

July 29, 1958

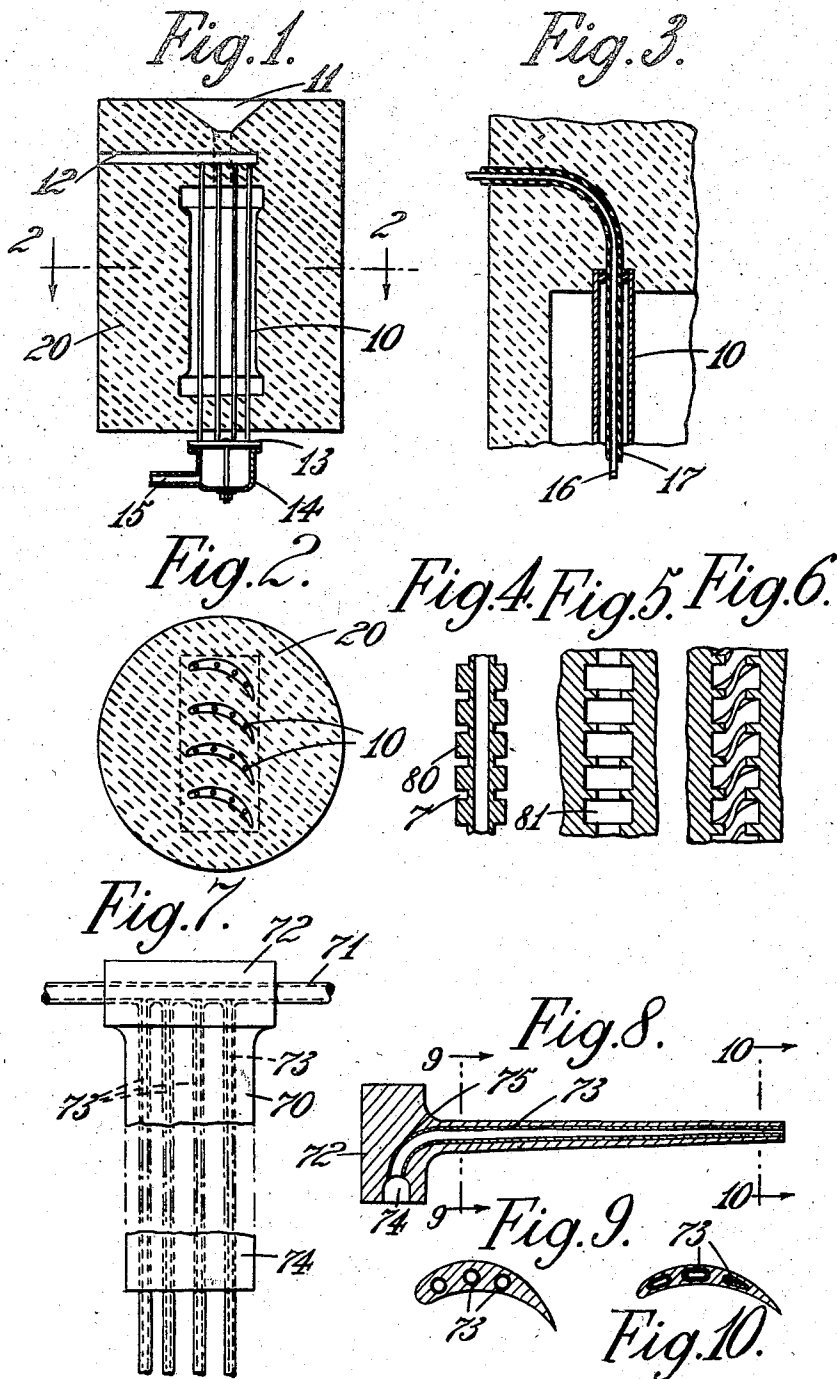
E. R. GADD ET AL

2,844,855

METHOD OF PRODUCING CASTINGS WITH ONE OR MORE INTERNAL PASSAGES

Filed Nov. 1, 1954

2 Sheets-Sheet 1



July 29, 1958

E. R. GADD ET AL

2,844,855

METHOD OF PRODUCING CASTINGS WITH ONE OR MORE INTERNAL PASSAGES

Filed Nov. 1, 1954

2 Sheets-Sheet 2

Fig. 11.

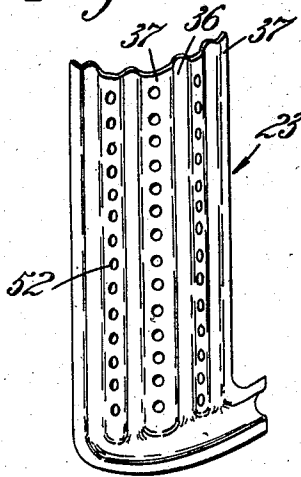


Fig. 12.

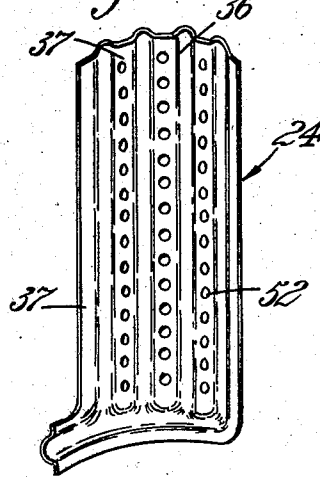


Fig. 13.

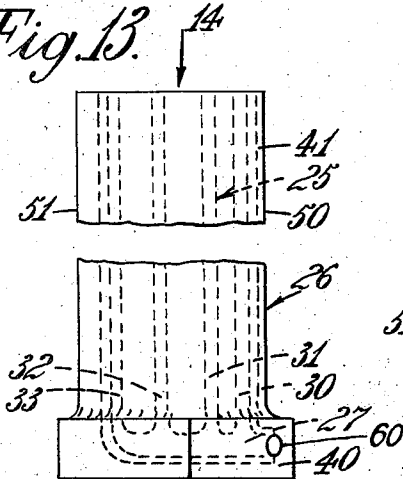


Fig. 14.

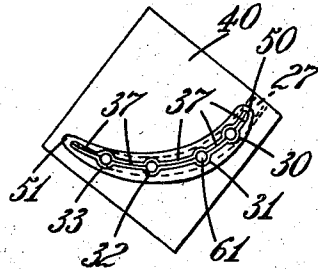
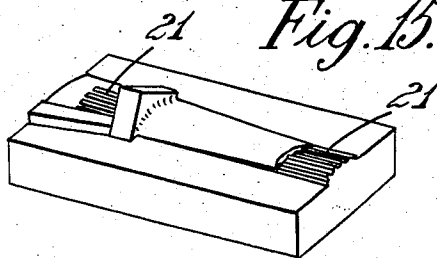


Fig. 15.



1

2,844,855

## METHOD OF PRODUCING CASTINGS WITH ONE OR MORE INTERNAL PASSAGES

Ernest Reginald Gadd and Dennis Frederick Bernard Tedds, Bristol, England, assignors, by mesne assignments, to Bristol Aero-Engines Limited, Bristol, England, a British company

Application November 1, 1954, Serial No. 466,136

Claims priority, application Great Britain November 5, 1953

10 Claims. (Cl. 22—204)

This invention relates to the production of metal castings with one or more internal passages, and is concerned primarily with the production of metal blades for turbines, compressors and other fluid-flow power conversion machines, in which blades it is necessary or desirable to provide one or more internal passages for the flow of a cooling or a heating medium. The invention is not, however, restricted to the production of such blades but may be employed generally for the production of any casting in which one or more internal passages are required.

According to the invention, a method of producing a metal casting having at least one internal passage comprises casting the casting in a mould in which is supported a metal tube forming a core at the position at which said passage is required.

According to a feature of the invention, the method may include the step of cooling the tube while the casting metal is being run into the mould and/or immediately after the casting metal has been run into the mould.

Such cooling may be effected by inserting a removable core of heat absorbing substance within the tube, the core being removed during or after the casting process, for example, in the case of a solid substance, by fusion or withdrawal. Alternatively, the cooling may be effected by passing a liquid coolant such as a molten metal or a gaseous coolant such as air through the tube.

By way of explanation, it is to be noted that when the tube is made of a metal having a melting temperature lower than the temperature of the casting metal being run into the mould it may be necessary to cool the tube in order to prevent its collapse, and the cooling by passing a fluid coolant through the tube should in this case be regulated so that the internal temperature of the tube does not exceed a value at which this might happen.

The cooling may, however, be regulated so that an outer superficial layer of the tube material is fused by heat from the metal run into the mould and promotes bonding of the tube with the metal of the casting.

In some cases where the tube is made of a metal having a lower melting temperature than the casting metal being run into the mould it may be sufficient, instead of cooling the tube, to insert a removable core in the tube to support the wall of the tube against collapse when the casting metal is run into the mould, the core being subsequently removed after the casting metal has cooled below the melting temperature of the metal of the tube. Where, on the other hand, the tube is made of a metal having a melting temperature higher than the temperature of the casting metal being run into the mould, such a tube may, according to another feature of the invention, be internally heated while the casting metal is being run into the mould, this to prevent excessive chilling of the casting metal coming into contact with the tube. Thus, the tube may be internally heated by inserting within the tube a removable core comprising electrical heat-

2

ing means and supplying electric current to the heating means, the core comprising the heating means being removed during or after the casting process.

According to yet another feature of the invention, the tube may be coated externally with a material promoting bonding of the cast metal with the metal of the tube. Thus, for example, in a high temperature casting process using, say, a "Nimonic" alloy as the casting metal, the external surface of the tube may be coated with a metal which is more resistant to oxidation than the metal of the tube itself. While in a low temperature casting process using, say, an aluminium alloy as the casting metal, the external surface of the tube may be coated with a flux film, or in a further example, a tube which is composed of a material having a melting temperature as high as or higher than the temperature of the casting metal being run into the mould may be coated externally with another metal having a melting temperature lower than the temperature of the metal to be run into the mould so that the coating fuses and promotes bonding as stated above.

According to yet another feature of the invention, the method may include the step of removing, by chemical, mechanical or electrical means after the casting process, at least part of the metal of the tube from the interior of the tube in order to enlarge the internal passage in the casting. Thus, the bore of the tube may be enlarged or the whole of the tube material may be removed.

According to yet another feature of the invention, the method may include removing by chemical, mechanical or electrical means not only the whole of the metal of the tube, but also part of the cast metal surrounding the tube so as further to enlarge the bore. Furthermore, the tube may itself be provided on its external surface with raised members in the form of fins or gills, so that when removed by chemical action a bore is left having fins or gills which are a negative counterpart of those on the tube.

Methods in accordance with the invention for the production of turbine blades will now be described by way of example, with reference to the accompanying drawings, whereof:

Figure 1 is a cross sectional elevation of a mould for casting a segment of nozzle guide blading for a gas turbine engine, a number of metal tubes being supported in the mould to form cores at positions at which internal passages are required in the blades of the segment,

Figure 2 is a cross-section on line 2—2 of Figure 1,

Figure 3 is a partial view in cross-section of a mould showing a tube supported therein and containing a core comprising an electrical heating element,

Figure 4 is a partial view in cross-section of a tube for casting into a casting in accordance with the invention to form an internal passage in the casting, the tube having external raised members,

Figures 5 and 6 show examples in cross-section of internal passages produced in accordance with the invention, the metal of the cast-in tube having been removed by chemical action in each case,

Figure 7 shows a blade produced in accordance with the present invention,

Figure 8 is a cross section of another blade produced in accordance with the present invention,

Figure 9 is a cross-section on line 9—9 of Figure 8,

Figure 10 is a cross-section on line 10—10 of Figure 8,

Figure 13 is an elevation of yet another blade produced in accordance with the present invention,

Figure 14 is a view of Figure 13 in the direction of arrow 14,

Figures 11 and 12 are elevations of a pair of sheet metal parts which together form the tubes which are cast into the blade shown in Figures 13 and 14, and Fig-

ure 15 is a perspective view of a pattern plate used in another method in accordance with the invention.

Referring to Figures 1 and 2, the segment of nozzle guide blading comprises four blades joined by inner and outer shroud ring segments.

The segment is cast from a cobalt-base alloy of the kind known by the trade name "Stellite," each blade having a number of embedded stainless steel tubes 10 of continuous or butt-jointed section or any other convenient construction running longitudinally through the blade and is produced in a manner which will now be described.

The segment of blading is made by a lost-wax precision casting method. The tubes 10, which may first be chromium plated to increase their resistance to oxidation, are embedded in their correct positions in a wax pattern of the blading segment and are of additional length so that their ends project well clear of the pattern. The pattern comprises a part corresponding to the segment of blading and a part corresponding to the pouring gate 11. The pattern is then surrounded with investment material 20 to form a mould while leaving the ends of the tubes projecting through the investment material. After the investment has set, the mould is heated sufficiently to expel the wax from the mould and is then fired at a temperature between 950° C. and 1000° C. which is a sufficiently high temperature to stabilize the investment material. When such firing is complete the molten casting alloy which is at a temperature between 1500° C. and 1550° C., is run directly into the mould through the gate 11 while the mould is at a temperature between 600° C. to 700° C.

The coating of chromium on the outside of the tubes 10, increases the resistance of the outer surfaces of the tubes to oxidation during firing of the mould and by the molten casting alloy when this is run into the mould. By preventing or reducing the formation of an oxide film, the chromium coating promotes the bonding of the cast metal to the tubes. Stainless steel has a melting temperature in the range of 1425° C. to 1470° C. which is slightly less than the temperature of the molten casting alloy. Unless the tubes 10 are of small bore and wall thickness, however, it is found that they do not collapse due to melting. If desired or necessary, a core of refractory material is inserted in each tube to support the tube against possible collapse when the casting metal is run into the mould, however, these cores of refractory material being removed when the metal has cooled or after it has finally set. The refractory material used may be any of those later mentioned with reference to Figure 3.

The method just described may also be used for embedding stainless steel tubes in a segment of turbine nozzle guide blading cast from nickel-chromium heat resisting alloys of the kind known by the trade name "Nimonic," but in this case, owing to the higher casting temperature of the alloy, namely 1550° C. to 1600° C., it is preferred to cool the tubes, especially any tubes of small bore and wall thickness, by passing a flow of cooling air through them.

To this end, referring again to Figures 1 and 2, the wax pattern previously described is provided with a part attached to one end of the tubes 10 in each group of tubes 10 in the four pattern parts corresponding to the blades of the segment to produce air outlets 12 in the mould leading from the groups of tubes to the outside of the mould. The other ends of the tubes are fixed into a tube plate 13 prior to the tubes being embedded in the wax pattern, the tube plate 13 being kept outside the investment material 20 when the pattern is invested to form the mould. When the mould is ready for casting a manifold 14 having a pipe 15 connected to a supply of cooling air under pressure is secured to the tube plate so that the ends of the tubes opening in the tube plate communicate with the interior of the manifold. The mould is then preheated to between 600° C. and 700° C. if the temperature of the mould after the firing has dropped below this range, and the casting alloy run into the mould

through the gate 11. The cooling air is turned on between the commencement of pouring and a time immediately after the pouring has been completed, and the cooling air flows from the manifold through each of the tubes and out of the outlets 12. When the temperature of the cast metal has fallen sufficiently to ensure that the tubes will not collapse under the heat of the cast metal, the air supply is turned off.

The cooling air supply is regulated so that the internal temperature of the tubes never exceeds a value at which the tubes might collapse due to melting.

Instead of passing cooling air through the tubes, molten metal at a temperature lower than the melting temperature of the stainless steel tubes 10 may be used. For example, molten lead, aluminum, brass or copper may be used as the coolant, the selection made depending on the degree of cooling required to ensure that the tubes do not collapse.

Whatever the cooling medium used, the cooling can also be regulated so that an outer superficial layer of the tubes 10 are fused by heat from the nimonic casting alloy run into the mould. This promotes bonding between the cast metal and the tubes. If the melting temperature of the metal of the tubes is, in another case to that being described, higher than the temperature of the molten alloy, a similar effect can be achieved by coating the tubes externally with a metal having a lower melting temperature than the temperature of the molten alloy so that the metal coating fuses when it comes into contact with the molten alloy and promotes bonding. For example, mild steel tubes which are to be embedded in a steel alloy of the nickel-chromium-tungsten type may be copper-plated externally to provide them with an external coating which will fuse on contact with the molten casting alloy.

Another method, according to the invention, for making a blade by the shell moulding process, this process being particularly convenient for casting separate blades, will now be described. In this case, a pair of metal pattern plates one of which is shown in Figure 15, are made with raised parts 21 corresponding to throughways in the mould shell required for the passage of the tubes which are to be embedded in the blade. The mould shells are made in the usual manner by dumping a mixture of sand and thermosetting resin upon the heated pattern plates and then completing the curing of the shells in an oven. The pattern plate shown in Figure 15 is a pattern of one-half of the blade and certain details such as dowels and ejector pins are not shown. This pattern plate is used to produce one-half of the shell mould, the other half being produced using a pattern plate corresponding to the other half of the blade. After removal from the pattern plates the shells are assembled together and the tubes are inserted between the mould parts, the tubes being supported between the mould parts with the ends of the tubes projecting one through each of said throughways to the outside of the mould. The tubes are made of mild steel in this case, since no pre-heating such as would give rise to surface oxidation of the tubes is required. A cooling air supply, if necessary, is arranged for the tubes as previously described, with reference to Figure 1, and the casting metal is poured into the mould. After removing the casting from the mould the excess lengths of tube are trimmed off, or the blade may first be subjected to chemical action by passing a suitable acid through one or more of the tubes to increase their bore or to remove them entirely.

Alternatively, the bores may be enlarged by drilling or by an ultrasonic machining process or by a spark or arc machining process, the original bore constituting a pilot hole for an inserted tool. A bore may also be enlarged by using a high frequency magnetic field to melt out a tube if the electrical properties of the metal of the tube are different from those of the cast metal. As well as removing the metal of the tubes, part of the surrounding cast metal may also be removed if desired

so as further to enlarge the bore of the internal passages.

By way of further example, a blade 26 (Figure 13) produced by any of the methods described has a cast-in insert composed of two sheets of metal 23, 24 (see Figures 11 and 12), formed by a pressing operation to constitute component parts of a manifold tube system generally indicated at 25 in Figure 13, this comprising a header 27 and four branch tubes 30, 31, 32 and 33. The metal sheets 23, 24 are thus formed with channels 36 which are then superposed face to face, the sheets 23, 24 being joined by spot welding along the portions 37 between the channels 36 and around the edges of the sheets or in any other convenient manner. The header part 27 of the tube system is arranged within the root portion 40 of the blade and the branch tubes 30, 31, 32 and 33 extend longitudinally through working portion 41 of the blade. The joint surfaces between the portions 37 are curved in conformity with the curvature of the blade as shown in Figure 14 so that the portions 37 form a central fin interconnecting the tubes 30, 31, 32 and 33 and extending into the leading and trailing edges 50 and 51 of the blade, such an arrangement being particularly advantageous when the tube system is pressed from a metal of higher conductivity than the cast metal since it greatly assists the conduction of heat to or from the leading and trailing edges of the blade which if sharp, cannot always be adequately cooled or heated by a medium passing through internal passages in the blade. As shown in Figures 11 and 12, registering holes 52 are provided in the portions 37 between the channels through which the cast metal flows. This helps in bonding the manifold tube system into the cast metal of the blade.

The manner of forming a plurality of tubes to be cast into a casting in accordance with the invention which has just been described may, it will be appreciated, be adopted in the case of a single tube. For example, the tubes 10 in Figures 1 and 2 may each be composed of a pair of sheet metal parts each having a channel such as 36 constituting one part of the wall of the tube and a flange part corresponding to portions 37 on each side and running the whole length of the channel, the flange parts having their long edges directed away from one another, and the sheet metal parts being joined together with the flange parts of one overlying the flange parts of the other, to form the tube.

It will be noted that in the manifold tube system described with reference to Figures 11 to 14, there are five openings to the outside of the casting, namely an inlet opening 60 and four outlet openings 61. This may also be achieved by embedding a branched tube in a casting by any of the methods described. This is illustrated in Figure 7 which shows a blade 70 having a cast in metal tube 71 extending through the root portion 72 of the blade, this tube having four branches 73 which extend from the portion of the tube transversing the root portion 72 at right angles thereto, and pass longitudinally through the working portion 74 of the blade. The projecting parts of the tubes are cut off when finish-machining the blade.

Furthermore, the portion of the tube 71 in the root portion 72 could for example, be arranged along one side of the root portion, this portion being subsequently removed by any of the mechanical, electrical or chemical means previously referred to to leave a header 74 (see Figure 8) in the blade root with which chamber the branches 73 communicate. The branches of the tube are in this case curved as at 75 to pass from the chamber 74 into the working portion of the blade, and are suitably varied as to cross-sectional area and/or cross-sectional shape along their length so that they are more easily accommodated in the working portion of the blade both at the centre and towards the leading and trailing edges of the blade. This feature is shown in Figures 9 and 10 from which it will be seen that the central branch 73 changes from circular cross-section at the root-end 72 of the blade to a narrow sector shaped cross-section

at the tip end, where in view of the thinness of the blade, the cast metal could not easily accommodate the tube if its cross-sectional shape and cross-sectional area were the same as at the root end. In a similar way, the branches adjacent the leading and trailing edges of the blade change from circular cross-section at the root end to a flattened somewhat triangular shape in cross-section at the tip end.

Where tubes cast into a casting by any of the methods hereinbefore described are to be subsequently removed to leave internal passages in the casting of larger bore than the tubes, the tubes may be provided on their external surfaces with raised members such as 80 in Figure 4 so that when the metal of the tube is removed the passage, being in shape a negative of the external shape of the tube, has recesses 81 (Figure 5) corresponding to the raised members 80. In this manner, internal passages in cast blades may be provided with such recesses as materially increase the heat exchange surface of the passage. The raised members 80 may take any desired form for example, plane ribs, flanges or gills, or they may be helically arranged around the outside of the tube like the turns of a multi-start thread. A tube having raised members in the last mentioned form gives rise to an internal passage as shown in Figure 6 when it is removed.

Such tubes may for example, be removed by chemical attack. When this method of removal is to be employed, the tube is of course made from a metal which is removable by the selected reagent to which the cast metal should be immune.

In general, the metal tubes may be made of mild steel, stainless steel, nickel-chromium heat-resisting alloy, copper or silver, and the cast metal of the blade may be aluminium alloy, bronze, mild steel, stainless steel, or a heat-resisting nickel-chromium or cobalt base alloy, the materials being appropriately chosen according to the intended working temperature of the blade and the stresses which it will be called upon to bear during use.

Where aluminium alloy is to be used as the casting alloy, tubes made of any of the metals or alloys mentioned above have a melting temperature higher than the temperature of the molten alloy run into the mould. In this case, in order to prevent chilling of the molten alloy coming into contact with the tubes the tubes may be heated internally, for example, by inserting into each before the molten metal is poured, a core comprising an electrical heating element 16 (see Figure 3) enclosed in an insulating heat resisting refractory material 17, and connecting the element to a source of electric supply. As soon as the molten alloy has been poured and the whole assumed an even temperature the current supply is switched off and the cores then removed either immediately, or after the cast metal has set.

To promote bonding of the aluminium alloy with the tubes the tubes are coated externally with flux before the alloy is poured. The refractory layer 17 on the electric heating element may be composed of silica, alumina, magnesia, or zirconia, all of which may be deposited on the heating element by electrophoresis. Aluminium blades having internal passages are used for example as compressor inlet guide blades or vanes, the internal passages serving for heating purposes to avoid icing of the blades.

We claim:

1. A method for producing a metal casting having a group of internal passages, which method comprises shaping each of a pair of metal sheets to form the sheet into a series of passage wall parts of passages corresponding to and grouped in the relation required for the passages in the casting with a flange part on each side of and running the whole length of each such wall part, joining said sheets together with the flange parts of one overlying the flange parts of the other to form a unitary core having passages corresponding to and grouped in the relation required for the passages in the casting, support-

7

ing said core in a mould of the required casting with the passages in the core at the position required for the passages in the casting and then casting the casting in the mould.

2. A method as claimed in claim 1, comprising making the core from sheet metal having a melting temperature higher than the temperature of the casting metal being run into the mould, and the core is internally heated while the casting metal is being run into the mould.

3. A method as claimed in claim 2, comprising internally heating the core by inserting within each of the passages of the core a removable plug comprising electrical heating means, and supplying electric current to the heating means.

4. A method as claimed in claim 1, comprising supporting the walls of the passages in said core against collapse when the casting metal is run into the mould by inserting a removable plug in each of the passages of said core before running the casting metal into the mould.

5. A method as claimed in claim 1, comprising, before running the casting metal into the mould, coating said core externally with a material which promotes bonding of the cast metal with the metal of the core.

6. A method as claimed in claim 5, wherein said coating is of a metal which is more resistant to oxidation than the metal of said core.

7. A method as claimed in claim 5, wherein the casting process is a low temperature casting process, and said coating is of flux.

8. A method as claimed in claim 5, comprising making the core of sheet metal parts of a metal having a melting temperature at least as high as the temperature of the casting metal to be run into the mould, said coating being of a metal having a melting temperature lower than the temperature of the casting metal to be run into the mould.

9. A method as claimed in claim 1, further comprising embedding said core in the desired position in a wax pattern of the casting to be produced, with the ends of said core projecting well clear of the pattern, investing the pattern with investment material to form a mould

8

while leaving the ends of the core projecting through the investment material, allowing the investment material to set, heating the invested pattern to expel the wax from the mould, firing the mould to stabilize the investment material, and then running the casting metal directly into the hot mould.

10. A method as claimed in claim 1, for producing a blade for a fluid flow machine, said blade having a working portion with leading and trailing edges, a root portion and a group of internal passages running longitudinally of the working portion, the method comprising making said sheet metal parts of a metal having a higher thermal conductivity than the casting metal with longitudinal edge portions which extend respectively into leading and trailing edge portions of the working portion of the blade.

#### References Cited in the file of this patent

##### UNITED STATES PATENTS

|           |                 |               |
|-----------|-----------------|---------------|
| 1,243,471 | Willis          | Oct. 16, 1917 |
| 1,416,412 | Pack            | May 16, 1922  |
| 1,710,534 | Field           | Apr. 23, 1929 |
| 1,912,889 | Couse           | June 6, 1933  |
| 2,074,007 | Wissler         | Mar. 16, 1937 |
| 2,085,324 | Lindner         | June 29, 1937 |
| 2,166,634 | Lesage          | July 18, 1939 |
| 2,274,580 | Bailey          | Feb. 24, 1942 |
| 2,294,959 | Campbell et al. | Sept. 8, 1942 |
| 2,362,875 | Zahn            | Nov. 14, 1944 |
| 2,479,039 | Cronstedt       | Aug. 16, 1949 |
| 2,510,735 | Bodger          | June 6, 1950  |
| 2,609,576 | Roush et al.    | Sept. 9, 1952 |
| 2,665,881 | Smith et al.    | Jan. 12, 1954 |
| 2,679,669 | Kempe           | June 1, 1954  |
| 2,687,278 | Smith et al.    | Aug. 24, 1954 |

##### FOREIGN PATENTS

|         |               |               |
|---------|---------------|---------------|
| 549,016 | Great Britain | Nov. 3, 1942  |
| 610,494 | Great Britain | Oct. 15, 1948 |
| 238,186 | Switzerland   | Nov. 1, 1945  |
| 287,296 | Switzerland   | Mar. 16, 1953 |