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(71) Applicant: DANIELI TECHNOLOGY, INC. [US/US]; 800 Cranberry Woods Drive, Suite 400, Cranberry Township, PA 16066 (US).

(72) Inventor: FELDBAUER, Stephen, L.; 92 Strausser Road, Jackson Center, PA 16133 (US).

(74) Agent: BAKER, James, N.; Armstrong, Westerman, Hattori McLeland & Naughton, Law & Finance Building, Suite 707, 429 Fourth Avenue, Pittsburgh, PA 15219 (US).

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(54) Title: METHOD AND APPARATUS FOR THE DIRECT PRODUCTION OF SCALE-FREE THIN METAL STRIP

(57) Abstract: A method and apparatus for the direct production, from molten metal, of scale-free thin metal strip. Hot thin metal strip exiting a continuous caster system is directed to a reducing chamber wherein a reducing gas reduces strip surface oxides while the cast metal strip is at an elevated temperature from retained heat from the molten metal. A cooling unit following the reducing chamber is used to cool the strip to a temperature below about 150 °C prior to exposing the strip to an oxidizing atmosphere. In various embodiments of the invention, strip thickness is reduced with use of hot and cold rolling mills and the scale-free surface of the strip is coated with protective coatings.

METHOD AND APPARATUS FOR THE DIRECT PRODUCTION OF SCALE-FREE THIN METAL STRIP

Field of the Invention

The present invention is a method and apparatus for the direct production from molten metal of scale-free, finished gage, metal strip by continuous casting of a hot thin strip. Surface oxide removal is with a reducing gas while the cast hot thin metal strip is at an elevated temperature from retained heat of the molten metal.

Background of the Invention

Production of flat rolled steel strip, by current state-of-the-art processes, is carried out by continuously casting refined steel into a thin slab, followed by hot rolling of the slab to reach a thickness which can be put into coil form for subsequent processing. In that process, the surface of the coiled, hot rolled steel is heavily oxidized from processing steps carried out at an elevated temperature while being exposed to the atmosphere. Such oxides (scale) typically consist of Fe_2O_3, Fe_3O_4 and FeO. A next step in the production of the flat rolled steel strip typically involves removing the oxides by processing the strip in an acid pickling solution prior to rolling the strip to finished gage in a cold rolling mill.

Current methods of processing flat rolled steel strip require use of hot and cold rolling mill equipment requiring significant capital expenditures, large amounts of energy for operating, and a large plant facility for its installation. In addition, use of acid pickling solutions for removing surface oxides and disposal of spent acid solution, present environmental concerns which are resulting in more stringent regulations and increased costs for disposal.

In an effort to reduce or eliminate hot and cold rolling steps, methods are being developed to continuously cast thin strip which approaches finished gage thickness. Oxides are still present on the surface however and problems associated with oxide removal with use of acid pickling solutions continue to exist.

OBJECT OF THE INVENTION

It is the object of the present invention to provide a process for producing finished gage thin steel strip free of surface oxides, without the use of acid pickling solutions, and without the use of extensive hot and cold rolling equipment.

SUMMARY OF THE INVENTION

The present invention is a method and apparatus for the direct production of scale-free thin metal strip from molten metal by continuously casting molten metal into a hot thin metal strip and, while the cast strip still retains heat from the molten metal, passing it through a chamber containing a reducing gas to remove oxides from the surface of the strip so as to produce a metal strip free of surface oxides. The hot strip is then cooled to a temperature below about 150°C prior to exposing the strip surface to any oxidizing atmosphere. In other embodiments of the invention, hot rolling of the hot thin metal strip and/or cold rolling of the cooled thin metal strip is carried out to reduce the strip thickness and modify mechanical properties of the metal. In still other embodiments of the invention the surface of the cooled thin metal strip is brushed, re-textured or coated with a protective or decorative coating.

Other specific features of the invention are described in more detail with reference being made to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of the process and apparatus of the invention for producing scale-free thin strip;

FIG. 2 is a schematic illustration of an embodiment of the process and apparatus of the invention for producing scale-free thin strip which incorporates a hot-rolling step prior to strip cleaning;

FIG. 3 is a schematic illustration of an embodiment of the process and apparatus of the invention for producing scale-free thin strip which incorporates a cold-rolling operation following a strip cooling step;

FIG. 4 is a schematic illustration of an embodiment of the process and apparatus of the invention for producing scale-free thin strip which incorporates means for shearing the strip into discreet pieces;

FIG. 5 is a schematic illustration of an embodiment of the process and apparatus of the invention for producing scale-free thin strip which incorporates a surface re-texturing step; and

FIG. 6 is a schematic illustration of an embodiment of the process and apparatus of the invention for producing scale-free thin strip which incorporates an accumulating device following a continuous caster system.

DETAILED DESCRIPTION OF THE INVENTION

In FIGS. 1-6, numeral **10** generally denotes a thin strip continuous caster system for producing hot thin metal strip having a thickness of between about 0.5 and 4 mm. Molten metal **12**, a product of an electric arc furnace, a BOF process, or other molten metal source is continuous cast into hot thin metal strip **14** which exits final casting rolls **16** of the continuous caster system. The molten metal, continuously cast into the hot thin metal strip, can be steel, stainless steel, copper, or other metals; however, the invention is disclosed in relation to production of scale-free thin steel strip.

The hot thin steel strip **14** exiting continuous caster system **10** retains heat from molten metal **12** and the continuous caster system is preferably controlled to discharge a hot thin metal strip having a surface temperature above about 400°C. The surface of the hot thin metal strip, which is usually exposed to a liquid cooling medium and to the atmosphere while being cast, is heavily oxidized with a surface oxide containing Fe_2O_3, Fe_3O_4, FeO, or combinations of those oxides, depending on conditions during the casting operation.

The hot thin metal strip **14**, (FIG. 1) having a surface temperature of above about 400°C, enters reducing chamber **18**, which encloses a reducing gas atmosphere. An example of a reducing chamber **18** is the type described in copending U.S. Patent Application Serial No. 09/144,003 filed August 31, 1998 in the name of Stephen L. Feldbauer, and in copending U.S. Patent Application Serial No. _____________ filed June 1, 2000 in the names of Stephen L. Feldbauer and Brian Braho, both of which are assigned to the assignee of the present invention and both of which are incorporated herein by reference. Reducing chamber **18** contains a reducing gas such as hydrogen or carbon monoxide, with hydrogen being the preferred gas. Hot thin metal strip **14** moves through chamber **18** in a direction indicated by arrow **20** while movement of the reducing gas is generally in an opposite direction as indicated by arrows **22**. The gas exits chamber **18** by way of vent **24** which can include a combustion means, such as a flame, for combusting unconsumed reducing gases exiting the chamber so as to provide for safe operation. Reduction of the strip surface oxides in the reducing chamber is optimized by providing a vigorous application of reducing gas to the surface of the strip. In a preferred embodiment the reducing gas is continuously introduced into the chamber through apertures in gas manifolds and directed toward the strip surface at a velocity which creates turbulence on impact with the strip. The reducing action of the gas on the surface oxides acts to reduce the oxides as well as undermine and loosen particles of oxide on the strip surface thus not requiring every oxide particle or oxide molecule to completely react with the reducing gas. Loosened oxides can be easily removed downstream by mechanical methods such as brushing, described below. To assure good contact of the reducing gas with strip **14**, fans (not shown) can be placed within the reducing chamber to provide turbulence to the gas so as to optimize the reduction reaction.

For proper operation of the reducing process, the surface temperature of hot thin metal strip **14** is above about 400°C. The reducing reaction must take place during a very short period of time as the strip may be moving through the chamber at a speed up to 750 feet per minute. In a preferred embodiment, the hot thin metal strip is at the preferred temperature solely from heat retained in the strip from the molten metal continuous casting operation. Strip cooling is controlled during casting in continuous caster system **10**, to provide sufficient heat for oxide removal in reducing chamber **18**.

Means can be provided within reducing chamber **18** to heat the hot thin metal strip if the strip is not at the preferred temperature. In FIG. 1, radiant heaters **26** are shown, as an example, for providing heat to the strip. Heaters **26** may be used during continuous caster start-up periods or slow-down periods, which might be caused by caster operating problems, so as to provide for the proper temperature for the strip surface. Heaters **26** are also necessary if a strip accumulating means is provided intermediate strip caster system **10** and reducing chamber **18**. A strip accumulating means is described below. In certain plants, use of heaters **26** may be required on a continual basis if optimum continuous caster operation does not allow a cast hot thin metal strip exit temperature as preferred.

In line, immediately following reducing chamber **18**, is cooling unit **28** wherein hot thin metal strip **14** is cooled to a temperature below about 150°C in an inert or reducing atmosphere. A reducing atmosphere is preferred as additional reduction of surface oxides can take place during an initial portion of the cooling process while the thin metal strip is still at an elevated temperature. Cooling unit **28** is preferably connected directly to reducing chamber **18** in order that thin metal strip **14** is not subjected to the atmosphere while at an elevated temperature.

Cooling is carried out in cooling unit **28** by introducing cooling gas through manifolds **30** and directing it toward the strip surface. The cooling gas is preferably an inert gas such as nitrogen combined with a reducing gas such as hydrogen. Seal **32** at the exit end of cooling unit **28** and seal **34** at the entrance end of reducing chamber **18** prevent oxidizing gases of the atmosphere from entering the system. A positive pressure within the reducing chamber and cooling unit helps to prevent the entrance of oxidizing gases.

As previously described, non-adhering particles of oxides can be present on the strip surface following the reduction reaction. Removal of those particles is accomplished with use of brushing unit **36** which provides brushes to act on the top and bottom surface of the cooled thin metal strip. Other suitable means can be employed for removal of the particles.

The scale-free cooled thin metal strip exiting brushing unit **36** is susceptible to oxidation, and, if not scheduled for immediate additional processing, can have an oil coating applied at coating station **38** prior to coiling at strip coiler **40**. Alternative procedures can consist of applying other coatings at coating station **38** such as a protective organic coating applied with an organic coating unit or other more durable coatings such as hot-dipped galvanizing applied with a hot-dipped galvanizing unit or electrolytically plated coatings applied with an electrolytic plating unit.

The process, as described in reference to FIG. 1, provides scale-free metal strip at a finished gage substantially equal to the gage of the continuously cast thin metal strip exiting continuous caster system **10**. FIG. 2 depicts a production system wherein at least one hot-rolling mill **42** is provided intermediate continuous caster system **10** and reducing chamber **18**. The configuration depicted in FIG. 2 provides a method and apparatus to conveniently reduce the finished gage of the strip from the thickness of the strip exiting the continuous caster system. Use of the hot-rolling mill, which results in a decrease in strip temperature, may require additional use of heaters **26** in reducing chamber **18** to provide the desired oxide reducing temperature; or, alternatively, the strip continuous caster system **10** can be controlled to exit the strip at a temperature higher than that preferred for the strip in reducing chamber **18**.

In FIG. 3, a method is depicted wherein at least one cold-rolling mill **44** is provided intermediate brushing unit **36** and coating station **38**. Locating cold-rolling mill **44** following brushing unit **36** is preferred so as not to embed any loosened oxide particles into the surface of the metal strip during cold rolling.

The inclusion of cold-rolling mill **44** in the processing line enables production of a thin metal strip having a finished gage less than that of the strip exiting continuous caster system **10**. Use of cold-rolling mill **44** can also provide a means for modifying mechanical properties of the strip. Use of cold-rolling mill **44** in combination with the hot-rolling mill, in a single processing line, can enable production of scale-free thin metal strip of various thicknesses having a range of mechanical properties. Thicknesses ranging from about 0.3 to 3.5 mm are possible using solely the hot-rolling or cold-rolling step, or the combined hot-rolling and cold-rolling step.

FIG. 4 depicts a processing line wherein discreet pieces of scale-free thin metal **46** are produced. The processing line for producing discreet pieces includes bridal rolls **48**, or other means, for maintaining strip tension, followed by severing means such as shear **50** for severing the continuous strip into discreet pieces. Configuration of the processing line prior to shear **50** can be as described in any of the previous embodiments.

In FIG. 5, a processing station **52** is depicted having means for re-texturing the surface of thin metal strip **14**. The re-textured surface can include, for example, an etched surface, obtained with use of a surface etching unit, a "brushed" surface appearance, obtained for example, with a wire brushing unit, an embossed surface, obtained with use of an embossing unit, etc. Although no rolling mill is shown in FIG. 5, rolling mills as depicted in configurations described above are possible.

FIG. 6 depicts a scale-free thin metal strip processing line wherein a strip accumulating means is provided as a buffer between continuous caster system **10** and reducing chamber **18**. Coil box **54** enclosing a strip coiler and a strip uncoiler can be used routinely during processing or can be by-passed and used solely when downstream equipment repairs, maintenance, or delays occur. Although means can be provided to prevent loss of strip temperature while in coil box **54**, use of heaters **26** in reducing chamber **18** would most likely be necessary. Other suitable strip accumulating devices can also be used.

While specific materials, parameters, and processing steps have been set forth for purposes of describing embodiments of the invention, various modifications can be resorted to, in light of the above teachings, without departing from Applicant's novel contributions; therefore in determining the scope of the present invention reference should be made to the appended claims.

What is claimed is:

1. A method for the direct production of scale-free thin metal strip from molten metal, comprising:

casting hot thin metal strip from molten metal in a thin strip continuous casting system;

passing the hot thin metal strip, while the same still retains heat from the molten metal, through a reducing chamber;

contacting the hot thin metal strip in the reducing chamber with a reducing gas to reduce oxides on the surfaces of the strip; and

cooling the hot thin metal strip to a temperature of below about 150°C, prior to exposure to an oxidizing atmosphere, to provide a cooled, thin metal strip.

2. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein the hot thin metal strip retains sufficient heat from the molten metal to be at a temperature of above about 400°C upon passing through the reducing chamber.

3. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein the hot thin metal strip is passed directly from the reducing chamber to a cooling unit for cooling without exposure to an oxidizing gas.

4. The method for the direct production of scale-free thin metal strip from molten metal as defined in of Claim 1, wherein the cooled thin metal strip is formed into a coil.

5. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein the hot thin metal strip is decreased in thickness to a predetermined gage by hot rolling prior to passing the strip through the reducing chamber.

6. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein, after cooling to a temperature below about 150°C, the cooled thin metal strip is decreased in thickness to a predetermined gage by cold rolling.

7. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein said hot thin metal strip has a thickness of between about 0.5 to 4 mm.

8. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 5 wherein, after decreasing in thickness, the cooled thin metal strip has a thickness of between about 0.3 to 3.5 mm.

9. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 6 wherein, after decreasing in thickness, the cooled thin metal strip has a thickness of between about 0.3 to 3.5 mm.

10. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein the thin metal strip is brushed after cooling.

11. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 10, wherein the brushed thin metal strip is decreased in thickness to a predetermined gage by cold rolling.

12. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 10, wherein the brushed thin metal strip has a coating applied to at least one of the surfaces.

13. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 12, wherein the coating is oil.

14. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein the thin metal strip is sheared into discreet pieces after cooling.

15. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein the thin metal strip has a coating applied to at least one of the surfaces after cooling.

16. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 15, wherein the coating is oil.

17. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein, after cooling, at least one of the surfaces of the cooled thin metal strip is re-textured.

18. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein the hot thin metal strip cast from the continuous caster system is accumulated prior to passing the strip through the reducing chamber to reduce surface oxides.

19. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein, the hot thin metal strip is decreased in thickness to a predetermined gage by hot rolling prior to passing the strip through the reducing chamber, and

following cooling to a temperature below about 150°C the cooled thin metal strip is further decreased in thickness to a predetermined gage by cold rolling.

20. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 1, wherein the hot thin metal strip, while retaining heat from the molten metal, is below about 400°C, and is heated to at least about 400°C upon passing through the reducing chamber.

21. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 20, wherein the hot thin metal strip is passed directly from the reducing chamber to a cooling unit without exposure to an oxidizing gas.

22. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 20, wherein the cooled thin metal strip is formed into a coil.

23. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 20, wherein the hot thin metal strip is decreased in thickness to a predetermined gage by hot rolling prior to passing through the reducing chamber.

24. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 20, wherein, after cooling to a temperature below about 150°C, the cooled thin metal strip is decreased in thickness to a predetermined gage by cold rolling.

25. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 20,

wherein said hot thin metal strip has a thickness of between about 0.5 to 4 mm.

26. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 23 wherein, after decreasing in thickness, the cooled thin metal strip has a thickness of between about 0.3 to 3.5 mm.

27. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 24 wherein, after decreasing in thickness, the cooled thin metal strip has a thickness of between about 0.3 to 3.5 mm.

28. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 20, wherein the thin metal strip is brushed after cooling.

29. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 20, wherein the thin metal strip is sheared into discreet pieces after cooling.

30. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 20, wherein the thin metal strip has a coating applied to at least one of the surfaces after cooling.

31. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 30, wherein the coating is oil.

32. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 20, wherein, after cooling, at least one of the surfaces of the cooled thin metal strip is re-textured.

33. A method for the direct production of scale-free thin metal strip from molten metal, comprising:

casting hot thin metal strip from molten metal in a thin strip continuous casting system;

passing the hot thin metal strip, while the same still retains heat from the molten metal, directly to, and through, a reducing chamber, while the hot thin metal strip retains sufficient heat from the molten metal to be at a temperature of above about 400°C;

contacting the hot thin metal strip in the reducing chamber with a reducing gas to reduce oxides on the surfaces of the strip;

passing the hot thin metal strip directly from the reducing chamber to a cooling unit for cooling without exposure to an oxidizing gas;

cooling the hot thin metal strip to a temperature of below about 150°C, prior to exposure to an oxidizing atmosphere, to provide a cooled thin metal strip; and

forming the cooled thin metal strip into a coil.

34. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 33, wherein the hot thin metal strip is decreased in thickness to a predetermined gage by hot rolling prior to passing the strip through the reducing chamber.

35. The method for the direct production of scale-free thin metal strip from molten metal as defined in Claim 33, wherein, after cooling to a temperature below about 150°C, the cooled thin metal strip is decreased in thickness to a predetermined gage by cold rolling.

36. An apparatus for the direct production of scale-free thin metal strip from molten metal, comprising:

a thin strip continuous caster system for producing a hot thin metal strip,

a reducing chamber, enclosing a reducing gas, arranged to receive the hot thin metal strip, to reduce metal oxides on the strip surfaces, and

a cooling unit, provided with a non-oxidizing gas, arranged to receive the hot thin metal strip following reduction of surface metal oxides, to cool the hot thin metal strip to a temperature below about 150°C prior to exposure to an oxidizing atmosphere.

37. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, wherein the cooling unit is disposed in relation to the reducing chamber so as to receive the hot thin metal strip without exposing the strip to an oxidizing atmosphere.

38. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, wherein said reducing chamber includes heating means for heating the hot thin metal strip to at least about 400°C.

39. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, further including a strip coiler, arranged to receive the cooled thin metal strip, to form the strip into a coil.

40. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, further including a hot-rolling mill, disposed intermediate the continuous caster system and the reducing chamber, for reducing the thickness of the hot thin metal strip to a predetermined gage.

41. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, further including a cold-rolling mill, disposed to receive the cooled thin metal strip, for reducing thickness of the cooled thin metal strip to a predetermined gage.

42. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, further including a means for brushing surfaces of the thin metal strip following cooling in the cooling unit.

43. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, further including means for shearing the thin metal strip into discreet pieces following cooling in the cooling unit.

44. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, further including means for coating the thin metal strip following cooling in the cooling unit.

45. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 44, wherein said means for coating is a coating device selected from at least one of:

an oil coater,
a hot-dipped galvanizing unit,
an electrolytic plating unit, and
an organic coating unit.

46. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, further including means for re-texturing the thin metal strip following cooling in the cooling unit.

47. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 46, wherein said means for re-texturing the thin metal strip is a re-texturing device selected from at least one of:

a surface etching unit,

a wire brushing unit, and

an embossing unit.

48. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, further including at least one processing device selected from at least one of:

a hot-rolling mill, a cold-rolling mill, a brushing unit, a shearing unit, a coiler, a coater, and a re-texturing unit.

49. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, wherein said reducing chamber includes means for providing turbulence to the reducing gas acting on the oxides of the thin strip surface.

50. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 36, further including means for accumulating hot thin metal strip cast in the continuous caster system, situated between the continuous caster system and the reducing chamber.

51. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 50, wherein the means for accumulating hot thin metal strip comprises a coil box, including a coiler and an un-coiler.

52. An apparatus for the direct production of scale-free thin metal strip from molten metal, comprising:

a thin strip continuous caster system for producing a hot thin metal strip;

a reducing chamber, enclosing a reducing gas, arranged to receive the hot thin metal strip, to reduce metal oxides on the strip surfaces;

a cooling unit, disposed in relation to the reducing chamber so as to receive the hot thin metal strip without exposing the strip to an oxidizing atmosphere, provided with a non-oxidizing gas, arranged to receive the hot thin metal strip following reduction of surface metal oxides, to cool the hot thin metal strip to a temperature below about 150°C prior to exposure to an oxidizing atmosphere; and

a strip coiler arranged to receive coated thin metal strip, to form the strip into a coil.

53. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 52, further including a hot-rolling mill, disposed intermediate the continuous caster system and the reducing chamber, for reducing the thickness of the hot thin metal strip to a predetermined gage.

54. The apparatus for the direct production of scale-free thin metal strip from molten metal as defined in Claim 52, further including a cold-rolling mill, disposed to receive the cooled thin metal strip, for reducing thickness of the cooled thin metal strip to a predetermined gage.

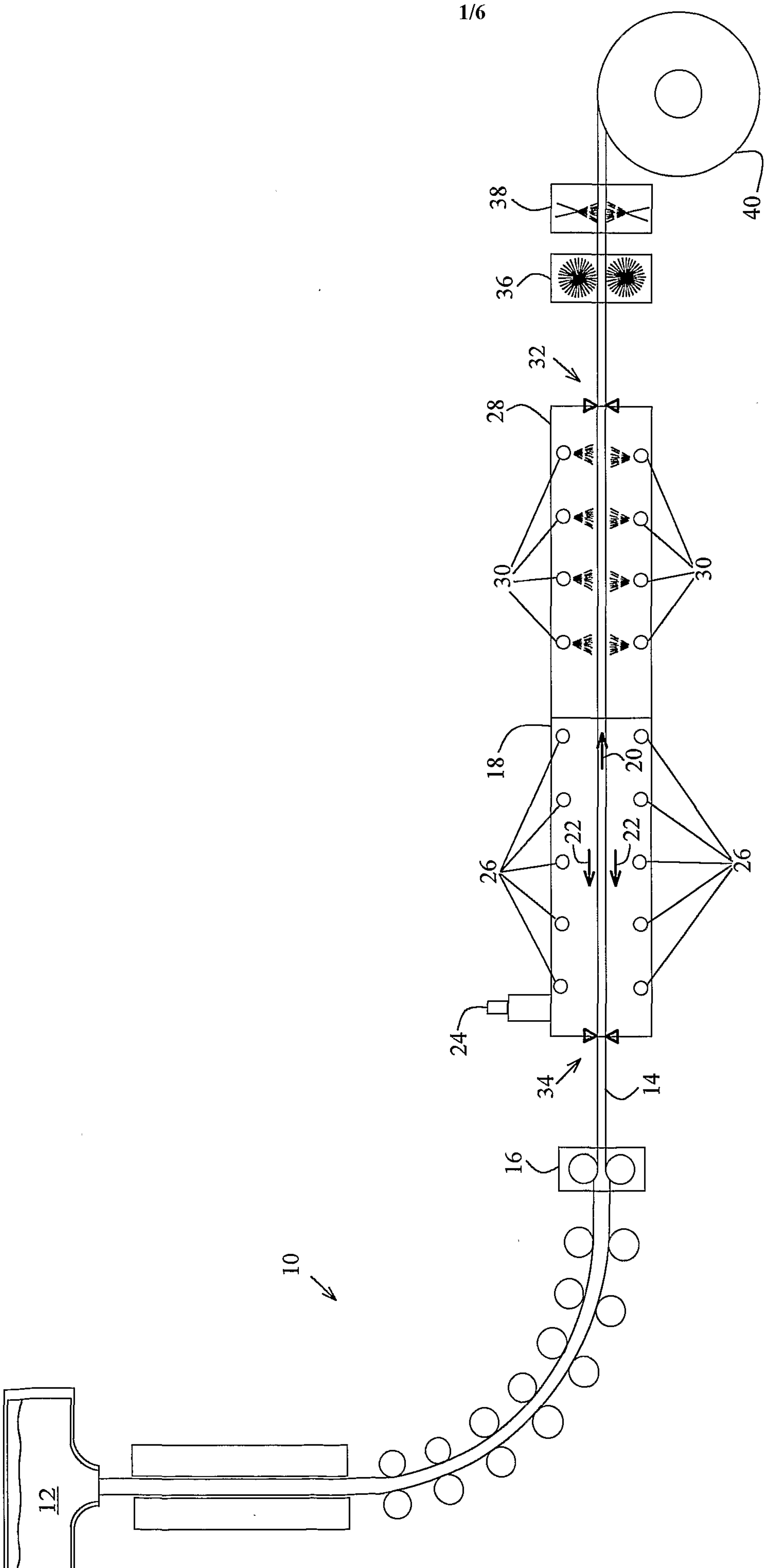

FIG. 1

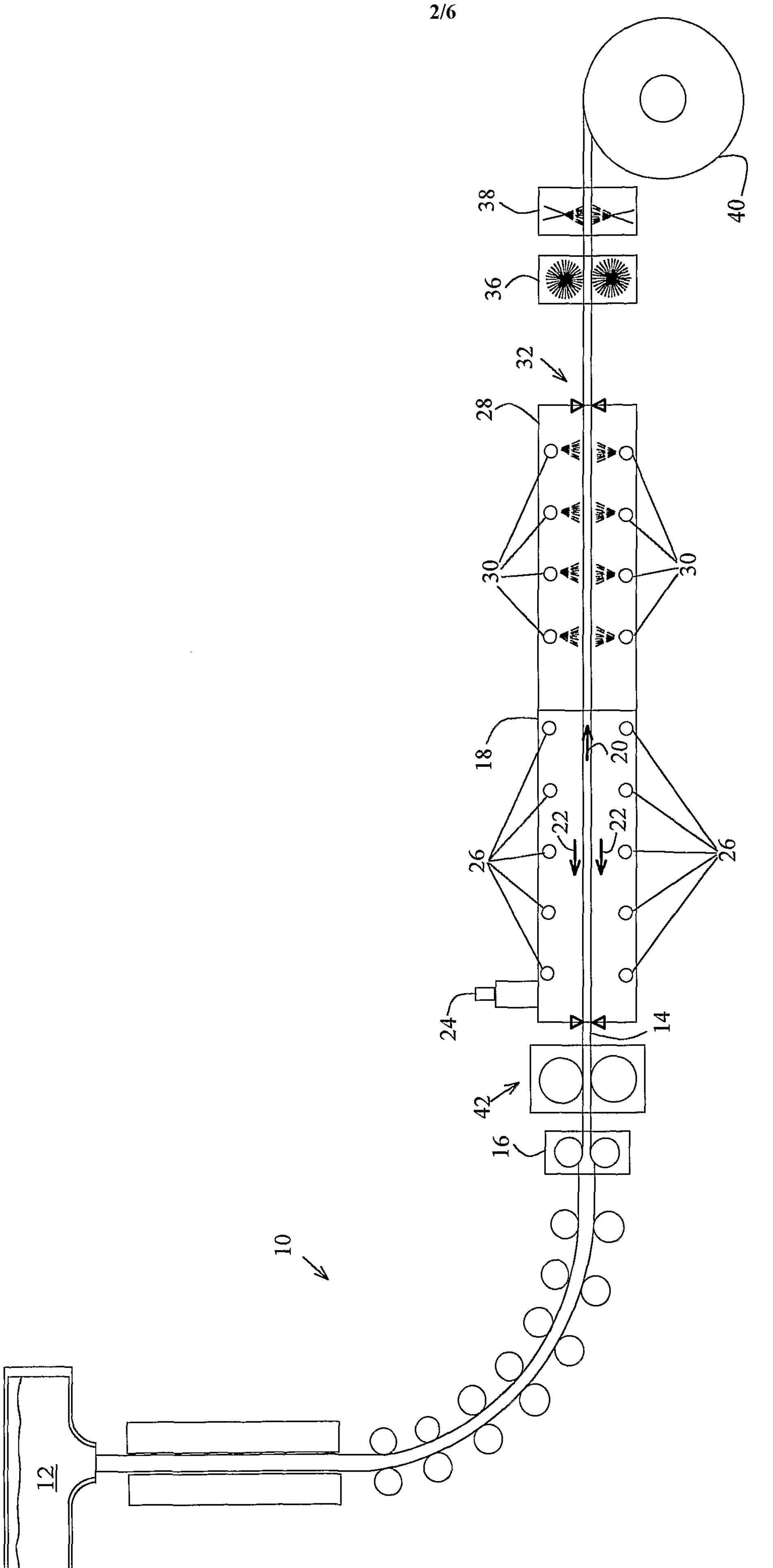

FIG. 2

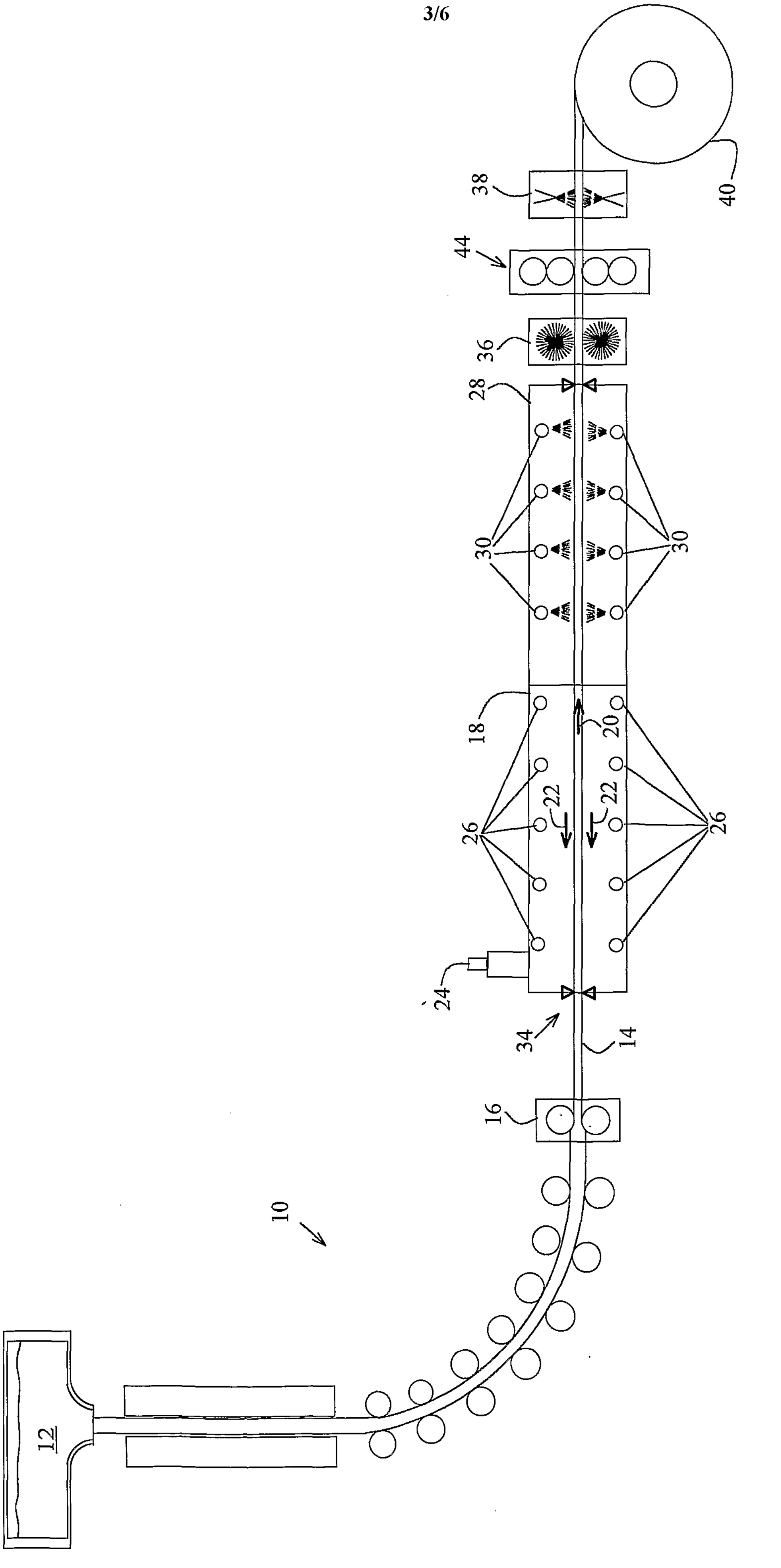

FIG. 3

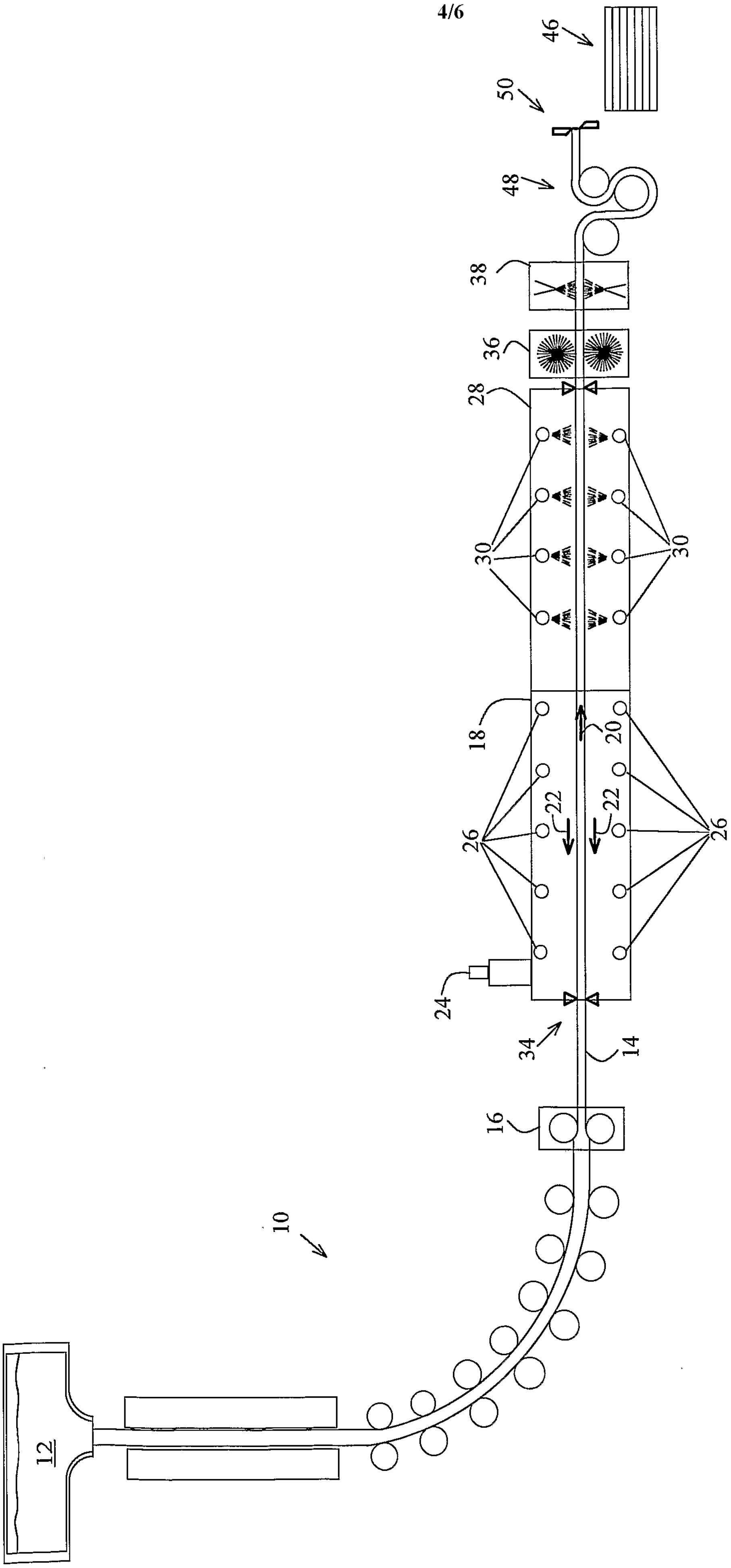

FIG. 4

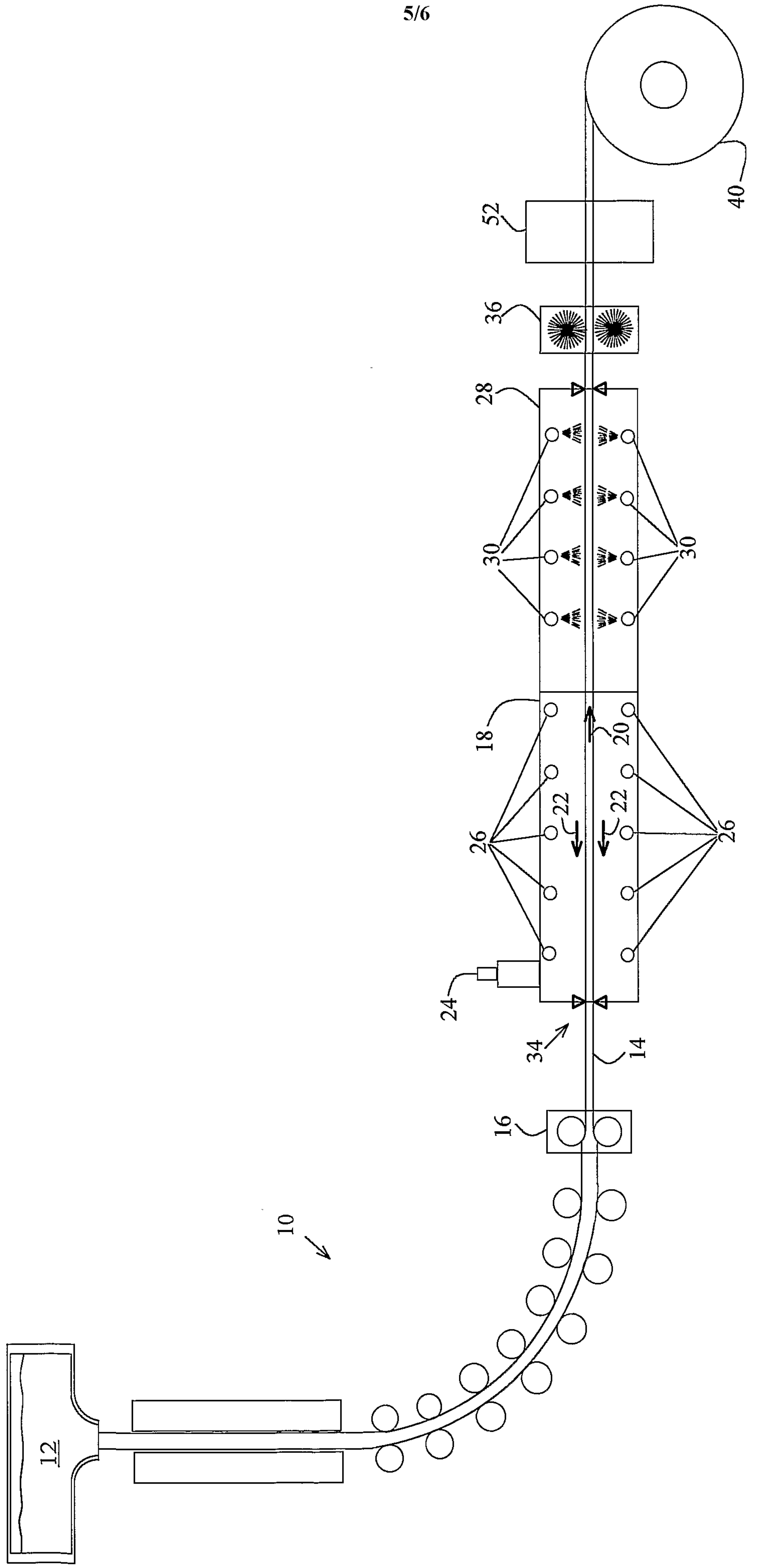

FIG. 5

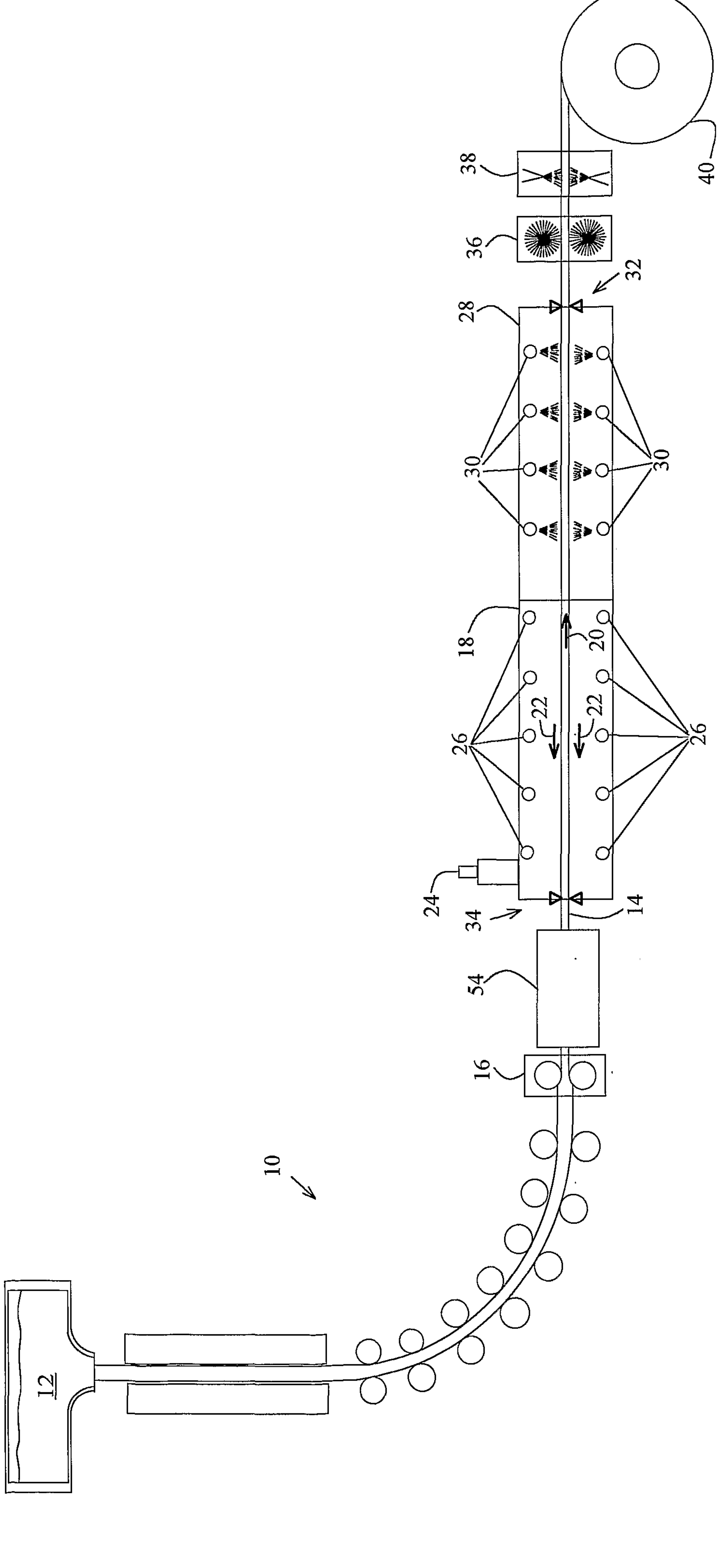

FIG. 6