Aug. 3, 1965 C. J. STANLEY 3,198,499

METHOD AND APPARATUS FOR SUPPORTING AND HEAT TREATING

Filed Aug. 11, 1961 6 Sheets-Sheet 1

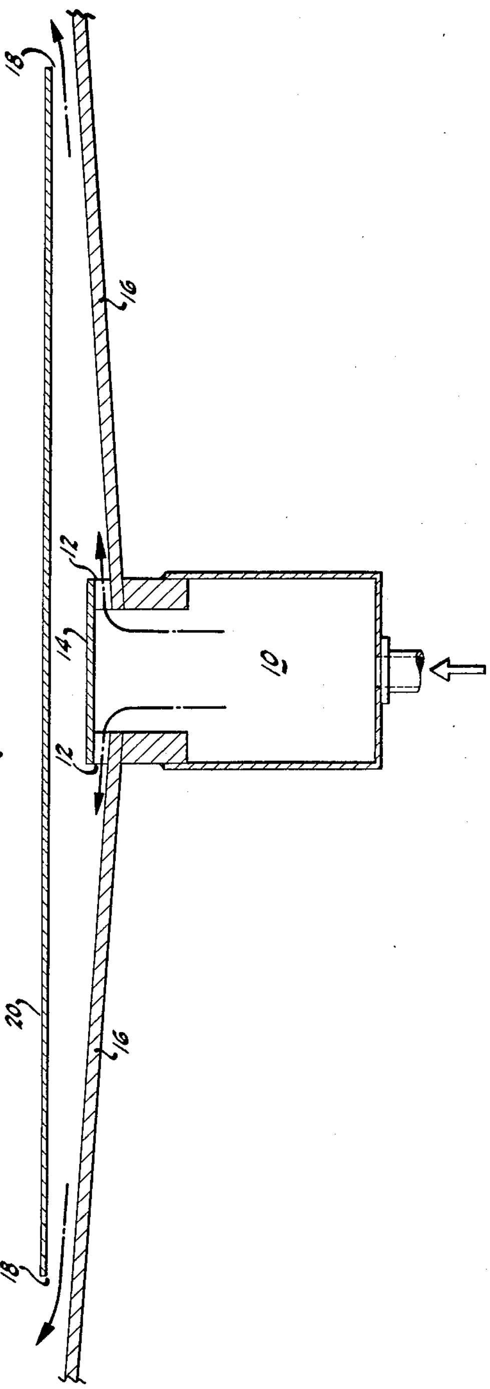

FIG-1

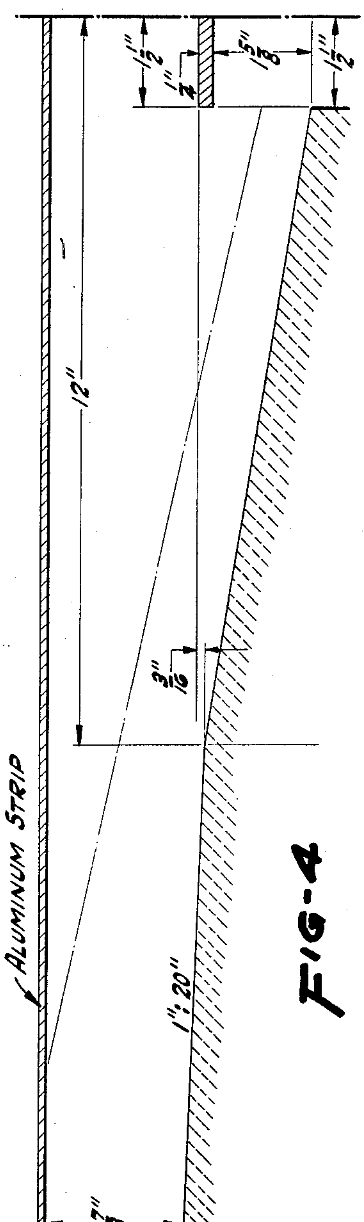

FIG-4

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METHOD AND APPARATUS FOR SUPPORTING AND HEAT TREATING

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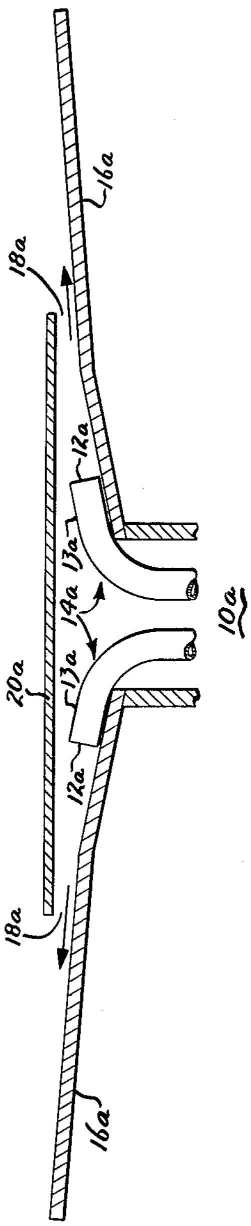

FIG-1a

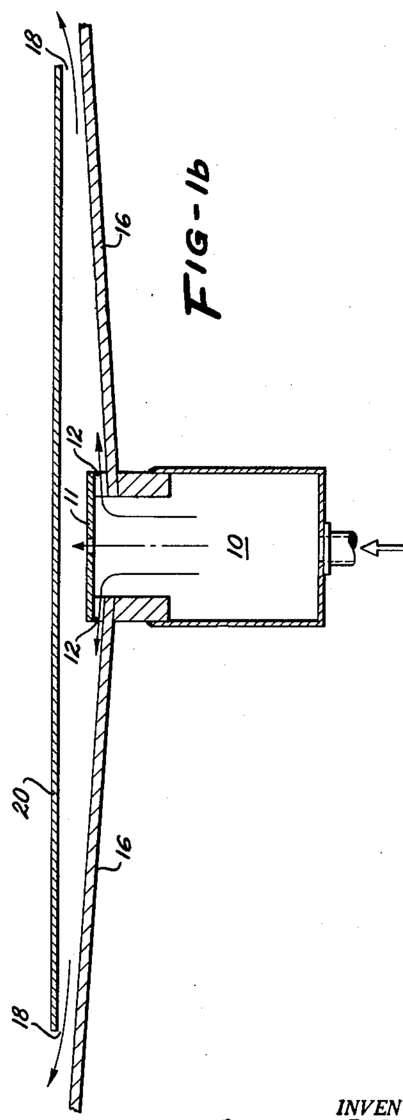

FIG-1b

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METHOD AND APPARATUS FOR SUPPORTING AND HEAT TREATING

Filed Aug. 11, 1961 6 Sheets-Sheet 3

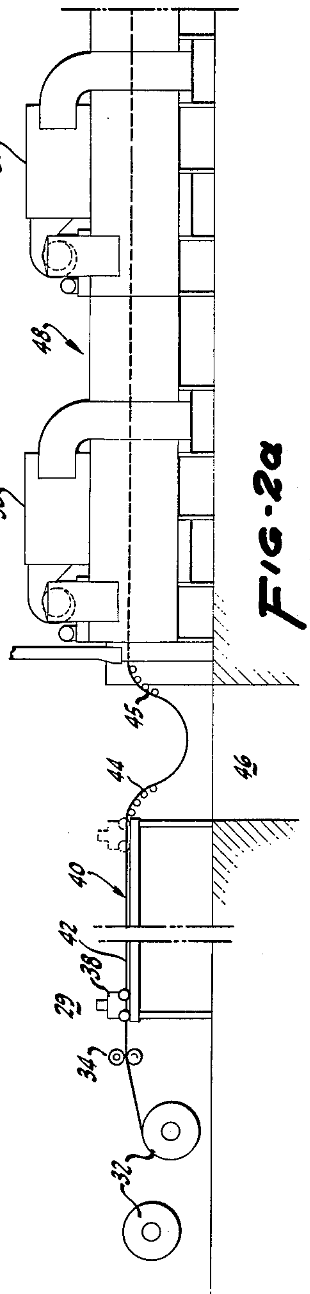

FIG-2a

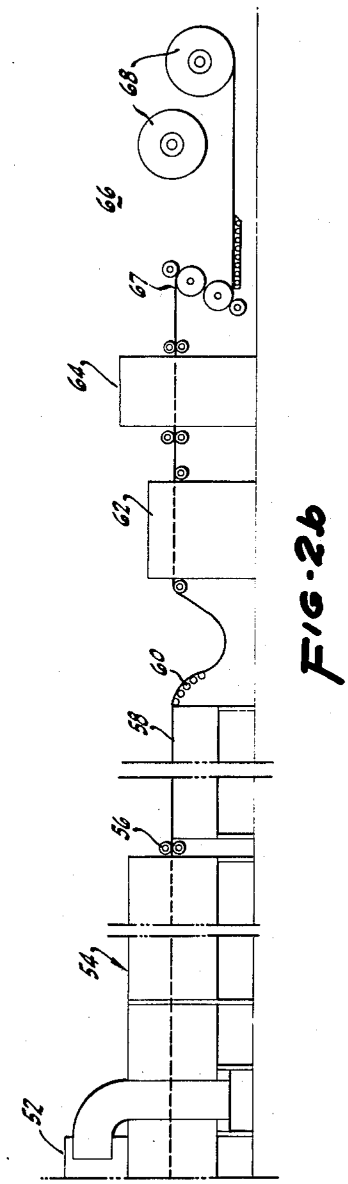

FIG-2b

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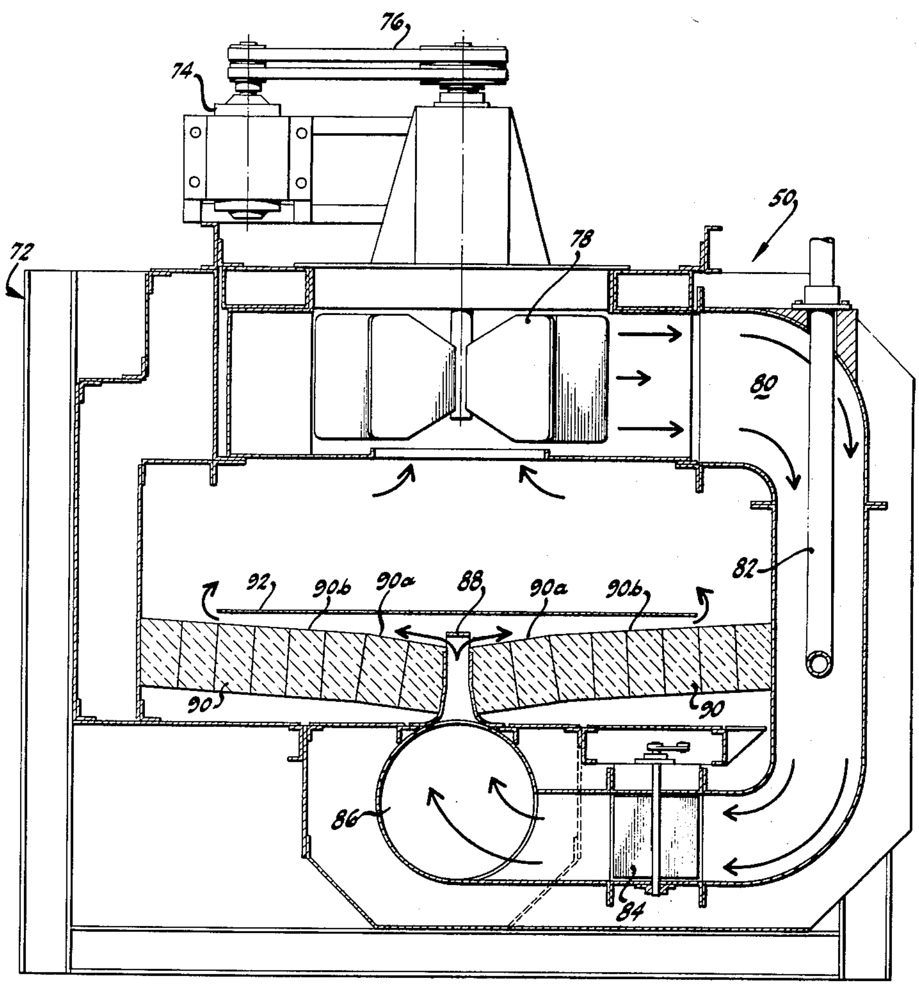

FIG-3

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METHOD AND APPARATUS FOR SUPPORTING AND HEAT TREATING

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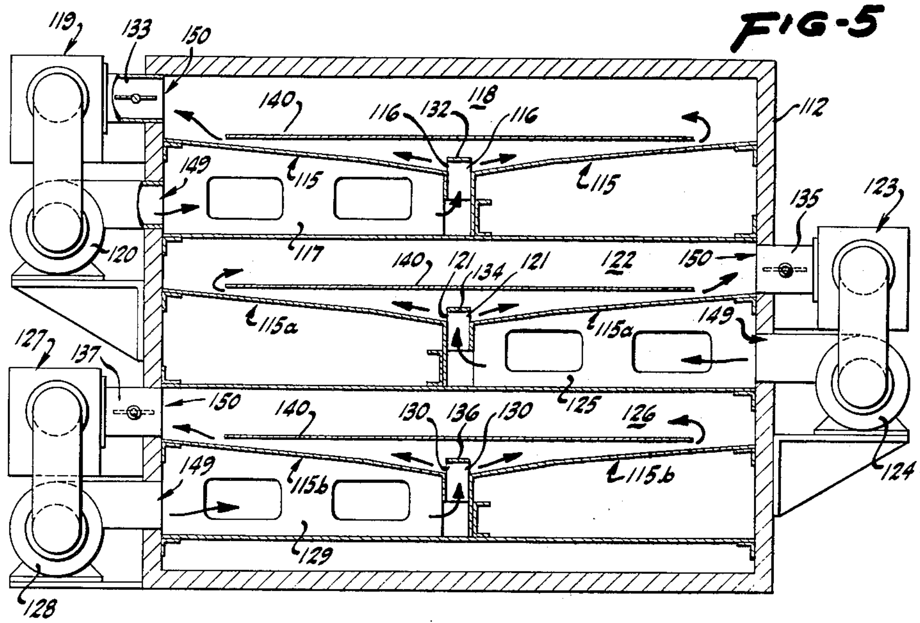
FIG-5



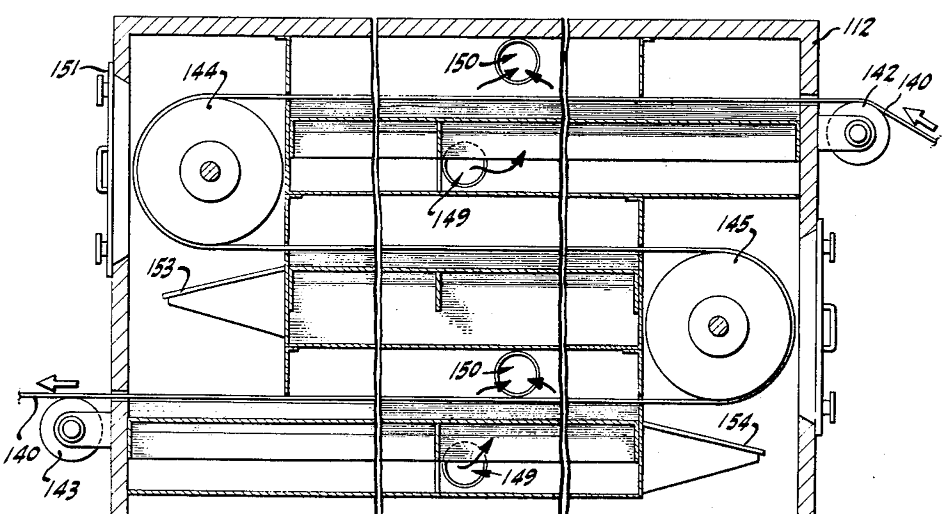


FIG-6

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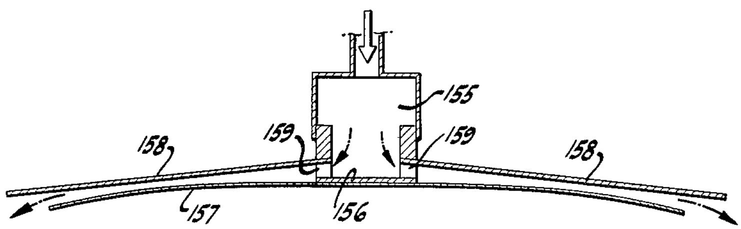

FIG-7

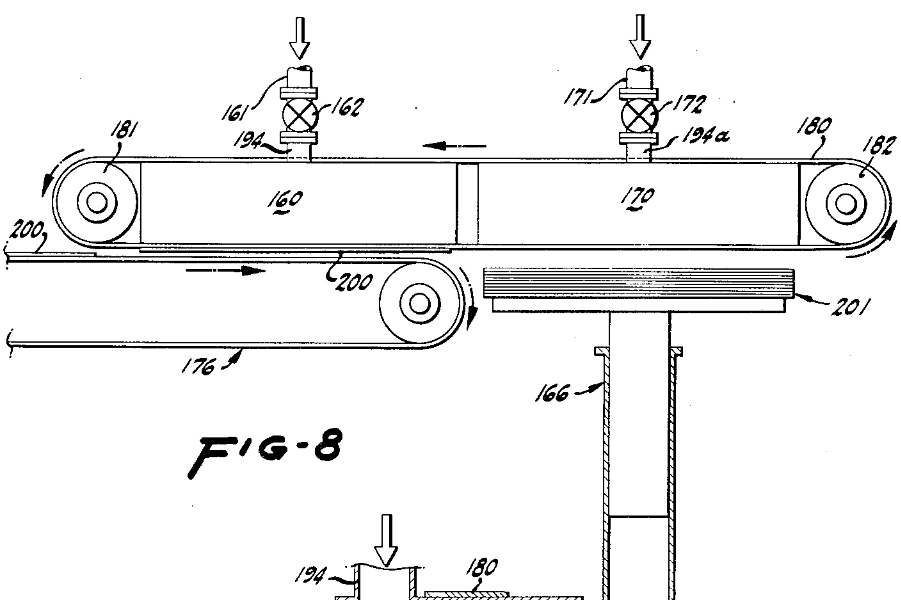

FIG-8

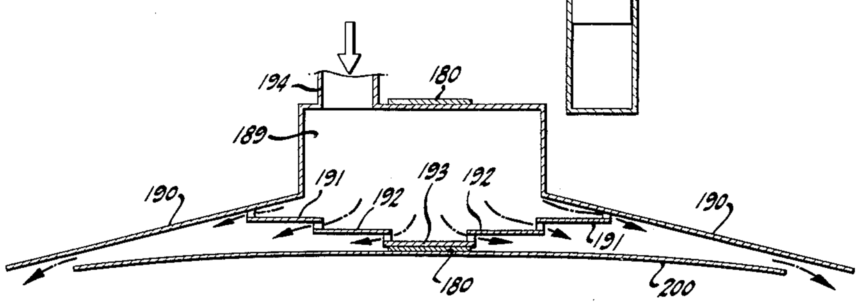

FIG-9

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United States Patent Office

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3,198,499

METHOD AND APPARATUS FOR SUPPORTING AND HEAT TREATING

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Filed Aug. 11, 1961, Ser. No. 130,839
12 Claims. (Cl. 263—3)

The present invention relates broadly to supporting members by utilizing a gaseous medium. The members may be supported in any direction by practicing the present invention. The invention is adaptable to lifting or conveying members in continuous or noncontinuous manner.

The invention has particular utility in supporting elongated members. More specifically, gaseous supporting, according to the invention, may be advantageously used to support thin members having little self-supporting ability and/or internal rigidity. In conjunction with this latter application, the invention is advantageously usable in the continuous heat treatment of thin metallic members wherein a metallic member is subjected to any given thermal treatment to produce various properties.

The lifting of members from the top side thereof is accomplished in one embodiment of the invention. Lifting may also be a continuous or noncontinuous operation.

Supporting and/or conveying by a gaseous medium such as air, has been known in the art along with methods and devices of different kinds for that purpose. Typical of conventional methods for conveying or supporting members involves the continuous discharge of a gaseous medium directly against the under surface of the member to be supported. Impingement of the gaseous medium against their under surface will support members in a vertical position if the force of the gaseous medium is sufficient to overcome the weight of the member. Such supporting devices typically comprise beds of various shapes containing numerous apertures for ejection of the gaseous medium.

Similarly, various top side lifting devices and methods have been proposed. Conventional lifting mechanisms typically involve merely the creation of a vacuum force of sufficient strength to pick up desired members and operate much in the same manner as the household vacuum cleaner.

The lifting and supporting devices above mentioned are capable of limited utility and, in general, are not satisfactory for the safe lifting or supporting of substantially flat members, in particular flat members having little or no self-supporting ability and/or internal rigidity.

The present invention provides new and improved methods and apparatus for safely supporting members, particularly those having substantially flat surfaces, with or without physical contact with solid supporting elements. That is to say, supporting such members with little or no risk of damage thereto.

The invention involves ejecting or emitting a gas and directing at least a part of the ejected gas toward opposing peripheral portions of the article to be supported and subsequently contacting the article with at least a portion of the directed gas, progressively confining the flow of the gas so as to provide restrictive openings for the discharge of gas along said peripheral portions of the article being supported. The ejecting and directing of the gas may be performed sequentially or simultaneously.

An apparatus according to the invention comprises gas emitting means having discharge opening means for directing at least a potrion of the emitted or ejected gas in divergent paths, said gas directing means, during the supporting operation being adapted to direct the gas in divergent paths toward peripheral portions of the article to be supported, means to confine the flow of said directed gas, said article to be supported being positioned so that at least part of the said gas directing means is located between the article and said discharge opening means, said gas confining means forming, with at least a portion of the periphery of the supported article, orifice means for discharging said gas. The gas emitting means and the gas directing means may comprise separate components or may be combined in a single structure.

One aspect of the present invention is the discovery that by proper distribution and direction of the supporting gas flowing beneath the member to be supported, it is possible to support thin, flat members in a substantially level plane without lateral bowing or humping. Moreover, it has been discovered that by supporting the member from the underside according to one embodiment of the invention, the weight of the supported member provides a restoring force which renders the support self-centering. Thus, it is possible to support and/or convey continuous strip of thin members in a substantially flat position without physical contact with solid supporting members and while simultaneously rendering the supported strip self-centering thereby eliminating the need for additional centering or guiding devices. The member, which may, for example, be metallic sheet or strip, supported in the manner of the invention tends to be self-centering in that it tends to stay symmetrical about the longitudinal center line of the gas support bed. Thus, if the strip is displaced side ways the supported sheet will return to the center position and has a tendency to remain in that position.

In the accompanying drawings are illustrated several embodiments of the invention wherein:

FIGS. 1, 1*a* and 1*b* are transverse cross-sections of supporting devices embodying the principles of the invention to support an article from the underside thereof.

FIG. 2, comprised of FIG. 2*a* and FIG. 2*b*, is a side elevational view of a continuous metal strip heat treating system utilizing the underside supporting embodiment of the invention described in FIG. 1.

FIG. 3 is a transverse cross-sectional view of an air support furnace shown in FIG. 2 which utilizes the underside supporting embodiment of the invention.

FIG. 4 is a schematic representation of an advantageous arrangement including the illustrative dimensional details of an air supporting unit according to an embodiment of the invention.

FIG. 5 is a transverse cross-sectional view of a triple pass continuous heat treating furnace utilizing the underside supporting unit embodiment of the invention.

FIG. 6 is a side elevational view of the triple pass continuous heat treating furnace utilizing the underside supporting embodiment of the invention such as shown in FIG. 5.

FIG. 7 is a transverse cross-sectional view of an embodiment of the invention for supporting an article from the topside thereof.

FIG. 8 is a side elevational view of a materials handling system utilizing the embodiment of topside supporting illustrated in FIG. 7.

FIG. 9 is a transverse cross-sectional view of a topside supporting unit as might be used in the material handling system depicted in FIG. 8.

As an illustration of one embodiment of the invention, reference is made to FIG. 1 in the accompanying drawings. As can be seen therein, gaseous supporting medium is ejected through suitable gas emitting means **10** preferably including a plenum and having at least one discharge opening disposed at one side (the underside) in this embodiment of the substantially flat surface member to be supported. The gaseous supporting medium may be any suitable substance. However, for purposes of simplification and illustration the invention will be described herein with respect to the use of air as a gaseous supporting medium. The air is discharged through discharge opening means 12 of the gas emitting means and at least a portion thereof is directed by gas directing means 14, which may be a plate as shown, disposed beween the first orifice means and the member to be supported 20. In this manner, at least a portion of the gas is deflected prior to contacting or impingement thereof against the member 20 to be supported and is thereby directed toward peripheral portions of the member. The flow of the gaseous medium is restricted by gaseous flow confining means 16. The gaseous medium flow confining means 16, which may be referred to as an inclined hearth, progressively confines the flow of said gas outwardly in diverging paths from the discharge opening means to peripheral portions of the supported member. The progressively confined flow results from providing a progressively decreasing cross-sectional area for the flow passageway. As can be seen by arrows indicating direction of flow of gaseous medium, the air upon ejection and discharge from gas emitting means 10 through the discharge opening or orifice means 12, is directed outwardly from a center line through the plenum of gas emitting means 10 toward portions of the edges of the member to be supported 20. The gaseous medium is ultimately discharged through second orifice means 18 resulting from the coaction of the edges or periphery of the member to be supported 20, and the flow confining means 16. Where the flow confining means 16 are inclined, the gas flow is correspondingly directed outwardly at angles inclined toward said member to be supported.

The member 20 is supported by static pressure which is dependent upon the volume, velocity and pressure of the gaseous medium projected from the gas emitting means 10. In operation the gas emitting means includes means for supplying air under pressure such as an air blower which blows air through a plenum pressure chamber and out at least one discharge opening. The air which discharges from a discharge opening, which may be a continuous slot or orifice 12 formed by gas directing means raised a suitable distance off the hearth plate 16 as shown in FIG. 1, is ejected from this orifice to the sides of the hearth plate with sensibly the same volume at each side of the center line through the plenum of gas emitting means 10. The air is ultimately discharged at the second orifice means 18 between the surface of hearth plate 16 and the underside of the member to be supported 20 by progressively confining the flow outwardly.

The self-centering characteristic of the invention described above is achieved because the gas support seeks to establish an equilibrium condition with the volume of gas being discharged equally at opposing peripheral portions of the supported member. Displacement of the supported member laterally disrupts the discharge by raising the member a greater distance above the flow confining means at one side thereof thereby in effect providing a larger orifice at one edge 18 in FIG. 1 and a smaller orifice at the opposite edge 18. The change in orifice size causes a change in velocity pressure at the respective orifices. The increased velocity pressure at one edge causes the member to move in that direction and the net effect is an ultimate balance of pressures and return to the equilibrium condition.

By adjusting the inclination of hearth plates 16, the height of orifice 12, the width of deflector plate 14, and/or the pressure of plenum 10, various effects in the supporting device can be achieved. An increase the inclination of hearth plates 16 reduces the gas velocity required to support a given flat member without lateral bowing or humping therein and reduces the support height clearance at orifice 18. Increasing the inclination of the hearth plate also increases the tendency of the flat member to be self-centering. As an illustration, an aluminum sheet 0.04" thick x 60" wide when supported in a flat position with the flow confining means inclined at a slope of 1" in 40" results in an orifice height at 18 (at the periphery of the supported sheet) of 7/16" when the static pressure in plenum 10 is 0.93" water column. When the same sheet is supported in a flat position on flow confining means inclined at a slope of 3⅝" in 40" the orifice height at 18 is reduced to 9/32" and the static pressure in plenum 10 is reduced to 0.7" water column. In both cases the orifice 12 is maintained constant at ¼" and the static pressure in the plenum adjusted to obtain a flow under the sheet which establishes a flat support therefor.

An increase in the orifice height at 12 with inclination of the flow confiing means and plenum pressure remaining constant enables the member to be supported flat at an increased height off the hearth at the edge 18. For example, referring to FIG. 1, a ¼" orifice 12 supports the above sheet at 9/32" off the hearth at 18 with 0.7" water column pressure in plenum 10. Using 0.8" water column in plenum 10 and increasing the plenum orifice 12 to ½" enables a sheet to be supported substantially flat at a height of ⅝" at the edge 18. In both cases the inclination of the flow confining means is the same, i.e., inclined at a slope of 3⅝" in 40".

By increasing the pressure in plenum 10 above that required to maintain the sheet or strip flat, other factors being constant, one can introduce a concave or downward bow in the sheet. Further increases in the pressure in the plenum enables the flat member to be held against the top of the deflector plate in such a manner that the flat member is effectively clamped. For illustration, with flow confining means inclined at a slope of ½" in 40" and the orifice maintained at a ¼", an aluminum sheet of 0.04" by 60" can be effectively clamped against the deflector plate at a plenum pressure of 3.75" water column. A sheet of 0.081" by 48" can be similarly clamped when the plenum pressure is 6" water column. Although the clamping action can be obtained at lower pressures than in the above examples, the degree of attachment to the deflector plate is determined by the pressure maintained in the plenum. The deflector plate can be of various sizes and if made wider, the required plenum pressures for a given clamping force can be reduced.

The supporting device as described above, may assume almost any configuration depending only upon design considerations. For example, if the members to be supported are of a suitable shape the hearth plates may be circular, rectangular, square, etc. It is necessary, however, that the gaseous medium being discharged from the plenum through the orifice, be ejected and at least a portion thereof directed outwardly in opposite directions from the discharge opening of the gas emitting means and toward opposing peripheral portions of the supported article.

It should also be noted that the means for directing the gas outwardly from orifice 12 in FIG. 1 may comprise divergent nozzles or other similar means in place of deflector plate 14. Thus, any means which directs the gaseous medium outwardly in a similar manner, other than a deflector plate, may also be suitably employed.

In this connection reference is made to FIG. 1*a* wherein is depicted flow confining means 16*a*, which in this illustration are shown with outer sections of decreased slope, and gas emitting means 10*a* which includes all the equipment used to supply the supporting gas. As is seen, divergent nozzles 14*a* are substituted for deflector plate 14 in FIG. 1. Discharge openings 12*a* of the nozzles function the same as the orifices 12 in FIG. 1 to provide air for the support of member 20*a*. Moreover, the flow of the gas is similarly progressively confined so as to result in the discharge thereof along opposing peripheral portions of the member 20a at restrictive openings 18a. Where divergent nozzles are employed in place of gas deflecting means, the nozzles themselves serve as the gas directing means to direct the gas toward opposing peripheral portions of the article to be supported. Thus, the gas directing means and the gas emitting means may comprise separate structural components as in FIG. 1 or alternatively, may be formed from the same structural unit as in FIG. 1a. In the latter arrangement the upper surface 13a of the nozzles may be considered the portion of the gas emitting means which functions as the means for directing the gas outwardly or, toward peripheral portions of the supported article, and the corresponding portions of the oppositely directed nozzles thereby coact to direct at least a portion of the gas toward opposing peripheral portions of the article to be supported. It is seen, therefore, that in all embodiments of the invention at least a part of the gas directing means is positioned or located so as to be between the discharge opening (or openings) of the gas emitting means and the article to be supported and at least a portion of the gas is so directed prior to contacting the article.

The nozzles 14a of the gas emitting means 10a may be attached to independent sources of gas and thus be independently controlled, or they may merge into a single header. Moreover, the nozzles may elbow and extend downwardly as shown or be extended axially at an inclined angle to be attached to a suitable pressure source.

It should also be noted that where a deflecting means, as in FIG. 1, is used for directing the gas outwardly toward peripheral portions of the article, the deflecting means need not be a single planar member as depicted in FIG. 1 or a unitary structure. The deflecting means comprise a plurality of components arranged to accomplish the intended function. Moreover, the deflecting means need not deflect all the gas emerging from the orifice, the deflecting means may comprise a perforated plate or two plates disposed adjacently leaving a slot therebetween, thereby allowing some of the gas to contact the article directly. In this connection reference is made to FIG. 1b which is substantially the same as FIG. 1 but illustrates a perforated deflector plate 11. However, in order to achieve the advantages of the invention it is necessary that at least a portion of the gas from the orifice be directed outwardly as described above because the outwardly directed gas provides the advantageous support realized by practicing the invention. The amount of gas which should be directed outwardly varies with the type, size and weight of the member to be supported, as well as the gas pressure, velocity, size of the orifice and inclination of the flow confining means, if any. However, the optimum values of the above variables are readily determined for a given system depending only upon the result desired, i.e., extent of support (off bottom hearth), clamping force (topside supporting), degree of flatness of support, etc.

Since the total pressure in the plenum of the gas emitting means equals the total pressure at the periphery of the supported member, plus losses, any arrangement is satisfactory for support which meets the above requirements and which enables the total plenum pressure to be converted to velocity pressure plus suitably distributed and controlled static pressure under the load of the member. Where flat support is desired, the static pressure under the load that is required is an amount sufficient to support the load flat without lateral bowing or humping.

The gas flow confining means, e.g., hearth plates, may be constructed as elongated members and together with an elongated plenum and corresponding elongated orifice means, can provide an elongated gaseous supporting device. Such a device is useful both as a support for substantially flat members and as a gaseous or air conveyor. The gas flow confining means progressively confines the flow by providing a flow passageway of gradually decreasing cross-sectional area. The supported member may be moved along the air support base by external means such as pull rolls, pulleys, etc. or the gaseous medium itself may impart a motion to a supported member. In the latter arrangement the elongated orifice or plenum may be periodically interrupted and inclined nozzles may be interposed which cause the gaseous medium to contact the member to be supported at an angle, thereby imparting a forward thrust or movement to the member. Similarly, the direction of some or all of the air emerging from orifice 12 may be inclined to the direction of movement of strip 20 so as to impart motion therein. Alternatively, the member to be supported may in effect be dragged or pulled across the air support. Air supporting according to the invention has the advantage of being able to provide, if desired, minimum frictional contact with solid supporting means thereby enabling only a very small force to move a member across an air supporting bed of the invention.

One important application of an air support of this type is in the metallurgical heat treating industry. The metals industry has long sought useful and efficient means for continuously heat treating long strips of thin, metallic sheet. This is particularly true in the heat treatment of metallic materials at temperatures approaching the melting point of the metals. In one type of heat treating aluminum alloys, for example, to impart high strength and the other desired properties it is necessary to subject the metals to two thermal treatments, namely, solution heat treatment and precipitation hardening or aging. Solution heat treatment consists of heating the metal to a temperature at which the soluble constituents of the alloy dissolve, holding the material at this temperature for a sufficient length of time to allow substantially all the soluble elements or constituents to go into solid solution and then rapidly quenching to prevent or retard precipitation of these two constituents from the supersaturated solid solution. The solution heat treating temperatures of heat treatable aluminum alloys generally vary from about 800–980° F. depending upon the alloying constituents and their amounts. The precipitation or age hardening treatment follows the solution heat treatment process and is carried on at either room temperature or at an elevated temperature depending upon the desired aging time and composition of the alloy. By precipitating, in a finely dispersed state, some of the dissolved constituents out of solid solution the age hardening treatment develops maximum mechanical properties of the metal. At the elevated temperatures required during solution heat treatment, the tensile strength of the metallic strip is very low, moreover, the metallic strip is very subject to marring, sticking and breakage. For these and other reasons a practical working continuous-heat-treating operation has, prior to the instant invention, not yet been devised although a number of proposals have been submitted and considered by the industry.

In the present practice of solution heat treating aluminum alloys the heat treating operation is conducted in essentially a batch-type process. One variation requires that the metal be in the form of small units such as individual sheets, coils of strip material, coils of wire, etc. Such processing is expensive and time consuming. As a further illustration, another conventional present day practice involves individually suspending sheets within an elongated vertical furnace maintained at a temperature within the solution heat treating range for a predetermined period, removing the heated sheets from the furnace and rapidly quenching the sheets. The sheets are lifted manually and suspended by clamping. This practice requires substantial amounts of labor, and results in considerable warpage and wrinkling of the sheets necessitating a straightening operation resulting in a high scrap loss. Conventional practice is to slit the edge of the sheets to remove the clamp marks after quenching and unclamping. In addition, during this operation the sheets are passed through a multi-roll flattener in which the effects of clamp buckles and qenching distortion are partially removed to a degree which allows the sheets to be subsequently processed through a skin pass mill.

Among the various proposals for continuously heat treating metallic strip have been systems wherein the metallic strip is conveyed along a substantially serpentine path supported along its travel by a plurality of rolls. Typical of this latter type is an annealing apparatus disclosed in the Earhard Jr. Patent 2,669,442. Other similar apparatus for continuously heat treating metallic strip are disclosed by J. D. Keller, Patent 2,232,391, and M. D. Stone et al., Patent 2,887,422. In all of these continuous heat treating systems the metallic strip, after and/or while being heated to the elevated temperatures required during the particular heat treating process, is in contact with and supported by various types of roll members. Moreover, conventional heat treating systems require the hot metallic strip in effect to be pulled through the heating zones within the furnaces. Since metallic strip, particularly aluminum, at the elevated temperatures required during most heat treating operations possesses low tensile strength, a common failing of such heat treating operations is the pulling apart of the metallic strip much in the same manner as hot taffy. Breakage of the metallic strip during heat treating occurs much too often in the systems as described where the hot metallic strip must be pulled through the furnace against rollers. Furthermore, the difficulties and expense encountered when metallic strip breaks within the furnace are obvious. Moreover, even if the metallic strip does not break while passing through the furnace, it is very often badly marked by the rollers because of the elements acting upon the hot metallic strip and the force exerted to pull the strip through the furnace or the weight of the metallic strip itself. When the blemishes on the heat treated metallic strip are excessive, the metal must be rejected and the scrap losses added to other costs may render the operation uneconomical.

To avoid some of the problems encountered in continuously heat treating metallic strip through the use of rollers disposed within the furnace and contacting the hot metal, various air support apparatus have been proposed to convey the hot metallic strip through the heat treating furnace. One such arrangement is disclosed in the patent to Hagen, No. 1,948,173. Various air conveyors have also been known to the arts and have been used to convey sheets of steel, etc. In general, the air support is provided by locating a number of apertures in a horizontal bed and blowing air or other gas through the holes in the horizontal bed against the under surface of the member to be supported. While in theory this method would avoid a number of the problems encountered in the aforementioned continuous heat treating operations, in practice these air supporting systems for conveying metallic strip to a furnace, encounter other difficulties rendering them inefficient and impractical. For example, where a substantially thin, lightweight member, such as metallic sheet, is to be supported, the velocity of the air or other gas emerging from the apertures or jets in a horizontal bed must be carefully controlled and regulated to maintain the support as uniform as possible and to avoid the turning and twisting of the thin member. Also, it has proven difficult to center the thin member on the air supported bed without the member to be supported wandering off the air support area. To counteract this effect and to achieve a degree of centering it has been necessary to provide guides along the edges of the air support horizontal bed. However, the guides of necessity make contact with the thin members being supported at high temperatures and tend to distort or otherwise damage the edge of the metallic member.

Another problem encountered in adapting these air supported conveyor systems to the heat treatment of metallic strips results from the direct impingement of the supporting gas from the horizontal bed against the hot metallic strip. Each stream of gas directed against the metallic member impinges on a relatively small area and, since the air must be at a substantial velocity in order to provide the support necessary, the metallic sheet may become deformed or blemishes may appear on the surface at the area of contact with the air. Furthermore, in the case where the high velocity gas is supplying the heat required for the heat treatment of the metallic member, localized heating with its attending disadvantages may result.

Another disadvantage of prior art air support device is the large wastage of air flow and corresponding power therefor, which results because the hearth must be big enough to accommodate members of different size, wide and narrow, etc. Thus, in order to accommodate wide and narrow members the air outlets must of necessity extend farther than would be required for supporting narrow members.

By adopting the supporting techniques of the present invention it is possible to provide a system for the continuous heat treatment of thin metallic sheet which is a great advance in the art. In adopting the present invention to heat treating metallic sheet an elongated air support bed is provided. The air support bed generally comprises elongated hearth plates and an elongated plenum or gaseous medium introductory means. By heat treating according to one embodiment of the invention it is possible to heat and support metallic sheet with a minimum of friction and without physical contact with solid supporting elements thereby providing a substantially zero tension condition in the metallic strip within the furnace at any given speed.

A continuous metallic strip heat treating system utilizing air support furnaces employing the underside supporting embodiment of the invention is depicted in FIGS. 2*a* and 2*b*. According to the preferred heat treating operation there is provided in tandem suitable metallic strip feeding assembly **29**, heat, treating furnace **48**, quenching assembly **54**, and rewind assembly **66**. The feeding assembly **29** comprises two "payoff" rolls **32**, which, with movable joining means **40**, enable metallic strip to be continuously fed into the heat treating system. When one of the payoff rolls has completed unwinding a feed coil, the other payoff roll may begin to feed metallic strip from its feed coil. From one of the feed rolls **32**, the metallic strip then passes through feed rolls **34** onto movable joining means **40**.

Before unwinding the coils into the furnace the end of the coiled strip may be trimmed by a strip end cutter to provide a uniform edging surface for joining to the end of the preceding metallic strip. After trimming, the coils are mounted on one of the two dual payoff rolls **32** from which the strip is passed through feed rolls **34**, onto joining means **40** which may be a stitching device. Preferably, stitching device **40** is the type which clamps ends of succeeding lengths of strip firmly within a traversing clamp and end stitcher **38** and traverses a support table **42**, during which time it stitches the succeeding lengths of strip in order to provide a feed of continuous metal strip for the heat treating furnace. The strip passes along rolls **44** and **45** into the air support furnace **48**. A pit **46** is provided to permit suitable looping of the metallic strip **30**.

Air support furnace **48** preferably comprises a plurality of individual air support sections or units, two of which are illustrated as **50** and **51** and part of one support unit as **52**. The heat treating furnace is advantageously divided into several heating and holding zones. Strip which has been heat treated in the furnace **48** then passes through a quenching assembly **54** from which it is drawn by pull-out pinch rolls **56**. In the embodiment illustrated, pull-out pinch rolls **56** provide the driving force for advancing the metallic strip through the furnace. Thus, the speed of the strip through the furnace **48** may be regulated by adjustment of pull-out pinch rolls **56**.

The quenched strip is then passed along inspection table **58**, over guide rolls **60** into a suitable flattening device **62**. After flattening, the strip is sheared in a shearing unit **64**, passed through tension bridle rolls **67** and then coiled on rewind assembly **66**. As illustrated, two rewind rolls **68** are provided to be consistent with the dual payoff rolls **32** illustrated at the beginning of the system. In practice, however, as many as desired may be provided.

The rate of heat treating strip through the heat treating system depends upon a number of factors including the length of the heating furnace, heat up rate and soak time. In one system a 200-foot furnace is capable of heating 0.06 inch thick aluminum strip at about 20 feet per minute.

As indicated above, the heat treating furnace, as shown in FIGS. 2*a* and 2*b*, generally comprises a plurality of individual air support sections. As an example, 10 twenty-foot individual air support sections may be advantageously arranged in tandem to form an air support furnace. The furnace may be constructed in multiples of two or three support sections with each section substantially identical. Each twenty-foot unit preferably comprises an air heating unit and a gas blower and is a complete and self contained unit with individual circulation, heating and control. The heated air is blown through suitable ducting or piping means into an elongated plenum chamber. In addition, each twenty-foot supporting unit contains a corresponding elongated deflector plate (or equivalent means) which directs the heated air outwardly from the center line of the plenum chamber toward the edges of the metallic strip being supported.

FIG. 3 is a transverse, cross-sectional view of a heat treating furnace across one of the air support sections **50** comprising heat treating furnace **48** in FIG. 2*a*. The heat treating furnace comprises an outer shell **72** and suitable equipment for providing the air support which, in combination, comprise the gas emitting means. A motor **74** is provided to energize belt drive **76** which in turn operates fan **78**. Fan **78** blows air through the air feeding assembly **80** which comprises ducting for air past a burner and radiant tube **82** which heats the air up to the desired heat treating temperature. The heated air may comprise the sole source of heat for the heat treating operation. A damper assembly **84** is provided to assist adjustment of the volume of air and pressure. Damper assembly **84** may advantageously comprise a plurality of substantially parallel levers, each of which is attached to a central lever system **85** for adjusting the air flow within the wind feeding assembly **80**. This damper may be automatically regulated to maintain a desired constant predetermined pressure in the plenum **86**. The heated air passes through plenum pressure chamber **86**, running longitudinally underneath the hearth **90**, against reflector plate **88** from which it is deflected outwardly in opposite directions away from the center line of the plenum pressure chamber **86**. The air is thereby substantially uniformly distributed and, depending upon velocity, pressure, etc., can provide substantial uniform support for member **92**. Air support hearth **90** functions as air flow confining means directing the deflected air outwardly toward the edges of metallic strip **92** being supported. Thus, at least part, and in general, most of the heated air is outwardly directed prior to contacting the metallic strip. As is seen in FIG. 3, the air support hearth **90** is substantially divergent, V-shaped members with the upwardly directed angle of inclination advantageously compounded in increments and illustrated at **90*a*** and **90*b***. Thus, the flow confining means has outer sections of decreased slope. The over all configuration of the flow confining means is such as to provide a flow pasageway of gradually decreasing cross-sectional area thereby progressively confining the flow outwardly. Air support hearth **90** is preferably made of stable and non-deforming plane sections such as refractory brick or castings inasmuch as the temperature of the air may be of the order of 1000° F. to heat treat the metallic strip.

It has been found that a multi-slope configuration in the hearth plates of the type described enables a more uniform temperature distribution across the cross-sectional area of the metallic sheet being supported and heat treated. Moreover, by compounding the slope of the inclined hearth plates, it is possible to increase the height of the strip over the discharge opening at the plenum while maintaining a relatively low inclination of the hearth. This is important where contact between the metallic strip and deflection plate is to be avoided and, particularly, where the metallic strip being supported is of a narow width.

An illustration of this advantageous feature of slope compounding is described in FIG. 4. The schematic representation shows illustrative dimensional details of an embodiment designed for the air support of any strip but showing 60″ wide aluminum strip being supported. A plenum pressure of 1.1 inch water column can support 0.40″ x 60″ wide aluminum sheet 1⅞″ off the hearth at the edge of the sheet. A 3″ plenum orifice and a 3″ deflector plate which is 1⅝″ above the inner edge of the inclined hearth plate are shown. The slope of the inclined hearth is compounded in increments with the inner increment or section providing a 1⅝″ elevation in 10½″, and the second increment or outer section with an elevation of 1″ in 20″. It is apparent, however, that particular dimensions for various systems can be readily determined.

An additional feature where the supporting air is used to heat the metallic strip during heat treatment is that, by adjusting the width of the deflector plate, improved temperature uniformity may be obtained. Thus, in accordance with the invention it is possible by adjusting the width of the deflector plate to achieve improved uniformity of temperature during heat up between the edge and center of the strip.

In a heat treating furnace comprising a plurality of individual support sections it is possible to vary the temperature within the heat treating furnace according to any desired heat treating cycle since the air used for supporting the metallic strip also functions to heat and maintain the strip at heat treating temperature. Because the temperature of the air used for support within each of the supporting units can individually be controlled, it is possible to obtain considerable refinement in temperature regulation during heat treatment. Thus, for example, if desired, a first zone comprising one or more sections may be used to preheat the metallic strip, and subsequent zones of one or more sections may be used to bring the strip up to heat treat temperature. The remaining sections can be used to maintain the strip at temperature and provide a holding zone for the heated strip.

An additional advantageous feature of a heating furnace having individually controlled sections is the flexibility of the heat treating system in changing to metallic strip of different gauges and widths or indeed of different composition. By sensing the position within the furnace of a "tail" end of an exiting strip joined to the "head" end of an entering strip it is possible to readjust the controlled pressure in the zone plenum underneath the entering strip in consecutive order from the entry end of the furnace as the strip enters. Thus, two strips of radically varying cross-section may be accommodated simultaneously within a furnace with minimum scrap loss at the stitched joint. One suitable manner of sensing the position of the strip joint within the furnace is by attaching a device, such as a pulse generator to the pull out pinch rolls through which the strip passes.

Of course a primary advantage of the heat treating furnace utilizing the present invention is the ability to heat treat metallic strip without physical contact thereof with any solid supporting element. This enables metallic strip to be heat treated without obtaining undue scrap losses resulting from marred or injured metallic sheet. Furthermore, since the strip is entirely supported by air while in the heated condition, frictional losses are virtually eliminated and the force required to propel the sheet through the heat treating zones is minute in comparison to systems wherein the hot metallic strip contacts solid supporting elements. Thus, the danger of pulling apart of the hot metallic strip by exerting force exceeding the ultimate tensile stress thereof is eliminated for all practical purposes. The tensile strength of hot metallic strip is relatively low.

As discussed hereinbefore, a member supported by gaseous medium according to the underside supporting embodiment of the present invention possesses a tendency for self centering. Thus, the metallic strip, while traveling through the heat treating furnace on the air support hearth, requires no guiding mechanism to maintain the strip on the air supported bed. The weight of the strip itself provides a sufficient restoring force so that the metallic strip remains substantially centered on the elongated V-shaped hearth, thereby eliminating the need for expensive tracking equipment.

In the event it is desirable to minimize the over-all length of the heat treating furnace, it is possible to arrange several individual units stacked vertically above one another. Referring to FIGS. 5 and 6 there is depicted a multi-pass continuous heat treating furnace utilizing the underside supporting embodiment of the invention.

As can be seen in FIG. 5 there is provided an outer furnace shell **112** and a plurality of sections. Three sections, **118**, **122** and **126** are depicted for illustrative purposes. Each air support assembly has associated with it independent gas emitting means having feeding units **119**, **123** and **127** respectively, and blowers **120**, **124** and **128** for independent control of each section. Heated air is blown from blowers **120**, **124** and **128** through pressure chambers **117**, **125** and **129** and out plenum orifices **116**, **121** and **130** (as shown by the arrows), wherein the heated air is directed outwardly toward lateral peripheral portions of the strip **140** by deflector plates **132**, **134** and **136** and is progressively confined. The heated air is recirculated as shown (by arrows) and dampers **133**, **135** and **137** are provided for regulation thereof.

As can be seen in FIG. 6, metallic strip **140** enters the triple pass furnace at the top over guide roll **142** and traverses the length of the furnace. Each section may comprise a plurality of individual air support zones (as many as desired) arranged in tandem, similar to the furnace **48**, shown in FIG. 2, extending substantially the length of the furnace as shown. Direction changing means are preferably disposed at alternate ends of the sections of the furnace for changing the direction of travel of the metallic strip and to direct the strip to an adjacent section. The turning means are advantageously located between adjacent sections. Thus, at the ends of each section the metallic strip is turned on suitable turning rolls **144** and **145** which may be, for example, air rolls or graphite-covered metal rolls. Metallic strip **140** preferably (but not necessarily) leaves the furnace from the side opposite that which it enters over guide roll **143**.

Heated air for the heat treating is introduced at **149**, circulates as indicated by the arrows in FIGS. 5 and 6 and is withdrawn at **150**. Doors **151** and **152** are provided for access to the furnace and to facilitate "threading" of the metallic strip **142** when necessary. Guides or shoes **153** and **154** serve to direct the strip onto the air support hearths. The furnace may contain as many horizontal passes as required, furthermore, the strip may enter at the top or bottom and leave at the same or opposite side from which it enters.

Another embodiment of the present invention is the use thereof for lifting members having a substantially flat surface from the top side of the member. In stacking and unstacking certain articles such as substantially flat thin members it is often difficult, if not impossible, to perform the operation without significant risk of damage to the members themselves. Typical of this category of articles are thin sheets of metal such as aluminum or thin sheets of glass, paper, etc.

In one present day operation thin sheets of aluminum are stacked and unstacked by devices employing suction cups or the like which are designed to contact the metallic sheet and apply a sufficient lifting force to transport the members. The suction cups generally leave marks on the metallic sheet and are rather unsatisfactory. The vacuum cups used to unstack sheets are additionally unsatisfactory in that the clamping action of the lip which may be of rubber or other material contacting the sheet results in a sliding or "squeegee" action of the cup lip on the sheet when the vacuum force is created. This contact further results in some cases of marking of the sheets and in addition the ring-like mark persists throughout subsequent sheet processing. The supporting device, according to the present invention, may advantageously be used to support from a topside position or, in other words, to lift substantially thin, flat members from above without the aforementioned difficulties.

As discussed previously, by increasing the pressure in the plenum above that required to maintain the sheet or strip flat it is possible to pull the center of the sheet tight against the deflector plate in such a manner that the sheet is effectively clamped. A deflector plate can be made as wide as required for adequate supporting contact with the surface of the supported member. Moreover, wider deflector plates allow reduction of plenum pressures required for an equivalent clamping force. Thus, by turning the support unit described with reference to FIG. 1 upside down, the invention can be adapted to lift substantially thin flat members such as aluminum sheet or thin sheets of glass from the topside of the member.

As can be seen in FIG. 7, gas emitting means comprising a plenum **155** attached to a suitable pressure source and deflector plate **156** are disposed above a flat member **157** to be lifted with the gas directing means (deflector plate) positioned between the member **157** and the discharge opening **159**. The gaseous flow confining means **158** may still be inclined uniformly to a plane substantially parallel to the flat member to be lifted, however, the V-shaped cross-section is inverted as shown. Thus, the gas flow is progressively confined outwardly to peripheral portions of member **157**. Discharge openings **159**, formed by the coaction of the deflector plate **156** with the inner edges of gaseous flow confining means **158**, are generally of smaller magnitude than required in supporting from the underside, and the flow confining means **158** are of a single uniform angle without slope compounding. At least part of the gas flow contacts the article subsequent to being outwardly directed. The member **157** will be clamped directly against deflector plate **156** by maintaining a suitable plenum pressure and wind velocity. Deflector plate **156** can be covered with a suitable material such as buff cloth or the like to provide a safe surface of large contact area without risk of injury to the surface of the member being lifted and clamped.

FIGS. 8 and 9 illustrate one application of the topside lifting embodiment of the invention wherein a plurality of individual supporting sections are used together. In this arrangement two independent lifting assemblies **160** and **170** as schematically depicted in FIG. 8 include gas emitting means having plenum pressure chambers, inclined V-shaped flow confining means and deflector plates. Air is introduced into the supporting sections at **161** and **171** respectively, under regulated pressure and from a suitable source, not shown, through appropriate piping means. Regulating means provided at 162 and 172 enable adjustment and regulation of the velocity pressure of the introduced air. The regulating means are preferably quick opening valves designed to introduce or shut off air to support units 160 and 170 as required. Shutting off the air will release the support provided by the lifting units. A continuous belt 180 on an independently controlled drive is arranged to travel along and beneath the lowermost deflector plate of independent air lifting units 160 and 170. As is shown, drive sheaves 181 and 182 support the continuous belt 180 at the ends of the contiguously arranged air supporting sections.

The air support structure is shown in more detail in FIG. 9 As can be seen lifting units 160 and 170 advantageously comprise a plurality of deflector plates 191, 192 and 193. Divergent V-shaped flow confining means 190 and deflector plates 191, 192 and 193 are arranged so as to be symmetrical about a center line through plenum pressure chamber 189 of the gas emitting means. Beneath the lowermost deflector plate 193 is the continuous conveyor belt 180. Endless conveyor belt 180 which is shown in FIG. 8 and FIG. 9 is motor-driven and individually controlled. The deflector plates are arranged at a predetermined distance apart so as to provide suitable discharge openings therebetween for the discharge of the wind introduced under pressure into plenum 189 from piping 194.

Three deflector plates are illustrated by way of example. As a practical matter a plurality of deflector plates are advantageously utilized in topside supporting or lifting to obtain uniform support of wide sheets and the number of deflector plates used would depend on size of sheet to be supported, weight, length of support, etc. The drawing in FIG. 9 is not to scale but serves to depict the relationship of the components. For one example, the slope of the gaseous flow confining means 190 might be ½" in 40" and the distances from the orifice defined by the top deflector plate, middle and bottom, to the center line of the plenum, may be 12", 7" and 2" respectively, with ⅛" orifices. The deflector plates can be $\frac{1}{16}$" thick and made of steel.

As shown in FIG. 8, continuous conveyor belt 180 operates across both lifting units 160 and 170 as shown which are arranged in tandem to be adjacent one another, (they may also be contiguous if desired), and rotate about drive sheaves 181 and 182. If desirable, the surface of the conveyor belt may be of soft cloth or similar material to prevent injury to the surface of the substantially thin flat members 200 to be lifted and transported.

As can be seen in FIG. 8, individual aluminum sheets or other material may be conveyed on handling means 176 and stacked onto the elevator platform 166 which is adjustable. The sheet handling means 176 is arranged a predetermined distance below lifting unit 160, or vice versa, so as to allow the sheet 200 to be brought within the air lifting force created by unit 160. As the flat plate or sheet is picked up by the forces generated by the lifting unit 160 it is effectively clamped against the continuous conveyor belt 180 and is thereafter transported by the belt 180 to lifting unit 170. When the sheet is over platform assembly 166 and is no longer within the lifting force of unit 160, lifting unit 170 may be turned off by valve means 172 allowing the sheet to fall onto the stack of sheets 201 lying on elevator platform 166. To prevent relative displacement (and subsequent sheet marking) between sheets 200 and conveyor 176 when picking sheets off conveyor 176, conveyor 180 should be traveling at the same speed as conveyor 176.

If desired, the lifting units may be suspended and provided with elevating means or alternatively conveyor 176 may be provided with elevating means. In such an arrangement when picking up the sheet from conveyor 176, conveyor belt 180 may be driven at a speed in excess of that of conveyor 176 thereby allowing sheet 200 to be positioned entirely underneath lifting unit 160 before pickup and then reducing the distance between belts 180 and 176 until the sheet is lifted by the action of lifting unit 160.

It is, of course, apparent that the system depicted in FIGS. 8 and 9 may be operated in reverse. Thus, stacked sheets may be loaded on elevator platform 166 and picked up by a lifting force generated in lifting unit 170, moved along by continuous conveyor belt 180 to lifting unit 160 wherein it is released and dropped onto suitable sheet handling means 176. Sheets of metallic strip or other material may be stacked or unstacked in this fashion as desired.

The foregoing examples of the various embodiments of the present invention are intended for illustrative purposes only. It is apparent that various changes and modifications of the instant invention may be made without departing from the principles and spirit of the invention. For these reasons the scope of the present invention should not be limited by the foregoing disclosure but rather only by the appended claims wherein,

What is claimed is:

1. In the heat treating of thin flexible metallic strip wherein gas is used as a supporting medium the improvement which comprises ejecting gas outwardly in opposite directions toward the lateral edges of the metallic strip from below, along and centrally of said strip, progressively confining in a decreasing cross-sectional area the flow of said outwardly ejected gas and discharging said gas along said lateral edges of the supported metallic strip, the rate of gas flow being sufficient to provide a controlled transverse cross-sectional configuration of the supported strip.

2. An improvement according to claim 1 wherein the strip is supported substantially flat.

3. An improvement according to claim 1 wherein the ejected gas is heated.

4. In the heat treating of thin flexible metallic strip wherein gas is used as a supporting medium, the improvment which comprises ejecting at least most of said supporting gas outwardly in opposite directions toward lateral edges of the metallic strip from below, along and centrally of said strip, progressively confining in a decreasing cross-sectional area the flow of said outwardly ejected gas and discharging said gas along said lateral edges of the supported metallic strip the rate of gas flow being sufficient to provide a controlled transverse cross-sectional configuration of the supported strip.

5. An apparatus for heat treating metallic strip comprising an elongated horizontally disposed furnace enclosure in which a metallic strip is adaptable to be supported during traverse therein, means for ejecting gas outwardly in opposite directions toward lateral edges of the metallic strip from below, along and centrally of said strip and means adapted to cooperate with said strip to progressively confine in a decreasing cross-sectional area the flow of said ejected gas.

6. A furnace for heat treating metallic strip having a heat treating chamber which includes therein an elongated centrally disposed plenum pressure chamber; divergent, V-shaped, gas flow confining surfaces extending laterally outwardly from said plenum pressure chamber, and means to eject gas from said plenum pressure chamber outwardly in opposite directions along the top side of the flow confining surfaces.

7. A furnace according to claim 6 wherein said means to eject gas from said plenum pressure chamber outwardly in opposite directions includes a gas deflecting plate disposed above said plenum pressure chamber.

8. A furnace according to claim 7 comprising a perforated gas deflecting plate.

9. A furnace according to claim 6 wherein said gas flow confining surfaces diverge from said plenum pressure chamber outwardly at uniform angles inclined to

the horizontal and have at least one increment of decreasing slope.

10. A heat treating furnace comprising a plurality of adjacently disposed sections in which a metallic strip is adaptable to be supported during traverse therein, each section comprising means for ejecting gas outwardly in opposite directions toward the lateral edges of the metallic strip from below, along and centrally of said strip, and means adapted to cooperate with said strip to progressively confine in a decreasing cross-sectional area the flow of said ejected gas.

11. In the method of supporting a member such as a sheet, plate, strip, or the like wherein gas is used as a supporting medium, the improvement which comprises ejecting gas outwardly in opposite directions toward lateral edges of the member from below, along and centrally of said member, progressively confining in a decreasing cross-sectional area the flow of said outwardly ejected gas and discharging said gas along said lateral edges of the supported member, the rate of gas flow being sufficient to support said member.

12. An apparatus for supporting a member such as a sheet, plate, strip or the like comprising an elongated centrally disposed plenum pressure chamber; divergent, V-shaped, gas flow confining surfaces extending laterally outwardly from said plenum pressure chamber, and means to eject gas from said plenum pressure chamber outwardly in opposite directions along the top side of the flow confining surfaces.

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