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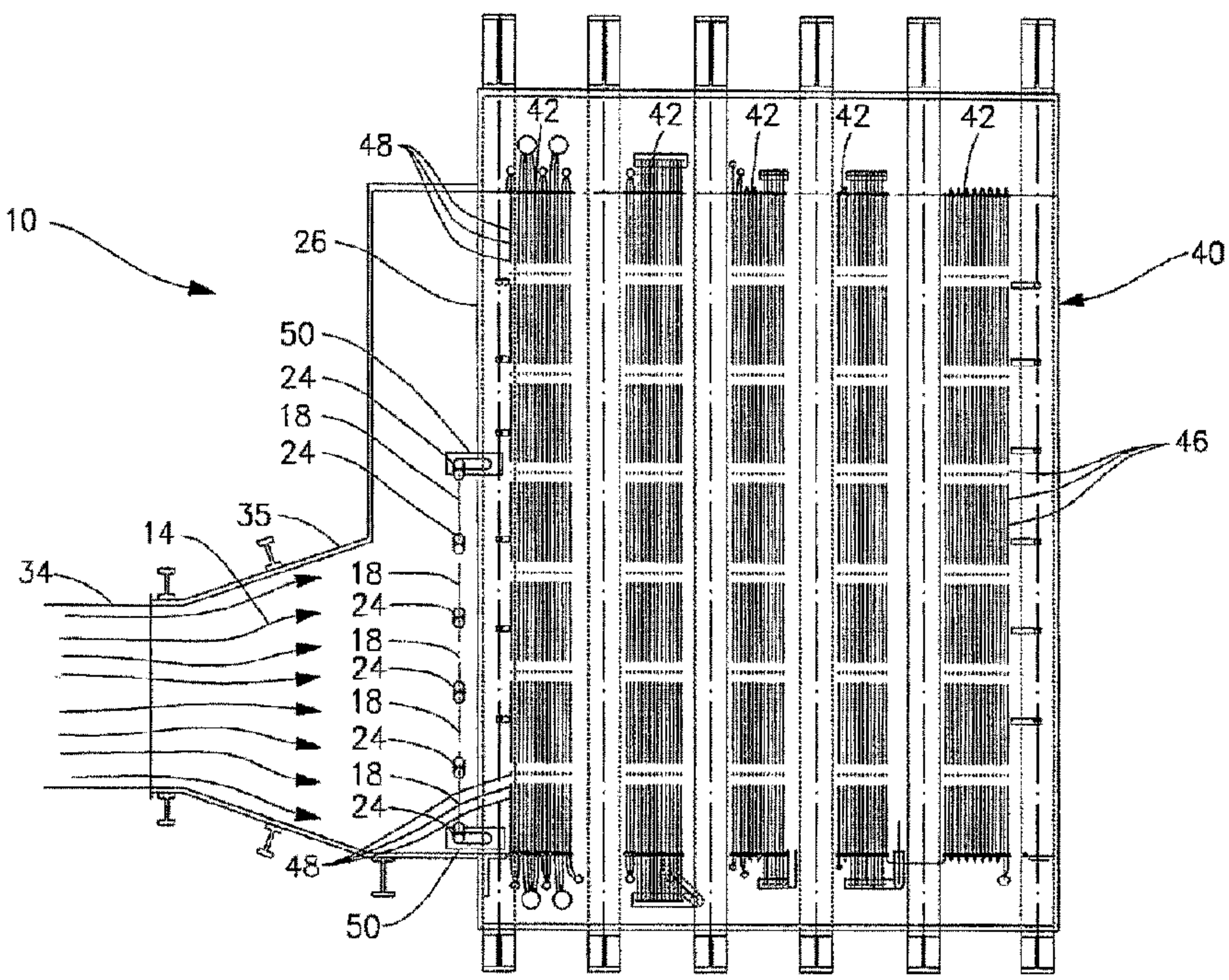
(54) **Titre :** APPAREIL ET PROCEDE D'ACCOUPLEMENT ETROIT DE GENERATEURS DE VAPEUR A RECUPERATION DE CHALEUR AVEC DES TURBINES A GAZ

(54) **Title:** APPARATUS AND METHOD FOR CLOSE COUPLING OF HEAT RECOVERY STEAM GENERATORS WITH GAS TURBINES



(57) **Abrégé/Abstract:**
A heat recovery steam generator ("HRSG") (40), which is closely coupled to a gas turbine, includes a flow controls structural array (10) disposed upstream of the tubes (42) of the HRSG (40). The structural array (10) is formed of a plurality of grate-like panels (18) secured to horizontal supports (24) mounted to the support structure of the HRSG (40). The structural array (10) diffuses the high velocity exhaust stream (14) exiting the gas turbine and redistributes the gas flow evenly throughout the HRSG (40). The structural array (10) reduces wear and damage of the tubes (46).

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(54) Title: APPARATUS AND METHOD FOR CLOSE COUPLING OF HEAT RECOVERY STEAM GENERATORS WITH GAS TURBINES

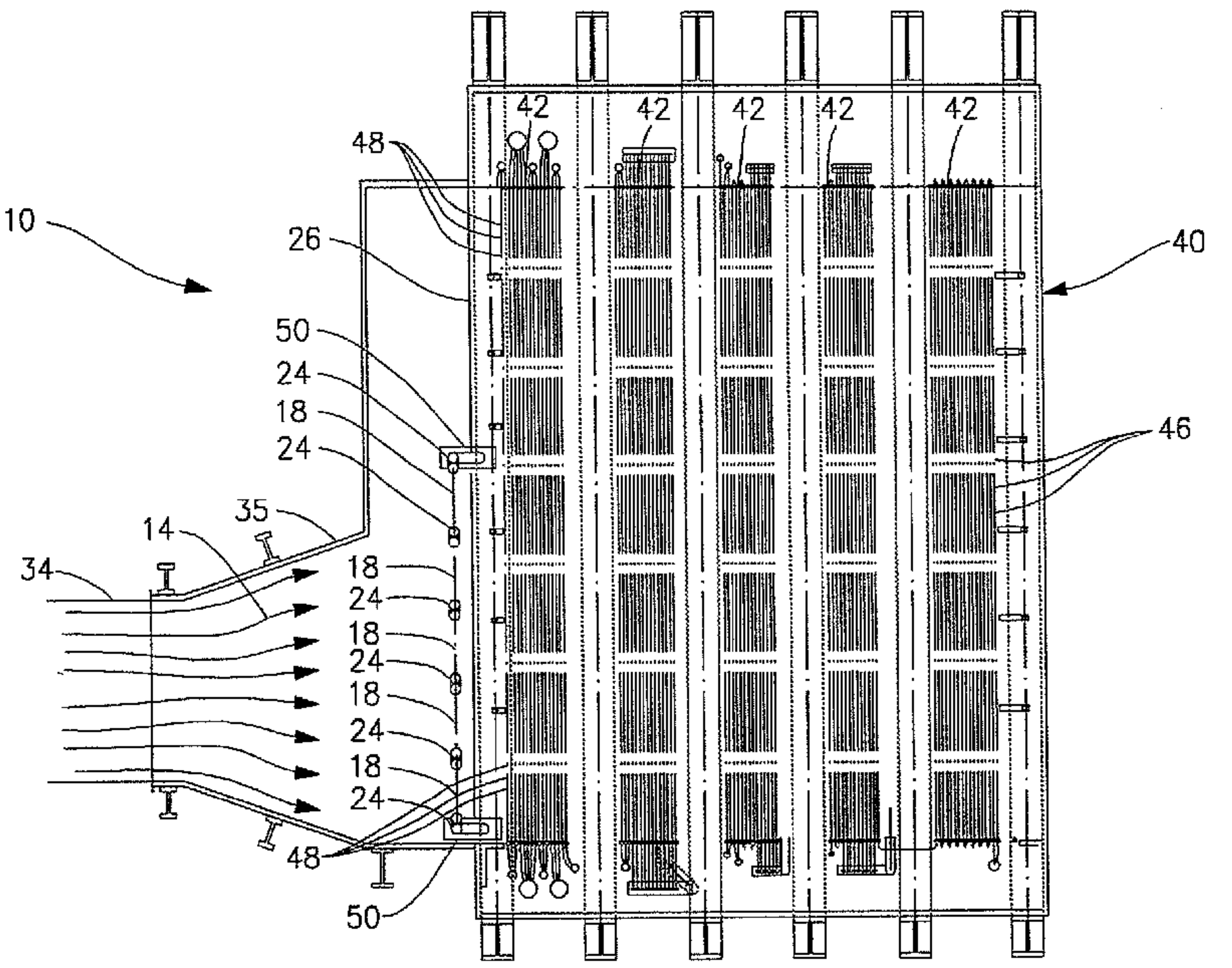

Figure 2

(57) Abstract: A heat recovery steam generator ("HRSG") (40), which is closely coupled to a gas turbine, includes a flow controls structural array (10) disposed upstream of the tubes (42) of the HRSG (40). The structural array (10) is formed of a plurality of grate-like panels (18) secured to horizontal supports (24) mounted to the support structure of the HRSG (40). The structural array (10) diffuses the high velocity exhaust stream (14) exiting the gas turbine and redistributes the gas flow evenly throughout the HRSG (40). The structural array (10) reduces wear and damage of the tubes (46).

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APPARATUS AND METHOD FOR CLOSE COUPLING OF HEAT RECOVERY STEAM GENERATORS WITH GAS TURBINES

TECHNICAL FIELD

[0001] The present invention relates generally to heat recovery steam generators (HRSGs), and more particularly, to a heat recovery steam generator having a structural array to control the exhaust flow exiting a gas turbine before passing through the heat recovery steam generator.

BACKGROUND

[0002] Combined Cycle power plants employ gas turbines with Heat Recovery Steam Generators (HRSGs) that use the thermal energy in the exhaust from gas turbines to generate steam for power generation or process use. The large stationary gas turbines used in such power plants may typically have average exhaust gas velocities in the range of 200 ft/sec. The velocity of the gas turbine exhaust is not uniform however and some recent gas turbines have local exhaust gas velocities in the range of 660 ft/sec. HRSGs may have flow areas in the range of 5 to10 times the gas turbines exit flow area and thus average entering velocities that are 5 to 10 times lower than those exiting the gas turbine. A diverging duct is therefore required to connect the gas turbine to the HRSG. A typical arrangement of the gas turbine exhaust diffuser, connecting duct and HRSG is shown in Figure 1. It is desirable to locate the HRSG close to the gas turbine in a compact duct arrangement to minimize the area required for the power plant and to minimize the size and cost of the connecting duct. This can result in a high velocity jet of gas impacting the region of the front rows of heat transfer tubes in the HRSG that are in line with the gas turbine exhaust diffuser. Such high velocities can cause flow-induced vibrations that will damage the heat transfer tubes. The high aerodynamic loading on the tube banks can also cause movement of the entire front tube bank resulting in damage to components in and around the tube bank. The non-uniform velocities entering the HRSG front tube rows also reduce the heat transfer effectiveness of these rows.

[0003] In some cases flow controls have been used in the diverging duct to redirect flow within the duct and improve flow distribution to the front rows of tubes in the HRSG. These flow controls would be subject to very high aerodynamic loadings in a compact duct due to close proximity to the gas turbine. In addition to the steady aerodynamic loading, the flow controls are subject to dynamic loading due to the high levels of turbulence in the duct and thermal stress due to going from ambient temperature to the high gas turbine exhaust temperature. These issues make it unlikely that flow controls located in the diverging duct 36 will survive long-term operation.

[0004] As will be described in greater detail hereinafter, a structural array disposed upstream of the front tubes of an HRSG will overcome such problems, particularly when the turbine and HRSG are closely coupled.

[0005] Currently there is a need for an effective and reliable means for diffusing an exhaust stream 14 from a turbine to recover heat.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Referring now to the Figures, which are exemplary embodiments, and wherein the like elements are numbered alike:

[0007] Fig. 1 is a partial cut-away side elevation view of an HRSG coupled in fluid communication with a gas turbine exhaust diffuser and an HRSG in accordance with the present invention.

[0008] Fig. 2 is a cross-sectional side elevation view of an HRSG having an inlet duct and a structural array disposed upstream of the tubes of the HRSG in accordance with the present invention.

[0009] Fig. 3a is a front view of the HRSG having a structural array secured thereto in accordance to the present invention.

[0010] Fig. 3b is a side elevation view of the structural array of Fig. 3a.

[0011] Fig. 4a is a front view of a grate-like panel of the structural array of Fig. 3a.

[0012] Fig. 4b is a side elevation view of the grate-like panel of Fig. 4a.

DETAILED DESCRIPTION

[0012a] Some embodiments disclosed herein relate to a heat recovery system comprising: a heat recovery steam generation (HRSG) chamber in fluid communication with an exhaust stream from a turbine; a plurality of tubes disposed in the HRSG chamber; and a grate-like structural array, including at least one grate-like panel having a plurality of openings, disposed upstream from the tubes wherein the openings of the at least one grate-like structural array are sized and spaced to provide a surface therebetween to dissipate the energy of the exhaust stream before passing through the tubes to reduce the aerodynamic loading exerted on the tubes, wherein the surface between the openings provide sufficient resistance to redirect a portion of the exhaust stream around the grate-like structural array.

[0012b] Some embodiments disclosed herein relate to a method for recovering heat from an exhaust stream from a turbine, said method comprising: providing the exhaust stream from the turbine to a heat recovery steam generation (HRSG) chamber, said HRSG having a plurality of tubes disposed therein; disposing upstream from the tubes a grate-like structural array, including at least one grate-like panel having a plurality of openings, wherein the openings of the at least one grate-like structural array are sized and spaced to provide a surface therebetween; dissipating the energy of the exhaust stream against the surface of the grate-like array to reduce the aerodynamic loading exerted on the tubes by contacting a portion of the exhaust stream against the surface between the openings which provides sufficient resistance to redirect a portion of the exhaust stream around the grate-like structural array, and passing a portion of the exhaust gas through the openings of the grate-like structure.

[0013] A new approach to flow controls is suggested in which an array 10 of structural components is placed in front of the front row of tubes 48 to diffuse the high velocity exhaust stream 14 exiting the gas turbine (not shown) and redistribute the gas flow into the HRSG 40. One such arrangement is shown in Figures 2 - 4b. Note that these figures show one possible arrangement. Other combinations could be used as long as the features discussed below are met by the design.

[0014] Fig. 2 is a cross-sectional side elevation view of an HRSG having an inlet duct and a structural array disposed upstream of the tubes of the HRSG in accordance with the present invention. Fig. 2 illustrates an HRSG 40 with a structural array 10.

[0015] Fig. 3a is a front view of the HRSG having a structural array secured thereto in accordance to the present invention.

[0016] Fig. 3b is a side elevation view of the structural array of Fig. 3a.

[0017] With reference now to Figures 2, 3a and 3b, structural array 10 is disposed upstream of the tube banks 42 of the HRSG 40. The structural array 10 is mounted or secured to structural elements or supports 26 at the upstream end of the HRSG 40 to control the flow of the exhaust stream 14 from a turbine (not shown), e.g., a gas turbine. As shown in Fig. 3a, the structural array 10 extends over the upstream end of the HRSG 40 over a sufficient area to engage or control the exhaust stream 14.

[0018] In the embodiment shown, the structural array 10 comprises a plurality of grate-like panels 18.

[0019] Fig. 4a is a front view of a grate-like panel of the structural array of Fig. 3a.

[0020] Fig. 4b is a side elevation view of the grate-like panel of Fig. 4a.

[0021] Panels 18 are now described with reference to Figures 4a and 4b. Panels 18 each have a plurality of horizontal bars 20 connected to a plurality of vertical bars 22. The bars 20, 22 may be solid, hollow or generally U-shaped. Furthermore, the cross section of each bar may be any geometric shape (i.e., round, oval, square, rectangular, octagonal, etc.) or U-shaped. The grid openings 12 may be uniform or irregular. Similarly, the spacing of the vertical and horizontal bars of the array may be uniform or varied. The vertical bars 22 of the panel 18 are U-shaped, wherein the orientation of the U-shaped bars are such that the openings of the bars open inwardly towards the center of the panel.

While the U-shaped vertical bars 22 are shown in such an orientation, the invention contemplates that the U-shaped bars may be disposed in any orientation.

[0022] Each of the panels 18 are mounted or secured (e.g., welded, bolted, or other means of attachment) to horizontal supports 24, which are in turn attach or secured to structural supports 26 of the HRSG 40. The mounting of the panels 18 to the structural supports 26 and not the tubes 46 of the HRSG reduce fatigue on the tubes. In the embodiment shown the horizontal supports 24 are formed of a pair of vertically disposed tubes 30 are welded together. However, the present invention contemplates that the horizontal supports 24 may be formed from any support bean.

[0023] Referring now back to Fig. 2, in the operation of the gas turbine (not shown) and the HRSG 40 with the flow control structural array 10, the exhaust stream 14 from the gas turbine flows through the connecting duct 34 and HRSG inlet duct 36. The high velocity flow passes through the grate-like structural array 10, wherein the exhaust stream 14 is diffused and further distributed across the tubes 46 of the HRSG 40.

[0024] The structural array 10 is constructed of structural components 20, 22, 24 to withstand the forces imparted by the high velocity exhaust stream 14. Pined and/or slip connections are used where appropriate to allow for thermal expansion. The size and spacing of the components 20, 22, 24 is arranged to provide sufficient resistance to redirect part of the high velocity exhaust stream 14 to the sections of the front row tubes 48 that would have had little or no gas flow, improving the distribution of gas flow into the HRSG 40. The structural components 20, 22, 24 are also sized and spaced such that the remaining flow passing though the array 10 is distributed through grid openings 12 into a large number of smaller jets. The smaller jets start with a diameter D the same as the grid openings 12. These are on the order of 1/10 of the distance from the structural array 10 to the tubes 46. This allows the small multiple jets to partially dissipate before reaching the tubes 46 and lowers the loading on the region of the tubes that would have been subjected to unacceptable velocities without the structural array 10.

[0025] The extent of the front row of tubes 46 that are protected by the structural array 10 and the diameter of the grid openings 12 will be based on physical flow modeling of the specific gas turbine and HRSG 40.

[0026] In an alternative embodiment, structural array 10 is on adjustable mounts (50 of Figure 2) such that the distance from the structural array and tubes 46 may be adjusted. This allows for adjustment of more or less dissipation of the exhaust jets as they impinge upon the tubes 46. Since more diffusion of the exhaust stream 14 result in higher exhaust back pressure, the system can be interactively optimized for both backpressure and diffusion.

[0027] While the invention has been described with reference to various exemplary embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A heat recovery system including:

a heat recovery steam generation (HRSG) chamber in fluid communication with a high velocity exhaust stream from a turbine;

an inlet duct to provide the high velocity exhaust stream from the turbine to the HRSG chamber;

a plurality of tubes disposed in the HRSG chamber, the plurality of tubes including front tubes disposed furthest upstream in relation to the direction of the high velocity exhaust stream; and

a grate-like structural array, including at least one grate-like panel having a plurality of openings, disposed within the HRSG chamber upstream of the front tubes within the HRSG chamber,

wherein the grate-like structural array provides resistance to diffuse and distribute exhaust gas by providing resistance to redirect part of the high velocity exhaust stream to an upper portion of the plurality of tubes to improve distribution of exhaust gas in the HRSG chamber, and wherein the grate-like structural array permits a remaining portion of the high velocity exhaust stream to pass through the openings of the at least one grate-like structural array to form a plurality of smaller jets which partially dissipate before contacting the front tubes to reduce the aerodynamic loading exerted on the front tubes.

2. The heat recovery system of claim 1, wherein the grate-like structural array is disposed downstream of the inlet duct of the HRSG in relation to the direction of the high velocity exhaust stream.

3. The heat recovery system of claim 2, wherein the grate-like structural array is spaced from an outlet of the inlet duct.

4. The heat recovery system of any one of claims 1-3, further including structural supports disposed within the HRSG chamber, wherein the grate-like structural array is secured to the structural supports.

5. The heat recovery system of any one of claims 1-4, wherein the at least one grate-like panel includes a first set of bars extending in one direction and a second set of bars extending in a second direction to form the openings.

6. The heat recovery system of claim 5, wherein the first set of bars extend generally horizontally and the second set of bars extend generally vertically.

7. The heat recovery system of claim 5, wherein the first set of bars are disposed upstream of the second set of bars or the second set of bars are disposed upstream of the first set of bars.

8. The heat recovery system of claim 5, wherein at least one of the first and second set of bars have a rectangular cross-section.

9. The heat recovery system of claim 5, wherein at least one of the first and second set of bars have a U-shaped cross-section.

10. The heat recovery system of any one of claims 1-9, wherein the at least one grate-like panel includes a plurality of grate-like panels.

11. The heat recovery system of claim 10, wherein the grate-like panels extend in a plurality of spaced horizontal rows.

12. The heat recovery system of claim 11 further including at least one horizontal support disposed between the grate-like panels to secure the grate-like panels together.

13. The heat recovery system of claim 12 wherein the at least one horizontal support provides resistance to redirect part of the high velocity exhaust stream to an upper portion of the plurality of tubes.

14. The heat recovery system of any one of claims 1-13, wherein the jets passing through the grate-like structural array have a diameter of approximately 1/10 of the spacing between the grate-like structural array and the plurality of tubes.

15. The heat recovery system of claim 4, wherein the grate-like structural array is adjustably secured to the structural supports to permit the distance between the grate-like structural array and the front tubes to be adjusted.

16. The heat recovery system of claim 15, further including adjustable mounts interconnecting the grate-like structural array and the structural supports to adjust the distance between the grate-like structural array and the front tubes.

17. The heat recovery system of any one of claims 1-16, wherein the grate-like structural array is sized to be positioned in a high velocity portion of the exhaust stream prior to passing through the plurality of front tubes.

18. The heat recovery system of any one of claims 1-17, wherein the turbine and the HRSG chamber are closely coupled such that direct exposure of the plurality of tubes to the exhaust stream would result in damage to the plurality of tubes.

19. The heat recovery system of any one of claims 1-18, wherein the high velocity exhaust stream flows only towards a lower portion of the front tubes, the grate-like structural array being sized to be positioned in the high velocity exhaust stream prior to passing through the front tubes.

20. A method for recovering heat from a high velocity exhaust stream from a turbine, said method including:

providing the high velocity exhaust stream from the turbine through an inlet duct to a heat recovery steam generation (HRSG) chamber, said HRSG having a plurality of tubes disposed therein, the plurality of tubes including front tubes disposed furthest upstream in relation to the direction of the high velocity exhaust stream;

disposing within the HRSG chamber upstream from the front tubes in relation to the direction of the high velocity exhaust stream, a grate-like structural array, including at least one grate-like panel having a plurality of openings, wherein the grate-like structural array provides resistance to diffuse and distribute the high velocity exhaust gas by providing resistance to redirect part of the high velocity exhaust stream to an upper portion of the plurality of tubes to improve distribution of the exhaust gas in the HRSG chamber;

passing a remaining portion of the high velocity exhaust stream through the openings of the at least one grate-like structural array to form a plurality of smaller jets which partially dissipate before contacting the front tubes to reduce the aerodynamic loading exerted on the front tubes.

21. The method of claim 20, wherein the grate-like structural array is disposed downstream of the inlet duct of the HRSG in relation to the direction of the high velocity exhaust stream.

22. The method of claim 21, wherein the grate-like structural array is spaced from an outlet of the inlet duct.

23. The method of any one of claims 20-22, wherein the grate-like structural array is secured to structural supports disposed within the HRSG chamber.

24. The method of any one of claims 20-23, wherein the at least one grate-like panel includes a first set of bars extending in one direction and a second set of bars extending in a second direction to form the openings.

25. The method of claim 24, wherein the first set of bars extend generally horizontally and the second set of bars extend generally vertically.

26. The method of claim 24, wherein the first set of bars are disposed upstream of the second set of bars or the second set of bars are disposed upstream of the first set of bars.

27. The method of claim 24, wherein at least one of the first and second set of bars have a rectangular cross-section.

28. The method of claim 24, wherein at least one of the first and second set of bars have a U-shaped cross-section.

29. The method of any one of claims 20-28, wherein the at least one grate-like panel includes a plurality of grate-like panels.

30. The method of claim 29, wherein the grate-like panels extend in a plurality of spaced horizontal rows.

31. The method of claim 24, further including disposing at least one horizontal support between the grate-like panels to secure the grate-like panels together.

32. The method of claim 31 wherein the at least one horizontal support provides resistance to redirect part of the high velocity exhaust stream to an upper portion of the plurality of tubes.

33. The method of any one of claims 20-32, wherein the jets passing through the grate-like structural array have a diameter of approximately 1/10 of the spacing between the grate-like structural array and the front tubes.

34. The method of claim 23, wherein the grate-like structural array is adjustably secured to the structural supports to permit the distance between the grate-like structural array and the front tubes to be adjusted.

35. The method of claim 34, further including interconnecting with adjustable mounts the grate-like structural array and the structural supports to adjust the distance between the grate-like structural array and the front tubes.

36. The method of any one of claims 20-35, wherein the grate-like structural array is sized to be positioned in the high velocity portion of the exhaust stream prior to passing through the front tubes.

37. The method of any one of claims 20-36, wherein the turbine and the HRSG chamber are closely coupled such that direct exposure of the tubes to the exhaust stream would result in damage to the tubes.

38. The method of any one of claims 20-37, wherein the high velocity exhaust stream flows only towards a lower portion of the front tubes, the grate-like structural array being sized to be positioned in the high velocity exhaust stream prior to passing through the front tubes.

39. A power plant including a turbine comprising:

a heat recovery steam generation (HRSG) chamber having an inlet, the HRSG chamber having a plurality of tubes disposed therein;

a diverging duct coupled therebetween the HRSG inlet and the turbine, and arranged to provide the exhaust stream from the turbine therethrough to the HRSG chamber inlet; and

a grate-like structural array, disposed within the HRSG chamber, downstream of the HRSG chamber inlet and upstream of the plurality of tubes, the structural array, including at least one grate-like panel having a plurality of grid openings, wherein the at least one grate-like structural array is sized and disposed to dissipate the energy of the entire portion of the exhaust stream received from the diverging duct to reduce the aerodynamic loading exerted on the plurality of tubes, wherein the surface between the grid openings provides resistance to redirect a portion of the exhaust stream, and wherein the grid openings are sized to pass the remaining portion of the exhaust stream therethrough.

40. The power plant of claim 39 wherein the diverging duct provides the exhaust stream directly only to the lower portion of the HRSG chamber.

41. The power plant of claim 39 further comprising structural supports disposed within the HRSG chamber. wherein the grate-like structural array is secured to the structural supports.

42. The power plant of claim 39 wherein the grid openings are disposed over the entire surface of the at least one grate-like panel and are sized and spaced to provide a surface thereon to absorb the aerodynamic loading of the exhaust stream.

43. The power plant of claim 39 wherein the at least one grate-like panel comprises a first set of bars extending in one direction and a second set of bars extending in a second direction to form the grid openings.

44. The power plant of claim 43 wherein the first set of bars extend generally horizontally and the second set of bars extend generally vertically.

45. The power plant of claim 43 wherein one of the first set of bars are disposed upstream of the second set of bars or the second set of bars are disposed upstream of the first set of bars.

46. The power plant of claim 43 wherein at least one of the first and second set of bars have a rectangular cross-section.

47. The power plant of claim 43 wherein at least one of the first and second set of bars have a U-shaped cross-section.

48. The power plant of claim 39 wherein the at least one grate-like panel includes a plurality of grate-like panels.

49. The power plant of claim 48 wherein each of the grate-like panels extend in a plurality of spaced horizontal rows.

50. The power plant of claim 49 further comprising at least one horizontal support disposed between the grate-like panels to secure the grate-like panels together.

51. The power plant of claim 50 wherein the horizontal support and grate-like panels are attached by pinned and/or slip connections to allow thermal expansion.

52. The power plant of claim 39 wherein the exhaust stream passing through the grate-like structural array form a plurality of jets having a diameter of approximately 1/10 of the spacing between the grate-like structural array and the tubes.

53. The power plant of claim 41 wherein the grate-like structural array is adjustably secured to the structural supports to permit the distance between the grate-like structural array and the tubes to be varied.

54. The power plant of claim 53 further includes adjustable mounts interconnecting the grate-like structural array and the structural supports to vary the distance between the grate-like structural array and the tubes.

55. The power plant of claim 39 wherein the grate-like structural array is sized to engage the exhaust stream prior to passing through the tubes and permitting the remaining portion of the exhaust stream to pass around the grate-like structural array to the tubes to thereby prevent the any of the exhaust gas from directly contacting the tubes.

56. The power plant of claim 39 wherein the turbine and the HRSG chamber are closely coupled such that direct exposure of the tubes to the exhaust stream would result in damage to the tubes.

57. The power plant of claim 39, wherein the diverging duct comprises an inlet duct having an inlet and outlet, the inlet duct coupled downstream of the turbine, and a diffusing duct coupled downstream of the inlet duct, the diffusing duct having an inlet and outlet shaped to provide and diffuse the turbine exhaust stream to the HRSG chamber inlet, and wherein the grate-like structural array is disposed downstream of the diffusing duct.

58. The power plant of claim 57, wherein the grate-like structural array is spaced from the outlet of the inlet duct.

59. The power plant of claim 39, further comprising structural supports disposed within the HRSG chamber, and wherein the grate-like structural array is secured to the structural supports.

60. The power plant of claim 39, wherein the grate-like structural array extends over and is disposed upstream of only a lower portion of the foremost tubes.

61. The power plant of claim 57, wherein the grate-like structural array is disposed across the entire portion of the tubes to prevent direct contact of the exhaust stream with the tubes.

62. The power plant of claim 50, wherein the at least one horizontal support includes a panel that provides a surface sized to provide sufficient resistance to redirect a portion of the exhaust stream above the grate-like structural array.

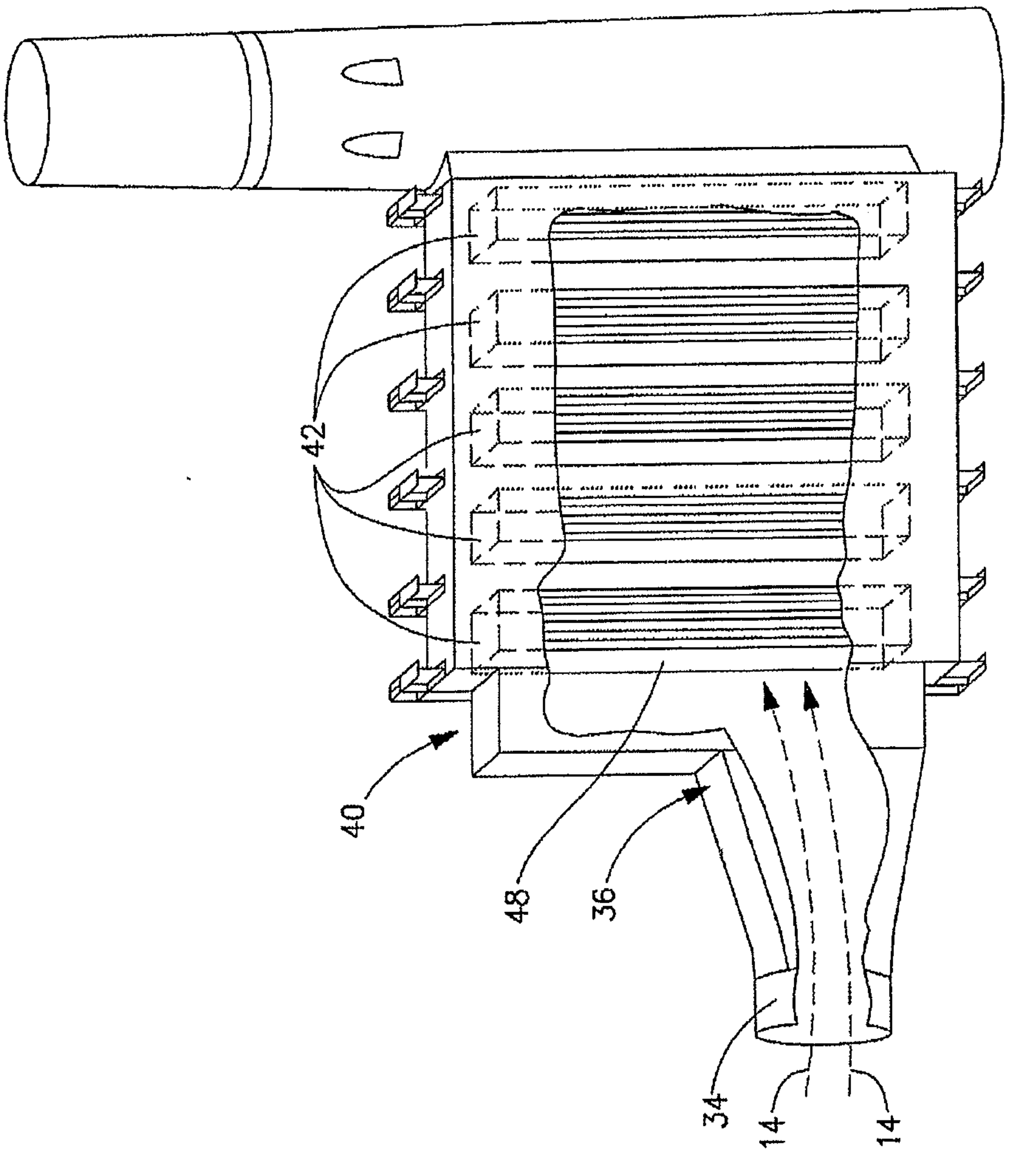

Figure 1

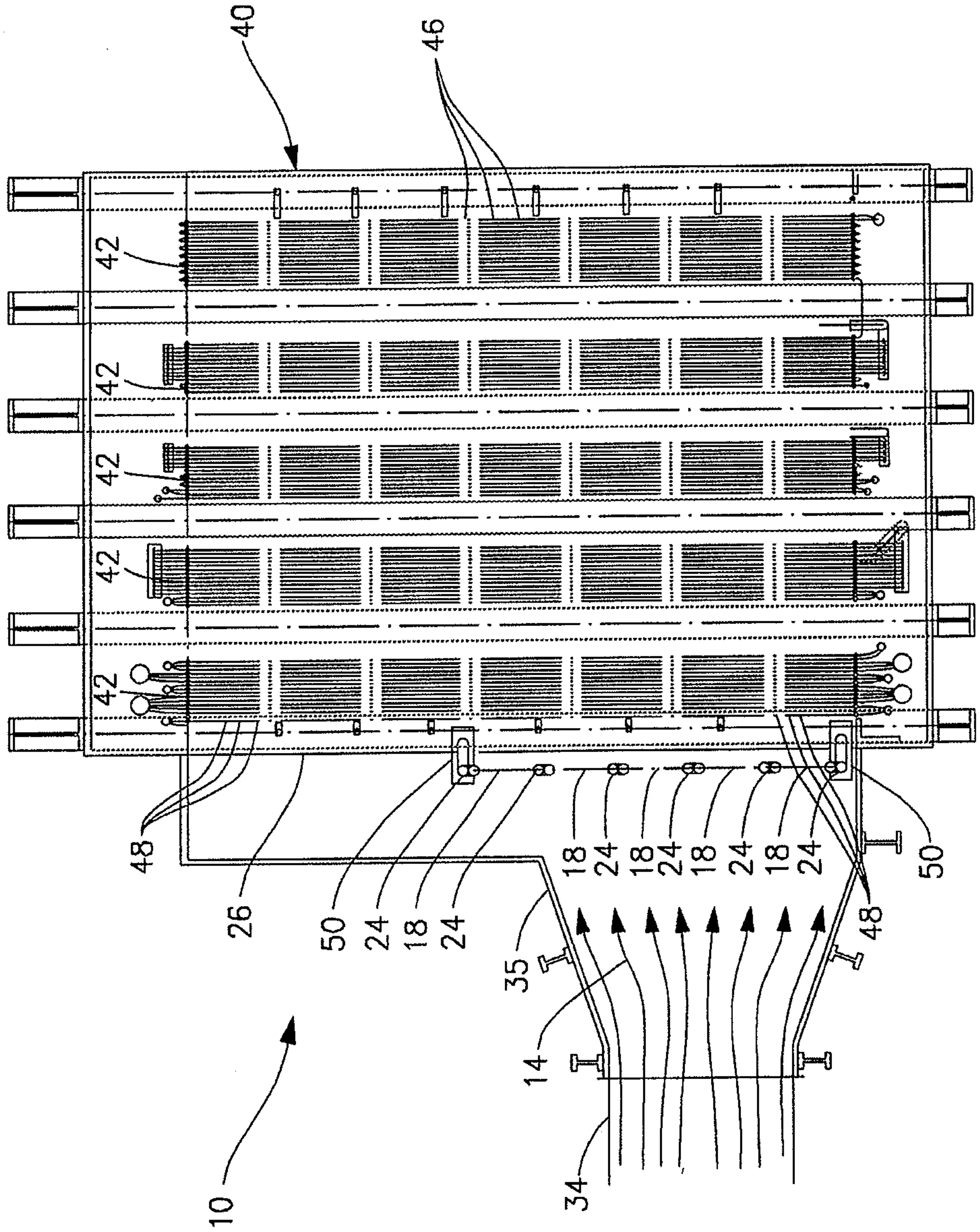
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Figure 2

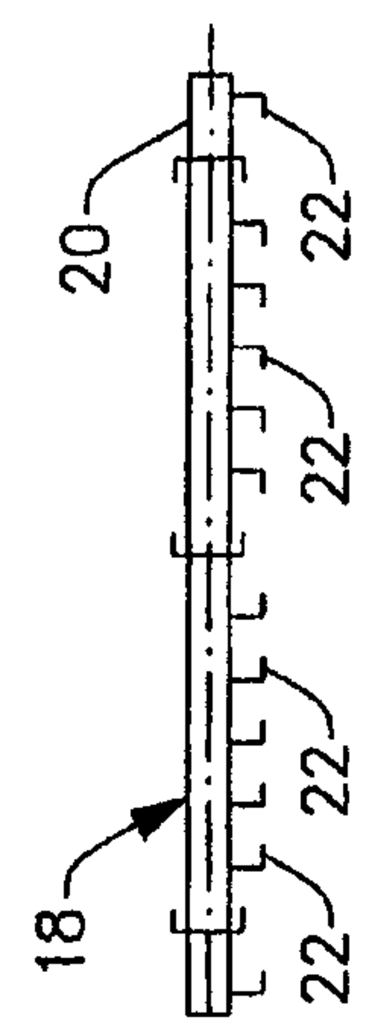

Fig. 4b

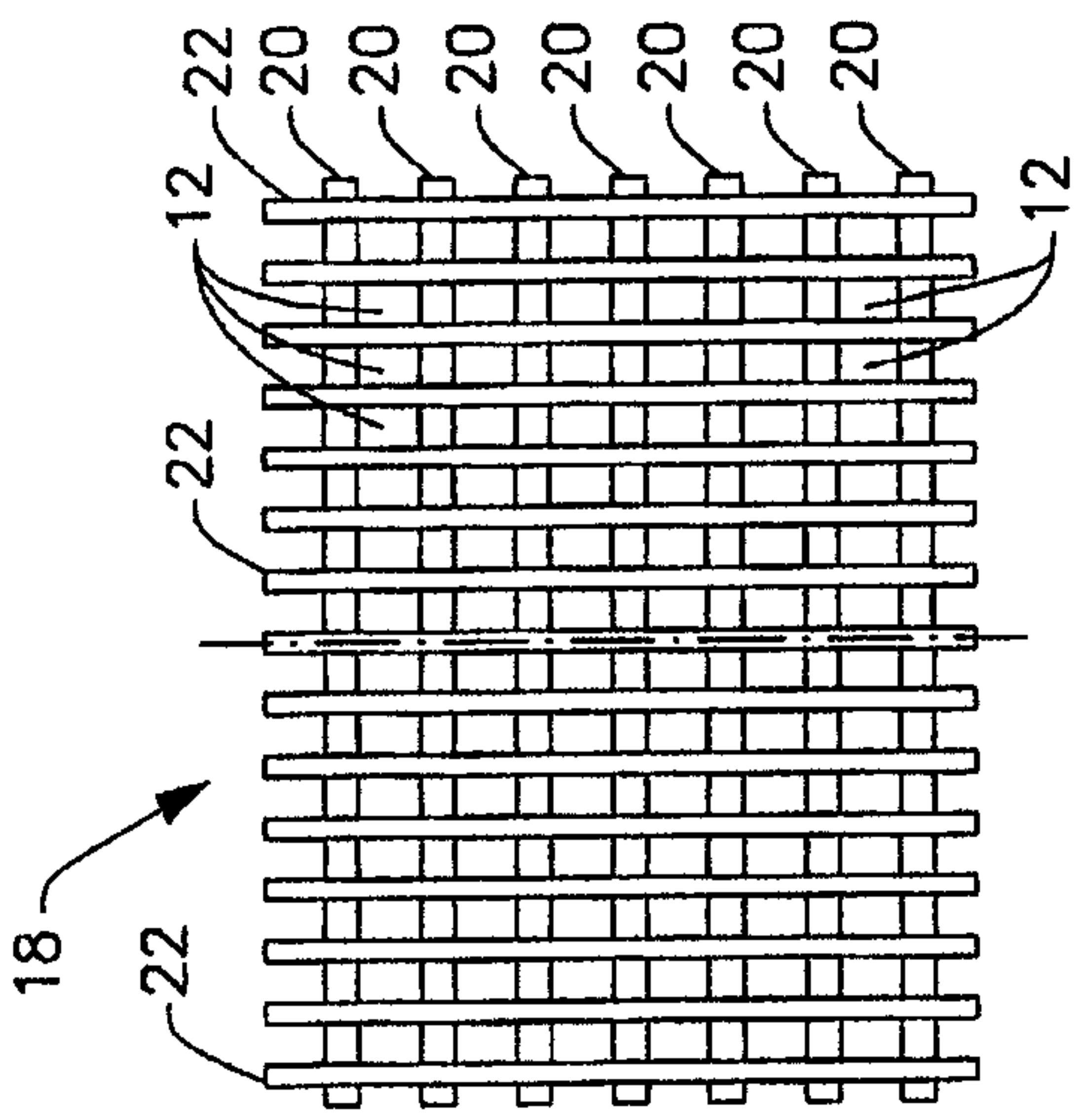

Fig. 4a

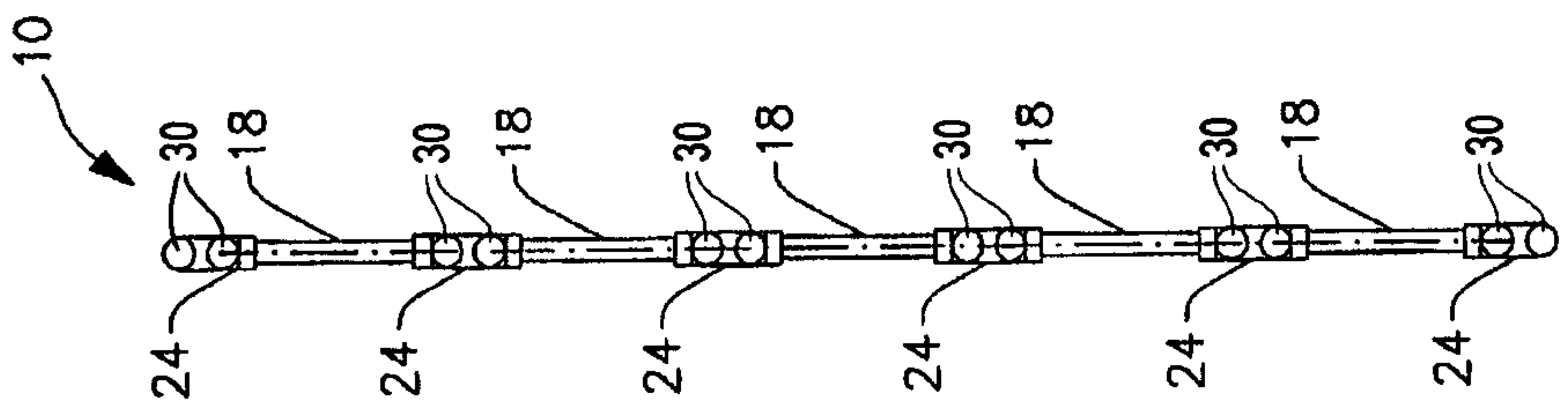

Fig. 3b

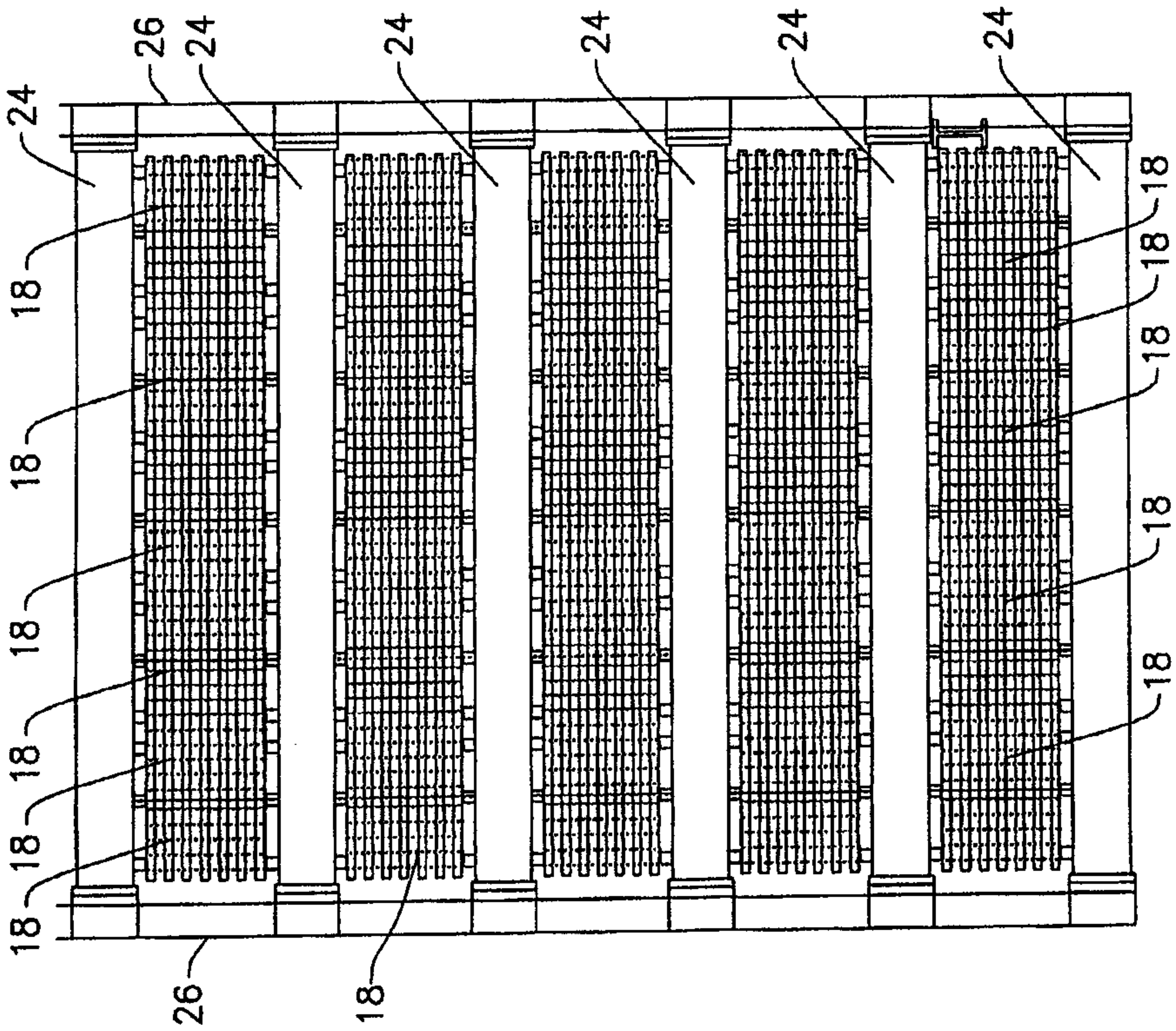

Fig. 3a

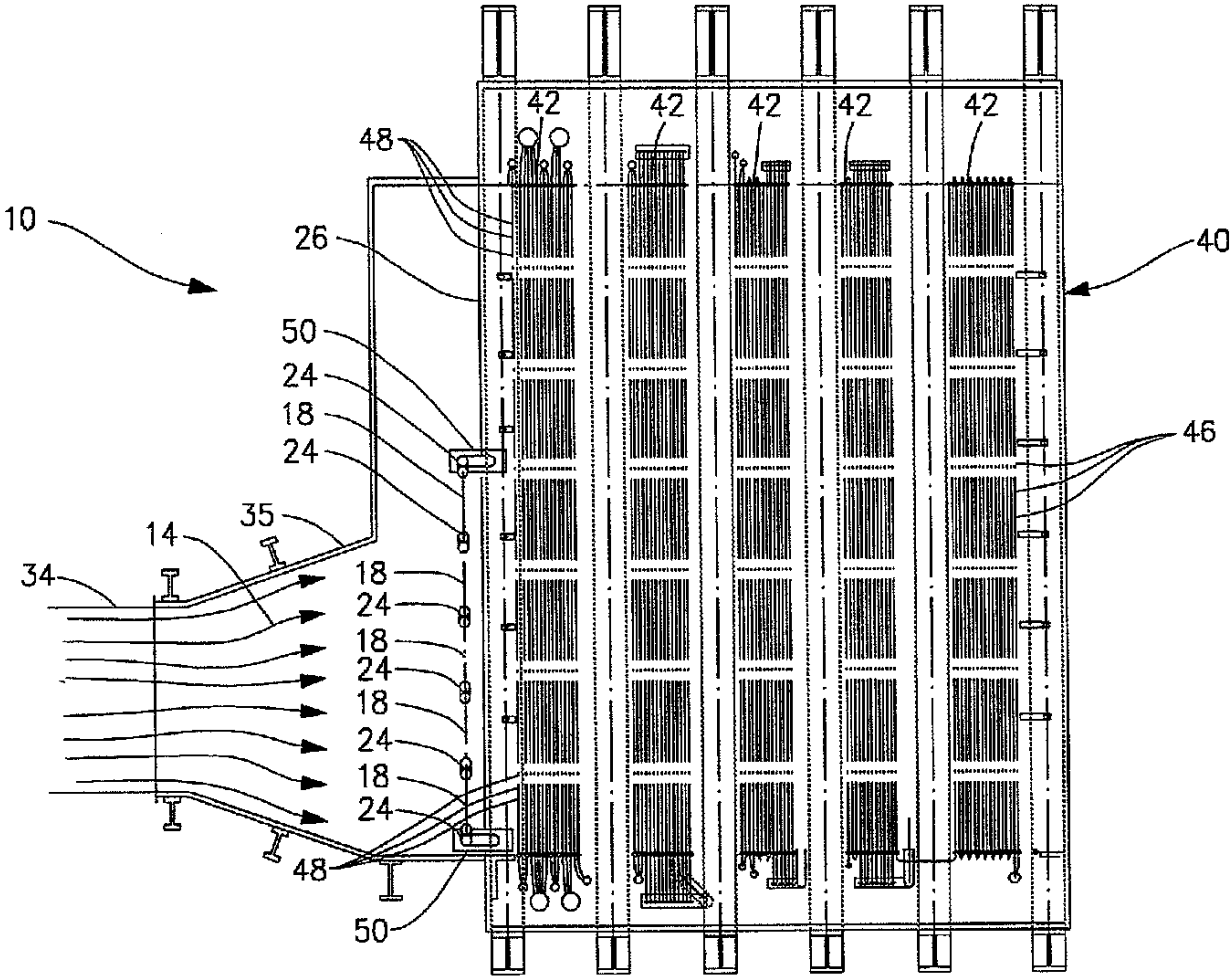
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Figure 2