Aug. 9, 1966 E. R. SUMMERS ETAL 3,264,695

METHOD OF CASTING ROTORS

Original Filed Jan. 6, 1960 5 Sheets-Sheet 1

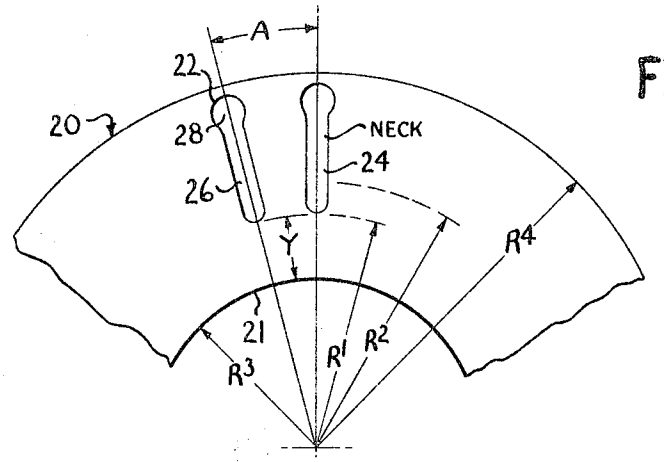


FIG. 1A

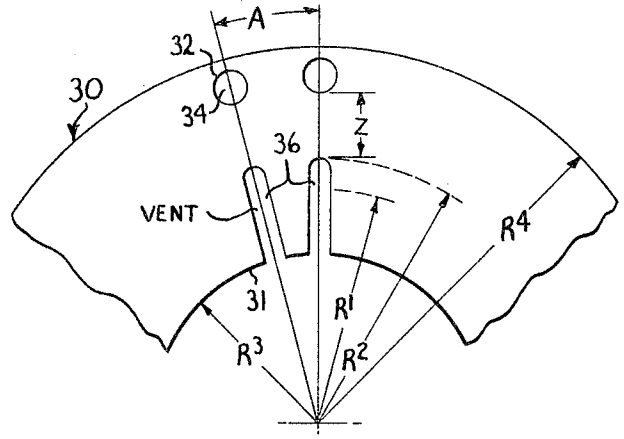


FIG. 1B

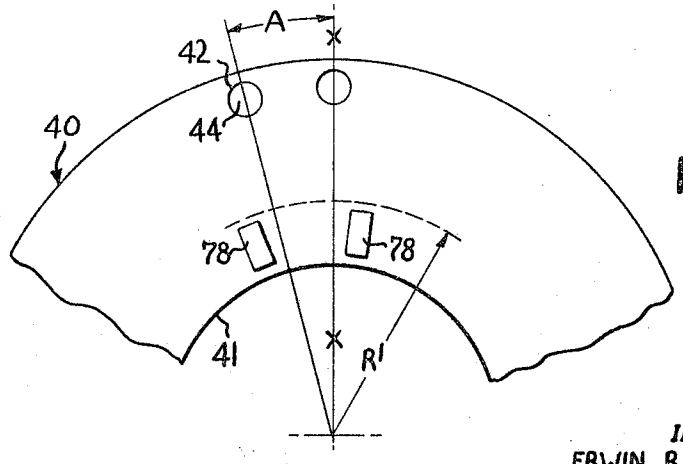


FIG. 1C

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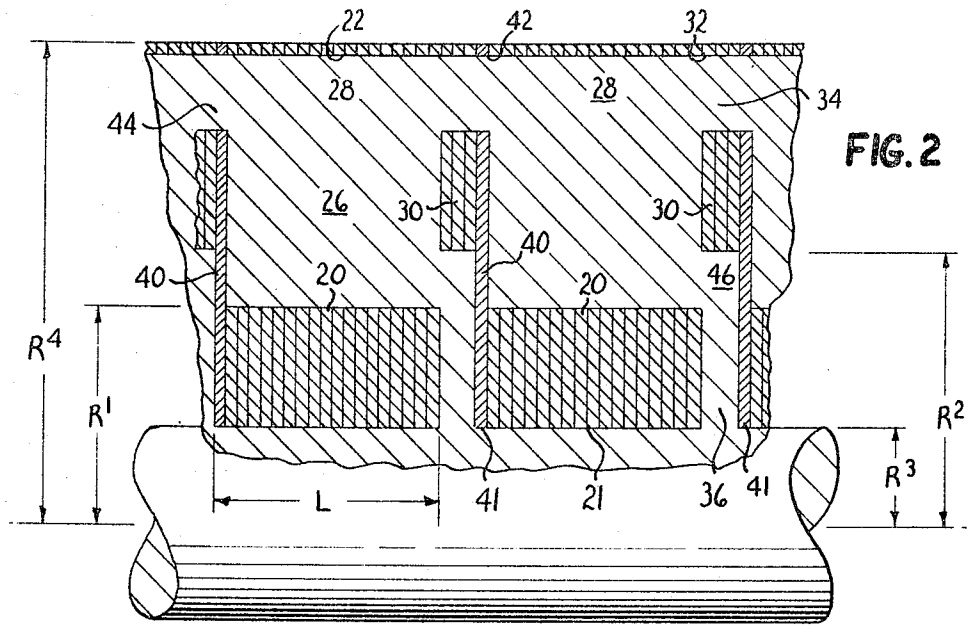


FIG. 2

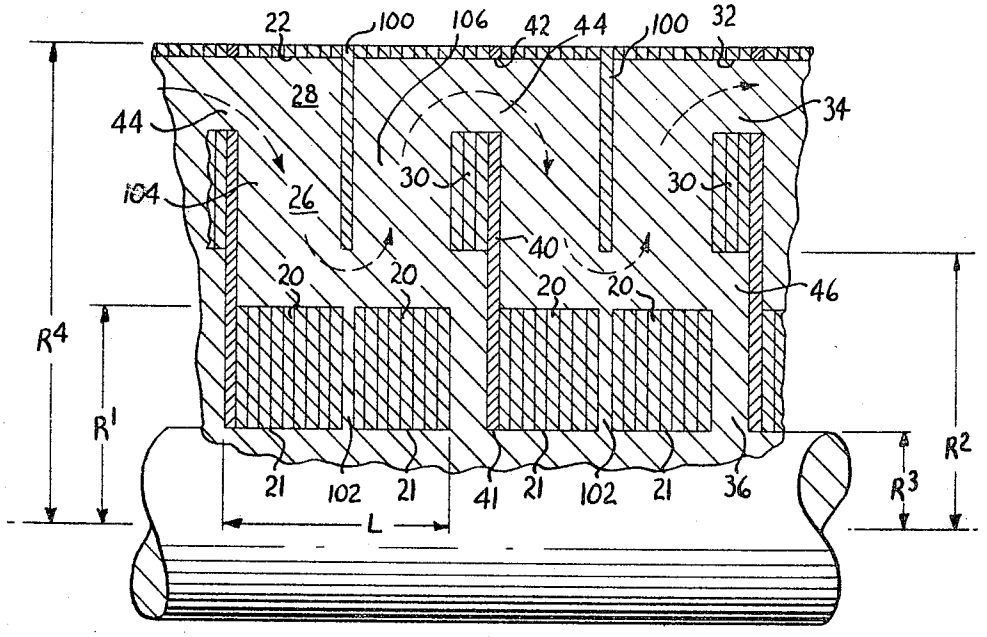


FIG. 6

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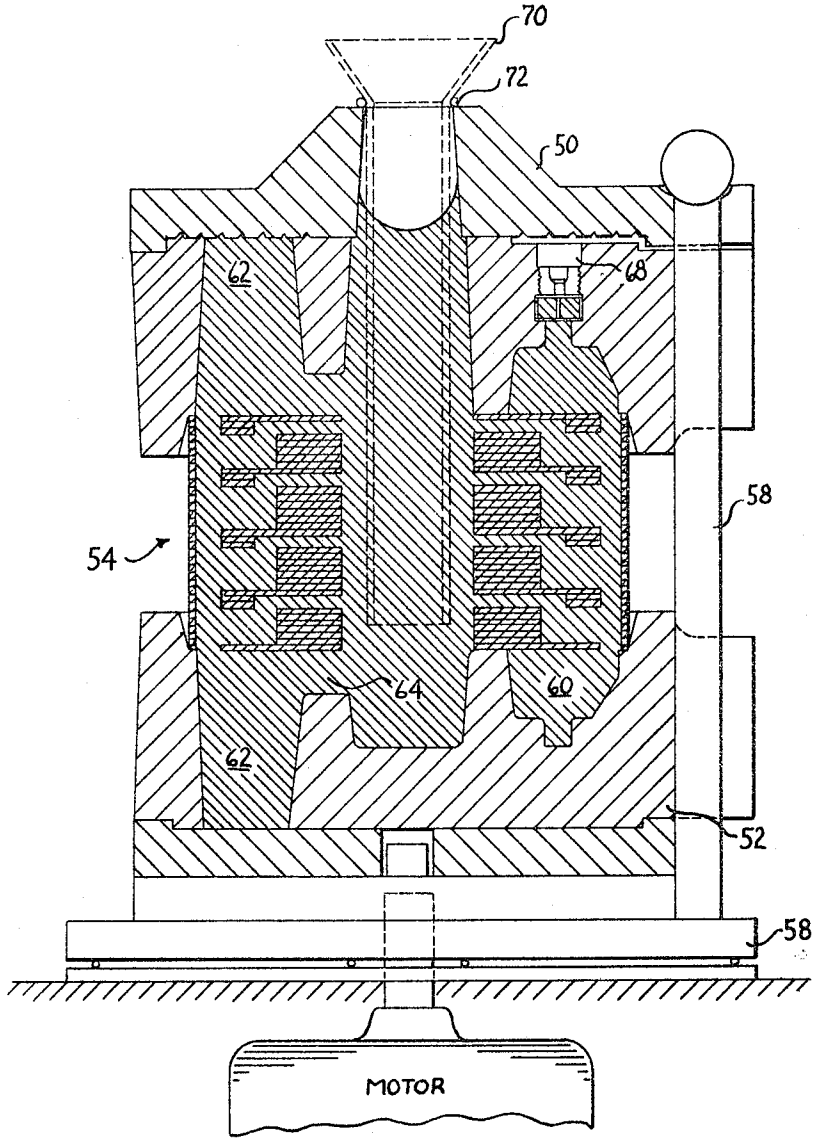


FIG. 3

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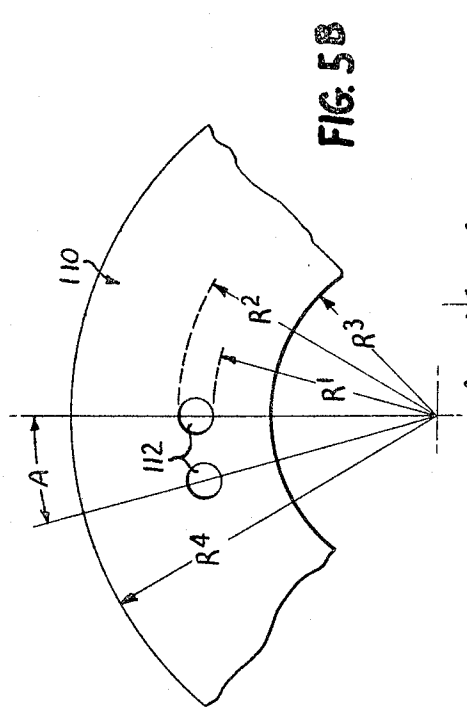


FIG. 5B

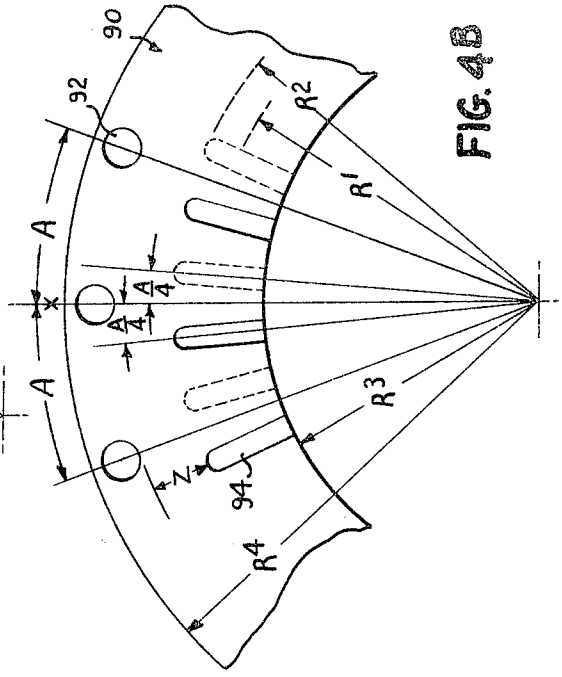


FIG. 4B

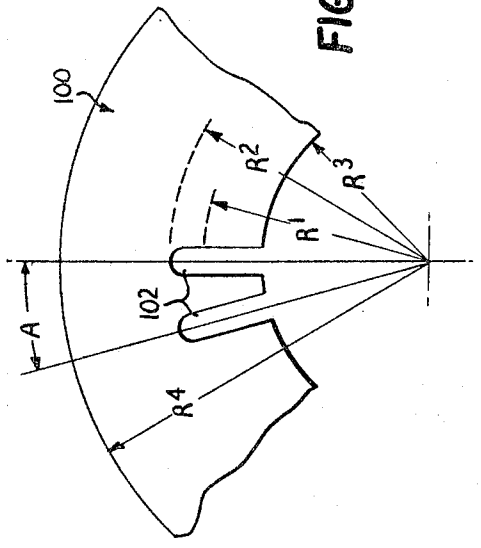


FIG. 5A

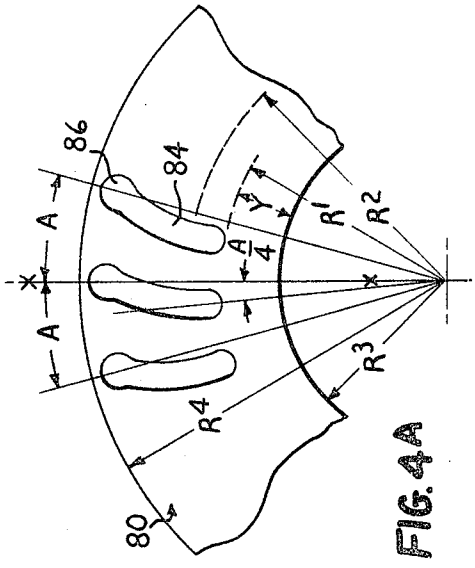


FIG. 4A

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FIG. 7

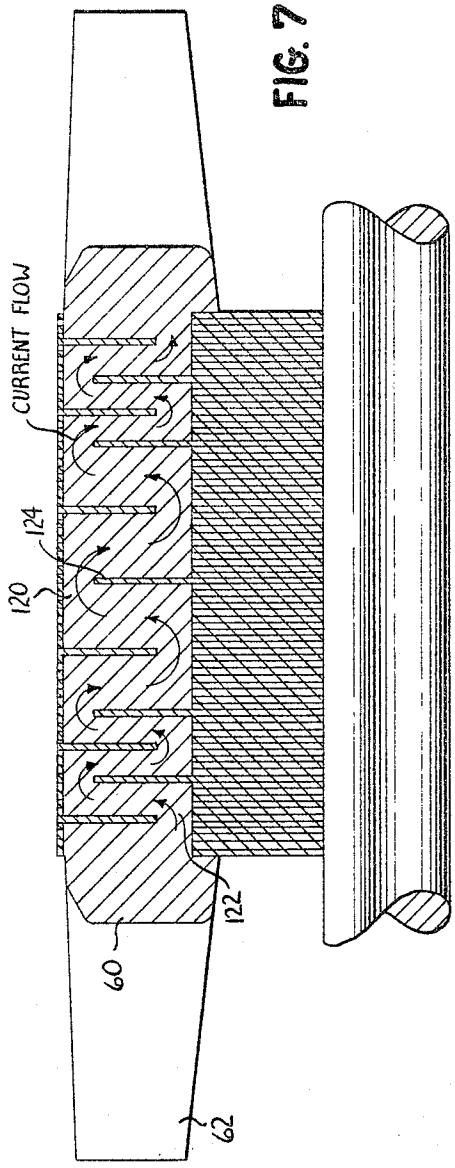
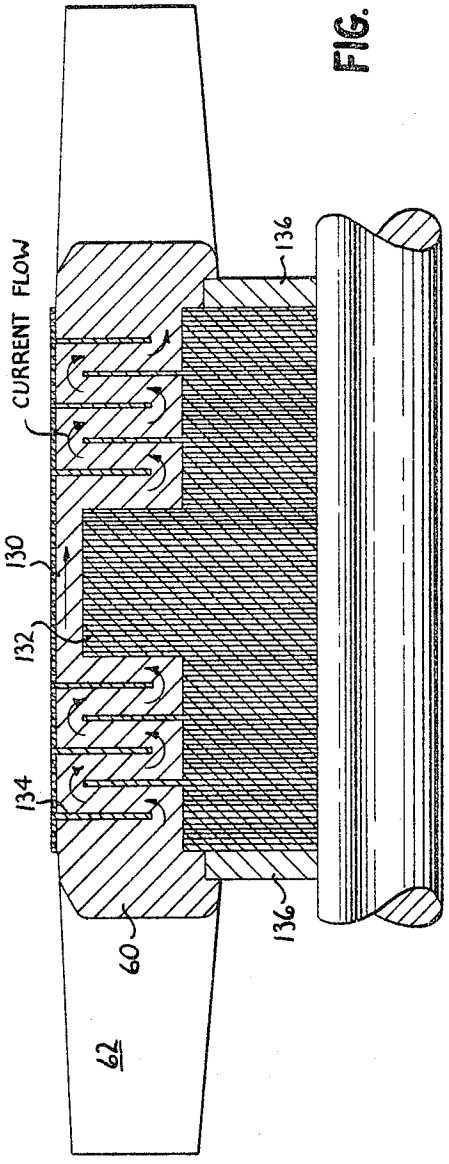


FIG. 8



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3,264,695

METHOD OF CASTING ROTORS

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Original application Jan. 6, 1960, Ser. No. 857, now Patent No. 3,213,306, dated Oct. 19, 1965. Divided and this application Jan. 28, 1965, Ser. No. 436,979

1 Claim. (Cl. 22—200.5)

This application is a division of our copending application Serial No. 857, filed January 6, 1960, now U.S. Patent No. 3,213,306, issued October 19, 1965.

The invention described herein relates to dynamoelectric machines and more particularly to a method of casting high resistance rotors, including an improved design of winding for securing a high degree of electrical performance during operation.

High resistance motors of the type classified as NEMA design D, normally are used in applications requiring high torque at starting and during acceleration; or where very high loads are suddenly applied when the motor is running at full speed, as in a punch press drive for example, and it is desired to have the motor electrical torque increase relatively slowly as the speed is reduced, such that the inertia, or a portion of the kinetic energy, of moving parts such as a flywheel can be utilized to cushion or reduce the peaks of electrical current and power input to the motor. These high slip rotors usually are made of preformed conductor bars or high resistance alloys which are cast in the conductor slots. Such cast alloys having suitable properties for windings, are presently limited to resistivities only moderately higher than aluminum, such that the conductor size and thermal inertia are relatively small and the thermal resistivity is correspondingly high, thereby making it difficult to dissipate heat to the surrounding iron, or to conduct heat axially along the winding to the end portions of rotor for transfer to ventilating air or other media.

It is generally recognized that small bar sections have the disadvantage of low thermal storage in addition to being expensive to construct and install in the rotor slots. The drawbacks of small bar sections have been successfully overcome by the construction disclosed and claimed in U.S. Patent 2,767,340 issued to Walter J. Martiny, Jr., and assigned to the same assignee as the present invention. The Martiny construction of having discontinuous high heat storage sections extending from the axial conductors toward the rotor bore permits adequate dissipation of heat generated in machines up to about 30 HP. Beyond that range, the construction is not too successful in transferring and dissipating heat from the rotor in quantities sufficient to obtain optimum performance in the NEMA design D motors having the higher slip ratings, such as 15% decrease in speed from no load to normal full load torque, or to provide suitable thermal storage capacity for stalled rotor or delayed acceleration.

Windings with indirect or elongated conductor paths of greater length than the punching stack, sometimes called a zigzag pattern, and of other configurations used for increasing the length cross section area and thermal storage capacity of the conductor path have been suggested,

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and although they have certain desirable attributes, acceptable casting processes have not been developed so that windings of this type have not been used as a practical matter in high slip rotors.

The problems associated with casting high resistance squirrel cage rotors is sizes greater than about 30 H.P. are extremely difficult to overcome. Pressure casting techniques are used successfully in small rotors and in carrying out this process, aluminum is cast at a high pressure such as 6000 p.s.i. thus compressing the trapped air to about $\frac{1}{400}$ or 0.25% of its initial volume, and the slots are, for all practical purposes, completely filled with aluminum as desired.

As now practiced however, pressure casting is not generally used with large rotors especially those having large end rings of the type used in two-pole motors. The two-pole end rings are large as compared to the effective conductor area of a slot or to the area of a sprue gate normally used in the pressure casting process. The molten aluminum freezes in the smaller sections of such a pressure cast winding before the complete winding can be solidified and as a result, large shrink holes are likely to be established in the end rings which may effectively interfere with dynamic balance and rotor current distribution. Also, because of the great size and uneconomically high cost of a massive pressure casting machine for large rotors, it becomes desirable to be able to cast such large rotors with less rugged equipment and at low pressures such as are used in the centrifugal casing process.

Consideration of centrifugal casting methods of the type disclosed and claimed in the copending patent application to E. R. Summers, Serial No. 681,519, filed September 3, 1957, and entitled, "Method of Casting Squirrel Cage Rotors," now U.S. Patent No. 2,976,773 issued August 22, 1961, leads one quickly to the conclusion that a centrifugal method that is satisfactory for casting metal in straight slots can be unsuccessful for casting conductors in zigzag slots or in slots having heat sinks of the Martiny type. When a rotor having slots of zigzag or other configuration is rotated about the vertical axis of the lamination stack and aluminum introduced therein, it will be seen that aluminum flows axially downward or upward through the conductor sections at the outermost portions of the slots, and the centrifugal force resulting from rotation is effective in keeping the aluminum in this zone of the slots. The relatively lighter air remains trapped at the smaller radius of rotation in the pockets at the bottom or inner portions of the slots, and can neither escape radially between the laminations of the compressed stack nor axially along the slots because of the barriers interposed by the flopped punchings which are used for obtaining the slots of zigzag configuration. Since very little liquid metal pressure is developed during centrifugal casting, this trapped air is not compressed appreciably, the aluminum does not fill the bottom portion of the slots and the desired thermal characteristics of the winding are not realized.

In view of the foregoing, it is evident that neither conventional pressure nor centrifugal casting methods can be used for producing acceptable windings in all sizes and types of high-slip rotors. Pressure casting methods create shrink holes in the larger end rings, because the aluminum freezes in the slots before the complete winding can become solidified. A sprue and gates of suitable size

and location are not available for feeding the additional aluminum necessary for preventing establishment of shrink holes and assuring a sound casting. Conventional centrifugal casting methods create air pockets in the zigzag slot pockets adjacent the rotor bore and prevent the molten metal from completely filling the slot cavities.

Therefore, the primary object of our invention is to provide an improved casting method for providing completely formed windings including sound end rings and conductors in the rotor slots of high resistance rotors.

Another object of our invention is the provision of a new squirrel cage winding for permitting improved performance of high resistance rotors.

In carrying out our invention we select a plurality of punchings, having slots of different configuration, and stack them in sections to form a rotor core for receiving a high resistance winding. Certain of the sections are separated by spacers at spaced points along the core length to form openings leading into the bore. During casting, the rotor is rotated and a molten metal or alloy is poured downward through a funnel in the bore and thrown outwardly by centrifugal force through radially extending gates in the bottom mold to fill the lower fan blade and end ring cavities and commence rising in the slots. Air displaced by the molten mass flows upwardly through the slots, inwardly through vent openings at the bore, and also from the slots through gates at the top mold. As the molten mass rises in the bore, the vent openings as they become submerged are successively utilized as a means for feeding molten material from the bore into the slots for assuring a sound casting in these areas. Gates in the upper mold facilitate casting of the upper fan blade and end ring cavities. Since it is necessary to preclude establishment of shrink holes in the various parts of the winding, the rotor bore is filled to the top of the mold and as the complete winding freezes, a quantity of molten aluminum is available to augment the aluminum in the winding as shrinkage occurs during freezing. The funnel is withdrawn before the sprue freezes in the bore. It will be apparent to those skilled in the art that the provision of this improved casting process provides new freedoms for designing slots for windings capable of more rapidly dissipating heat to zones of lower temperature in the rotor.

The subject matter which we regard as our invention is particularly pointed out and distinctly claimed in the concluding portion of this specification. Our invention however, both as to organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

FIGURES 1*a*, 1*b*, and 1*c* are views in elevation of a portion of laminations used in this invention;

FIGURE 2 is a view in elevation, partly in section, of a portion of a rotor illustrating the arrangement of the punchings of FIGURES 1*a*–1*c* and including parts of a winding cast therein;

FIGURE 3 is a sectional view in elevation of mold apparatus;

FIGURES 4*a* and 4*b* illustrate two different types of punchings which may be used for providing the same construction shown in FIGURE 2;

FIGURES 5*a* and 5*b* show two different types of punchings either of which may be combined with the punchings of FIGURES 1*a*–1*c* to form a rotor core;

FIGURE 6 is a view in elevation, partly in section, showing a portion of rotor winding which utilizes the punchings of FIGURES 5*a* and 5*b*;

FIGURE 7 is a sectional view in elevation of a portion of a rotor illustrating the arrangement of laminations used for obtaining less generation of heat at and better heat flow away from the center part of the rotor; and

FIGURE 8 is a view similar to FIGURE 7 except that the laminations are designed in a different manner for providing a short straight section of conductor located in the center part of the rotor.

Referring now to the drawings wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIGURES 1*a*–1*c*, three separate designs of silicon or other types of steel laminations or punchings. It will be understood that although only a few slots are shown in each lamination, the slots are equally spaced and extend completely around the punching in the same conventional manner as that known in the prior art. In FIGURE 1*a*, the lamination **20** has a central bore **21** and a bridge **22** between the outer diameter and a plurality of slots **24**, each of which includes a neck **26** for thermal storage and a conductor section **28** for conduction of current.

The lamination **30** of FIGURE 1*b* has a central bore **31**, is of the same outer diameter as lamination **20** and is equipped with a bridge **32** of a radial length equal to bridge **22**. The slots **34** and **36** however are of a different configuration. Slots **34** comprise circular openings which constitute the main conductor section while slots **36** are used as vents and/or gates in the bore as described more fully hereafter.

The lamination **40** of FIGURE 1*c* likewise has the same size bore **41** and outer diameter and bridge **42** as punchings **20** and **30** of FIGURES 1*a* and 1*b*. However, it is equipped with conductor slots **44** only. Although the slots in the conductor sections are shown of a specific design, it is obvious that slots of any well known configuration may be used.

FIGURE 2 shows a sectional view of a portion of a rotor and illustrates how sections or groups of laminations **20**, **30** and **40** are assembled to form the rotor core. FIGURE 3 illustrates the rotor core positioned in molds and the disposition of the winding in the slots is shown by appropriate shading such that the winding stands in relief. The conductor slots are illustrated as being closed but in many instances it is desirable to have them open to the rotor surface. Casting problems are not encountered because a hardenable asbestos type of putty can be packed in the surface openings for preventing escape of molten metal when the winding is cast. A particular benefit achieved is that the openings can be used for aligning the laminations, especially in rotors designed for a zigzag winding since they do not contain uninterrupted axial slot openings as in most rotors. When the slot is buried deep in the laminations, index markings can be punched in the outer peripheral surface directly opposite the slot for facilitating alignment.

The casting apparatus shown is described more specifically in the above mentioned copending patent application. Referring specifically to FIGURE 3, the apparatus shown comprises upper and lower molds **50** and **52** enclosing the rotor core **54** in the manner shown. Upon insertion of the rotor core within the molds, hydraulically actuated arms **56** attached to the apparatus are used for drawing the molds toward one another and thereby effectively compressing the rotor core positioned therein. To obtain rotation and consequent displacement of aluminum radially outwardly from the bore and into the conductor slots, the apparatus is placed on a turntable **58** and rotated by an appropriately sized motor. Both the upper and lower molds **50** and **52** are equipped with fan blade and end ring cavities **60** and **62** which are connected to the bore by gates **64** formed by circumferentially spaced slots cut in an annular member in the mold. Obviously, fan blade cavities will not be used where the rotor is of a type where fan blades cannot conveniently be cast or used with the winding. A venting arrangement **68** is located in the upper mold for completely venting air from the upper end ring cavities when the winding is cast in the rotor. As shown, a funnel **70** is used for introducing molten aluminum into the rotor bore and is

designed to have its discharge end terminate at a position within the rotor bore below the lowermost radial vent in the lamination stack. The bottom of the funnel extends below the lowermost radial vent opening to the bore, such that, by virtue of the paraboloid of fluid revolution, the air can pass radially inward through said vents as the molten aluminum fills the corresponding pockets in slots before entering the radial vents communicating thereto. In order to permit venting of air past the funnel during the casting process, spaced spacers **72** are affixed to the outer periphery of the funnel for permitting air to ascend from the rotor and mold cavities and past the funnel prior to discharge from the mold apparatus.

Referring to FIGURES 2 and 3, the conductor sections corresponding respectively to apertures **28**, **34** and **44** have the same slot pitch A (FIGURES 1*a*–1*c*) and are co-extensive throughout the length of the rotor. The punching stack is welded along the inner diameter axially between the vents and across spacers **78** for holding the laminations together. When the winding is cast, the aluminum in this area constitutes the effective current carrying portion of the winding. The yoke Z of lamination **30** overlaps a part of neck **26**, thus leaving an area designated **46** equal to the difference between R_2 and R_1, through which aluminum can obtain access to the vent slots **36** during casting. Lamination **40** is equipped only with the apertures **44** and serves to interrupt the neck at interval L, thereby making the bottom portion of the slots discontinuous with respect to current flow. An alternate method of providing vents **36** is to weld or otherwise attach spacers **78** to punching **40** within radius R_1, as shown dotted in FIGURE 1*c*, and to make the continuous bore of punching **30** at R_2 instead of R_3, in which case the number of spacers **78** may be less than the number of slots **44**. It is evident that the size of the vents at the bore may be varied by using a different number and size of laminations **30** and spacers in each group.

During casting, the mold apparatus is rotated and molten aluminum poured downwardly through funnel **70** into the bore. Centrifugal forces move the molten metal outwardly through the lower gates **64** in the mold where it fills the lower fan blade and end ring cavities **60** and **62**. Air therefrom is displaced upwardly through the slots **44**, followed by aluminum which fills the individual necks **26** and integrally joined conductor sections **28** in each slot **24**, which are equally spaced circumferentially around the rotor core. Since the molten aluminum assumes a paraboloid of revolution as shown by the concave top surface of the molten aluminum in FIGURE 3, the aluminum will flow through conductor slots **44** in the next group of punchings before the necks in the first section are filled. The slots **36** or alternative spacers **78** in laminations **30**, provide vents which serve to allow air to escape from the neck portion of the slot into the bore prior to flowing upwardly past the funnel for discharge from the mold apparatus. This process of filling the slot portions with molten metal along the rotor core length is continued until the upper end ring and fan blade cavities are completely cast, whereupon casting is continued to provide a molten mass having its upper end positioned above the level of the fan blades and end ring in the mold. The funnel **70** is then withdrawn from the mold apparatus before the molten sprue mass freezes in the punching bore.

As the poured casting freezes, shrinkage in the aluminum occurs and in order to prevent establishment of shrink holes in the various parts of the winding, the sprue provided in the rotor bore serves as a reservoir which continues to feed aluminum into those parts where shrinkage occurs and thereby provide a casting which is sound in all respects. It is evident that the necks of the various conductor slots may develop shrink holes unless they are fed with aluminum. The vents provided along the bore length are therefore subsequently used as gates which serve to augment the aluminum initialy cast in these necks. The mold apparatus is rotated continuously and for a period of time sufficient to permit freezing of the aluminum in the winding and when freezing is accomplished, the molds are then removed from the rotor core and the sprue thereafter removed as described in the above copending application. Difficulty in sprue removal is not encountered because the wall sections forming the gates at either end are accessible and can be cut easily. The aluminum connecting the vent openings with the sprue are of such small cross section that they easily break and do not strongly bind the sprue in the rotor bore.

It is evident that in those situations where it is desirable to have the vents serve only a venting function, they accordingly will be made sufficiently small so that air can be vented into the bore without permitting the passage of molten material through the vents. Obviously, when used as a combination vent and gate, the vent openings are made of a size sufficient for aluminum freely to pass from the bore into the neck area of the slots. When the combination vent and gate arrangement is used, static casting methods may be employed for casting the winding, especially that method where the cast material is introduced from beneath the rotor.

Many different punching designs may be used for providing a neck portion in the slots which serves as a thermal storage area or heat sink and as vents and/or gates for facilitating casting of the winding. As illustrated in FIGURES 4*a* and 4*b* for example, two different kinds of laminations are used for forming the same construction illustrated in FIGURE 2. In this arrangement, the lamination **80** of FIGURE 4*a* is equipped with inner and outer diameters R_3 and R_4 and has equally spaced slots **82** disposed circumferentialy around the punching. Each slot consists of a curved neck portion **84** and a conductor section **86**.

The lamination **90** of FIGURE 4*b* is of the same inner and outer diameter, has conductor sections **92** spaced around the lamination and is equipped with open ended slots **94** which serve as vents when the laminations are assembled to form a rotor.

In this arrangement, the bottom of the neck **84** is displaced ¼ slot pitch (A/4) circumferentially from the center of conductor section **86**. The vents **94** of punchings **90** are displaced a like amount from the conductor sections **92** as shown, with the vents overlapping the bottom portions of the necks by a distance R_2 less R_1. When punching **90** is rotated about axis X—X, the openings illustrated by dotted lines then fall midway between the necks of punching **80** and the bottoms of the slots are interrupted at intervals of L along the stack in the same manner as that previously described.

If the yoke section Y of punchings **20** and **80** are made equal to the yoke section Z of punchings **30** and **90**, the permeance of the two kinds of punchings will be essentially equal, no unusual distortion of flux fields will occur and the entire length of the punching stack is effectively utilized. The desired torque characteristics and the effective conductor section-area for current flow correspond essentially to the area only of the continuous conductor section at the top of the slots; whereas the heat storage capacity of the complete winding and the rate of heat transfer to laminations correspond to total slot volume, i.e., conductor sections plus neck portions, and to the total slot perimeter, respectively. Small conductor sections are required to obtain the desired torque, but large masses of material in the complete slots and large surface areas are needed to store and to dissipate the large amount of I^2_R loss corresponding to high torque and high slip. The construction described above effectively permits the transfer of large quantities of heat from the casting while still providing highly desirable torque characteristics.

The above described constructions are primarily used for the purpose of providing a heat sink for and better

dissipation of heat generated in the rotor during operation. Another fundamental method of increasing the rotor resistance is that of increasing the length of the conduction path so that it effectively is much longer than the core stack length. This is accomplished in the invention by utilizing the laminations illustrated in FIGURES 1*a*, 1*b* and 1*c* above and combining with them the lamination illustrated in FIGURES 5*a* or 5*b*. As shown, the lamination **100** is substantially the same as that illustrated in FIGURE 1*b* except that it does not include the circular conduction section openings **34**. It has the same inner and outer diameter and is equipped with vent slots **102**, similar to **36**, which open into the bore of the lamination. The lamination **110** in FIGURE 5*b* is similar to that illustrated in FIGURE 5*a* except the conductor opening **112** does not extend to the bore of the lamination. The dimensions R_1 through R_4 in FIGURES 5*a* and 5*b* are the same as that for the lamination FIGURE 1*b*.

Referring to FIGURE 6 it will be seen that an increase in length in the conductor path is made possible by the insertion of laminations **100**. If lamination **110** is substituted for **100**, the vent **102** is eliminated but vent **36** is retained. By making this modification with either lamination **100** or **110** it will be seen that the current now is required to traverse the path illustrated by the dotted lines in FIGURE 6. During casting, the molten aluminum flows through openings **44** and fills the first section **104** of the rotor, displacing air through vents **102** and **36** during the casting process. Since air is then not available to trap, exclude or interfere with the molten mass in the various sections, the metal is then permitted to flow freely into section **106** and displace air upwardly and inwardly through the sections positioned thereabove, and through the vents which communicate with the rotor bore. It is generally desirable to utilize only one or two of these laminations **100** or **110** at each location so that the main flux will not by-pass the conductor and result in high leakage reactance, low torque, and low power factor. By reference to FIGURE 6 it will be seen that the path for current flow is made considerably longer than the core stack thus making it easy to obtain a high resistance in the winding without utilizing special materials and still maintain a large value of thermal capacity.

A particular advantage derived from the use of a construction permitting venting to the bore along the stack length lies in the many different designs of conductor sections and necks which constitute the heat sinks that may be used in squirrel cage windings. The parts of the rotor core from which it is most difficult to dissipate heat are located at the middle of the punching stack. The construction shown in FIGURE 7 is used for obtaining a smaller I^2_R loss in the middle area by using a graduated zigzag conductor having a larger cross section for radial current flow at the middle **120** rather than at the ends **122** of the rotor. This is accomplished by spacing the barrier laminations **124** a greater distance in the central portion of the core than those at the rotor ends. Since there is less resistance to current flow in the middle, the amount of heat generated is not as high and a corresponding reduction in the temperature gradient therefore takes place. Since a larger percentage of total heat loss will occur in the end portions of the slots, the heat can be dissipated more readily to the fan blades and end rings and then be effectively carried away by ventilating air. The arrows of FIGURE 7 show current flow. The construction shown in FIGURE 7, which does not illustrate venting to the bore, would be suitable for some arrangements of static casting, and also for pressure casting if the end ring section were not excessively large compared to that of the total cross sectional area of the zigzag conductor. However, in view of the teachings of this application, it will be evident that radial vents similar to **36** in FIGURE 6 can be readily added to the arrangement of FIGURE 7 to adapt it to the centrifugal casting method.

The design of FIGURE 8 is made to serve the same purpose as the construction illustrated in FIGURE 7. As shown, a zigzag arrangement for the winding is used but a relatively long conductor section **130** extends axially of the rotor and is located in the middle portion thereof. Two different types of laminations **132** and **134** are used in providing the construction shown. Laminations **132** are merely equipped with a plurality of circular openings equally spaced from each other and from the vertical axis of the lamination, while laminations **134** are provided with similar openings except that they are spaced inwardly from the openings which are used for providing the axially extending slot **130**.

In some instances the punchings delaminate slightly near the ends of the rotor when it is removed from the molds after casting. In order to reduce this undesirable effect, a precautionary measure can be resorted to which consists of locating either a temporary or permanently mounted ring **136** on opposite ends of the punching stack. It may be welded or otherwise sceured to the punching stack before casting. The use of such a ring exerts an axial compressive force on the laminations, and also resists the tendency of the aluminum end ring to decrease in diameter as it cools, so that parting of the laminations at the outer surface is less likely to occur, particularly in those cases when the aluminum is still hot and in a very flexible state.

The advantage derived from practicing a casting method of the type disclosed herein is that it is possible to obtain high resistance rotors having high conductivity alloys. A high value of heat capacity can be maintained in the rotor by employing larger quantities of the conductor material than that which has been possible by other methods and constructions. Larger conductor and neck sections may be used which result in lower current densities and the provision of a zigzag current path exposes the larger surfaces of the conductor material to a larger mass of iron in which it is embedded. Since the same design pattern of different punchings is used and repeated throughout the length of a single rotor core, the resistance of the winding in succeeding cores may be readily adjusted merely by varying the number of each type of punching and the spacing between repeating sections. The rotor is mechanically more flexible in the axial direction and fracture of the bars from thermal stresses during casting and duty cycle operations are not likely to occur.

In view of the above, it will be evident that many modifications and variations are possible in light of the above teachings. It therefore is to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What we claim as new and desire to secure by Letters Patent of the United States is:

The process of making an induction motor rotor with a high resistance cast squirrel cage winding, said process comprising:

(a) stacking contiguously a plurality of annular magnetic laminations assembled in sections to provide a rotor core having a central bore, aligned apertures formed in the laminations of said sections communicating between adjacent sections and establishing a plurality of continuous passages by varying radial dimension through the rotor core, and vent openings formed in the laminations of selected ones of said sections communicating from said passages into said bore;

(b) positioning an upper and a lower casting mold at corresponding ends of said core, each of said molds including end ring cavities communicating with respective ends of each of said passages and gates interconnecting said cavities and said bore, said upper

mold having an aperture formed therethrough aligned with said bore and a vent opening in the top of said upper mold;

(c) rotating said core and molds about an axis through said bore;

(d) pouring conductive molten metal through the aperture in said upper mold into said bore; and,

(e) venting air displaced by the rising molten metal axially inwardly to the bore from said passages through said vent openings in the laminations, whereby trapping of air in said passages is avoided and molten metal is permitted to completely fill said passages.

References Cited by the Examiner

UNITED STATES PATENTS

1,190,009	7/1916	Reist et al.	
2,368,295	1/1945	Goran	22—203
2,996,773	8/1961	Summers	22—200.5

FOREIGN PATENTS

534,071	12/1921	France.

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