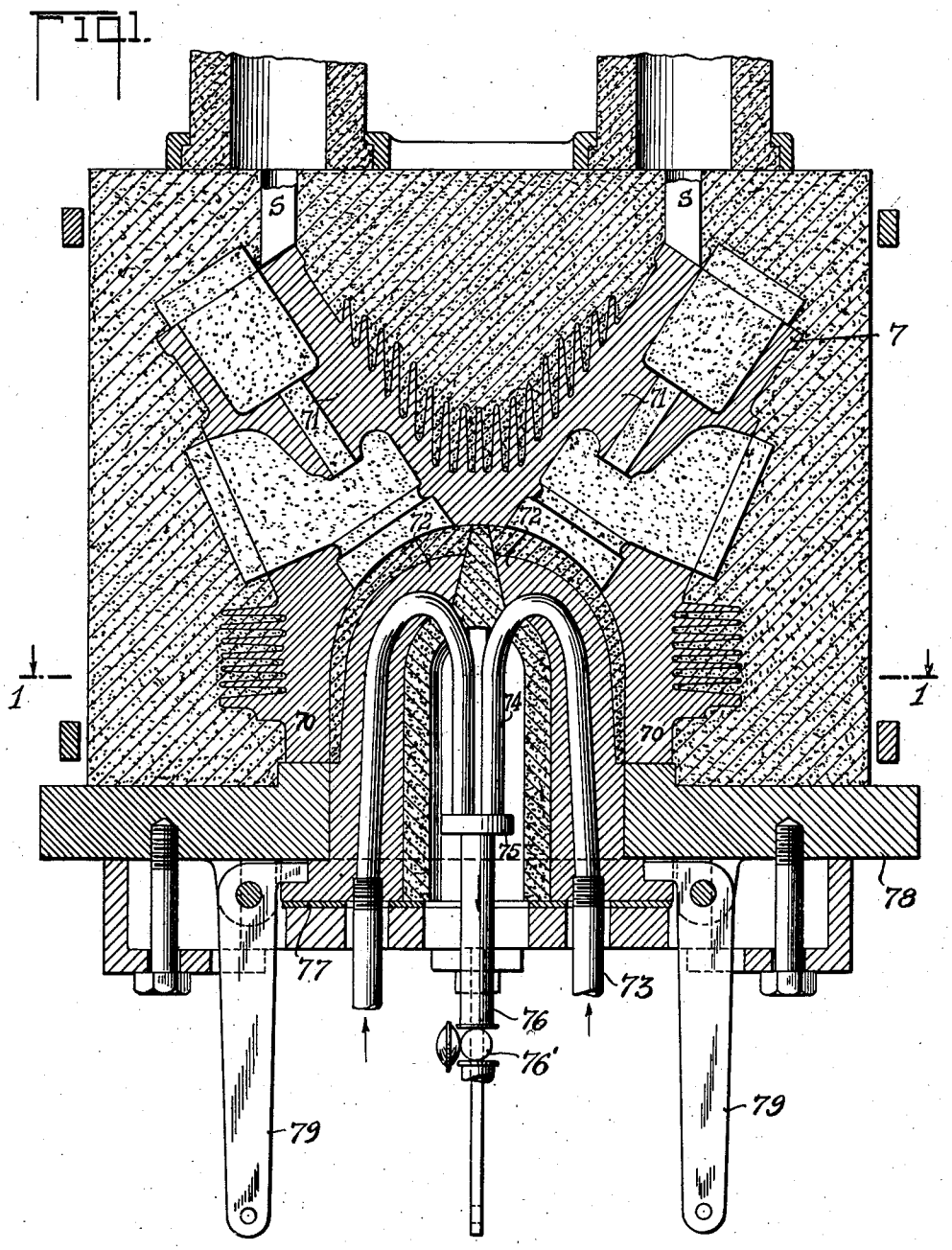
Aug. 26, 1941. H. F. HAGEMEYER 2,253,903

MOLD

Filed Aug. 2, 1938 2 Sheets-Sheet 1

Fig. 1.



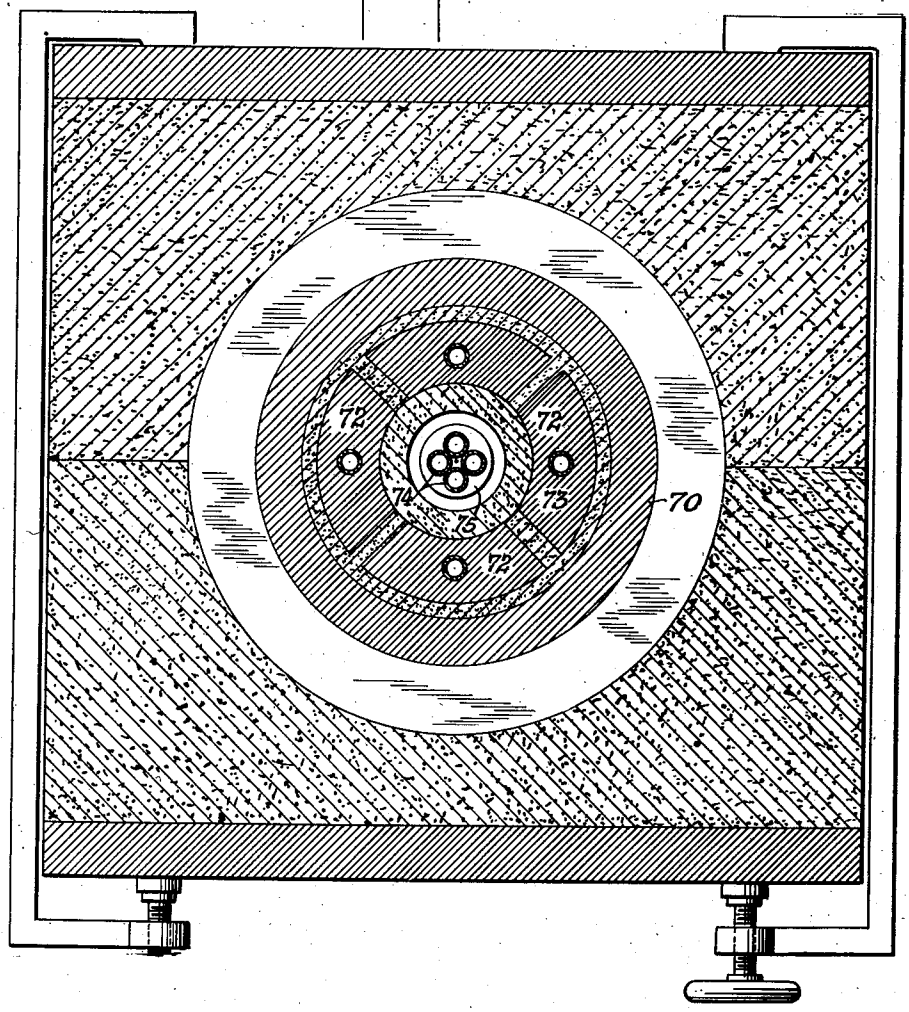
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Filed Aug. 2, 1938 2 Sheets-Sheet 2

FIG. 2.



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2,253,903

MOLD

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Application August 2, 1938, Serial No. 222,599

1 Claim. (Cl. 22—126)

My invention relates to methods and apparatus for controlling the temperature of metal which has been poured into a mold in a casting operation, and more particularly to such methods and apparatus for expediting the cooling of the poured metal in a controlled manner, whereby the characteristics of the metal in the casting may be regulated.

In conventional casting practice cooling of the poured metal is usually uncontrolled, so that, as the heat is dissipated, the temperature in different parts of the casting will vary according to the body of such parts. By body I mean the relative sizes of the various component portions of the casting. Thus a part of large body or size will cool more slowly than a smaller one, for all parts of the casting are subjected to approximately the same temperature differential and are substantially equally insulated from the atmosphere. Such difference in cooling rate occurs, of course, because the larger sections have less heat radiating surface in proportion to their volume and heat content than have the smaller sections. As the metal in the casting solidifies and cools shrinkage takes place, so that additional metal tends to flow toward the solidifying parts from portions of the casting which are still fluid, to compensate for the deficiency caused by such shrinkage. If there are no adjacent fluid sections, as where a liquid pocket or central section is solidifying, sunken portions on the surface of the casting or internal shrinkage faults may result, which are undesirable.

By the employment of my controlled cooling method the order of solidification of the various portions of the casting may be predetermined to avoid leaving fluid pockets or centers wholly surrounded by set metal, the feeders supplying the deficiency caused by the metal shrinkage. Within the term feeder I include the usual gate through which the metal enters the casting cavity, as well as risers, shrink pins, or shrink bobs which may be provided on portions of the casting remote from the gate. Thus there will be no internal shrinkage in the casting, tending to make internal fissures, or sunken portions in the metal surface, for the shrinkage deficiency of all solidifying portions will be replaced successively from the next portions to solidify, and the last portions of the casting to solidify will be filled from reservoirs of molten metal formed by such feeders outside of the casting proper. The essence of my process lies in controlling the cooling so that the portions of the casting most remote from the feeder will solidify first, and thereafter portions progressively nearer to the connection of a feeder with the casting will solidify, so that the last portion or portions of the casting to solidify will be that or those at the feeder junction or junctions.

In carrying out my method, therefore, the portion of the casting most remote from the connection of a feeder therewith is cooled very rapidly, and the portions between such most remote portion and the feeder connection are cooled at varying rates, the heat being removed more rapidly from those portions of the casting which are of larger body and which are more remote from the feeder connection as necessary to obtain progressive solidification of the various parts in the sequence above stated.

Another type of mechanism may embody a hollow cooling member, the chamber of which contains a cooling medium either at rest or as a liquid flowing therethrough. In the latter case the rate of flow through the cooling member may be thermostatically controlled, the flow volume varying according to the temperature of the cooling fluid. Also the course of the fluid over the casting may be arranged so that the flow will be toward the feeder connection, that is, from the parts to be cooled most quickly toward the parts to be cooled at a less rapid rate, the temperature differential between the fluid and the metal thereby progressively decreasing in the direction of flow. A further variation of cooling rate may be obtained by regulating the flow quantity of cooling fluid so that the volume flowing over the portions of the casting to be cooled most rapidly is greater than the volume flowing over other portions of the casting. Such a volume control may be combined with a flow course toward the feeder connection, if desired, portions of the cooling fluid being tapped off at intervals along the course to produce the proper quantity variation.

The principal object of my invention, therefore, is to obtain a controlled cooling of a casting within a mold, so that the portions most remote from the connection of a feeder with the casting will be solidified and cooled first and the solidification will proceed progressively toward the feeder connection.

Another object is to remove heat in controlling the cooling of various portions of a casting, not only in proportion to the respective distances of such portions from a feeder connection, but also in proportion to the body or size of the various casting portions.

Still another object is to insure that the cast-

ing proper will in each case be entirely solidified, and cooled as much as possible, prior to the solidification of a feeder or feeders connected therewith, so that deficiencies of metal in the casting caused by the shrinkage which takes place during such solidification and cooling may be replaced from the still fluid feeders instead of from a surface of the casting, causing a depression therein, or from the interior of the casting, creating internal flaws and fissures.

An additional object of my novel method is not only to control the cooling of a casting so that the parts thereof will be solidified in a desired sequence, but also to control the rate at which the various parts are cooled in order to obtain desired grain structure and physical characteristics in the cast metal.

It is also desired to accomplish the aforementioned objects by mechanism of simple though effective design, which may be readily adapted to carry out my cooling method on castings of a wide variety of shapes and sizes.

Specifically it is an object to provide appropriate cooling fins, specially proportioned molds, or supplementary artificial cooling mechanism, or a combination of these features, most suited to the proper cooling of a particular casting in the manner desired.

More specific objects, inherent in the examples of mechanism shown in the drawings, will be understood from the following description thereof. The drawings illustrate the application of my method to, and the use of apparatus in carrying out such method on castings of simple shapes, the principles governing such apparatus being capable of incorporation in mechanism for other and more complicated types of castings by one skilled in the casting art.

Fig. 1 is a vertical section through an assembled mold and associated mechanism, illustrated cooling apparatus combining a plurality of expedients employed separately in the previous figures.

Fig. 2 is a transverse sectional view taken along line I—I of Fig. 1.

In the casting of metal the general practice heretofore has been to provide a sprue, a runner, and risers if necessary, positioned and dimensioned only to obtain complete filling of the mold cavity. There has been no effort to proportion the runner or riser to have a definite relationship to the size or shape of the casting to be produced for the purpose of maintaining such feeder fluid until the casting is completely solidified. Despite the insulating quality of the mold material therefore, the feeders and their connections with the casting often solidified before all the metal in the casting had reached the solid state, so that such feeders could not act as a reservoir from which the deficiency in the metal of the casting, caused by its shrinkage during solidification and cooling, might be drawn. As a result, when the metal in the casting proper shrinks a greater or lesser amount depending on its composition, the contraction is manifested either as internal shrinkage faults, or as depressions in the casting surface by metal moving therefrom toward the center of the casting. If these defects are to be avoided, the metal in the feeder or feeders and their connections with the casting must remain liquid until all the metal of the casting proper has solidified, so that the feeders may act as reservoirs to make up for the shrinkage deficiency in the casting.

A bar casting of the same size as the gate will not have internal shrink faults or surface depressions even when cast without special cooling control, because the metal will naturally solidify from the end farther from the gate, which is poured first. The same natural proper directional solidification will occur unassisted where the casting tapers from the size of the gate outward, the solidification progressing from the end most remote from the gate toward the connection of the gate with the cavity, and the gate will be the last to become solid, so that deficiencies caused by the metal shrinkage in the casting may be replaced from the gate. Few castings are of these types, however, and where the gate or other feeder is of smaller cross section than the portion of the casting to which it is joined, as is usually the case, the metal in the feeder tends to solidify before the metal in the casting, thus cutting off the possibility of the casting being fed during solidification from an external reservoir. In such cases my cooling method insures proper directional solidification by artificially expediting cooling of the casting to control the sequence in which the parts thereof solidify, and to obtain its complete solidification prior to solidification of the feeders.

In carrying out my process therefore, the cooling of the parts of a casting should be such that the part most remote from a feeder connection will be caused to solidify first. Thereafter, parts progressively nearer the feeder connections will in turn solidify and this order of solidification will be preserved regardless of the casting's shape, or variation in body, that is, either thickness or width or both, of the several portions of the casting.

In cooling an aircooled airplane engine cylinder head casting, such as shown in Figs. 1 and 2, fins, fluid cooling mechanism, and a shell mold may all be employed. In this instance the fins, instead of being added especially to carry out my method, are desired as part of the finished casting, but their function as heat radiating devices may be utilized conveniently as part of the apparatus for carrying out my method. When such fins are employed without the additional cooling arrangement to be described, their heat radiating action is a disadvantage and the cooling procedure is worse than if no fins are present, unless a very thick mold wall is employed to minimize the heat radiating effect of the fins.

Considering first the manner in which the casting would solidify if no fins were formed thereon, and no other auxiliary cooling mechanism were provided, the solidification would take place in approximately the correct sequence if the rocker boxes 11 are sufficiently heavy. The skirt 10 of the casting 7 would solidify first, the metal being poured into this portion first, and the solidification would progress toward the sprues S, since the cross section of the casting increases fairly uniformly to the connection of the sprues therewith. The only difficulty might be in the tendency of the sprues S to solidify prior to complete solidification of the heavy casting, in which case internal shrinkage or a sunken surface on the rocker boxes might result.

In this particular type of casting, however, the fins are required as a vital, integral part of the finished casting. The provision of fins on the exterior of this casting without additional artificial cooling mechanism not only tends to set up strains caused by the unequal cooling resulting from the greater heat radiation surface afforded by the fins, but also tends to cool more

rapidly and causes to solidify first isolated parts of the head, instead of effecting a properly controlled cooling sequence. While in the application of my cooling method to some castings the heat may be removed in a controlled manner almost entirely from one side only thereof because of the thinness of the metal, this procedure will not operate satisfactorily upon a thick walled casting such as the cylinder head shown in Fig. 1. The reentrant portion of the skirt 70 would not solidify until after solidification of the finned rocker boxes 71 had cut off passage therethrough for fluid metal from the sprue S to the skirt 70, to compensate for metal shrinkage therein. A sunken surface within the skirt and dome would result. It is therefore necessary to provide artificial cooling mechanism both for the interior and for the exterior surfaces of the skirt 70, so that it will be solidified completely before the axial parts of the rocker boxes 71 solidify.

In cooling the cylinder head according to my method I prefer to employ metal formers 72 which are inserted within the reentrant portion of the skirt 70 and may be spaced therefrom as shown in Fig. 1. This intervening space is filled with an annulus of mold material gradually increasing in thickness from the edge of the skirt toward the central portion of the dome. Because the plurality of fins provides so much heat radiating surface it may be necessary to use additional means for expediting the removal of heat from the inner surface, such as cooling fluid flowing through passages 73 in the formers. The direction of flow should be as indicated by the arrows in Fig. 1, the fluid flowing first past the skirt 70 and being warmed as it flows toward the sprue or feeder connection, the warmest fluid being discharged from the formers near their upper ends through pipes 74, which may all unite in a header 75 discharging into an outlet conduit 76 having therein a thermostatic valve 76'. The operation of this complete mechanism will effect proper directional cooling, because the combined action of the skirt fins on the outside with the fluid and metal cooling means on the inside will cause rapid solidification of the skirt from its edge toward its base. The fins on and between the rocker boxes 71 will hasten their solidification, but this will not be complete prior to the entire solidification of the skirt and dome portions, yet will increase heat dispersion sufficiently so that even the largest cylinder head parts will have solidified prior to solidification of the sprues S which will cool only at their normal rate.

Thus instead of the sprues solidifying before all portions of the casting have solidified and certain portions of the casting remaining fluid although completely surrounded by solidified portions, such fluid pockets causing shrinkage faults upon solidification, the solidification of the entire casting will be progressive from the edge of the skirt 70 upward to the bases of the rocker boxes and thence to their upper ends. All the solidification in the casting will take place while the sprues S are still in the fluid state so that they will serve as reservoirs from which metal may be supplied throughout the entire solidification of the casting, to compensate for the deficiency of metal in the casting cavity caused by the shrinkage of the solidifying metal.

As has been stated, the fins which expedite cooling of the exterior wall of the casting are formed as part of the finished casting. While temporary fins might be provided in the reentrant portion of the cylinder head skirt to balance the cooling action of the exterior fins if arranged in the vertical direction, their formation would be difficult. I prefer, therefore, to use a core incorporating metal cooling formers as described. Since the cast metal contracts in cooling, the cavity likewise will become smaller, and to prevent fracturing the casting by resisting such contractive stress, the formers 72 encircling the cavity are yieldably mounted. Four such formers may conveniently be employed, as shown in Fig. 2. Between the adjacent edges and ends of these formers should be placed some crushable substance, such as mold material which may be of the gypsum base type, capable of yielding under the stress created by the contracting cylinder head skirt. No appreciable resistance to the contraction of the cast metal will therefore be offered, so that no strains will be developed in the casting as would be the case if the core were of rigid construction. The members 72, supported on plate 77, may slide substantially unrestrainedly away from the mold supporting plate under the pressure of the shrinking cast metal. Pivoted levers 79, suspended from a mold form base plate 78, may be provided, which engage the bases of the formers 72, for use in drawing them from the casting cavity after the metal has solidified. Such withdrawal may be made at any temperature desired after solidification to allow further cooling to take place more slowly without using the artificial cooling means of the core, or the cooling may be delayed by passing hot fluid through the passages 73. Within the circle of formers a thin wall of mold material may be employed to support their backs, as shown, if necessary to enable the core to withstand the force of the inrushing metal without deformation.

This process may be used in either sand or plaster molding operations, but it is most useful where gypsum base molds of sufficient porosity to allow the pouring gases to seep through the mold body are used. Every riser added for a shrinkage reservoir requires additional pattern expense, an excessive amount of casting metal, and necessitates additional machining in the finishing operation. With my process applied to a porous gysum molding operation, ordinarily the only exterior reservoir of molten metal will be the gate, runner and sprue arrangement which is a necessary provision in every case. If for an intricate casting an additional feeder is found to be necessary when my directional cooling process is employed, several more feeders would be necessary if my process were not used, one for each part of the casting where an isolated molten pocket would occur in natural cooling. Hence considerable expense is eliminated, as well as a better product obtained, by the use of my process, and castings can be made where it is employed which could not be produced without flaws if such process were not used.

As my invention, I claim:

In a mold having therein a cavity for casting an internal combustion engine cylinder head, the combination of a centrally apertured base plate supporting the mold, a plurality of rigid metal members projecting upward through the base plate aperture in laterally spaced relation, mold material covering said members to form a reentrant wall for the casting cavity and further mold material interposed between adjacent members, means supporting said members from said base plate for individual lateral movement with respect thereto toward the center of its aper-

ture under pressure of the cast metal shrinking during cooling, a lever for each of said members pivoted upon said base plate and engaging the lower end of its member for withdrawing it at will from the mold through the aperture in said base plate, said rigid metal members having passages therethrough, an individual cooling liquid supply conduit connected to each of said members, a common discharge manifold for said members and thermostatic means controlling the discharge of cooling fluid from said manifold.

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