



(51) International Patent Classification:
E02F 5/14 (2006.01) *E02F 9/22* (2006.01)

(21) International Application Number:
PCT/US2009/040503

(22) International Filing Date:
14 April 2009 (14.04.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/168,146 9 April 2009 (09.04.2009) US

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(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, 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.

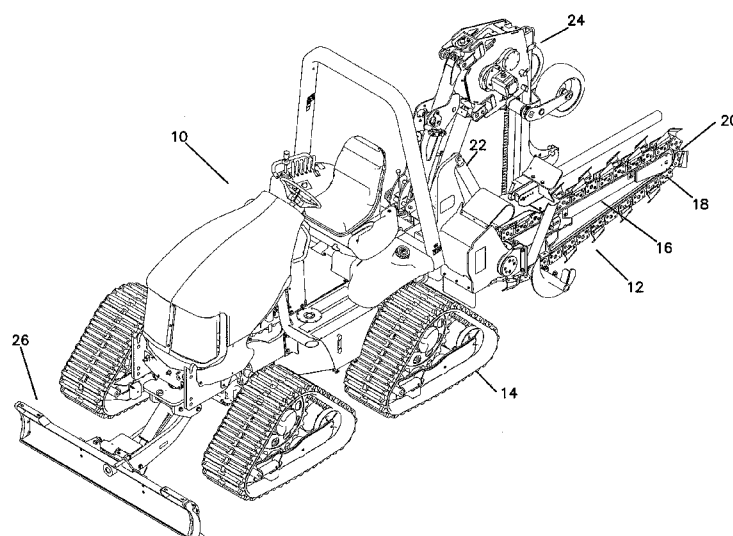
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, 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).

Published:

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

(54) Title: WORK MACHINE ATTACHMENT BASED SPEED CONTROL SYSTEM

FIG. 1



(57) Abstract: The present disclosure provides a machine 8109 configured so that its ground speed is at least in part dependent on the measured force that is applied to an attachment (12) attached thereto. The present disclosure also provides an attachment for a machine that is configured to provide feedback to the machine it is configured to be attached to, wherein the feedback is representative of the force applied to the attachment. The present disclosure also provides a method of automatically controlling the ground speed of a machine based on feedback measured in an attachment attached to the machine.

WORK MACHINE ATTACHMENT BASED SPEED CONTROL SYSTEM

This application is being filed on 14 April 2009, as a PCT International Patent application in the name of Vermeer Manufacturing Company, a U.S. national corporation, applicant for the designation of all countries except the US, and Casey Dean Berg, a citizen of the U.S., Oleg Khalamendik, a citizen of Russia, and Ted Jay Sanders, a citizen of the U.S., applicants for the designation of the US only, and claims priority to U.S. Provisional patent application Serial No. 61/168,146, filed April 9, 2009.

Technical Field

10 The present disclosure relates to machinery with attachments having a control mechanism that minimizes overloading the attachment.

Background

Typically, machine attachments are constructed such that the machine cannot apply enough force to the attachment to cause the attachment to prematurely fail. For example, a digger boom on a trencher is traditionally designed and engineered to withstand the maximum amount of force that can possibly be applied to it by the tractor that it is configured to be used with. Digger booms and other machine attachments are traditionally designed to be used with a particular size machine. However, it can be desirable to use relatively light attachments on relatively heavy machines, or to provide interchangeable machine attachments.

Summary

The present disclosure provides a machine configured so that its ground speed is at least in part dependent on the measured force that is applied to an attachment attached thereto. The present disclosure also provides an attachment for a machine that is configured to provide feedback to the machine it is configured to be attached to, wherein the feedback is representative of the force applied to the attachment. The present disclosure also provides a method of automatically controlling the ground speed of a machine based on feedback measured in an attachment attached to the machine.

A method of protecting an attachment according to an embodiment of the present disclosure comprises the step of monitoring the load applied to an attachment by a machine due to the motion of the machine; and automatically decreasing the drive speed of the machine based on the load.

5 A machine according to an embodiment of the present disclosure comprises a chassis; a trencher attachment connected to the chassis; a hydraulic cylinder that extends and retracts to adjust the orientation of a portion of the trencher attachment relative to the chassis; a transducer configured to measure the pressure of the cylinder; and a drive control unit that receives the measured pressure and is
10 configured to adjust a ground drive speed of the machine.

A machine attachment according to an embodiment of the present disclosure comprises a boom configured to support a material reduction device; a hydraulic cylinder arranged to adjust the orientation of the boom, wherein the hydraulic cylinder is arranged such that the flow of hydraulic fluid into and out of the cylinder
15 can be limited to less than 5 drops per minutes; and a transducer configured to measure the pressure within the cylinder.

Brief Description of the Figures

Figure 1 is a perspective view of a machine with an attachment according to the principles of the present disclosure;

20 Figure 2 is a side view of the machine of Figure 1 with a digger attachment shown in a generally horizontal orientation;

Figure 3 is a side view of the machine of Figure 1 with a digger attachment shown in a lowered orientation;

25 Figure 4 is a combined hydraulic circuit diagram and control schematic of the machine with an attachment shown in Figure 1;

Figure 5 is a flow diagram showing an embodiment of the control system according to the present disclosure.

Detailed Description

Machines with tool attachments are commonly used in construction
30 related applications. The machine typically includes a chassis, which is also commonly referred to as a frame, and is supported on tires or tracks. An engine supported on the chassis generates power to run the tires or tracks as well as any

attachments connected to the chassis. The term "attachments" is used herein to refer to tools that are configured to be connected to the chassis. Attachments include, but are not limited to, backhoe, diggers with chains, plows, lift buckets, rock wheels, terrain levelers, etc. Trenching type attachments include, but are not limited to, attachments that are configured to create a trench in the ground (e.g., rock wheels, diggers with chains, etc.).

Referring to Figures 1-3, an example of a machine having an attachment according to the present disclosure is shown and described. In the depicted embodiment the machine is a trencher 10 having a digger 12 attachment, a vibratory plow attachment 24, and a backfill attachment 26. The trencher 10 is supported on four tracks 14. The digger 12 includes a boom 16 and a chain 18 that rotates around the boom 16. In operation the chain 18 is rotated and the boom 16 is lowered into the ground to a particular depth. The trencher 10 is then driven by an operator along a path that is in a direction that is generally away from the distal end 20 of the digger 12, thereby forming a trench behind the trencher 10.

In the depicted embodiment the orientation of the boom 16 is controlled by actuating a hydraulic cylinder 22. The further the hydraulic cylinder 22 is extended, the deeper the boom 16 is plunged into the ground (Figure 3). For a more detailed description of controlling a boom orientation using a hydraulic cylinder see US Pat. Application Serial No. 11/771,171 (US Pub. No. 2009/0000154), which is hereby incorporated in its entirety by reference. In applications where it is desirable to trench at a constant depth, the hydraulic cylinder 22 is locked off from the hydraulic circuit once the desired cut depth is reached. Allowing additional fluid flow into the cylinder 22 would result in the boom 16 plunging deeper than desired, and allowing additional fluid flow out of the cylinder 22 would result in the boom 16 cutting shallower than desired.

In the example embodiment, the pressure in the hydraulic cylinder 22 varies during the trenching operation depending on a number of factors. Assuming the trencher 10 is moving at a constant ground speed (e.g., 5 fpm), the pressure in the hydraulic cylinder 22 will be greater when the trencher moves through denser soil than when it moves through less dense soil. The load on the boom 16 is proportional to the pressure in the hydraulic cylinder 22. Accordingly, the variations

in the pressure in the hydraulic cylinder 22 represent variations of the load on the boom 16.

In the depicted embodiment, the pressure in the hydraulic cylinder 22 is generally correlated to the variation in pressure of the hydraulic fluid that drives the chain 18. However, since the pressure in the hydraulic fluid that drives the chain 18 is dependent on the engagement between the chain 18 and the material it contacts, the pressure in the hydraulic cylinder 22 may in some cases be very different than the pressure in the hydraulic fluid that drives the chain. For example, if the trencher 10 moves over a large boulder, the chain 18 may slip rather than bite into the rock, and the pressure in the hydraulic fluid that drives the chain 18 may be relatively low while the pressure in the hydraulic cylinder 22 may be extremely high. Accordingly, monitoring the pressure in the chain drive as disclosed in US Pat. Application Serial No. 11/770,940 (US Pub. No. 2009/0000157), which is hereby incorporated in its entirety by reference, may not be sufficient to detect overloading of the boom.

In the depicted embodiment, the pressure in the hydraulic cylinder 22 is generally correlated to the variation in the pressure of the hydraulic fluid that drives the tracks 14. However, since the pressure in the hydraulic fluid that drives the tracks 14 is dependent on whether the trencher 10 is moving uphill (relatively higher pressure) or downhill (relatively lower pressure), the pressure in the hydraulic cylinder 22 may in some cases be very different than the pressure in the hydraulic fluid that drives the tracks 14. For example, if the trencher 10 is moving down a steep inclined, the pressure in the hydraulic fluid that drives the tracks 14 may be relatively low while the pressure in the hydraulic cylinder 22 may be extremely high.

In the depicted embodiment, the pressure in the hydraulic cylinder 22 may or may not be correlated to the variation in engine speed of the trencher 10. If the engine of the trencher 10 is relatively low power, the engine speed decreases when the pressure in the hydraulic cylinder 22 is high. However, when the engine is relatively high power, the increase in load on the digger 12 will not draw down the engine speed. Also, since the engine would also typically power the tracks 14 and the rotation of the chain 18, the engine speed is also dependent on the variation in the load on these functions which, as described above, may or may not correlate

with the load on the hydraulic cylinders 22. Therefore, controlling the ground speed based on engine speed as disclosed in US Pat. Application Serial No. 11/770,909 (US Pub. No. 2009/0000156), which is hereby incorporated in its entirety by reference, may not be sufficient to detect overloading the boom.

5 Referring to Figure 4, the hydraulic circuit and electronic control system of the example embodiment are described in greater detail. In the depicted embodiment the hydraulic circuit includes at least one relief valve 38 in fluid communication with the hydraulic cylinder. The relief valve 38 allows hydraulic fluid to flow out of the hydraulic cylinder 22 when the cylinder is actuated and the
10 pressure in the cylinder exceeds a certain pressure. However, when the hydraulic cylinder is locked out, the hydraulic cylinder 22 is isolated (cut off from) the relief valve. As discussed above, lock out is used in the depicted embodiment so that the position of the boom 16 remains constant during a trenching operation to maintain constant trench depth. If the hydraulic cylinder 22 was not locked out, the boom 16
15 would in some applications move up gradually as fluid would escape periodically through the relief valve. In the depicted embodiment a pressure transducer is located in fluid communication with the lock out portion of the hydraulic circuit.

In the depicted embodiment, the pressure in the lock out portion is measured, and the pressure data is sent to a control processor 30 that determines
20 whether the pressure is high enough to warrant slowing the ground speed of the trencher 10 and, if so, by how much should the ground speed be slowed. For example, if the measured pressure is within a predetermined range, the ground speed may be slowed proportional to the magnitude of the pressure, and if the measured pressure is high enough, the trencher may be stopped.

25 Referring to Figures 4 and 5, an example system for controlling the ground speed of a machine based in part on the measured force applied to the attachment is shown. In the depicted embodiment a pump 36 drives hydraulic fluid from a tank 35 past a relief valve 38 through a three position valve 42 and through either of check valves A or B to the hydraulic cylinder 22. The pressure of the
30 hydraulic cylinder 22 is measured by a pressure transducer 32, and data that is representative of the measured pressure is sent to a computer network 30 that includes a processor. The processor determines whether and how to adjust

configuration of the ground drive pump 44 to increase or decrease the speed of a ground drive motor 46, which in turn dictates the ground drive speed of the machine.

In the depicted embodiment the transducer 32 measures the hydraulic pressure in a portion of the hydraulic circuit that can be locked out from the rest of the hydraulic circuit. The portion that can be locked out is referred to herein as the locked out portion. In the depicted configuration the locked out portion includes the hydraulic cylinder 22 and the hydraulic lines that extend from the hydraulic cylinder to check valve A and check valve B. The pressure in the locked out portion can be different than the pressure in other components connected to the pump 36 or tank 35. In the depicted embodiment the locked out portion of the hydraulic circuit is selectively in fluid communication with a relief valve 38. However, if the pressure in the depicted portions of the hydraulic circuit outside of the locked out portion exceeds a predetermined value (e.g., 2500 psi), the relief valve allows hydraulic fluid to escape from the circuit to prevent overload.

In the depicted orientation the locked out portion is shown locked out (isolated from the rest of the circuit including the relief valve 38) thereby preventing the cylinder 22 from extending or retracting. In the depicted configuration and orientation of the valve 42, flow from the pump 36 bypasses the cylinder 22 via the power beyond path 40. When the valve 42 is moved schematically to the left, hydraulic fluid flows through check valve A and the cylinder 22 extends. When the valve 42 is moved schematically to the right, the hydraulic fluid flows through check valve B and the cylinder 22 is retracted. In the depicted embodiment, when the valve 42 is moved either to the left or right, the locked out portion is in fluid communication (not isolated) from the rest of the hydraulic circuit including the relief valve 38.

As discussed above, the data that is representative of the pressure of the hydraulic cylinder 22 measured by the transducer 32, which is representative of the load on the boom 16, is sent to the computer network 30 to be processed. In one embodiment of the present disclosure averages of the data received on a 1/3 second sliding average (the data measured in any 1/3 of second in time is averaged) is calculated. The calculated average pressure is compared to a lower and upper pressure limit (e.g., 1800 psi lower limit and 2300 psi upper limit).

If the calculated average pressure is lower than the lower pressure limit, the controller multiplies the value by 1, thereby doing nothing to change the ground speed (via the ground drive pump 44 or ground drive motor 46). When the calculated average pressure is between the lower and upper limits, the control signal
5 output to the pump 44 is multiplied by a number between one and zero, proportional to the distance between the two limits, with zero being the multiplier at the upper limit. If the calculated average pressure exceeds the upper limit, the control signal output to the pump 44 is multiplied by zero which signals the machine to stop. Accordingly, the flow rate from the pump 44 to the ground drive motor 46, which
10 dictates the speed of the tracks 14, changes depending on the data measured from the transducer 32.

It should be appreciated that the above description is simply one of many examples of embodiments of the present disclosure. For example, the present disclosure is not limited to trenchers. The present disclosure relates to any machines
15 having tool attachments that could fail if overloaded, for example, it relates to any machine having tool attachments with a boom that extends from the machine wherein the tool attachment could fail if the machine applies too much load to the boom.

Also, it should be appreciated that there are many alternative ways to
20 apply the principles of the present disclosure to trenchers. For example, in alternative embodiments of the present disclosure the orientation of the attachment relative to the machine can be controlled by hydraulic cylinders that are part of the machine itself or directly connected to the machine and the attachment, rather than part of the attachment as shown. In addition, the attachment can be different. For
25 example, the attachment could be a rock wheel rather than a digger with a chain. In other alternative embodiments the load on the attachment can be measured using a strain gauge that is attached to a member that supports the attachment relative to the machine. For example, the load on a vibratory plow attachment may be measured via a strain gauge, and the speed of the tractor attached thereto can be adjusted
30 accordingly. Many other variations in accordance with the present disclosure are also possible.

The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since

many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.

WE CLAIM:

1. A machine comprising:
 - a chassis;
 - a trencher attachment connected to the chassis;
 - a hydraulic cylinder that extends and retracts to adjust the orientation of a portion of the trencher attachment relative to the chassis;
 - a transducer configured to measure the pressure of the cylinder; and
 - a drive control unit that receives the measured pressure and is configured to adjust a ground drive speed of the machine.
2. The machine of claim 1, wherein the hydraulic cylinder is arranged such that the flow of hydraulic fluid into and out of the cylinder is limited to less than 5 drops per minute when the hydraulic cylinder is locked out relative to a relief valve that is a common hydraulic circuit.
3. The machine of claim 2, wherein the transducer is located within the hydraulic cylinder.
4. The machine of claim 1, further comprising at least two pairs of drive tracks connected to the chassis, wherein the drive tracks are driven by hydraulic fluid.
5. The machine of claim 1, wherein the trencher attachment includes a boom that supports a material reduction tool and the hydraulic cylinder adjusts the orientation of the boom.
6. The machine of claim 5, wherein the material reduction tool is a chain.
7. The machine of claim 5, wherein the material reduction tool is a rock wheel.
8. The machine of claim 1, wherein the drive control is configured to slow the ground speed of the trencher based at least in part on the measured pressure in the cylinder.

9. The machine of claim 8, wherein the drive control is configured to slow the ground speed of the trencher independent of an engine speed of the machine.
10. The machine of claim 4, wherein the drive control is configured to slow the ground speed of the trencher based at least in part on the measured pressure in the cylinder independent of a pressure in the hydraulic fluid that drives the drive tracks.
11. The machine of claim 5, wherein the drive control is configured to slow the ground speed of the trencher based at least in part on the measured pressure in the cylinder independent of the pressure of the hydraulic fluid that drives a material reduction tool.
12. A machine attachment comprising:
 - a boom configured to support a material reduction device;
 - a hydraulic cylinder arranged to adjust the orientation of the boom, wherein the hydraulic cylinder is arranged such that the flow of hydraulic fluid into and out of the cylinder can be limited to less than 5 drops per minutes; and
 - a transducer configured to measure the pressure within the cylinder.
13. The machine attachment of claim 12, wherein the boom is configured to support a chain.
14. The machine attachment of claim 12, wherein the transducer is located in hydraulic fluid that is at the same pressure of fluid in the hydraulic cylinder.
15. The machine attachment of claim 12, wherein the transducer is operably connected to a drive control unit.
16. A method of protecting an attachment comprising:
 - monitoring the load applied to an attachment by a machine due to the motion of the machine; and
 - automatically decreasing the drive speed of the machine based on the load.

17. The method of claim 16, wherein monitoring the load includes monitoring the pressure in a hydraulic cylinder, wherein the cylinder is arranged to adjust the orientation of the attachment.
18. The method of claim 16, wherein monitoring the load includes monitoring the strain on a support element of the attachment.
19. The method of claim 17, wherein the step of changing the drive speed includes automatically stopping drive when the pressure in the hydraulic cylinder exceeds a predetermined value.
20. The method of claim 17, wherein the predetermined value corresponds to the physical characteristics of the attachment.
21. The method of claim 17, wherein the predetermined value is independent of the physical characteristics of a trencher that the trencher attachment is configured to be mounted thereto.
22. The method of claim 17, wherein the magnitude of the speed is decreased based on the magnitude of the pressure.

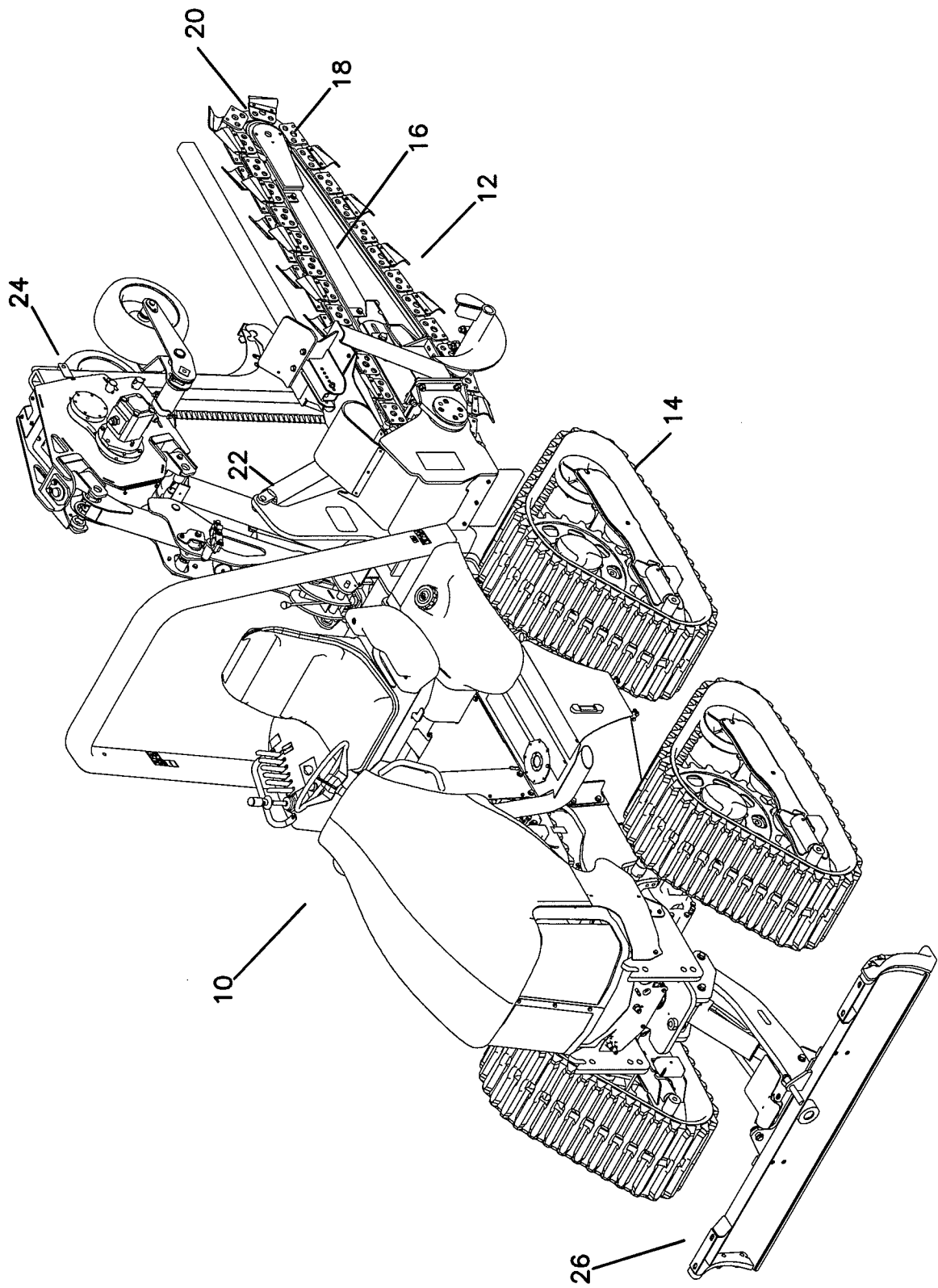


FIG. 1

FIG. 2

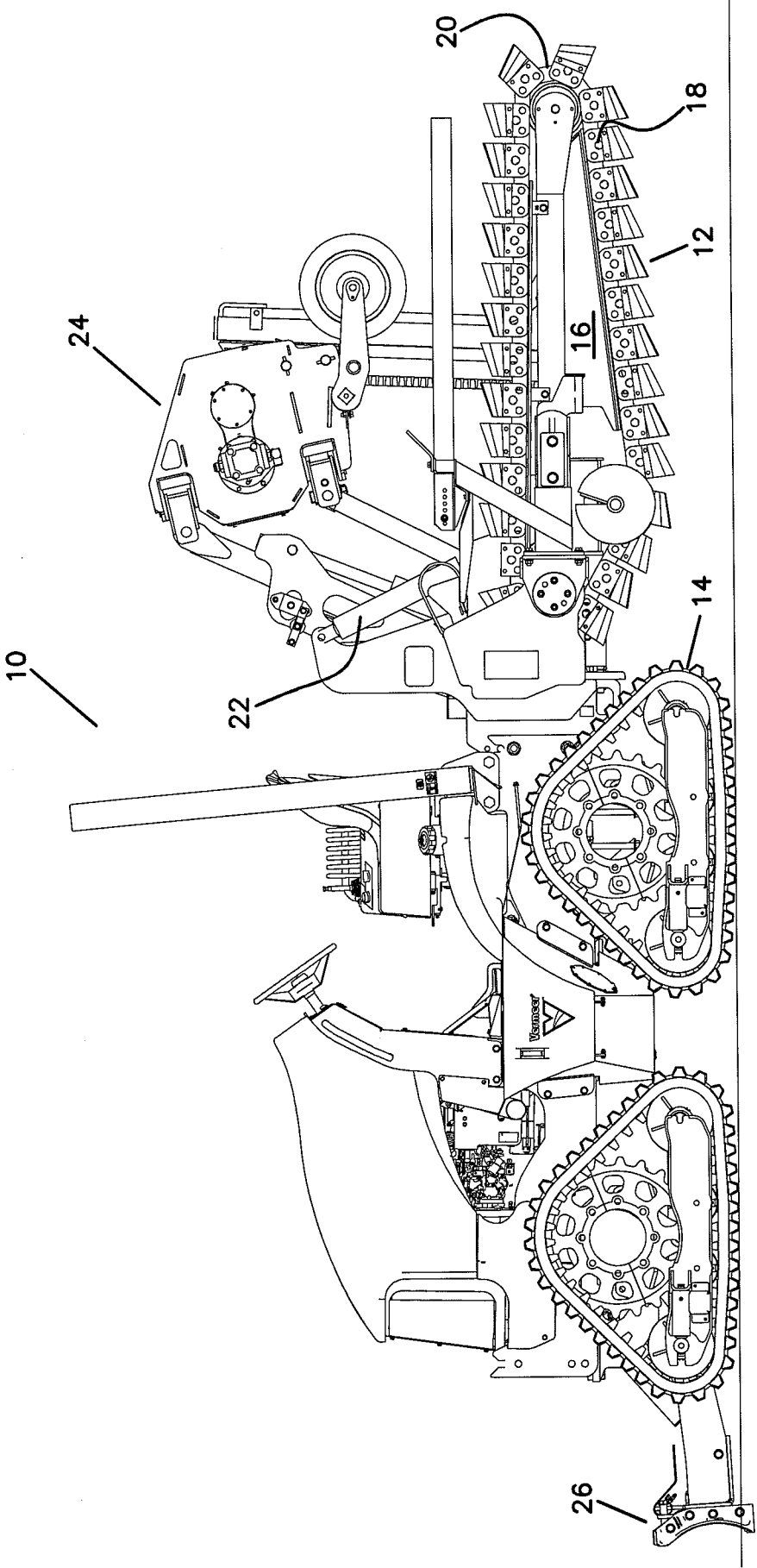


FIG. 3

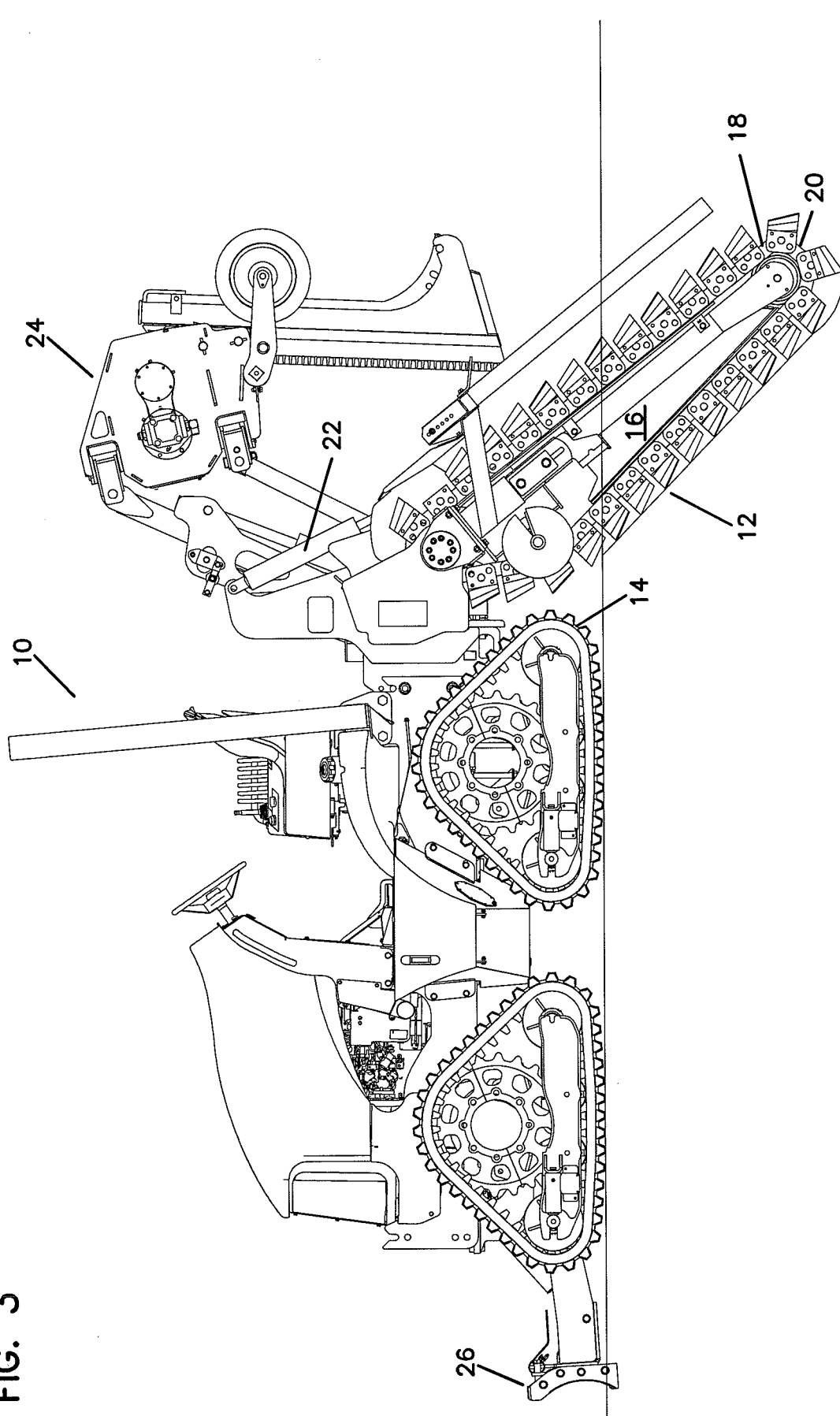
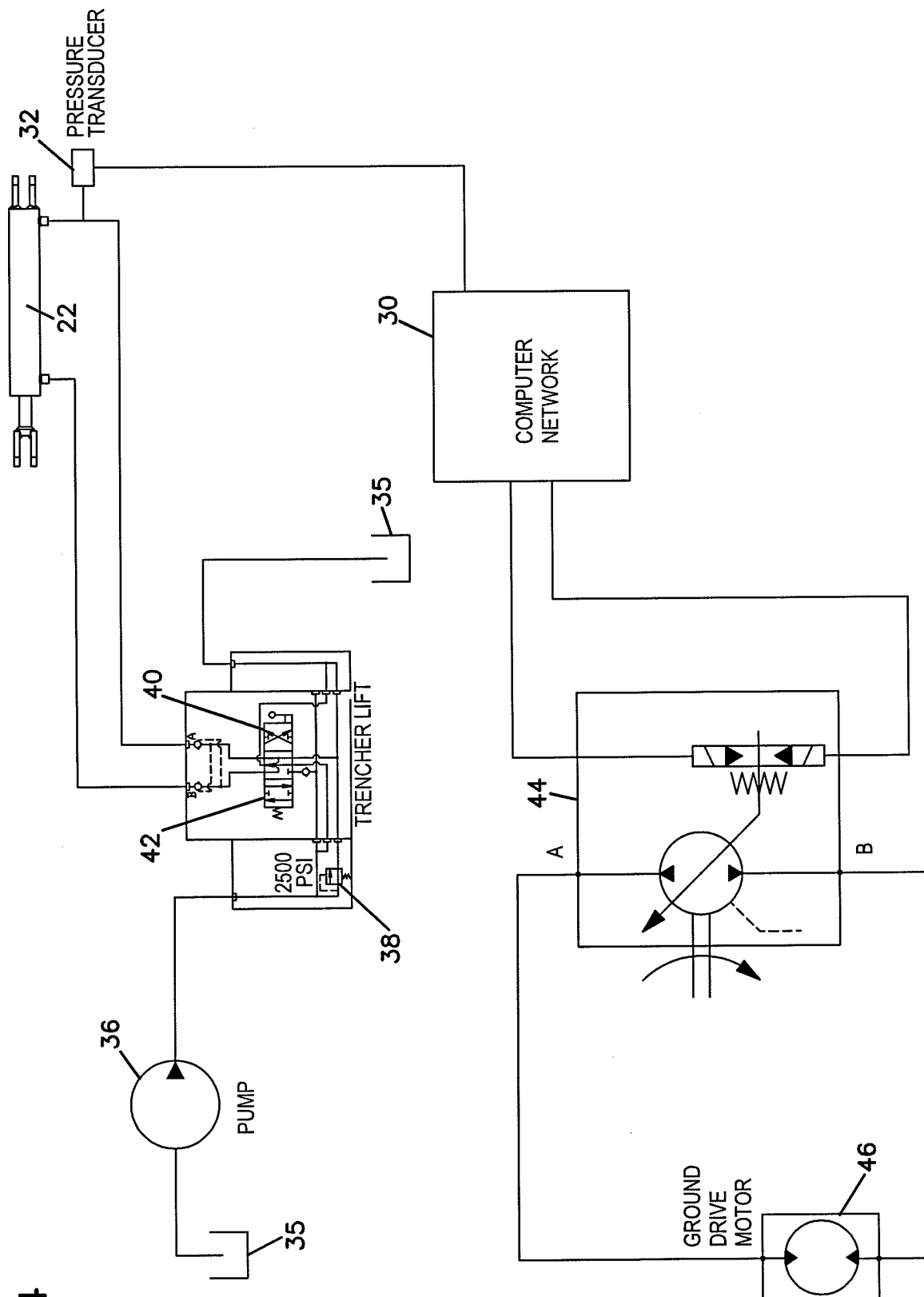
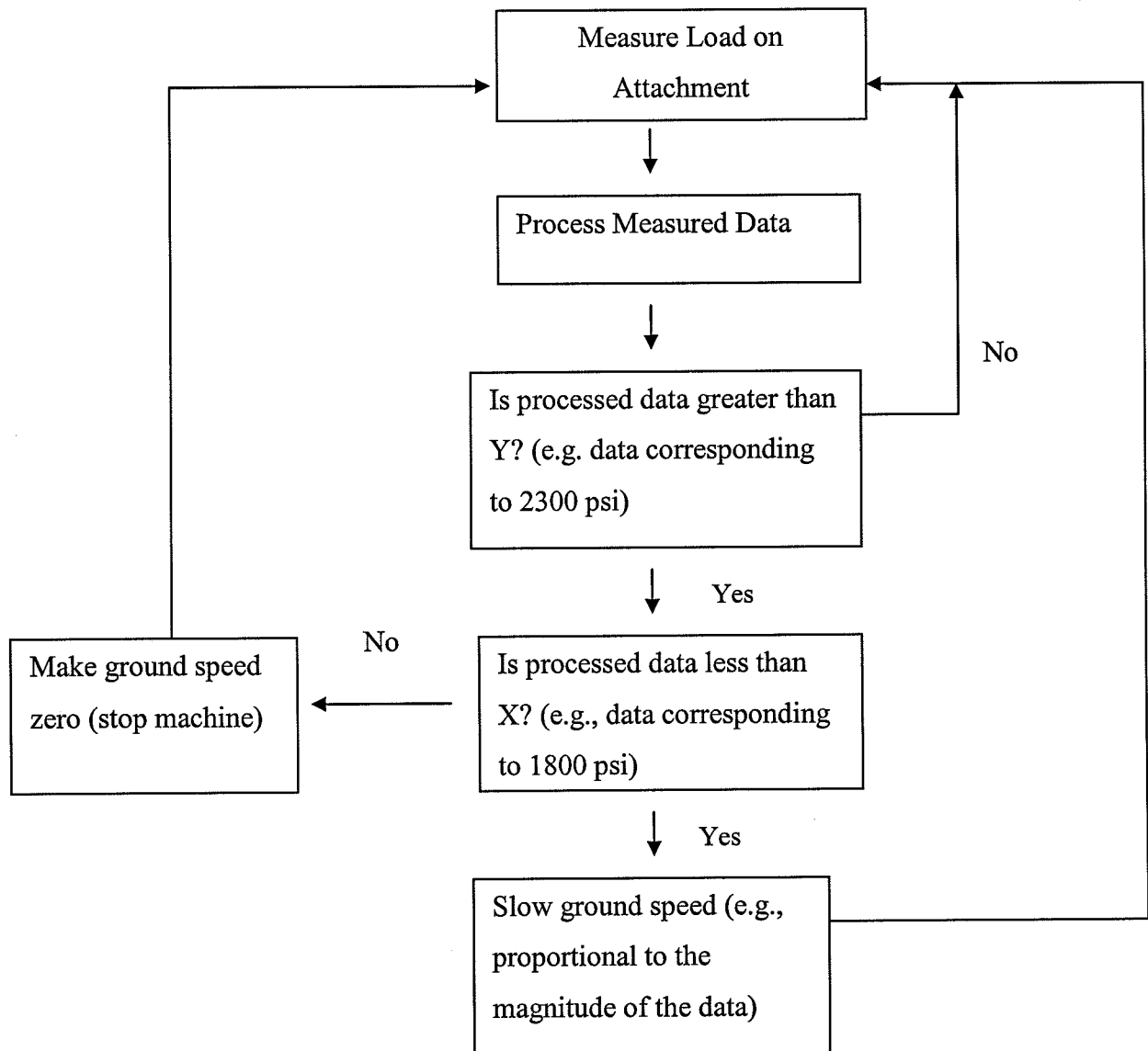


FIG. 4



**Figure 5**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/040503A. CLASSIFICATION OF SUBJECT MATTER
INV. E02F5/14 E02F9/22

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)

E02F A01G F15B G05D A01B B60W

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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 28 00 631 B1 (PAURAT F) 21 December 1978 (1978-12-21) column 1, lines 57-61 column 2, lines 52-58 column 3, line 6 - column 4, line 6; figure 1	1-11
Y	WO 03/068660 A (KALMAR IND SVERIGE AB. [SE]; LOENN JAN [SE]) 21 August 2003 (2003-08-21) page 5, lines 22-35	1-11
A	US 2009/000154 A1 (HARTWICK TY [US]) 1 January 2009 (2009-01-01) cited in the application paragraphs [0004], [0005]	6,7
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☒ 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.
- * & * document member of the same patent family

Date of the actual completion of the international search

3 July 2009

Date of mailing of the international search report

16/09/2009

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2009/040503

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 750 762 A (EATON W) 7 August 1973 (1973-08-07) column 1, lines 49-59 -----	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2009/040503

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

see additional sheet(s)

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US2009 /040503

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-11

mitigation of overloading of a trencher attachment of a machine.

2. claims: 12-15

an orientation means for an attachment of a machine.

3. claims: 16-22

a speed control method for the engine of a machine.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2009/040503

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 2800631	B1	21-12-1978	NONE
WO 03068660	A	21-08-2003	AU 2003207240 A1 04-09-2003
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