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(54) LIQUID PROCESSING SYSTEM AND RELATED METHODS

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(73) Assignee: **GRAIL, Inc.**, Menlo Park, CA (US)

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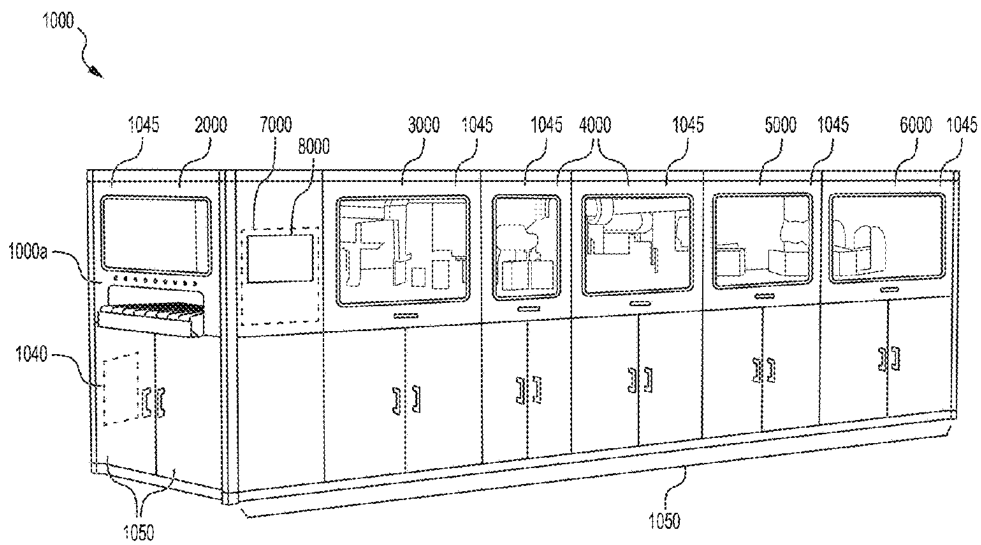
G01N 35/00	(2006.01)

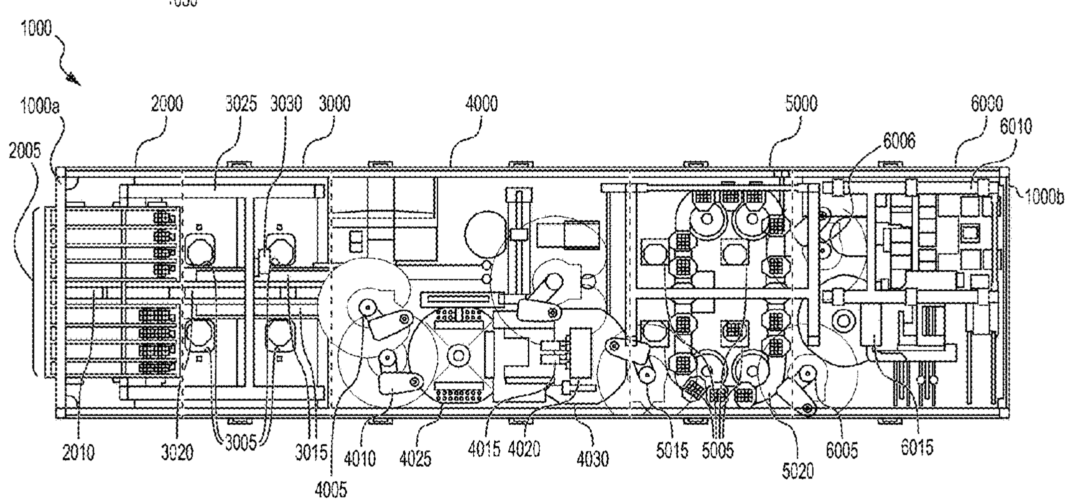
(52) **U.S. Cl.**

CPC ***G01N 1/4077*** (2013.01); ***G01N 21/251*** (2013.01); ***G01N 35/00732*** (2013.01)

(57) **ABSTRACT**

In an automated liquid processing system, a first centrifuge performs a centrifuging cycle on a plurality of first inserts, a pairing robot to places first tubes, including pairs of first tubes, from the first inserts on a pairing platform, an excising station excises labels on the first tubes, captures an image of the excised first tubes, and determines, using an image analysis process, a height of a portion of the liquid within the first tubes. A first liquid handling station combines a portion of the liquid within first tubes, including pairs of first tubes, into a second tube. A second centrifuge performs a second centrifuging cycle, and a second liquid handling station aspirates liquid from the second tube and dispenses the liquid into an output container.





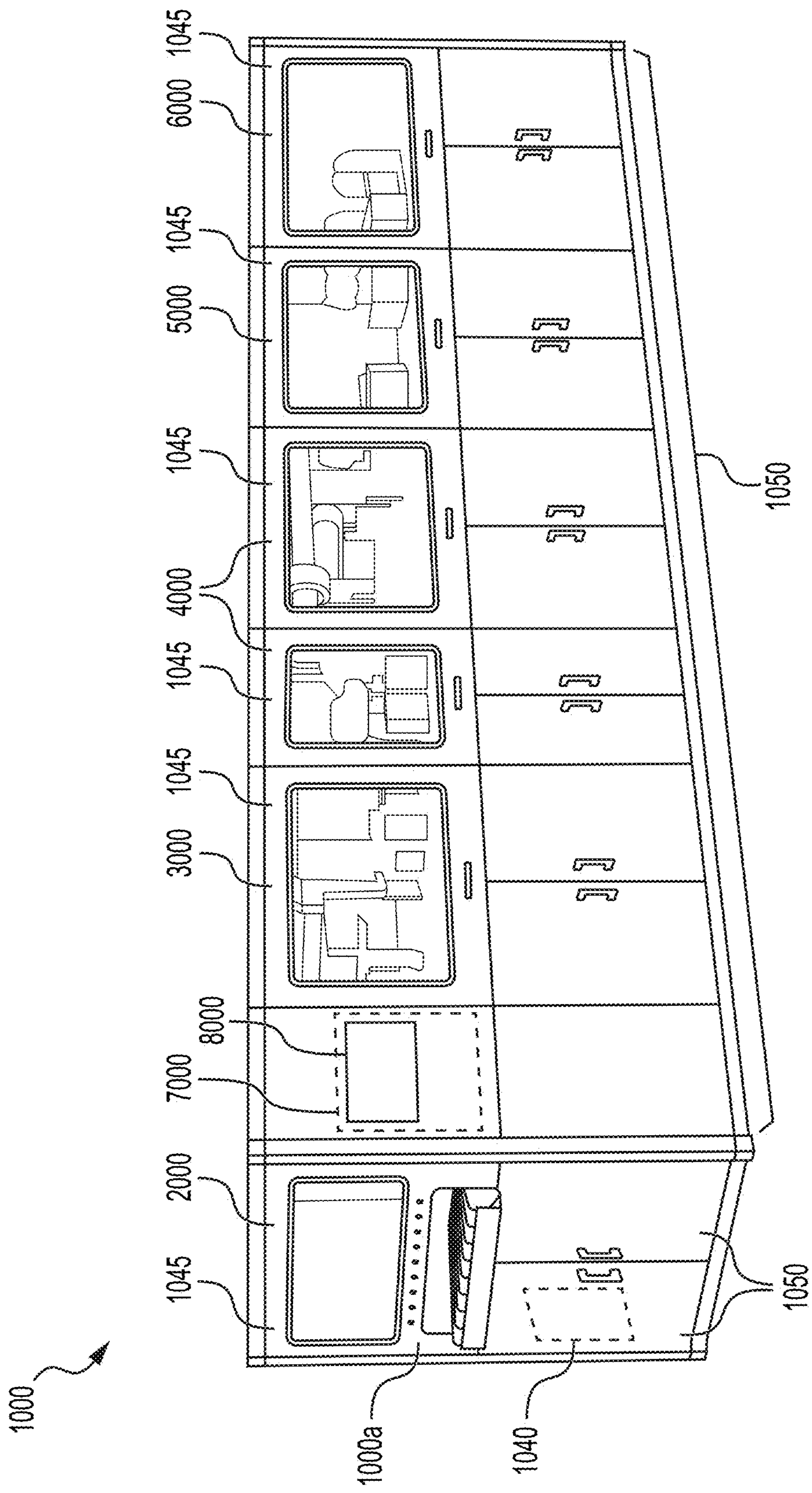

1045
6000
1045
5000
1045
4000
1045
1045
3000
8000
7000
2000
1045
1050
1050
1000
1000a
1040

FIG. 1A

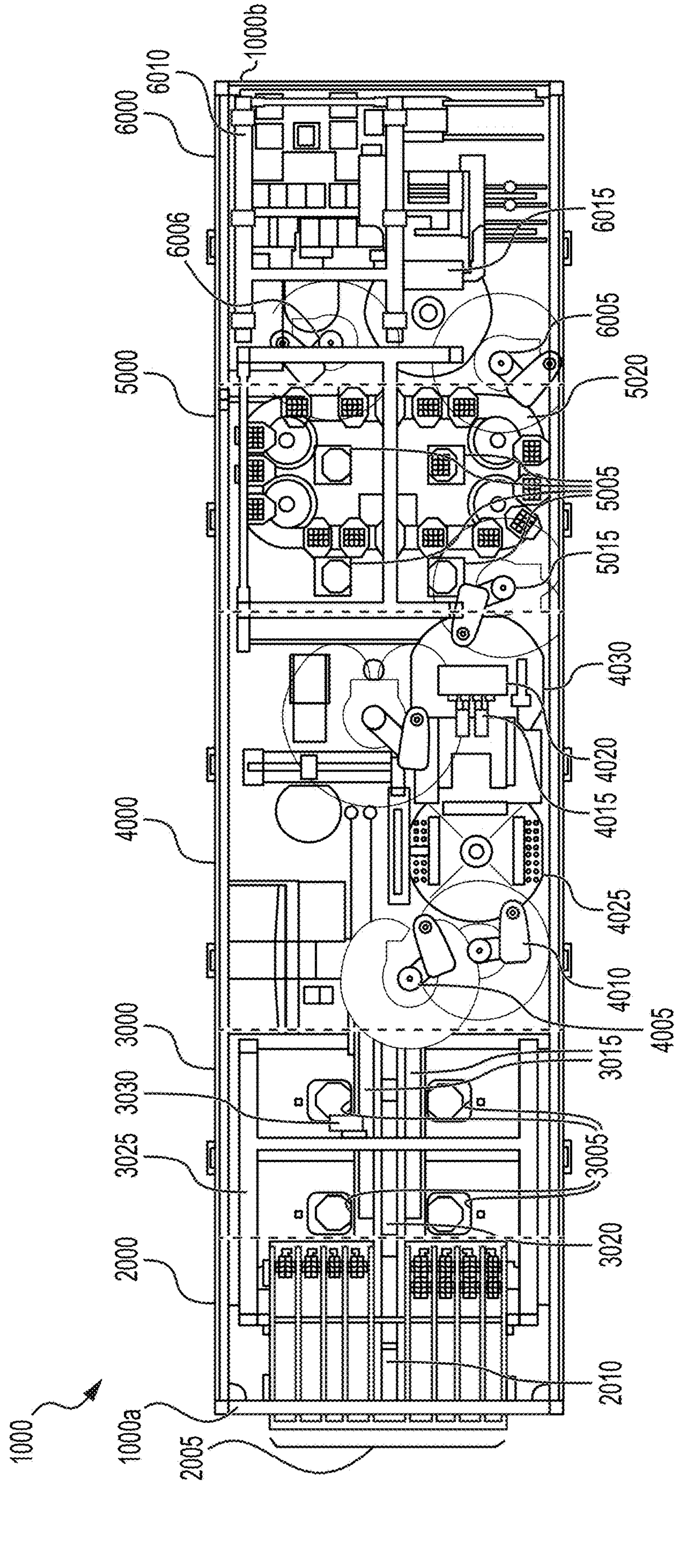

1000b
6010
6000
6006
6015
6005
5000
5020
5005
5015
4030
4020
4015
4000
4025
4010
4005
3000
3015
3030
3005
3025
3020
2000
2010
1000
1000a
2005

FIG. 1B

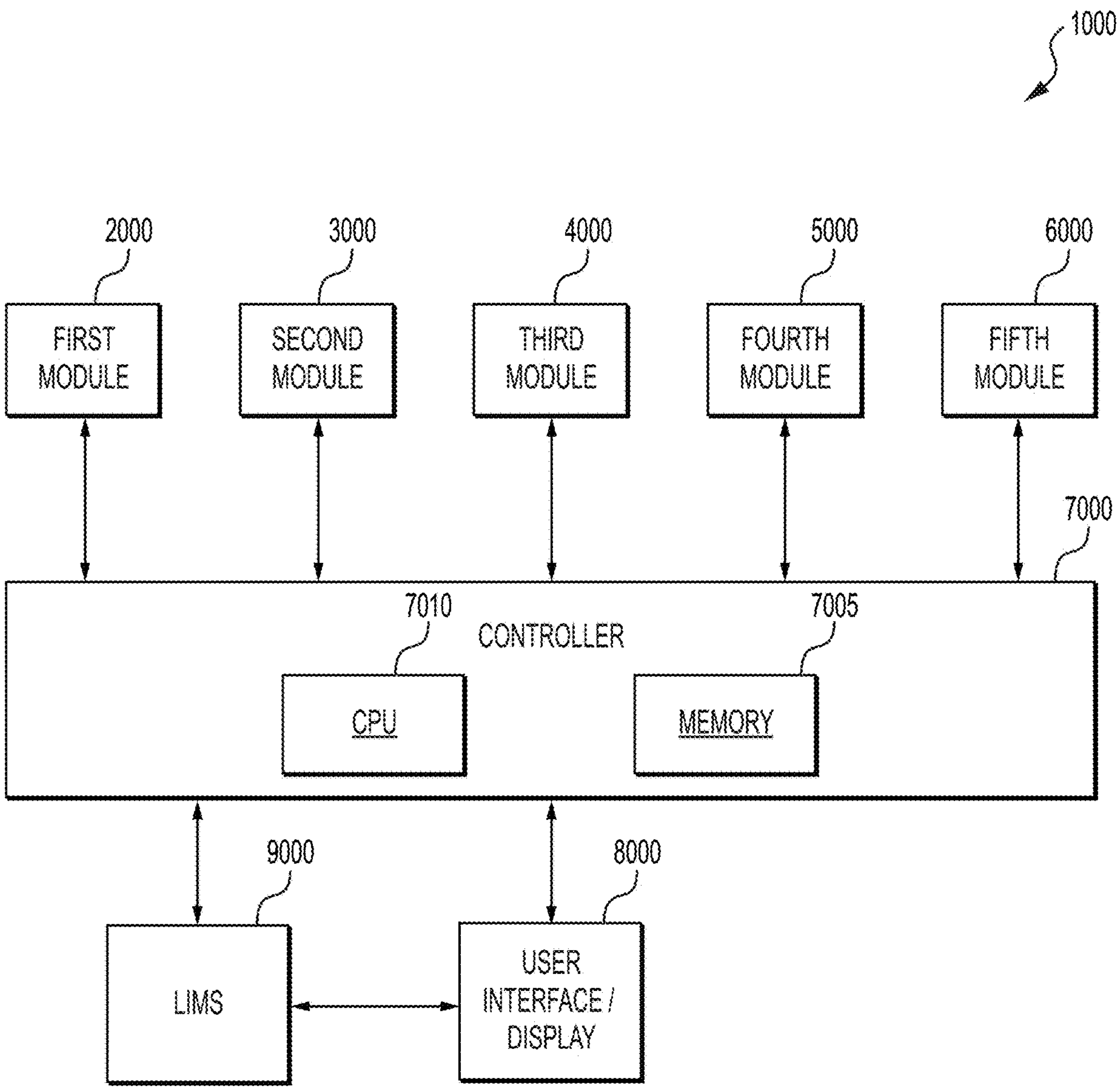

1000
2000
FIRST MODULE
3000
SECOND MODULE
4000
THIRD MODULE
5000
FOURTH MODULE
6000
FIFTH MODULE
7000
CONTROLLER
7010
CPU
7005
MEMORY
9000
LIMS
8000
USER INTERFACE / DISPLAY

FIG. 2

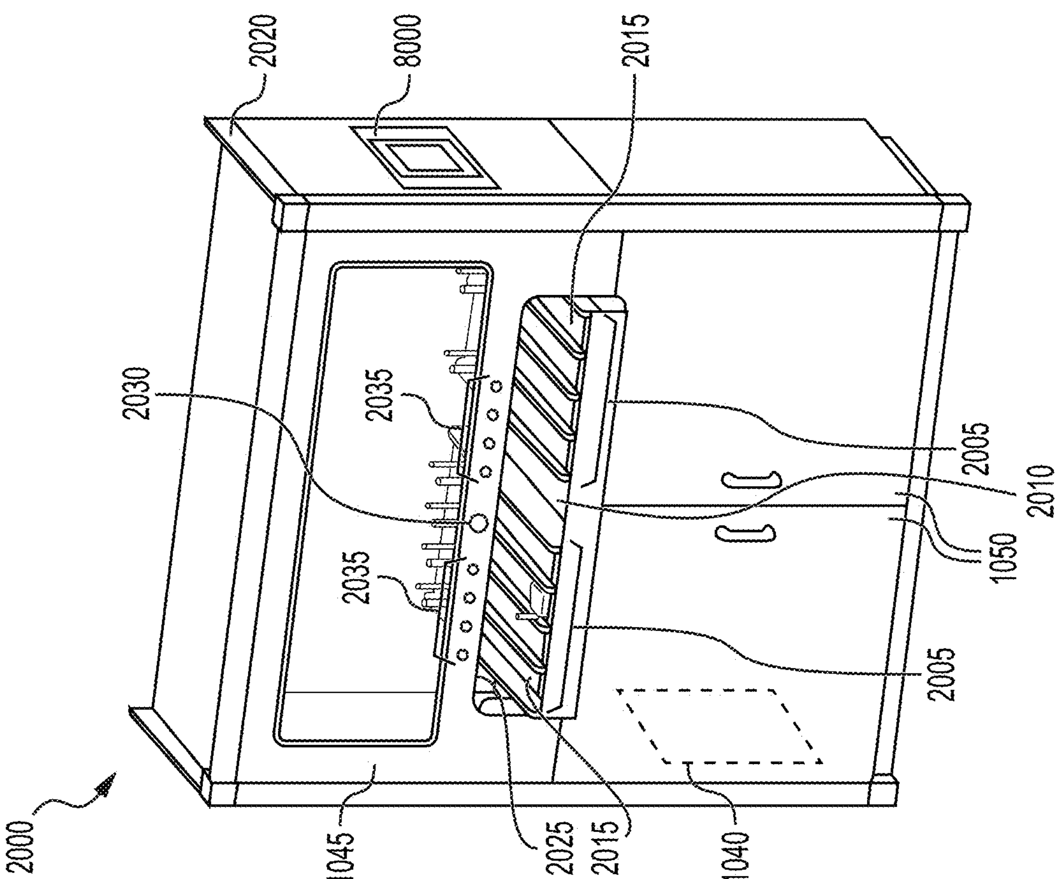

2000
1045
2025
2015
1040
2030
2035
2035
2020
8000
2015
2005
2010
1050
2005

FIG. 3

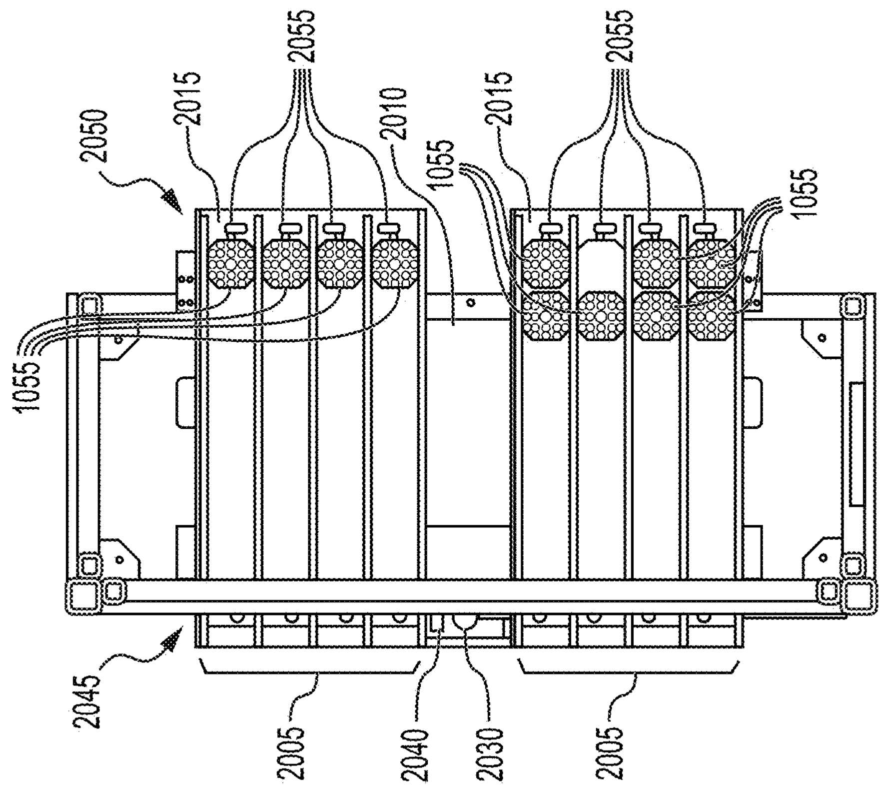
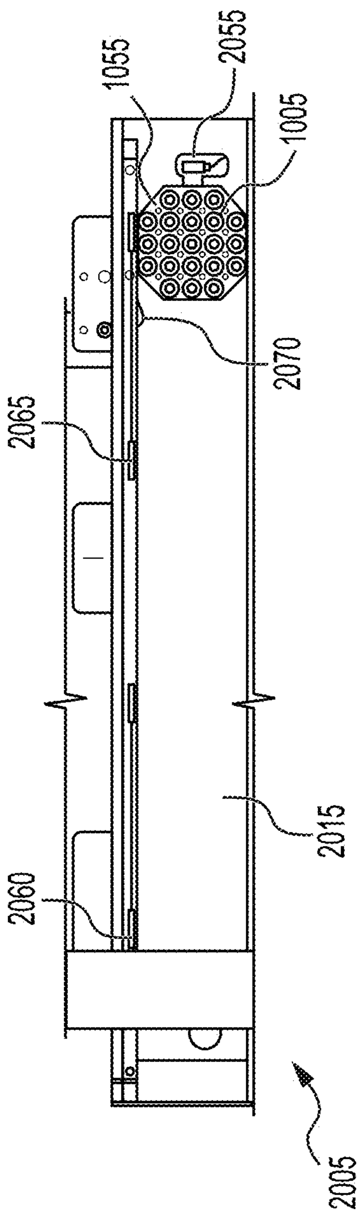
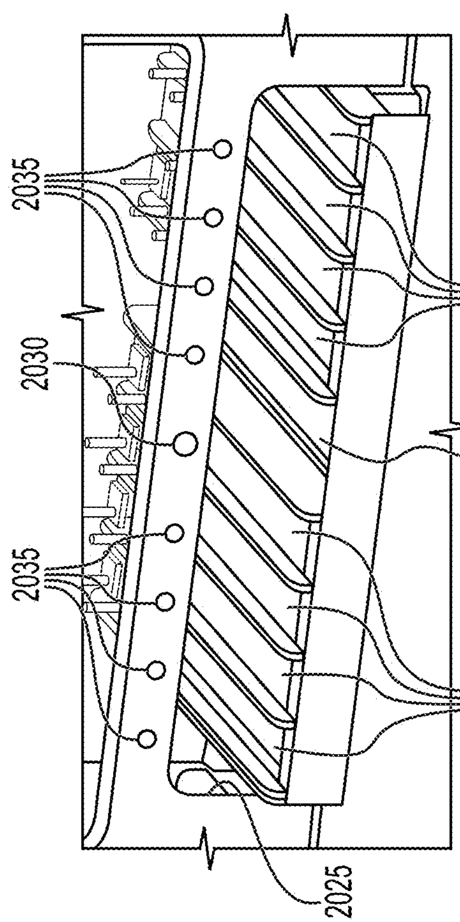

1055
2045
2005
2040
2030
2005
2050
2015
2055
2010
1055
2015
2055
1055

FIG. 4



1055
2055
1005
2070
2065
2015
2060
2005

FIG. 5



2035
2030
2035
2005
2010
2005
2025

FIG. 6

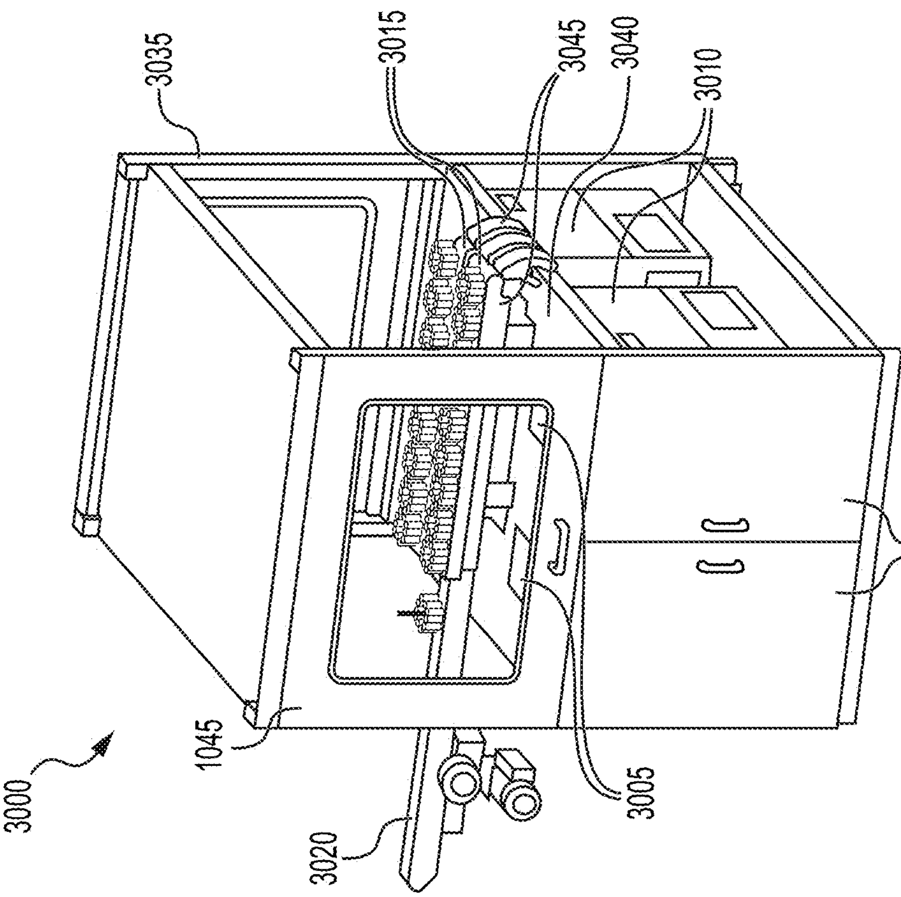

3035
3015
3045
3040
3010
3000
1045
3020
3005
1050

FIG. 8

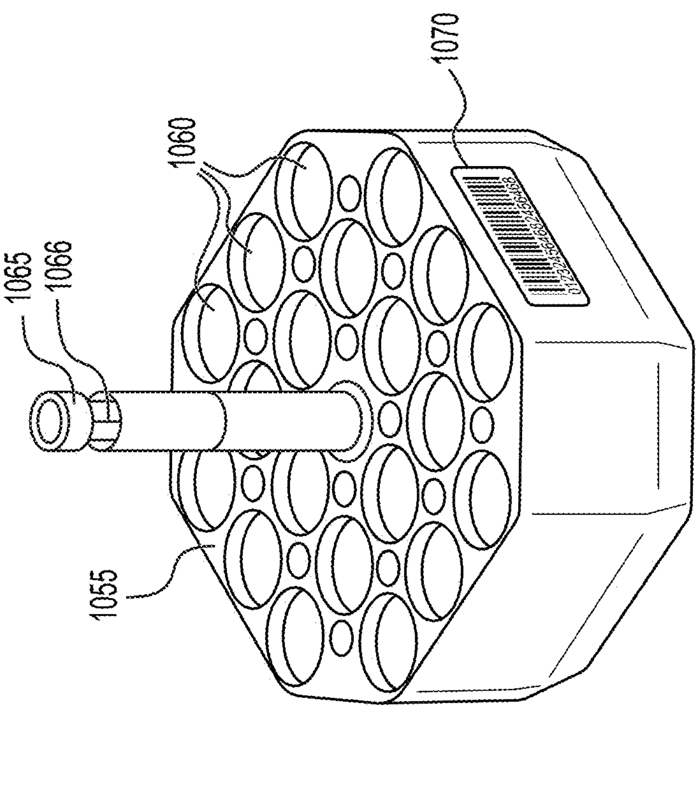

1065
1066
1060
1070
1055

FIG. 7

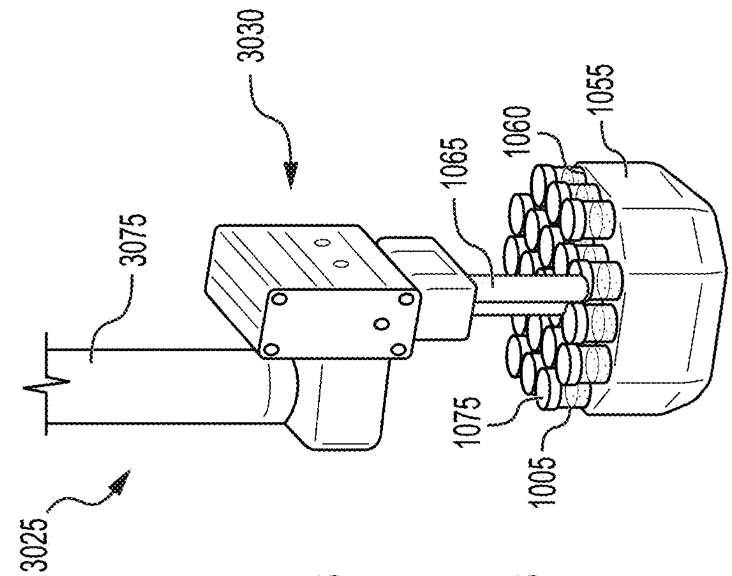

3030
3075
1065
1060
1055
1075
1005
3025

FIG. 10

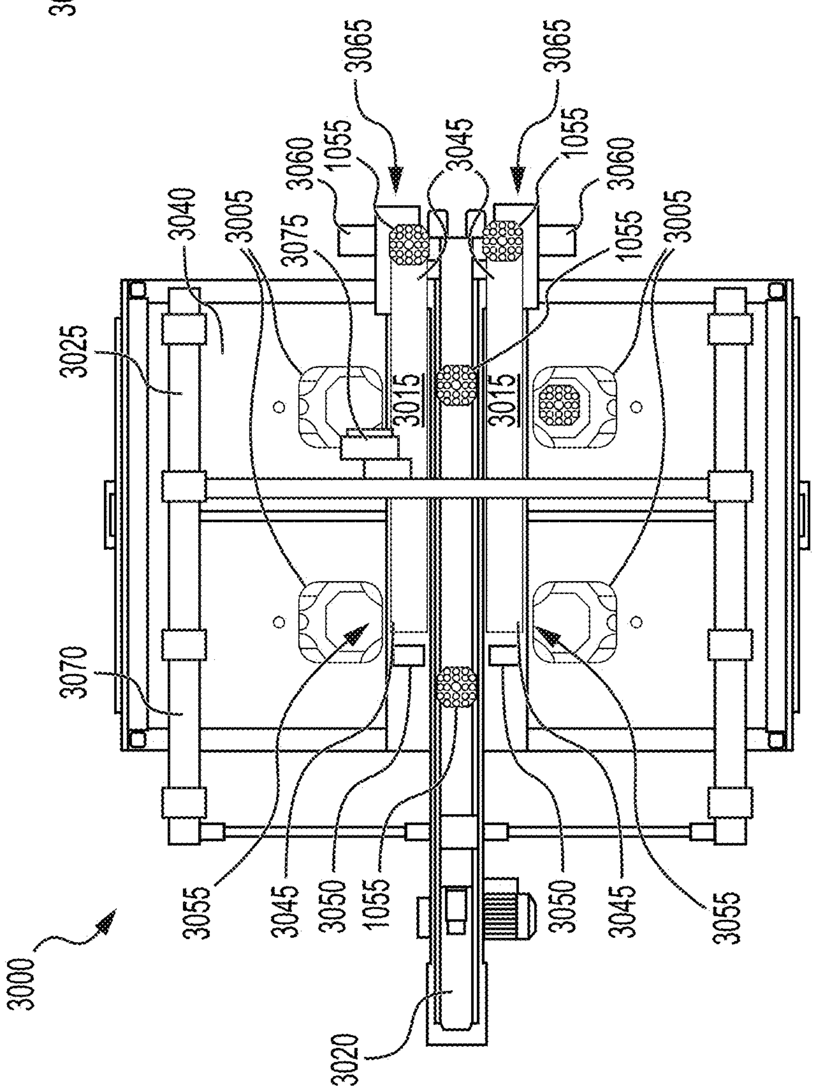

3000
3020
3055
3045
3050
1055
3050
3045
3055
3070
3025
3040
3005
3075
3060
1055
3065
3045
3065
1055
3060
1055
3005
3015
3015

FIG. 9

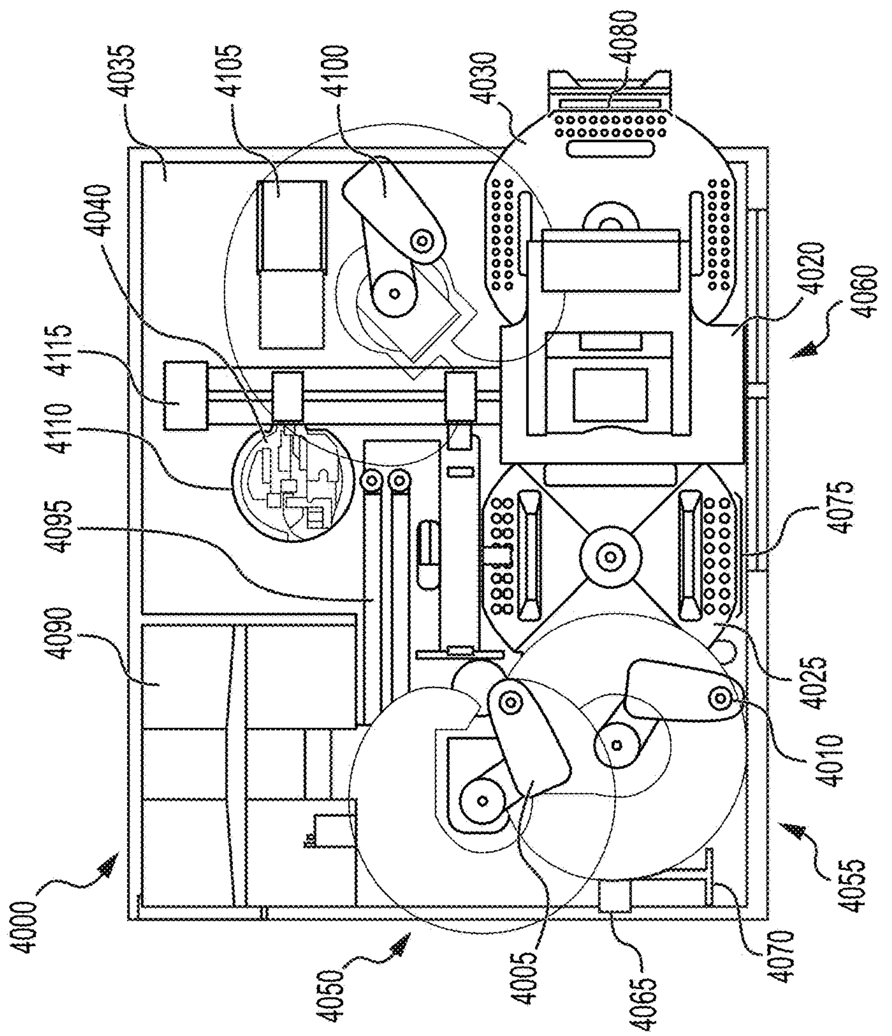

4000
4035
4105
4100
4030
4080
4040
4115
4110
4095
4090
4020
4060
4075
4025
4010
4005
4050
4065
4070
4055

FIG. 12

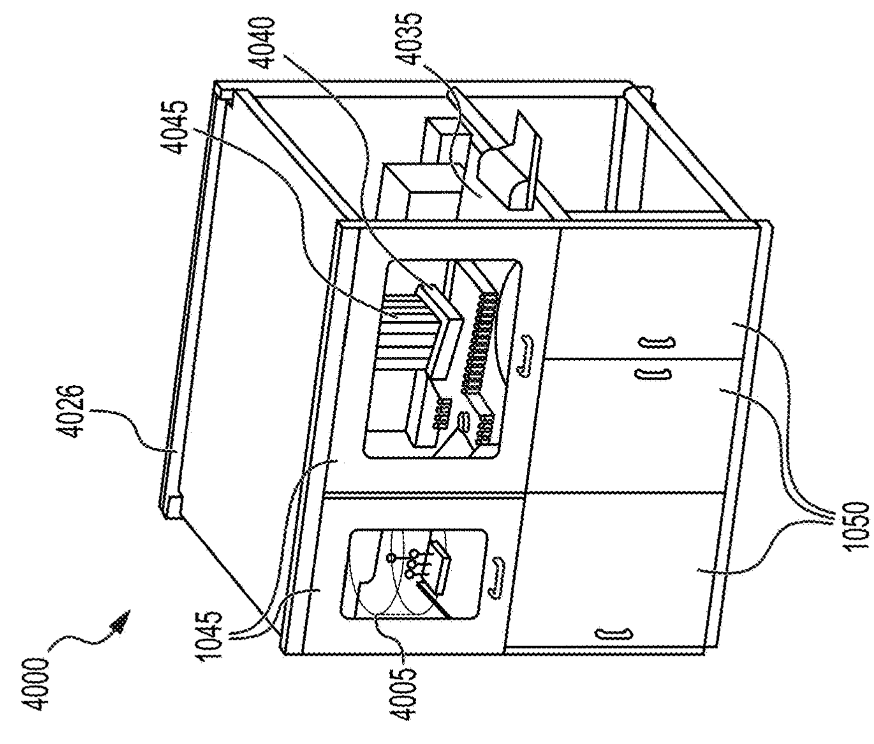

4000
4026
4045
4040
4035
1045
4005
1050

FIG. 11

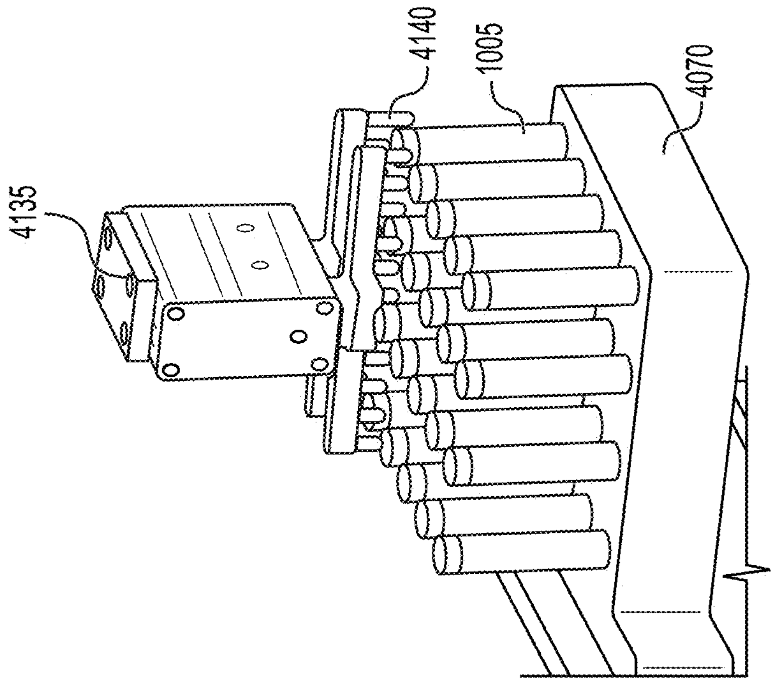


FIG. 14

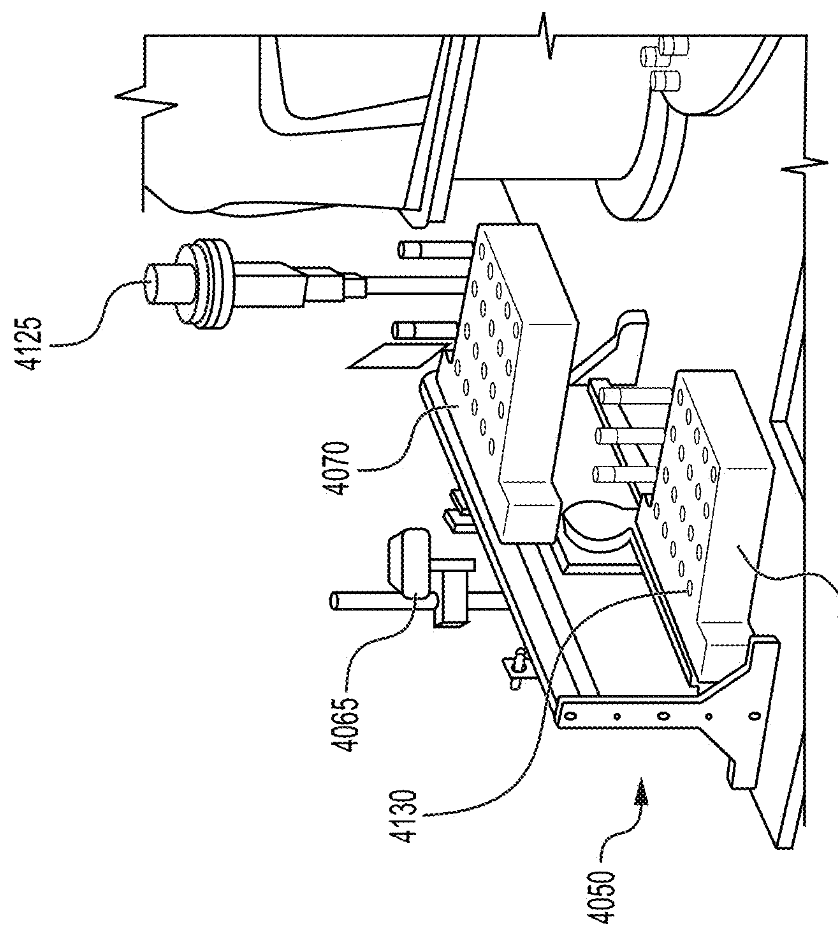


FIG. 13

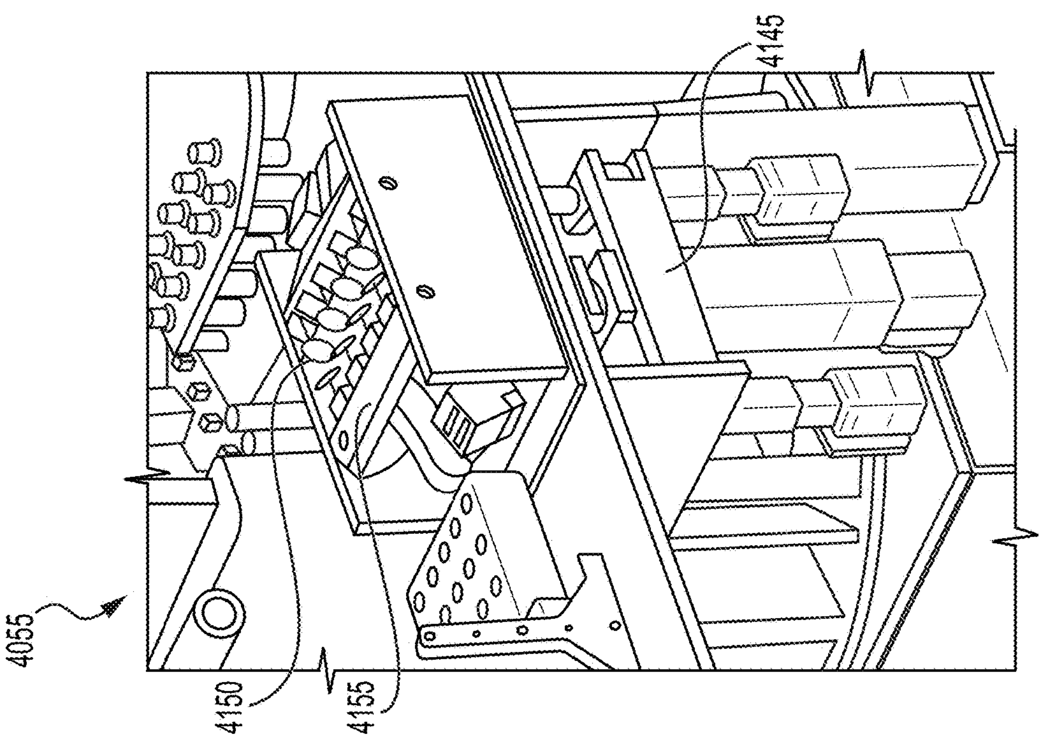


FIG. 15

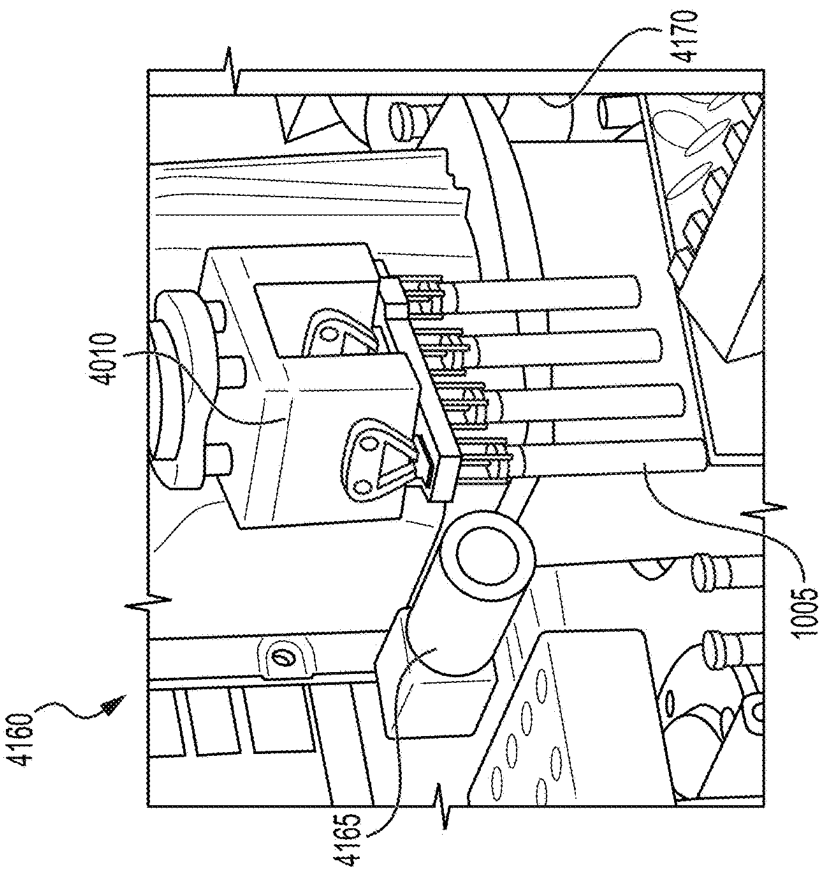


FIG. 16

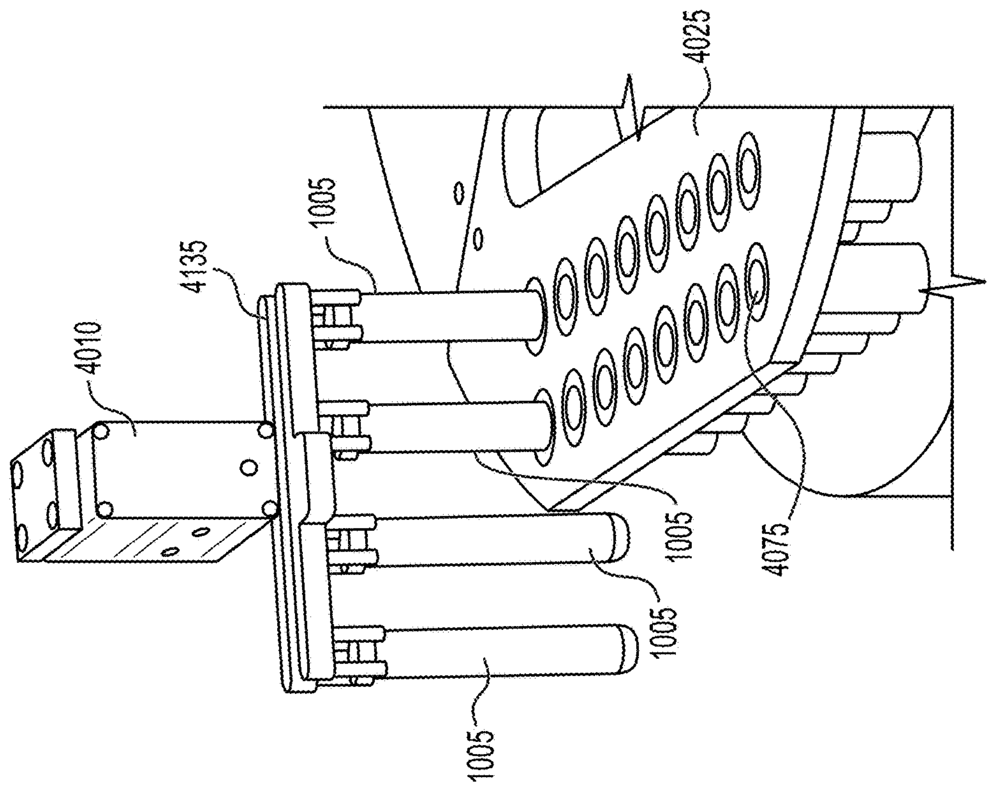

4025
4010
4135
1005
1005
1005
1005
1005
4075

FIG. 18

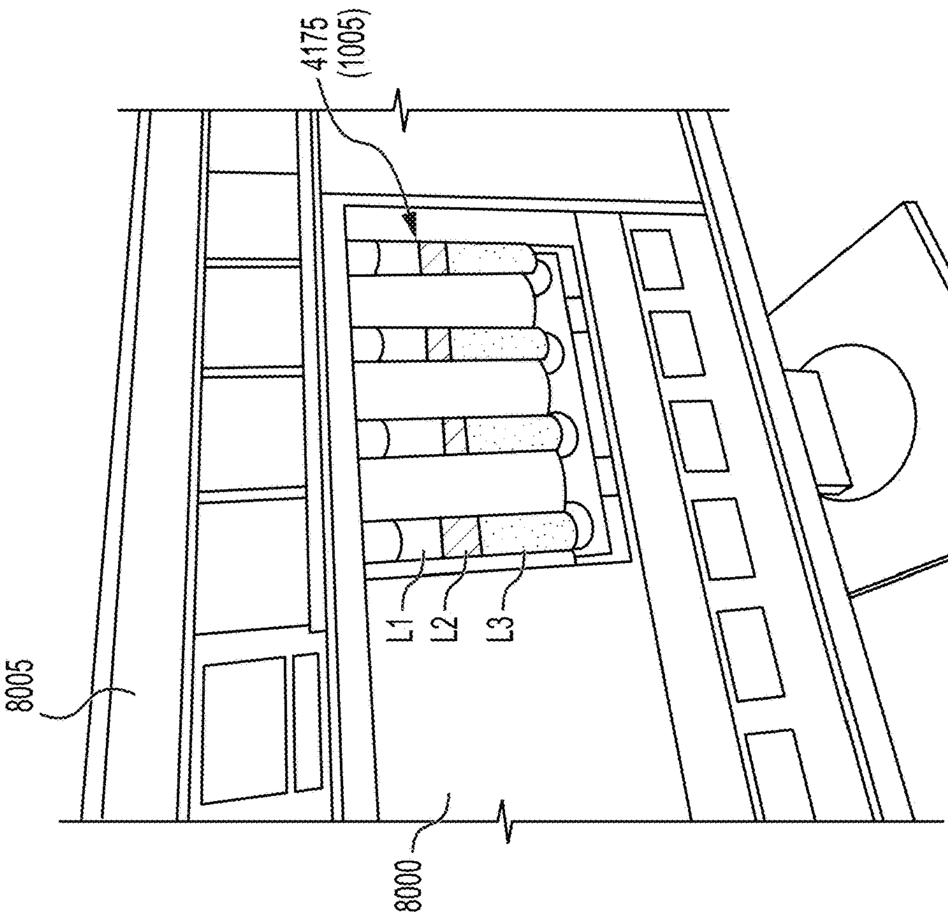

4175
(1005)
8005
L1
L2
L3
8000

FIG. 17

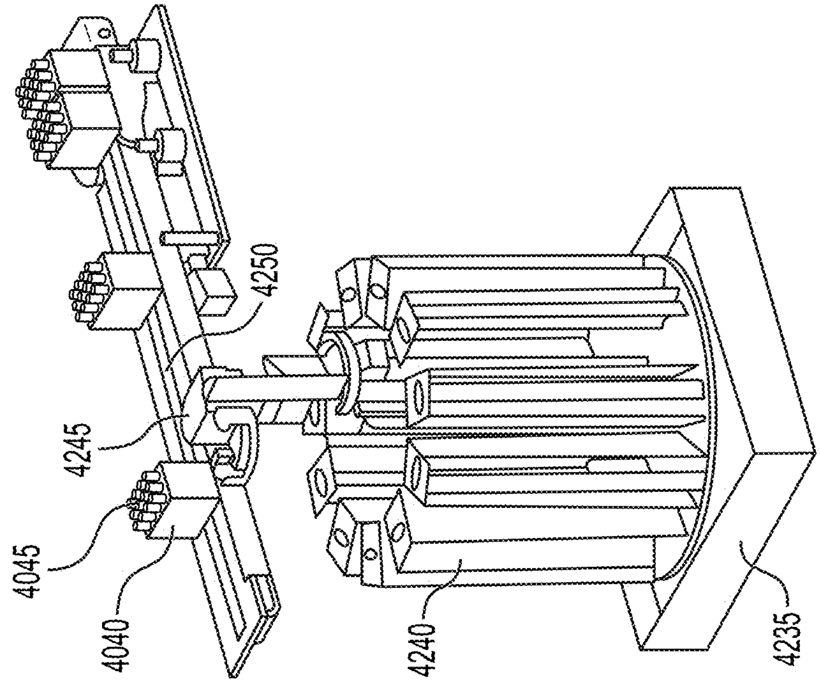

4045
4040
4245
4250
4240
4235

FIG. 20

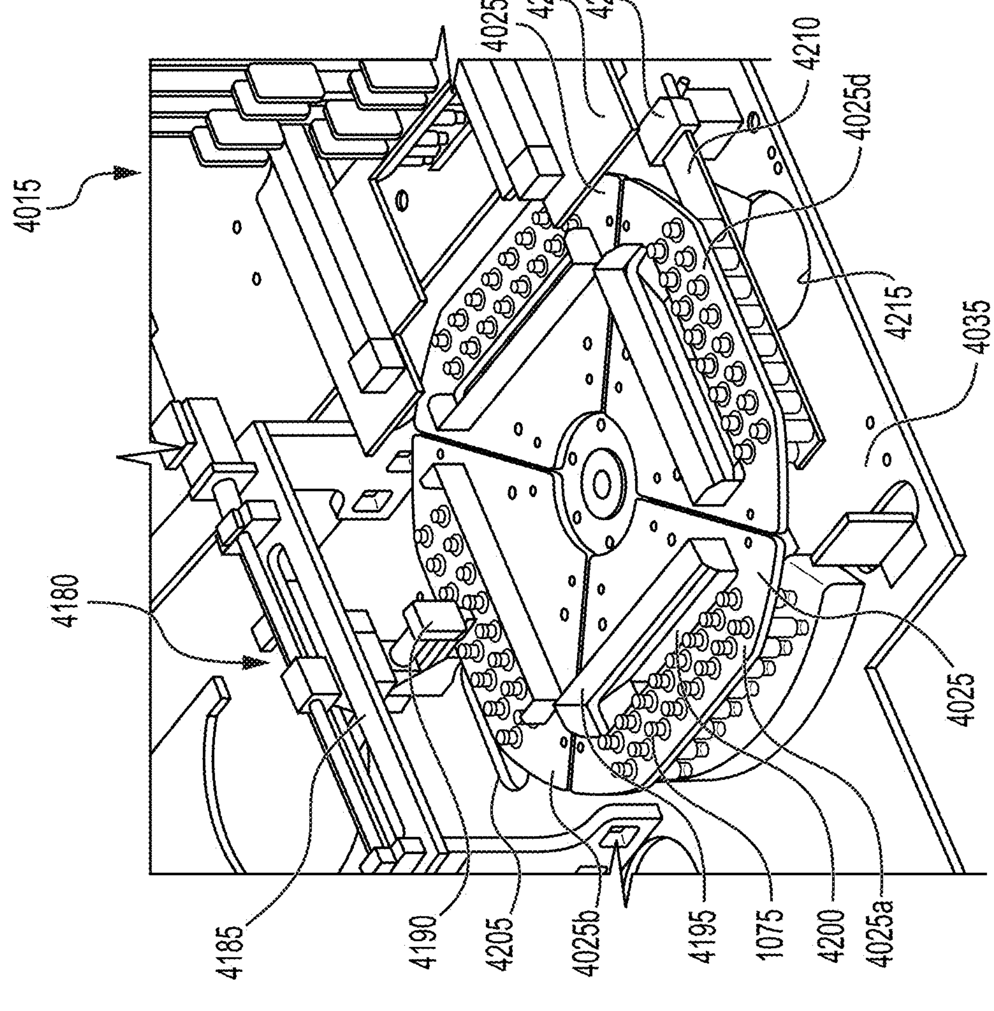

4015
4180
4185
4190
4205
4025b
4195
1075
4200
4025a
4025
4035
4215
4025d
4210
4220
4225
4025c

FIG. 19

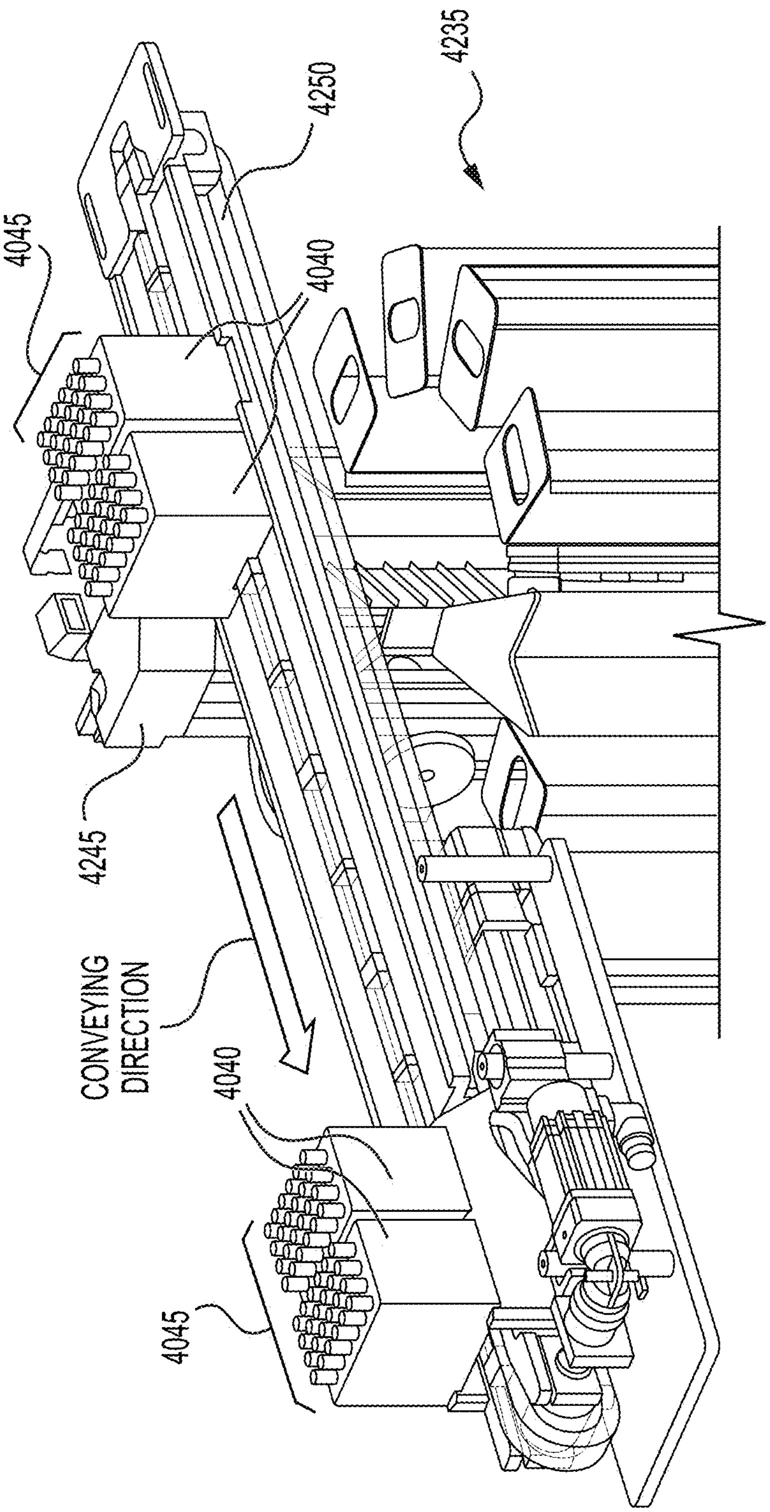


FIG. 21

FIG. 22A

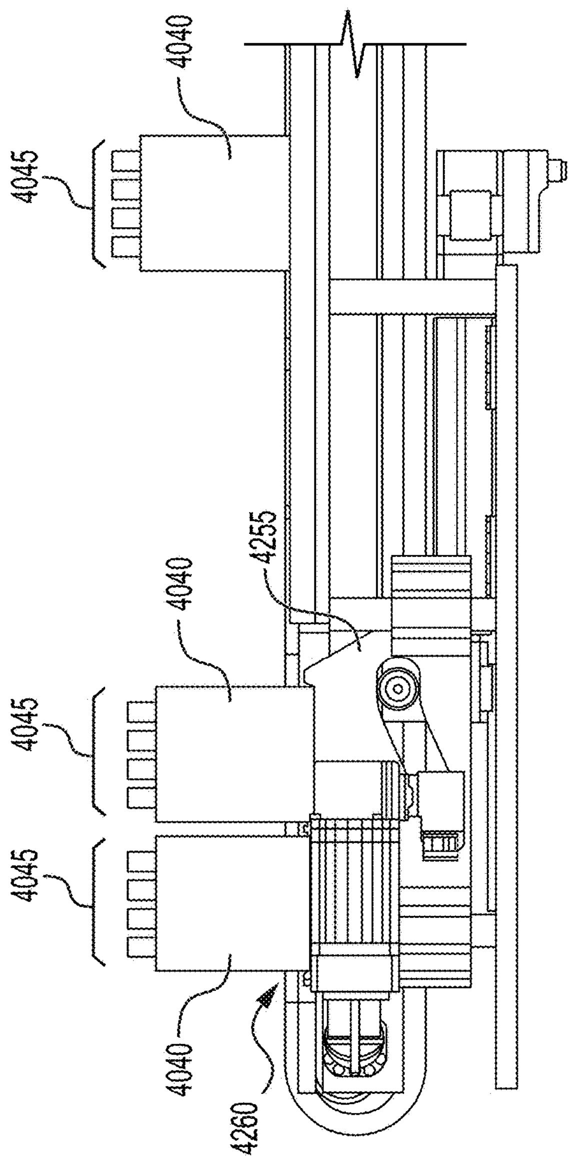
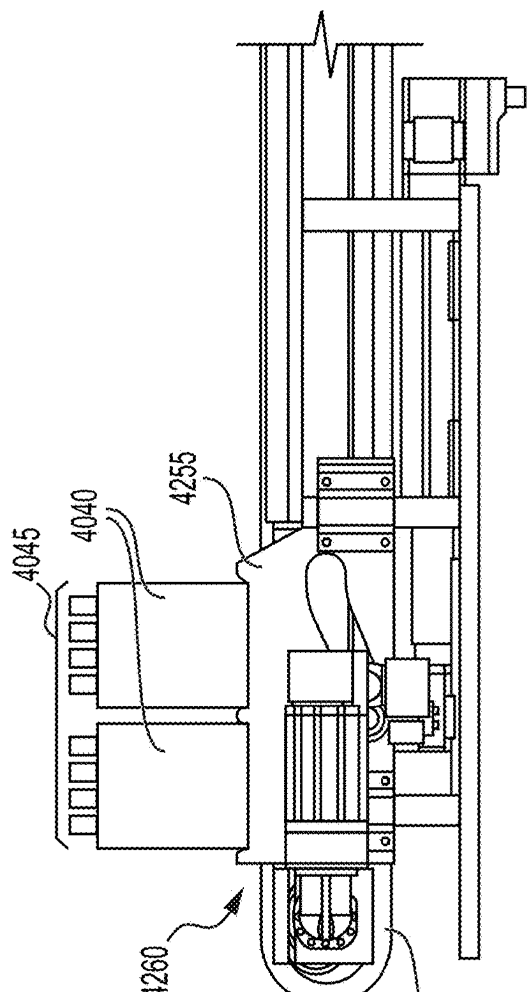


FIG. 22B



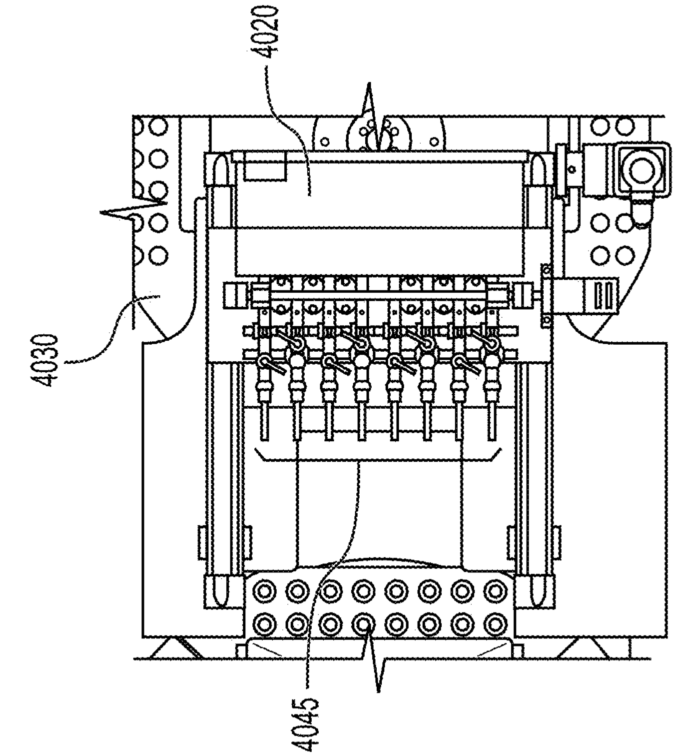


FIG. 24

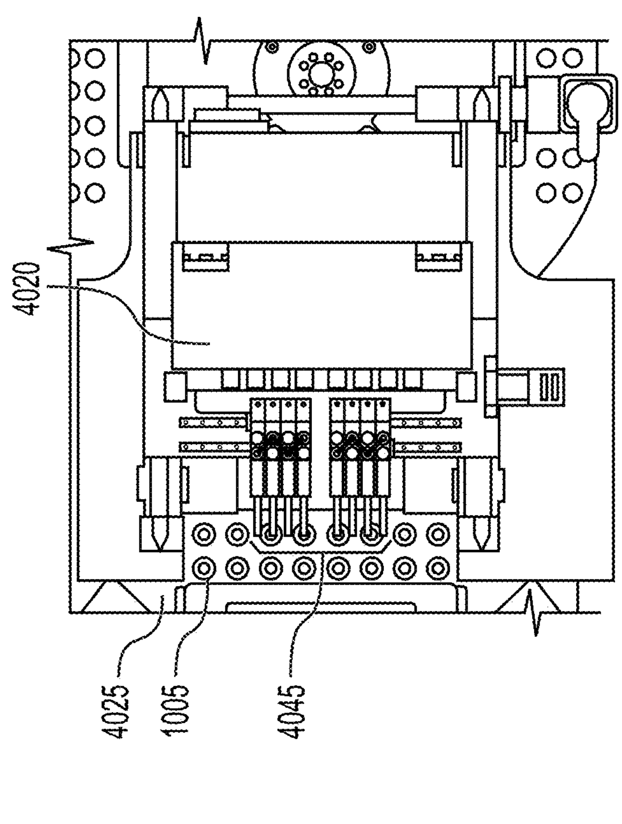


FIG. 23

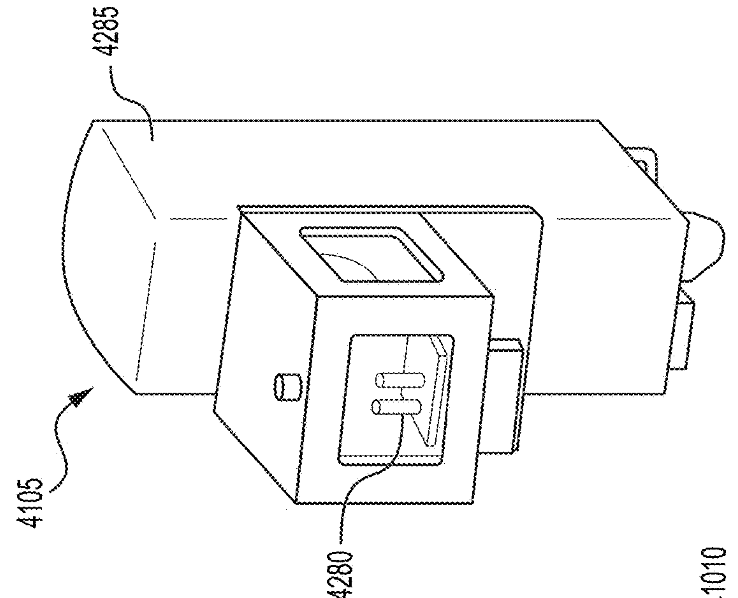


FIG. 26

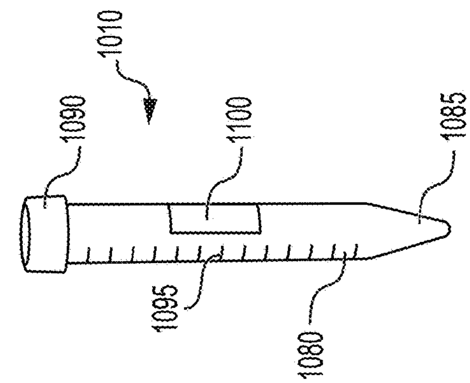


FIG. 25B

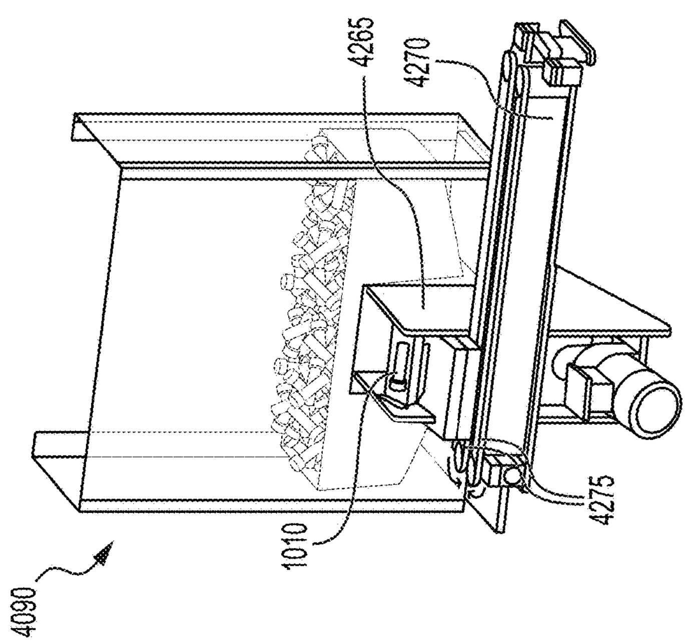


FIG. 25A

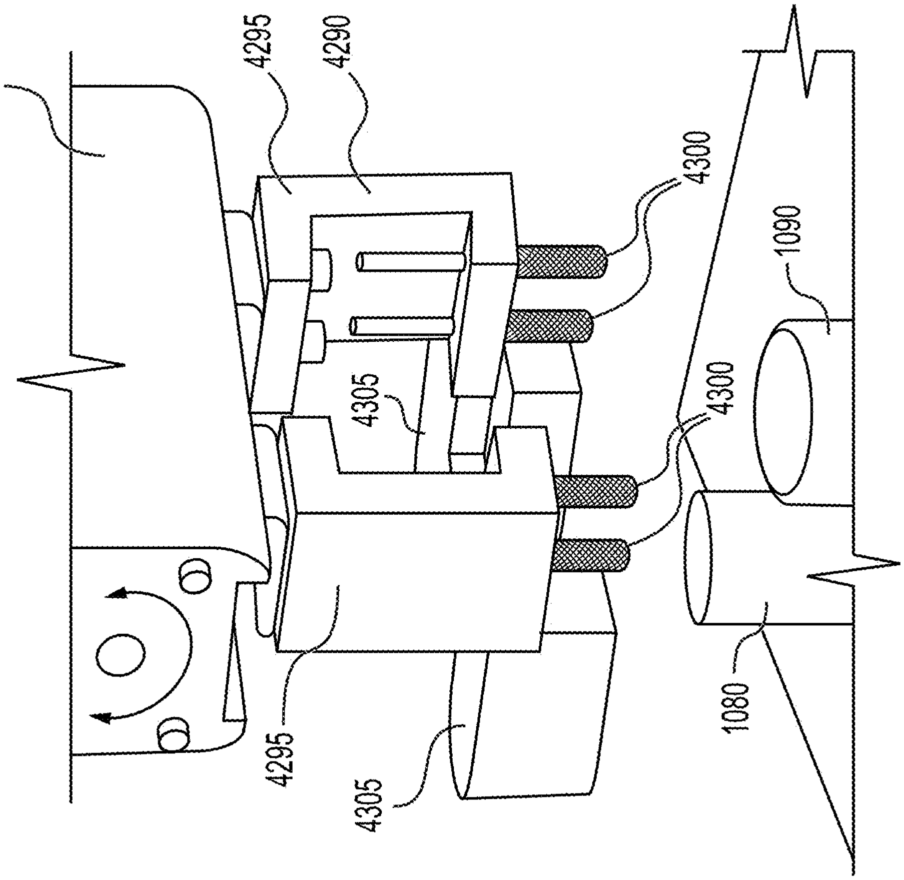


FIG. 27B

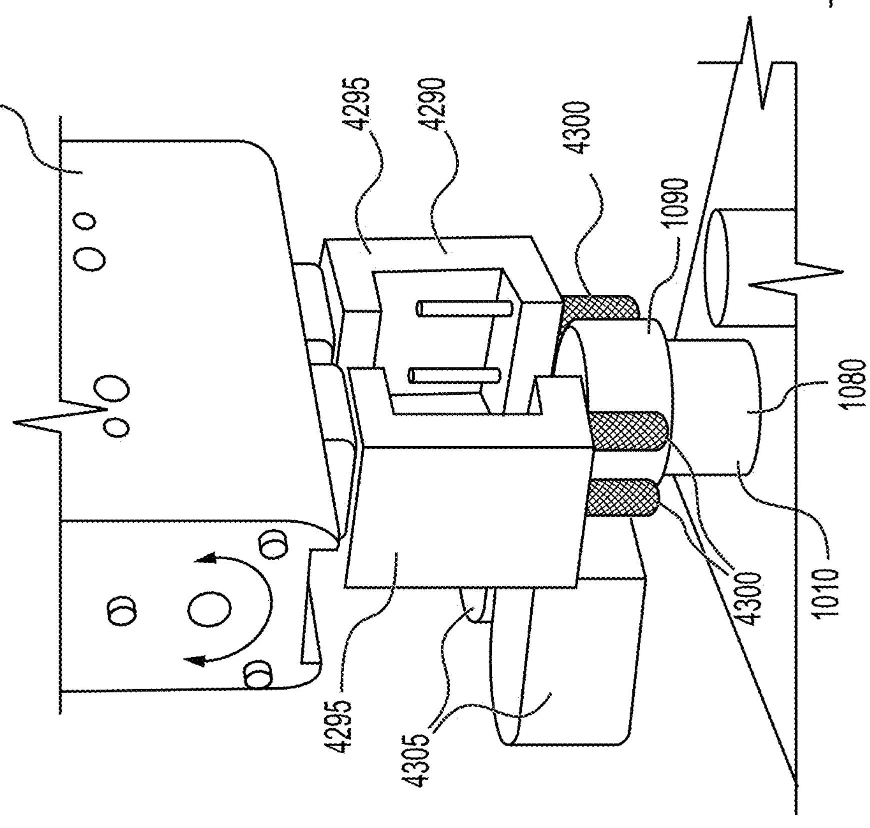


FIG. 27A

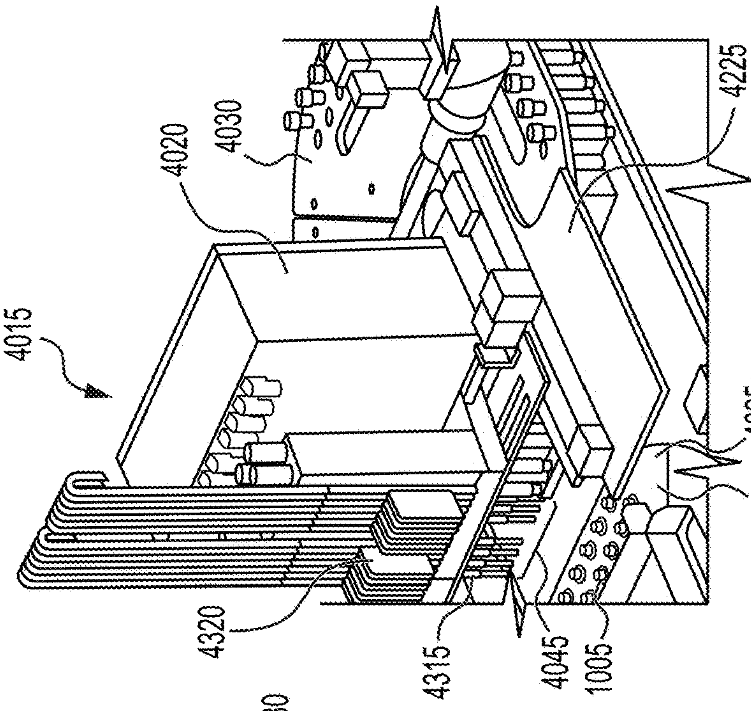

4015
4020
4030
4225
4025c
4025
4320
4315
4045
1005

FIG. 29

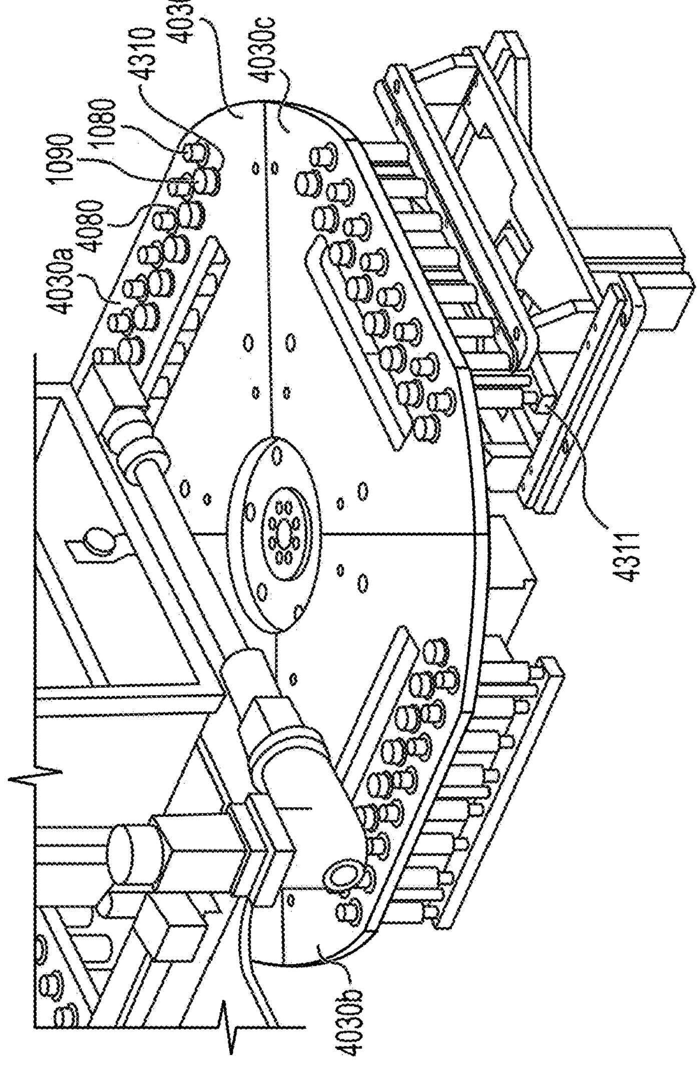

4030
4030c
4310
1080
1090
4080
4030a
4311
4030b

FIG. 28

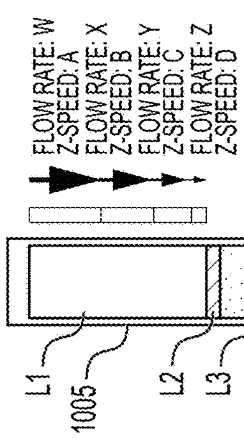


FIG. 30A

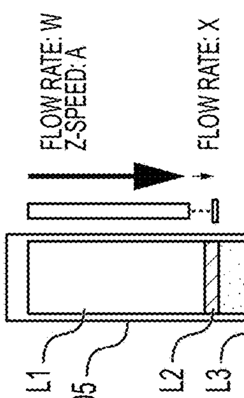


FIG. 30B

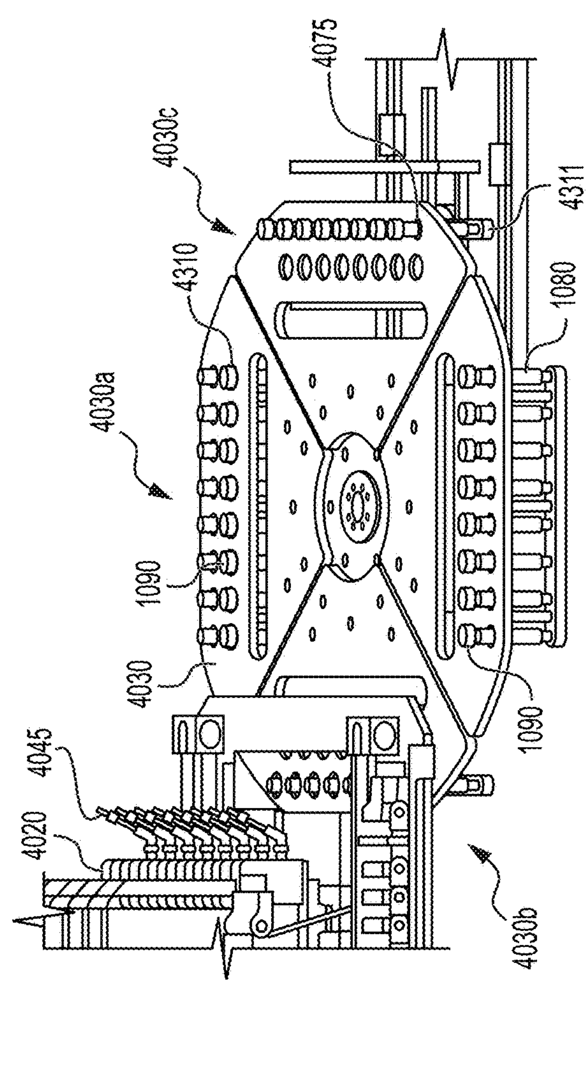


FIG. 31

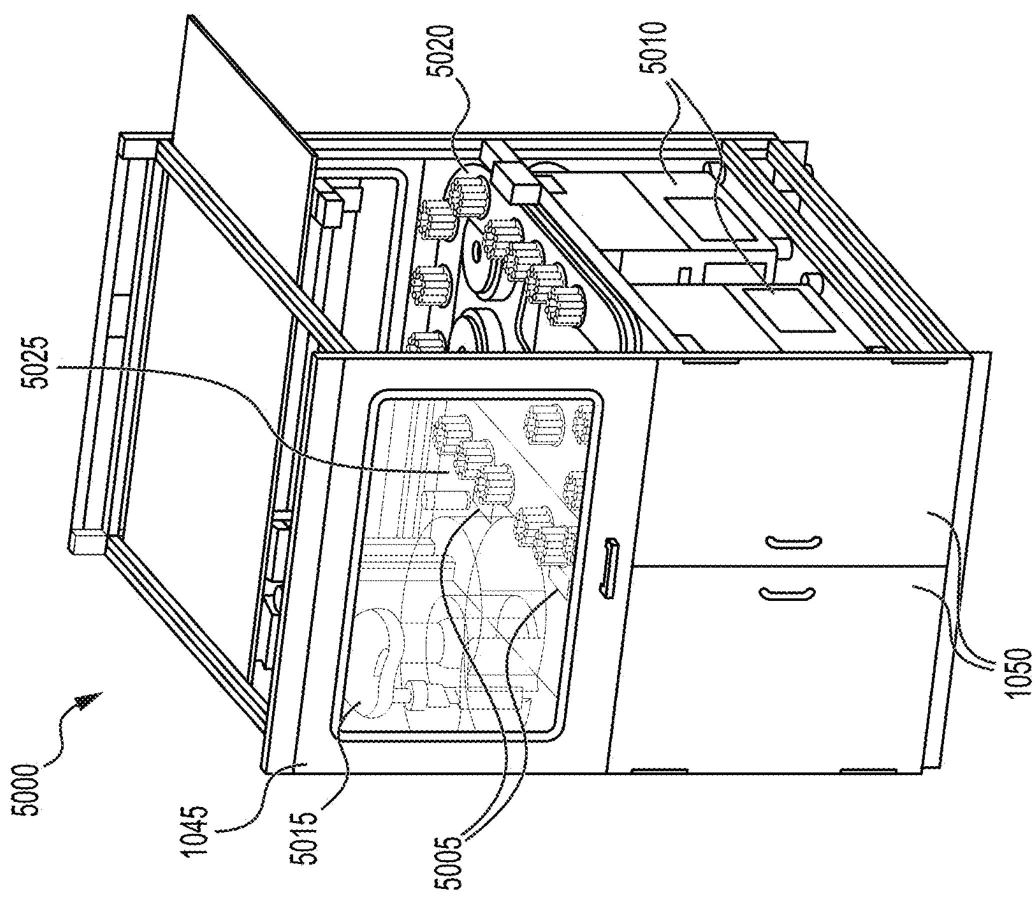

5000
1045
5015
5005
5025
5020
5010
1050

FIG. 32

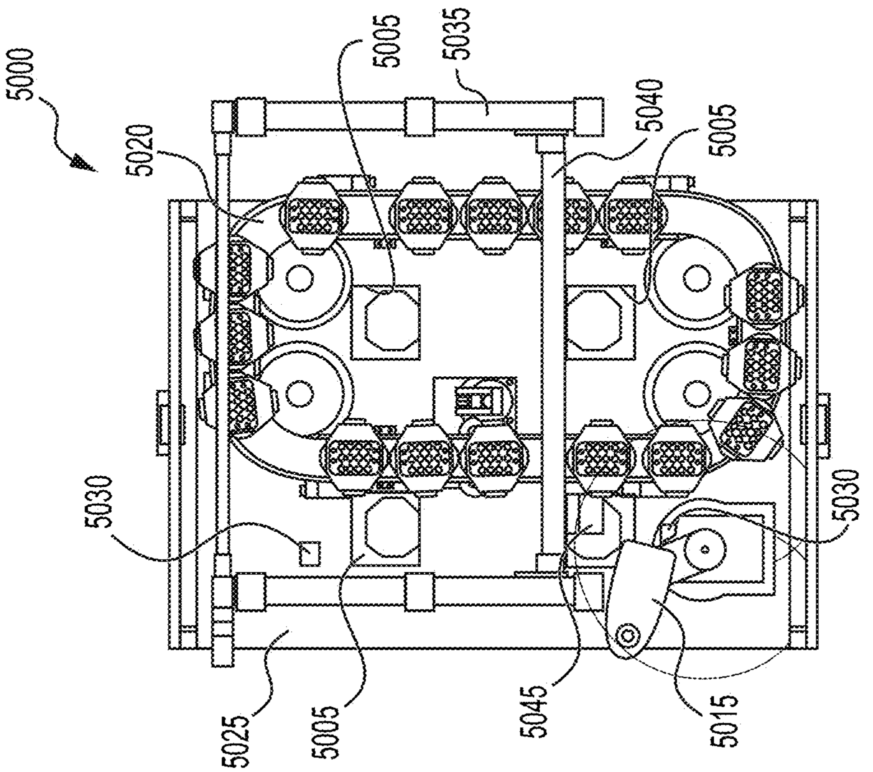

5000
5020
5005
5035
5040
5005
5030
5025
5005
5045
5015
5030

FIG. 33

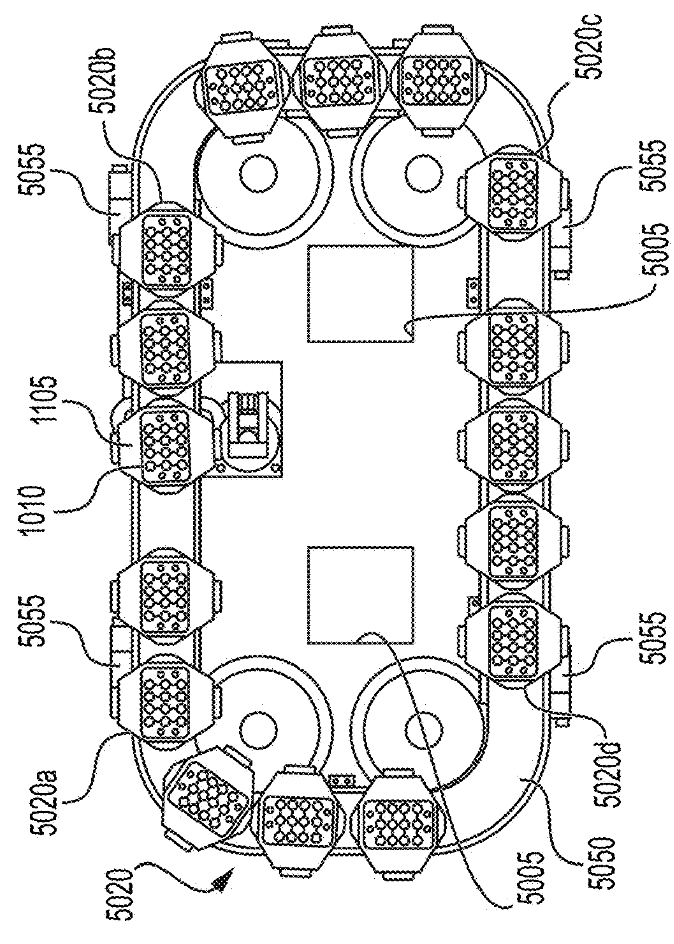

5020
5020a
5055
1010
1105
5055
5020b
5020c
5055
5005
5055
5020d
5005
5050

FIG. 34

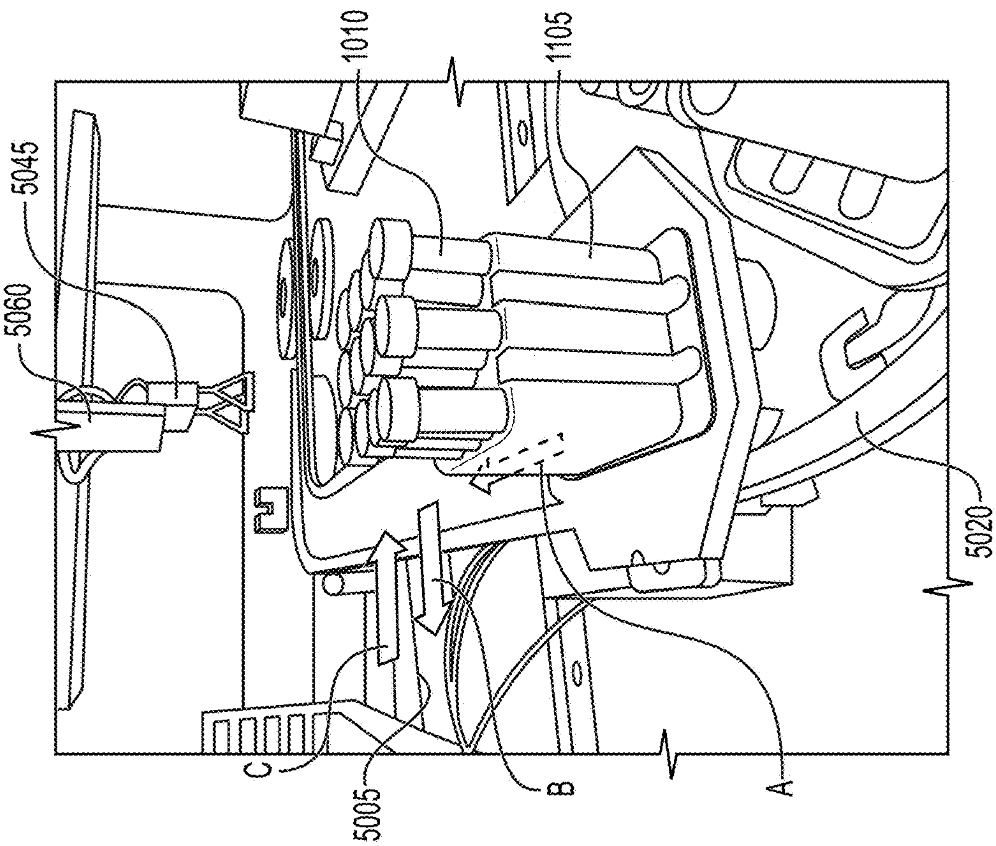

5060
5045
1010
1105
5020
A
B
5005
C

FIG. 35

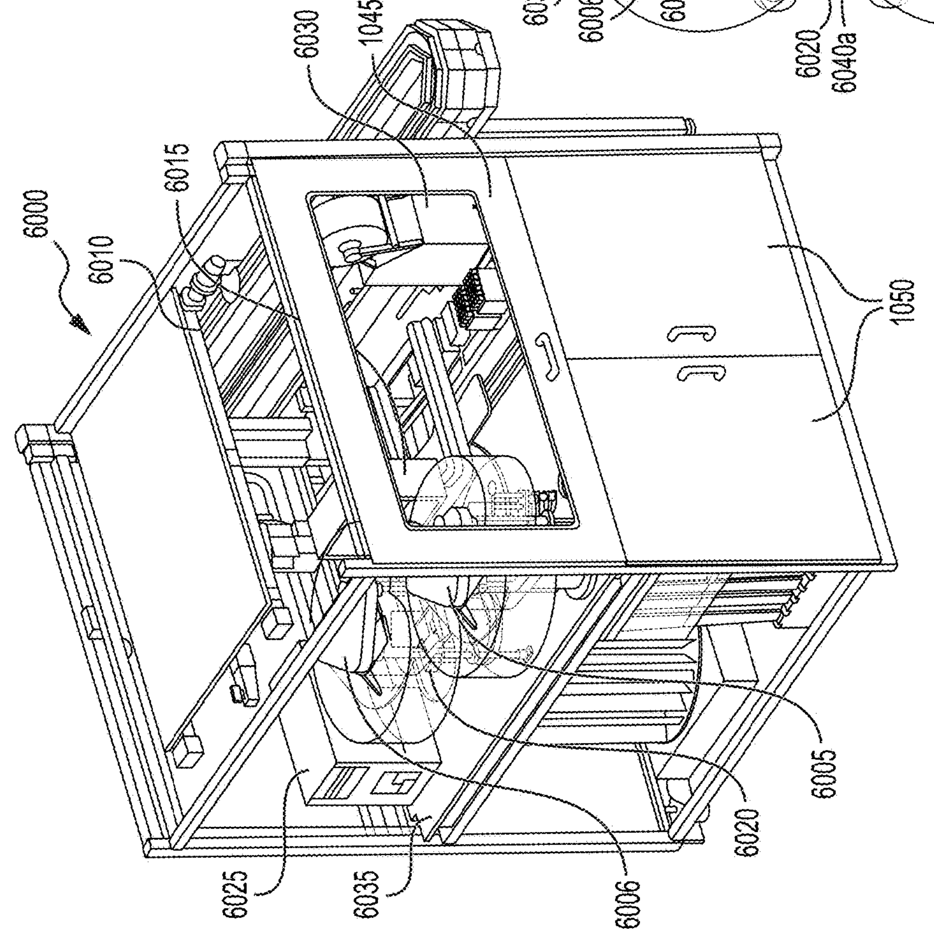

6000
6010
6015
6030
1045
1050
6005
6020
6006
6035
6025

FIG. 36

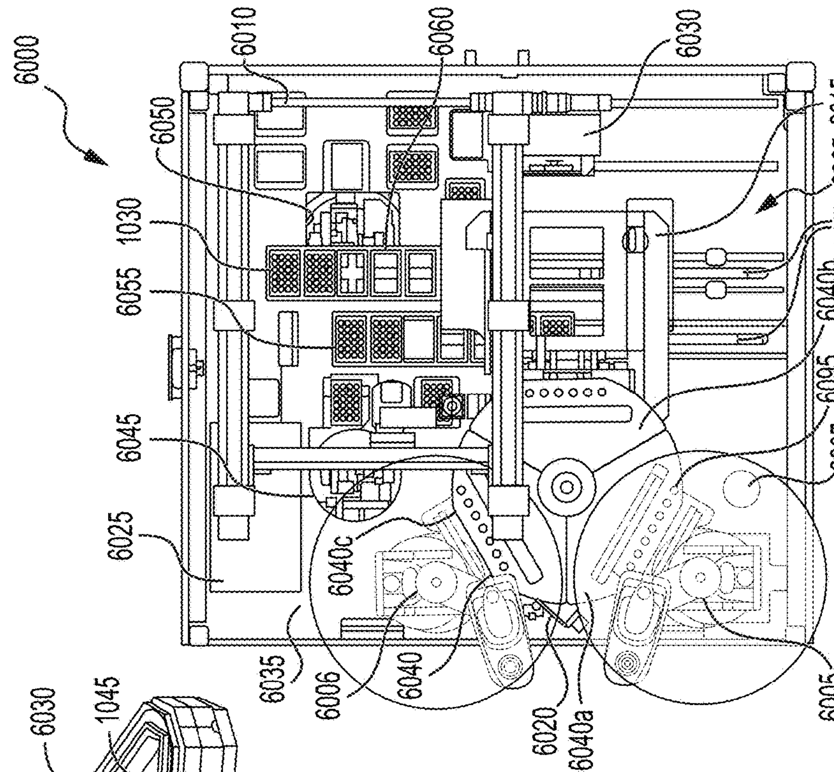
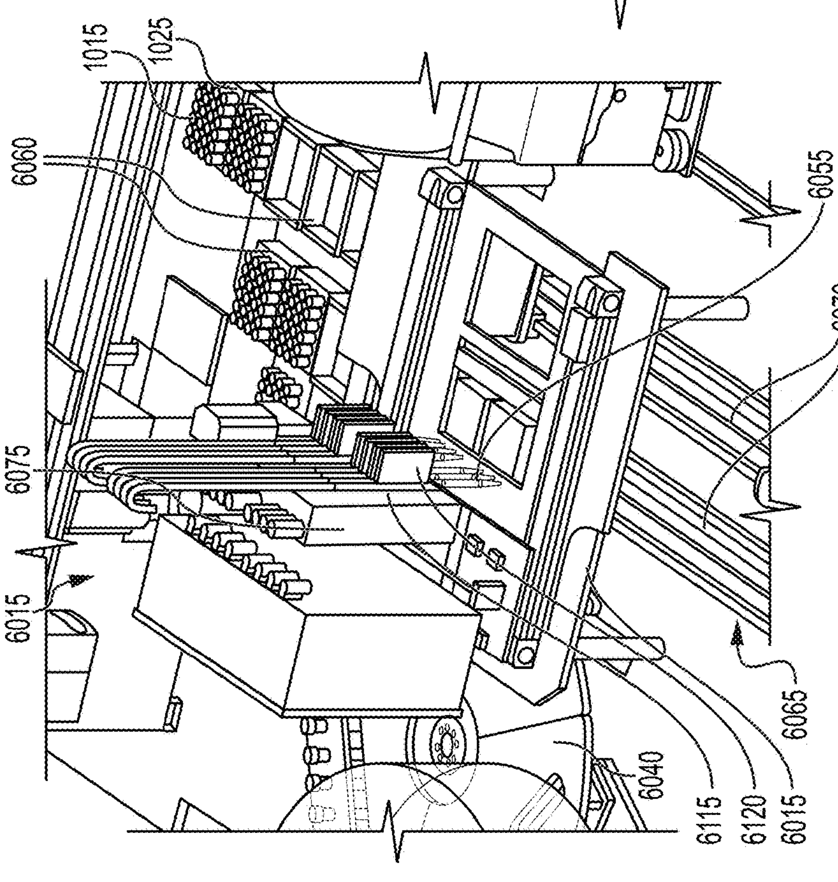
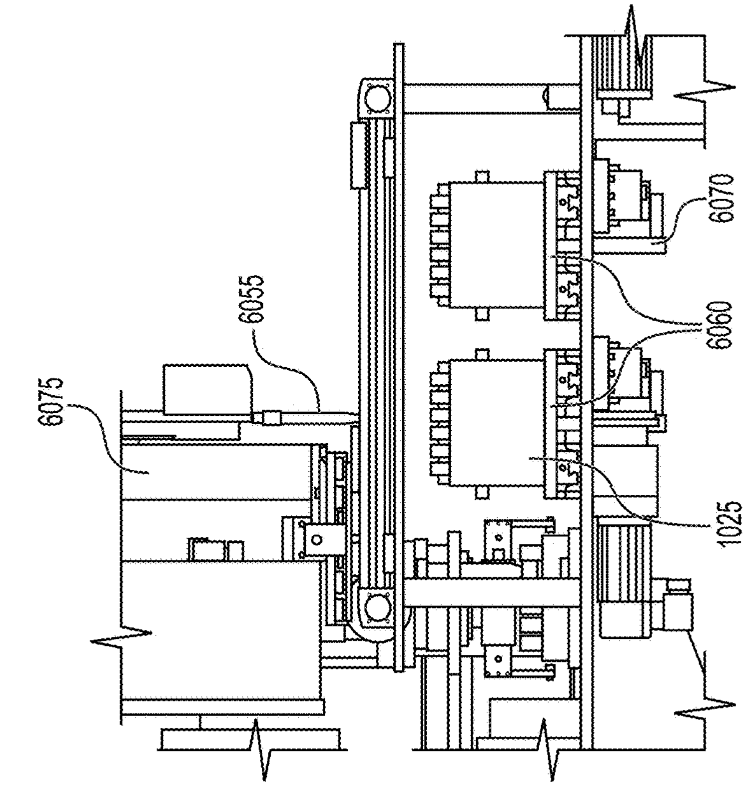

6000
6010
6060
6030
6050
1030
6055
6045
6025
6040c
6035
6006
6040
6020
6040a
6005
6007
6095
6040b
6070
6065
6015

FIG. 37


6015
6075
6060
1015
1025
6055
6070
6065
6015
6120
6115
6040
FIG. 38


6075
6055
6070
6060
1025
FIG. 39

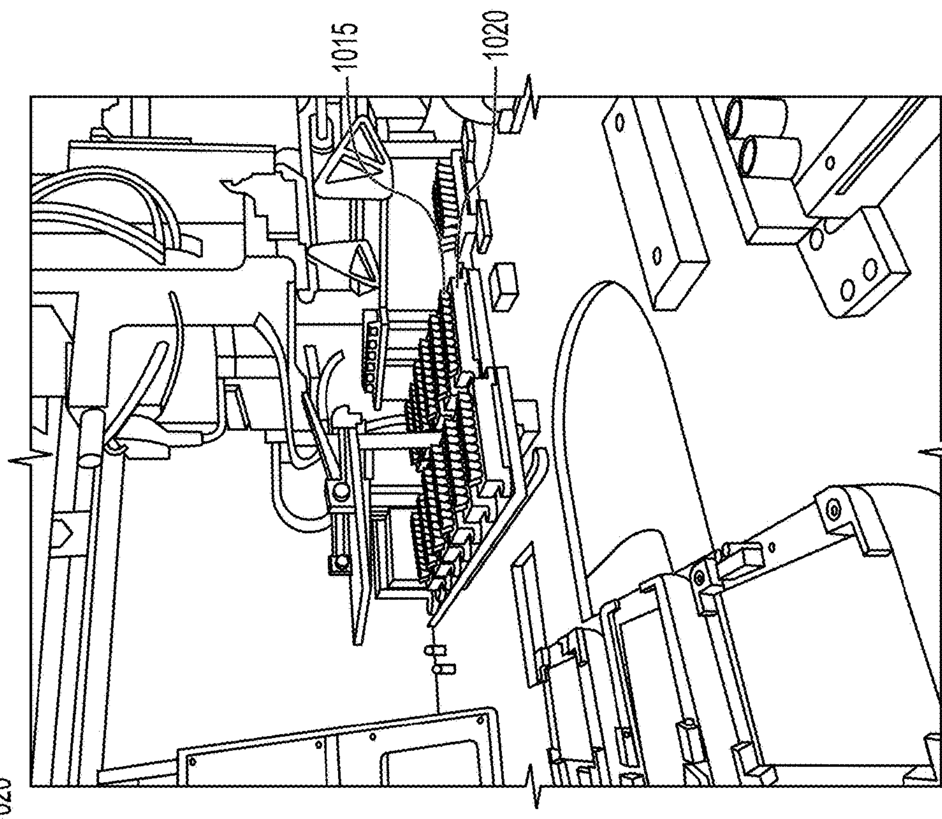

1015
1020

FIG. 41

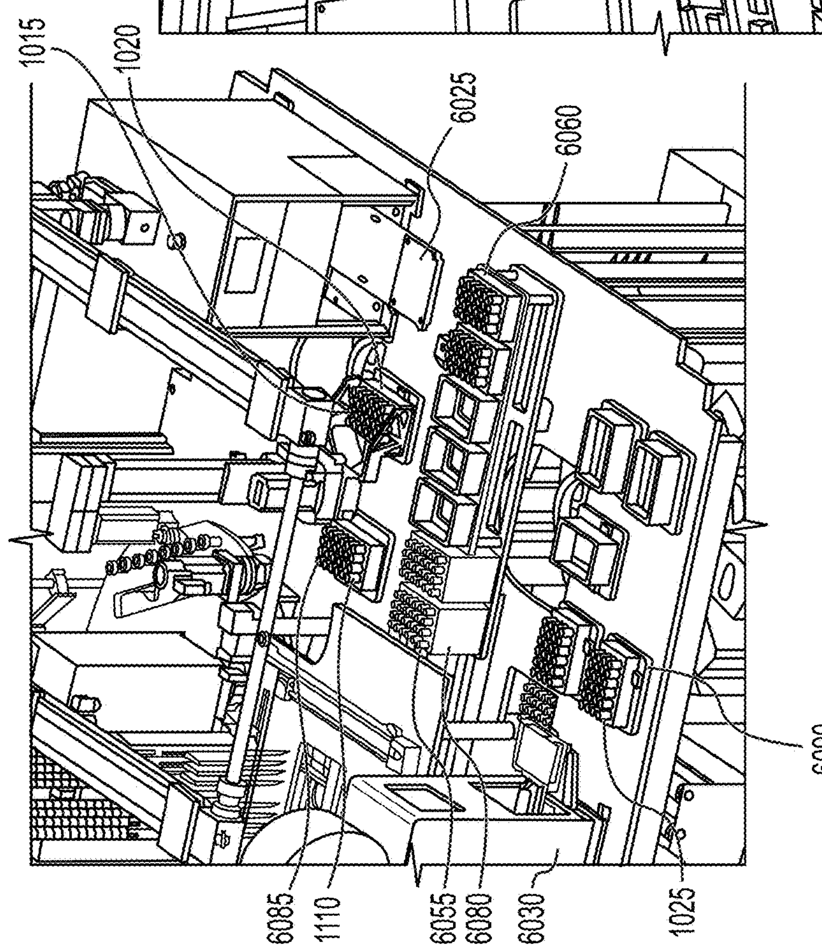

1015
1020
6025
6060
6090
6085
1110
6055
6080
6030
1025

FIG. 40

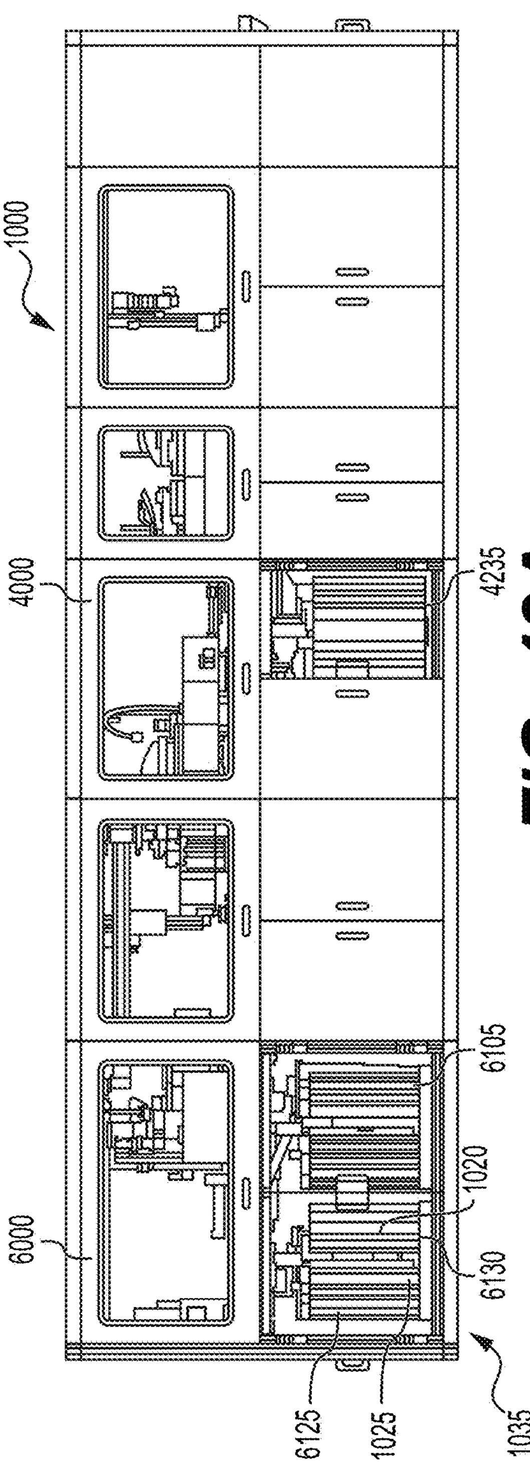


FIG. 42A

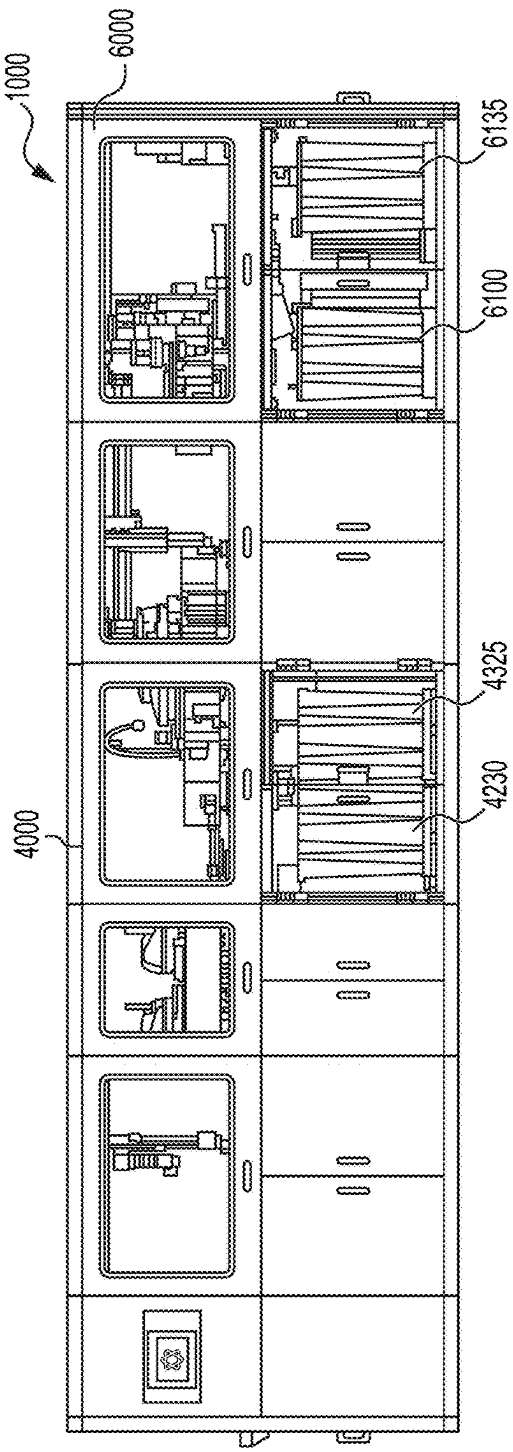


FIG. 42B

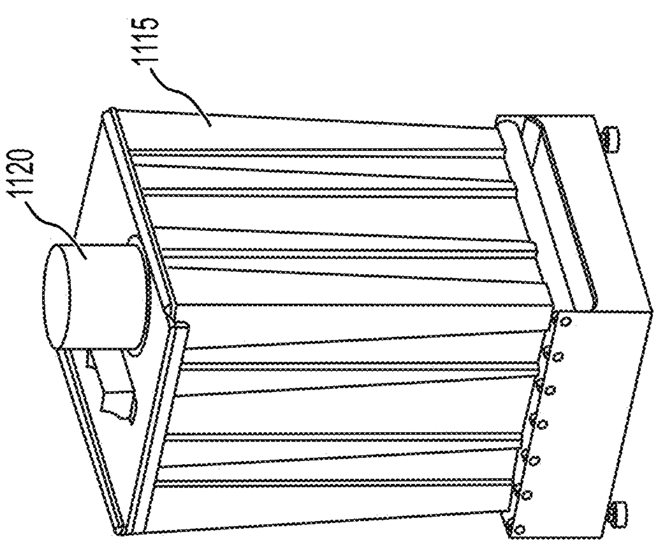


FIG. 43

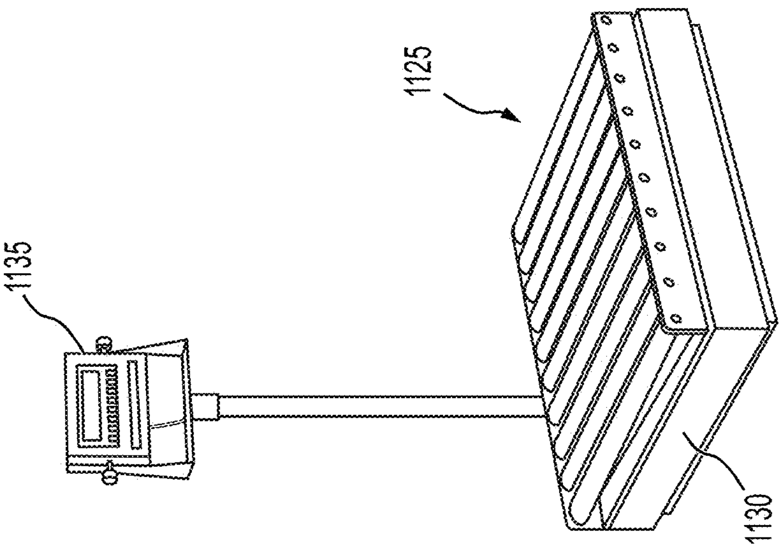


FIG. 44

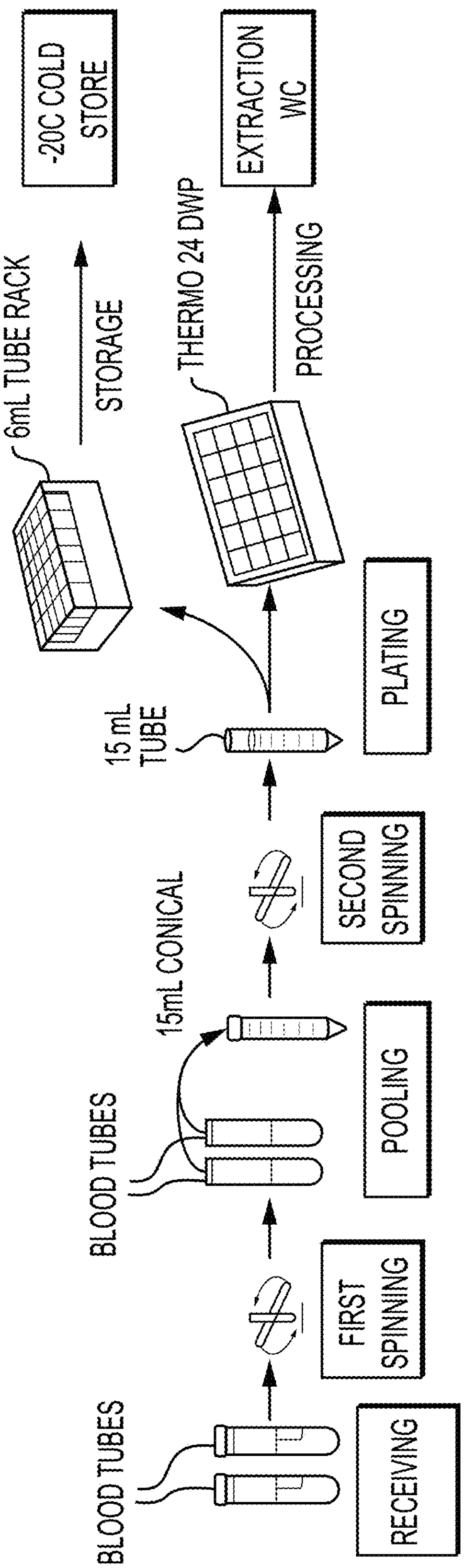

BLOOD TUBES
RECEIVING
FIRST SPINNING
BLOOD TUBES
POOLING
15mL CONICAL
SECOND SPINNING
15 mL TUBE
PLATING
MICRONIC 24 6mL TUBE RACK
STORAGE
-20C COLD STORE
THERMO 24 DWP
PROCESSING
EXTRACTION WC

FIG. 45

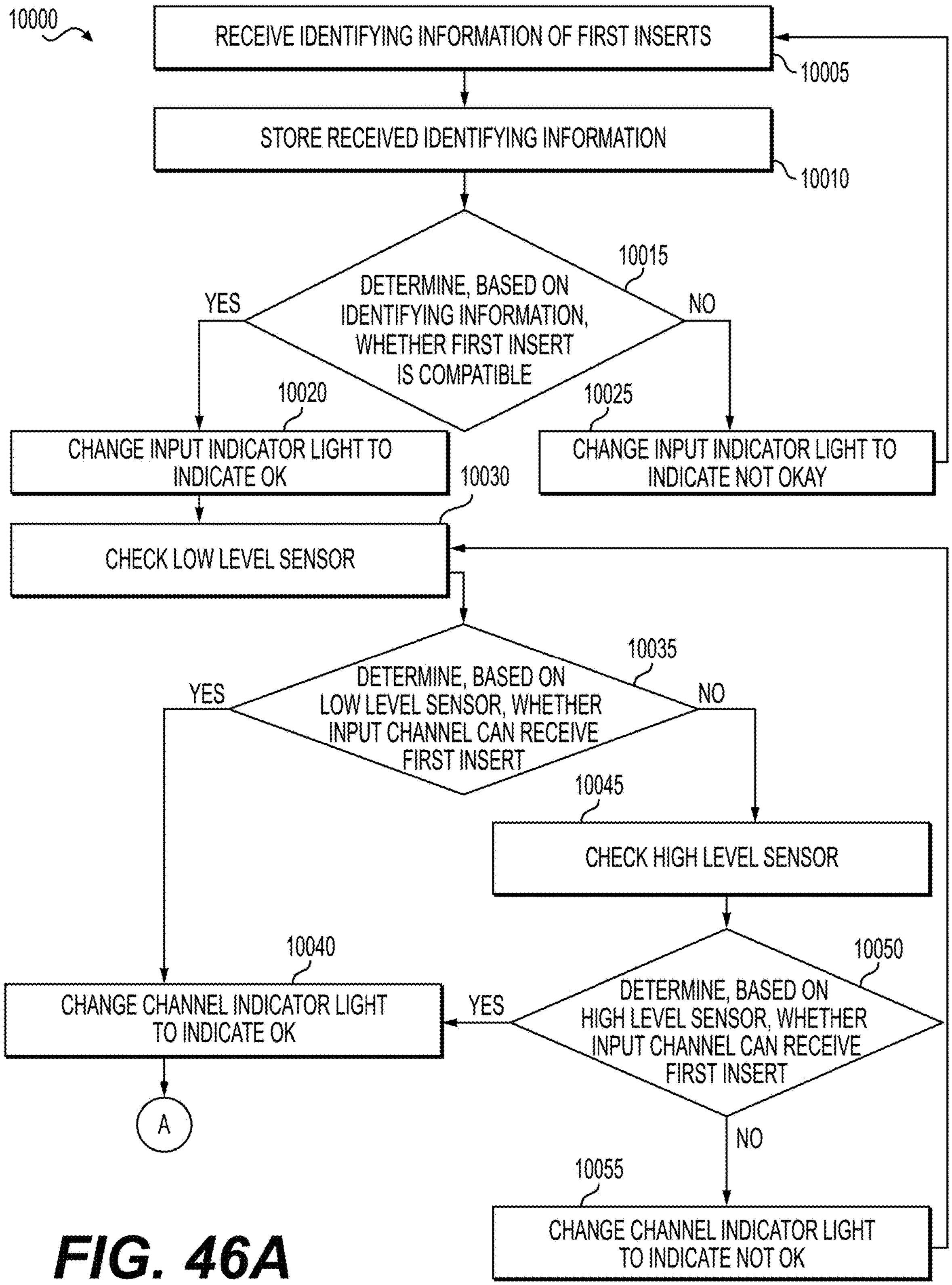

10000
RECEIVE IDENTIFYING INFORMATION OF FIRST INSERTS
10005
STORE RECEIVED IDENTIFYING INFORMATION
10010
DETERMINE, BASED ON IDENTIFYING INFORMATION, WHETHER FIRST INSERT IS COMPATIBLE
10015
YES
NO
10020
CHANGE INPUT INDICATOR LIGHT TO INDICATE OK
10025
CHANGE INPUT INDICATOR LIGHT TO INDICATE NOT OKAY
10030
CHECK LOW LEVEL SENSOR
DETERMINE, BASED ON LOW LEVEL SENSOR, WHETHER INPUT CHANNEL CAN RECEIVE FIRST INSERT
10035
YES
NO
10045
CHECK HIGH LEVEL SENSOR
10040
CHANGE CHANNEL INDICATOR LIGHT TO INDICATE OK
YES
DETERMINE, BASED ON HIGH LEVEL SENSOR, WHETHER INPUT CHANNEL CAN RECEIVE FIRST INSERT
10050
A
NO
10055
CHANGE CHANNEL INDICATOR LIGHT TO INDICATE NOT OK

FIG. 46A

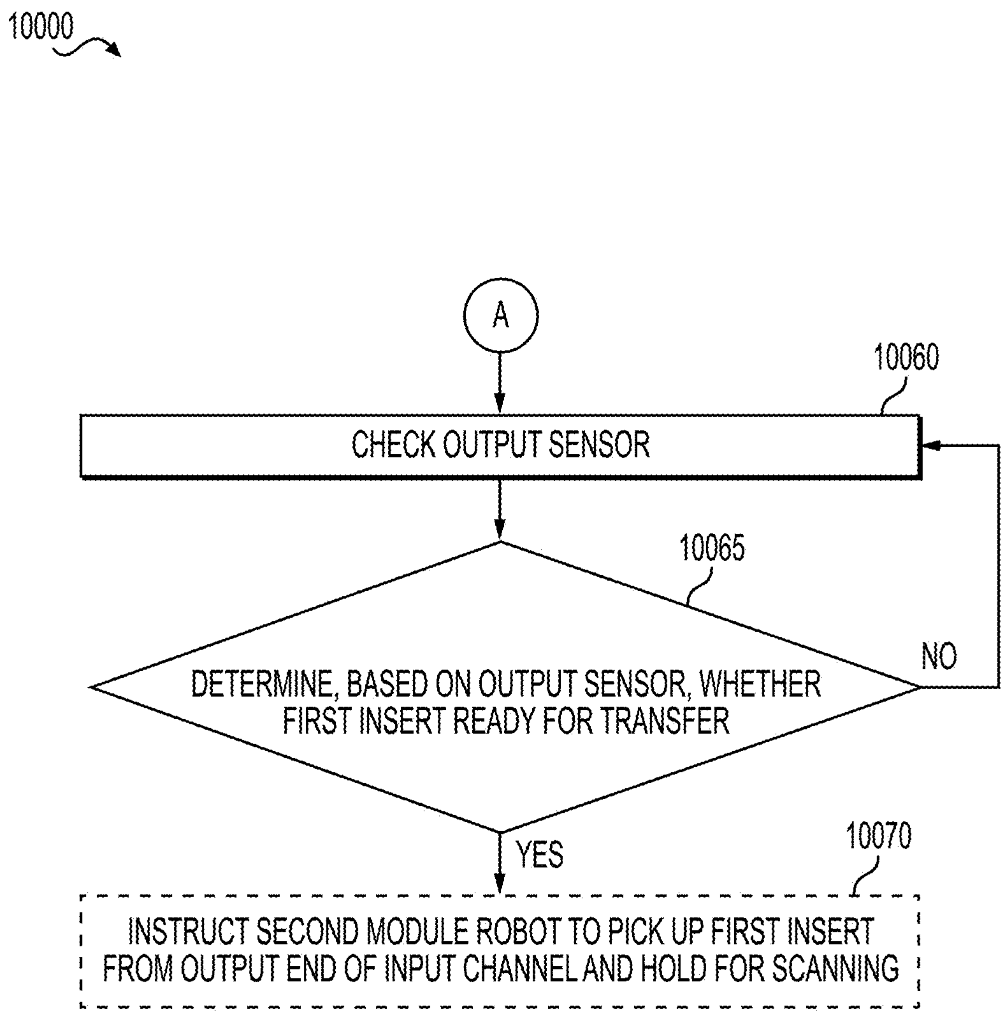

10000
A
10060
CHECK OUTPUT SENSOR
10065
DETERMINE, BASED ON OUTPUT SENSOR, WHETHER FIRST INSERT READY FOR TRANSFER
NO
YES
10070
INSTRUCT SECOND MODULE ROBOT TO PICK UP FIRST INSERT FROM OUTPUT END OF INPUT CHANNEL AND HOLD FOR SCANNING

FIG. 46B

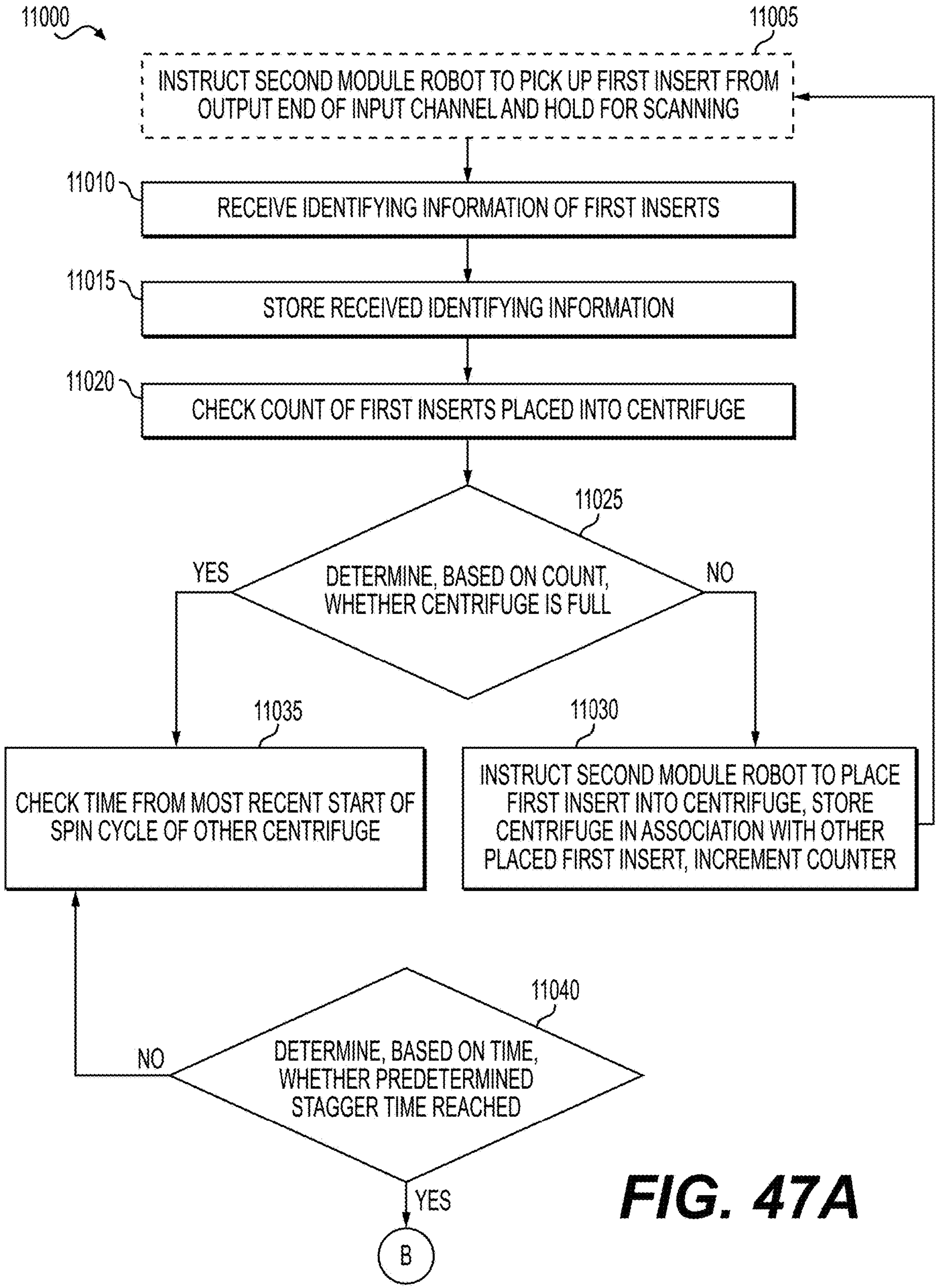

11000
11005
INSTRUCT SECOND MODULE ROBOT TO PICK UP FIRST INSERT FROM OUTPUT END OF INPUT CHANNEL AND HOLD FOR SCANNING
11010
RECEIVE IDENTIFYING INFORMATION OF FIRST INSERTS
11015
STORE RECEIVED IDENTIFYING INFORMATION
11020
CHECK COUNT OF FIRST INSERTS PLACED INTO CENTRIFUGE
11025
DETERMINE, BASED ON COUNT, WHETHER CENTRIFUGE IS FULL
YES
NO
11035
CHECK TIME FROM MOST RECENT START OF SPIN CYCLE OF OTHER CENTRIFUGE
11030
INSTRUCT SECOND MODULE ROBOT TO PLACE FIRST INSERT INTO CENTRIFUGE, STORE CENTRIFUGE IN ASSOCIATION WITH OTHER PLACED FIRST INSERT, INCREMENT COUNTER
11040
DETERMINE, BASED ON TIME, WHETHER PREDETERMINED STAGGER TIME REACHED
NO
YES
B

FIG. 47A

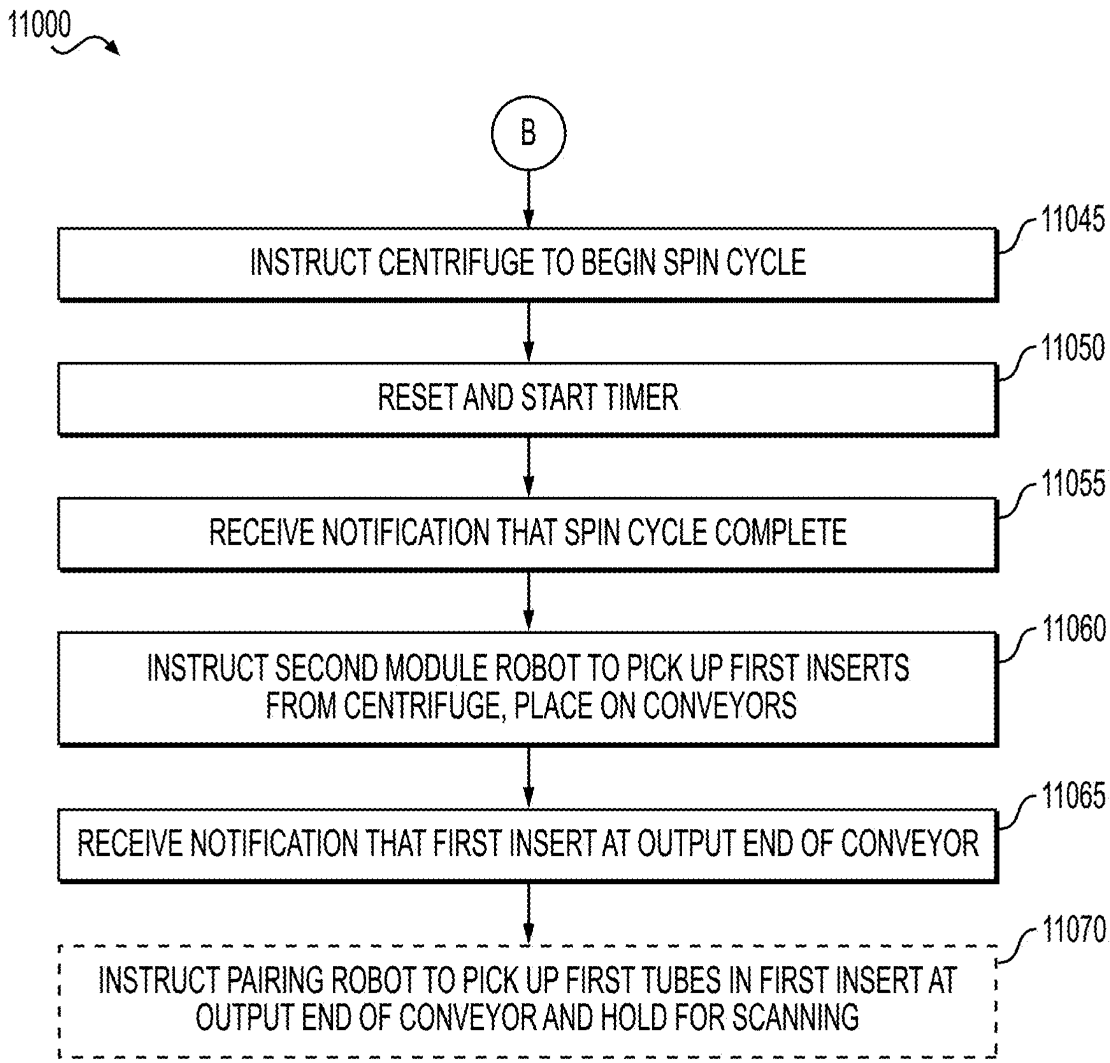

11000
B
INSTRUCT CENTRIFUGE TO BEGIN SPIN CYCLE
11045
RESET AND START TIMER
11050
RECEIVE NOTIFICATION THAT SPIN CYCLE COMPLETE
11055
INSTRUCT SECOND MODULE ROBOT TO PICK UP FIRST INSERTS FROM CENTRIFUGE, PLACE ON CONVEYORS
11060
RECEIVE NOTIFICATION THAT FIRST INSERT AT OUTPUT END OF CONVEYOR
11065
INSTRUCT PAIRING ROBOT TO PICK UP FIRST TUBES IN FIRST INSERT AT OUTPUT END OF CONVEYOR AND HOLD FOR SCANNING
11070

FIG. 47B

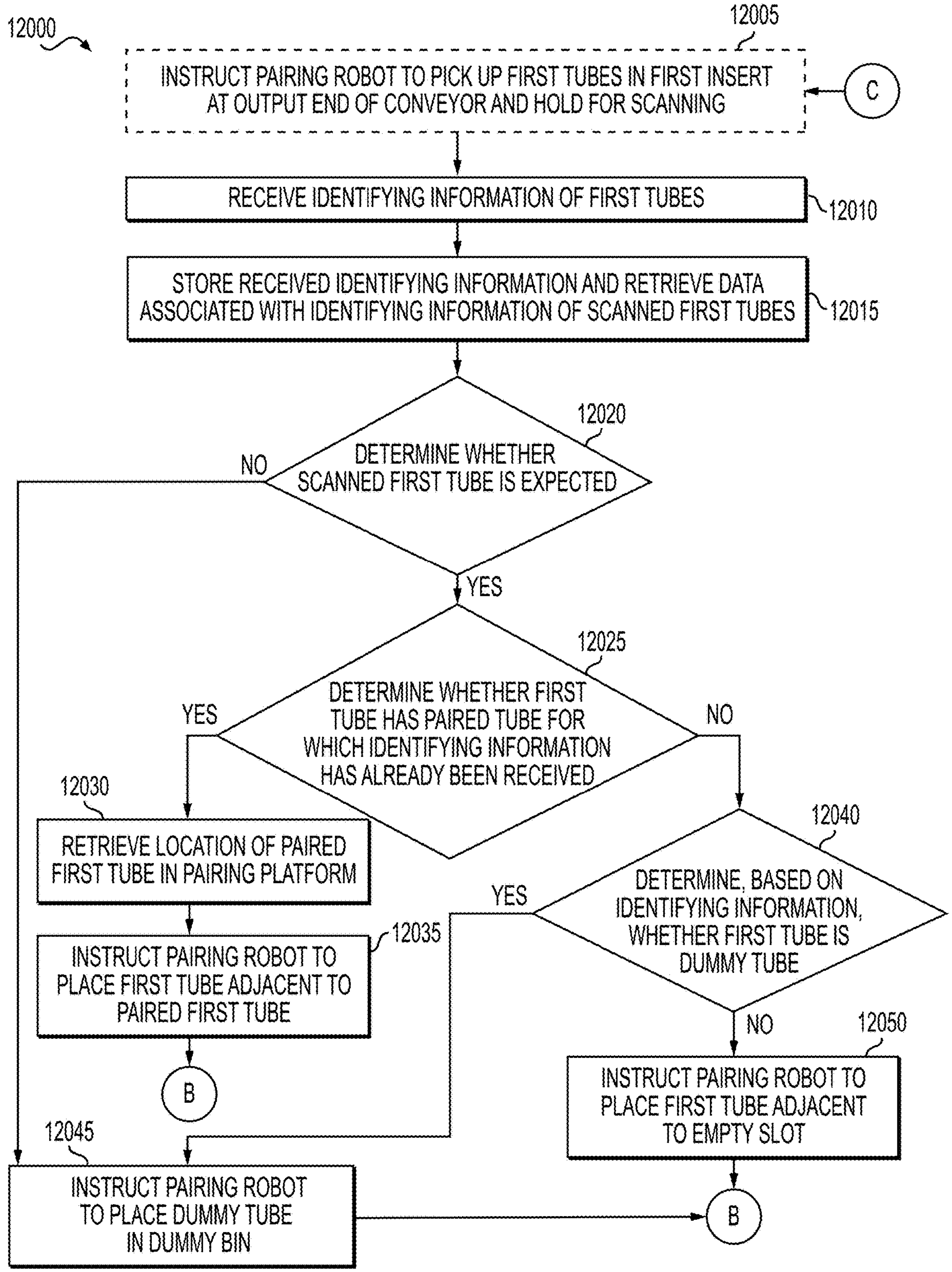

12000
12005
INSTRUCT PAIRING ROBOT TO PICK UP FIRST TUBES IN FIRST INSERT AT OUTPUT END OF CONVEYOR AND HOLD FOR SCANNING
C
RECEIVE IDENTIFYING INFORMATION OF FIRST TUBES
12010
STORE RECEIVED IDENTIFYING INFORMATION AND RETRIEVE DATA ASSOCIATED WITH IDENTIFYING INFORMATION OF SCANNED FIRST TUBES
12015
12020
DETERMINE WHETHER SCANNED FIRST TUBE IS EXPECTED
NO
YES
12025
DETERMINE WHETHER FIRST TUBE HAS PAIRED TUBE FOR WHICH IDENTIFYING INFORMATION HAS ALREADY BEEN RECEIVED
YES
NO
12030
RETRIEVE LOCATION OF PAIRED FIRST TUBE IN PAIRING PLATFORM
12035
INSTRUCT PAIRING ROBOT TO PLACE FIRST TUBE ADJACENT TO PAIRED FIRST TUBE
B
12040
DETERMINE, BASED ON IDENTIFYING INFORMATION, WHETHER FIRST TUBE IS DUMMY TUBE
YES
NO
12050
INSTRUCT PAIRING ROBOT TO PLACE FIRST TUBE ADJACENT TO EMPTY SLOT
12045
INSTRUCT PAIRING ROBOT TO PLACE DUMMY TUBE IN DUMMY BIN
B

FIG. 48A

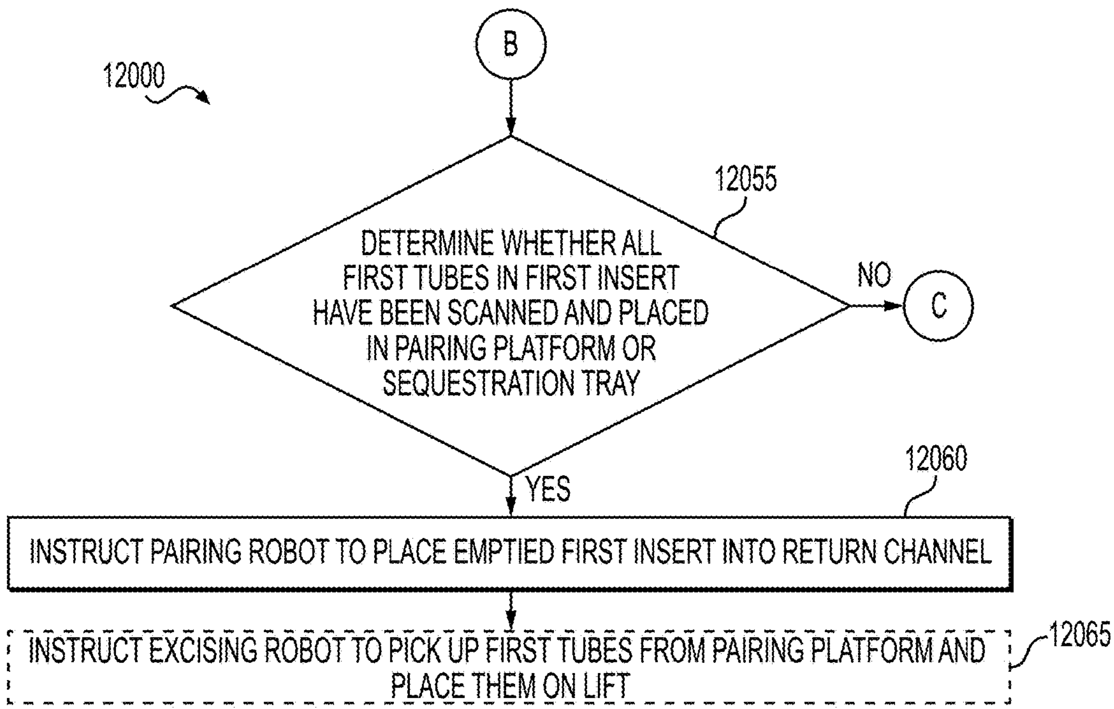


FIG. 48B

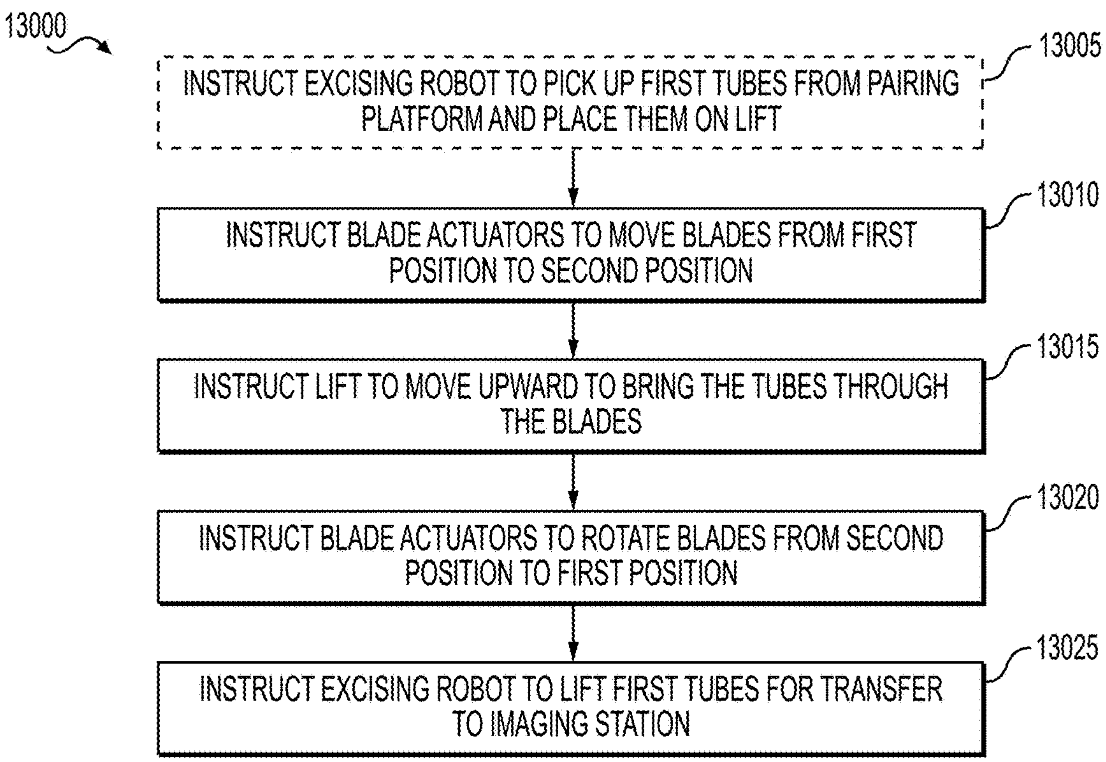


FIG. 49

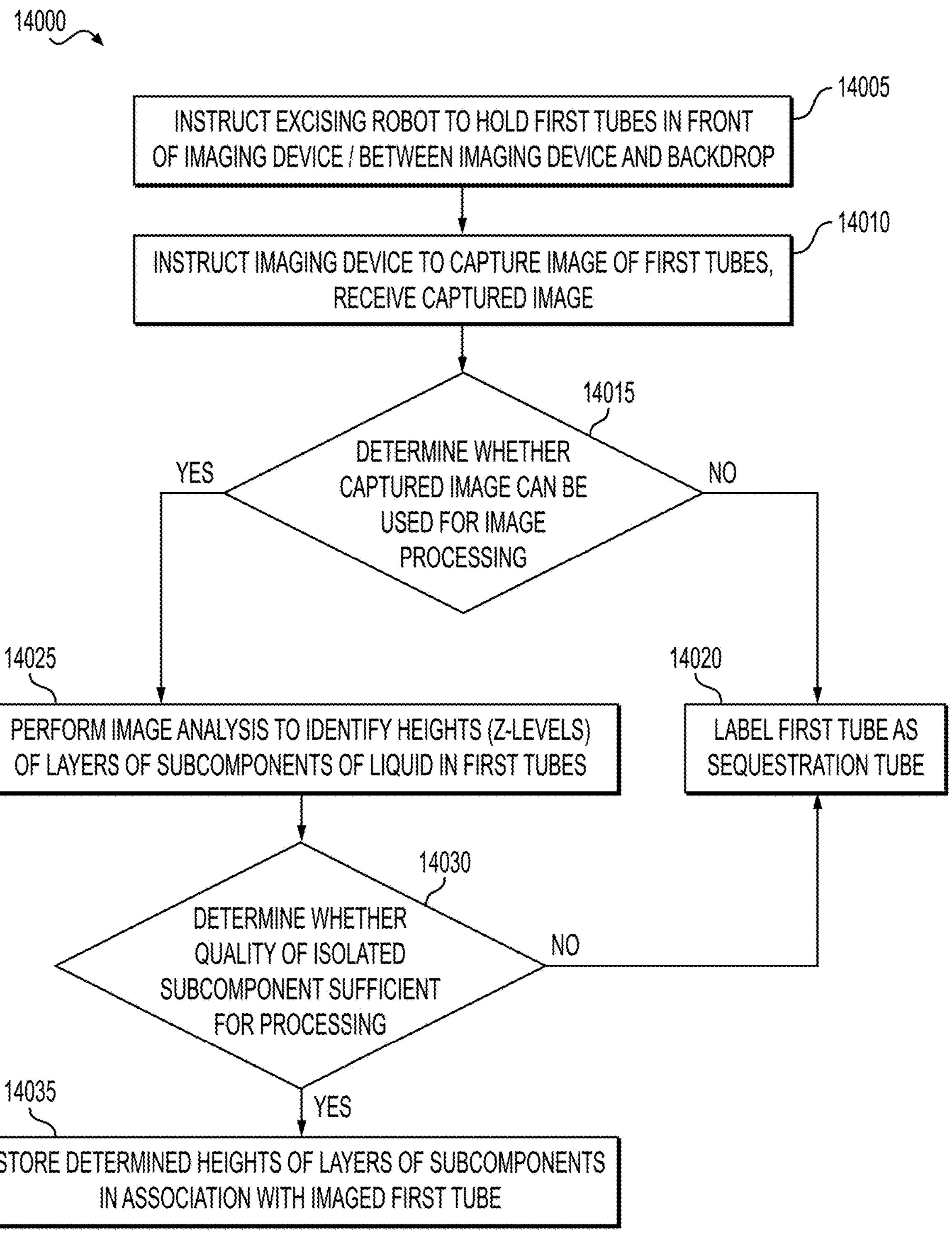

14000
14005
INSTRUCT EXCISING ROBOT TO HOLD FIRST TUBES IN FRONT OF IMAGING DEVICE / BETWEEN IMAGING DEVICE AND BACKDROP
14010
INSTRUCT IMAGING DEVICE TO CAPTURE IMAGE OF FIRST TUBES, RECEIVE CAPTURED IMAGE
14015
DETERMINE WHETHER CAPTURED IMAGE CAN BE USED FOR IMAGE PROCESSING
YES
NO
14025
PERFORM IMAGE ANALYSIS TO IDENTIFY HEIGHTS (Z-LEVELS) OF LAYERS OF SUBCOMPONENTS OF LIQUID IN FIRST TUBES
14020
LABEL FIRST TUBE AS SEQUESTRATION TUBE
14030
DETERMINE WHETHER QUALITY OF ISOLATED SUBCOMPONENT SUFFICIENT FOR PROCESSING
NO
YES
14035
STORE DETERMINED HEIGHTS OF LAYERS OF SUBCOMPONENTS IN ASSOCIATION WITH IMAGED FIRST TUBE

FIG. 50

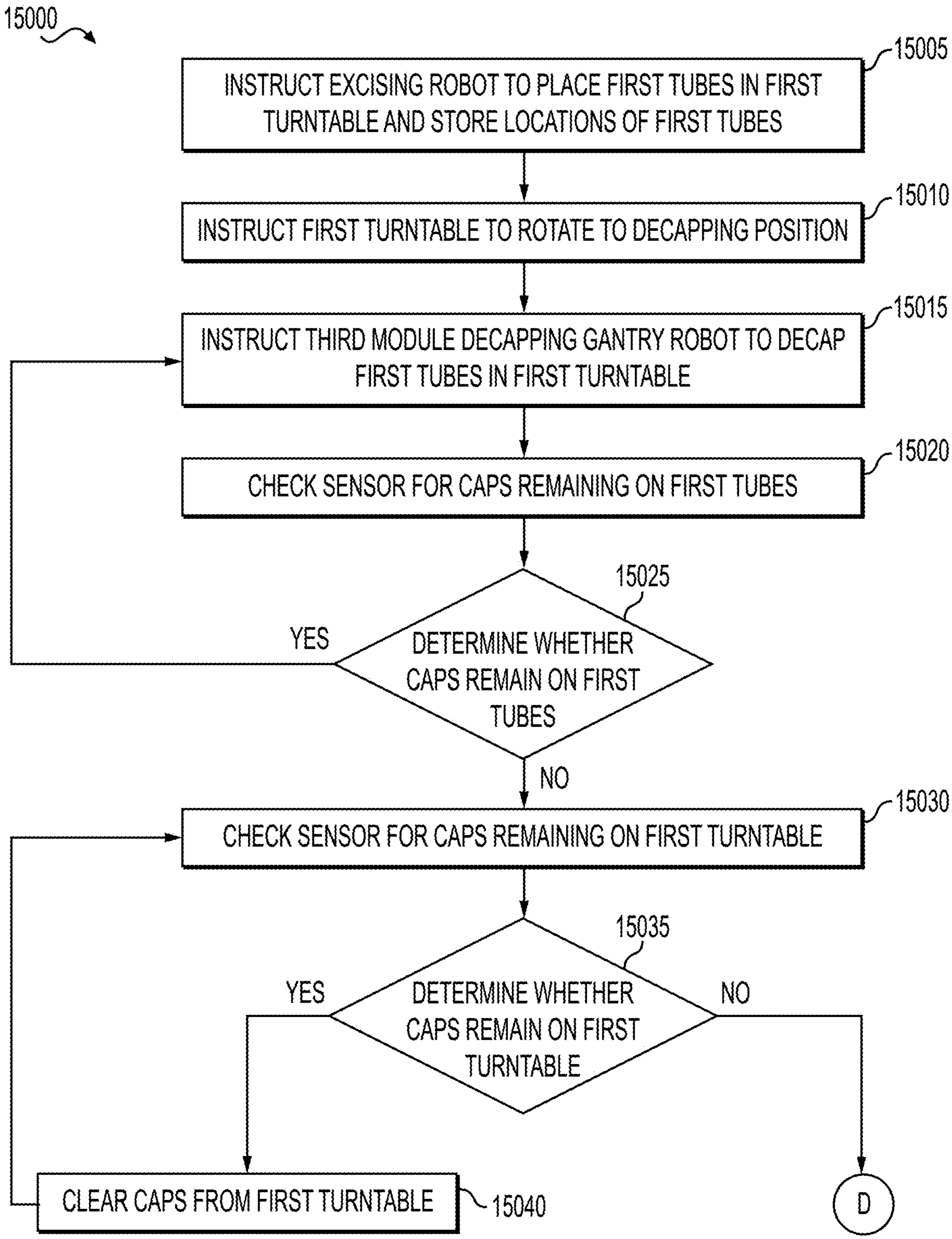

15000
INSTRUCT EXCISING ROBOT TO PLACE FIRST TUBES IN FIRST TURNTABLE AND STORE LOCATIONS OF FIRST TUBES
15005
INSTRUCT FIRST TURNTABLE TO ROTATE TO DECAPPING POSITION
15010
INSTRUCT THIRD MODULE DECAPPING GANTRY ROBOT TO DECAP FIRST TUBES IN FIRST TURNTABLE
15015
CHECK SENSOR FOR CAPS REMAINING ON FIRST TUBES
15020
DETERMINE WHETHER CAPS REMAIN ON FIRST TUBES
15025
YES
NO
CHECK SENSOR FOR CAPS REMAINING ON FIRST TURNTABLE
15030
DETERMINE WHETHER CAPS REMAIN ON FIRST TURNTABLE
15035
YES
NO
CLEAR CAPS FROM FIRST TURNTABLE
15040
D

FIG. 51A

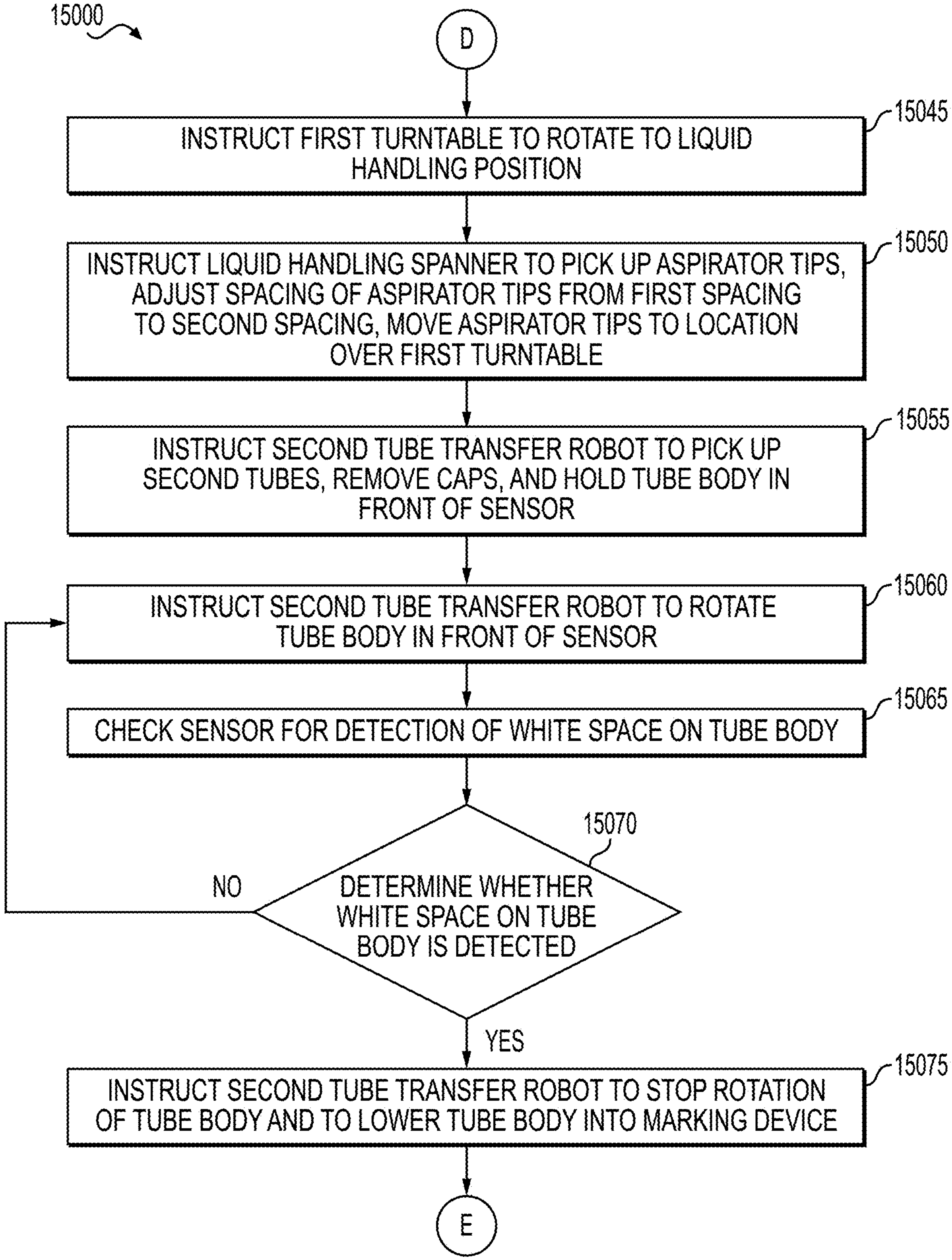

15000
D
INSTRUCT FIRST TURNTABLE TO ROTATE TO LIQUID HANDLING POSITION
15045
INSTRUCT LIQUID HANDLING SPANNER TO PICK UP ASPIRATOR TIPS, ADJUST SPACING OF ASPIRATOR TIPS FROM FIRST SPACING TO SECOND SPACING, MOVE ASPIRATOR TIPS TO LOCATION OVER FIRST TURNTABLE
15050
INSTRUCT SECOND TUBE TRANSFER ROBOT TO PICK UP SECOND TUBES, REMOVE CAPS, AND HOLD TUBE BODY IN FRONT OF SENSOR
15055
INSTRUCT SECOND TUBE TRANSFER ROBOT TO ROTATE TUBE BODY IN FRONT OF SENSOR
15060
CHECK SENSOR FOR DETECTION OF WHITE SPACE ON TUBE BODY
15065
DETERMINE WHETHER WHITE SPACE ON TUBE BODY IS DETECTED
15070
NO
YES
INSTRUCT SECOND TUBE TRANSFER ROBOT TO STOP ROTATION OF TUBE BODY AND TO LOWER TUBE BODY INTO MARKING DEVICE
15075
E

FIG. 51B

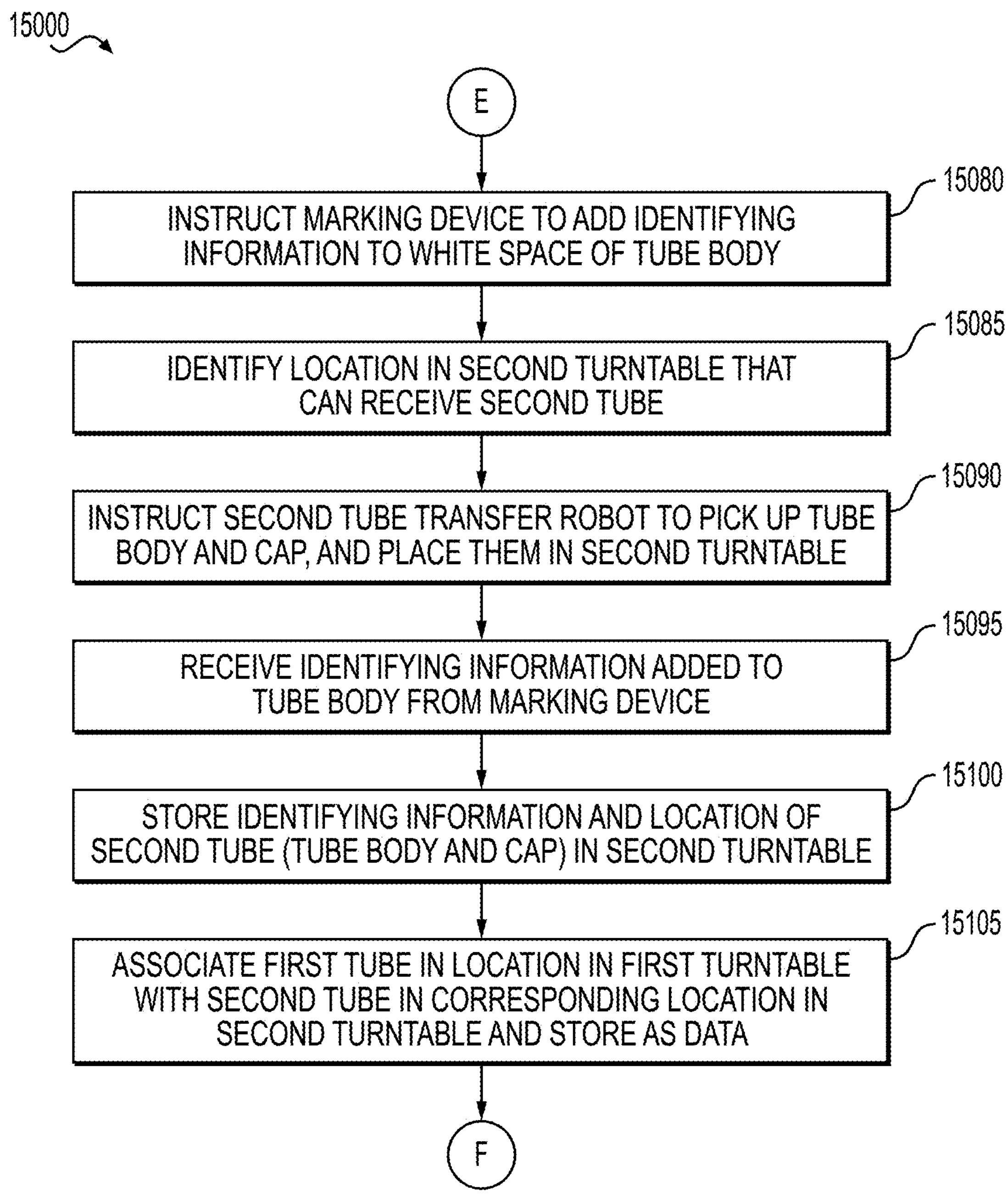

15000
E
INSTRUCT MARKING DEVICE TO ADD IDENTIFYING INFORMATION TO WHITE SPACE OF TUBE BODY
15080
IDENTIFY LOCATION IN SECOND TURNTABLE THAT CAN RECEIVE SECOND TUBE
15085
INSTRUCT SECOND TUBE TRANSFER ROBOT TO PICK UP TUBE BODY AND CAP, AND PLACE THEM IN SECOND TURNTABLE
15090
RECEIVE IDENTIFYING INFORMATION ADDED TO TUBE BODY FROM MARKING DEVICE
15095
STORE IDENTIFYING INFORMATION AND LOCATION OF SECOND TUBE (TUBE BODY AND CAP) IN SECOND TURNTABLE
15100
ASSOCIATE FIRST TUBE IN LOCATION IN FIRST TURNTABLE WITH SECOND TUBE IN CORRESPONDING LOCATION IN SECOND TURNTABLE AND STORE AS DATA
15105
F

FIG. 51C

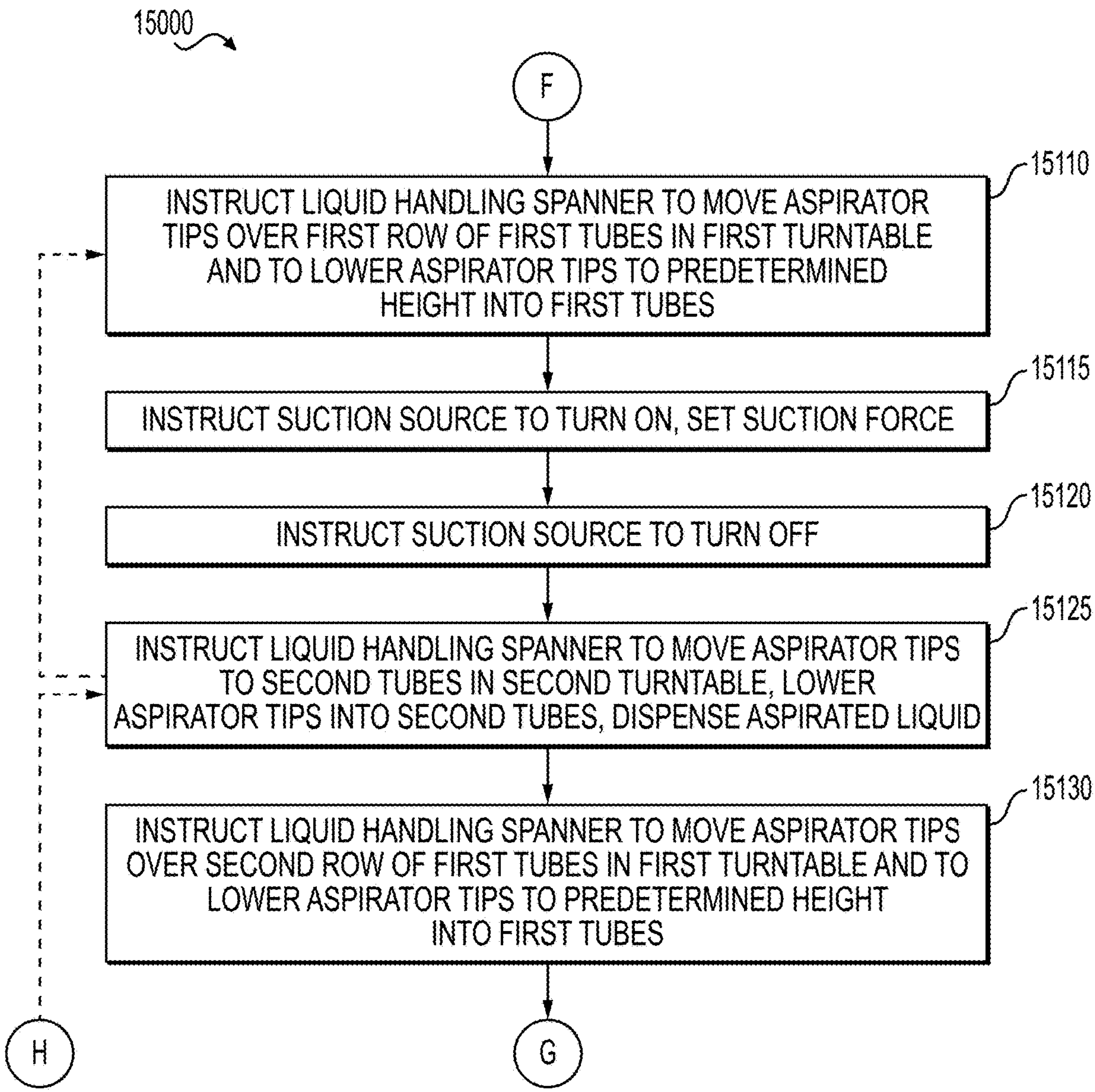

15000
F
INSTRUCT LIQUID HANDLING SPANNER TO MOVE ASPIRATOR TIPS OVER FIRST ROW OF FIRST TUBES IN FIRST TURNTABLE AND TO LOWER ASPIRATOR TIPS TO PREDETERMINED HEIGHT INTO FIRST TUBES
15110
INSTRUCT SUCTION SOURCE TO TURN ON, SET SUCTION FORCE
15115
INSTRUCT SUCTION SOURCE TO TURN OFF
15120
INSTRUCT LIQUID HANDLING SPANNER TO MOVE ASPIRATOR TIPS TO SECOND TUBES IN SECOND TURNTABLE, LOWER ASPIRATOR TIPS INTO SECOND TUBES, DISPENSE ASPIRATED LIQUID
15125
INSTRUCT LIQUID HANDLING SPANNER TO MOVE ASPIRATOR TIPS OVER SECOND ROW OF FIRST TUBES IN FIRST TURNTABLE AND TO LOWER ASPIRATOR TIPS TO PREDETERMINED HEIGHT INTO FIRST TUBES
15130
H
G

FIG. 51D

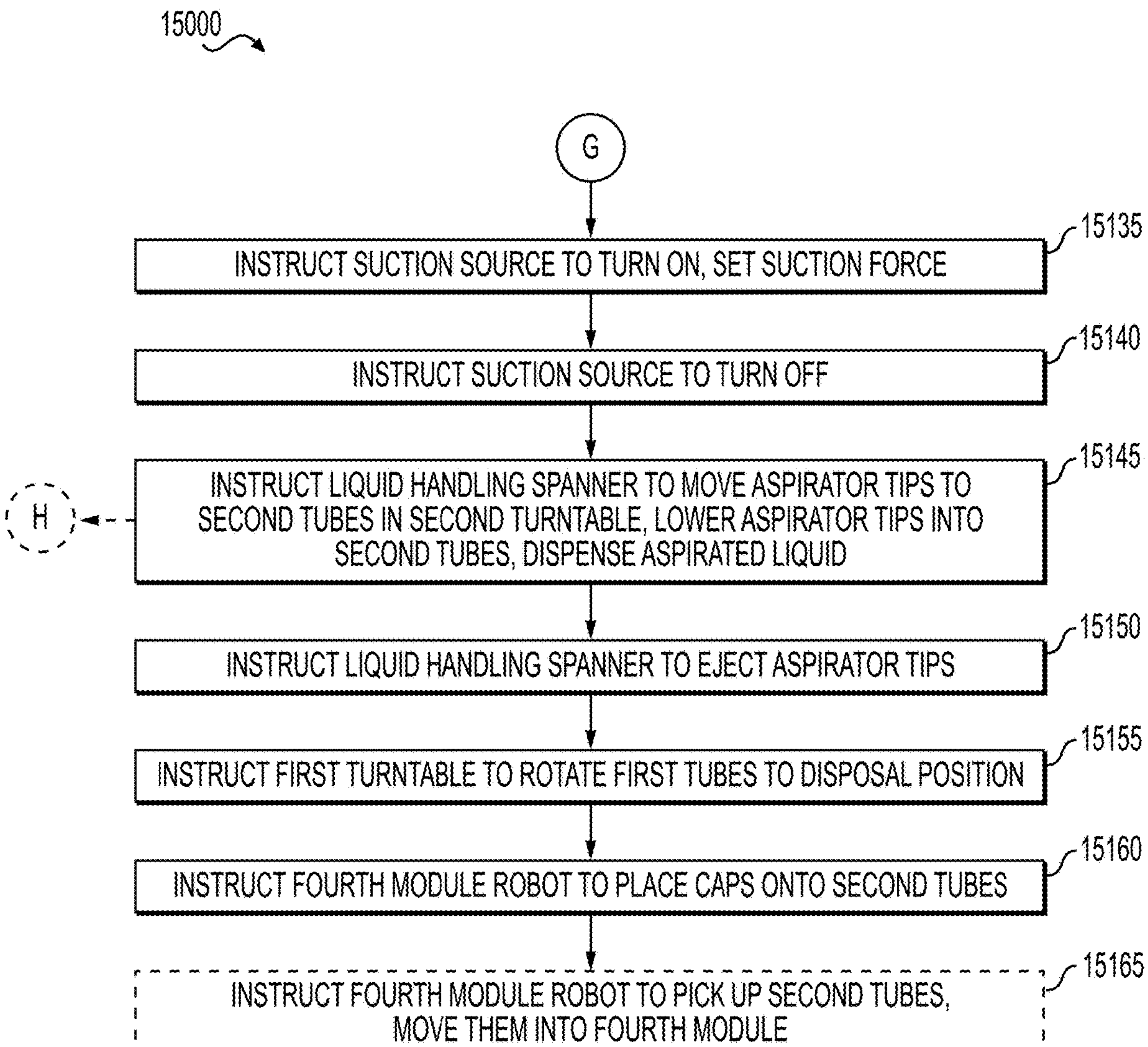

15000
G
INSTRUCT SUCTION SOURCE TO TURN ON, SET SUCTION FORCE
15135
INSTRUCT SUCTION SOURCE TO TURN OFF
15140
INSTRUCT LIQUID HANDLING SPANNER TO MOVE ASPIRATOR TIPS TO SECOND TUBES IN SECOND TURNTABLE, LOWER ASPIRATOR TIPS INTO SECOND TUBES, DISPENSE ASPIRATED LIQUID
15145
H
INSTRUCT LIQUID HANDLING SPANNER TO EJECT ASPIRATOR TIPS
15150
INSTRUCT FIRST TURNTABLE TO ROTATE FIRST TUBES TO DISPOSAL POSITION
15155
INSTRUCT FOURTH MODULE ROBOT TO PLACE CAPS ONTO SECOND TUBES
15160
INSTRUCT FOURTH MODULE ROBOT TO PICK UP SECOND TUBES, MOVE THEM INTO FOURTH MODULE
15165

FIG. 51E

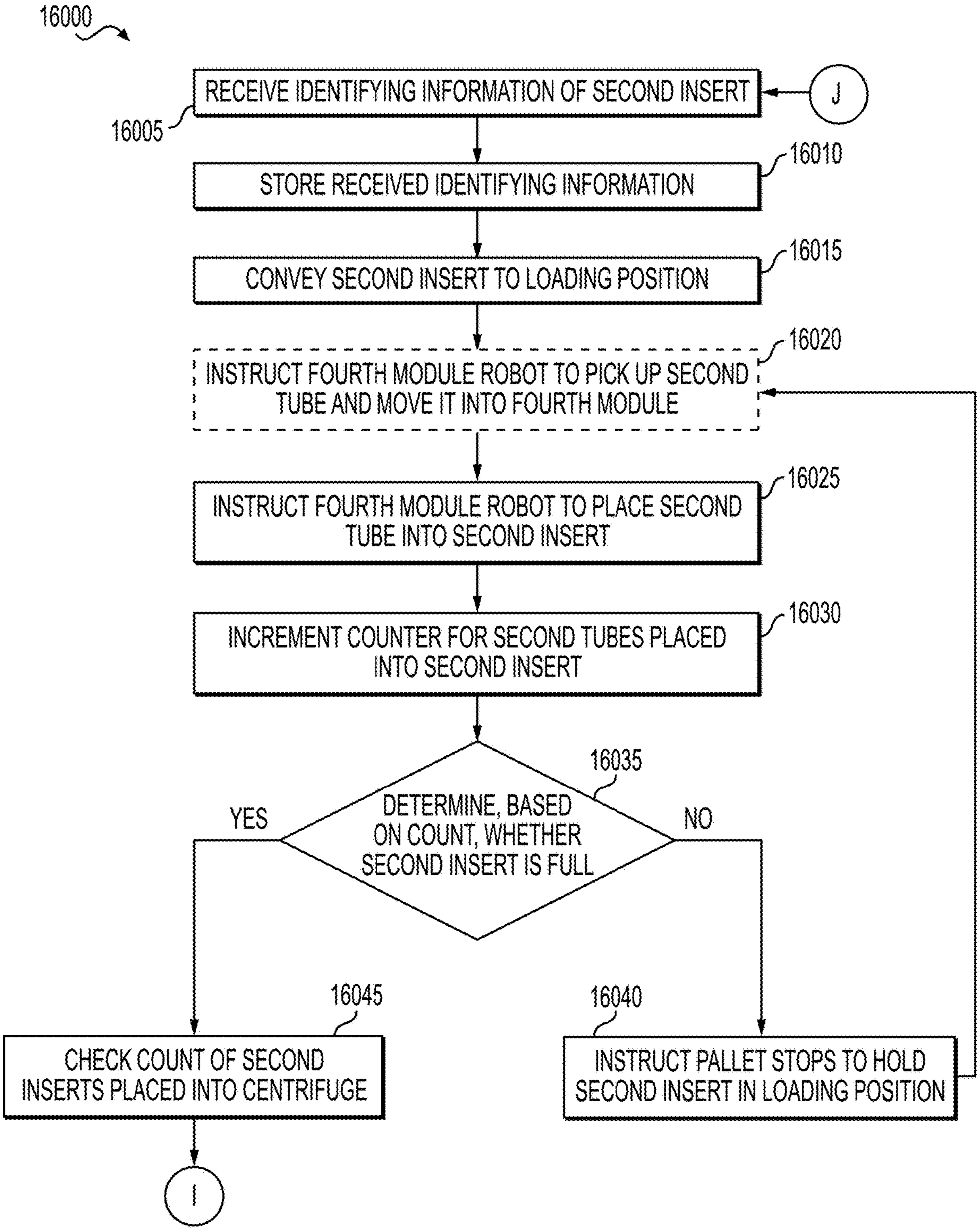

16000
RECEIVE IDENTIFYING INFORMATION OF SECOND INSERT
J
16005
STORE RECEIVED IDENTIFYING INFORMATION
16010
CONVEY SECOND INSERT TO LOADING POSITION
16015
INSTRUCT FOURTH MODULE ROBOT TO PICK UP SECOND TUBE AND MOVE IT INTO FOURTH MODULE
16020
INSTRUCT FOURTH MODULE ROBOT TO PLACE SECOND TUBE INTO SECOND INSERT
16025
INCREMENT COUNTER FOR SECOND TUBES PLACED INTO SECOND INSERT
16030
DETERMINE, BASED ON COUNT, WHETHER SECOND INSERT IS FULL
16035
YES
NO
CHECK COUNT OF SECOND INSERTS PLACED INTO CENTRIFUGE
16045
INSTRUCT PALLET STOPS TO HOLD SECOND INSERT IN LOADING POSITION
16040
I

FIG. 52A

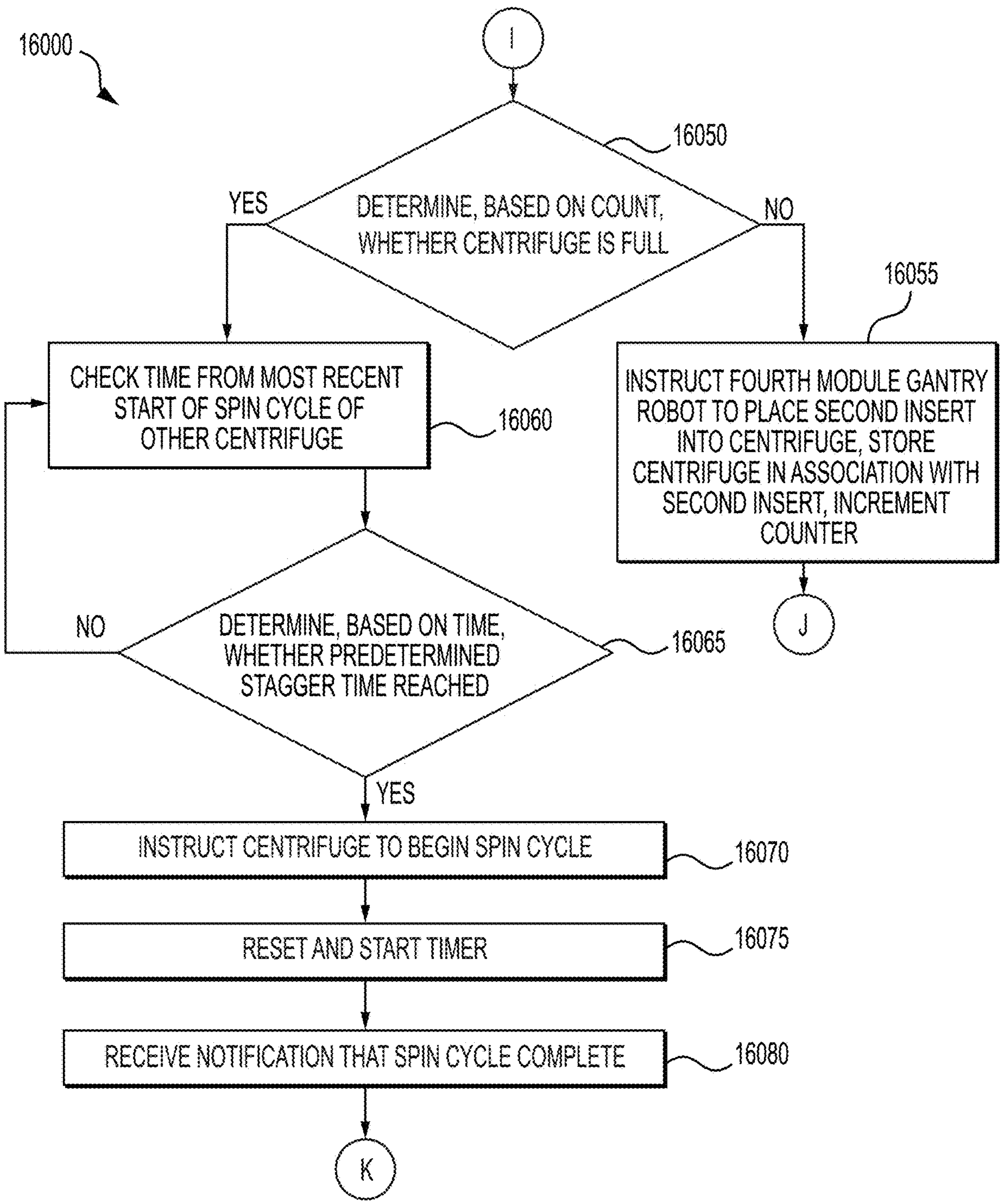

16000
I
DETERMINE, BASED ON COUNT, WHETHER CENTRIFUGE IS FULL
16050
YES
NO
16055
INSTRUCT FOURTH MODULE GANTRY ROBOT TO PLACE SECOND INSERT INTO CENTRIFUGE, STORE CENTRIFUGE IN ASSOCIATION WITH SECOND INSERT, INCREMENT COUNTER
J
CHECK TIME FROM MOST RECENT START OF SPIN CYCLE OF OTHER CENTRIFUGE
16060
DETERMINE, BASED ON TIME, WHETHER PREDETERMINED STAGGER TIME REACHED
16065
NO
YES
INSTRUCT CENTRIFUGE TO BEGIN SPIN CYCLE
16070
RESET AND START TIMER
16075
RECEIVE NOTIFICATION THAT SPIN CYCLE COMPLETE
16080
K

FIG. 52B

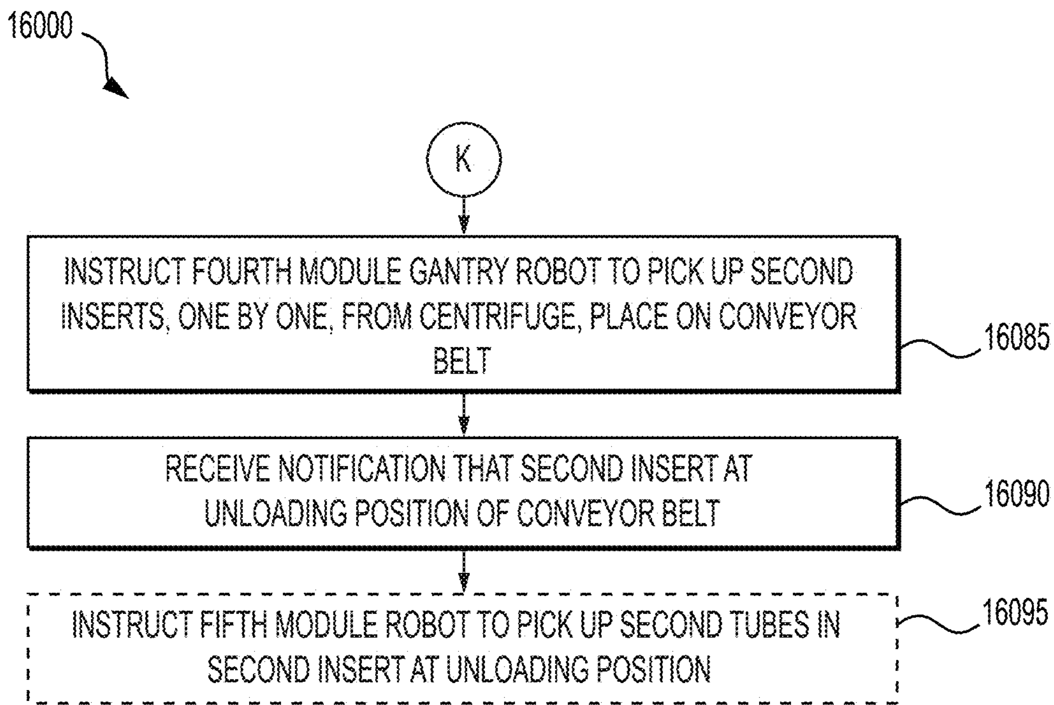

16000
K
INSTRUCT FOURTH MODULE GANTRY ROBOT TO PICK UP SECOND INSERTS, ONE BY ONE, FROM CENTRIFUGE, PLACE ON CONVEYOR BELT
16085
RECEIVE NOTIFICATION THAT SECOND INSERT AT UNLOADING POSITION OF CONVEYOR BELT
16090
INSTRUCT FIFTH MODULE ROBOT TO PICK UP SECOND TUBES IN SECOND INSERT AT UNLOADING POSITION
16095

FIG. 52C

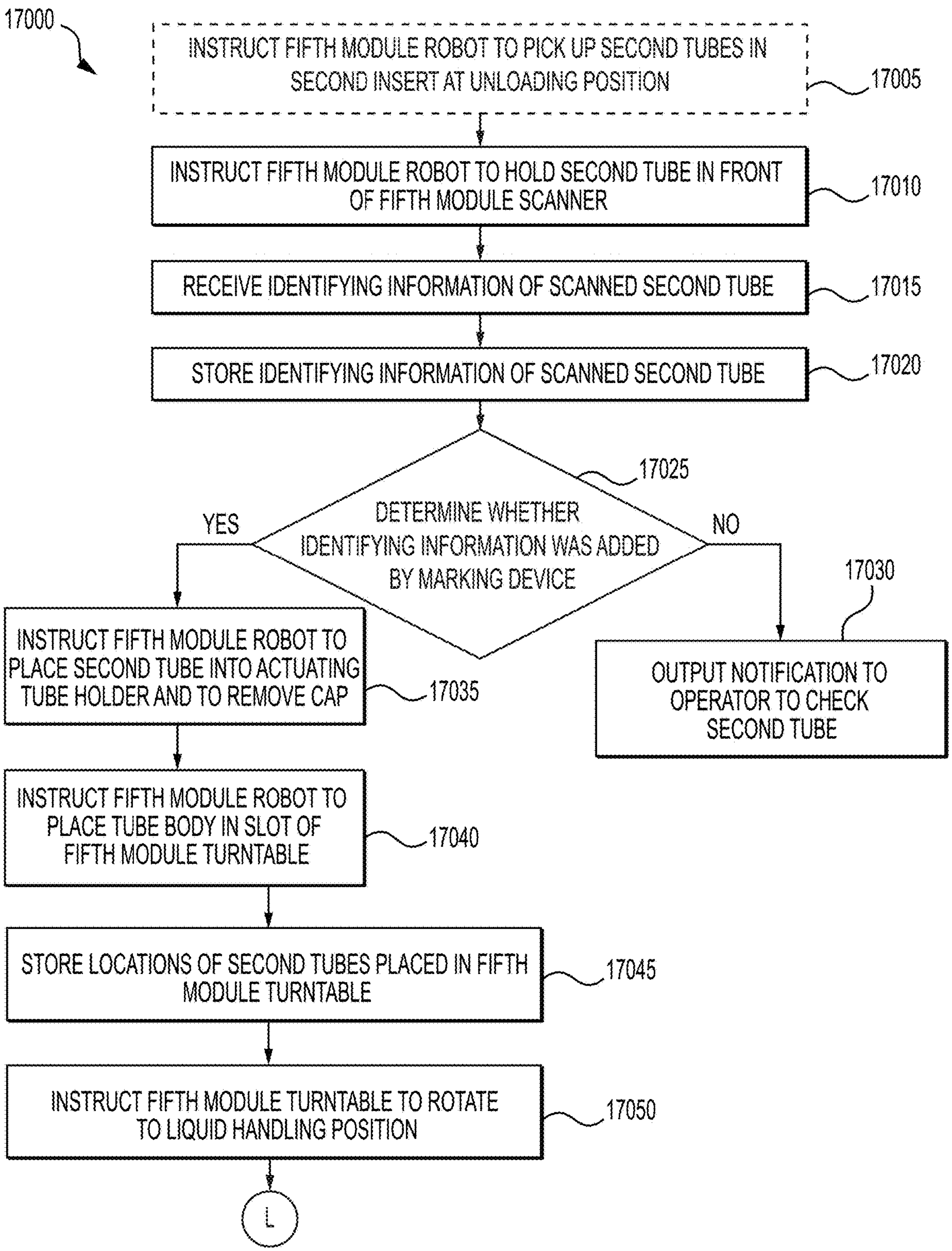

17000
INSTRUCT FIFTH MODULE ROBOT TO PICK UP SECOND TUBES IN SECOND INSERT AT UNLOADING POSITION
17005
INSTRUCT FIFTH MODULE ROBOT TO HOLD SECOND TUBE IN FRONT OF FIFTH MODULE SCANNER
17010
RECEIVE IDENTIFYING INFORMATION OF SCANNED SECOND TUBE
17015
STORE IDENTIFYING INFORMATION OF SCANNED SECOND TUBE
17020
DETERMINE WHETHER IDENTIFYING INFORMATION WAS ADDED BY MARKING DEVICE
17025
YES
NO
17030
INSTRUCT FIFTH MODULE ROBOT TO PLACE SECOND TUBE INTO ACTUATING TUBE HOLDER AND TO REMOVE CAP
17035
OUTPUT NOTIFICATION TO OPERATOR TO CHECK SECOND TUBE
INSTRUCT FIFTH MODULE ROBOT TO PLACE TUBE BODY IN SLOT OF FIFTH MODULE TURNTABLE
17040
STORE LOCATIONS OF SECOND TUBES PLACED IN FIFTH MODULE TURNTABLE
17045
INSTRUCT FIFTH MODULE TURNTABLE TO ROTATE TO LIQUID HANDLING POSITION
17050
L

FIG. 53A

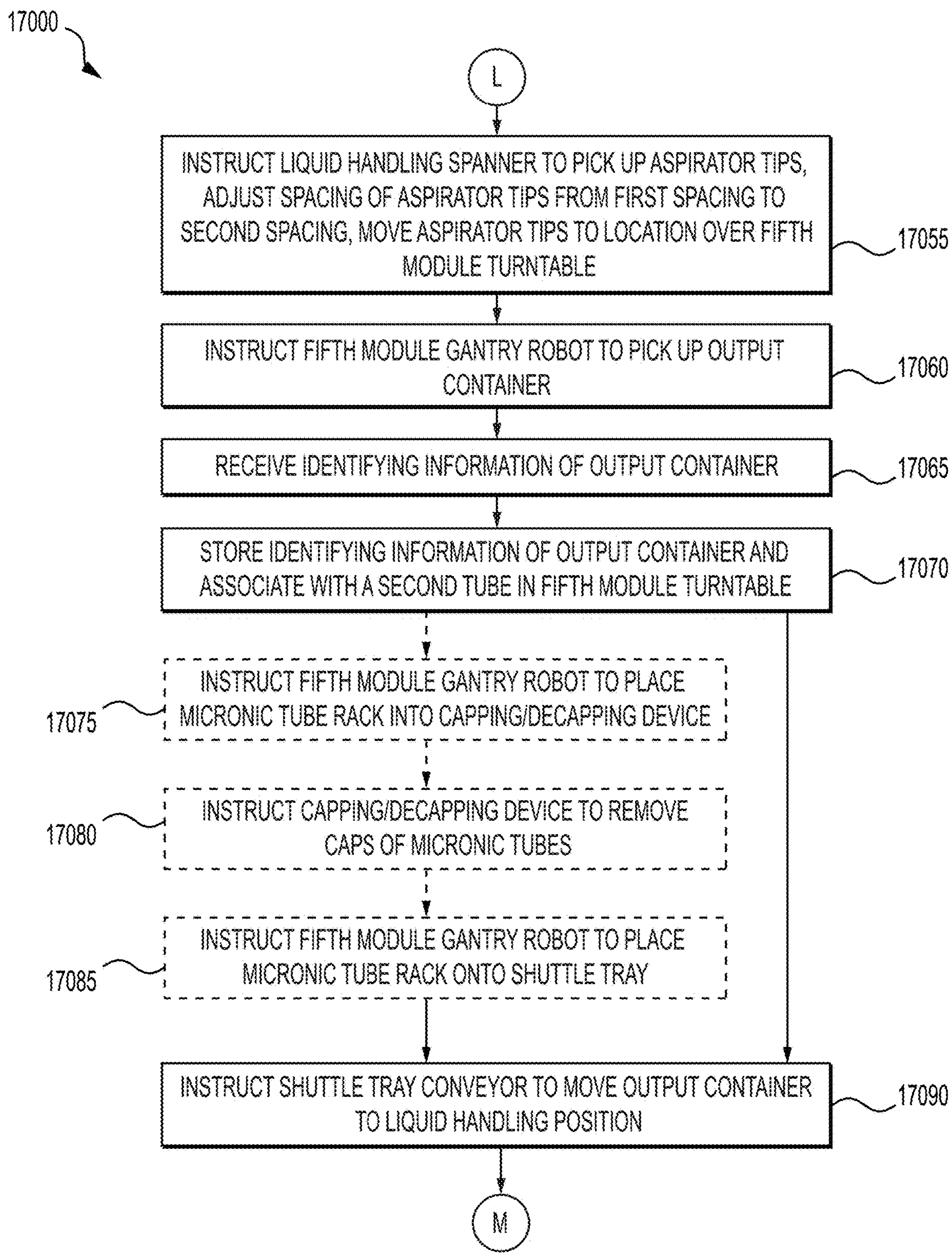

17000
L
INSTRUCT LIQUID HANDLING SPANNER TO PICK UP ASPIRATOR TIPS, ADJUST SPACING OF ASPIRATOR TIPS FROM FIRST SPACING TO SECOND SPACING, MOVE ASPIRATOR TIPS TO LOCATION OVER FIFTH MODULE TURNTABLE
17055
INSTRUCT FIFTH MODULE GANTRY ROBOT TO PICK UP OUTPUT CONTAINER
17060
RECEIVE IDENTIFYING INFORMATION OF OUTPUT CONTAINER
17065
STORE IDENTIFYING INFORMATION OF OUTPUT CONTAINER AND ASSOCIATE WITH A SECOND TUBE IN FIFTH MODULE TURNTABLE
17070
INSTRUCT FIFTH MODULE GANTRY ROBOT TO PLACE MICRONIC TUBE RACK INTO CAPPING/DECAPPING DEVICE
17075
INSTRUCT CAPPING/DECAPPING DEVICE TO REMOVE CAPS OF MICRONIC TUBES
17080
INSTRUCT FIFTH MODULE GANTRY ROBOT TO PLACE MICRONIC TUBE RACK ONTO SHUTTLE TRAY
17085
INSTRUCT SHUTTLE TRAY CONVEYOR TO MOVE OUTPUT CONTAINER TO LIQUID HANDLING POSITION
17090
M

FIG. 53B

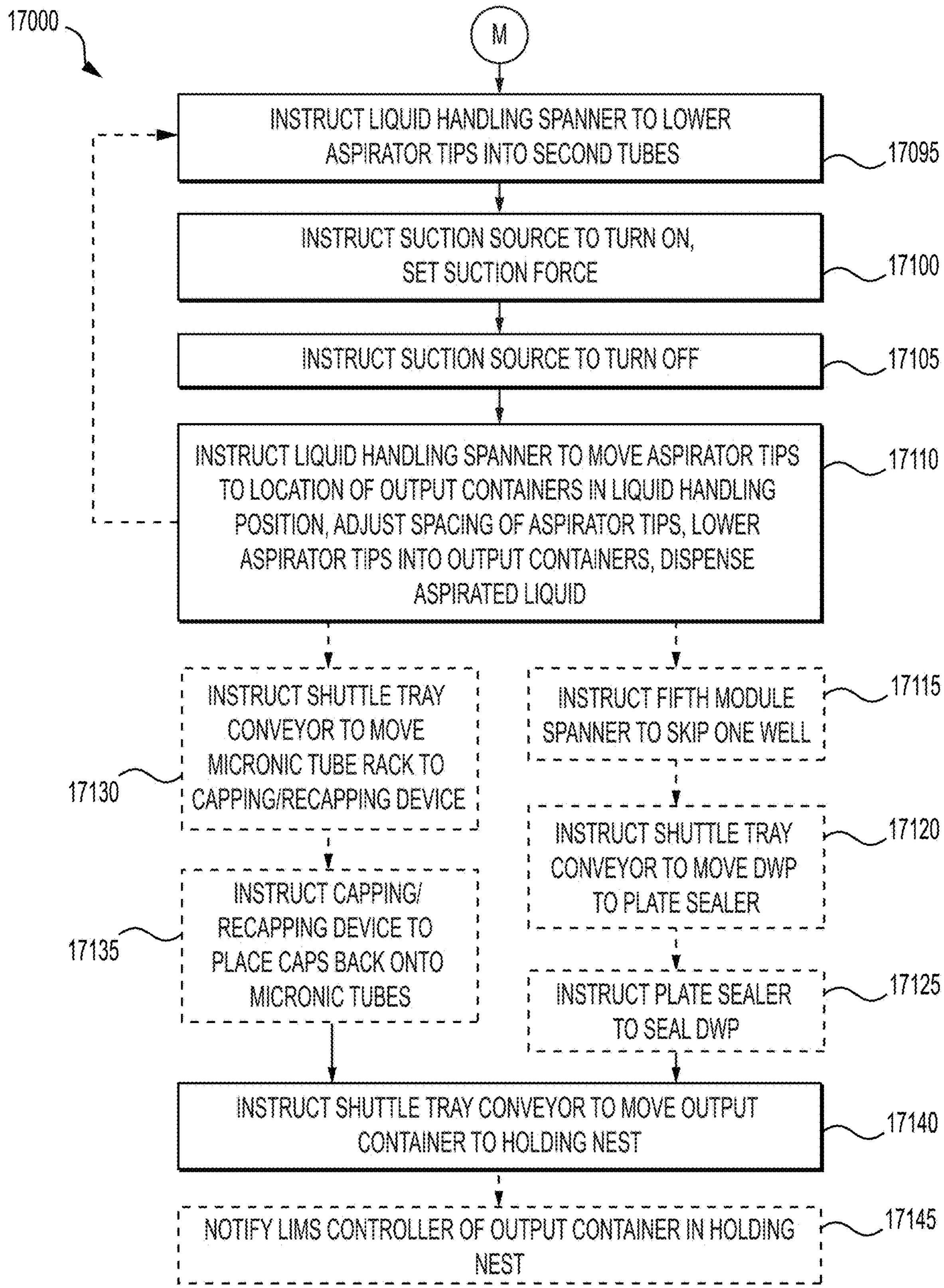

17000
M
INSTRUCT LIQUID HANDLING SPANNER TO LOWER ASPIRATOR TIPS INTO SECOND TUBES
17095
INSTRUCT SUCTION SOURCE TO TURN ON, SET SUCTION FORCE
17100
INSTRUCT SUCTION SOURCE TO TURN OFF
17105
INSTRUCT LIQUID HANDLING SPANNER TO MOVE ASPIRATOR TIPS TO LOCATION OF OUTPUT CONTAINERS IN LIQUID HANDLING POSITION, ADJUST SPACING OF ASPIRATOR TIPS, LOWER ASPIRATOR TIPS INTO OUTPUT CONTAINERS, DISPENSE ASPIRATED LIQUID
17110
INSTRUCT SHUTTLE TRAY CONVEYOR TO MOVE MICRONIC TUBE RACK TO CAPPING/RECAPPING DEVICE
17130
INSTRUCT CAPPING/ RECAPPING DEVICE TO PLACE CAPS BACK ONTO MICRONIC TUBES
17135
INSTRUCT FIFTH MODULE SPANNER TO SKIP ONE WELL
17115
INSTRUCT SHUTTLE TRAY CONVEYOR TO MOVE DWP TO PLATE SEALER
17120
INSTRUCT PLATE SEALER TO SEAL DWP
17125
INSTRUCT SHUTTLE TRAY CONVEYOR TO MOVE OUTPUT CONTAINER TO HOLDING NEST
17140
NOTIFY LIMS CONTROLLER OF OUTPUT CONTAINER IN HOLDING NEST
17145

FIG. 53C

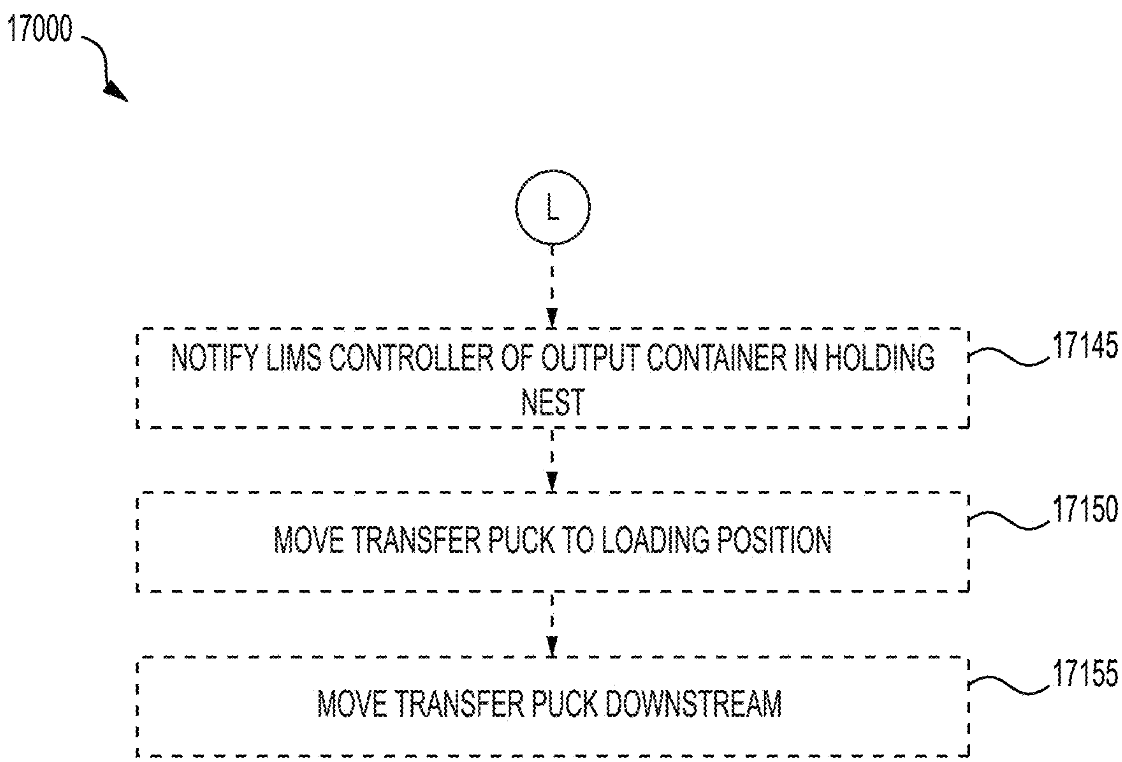

17000
L
NOTIFY LIMS CONTROLLER OF OUTPUT CONTAINER IN HOLDING NEST
17145
MOVE TRANSFER PUCK TO LOADING POSITION
17150
MOVE TRANSFER PUCK DOWNSTREAM
17155

FIG. 53D

LIQUID PROCESSING SYSTEM AND RELATED METHODS

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Application No. 63/551,827, filed on Feb. 9, 2024, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD OF THE INVENTION

[0002] This invention relates to an automated liquid processing system and related control methods and, more specifically, relates to an automated system for isolating subcomponents of liquids from liquid samples for downstream analysis and related control methods.

BACKGROUND OF THE INVENTION

[0003] Isolating subcomponents of liquids, such as plasma from blood samples, can be a relatively time consuming and complicated process. When isolating plasma from blood samples, for example, large volumes of blood from patients are needed to produce a sufficient volume of isolated plasma for analysis. The problems are magnified when isolating specific components from the blood samples, such as extracting cell-free DNA (cfDNA) for analysis. Current systems provide plasma volumes on the order of hundreds of micrometers, which is a relatively small amount that may not be sufficient to also provide for a back-up volume of plasma, which may be needed due to failure of tubes or samples or to perform subsequent analysis. In addition, current systems are also manual or require regular manual intervention, which is labor intensive, time consuming, and generally inefficient. Further, current systems require relatively long processing times, on the order of days, with processes comprising hundreds of steps with limited throughput. For example, current systems may only be able to process a single tube at one time, before plasma is ready for analysis, which typically requires at least an additional 24 hours. This may make large-scale or population-scale analysis impossible. Still further, current systems centrifuge blood samples to separate red blood cells from plasma, but a buffy coat layer of blood may remain in between the red blood cells and plasma, which can reduce the usable volume of plasma obtained from the sample.

[0004] The present invention is directed to overcoming one or more of these above-referenced challenges with processing fluid samples.

SUMMARY OF THE EMBODIMENTS

[0005] In one aspect, the present disclosure is directed to a method of processing liquid samples, the method comprising: receiving a plurality of liquid samples, each liquid sample being contained within a sample collection tube, and wherein the plurality of liquid samples include either or both of (i) two liquid samples from the same individual, or (ii) one liquid sample from an individual; centrifuging the plurality of liquid samples a first time to separate out a subcomponent of interest; imaging the plurality of liquid samples to determine a height of the subcomponent of interest in each sample collection tube; aspirating out the subcomponent of interest from the plurality of sample collection tubes and dispensing the aspirated subcomponent of interest into a plurality of processing tubes, wherein all of the aspirated subcomponent of interest for the same individual is deposited into one processing tube, such that the subcomponent of interest from the two liquid samples from the same individual are deposited into one processing tube, and the subcomponent of interest from the one liquid sample from the individual is deposited into one processing tube; centrifuging the plurality of liquid samples in the plurality of processing tubes a second time to further separate out the subcomponent of interest; and outputting the separated subcomponent of interest from each of the plurality of liquid samples in the plurality of processing tubes into a plurality of output containers.

[0006] In another aspect, the present disclosure is direct to an input module of an automated liquid processing system, the input module comprising: a scanner configured to scan and output identifying information of an insert, of a plurality of inserts, to be placed in the input module; a plurality of conveyor channels each extending from an input end to an output end and configured to receive one or more of the plurality of inserts; one or more conveyor belts, provided below the plurality of conveyor channels, and configured to convey the plurality of inserts from the input end to the output end of the plurality of conveyor channels; a plurality of sensors, each of the plurality of sensors being located at a region of the output end of each of the one or more conveyor channels, the plurality of sensors being configured to detect a presence of an insert, of the one or more inserts, at the output end of the one or more conveyor channels; and a controller including at least one memory that stores instructions for a control method of the input module, and at least one processor that executes the instructions to: receive the identifying information of a scanned insert, of the plurality of inserts, from the scanner; store the received identifying information in the at least one memory; determine, based on the received identifying information, whether the scanned insert is compatible with a centrifuge into which the insert is to be placed; receive, from a first sensor of the plurality of sensors, a notification that an insert, of the plurality of inserts, is detected at the output end of a first conveyor channel, of the plurality of conveyor channels; and output a notification, upon receiving the notification from the first sensor of the plurality of sensors that the insert is detected at the output end of the conveyor channel, that the detected insert is ready for transfer.

[0007] In still another aspect, the present disclosure is directed to a centrifuging module of an automated liquid processing system, the centrifuging module comprising: at least one scanner configured to scan and output identifying information of an insert, of a plurality of inserts; a plurality of centrifuges, each centrifuge configured to receive a predetermined number of inserts, of the plurality of inserts, and configured to perform a centrifuging cycle; one or more conveyor channels configured to receive and convey the plurality of inserts to an output end of the one or more conveyor channels; a gantry robot configured to pick up an insert, of the plurality of inserts, hold the insert in front of the at least one scanner, place the insert into and pick the insert up from the plurality of centrifuges, and place the insert onto one of the one or more conveyor channels; and a controller, including at least one memory that stores instructions for a control method of the centrifuging module, and at least one processor configured to execute the instructions to: instruct the gantry robot to pick up the insert, of the plurality of inserts, and to hold the insert in front of the at least one scanner; receive, from the at least one scanner, the identifying information of the scanned insert; instruct the gantry robot to place the insert into a centrifuge, of the plurality of centrifuges; instruct the centrifuge, of the plurality of centrifuges, to perform a centrifuging cycle; and upon completion of the centrifuging cycle, instruct the gantry robot to retrieve inserts, of the plurality of inserts, from the centrifuge and place the inserts onto one of the one or more conveyor channels.

[0008] In yet another aspect, the present disclosure is directed to a liquid handling module of an automated liquid processing system, the liquid handling module comprising: a pairing station including: a pairing robot configured to pick up a plurality of first tubes and to place the plurality of first tubes, in pairs of first tubes or as single first tubes; a pairing scanner configured to scan the plurality of first tubes; and at least one pairing platform having a plurality of pairing platform slots configured to receive the plurality of first tubes; an excising station configured to excise portions of one or more labels on outer surfaces of the plurality of first tubes; an imaging station configured to capture images of the plurality of first tubes following excision of the portions of the one or more labels; a liquid handling station configured to aspirate at least a portion of liquid within at least each pair of first tubes, of the plurality of first tubes, and to dispense the aspirated portion of the liquid to a second tube, of a plurality of second tubes; and a controller having at least one memory that stores instructions for control of the liquid handling module, and at least one processor configured to execute the instructions to: instruct the pairing robot to pick up the plurality of first tubes and to hold the first tubes in front of the pairing scanner; receive, from the pairing scanner, identifying information of each scanned first tube, of the plurality of first tubes picked up by the pairing robot; determine, based on the received identifying information of each scanned first tube, pairs of first tubes and single first tubes; instruct the pairing robot to place the pairs of first tubes and the single first tubes on a pairing platform, with first tubes of a pair of first tubes in adjacent slots of the plurality of slots on the pairing platform and single first tubes being placed next to an empty adjacent slot of the plurality of slots on the pairing platform; instruct the excising station to perform an excising process by which the portions of one or more labels on outer surfaces of the plurality of first tubes are removed; instruct the imaging station to perform an imaging process in which an image of one or more first tubes, of the plurality of first tubes, is captured; receive the captured image and perform an image analysis process, in which the captured image of the one or more first tubes is analyzed to determine at least a height of the portion of the liquid within the one or more first tubes; and instruct the liquid handling station to perform a liquid handling process, in which portions of the liquid from within pairs of the one or more first tubes are aspirated from the pairs of first tubes and dispensed into a same second tube, of the plurality of second tubes, so as to combine the portions of liquid from pairs of first tubes into the same second tube.

[0009] In another aspect, the present disclosure is directed to a centrifuging module of an automated liquid processing system, the centrifuging module comprising: at least one scanner configured to scan and output identifying information of an insert, of a plurality of inserts; a plurality of centrifuges, each centrifuge configured to receive a predetermined number of inserts, of the plurality of inserts, and configured to perform a centrifuging cycle; a tube transfer robot configured to pick up and place a plurality of tubes into an insert, of the plurality of inserts; a gantry robot configured to pick up an insert, of the plurality of inserts, hold the insert in front of the at least one scanner, and place the insert into a centrifuge, of the plurality of centrifuges; a conveyor system configured to convey the plurality of inserts within the centrifuging module; and a controller, including at least one memory that stores instructions for a control method of the centrifuging module, and at least one processor configured to execute the instructions to: receive, from the at least one scanner, identifying information of an insert, of the plurality of inserts; store the received identifying information; instruct the tube transfer robot to pick and up and place tubes, of the plurality of tubes, into an insert, of the plurality of inserts; instruct the gantry robot to pick up an insert, of the plurality of inserts, that is filled with tubes, and to place the filled insert into a centrifuge, of the plurality of centrifuges; instruct a centrifuge, of the plurality of centrifuges, to perform a centrifuging cycle; and upon completion of a centrifuging cycle of a centrifuge, instruct the gantry robot to retrieve inserts, of the plurality of inserts, from the centrifuge and place the inserts onto the conveyor system.

[0010] In still another aspect, the present disclosure is directed to a batching module of an automated liquid processing system, the batching module comprising: a scanner configured to scan and output identifying information of a tube, of a plurality of tubes; a tube transfer robot configured to pick up a tube, of the plurality of tubes, and hold it in front of the scanner; a liquid handling station including: a turntable having a plurality of portions, each portion including a plurality of tube slots, and each portion being configured to rotate through (a) a loading position, in which a plurality of tubes are placed into the plurality of tube slots, (b) a liquid handling position, in which liquid within the tubes is aspirated, and (c) a disposal position, in which the tubes are disposed from the turntable, wherein the tube transfer robot is further configured to place the plurality of tubes on the turntable; a liquid handling spanner configured to aspirate liquid within at least one tube, of a plurality of tubes, and to dispense the liquid into one or more output containers, the liquid handling spanner having: a plurality of aspirator tip mounting portions on which a plurality of aspirator tips are configured to be mounted; a plurality of flowmeters configured to measure a flow of liquid into each aspirator tip mounted to the plurality of aspirator tip mounting portions; and a connector configured to connect to a suction source; a liquid dispensing platform on which at least one output container, of a plurality of output containers, is loaded for receiving liquid from the plurality of aspirator tips; and a controller having at least one memory that stores instructions for control of the batching module, and at least one processor configured to execute the instructions to: receive identifying information of a scanned tube, of the plurality of tubes; store the received identifying information to register or track the tube as the tube enters the batching module; and instruct the liquid handling station to perform a liquid handling process including: instruct the liquid handling spanner to move to a position over the plurality of tubes in the turntable; instruct the liquid handling spanner to perform a suction process to aspirate at least a portion of the liquid within the plurality of tubes and to hold the aspirated portion of the liquid therein; instruct the liquid handling spanner to move to a position over the output container on the liquid dispensing platform; and instruct the liquid handling spanner to dispense the aspirated portion of the liquid into the at least one output container.

[0011] In yet another aspect, the present disclosure is directed to an automated liquid processing system comprising: a first scanner configured to scan and output identifying information of a first insert, of a plurality of first inserts to be placed in the automated liquid processing system; one or more first conveyor channels configured to receive and convey one or more of the plurality of first inserts from an input end to an output end of the one or more first conveyor channels; one or more first conveyor channel output sensors, at the output end of each of the one or more first conveyor channels, configured to output a notification when a first insert is detected at the output end of the one or more first conveyor channels; at least one second scanner configured to scan and output identifying information of a first insert, of the plurality of first inserts transferred from the output ends of the one or more first conveyor channels; a plurality of first centrifuges, each first centrifuge of the plurality of first centrifuges configured to receive a predetermined number of first inserts, of the plurality of first inserts, and configured to perform a first centrifuging cycle; one or more second conveyor channels configured to receive and convey the plurality of first inserts to an output end of the one or more second conveyor channels; one or more second conveyor channel output sensors, at the output end of each of the one or more second conveyor channels, configured to output a notification when a first insert is detected at the output end of the one or more second conveyor channels; a first gantry robot configured to pick up a first insert, of the plurality of first inserts, hold the first insert in front of the at least one second scanner, place the first insert into and pick the first insert up from one of the plurality of first centrifuges, and place the first insert onto the one or more second conveyor channels; a pairing station including: a pairing robot configured to pick up a plurality of first tubes from a first insert, of the plurality of first inserts, at the output end of the one or more second conveyor channels, and to place the plurality of first tubes, in pairs of first tubes or as single first tubes, and at least one pairing platform having a plurality of pairing platform slots configured to receive the plurality of first tubes, and a pairing scanner configured to scan and output identifying information of the plurality of first tubes picked up by the pairing robot, prior to placement of the plurality of first tubes on the at least one pairing platform; an excising station configured to excise at least portions of labels on outer surfaces of the plurality of first tubes; an imaging station configured to capture images of the plurality of first tubes; a first liquid handling station configured to aspirate a portion of a liquid within at least each pair of first tubes, of the plurality of first tubes, and to dispense the aspirated portion of the liquid to a second tube, of a plurality of second tubes, so as to combine the portions of liquid within pairs of first tubes in the same second tube; at least one third scanner configured to scan and output identifying information of a second insert, of a plurality of second inserts; a plurality of second centrifuges, each second centrifuge configured to receive a predetermined number of second inserts, of the plurality of second inserts, and configured to perform a centrifuging cycle; a first tube transfer robot configured to pick up and place the plurality of second tubes into a second insert, of the plurality of second inserts; a second gantry robot configured to pick up a second insert, of the plurality of second inserts, hold the second insert in front of the at least one third scanner, and place the second insert into a second centrifuge, of the plurality of second centrifuges; a conveyor system configured to receive the plurality of second inserts from the second gantry robot and to convey the second inserts in a loop, between a loading position, an insert pick up position, an insert placing position, and an unloading position; a fourth scanner configured to scan and output identifying information of a second tube, of the plurality of second tubes; a second tube transfer robot configured to pick up a second tube, of the plurality of second tubes, from a second insert in the unloading position of the conveyor system, and hold it in front of the fourth scanner; and a second liquid handling station configured to aspirate a portion of a liquid within a second tube, of the plurality of second tubes, and to dispense the aspirated portion of the liquid to an output container, of a plurality of output containers.

[0012] In another aspect, the present disclosure is directed to a method for controlling an input module of an automated liquid processing system, the method comprising: receiving, from a scanner, identifying information of a scanned insert, of a plurality of inserts, to be input into the automated liquid processing system; storing the received identifying information in at least one memory; determining, based on the received identifying information, whether the scanned insert is compatible with a centrifuge of the automated liquid processing system into which the insert is to be placed; receiving, from an output sensor of one or more output sensors located at an end region of one or more conveyor channels, which are configured to carry the plurality of inserts input into the automated liquid processing system, a notification that an insert is detected in an output end of a conveyor channel, of one or more conveyor channels; and outputting a notification, upon receiving the notification from the output sensor that the insert is detected at the output end of the conveyor channel, that the insert is ready for transfer.

[0013] In still another aspect, the present disclosure is directed to a controller of an input module of an automated liquid processing system, the controller including at least one memory that stores instructions for a control method of the automated liquid processing system, and at least one processor that executes the instructions to: receive, from a scanner of the input module, identifying information of a scanned insert, of a plurality of inserts, to be input into the automated liquid processing system; store the received identifying information in the at least one memory; determine, based on the received identifying information, whether the scanned insert is compatible with a centrifuge of the automated liquid processing system into which the insert is to be placed; receive, from an output sensor of one or more output sensors located at an end region of one or more conveyor channels of the input module, which are configured to carry the plurality of inserts input into the automated liquid processing system, a notification that an insert is detected in an output end of a conveyor channel, of one or more conveyor channels; and output a notification, upon receiving the notification from the output sensor that the insert is detected at the output end of the conveyor channel, that the insert is ready for transfer.

[0014] In yet another aspect, the present disclosure is directed to a method for controlling a centrifuging module of an automated liquid processing system, the method comprising: instructing a gantry robot to pick up an insert, of a plurality of inserts, and to hold the insert in front of at least one scanner; receiving, from the at least one scanner, identifying information of a scanned insert; instructing the gantry robot to place the insert into a centrifuge, of a plurality of centrifuges; instructing a centrifuge, of the plurality of centrifuges, to perform a centrifuging cycle; and upon completion of the centrifuging cycle of the centrifuge, instructing the gantry robot to retrieve inserts, of the plurality of inserts, from the centrifuge and place the inserts onto one or more conveyor channels.

[0015] In another aspect, the present disclosure is directed to a controller of a centrifuging module of an automated liquid processing system, the controller including at least one memory that stores instructions for a control method of the automated liquid processing system, and at least one processor that executes the instructions to: instruct a gantry robot of the centrifuging module to pick up an insert, of a plurality of inserts, and to hold the insert in front of at least one scanner of the centrifuging module; receive, from the at least one scanner, identifying information of a scanned insert; instruct the gantry robot to place the insert into a centrifuge, of a plurality of centrifuges of the centrifuging module; instruct a centrifuge, of the plurality of centrifuges, to perform a centrifuging cycle; and upon completion of the centrifuging cycle of the centrifuge, instruct the gantry robot to retrieve inserts, of the plurality of inserts, from the centrifuge and place the inserts onto one or more conveyor channels.

[0016] In still another aspect, the present disclosure is directed to a method for controlling a liquid handling module of an automated liquid processing system, the method comprising: instructing a pairing robot of a pairing station of the liquid handling module to pick up a plurality of first tubes and to hold each first tube in front of a pairing scanner of the pairing station; receiving, from the pairing scanner, identifying information of each scanned first tube, of the plurality of first tubes picked up by the pairing robot; determining, based on the received identifying information of each scanned first tube, pairs of first tubes and single first tubes; performing, using an excising station of the liquid handling module, an excising process by which at least portions of labels on the plurality of first tubes are excised; performing, using an imaging station of the liquid handling module, an imaging process in which an image of one or more first tubes, of the plurality of first tubes, is captured; performing an image analysis process, in which the captured image of the one or more first tubes is analyzed to determine at least a height of a portion of the liquid within the one or more first tubes; and performing, using a liquid handling station of the liquid handling module, a liquid handling process, in which the portion of the liquid within the one or more first tubes is aspirated from a pair of first tubes or from a single first tube, and is dispensed into a second tube, of a plurality of second tubes, so as to combine the portions of liquid from pairs of first tubes into the same second tube.

[0017] In yet another aspect, the present disclosure is directed to a controller of a liquid handling module of an automated liquid processing system, the controller including at least one memory that stores instructions for a control method of the automated liquid processing system, and at least one processor that executes the instructions to: instruct a pairing robot of a pairing station of the liquid handling module to pick up a plurality of first tubes and to hold each first tube in front of a pairing scanner of the pairing station; receive, from the pairing scanner, identifying information of each scanned first tube, of the plurality of first tubes picked up by the pairing robot; determine, based on the received identifying information of each scanned first tube, pairs of first tubes and single first tubes; perform, using an excising station of the liquid handling module, an excising process by which at least portions of labels on the plurality of first tubes are excised; perform, using an imaging station of the liquid handling module, an imaging process in which an image of one or more first tubes, of the plurality of first tubes, is captured; perform an image analysis process, in which the captured image of the one or more first tubes is analyzed to determine at least a height of a portion of the liquid within the one or more first tubes; and perform, using a liquid handling station of the liquid handling module, a liquid handling process, in which the portion of the liquid within the one or more first tubes is aspirated from a pair of first tubes or from a single first tube, and is dispensed into a second tube, of a plurality of second tubes, so as to combine the portions of liquid from pairs of first tubes into the same second tube.

[0018] In another aspect, the present disclosure is directed to a method for controlling a centrifuging module of an automated liquid processing system, method comprising: receiving, from at least one scanner of the centrifuging module, identifying information of an insert, of a plurality of inserts; storing the received identifying information; instructing a tube transfer robot of the centrifuging module to pick and up and place tubes, of a plurality of tubes, into an insert, of the plurality of inserts; instructing a gantry robot of the centrifuging module to pick up an insert, of the plurality of inserts, that is filled with tubes, and to place the filled insert into a centrifuge, of a plurality of centrifuges; instructing the centrifuge, of the plurality of centrifuges, to perform a centrifuging cycle; and upon completion of the centrifuging cycle of the centrifuge, instructing the gantry robot to retrieve inserts, of the plurality of inserts, from the centrifuge and place the inserts onto a conveyor system of the centrifuging module.

[0019] In still another aspect, the present disclosure is directed to a controller of a centrifuging module of an automated liquid processing system, the controller including at least one memory that stores instructions for a control method of the automated liquid processing system, and at least one processor that executes the instructions to: receive, from at least one scanner of the centrifuging module, identifying information of an insert, of a plurality of inserts; store the received identifying information in the at least one memory; instruct a tube transfer robot of the centrifuging module to pick and up and place tubes, of a plurality of tubes, into an insert, of the plurality of inserts; instruct a gantry robot of the centrifuging module to pick up an insert, of the plurality of inserts, that is filled with tubes, and to place the filled insert into a centrifuge, of a plurality of centrifuges; instruct the centrifuge, of the plurality of centrifuges, to perform a centrifuging cycle; and upon completion of the centrifuging cycle of the centrifuge, instruct the gantry robot to retrieve inserts, of the plurality of inserts, from the centrifuge and place the inserts onto a conveyor system of the centrifuging module.

[0020] In yet another aspect, the present disclosure is directed to a method for controlling a batching module of an automated liquid processing system, the method comprising:

receiving, from a scanner of the batching module, identifying information of each of a plurality of tubes; storing the received identifying information to register or track the plurality of tubes as each tube enters the batching module; and instructing a liquid handling station of the batching module to perform a liquid handling process including: instructing a liquid handling spanner of the liquid handling station to move to a position over the plurality of tubes placed in a turntable of the liquid handling station; instructing the liquid handling spanner to aspirate at least a portion of the liquid within the plurality of tubes and to hold the aspirated portion of the liquid therein; instructing the liquid handling spanner to move to a position over at least one output container on a liquid dispensing platform of the batching module; and instructing the liquid handling spanner to dispense the liquid into the at least one output container.

[0021] In another aspect, the present disclosure is directed to a controller of a batching module of an automated liquid processing system, the controller including at least one memory that stores instructions for a control method of the automated liquid processing system, and at least one processor that executes the instructions to: receive, from a scanner of the batching module, identifying information of each of a plurality of tubes; store, in the at least one memory, the received identifying information to register or track the plurality of tubes as each tube enters the batching module; and instruct a liquid handling station of the batching module to perform a liquid handling process including: instructing a liquid handling spanner of the liquid handling station to move to a position over the plurality of tubes placed in a turntable of the liquid handling station; instructing the liquid handling spanner to aspirate at least a portion of the liquid within the plurality of tubes and to hold the aspirated portion of the liquid therein; instructing the liquid handling spanner to move to a position over at least one output container on a liquid dispensing platform of the batching module; and instructing the liquid handling spanner to dispense the liquid into the at least one output container.

[0022] In still another aspect, the present disclosure is directed to a method for controlling an automated liquid processing system, the method comprising: receiving identifying information of a first insert, of a plurality of first inserts to be input into the automated liquid processing system, from a first scanner; storing the received identifying information of a scanned first insert in at least one memory; determining, based on the received identifying information of the scanned first insert, whether the scanned first insert is compatible with a first centrifuge, of a plurality of first centrifuges of the automated liquid processing system, into which the first insert is to be placed; receiving, from a first conveyor channel output sensor, of one or more first conveyor channel output sensors of the automated liquid processing system, a notification that a first insert, of the plurality of first inserts, is detected in an output end of a first conveyor channel, of one or more first conveyor channels of the automated liquid processing system; instructing, upon receiving the notification from the first conveyor channel output sensor that the first insert is detected at the output end of the one or more first conveyor channels, a first gantry robot of the automated liquid processing system to pick up a first insert, of the plurality of first inserts, and to hold the first insert in front of at least one second scanner; receiving, from the at least one second scanner, identifying information of the scanned first insert; storing the received identifying information of the scanned first insert in the at least one memory; instructing the first gantry robot to place the scanned first insert into a first centrifuge, of the plurality of first centrifuges; instructing a first centrifuge, of the plurality of first centrifuges, to perform a centrifuging cycle; upon completion of the centrifuging cycle of the first centrifuge, instructing the first gantry robot to retrieve the first inserts, of the plurality of first inserts, from the first centrifuge and place the first inserts onto one or more second conveyor channels of the automated liquid processing system; instructing, upon receiving the notification from a second conveyor channel output sensor that a first insert is detected at the output end of the one or more second conveyor channels, a pairing robot of the automated liquid processing system to pick up a plurality of first tubes from the first insert at the output end of the one or more second conveyor channels, and to hold the first insert in front of a pairing scanner of the automated liquid processing system; receiving, from the pairing scanner, identifying information of each scanned first tube, of the plurality of first tubes picked up by the pairing robot; determining, based on the received identifying information of each scanned first tube, pairs of first tubes and single first tubes; placing the pairs of tubes and the single first tubes on a pairing platform of the automated liquid processing system, with first tubes of a pair of first tubes in adjacent slots of the plurality of slots on the pairing platform and single first tubes being placed next to an empty adjacent slot of the plurality of slots on the pairing platform; performing an excising process by which portions of labels on the plurality of first tubes from the pairing platform are excised; performing an imaging process in which an image of one or more first tubes, of the plurality of first tubes, is captured; performing an image analysis process, in which the captured image of the one or more first tubes is analyzed to determine at least a height of a portion of the liquid within the one or more first tubes; performing a first liquid handling process, in which the portion of the liquid within the one or more first tubes is aspirated from a pair of first tubes or from a single first tube, and is dispensed into a second tube, of a plurality of second tubes, so as to combine the portions of liquid from pairs of first tubes into the same second tube; receiving, from at least one third scanner of the automated liquid processing system, identifying information of a second insert, of a plurality of second inserts; storing the received identifying information of the scanned second insert in the at least one memory; instructing a second tube transfer robot of the automated liquid processing system to pick up and place second tubes, of the plurality of second tubes, into a second insert, of the plurality of second inserts; instructing a second gantry robot of the automated liquid processing system to pick up a second insert, of the plurality of second inserts, that is filled with second tubes, and to place the filled second insert into a second centrifuge, of a plurality of second centrifuges of the automated liquid processing system; instructing a second centrifuge, of the plurality of second centrifuges, to perform a second centrifuging cycle; and upon completion of the second centrifuging cycle of the second centrifuge, instructing the second gantry robot to retrieve second inserts, of the plurality of second inserts, from the second centrifuge and place the second inserts onto a conveyor system of the automated liquid processing system; receiving identifying information of a scanned second tube from a fourth scanner of the automated liquid processing system; storing the received identifying information of the scanned second tube in the at least one memory; and performing a second liquid handling process, in which the portion of the liquid within the second tubes is aspirated from the second tubes, and is dispensed into a plurality of output containers.

[0023] In yet another aspect, the present disclosure is directed to a controller of an automated liquid processing system, the controller including at least one memory that stores instructions for a control method of the automated liquid processing system, and at least one processor that executes the instructions to: receive identifying information of a first insert, of a plurality of first inserts to be input into the automated liquid processing system, from a first scanner; store the received identifying information of a scanned first insert in at least one memory; determine, based on the received identifying information of the scanned first insert, whether the scanned first insert is compatible with a first centrifuge, of a plurality of first centrifuges of the automated liquid processing system, into which the first insert is to be placed; receive, from a first conveyor channel output sensor, of one or more first conveyor channel output sensors of the automated liquid processing system, a notification that a first insert, of the plurality of first inserts, is detected in an output end of a first conveyor channel, of one or more first conveyor channels of the automated liquid processing system; instruct, upon receiving the notification from the first conveyor channel output sensor that the first insert is detected at the output end of the one or more first conveyor channels, a first gantry robot of the automated liquid processing system to pick up a first insert, of the plurality of first inserts, and to hold the first insert in front of at least one second scanner; receive, from the at least one second scanner, identifying information of the scanned first insert; store the received identifying information of the scanned first insert in the at least one memory; instruct the first gantry robot to place the scanned first insert into a first centrifuge, of the plurality of first centrifuges; instruct a first centrifuge, of the plurality of first centrifuges, to perform a centrifuging cycle; upon completion of the centrifuging cycle of the first centrifuge, instruct the first gantry robot to retrieve the first inserts, of the plurality of first inserts, from the first centrifuge and place the first inserts onto one or more second conveyor channels of the automated liquid processing system; instruct, upon receiving the notification from a second conveyor channel output sensor that a first insert is detected at the output end of the one or more second conveyor channels, a pairing robot of the automated liquid processing system to pick up a plurality of first tubes from the first insert at the output end of the one or more second conveyor channels, and to hold the first insert in front of a pairing scanner of the automated liquid processing system; receive, from the pairing scanner, identifying information of each scanned first tube, of the plurality of first tubes picked up by the pairing robot; determine, based on the received identifying information of each scanned first tube, pairs of first tubes and single first tubes; place the pairs of tubes and the single first tubes on a pairing platform of the automated liquid processing system, with first tubes of a pair of first tubes in adjacent slots of the plurality of slots on the pairing platform and single first tubes being placed next to an empty adjacent slot of the plurality of slots on the pairing platform; perform an excising process by which portions of labels on the plurality of first tubes from the pairing platform are excised; perform an imaging process in which an image of one or more first tubes, of the plurality of first tubes, is captured; perform an image analysis process, in which the captured image of the one or more first tubes is analyzed to determine at least a height of a portion of the liquid within the one or more first tubes; perform a first liquid handling process, in which the portion of the liquid within the one or more first tubes is aspirated from a pair of first tubes or from a single first tube, and is dispensed into a second tube, of a plurality of second tubes, so as to combine the portions of liquid from pairs of first tubes into the same second tube; receive, from at least one third scanner of the automated liquid processing system, identifying information of a second insert, of a plurality of second inserts; store the received identifying information of the scanned second insert in the at least one memory; instruct a second tube transfer robot of the automated liquid processing system to pick up and place second tubes, of the plurality of second tubes, into a second insert, of the plurality of second inserts; instruct a second gantry robot of the automated liquid processing system to pick up a second insert, of the plurality of second inserts, that is filled with second tubes, and to place the filled second insert into a second centrifuge, of a plurality of second centrifuges of the automated liquid processing system; instruct a second centrifuge, of the plurality of second centrifuges, to perform a second centrifuging cycle; and upon completion of the second centrifuging cycle of the second centrifuge, instruct the second gantry robot to retrieve second inserts, of the plurality of second inserts, from the second centrifuge and place the second inserts onto a conveyor system of the automated liquid processing system; receive identifying information of a scanned second tube from a fourth scanner of the automated liquid processing system; store the received identifying information of the scanned second tube in the at least one memory; and perform a second liquid handling process, in which the portion of the liquid within the second tubes is aspirated from the second tubes, and is dispensed into a plurality of output containers.

[0024] In another aspect, the present disclosure is directed to a label excising station, comprising: a pair of blades spaced apart from one another and located opposite from one another; a pair of blade actuators, wherein each blade of the pair of blades is rotatably mounted on one of the pair of blade actuators; and a platform positioned below the pair of blades, wherein the platform is configured to receive a sample collection tube, wherein the platform is configured to move between a first position and a second position, wherein in the first position, the platform is spaced relatively further away from the pair of blades, and wherein in the second position, the platform is spaced relatively closer to the pair of blades.

[0025] In still another aspect, the present disclosure is directed to a method of excising a label from a sample collection tube, the method comprising: placing the sample collection tube on a platform; moving a pair of blade actuators so as to position blades rotatably mounted on the pair of actuators apart from one another a distance approximately equal to a width of the sample collection tube; and moving the platform towards the blades so that the sample collection tube is pushed upwards between the blades mounted on the pair of actuators while the blades contact opposing sides of the sample collection tube.

[0026] Additional objects and advantages of the disclosed embodiments will be set forth in part in the description that follows, and in part will be apparent from the description, or may be learned by practice of the disclosed embodiments. The objects and advantages of the disclosed embodiments will be realized and attained by means of the elements and combinations particularly pointed out in the appended claims.

[0027] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosed embodiments, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments and together with the description, serve to explain the principles of the disclosure.

[0029] FIG. **1**A is a schematic drawing of an automated liquid processing system, in accordance with the present invention.

[0030] FIG. **1**B is a schematic drawing of a top view of the processing portions of the automated liquid processing system shown in FIG. **1**A.

[0031] FIG. **2** is a schematic drawing of connections between a plurality of modules, a controller, and a user interface of the automated liquid processing system shown in FIGS. **1**A and **1**B, and connectivity between these portions and a laboratory information management system (LIMS) controller.

[0032] FIG. **3** is a schematic drawing of a first module of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0033] FIG. **4** is a schematic drawing of a top view of the processing portion of the first module shown in FIG. **3**.

[0034] FIG. **5** is a schematic drawing of a detail view of a conveyor belt of the first module shown in FIGS. **3** and **4**.

[0035] FIG. **6** is a schematic drawing of a detail view of an input opening of the first module shown in FIGS. **3** and **4**.

[0036] FIG. **7** is a schematic drawing of a first insert for use with the first module shown in FIGS. **3** and **4**.

[0037] FIG. **8** is a schematic drawing of a second module of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0038] FIG. **9** is a schematic drawing of a top view of the processing portion of the second module shown in FIG. **8**.

[0039] FIG. **10** is a schematic drawing of a portion of a gantry robot of the second module shown in FIGS. **8** and **9**, holding a first insert.

[0040] FIG. **11** is a schematic drawing of a third module of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0041] FIG. **12** is a schematic drawing of a top view of the processing portion of the third module shown in FIG. **11**.

[0042] FIG. **13** is a schematic drawing of a detail view of a portion of a pairing station of the third module shown in FIGS. **11** and **12**.

[0043] FIG. **14** is a schematic drawing of an effector of the pairing robot of the pairing station of the third module shown in FIGS. **11** and **12**.

[0044] FIG. **15** is a schematic drawing of a detail view of an excising station of the third module shown in FIGS. **11** and **12**.

[0045] FIG. **16** is a schematic drawing of a detail view of an imaging station of the excising station shown in FIG. **15**.

[0046] FIG. **17** is a schematic drawing of a detail view of a user interface of a controller optionally used during an imaging analysis process, following imaging by the imaging station shown in FIG. **16**.

[0047] FIG. **18** is a schematic drawing of a detail view of an end effector of one of the pairing robots of the pairing station of the third module shown in FIGS. **11** and **12**.

[0048] FIG. **19** is a schematic drawing of the first turntable and a decapping station of the third module shown in FIGS. **11** and **12**.

[0049] FIG. **20** is a schematic drawing of a detail view of a third module tip rack hotel used to supply third module aspirator tips to the third module liquid handling station shown in FIGS. **11** and **12**.

[0050] FIG. **21** is a schematic drawing of third module aspirator tip racks holding the third module aspirator tips from the third module tip rack hotel shown in FIG. **20**.

[0051] FIG. **22**A and FIG. **22**B are schematic drawings of the third module aspirator tip racks carrying the third module aspirator tips on the third module aspirator tip conveyor belt, within the third module shown in FIGS. **11** and **12**.

[0052] FIG. **23** is a schematic drawing of spacing between the third module aspirator tips within the third module liquid handling station.

[0053] FIG. **24** is a schematic drawing of spacing between the third module aspirator tips within the third module liquid handling station.

[0054] FIG. **25**A is a schematic drawing of a hopper, a step feeder, and a second tube conveyor, for supplying second tubes to the third module liquid handling station, and FIG. **25**B is a schematic drawing of a second tube.

[0055] FIG. **26** is a schematic drawing of a gripping and marking device of the third module shown in FIGS. **11** and **12**.

[0056] FIG. **27**A and FIG. **27**B are schematic drawings of the end effector of the second tube transfer robot.

[0057] FIG. **28** is a schematic drawing of the second turntable of the third module shown in FIGS. **11** and **12**.

[0058] FIG. **29** is a schematic drawing of a detail view of the third module liquid handling station shown in FIGS. **11** and **12**.

[0059] FIG. **30**A and FIG. **30**B are schematic drawings of first tubes and exemplary flow rates and Z-speeds for withdrawal of liquid from the first tubes using the third module liquid handling station shown in FIGS. **11** and **12**.

[0060] FIG. **31** is a schematic drawing of the second turntable of the third module shown in FIGS. **11** and **12**.

[0061] FIG. **32** is a schematic drawing of a fourth module of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0062] FIG. **33** is a schematic drawing of a top view of the processing portion of the fourth module shown in FIG. **32**.

[0063] FIG. **34** is a schematic drawing of a top view of a pallet conveyor of the fourth module shown in FIGS. **32** and **33**.

[0064] FIG. **35** is a schematic drawing of a second insert, into which the second tubes **1010** are placed within the fourth module shown in FIGS. **32** and **33**.

[0065] FIG. **36** is a schematic drawing of a fifth module of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0066] FIG. **37** is a schematic drawing of a top view of the processing portion of the fifth module shown in FIG. **36**.

[0067] FIG. **38** is a schematic drawing of a detail view of the liquid handling station of the fifth module shown in FIGS. **36** and **37**.

[0068] FIG. **39** is a schematic drawing of a detail view of deep well plates (DPWs) on plate shuttles in the fifth module shown in FIGS. **36** and **37**.

[0069] FIG. **40** is a schematic drawing of a detail view of tray handling in the fifth module shown in FIGS. **36** and **37**.

[0070] FIG. **41** is a schematic detail view of a capping and decapping device of the fifth module shown in FIGS. **36** and **37**.

[0071] FIG. **42**A is a schematic diagram showing consumable supply storage in the third module and the fifth module of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0072] FIG. **42**B is a schematic diagram showing consumable disposal containers of the third module and the fifth module of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0073] FIG. **43** is a schematic drawing of a disposal container provided within the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0074] FIG. **44** is a schematic drawing of a disposal scale provided within the third module and the fifth module of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0075] FIG. **45** is a schematic drawing of an automated plasma isolation process, as an example of an automated liquid isolation process performed by the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0076] FIGS. **46**A and **46**B show a flowchart of a first module control method performed by the controller of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0077] FIGS. **47**A and **47**B show a flowchart of a control method for the second module performed by the controller of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0078] FIGS. **48**A and **48**B show a flowchart of a control method for the pairing station of the third module, the control method being performed by the controller of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0079] FIG. **49** shows a flowchart of a control method for the excising station of the third module, the control method being performed by the controller of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0080] FIG. **50** is a flowchart of a control method for the imaging station of the third module, the control method being performed by the controller of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0081] FIGS. **51**A, **51**B, **51**C, **51**D, and **51**E show a flowchart of a control method for the liquid handling station of the third module, the control method being performed by the controller of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0082] FIGS. **52**A, **52**B, and **52**C show a flowchart of a control method for the fourth module, the control method being performed by the controller of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

[0083] FIGS. **53**A, **53**B, **53**C, and **53**D show a flowchart of a control method for the fifth module, the control method being performed by the controller of the automated liquid processing system shown in FIGS. **1**A, **1**B, and **2**.

DETAILED DESCRIPTION

[0084] The terminology used below may be interpreted in its broadest reasonable manner, even though it is being used in conjunction with a detailed description of certain specific examples of the present disclosure. Indeed, certain terms may even be emphasized below; however, any terminology intended to be interpreted in any restricted manner will be overtly and specifically defined as such in this Detailed Description section. Both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the features, as claimed.

[0085] The subject matter of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings, which form a part hereof, and which show, by way of illustration, specific exemplary embodiments. An embodiment or implementation described herein as "exemplary" is not to be construed as preferred or advantageous, for example, over other embodiments or implementations; rather, it is intended to reflect or indicate that the embodiment(s) is/are "example" embodiment(s). Subject matter may be embodied in a variety of different forms and, therefore, covered or claimed subject matter is intended to be construed as not being limited to any exemplary embodiments set forth herein; exemplary embodiments are provided merely to be illustrative. Likewise, a reasonably broad scope for claimed or covered subject matter is intended. Among other things, for example, subject matter may be embodied as methods, devices, components, or systems. Accordingly, embodiments may, for example, take the form of hardware, software, firmware, or any combination thereof. The following detailed description is, therefore, not intended to be taken in a limiting sense.

[0086] Throughout the specification and claims, terms may have nuanced meanings suggested or implied in context beyond an explicitly stated meaning. Likewise, the phrase "in one embodiment" or "in some embodiments," or "in one aspect" or "in some aspects" as used herein does not necessarily refer to the same embodiment or aspect, and the phrase "in another embodiment" or "in another aspect" as used herein does not necessarily refer to a different embodiment or aspect. It is intended, for example, that claimed subject matter include combinations of exemplary embodiments in whole or in part.

I. Overview of Automated Liquid Processing System

[0087] FIG. **1**A is a schematic drawing of an automated liquid processing system **1000**, in accordance with the present invention. The automated liquid processing system **1000** is configured to receive and process first tubes **1005** (FIG. **5**) containing a liquid, to isolate one or more subcomponents of the liquid, to transfer the isolated subcomponent (s) of the liquid to second tubes **1010** (FIG. **21**), to process the second tubes **1010** to further isolate the subcomponent (s), and to transfer the twice-isolated subcomponent(s) into one or more output containers **1030** (FIG. **37**), for subsequent processing. In further descriptions, isolating "a" subcomponent is described for brevity, although it is within the scope of the invention to use the automated liquid processing system **1000** to isolate one or more subcomponents. As an example, the automated liquid processing system **1000** may be configured to receive and process blood tubes, as first tubes **1005**, containing blood, isolate plasma from the blood (and/or e.g., red blood cells, buffy coat, or other blood components), as the one or more subcomponents, transfer the isolated plasma to tubes of a different size, e.g., 15 mL tubes, as second tubes **1010**, process the second tubes to isolate the plasma a second time, and transfer the twice-isolated plasma to one or both of micronic tubes **1015** on micronic tube rack **1020** and deep well plates (DWPs) **1025**, as output containers **1030**. The example of 'blood tubes,' '15 mL tubes,' 'DWPs' **1025**, and 'micronic tubes' **1015**, 'blood samples,' and 'isolated plasma' may also be referenced herein, although it is within the scope of the invention to use the automated liquid processing system **1000** to receive other types of liquid containers in place of the first tubes **1005**, the second tubes **1010**, and/or the output containers **1030**, to process other types of liquids. As an example, any suitable type of liquid sample (e.g., a biological liquid sample) may be used in conjunction with automated liquid processing system **1000**, such as a urine sample, a saliva sample, a tissue sample, a bone marrow sample, other bodily fluids, etc. Further, although plasma is referenced as the subcomponent to be isolated, other portions of a liquid sample may be isolated using automated liquid processing system **1000** alone or in conjunction with the plasma.

[0088] The automated liquid processing system **1000** includes at least a first module **2000** at a first end **1000***a*, the first module **2000** being configured to receive the first tubes **1005**, a second module **3000** adjacent to the first module **2000**, the second module **3000** being configured to centrifuge the received first tubes **1005** to isolate the subcomponent (e.g., plasma), a third module **4000** adjacent to the second module **3000**, the third module **4000** being configured to pair the first tubes **1005** with the isolated subcomponent (e.g., plasma), to excise labels on the first tubes **1005**, to image the first tubes **1005**, to perform liquid handling to transfer the isolated subcomponent of liquid into second tubes **1010**, and to add a label to the second tubes **1010**, a fourth module **5000** adjacent to the third module **4000**, the fourth module **5000** being configured to centrifuge the second tubes to isolate the subcomponent (e.g., plasma) a second time, and a fifth module **6000**, adjacent to the fourth module **5000** and at a second end **1000***b* of the automated liquid processing system **1000**, the fifth module **6000** being configured to batch and output the twice-isolated subcomponent (e.g., plasma) into one or more output containers **1030** (e.g., micronic tubes **1015**, micronic tube racks **1020**, and/or DWPs **1025**). The automated liquid processing system **1000** may also include a controller **7000** for controlling one or more modules and/or one or more subcomponents of the modules, and a user interface **8000**, or a display, through which an operator may also perform such control. The controller **7000** may also serve as an interface between controllers of other systems, such as a laboratory information management system (LIMS) controller **9000** (FIG. **2**).

[0089] As disclosed herein, controller **7000** may be used to facilitate communications between itself, the user interface **8000**, the first to fifth modules, one or more databases, and any other suitable system or device through a wired or wireless network connection. Any communication protocol/device may be used, including without limitation a modem, an Ethernet connection, a network card (wireless or wired), an infrared communication device, a wireless communication device, and/or a chipset (such as a Bluetooth™ device, an 802.11 device, a WiFi device, a WiMax device, cellular communication facilities, etc.), a near-field communication (NFC), a Zigbee communication, a radio frequency (RF) or radio-frequency identification (RFID) communication, a PLC protocol, a 3G/4G/5G/LTE based communication, and/or the like. For example, controller **7000** may communicate with another system or device with the same platform, a regular user device without the same platform (e.g., a regular smartphone), a remote server, a physical device of a remote loT local network, a wearable device, a user device communicably connected to a remote server, etc.

[0090] As discussed in more detail below, the controller **7000** may continually or intermittently communicate with LIMS controller **9000** to ensure first tubes **1005** are acceptable for inputting into the first module **2000**, to monitor one or more of the modules for error notifications, to verify incoming consumables **1035** and the identifying information, for example, barcodes, of those consumables **1035**, and to verify outputs from each of the modules based on identifying information on first tubes **1005** and consumables **1035**.

[0091] Although first module **2000**, second module **3000**, third module **4000**, fourth module **5000**, and fifth module **6000** are described together in terms of automated liquid processing system **1000**, any one module may be a standalone module, separate from the other modules of automated liquid processing system **1000**, and may be configured to receive inputs and/or output outputs from another system component or from a user. Therefore, within the scope of the invention, the modules may not be directly adjacent. In other aspects, automated liquid processing system **1000** may only include a subset of modules. In still other aspects, each module described herein may be included in automated liquid processing system **1000** so that the modules are operatively coupled to one another such that the outputs of one module are received as the inputs of the subsequent module until an output is output from fifth module **6000** and thus form automated liquid processing system **1000**.

[0092] An electrical power supply connection **1040** may be provided within any of the first to fifth modules, or on multiple modules, and in the embodiment shown in FIG. **1**A, the electrical power supply connection **1040** is included as part of the first module **2000**. In some embodiments, each of the modules may have an electrical power supply connection **1040** to power the components therein. One or more disposal containers, scales, alarms, venting, temperature and humidity sensors may also be provided within one or more of the first to fifth modules, as described in more detail below with reference to FIGS. **42**A and **42**B. Further, each module may have at least one upper door **1045** and at least one lower door **1050**, which an operator may open to input and/or retrieve disposed items or consumables **1035** or to perform inspection, maintenance, or repairs at any point within the automated liquid processing system **1000**. In the embodiment shown in FIG. **1**A, the upper door **1045** and the lower doors **1050** of the first module **2000** may face the first end **1000***a* of the automated liquid processing system **1000**, and the upper door **1045** and lower doors **1050** of the second to fifth modules face a front side of the automated liquid processing system **1000**. However, the doors of the modules may face directions other than those shown.

[0093] FIG. **1**B is a schematic drawing of a top view of the processing portions of the automated liquid processing system **1000** shown in FIG. **1**A (i.e., with the roof of the automated liquid processing system **1000** removed). FIG. **1**B shows the first module **2000**, including a plurality of first module conveyor channels **2005** and a first module return channel **2010**. FIG. **1**B also shows the second module **3000** including openings **3005** to a plurality of second module centrifuges **3010** (FIG. **8**), second module conveyor belts **3015**, a second module return channel **3020**, and a second module gantry robot **3025** with a second module gantry robot end effector **3030**. FIG. **1**B further shows the third module **4000**, including a pairing robot **4005**, an excising robot **4010**, a third module liquid handling station **4015**, a third module liquid handling spanner **4020**, a first turntable **4025**, and a second turntable **4030**. FIG. **1**B also shows the fourth module **5000**, including openings **5005** to a plurality of fourth module centrifuges **5010** (FIG. **32**), a fourth module robot **5015**, and a fourth module pallet conveyor system **5020**. Lastly, FIG. **1**B shows the fifth module **6000**, including a fifth module turntable load robot **6005**, a fifth module turntable unload robot **6006**, a fifth module gantry robot **6010**, and a fifth module liquid handling station **6015**. These and other features are described in more detail below.

[0094] FIG. **2** is a schematic drawing of connections between the first to fifth modules, the controller **7000**, and the user interface **8000** of the automated liquid processing system **1000** shown in FIGS. **1**A and **1**B, and connectivity between these portions and the LIMS controller **9000**. Each of the first to fifth modules may be operably connected to the controller **7000**, and the controller **7000** may be operably connected to the user interface **8000** and to the LIMS controller **9000**. In the embodiment shown in FIG. **2**, the controller **7000** is separate from the LIMS controller **9000**, however, these may be incorporated as part of the same controller. In addition, the user interface **8000** may be operably connected to the LIMS controller **9000**. By virtue of these connections, the methods or processes performed within each of the first to fifth modules of the automated liquid processing system **1000** may be automated, and updates regarding the status of the system may be provided to an operator and/or to the LIMS controller **9000**. In addition, the operator may intervene, if needed, for example, to stop, modify, inspect, or otherwise interact with one or more processes if, for example, an error notification is issued by the controller **7000**.

[0095] The controller **7000** may include at least one memory **7005**, including program storage and data storage for various data files and information to be stored, processed, and/or communicated by the controller **7000**. The controller **7000** may also include a central processing unit (CPU) **7010**, in the form of one or more processors that are configured to execute the program instructions stored in the memory **7005** of the controller **7000**. The controller **7000** may control end-to-end functions of the automated liquid processing system **1000**, and/or may control the functions of one or more individual modules **2000**, **3000**, **4000**, **5000**, **6000**.

[0096] The user interface **8000** may provide notifications to an operator relating to one or both of alarms or error notifications. The user interface **8000** may allow an operator to set one or more components of the first to fifth modules to an automated mode or a manual mode, and may provide a user with control over the components of the first to fifth modules. In addition, an operator may be able to access information stored by controller **7000** in the memory **7005**, during the processing of samples, e.g., to determine a location of a specific sample in the process, that is, a location in a specific module using, for example, the user interface **8000**. The user display is a human-machine interface. The user interface **8000** may be understood to be a graphical user interface, with unique displays relating to the first to fifth modules of the automated liquid processing system **1000**.

[0097] Functions of and interactions between the modules, controller, LIMS controller, and/or user interface with be described herein in further detail.

II. First Module

[0098] The first module **2000** will be described further with reference to FIGS. **3** to **7**. As noted above, the first module **2000** is configured to receive one or more first tubes **1005**. The first module **2000** may also be referred to as an input module. To facilitate the receipt of one or more first tubes **1005**, the first module **2000** includes the plurality of first module conveyor channels **2005**, as well as one or more first module return channels **2010** (only one first module return channel **2010** is depicted in FIG. **3**, although more may be included).

[0099] FIG. **3** is a schematic drawing of a first module **2000** of the automated liquid processing system **1000**, and in particular, shows the plurality of first module conveyor channels **2005**, including two first module conveyor belts **2015**, and the first module return channel **2010**, as well as a first module frame **2020**, the upper door **1045** and the lower doors **1050** of the first module **2000**, the user interface **8000**, an input opening **2025**, an input indicator light **2030**, indicator lights **2035** for the first module conveyor channels **2005**, and the electrical power supply connection **1040**. FIG. **4** is a schematic drawing of a top view of the first module **2000** shown in FIG. **3** (with the roof of first module **2000** removed), and shows the first module conveyor belts **2015**, the first module return channel **2010**, a first module scanner **2040** located toward an input end **2045** of the first module, and a plurality of first inserts **1055** located toward an output end **2050** of each first module conveyor channel **2005**. FIG. **4** also shows an output sensor **2055** at the back end of each first module conveyor belt **2015**. Each first module conveyor belt **2015** may extend across multiple, e.g., four, conveyor channels **2005**, with one first module conveyor belt **2015** being located on one side of the first module return channel **2010**, and the other first module conveyor belt **2015** being located on the other side of the first module return channel **2010**. In other aspects, each conveyor channel **2005** may have its own distinct conveyor belt **2015**. In some embodiments, the first module conveyor belts **2015** may be configured to continuously rotate. In other embodiments, the first module conveyor belts **2015** may rotate based on signals output by the controller **7000**. Although two conveyor belts **2015** and eight conveyor channels **2005** are shown, with a single first module return channel **2010** located centrally between them, in FIGS. **3** and **4**, any suitable number of channels and conveyor belts and/or arrangement of channels and conveyor belts may be used. In some aspects, for example, the number of first module conveyor channels **2005**, first module conveyor belts **2015**, and/or first module return channels **2010** incorporated in the first module **2000** may depend, at least in part, on the maximum intended processing volume of liquid samples through the system.

[0100] FIG. **5** is a schematic drawing of a detail view of one of the first module conveyor channels **2005**, and shows a first insert **1055**, with a plurality of first tubes **1005** therein, located at the output end **2050** of the first module conveyor channel **2005**, as well as the output sensor **2055**. FIG. **5** also shows a high level sensor **2060**, a low level sensor **2065**, and an insert hold back protrusion **2070** in the first module conveyor channel **2005**. FIG. **6** is a schematic drawing of a detail view of the input opening **2025** of the first module **2000**, and shows the indicator lights **2035**, the input indicator light **2030**, a first module scanner push button of the first module **2000**, the first module conveyor channels **2005**, and the first module return channel **2010**. FIG. **7** is a schematic drawing of a first insert **1055** to be input into the first module **2000**, and in particular, shows a plurality of slots **1060** for receiving the first tubes **1005**, a projection **1065** to facilitate handling of the first insert **1055**, and a first insert label **1070**.

[0101] The first module conveyor channels **2005** are configured to receive one or more first inserts **1055** through the input opening **2025**. The first inserts **1055** include the plurality of slots **1060** that are configured to hold the first tubes **1005** and, in the embodiment shown in FIGS. **3** to **7**, the first inserts **1055** have 20 slots **1060**, although any suitable number of slots **1060** may be included. Further, the size, shape, and arrangement of slots **1060** may depend, at least in part, on the size of the first tubes **1005** that slots **1060** are configured to receive. The first inserts **1055** may also have one or more first insert labels **1070** with identifying information, for example, a label adhered to the first insert **1055** with a unique barcode for each first insert **1055**. The identifying information is not limited to a barcode, and may be a quick-response (QR) code (or other two-dimensional barcode or data matrix, referred to collectively as a "QR code" herein), alphanumeric symbols, sequences, identification chips, colors, or any other suitable label for identification.

[0102] The first inserts **1055** may receive one or more first tubes **1005** that contain liquid samples, e.g., blood samples from patients, and other first tubes **1005** that are placeholders, devoid of any liquid samples for processing, also referred to as "dummy tubes." The dummy tubes **1005** may be input into the automated liquid processing system **1000** for the purpose of balancing during spin cycles of the second module centrifuges **3010**, as described in more detail below. Each of the first tubes **1005**, including the dummy tubes **1005**, may also have labels with identifying information, for example, a label (not shown) adhered to each first tube **1005** with a unique barcode. The identifying information is not limited to a barcode, and may be a QR code, alphanumeric symbols, sequences identification chips, colors, or any other suitable label for identification. Of the first tubes **1005** that contain blood samples from patients, there may be pairs of first tubes **1005** that contain blood samples from the same patient.

[0103] Before being placed on a first module conveyor belt **2015**, each first insert **1055** may be scanned by the first module scanner **2040**. An operator may initiate the scanning process by pressing the first module scanner push button, or another suitable actuator, which may also serve as the input indicator light **2030**. Alternatively, the first module scanner **2040** may be on, while the automated liquid processing system **1000** remains on, and ready to scan a first insert **1055** held under a scanner light (not shown) of the first module scanner **2040**. The first module scanner **2040** may communicate the identifying information of the one or more scanned first inserts **1055** to the controller **7000**, and the controller **7000** may receive and store the identifying information of the scanned first insert **1055** in the memory **7005** of the controller **7000**. The controller **7000** may also determine whether the first insert **1055** may be input into the first module **2000** and may be configured to change the input indicator light **2030** depending on the determination, as described in more detail below with reference to FIGS. **46**A and **46**B. That is, the controller **7000** may determine if a first insert **1055** is compatible by, for example, comparing the identifying information of the scanned first insert **1055** to a manifest listing expected or allowed first inserts **1055** and their corresponding identifying information. In addition or alternatively, determining compatibility may include confirming that the first insert **1055** may be used with the second module centrifuges **3010**. As a specific example, if the first insert **1055** is compatible, the controller **7000** may turn on the input indicator light **2030**, to indicate that the first insert **1055** may be put into the first module **2000**. If the first insert **1055** is not compatible, the controller **7000** may turn off the input indicator light **2030**, to indicate that the first insert **1055** may not be put into the first module **2000**. In some embodiments, a color of the input indicator light **2030** may be changed, for example, from green, indicating the first insert **1055** may be input into the first module **2000**, to red, indicating the first insert **1055** may not be input into the first module **2000**, instead of turning the input indicator light **2030** on and off. In other aspects, other suitable visual indicators other than lights may be used, for example, a display may show a first alphanumeric message or symbol if the first insert **1055** may not be input into the first module **2000** and a second alphanumeric message or symbol if the first insert **1055** may be input into the first module **2000**. In still other aspects, suitable audio or haptic feedback may be utilized to indicate whether a user may input the first insert **1055** into the first module **2000**. A first insert **1055** may be rejected by the controller **7000** if, for example, the first module scanner **2040** cannot read or detect an identifying label, e.g., a barcode, on the first insert **1055**, because it would not be possible to track the first insert **1055** through the automated liquid processing system **1000** if it does not have a readable identifying label, e.g., barcode.

[0104] After scanning of the first inserts **1055** and confirming they may be input into the automated liquid processing system **1000**, the first inserts **1055** may be placed into one of the first module conveyor channels **2005**, onto one of the first module conveyor belts **2015**. Each first module conveyor channel **2005** may have an indicator light **2035** or other suitable indicator that indicates whether it can receive a first insert **1055**. This determination of whether a first module conveyor channel **2005** may receive a first insert **1055** may be made by the controller **7000**, as part of the first module control method described below with reference to FIGS. **46**A and **46**B. In the embodiment shown in FIGS. **3** to **7**, an indicator light **2035** is located above each of the first module conveyor channels **2005**, however the indicator light **2035** may be at other locations related to the first module conveyor channels **2005**, and/or indicators may appear on the user interface **8000**, instead of or in addition to indicator lights **2035**. For example, in some embodiments, a green indicator light **2035** above one of the first module conveyor channels **2005** may indicate that first inserts **1055** may be placed in that first module conveyor channel **2005**, and a red indicator light **2035** may indicate that first inserts **1055** may not be placed in that first module conveyor channel **2005**. The high level sensor **2060** and the low level sensor **2065** of each first module conveyor channel **2005** may be used to determine whether a first insert **1055** may be placed in each first module conveyor channel **2005**. That is, if the low level sensor **2065** does not detect a first insert **1055** at a location in the first module conveyor channel **2005** corresponding to that of the low level sensor **2065**, the low level sensor **2065** may be configured to output a notification to the controller **7000** that the first module conveyor channel **2005** has room to receive additional first inserts **1055**. If the low level sensor **2065** does detect a first insert **1055** at the location in the first module conveyor channel **2005** corresponding to that of the low level sensor **2065**, then the high level sensor **2060** may be checked to determine whether a first insert **1055** at a location in the first module conveyor channel **2005** corresponding to that of the high level sensor **2060**. If the high level sensor **2060** detects a first insert, the high level sensor **2060** may be configured to output a notification to the controller **7000** that the first module conveyor channel **2005** is full and cannot receive any additional first inserts **1055** until at least the high level sensor **2060** no longer detects a first insert **1055** at that location.

[0105] In some aspects, the first module **2000** may be configured such that multiple first inserts **1055** may be received and maintained within a single conveyor channel **2005** until the first module conveyor channel **2005** is completely full, or a predetermined number of first inserts **1055** have been received in a single conveyor channel **2005**. The first inserts **1055** may be held within the single conveyor channel **2005** until the second module **3000** is ready to receive one or more of the first inserts **1055**. This is shown, for example, in FIG. **4**. For example, if only the low level sensor **2065** detects the presence of a first insert **1055** in a given first module conveyor channel **2005**, then an indicator may indicate that the first module conveyor channel **2005** is able to accept another first insert **1055**. However, if the high level sensor **2060** detects the presence of a first insert **1055** in a given first module conveyor channel **2005**, then an indicator may indicate that the first module conveyor channel **2005** is unable to accept another first insert **1055**.

[0106] After one or more first inserts **1055** are placed in one of the first module conveyor channels **2005**, the first inserts **1055** may be conveyed on the first module conveyor belts **2015**, from the input end **2045** toward the output end **2050**. In some aspects, an insert hold back protrusion **2070** may be included. The insert hold back protrusion **2070** in each first module conveyor channel **2005** may be spring-loaded and configured to protrude into a path of first inserts **1055** in the first module conveyor channel **2005**, and on the first module conveyor belt **2015**, to prevent first inserts **1055** that have passed the insert hold back protrusion **2070** from regressing or moving back toward the input end **2045**.

[0107] Each of the first module conveyor channels **2005** may also have an output sensor **2055** at the output end **2050** configured to detect the presence of a first insert **1055** at the output end **2050**. When the output sensor **2055** detects the presence of a first insert **1055**, a notification may be sent to the controller **7000** to indicate that a first insert **1055** is ready for transfer to the second module **3000**. The controller **7000** may also use these notifications to control the second module by communicating to the second module gantry robot **3025** to pick up the first inserts **1055** and bring them to the second module **3000**. Alternatively, if the first module **2000** is a stand-alone module, the first inserts **1055** may be output to an operator.

[0108] With reference to FIG. **7**, each of the first inserts **1055** may have a projection **1065** in a center region thereof, and a squared gripping neck **1066**, below a top portion of the projection **1065**, which may be grasped by the second module gantry robot end effector **3030**. The squared gripping neck **1066** may facilitate grasping of the first insert **1055**, while avoiding rotation of the first insert **1055** after it is grasped by the second module gantry robot **3025**. Although a squared gripping neck is shown and described in reference to FIG. **7**, any suitable shaped gripping neck may be used. In some aspects, one or more notches may be present on the gripping neck, which may also facilitate grasping of the first insert **1055**. Although the projection **1065** of the first insert **1055** in FIG. **7** is at a center of the first insert **1055**, the projection **1065** may be at other locations on the first insert **1055**. In addition, although the first insert **1055** in FIG. **7** has one projection **1065**, more than one projection **1065** may be provided on the first insert **1055**. Further, although a projection **1065** with a squared gripping neck **1066** is depicted, any other suitable mechanism to facilitate grasping may be included as part of the first insert **1055**, for example, a handle, a hook, a loop, etc. Projection **1065** may be compatible with robotic end effectors throughout the automated liquid processing system **1000** to facilitate the movement of first insert **1055** through the automated liquid processing system **1000**. The first inserts **1055** also are depicted as having an octagonal outer circumferential shape. However, inserts having other outer circumferential shapes may be used, including circular-shaped, oval-shaped, rectangle-shaped, square-shaped, and other polygonal-shaped inserts. The shape of the first insert **1055** may be determined at least in part based on the type of centrifuge included in the second module **3000**, such that the first tubes **1005** received in the first module **2000** do not need to be placed in a different container or adapter prior to being placed within the second module centrifuges **3010**. In other words, the first inserts **1055** may be selected based on their compatibility with the second module centrifuges **3010**.

[0109] The first module **2000** also may include the first module return channel **2010**, shown in FIGS. **3**, **4**, and **6**, through which empty first inserts **1055** returned from the second module **3000** may be returned to an operator through the input opening **2025** of the first module **2000**. Although one, centrally located first module return channel **2010** is depicted, the first module return channel **2010** may be located in any suitable position relative to the first module conveyor channels **2005**, or more than one first module conveyor channels **2005** may be included.

III. Second Module

[0110] The second module **3000** of the automated liquid processing system **1000** will be described with reference to FIGS. **8** to **10**. As noted above, the second module **3000** is configured to centrifuge the received first tubes **1005** to isolate plasma. The second module **3000** may also be referred to as a centrifuging module.

[0111] FIG. **8** is a schematic drawing of the second module **3000**, and shows a second module frame **3035**, a second module deck **3040**, two openings **3005** in the second module deck **3040** to allow access to the second module centrifuges **3010**, two second module centrifuges **3010** below the second module deck **3040**, two second module conveyor channels **3045**, including the second module conveyor belts **3015**, the second module return channel **3020**, which may be continuous and/or configured to operably align with the first module return channel **2010**, and the upper door **1045** and the lower doors **1050** of the second module **3000**.

[0112] FIG. **9** is a schematic drawing of a top view of the second module **3000**, with the roof of the second module **3000** removed. FIG. **9** shows the second module deck **3040** with the openings **3005** to allow access to each of the second module centrifuges **3010**. The second module **3000** also includes the second module conveyor channels **3045**, including second module conveyor belts **3015**, second module scanners **3050** at upstream ends **3055** of each of the second module conveyor channels **3045**, an insert sensor **3060** at an output end **3065** of the second module conveyor channels **3045**, and the second module return channel **3020**. The second module **3000** further includes the second module gantry robot **3025**, including a second module gantry robot frame **3070** and a second module gantry robot arm **3075**. FIG. **9** depicts first inserts **1055** on the second module conveyor belts **3015**, the second module return channel **3020**, and in one of the second module centrifuges **3010**.

[0113] FIG. **10** is a schematic drawing of a portion of the second module gantry robot **3025** holding a first insert **1055**. In particular, FIG. **10** shows the second module gantry robot arm **3075**, which extends down from the second module gantry robot frame **3070**, shown in FIG. **9**, and a second module gantry robot end effector **3030** connected to an end of the second module gantry robot arm **3075**, the second module gantry robot end effector **3030** holding the projection **1065** of the first insert **1055**. In addition, FIG. **10** shows a first tube **1005** with a first tube cap **1075**, within a slot **1060** of the first insert **1055**.

[0114] Based on receipt of instructions from the controller **7000**, the second module gantry robot arm **3075** is configured to move to the output ends **2050** of the first module conveyor channels **2005** of the first module **2000**, and, using the second module gantry robot end effector **3030**, to pick up a first insert **1055**, e.g., by grasping projection **1065**. Then, the second module gantry robot arm **3075** is configured to hold the first insert **1055** in front of one of the second module scanners **3050**. The second module scanners **3050** are configured to read identifying information, such as a barcode on a stuck-on label, on each of the first inserts **1055**, and output the identifying information to the controller **7000**. In addition to storing the information output by the second module scanners **3050**, the controller **7000** may store, as information associated with the first insert **1055**, the specific second module centrifuge **3010** into which each first insert **1055** is to be placed, coordinating the subsequent placement of the first insert **1055** into a specific second module centrifuge **3010** within the second module gantry robot **3025**. By this arrangement, the controller **7000** may be capable of tracking the first inserts **1055** through the second module **3000**. In some aspects, this arrangement may allow the controller **7000** to monitor performance of each of the second module centrifuges **3010**, e.g., in case blood samples in first tubes **1005** in a specific first insert **1055** are determined, based on image analysis performed in the third module **4000**, to be insufficiently separated into layers from the spin cycle performed in the second module **3000**.

[0115] After scanning, the first insert **1055** may then be placed into one of the openings **3005** to the second module centrifuges **3010**. In some aspects, each of the second module centrifuges **3010** may be configured to hold one first insert **1055**. In other aspects, each second module centrifuge **3010** may hold a plurality of first inserts **1055** per spin cycle. As one example, each second module centrifuge **3010** may be configured to hold up to four first inserts **1055**. Once a second module centrifuge **3010** is filled, and in this example, is filled with four first inserts **1055**, the second module centrifuge **3010** may be configured to perform a spin cycle to isolate one or more components of a liquid sample within the first tubes **1005**. In the event that the first tubes **1005** contain blood samples, centrifugation may result in isolation of plasma within the first tubes **1005**. More specifically, the spin cycle may cause relatively less dense portions of blood in the first tubes **1005** to move upward within the first tubes **1005**, and relatively more dense portions of blood to move downward within the first tubes **1005**. As a result of a spin cycle by the second module centrifuges **3010**, blood in the first tubes **1005** may separate into a lower red blood cell layer L**3** and an upper plasma layer L**1** (FIG. **17**). In addition, a buffy coat red layer L**2** may remain in between the lower red blood cell layer L**3** and the upper plasma layer L**1**, the buffy coat red layer L**2** containing contents of white blood cells and platelets (FIG. **17**).

[0116] A timer (not shown) may be used to control and, in some aspects, to stagger start times of spin cycles of the four second module centrifuges **3010**. This may promote efficient and/or continuous processing of first tubes **1005** in first inserts **1055**, and regular or continuous flow of the first inserts **1055** downstream, to the third module **4000**. The second module centrifuges **3010** may be operably coupled to and configured to communicate to the controller **7000** when a spin cycle has started and when a spin cycle has completed. Other mechanisms may be used to control the operation of the second module centrifuges **3010**. As one example, each second module centrifuge **3010** may be configured to detect when the liquid samples within the first tubes **1005** placed in the second module centrifuge **3010** are sufficiently separated, stop the spin cycle, and communicate this information to the controller **7000**. Although four centrifuges **3010** are depicted in FIG. **9**, any suitable number of centrifuges may be included. In some aspects, for example, the number of centrifuges **3010** incorporated in the second module **3000** may depend, at least in part, on the maximum intended processing volume of liquid samples through the system.

[0117] Following the spin cycle, controller **7000** may receive a signal from one or more centrifuges **3010**, and, in response, controller **7000** may communicate to the second module gantry robot end effector **3030** to pick up the first inserts **1055** from one or more of the second module centrifuges **3010**, and to place the first inserts **1055** on one of the second module conveyor belts **3015** of the second module conveyor channels **3045**. The first inserts **1055** may then be then conveyed toward the third module **4000**. The second module conveyor belts **3015** may be indexing conveyor belts, although other types of conveyor belts may be used. Insert sensors **3060** near or at output ends **3065** of the second module conveyor channels **3045** may be configured to detect first inserts **1055** ready to exit the second module **3000** and ready to enter the third module **4000**. Alternatively, if the second module **3000** is a stand-alone module, the first inserts **1055** may be received from or input by an operator, and/or the first inserts **1055** may be output to an operator.

[0118] After the first tubes **1005** are removed from the first inserts **1055** by a pairing robot **4005** of the third module **4000**, as discussed in more detail below, the emptied first inserts **1055** may be returned to the second module return channel **3020** for disposal or for reuse for receipt of more first tubes **1005**. In some aspects, the second module return channel may be continuous and/or configured to operably align with the first module return channel **2010**. In such cases, the number or arrangement of second module return channel(s) **3020** may correspond to the number or arrangement of the first module return channel(s) **2010**. In the figures included herein, the first module **2000** includes one central first module return channel **2010**, and thus the second module **3000**, too, includes one central second module return channel **3020**.

IV. Third Module

[0119] The third module **4000** will be described with reference to FIGS. **11** to **30**. As noted above, the third module **4000** is configured to pair the first tubes **1005** containing the isolated component (e.g., plasma), excise labels on the first tubes **1005**, image the first tubes **1005**, perform liquid handling to transfer the subcomponent(s) of liquid into second tubes **1010**, and add a label to the second tubes **1010**. The third module **4000** may also be referred to as a pooling module.

[0120] FIG. **11** is a schematic drawing of the third module **4000**, and shows a third module frame **4026**, a third module deck **4035**, the pairing robot **4005**, a third module aspirator tip rack **4040** containing a plurality of third module aspirator tips **4045**, and the upper doors **1045** and lower doors **1050** of the third module **4000**. FIG. **12** is a schematic drawing of a top view of the third module **4000**, with the roof removed, and shows the third module deck **4035**, a pairing station **4050**, an excising station **4055**, and a liquid handling station **4060**. FIG. **12** also shows the pairing robot **4005**, a pairing scanner **4065**, and pairing platforms **4070** of the pairing station **4050**, and the excising robot **4010** of the excising station **4055**. In addition, FIG. **12** shows the first turntable **4025** in between the excising station **4055** and the liquid handling station **4060**, the second turntable **4030** downstream (to the right in FIG. **12**) of the liquid handling station **4060**, each of the first turntable **4025** and the second turntable **4030** being subdivided into portions, e.g., quarters, that rotate between the different positions, with each portion of the first turntable **4025** having a group of slots **4075**, and each portion of the second turntable **4030** having a group of slots **4080**. FIG. **12** also shows a third module liquid handling spanner **4020** of the liquid handling station **4060**. Further, FIG. **12** shows a hopper **4090** for supplying second tubes **1010** to the liquid handling station **4060**, a second tube conveyor **4095** for conveying the second tubes **1010**, a second tube transfer robot **4100**, and a decapping and marking device **4105**. Still further, FIG. **12** shows an opening **4110** in the third module deck **4035** through which third module aspirator tips **4045** are supplied to the liquid handling station **4060**, a third module aspirator tip rack conveyor **4115** that moves the supplied third module aspirator tips **4045** to the liquid handling station **4060**, and an opening **4120** in the third module deck **4035** through which the third module aspirator tips **4045** (FIGS. **1**, **20-24**, **29**, and **31**) are to be disposed. FIG. **13** is a schematic drawing of a detail view of a portion of the pairing station **4050**, and shows the pairing scanner **4065**, a pairing robot end effector **4125**, the pairing platforms **4070** of the pairing station **4050**, and slots **4130** of the pairing platforms **4070**.

A. Pairing Station of Third Module

[0121] With reference to FIGS. **11** to **13**, the pairing robot **4005** is configured to pick up and remove the first tubes **1005** from the first inserts **1055** at the ends of the second module conveyor channels **3045** (shown in FIGS. **8** and **9**), and to hold the first tubes **1005** in front of the pairing scanner **4065**. The pairing scanner **4065** is configured to read identifying information on each first tube **1005** and to communicate the identifying information to the controller **7000** for a verification process to identify first tubes **1005**, including paired first tubes **1005** that contain blood samples from the same patient, unpaired first tubes **1005** that contain one blood sample from one patient, and dummy tubes **1005**, which do not contain a blood sample, and with which unpaired first tubes **1005** are coupled.

[0122] The verification process may include the controller **7000** storing the received identifying information of each first tube **1005** in a database, and retrieving data associated with the identifying information, for example, a patient identifier, a patient name and/or a patient date of birth, from the memory **7005**, and retrieving data associated with any previously scanned first tubes **1005**. The verification process may then include comparing the data of one first tube **1005** with the data of the previously scanned first tubes **1005**, and, based on the comparison, the controller **7000** may instruct the pairing robot **4005** to place the first tube **1005** removed from the first insert **1055** in a slot **4130** on one of the pairing platforms **4070** that is adjacent to a paired first tube **1005** or that has an open adjacent slot **4130** for receiving the paired first tube **1005**. In a case in which the data of one first tube **1005** matches data of a previously scanned first tube **1005**, the controller **7000** may instruct the pairing robot **4005** to place the one first tube **1005** in the slot **4130** adjacent to the previously scanned first tube **1005** having the matching data. And, in a case in which the data of the one first tube **1005** does not match data of any previously scanned first tubes **1005**, the controller **7000** may instruct the pairing robot **4005** to place the first tube **1005** into a slot **4130** that has an empty adjacent slot **4130** (that is, the unmatched first tube **1005** is placed by itself into one slot **4130** of a pair of slots **4130** on the pairing platform **4070**). This would leave an empty adjacent slot **4130** available for later receiving a subsequent first tube **1005** for which the data matches that of the one first tube **1005**.

[0123] The first tube **1005** placed into the slot **4130** with an adjacent empty slot **4130** may be designated by the controller **7000** as an "unpaired first tube," and may remain so designated unless and until another first tube **1005** is scanned and confirmed to have matching data. In a case in which a first tube **1005** with matching data is subsequently scanned, the controller **7000** may change the designation of the first-placed first tube **1005** to "paired first tube." In some embodiments, following subsequent tube handling, the controller **7000** may instruct the pairing robot **4005** to place first tubes **1005** on a sequestration tray (not shown) if the first tube **1005** is identified but not expected by controller **7000** or a first tube **1005** having been placed in the pairing platform **4070** is missing its corresponding pair after the its first insert **1055** has been emptied. The sequestration tray may be located next to the pairing platforms **4070** and/or next to the first turntable **4025**. This verification process may ensure that any unexpected or unpaired first tubes **1005** are identified for sequestration and/or identified for downstream processing, particularly splitting of isolated plasma in the fifth module **6000**. Also as part of the verification process, the controller **7000** may also identify dummy tubes **1005** among the first tubes **1005** picked up from a first insert **1055**, and the controller **7000** may instruct the pairing robot **4005** to place the dummy tubes **1005** in a dummy tube bin (not shown) for disposal or reuse following the tube handling process.

[0124] The slots **4130** of the pairing platforms **4070** may be arranged in a grid, for example, a 4 by 5 grid of slots, such as shown in the accompanying figures. Although a 4 by 5 grid is shown in the exemplary embodiments, any suitable even number of slots may be used. A first tube **1005** of each pair of first tubes **1005** may be placed in an outer slot **4130**, and another first tube **1005** of a pair of first tubes **1005** may be placed in an inner slot **4130**, inside of and adjacent to the outer slot containing the first tube **1005**. Unpaired first tubes **1005** may be placed in the outer slots **4130**, with no accompanying, paired first tube **1005** being placed adjacent to those unpaired first tubes **1005**. The locations of the paired first tubes **1005** and the unpaired first tubes **1005** in the pairing platforms **4070** may also be stored, e.g., in memory **7005**, as information associated with the first tubes **1005**. Next, the first tubes **1005** are ready to be moved to the excising station **4055**.

B. Excising Station of Third Module

[0125] Aspects of the excising station are shown in FIG. **12**, described above, and in FIG. **14** and FIG. **15**, and the excising process will be described with reference to these figures. FIG. **14** is a schematic drawing of an excising robot end effector **4135**, including tube grips **4140** for grasping first tubes **1005** from one of the pairing platforms **4070**. FIG. **15** is a schematic drawing of a detail view of the excising station **4055**, showing a lift **4145**, a plurality of blades **4150**, and a plurality of blade actuators **4155** of the excising station **4055**.

[0126] During the excising process, the excising robot **4010** is configured to pick up a subset of first tubes **1005** from the pairing platform **4070** (FIG. **14**), and place the first tubes **1005** on the lift **4145** of the excising station **4055** (FIG. **15**). The lift **4145** may also be referred to as an excising platform. In the embodiment shown in FIGS. **12**, **14**, and **15**, the excising robot **4010** is capable of picking up a row of the first tubes **1005**, e.g., a row of four first tubes of the 4 by 5 grid at a time, however, the excising robot **4010** may be configured for picking up a lesser or a greater number of first tubes **1005**. In other aspects, the number of first tubes **1005** that the excising robot **4010** is configured to pick up may or may not correspond to the number of first tubes **1005** in a row of the pairing platform **4070**. To pick up the first tubes **1005** four at a time, the excising robot end effector **4135** may have four sets of tube grips **4140**, e.g., with each set containing four tube grips **4140**. The tube grips **4140** may move from a spaced-apart position, which allows for the excising robot end effector **4135** to lower the tube grips **4140** around upper ends of the first tubes **1005** on the pairing platforms **4070**, and a gripping position, in which the tube grips **4140** move toward each other to thereby grip the upper ends of the first tubes **1005** on the pairing platforms **4070**. In other aspects, the tube grips **4140** may not move relative to one another and instead may be capable of flexing outward relative to one another in order to friction fit around a first tube **1005** as the tube grips **4140** are moved down onto a top portion of a first tube **1005**. In some aspects, each set of tube grips **4140** may include one or more force or pressure sensors (not shown), or feedback sensors, that may be configured to detect the presence of a first tube **1005**, e.g., when the tube grips **4140** are moved to the gripping position. In a case in which the force sensor does not detect the presence of a first tube **1005** in a given set of tube grips **4140**, the excising robot **4010** may issue a notification to the controller **7000**. As an example, a first tube **1005** may correctly not be present if an unpaired first tube **1005** has been placed in the pairing platform **4070** and no paired first tube **1005** has been added (i.e., there is an empty slot **4130**). As another example, a first tube **1005** may not be present in a case in which a first tube **1005** breaks. In these instances, the excising robot **4010** may output the notification to the controller **7000** that no first tube **1005** is present, and the controller **7000** may either store this information in the memory **7005**, determine whether there should or should not be a first tube **1005** present, or outputs a notification to an operator, e.g., via the user interface **8000**, to check the third module **4000** for a broken or dropped first tube **1005**.

[0127] The blade actuators **4155** may moveably support the blades **4150**, and in particular, may be configured to move, e.g., rotate, the blades **4150** from a first position, in which the blades **4150** are relatively spaced apart from each other (that is, the blades **4150** are spaced at a first distance), to a second position, in which the blades **4150** are relatively closer together (that is, the blades **4150** are spaced at a second distance smaller than the first distance). In the embodiment shown in FIG. **15**, the excising station **4055** may include eight blades **4150**, including four sets of two blades **4150** facing each other, and eight blade actuators **4155**, one blade actuator **4155** for each of the blades **4150**. A greater or lesser number of blades **4150** may be used in the excising station **4055**, and the number of blades **4150** (and corresponding number of blade actuators) may be based on a number of first tubes **1005** supported by the lift **4145** and/or picked up at a time and transferred by the excising robot **4010**.

[0128] Once the four first tubes **1005** have been placed on the lift **4145**, the blade actuators **4155** may move, e.g., rotate, the blades **4150** from the first position to the second position. In being moved by the blade actuators **4155** to the second position, the blades **4150** may move to a fixed point, so that a distance between each pair of blades **4150** is controlled, to ensure sufficient contact with the first tubes **1005** to scrape off labels on the first tubes **1005**, if present, without causing damage or compromising the integrity of the first tubes **1005**. In some aspects, the blades **4150** may be spaced apart from each other in the second position a distance that is approximately equal to, or slightly less than, a width of a first tube **1005**. Then, the lift **4145** may move the four first tubes **1005** upward, so that the length of each of the first tubes **1005** passes through a corresponding pair of the blades **4150**. The lift **4145** may include a force sensor (not shown), or a feedback sensor, such that if a force counteracting the upward movement of the lift **4145** exceeds a predetermined limit, the sensor outputs a notification to the controller **7000**, which may stop the excision process, move, e.g., rotate, the blade actuators **4155** so that the blades **4150** are in the first position, stop the lifting of the first tubes **1005**, and/or issue a notification to an operator to check the blades

4150 and/or the blade actuators **4155**. This may help to protect against the breaking of one or more first tubes **1005**. As examples, if the blade actuators **4155** move, e.g., rotate, the blades **4150** too far inward, or too close to an opposing blade **4150** of a pair of blades **4150**, the blades **4150** may exert an excessive force on the lift **4145** as it moves upward, so the sensor outputs the notification. In some cases, the controller **7000** will output a notification to an operator to check the blade actuators **4155** and/or blades **4150** for calibration issues or for damage.

[0129] Although it is described above that the lift **4145** pushes the first tubes **1005** up through the pairs of blades **4150** to excise portions of labels on the first tubes **1005**, in other aspects, the lift **4145** may alternatively move the first tubes **1005** down relative to the pairs of blades **4150**, with the angles of the pairs of blades **4150** adjusted accordingly. In yet other embodiments, the first tubes **1005** may remain stationary on the lift **4145**, and the blade actuators **4155** may be configured to move the pairs of blades **4150** up or down relative to the first tubes **1005** to excise portions of labels on the first tubes **1005**. In still other embodiments, both the pairs of blades **4150** and the first tubes **1005** may be moved in opposite directions relative to one another in order to excise portions of labels on the first tubes **1005**.

[0130] Each first tube **1005** passes through a pair of two blades **4150**, the blades **4150** being on opposing sides of the first tube **1005**. The blades **4150** may be razors, and may be disc-shaped or any other suitable shape, so long as they have at least one sharp edge. In a case in which the blades **4150** are disc-shaped, the blades **4150** may be rotated periodically, in order to inhibit excessive wear on a particular point on the blades **4150**. Alternatively, in the case in which the blades **4150** are disc-shaped, the blades **4150** may be spun (that is, continuously rotated) about a center thereof, which may also inhibit excessive wear on a particular point on the blades **4150**.

[0131] As each first tube **1005** passes through the blades **4150**, material, such as labels, on opposing sides of an exterior surface of the first tube **1005**, if present, may be scraped off, creating a "window" through the first tube **1005**. As a result, a level or a height of each separated layer of liquid in the first tubes **1005** may be visible through the so-formed window, for use in a subsequent imaging process. More specifically, building on the example of blood samples noted above, the window of each first tube **1005** may allow for visualizing a height of a plasma layer L**1**, a height of a red blood cell layer L**3**, and a height of a buffy coat red layer L**2** in between the plasma layer L**1** and the red blood cell layer L**3**, these layers resulting from the first spin carried out in the second module **3000**. More generally, the window created on opposing surfaces of each first tube **1005** may allow for visualizing the liquid within each first tube **1005** and whether a component of that liquid has sufficiently been isolated.

[0132] In some embodiments, a suction source (not shown), such as a vacuum, may be located under the excising station **4055**, to suction scraped material, such as labels, downward and away from the blades **4150** and the lift **4145**. This may help to prevent debris from building up in the excising station **4055**, so that the excising station **4055** can process the next set of first tubes **1005** picked up by the excising robot **4010**.

[0133] As noted above, the excising robot end effector **4135** may include a force sensor, and if the sensor does not detect a force when the excising robot **4010** retrieves the first tubes **1005** from the excising station **4055**, a notification may be send to the controller **7000** to indicate a first tube **1005** is missing. This may happen, for example, if a first tube **1005** breaks during the excising process.

[0134] After the excising process, the first tubes **1005** may be ready for imaging.

C. Imaging Station of Third Module

[0135] An imaging station **4160** and the imaging and imaging analysis processes will be described with reference to FIGS. **16** and **17**. FIG. **16** is a schematic drawing of a detail view of the imaging station **4160** of the third module **4000**, and shows an imaging device **4165**, a backdrop **4170**, and the excising robot **4010** holding first tubes **1005** in between the imaging device **4165** and the backdrop **4170**. FIG. **17** is a schematic drawing of a detail view of an exemplary user interface **8000** of the controller **7000**, which can optionally be shown during the imaging analysis process.

[0136] During the imaging process, the excising robot **4010** may be configured to pick up the four first tubes **1005** from the lift **4145** and move the first tubes **1005** in between the imaging device **4165**, such as a camera, and the backdrop **4170**. The backdrop **4170** may be a plain back-lit backdrop. The excising robot **4010** may be configured to hold the four first tubes **1005** so that the windows where any label has been removed are facing and aligned with the imaging device **4165** and the backdrop **4170**, such that, from the viewpoint of the imaging device **4165**, the liquid within each of the four first tubes **1005**, e.g., the levels of the layers of the blood sample, are visible. Then, the imaging device **4165** may be configured to capture an image **4175** (FIG. **17**) of the first tubes **1005**, and output the captured image to the controller **7000** for an image analysis.

[0137] Although FIGS. **16** and **17** and the accompanying text describe the excising robot **4010** being configured to pick up and image four first tubes **1005** at a time, any suitable number of first tubes **1005** may be imaged at a time. For example, one, two, three, or more than four first tubes **1005** may be imaged at a time.

[0138] In some aspects, imaging device **4165** and/or an associated sensor may be configured to detect whether the windows of the first tubes **1005** are aligned with the imaging device **4165** prior to, during, or following the image capture. For example, a light, e.g., a light emitting diode (LED), may be shone in the direction of the first tubes **1005** in line with the imaging device **4165**. One or more sensors on an opposite side of the first tubes **1005** may be configured to detect whether the light passes through the first tubes **1005**, which would indicate that the windows of the first tubes **1005** are accurately positioned. Alternatively, if the one or more sensors do not detect light having passed through one or more of the first tubes **1005**, this would indicate that the window of at least one of the first tubes **1005** is not aligned with the imaging device **4165**. If this occurs, then the misalignment may be communicated to the controller **7000**, which may reposition the excising robot **4010**, control the excising robot **4010** to rotate one or more of the first tubes **1005**, and/or send an alert to an operator that one or more of the first tubes **1005** in the imaging station **4160** of the third module **4000** is not aligned.

[0139] FIG. **17** shows the captured image **4175** output by the imaging device **4165** on the user interface **8000** via a display **8005**. The output of the image analysis may or may not be displayed on the user interface **8000** via a display **8005**. In FIG. **17**, the layers of the liquid in the first tubes **1005** captured in the image are shown using different types of fill. As an example in which the liquid is blood, in each first tube **1005** in the image, the plasma is shown as the top layer L**1** with no fill, the buffy coat red layer L**2** is below the plasma layer L**1** with hatching fill, and the red blood cell layer L**3** is shown below the buffy coat red layer L**2**, with dot fill. During the image analysis process, for each first tube **1005**, the controller **7000** may be configured to analyze the captured image **4175** and identify a height of each of the layers of the blood, and store this information in the memory **7005**.

[0140] The image analysis may also include running a program, using the controller **7000**, which may be configured to evaluate an amount of red within the plasma layer L**1** of the imaged first tubes **1005** in the case of blood samples. If a plasma layer L**1** of a given first tube is too red, this may mean that the blood sample is homolycized, and in that case, the image analysis may be configured to output a notification that the first tube **1005**, and its pair, should be sequestered, as the blood sample may not be of sufficient quality for processing downstream of the automated liquid processing system **1000**. The sequestration of the first tube **1005**, and its pair, may also occur if the image analysis is unable to properly identify the layer interfaces, previously described, expected in the first tube **1005**.

[0141] To perform the color analysis, the program may include comparing the portion of the image **4175** showing the plasma layer L**1** to a color chart or to a color value, stored in the memory **7005**, and assessing a redness level of the plasma layer L**1** compared to the color chart or to the color value. For example, in a case in which a color chart is used, the shade of red on the color chart that is closest to the shade of red in the image corresponding to the plasma layer L**1** may be identified. The result of this comparison may be termed a "hemolysis grade," and if the shade of red of the plasma layer L**1** is too dark (or too severe), the sample may be identified as failing the imaging analysis. The hemolysis grade may be used to identify a quantity of hemoglobin per mL (for example, X g of hemoglobin per mL of plasma), using the color chart as a guide. The value of X may be predetermined and modified as needed. The program used to measure the hemolysis grade may be a trained software program, trained using previously-acquired images of first tubes **1005**, specifically showing plasma layers L**1**, and the color chart.

[0142] In a case in which the image analysis cannot be completed because of labels remaining on the exterior of the first tube **1005**, for example, the image analysis program may send a notification to the controller **7000** indicating the first tube **1005** is not usable or to check the blades **4150** of the excising station **4055**, as they may be worn and not sufficiently contacted the first tubes **1005** to scrape off the material and form the window.

[0143] The image analysis may also provide confirmation of the presence of one or more dummy tubes **1005**, in a case in which no liquid levels are detected in one or more of the first tubes **1005** of a captured image **4175**, or only a clear dummy liquid is detected. The image analysis similarly may confirm the presence of unpaired first tubes **1005**, in a case in which a captured image **4175** includes less than four first tubes **1005** (that is, there is an empty space in one or more of the spaces where a first tube **1005** should be). The image analysis may also confirm presence of first tubes **1005** and proper removal of first tubes **1005** from the pairing platform **4070**. If a captured image **4175** is missing an expected first tube **1005**, the image analysis may be configured to output a notification that a first tube **1005** was not properly transferred from the pairing platform **4070**.

[0144] Following image analysis, the first tubes **1005** may be ready for transfer to the third module liquid handling station **4015**.

D. Liquid Handling Station of Third Module

[0145] The third module liquid handling station **4015** and liquid handling process will be described with reference to FIGS. **18** to **30**.

1. Loading of First Turntable of Third Module

[0146] FIG. **18** is a schematic drawing of a detail view of the excising robot end effector **4135** placing the first tubes **1005** in pairs on the first turntable **4025** of the third module **4000**, after an image **4175** of the first tubes **1005** has been captured. That is, after the imaging device **4165** captures the image **4175**, the excising robot **4010** may be configured to move the four first tubes **1005** (or the number of first tubes **1005** held by the excising robot **4010** if not four) to the first turntable **4025**, and to place the first tubes **1005**, two at a time, into two adjacent slots **4075** on a portion of the first turntable **4025** that is in a loading position. The slots **4075** on the first turntable may be arranged in a 2 by X configuration, with X being an integer. In the embodiment shown in FIG. **18**, the slots **4075** are in a 2 by 8 configuration, such that 8 pairs of first tubes **1005** can be placed in the portion of the first turntable **4025**. The number of slots **4075** provided on the first turntable **4025** may be based, at least in part, on an overall size of the first turntable **4025**, and the portion thereof, on a size of the first tubes **1005**, and/or on the maximum intended processing volume of liquid samples through the system. After the first tubes **1005** have been loaded into the first turntable **4025**, they may be ready for decapping.

2. Decapping of First Tubes

[0147] FIG. **19** is a schematic drawing of the first turntable **4025** and a decapping station **4180** of the third module **4000**, and shows a third module decapping gantry robot **4185**, a third module decapping end effector **4190**, a cap stop **4195**, a cap disposal opening **4200** in the first turntable **4025**. A cap disposal opening **4205** is shown in the third module deck **4035**, as well as a tube disposal opening **4215** in the third module deck **4035**. FIG. **19** also shows a tube clear sensor **4220**, a stay **4210**, and the liquid handling station **4015**. FIG. **19** also shows a drip tray **4225**. FIG. **19** further depicts the positions of the first turntable **4025**, through which the four portions of the first turntable **4025** rotate, namely, the loading position **4025***a* in which the first tubes **1005** are loaded into the first turntable **4025** by the excising robot **4010**, as described above, a decapping position **4025***b* in which first tube caps **1075** are removed from the first tubes **1005**, a liquid handling position **4025***c* in which plasma is aspirated from the opened (i.e., uncapped) first tubes **1005**, and a tube disposal position **4025***d* in which the first tubes

1005 are moved to a first tube disposal container **4230** (shown in FIG. **42**B), such as a sharps container or a biohazard disposal container.

[0148] The first turntable **4025** may be configured to rotate, so that the portion of the first turntable **4025** holding the first tubes **1005** is in the decapping position **4025***b*. Then, once the first tubes **1005** are in the decapping position **4025***b*, the third module decapping gantry robot **4185** may move the decapping end effector **4190** first to a central position, in between a pair of first tubes **1005** on the portion of the first turntable **4025**, then in a first direction, for example, outward from a center of the first turntable **4025**, and then in a second direction, opposite to the first direction, for example, inward towards the center of the first turntable **4025**, to push out/off the first tube caps **1075** (for example, rubber stoppers) in the first tubes **1005**. The decapping end effector **4190** may then move back to the central position and subsequently move in between the next adjacent pair of first tubes **1005** on the portion of the first turntable **4025**, and may repeat the movements in the first direction and the second direction to uncap the next pair of first tubes **1005**. The decapping end effector **4190** may sequentially move in between adjacent pair of first tubes **1005** and then in the first direction and the second direction, until all first tube caps **1075** of the first tubes **1005** in that portion of the first turntable **4025** in the decapping position **4025***b* have been removed. The decapping end effector **4190** may, however, move in different directions and/or in a different order, in order to remove the first tube caps **1075** from the first tubes **1005**. For example, the decapping end effector **4190** may move in the second direction and then the first direction, or may move from one end of the rows of first tubes **1005** to the other, or vice versa, or in any other suitable order. Additionally or alternatively, the decapping end effector **4190** may be wide enough so that a single actuation in the first direction or the second direction is able to decap multiple adjacent first tubes **1005**.

[0149] Movement of the decapping end effector **4190** between pairs of first tubes **1005** and then inward and outward movement of the decapping end effector **4190** to remove the first tube caps **1075** may inhibit removed first tube caps **1075** from landing in between the pairs of first tubes **1005**, where they may be harder to clear. Pushing the first tube caps **1075** towards or over the edge of the first turntable **4025** in the first direction to remove the first tube caps **1075** may facilitate disposal of the removed first tube caps **1075** in the cap disposal opening **4205** in the third module deck **4035**. Pushing the first tube caps **1075** towards the center of the first turntable **4025** in the second direction to remove the first tube caps **1075** may facilitate disposal of the removed first tube caps **1075** in the cap disposal opening **4200** in the first turntable **4025**. Further, movement of the decapping end effector **4190** between the pairs of first tubes **1005** and then outwards and inwards may provide for more efficient movement and may reduce the time needed for the decapping end effector **4190** to maneuver into position and push out first tube caps **1075**. That said, the decapping end effector **4190** may move in any suitable manner to remove the first tube caps **1075** from each of the first tubes **1005**.

[0150] Sensors (not shown) may be included and positioned relative to the first tubes **1005** to detect if any first tube caps **1075** remain on the first tubes **1005** once the decapping end effector **4190** has passed through each pair of first tubes **1005** in that portion of the first turntable **4025**. If a first tube cap **1075** is detected on one of the first tubes **1005**, a signal may be output to the controller **7000** to notify an operator that one or more first tube caps **1075** need to be removed from one or more of the first tubes **1005**. The same sensor(s) or different sensor(s) may be configured to detect the presence of once or more first tube caps **1075** located on the turntable **4025**, e.g., in between or to a side of first tubes **1005**. In a case in which a first tube cap **1075** is detected by a sensor to a side of or in between first tubes **1005**, a signal may be output to the controller **7000** to notify an operator that one or more first tube caps **1075** need to be removed from the portion of the first turntable **4025**.

[0151] The removed first tube caps **1075** should, however, fall into either the cap disposal opening **4200** in the first turntable **4025** or into the cap disposal opening **4205** in the third module deck **4035** during the uncapping process. In addition, a wing piece (not shown) of the decapping station **4180**, located under the first turntable **4025** may be configured to make multiple passes along that portion of the first turntable **4025** during or subsequent to operation of the decapping end effector **4190** to sweep any removed first tube caps **1075** into the cap disposal opening **4205** in the third module deck **4035**. Incorporation of the cap disposal openings **4200** and **4205** and the wing piece may facilitate clearing of the removed first tube caps **1075** from the third module deck **4035** and from the first turntable **4025**. Once the first tubes **1005** have been decapped, they may be ready to be moved to the third module liquid handling station **4015**.

3. Supply and Loading of Third Module Aspirator Tips

[0152] FIG. **20** is a schematic drawing of a detail view of a third module tip rack hotel **4235** used to supply third module aspirator tips **4045** to components of the third module liquid handling station **4015**. In particular, FIG. **20** shows the third module tip rack hotel **4235** holding a plurality of third module aspirator tip rack supports **4240**, each of which may hold a third module aspirator tip rack **4040** containing a plurality of third module aspirator tips **4045** to be picked up by the third module liquid handling spanner **4020** (FIG. **23**). In addition, FIG. **20** shows a third module aspirator tip rack loading mechanism **4245**, and a third module aspirator tip conveyor belt **4250**.

[0153] The third module aspirator tips **4045** may be, e.g., 5 mL, 4-inch aspirator tips, for example, however, aspirator tips **4045** of greater or lesser volumes or sizes may be used. The volume or size of the aspirator tips **4045** used in the third module liquid handling station **4015** may be selected based, at least in part, on a size of the first tubes **1005**, a quantity of the first tubes **1005** loaded into the first turntable **4025**, and/or a number of passes or liquid transfer to be performed by the third module liquid handling station **4015**. Building on the specific example with the first tubes **1005**, the 5 mL, 4-inch aspirator tips **4045** may reduce a number of passes to be made by the third module liquid handling spanner **4020**, between the first turntable **4025** and the second turntable **4030**, which in turn may reduce an amount of time required for transfer of liquid from the first tubes **1005** in the first turntable **4025** to second tubes **1010** in the second turntable **4030**.

[0154] The third module aspirator tip rack hotel **4235** may be located in a bottom portion of the third module **4000**, under the opening **4110** in the third module deck **4035** through which third module aspirator tips **4045** are supplied to the third module deck **4035**, shown in FIG. **12**. The third module aspirator tip racks **4040** stored in the third module tip rack hotel **4235** may be transferred by the third module aspirator tip rack loading mechanism **4245**, from the third module aspirator tip rack supports **4240**, onto the third module aspirator tip rack conveyor belt **4250**. The third module aspirator tip rack conveyor belt **4250** may be an indexing conveyor belt, however, other types of conveying mechanisms may be used.

[0155] FIG. **21** is a schematic drawing of an upper portion of the third module tip rack hotel **4235** and the third module aspirator tip rack conveyor belt **4250**. Specifically, FIG. **21** shows the third module aspirator tip rack loading mechanism **4245**, the third module aspirator tip rack conveyor belt **4250**, third module aspirator tip racks **4040** with third module aspirator tips **4045** loaded thereon, and a conveying direction of the third module aspirator tip racks **4040**. In FIG. **21**, the third module aspirator tip racks **4040** may be moved from the third module aspirator tip rack hotel **4235** to the third module aspirator tip rack conveyor belt **4250** by the third module aspirator tip rack loading mechanism **4245**. Then, the third module aspirator tip racks **4040** may be moved in a conveying direction, shown by the arrow, toward the third module liquid handling station **4015**.

[0156] FIGS. **22**A and **22**B are schematic drawings of the third module aspirator tip racks **4040** carrying the third module aspirator tips **4045** on the third module aspirator tip conveyor belt **4250**, within the third module **4000**. In particular, FIG. **22**A shows the third module aspirator tip racks **4040** on the third module aspirator tip rack conveyor belt **4250**, on a lift **4255** at an output end **4260** of the third module aspirator tip rack conveyor belt **4250** that is in a low position, in which the third module aspirator tip racks **4040** are received, and FIG. **22**B shows the lift **4255** in a raised position, in which the third module aspirator tip racks **4040** are lifted toward the third module liquid handling spanner **4020**. The location at which the third module aspirator tip racks **4040** are lifted by the lift **4255**, that is, the location of the output end **4260** of the third module aspirator tip rack conveyor belt **4250**, may be in the aspirator tip loading and disposal opening **4120** in the third module deck **4035**, shown in FIG. **12**. This location is between the first turntable **4025** and the second turntable **4030** of the third module **4000**, and the third module liquid handling spanner **4020** may pick up one or a plurality of the third module aspirator tips **4045** at or near this opening **4120**, and dispose of used third module aspirator tips **4045** through the same opening **4120**, or a different opening.

[0157] FIG. **23** is a schematic drawing of spacing between the third module aspirator tips **4045** once picked up by the third module liquid handling spanner **4020** of the third module liquid handling station **4015**. In particular, FIG. **23** shows the third module aspirator tips **4045** loaded into the liquid handling spanner **4085**, in a first spacing configuration after being picked up from the third module aspirator tip racks **4040** by the liquid handling spanner **4085**, and positioned over the first tubes **1005** in the liquid handling position **4025***c* on the first turntable **4025**. FIG. **24** is a schematic drawing of spacing between the third module aspirator tips **4045** within the third module liquid handling station **4015**, and in particular, shows the third module aspirator tips **4045** in a second spacing configuration, for aspirating and dispensing plasma, as the third module aspirator tips **4045** move between the first turntable **4025** and the second turntable **4030**. In the second spacing configuration, the third module aspirator tips **4045** may be spaced to correspond in position to the first tubes **1005** on the first turntable **4025** and second tubes **1010** loaded on the second turntable **4030**, for aspirating and dispensing plasma from those tubes, respectively. In some aspects, the spacing between the third module aspirator tip racks **4040** and the spacing of the slots **4075** may be the same, and no movement or adjustment may be needed.

4. Supply of Second Tubes

[0158] The supply and loading of second tubes **1010** will be described with reference to FIGS. **25**A and **25**B. FIG. **25**A is a schematic drawing of the hopper **4090**, a step feeder **4265**, and a second tube conveyor **4270**, for supplying second tubes **1010** to the third module liquid handling station **4015**, and FIG. **25**B is a schematic drawing of a second tube **1010**. In particular, FIG. **25**A shows the hopper **4090** with second tubes **1010** loaded therein, the step feeder **4265**, and the second tube conveyor **4270**, including two conveyor belts **4275**, and two second tubes **1010** as they are dispensed by the step feeder **4265** into and oriented vertically by the two second tube conveyor belts **4275**. And FIG. **25**B shows the second tubes **1010**, which have a tube body **1080** with a conical tip **1085** at a bottom thereof, a second tube cap **1090** at a top thereof, markings **1095** to indicate fill levels of liquids contained by the second tubes **1010**, and a white space **1100**. The second tubes **1010** may be, for example, 15 mL, 4-inch conical tubes, although other volumes and sizes of tubes may be used. The second tubes **1010** may be a different size relative to the first tubes **1005**. For example, the second tubes **1010** may be relatively larger in volume or capacity as compared to the first tubes **1005**. In the specific example referenced above, the second tubes **1010** have a greater volume than the first tubes **1005**.

[0159] The hopper **4090** may be configured to receive the second tubes **1010** in bulk, and the step feeder **4265** may be configured to feed the second tubes **1010**, one by one, from the hopper **4090** into the second tube conveyor **4270**. The second tubes **1010** may be output by the step feeder **4265** in any orientation, but as the second tube **1010** reaches the two conveyor belts **4275** of the second tube conveyor **4270**, the two conveyor belts **4275** may be configured to catch the second tube cap **1090** of each second tube **1010**, thereby holding the second tube **1010**, while the tube body **1080** falls downward in between the two conveyor belts **4275**. A spacing between the two conveyor belts **4275** may be determined based on a maximum diameter of the tube body **1080** and a diameter of the second tube cap **1090**. That is, the two conveyor belts **4275** may be spaced to allow the tube body **1080** to drop from the step feeder **4265** into the space between the two conveyor belts **4275**, while the two conveyor belts **4275** hold the second tube cap **1090**. By this arrangement, each second tube **1010** dispensed from the step feeder **4265** may fall in between the two conveyor belts **4275**, into a vertical orientation, while the two conveyor belts **4275** hold the second tube **1010** by its cap **1090**. Then, the second tube **1010** may be conveyed toward the gripping and marking device **4105**.

5. Decapping and Marking of Second Tubes

[0160] The decapping and marking of the second tubes **1010** will be described with reference to FIGS. **26**, **27**A, and

27B. FIG. **26** is a schematic drawing of the gripping and marking device **4105** of the third module **4000**. The gripping and marking device **4105** has a tube grip **4280** configured to hold the tube bodies **1080** of the second tubes **1010**, in conjunction with the second tube transfer robot **4100**. The gripping and marking device **4105** also has a marking device **4285**. FIGS. **27**A and **27**B are schematic drawings of a second tube transfer robot end effector **4290**. The second tube transfer robot end effector **4290** may have a plurality, e.g., two, arm portions **4295**, and each arm portion **4295** may have a plurality, e.g., two cap grip portions **4300** and one or more tube grip portions **4305**. FIG. **27**A shows the second tube transfer robot end effector **4290** in a closed position, gripping a second tube cap **1090** of a second tube **1010**, and FIG. **27**B shows the second tube transfer robot end effector **4290** in an open position, after the second tube cap **1090** has been removed from the second tube **1010**.

[0161] In one embodiment, the second tube transfer robot **4100** may be configured to pick up one second tube **1010** by the cap **1090**, using the cap grip portions **4300** of the second tube transfer robot end effector **4290**, and place the tube body **1080** in a slot (not shown) within the third module deck **4035** that grips the tube body **1080** so that it cannot rotate within the slot. The second tube transfer robot **4100** then may be configured to rotate the cap **1090** in a counterclockwise direction to unscrew the cap **1090** and then lift the unscrewed cap **1090** upward. The second tube transfer robot **4100** may be configured to then rotate and lower to pick up the tube body **1080** from the slot, using the tube grip portions **4305** of the second tube transfer robot end effector **4290**. In this embodiment, the cap **1090** may have an inner threaded surface, and a top end of the tube body **1080** may have an outer threaded surface. The inner threaded surface of the cap **1090** and the outer threaded surface of the tube body **1080** are engaged, that is, the cap **1090** and tube body **1080** are threadably connected, and the cap **1090** can be removed from the tube body **1080** by rotating or "unscrewing" the cap **1090**.

[0162] After decapping of the second tube **1010**, the second tube transfer robot **4100** may be configured to hold the tube body **1080** in front of a sensor (not shown) near the marking device **4285**, and rotate the tube body **1080** until the sensor detects the free space on the tube body **1080**, such as the white space **1100**. Once the sensor detects the white space **1100**, the second tube transfer robot **4100** may stop rotating the tube body **1080**, and may lower the tube body **1080** into the tube grip **4280** of the marking device **4285**. The marking device **4285** may then add identifying information to the white space **1100** on the tube body **1080** held in the tube grip **4280**. As an example, the sensor may be a camera, and the marking device **4285** may be an etcher configured to etch a barcode onto the white space **1100** of each of the tube bodies **1080**. Other types of marking devices, such as devices that print and apply labels with glue or other adhesive may be used. In addition, other types of identifying information other than barcodes may be used (e.g., applied, etched, or otherwise provided onto the tube bodies **1080**), such as QR codes, alphanumeric symbols, sequences, identification chips, colors, or any other suitable label for identification. As noted above, the marking device **4285** may add barcodes, as an example of the identifying information, however the identifying information may be other types of information.

[0163] After the second tubes **1010** have been marked, the second tube transfer robot end effector **4290** may be configured to lift each tube body **1080** out of the tube grip **4280** of the gripping and marking device **4105**, and move and transfer the tube body **1080** and the respective cap **1090** to the second turntable **4030** for liquid handling. The marking device **4285** may output the added identifying information for each second tube **1010** to the controller **7000**, and based on this output and the subsequent movement/positioning of the second tube transfer robot **4100**, the controller **7000** may be configured to register and/or track and store the location of each labeled second tube **1010** in the second turntable **4030**.

[0164] Although the decapping and marking of the second tubes **1010** is described above in the order of decapping then marking, the process may be switched, in that the second tubes **1010** may first be marked and then decapped. In still other aspects, the second tubes **1010** received by the third module **4000** may be pre-labeled and scanned instead of labeled as described above. In other aspects, the second tubes **1010** may be received by the third module **4000** already uncapped, and the third module **4000** may not perform uncapping.

6. Loading of Second Tubes

[0165] FIG. **28** is a schematic drawing of the second turntable **4030** of the third module **4000**, and shows positions through which four portions of the second turntable **4030** rotate, namely, a loading position **4030***a*, in which the second tubes **1010** and caps **1090** are loaded into the second turntable **4030**, a liquid handling position **4030***b*, in which the plasma held by the third module aspirator tips **4045** is dispensed (or deposited) into the second tubes **1010**, and which is shown in FIG. **31**, and a recapping position **4030***c*, in which the caps of the second tubes **1010** are placed back on the second tubes **1010**. FIG. **28** also shows an actuating tube holder **4311**, near the portion of the second turntable **4030** in the recapping position **4030***c*, and discussed in more detail below with respect to the fourth module **5000**.

[0166] The second turntable **4030** has a plurality of tube slots **4080** and a plurality of cap slots **4310** or carve outs, which are relatively shallow compared to the tube slots **4080**, and which are adjacent to and spaced radially inside of the tube slots **4080**, relative to a center of the second turntable **4030**. The tube slots **4080** are configured to receive the tube bodies **1080** of the second tubes, and the cap slots **4310** are configured to receive caps **1090** of the second tubes **1010**. The tube slots **4080** and the cap slots **4310** are collectively arranged in a 2 by X configuration, where X is an integer, with a tube body **1080** and a cap placed in 2 adjacent slots, and other tube bodies **1080** and corresponding caps **1090** placed similarly, in a line. In the embodiment shown in FIG. **28**, the tube slots **4080** and cap slots **4310** are collectively in a 2 by 8 configuration.

[0167] As noted above, the controller **7000** is configured to store the locations of each labeled second tube **1010**. Using this information, the controller **7000** may be configured to associate each second tube **1010** placed on the second turntable **4030** with a pair of first tubes **1005** loaded into the first turntable **4025**. As an example, each pair of first tubes **1005** in a portion of the first turntable **4025** may be associated with one second tube **1010** in a portion of the second turntable **4030** by the controller **7000**. In a case in which the portion of the first turntable **4025** has eight pairs of first tubes **1005**, in pairs of slots **4075** designated one through eight, and the portion of the second turntable **4030** has eight second tubes **1010**, designated one through eight, the controller **7000** associates the pair of first tubes **1005** in the first slots **4075** on the first turntable **4025** with the second tube **1010** in the first slot **4310** on the second turntable **4030**, the pair of first tubes **1005** in the second slots **4075** on the first turntable **4025** with the second tube **1010** in the second slot **4310** on the second turntable **4030**, and so on.

[0168] And, based on the verification process of the first tubes **1005** at the pairing station **4050** and/or based on the image analysis of the first tubes **1005** at the imaging station **4160**, the controller **7000** may be configured to determine whether a second slot **4310** on the second turntable **4030** should remain empty (that is, no second tube **1010** will be placed in that second slot **4310**). This may be the case where the verification process and/or the image analysis identifies an unpaired first tube **1005** (i.e., a single first tube **1005**) that is placed in a first slot **4075** of the first turntable **4025**, or in a case in which a dummy tube **1005** is placed in a first slot **4075** of the first turntable **4025**, or in a case in which a first tube **1005** or was otherwise sequestered earlier in the process. By this arrangement, second tubes **1010** may only be provided for collecting plasma from pairs of first tubes **1005**. In some embodiments, however, a second tube **1010** may be placed in a corresponding slot **4310** for an unpaired first tube **1005** in the first turntable **4025**, and by this arrangement, second tubes **1010** may only be provided for collecting plasma from first tubes **1005**, and will not be provided in slots **4310** on the second turntable **4030** corresponding to locations of dummy tubes **1005**.

7. Aspiration from First Tubes

[0169] FIG. **29** is a schematic drawing of a detail view of the third module liquid handling station **4015**, and shows the liquid handling spanner **4020** holding a plurality of third module aspirator tips **4045** over the first tubes **1005** in the portion of the first turntable **4025** in the liquid handling position **4025***c*. The third module liquid handling spanner **4020** may have a plurality of third module aspirator mounting portions **4315**, which may be inserted into the third module aspirator tips **4045** on the third module aspirator tip racks **4040** (shown in FIGS. **20**, **21**, **22**A, and **22**B). The third module aspirator mounting portions **4315** may be sized to create a press fit within upper ends of the third module aspirator tips **4045**.

[0170] The third module liquid handling spanner **4020** may also have a flowmeter **4320** above each third module aspirating mounting portion **4315**, and each flowmeter **4320** may be configured to detect flow of a liquid as it is drawn into a corresponding third module aspirator tip **4045**. If the flowmeter **4320** of a third module aspirator tip **4045** detects that no liquid is being drawn or suctioned into a given third module aspirator tip **4045**, the flowmeter **4320** may be configured to output a notification to the controller **7000**, which in turn may issue an error notification to an operator. As an example, the flowmeter **4320** may output such a notification when the flowmeter **4320** does not detect suction of liquid and instead, air is suctioned into the third module aspirator tip **4045**. In other aspects, the flowmeter **4320** may output such a notification when the flowmeter **4320** detects insufficient flow of liquid into the third module aspirator tip **4045**, or if both liquid and air are detected flowing into the third module aspirator tip **4045**. Further, the third module liquid handling spanner **4020** may include connections (or connectors) between each of the third aspirator mounting portions **4315** and a suction source, such that a suction generated by the suction source is generated within the mounted third module aspirator tips **4045**.

[0171] The liquid handling spanner **4020** may be configured to move the third module aspirator tips **4045** over a first row of first tubes **1005** in the portion of the first turntable **4025**, and then the third module aspirator tips **4045** may be lowered into the first tubes **1005** of the first row. Then, based on instructions from the controller **7000** and the image analysis of the captured image **4175** of the first tubes **1005** in the first row showing a height of the various liquid layers within the first tubes **1005**, the third module aspirator tips **4045** may aspirate a volume of an isolated liquid component, e.g., plasma, from each first tube **1005**. The liquid handling spanner **4020** then may move the third module aspirator tips **4045** to the second turntable **4030**, for dispensing of the aspirated plasma into second tubes **1010**, as described in more detail below. The liquid handling spanner **4020** may then return the third module aspirator tips **4045** to the first turntable **4025**, and lower them into the first tubes **1005** in the second row so that each third module aspirator tip **4045** is lowered into the first tube **1005** in the second row that is the pair of the first tube **1005** in which that third module aspirator tip **4045** was previously lowered into in the first row.

[0172] The same third module aspirator tips **4045** can be used in the associated pairs of first tubes **1005**, without cross-contamination among the aspirator tips **4045**, because the pairs of first tubes **1005** contain blood samples from the same patient and because the spacing of the third module aspirator tips **4045** is matched to that of each pair of first tubes **1005**. That is, by moving the third module aspirator tips **4045** into the second spacing configuration shown in FIG. **24**, the third module aspirator tips **4045** align with one pair of first tubes **1005** in the first turntable **4025** and one second tube **1010** in the second turntable **4030**, and therefore do not pass over other first tubes **1005** or other second tubes **1010** with samples from different patients, which inhibits or prevents cross-contamination of the blood samples and the isolated liquid components, e.g., plasma.

[0173] Based on instructions from the controller **7000**, the third module aspirator tips **4045** may withdraw a volume of isolated liquid component, in this example, plasma, from each first tube **1005**, the volume being determined by the controller **7000** based on the image analysis of the captured image **4175** of the first tubes **1005** in both the first row and the second row. FIGS. **30**A and **30**B are schematic drawings of first tubes **1005** and exemplary flow rates and z-speeds (the rate at which the third module aspirator tips move in a z, or vertical, direction within the first tubes **1005**) for aspirating liquid from the first tubes **1005** using the third module liquid handling station **4015**.

[0174] The flow rate of aspiration and the z-speed of the third module aspirator tips **4045** may be individually controllable, based on one or more of the image analyses of the captured images **4175** of the first tubes **1005** and the determined z-heights of the plasma layer L**1**, the buffy coat red layer L**2**, and the red blood cell layer L**3**, a diameter of an orifice size of the third module aspirator tips **4045**, through which the plasma is to be aspirated, a density of the blood sample and/or of the plasma (for example, blood samples from different human or animal sources may have different densities), and/or the power of the suction source connected to the third module liquid handling station **4015** via a connector. One or both of the flow rate and the z-speed may be constant or varied. In addition or alternatively, the controller **7000** may also determine an amount (that is, a volume) of plasma to be aspirated from each first tube **1005** based on the z-heights of the plasma layer L**1**, the buffy coat red layer L**2**, and the red blood cell layer L**3**, determined from the image analysis, in order to set the flow rates and z-speeds.

[0175] FIG. **30**A shows the plasma layer L**1**, the buffy coat red layer L**2**, and the red blood cell layer L**3** of a first tube **1005**, as determined based on the image analysis, as well as the determined varied flow rates at which the plasma in the first tube **1005** is to be aspirated, and the varied z-speeds at which the third module aspirator tip **4045** is to be moved down into the first tube **1005** to aspirate the plasma, with both the flow rates and the z-speeds being incrementally decreased as the third module aspirator tip **4045** is lowered into the first tube **1005**. That is, in the embodiment shown in FIG. **30**A, the third module aspirator tips **4045** may be moved at a varying speeds and may suction at varying speeds, relatively fast at first and slower and slower as the third module aspirator tips **4045** move further down in the z-direction, into the first tubes **1005**. Although four different flow rates and four different movement speeds in the z-direction are shown in FIG. **30**, fewer or more decreases in flow rates and movement speeds may be used. Further, because each first tube **1005** may contain different heights of layers L**1**, L**2**, and L**3**, the controller **7000** may be able to control the flow rate and/or speed in a z-direction of each of the third module aspirator tips **4045** individually. That is, individual third module aspirator tips **4045** may aspirate liquid from individual first tubes **1005** at distinct flow rates and/or may move at distinct speeds in the z-direction from the other third module aspirator tips **4045** loaded onto the third module liquid handling spanner **4020**. In other aspects, each of the third module aspirator tips **4045** may not be individually controlled, and, for example, each of the third module aspirator tips **4045** may be set to the same suction force and/or speed in the z-direction, and the suction force and/or speed in the z-direction may be determined based at least in part on the smallest (shortest) plasma layer among the first tubes **1005** in one row of the first turntable **4025**.

[0176] In the variable speed embodiment of FIG. **30**A, the first flow rate W and first z-speed A may be relatively fast, while the last flow rate Z and last z-speed D may be relatively slow. Starting with a fast flow rate W and z-speed A may promote efficient aspiration, while ending with a slower flow rate Z and z-speed D may inhibit or prevent disruption of the buffy coat red blood layer L**2** or the red blood cell layer L**3**.

[0177] FIG. **30**B shows the plasma layer L**1**, the buffy coat red layer L**2**, and the red blood cell layer L**3** of a first tube **1005**, as determined based on the image analysis, as well as the determined varied flow rates at which the plasma in the first tubes **1005** is aspirated and the determined z-speed at which the third module aspirator tips **4045** are moved down into the first tubes **1005** to aspirate the plasma. That is, in the embodiment shown in FIG. **30**B, the third module aspirator tips **4045** are moved in a z-direction at a constant speed, while the flow rate at which the plasma is suctioned up by the third module aspirator tips **4045** may vary. The controller **7000** may determine the z-heights at which distinct flow rates for each individual first tube **1005** start and stop (that is, the height at which one of the third module aspirator tip **4045** is placed, a specific flow rate of suction is administered), based on the image analysis of each individual first tube **1005**. This may be done using an offset value of a height above the determined height of the buffy coat red layer L**2**, to perform aspiration (for example, a final or subsequent aspiration) at a relatively lower flow rate, so as not to disturb the buffy red coat layer L**2** or the red blood cell layer L**3**. In addition or alternatively, the controller may determine z-heights and/or z-speed values and individually control movement of the third module aspirator tip **4045** for each first tube **1005** to move at those determined values, to withdraw as much of the isolated plasma in each first tube **1005** as possible, without significantly disturbing the buffy coat red blood layer L**2** or the red blood cell layer L**3**.

[0178] Based on instructions from the controller **7000**, the third module aspirator tips **4045** may withdraw a first volume or a first portion of isolated liquid component, in this example, plasma, from each first tube **1005** in a first pass, the volume being determined by the controller **7000** based on the image analysis of the captured image **4175** of the first tubes **1005** in both the first row and the second row, and then withdraw a second volume or a second portion of isolated liquid component, again in this example, plasma, from each first tube **1005** in a second pass. That is, the liquid handling spanner **4020** may aspirate the isolated liquid component from the first row of first tubes **1005** twice and from the second row of first tubes **1005** twice. Although the liquid handling spanner **4020** is described as performing multiple passes when aspirating from each pair of tubes, in other aspects, a single volume or a single portion of the isolated liquid component may be aspirated at once from each first tube **1005**, so that the third module liquid handling spanner **4020** makes only two passes total (i.e., one for the first tube **1005**, of a pair of tubes, in the first row, and one for the second tube **1005**, of the pair of tubes, in the second row). In still other aspects, the isolated liquid component from both first tubes **1005** of a pair of tubes may be aspirated within a single pass.

[0179] In each pass, the controller **7000** may vary one or both of the flow rate at which the isolated liquid component is aspirated from the first tubes **1005** and the z-speed at which the third module aspirator tips **4045** are moved downward within the first tubes **1005**. As one example, the flow rate may be constant (e.g., relatively high) when aspirating the first volume from each of the first tubes **1005**, and the flow rate may be varied to decrease when aspirating the second volume from the same first tubes **1005** in the second pass. Alternatively, as another example, the flow rate may be variable when aspirating both the first volume and the second volume from each of the first tubes **1005**, or the flow rate may be constant when aspirating both the first volume and the second volume from each of the first tubes **1005**.

[0180] After aspirating the plasma from the first row of first tubes **1005** or the second row of first tubes **1005**, the third module liquid handling spanner **4020** may be configured to move over the drip tray **4225**, shown in FIGS. **19** and **29**. The drip tray **4225** may be included to protect consumables **1035** that may be stored below the third module liquid handling station **4015** from contamination, e.g., if liquid drips or leaks from one or more of the third module aspirator tips **4045**. Then liquid handling spanner **4085** may then move the third module aspirator tips **4045** to the second turntable **4030**, for dispensing of the aspirated plasma into second tubes **1010**.

8. Dispensing into Second Tubes

[0181] FIG. **31** is a schematic drawing of the second turntable **4030** of the third module **4000**, with second tubes **1010** loaded into the tube slots **4075** and caps **1090** loaded into the cap slots **4310** in the loading position **4030***a*. FIG. **31** also shows the actuating tube holder **4311** adjacent to second tubes **1010** in the portion of the second turntable **4030** in the recapping position **4030***c*, and discussed in detail below with respect to the fourth module **5000**.

[0182] The portion of the second turntable **4030** containing these second tubes **1010** and caps **1090** may be rotated, in a counter-clockwise direction in FIG. **31**, to the liquid dispensing position, and the third module aspirator tips **4045** may be moved by the third module liquid handling spanner to be positioned over the second tubes **1010**. Then, the plasma from the first pass of first tubes **1005** held by the third module aspirator tips **4045** may be dispensed into the second tubes **1010**. The third module aspirator tips **4045** may be first lowered into an upper region of the second tubes **1010** to inhibit or prevent splatter and/or loss of any of the aspirated plasma. This process may be repeated with plasma from the second pass of first tubes **1005**, so that the plasma from both first tubes **1005** of each pair of first tubes **1005** is combined into one second tube **1010** on the second turntable **4030**. By this arrangement, a relatively large volume of isolated plasma from two blood samples of a single patient may be combined into the second tube **1010** for further processing.

[0183] Building on the example of using 5 mL aspirator tips and 15 mL tubes, as described above, the estimated volume of plasma dispensed into each 15 mL tube may be approximately 10 mL. Using estimated values, as an example of the liquid handling process, the third module aspirator tips **4045** may aspirate 2.5 mL of plasma from a first tube **1005** in the first row on the first turntable **4025**, and then perform a second 2.5 mL aspiration of plasma from the second row first tube **1005**, and transfer and dispense the aspirated 5 mL into the 15 mL tube. Thus, the 15 mL tube may contain an estimated 2.5 mL of plasma from the first tube **1005** in each row. In the first pass, the third module aspirator tips **4045** may be controlled to aspirate the plasma at a relatively high flowrate and a relatively high z-speed, capturing isolated plasma in the upper portion of the first tubes **1005**.

[0184] And, in the second pass, the third module aspirator tips **4045** may be controlled to aspirate the plasma at a relatively low flowrate and a relatively low z-speed, to capture the remaining 2.5 mL isolated plasma in the first tubes **1005** without disturbing the buffy coat red layer L**2** or the red blood cell layer L**3**. Thus, the 15 mL tube may contain an estimated 10 mL of plasma total, from a single patient's combined blood samples.

[0185] After the plasma has been dispensed into the second tubes **1010**, the portion of the second turntable **4030** may rotate, in a counter-clockwise direction in FIG. **31**, to the recapping position, where the fourth module robot **5015** may be configured to pick up and place the caps **1090** back onto the second tubes **1010** (i.e., to recap the second tubes **1010**), pick up the recapped second tubes **1010**, and move them into the fourth module **5000**. Alternatively, if the third module **4000** is a stand-alone module, the first tubes **1005** may be received from or input by an operator, and/or the second tubes **1010** may be output to an operator.

E. Disposal of First Tubes

[0186] Disposal of the first tubes **1005** will be described with reference to FIG. **19**. After the plasma has been withdrawn from each of the first tubes **1005** in the liquid handling position of the first turntable **4025**, the first turntable **4025** may rotate, in a clockwise direction in FIG. **19**, to the tube disposal position **4025***d*. The stay **4210** may be included and may support the first tubes **1005** while the first turntable **4025** rotates to the tube disposal position **4025***d*. The stay **4210** may then move or retract to allow the first tubes **1005** to fall through the tube slots **4075** in the first turntable **4025**, and through the tube disposal opening **4215** into the first tube disposal container **4230** under the third module deck **4035**, as shown in FIG. **42**B and described below. The tube clear sensor **4220**, at one end of the stay **4210**, may be configured to detect whether any first tubes **1005** remain in the slots **4075** of the portion of the first turntable **4025**. If no first tubes **1005** are detected by the tube clear sensor **4220**, the portion of the first turntable **4025** may be free to rotate to the loading position **4025***a* to receive new first tubes **1005** to repeat this process again. If first tubes **1005** are detected by the tube clear sensor **4220**, a signal may be sent to the controller **7000**, which may in turn issue an error notification to an operator. This arrangement may provide for automated disposal of the first tubes **1005** without the need for an operator to manually pick up the first tubes **1005** and place them in the first tube disposal container **4230**.

F. Disposal of Third Module Aspirator Tips

[0187] With reference to FIG. **12**, after the third module liquid handling process has completed, the third module liquid handling spanner **4020** may move the third module aspirator tips **4045** over the aspirator tip disposal opening **4120** in the third module deck **4035**. Then, the third module aspirator tips **4045** may be removed, passively or actively (e.g., forcibly ejected) from the aspirator tip mounting portions **4315** of the third module liquid spanner **4085**, and may fall through the aspirator tip disposal opening **4120** into a third module aspirator tip disposal container **4325** located under the third module deck, as shown in FIG. **42**B and described below.

V. Fourth Module

[0188] The fourth module **5000** will be described with reference to FIGS. **32** to **35**. FIG. **32** is a schematic drawing of a fourth module **5000** of the automated liquid processing system **1000**. As noted above, the fourth module **5000** may be configured to spin the plasma in the second tubes **1010** to isolate the plasma a second time, e.g., from any residual red blood cells or contents of white blood cells and platelets. The fourth module **5000** may also be referred to as a centrifuging module. As also noted above, the fourth module **5000** includes fourth module centrifuges **5010**, a fourth module robot **5015**, and a fourth module pallet conveyor system **5020**. FIG. **32** also shows a fourth module deck **5025**, an upper door **1045** and lower doors **1050** of the fourth module **5000**, and the openings **5005** in the fourth module deck **5025** to the fourth module centrifuges **5010**. FIG. **33** is a schematic drawing of a top view of processing portions of the fourth module **5000** (with a roof of the fourth module **5000** being removed), and shows the fourth module robot **5015**, two fourth module scanners **5030**, the pallet conveyor system **5020**, the openings **5005** in the fourth module deck **5025** to the fourth module centrifuges **5010**, and a fourth module gantry robot **5035** having a fourth module gantry robot frame **5040** and a fourth module gantry robot end effector **5045**.

[0189] FIG. **34** is a schematic drawing of a top view of the pallet conveyor system **5020** of the fourth module **5000**, as well as two of the openings **5005** to the fourth module centrifuges **5010**. Specifically, FIG. **34** shows the pallet conveyor system **5020** including a fourth module conveyor belt **5050**, a plurality of second inserts **1105** configured to hold the second tubes **1010**, for example, the 15 mL tubes, and a plurality of pallet stops **5055**, and FIG. **34** also shows various positions along the pallet conveyor system **5020** at which the second inserts **1105** are processed in a loop, namely, a loading position **5020***a* in which the second tubes **1010** are loaded into the second inserts **1105**, an insert pick up position **5020***b* in which the fourth module gantry robot end effector **5045** picks up the second inserts **1105** and places them into one of the fourth module centrifuges **5010** via the openings **5005**, an insert placing position **5020***c*, in which the fourth module gantry robot end effector **5045** places the second inserts **1105** following a spin cycle by one of the fourth module centrifuges **5010**, and an unloading position **5020***d*, in which the second tubes **1010** are unloaded by the fifth module turntable load robot **6005**.

[0190] FIG. **35** is a schematic drawing of the second insert with the second tubes **1010**, as examples of the second tubes **1010**, placed therein. FIG. **35** also shows a fourth module gantry robot arm **5060** as well as the fourth module gantry robot end effector **5045**, a portion of the pallet conveyor system **5020**, and arrows indicating movement directions of the second inserts **1105**.

[0191] The fourth module robot **5015** is configured to pick up the caps **1090** on the portion of the second turntable **4030** in the third module **4000** in the recapping position **4030***c*, place the caps **1090** on the tops of the adjacent tube bodies **1080** in the same portion of the second turntable **4030**, and rotate the caps **1090** to secure the caps **1090** to the tube bodies **1080**, thus recapping the second tubes **1010**. In addition, the actuating tube holder **4311** is configured to actuate to grip the tube bodies **1080** of the second tubes **1010** on the portion of the second turntable **4030** in the recapping position **4030***c*, to secure the tube bodies **1080** as the fourth module robot **5015** rotates the caps **1090** onto the tube bodies **1080**. Although screw-on caps **1090** are described herein, other suitable caps, such as those that attach by friction fit, may be used, in which case the movements of the fourth module robot **5015** may be changed accordingly. The fourth module robot **5015** may then pick up the recapped second tubes **1010**, and move and place them into a second insert **1105** located in the loading position **5020***a* on the conveyor belt **5050** of the pallet conveyor system **5020**. The controller **7000**, having stored locations of specific second tubes **1010** within the second turntable **4030**, may register and/or track the placement of the specific second tubes **1010** into a specific second insert **1105**.

[0192] Empty slots on the portion of the second turntable **4030** in the recapping position **4030***c* may result from the sequestration of unpaired first tubes **1005**, dummy tubes **1005**, and/or broken first tubes **1005** or second tubes **1010**, in the third module **4000**, and the fourth module robot **5015** will, therefore, only pick up and move second tubes **1010** containing plasma. The fourth module robot **5015** may fill each of the second inserts **1105** with second tubes **1010** containing plasma. That is, no empty second tubes **1010** are placed into the second inserts **1105**, and any gaps that may have resulted from the identification of unpaired first tubes **1005** or dummy first tubes **1005** or broken first tubes **1005** in the third module **4000** may be omitted at this step.

[0193] The pallet stops **5055** of the pallet conveyor system **5020** may be designed to stop or hold positions of the second inserts **1105** for an amount of time, so that processes, such as loading of second tubes **1010** into second inserts **1105** in the loading position **5020***a*, may be completed. In other aspects, pallet stops **5055** may not be needed, and the conveyor system **5020** may stop moving until all processes at each position of the pallet conveyor system **5020** are complete. When a second insert **1105** is filled with second tubes **1010**, the pallet conveyor system **5020** may move the second insert **1105** to the insert pick up position **5020***b*, where the fourth module gantry robot end effector **5045** may pick up the second inserts **1105**, one at a time or, optionally, multiple at a time, and place the second inserts **1105** into the fourth module centrifuges **5010**. As discussed previously, any suitable number of fourth module centrifuges **5010** may be included in fourth module **5000**, and the number of centrifuges included may depend, at least in part, on the maximum intended processing volume of liquid samples through the system **1000**.

[0194] With reference to FIG. **35**, the second inserts **1105** may be first conveyed in a direction shown by a first arrow A, to a position that aligns with one of the openings **5005** in the fourth module deck **5025**. Then the fourth module gantry robot end effector **5045** may pick up the second insert **1105** and hold it in front of one of the fourth module scanners **5030**, for scanning and storing of identifying information of the second insert **1105**, prior to placement into one of the fourth module centrifuges **5010**. The fourth module scanners **5030** may be configured to read identifying information on the second inserts **1105**, and this reading may be output to the controller **7000**. The controller **7000** may be configured to store the received identifying information into the memory **7005**, and may instruct the fourth module gantry robot **5035** to place the scanned second insert **1105** into one of the fourth module centrifuges **5010** via one of the aligned openings **5005** in the fourth module deck **5025**. In the example shown in FIG. **35**, the fourth module gantry robot end effector **5045** may move the second insert **1105** in a second direction, shown by a second arrow B, and lower it into the fourth module centrifuge **5010** below the opening. The controller **7000** may be configured to receive and/or store information regarding into which centrifuge, of the fourth module centrifuges **5010**, the scanned second insert **1105** is placed. By virtue of tracking the second tubes **1010** and their placement into particular second inserts **1105**, the controller **7000** may be able to track the second tubes **1010** through the fourth module **5000**, as well.

[0195] In the embodiment shown in FIGS. **32** to **35**, the fourth module **5000** has four fourth module centrifuges **5010**, with each of the fourth module centrifuges **5010** holding four second inserts **1105** per spin cycle. The number of fourth module centrifuges **5010** may be greater than or less than four, and the number of second inserts **1105** that can be loaded into the fourth module centrifuges **5010** per spin cycle may be greater than or less than four. After a fourth module centrifuge **5010** is filled (in this example, after four second inserts **1105** have been loaded into a fourth module centrifuge **5010**), the fourth module centrifuge **5010** performs a spin cycle, which further isolates plasma in the second tubes **1010**. The timing of the spin cycles and control of the fourth module centrifuges **5010** may be similar to that described in reference to centrifuges **3010** of the second module **3000**.

[0196] The inclusion of two sets of centrifuges (that is, one set of centrifuges **3010** in the second module **3000** and another set of centrifuges **5010** of the fourth module **5000**) in the automated liquid processing system **1000** may allow samples processed by the automated liquid processing system **1000** to even further isolate components of the processed liquid. In the examples herein, this may mean that in the case of blood plasma isolation, two centrifugation cycles may allow for the pull down of a bit of extra sediment that may not be fully separated out with only one centrifugation cycle. This may facilitate the running of any downstream tests, etc., that may be performed on the isolated plasma.

[0197] After the spin cycle is completed, the second inserts **1105** may be picked up by the fourth module gantry robot end effector **5045** through the openings **5005** in the fourth module deck **5025**, and placed back onto the conveyor belt **5050** of the pallet conveyor system **5020**, at the insert placing position **5020***c*. With reference to FIG. **35**, the fourth module gantry robot end effector **5045** may pick up the second inserts **1105** and move them in the direction of a third arrow C, placing them back onto the conveyor belt **5050**.

[0198] In some embodiments, an end-of-day process may be performed, in which an operator may introduce second tubes **1010** containing another liquid (for example, water), into the second inserts **1105**, in a case in which the last set of second tubes **1010** coming into the fourth module **5000** for spinning do not completely fill a second insert **1105** and/or additional second inserts **1105** need to be filled with second tubes **1010** and loaded into one of the fourth module centrifuges **5010** for load balancing. The operator may introduce the second tubes **1010** filled with the other liquid by opening the upper door **1045** of the fourth module **5000**, and placing the second tubes **1010** into one or more second inserts **1105**.

[0199] Following completion of the spin cycle and placement of the second inserts **1105** back onto the conveyor belt **5050**, the second inserts **1105** may be conveyed to the unloading position **5020***d*, where the fifth module turntable load robot **6005** may pick up the second tubes **1010** one at a time or, optionally, multiple at a time, and move them into the fifth module **6000** for further processing. Alternatively, if the fourth module **5000** is a stand-alone module, the second tubes **1010** may be received from or input by an operator, and/or the second inserts **1105** may be output to an operator.

VI. Fifth Module

[0200] The fifth module **6000** will be described with reference to FIGS. **36** to **41**. FIG. **36** is a schematic drawing of the fifth module **6000** of the automated liquid processing system **1000**. As noted above, the fifth module **6000** is configured to batch and output the twice-isolated plasma (or other liquid component) into one or more output containers **1030**, for subsequent processing. The fifth module **6000** may also be referred to as a batching module. As an example, the output containers **1030** may include one or both of micronic tubes **1015** and deep well plates (DWPs) **1025**, although other types of containers may be used as the output containers **1030**. In one exemplary use case described further below, a liquid patient sample may be aspirated into a DWP **1025** for further processing. If sufficient amounts of the liquid patient sample are available, then a portion of the liquid patient sample may also be aspirated into a micronic tube **1015**, which may be set aside or stored (e.g., in cold storage) in the event that the liquid dispensed in the DWPs **1025** fails quality testing during subsequent processing, or back-up liquid patient sample is needed for any reason. In general, assuming that there is a sufficient amount of liquid to be divided between DWPs **1025** and micronic tubes **1015** (or other output containers **1030**), then as much liquid as possible may be dispensed into the DWPs **1025**, while reserving enough liquid for allocation to a micronic tube **1015** for back-up storage as would be useful, e.g., for re-processing a sample. As with the aspiration that occurs in the third module **4000**, aspiration in the fifth module **6000** may occur in one pass or in multiple passes. For example, a first pass may allocate liquid to a first output storage container **1030** (e.g., DWP **1025**), and a second pass may allocate liquid to a second storage container **1030** (e.g., micronic tube **1015**).

[0201] FIG. **36** shows the fifth module turntable load robot **6005**, the fifth module turntable unload robot **6006**, a fifth module scanner **6020**, a capping and decapping device **6025**, the fifth module gantry robot **6010**, the fifth module liquid handling station **6015**, a plate sealer **6030**, a fifth module deck **6035**, and the upper door **1045** and the lower doors **1050** of the fifth module **6000**. FIG. **37** is a schematic drawing of a top view of processing portions of the fifth module **6000** (with a roof of the fifth module **6000** removed), shown in FIG. **36**, and shows the fifth module turntable load robot **6005**, the fifth module turntable unload robot **6006**, an actuating tube holder **6007**, the fifth module scanner **6020**, a fifth module turntable **6040**, the fifth module liquid handling station **6015**, the plate sealer **6030**, the fifth module gantry robot **6010**, the fifth module deck **6035** with an opening **6045** to a supply of output containers **1030**, and another opening **6050** to a supply of fifth module aspirator tips **6055**, the capping and decapping device **6025**, plate shuttles **6060**, and a plate shuttle conveyor system **6065** on which the plate shuttles are conveyed. FIG. **37** also shows slots **6095** on the fifth module turntable **6040**, and the positions through which portions of the fifth module turntable **6040** rotate, namely, a loading position **6040***a*, a liquid handling position **6040***b*, and a disposal position **6040***c*.

[0202] FIG. **38** is a schematic drawing of a detail view of the fifth module liquid handling station **6015**, and in particular, shows DWPs **1025**, as examples of output containers **1030**, on plate shuttles **6060**. FIG. **38** also shows plate shuttle tracks **6070** of the plate shuttle conveyor system **6065**, the fifth module turntable **6040**, a fifth module liquid handling spanner **6075**, and a plurality of fifth module aspirator tips **6055** loaded into the fifth module liquid handling spanner **6075**. FIG. **39** is a schematic drawing of a detail view of the DWPs **1025** on the plate shuttles **6060**, and in particular, shows the fifth module liquid handling spanner **6075**, one of the fifth module aspirator tips **6055** on the fifth module liquid handling spanner **6075**, the plate shuttle tracks **6070**, and the DWPs **1025** on the plate shuttles **6060**.

[0203] FIG. **40** is a schematic drawing of a detail view of tray handling in the fifth module **6000**, and in particular, shows the fifth module aspirator tips **6055** on fifth module aspirator tip racks **6080**, the capping and decapping device **6025**, the plate shuttles **6060**, a cap hold **6085**, the plate sealer **6030**, and holding nests **6090**, which hold the DWPs **1025** and racks **1020** of micronic tubes **1015** following liquid handling in the fifth module **6000**. FIG. **41** is a schematic detail view of the capping and decapping device **6025**, and in particular, shows the micronic tubes **1015** on micronic tube rack **1020**.

A. Loading of Fifth Module Turntable

[0204] The fifth module turntable load robot **6005** may be configured to pick up the second tubes **1010** one at a time, or, optionally, multiple at a time, from the second inserts **1105** on the pallet conveyor system **5020** of the fourth module **5000**, and move them into the fifth module **6000**. Each second tube **1010** may be scanned by the fifth module scanner **6020**, which may output the identifying information for each second tube **1010** to the controller **7000**. Building on the example above, in a case in which barcodes are etched onto the second tubes **1010** by the marking device **4285** of the third module **4000**, the etched barcodes may be scanned by the fifth module scanner **6020**. By this arrangement, the controller **7000** may register and/or track the second tubes **1010** entering the fifth module **6000**. That is, the controller **7000** may receive the scanned identifying information for each second tube **1010** and verify that the second tube **1010** is one that was scanned in prior modules and in upstream processing, such that the controller **7000** may expect the second tube **1010** to arrive at the fifth module **6000**. If, for any reason, the received identifying information is not information that the controller **7000** expected, the controller **7000** may issue an error notification to an operator to remove the second tube **1010** from the fifth module **6000** and/or to confirm whether the second tube **1010** should be processed in the fifth module **6000**. An error notification may also be communicated to an operator if, e.g., the fifth module turntable load robot **6005** encounters a missing or unidentifiable second tube **1010**.

[0205] Once scanned, the second tubes **1010** may be placed into slots **6095** on a portion of the fifth module turntable **6040** where they are decapped by the fifth module turntable load robot **6005**. The caps **1090** may be removed by placing the second tubes **1010** into the actuating tube holder **6007** (FIG. **37**), which may be configured to hold and grip the tube bodies **1080**, and rotating the caps **1090** in a direction (e.g., a counter-clockwise direction). Once removed, the caps **1090** may be disposed into a second tube disposal container **6100** below the fifth module deck **6035**, shown in FIG. **42**B.

[0206] In some aspects, similar to the decapping station **4180** of the third module **4000**, the fifth module **6000** may include one or more sensors (not shown) to detect if any second tube caps **1090** remain on the second tubes **1010** once the decapping is completed. If a second tube cap **1090** is detected on one of the second tubes **1010**, a signal may be output to the controller **7000** to notify an operator that one or more second tube caps **1090** need to be removed from one or more of the second tubes **1010**. Alternatively, the controller **7000** may instruct the fifth module turntable load robot **6005** to remove the second tube caps **1090** remaining on the second tubes **1010**.

[0207] In the embodiment shown in FIGS. **36** to **41**, the fifth module turntable **6040** has three portions, and each portion has a row of eight slots **6095**, for holding the second tubes **1010**. Although eight slots **6095** are shown, any suitable number of slots **6095** may be used. The fifth module turntable **6040** may rotate each portion through the loading position **6040***a*, in which the second tubes **1010** are loaded into the slots **6095** and decapped by the fifth module turntable load robot **6005**, the liquid handling position **6040***b*, in which the plasma in the second tubes **1010** is aspirated by the fifth module aspirator tips **6055**, and the disposal position **6040***c*, in which the second tubes **1010** are disposed by the fifth module turntable unload robot **6006**, following completion of the liquid handling process. That is, the fifth module turntable unload robot **6006** may pick up each second tube **1010** from the portion of the fifth module turntable **6040** in the disposal position **6040***c*, and move it over a disposal opening within the fifth module deck **6035**. After the loading and decapping of the second tubes **1010**, the portion of the fifth module turntable **6040** may be rotated to the liquid handling position **6040***b*.

B. Supply and Loading of Fifth Module Aspirator Tips

[0208] With reference to FIGS. **37** and **38**, a plurality of fifth module aspirator tips **6055** are supplied from a fifth module tip rack hotel **6105** under the fifth module deck **6035**, as shown in FIG. **42**A. The fifth module tip rack hotel **6105** may be similar to or the same as the third module tip rack hotel **4235** shown in FIG. **20**. The fifth module tip rack hotel **6105** has a plurality of fifth module aspirator tip rack supports **6110** holding fifth module aspirator tip racks **6080** (shown in FIG. **40**), which in turn hold the fifth module aspirator tips **6055**. The fifth module aspirator tip racks **6080** may be lifted up to the fifth module deck **6035** by a lifting mechanism (not shown), similar to the third module aspirator tip rack loading mechanism **4245**.

[0209] Similar to the third module liquid handling spanner **4020**, the fifth module liquid spanner **6075** may have a plurality of aspirator mounting portions **6115** (shown in FIG. **38**), which are inserted into the fifth module aspirator tips **6055** on the fifth module aspirator tip racks **6080**. The aspirator mounting portions **6115** may be sized to create a press fit within upper ends of the fifth module aspirator tips **6055**. The fifth module liquid handling spanner **6075** may also have flowmeter **6120** above each aspirating mounting portion **6115**, and each flowmeter **6120** may be used to detect flow of a liquid as it is withdrawn into a corresponding fifth module aspirator tip **6055**. If the flowmeter **6120** of a fifth module aspirator tip **6055** detects that no liquid is being withdrawn or suctioned into the fifth module aspirator tip **6055**, the flowmeter **6120** may output a notification to the controller **7000**, which in turn may issue an error notification to an operator. In other aspects, the flowmeter **6120** may output such a notification when the flowmeter **6120** detects insufficient flow of liquid into the fifth module aspirator tip **6055**, or if both liquid and air are detected flowing into the third module aspirator tip **6055**. As an example, the flowmeter **6120** may output such a notification when the flowmeter **6120** does not detect suction of liquid and instead, air is suctioned into the fifth module aspirator tip **6055**. Further, the fifth module liquid handling spanner **6075** may include connections (or connectors) between each of the aspirator mounting portions **6115** and a suction source, such that a suction generated by the suction source is generated within the mounted third module aspirator tips **6055**.

[0210] The fifth module liquid handling spanner **6075** may be configured to move to a position over the opening in the fifth module deck **6035**, and pick up the fifth module aspirator tips **6055** from the fifth module aspirator tip racks **6080** using the aspirator mounting portions **6115**. In the embodiment shown in FIG. **37**, the fifth module liquid handling spanner **6075** picks up eight fifth module aspirator tips **6055** at a time, to correspond to the eight slots **6095** holding the second tubes **1010** on the fifth module turntable **6040**, although any number of aspirator tips **6055** may be picked up at a time, depending on the number of slots **6095** and aspirator mounting portions **6115** are present in a given embodiment.

[0211] As with the third module liquid handling spanner **4020**, the fifth module liquid handling spanner **6075** may be configured to pick up the fifth module aspirator tips **6055** at a first spacing, based on the spacing of the fifth module aspirator tips **6055** in the fifth module aspirator tip racks **6080**, and then move the fifth module aspirator tips **6055** to a second spacing, based on the spacing of the slots **6095** holding the second tubes **1010** in the fifth module turntable **6040**. In some aspects, the spacing between the fifth module aspirator tip racks **6080** and the spacing of the slots **6095** may be the same, and no movement or adjustment may be needed.

C. Supply and Loading of Output containers

[0212] With reference to FIGS. **37** to **42**A, the supply of DWPs **1025** and micronic tubes **1015**, as examples of output containers **1030**, will be described. A DWP hotel **6125** and a micronic tube rack hotel **6130** may be located under the fifth module deck **6035**, as shown in FIG. **42**A. The DWPs **1025** and the micronic tube racks **1020** may be lifted up to the fifth module deck **6035** by a lifting mechanism (not shown), and may be picked up by the fifth module gantry robot **6010** (FIG. **37**) and placed onto plate shuttles **6060** on the plate shuttle tracks **6070**. Each DWP **1025** and micronic tube rack **1020** (and/or the micronic tubes **1015** thereon) loaded onto the fifth module deck **6035** (or any other output container **1030**) may be scanned by a fifth module scanner **6020**, shown in FIG. **36**. More specifically, the micronic tube rack **1020** may be brought to a designated location (shown in FIG. **37** but not labeled) where a barcode reader may scan and identify downward-facing, two-dimensional labels on the micronic tubes **1015**. The identifiers of the micronic tubes **1015** and their positions within the micronic tube rack **1020** may then be associated with identifying information of the micronic tube rack **1020**. That information may then be stored in the memory **7005** of the controller **7000**. The plate shuttles **6060** containing the micronic tubes **1015** on the micronic tube rack **1020** may then be conveyed to the capping and decapping device **6025**, for removal of caps **1110** from the micronic tubes **1015**. After the micronic tubes **1015** are decapped, the plate shuttles **6060** containing the micronic tube racks **1020** may be conveyed to the liquid handling station **6015**, back to the capping and decapping device **6025** for recapping, and then to the holding nests **6090**. Plate shuttles **6060** containing the DWPs **1025** may be conveyed to the fifth module liquid handling station **6015**, to the plate sealer **6030**, and then to the holding nests **6090**.

[0213] FIG. **41**, in particular, shows the micronic tubes **1015** positioned in the capping and decapping device **6025**. The capping and decapping device **6025** may include an end effector (not shown) configured to remove the caps **1110** from the micronic tubes **1015**, place the caps **1110** on the cap hold **6085** (FIG. **40**), and place the caps **1110** back onto the micronic tubes **1015**. In one embodiment, each cap **1110** has an inner threaded surface, and a top end of the micronic tubes **1015** has an outer threaded surface. The inner threaded surface of the cap **1110** and the outer threaded surface of the micronic tubes **1015** are engaged, that is, the cap **1110** and micronic tubes **1015** are threadably connected, and the cap **1110** can be removed from the micronic tubes **1015** by rotating in one direction (e.g., a counter-clockwise direction), based on the arrangement of the threads, and placed back on the micronic tube **1015** by rotating an opposite direction (e.g., a clockwise direction).

[0214] Once the micronic tubes **1015** have been decapped, the micronic tube racks **1020** may be conveyed on the plate shuttles **6060** to the liquid handling station **6015**. Or, in a case in which DWPs **1025** are used, the DWPs **1025** do not require decapping and may simply be conveyed to the liquid handling station **6015**.

D. Liquid Handling Station of Fifth Module

[0215] The fifth module liquid handling spanner **6075** may hold the fifth module aspirator tips **6055** in the second spacing, and may move the fifth module aspirator tips **6055** over the opened second tubes **1010** in the portion of the fifth module turntable **6040** in the liquid handling position **6040***a*. Then, the fifth module liquid handling spanner **6075** may lower the fifth module aspirator tips **6055** into the second tubes **1010**, and the plasma (or other isolated liquid component) may then be aspirated from the second tubes **1010** into the fifth module aspirator tips **6055**. As with the aspirating process in the third module **4000**, the amount of plasma (or other isolated liquid component) aspirated from each second tube **1010** may be controlled by the controller **7000**. The amounts aspirated may be predetermined by the controller **7000** and/or based on amounts of plasma obtained during the liquid handling process in the third module **4000**. The controller **7000** may determine the flow rate(s) for aspiration and/or z-speed(s) of movement of the fifth module aspirator tips **6055** for each individual second tube **1010** and may individually control movement of the fifth module aspirator tip **6055** for each second tube **1010** to aspirate liquid and to move at those determined values, to withdraw as much of the isolated plasma in each second tube **1010** as possible, without disturbing a buffy coat red blood layer L**2** or a red blood cell layer L**3** that may have been produced by the second centrifugation process in the fourth module **5000**. In other aspects, the same z-speed(s) of movement and/or flow rate(s) of aspiration may be used for each of the fifth module aspirator tips **6055**.

[0216] In some aspects, the fifth module liquid handling spanner **6075** may include one or more liquid level sensors for determining the liquid level in each of the second tubes **1010**. If the one or more liquid level sensors detects that one or more of the second tubes **1010** contains less liquid than is anticipated, then a signal may be sent to the controller **7000**, and an error notification may be sent to the operator. In some aspects, the z-speed(s) and/or the flow rate(s) of the fifth module aspirator tips **6055** may be determined, at least in part, based on a liquid level detected by the one or more liquid level sensors.

[0217] After aspirating the plasma from the second tubes **1010**, the fifth module liquid handling spanner **6075** may move the fifth module aspirator tips **6055** over to the DWPs **1025** and micronic tubes **1015** located in the liquid handling station **6015**, and may dispense the plasma (or other isolated liquid component) into the DWPs **1025** and/or micronic tubes **1015**.

[0218] The amount of plasma (or other isolated liquid component) dispensed into wells of the DWPs **1025** and/or into the micronic tubes **1015** may be controlled by the controller **7000**. The amount aspirated in a given pass, and/or the output container **1030** into which the liquid is allocated may be determined based on the volume of isolated liquid sample component (in this example, plasma) in each second tube **1010**. A logic sequence may be used to determine volumes of plasma to be dispensed into DWPs **1025** and/or into micronic tubes **1015**.

[0219] For example, if a total volume of plasma in a second tube **1010** is less than a first threshold, then all of the plasma may be dispensed into one output container **1030** (e.g., a DWP **1025**), and none of the plasma may be dispensed into another output container **1030**. In some aspects, the first threshold may be 0.5 mL, 1 mL, 2 mL, 3 mL, 4 mL, or 5 mL, although any suitable threshold may be used, depending on the amount of liquid available, the type of liquid, the size of the output containers **1030**, the size of the second tubes **1010**, and/or the size of the fifth module aspirator tips **6055**. If a total volume of plasma in a second tube **1010** is greater than or equal to the first threshold but less than a second threshold, then the volume of plasma may optionally be divided between two different output containers **1030** (e.g., a DWP **1025** and one or more micronic tubes **1015**), with a volume of plasma being dispensed into a first output container **1030** (e.g., a DWP **1025**), and the remaining plasma being dispensed into a second output container **1030** (e.g., one or more micronic tubes **1015**). In some aspects, the second threshold may be 3 mL, 4 mL, 5 mL, 6 mL, 7 mL, or 8 mL, although as stated previously, any suitable threshold may be used. If a total volume of plasma in a second tube **1010** is greater than or equal to the second threshold, then the volume of plasma may be divided for dispensing between two different output containers **1030** (e.g., a DWP **1025** and one or more micronic tubes **1015**). The division may be weighted toward one of the two different output containers **1030**, for example based on the intended use of the particular output container **1030** (e.g., testing or long-term storage), with the weights further based on the volume already distributed between the output containers **1030** and the volume remaining, or may be divided equally.

[0220] Although two thresholds are described in the previous example, in other aspects, only one threshold may be used. For example, if a total volume of plasma in a second tube **1010** is less than or equal to a first threshold, then all of the plasma may be dispensed into one output container **1030** (e.g., a DWP **1025**), and none of the plasma may be dispensed into another output container **1030**. If a total volume of plasma in a second tube **1010** is greater than the threshold, then the volume of plasma may be divided for dispensing between two different output containers **1030** (e.g., a DWP **1025** and one or more micronic tubes **1015**), with a volume of plasma being dispensed into a first output container **1030** (e.g., a DWP **1025**), and the remaining plasma being dispensed into a second output container **1030** (e.g., one or more micronic tubes **1015**).

[0221] In some aspects, if the plasma in a second tube **1010** is derived from an unpaired first tube **1005**, meaning there was only one liquid sample available from a patient instead of two, then, in some aspects, controller **7000** may determine that the plasma sample should not be split, and all plasma may be aspirated into one output container **1030** (e.g., a DWP **1025**). In such a scenario, it is possible that a total volume of plasma obtained from the unpaired first tube **1005** would be less than the threshold amount and therefore, there may not be a sufficient amount of plasma for splitting between two output containers, e.g., DWPs **1025** and micronic tubes **1015**. In other embodiments, however, even plasma in a second tube **1010** derived from an unpaired first tube **1005** may be assessed and allocated according to the logic described above (e.g., according to the single threshold or multiple threshold logic).

[0222] In some embodiments, the plasma may be dispensed into a DWP **1025**, leaving one or more wells aside as a control (for example, 22 of 24 wells of a DWP **1025** may be filled with plasma, the 23rd may be filled with a control, and the 24th well may be left empty). Leaving an empty well in a DWP **1025**, or dispersing a control at this stage, may save a step of emptying one or more wells of a DWP **1025** as part of downstream processing. For example, the empty well may be used for a control in downstream processing. In addition or alternatively, the micronic tubes **1015** may only be filled with plasma if the DWP **1025** is filled (filled meaning, for example, all wells are filled leaving one well empty as a control), in which case the plasma may be dispensed into one or more micronic tubes **1015** for cold storage and for use as a back-up if the plasma dispensed in the DWPs **1025** fails quality testing during subsequent processing. Which well is left empty may vary and may be determined by randomization by controller **7000** and/or the LIMS controller **9000**.

E. Sealing and Outputting of DWPs and Recapping and Outputting of Micronic Tubes

[0223] After the liquid handling process is completed, the plate shuttles **6060** holding the DWPs **1025** may be conveyed to the plate sealer **6030**. The DWPs **1025** may be loaded into the plate sealer **6030**, where they may be sealed. Then, the sealed DWPs **1025** may be output by the plate sealer **6030** back onto a plate shuttle **6060**, and conveyed to the holding nests **6090**, where they may be picked up by a robot or transferred onto a downstream conveyor system, for subsequent processing or storage. As one example of subsequent processing, the DWPs **1025** may be output for extraction and processing of cfDNA contained within the plasma. The sealed DWPs **1025** may be transferred or output without operator intervention (that is, without manual intervention). In other aspects, an operator may pick up the DWPs **1025**.

[0224] After the liquid handling process is completed, the plate shuttles **6060** holding the micronic tube racks **1020** may be conveyed back to the capping and decapping device **6025**. The caps **1110** may be placed back onto the micronic tubes **1015**, as described above, and the micronic tube rack **1020** may be placed back onto a plate shuttle **6060** and conveyed to the holding nests **6090**, where they can be picked up by a robot or transferred onto a downstream conveyor system, for subsequent processing or storage. As one example of subsequent storage, the plasma in the micronic tubes **1015** may be output for long-term cold storage. The recapped micronic tubes **1015** may also be transferred or output without operator intervention.

[0225] The holding nests **6090** may include sensors for detecting the presence of the DWPs **1025** and/or the micronic tube rack **1020**, and the sensor may output notifications to the controller **7000** which may, in turn, notify the LIMS controller **9000** that one or more sealed DWPs **1025** and/or micronic tube racks **1020** are ready for subsequent processing and/or storage. The LIMS controller **9000** may coordinate automatic unloading of the sealed DWPs **1025** and/or micronic tube rack **1020**. For example, the gantry robot **6010** may pick up the sealed DWPs **1025** and/or micronic tubes **1015** from the holding nests **6090**, and place them onto a track, which may convey them to other systems for the processing and/or storage. As another example, the LIMS controller **9000** may control a robot, outside of the automated liquid processing system **1000**, which may pick up the sealed DWPs **1025** and/or micronic tubes **1015** from the holding nests **6090**, and place them onto a track, which may convey them to other systems for the processing and/or storage. Alternatively, if the fifth module **6000** is a stand-alone module, the second tubes **1010** may be received from or input by an operator, and/or the output containers **1030** may be output to an operator.

F. Disposal of Second Tubes and Fifth Module Aspirator Tips

[0226] After the liquid handling process has been completed for a set of eight second tubes **1010** and fifth module aspirator tips **6055**, the second tubes **1010** and the fifth module aspirator tips **6055** may be disposed. The fifth module turntable unload robot **6006** retrieves each tube body **1080** of the second tubes **1010** from the portion of the fifth module turntable **6040** in the disposal position **6040***c*, and moves and disposes of the tube body **1080** into an opening in the fifth module deck **6035** to the second tube disposal container **6100**, shown in FIG. **42**B. In another embodiment, the portion of the fifth module turntable **6040** holding the second tubes **1010** may be rotated to the disposal position **6040***c*, and, in a similar manner to the disposal of the first tubes **1005** in the third module **4000**, a stay (not shown) under the second tubes **1010** in the disposal position **6040***c* may be moved, allowing the second tubes **1010** to fall through an opening to the second tube disposal container **6100**, shown in FIG. **42**B, under the fifth module deck **6035**. The fifth module aspirator tips are also disposed into a fifth module aspirator tip disposal container **6135**, also shown in FIG. **42**B, located under the fifth module deck **6035**. As with the third module aspirator tips **6055**, the fifth module aspirator tips **6055** may be removed by the fifth module liquid handling spanner **6075** through an opening in the fifth module deck **6035** between the fifth module turntable **6040** and the end of the plate shuttle tracks **6070**.

VII. Consumable Storage and Disposal

[0227] Storage of consumables **1035** supplied to the third module **4000** and the fifth module **6000** and storage of disposal from the third module **4000** and the fifth module **6000** will be described with reference to FIGS. **42**A, **42**B, **43**, and **44**.

[0228] FIG. **42**A is a schematic diagram showing consumable supply storage in the third module **4000** and the fifth module **6000** of the automated liquid processing system **1000**. FIG. **42**A shows a back side of the automated liquid processing system **1000**, with the fifth module **6000** on the left side of the figure. FIG. **42**A shows the third module aspirator tip hotel **4235**, located under the third module deck **4035**, and which supplies the third module aspirator tips **4045** on the third module aspirator tip racks **4040**, for the third module liquid handling process. FIG. **42**A also shows a DWP **1025** and micronic tube rack **1020** supply of the fifth module **6000**, located under the fifth module deck **6035**, and which supply the DWPs **1025** and micronic tube rack **1020** for the fifth module liquid handling process. Further, FIG. **42**A shows the fifth module tip rack hotel **6105**, also located under the fifth module deck **6035**, and which supplies the fifth module aspirator tips **6055** on the fifth module aspirator tip racks **6080**, for the fifth module liquid handling process. Each of the third module aspirator tip hotel **4235** and the fifth module aspirator tip hotel **6105** may be a rotating carousel that is configured to rotate at intervals, and lift third module aspirator tip racks **4040** and fifth module aspirator tip racks **6080** up to the third module deck **4035** and the fifth module deck **6035**, respectively. The DWP **1025** and micronic tube rack **1020** supply of the fifth module **6000** may also include a carousel for supplying DWPs **1025** and a carousel for supplying the micronic tube rack **1020**, each carousel rotating in intervals and lifting up DWPs **1025**, one or multiple at a time, and micronic tube rack **1020**, one or multiple at a time, onto the fifth module deck **6035**.

[0229] FIG. **42**B is a schematic diagram showing consumable disposal containers of the third module **4000** and the fifth module **6000** of the automated liquid processing system **1000**. FIG. **42**B shows a front side of the automated liquid processing system **1000**, with the fifth module **6000** on a right side of the figure. FIG. **42**B shows the first tube and cap disposal container **4230**, located under the third module deck **4035**, and which receives first tubes **1005** and first tube caps **1075** following the third module liquid handling process. In addition, FIG. **42**B shows the third module aspirator tip disposal container **4325**, also located under the third module deck **4035**, which receives the third module aspirator tips **4045** following the third module liquid handling process.

[0230] FIG. **42**B also shows the second tube and cap disposal container **6100** of the fifth module **6000**, under the fifth module deck **6035**, and which receives the second tubes **1010** and the caps **1090** following the fifth module liquid handling process. Further, FIG. **42**B shows the fifth module aspirator tip disposal container **6135**, also located under the fifth module deck **6035**, and which receives the fifth module aspirator tips **6055** following the fifth module liquid handling process.

[0231] FIG. **43** is a schematic drawing of a disposal container **1115**, which may be used as one or more of the first tube can cap disposal container **4230**, the third module aspirator tip disposal container **4325**, the second tube and cap disposal container **6100**, or the fifth module aspirator tip disposal container **6135**, provided within the automated liquid processing system **1000**. The disposal container **1115** has an opening **1120** on a top for receiving liquid containers, such as first tubes **1005** or second tubes **1010**, caps, and aspirator tips.

[0232] FIG. **44** is a schematic drawing of a disposal scale **1125** provided within the third module **4000** and the fifth module **6000** of the automated liquid processing system **1000**. In particular, the disposal scale **1125** has a platform

1130 that is configured to hold a container **1115**, and may have a weight measurement display **1135** for displaying a measured weight of the container **1115**. A disposal scale **1125** may be provided under one or more (or all) of the consumable disposal containers **1115** of the third module **4000** and the fifth module **6000**, namely, the first tube and cap disposal container **4230** and the third module aspirator tip disposal container **4325** of the third module **4000**, and the second tube and cap disposal container **6100** and the fifth module aspirator tip disposal container **6135** of the fifth module **6000**. If included, the disposal scale **1125** may be configured to send a signal to controller **7000** when a weight of a consumable disposal container **1115** indicates that it may be full or nearing full. Controller **7000** may, in response to receiving a signal from the disposal scale **1125**, output a notification to an operator or another control system that one or more consumable disposal containers **1115** is full or needs to be emptied. In some aspects, the notification may include specific information about which consumable disposal container **1115** is full. In some aspects, the disposal scale **1125** may continuously or intermittently send information to the controller **7000** regarding the weight of the consumable disposal container **1115**. In such an aspect, a fill level of one or more consumable disposal containers may be made available to the operator so that fill levels may be monitored during processing.

VIII. Automated Liquid Isolation Process

[0233] FIG. **45** is a schematic drawing of an automated plasma isolation process, as an example of an automated liquid isolation process performed by the automated liquid processing system **1000** described herein. In a first step of the process, first tubes **1005** containing liquid (e.g., blood) samples from a patient may be received by the first module **2000** of the automated liquid processing system **1000**. Two first tubes **1005** per patient are received by the first module **2000** in this example. As described above, however, in some aspects, only one first tube **1005** sample may be received for a given patient. In a second step, the received first tubes **1005** may undergo a first spinning process, using centrifuges **3010**, in the second module **3000**. The first spinning process may separate the liquid samples, e.g., blood samples, into a plurality of layers to isolate one or more components. In the example of a blood sample, the plurality of layers may include a plasma layer L**1** at a top of the first tubes **1005**, a red blood cell layer L**3** at a bottom of the first tubes **1005**, and a buffy coat red layer L**2** in between the plasma layer L**1** and the red blood cell layer L**3**. The first tubes **1005** may then undergo pooling, or liquid handling, in the third module **4000**, where the isolated liquid component, e.g., plasma, is aspirated from the pairs of first tubes **1005** from the same patient and pooled together in a second tube **1010**. The pooled plasma in the second tubes **1010** may then move to the fourth module **5000** and undergo a second spinning process, where the liquid component, e.g., plasma, is further isolated from other components of the blood samples that may remain. The second tubes **1010** may then move to the fifth module **6000**, where the isolated liquid component, e.g., plasma, is aspirated from the second tubes **1010** and dispensed into output containers **1030**, e.g., DWPs **1025** for processing, such as an extraction process, and/or into micronic tubes **1015** for storage. This is one example of an automated liquid isolation process that the automated liquid processing system **1000** may perform, but other types of liquids may be processed for isolation of one or more components thereof.

[0234] Further, although the disclosure above describes the automated liquid processing system **1000** as having certain functions being performed by one of a series of five modules, it is possible that the same functions may be performed by any suitable number of modules. For example, the functions and features of one module may be combined with the functions or features of another module, or the functions and features of one module may be split apart amongst other modules, so long as the functions and features described herein are performed by the automated liquid processing system **1000** as a whole. Additionally, it is possible that any given module may exist independently, in which case the input or outputs of a given module may interface with an operator.

IX. Control Method

[0235] Control methods performed by the controller **7000** of the automated liquid processing system **1000** will be described with reference to FIG. **2** and FIGS. **46**A to **53**C.

A. First Module Control

[0236] FIGS. **46**A and **46**B show a flowchart of a first module control method **10000**. With reference to FIG. **46**A, the method **10000** includes a step **10005** of receiving, from the first module scanner **2040**, identifying information of each of the first inserts **1055** to be inserted into the first module **2000** of the automated liquid processing system **1000**. The method **10000** may further include a step **10010** of storing the received identifying information of each of the first inserts **1055** in the memory of the controller **7000**. The method **10000** may also include a step **10015** of determining, based on the identifying information, whether the first insert **1055** is compatible with the second module centrifuges **3010**, and therefore, whether the first insert **1055** may be input into the first module **2000**. In a case in which the first insert **1055** is compatible (YES in step **10015**), and may be input into the first module **2000**, the method **10000** next includes a step **10020** of changing an input indicator light **2030** to indicate that the first insert **1055** may be input. On the other hand, in a case in which the first insert **1055** is not compatible (NO in step **10015**), and may not be input into the first module **2000**, the method **10000** includes a step **10025** of changing the input indicator light **2030** to indicate that the first insert **1055** may not be input. As an example, the input indicator light **2030** may be turned on to indicate that the first insert **1055** may be input into the first module **2000**, or the input indicator light **2030** may be turned off to indicate that the first insert **1055** may not be input into the first module **2000**. As another example, the input indicator light **2030** may be changed to a first color, e.g., a green color, to indicate that the first insert **1055** may be input into the first module **2000**, and may be changed to a second color, e.g., a red color to indicate that the first insert **1055** may not be input into the first module **2000**. Additionally, although a light indicator is discussed herein, any suitable indicator, such as a visual, auditory, or haptic indicator, may be used. Then, the method **10000** may return to the step **10005** of receiving identifying information of another first insert **1055** from the first module scanner **2040**. Further, in some embodiments, an operator may need to intervene to clear the indicator, such as an auditory alarm, and thereafter, the method **10000** returns to step **10005**, to await a new first insert **1055** to scan.

[0237] When it is determined that the first insert **1055** may be input into the first module **2000**, the method **10000** may include a step **10030** of checking a low level sensor **2065** of a first module conveyor channel **2005**, and a step **10035** of determining, based on an output from the low level sensor **2065**, whether the first module conveyor channel **2005** can receive a first insert **1055**. Specifically, in a case in which the low level sensor **2065** of the first module conveyor channel **2005** outputs an indication that no first insert **1055** is detected, the controller **7000** determines that the first insert may be placed on the first module conveyor channel **2005** (YES in step **10035**), and the method **10000** proceeds to a step **10040**, in which the indicator light is changed to indicate that the first insert may be placed on the first module conveyor channel **2005**. And in a case in which the low level sensor **2065** of the first module conveyor channel **2005** outputs an indication that a first insert **1055** is detected (NO in step **10035**), the method **10000** may include a step **10045** of checking the high level sensor **2060** of the first module conveyor channel **2005**, and a step **10050** of determining, based on an output from the high level sensor **2060**, whether the first module conveyor channel **2005** can receive the first insert **1055**. In a case in which the high level sensor **2060** outputs an indication that no first insert **1055** is detected and a first insert can be placed on the first module conveyor channel **2005** (YES in step **10050**), the method **10000** may proceed to the step **10040** of changing the indicator light **2030** to indicate that the first module conveyor channel **2005** can receive the first insert **1055**. For example, the indicator light **2035** above the first module conveyor channel **2005** may be turned on, and/or changed to a green color.

[0238] On the other hand, in a case in which the high level sensor **2060** outputs an indication that a first insert **1055** is detected, and a first insert cannot be placed on the first module conveyor channel **2005** (NO in step **10050**), the method **10000** may proceed to a step **10055** of changing the indicator light **2035** above that first module conveyor channel **2005** to indicate the first insert **1055** may not be placed in that first module conveyor channel **2005**. For example, the indicator light **2035** above the first module conveyor channel **2005** may be turned off or, alternatively, changed to red. Then, the method **10000** may return to the step **10030** of checking a high level sensor **2060** and a low level sensor **2065** of a subsequent or adjacent first module conveyor channel **2005**, and repeating the process until it is determined that one of those subsequent or adjacent first module conveyor channels **2005** can receive a first insert **1055**.

[0239] In some embodiments, if all high level sensors **2060** of all first module conveyor channels **2005** indicate that they are all full and cannot receive first inserts **1055**, the method **10000** may include outputting an error notification to an operator via the user interface **8000**. This may occur, for example, if the second module gantry robot **3025** experiences a malfunction and is not picking up the first inserts **1055** from the output ends **2050** of the first module conveyor channels **2005**.

[0240] With reference to FIG. **46**B, the method **10000** may also include a step **10060** of checking output sensors **2055** at the output ends **2050** of the first module conveyor channels **2005** and a step **10065** of determining whether a first insert **1055** is ready to be picked up and transferred to the second module **3000**. In one embodiment in which the first module conveyor belts **2015** continuously rotate, the output sensor **2055** may output a notification that a first insert **2055** is at the output end **2050** of a first module conveyor channel **2005** (YES in step **10065**), and the method **10000** may include a step **10070** of instructing the second module gantry robot **3025** to pick up the first insert **1055** from the output end **2050** of the first module conveyor channel **2005** and hold it in front of one of the second module scanners **3050**. This latter step may, however, be performed as part of the control method of the second module **3000**. And, if the output sensor **2055** does not output a notification that a first insert **2055** is at the output end **2050** of a first module conveyor channel **2005** (NO in step **10065**), the method **10000** may return to step **10060** of checking output sensors **2055**.

[0241] In an embodiment in which the first module conveyor belts **2015** do not continuously rotate, the method **10000** may include a step, before step **10060**, of instructing the first module conveyor belts **2015** to rotate to convey the first inserts **1055** to the output ends **2050** of the first module conveyor channels **2005**, and, if the output sensor **2055** outputs a notification that no first insert **1055** is at the output end **2050** of a first module conveyor channel **2005** (NO in step **10065**), then the method **10000** may return to the step of instructing the conveyor channel belts **2015** to rotate and carry any input first inserts **1055** to output ends **2050** of the first module conveyor channels **2005**. Then, the output sensor **2055** outputs a notification that a first insert **1055** is at an output end **2050** of a first module conveyor channel **2005** (YES in step **10065**), and the method **10000** may proceed to step **10070** of instructing the second module gantry robot **3025** to pick up the first insert **1055** from the first module conveyor channel **2005** and hold it in front of one of the second module scanners **3050**.

B. Second Module Control

[0242] FIGS. **47**A and **47**B show a flowchart of a second module control method **11000**. With reference to FIG. **47**A, the method **11000** may include a step **11005** of instructing the second module gantry robot **3025** to pick up a first insert **1055** at an output end **2050** of one of the first module conveyor channels **2005**, and to hold the first insert **1055** in front of one of the second module scanners **3050** for scanning. The method **11000** may also include a step **11010** of receiving, from one of the second module scanners **3050**, identifying information of the first insert **1055**, and a step **11015** of storing the received identifying information. In addition, the method **11000** includes a step **11020** of checking a count of a number of first inserts **1055** previously placed into a second module centrifuge **3010**. The method **11000** also includes a step **11025** of determining, based on the count and a predetermined limit or capacity of the second module centrifuge **3010**, if the predetermined limit has been reached, and, therefore, whether the first insert **1055** may be placed into the second module centrifuge **3010**. In the example used above, the predetermined limit or capacity of the second module centrifuges **3010** may be four, or may be more or less, depending on the type and/or size of centrifuge **3010** used.

[0243] If the predetermined limit has not been reached (NO in step **11025**), the method **11000** includes a step **11030** of instructing the second module gantry robot **3025** to place the first insert **1055** into the second module centrifuge **3010**, storing in the memory **7005** the second module centrifuge **3010** in association with the first insert **1055** placed therein, and incrementing the count of first inserts **1055** that have been placed into the second module centrifuge **3010**. Then, the method **11000** may return to the step **11005** of instructing the second module gantry robot **3025** to pick up a first insert **1055** from the first module **2000**, to continue loading of the second module centrifuge **3010** until it reaches its capacity.

[0244] If, however, the limit has been reached (YES in step **11025**), then the method **11000** may include a step **11035** of checking a time, using a timer, from a most recent start of a spin cycle of another second module centrifuge **3010**. Then, the method **11000** includes a step **11040** of determining whether the time has reached a predetermined stagger time. If the timer has not yet reached the predetermined stagger time (NO in step **11040**), the method **11000** may continue in a loop to check the time until it is determined that the predetermined stagger time has been reached. If the timer has reached the predetermined stagger time (YES in step **11040**), then, with reference to FIG. **47**B, the method **11000** includes a step **11045** of instructing the second module centrifuge **3010** filled with first inserts **1055** to begin a spin cycle.

[0245] The method **11000** also includes a step **11050** of resetting and starting the timer for the most recent start of the spin cycle, based on the starting of the spin cycle by the second module centrifuge **3010**. The method **11000** may also include a step **11055** of receiving a notification from the second module centrifuge **3010** that the spin cycle has been completed, and instructing the second module gantry robot **3025** to pick up the first inserts **1055** in the second module centrifuge **3010** that has completed the spin cycle, and to place the first inserts **1055** on one of the second module conveyor belts **3015**. Further, the method **11000** may include a step **11065** of receiving a notification from an insert sensor **3060** at an output end **3065** of one of the second module conveyor channels **3045**, indicating the presence of a first insert **1055** at the output end of the one of the second module conveyor channels. The method **11000** may also include a step **11070** of instructing the pairing robot **4005** to pick up the first tubes **1005** in the first insert **1055** at the output end **3065** of the second module conveyor channel **3045**. This latter step may be performed as part of the control method of the pairing station **4050** of the third module **4000**.

C. Third Module Control

1. Pairing Station Control

[0246] FIGS. **48**A and **48**B show a flowchart of a control method **12000** for the pairing station of the third module **4000**. With reference to FIG. **48**A, as noted above, the method **12000** may include a step **12005** of instructing the pairing robot **4005** of the pairing station **4050** to pick up a first tube **1005** in the first insert **1055** at the output end **3065** of one of the second module conveyor channels **3045**, and to hold the first tube **1005** in front of a pairing scanner **4065**. The method **12000** may include a step **12010** of receiving, from the pairing scanner **4065**, identifying information of the first tube **1005**, and a step **12015** of storing the received identifying information in the memory **7005**, and, in some aspects, retrieving data associated with the received identifying information of the first tube **1005**, as well as data associated with identifying information of previously scanned first tubes **1005**, from the memory **7005**. As an example, this data may include, for each first tube **1005** and its identifying information, a patient name, a patient ID number, and/or a patient date of birth.

[0247] Further, the method **12000** may include a step **12020** of determining whether a scanned first tube **1005** is expected, based on the identifying information retrieved for the scanned first tube **1005**. If the scanned first tube **1005** is expected (YES in step **12020**), the method may proceed to a step **12025** of determining, using a verification process, whether the first tube **1005**, for which the identifying information has been received, has a paired tube for which data of the identifying information of the first tube **1005** matches data of identifying information of the paired tube **1005**. If the scanned first tube **1005** is not expected (NO in step **12020**), the method **12000** may proceed to a step **12045** of instructing the pairing robot **4005** to place the first tube **1005** into a dummy tube bin of the second module **3000**, for disposal.

[0248] The determining step **12025** may include comparing the data of the first tube **1005** with the data of the previously scanned first tubes **1005** to determine if the data matches for the first tube **1005** and any of the previously scanned first tubes **1005**. In a case in which the data of the first tube **1005** matches data of one of the previously scanned first tubes **1005**, as a paired first tube, a determination is made that the first tube **1005** has a paired first tube that has already been placed in the pairing platform **4070** (YES in step **12025**). Then, the method **12000** includes a step **12030** of retrieving a stored location of the paired first tube **1005** in one of the pairing platforms **4070**, and a step **12035** of instructing the pairing robot **4005** to place the first tube **1005** in a slot adjacent to the location of the paired first tube **1005**.

[0249] And, in a case in which the data of the one other tube does not match data of any other first tubes **1005** scanned up to that point in time (NO in step **12025**), the method **12000** may then include a step **12040** of determining, based on the identifying information, whether the first tube **1005** is a dummy tube **1005**. The identifying information of dummy tubes **1005** may be stored in a database and/or in the memory **7005**, and the determination may include retrieving the identifying information of dummy tubes **1005**, comparing the identifying information of the first tube **1005**, and if the identifying information has a match in the retrieved identifying information (YES in step **12040**), then the determination is made that the first tube **1005** is a dummy tube **1005**. Then, the method **12000** may proceed to the step **12045** of instructing the pairing robot **4005** to place the dummy tube **1005** into the dummy tube bin for disposal.

[0250] If the identifying information of the first tube **1005** does not match identifying information of dummy tubes **1005** retrieved from the database (NO in step **12040**), then the first tube **1005** is determined not to be a dummy tube **1005**. Then, the method **12000** includes a step **12050** of instructing the pairing robot **4005** to place the first tube **1005** in the pairing platform **4070**, adjacent to an empty slot **4075**, to allow for placement of a paired tube if such a paired tube is identified during subsequent processing of the remainder of the first tubes **1005** in the first insert **1055**. The location of the unpaired tube and the adjacent empty slot **4075** in the pairing platform **4070** may also be stored, and the first tube **1005** may be assigned a label of "unpaired tube." If, during subsequent processing of the remainder of the first tubes **1005** in the first insert **1055**, a first tube **1005** with matching data is scanned by the pairing scanner **4065**, then the label of "unpaired tube" may be changed to "paired tube."

[0251] With reference to FIG. **48**B, after placing a first tube **1005** into one of the slots **4075** of the pairing platform **4070** or placing a dummy tube **1005** into the dummy tube bin, the method **12000** proceeds to a step **12055** of determining whether all first tubes **1005** in a first insert **1055** have been scanned and placed on the pairing platform **4070**, the sequestration tray, or the dummy tube bin. This determination may be made by comparing a count of a number of first tubes **1005** picked up from a first insert **1055** to a predetermined total number of first tubes **1005** contained in the first insert **1055**. When the count has not yet reached the predetermined total number of tubes (NO in step **12055**), the method **12000** will return to the step **12005** of instructing the pairing robot **4005** to pick up another first tube **1005** from the first insert **1055**. And, when the count has reached that predetermined total number (YES), this indicates that all first tubes **1005** have been scanned and placed in the second module **3000**. The method **12000** may also include a step **12060** of instructing the pairing robot **4005** to place the emptied first insert **1055** into the second module return channel **3020** for disposal or reuse. The method **12000** shown in FIGS. **48**A and **48**B may be repeated each time the second module control method **11000** is performed and indicates a first insert **155** with first tubes **1005** is located at an output end **2050** of a second module conveyor channel **2005**. The method **12000** may also include a step **12065** of instructing the excising robot **4010** to pick up the first tubes **1005** from the pairing platform **4070** and place them on the lift **4145**. This latter step may be performed as part of the control method of the excising station **4055** of the third module **4000**.

2. Excising Station Control

[0252] FIG. **49** is a flowchart of a control method **13000** for the excising station **4055** of the third module **4000**. The method **13000** may include a step **13005** of instructing the excising robot **4010** to pick up first tubes **1005** from the pairing platform **4070** and place the first tubes **1005** on the lift **4145** of the excising station **4055**. The method **13000** may further include a step **13010** of instructing the blade actuators **4155** to rotate or move the blades **4150** from the first position to the second position, or otherwise moving the blades **4150** to a position in which they are able to make contact with the first tubes **1005** in step **13015**, if the blades **4150** are not in such a position. If the blades **4150** are in a position to contact the first tubes **1005** in step **13015**, then step **13010** may be omitted from method **13000**. Further, the method **13000** may include a step **13015** of instructing the lift **4145** to move upward, bringing the first tubes **1005** through the blades **4150** in the second position, for excising or scraping of material on exterior surfaces of the first tubes **1005**. The method **13000** may also include a step **13020** of instructing the blade actuators **4155** to rotate the blades **4150** back to the first position, to be spaced relatively further apart from one another. Then, the method **13000** includes a step **13025** of instructing the excising robot **4010** to lift the first tubes **1005** from the lift **4145**, for subsequent image processing.

[0253] In some embodiments, the excising station **4055** may not include a lift **4145** and instead, the method **13000** may include a step of instructing the excising robot **4010** to pick up the first tubes **1005** from the pairing platform **4070**, and to lower the first tubes **1005** in between the blades **4150**, while the blades **4150** are in the first position. Then, the method **13000** may include a step (not shown) of instructing the blade actuators **4155** to rotate the blades **4150** from the first position to the second position. Then, the method **13000** may include instructing the excising robot **4010** to move the first tubes **1005** upward or downward, between the blades **4150** in the second position. Then, the first tubes **1005** may be moved to the imaging station **4160** for imaging processing.

3. Imaging Station Control

[0254] FIG. **50** is a flowchart of a control method **14000** for the imaging station **4160** of the third module **4000**. The method **14000** may include a step **14005** of instructing the excising robot **4010** to pick up the first tubes **1005** from the lift **4145** of the excising station **4055** and move the first tubes **1005** to a location between the imaging device **4165** and the backdrop **4170**. Then, the method **14000** includes a step **14010** of instructing the imaging device **4165** to capture an image **4175** of the first tubes **1005**, and receiving the captured image **4175** from the imaging device **4165**. Then, the method **14000** may include a step **14015** of determining whether the captured image **4175** can be used for image analysis. As an example, the captured image **4175** of one or more of the imaged first tubes **1005** may be used for image analysis in a case in which an image processing program can discern, from the captured image **4175** of a given first tube **1005**, heights (z-heights) of layers of subcomponents of the liquid in the first tube **1005**. If the heights of the layers of subcomponents can be discerned (YES in step **14015**), then the captured image **4175** is considered usable for image analysis as to that first tube **1005**. In a case in which the image processing program cannot discern z-heights of layers of subcomponents of the liquid in a given first tube **1005** (NO in step **14015**), then the method **14000** includes a step **14020** of labelling the first tube **1005** as a tube to be sequestered, or as a "sequestration tube," to be disposed of downstream in processing. As an example, heights of layers of subcomponents may not be discernable if portions of labels remain on an exterior surface of the first tube **1005** following the excising process. First tubes **1005** labelled for sequestration may then be placed into a sequestration rack (not shown) and may not get placed in the first turntable **4025**. Further, if one first tube **1005** of a pair is labelled for sequestration, the other first tube **1005** of the pair is also labelled for sequestration, and both first tubes **1005** of the pair are placed into the sequestration rack. In some embodiments, the method **14000** may include a step (not shown) of outputting a notification to an operator to check the excising station **4055** for issues or malfunctions, such as damaged or worn blades, e.g., upon determining that layers of subcomponents are not discernable in one or more first tubes **1005**.

[0255] In other aspects, in a case in which the image processing program cannot discern z-heights of layers of subcomponents of the liquid in a given first tube **1005** (NO in step **14015**), then the excising robot **4010** may be instructed to rotate the first tube **1005**, and the imaging device **4165** may be instructed to capture another image **4175** of the first tubes **1005**, prior to labelling the tube as a "sequestration tube." This may prevent a first tube **1005** from being labeled as a "sequestration tube" in the event that the window where labels had been excised on the tube simply hadn't aligned properly with the imaging device **4165**.

[0256] Upon determining that the captured image **4175** can be used for image analysis (YES in step **14015**), the method **14000** may further include a step **14025** of performing the image analysis, which may include analyzing the received image **4175** to determine a height of different layers of subcomponents of the liquid in the first tubes **1005**. As an example, the image analysis may include identifying an individual first tube **1005** in the image, including a top end and a bottom end, and detecting points between the top end and the bottom end at which there is a color change, the color change indicating a height of one of the layers of the subcomponents, and storing, as information associated with the first tube **1005**, these points as determined heights of layers of subcomponents of the liquid. As a specific example, the layers may be a red blood cell layer L**3**, a buffy coat red layer L**2**, and a plasma layer L**1**.

[0257] The method **14000** may also include a step **14030** of determining, using another image analysis, whether a quality of one of the layers of subcomponents is sufficient for downstream processing. As a specific example, in a case where one of the layers is a plasma layer L**1**, as a subcomponent of blood from a blood sample, the image analysis may include evaluating an amount of red within the plasma layer L**1**, by comparing a color of the plasma layer L**1** to a color chart, stored in the memory **7005**.

[0258] The output from the comparison to the color chart may be referred to as a "hemolysis grade." In some embodiments, the hemolysis grade may also be a quantity of hemoglobin per mL (for example, X g of hemoglobin per mL of plasma), using the color chart a guide. The value of X can be predetermined and modified as needed. If the hemolysis grade is low, meaning the plasma layer L**1** is darker than a predetermined limit on the color chart, the sample fails, and the first tube containing the too-red-plasma layer L**1** is labeled as a sequestration tube.

[0259] If the plasma layer L**1** is too red, that may indicate the blood sample is homolycized, and the quality of the plasma is determined to be not sufficient for processing (NO in step **14030**). In that case, controller **7000** will store, as data associated with the first tube **1005** containing the blood sample, an indicator that the first tube **1005**, and its pair, should be sequestered, as the blood sample will not be of sufficient quality for processing downstream of the automated liquid processing system **1000**.

[0260] If the hemolysis grade is high, meaning the plasma layer L**1** is lighter than the predetermined limit on the color chart, then the plasma of that first tube **1005** is determined to be of sufficient quality for subsequent processing (YES in step **14030**), and the method **14000** includes a step **14035** of storing the determined heights of the layers of subcomponents of the liquid with that first tube **1005**, in association with the imaged first tube **1005**, in the memory **7005**.

4. Liquid Handling Station Control

[0261] FIGS. **51**A, **51**B, **51**C, **51**D, and **51**E show a flowchart of a control method **15000** for the liquid handling station **4015** of the third module **4000**. With reference to FIG. **51**A, the method **15000** may include a step **15005** of instructing the excising robot **4010** to place the first tubes **1005** in a portion of the first turntable **4025** in the loading position **4025***a*. The pairs of first tubes **1005** are placed in two adjacent slots **4075**. Any unpaired first tubes **1005** may be placed in a first, inner row of slots **4075**, and the adjacent outer slot **4075** may remain empty. The method **15000** may further include a step **15010** of instructing the first turntable **4025** to rotate the portion which received the first tubes **1005** to the decapping position **4025***b*, and a step **15015** of instructing the third module decapping gantry robot **4185** to remove the first tube caps **1075** from the first tubes **1005**. This may include instructions to move to a position in between a first pair of the first tubes **1005** in the decapping position, then to move in a first direction, knocking a first tube cap **1075** out of one of the pair of the first tubes **1005**, and then in a second, opposite direction, knocking a first tube cap **1075** out of the other of the pair of the first tubes **1005**. This step **15015** may be repeated for each of the pairs of first tubes **1005** on the first turntable **4025** in the decapping position **4025***b*.

[0262] The method **15000** may also include a step **15020** of checking a sensor configured to detect the presence of first tube caps **1075** on the first tubes **1005**, and determining, based on an output from the sensor, whether any first tube caps **1075** remain on the first tubes **1005**. If it is determined that any first tube caps **1075** remain on the first tubes **1005** (YES in step **15025**), then the method **15000** returns to the step **15015** of instructing the third module decapping gantry robot **4185** to remove the first tube caps **1075**, and the process is repeated until it is determined that no first tube caps **1075** remain on the first tubes **1005**. Then, when it is determined that no first caps **1075** remain on the tubes (NO), the method **15000** proceeds to a step **15030** of checking a sensor, located on the first turntable **4025**, that is configured to detect the presence of first tube caps **1075** on the surface of the first turntable **4025**, e.g., in between the rows of first tubes **1005**. The method **15000** then includes a step **15035** of determining, based on an output from the sensor, whether any first tube caps **1075** remain on the surface of the first turntable **4025** in between the rows of first tubes **1005**. If it is determined that any first tube caps **1075** remain on the first turntable (YES in step **15035**), then the method **15000** includes a step **15040** of instructing the third module decapping gantry robot **4185** to sweep through the space between the rows of first tubes **1005**, to clear the first tube caps **1075** from the first turntable **4025**. With reference to FIG. **51**B, after the first tube caps **1075** have been cleared from the first turntable **4025**, and in a case in which no first tube caps **1075** are detected on the first turntable (NO in step **15035**), the method **15000** includes a step **15045** of instructing the first turntable **4025** to rotate the portion of holding the decapped first tubes **1005** to the liquid handling position **4025***c*, for the liquid handling process.

[0263] Again, with reference to FIG. **51**B, as part of the liquid handling process, the method **15000** includes a step **15050** of instructing the third module liquid handling spanner **4020** to pick up third module aspirator tips **4045** from the third module aspirator tip racks **4040** loaded onto the third module aspirator tip rack conveyor **4115**. The step **15050** may also include instructing the third module liquid handling spanner **4020** to change a spacing (if needed) of the picked up third module aspirator tips **4045** from a first spacing, in which the third module aspirator tips **4045** were picked up, to a second spacing, which corresponds to a spacing of the first tubes **1005** in the slots **4075** on the first turntable **4025**. In addition, the method **15000** may include instructing the third module liquid handling spanner **4020** to move the third module aspirator tips **4045** over the portion of the first turntable **4025** that is in the liquid handling position **4025***c*. In some aspects, the spacing between the third module aspirator tip racks **4040** and the spacing of the slots **4075** may be the same, and no movement or adjustment may be needed.

[0264] The method **15000** may further include a step **15055** of instructing the second tube transfer robot **4100** to pick up a second tube **1010** and place the tube **1010** in a slot on the third module deck **4035**. The step **15055** may also include instructing the second tube transfer robot **4100** to remove the cap **1090** from the second tube **1010** in the slot, to pick up the tube body **1080** remaining in the slot, and to hold the tube body **1080** in front of a sensor on the gripping and marking device **4105**. Further, the method **15000** includes a step **15060** of instructing the second tube transfer robot **4100** to rotate the tube body **1080** until the sensor detects the white space **1100** on the tube body **1080**. The method **15000** may include a step **15065** of checking the sensor for detection of the white space **1100** on the tube body **1080**, and a step **15070** of determining whether the white space **1100** on the tube body **1080** is detected. If the white space **1100** on the tube body **1080** is not detected (NO in step **15070**), then the method **15000** returns to the step **15060** of instructing the second tube transfer robot **4100** to rotate the tube body **1080** in front of the sensor, and the process is repeated until the white space **1100** on the tube body **1080** is detected. Once the white space **1100** on the tube body **1080** is detected (YES in step **15070**), the method **15000** includes a step **15075** of instructing the second tube transfer robot **4100** to stop rotation of the tube body **1080** and to lower the tube body **1080** into the marking device **4285**. Then, with reference to FIG. **51**C, the method **15000** includes a step **15080** of instructing the marking device **4285** to add identifying information to the white space **1100** on the tube body **1080**.

[0265] Again, with reference to FIG. **51**C, the method **15000** may also include a step **15085** of identifying a location in the second turntable **4030** that can receive a second tube **1010**. This identifying process may include receiving locations of sequestration tubes identified based on the image analysis, shown in FIG. **50**, and the stored locations of the first tubes **1005** in the first turntable **4025**. Based on the locations of the sequestration tubes, the step **15085** may include designating slots in the second turntable **4030** which correspond in location in a grid, e.g., a one by eight grid, to slots on the first turntable **4025** that contain sequestration tubes, as “skip slots,” which the second tube transfer robot **4100** is to skip when placing second tubes **1010** into the second turntable **4030**.

[0266] Then, the method **15000** includes a step **15090** of instructing the second tube transfer robot **4100** to pick up the tube body **1080** from the marking device **4285**, and the cap **1090** for the tube body **1080**, and to place the tube body **1080** and the cap **1090** in adjacent slots **4080** on a portion of the second turntable **4030** in the loading position **4080***a*. The method **15000** may also include a step **15095** of receiving the added identifying information for a second tube **1010** from the marking device **4285**, and a step **15100** of storing, as data associated with the second tube **1010**, the received identifying information and a location of the second tube **1010** once placed in the second turntable **4030**. The method **15000** may also include a step **15105** of associating the second tube **1010** and its location with a first tube **1005** in a corresponding location on the first turntable **4025**, and storing this association in the memory **7005**.

[0267] With reference to FIG. **51**D, next, the method **15000** includes a step **15110** of instructing the third module liquid handling spanner **4020** to move the third module aspirator tips **4045** over the first row of the first tubes **1005** in the portion of the first turntable **4025** in the liquid handling position **4025***c*. Then, the third module liquid handling spanner **4020** may lower the third module aspirator tips **4045** into the first tubes **1005** in the first row. The method **15000** also includes a step **15115** of instructing the suction source to turn on, thereby providing a suction force to aspirate plasma from the first tubes **1005**. As described above, a flowrate and/or a z-speed of the third module aspirator tips **4045** may be set to variable or constant values, based on the image analysis and a determined volume (or height) of plasma in each first tube **1005**. The flowrate and the z-speed may also be based on the determined heights of the layers of the blood samples, a diameter of an orifice size of the third module aspirator tips **4045**, a density of the blood sample and/or of the plasma, and the power of the suction source. Once the plasma has been aspirated, the method **15000** includes a step **15120** of turning the suction source off. This step **15120** may include closing an opening at a top of the third module aspirator tips **4045** through which suction may be communicated, so that the plasma aspirated into the third module aspirator tips **4045** is held in the third module aspirator tips **4045** for the next step of the method **15000**.

[0268] Then, the method **15000** includes a step **15125** of instructing the third module liquid handling spanner **4020** to move the third module aspirator tips **4045** to the second turntable **4030**. By moving the third module liquid handling spanner **4020** to the second turntable **4030**, the controller **7000** moves the third module aspirator tips **4045** to be above the second tubes **1010**. This step **15125** may also include instructing the third module liquid handling spanner **4020** to lower the third module aspirator tips **4045** into the second tubes **1010**, and to dispense the plasma held in each of the second tubes **1010**. The instruction to dispense the plasma may include opening a top (or unsealing an opening at a top) of the third module aspirator tips **4045**, to allow the plasma to fall into the second tubes **1010**.

[0269] The method **15000** may include a step **15130** of instructing the third module liquid handling spanner **4020** to return to the first turntable **4025**, and to position the third module aspirator tips **4045** over first tubes **1005** in a second row on the first turntable **4025**, and to lower the third module aspirator tips **4045** into the first tubes **1005** in the second row. With reference to FIG. **51**E, the method **15000** may further include a step **15135** of instructing the suction source to begin suction of plasma from the first tubes **1005** in the second row, a step **15140** of instructing the suction force to turn off and/or closing the opening at the top of the third module aspirator tips **4045** to hold the aspirated plasma within the third module aspirator tips **4045**, and a step **15145** of instructing the third module liquid handling spanner **4020** to move the third module aspirator tips **4045** to the second turntable **4030**, to lower the third module aspirator tips **4045** into the second tubes **1010**, and to dispense the plasma into the second tubes **1010**. In some embodiments, the method may include instructing the liquid handling spanner **4085** to repeat the steps relating to aspirating plasma from the first row of first tubes **1005** and dispensing the plasma into the second tubes **1010**, and instructing the liquid handling spanner **4085** to also repeat the steps relating to aspirating plasma from the second row of first tubes **1005** and dispensing the plasma into the second tubes **1010**.

[0270] The method **15000** may also include a step **15150** of instructing the third module liquid handling spanner **4020** to eject the third module aspirator tips **4045** after completing the transfer of plasma from one or more pairs of first tubes **1005** on the first turntable **4025** to corresponding second tube **1010** on the second turntable **4030**. Further, the method **15000** may include a step **15155** of instructing the first turntable **4025** to rotate to the tube disposal position **4025*d***, such that the first tubes **1005** fall through the slots **4075** on the first turntable **4025**, through the first tube disposal opening **4215**, and into a first tube disposal container **4325**. The method **15000** may also include a step **15160** of instructing a fourth module robot **5015** to pick up the caps **1090** on the second turntable **4030** and place the caps **1090** back onto the second tubes **1010**. The method **15000** may also include a step **15165** of instructing the fourth module robot **5015** to pick up and move the recapped second tubes **1010** into the fourth module **5000**. This latter step may be included as part of the control method of the fourth module **5000**.

D. Fourth Module Control

[0271] FIGS. **52**A, **52**B, and **52**C show a flowchart of a control method **16000** for the fourth module **5000**. With reference to FIG. **52**A, the method **16000** may include a step **16005** of receiving, from one of the fourth module scanners **5030**, a second insert **1105** loaded onto the pallet conveyor system **5020**, and a step **16010** of storing identifying information of the scanned second inserts **1105** in memory **7005** of controller **7000**. Then, the method **16000** may include a step **16015** of conveying the second insert **1105** to a loading position **5020*a***. Then, the method **16000** may include a step **16020** of instructing the fourth module robot **5015** to pick up the second tubes **1010** from the second turntable **4030** in the third module **4000**, and a step **16025** of instructing the fourth module robot **5015** to place the second tubes **1010** into slots in the second insert **1105** located in the loading position **5020*a***. The step **16025** may also include storing, in the memory **7005**, the identifying information of the second tubes **1010** picked up from the second turntable **4030** in association with the second insert **1105** into which the second tubes **1010** are placed, thus registering and/or tracking the second tubes **1010** entering the fourth module **5000**. Then, the method **16000** may include a step **16030** of incrementing a counter for each second tube **1010** placed into the second insert **1105**. Then, the method **16000** includes a step **16035** of determining, based on a total count of the counter, whether the second insert **1105** is full. If the second insert **1105** is not full (NO in step **16035**), the method **16000** may include a step **16040** of instructing pallet stops **5055** of the pallet conveyor system **5020** to hold the second inserts **1105** in position, and then returning to the step **16020** of instructing the fourth module robot **5015** to pick up second tubes **1010** from the second turntable **4030**. Upon determining that the second inserts are full (YES in step **16035**), the method **16000** includes a step **16045** of instructing the conveyor belt **5050** of the pallet conveyor system **5020** to rotate, thereby moving the full second insert **1105** to the pick-up position **5020*b***.

[0272] The method **16000** may then include a step **16045** of checking a count of second inserts **1105** placed into the fourth module centrifuges **5010**. With reference to FIG. **52**B, the method **16000** may then include a step **16050** of determining, based on the count, whether the fourth module centrifuge **5010** is full. If the fourth module centrifuge **5010** is not full (NO in step **16050**), then the method **16000** may include a step **16065** of instructing the fourth module gantry robot **5035** to pick up the second insert **1105** and place it into one of the fourth module centrifuges **5010**. This step may include storing in memory **7005**, as information associated with the second insert **1105**, an identifier of the fourth module centrifuge **5010** into which the second insert **1105** was placed. This step may also include incrementing a count of a number of second inserts **1105** placed into the fourth module centrifuge **5010**.

[0273] Again, with reference to FIG. **52**B, if it is determined that the fourth module centrifuge **5010** is full (YES in step **16050**), then, in one embodiment, the method **16000** may also include a step **16060** of checking a time from a most recent start of a spin cycle of another one of the fourth module centrifuges **5010**, and a step **16065** of determining, based on the time, whether a predetermined stagger time has been reached. If the predetermined stagger time has not been reached (NO in step **16065**), then the method **16000** returns to the step **16060** of checking the time from the most recent start of the spin cycle of another fourth module centrifuge **5010**. If the predetermined stagger time has been reached (YES in step **16065**), then the method **16000** may include a step **16070** of instructing the full fourth module centrifuge **5010** to begin the spin cycle. Then, the method **16000** includes a step **16075** of resetting and starting the timer. The method **16000** may also include a step **16080** of receiving a notification from the fourth module centrifuge **5010** that the spin cycle has been completed. In other embodiments, e.g., if the timing of the fourth module centrifuges is not staggered, then the method **16000** may proceed from the step **16050** directly to step **16070**, and from **16070** directly to step **16080**.

[0274] With reference to FIG. **52**C, the method **16000** may include a step **16085** of instructing the fourth module gantry robot **5035** to pick up the second inserts **1105** in the fourth module centrifuge **5010** that has completed the spin cycle, and to place the second inserts **1105** on the pallet conveyor belt **5050**. The second inserts **1105** are then conveyed to the unloading position **5020*d*** of the pallet conveyor system **5020**. The method **16000** may also include a step **16090** of receiving a notification that a second insert **1105** is located in the unloading position **5020*d*** of the conveyor belt **5050**. The method **16000** may then include a step **16100** of instructing the fifth module turntable load robot **6005** to pick up the second tubes **1010** from the fourth module **5000** and place the second tubes **1010** into a fifth module turntable **6040**. The latter step may be part of the control method of the fifth module **6000**, described below.

E. Fifth Module Control

[0275] FIGS. **53**A, **53**B, **53**C, and **53**D show a flowchart of a control method **17000** for the fifth module **6000**. The method **17000** may include a step **17005** of instructing the fifth module turntable load robot **6005** to pick up the second tubes **1010**, one at a time or multiple at a time, from the second inserts **1105** in the unloading position **5020*d*** of the pallet conveyor system **5020**. The method **17000** may further include a step **17010** of holding each picked up second tube **1010** in front of the fifth module scanner **6020** and a step **17015** of receiving, from the fifth module scanner **6020**, identifying information for the second tube **1010**. The method **17000** may also include a step **17020** of storing, in the memory **7005**, the received identifying information of the second tube **1010**, to register and/or track the location of that second tube **1010** as it enters the fifth module **6000**. The method **17000** may also include a step **17025** of determining whether the identifying information of the scanned second tube **1010** corresponds to identifying information that was added to the second tube **1010** by the marking device **4285** in the third module **4000**. In a case in which the identifying information of the second tube **1010** does not correspond to identifying information added to any second tube **1010** by the marking device **4285** (NO in step **17025**), the method **17000** may include a step **17030** of outputting a notification to prompt the operator to confirm whether the second tube **1010** should continue being processed. If it is determined that the identifying information of the second tube **1010** does correspond to identifying information added by the marking device **4285** (YES in step **17025**), the method **17000** then includes a step **17035** of instructing the fifth module turntable load robot **6005** to place the second tubes **1010** into the actuating tube holder **6007**, and to remove the cap **1090** from the tube body **1080**. Then, the method **17000** includes a step **17040** of instructing the fifth module turntable load robot **6005** to place the tube body **1080** into a slot **6095** on a portion of the fifth module turntable **6040** that is in the loading position **6040***a*. The method **17000** may also include a step **17045** of storing, in the memory **7005**, the locations of the slots **6095** into which each tube body **1080** of each scanned second tube **1010** is placed, in order to register and/or track the location of each tube body **1080** of the scanned second tube **1010** in the fifth module **6000**. In some embodiments, the fifth module turntable load robot **6005** may be instructed to remove the caps **1090** of the second tubes **1010** after the second tubes **1010** have been placed in the fifth module turntable **6040**. After the slots **6095** on the portion of the fifth module turntable **6040** are filled with tube bodies **1080** of second tubes **1010**, the method includes a step **17050** of instructing the fifth module turntable **6040** to rotate the portion containing the tube bodies **1080** (that is, the decapped second tubes **1010**) to the liquid handling position **6040***b*.

[0276] With reference to FIG. **53**B, the method **17000** may further include a step **17055** instructing the fifth module liquid handling spanner **6075** to pick up fifth module aspirator tips **6055** from the fifth module aspirator tip racks **6080** loaded onto plate shuttles **6060** on the fifth module deck **6035**, to adjust (if needed) a spacing of the picked up fifth module aspirator tips **6055** from a first spacing, in which the fifth module aspirator tips **6055** were picked up, to a second spacing, which corresponds to a spacing of the second tubes **1010** in the slots **6095** on the fifth module turntable **6040**, and to move the aspirator tips **6055** to a location over the uncapped second tubes **1010** in the portion of the fifth module turntable **6040** in the liquid handling position **6040***b*.

[0277] The method **17000** may also include a step **17060** of instructing the fifth module gantry robot **6010** to pick up an output container **1030**, for example, a DWP **1025** and/or a micronic tube rack **1020**, loaded onto the fifth module deck **6035**. The method **17000** may also include a step **17065** of receiving, from the fifth module scanner **6020**, identifying information of the picked up DWP **1025** and/or the micronic tube rack **1020**, and a step **17070** of storing the received identifying information. In a case in which a micronic tube rack **1020** is picked up, the method **17000** may include a step **17075** of instructing the fifth module gantry robot **6010** to place the micronic tube rack **1020** into the capping and decapping device **6025**, and a step **17080** of instructing the capping and decapping device **6025** to remove the caps **1110** from the micronic tubes **1015** on the micronic tube rack **1020**. Then, the method **17000** includes a step **17085** of instructing the fifth module gantry robot **6010** to place the micronic tube rack **1020** with the decapped micronic tubes **1015** onto the plate shuttles **6060** on the plate shuttle tracks **6070**, and a step **17090** of instructing the plate shuttle conveyor system **6065** to move the plate shuttles **6060** to a liquid handling position.

[0278] With reference to FIG. **53**C, the method **17000** includes a step **17095** of instructing the fifth module liquid handling spanner **6075** to lower the fifth module aspirator tips **6055** into the second tubes **1010**. Then, the method **17000** may include a step **17100** of instructing the suction source to begin suction of plasma from the second tubes **1010**. As described above, an amount of plasma aspirated from each second tube **1010** may be determined by the controller **7000** based on amounts of plasma obtained and pooled during the liquid handling process in the third module **4000**. Once the plasma has been aspirated, the method **17000** includes a step **17105** of instructing the suction force to turn off. This step may include instructing the suction source to stop suction and/or to close an opening at a top of the fifth module aspirator tips **6055** through which suction may be communicated, so that the plasma aspirated into the fifth module aspirator tips **6055** is held in the fifth module aspirator tips **6055** as the fifth module liquid handling spanner **6075** moves to the liquid dispensing position. Then, the method includes a step **17100** of instructing the fifth module liquid handling spanner **6075** to remove the fifth module aspirator tips **6055** from the second tubes **1010** and to move the aspirator tips **6055** to a location over the DWPs **1025** and/or micronic tubes **1015** located at the liquid handling position. This step may also include instructing the fifth module liquid handling spanner **6075** to adjust (if needed) a spacing of the fifth module aspirator tips **6055** to correspond to a spacing of wells within the DWP **1025** or to a spacing of micronic tubes **1015** in the micronic tube rack **1020**, depending on which type of output container **1030** is located in the liquid dispensing position, and instructing the fifth module liquid handling spanner **6075** to lower the fifth module aspirator tips **6055** into the DWP **1025** or the micronic tubes **1015**, and to dispense the plasma. The instruction to dispense the plasma may include opening a top (or unsealing an opening at a top) of the fifth module aspirator tips **6055**, to allow the plasma to fall into the wells of the DWP **1025** or into the micronic tubes **1015**.

[0279] In some embodiments, the method **17000** may include instructing the fifth module liquid handling spanner **6075** to repeat the steps relating to aspirating plasma from the second tubes **1010** and dispensing the plasma into wells of the DWP **1025** or into micronic tubes **1015**.

[0280] In some embodiments, the step **17110** includes receiving at controller **7000**, from the liquid handling spanner **6075** of the third module **4000**, a value of an amount of plasma dispensed into a second tube **1010**, and determining, based on the received value of the amount of plasma, an amount of plasma to be dispensed into each well of the DWP **1025**, into each micronic tube **1015**, and/or into the DWP **1025** and into the micronic tubes **1015**. That is, this step may include applying logic (described previously in section D. Liquid Handling Station of Fifth Module) to determine (1) an amount of plasma to be dispensed into each well of a DWP **1025**, (2) an amount of plasma to be dispensed into each micronic tube **1015**, or (3) amounts of plasma to be dispensed into the wells of the DWP **1025** and into micronic tubes **1015**, for splitting of the plasma between the two types of output containers **1030**.

[0281] In a case in which the plasma is dispensed into a DWP **1025**, the method **17000** may include a step **17115** of instructing the fifth module liquid handling spanner **6075** to skip one well of the DWP **1025**, which is to be a control. The determination of which well is to be skipped (that is, left empty) may be randomly determined by the controller **7000**, for example, as a part of this control method **17000**. Then, the method **17000** may include a step **17120** of instructing the plate shuttle conveyor system **6065** to move the DWP **1025** to the plate sealer **6030**, and a step **17125** of instructing the plate sealer **6030** to seal the filled DWP **1025**.

[0282] In a case in which the plasma is dispensed into micronic tubes **1015**, the method **17000** may include a step **17130** of instructing the plate shuttle conveyor system **6065** to move the micronic tube rack **1020** to the capping and decapping device **6025**, and a step **17135** of instructing the capping and decapping device **6025** to place the caps **1110** back onto the filled micronic tubes **1015**. Then, the method may include a step **17140** of instructing the plate shuttle conveyor system **6065** to move the output container **1030**, e.g., the DWP **1025** or the micronic tube rack **1020**, to the holding nest **6090**.

[0283] Then, with reference to FIG. **53**D, the method **17000** may also include a step **17145** of notifying the LIMS controller **9000** that an output container **1030** is located in one of the holding nests **6090** and is ready for pick up and downstream processing. Further, the method **17000** may also include a step **17150** of moving a transfer puck on an adjacent track system to a loading position, in which the output container may be placed on the transfer puck by the fifth module gantry robot **6010**, and a step **17155** of moving the transfer puck downstream on that adjacent track system to another location.

[0284] Although the control methods for each of the modules is described as a separate control method above, the control methods may be combined as a singular control method to control the entire automated liquid processing system **1000**.

[0285] Further, although the control methods are described as including the steps noted above, the methods may include all or some of the steps described above. That is, the control method for each module may include a subset of the steps described above, or may include additional steps. Further one or more steps may be repeated, as needed, or may be performed in a different order that what is specifically described above.

[0286] In addition to the control methods described above, the controller **7000** may control intercommunication among the first to fifth modules and communication between the automated liquid processing system **1000** and the LIMS controller **9000**.

X. Benefits

[0287] The automated liquid processing system **1000** and related control method described herein may be capable of processing a relatively greater quantity of liquid samples, for example, blood samples, as compared to known systems and methods. Specifically, the automated liquid processing system **1000** and related control method may be capable of processing liquid samples taken on a population level, rather than just a sample of individuals. In some aspects, automated liquid processing systems of the present disclosure may be designed to process up to 500 tubes per 1 hour, which correlates to processing first tubes **1005** for up to one million patients per year. Using more than one automated liquid processing system **1000** correspondingly increases these estimated processing throughput quantities. The automated liquid processing system **1000** may also be capable of processing both single tubes and pairs of tubes simultaneously, which may eliminate the need for separate systems for processing single tubes versus pairs of tubes.

[0288] The ability of the automated liquid processing system **1000** to keep together and process two different patient samples in two different sample tubes, and then pool together isolated components from each liquid patient sample tube, may result in the ability to output from the automated liquid processing system **1000** more of the isolated component of interest than traditional processing systems. Depending on the type of liquid being processed, this may be important and may mean that downstream processing of the samples may be more accurate as a result of a larger amount of the relevant sample component may be available. In the example of a blood sample, the component of interest may be plasma. Certain components, such as plasma, may be difficult to extract sufficient quantities of from a single blood sample using traditional processing systems. In one aspect, if downstream testing and processing requires the analysis of cell free DNA (cfDNA), it may be difficult to have sufficient amounts of cfDNA in the plasma, or other liquid biopsy sample, to test, because of the low concentration of cfDNA available in a liquid biopsy sample. Accordingly, when an assay is performed on blood plasma, it may be difficult to generate sufficient signal to provide accurate test results to a patient. Automated liquid processing systems and methods provided herein may thus result in pooled sample components that may provide for more reliable assay results in downstream testing, and thus more accurate information to relay to the patient.

[0289] By virtue of controlling movement and aspiration of each third module aspirator tip **4045** for each first tube **1005**, based on the image analysis of a captured image **4175** of the first tube **1005**, it may be possible to withdraw as much of the isolated plasma in each first tube **1005** as possible, without disturbing the buffy coat red blood layer L**2** or the red blood cell layer L**3**. This, in turn, may allow for extraction of relatively greater quantities of plasma from blood samples, whether the samples come from a single first tube **1005** or a pair of tubes **1005**, on the order of milliliters, compared to the quantities obtained using other systems, which are on the order of hundreds of micrometers. This arrangement also ensures that genomic components of the cfDNA are collected in the plasma.

[0290] By virtue of spinning blood samples to isolate plasma, and then transferring the isolated plasma and spinning that plasma a second time, it is possible to refine the quality of the plasma isolated from the blood sample, by minimizing the presence of red blood cells or buffy coat red matter (e.g., contents of white blood cells and platelets) in the plasma output to the output containers **1030**. This may promote the accuracy of subsequent processing and/or testing.

[0291] The automated liquid handling system **1000** may additionally or alternatively provide for continued processing that does not require human intervention, or requires little human intervention. This may inhibit the risk of contamination and/or misplacement of samples, which may occur when samples are handled and/or transferred manually. Further, the automated systems described herein may provide in-line quality control that may otherwise be difficult and/or time consuming with traditional liquid processing. In other words, the automated liquid processing system **1000** may avoid human error in the liquid handling processes described herein. The automated liquid handling system **1000** may also provide traceability of blood samples and plasma through the entire system **1000**. That is, the precise location of any blood sample and/or volume of isolated plasma from a blood sample may be determined by the controller **7000**, if needed.

[0292] Specifically with regards to the excising station **4055**, the relative arrangement of the first tubes **1005** on the lift **4145** and the blades **4150** on blade actuators **4155**, and the relative motion of the lift **4145** to the blades **4150**, may allow for removal of any material, such as labels, on an exterior surface of the first tube **1005**, and for promoting consistency in creating a "window" through each first tube **1005** for viewing layers of subcomponents of a liquid within the first tube **1005**. That is, opposing exterior sides of the first tube **1005** are scraped and cleared of material, and as a result, a level or a height of each separated layer of liquid in the first tubes **1005** may be visible through the window. More specifically, building on the example of blood samples noted above, the window of each first tube **1005** may allow for clear and consistent visual inspection of a height of a plasma layer L**1**, a height of a red blood cell layer L**3**, a height of a buffy coat red layer L**2** in between the plasma layer L**1** and the red blood cell layer L**3**, these layers resulting from the first spin carried out in the second module **3000**. Further, the excising station **4055** may create a consistent viewing window on the first tubes **1005** regardless of the number of labels on the first tubes **1005** or the locations of the labels on the first tubes **1005**.

[0293] In addition, by virtue of the lift **4145** holding the first tubes **1005** steady and moving in a single, upward direction, while the blades **4150** move to scrape the material off the first tubes **1005**, and then imaging the first tubes **1005** immediately thereafter, as described herein, the first tubes **1005** may be maintained in the same orientation throughout the excising process (that is, the first tubes **1005** remain upright), to inhibit or prevent disturbance of the separated subcomponents of the liquid in the first tubes **1005**. Further, by pushing the lift **4145** up from a bottom thereof, a sufficient pushing force may be generated, without jeopardizing the integrity of the first tubes **1005** or causing misalignment or tilting of the first tubes **1005**. Accordingly, this arrangement may inhibit breakage of the first tubes **1005**.

[0294] In this disclosure, the term "based on" means "based at least in part on." The singular forms "a," "an," and "the" include plural referents unless the context dictates otherwise. The term "exemplary" is used in the sense of "example" rather than "ideal." The terms "comprises," "comprising," "includes," "including," or other variations thereof, are intended to cover a non-exclusive inclusion such that a process, method, or product that comprises a list of elements does not necessarily include only those elements, but may include other elements not expressly listed or inherent to such a process, method, article, or apparatus. Relative terms, such as "about," "approximately," "substantially," and "generally," are used to indicate a possible variation of +10% of a stated or understood value. In addition, the term "between" used in describing ranges of values is intended to include the minimum and maximum values described herein. The use of the term "or" in the claims and specification is used to mean "and/or" unless explicitly indicated to refer to alternatives only if the alternatives are mutually exclusive, although the disclosure supports a definition that refers to only alternatives and "and/or." As used herein "another" may mean at least a second or more.

[0295] As used herein, the term "user" generally encompasses any person or entity, such as a researcher and/or a care provider (e.g., a doctor, etc.), that may desire information, resolution of an issue, or engage in any other type of interaction with a provider of the systems and methods described herein (e.g., via an application interface resident on their electronic device, etc.). The term "electronic application" or "application" may be used interchangeably with other terms like "program," or the like, and generally encompasses software that is configured to interact with, modify, override, supplement, or operate in conjunction with other software.

[0296] Program aspects of the technology may be thought of as "products" or "articles of manufacture" typically in the form of executable code and/or associated data that is carried on or embodied in a type of machine-readable medium. "Storage" type media include any or all of the tangible memory of the computers, processors or the like, or associated modules thereof, such as various semiconductor memories, tape drives, disk drives and the like, which may provide non-transitory storage at any time for the software programming. All or portions of the software may at times be communicated through the Internet or various other telecommunication networks. Such communications, for example, may enable loading of the software from one computer or processor into another, for example, from a management server or host computer of the mobile communication network into the computer platform of a server and/or from a server to the mobile device. Thus, another type of media that may bear the software elements includes optical, electrical and electromagnetic waves, such as used across physical interfaces between local devices, through wired and optical landline networks and over various air-links. The physical elements that carry such waves, such as wired or wireless links, optical links, or the like, also may be considered as media bearing the software. As used herein, unless restricted to non-transitory, tangible "storage" media, terms such as computer or machine "readable medium" refer to any medium that participates in providing instructions to a processor for execution.

[0297] Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those skilled in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

[0298] Thus, while certain embodiments have been described, those skilled in the art will recognize that other and further modifications may be made thereto without departing from the spirit of the invention, and it is intended to claim all such changes and modifications as falling within the scope of the invention. For example, functionality may be added or deleted from the block diagrams and operations may be interchanged among functional blocks. Steps may be added or deleted to methods described within the scope of the present invention.

[0299] The above disclosed subject matter is to be considered illustrative, and not restrictive, and the appended claims are intended to cover all such modifications, enhancements, and other implementations, which fall within the true spirit and scope of the present disclosure. Thus, to the maximum extent allowed by law, the scope of the present disclosure is to be determined by the broadest permissible interpretation of the following claims and their equivalents, and shall not be restricted or limited by the foregoing detailed description. While various implementations of the disclosure have been described, it will be apparent to those of ordinary skill in the art that many more implementations are possible within the scope of the disclosure. Accordingly, the disclosure is not to be restricted except in light of the attached claims and their equivalents.

[0300] It should be understood that although the present disclosure has been made with reference to preferred embodiments, exemplary embodiments, and optional features, modifications and variations of the concepts herein disclosed may be resorted to by those skilled in the art, and that such modifications and variations are considered to be within the scope of this disclosure as defined by the appended claims. The specific embodiments and examples provided herein are examples of useful embodiments of the present disclosure and are non-limiting and illustrative only. It will be apparent to one skilled in the art that the present disclosure may be carried out using a large number of variations of the devices, device components, methods, and steps set forth in the present description. As will be recognized by one of skill in the art, methods and devices useful for the present methods can include a large number of various optional compositions and processing elements and steps.

1. A method of processing liquid samples, the method comprising:

receiving a plurality of liquid samples, each liquid sample being contained within a sample collection tube, and wherein the plurality of liquid samples include either or both of (i) two liquid samples from the same individual, or (ii) one liquid sample from an individual;

centrifuging the plurality of liquid samples a first time to separate out a subcomponent of interest;

imaging the plurality of liquid samples to determine a height of the subcomponent of interest in each sample collection tube;

aspirating out the subcomponent of interest from the plurality of sample collection tubes and dispensing the aspirated subcomponent of interest into a plurality of processing tubes, wherein all of the aspirated subcomponent of interest for the same individual is deposited into one processing tube, such that the subcomponent of interest from the two liquid samples from the same individual are deposited into one processing tube, and the subcomponent of interest from the one liquid sample from the individual is deposited into one processing tube;

centrifuging the plurality of liquid samples in the plurality of processing tubes a second time to further separate out the subcomponent of interest; and

outputting the separated subcomponent of interest from each of the plurality of liquid samples in the plurality of processing tubes into a plurality of output containers.

2. The method of claim **1**, wherein the plurality of liquid samples are blood samples.

3. The method of claim **2**, wherein the subcomponent of interest is plasma.

4. The method of claim **1**, wherein the plurality of liquid samples are urine samples.

5. The method of claim **1**, wherein the plurality of output containers includes at least one of deep well plates or micronic tubes.

6. The method of claim **5**, wherein the plurality of output containers includes deep well plates, and when the separated subcomponent of interest is output into a deep well plate, one or more wells of the deep well plate is left empty.

7. The method of claim **5**, wherein the plurality of output containers includes both deep well plates and micronic tubes.

8. The method of claim **7**, wherein the outputting step further comprises determining a total volume of the subcomponent of interest in a given processing tube of the plurality of processing tubes relative to a first threshold or a second threshold, wherein:

if the total volume of the subcomponent of interest is less than the first threshold, then all of the subcomponent of interest is deposited into a deep well plate,

if the total volume of the subcomponent of interest is greater than or equal to the first threshold and less than the second threshold, then a predetermined volume of the subcomponent of interest is deposited into the deep well plate, and a remaining volume of the subcomponent of interest is deposited into a micronic tube, and

if the total volume of the subcomponent of interest is greater than or equal to the second threshold, then the volume of the subcomponent of interest is divided between the deep well plate and the micronic tube.

9. The method of claim **7**, wherein the outputting step further comprises determining whether the total volume of the subcomponent of interest in a given processing tube of the plurality of processing tubes is greater than or less than a threshold, wherein:

if the total volume of the subcomponent of interest is less than or equal to a threshold, then all of the subcomponent of interest is deposited into a deep well plate, and

if the total volume of the subcomponent of interest is greater than the threshold, then a predetermined volume of the subcomponent of interest is deposited into the deep well plate, and a remaining volume of the subcomponent of interest is deposited into a micronic tube.

10. The method of claim **1**, further comprising excising portions of a label on opposite outer surfaces of each of the sample collection tubes prior to the imaging step.

11. The method of claim **1**, wherein after the imaging step, the method further comprises performing a color analysis on a portion of a captured image showing the subcomponent of interest to determine whether a quality of the subcomponent of interest is sufficient for processing.

12. The method of claim **11**, wherein performing the color analysis comprises comparing the portion of the captured image to a color chart, and assessing a color of the subcomponent of interest relative to the color chart.

13. The method of claim **11**, wherein performing the color analysis comprises assessing a color of the subcomponent of interest relative to a stored color value.

14. A label excising station, comprising:

a pair of blades spaced apart from one another and located opposite from one another;

a pair of blade actuators, wherein each blade of the pair of blades is rotatably mounted on one of the pair of blade actuators; and

a platform positioned below the pair of blades, wherein the platform is configured to receive a sample collection tube, wherein the platform is configured to move between a first position and a second position, wherein in the first position, the platform is spaced relatively further away from the pair of blades, and wherein in the second position, the platform is spaced relatively closer to the pair of blades.

15. The label excising station of claim **14**, wherein the pair of blade actuators is configured to move between a first spacing and a second spacing, wherein in the first spacing, a first blade of the pair of blades is spaced apart from a second blade of the pair of blades a distance that is approximately equal to a width of the sample collection tube to be received on the platform, and wherein in the second spacing, the first blade of the pair of blades is spaced apart from the second blade of the pair of blades a distance that is greater than the first spacing.

16. The label excising station of claim **14**, comprising a plurality of pairs of blades and a plurality of pairs of blade actuators.

17. The label excising station of claim **14**, further comprising a force sensor operably coupled to at least one of the blade actuators or the platform.

18. The label excising station of claim **14**, further comprising an excising robot having an end effector, wherein the end effector is configured to grip the sample collection tube, and the excising robot is configured to move the sample collection tube onto the platform while the end effector grips the sample collection tube.

19. The label excising station of claim **18**, wherein the end effector comprises a set of tube grips configured to grasp a top of the sample collection tube.

20. A method of excising a label from a sample collection tube, the method comprising:

placing the sample collection tube on a platform;

moving a pair of blade actuators so as to position blades rotatably mounted on the pair of actuators apart from one another a distance approximately equal to a width of the sample collection tube; and

moving the platform towards the blades so that the sample collection tube is pushed upwards between the blades mounted on the pair of actuators while the blades contact opposing sides of the sample collection tube.

21. The method of claim **20**, further comprising rotating the blades on the pair of blade actuators so that different portions of the blades are configured to contact a subsequent sample collection tube passing therebetween.

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