles.

For example, conduit 16, FIG. 1, could be used as a means for providing charged coolant particles from the apparatus of FIG. 2 for cooling either molten metal jet 3 or for further cooling metal filament 4. In this case cathode 8, with wires 15 removed, could be extended downward to provide the electrostatic field for the charged particles introduced through conduit 16 to be attracted to filament 4. The depositing electrodes, FIG. 1, can be at a voltage of 500 to 5,000 volts.

Other suitable means for generating a fine dispersion of either liquid or solid coolant particles can be used by those skilled in the art. Finely divided particles of the type used in the present invention are commercially available in micron and submicron particle size. Mechanical means of dispersing the particles to obtain the fine dispersions suitable for charging in the present invention are also commercially available.

The invention is further illustrated by the accompanying examples which are given merely as illustrative and not limiting in any way.

EXAMPLE 1

In this example nickel is cast into a continuous metal fiber of 0.005 inch diameter, having surrounding it a protective sheath of silica of 0.001 inch thickness. The nickel is heated to a temperature of about 1,455° to 1,475° C. at which it is molten. Nickel is cast under pressure to obtain a continuous stream of molten nickel which is directed through an area containing finely divided silica particles of 0.1—1.0 micron in size.

The silica particles are made by reacting silicon tetrachloride diluted with helium and steam which produces a cloud of silica particles dispersed in a gas consisting of helium and hydrogen chloride. A negative electrostatic charge is imposed on the silica particles by passing silica particles through a high electrostatic field gradient imposed on the system by providing a voltage of 4,000 volts to the cylindrical cathode placed about 1 inch distance from the molten metal nickel jetstream anode. The silica particles are quickly attracted to the nickel jetstream, melt on the stream and adhere thereto, rapidly cooling the jet by absorbing the heat of fusion and solidifying the nickel stream. A composite wire filament is continuously cast at a rate of 500 ft. per minute having a center core of nickel of 0.005 inch diameter and an outer protective sheath of silica of 0.001 inch thickness.

EXAMPLE 2

Copper is continuously cast into copper filament having a diameter of .005 inch at the rate of approximately 600 ft. per minute. The cooling and stabilizing medium is a mixture of boron nitride and boron oxide particles which are produced by the reaction of boron trichloride, ammonia and steam. The cooling and stabilizing particles are charged by passing them through a corona discharge, between electrodes, at 8,000 volts potential difference and collecting them on the molten copper jetstream electrode at 2,000 volts. The distance

between the cathode and the jet in the collecting region is 1-1/2 inches. The 0.005 inch diameter copper filament has a coating of boron nitride and boron oxide deposited thereon of approximately .001 inch thickness which can, if desired, be removed by washing in hot water.

EXAMPLE 3

Molten silicon melting at 1,420° C. is cast from an 0.003 inch diameter orifice in a crucible at a pressure of 45 p.s.i., forming a jet of molten silicon. Carbon particles, produced by thermal decomposition of benzene, are electrostatically deposited, at a voltage of between 5,000 and 10,000 volts, on the silicon jet beginning at approximately 2 inches below the crucible orifice. At approximately 8 inches below the crucible orifice, silicon dioxide particles are deposited on the jet at 5,000 to 10,000 volts in a second deposition step which prevents further deposition and contact between the carbon and molten silicon. The carbon particles react with the molten silicon, producing silicon carbide which dissolves in the molten silicon. The extent of the reaction between the carbon and silicon is controlled by the distance from the crucible orifice that the silicon dioxide is deposited and by the rate of carbon deposition. The deposited silicon dioxide further stabilizes and cools the silicon-silicon carbide jet. Since the reaction between silicon and carbon is exothermic, a still further cooling step may be necessary and this is accomplished by depositing water droplets on the jet at approximately 24 inches below the crucible orifice. The water droplets may or may not be charged, depending on the amount of additional cooling needed. This quenches the reaction and further cools and solidifies the partially molten filament. The resulting filament is composed of controlled proportions of silicon and silicon carbide. The final diameter of the filament is approximately .0035 inch, including a thin coating of silicon dioxide of approximately .0002 inch thick. The filament production rate is approximately 600 ft. per minute.

EXAMPLE 4

A high carbon alloy steel is melted and cast through an .0035 inch orifice at 1,500° C. and 35 p.s.i. pressure. A mixture of boron nitride and a small percentage of boron oxide particles is deposited at about 8,000 volts on the molten jet stream, stabilizing and cooling the jet of molten steel and forming a continuous filament with a thin sintered boron nitrideboron oxide coating. The final diameter of the filament is approximately .0035 inch. The filament production rate is approximately 600 ft. per minute.

In a similar manner the following metals may be continuously cast by using the indicated materials as finely divided coolant particles.

Metal:	Particles deposited
Iron, steels.....	BN + B ₂ O ₃
Stainless steels.....	SiO ₂
Boron.....	BN + B ₂ O ₃
Titanium and titanium alloys.....	TiN, TiO ₂
Zirconium.....	C + ZrN

It can thus be appreciated that, according to the present invention, the molten metals being cast and the coolant medium are selected to provide an end product filament of desired physical and chemical characteristics. Metal filaments cast in accordance with the present invention find ready use as conductors, as structural strength members and have other known uses.

Obviously many modifications and variations of the present invention are possible and may appear obvious to one skilled

in the art in light of the above teachings and are intended to be included within the scope of the claimed invention.

I claim:

1. A process for forming filaments from molten metal which comprises continuous casting of a molten jetstream of said metal, rapidly cooling and stabilizing said stream to prevent droplet formation by contacting said stream with a coolant medium of finely dispersed coolant particles, imposing on said particles an electric charge, imposing on said stream a charge of opposite polarity to that on said particles, the difference in said charges being sufficient to attract said coolant particles to said molten jetstream attracting said particles to said jet, thereby cooling and solidifying said jet, and recovering a composite cast filament.

2. The process of claim 1 wherein said coolant medium comprises finely dispersed solid particles.

3. The process of claim 1 wherein said coolant medium comprises finely dispersed solid particles which react with said molten jetstream.

4. The process of claim 1 wherein said coolant medium comprises a fine dispersion of solid particles, which particles on contact with said molten jet melt and form a protective sheath.

5. The process of claim 1 wherein said coolant medium comprises a fine dispersion of solid particles, which particles on contact with said molten jet react with said jet, forming a reaction product on the surface of said jet which cools and stabilizes said jet.

6. The process of claim 1 wherein said coolant medium comprises a fine dispersion of liquid particles, which on contact with said molten jet vaporizes, cools and absorbs at least a part of the heat of fusion of said molten jet.

7. The process of claim 1 wherein said coolant medium comprises a fine dispersion of liquid particles, which particles on contact with said molten jet decompose, react with said molten jetstream, and form a reaction product on the surface of said molten jet, thereby stabilizing and solidifying said jet.

8. The process of claim 1 wherein said coolant medium comprises a fine dispersion of liquid particles, which dispersion contains dissolved therein an inorganic salt.

9. The process of claim 1 wherein said coolant medium comprises a fine dispersion of particles which are soluble in said molten jetstream and which, on contact with said jetstream, dissolve therein and form a solution of said molten jetstream and said coolant particles.

10. A process for forming filaments from molten metal which comprises continuous casting of a molten jetstream of said metal of 0.0001 to 0.050 inch diameter, rapidly cooling and stabilizing said stream to prevent droplet formation by contacting said stream, in an electric field of 2,000 to 20,000 volts, with a coolant medium comprising finely dispersed charged coolant particles, imposing on said coolant particles an electric charge by having said particles pass through an electric field of 2,000 to 20,000 volts, imposing on said molten jetstream a charge of opposite polarity to that on said particles, the difference in said charges be sufficient to attract said particles to said jet, thereby cooling, solidifying and stabilizing said jet, and recovering a continuous cast filament.

11. The process of claim 10 wherein the electric charge is imposed on said coolant particles by passing said particles through an electric field of 5,000 to 20,000 volts and subsequently attracting said particles to said molten jetstream in an electric field of 500 to 5,000 volts.

12. The process of claim 10 wherein said molten metal is a member selected from the group consisting of copper, nickel, chrome, titanium, beryllium, boron, nickel and chrome alloys, vanadium, manganese and zirconium and wherein said coolant particle is a solid particle and is a member selected from the group consisting of aluminum, copper, zinc, tin, graphite, tungsten, boron, boron nitride, silicon and silicon dioxide.