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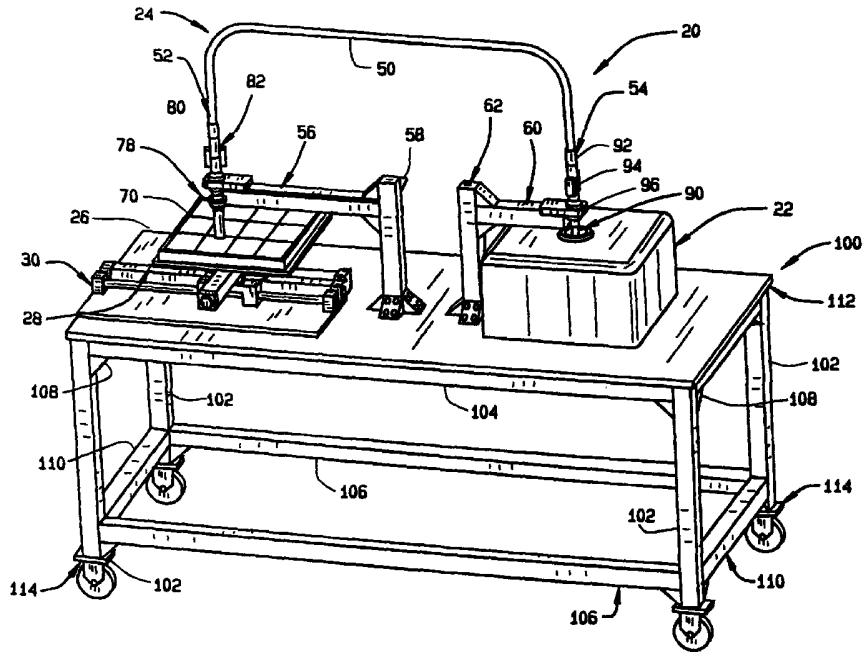
(54) Title: AUTOMATED TESTING OF SEEDS



(57) **Abstract:** An apparatus for the automated testing of seeds includes a testing device having a testing stage, for analyzing a seed delivered to the testing stage; and a conveyor for automatically individually conveying each of a plurality of seeds in a tray between individual compartments in the tray and the testing stage of the testing device.

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AUTOMATED TESTING OF SEEDS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This invention claims priority of U.S. Provisional Patent Application Serial No. 60/604,628, filed August 24, 2004, the entire disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] This invention relates to the testing of seeds, and in particular to the automating of testing of seeds.

[0003] *In developing high performance seeds, it is often desirable to ensure* that each seed in a given population exhibits a particular characteristic. For example in the development of corn seeds, it might be desirable to ensure that each seed in the population has a given oil content, e.g. an oil content of at least 5-6 percent. One method of non-destructively determining characteristics of a seed such as the oil content of a seed is through analysis of the seed, and in particular nmr testing of the seed. It would be very time consuming and tedious, and thus very expensive, to individually test each seed in a large population manually, and thus most seed development programs rely upon testing of representative samples of the population, however, because of the variations among seeds even from the same plants, representative sampling is not as effective as testing all seeds.

SUMMARY OF THE INVENTION

[0004] The present invention provides apparatus and methods for automating the testing of each seed in a large population, thereby improving the development of high performance seeds.

One preferred embodiment of an apparatus constructed according to the principles of this invention generally comprises a testing device having a testing stage, for analyzing a seed delivered to the testing stage; and a conveyor for automatically individually conveying each of a plurality of seeds in a tray between individual compartments in the tray and the testing stage of the testing device.

[0005] One preferred embodiment of a method according to the principles of this invention generally comprises the steps of disposing the seeds in individual compartments in a seed tray; and successively conveying each seed from its compartment in the seed tray to a testing device; testing the seed; and conveying the seed back to its compartment in the tray.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Fig. 1 is a perspective view of a preferred embodiment of an automated testing system constructed according to the principles of this invention;

[0007] Fig. 2 is a perspective view of the two dimensional translation system employed in the preferred embodiment of the automated testing system;

[0008] Fig. 3 is a perspective view of the first end of the seed conveyor in the preferred embodiment of the automated testing system;

[0009] Fig. 4 is a perspective view of the second end of the seed conveyor in the preferred embodiment of the automated testing system;

[0010] Fig. 5 is a perspective view of an air amplifier used in the seed conveyor of the preferred embodiment of the automated testing system; and

[0011] Fig. 6 is a perspective view of the seed sensors used in the seed conveyor of the preferred embodiment of the automated testing system.

[0012] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0013] A preferred embodiment of an apparatus for the testing of seeds constructed according to the principles of this invention is indicated generally as 20 in Fig. 1. Generally, the apparatus 20 comprises a testing device 22, having a testing stage, for analyzing a seed delivered to the testing stage; and a conveyor 24 for automatically individually conveying each of a plurality of seeds in a tray 26 between individual compartments in the tray and the testing stage of the testing device 22.

[0014] In this preferred embodiment, the testing device 22 is a Nuclear Magnetic Resonance (NMR) testing device, such as a MARAN Ultra Low Resolution NMR available from Resonance Instruments Ltd. While in this preferred embodiment the testing device is an NMR testing device, the invention is not so limited, and the testing could be some other type of testing device, such as spectral imaging device, etc.

[0015] The apparatus 20 preferably also includes a seed tray support, such as stage 28 for supporting one or more seed trays 26. The stage 28 is preferably mounted on a two-directional positioner 30 for selectively bringing the compartments of the supported seed trays 26 into alignment with a first end of the seed conveyor 24. The

two-directional positioner 30 preferably comprises a first linear positioner 32, a second linear positioner 34, and slide 36. The first linear positioner 32 has translating carriage 38 that moves as the positioner operates, and the second linear positioner 34 has a translating carriage 40 that moves as the positioner operates. The slide 36 has a rail 42 and a carriage 44 that slides on the rail. The second linear positioner 34 is mounted on the carriage 38 of the first linear positioner, and the carriage 44 of the slide 36, so that the second carriage translates in a first direction parallel to the axis of the first linear positioner 32. The stage 28 is mounted on the carriage 40 of the second linear positioner 34, so that the stage translates in a second direction parallel to the axis of the second linear positioner. A controller can operate the positioners 32 and 34 of the two-directional positioner 30 to successively bring each compartment of each of the trays 26 mounted on the stage 28 into alignment with the first end 30 of the conduit.

[0016] The seed conveyor 24 comprises a conduit 50 having a first end 52 adjacent the trays and a second end 54 adjacent the testing device 22. The first end 52 of the conduit 50 is preferably mounted in a fixed position, so that movement of the stage 28 brings individual compartments of the trays into alignment with the end of the conduit. (Alternatively, the first end 52 can be mounted to move relative to the compartments of the trays, and the end moved into alignment with each compartment). As shown in Fig. 1 the first end 52 of the conduit can be held by a mounting arm 56, extending generally horizontally from a generally vertical post 58. The second end 54 of the conduit 50 is preferably mounted in a fixed position relative to the testing device 22. As shown in Fig. 1, the second end can be held in a mounting arm 60 extending generally horizontally from a generally vertical support 62, in a fixed location.

[0017] As shown in Fig. 3, the first end 52 of the conduit 50 comprises a seed tube 70, a magnet bottom 72, a magnet ring 74, and a magnet top 76. An air amplifier 78 is positioned above this assembly, and a seed sensor tube 80, with seed sensors 82 mounted thereon, is positioned about the air amplifier 78. The air amplifier 78 is adapted to be operated with the application of compressed air to create an air flow in the conduit 50 toward the second end 54. This air flow helps entrain and carry a seed from the compartment in tray 26 aligned with the first end 52 of the conduit, and also helps to brake the movement of the seed from the testing device 22 back to the compartment in the tray 26, to reduce the risk of damage to the seed.

[0018] As shown in Fig. 4, the second end 54 of the conduit 50 comprises an air amplifier 90, a seed sensor tube 92, with seed sensors 94 mounted thereon, is positioned about the air amplifier 90. The second end 54 also includes a bracket 96 for mounting the second end on the arm 60. The air amplifier 90 is adapted to be operated with the application of compressed air to create an air flow in the conduit 50 toward the first end 52. This air flow helps entrain and carry a seed from the testing device 22 to the compartment in tray 26 aligned with the first end 52 of the conduit, and also helps to brake the movement of the seed from the tray 26 to the testing device 22, to reduce the risk of damage to the seed.

[0019] As indicated above, the seeds are preferably disposed in individual compartments in one or more seed trays 26. The process of loading the seeds into compartments in tray 26 can also be automated, if desired.

[0020] As shown in Fig. 1, in the first preferred embodiment the apparatus 20 is conveniently carried on a wheeled cart 100, having four vertical posts 102 connected by upper and lower longitudinal members 104 and 106, at the front and back, and upper and lower transverse members 108 and 110 at the left and right sides, and a table top 112 mounted therein. A caster 114 can be mounted at the bottom of each post 102 to facilitate moving the cart 100. The details of the construction of the cart 100 are not critical to the invention, and thus the cart 100 could have some other configuration, or some other structure can be provided to support the apparatus 20 without departing from the principles of this invention.

OPERATION

[0021] In operation, a control operates the linear positioners 32 and 34 to bring a particular compartment of tray 26 into alignment with the first end 52 of the conduit 50 of the seed conveyor 24. The control operates the air amplifier 78 to initiate an air flow through the conduit 50 toward the second end 54. The air flow lifts the seed out of the compartment in tray 26 and carries it through the conduit 50 toward the second end 54. The control then operates the air amplifier 90 to create an air flow from the second end 54 toward the first end 52, to slow the seed. The sensors 82 and 94 detect the position of the seed before it reaches the end of the conduit 50. The seed is preferably slowed sufficiently so that it drops into the testing chamber of the testing device 22 without damaging the seed. In the preferred embodiment, the seed is actually stopped before reaching the second end of the conduit 52, and drops

under gravity into the testing chamber. When the analysis is completed, the control operates the air amplifier 90 to create an air flow from the second end 54 toward the first end 52. The air flow lifts the seed out of the testing chamber of the testing device 22 and carries it through conduit 50 toward the first end 52 of the conduit. The control then operates the air amplifier 78 to create an air flow from the first end 52 toward the second end 54, to slow the seed. The seed is preferably slowed sufficiently so that it drops into the compartment of tray 26 without damaging the seed. In the preferred embodiment, the seed is actually stopped before reaching the first end of the conduit 50, and drops under gravity into the compartment in the tray. The control then operates linear positioners to bring the next compartment into alignment with the first end 50, and the process is repeated.

[0022] Thereafter the test data for each seed can be correlated with location within the tray, and the seeds having the desired characteristic can be separated from the seeds that do not have the desired characteristic. This can be a simple separation into the groups, those with and those without the desired characteristic, or it can be a separation into multiple groups each exhibiting a different characteristic or different degrees of the same characteristic.

[0023] The controller that controls the movement of the table can output position information to correlate the seed location with test data. Alternatively, position sensors can be used to provide position information to correlate the seed location with test data.

What is claimed is:

1. An apparatus for the automated testing of seeds, the apparatus comprising:

a testing device having a testing stage, for analyzing a seed delivered to the testing stage;

a conveyor for automatically individually conveying each of a plurality of seeds in a tray between individual compartments in the tray and the testing stage of the testing device.

2. The apparatus according to claim 1 wherein the testing device is an nmr testing device.

3. The apparatus according to claim 2 wherein the conveyor comprises a conduit having a first end and a second end adjacent the testing stage of the nmr testing device.

4. The apparatus according to claim 3 wherein the first end of the conduit has a fixed location, and further comprising a seed tray support for supporting a compartmented seed tray and for selectively bringing the compartments of the supported seed tray into alignment with the first end of the conveyor.

5. The apparatus according to claim 3 wherein the first end of the conduit has a fixed location, and further comprising a table for supporting at least one compartmented seed tray, and a two-dimensional positioning system for positioning the table to bring the compartments of the trays on the table into alignment with the first end of the conduit.

6. The apparatus according to claim 5 further comprising a controller for operating the two-dimensional positioning system to successively bring individual compartments of the tray into alignment with the first end of the conduit, and operating the conveyor to convey a seed from its compartment to the testing stage of the nmr testing device and to return the seed from the testing stage of the nmr testing device to its compartment.

7. The apparatus according to claim 2 wherein the conveyor is a pneumatic conveyor.

8. The apparatus according to claim 7 wherein the pneumatic conveyor comprises a conduit having a first end and a second end adjacent the testing stage of the nmr testing device.

9. The apparatus according to claim 8 wherein the first end of the conduit has a fixed location, and further comprising a seed tray support for supporting a compartmented seed tray and for selectively bringing the compartments of the supported seed tray into alignment with the first end of the conduit.

10. The apparatus according to claim 8 wherein the first end of the conduit has a fixed location, and further comprising a table for supporting at least one compartmented seed tray, and a two dimensional positioning system for positioning the table to bring the compartments of the trays on the table into alignment with the first end of the conduit.

11. The apparatus according to claim 10 further comprising a controller for operating the two-dimensional positioning system to successively bring individual compartments of the tray into alignment with the first end of the conduit, and operating the pneumatic conveyor to convey a seed from its compartment to the testing stage of the nmr testing device and to return the seed from the testing stage of the nmr testing device to its compartment.

12. The apparatus according to claim 8 wherein the pneumatic conveyor further comprises a first venturi for creating an air flow through the conduit toward the second end of the conduit, and a second venturi for a creating an air flow through the conduit toward the first end of the conduit.

13. The apparatus according to claim 12 further comprising a controller for operating the first venturi to create an air flow in the conduit to draw a seed from its compartment into the conduit and propel it toward the testing stage of the nmr testing device, and for operating the second venturi to create an air flow in the conduit to slow the seed before it reaches the testing stage of the nmr testing device.

14. The apparatus according to claim 13 further comprising at least one position sensor for sensing the position of a seed in the conduit, and wherein the controller operates the second venturi in response to the at least one position sensor.

15. The apparatus according to claim 12 further comprising a controller for operating the second venturi to create an air flow in the conduit to draw a seed from the testing stage of the nmr testing device into the conduit and to propel it toward its compartment in the seed tray, and for operating the first venturi to create an air flow in the conduit to slow the seed before it reaches the testing stage of the nmr testing device.

16. The apparatus according to claim 15 further comprising at least one position sensor for sensing the position of a seed in the conduit, and wherein the controller operates the second venturi in response to the at least one position sensor.

17. The apparatus according to claim 8 wherein the pneumatic conveyor further comprises a first venturi for creating an air flow through the conduit toward the second end of the conduit to draw a seed from its compartment and propel it toward the testing stage of the nmr testing device, and a second venturi for a creating an air flow through the conduit toward the first end of the conduit to draw a seed from the testing stage of the nmr testing device and propel it toward its compartment.

18. The apparatus according to claim 8 wherein the pneumatic conveyor further comprises a first venturi for creating an air flow through the conduit toward the second end of the conduit, a second venturi for a creating an air flow through the conduit toward the first end of the conduit, at least one sensor to sense a seed in the conduit; and a controller for operating the first venturi to draw a seed from its compartment into the conduit and propel it toward the testing stage of the nmr testing device, and for operating the second venturi in response to a sensor to slow the seed before it reaches the testing stage of the nmr testing device, and for operating the second venturi to draw the seed from the imaging stage of the nmr testing device and propel it toward its compartment, and for operating the first venturi in response to a sensor to slow the seed before it reaches its compartment.

19. The apparatus according to claim 18 wherein the first end of the conduit has a fixed location, and further comprising a seed tray support for supporting a compartmented seed tray and for selectively bringing the compartments of the supported seed tray into alignment with the first end of the conveyor.

20. The apparatus according to claim 18 wherein the first end of the conduit has a fixed location, and further comprising a table for supporting at least one compartmented seed tray, and a two dimensional positioning system for positioning the table to bring the compartments of the trays on the table into alignment with the first end of the conduit.

21. An apparatus for the automated nmr testing of seeds, the apparatus comprising:

an nmr testing device having a testing stage, for analyzing a seed delivered to the testing stage;

a pneumatic conveyor comprising a conduit having a first end with a fixed location and a second end adjacent the testing stage of the nmr testing device for automatically individually conveying each of a plurality of seeds in a tray between individual compartments in the tray and the testing stage of the nmr testing device; and

a two-dimensional positioning system for positioning the table to bring the compartments of the trays on the table into alignment with the first end of the conduit.

22. The apparatus according to claim 21 further comprising a controller for operating the two-dimensional positioning system to successively bring individual compartments of the tray into alignment with the first end of the conduit, and operating the pneumatic conveyor to convey a seed from its compartment to the testing stage of the nmr testing device and to return the seed from the testing stage of the nmr testing device to its compartment.

23. The apparatus according to claim 22 wherein the pneumatic conveyor further comprises a first venturi for creating an air flow through the conduit toward the second end of the conduit, and a second venturi for a creating an air flow through the conduit toward the first end of the conduit.

24. The apparatus according to claim 23 wherein the controller for operating the pneumatic conveyor operates the first venturi to create an air flow in the conduit to draw a seed from its compartment into the conduit and propel it toward the testing stage of the nmr testing device, and operates the second venturi to create an air flow in the conduit to slow the seed before it reaches the testing stage of the nmr testing device.

25. The apparatus according to claim 24 further comprising at least one position sensor for sensing the position of a seed in the conduit, and wherein the controller operates the second venturi in response to the at least one position sensor.

26. The apparatus according to claim 23 wherein the controller for operating the pneumatic conveyor operates the second venturi to create an air flow in the conduit to draw a seed from the testing stage of the nmr testing device into the conduit and to propel it toward its compartment in the seed tray, and for operating the first

venturi to create an air flow in the conduit to slow the seed before it its compartment in the seed tray.

27. The apparatus according to claim 26 further comprising at least one position sensor for sensing the position of a seed in the conduit, and wherein the controller operates the first venturi in response to the at least one position sensor.

28. The apparatus according to claim 22 wherein the pneumatic conveyor further comprises a first venturi for creating an air flow through the conduit toward the second end of the conduit, a second venturi for a creating an air flow through the conduit toward the first end of the conduit, at least one sensor to sense a seed in the conduit; and wherein the controller operates the first venturi to draw a seed from its compartment into the conduit and propel it toward the testing stage of the nmr testing device, and operates the second venturi in response to the at least one sensor to slow the seed before it reaches the testing stage of the nmr testing device, and operates the second venturi to draw the seed from the testing stage of the nmr testing device and propel it toward its compartment, and operates the first venturi in response to the at least one sensor to slow the seed before it reaches its compartment.

29. A method for the automated testing of individual seeds, the method comprising:

disposing the seeds in individual compartments in a seed tray;

successively conveying each seed from its compartment in the seed tray to a testing device; testing the seed; and conveying the seed back to its compartment in the tray.

30. The method according to claim 29 wherein the testing is nmr testing with an nmr testing device.

31. The method according to claim 30 wherein the step of conveying each seed from its compartment in the seed tray to a testing device comprises pneumatically conveying the seed from its compartment in the seed tray to the nmr testing device.

32. The method according to claim 31 wherein the step of conveying the seed back to its compartment in the tray comprises pneumatically conveying the seed from the nmr testing device to its compartment.

33. The method according to claim 31 wherein the step of conveying the seed back to its compartment in the tray comprises pneumatically conveying the seed from the nmr testing device to its compartment.

34. The method according to claim 32 wherein the steps of pneumatically conveying each seed from its compartment in the seed tray to an nmr testing device; and pneumatically conveying the seed back to its compartment in the tray are performed with a pneumatic conveyor having a fixed first end and a fixed second end adjacent the nmr testing device.

35. The method according to claim 34 wherein the compartments of the seed tray are successively aligned with the fixed first end of the pneumatic conveyor.

36. The method according to claim 35 wherein each seed tray is mounted on a table and wherein the table is moved to bring each compartment into alignment with fixed first end of the pneumatic conveyor.

37. The method according to claim 36 comprising storing information about the nmr seed test with information relating to the seed location.

38. The method according to claim 35 wherein the seed tray is mounted on a table, and wherein the table is moved with a two-dimensional positioner.

39. The method according to claim 38 further comprising storing information about the nmr test of a seed in association with information about the seed location from the two-dimensional positioner.

40. The method according to claim 35 wherein the step of conveying the seed from its compartment to the nmr testing device comprises inducing an air flow in a conduit to draw a seed from its compartment and propel it toward the nmr testing device.

41. The method according to claim 40 wherein the step of inducing an air flow in the conduit employs a venturi.

42. The method according to claim 40 further comprising slowing the seed in the conduit before it reaches the nmr testing device.

43. The method according to claim 42 wherein the step of slowing the seed in the conduit before it reaches the nmr testing device comprises inducing an air flow in the conduit to slow the seed.

44. The method according to claim 35 wherein the step of conveying the seed from the nmr testing device to its compartment comprises inducing an air flow in a conduit to draw a seed from the nmr testing device and propel it toward its compartment.

45. The method according to claim 44 wherein the step of inducing an air flow in the conduit employs a venturi.

46. The method according to claim 44 further comprising slowing the seed in the conduit before it reaches its compartment.

47. The method according to claim 46 wherein the step of slowing the seed in the conduit before it reaches its compartment comprises inducing an air flow in the conduit to slow the seed.

48. The method according to claim 35 wherein the step of conveying the seed from its compartment to the nmr testing device comprises inducing an air flow in a conduit extending between the compartment and the nmr testing device, and wherein the step of conveying the seed from the nmr testing device to its compartment comprises inducing an air flow in a conduit extending between the compartment and the nmr testing device.

49. The method according to claim 35 further comprising storing information relating to the nmr test of the seed in association with information about the location of the seed.

50. The method of claim 49 wherein the information about the seed is information from a positioning system that positions the seed tray.

51. The method of claim 49 wherein the information about the seed is derived from information from a positioning system that positions the seed tray.

52. A method for the automated nmr testing of individual seeds, the method comprising:

disposing the seeds in individual compartments in a seed tray;

pneumatically conveying a seed from its compartment in the seed tray to an nmr testing device via a conduit; testing the seed; and pneumatically conveying the seed back to its compartment in the tray via the conduit, the conduit having a having a fixed first end and a fixed second end adjacent the nmr testing device, and moving the tray to successively bring the compartments of the tray into alignment with the first end of the conduit.

53. The method according to claim 52 wherein the step of pneumatically conveying the seed from its compartment to the nmr testing device comprises inducing an air flow in the conduit to draw a seed from its compartment and propel it toward the nmr testing device.

54. The method according to claim 52 wherein the step of pneumatically conveying the seed from its compartment to the nmr testing device comprises inducing an air flow in the conduit to draw a seed from its compartment and propel it

toward the nmr testing device, sensing the position of the seed, and in response to sensing the position of the seed inducing an air flow in the conduit in an opposite direction to slow the seed before it reaches the nmr testing device.

55. The method according to claim 52 wherein the step of pneumatically conveying the seed from the nmr testing device to its compartment comprises inducing an air flow in the conduit to draw a seed from the nmr testing device and propel it toward its compartment.

56. The method according to claim 55 wherein the step of pneumatically conveying the seed from the nmr testing device to its compartment comprises inducing an air flow in the conduit to draw a seed from the nmr testing device and propel it to its compartment, sensing the position of the seed, and in response to sensing the position of the seed inducing an air flow in the conduit in an opposite direction to slow the seed before it reaches its compartment.

57. The method according to claim 52 wherein the step of pneumatically conveying the seed from its compartment to the nmr testing device comprises inducing an air flow in the conduit to draw a seed from its compartment and propel it toward the nmr testing device, sensing the position of the seed, and in response to sensing the position of the seed inducing an air flow in the conduit in an opposite direction to slow the seed before it reaches the nmr testing device, and wherein the step of pneumatically conveying the seed from the nmr testing device to its compartment comprises inducing an air flow in the conduit to draw a seed from the nmr testing device and propel it to its compartment, sensing the position of the seed, and in response to sensing the position of the seed inducing an air flow in the conduit in an opposite direction to slow the seed before it reaches its compartment.

58. The method according to claim 57 wherein the steps of inducing air flows in the conduit are accomplished with venturi devices.

59. The method according to claim 52 wherein the step of pneumatically conveying the seed from its compartment to the nmr testing device comprises operating a first venturi to initiate an air flow in the conduit toward the second end of the conduit to draw the seed from the compartment and propel it toward the nmr testing device.

60. The method according to claim 59 wherein the step of pneumatically conveying the seed from its compartment to the nmr testing device further comprises

operating a second venturi to initiate an air flow in the conduit toward the first end of the conduit to slow the seed before it reaches the nmr testing device.

61. The method according to claim 59 wherein the step of pneumatically conveying the seed from the nmr testing device to its compartment comprises operating the second venturi to initiate an air flow in the conduit toward the first end of the conduit to draw the seed from the nmr testing device and propel it toward the compartment.

62. The method according to claim 61 wherein the step of pneumatically conveying the seed from the nmr testing device to its compartment further comprises operating the first venturi to initiate an air flow in the conduit toward the second end of the conduit to slow the seed before it reaches its compartment.

63. The method according to claim 52 wherein the step of pneumatically conveying the seed from the nmr testing stage to its compartment comprises operating a first venturi to initiate an air flow in the conduit toward the first end of the conduit to draw the seed from the nmr testing device and propel it toward the compartment.

64. The method according to claim 63 wherein the step of pneumatically conveying the seed from the nmr testing stage to its compartment further comprises operating a second venturi to initiate an air flow in the conduit toward the second end of the conduit to slow the seed before it reaches its compartment.

65. The method according to claim 52 further comprising associating seed information from the nmr testing device with seed location information.

66. The method of claim 65 wherein the information about the seed is information from a positioning system that positions the seed tray.

67. The method of claim 65 wherein the information about the seed is derived from information from a positioning system that positions the seed tray.

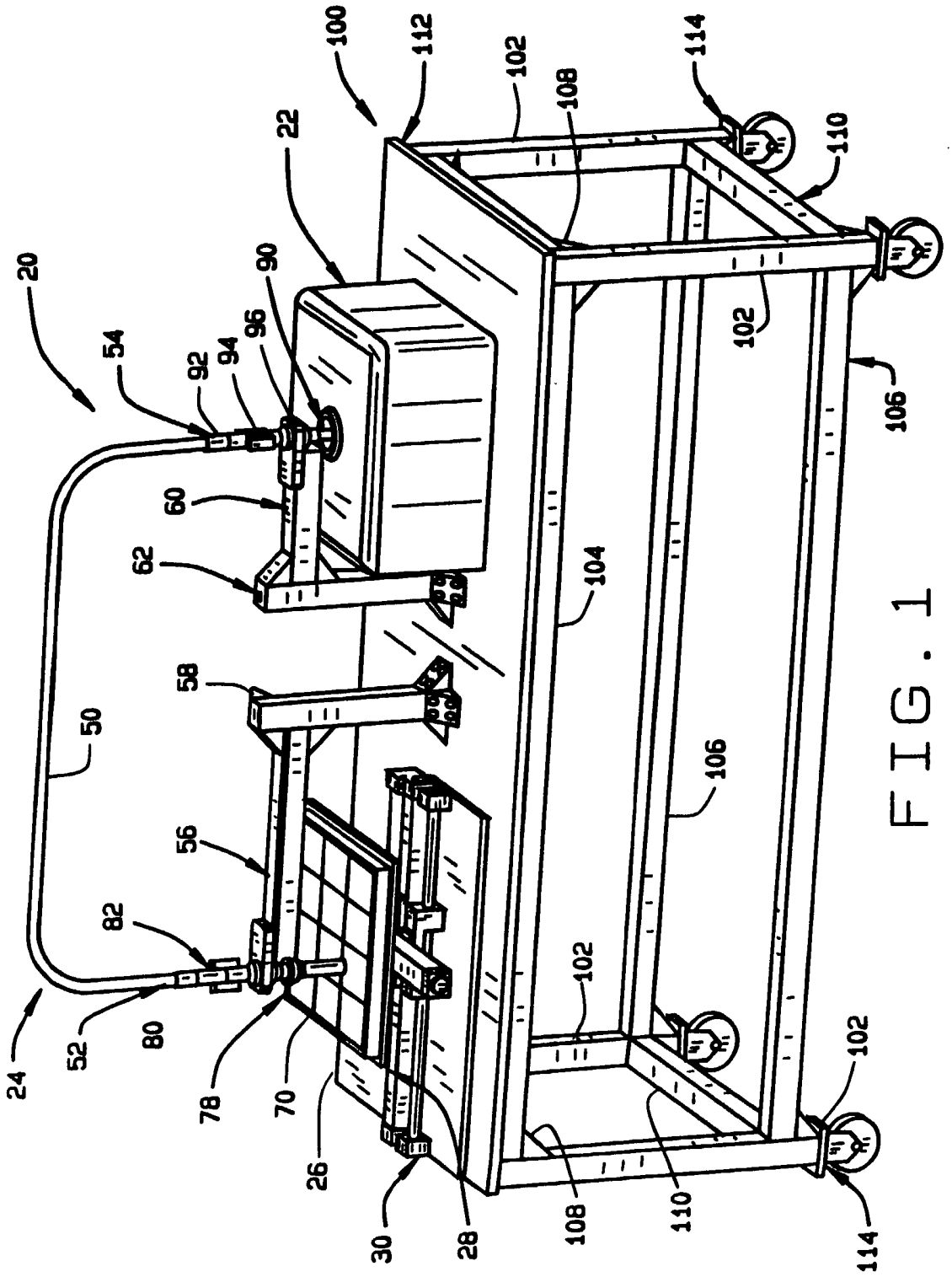
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FIG. 1

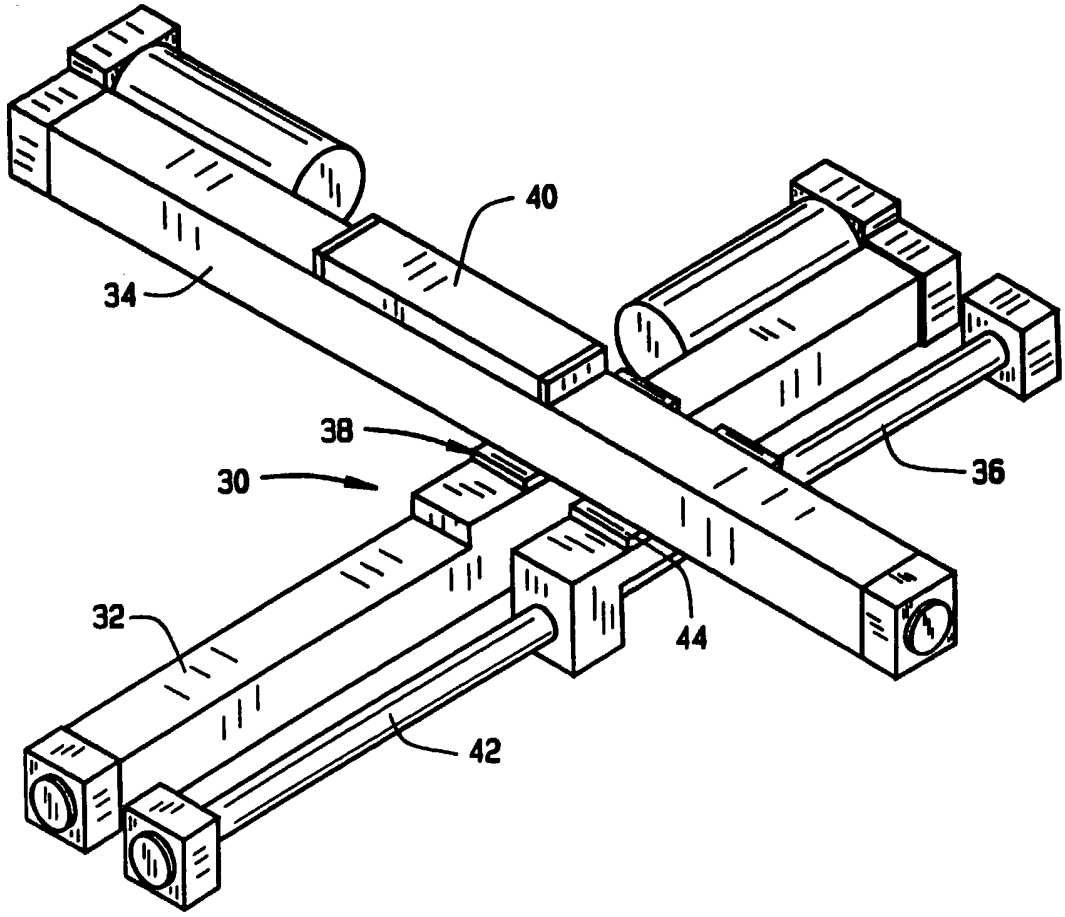

FIG. 2

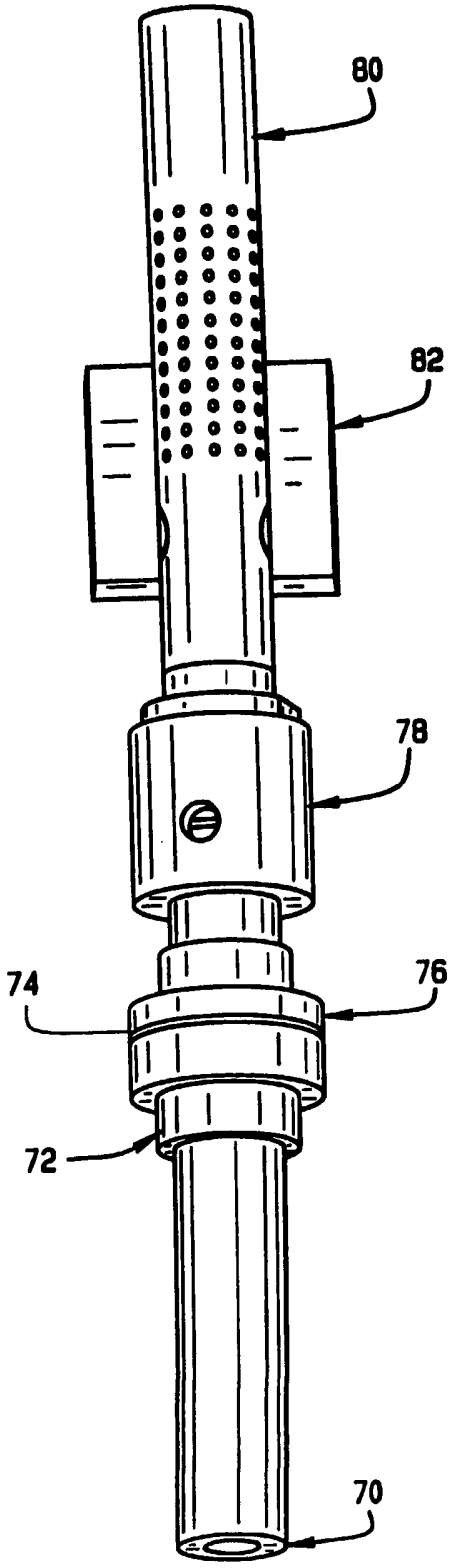

FIG. 3

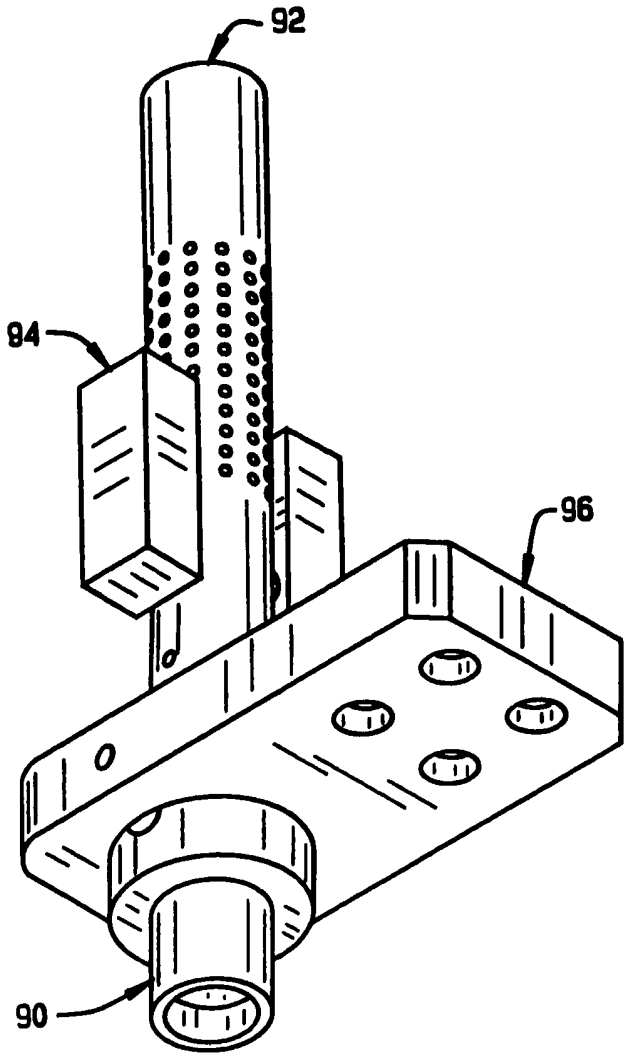

FIG. 4

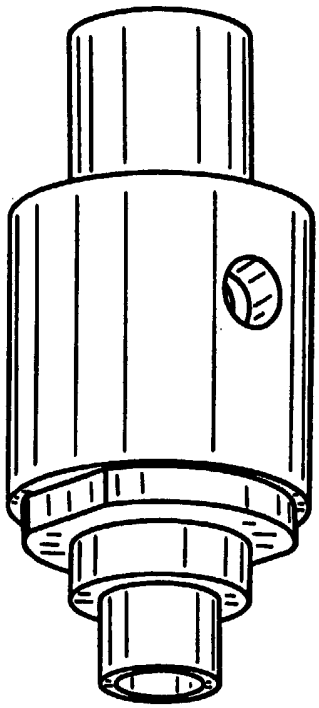

FIG. 5

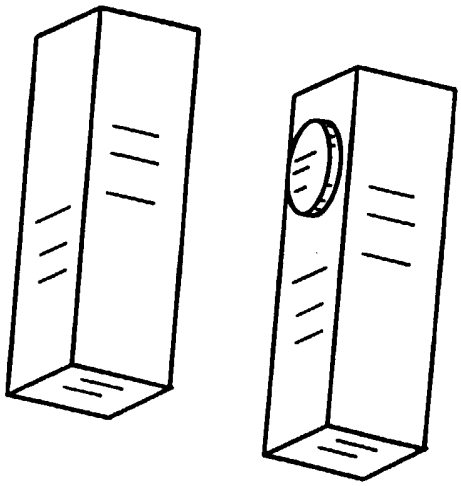

FIG. 6