Feb. 28, 1956 H. S. ORR ET AL 2,736,548
APPARATUS FOR ACCELERATING CONVECTIVE HEAT
TRANSFER BETWEEN A SOLID AND A GAS
Filed Nov. 14, 1952 4 Sheets-Sheet 1

FIG. 1.

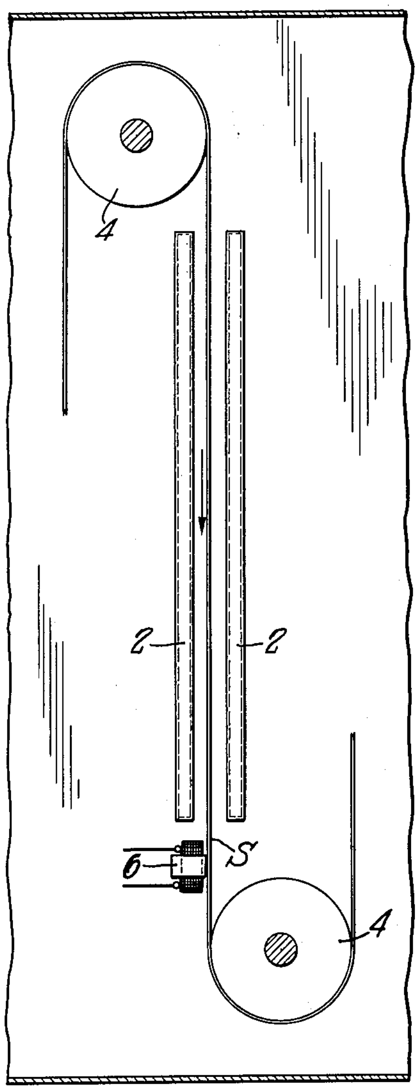
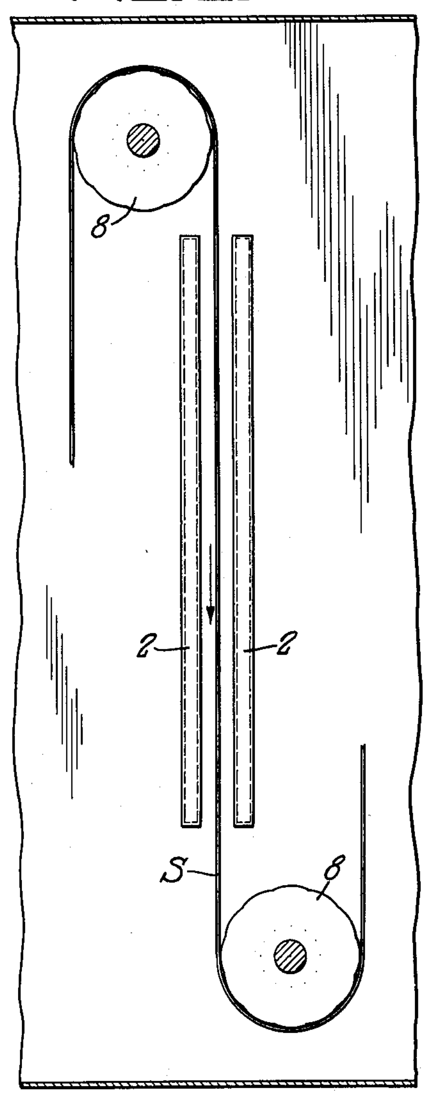


FIG. 2.



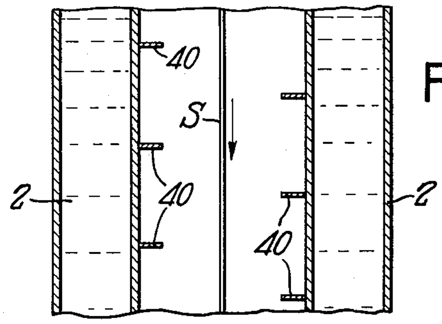


FIG. 6.

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FIG. 3.

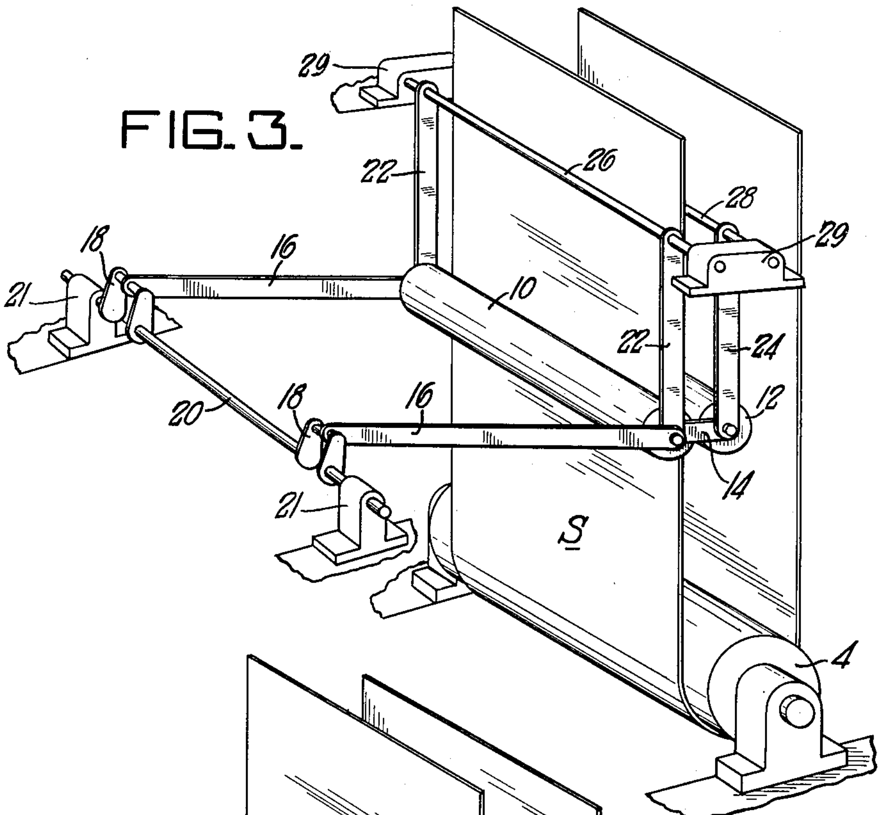


FIG. 4.

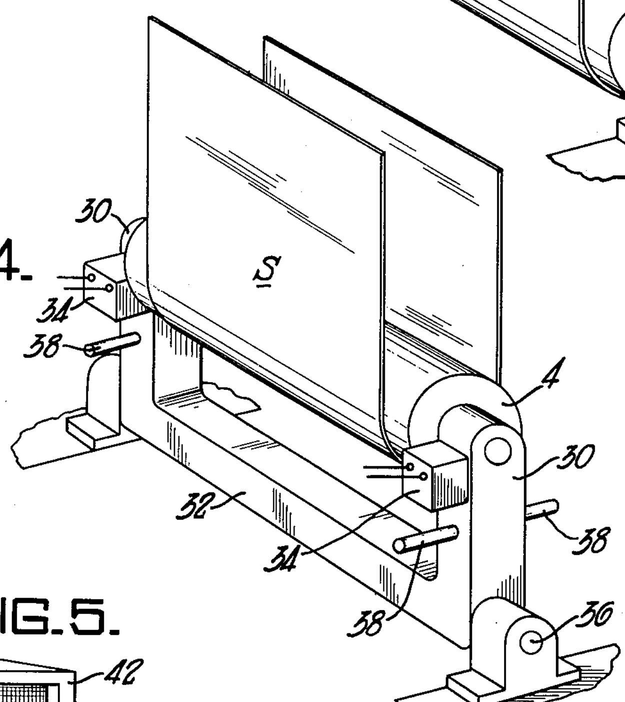
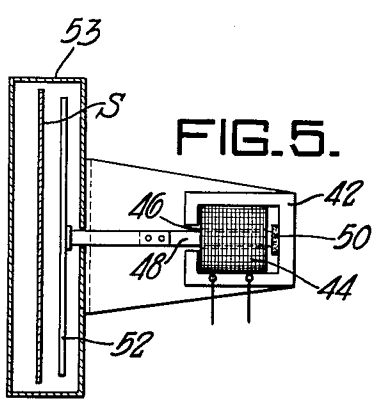


FIG. 5.



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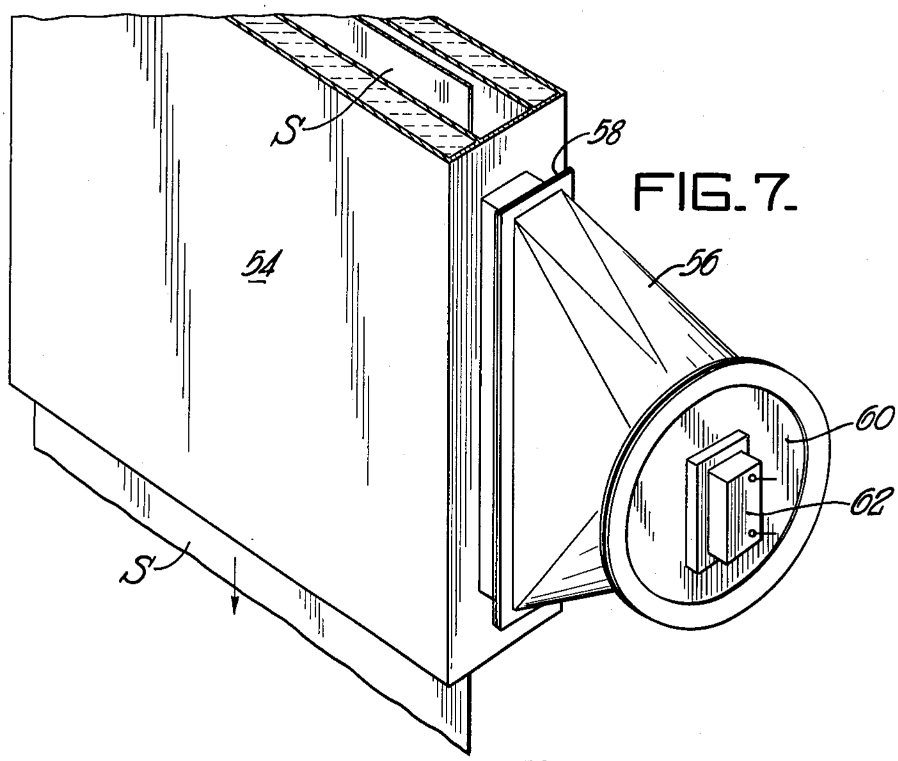

FIG. 7.

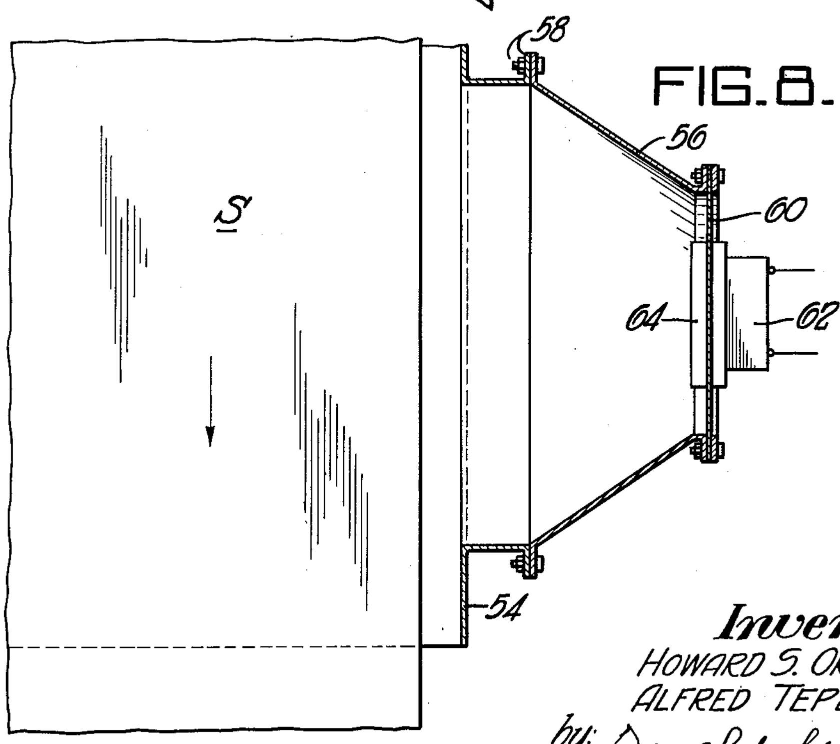

FIG. 8.

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FIG. 9.

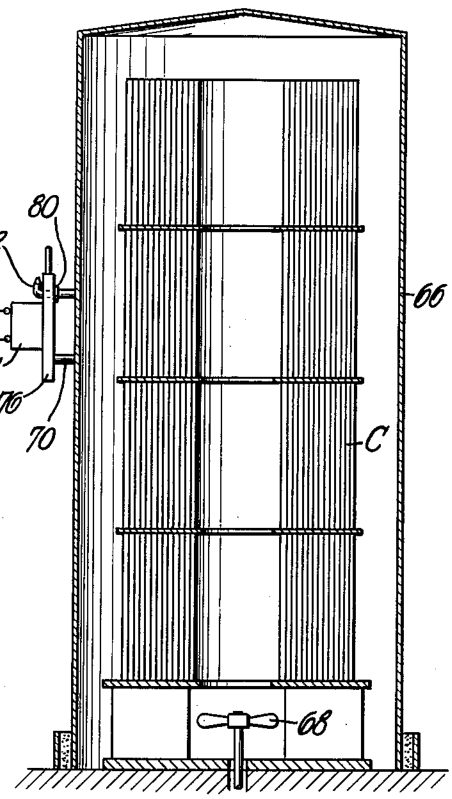


FIG. 11.

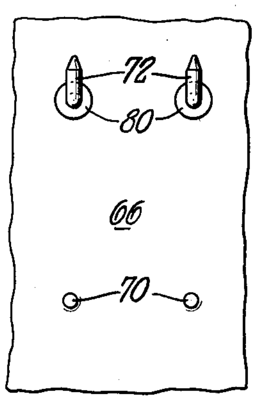


FIG. 10.

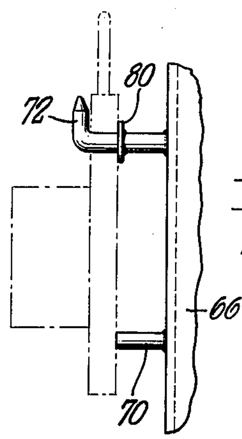


FIG. 12.

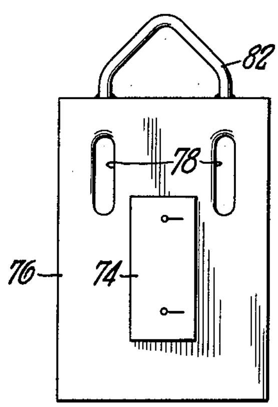
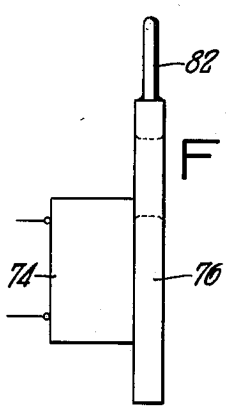


FIG. 13.



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Patented Feb. 28, 1956

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2,736,548

APPARATUS FOR ACCELERATING CONVECTIVE HEAT TRANSFER BETWEEN A SOLID AND A GAS

Howard S. Orr and Alfred Teplitz, Pittsburgh, Pa., assignors to United States Steel Corporation, a corporation of New Jersey

Application November 14, 1952, Serial No. 320,571

3 Claims. (Cl. 263—3)

This invention relates to apparatus for accelerating convective heat transfer between a solid and a gas adjacent thereto and is particularly adapted for accelerating heat transfer between a gas and a strip passing therethrough.

In a continuous annealing of strip steel it is necessary to cool the strip within a relatively short time. In so doing the smooth strip passes between smooth parallel water jackets. We have found that the strip carries with it a large volume of the furnace atmosphere gas, but because of the smoothness of both the strip and the water cooled walls the gas moves in a streamline manner. Thus, there is no mixing between the various layers of the gas and the rate of heat transfer from the strip to the gas and from the gas to the cold walls is small.

We have found that to obtain an increased rate of heat transfer it is necessary to break up the streamline gas flow and create a turbulent flow condition. Insofar as the stationary surfaces of the water jackets are concerned this may be easily done by providing projections such as fins upon the walls of the water jackets. Breaking up the boundary surfaces adjacent the strip presents a more difficult problem since nothing can be done that might permanently deform the strip.

We have found that by vibrating the strip as it passes between the water jackets and/or by vibrating the atmospheric gas, not only will turbulence be created in the gas, but the boundary layers of the gas will be broken up and the heat transfer rate greatly improved.

It is therefore an object of our invention to provide apparatus for accelerating convective heat transfer between a solid, particularly a flat object of considerable area, and a gas adjacent thereto.

This and other objects will be more apparent after referring to the following specification and attached drawings, in which:

Figure 1 is a schematic vertical view, partly in section, of one embodiment of our invention;

Figure 2 is a schematic view, similar to that of Figure 1, showing a second embodiment of our invention;

Figure 3 is a schematic isometric view of a third embodiment of our invention showing the vibrating means but omitting the cooling chamber;

Figure 4 is a view, similar to Figure 3, showing another embodiment of our invention;

Figure 5 is a schematic view, partly in cross section, showing means for vibrating the gas in the cooling chamber;

Figure 6 is an enlarged sectional view showing fins located in the cooling chamber;

Figure 7 is an isometric view showing means for vibrating the gas within the cooling chamber;

Figure 8 is a view, partly in section, showing the vibrating means of Figure 7;

Figure 9 is a vertical sectional view of our invention as applied to the annealing of coils of steel strip located within an inner cover;

Figure 10 is an enlarged fragmentary view of the supporting means for the vibrator;

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Figure 11 is a side view of Figure 10;

Figure 12 is an enlarged side view of the supporting plate for the vibrator; and

Figure 13 is an end view of Figure 12.

Referring more particularly to Figure 1 of the drawings, the reference numeral **2** indicates the cold walls of a water jacket through which passes a moving steel strip S which is supported by spaced apart rolls **4**. Suitable means such as bridle rolls (not shown) may be used to pull the strip over the rolls **4**. A magnetic vibrator **6** is mounted adjacent the strip at the exit end of the water jacket. The magnetic vibrator consists of a 60 cycle A. C. electromagnet which becomes magnetized and demagnetized, thus attracting the strip S 60 times per second to cause it to vibrate rapidly. The vibrator is spaced from the strip a distance sufficient to prevent the strip from actually contacting the vibrator.

Figure 2 shows a second means for vibrating the strip which may be used with non-magnetic material as well as with steel strip. In this embodiment a fluted roll **8** is substituted for each of the rolls **4**. The rate at which the strip vibrates depends upon the number of flutes in the roll, the diameter thereof and the speed at which the strip travels. The amplitude of the vibrations depends upon the depth of the flutes.

Figure 3 shows another means for vibrating the strip S. In this embodiment a pair of rolls **10** and **12** are mounted one on each side of the strip S and are adapted to be rotated by contacting the strip lightly. The rolls are connected by means of a link **14** at each end thereof. A link **16** is attached to each end of the roll **10** and extends away from the strip S with its free end thereof being attached to the arm of a crank **18**. The shaft **20** of the crank is mounted in suitable stationary bearings **21** and is rotated by means of a motor, not shown. The rolls **10** and **12** are suspended by means of links **22** and **24**, respectively, from shafts **26** and **28** which are mounted in suitable stationary bearings **29**. Rotation of the crank produces an oscillation of the rolls **10** and **12** causing the strip to vibrate rapidly.

Figure 4 shows still another embodiment of our invention. In this embodiment the lower roll **4** is mounted in bearings **30** which in turn are mounted on a U-shape frame **32**. A suitable electro magnet vibrator **34** is mounted on the frame **32** adjacent each of the bearings **30**. The U-shape frame **32** is pivotally mounted on pins **36**. Adjustable stops **38** are mounted adjacent the vertical legs of the U-shape frame to limit the amount of movement of the frame **32** about its pivots. When the vibrators **34** are operated the U-shape frame **32** carrying the roll **4** will vibrate rapidly about the pins **36** thus causing the strip S to vibrate.

In all instances fins **40** (see Fig. 6) are preferably mounted in the cooling chamber to increase the rate of heat transfer.

In addition to or in place of vibrating the traveling strip the atmosphere in the furnace may be vibrated, thus further increasing the rate of heat transfer. As shown in Figure 5 this may be done by providing a steel core **42** within which is mounted a coil **44** having an opening **46** therein for receiving armature **48**. A rubber bumper **50** is provided on the core **42** in order to prevent the armature **48** from contacting the core. A light weight plate **52** is attached to the armature **48** and is positioned in the cooling chamber **53** adjacent the strip S. By connecting the coil **44** to an A. C. current of 110 volts the plate **52** is caused to reciprocate rapidly, thus vibrating the gas surrounding the strip S.

Figures 7 and 8 show another manner in which the atmosphere in the cooling chamber may be vibrated. In this embodiment an opening is made in the walls of the water jacket **54** and a transition piece **56** is mounted on a flange **58** surrounding the opening. A circular diaphragm **60** is mounted on the outer end of the transition piece. A vibrator **62** is mounted on the diaphragm **60** and is provided with a backing piece **64**. It will be seen that the transition piece **56** has a substantially constant cross sectional area throughout its length and changes from a rectangular shape at the flange **58** to a circular shape at its outer end. Energization of the vibrator **62** causes the atmosphere surrounding the strip S to vibrate rapidly.

Figures 9 to 13 show the application of our invention to the annealing of coils C of steel strip located within an inner cover **66**. A protective atmosphere is located within the cover **66** and is circulated through and around coil C by means of a fan **68** in the usual manner. A pair of straight pins **70** are welded to the outside of the inner cover **66** beneath a pair of L-shaped pins **72**. A vibrator **74** is mounted on a plate **76** having two elongated openings **78** therein which fit over the pins **72**. If desired a washer **80** may be welded to the pins **72** to hold the plate **76** in a vertical position. A hook **82** is attached to the upper end of plate **76** so that the plate can be placed in position and removed by means of a crane. After the strip has been heated to the desired temperature and when the outer cover has been removed the vibrator 74 mounted on the plate **76** is placed over the hooks **72** as shown in Figures 9 and 10 and the vibrator is caused to operate thus vibrating the inner cover **66**. This increases the rate of heat transfer from the strip S to the protective atmosphere into the cover **66** and from the cover **66** to the surrounding atmosphere.

While several embodiments of our invention have been shown and described it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

We claim:

1. Apparatus for cooling heated strip which comprises vertically spaced rotatable rolls for supporting said strip, a cooling chamber between said rolls throughout the majority of the distance between the rolls, means for supplying a cooling medium to the cooling chamber, and means for moving the peripheral surface of the strip in a non-circular path while in contact with at least one of the rolls to rapidly vibrate the strip in its passage between the rolls whereby heat transfer from the strip is accelerated.

2. Apparatus for cooling heated strip according to claim 1 in which the means for moving the strip in a non-circular path includes flutes in the peripheral surface of at least one of said rolls.

3. Apparatus for cooling heated strip according to claim 1 in which the means for moving the strip in a non-circular path includes a frame for supporting at least one of said rolls, a pivot support for said frame, and means for rapidly vibrating said support about its pivot.

References Cited in the file of this patent

UNITED STATES PATENTS

485,694	Haskell	Nov. 8, 1892
1,765,955	von Maltitz et al.	June 24, 1930
2,326,163	Patterson	Aug. 10, 1943
2,351,163	Thomas	June 13, 1944
2,351,549	Schwartz	June 13, 1944
2,393,243	Fanz	Jan. 22, 1946
2,514,797	Robinson	July 11, 1950
2,572,484	Howle et al.	Oct. 23, 1951
2,613,070	Verwohlt	Oct. 7, 1952
2,645,031	Edwards	July 14, 1953

FOREIGN PATENTS

532,144	Great Britain	Jan. 17, 1941