

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
10 December 2009 (10.12.2009)

(10) International Publication Number
WO 2009/146936 A1

(51) International Patent Classification:
B05B 12/04 (2006.01) *B05B 15/12* (2006.01)
B05B 12/14 (2006.01) *B25J 5/02* (2006.01)
B05B 13/04 (2006.01)

[US/US]; 6365 Stonewood Drive, White Lake, MI 48383 (US).

(21) International Application Number:
PCT/EP2009/004062

(74) Agent: **BEIER, Ralph**; V. Bezold & Partner, Akademiestrasse 7, 80799 München (DE).

(22) International Filing Date:
5 June 2009 (05.06.2009)

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/059,170 5 June 2008 (05.06.2008) US
61/059,555 6 June 2008 (06.06.2008) US
12/478,510 4 June 2009 (04.06.2009) US

(71) Applicant (for all designated States except US): **DÜRR SYSTEMS GMBH** [DE/DE]; Otto-Dürr-Strasse 8, 70435 Stuttgart (DE).

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **HELDT, Robert, F.** [US/US]; 677 Doral, Oxford, MI 48371 (US). **GRIGOLEIT, Jan** [DE/DE]; Emil-Klumpp-Strasse 14, 74321 Bietigheim-Bissingen (DE). **SOUGIOLTZIS, Vassilios** [GR/DE]; Christophstrasse 6, 74321 Bietigheim-Bissingen (DE). **BUCKNELL, Thomas, A.**

Declarations under Rule 4.17:

[Continued on next page]

(54) Title: COMPACT PAINT BOOTH AND METHOD

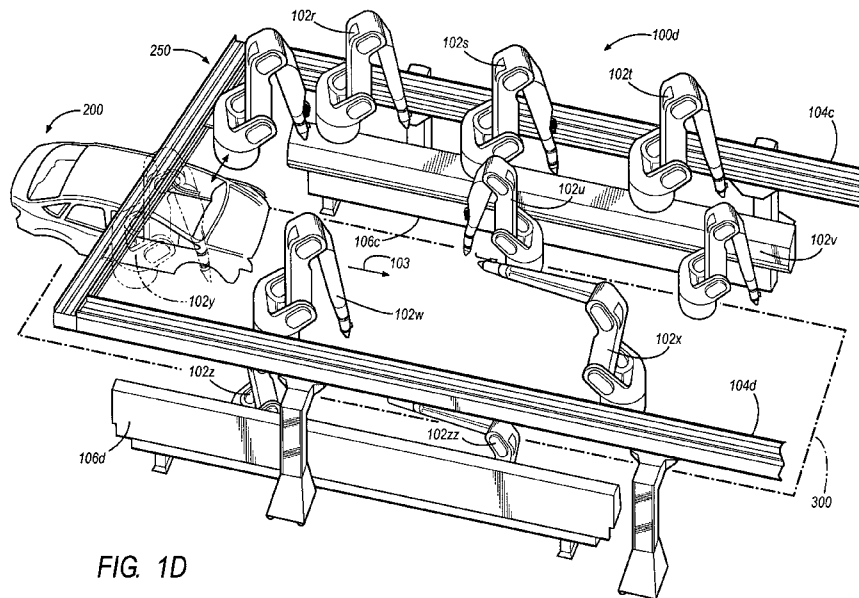


FIG. 1D

(57) Abstract: Paint booths for applying paint to an object, as well as methods for degrading coating operations associated with a paint booth, are disclosed. Paint booth may generally include one or more robot rails positioned parallel to the path of the conveyor, and one or more robots positioned on at least one of the rails. Robots may be configured to simultaneously apply a first paint layer to the interior and exterior surfaces of the object. Paint booths may further include one or more additional robots positioned on at least one of the rails and configured to simultaneously apply a second paint layer to the interior and exterior surfaces of the object.



WO 2009/146936 A1

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

Compact Paint booth and method

5 CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority from U.S. Provisional Patent Application Serial No. 61/059,170 and 61/059,555, which were filed on June 5, 2008 and June 6, 2008, respectively. The contents of each are expressly incorporated
10 herein by reference in their entireties.

Background

15 Painting or coating applications for motor vehicle applications generally entail large, expensive installations within a vehicle assembly plant. Ongoing efforts to reduce costs and increase plant efficiencies have led to a desire for increasingly smaller coating plants, as smaller coating installations
20 generally consume less energy during operation than larger installations. Further, smaller coating installations offer increased installation flexibility and greater utilization rates of plant floor space.

25 Quality and environmental concerns generally require large coating installations having separate booths for application of different coating layers, e.g., an exterior paint layer and interior paint layer. For example, generally an interior paint booth and an exterior paint booth are provided separately along a coating installation line. The separate interior
30 and exterior booths are provided in order to ensure that application of different coating layers, minimize overspray of coating materials, especially where different materials are applied in different layers. Therefore traditionally the

interior and exterior booths are separated from one another, and include separate support systems such as coating waste disposal mechanisms, manual backup zones for application robots, etc.

5

Accordingly, there is a need for a coating installation that allows for application of different coating layers and/or different coating materials within a reduced footprint as compared with traditional coating installations having separate booths.

10

Brief Description of the Drawings

Referring now to the drawings, exemplary illustrations are shown in detail. Although the drawings represent some examples, the drawings are not necessarily to scale and certain features may be exaggerated, removed, or partially sectioned to better illustrate and explain the present invention. Further, the exemplary illustrations set forth herein are not intended to be exhaustive or otherwise limit or restrict the claims to the precise forms and configurations shown in the drawings and disclosed in the following detailed description:

15
20

FIG. 1A is an isometric view of an exemplary coating installation;

25

FIG. 1B is an isometric view of another exemplary coating installation;

FIG. 1C is an isometric view of another exemplary coating installation;

30

FIG. 1D is an isometric view of another exemplary coating installation;

FIG. 2 is an isometric view of a vehicle body for coating within an exemplary coating installation, the vehicle body including a plurality of application zones;

5

FIG. 3 is a process flow diagram for an exemplary process for applying a coating material to an object; and

FIG. 4 is a process flow diagram for an exemplary process for
10 degrading a coating installation.

Detailed Description

Various exemplary illustrations of a coating installation, methods of applying a coating material to an object, and methods of degrading a coating installation, i.e., reassigning application robot tasks during a malfunction of one of the robots, are disclosed herein. Examples of coating installations provided herein generally include paint booths in a vehicle assembly plant, but a wide variety of other applications are also possible.
15
20

Generally, a coating installation or paint booth may be provided for applying coating materials such as primer and base coat paint where coating robots are applying coating materials simultaneously to interior and exterior surfaces of a vehicle body. The exemplary coating installation includes a first section where coating robots positioned on high and low rails simultaneously apply a primer coat to a vehicle body
25
30 both to the body's interior and exterior surfaces. A second section may also be possible where a base coat paint material is simultaneously applied to both the interior and exterior surfaces of the vehicle body. As described in the exemplary embodiment the coating robots may in some circumstances in-

clude an appendage configured to allow a coating robot to selectively operate as an opener robot. By allowing a coating robot to selectively operate as an opener robot the total number of robots in a paint booth may be reduced.

5

The coating installation may further include a scrubber for paint application waste disposal. The paint application waste disposal defines a predetermined length encompassing each of the coating robots in the paint booth.

10

Additionally, a method of painting an object, e.g., a motor vehicle body, in a paint booth is disclosed. Exemplary methods may include simultaneously applying a first paint layer to first and second portions of the object, for example interior and exterior surfaces of the object followed by simultaneously applying a second paint layer to the first and second portions of the object.

15

Methods for degrading a coating installation are also disclosed. An exemplary method generally includes a process for selecting a replacement robot, or robot to carry out tasks previously assigned to a robot that has failed (either in part or completely) These tasks may be prioritized; for example replacement robots may paint the exterior of the car ahead of the engine compartment and the engine compartment ahead of door jams. In this way tasks that are highly visible or labor intensive are done on a priority basis. The method, for example, may allow a robot that was previously assigned to paint a door jam to be reassigned to painting the exterior of the car if a coating robot assigned to the exterior of the car is not available. This method may be further enhanced where the coating robots are configured to also act as opener robots insofar as coating robots may step in and perform ope-

20

25

30

ning operations if a robot assigned the task of opening is not available.

Turning now to FIGS. 1A-1D, exemplary coating installations or paint booths 100 are described in further detail. FIGS. 1A and 1B illustrate an exemplary in line coating operation where a vehicle body 200 continuously moves through the paint booth. As body 200 moves through the booth, a plurality of robots 102a, b, c, d, e, f, g, h, i, j (collectively, 102) operate to coat the vehicle, both on its interior and exterior surfaces. Robots 102 may include any coating application robot that is convenient, for example multi-axis robots, e.g., 6-axis or 7-axis robots that are capable of various kinematics or movements that allow the robots to perform spraying and/or handling operations associated with a painting operation. Robots 102 may also apply different types of materials, for example primer and base coat, to body 200 to affect a complete coating/painting operation. As shown, a rail system including upper rails 104 and lower rails 106 is provided for the mounting of the robots 102. Specifically, upper rails 104a, b (collectively, 104) may support six (6) of the robots 102a, b, c, d, e, and f for movement in a generally longitudinal direction that is generally parallel to the path of body 200. It is understood that fewer than six robots may be used and the number of robots within paint booth 100 may be fewer.

As shown, robots 102a, b, d, g and j may operate to coat body 200 with a first coating material such as a primer on both the body's interior and exterior surfaces. Thereafter, as vehicle body 200 progresses through the booth in the direction of arrow 103 and robots 102 g, j, e, f and c may operate to coat body 200 with a second coating material, for example a tinted basecoat. As described in more detail below, robots

102 may be configured to operate both as painting robots and as opener robots. Further, when the base coat is being applied, another vehicle body (not shown) may receive a primer coat within the booth 100a.

5

The application robots 102 illustrated in FIG. 1 are generally configured to apply coating materials to the body 200 as it moves through the paint booth in the direction 103. The robots 102 may each be provided with an atomizer 108 that is configured to apply a paint material to a vehicle body. For example, various atomizers are generally provided in United States Patent Nos. 6,189,804, 6,360,962, and 6,623,561, each of which are hereby expressly incorporated by reference in their entireties.

15

The atomizer may also be capable of applying different materials to the object 200, even in succession. For example, the atomizer 108 is capable, if necessary, of applying a first coating material, such as to one portion of a vehicle 200, for example a primer coat to the exterior, and then subsequently applying a second coating material, such as to another portion of the vehicle 200, for example a base coat to an exterior surface. Various examples of such atomizers are also provided by United States Patent Application Serial No. 12/300,741, which is the United States National Stage application of WO 2007/131636, each of which are hereby expressly incorporated by reference in their entireties. Accordingly, the atomizer 108 may apply a second coating material without mixing any of the prior coating material that may remain in the atomizer 108 after its application. Thus, the robots 102 may apply different coating materials, e.g., paint, within the same paint booth 100a to the body 200. The robots 102 may even be individually capable of applying different coating materials in succession; for example a given robot 102 may

apply a primer, base coat, and clear coat to a given vehicle or object.

As part of this capability, the atomizer 108 may include a
5 cleaning feature. For example, as best seen in FIG. 1B, robot
1021 has an associated cleaning wash bowl 112. The cleaning
wash bowl 112 allows for insertion of the atomizer 108 into
the bowl 112 for cycling a cleaning fluid throughout the at-
10 omizer 108, thereby generally entirely removing traces of a
coating material left within the atomizer 108 after applica-
tion.

The various robots 102 may be controlled by a central motion
controller (not shown) associated with the paint booth. For
15 example, a motion controller may be provided that generally
provides instructions to the robots 102 regarding movement
during a coating operation. It is understood that these in-
structions may be input based on the specifics of vehicle bo-
dy 200. Further, a controller may also include a computer-
20 readable medium that includes instructions executable for
performing various tasks as part of the processes and method
discussed herein.

As described above, the booth 100a includes a rail system in-
25 cluding upper rails 104 and lower rails 106 that generally
allow selective placement of the robots 102 at various posi-
tions within the booth 100a for application of a coating lay-
er and/or other functions e.g., opening a closure panel of a
vehicle. Each of the upper and lower rails 104, 106 generally
30 extend in a direction parallel to a path defined by the ob-
ject to be coated as the object moves through the paint
booth. Each of the robots may thus be secured to its respec-
tive rail 104 or 106 for movement along the rail.

The robots may be generally grouped for application of various different coating materials, such as paint. In another example, robots 102a, 102d, and 102i may cooperate to apply a first primer coat to both the interior and exterior portion
5 of the body 200. Further, robots 102b 102g and 102j may be grouped together to apply a primer coat of paint to both underhood (interior) and deck areas (exterior) of the body 200. Each of robots 102c, 102e, 102f, and 102h may be grouped for application of an exterior base coat layer to the body 200,
10 e.g., to interior and exterior surfaces of a motor vehicle.

The specific groupings discussed herein may be convenient, as the robots grouped together for a given coating layer are generally disposed adjacent one another in the longitudinal direction, e.g., direction 103, of the paint booth 100a. While
15 these groupings may be convenient from the standpoint of applying a particular layer of paint to the body 200 in a single region of the paint booth 100a, any other grouping of the robots 102 for application of one or more layers of paint
20 may be employed that is convenient.

Various coatings that are applied to the vehicle may advantageously have a reduced flash time, the flash time including a predetermined period of time after which a coating is applied
25 prior to a follow on coating. As flash times are reduce by paint manufactures it is understood that the dimensions of the exemplary paint booth 100 may be reduced.

Turning now to FIG. 1B, the operation of the robots will be
30 described in further detail. While the robots 102 have been generally described as application robots capable of spraying or applying a coating material, e.g., a primer or base coat of paint, to an object, the robots may also be configured to perform other tasks that may be necessary during application

of a coating material to the vehicle. For example, the robots 102 may each be configured to manipulate closure panels, e.g., doors, a hood, or a decklid, of a vehicle between open and closed positions with respect to the vehicle. This configuration advantageously allows robots 102 to perform functions other than applying a desired coating material, such additional functions being opening and closing closure panels of the vehicle to allow application of the coating material to all surfaces of the vehicle. Robots 102 may be provided with a feature allowing the robot 102 to grasp a portion of the closure panel. For example, as seen in FIG. 1B, a hook 110 may be provided on the robot wrist to allow a robot 102k to open and close a hood (or door, or truck deck) of vehicle 200 as desired. By providing coating robot with the ability to open and close portions of the vehicle it is possible to reduce costs as fewer robots are needed.

As briefly described above, the paint booth 100 is generally configured to apply a coating material to various portions of the vehicle 200. FIG 1C is an exemplary drawing of robot 102 simultaneously applying a coating material to exterior and interior surfaces of vehicle body. The exterior coating may be applied to an outer surface 204a of a door panel 202 of vehicle body 200 by a robot 102p while an interior coating robot 102q may apply an interior coating layer to an inside surface 204b of the door panel 202. A third robot 102o may generally manipulate the door 202 relative to the vehicle body 200, e.g., by opening and closing the door 202 to allow painting of the interior and exterior surfaces 204a, 204b of the door 202.

As the robots 102p and 102q may generally apply a wet coating material to the door 202 generally simultaneously in some examples, it may be necessary to provide a device for prevent-

ing contact between door and body surfaces while each are still wet. For example, a door clip (not shown) may be provided that generally spaces apart the door (or any other closure panel) from the body after the door is moved back to its closed position. In one known example, a door clip engages 5 striker features of the door and body, thereby spacing them apart while not contacting visible components of the door or body.

10 As best seen in FIG. 1A, the paint booth may further include a scrubber 300, i.e., a paint application waste disposal area, that is in communication with each of the application robots 102 within the booth 100a. Paint waste from each of the robots 102 is carried away by the paint application waste 15 disposal 300. The paint application waste disposal or scrubber 300 defines a predetermined length encompassing each of the application robots 102. In other words, each of the application robots 102 are generally contained within a single paint booth 100a, where the length of the booth 100a may generally be defined by the longitudinal extent of the scrubber 20 or waste disposal system 300 that services the robots 102 of the paint booth 100a.

Various features and methodologies described herein generally 25 permit the provision of exterior and interior coating robots within a single paint booth 100, as generally illustrated in the exemplary booths of FIGS. 1A, 1B, and 1C.

As shown in FIG. 1D, transverse rails may also be provided 30 for even greater flexibility of applying a coating layer. For example, a lateral rail 250 extending horizontally across a paint booth 100d may be provided that supports an additional robot 102y. Further, an additional lateral rail (not shown) may be provided at an end of the booth 100d longitudinally

opposite the end at which the lateral rail 250 is provided. This may add two additional robots at both the point where the vehicle body 200 enters the paint booth and where the vehicle body 200 exits the paint booth. By providing additional
5 coating robots it is possible to apply additional coating layers in an even more compressed footprint. In such an example, it may be that robot 102y is involved with a primer coat and other robots, within the same paint booth performing
10 other coating operations, for example base coat and clear coat painting operations. As shown in FIG. 1D, the example having one or more transverse rails may also include upper and lower rails 104, 106, respectively, that support additional robots 102.

15 Turning now to FIG. 2, a vehicle 200 is shown having various exterior application zones 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16. Arrows 20 represent the path of a coating robot along the surface of vehicle 200 with the path being defined by a set of computer instructions available to
20 the coating robot assigned to apply a coating to any given zone. Each of the zones 1-16 represents an area of exterior layer application that is assigned to one of the robots 102 within the booth 100. Coating application zones for interior portions of vehicle body 200 may be likewise provided albeit
25 not shown in Fig 2. For example, as referenced above in regard to FIG. 1A, different robots may simultaneously coat different parts of the vehicle including simultaneous application of coating materials to both internal and external surfaces. In the exemplary embodiment the computer instruc-
30 tions associated with each zone may be available to every robot in the painting booth. As described below by making the instructions available to all robots the coating system of the exemplary embodiment may provide a method to continue painting operations in the event that a robot fails.

It should be noted that zones 1-16 are much smaller than is traditional. For example, the six horizontal zones 1, 7, 8, 9, 15, and 16 may be divided into two zones in the prior art, a left zone and a right zone. By dividing the horizontal surfaces into smaller sections additional robots may be able to work to apply a coating to vehicle 200. While it is therefore beneficial to reduce the size of assigned zones in order to allow greater flexibility of the robots 102, this may also be influenced by overall size and complexity of an object being coated or painted. Therefore a particular size of the zones 1-16 may be influenced not only by a desire for greater flexibility of robot tasks, but also by an overall size of a vehicle and surface complexity.

15

Turning now to FIG. 3, a process 301 for coating an object in a coating installation is illustrated. Process 301 may generally begin at 302, where a first paint layer, for example a primer, is applied to both the interior and exterior surfaces of a vehicle body with a first group of robots. In certain applications separate primer materials may be applied to the interior and exterior surfaces of a vehicle body. Process 301 then proceeds to 304. At 304, a second paint layer, for example a base coat is applied to the interior and exterior surfaces of a vehicle body with a second group of robots

20
25

As described above, the exemplary paint booth 100 generally allows application of both an interior and an exterior paint layer within a single paint booth 100. Further process 304 may occur relative to a first vehicle body while process 302 occurs with respect to a second vehicle body within a single paint booth 100. Alternatively, the first and second layers may be applied one after the other, in any order that is convenient.

30

At process 306, paint application waste may be carried away from the first and second application robots via a paint application waste disposal. The paint application waste disposal may define a predetermined length encompassing each of the first and second application robots and may occur at any time. It is contemplated that the predetermined length of the scrubber may be as little as 45 feet in some applications as a result of providing all interior and exterior robots within a single booth 100a. Process 301 may then terminate.

Turning now to FIG. 4, an exemplary process for degrading a coating installation is described. Degrading a coating installation generally includes reassignment of robots with various application and handling tasks associated with a coating operation due to a partial or complete malfunction of at least one of the application and/or opener robots. For example, where an application robot requires service, becomes inoperable, or is otherwise unavailable for applying a coating material, manipulating a closure panel of a vehicle, or performing some other task assigned to it during normal operation, it will be necessary for another robot to perform the task. If multiple robots become unavailable further reassignment may be necessary. Further, it may be necessary to reorganize other application tasks amongst the remaining robots in order to continue the painting operation using only the robots. This may be referred to as a "lights out" application, that is, entirely without manual intervention.

Generally, exemplary degrade processes follow a hierarchy of assigning robot tasks according to various factors. In select applications, but not all applications, at least one extra or "degrade" robot may be provided within a paint booth. For

example as seen above in FIG. 1A robot 102g may be assigned normal painting tasks or may in other circumstances be assigned more of a complete or partial stand by mode and act as the degrade robot 102g. The degrade robot may pick up the task previously performed by the malfunctioning robot, or tasks may be reassigned amongst other robots including the previously idle degrade robot.

Generally, the reassignment of robot tasks follows a hierarchy or priority scheme. For example, a task, such as applying a particular coating layer to a given portion of a vehicle, may be assigned to another robot based upon the proximity of the other available robot to the disabled robot. For this reason, if a degrade robot is provided, it may be convenient to locate a degrade robot, e.g., degrade robot 102g, generally within a middle portion of a paint booth. Furthermore, any robot 102 specifically designated as a degrade robot may have a maximum level of task flexibility, e.g., the degrade robot 102g can apply different materials, handle different closure panels of the vehicle, etc., thereby allowing the degrade robot 102g to step in to perform the tasks of a maximum number of other robots. The reassignment of robot tasks may also involve shuffling of tasks amongst available robots. For example, where the degrade robot is inconveniently located with respect to a malfunctioning robot, such that the degrade robot would not adequately be able to perform the malfunctioning robot's task, it may be more convenient to reassign the malfunctioning robot's task to a third robot that is functioning properly, and then reassigning the third robot's task to the degrade robot. Accordingly, all tasks continue operation in a "lights out" fashion, such that no manual application is needed.

Furthermore, while examples are provided herein regarding a degrade robot where initially the degrade robot, e.g., robot 102g, is completely idle, degrade robots need not necessarily be entirely idle initially or during normal operation. For
5 example, any robot that is not being used to its full capacity during normal operation may function as a degrade robot and pick up additional tasks as necessary.

Nonetheless, if and when a second robot malfunctions, it may
10 become necessary to degrade the application further and further reassign robots to accomplish coating operations. Providing an increased number of painting zones and making the computer instructions associated with each zone available to all robots within the paint booth facilitates a robust de-
15 grade operation within a compact footprint. As a matter of priority the tasks involving the most amount of manual work may be determined and given priority within a degrade hierarchy. For example, exterior panels will require much higher quality as a result of the high visibility to the customer,
20 and therefore require significant attention to detail and minimizing disruptions and thus if an exterior operation fails it may receive top priority. Another factor may be that interior portions of a vehicle having multiple surface undulations or features, e.g., an engine compartment, will require
25 a greater amount of work to apply a coating layer than, for example, an interior coating layer of a body interior. Thus, painting of an engine compartment will be prioritized over a door jam. In this way, if any manual intervention is necessary it will be of the least important features. In other em-
30 bodiments line speed associated with vehicle 200 may be decreased, or as described above even stopped entirely for a period of time, to allow the remaining robots to complete all painting operations without manual intervention. In cases where manual intervention is desired or necessary, i.e., whe-

re the enough robots 102 have malfunctioned such that remain-
ing robots cannot pick up all of the tasks assigned to the
malfunctioning robots, it may be advantageous to assign low-
est priority tasks to the manual spraying devices. For exam-
5 ple, where a task assigned to a malfunctioning robot includes
surfaces that are generally smooth and undulating, or are not
in areas of a vehicle often visible to a potential customer,
these tasks will be assigned to a manual spraying device when
necessary before tasks associated with more complex or visi-
10 ble features.

Additionally, in examples where a first degrade robot 102 is
not fully idle during normal operation, i.e., the degrade ro-
bot 102 performs at least some task, there may be greater po-
15 tential for requiring use of a manual sprayer when other ro-
bots malfunction. Greater utilization rates associated with a
degrade robot during normal operation may therefore be toler-
ated by accepting greater potential for needed manual inter-
vention, as a degrade robot may in these cases be less avail-
20 able to pick up additional tasks from malfunctioning robots.
Conversely, lower utilization rates initially associated with
a degrade robot, e.g., robot 102g, may allow greater flexi-
bility to pick up tasks from other robots 102 that are mal-
functioning, thereby decreasing the potential need for manual
25 intervention when one or more robots malfunction. Further, a
degrade robot having a lower initial utilization rate will
necessarily be capable of picking up a greater number of
tasks, even performing tasks of more than one robot in some
cases.

30

Maintaining a "lights out" operation for a given painting op-
eration, i.e., without any manual sprayer, may even be possi-
ble by taking other measures to allow greater utilization of
the robots 102. For example, a given line speed, i.e., a rate

of motion of a conveyor associated with a paint booth 100, manual intervention may be required more often than if the line speed is simply lowered, thereby allowing a longer time period for robots 102 to collectively complete the assigned tasks. Further, a line speed may be entirely stopped during a particular painting operation, thereby allowing completion of the collective tasks by the robots 102, and avoiding a need for assignment of any of the robot tasks to a manual spraying device.

10

Process 400 may generally begin at 402, where a plurality of robots are provided for applying a coating material to an object moving through the coating installation. Further, the robots are configured to move closure panels of the object relative to the object. For example, as described above a plurality of robots 102 may be provided in a booth 100a, where the robots 102 may each perform a series of handling and application tasks in order to apply a coating material. Process 400 may then proceed to 404.

20

At 404, process 400 queries whether a malfunction has been detected one of the robots. A malfunction may generally prevent a given robot from performing a first assigned task. If a robot malfunctions it will typically return to a home position where collisions will be minimized. For example, a coating application controller may detect that one of the robots 102 can no longer apply paint because its paint lines will not clear or otherwise requires service or replacement, or any other situation where a robot cannot perform its assigned task adequately. Where a malfunction is not detected, process 400 then proceeds to 406, where normal operation of the coating application continues, then returning to 404 for continual monitoring. Where a malfunction is detected at 404, process 400 proceeds to 408.

At 408, the malfunctioning robot is identified. For example, a controller of the coating installation may identify that a particular robot 102 has become disabled on an associated
5 rail along which the robot 102 moves. Process 400 then proceeds to 410.

At 410, the position and last painting function of the malfunctioning robot position is identified. For example, a controller of the coating installation may determine where along
10 path 20 the robot has ceased painting operations, and how that location has become adjusted as vehicle body continues to advance through the paint booth. Process 400 may then proceeds to 412.

15

At 412, a second one of the robots is selected to perform the first assigned task, e.g., based upon a degrade priority scheme. The degrade priority scheme may select the second one of the robots based upon a proximity of the second robot to
20 the first robot as well as the task currently assigned to the second one of the robots. Alternatively or in addition, the degrade priority scheme may select the second one of the robots based upon a proximity of an idle one of the robots, i.e., a degrade robot, to the first (malfunctioning) robot.
25 The second robot that is selected may be the idle (i.e., degrade) robot, or alternatively may be another functioning robot, for example where the degrade robot is inconveniently positioned with respect to the task needed to be performed. The second robot may thus initially be performing another
30 task, e.g., closing/opening closure panels of the vehicle, applying a coating material, or any other task needing to be performed as part of the application process. The provision of dual-capability robots, i.e., robots that are capable of applying a coating material and also of opening/closing the

closure panels of the vehicle, as described above, may be especially advantageous in this respect, as robots may be freely reassigned tasks with maximum flexibility. Further, in some cases it may be necessary to assign tasks to a manual spraying device where there is not enough remaining capacity amongst the robots 102 to pick up all of the tasks assigned to one or more malfunctioning robot 102. In making a determination of what task to assign to a manual spraying device, a task currently assigned to a robot being considered for taking over the task of the malfunctioning robot(s) may be compared with the task(s) of the malfunctioning robot, or other robots being considered to take over the task of the malfunctioning robot, in order to determine which task is a lowest priority task that may be re-assigned to a manual application device. Process 400 then proceeds to 414.

At 414, a new path is determined for the second available robot that is taking over for the malfunctioning robot. This path will allow the substitute robot to travel to the last known location of painting operation and pick up where the painting operations previously ceased. This new path may precisely match the location of the last known painting operation or may operate to an approximation. For example, where the malfunctioning robot is disabled from movement, it may be necessary for the robot taking over the task of the malfunctioning robot to avoid the disabled robot, while still completing the task of the malfunctioning robot. In another example, a particular module being coated when a given robot malfunctions may be entirely re-applied by a robot taking over for the malfunctioning robot. Thus, instead of merely finishing a module or area of a vehicle left incomplete as a result of a malfunctioning robot, a robot taking over the task may entirely re-do the module, thereby minimizing potential coating imperfections that might otherwise result from

an interrupted coating operation. A controller of the coating installation may generally take into account the location of the malfunctioning robot, e.g., as determined in at 410, and adjust a path associated with the task now being performed by the available robot accordingly. Process 400 may then proceed to 416.

At 416, the coating operation may continue. In one example, the controller reassigns an available robot to complete any uncompleted portions of the task of a malfunctioning robot. The available robot(s) thus may continue a coating operation of a vehicle even where another robot becomes disabled during the specific coating task it is initially assigned. For example, the controller may assign the task of the disabled robot to an available robot, thereby allowing the available robot to take over where the disabled robot left off and finishing the coating operation of the vehicle. Further, as described above an available robot may completely re-do a particular task left partially completed by a malfunctioning robot.

Alternatively, 416 may include a command from the controller of the coating operation to simply reassign the task of the malfunctioning robot to an available robot, continuing the coating operation on the next subsequent vehicle moving through the paint booth.

Reference in the specification to "one example," "an example," "one embodiment," or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the example is included in at least one example. The phrase "in one example" in various places in the specification does not necessarily refer to the same example each time it appears.

With regard to the processes, systems, methods, heuristics, etc. described herein, it should be understood that, although the steps of such processes, etc. have been described as occurring according to a certain ordered sequence, such processes could be practiced with the described steps performed in an order other than the order described herein. It further should be understood that certain steps could be performed simultaneously, that other steps could be added, or that certain steps described herein could be omitted. In other words, the descriptions of processes herein are provided for the purpose of illustrating certain embodiments, and should in no way be construed so as to limit the claimed invention.

Accordingly, it is to be understood that the above description is intended to be illustrative and not restrictive. Many embodiments and applications other than the examples provided would be upon reading the above description. The scope of the invention should be determined, not with reference to the above description, but should instead be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. It is anticipated and intended that future developments will occur in the arts discussed herein, and that the disclosed systems and methods will be incorporated into such future embodiments. In sum, it should be understood that the invention is capable of modification and variation and is limited only by the following claims.

All terms used in the claims are intended to be given their broadest reasonable constructions and their ordinary meanings as understood by those skilled in the art unless an explicit indication to the contrary is made herein. In particular, use of the singular articles such as "a," "the," "said," etc. should be read to recite one or more of the indicated ele-

ments unless a claim recites an explicit limitation to the contrary.

CLAIMS

- 5 1. A paint booth for applying paint to an object, the ob-
ject including interior and exterior surfaces, the ob-
ject moving through the paint booth along a conveyor,
the conveyor defining a path, the paint booth compris-
ing:
10 a first and second robot rail positioned parallel to
the path of the conveyor;
at least a first and second robot positioned on at
least one of the rails and configured to simultaneously
apply a first paint layer to the interior and exterior
15 surfaces of the object; and
at least a third and a fourth robot positioned on at
least one of the rails and configured to simultaneously
apply a second paint layer to the interior and exterior
surfaces of the object.
20
2. The paint booth of claim 1, further comprising third
and fourth rails, wherein the first through fourth
rails are positioned in lower and upper positions on
opposite sides of the conveyor.
25
3. The paint booth of claim 2, further comprising a fifth
rail extending in said direction generally perpendicu-
lar to the conveyor and at least one robot positioned
on the fifth rail.
30
4. The paint booth of claim 3 wherein the robot positioned
on the fifth rail is configured to apply a third paint
layer to the object.

5. The paint booth of claim 1, wherein said first and second robots are further configured to open and close a door on the object.
- 5 6. A method of degrading operation in a paint booth, the paint booth including a plurality of robots, the plurality of robots having individual assignments related to applying a coating to an object, the object including exterior and interior surfaces, the method comprising:
- 10 ing:
detecting a malfunction in one of the plurality of robots wherein the malfunction prevents the robot from performing its individual assignment;
identifying the assignment of the robot that has malfunctioned, and
- 15 selecting from the plurality of robots a first robot to perform the task previously assigned to the robot detected to be malfunctioning based upon at least a relative priority of the assignments that the robots have.
- 20
7. The method of claim 6 wherein one of the plurality of robots is designated as a degrade robot and is preferentially selected to perform the assignment of any robot detected to be malfunctioning.
- 25
8. The method of claim 6 wherein the relative priority is that exterior surfaces are preferred over interior surfaces.
- 30 9. The method of claim 8, wherein a path is calculated for the robot selected to perform the task previously assigned to the robot that was detected to be malfunctioning.

10. The method of claim 6, further comprising:
detecting a second malfunction of a second of the plu-
rality of robots, said second malfunction preventing
said second robot from performing its assigned task;
5 comparing the tasks assigned to the first and second
robots that have been detected to be malfunctioning;
and
selecting from the plurality of robots a first robot to
perform the task previously assigned to the first robot
10 detected to be malfunctioning based upon the proximity
of the robot to perform the assignment of the robot
that has malfunctioned and based upon the relative pri-
ority of the assignments that the robots have and se-
lecting from the plurality of robots a second robot to
15 perform the task previously assigned to the second ro-
bot detected to be malfunctioning based upon the prox-
imity of the robot to perform the assignment of the
second robot that has malfunctioned and the relative
priority of the assignments that the robots have.
20
11. The method of claim 10, wherein exterior surfaces are
given a higher priority than interior surfaces of the
object.
- 25 12. The method of claim 6, wherein the selecting from the
plurality of robots the first robot to perform the task
previously assigned to the robot detected to be mal-
functioning is additionally based upon a proximity of
the robot to perform the assignment of the robot that
30 has malfunctioned.

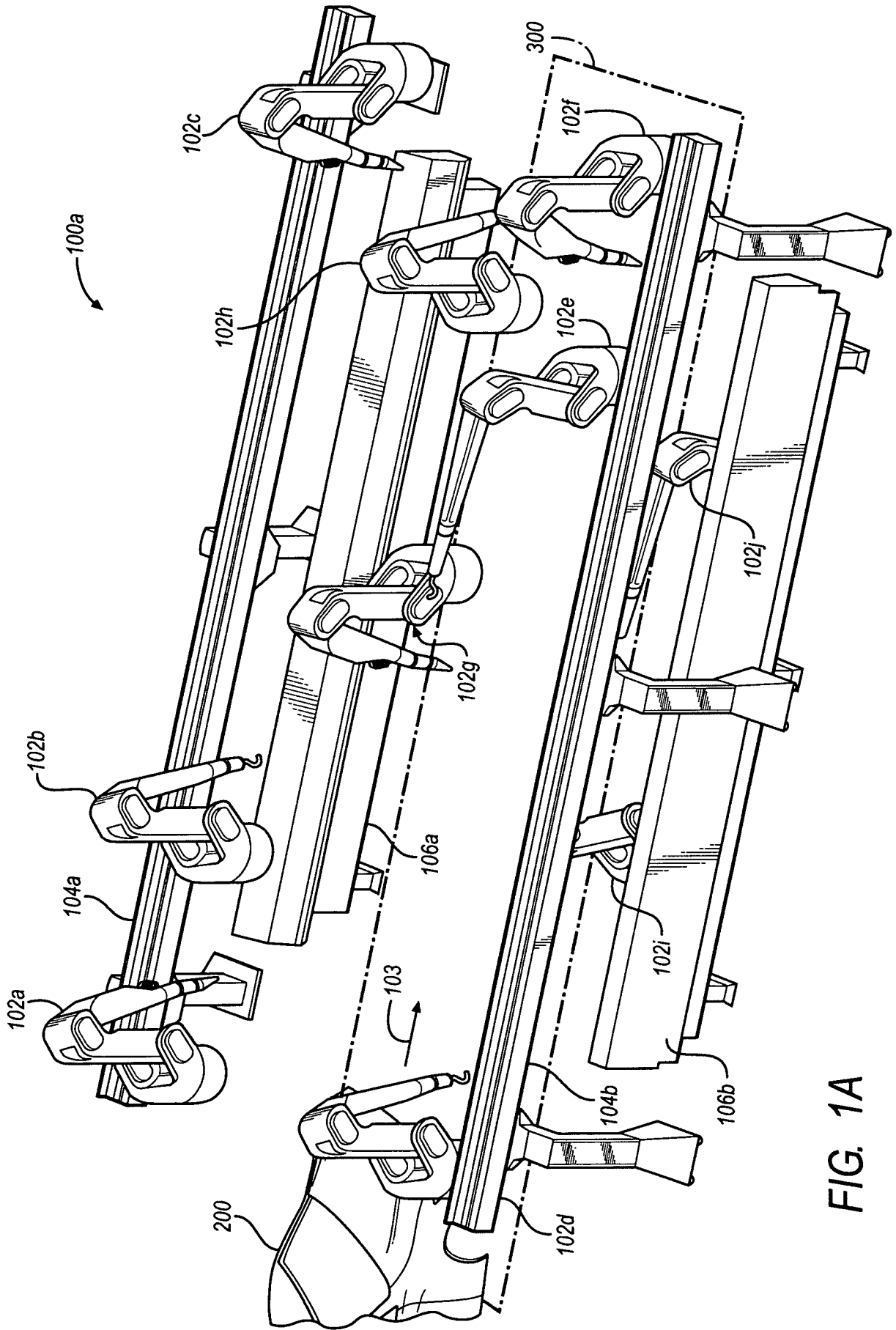


FIG. 1A

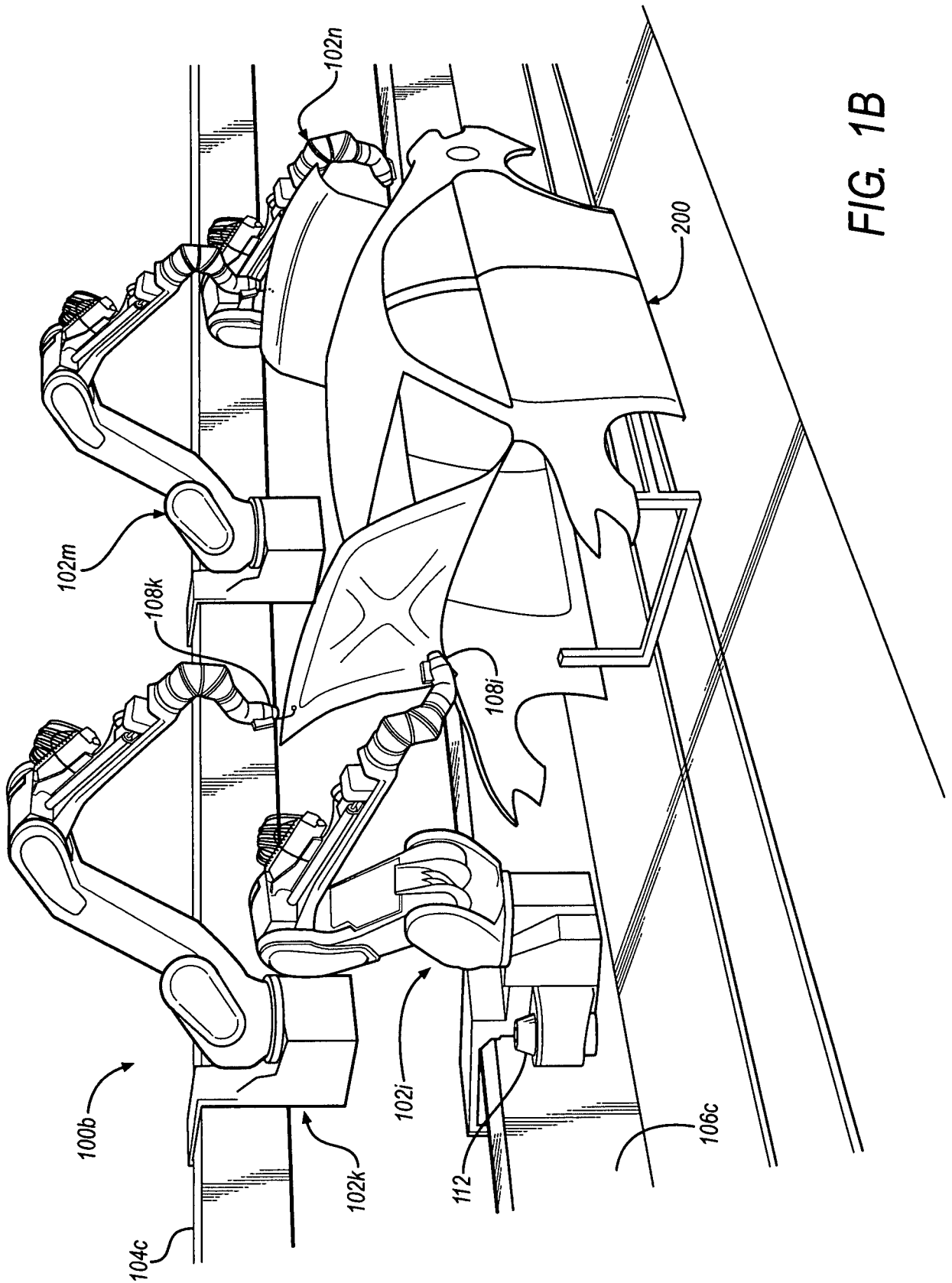


FIG. 1B

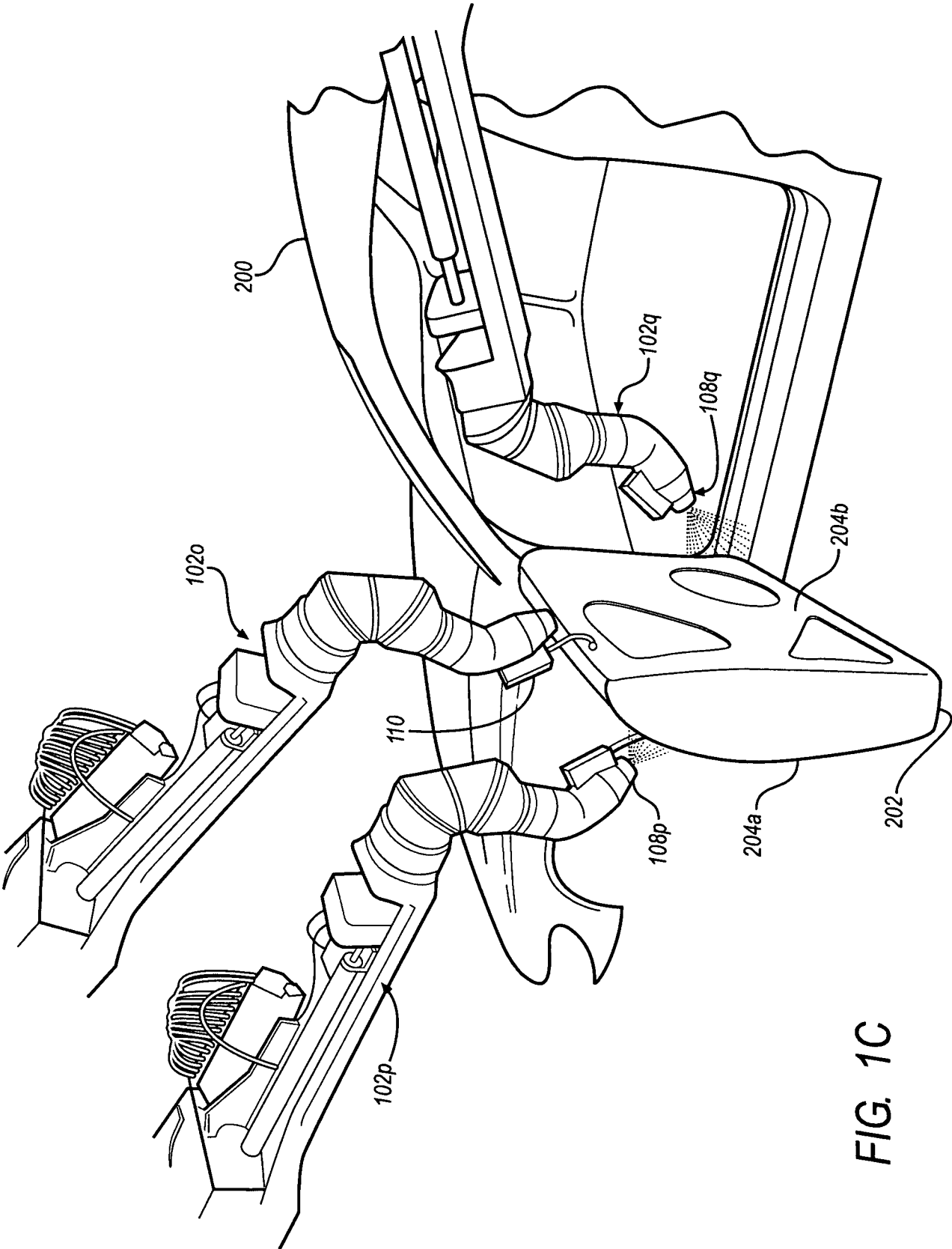


FIG. 1C

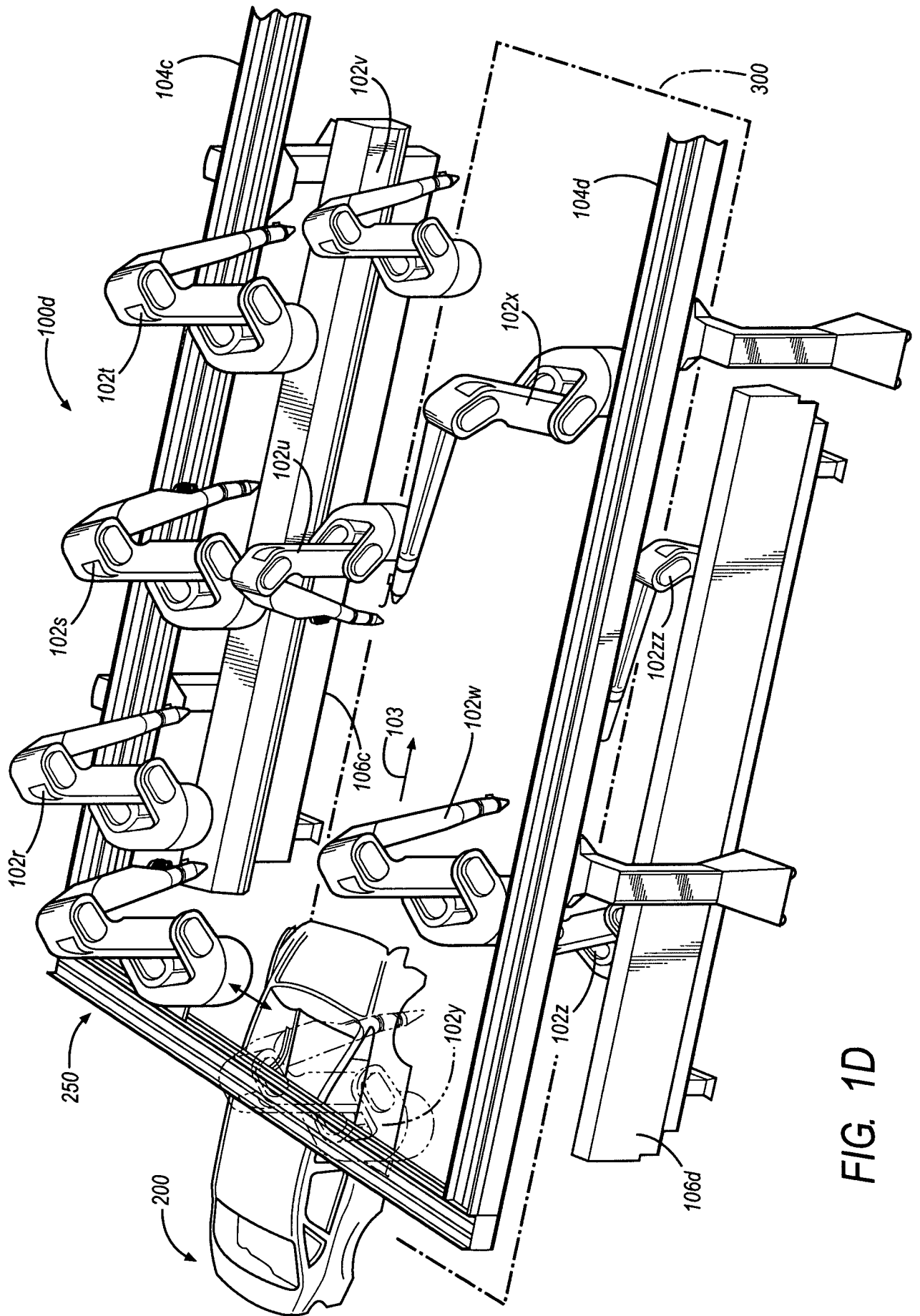


FIG. 1D

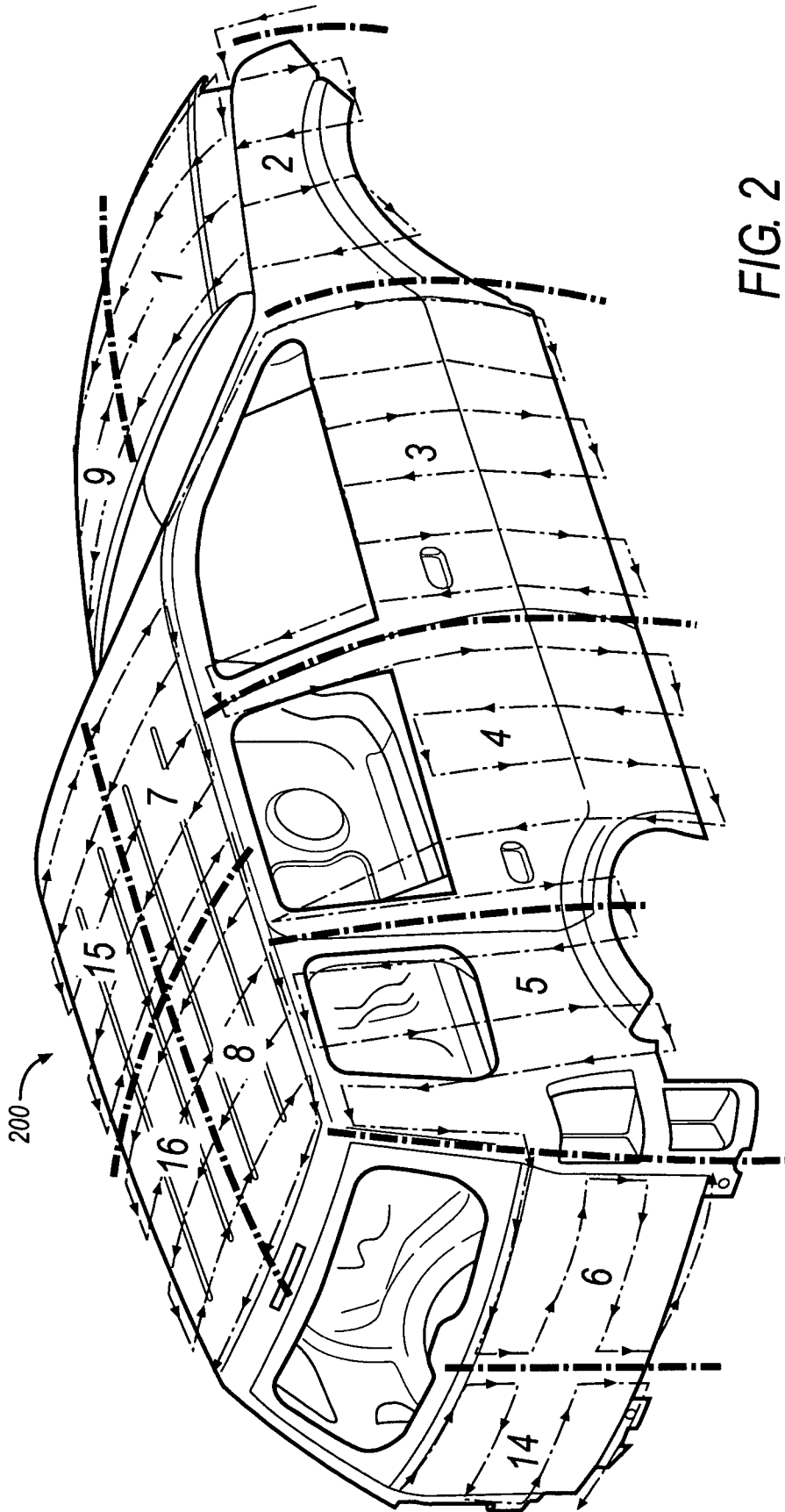


FIG. 2

FIG. 3

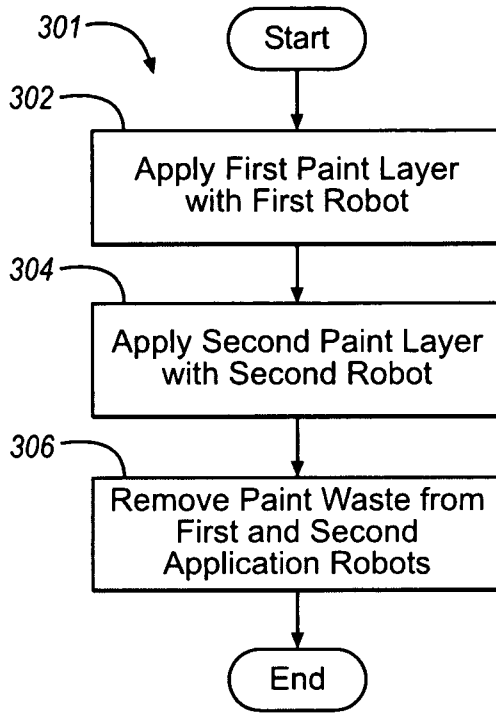
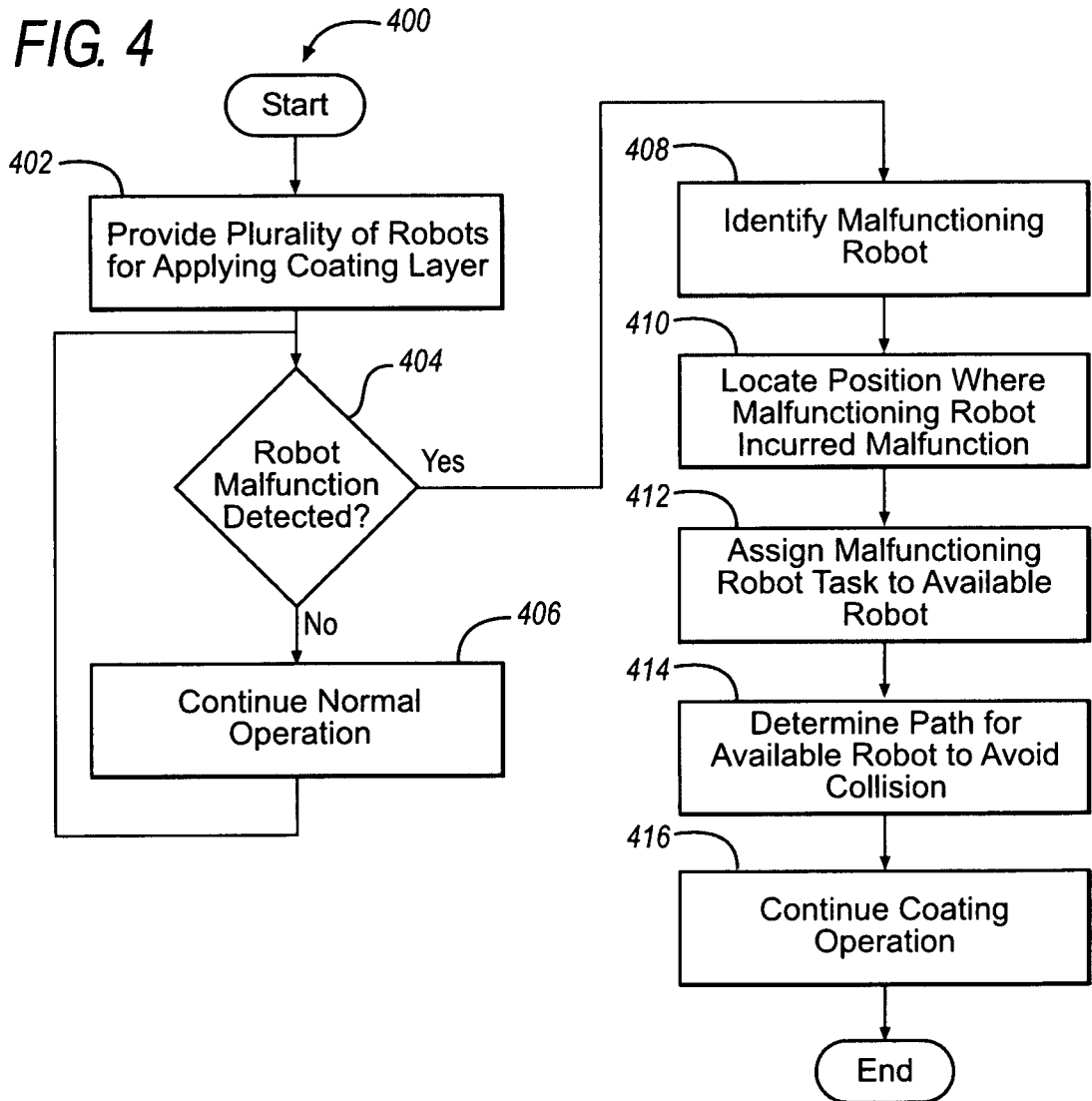


FIG. 4



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2009/004062

A. CLASSIFICATION OF SUBJECT MATTER

INV. B05B12/04 B05B12/14 B05B13/04 B05B15/12 B25J5/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B05B B25J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|-----------|--|-----------------------|
| X | EP 1 609 532 A (DUERR SYSTEMS GMBH [DE]) 28 December 2005 (2005-12-28) paragraphs [0007], [0008] | 6, 12 |
| Y | figures 1-6c | 1, 2, 5 |
| Y | ----- WO 2007/131660 A (DUERR SYSTEMS GMBH [DE]; HERRE FRANK [DE]; SIEWERT UWE [DE]; WEIHERMUE) 22 November 2007 (2007-11-22) page 26, lines 28-31; claim 65; figure 8 | 1, 2, 5 |
| A | ----- JP 05 265535 A (N.N.) 15 October 1993 (1993-10-15) the whole document | 6-12 |
| A | ----- US 2005/256610 A1 (ORITA ATSUO [JP]) 17 November 2005 (2005-11-17) paragraphs [0064], [0121] | 6-12 |

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents :

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

- *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- *X* document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- *Y* document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- *8* document member of the same patent family

Date of the actual completion of the international search

16 September 2009

Date of mailing of the international search report

23/09/2009

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Schork, Willi

INTERNATIONAL SEARCH REPORT

Information on patent family members

| |
|---|
| International application No PCT/EP2009/004062 |
|---|

| Patent document cited in search report | A | Publication date | Patent family member(s) | Publication date |
|--|----|------------------|-----------------------------------|--------------------------|
| EP 1609532 | A | 28-12-2005 | AT 412470 T ES 2315755 T3 | 15-11-2008 01-04-2009 |
| WO 2007131660 | A | 22-11-2007 | EP 2018230 A1 US 2009117283 A1 | 28-01-2009 07-05-2009 |
| JP 5265535 | A | 15-10-1993 | NONE | |
| US 2005256610 | A1 | 17-11-2005 | JP 2005324278 A | 24-11-2005 |