United States Patent [19]
Gerding

[11] **3,845,810**
[45] **Nov. 5, 1974**

[54] **STRIP CASTING APPARATUS**

[75] Inventor: **Charles Christian Gerding,** Pittsburgh, Pa.

[73] Assignee: **Jones Laughlin Steel Corporation,** Pittsburgh, Pa.

[22] Filed: **Oct. 6, 1972**

[21] Appl. No.: **295,621**

Related U.S. Application Data

[62] Division of Ser. No. 188,049, Oct. 12, 1971, Pat. No. 3,712,366.

[52] **U.S. Cl.** .... **164/276,** 164/283 M, 165/89
[51] **Int. Cl.** **B22d 11/06**
[58] **Field of Search** .... 164/87, 89, 276–278, 164/283 M; 165/89–91

[56] **References Cited**

UNITED STATES PATENTS

1,868,436	7/1932	Stancliffe	165/91
2,450,428	10/1948	Hazelett	164/277
3,338,295	8/1967	Scribner	164/89
3,537,506	11/1970	Griffiths	164/276

FOREIGN PATENTS OR APPLICATIONS

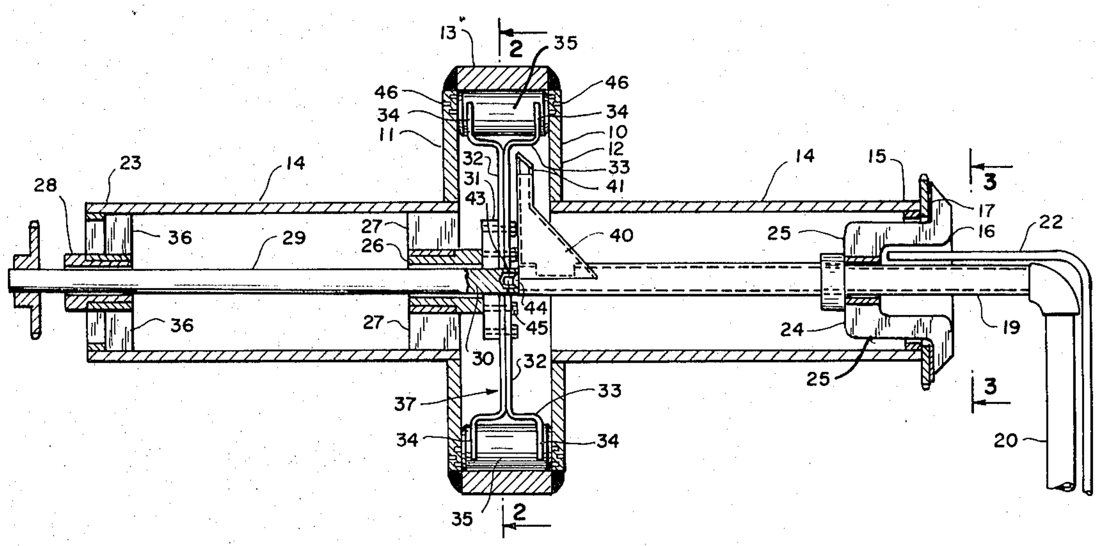
1,141,772	12/1962	Germany	165/89

Primary Examiner—R. Spencer Annear
Attorney, Agent, or Firm—G. R. Harris

[57] **ABSTRACT**

An internally liquid cooled rotatable drum open to the atmosphere for continuously solidifying molten metal on its outer surface is provided with a coaxially rotating spider carrying rollers in radial slots which under the action of centrifugal force roll on the drum inner surface. The spider is rotated at a speed sufficient to throw a rotating layer of cooling liquid against the inside surface of the drum by centrifugal force, and the action of the rollers on the surface being cooled breaks up incipient film boiling.

10 Claims, 4 Drawing Figures



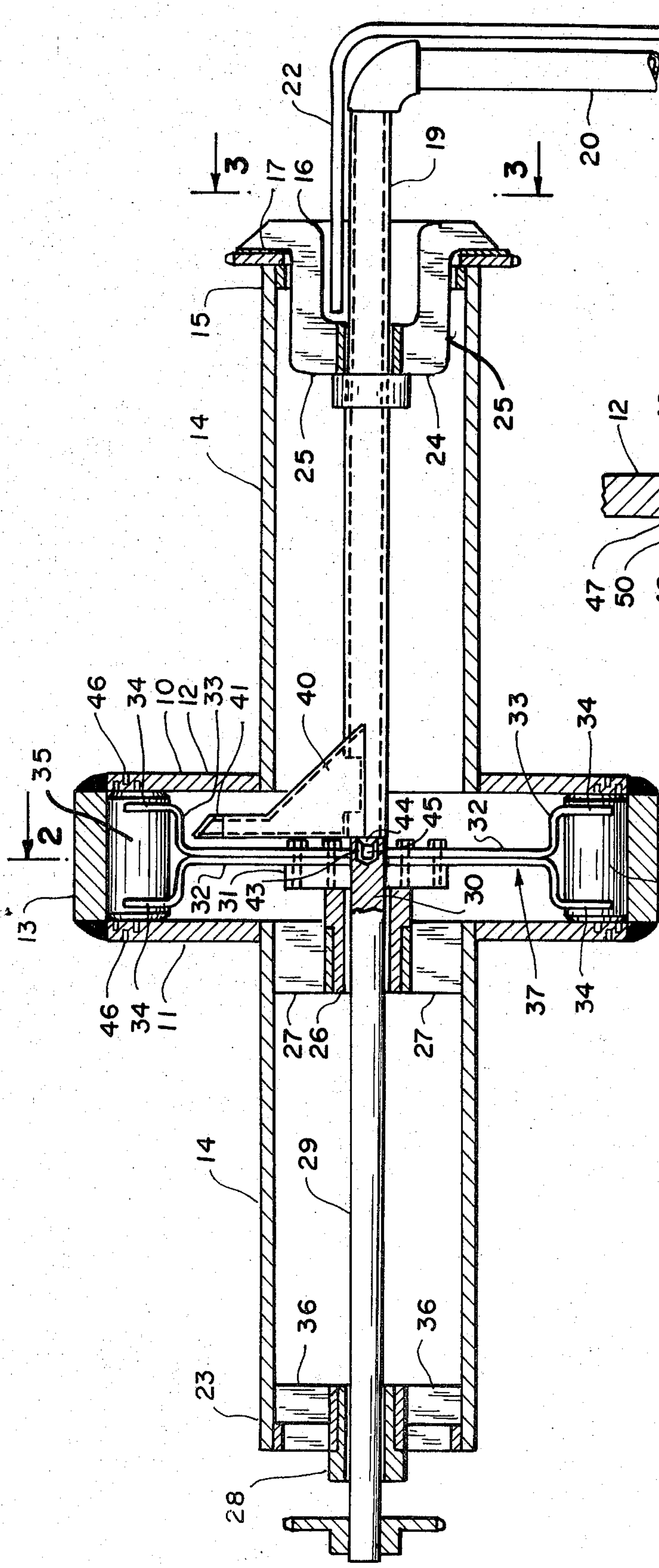


Fig.1.

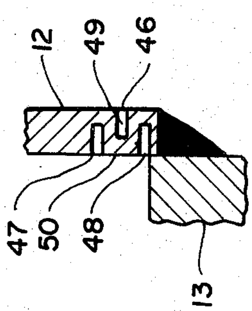


Fig.4.

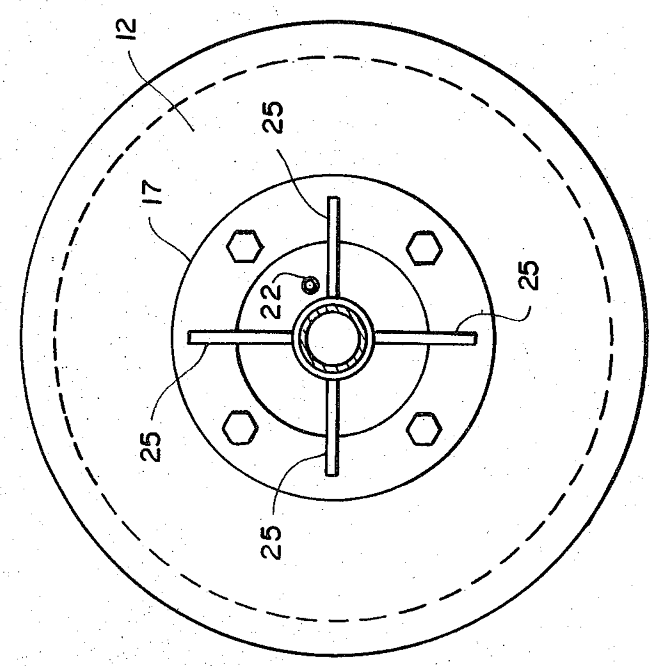

12
17
22
25
25
25
25
25

Fig.3.

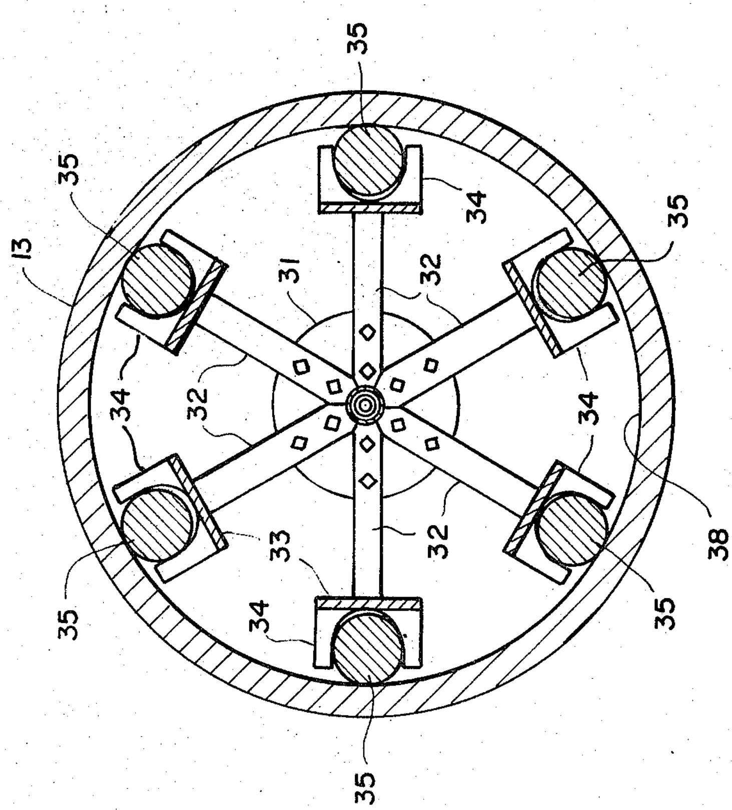

13
31
32
32
32
32
33
33
34
34
34
34
34
35
35
35
35
35
35
38

Fig.2.

STRIP CASTING APPARATUS

This is division, of application Ser. No. 188,049 filed Oct. 12, 1971, and now U.S. Pat. No. 3,712,366.

This invention is concerned with the continuous solidification of strip from molten metal. It is more particularly concerned with method and apparatus for solidifying metal on the outer surface of a rotating drum partially immersed in the molten metal.

It has been known for a number of years that molten metal can be solidified on the surface of a rotating chilled drum so as to produce continuous metal strip. A relatively simple embodiment of such an operation involves rotating the drum about its axis mounted horizontally so that a portion of the drum surface dips into a crucible holding molten metal. If the drum is chilled or cooled internally, the metal solidifies on the circumferential drum surface and is removed continuously as cast strip. Cyclic heating and cooling, however, tend to warp the drum, which leads to cracking and eventual destruction. More uniform cooling is desirable, but it is difficult to distribute cooling liquid around the inside of the drum by nozzles, baffles and the like. These can operate only by increasing the pressure drop through the cooling system so that the pressure in the drum is above that of the atmosphere. This condition is not desirable in apparatus processing molten metal, such as steel at a temperature of 2,800°F or thereabouts, as a plugged cooling channel can result in an explosive build-up of pressure. Moreover, the effectiveness of the cooling liquid, usually water, is greatly reduced by the formation of a layer of steam or vapor on the inside surface of the drum. The film-boiling action of this layer tends to insulate the drum surface from the cooling liquid.

It is an object of my invention, therefore, to provide apparatus for continuously solidfying molten-metal on the outside surface of a rotating drum with internal cooling means which more effectively distribute the cooling liquid employed. It is another object to provide such apparatus which is open to the atmosphere. It is yet another object to provide apparatus which breaks up the layer of vapor which otherwise tends to form between the surface to be cooled and the cooling liquid. It is still another object to provide a more effective process of cooling a strip casting drum. Other objects will appear in the course of the description of my invention which follows.

When cooling liquid is introduced into a casting drum and withdrawn therefrom, its tendency, of course, is to collect in the bottom portion of the drum. Since the drum is rotating, constantly bringing regions of its surface which were above the level of the molten metal beneath that level and other regions which were below that level above it, one might expect temperature nonuniformities to even out. The fact is, however, that the rate of solidification of molten metal on the drum surface is low. A two-foot diameter drum caster for the direct casting of steel with which I am familiar operates typically at the rate of about 2 rpm, and as it is the lineal speed of the drum surface that is controlling, a larger drum would rotate even more slowly. Extreme temperature differences are found between opposite portions of the drum surface. I have discovered that if the drum is provided with an internal structure rotating at a faster rate sufficient to throw the cooling liquid against the drum wall by centrifugal force and maintain a rotating layer of cooling liquid therein, more

uniform cooling of the entire circumference of the drum results. It is not necessary to maintain any pressure drop through the cooling system, and the drum can be open to the atmosphere. My rotating element is an improvement over rotary heat transfer apparatus such as is described in U.S. Pat. No. 1,868,436 issued July 19, 1932 to C. W. Stancliffe. I have also discovered that if the rotating structure is provided with elements which contact the drum surface so as to shear the liquid film thrown against it and thereby break up any incipient vapor the rate of cooling is considerably increased. An embodiment of my invention presently preferred by me is illustrated in the attached figures, to which reference is now made.

FIG. 1 is a plan view in cross-section of apparatus of my invention.

FIG. 2 is a cross section taken on the plane 2—2 of FIG. 1.

FIG. 3 is an end elevation of my apparatus taken on the plane 3—3 of FIG. 1.

FIG. 4 is a cross sectional detail of a portion of my apparatus.

I describe hereinafter only the rotating drum portion of strip casting apparatus embodying my invention as the crucible which holds the molten metal is wholly conventional and forms no part of it. My apparatus comprises a strip casting drum **10** which is mounted upright for rotation about its horizontal axis. Drum **10** has two opposite circular end faces **11** and **12** and a circumferential rim or surface **13** upon which the molten metal is cast. End faces **11** and **12** are joined to rim **13** by a junction **46** to be described. Drum **10** is mounted on a hollow cylindrical shaft **14** which extends therefrom in both directions, from end plates **11** and **12** respectively. The ends of shaft **14** are journaled in bearings, not shown, so that the rim **13** of drum **10** is immersed in molten metal contained within a crucible.

To end **15** of shaft **14** is attached a fitting **16** which extends therein. Through bearing **24** in the center of fitting **16** a stationary pipe **19** projects into shaft **14** and terminates within drum **10** at a position which will be defined hereinafter. This pipe **19** is the drain pipe through which cooling liquid supplied to drum **10** is withdrawn. Its outer end is connected to a conduit **20** which leads to a sewer or sink, not shown. Fitting **16** comprises a ring **17** carrying four inwardly extending ribs **25—25** which support a centrally located bearing **24** through which pipe **19** passes. The spaces between ribs **25—25** are open. Cooling liquid is supplied to internal hollow shaft **14** by pipe **22** which is positioned parallel to pipe **19** and which extends up to fitting **16.**

The opposite end **23** of shaft **14** is fitted with a centrally located bearing **28** supported by four ribs **36—36.** A second bearing **26** is aligned with bearing **28** by ribs **27—27** at the intersection of the plane of drum end **11** with shaft **14.** In bearings **26** and **28** is journaled a rotatable shaft **29.** The inside end **30** of shaft **29** carries a circular plate **31** to which are attached six radial arms **32—32,** forming a spider **37.** Each arm terminates at its outer end in a bifurcated cradle **33** which has spaced outwardly extending ends **34—34.** These ends **34—34** are U-shaped with the open portion extending outwardly to form a slot, and in the slots of each cradle **33** is a roller **35.** The length of roller **35** is greater than the spacing between ends **34—34** of cradle **33** but less than the spacing between end faces **11** and

12 of the drum. The length of arms 32—32 is proportioned so that a roller 35 at the bottom position rolls freely on the inner face 38 of drum rim 13, but within ends 34—34 of its cradle 33. At its uppermost position with the apparatus stationary or turning slowly roller 35 is supported by the U-shaped ends 34—34 of its cradle 33 so that there is clearance between it and the inner face 38 of drum rim 13.

Pipe 19 previously mentioned stops short of the spider 37. At this inner end of pipe 19 is attached a scoop 40 which extends at right angles to pipe 19 in a horizontal position within drum 10. Its extreme outer end 41 opens upwardly, so as to face into the oncoming rotating ring of liquid, and the scoop 40 communicates with the inside of pipe 19. Outer end 41 is proportioned to be somewhat shorter than radial arms 32—32. The ends of rollers 35 overhang scoop 41.

The inside end of shaft 29 extends through plate 31 and is provided with centrally located hole 43. The inside end of pipe 19 is closed by plug 44 terminating in a stub shaft 45 which is journaled in hole 43 of shaft 29.

The junction 46 between end faces 11 and 12 and rim 13 of drum 10 is rendered flexible to some degree by providing each of end faces 11 and 12 with a spaced pair of circular grooves 47 and 48 in its inner face adjacent rim 13 and a circular groove 49 in its outer face positioned between grooves 47 and 48. The web 50 between the grooves above mentioned is thinner than either end face 11 or rim 13 and is folded in the manner of a circular bellows.

My apparatus is provided with means for rotating shaft 14 at a low speed, which are not shown because they are conventional. It is also provided with means for rotating shaft 29 at a higher speed, which likewise are not shown because they are conventional.

In the operation of my apparatus, the means for rotating shaft 14 are adjusted to rotate it at a speed of a few revolutions per minute. Cooling water is supplied to inlet pipe 22 at a sufficient pressure to project a stream from the mouth of the pipe. This stream passes through the open spaces between ribs 25 as shaft 14 is rotated, into the shaft and through it into drum 10. The speed of rotation of drum 10 is necessarily slow because it is limited by the rate at which molten metal, such as steel, solidifies on the rim 13. The cooling water, therefore, tends to run down into the lowermost portion of drum 10 as the latter does not turn fast enough to throw the water outward by centrifugal force.

The means for rotating shaft 29 are adjusted to rotate it at a considerably higher rate than that of drum 10. Shaft 29 rotates spider 37 which pulls rollers 35 with it, as well as water in drum 10. The speed of rotation of spider 37 is maintained above that at which centrifugal force throws the cooling water outwardly against the inside surface 38 of rim 13. The water inside drum 10 thus takes the form of a rotating ring of liquid around its inside surface. The open end 41 of scoop 40 is positioned to strip water off the inside of this ring and discharge it through pipe 19, and the spacing between scoop end 41 and surface 38 controls the volume of cooling water in drum 10.

Rollers 35 roll on the inside surface 38 of rim 13 around the bottom portion of drum 10 and are held there by the combined forces of gravity and centrifugal action. When they are in the uppermost arc of their path of travel the rollers 35 are thrown outward centrifugally just as the fluid is, but here they are held to the inside surface by a difference force-that of centrifugal action less that of gravity. The rolling of rollers 35 on surface 38 squeezes out or shears the liquid and breaks up any steam or vapor film formed between liquid and drum rim.

The rotational speed of spider 37 need be only that which causes the cooling liquid to spread out in a ring around drum 10. For a drum two feet in diameter, the critical speed is about 55 rpm, and it is less for larger drums.

Flexible joint 46 permits rim 13 to deform somewhat as a result of any unbalanced thermal stresses set up therein. Rollers 35 roll on inside surface 38 even if the latter is deformed because they are free to move radially in their cradles 33.

It will be understood that the preferred embodiment of my apparatus here described is susceptible to modifications. The spider, for example, need not comprise six arms but may have more or less. The rolls themselves need not rotate in U-shaped slots but may be provided with axles of smaller diameter which rotate in appropriately dimensioned slots. The rollers may be of steel, or of other material, and may be coated with rubber or other resilient material. Other modifications of this nature will occur to those skilled in the art.

I claim:

1. Apparatus for continuously solidifying molten metal in the form of strip comprising a hollow cylindrical drum open to the atmosphere and positioned with its axis horizontal, means for introducing cooling liquid into the drum through an end thereof, means for rotating the drum at a speed below that to which cooling liquid is thrown against the inside surface of the drum by centrifugal force, means extending radially into the drum for withdrawing cooling liquid therefrom through an end thereof, and means for improving heat transfer from drum surface to cooling liquid comprising spider means rotatable inside the drum coaxially therewith, a plurality of drum surface contacting elements for breaking up incipient vapor and carried by the spider means and rotatable therewith, radial slot means for mounting the surface contacting elements in the spider means adapted and adjusted to permit radial displacement of the drum surface contacting elements from contact with the drum surface to a position spaced from the drum surface and means for rotating the spider means at a speed above that at which cooling liquid is thrown against the inside surface of the drum by centrifugal force.

2. Apparatus of claim 1 in which the drum surface contacting elements are contoured to create shear in the cooling liquid.

3. Apparatus of claim 1 in which the radial slot means have parallel sides open at their outer ends.

4. Apparatus of claim 1 in which the drum surface contacting elements are rollers.

5. Apparatus of claim 4 in which the radial slot means are semicircular at their inner ends and journal the rollers therein.

6. Apparatus of claim 1 in which the means for withdrawing cooling liquid from the drum extend through an end of the drum and the means for rotating the spider extend through the opposite end of the drum.

7. Apparatus of claim 6 in which the means for withdrawing cooling liquid from the drum are stationary

and the inside end thereof is pivotally supported by the means for rotating the spider.

8. Apparatus of claim 1 including a hollow shaft of smaller diameter than the drum coaxial therewith through which the cooling liquid is introduced and withdrawn, the hollow shaft being open to the atmosphere at at least one end.

9. Apparatus of claim 8 in which the cooling liquid is introduced through one end of the hollow shaft, and

including a pipe coaxial with the hollow shaft and exiting therefrom through the same end thereof through which the cooling liquid is introduced, the cooling liquid being withdrawn through the pipe.

10. Apparatus of claim 1 including means flexibly joining the drum end faces and rim so as to permit relative movement therebetween.

* * * * *