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Operation and Maintenance Manual

SU488 L Scoop

128VAC Machines

SAFETY.CAT.COM

This manual is intended to provide GENERAL product information for the SU488 L model Scoop. The illustrations, descriptions and procedures contained in this publication apply only to THESE machines. Caterpillar reserves the right to revise models and designs without prior notice.

This machine was manufactured under the guidelines, procedures and requirements of the appropriate government regulatory agencies. At the completion of the manufacturing process, this unit was issued the appropriate approval numbers and nameplates indicating it met the technical requirements of these regulatory agencies. Any change to the design or structure of this unit, without the consent of Caterpillar and these regulatory agencies, or any repair or replacement of parts contrary to Caterpillar's instructions, may invalidate these approvals and render this unit unsafe to operate.

Strict compliance with all local and national laws, regulations and practices regarding the safe operation and maintenance of underground mining equipment and strict adherence to the instructions in this manual is necessary for the personal safety of those working on or around this unit.

While this manual attempts to anticipate the most important operations and maintenance needs for this unit, unforeseen circumstances may arise that have not been addressed in this manual. If any concerns or questions arise, please contact your Service Representative immediately.

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1 About this manual

About this manual

This chapter provides important information making it easier for you to use this manual. You will also be given information on the structure of the manual and the symbols and characters used.

Before starting to work

applicable operating manual

Take care to ensure that the operating manual available to you is applicable for the type of equipment or machine used.

machine type

This operating manual is intended for:

CAT® Model SU488 L

and is only permitted to be used for equipment of this type.

new operation manual

The operating manual must be accessible at all times to all persons working on or with the machine. It should, if possible, always be available at the place of operation.

Send for a new operation manual immediately if the present manual is no longer complete or has become illegible.

Who is this operating manual intended for?

This operating manual is intended for those persons who work with or on the machine. Every person working on the face or in the intersection between face and entry or in the entry must read this operating manual.

This includes persons who:

- are in charge of transport
- perform assembly / disassembly work
- operate the machine
- eliminate faults
- perform daily routine work on the face or in the entry
- perform maintenance work
- perform repair work

supervisory personnel who:

- initiate and/or
- supervise the activities just indicated.

What is the purpose of this operating manual?

This operating manual is intended to help you work efficiently and safely with our product. It contains important information on all the activities related to the machine.

Read this operating manual completely and at ease. Pay special attention to the safety instructions. Try to memorize the appearance and the meaning of the safety and instruction symbols.

service If any details are not clearly understood, please contact our service department. Our service address is given in the chapter titled “For your information”.

safety Read the chapter “For your safety” with special attention. The chapter contains important information indicating possible hazards. Observe the information given and follow the procedural instructions.

Characters and symbols used

The following characters and symbols are used for safety instructions and important information in the operating manual.

Try to memorize the symbols and their meanings.

DANGER!
Points in the text marked with this symbol draw your attention to immediately impending danger. Possible consequences are: very serious injury or even death.

WARNING!
These points contain information on dangerous situations. Possible consequences are: very serious injury or even death.

CAUTION!
This symbol draws attention to dangerous situations. Possible consequences are: light to moderately serious injuries and machine damage.

NOTICE!
Points in the text marked with this symbol draw attention to harmful situations. Possible consequences are: damage to the machine or damage in the immediate vicinity.

IMPORTANT!
Points in the text marked with this symbol contain useful tips and information intended to facilitate work for you. They do not warn about harmful or dangerous situations.

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Before starting to work

2 Your safety

Your safety

This chapter provides vital information for your safety. Pay special attention to this chapter. The safety instructions and rules of procedure will help you to avoid hazardous situations and to perform the necessary work as safely as possible.

state of the art

The machine has been manufactured in accordance with the state of the art and generally recognized safety standards and regulations. You and others can nevertheless be exposed to dangerous situations e.g. as a result of environmental influences, machine damage or operator errors.

Do not make any alterations or modifications which could impair the safety of the machine. All modifications and changes must be approved by CAT® .

Use only original spare parts from CAT® . Note that the use of parts from other manufacturers will void the guarantee.

In addition to this operating manual be sure to also observe the respective legal provisions and regulations in your country.

Observe the safety and accident prevention regulations:

- of the mine,
- of the mine inspector, and
- of the mining supervisory authorities.

further operating manuals

Please read the operating manuals of the components required for operation, e.g. of gearboxes, electric motors, etc., carefully and thoroughly. Clarify any questions **before** starting work.

Personnel

Operation

training

The machine may only be operated by qualified, trained personnel.

The machine is only allowed to be operated by qualified personnel who can provide proof of having been trained on this unit.
Reading of the operation manual, especially the chapter on safety, shall constitute a part of this training.

You must have adequate knowledge of the

- mechanics,
- hydraulics, and
- control engineering

and must be able to prove this knowledge.

Installation and repair

As a fundamental rule, installation and repair work may only be carried out by personnel who have been adequately trained for these particular requirements.
Installation and repair work on:

- safety components (pressure relief valves, extinguishers, etc.),
- the electrics (motors, controllers, etc.), and
- the hydraulics (controls, cylinders, etc.)

may only be carried out by service engineers from CAT® or by specially qualified personnel of the mine.

Operating conditions

Intended use

Intended uses include:

- the transport of materials.
- use during clean up and utility work.

Unauthorized use

Applications not expressly listed as intended uses are unauthorized uses and are not allowed to be performed with the machine. This includes:

- the transport of persons

CAT® accepts no liability for any damage resulting from any such unauthorized use.

Safety instructions

General rules

general

Always work with full concentration.

Familiarize yourself with your working environment.

noise emissions

Always wear your personal protective equipment. This also includes ear protectors as the noise emitted by other equipment in the area may at times exceed 85 db(A).

Inform your colleagues of:

- your exact location,
- the work you are performing, and
- the time that you will probably require.

safety equipment

Start the machine only when it is in a good and safe operating condition and all protective devices, e.g. EMERGENCY STOP devices, cover plates, etc. are correctly installed. Observe the acoustic and optical start-up warnings of the machine (if equipped).

symbol plates

Observe the symbol plates on the machine.

emergency stopping

Press the an emergency stop switch or tape strip stop switch immediately in the event of fault or irregularities in operation. Report any peculiarity to your superior so that necessary measures can be taken immediately.

battery

Disconnect the battery while performing:

- maintenance work,
- inspection work, and
- repair work.

work area

Cordon off your working area widely for the machine.

moving parts

Never allow parts of your body to come between parts which could move, such as:

- bucket/fork lifts
- pivot points
- battery lifts

steering lockout

Connect the steering lockout device before performing maintenance or repairs on the machine.

Storage and transport

Maintain the prescribed storage periods and observe the instructions for storage.

Do not store materials or parts in the travel way or in your working area.

Inform the persons involved about the intended transport route and the anticipated duration of the transport.

transport safety device

Ensure that the transport safety devices are correctly fitted.

Fix all moving parts with transport locks.

Never stand under unsupported parts or suspended loads.

means of attachment

Connect the lifting equipment only to the points of attachment provided for that purpose. Observe the different load limits of the attachment points. Also observe the instructions on the transport sheet.

Only use means of attachment which are in good condition and have been designed for the loads to be handled.

For round components use transport straps, only. Never use chains or steel cables for this purpose.

Do not damage the treated or polished surfaces of shafts, sealing surfaces, etc.

mobile handling equipment

When using mobile handling systems for transport make sure that the center of gravity is as low as possible.

Pre-start inspection

operation

Read this entire guide before attempting to operate this machine.

inspection

Inspect the machine and have any malfunctioning, broken or missing parts corrected or replaced before use.

maintenance

Verify that all maintenance has been performed.

instruction and safety tags

Verify that all instruction and safety tags are in place and readable. These are as important as any other equipment on the machine.

operator’s compartment

Clean any foreign material from the operator’s compartment.

cab/canopy

This machine was shipped from the factory equipped with a protective cab/canopy. The cab/canopy must be securely in place before operating the unit.

Installation and start-up

inclined face On inclined faces secure all component parts by chains, e.g. to the support.

environmental acceptability When working with oils, greases and other chemical substances, observe the safety regulations applicable to the product.

Dispose of cleaning rags, etc. which have been soiled with oil, grease or other chemical substances in an environmentally safe manner.

controls When starting up machine, do not operate any controls located inside the operator's compartment from outside the compartment.

starting procedures Follow the starting procedure instructions in chapter 5 of this manual.

hazard zone Do not operate any levers, pedals or controls if anyone is in the hazard zone. (See Hazard zone in Chapter 5 of this manual)

Operation

training Operate the machine only if you have a profound knowledge of the control elements and their functions. It is necessary that you have been task trained on the respective SU488 L Scoop.

before start-up Before start-up, ensure that there are no persons or obstructions in your line of travel or in the articulation area when steering the unit.

protective devices Check that all protective devices are installed on the machine and function properly.

operator's compartment Clean the operator's compartment at regular intervals. Ensure that the operating symbols are legible in order to avoid any operator errors and resulting accidents.

Never climb onto, or climb out of the machine while it is in motion.

Do not operate the machine with any part of your body outside of the operator's compartment in order to prevent body parts from being crushed between the machine and outside objects .

traveling Use extreme caution when traveling in close quarters or in congested or blind-travel areas. The warning gong should be sounded to alert personnel of your movement.

passengers Never carry passengers to prevent the passengers from being thrown off or crushed between the machine and outside objects.

safety rules Always follow all safety rules of each particular mine when operating the machine.

problems and malfunctions If problems or malfunctions are encountered while operating the unit, it must be properly shutdown and the problem corrected immediately.

Stopping

operator's compartment

Do not leave the operator's compartment with the unit running. Always properly shutdown the unit before leaving the operator's compartment.

parking

Always park the unit on solid, level ground. If this is not possible, park the unit at a right angle to the slope to prevent accidental movement of the machine.

Use proper flags, warnings or barriers when parking in areas of traffic. Chock all four (4) wheels in both directions whenever possible.

Maintenance and repair

Be sure to observe the prescribed maintenance and inspection intervals.

Inform the supervisory personnel and the face crew of any maintenance and repair operations. Give them information on the intended operations and the anticipated duration.

securing

Secure your working area over a wide range, in order to avoid endangering other persons.

Disconnect the battery from the machine to prevent unauthorized and unintentional restarting.

Protect your work area against falling rocks.

replacing components

Disconnect the battery from machine to prevent from restarting before replacing any defective components.

Pass defective components removed on for servicing without delay in order to prevent these parts being reinstalled elsewhere.

original parts

Use only spare parts which satisfy the specified technical requirements.
This is only ensured with original CAT® spare parts.
Please refer to the spare parts lists for the order numbers.

lifting

For raising the SU488 L use only:

- crib blocks with adequate load-holding capacity.
- hoists, jacks or cranes with adequate load-carrying capacity.

handling of hydraulic fluids

Avoid direct contact between the skin and hydraulic fluids.
Hydraulic fluid can penetrate the skin and cause serious infection.

Never use hydraulic fluid for rinsing or cleaning. Hydraulic fluid represents a very serious danger to health.

maintenance, repair

Only persons who have and can demonstrate a special knowledge of hydraulics are allowed to work on the hydraulic system.

Avoid, whenever possible, servicing, cleaning or examining the machine in congested areas.

Avoid, whenever possible, servicing or providing maintenance to the unit unless the wheels are chocked and steering lockout device is connected to prevent accidental movement of the unit.

Do not alter the electrical or hydraulic settings from that indicated in this manual or as set at the factory.

Always replace damaged or lost decals and metal instruction plates.

Disconnect the battery when working with the electrical system, or when welding on the unit to prevent electrical shock.

Be sure the battery area is well ventilated (clear of fumes) when it is necessary to connect battery charger. Fumes from the battery could ignite from a spark and explode.

Always follow all safety procedures of each particular mine when performing maintenance.

It is important that any procedure not specifically recommended in this guide be thoroughly evaluated from the standpoint of safety before it is implemented.

Some illustrations in this manual show guards or cover panels removed for purposes of clarity. Never operate unit without guards or cover panels in place.

Carry out a visual inspection of all the hydraulic components at regular intervals. In particular check that:

- the hoses are not pinched or trapped,
- the hoses have no bubbles or blisters,
- the hose or outer sheathes of the hose are not abnormally rigid or hard,
- the outer sheath of the hoses is not damaged,
- the connectors are securely inserted into the sockets, and
- the connections are leak-tight.

Ensure that no dirt enters the hydraulic system during repair work. Dirt in the hydraulic system can cause serious damage in the whole system! Flush out the hydraulic lines thoroughly before connecting.

If hydraulic hose couplers are difficult to disconnect or cannot be disconnected, the hydraulic line may still be pressurized. Be sure to depressurize the line before disconnecting couplers.

Secure the connectors of the hydraulic elements only with the proper coupling clamps. Always fasten the clamps completely and with both sides. Never use nails, wire or similar materials for securing.

After finishing repair work, check all connectors and connections for leaks before pressurizing the system again.

permissible hoses

Use only hydraulic hoses approved for the prevailing pressures.

Do not use any hydraulic hoses with damaged connectors or worn o-rings.

Replace hydraulic hoses only with hoses of the same or a higher quality.

Observe the date of manufacture stamped on the hydraulic hoses. Never use hydraulic hoses which are more than 2 years old, even if they have no visible signs of damage.

Never try to hold a jumping hydraulic hose. Depressurize the line in question immediately.

Never try to repair damaged hydraulic hoses.

Replace hydraulic hoses at the first suspicion of damage.

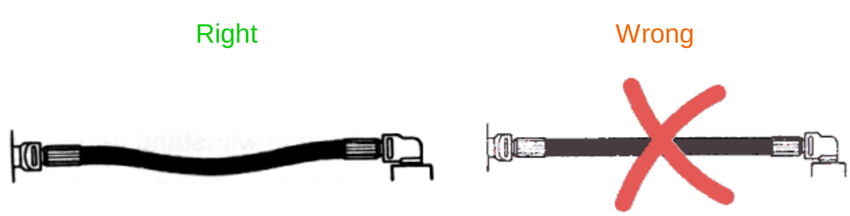
laying hydraulic hoses

Lay the hydraulic hoses properly behind the brackets and clamps provided for them.

Always lay hydraulic hoses so they:

- always have a little slack.

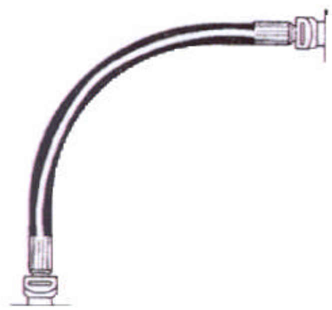
Fig. 1: Laying hydraulic hoses, slack



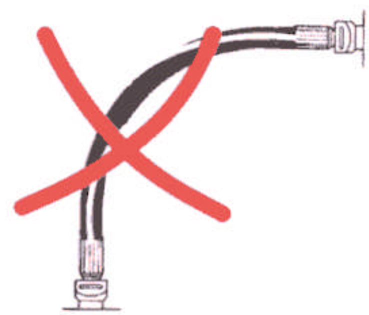
- are not twisted.

Fig. 2: Laying hydraulic hoses, twisting

Right



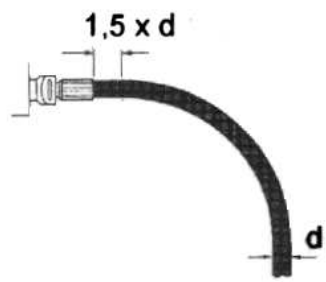
Wrong



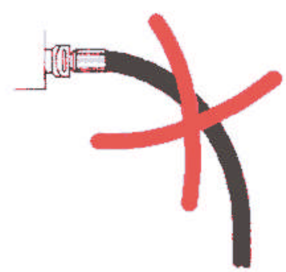
- are not bent directly behind the connections.
  (distance min. 1.5 x nominal diameter).

Fig. 3: Laying hydraulic hoses, bending

Right



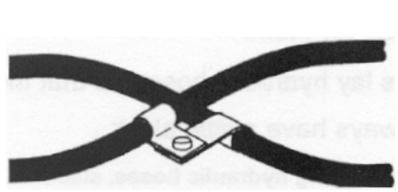
Wrong



- always have a little slack.

Fig. 4: Laying hydraulic hoses, crossing

Right



Wrong

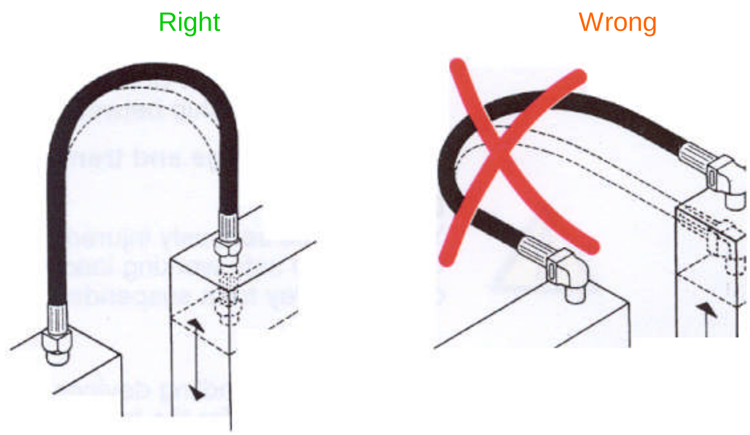
- are not kinked.
- do not have to withstand tensile strains.
- are protected against thermal radiation.
- are accessible at all times.

Push hydraulic hoses into the sockets only by hand. Never try to drive the hydraulic hoses in with a tool as this will damage the connections.

When installing the hydraulic hoses, ensure that they cannot be:

- torn out,
- kinked,
- crushed,
- driven over or
- twisted by movement of the machine.

Fig. 5: Laying hydraulic hoses, connections on moving parts



3 Storage and transport

Storage and transport

This chapter contains important information on the correct storage and transport of the SU488 L. Observance of the instructions and tips will increase the service life and availability of the machine. You will also be able to carry out the transport work quicker and more safely. Careful attention to the points in this chapter will help you to simplify your day-to-day work.

Storage

corrosion protection

Components coated with temporary corrosion inhibitor are protected for approximately six months.

Before delivery, the hydraulically operated equipment is operated and all axles, gear boxes, hydraulic oil tank, etc. are filled to their maximum fill point.

Storage of the machine and spare parts

no direct exposure to sunlight

Store the equipment indoors or cover with a tarpaulin to protect against direct exposure to sunlight. Store the electrical equipment, electronic components, spare parts of rubber or plastic – such as seals and hoses – and hydraulic fluids only in closed rooms at temperatures of (15° C to 25°C (60° F to 77° F).

dirt and moisture

Protect the equipment and all spare parts stored outdoors against moisture and dirt, e.g. using tarpaulins.

The mounting surfaces of hydraulic components must be protected against corrosion and sealed with blind plates. Protect the hydraulic plug connectors and the connectors of the electrical cables with the caps and plugs supplied.

short-term storage

During short-term storage (approximately 4 weeks) of equipment outdoors, but at temperatures above freezing, electrical components need not be removed. Such components must be particularly protected against excessive temperatures, dirt and moisture.

long-term storage

If the equipment is to be stored more than six months, the hydraulic components must be completely filled with a corrosion inhibiting/frost-proofing fluid.

Fill the hollow areas of hydraulic components (e.g. the piston chambers) in horizontal position (ports facing upwards) until they start to overflow.
Then seal the ports with plastic or steel plugs.

The equipment must be stored in a well ventilated, dry room. Do not store outdoors.

plastic deformation

In order to prevent plastic deformation of the seal elements, cylinders must be stored in an upright position. Some cylinders must be removed so that they can be stored upright.

random sample inspection

After a storage period of approximately two years, a random sample inspection must be performed to determine whether the measures taken and the method of storage has prevented damage. On request, the inspection can be carried out by CAT® .

natural aging

Even with proper storage, seals and hoses are subject to natural ageing. Do not use these parts if they have been stored for more than two years.

HFA fluids

Instructions on the storage of concentrates for hydraulic fluids can be found, if required, in chapter 6 in this operating manual.

IMPORTANT!
Take care to insure that new supplies are stored separately from existing stock and that removal takes place on the "first in, first out" principle.

Transport

Load units; dimensions and weights

Observe the transport sheets for the machine and spare parts. They contain information on:

- dimensions,
- weight,
- lifting points, etc.

Additional information on the dimensions and weights can be found in chapter 6 in this operating manual.

WARNING!
Use only load handling devices complying with the technical and legal regulations for the transport of loads. You could be seriously injured or even killed by falling loads. Use only suitable load handling devices.

Before transport

temperatures below freezing

Before transporting the equipment at temperatures below freezing, all hydraulic components operated with emulsion (HFAE or HFAS) must be completely drained and then filled with a corrosion inhibitor/frost-proofing fluid.

Transport of equipment at temperatures between -21° C and -40° C (-6° F and -40° F) is only permissible when certain measures were taken to meet these conditions at the design and manufacture stages. Nevertheless, the individual parts and devices of this equipment must not be subjected to sudden impact loads at such low temperatures and may only be loaded statically or quasi-statically.

During transport of this equipment with floor-mounted vehicles at such low temperatures, measures must also be taken to ensure that the parts and devices are not subjected to sudden impact loads. At very low temperatures and on poor roads, the transport vehicle speed must therefore be limited to a maximum of 25 kph (15 mph) for truck transport.

electronic components

Electrical and electronic components must be removed for overseas transport or prolonged storage outdoors unless these components or the complete equipment is protected against harmful environmental influences by a suitable packaging.

The electrical cables remain in the equipment. They must be carefully protected against transport damage and soiling of the connections.

Storage and transport

4 Installation

Installation

Points to observe prior to installation

Who is allowed to carry out installation?

Installation is only allowed to be carried out by personnel having received adequate training to perform this task.

Work on:

the safety components (pressure relief valves, fire extinguishing equipment etc.),

the electrical equipment (control units, signaling devices, etc.), and

the hydraulic equipment (cylinders, directional control valves, hoses etc.)

should only be carried out by CAT® service engineers or by specially trained personnel.

Which tools are required for installation?

tool box

No special tools are required to put the SU488 L into service.

The battery plugs and receptacles come with a special wrench for connecting and disconnecting battery plugs and receptacles.

Various items of auxiliary equipment and machines may be required at the point of installation. These include:

- hoists with adequate lifting capacity
- means of attachment with adequate lifting capacity
- unloading dock
- jacks with adequate lifting capacity

Notes on installation

CAUTION!
Serious damage can be caused to the SU488 L as a result of incorrect installation. The unit should therefore only be installed under the instruction of specialists from CAT® .

installation plan

The sequence of operations during installation must be adapted to the individual conditions prevailing at the site. Before starting the work a detailed list of steps to be taken with respect to transport and assembly should be prepared and a corresponding plan established.

IMPORTANT!
The sequence of operations during installation must be adapted to the individual conditions prevailing at the site. Before starting the work a detailed list of steps to be taken with respect to transport and assembly should be prepared and a corresponding plan established

Pre-installation check list

NOTICE!
The machine was inspected prior to shipment from the factory to ensure proper functioning and installation of all components. However, to ensure that no transit damage has occurred, the following pre-startup checks should be performed:

- perform daily maintenance
- visually inspect all hydraulic hoses and electrical cables for damage
- clean any foreign material from the operator's compartment
- if equipped with bucket, clean any foreign material from behind the ejector blade
- check safety provisions for operational condition on fire suppression system
- start up the machine and check for correct operation of the emergency stop switches, located inside the operator's compartment
- check that all covers and guards are in place and secure
- check that all tags and instruction labels are in place and secure
- check that operator's canopy is secure and in place
- start the machine and allow the hydraulic system to warm up for five (5) to ten (10) minutes
- check hydraulic system pressures (refer to the hydraulic schematic supplied for your particular machine for pressure settings)
- check all control handles and switches to ensure all machine functions are operating properly

Safety features

NOTICE!
The operator must become familiar with all the safety features and their location on the machine prior to installation or operation.

Safety features include (Reference Fig. 6):

tape strip stop switch

The machine is equipped with two (2) tape strip stop switches located inside the operator's compartment. One is located to the right and one is located to the left of the operator while sitting in the operator's seat. The switches are used to break the control circuit, stopping all motors and applying the park brake. Striking with a small amount of force will actuate the switch.

canopy/cab

The machine was shipped from the factory with a protective canopy/cab. Ensure that the canopy/cab is in place and secure at all times to protect the operator from falling debris.

fire suppression

The machine is equipped with two (2) fire suppression (remote) actuators. One is located to the operator's right inside the operator's compartment and the other is located beside the controller box assembly on the off-side. This particular suppression system is pneumatically actuated and extinguishes with dry chemicals. To actuate the system from either of the two (2) actuators, pull the safety pin and strike downward on the plunger. Immediately after the plunger is struck, dry chemical will be dispensed throughout the machine. The fire suppression system must be completely recharged with dry chemicals and expellants after it has been actuated.

WARNING!
If either of the fire suppression actuators is actuated, the system must be completely recharged with dry chemicals and expellants.

guards and covers

The machine is equipped with guards and covers to reduce the possibility of personnel coming in contact with rotating or moving parts. All guards and covers must be installed and securely fastened during operation.

DANGER!
Do not operate the machine with any of the guards or covers removed. You or other personnel could be seriously injured from moving or rotating parts.

steering lockout

The machine is equipped with a steering lockout. The lockout should be connected and secure during shutdown and while performing maintenance on the machine.

optional audible alarms

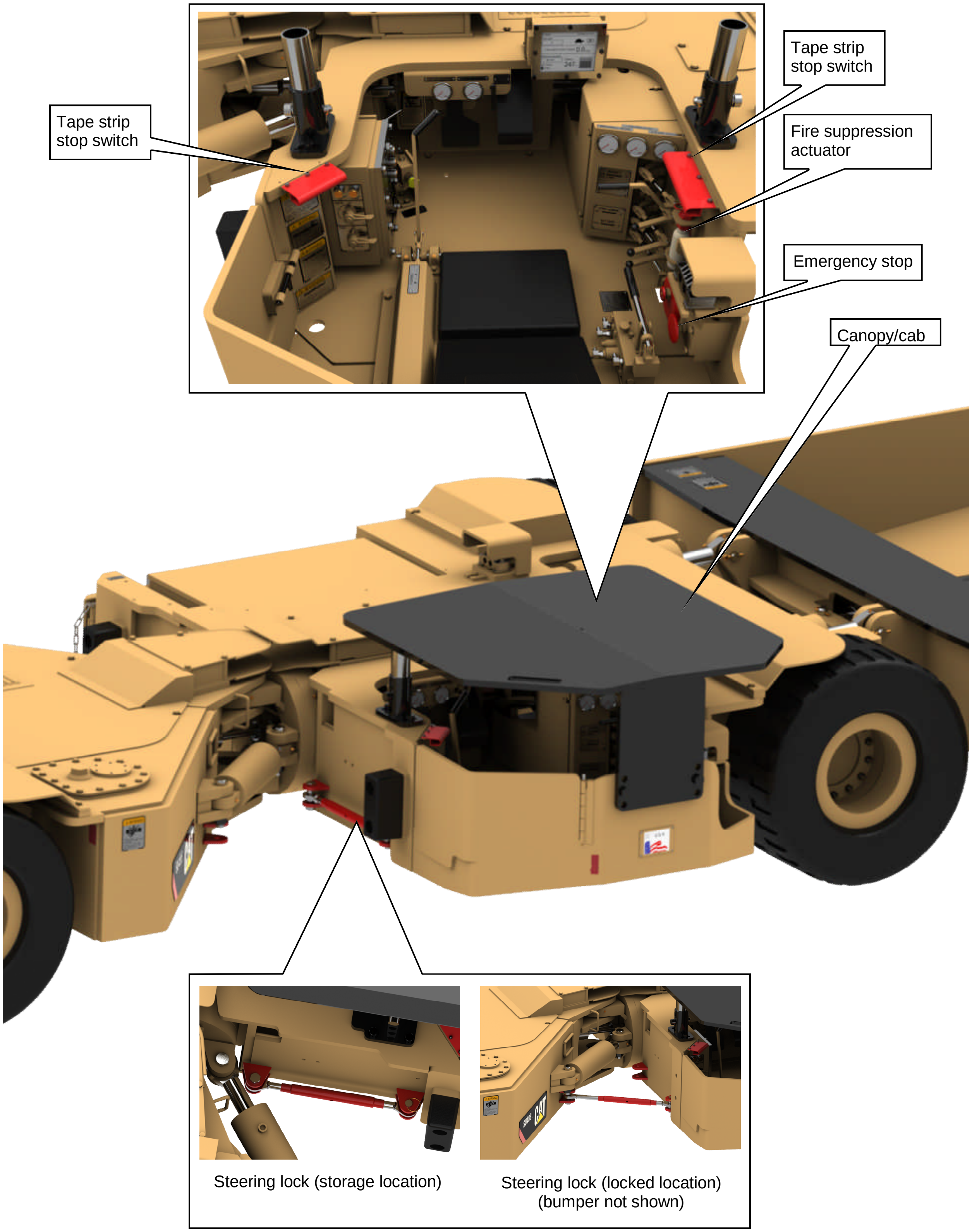
When the machine is running, a warning horn can be activated by pushing the "PUMP START" button.

emergency stop buttons

There is one emergency stop buttons located in the operator's compartment. It is located on the operator's right.

Pushing the emergency stop button on the operator's right trips the machine circuit breaker. The circuit breaker must be reset and diagnostics run (see start up procedures) before the machine can be restarted.

Fig. 6: Safety features



5 Operation

Operation

This chapter contains important information on the operation and maintenance of the machine. Read this chapter carefully and thoroughly. In particular, observe the safety instructions in chapter 2 “Your safety”.

How to operate the SU488 L

DANGER!
Incorrect operation of the machine is often the cause of very serious accidents. Operate the unit only after being sufficiently trained on the machine and reading and understanding this operating manual. Should anything be unclear, please contact your immediate supervisor.

Who is allowed to operate the SU488 L?

This machine is only allowed to be operated by persons with adequate knowledge of the complete machine. This includes:

- what safety devices are installed on the machine,
- where these safety devices are located, and
- how these safety devices are to be operated.

When can operation be started?

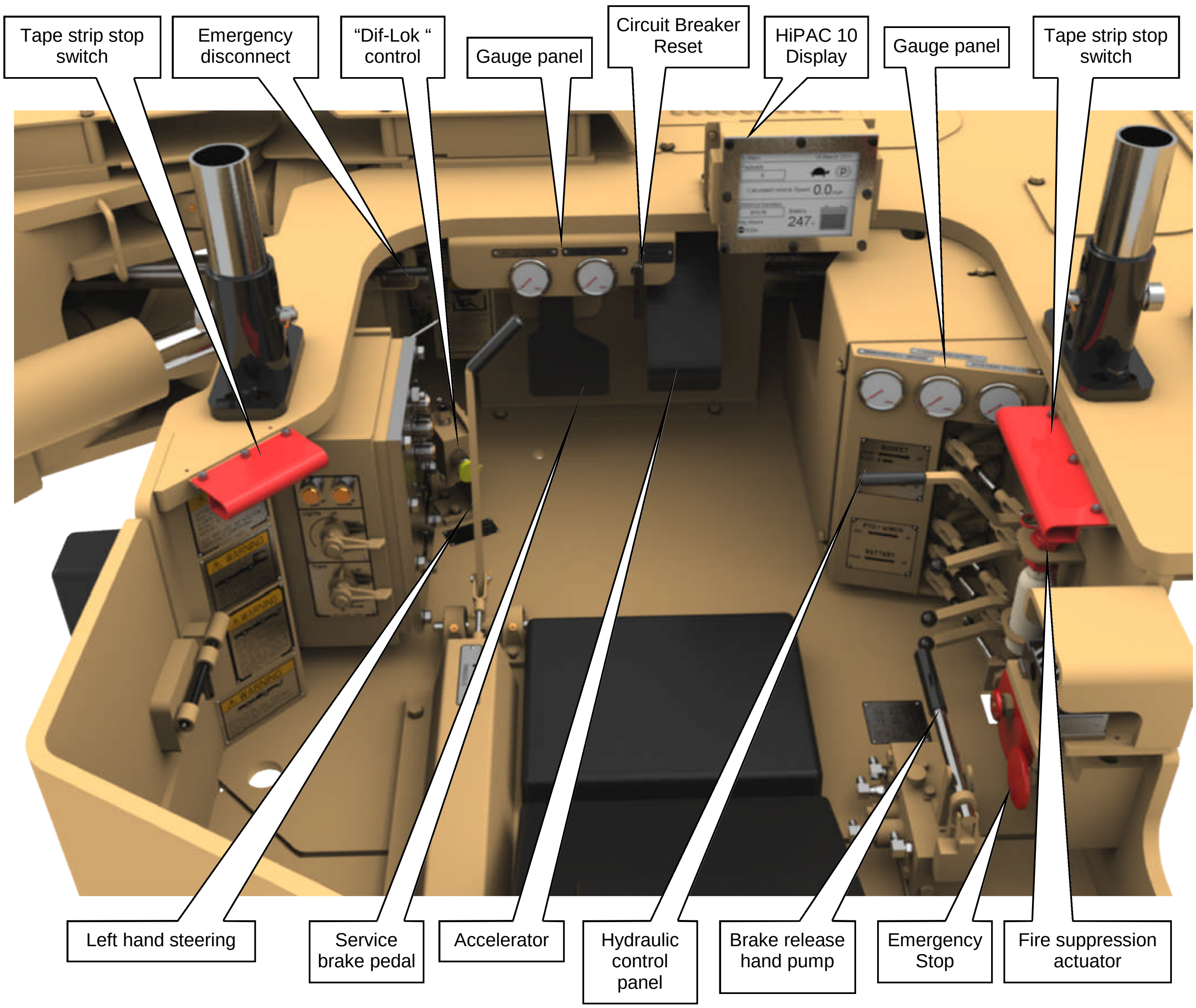
Operation must not be started until the safe condition and proper function of the complete machine has been checked and the daily maintenance operations have been carried out.

Controls and indicators

Operator's compartment

The primary controls for the machine are located in the operator's compartment (Fig. 8).

Fig. 8: Operator's compartment

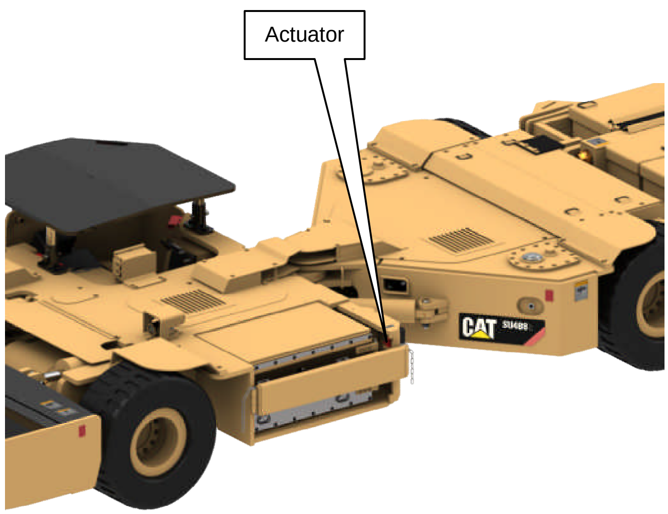


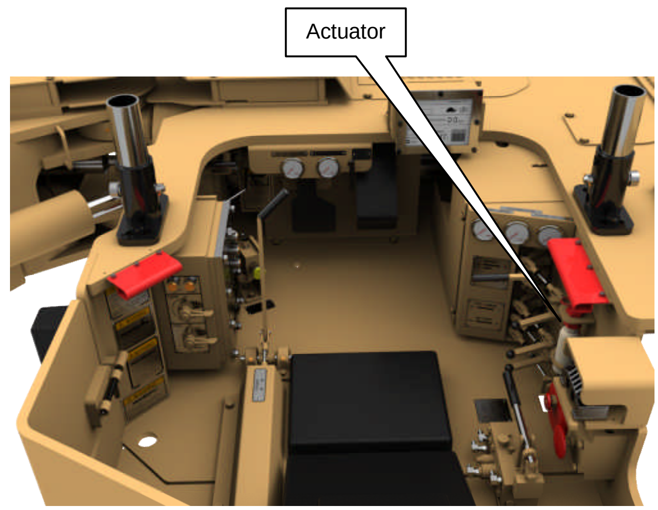
fire suppression actuators

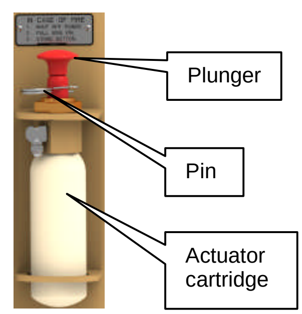
The machine is equipped with two (2) fire suppression (remote) actuators (Fig. 9). One is located to the operator's right inside the operator's compartment and the other is located beside the controller box on the off-side of the machine. This particular suppression system is pneumatically actuated and extinguishes with dry chemicals. To actuate the system from either of the two (2) actuators, pull the safety pin and strike downward on the plunger. Immediately after the plunger is struck, dry chemical will be dispensed throughout the machine. The fire suppression system must be completely recharged with dry chemicals and expellants after it has been actuated.

WARNING!
If either of the fire suppression actuator are actuated, the system must be completely recharged with dry chemicals and expellants.

Fig. 9: Fire suppression locator (typical)







Typical actuator

brake pedal (service)

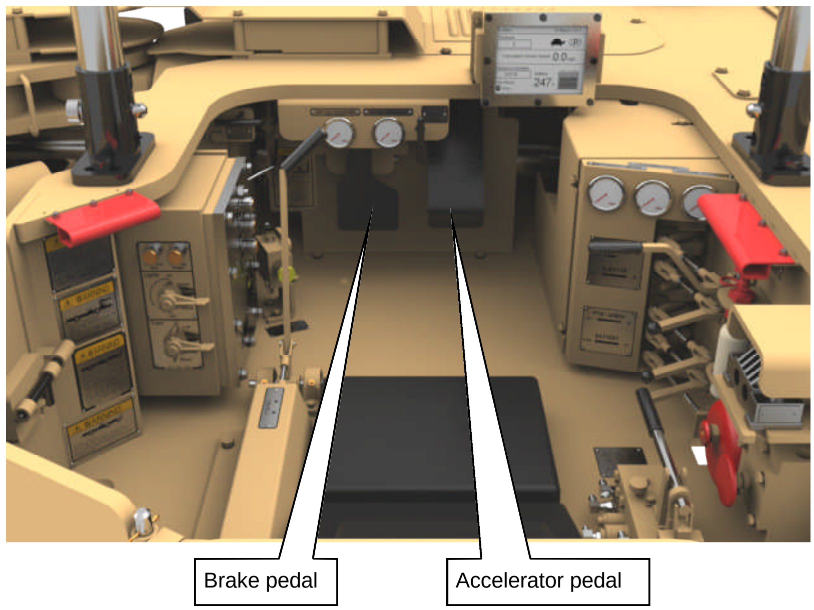
The service brake pedal (Fig. 10), operated by the left foot, is used to apply the service brakes.

accelerator pedal

The accelerator pedal (Fig. 10), operated by the right foot, is used to start the tram (traveling) motors and regulate the speed of the machine.

CAUTION!
The accelerator pedal should not be depressed at the same time as the foot brake pedal or when the parking brakes are set. To do so may overload the tram motors. Although the machine is provided with overload protection, continued abuse can shorten motor and brake life.

Fig. 10: Brake and accelerator pedals



tape strip stop switch

The machine is equipped with two (2) tape strip stop switches (Fig. 11) located to the left and right of the operator in the operator's compartment. The switches are used to break the control circuit, stopping all motors, and applying the park brake. Striking with a small amount of force will actuate the switch.

emergency stop button

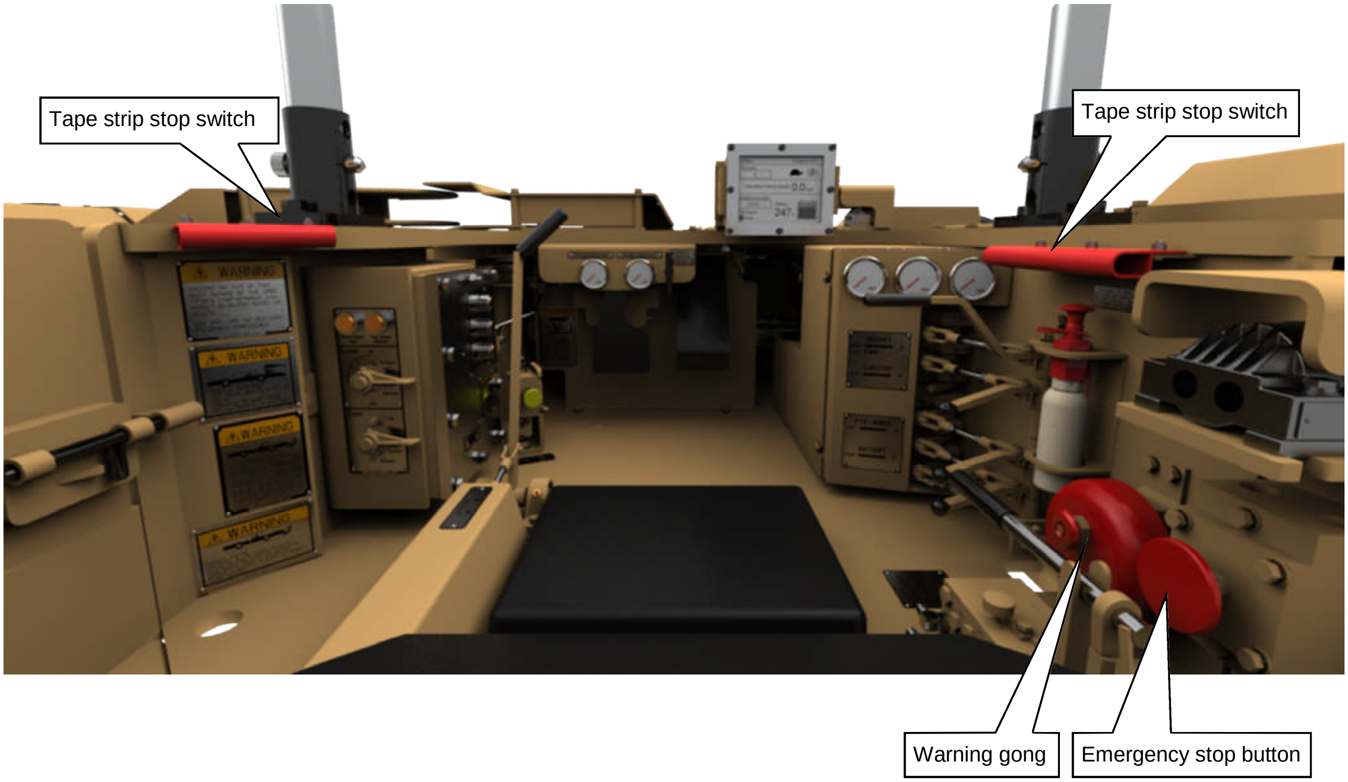
There is one emergency stop buttons located in the operator's compartment (Fig. 11). It is located to the operator's right.

Pushing the emergency stop button on the operator's right trips the machine circuit breaker, stopping all motors and applying the park brake. The circuit breaker must be reset, using the lever located in front of the operator and diagnostics run, before the machine can be restarted.

warning gong

The warning gong (Fig. 11) is located to the right of the operator. Striking the center with a small amount of force will sound the gong. Follow all regulations for sounding the warning gong.

Fig. 11: Tape strip stop switches and emergency stop button



Hydraulic control panel

The hydraulic control panel (Fig. 12), located to the right of the operator, has a group of levers used to control the following:

"BUCKET"

The "BUCKET" lever is used to raise or lower the front bucket. To raise the bucket, pull the lever towards the operator and to lower the bucket, push the lever away from the operator. Note: To activate the "FLOAT" operation of the bucket, push the control lever full over, to engage the spool detent; which will allow the bucket to follow the existing floor contour. Simply pull the handle to restore manual bucket operation

"EJECTOR"

The "EJECTOR" lever controls the bucket ejector blade. The ejector blade pushes out everything in its path, emptying the bucket. When the "EJECTOR" lever is pushed away from the operator, the ejector blade should move toward the front of the bucket (extend). When the "EJECTOR" lever is pulled toward the operator, the ejector blade should move toward the back of the bucket (retract). When the ejector blade is not being used, it should be resting in the retracted position.

WARNING!
Before moving the "EJECTOR" control lever, verify that no one has any part of his body between the ejector blade and the back of the bucket. Also, keep all obstructions from behind the ejector blade so it can return completely to the back of the bucket.

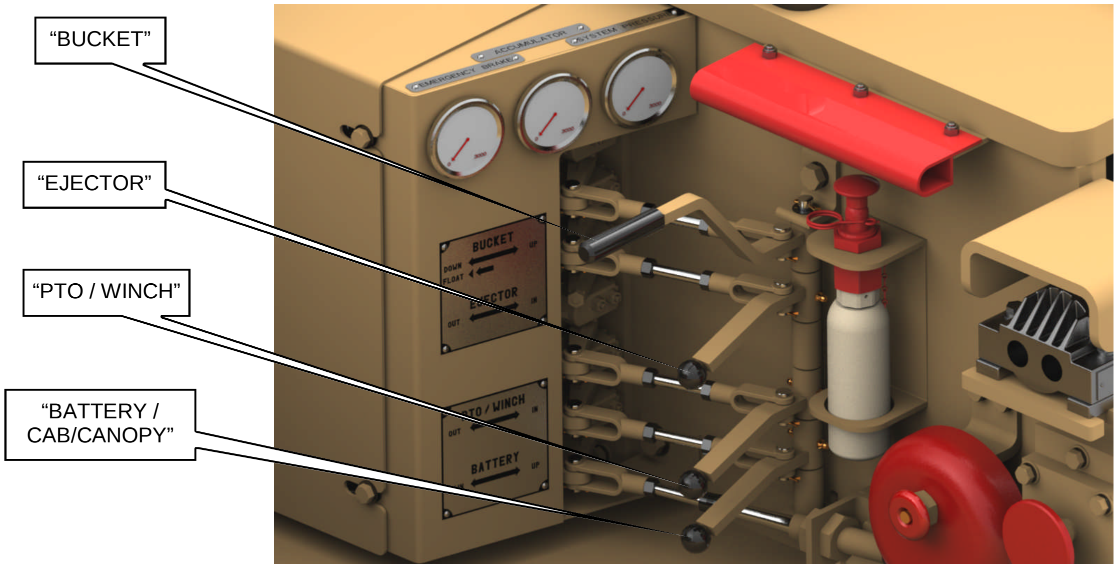
"PTO / WINCH"

This lever is used to chose which PTO port is active. Pulling the "PTO" lever towards the operator pressurizes the "B" port. Pushing the control lever away pressurizes the "A" port. Alternatively, if the machine is fitted with a winch option, select winch position via an auxiliary diverter valve and this lever will control the winch operation.

"BATTERY/CAB "

This lever controls the battery lift function and/or the cab/canopy function when the cab/canopy option is employed. To lower the battery or canopy, push the lever away from the operator. To raise the battery or canopy, pull the lever toward the operator. The battery and/or cab/canopy selection is achieved via the position of an auxiliary diverter valve that is supplied with the optional cab/canopy assembly.

Fig. 12: Hydraulic control system



pressure gauge panels

The gauge panels (Fig. 14) consists of five pressure gauges, divided into 2 locations: “DIF-LOK” and “BRAKE PRESSURE” are located directly in front of the operator, “EMERGENCY BRAKE”, “ACCUMULATOR”, and ‘SYSTEM PRESSURE” are located above the valve bank to the operator’s right.

The “DIF-LOK PRESSURE” gauge should read 41 bar (600 psi) maximum when the differential lock (traction assist) function is engaged.

The “BRAKE PRESSURE” gauge should read a maximum of 45 bar (650 psi) when the brakes are applied.

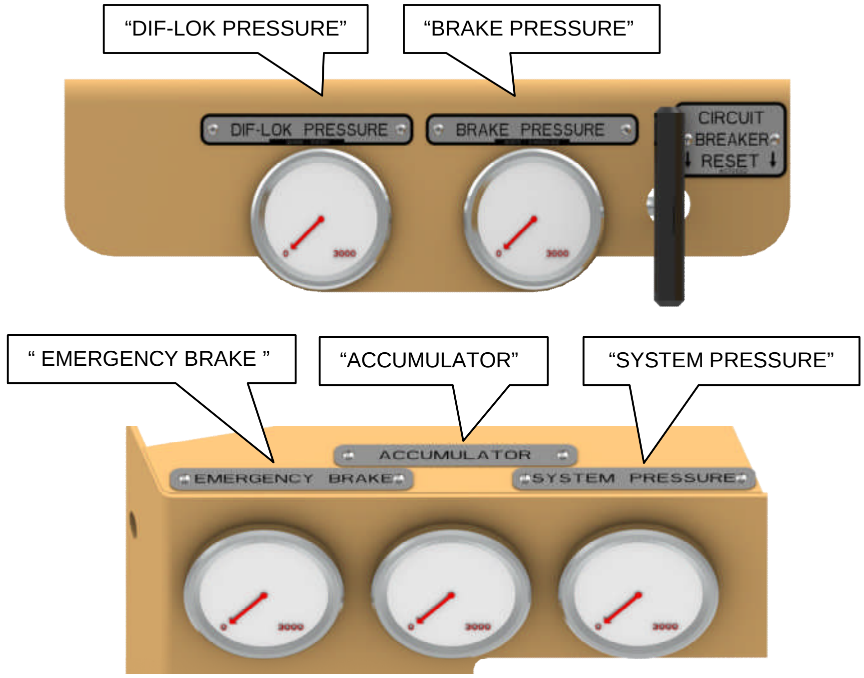
The “EMERGENCY BRAKE” pressure gauge should read 138 to 152 bar (2,000 to 2,200 psi).

The “ACCUMULATOR” gauge should read 103 to 152 bar (1,500 to 2, 200 psi).

The hydraulic system pressure relief valve is set to relief at 207 bar (3,000 psi) and the “SYSTEM PRESSURE” is set at 155 bar (2,250 psi).

WARNING!
If any of the above gauges read above or below the pressures listed, shutdown the machine and call a maintenance person (see Shutdown procedure in this Chapter).

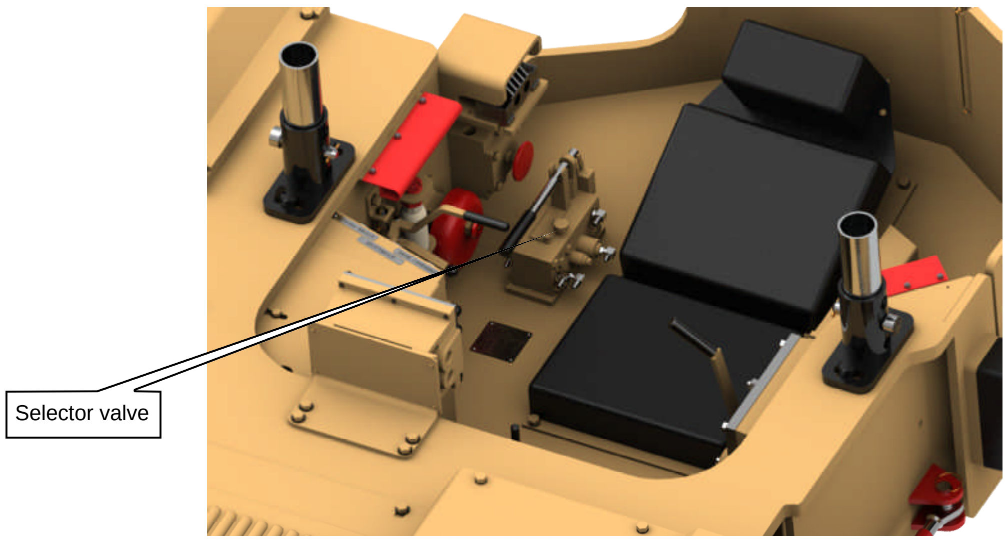
Fig.14: Pressure gauge panels



brake release hand pump

The automatic emergency brakes are spring-applied (on), pressure-release (off) brakes located in the axles. The automatic (park) brake is normally released using the "PARK BRAKE" release button on the control station. Should hydraulic system failure occur, the automatic (park) brake can be released using the manual brake release hand pump. To release the brakes using the hand pump (Fig. 15), turn the hand pump selector valve to the set position. Pump the hand pump until the "EMERGENCY BRAKE" pressure gauge indicates the required minimum pressure of 2,000 psi (138 bar).

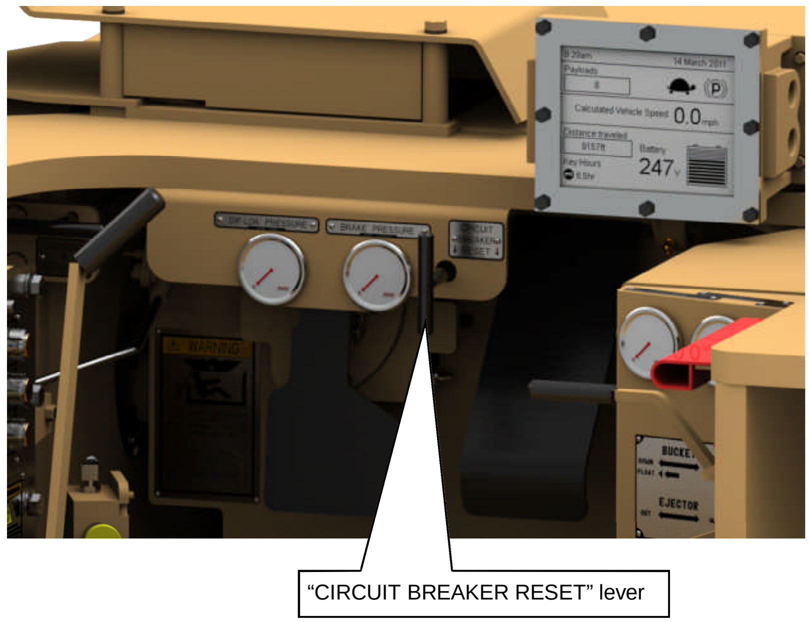
Fig. 15: Brake release hand pump



“CIRCUIT BREAKER RESET” lever

The “CIRCUIT BREAKER RESET” lever (Fig. 16) is used to reset the machine circuit breaker when it has tripped. If the breaker has tripped, the breaker must be reset following the start up procedure. Note: the breaker cannot be reset until diagnostics have been run and an “OK message” is received.

Fig. 16: “CIRCUIT BREAKER RESET” lever



WARNING!
The circuit breaker de-energizes the electrical controller and motors. However, electrical power is still present inside the connection box to the circuit breaker. If the circuit breaker inside the connection box requires service, the battery plugs must be disconnected from the batteries.

The circuit breaker is not intended as an "ON-OFF" switch for normal operation. Except in an emergency, the machine should be shut down using the “STOP” button on the Control Station.

WARNING!
The circuit breaker should be in the “OFF” position and the parking brake set before the operator leaves the operator’s seat.

Control Station

IMPORTANT!
For detailed control station operating instructions, see the Starting, Operating, and Shutdown procedures in this chapter.

The control station (Fig. 17) located to the left of the operator has a group of buttons and switches that control the following:

"DIFFERENTIAL LOCK" Press to engage traction assist (differential lock / "DIF-LOK"). Spring return to disengage when released.

CAUTION!
Traction assist should not be engaged during spin-out or while in a turn or damage to the axles can occur.

"PUMP MOTOR START" Used to start the pump motor. To start the pump motor, press and hold the "PUMP MOTOR START" until the pump motor starts. Note: motor will only start with TRAM rotary switch in PARK, FORWARD, or REVERSE position.

"PARK BRAKE RELEASE" Used to release the park brake. To set the park brake rotate the TRAM rotary switch to "PARK" and leave pump motor running. To release the park brake (pump motor must be running), press and hold the "PARK BRAKE RELEASE" button until the dashboard display indicates "PARK BRAKE RELEASED". Note: TRAM rotary switch must be in either FORWARD or REVERSE position to release park brake.

"LIGHTS" Used to activate the headlights. To activate rotate the switch to the desired light direction (OFF, FORWARD, REVERSE, or AUTO). When in the AUTO position headlights follow tram direction. The lights will stay in auto position until the "LIGHTS" switch is rotated to another position.

"TRAM" Used to enable a tramming direction (pump motor must be running and the park brake must be released).

To activate a tramming direction, rotate the switch to the desired tram direction (FORWARD, or REVERSE) until the dashboard display indicates direction of travel.

To set the park brake rotate the switch to "PARK"

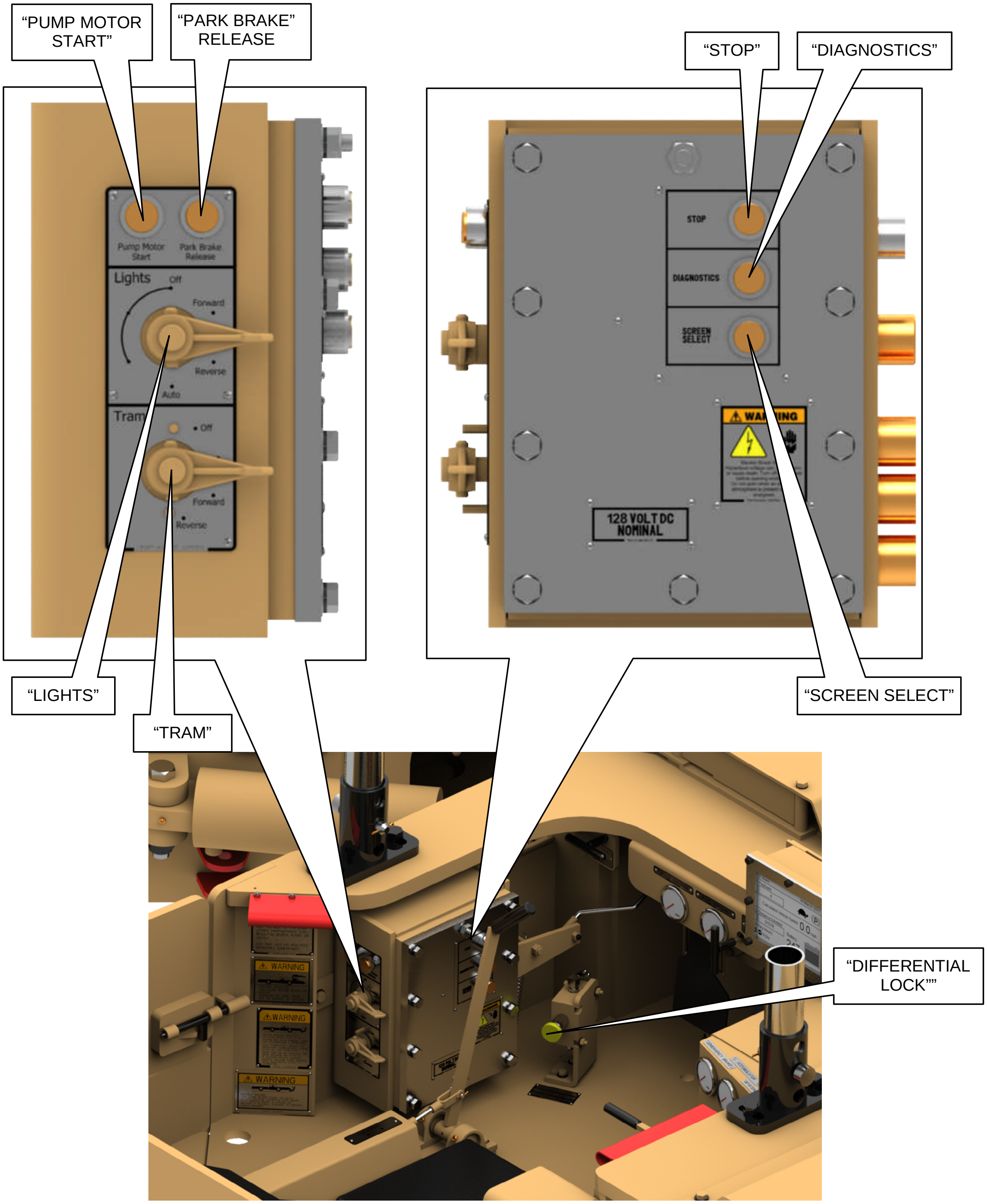
To disable tramming and pump motor, rotate the switch to the "OFF" position.

"STOP" Press the "STOP" button to shutdown motors, turn off the lights, and set the park brake.

"DIAGNOSTICS" Used to activate machine diagnostics.

"SCREEN SELECT" The in-position button used to enable a function

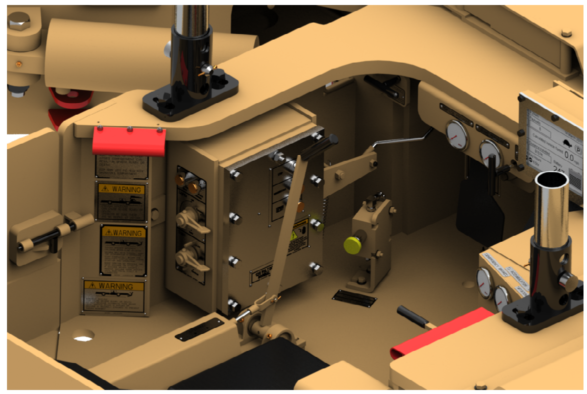
Fig. 17: Control Station



left hand steering control lever

The left-hand steering control Lever (Fig. 18) is used to steer the machine. To steer left while moving forward (right while moving in reverse), push the steering control lever slowly away from the operator. To turn right while moving forward (left while moving in reverse), pull the steering control lever slowly toward the operator.

Fig. 18: Left hand steering control lever

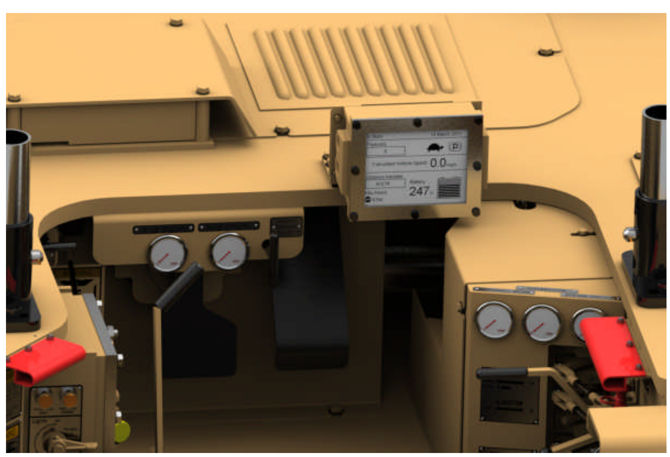


HiPAC 10 display

The HiPAC display module (Fig. 19) provides the operator a means of determining the status of the drive system and is used for troubleshooting purposes. In addition to faults, warnings, and configuration screens, the display provides many vehicle performance parameters, such as battery voltage and battery shift life remaining.

The display has multiple screens and needs to toggle among the screens based on the selection of the diagnostics switch input (only after the main circuit breaker is closed). The system will always start with the same splash screen and then, after the main circuit breaker is closed, default to the main operating screen. When an alternate screen is selected, that screen will remain until the operator selects another alternate screen or the unit is powered down. Alternate screens are selected by toggling the diagnostic switch up twice consecutively in approximately one second activations.

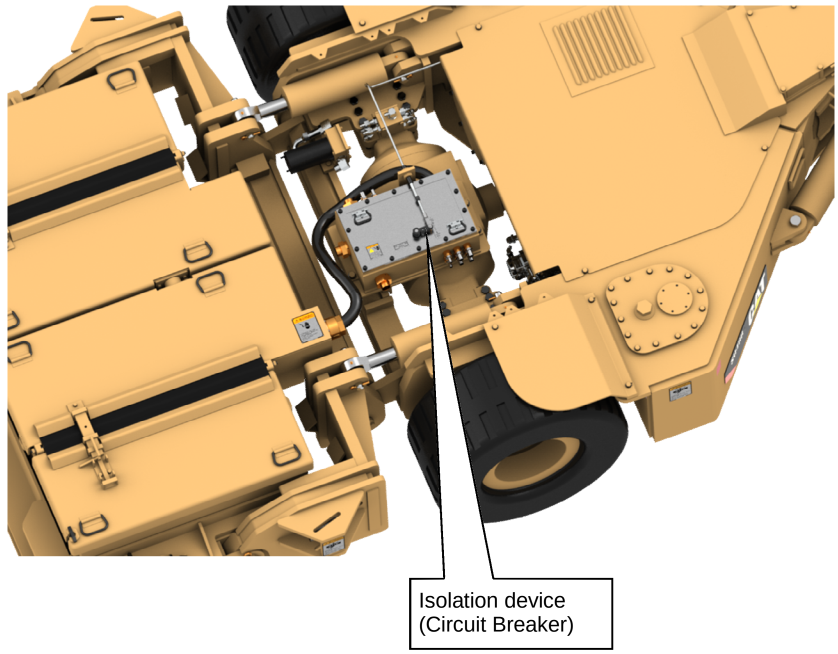
Fig. 19: HiPAC10 display

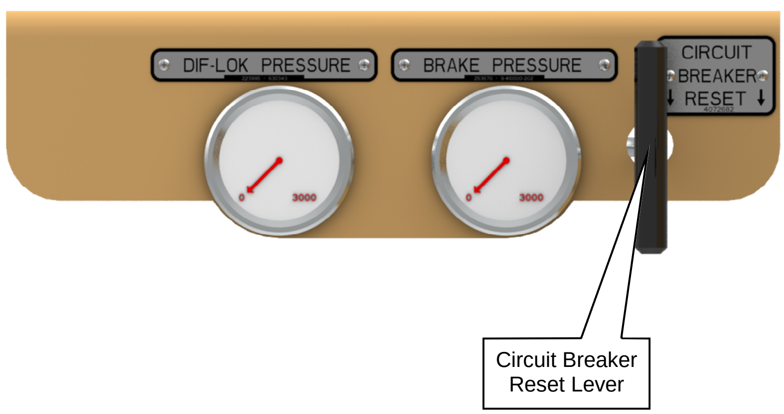


battery connection box

The battery connection box is provided with a manually actuated circuit breaker that will isolate the supply of electricity from the connection box forward in the system, when tripped it must be reset by cycling the reset lever located in the operator's cab. (Fig. 20). .

Fig. 20: Battery connection box



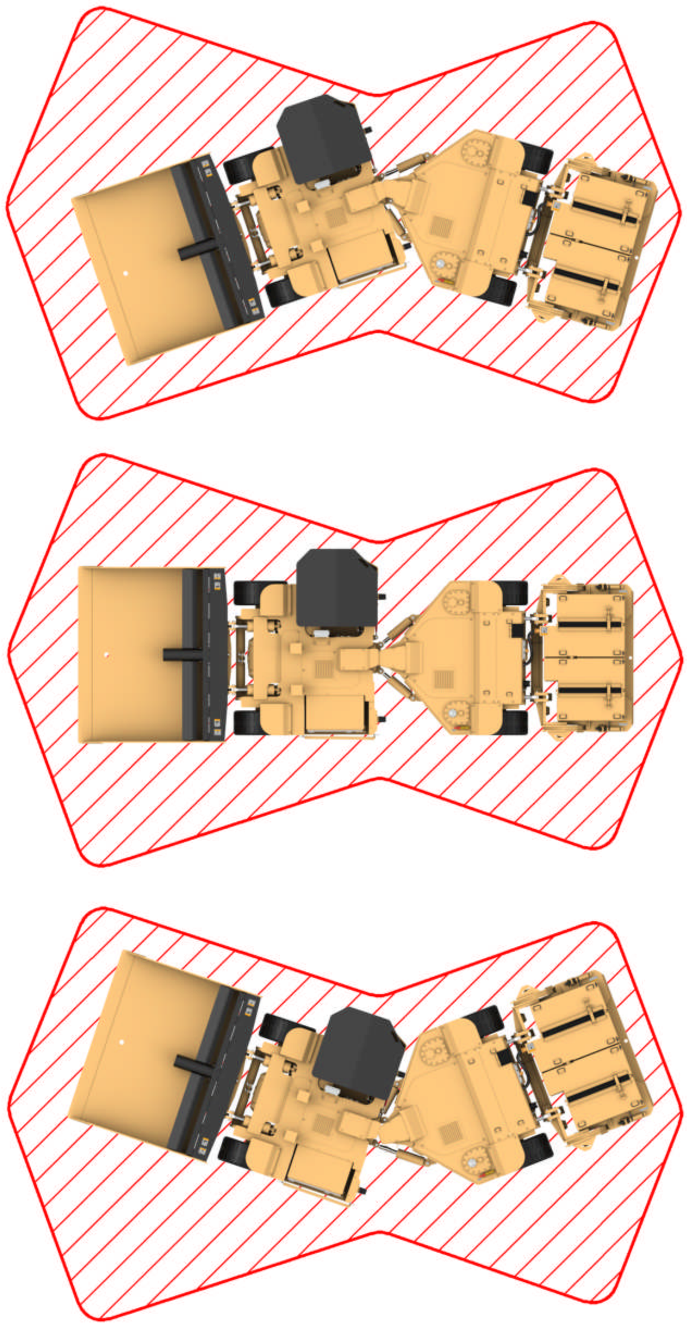


Hazard zone

The hazard zone exists unless:

- The battery plug is disconnected from the battery, OR;
- The battery circuit breaker is in the “OFF” or “TRIPPED” position.

Fig. 21: Hazard zone



Starting and operating procedures

After reading the previous descriptions and locating each control, the operator is ready to operate the SU488 L. An experienced operator should monitor a new operator's indoctrination to the starting procedure.

WARNING!
Check the battery connections and the battery covers. They must be in place and locked to be permissible.

WARNING!
Never operate any levers or pedals from outside the operator's compartment. All switches in the operator's compartment must be in the "OFF" position before the battery circuit breaker is moved to the "ON" position.

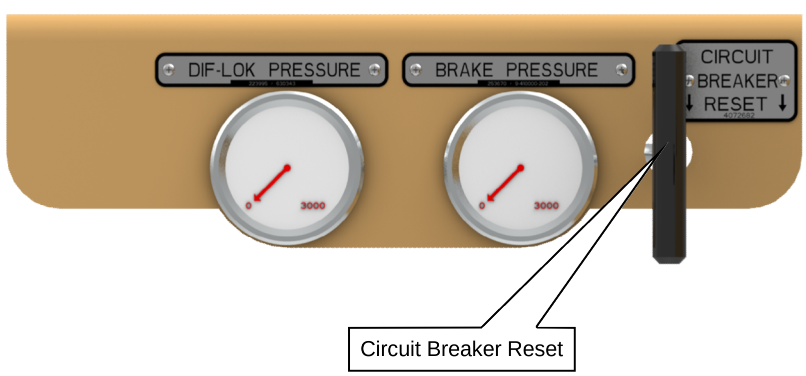
WARNING!
This unit is equipped with a cab or canopy. Be careful not to hit your head when entering or leaving the operator's compartment. This machine must not be operated without the canopy in place.

General

1. Disconnect the steering lockout device and store in the lugs provided.
2. The right emergency stop button shall not be depressed.

   The battery plugs must be engaged
3. Sit in the operator's seat and adjust the seat position relative to the foot and hand controls.

Fig. 22: Machine circuit breaker reset (in cab)



WARNING!
Be sure no one is in the Hazard zone (Fig. 21) before operating any levers or pedals.

Never try to adjust the operator's seat while the machine is in motion. Do not operate the machine with any part of your body outside the operator's compartment to prevent having body parts caught between the unit and outside objects.

Note: Either tape strip stop switch may be pressed at any time to trip the machine circuit breaker, set the park brake, and to de-energize the tram and pump motors.

Note: The “STOP” button may be pressed at any time to set the park brake and to de-energize the tram and pump motors (Fig. 23).

4. Depress and hold the service brake pedal.

5. Press the “DIAGNOSTICS” button on the Control Station to begin on board diagnostics. Hold the button until a message is displayed on the HiPAC 10 display. If the display message indicates “SYSTEM OKAY”, continue. If any other message is displayed, press the ’STOP” button and contact a CAT® service representative.

6. Set the machine circuit breaker. After receiving the “System OK Message” (Fig.22)

7. Test the Emergency stop tape switches before beginning each shift. Pressing either the right or left tape switch should break the control circuit; stopping all motors and applying the park brake. If the tape switch fails to trip, press “STOP” on the Control Station and contact a CAT® service representative. After testing one side repeat steps 4 through 6 (for the other side) and if both tape switches work correctly, proceed to step 8.

8. Test all Control Station functions before beginning each shift following steps 9 through 22. If any function does not operate correctly, turn off the machine circuit breaker and contact a CAT® service representative.

9. To start the pump motor, press and hold the “PUMP MOTOR START” button on the Control Station until the pump motor starts. Note: Can only be started in “PARK, FORWARD, or REVERSE” on the TRAM rotary switch.

10. To turn off the pump motor, press “STOP” on the Control Station. Or rotate the TRAM rotary switch to the off position

11. To release the park brake (pump motor must be running), press and hold the “PARK BRAKE RELEASE” on the Control Station until the dashboard display indicates “PARK BRAKE RELEASED”. The TRAM rotary switch must be in either FORWARD or REVERSE for the park brake to be released.

12. To set the park brake and leave the pump motor running, rotate the TRAM switch to the “PARK” position

13. To turn off the pump motor and set the park brake, press “STOP” or rotated the TRAM rotary switch to “OFF”

14. To activate a tramming direction (the pump motor must be running and the park brake must be released), rotate the TRAM switch to the desired direction until the dashboard display indicates direction of travel.

15. The accelerator pedal may now be depressed to control the machine.

WARNING!
The machine is equipped with a solid state speed controller. This means that the farther the speed switch foot pedal is depressed, the faster the machine will tram.

16. To change direction of travel, rotate the TRAM switch to the desired direction, the dashboard display will indicates direction of travel.

17. Each time the direction of travel is changed, the accelerator pedal will require recycling through the off position.

18. To disable tramming, rotate the TRAM switch to the “OFF” or “PARK” position.

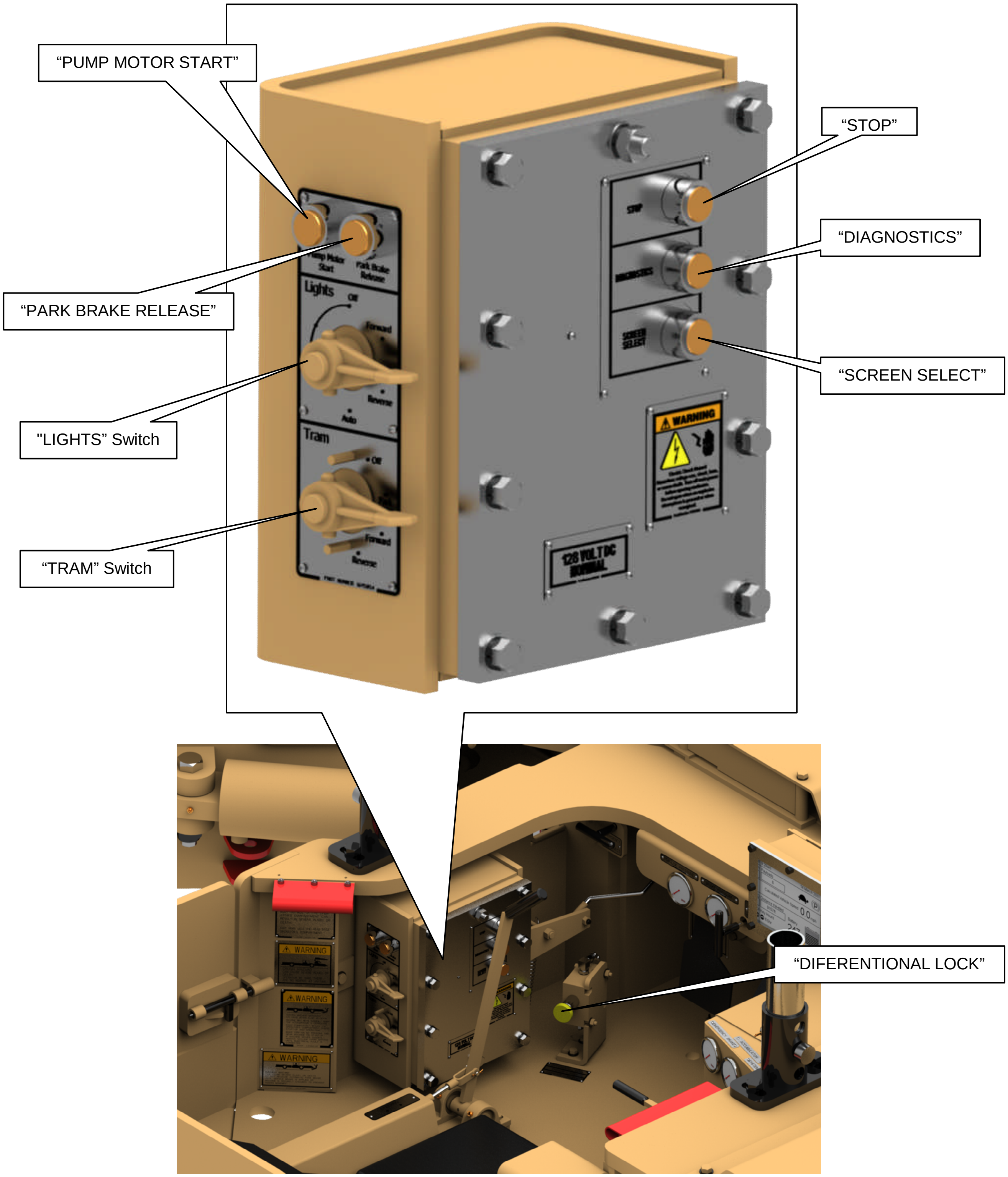
19. To leave pump motor running, set park brake, and disable tramming, Rotate the TRAM rotary switch to “PARK”

20. To disable tramming, turn off the pump motor, and set the park brake, press the “STOP” button on the Control Station, or press either Emergency tape strip switches.

21. Rotate the LIGHTS switch on the Control Station to the desired light direction.

22. For auto position headlights, rotate the “LIGHTS” switch on the Control Station to the “AUTO” position where the headlights follow the tram direction.

Fig. 23: Control Station



Shutdown procedure

1. Tram the machine to its designated parking place and stop by releasing the accelerator pedal and depressing the foot brake pedal. When the speed-switch foot pedal is released, the tram (traveling) motors will slow down and stop pending grade. Applying the foot brake will stop forward (or reverse) motion. The hydraulic pump's electric motor will still be running.

2. Ensure that the attachment is lowered to the surface. If equipped with a bucket, ensure that the ejector blade is returned to the back of the bucket. There should be no obstructions between the back of the bucket and ejector blade.

WARNING!
Always check before moving the ejector blade control lever to make sure no one has any part of their body between the ejector blade and the back of the bucket.

Note: Refer to Fig. 23 for illustration of Control Station.

3. Press “STOP” to turn off the machine. Do not leave the operator’s compartment before turning the machine off.

4. Press the emergency stop switch, turning off the machine circuit breakers.

5. Connect the steering lockout device (Fig. 24):

   a. disconnect the hitch pin from the end of the lockout device closest to the center section

   b. adjust turnbuckle until holes line up between the turnbuckle lug and the front section lug

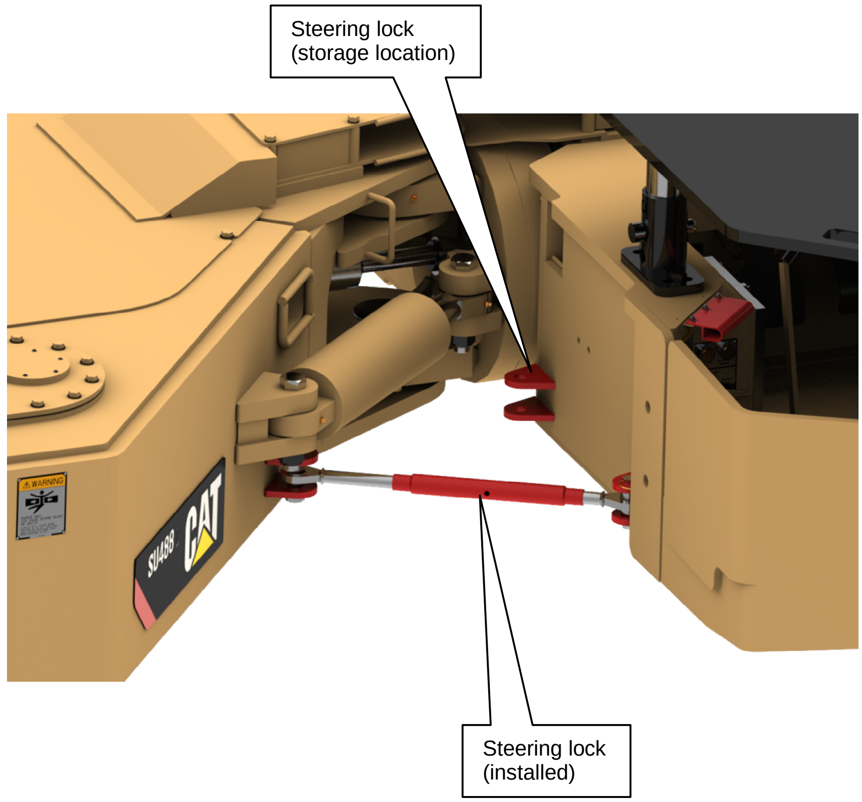
   c. insert the hitch pin into the rear section lug through the turnbuckle

WARNING!
Never enter the articulation area while the machine is running. Completely shutdown the machine as outlined before connecting the steering lockout device. Failure to observe this precaution may result in injury or death.

CAUTION!
This unit is equipped with a cab/canopy. Be careful not to hit your head when entering or leaving the operator's compartment.

WARNING!
In the event of an emergency, the machine may be shut down by striking either tape strip stop switch or either emergency stop button.

Fig. 24: Steering lockout device



Towing a disabled machine

WARNING!
It is not possible within the scope of this guide to anticipate all possible arrangements for towing a disabled vehicle. All possible precautions must be taken to protect the operators and all personnel around either vehicle from being injured by the towing vehicle, the towing device used (cables, bars, etc.), or the towing vehicle (scoop, tractor, etc.). The towing vehicle must be strong and heavy enough to maintain control of both vehicles through all bottom conditions that may be encountered. Safety chains or other safety devices must be used in case of failure of the primary towing device. Both operators must be alert at all times to prevent either unit from running away during towing. The vehicle to be towed must be securely coupled to the towing vehicle before the brakes are released on the disabled unit. The operator of the towing vehicle must be in place in the towing vehicle with the brakes applied before the brakes of the disabled vehicle are released.

1. Couple the towing vehicle securely to the disabled vehicle.
2. Close the valve to tank circuit that is on the hand pump to isolate the park brake solenoid from the circuit.
3. Begin pumping the hand pump. The building pressure moves the shuttle valve and allows the park brake system to be pressurized.
4. The park brake should be released when the “EMERGENCY BRAKE” pressure gauge reads 138 bar (2,000 psi).

CAUTION!
For long distance towing, disconnect and remove front and rear drive lines.

WARNING!
At no time during towing should anyone ride in or on the vehicle being towed or stand in between the towing vehicle and the disabled vehicle.

5. Begin towing the vehicle.
6. Once the destination is reached, stop both vehicles and set the parking brake on the disabled vehicle before removing the towing devices. The disabled vehicle should be chocked in both directions at all four wheels for additional stability. The brake is set by turning the valve handle on the hand pump to “NORMAL RE-APPLY”.

WARNING!
Failure to set the parking brake on the disabled vehicle before removing the towing device could allow the disabled vehicle to roll away uncontrolled.

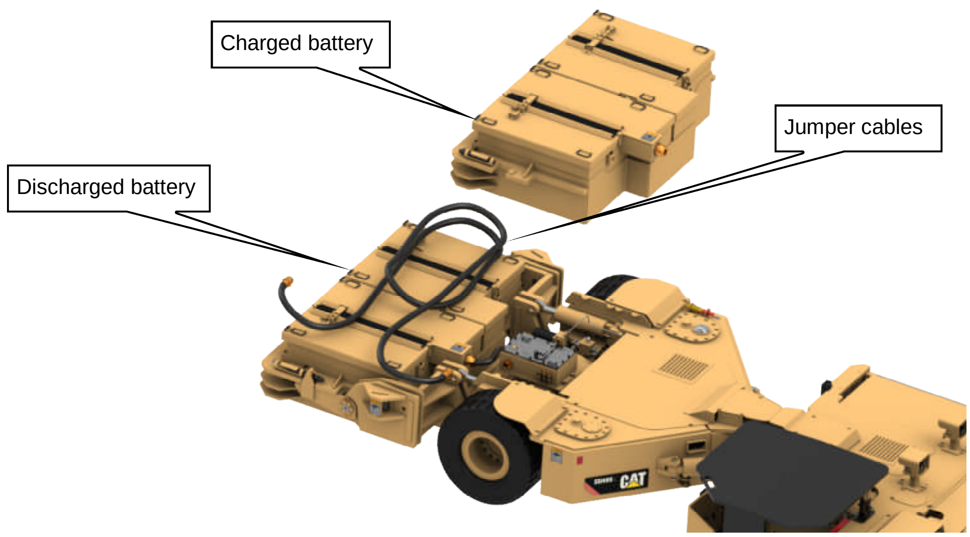
Battery change procedure

Two people are needed to change the battery.

DANGER!
The person disconnecting and connecting the battery will be in the Hazard Zone, therefore, the machine operator must be very careful and look each time before moving any levers or pedals. Take time now to familiarize yourself with the Hazard Zone.

1. Line up the battery end of the machine with the place where the battery is to be deposited (Fig. 25).

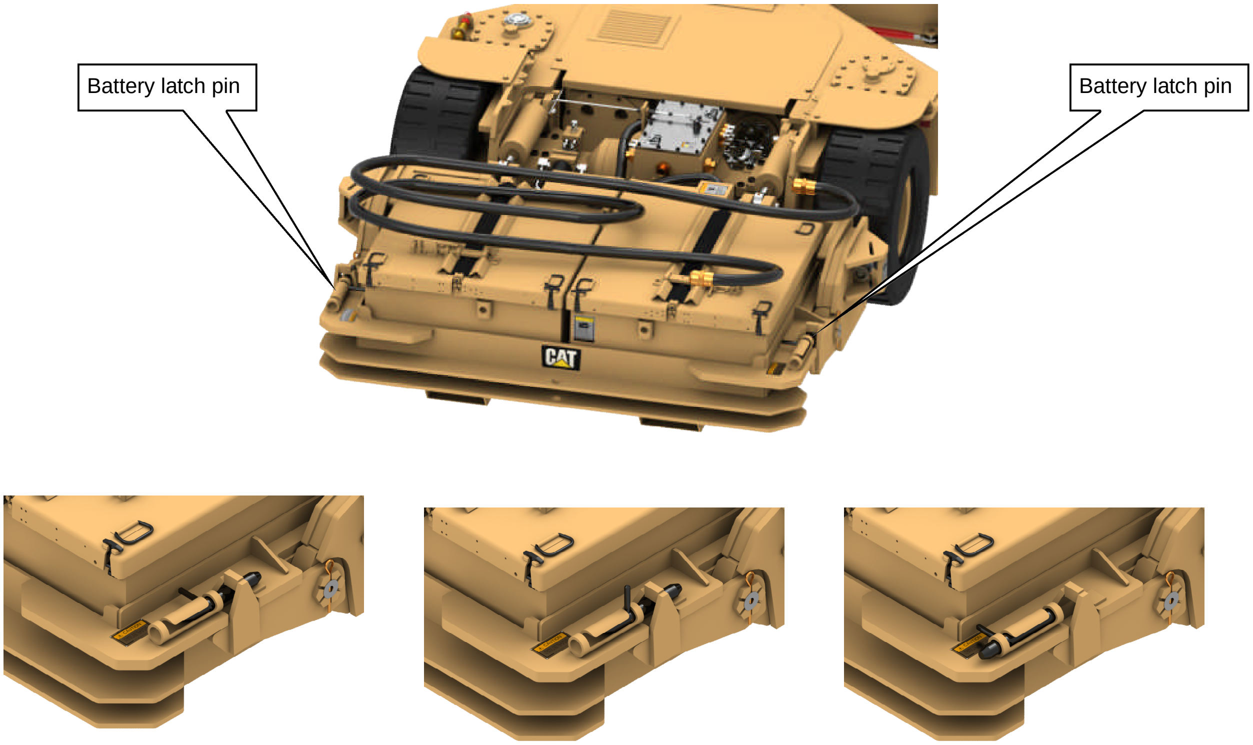
Fig. 25: Battery change procedure



WARNING!
The battery change control lever should never be operated except at a battery change station or when it is necessary to adjust the battery's terrain clearance. If the battery change control lever is operated in a low roof area, the battery may be damaged.

2. Unlatch both battery latch pins before placing the battery on the ground (Fig. 26). If difficulty is encountered in unlatching the latch pins, it may be necessary to gently shake the battery up and down by using the battery "BATTERY" control lever.

Fig. 26: Battery pins



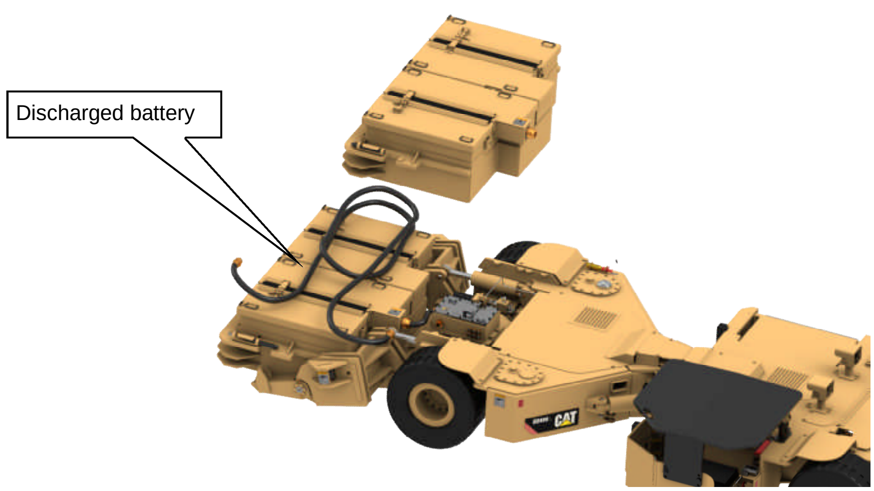
Latch pin shown in locked position

Latch pin shown in raised position

Latch pin shown in unlocked position

3. Lower the battery completely to the surface by pushing the “BATTERY” control lever away from the operator. The bottom of the battery should touch the surface (Fig. 27).

Fig. 27: Lowered battery



4. After the battery is fully lowered, shutdown-the machine (see Shutdown Procedure in this manual).

5. Disconnect the discharged battery (Fig. 28):

   a. Unlock and remove the padlock at the battery connector.

   b. Grasp the threaded lock ring and rotate it counterclockwise (CCW) until the threads are disengaged and it is free to slide away from the locking lug; the lock ring is designed to move freely but to not come off the plug.

   c. Grasp the plug and pull it out until the plug is completely disconnected from the receptacle; the plug is made to fit very tightly inside the battery receptacle and-should not be driven out of the receptacle, dropped, or handled roughly; if the plug (or receptacle) is damaged, it will not fit together properly.

   d. Install the cap which is secured to a receptacle on the battery by a small chain; this cap is placed over the threaded receptacle and rotated in a clockwise (CW) direction until hand tight and until a padlock will fit into the locking lug; the padlocks all use the same key.

6. Connect the jumper cable:

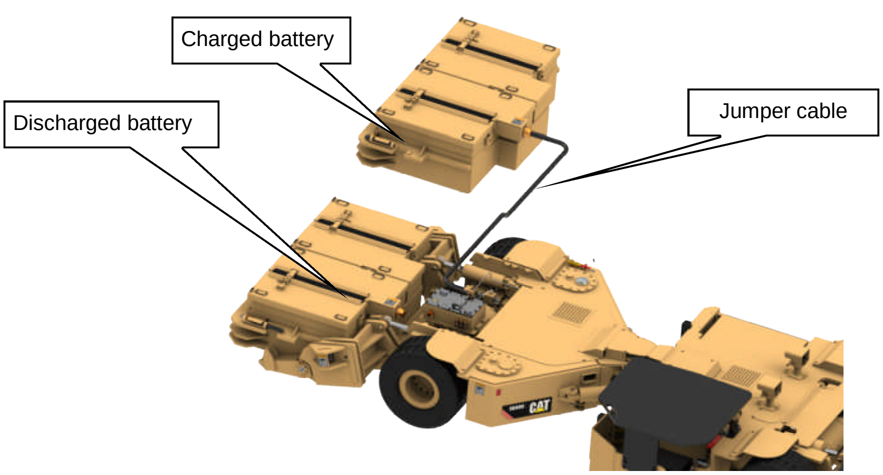
   a. Connect the receptacle end of the jumper cable to the plug coming out of the connection box on the machine (Fig. 28).

   b. Connect the plug end of the jumper cable to the fully charged battery.

   c. Secure the jumper cable connections by using the threaded lock rings. These lock rings must be hand tight but do not have to be padlocked.

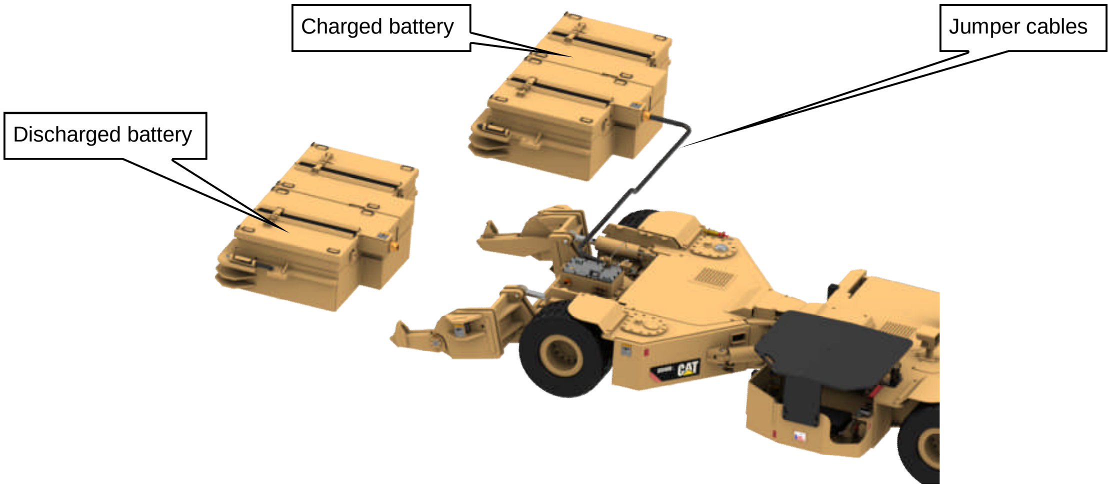
   d. Ensure that the jumper cable is secure and will not be damaged or be run over when the machine is moved.

Fig. 28: Jumper cable connection



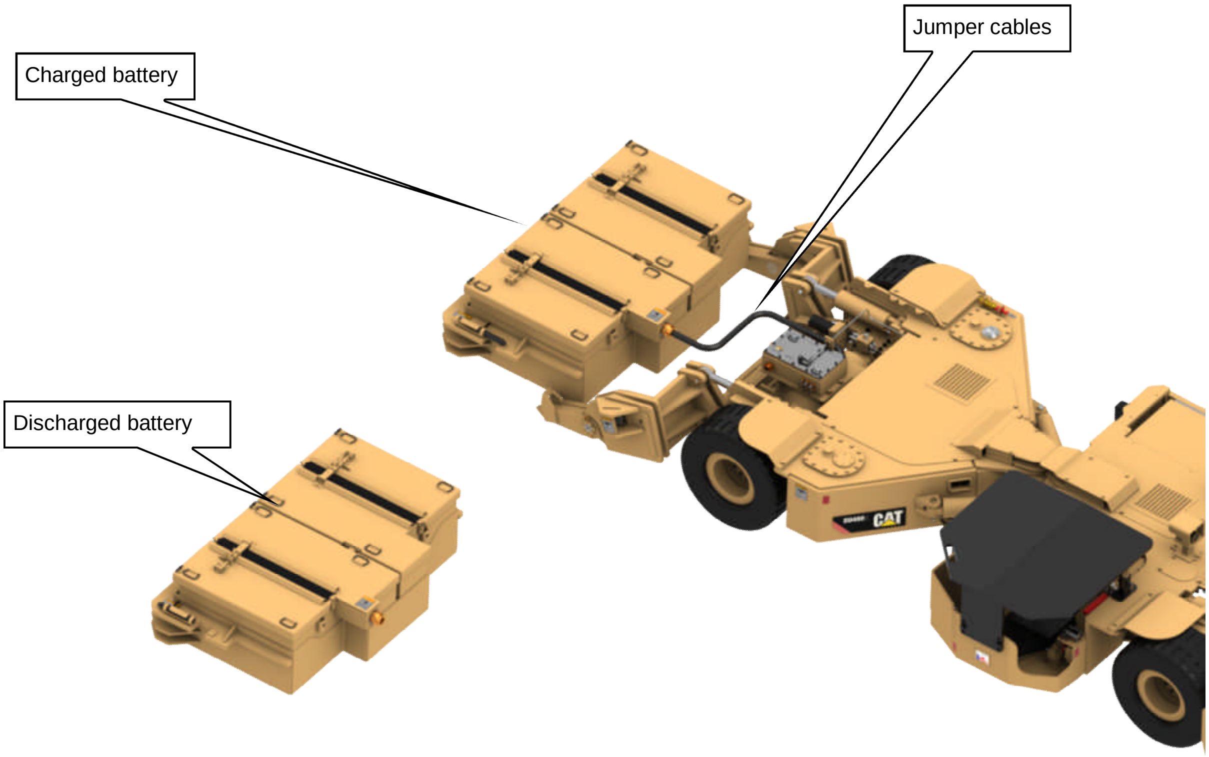
7. Start the machine (see Starting Procedure in this manual). Gently pull away from the discharged battery. Ensure that the jumper cable is secure from possible damage (Fig. 29).

Fig 29: Discharged battery removed



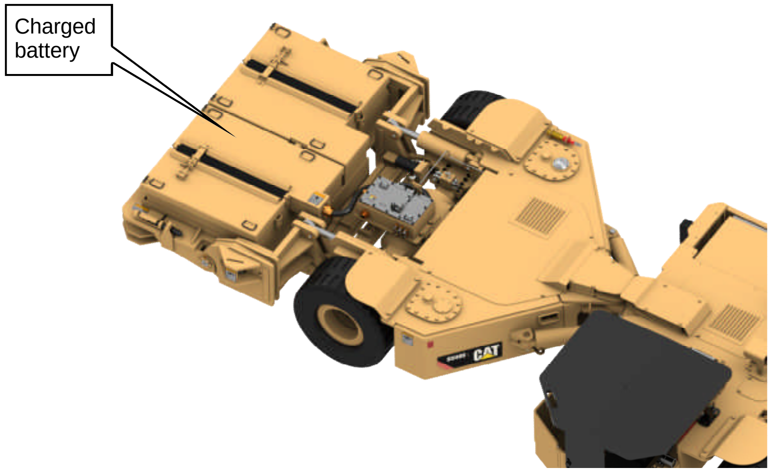
8. Line up the machine with the fully charged battery. Move the machine back until the lift arms are aligned with the sides of the battery (Fig. 30).

Fig. 30: Machine in position with charged battery



9. Raise the battery to the carry position by pulling the "BATTERY" lever toward the operator (Fig. 31).

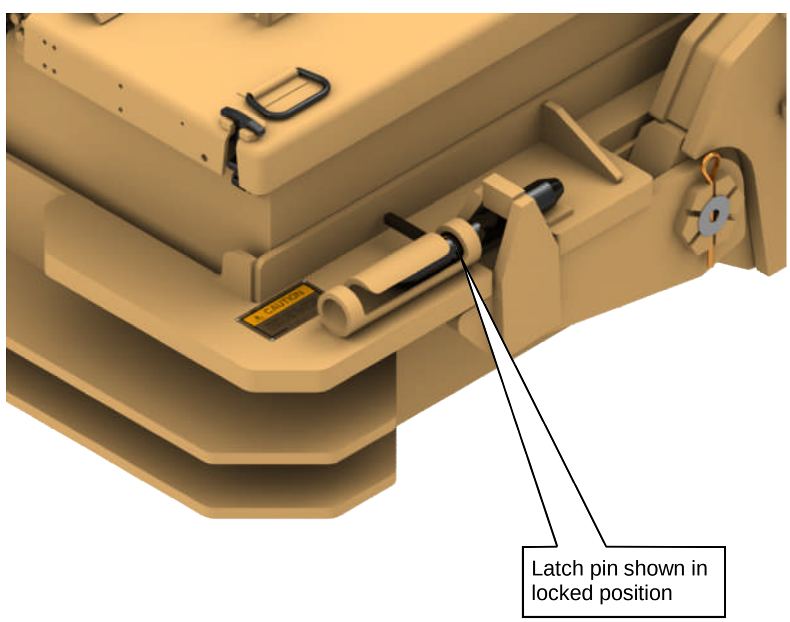
Fig. 31: Charged battery in carry position



10. Reinsert the latch pins on both sides of the battery (Fig. 32). If difficulty is encountered in latching the latch pins, it may be necessary to gently shake the battery up and down by using the battery "BATTERY" control lever.

11. Shutdown the machine (see Shutdown Procedure in this manual).

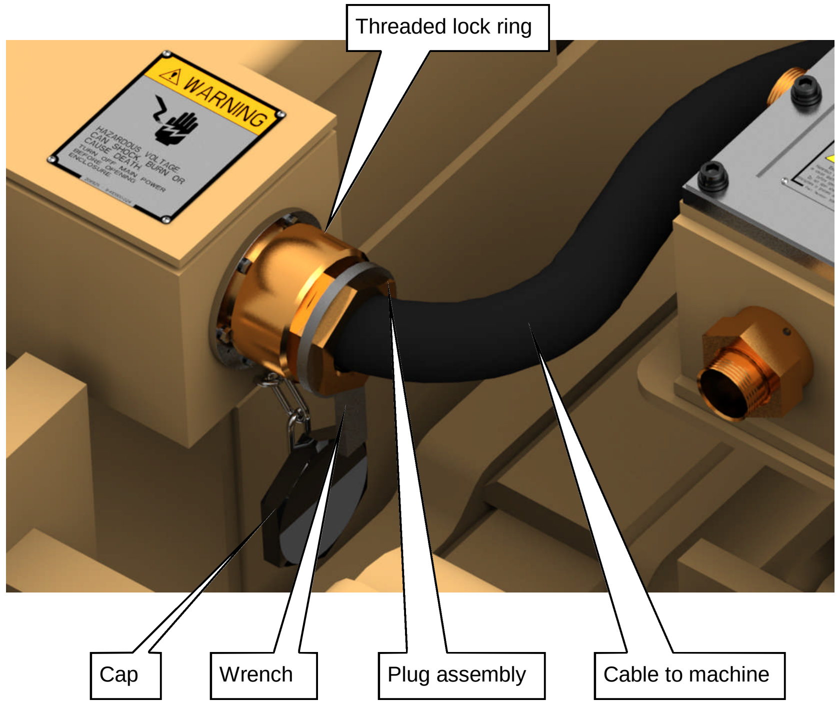
Fig. 32: Latched battery pins



12. Disconnect the jumper cable and connect the charged battery directly to the machine's cable (Fig. 33). Remember to be careful with the plugs. After the plug is in the receptacle, the lock ring should be rotated clockwise (CW) until hand tight. The padlock must be in the locking lug and locked for this connection to be permissible.

13. Start the machine (see Starting Procedure in this manual).

Fig. 33: Battery plug and receptacle assembly (typical)



Instructions on the maintenance

Maintenance at regular intervals increases the operational safety and prolongs the service life of the machine. In particular, observe the safety instructions in chapter 2 “Your safety”.

Important notes

Please observe the following:

- In order to avoid individual components not being serviced or being only inadequately serviced during maintenance work on the machine as a whole, we recommend that a general maintenance plan be drawn up. You can, for example, draw up a checklist using this operation manual and the manuals of the other components.
- Inadequate maintenance can result in machine damage which leads to considerable costs.
- Use only suitable and approved tools for maintenance work.
- Use only original CAT® spare parts when replacing components.
- All electrical work must be supervised and inspected by a certified electrician.
- Anyone performing maintenance on this equipment must be trained to operate it and be familiar with this operation and maintenance manual.

Before maintenance

Please observe the following:

- Shutdown the machine on level ground.
- Disconnect the electrical power by placing the battery circuit breaker in the "OFF" position. If work is to be done inside the electrical controller, the battery should be disconnected. Also, make sure the capacitor discharge module indicates that the capacitors are discharged before working inside the controller.

WARNING!
Before performing maintenance on the machine, disconnect the electrical power by placing the battery circuit breaker in the "OFF" position. If work is to be done inside the electrical controller, the battery should be disconnected. Also make sure the capacitor discharge module indicates that the capacitors are discharged before working inside the controller. Electrical shock and accidental machine movement can cause serious injuries or death.

- Test the controls to ensure that the unit will not move.
- Chock all four (4) wheels in each direction.
- Connect steering lockout device.

WARNING!
Do not move any hydraulic control lever unless you are certain that everyone is completely clear of any machine movement. Accidental machine movement can cause serious injuries or even death to you or the maintenance person.

- During maintenance or servicing, if drive motors are to be run, the machine must be jacked clear of the ground and securely blocked. All four wheels must be free to rotate. The center section should also be blocked securely.

WARNING!
You could be seriously injured or killed by falling loads. Observe the safe working load limits of lifting or blocking devices and keep a safe distance from suspended loads.

- Do not perform maintenance on a circuit while there is a load resting on the hydraulic cylinder. Booms must be securely blocked if maintenance is to be performed with the boom in the raised position.

WARNING!
Never disconnect a hydraulic hose if the circuit is pressurized or if there is a load on the circuit. If a hose is disconnected while the circuit is pressurized or a load is on the circuit, the load will fall causing damage to the machine or serious injury or death to you or other workers.

WARNING!
Do not lift the front or rear wheels of the machine off the surface by tilting the lift attachment down and lowering the battery, except for maintenance procedures.

- Do not perform maintenance in a congested area. This could endanger the maintenance person or others in the vicinity.
- Whenever a potential problem is uncovered during a periodic maintenance check, it is imperative that it be corrected immediately by a qualified maintenance technician.
- Cleanliness can not be overemphasized as the essential ingredient of a good maintenance program. Machines should be kept as free as possible of dirt and debris which could impede performance or infiltrate systems and cause premature wear or failure.

WARNING!
If any welding is to be done to the machine, the circuit breakers must be in the "OFF" position and the battery disconnected. Failure to do so may cause electrical component damage.

Critical torque values

Torque values are expressed in lubricated values.

Table 1: Critical torque values

Location	Bolt size	Grade	Lubricated
Steering cylinder pins	2” x 7.5”	8	460
Tire-Wheel mounting nuts	3/4-16 x 2 1/2”	8	300
Drive motor-to-gear case mounting bolts	3/4” NC X 2-3/4”	5	282 (382 m-n)

Lubricants, fluids and capacities

Table 2: Lubricants, fluids and capacities

Location	Specification	Approximate capacity	Notes
Hydraulic oil tank	Spec. 100-1	40 gal (151.5 l)	1
Gear box (reducer)	Spec. 100-6	As Required	
Lubrication points	Spec. 100-3	As Required	3
Axle housing	John Deere Hy-Gard Oil	As Required	2
Planetary differential	John Deere Hy-Gard Oil	As Required (each wheel end)	2
Wet disc brakes	Spec. 100-12	As Required	2

Notes:

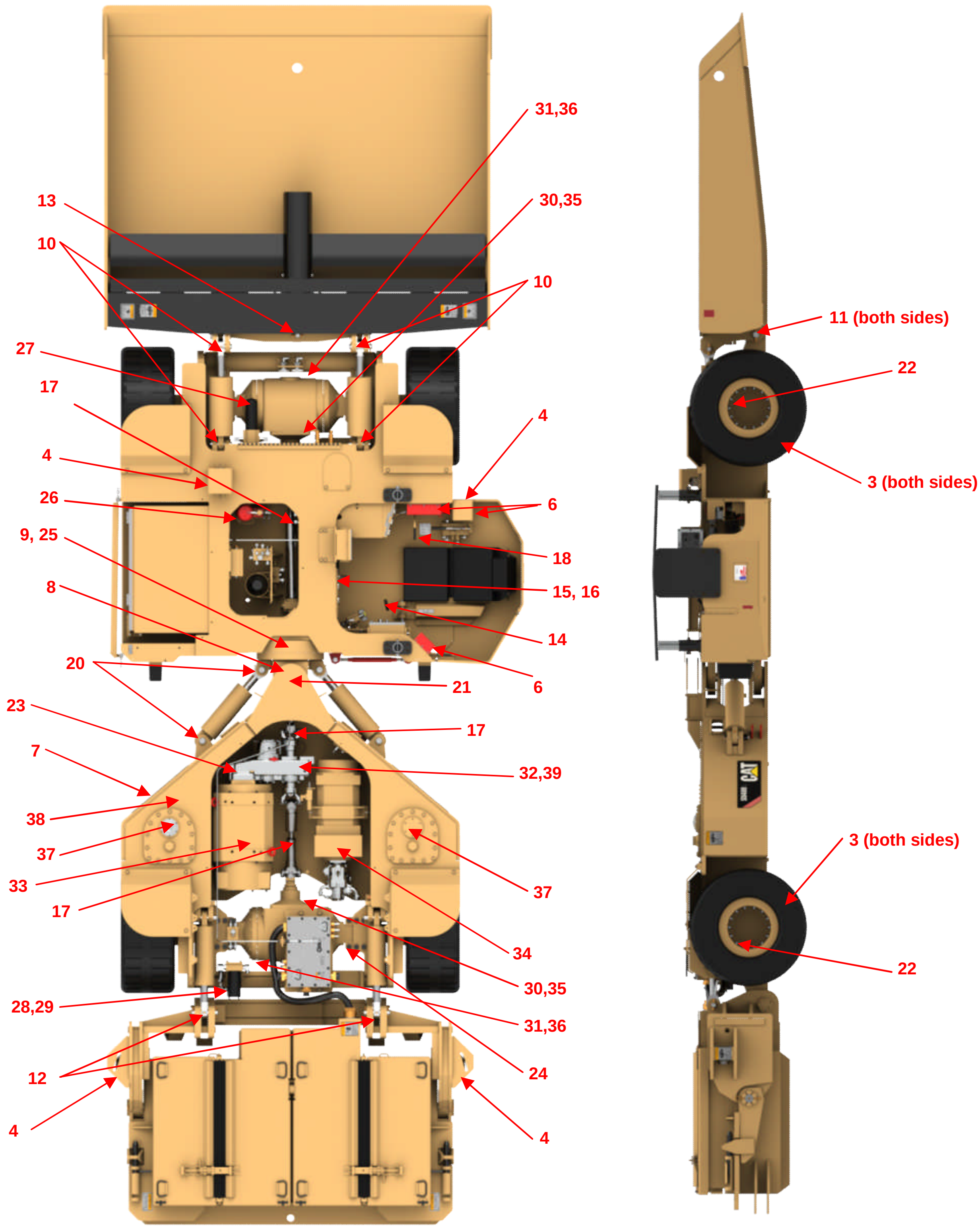
1. With ejector blade completely retracted.
2. The axle housing, brake cooling sumps, and planetary wheel end assemblies do not have a common oil source. Each assembly must be filled separately. Make sure the level and fill hole in the planetary wheel end cover is in the proper position. Rotate the wheel end as required to bring the fill hole to either the 3 o'clock or 9 o'clock position. When filling the axle housing and planetary wheel ends, allow enough time for the lubricant to fill the various cavities and around component parts in each assembly. Continue adding oil into each assembly until the required oil level is reached
3. Pump grease into fitting until old grease can be observed coming out of component.
4. When bleeding brakes, bleed both ports at the same time.

Table 3: Lubrication and maintenance schedule

Item	Description	Places	Lubricant	Specification
	Every shift			
1	Electrical cables and conduits	Inspect		
2	Hydraulic hoses and fittings	Inspect		
3	Tires (Inspect)	4		
4	Headlights (Inspect)	4		
5	Warning tags and reflectors	Inspect		
6	Emergency stop switches (Check)	3		
7	Hydraulic oil level	1		Spec. 100-1
	Weekly			
8	Center section pivots	2		Spec. 100-3
9	Oscillating bearing (Grease)	8		Spec. 100-3
10	Attachment tilt cylinders (rods & bases)	4		Spec. 100-3
11	Tilt plate attachment pivot point	2		Spec. 100-3
12	Battery lift cylinders (rod ends only)	4		Spec. 100-3
13	Ejector cylinder	1		Spec. 100-3
14	Left hand steering	2		Spec. 100-3
15	Accelerator pedal	2		Spec. 100-3
16	Brake pedal	1		Spec. 100-3
17	Drive line	6		Spec. 100-3
18	Valve handles	5		Spec. 100-3
19	Fasteners (Nuts, bolts, and screws)	Inspect		
20	Steering cylinder pins	Inspect		
21	Center section pins and nuts	Inspect		
22	Tire-Wheel mounting bolts	Inspect		
23	Drive motor to gear case mounting bolts	Inspect		
24	Axle mounting bolts	Inspect		
25	Oscillating bearing mounting bolts	Inspect		
26	Fire suppression system	Inspect		
27	Return filter (Change as required)	1		
28	Pressure filter (Change as required)	1		
29	Mini in-line filter (Change as required)	1		
30	Axle oil level (Check)	2	John Deere Hy-Gard	
31	Planetary differential oil level (Check)	4	John Deere Hy-Gard	
32	Speed reducer (gear case) oil (Check)	1		Spec. 100-6
	Monthly			
33	Drive motor	Inspect		
34	Pump motor	Inspect		
	Every 3 months			
35	Axle oil (Change)	2	John Deere Hy-Gard	
36	Planetary differential oil (Change)	4	John Deere Hy-Gard	
37	Hydraulic oil (Change)	1		Spec. 100-1
38	Tank suction strainer	1		
39	*Speed reducer (gear case) oil (Change)	1		Spec. 100-6

* Change after the first 500 hours of operation and then every three months.

Fig. 34: Lubrication & Inspection chart



Every shift

electrical cables and conduits hydraulic hoses and fittings tires and headlights

Inspect all electrical cables, conduits, hydraulic hoses, fittings, tires, and headlights for signs of wear or damage. Repair or replace any damaged item.

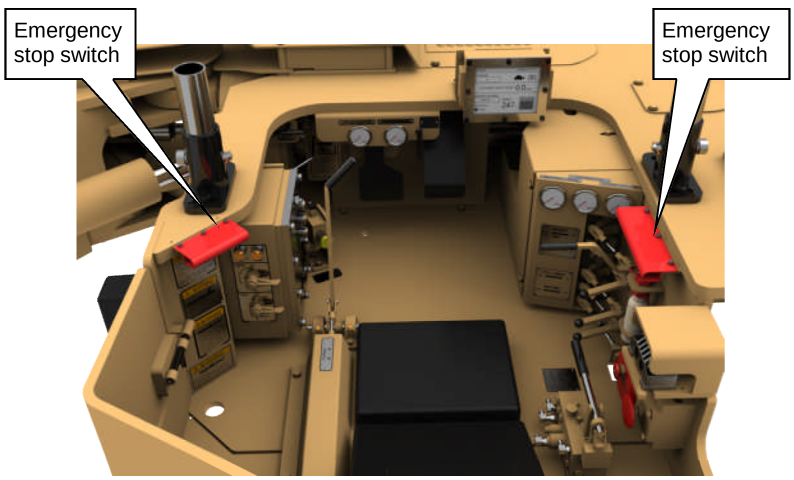
warning tags and reflectors

Visually inspect the condition and readability of all warning tags, labels, and reflectors. Replace all that are found missing or damaged.

emergency stop switches

Check the emergency stop switches located inside the operator's compartment (Fig. 35) (see Start up procedure).

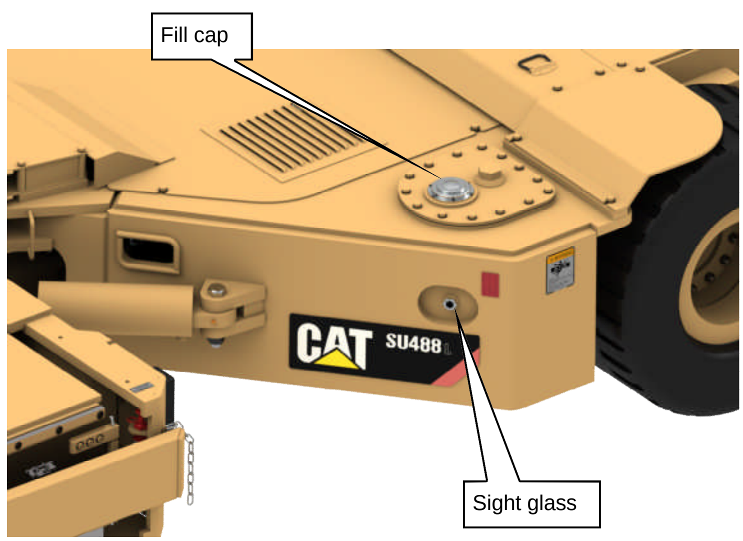
Fig. 35: Emergency stop switch locations



hydraulic oil level

Check the hydraulic oil level by looking at the sight glass located on the oil tank (Fig. 36). If the oil level is low, add oil (Spec. 100-1).

Fig. 36: Hydraulic oil level (typical both tanks)

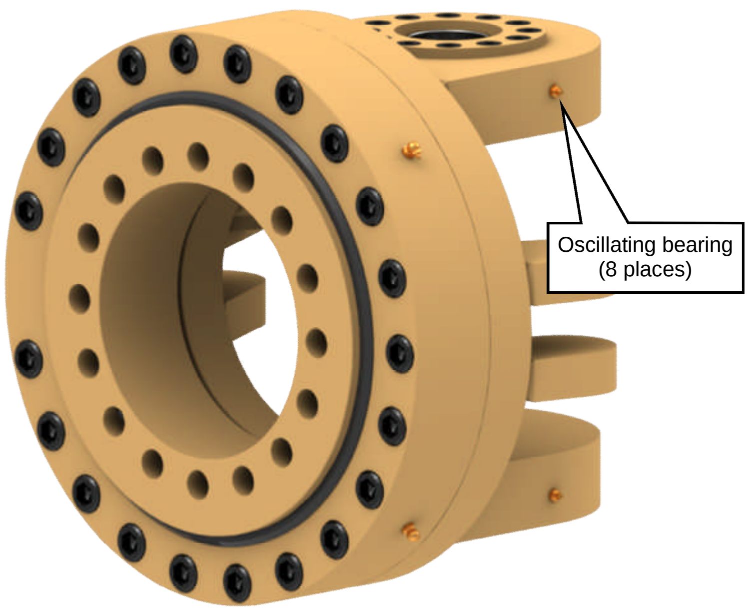


Weekly

oscillating bearing

Lubricate the oscillating bearing (8 places) with Spec. 100-3 grease through the grease fittings located around the bearing (Fig. 38). Pump grease into the fittings until new grease can be observed coming out of the bearing.

Fig. 38: Oscillating bearing lubrication points



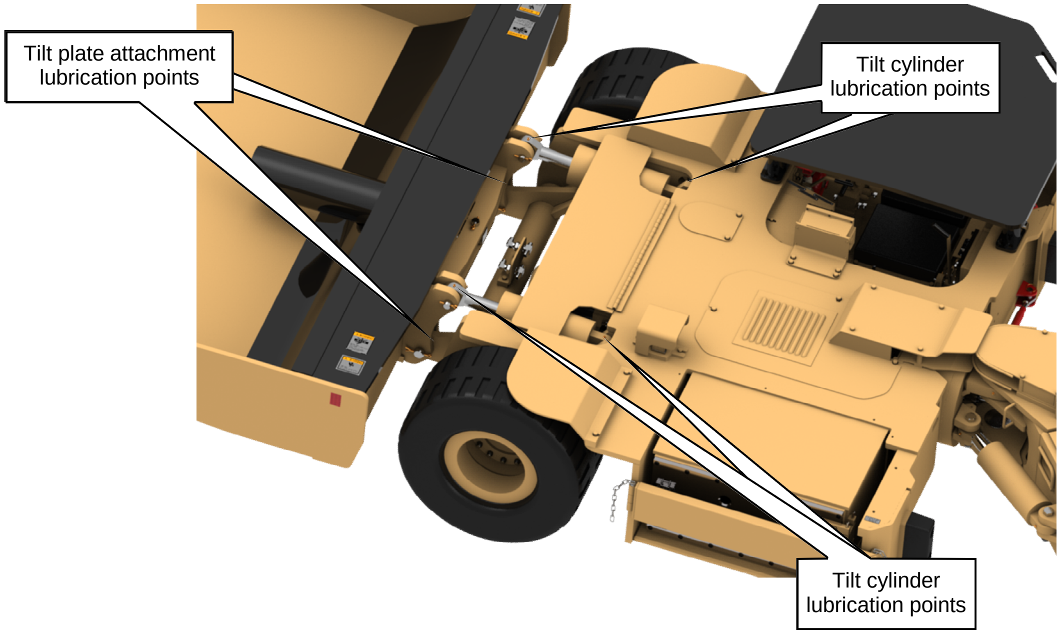
tilt cylinders (rod ends)

Lubricate the tilt cylinder (4 places) with Spec. 100-3 grease through the grease fittings located on the rod ends and bases of each cylinder (Fig. 39). Pump grease into the fittings until new grease can be observed coming out of the pins.

tilt plate attachment pivot point

Lubricate the lift plate attachment pivot points (2 places) with Spec. 100 -3 grease through the grease fitting located on the bearing (Fig. 39). Pump grease into the fitting until new grease can be observed coming out of the bearing.

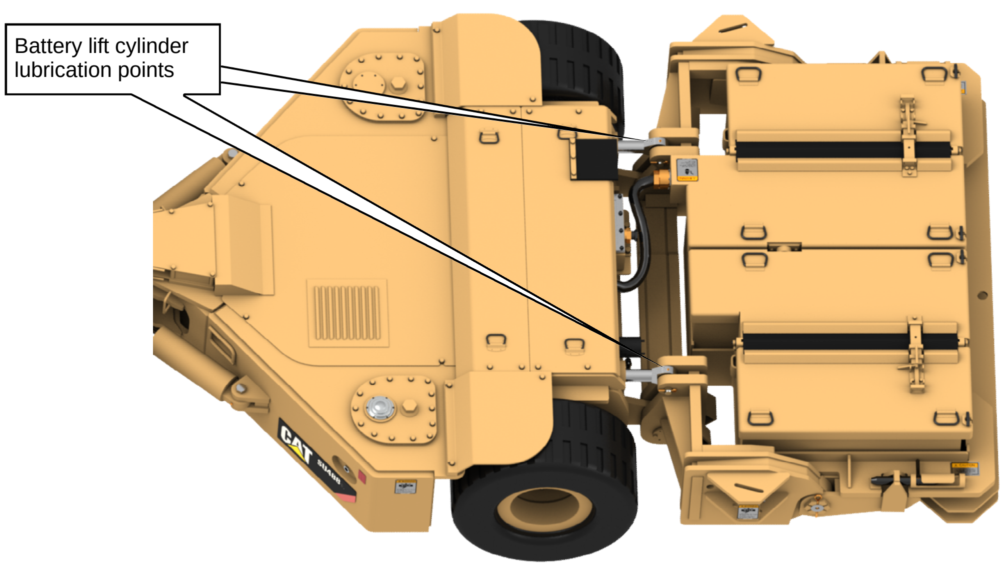
Fig. 39: tilt cylinder and tilt plate lubrication points



battery lift cylinders (rod ends)

Lubricate the battery lift cylinders (2 places) with Spec. 100-3 grease through the grease fittings located on the rod end of each cylinder (Fig. 40). Pump grease into the fittings until new grease can be observed coming out of the pins.

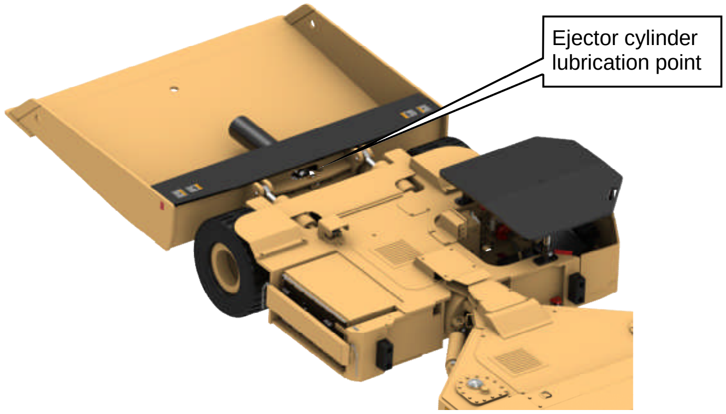
Fig. 40: Battery lift cylinder lubrication points



ejector cylinder

Lubricate the ejector cylinder rod end (1 place) with Spec. 100-3 grease through the grease fitting located at the back of the bucket (Fig. 41). Pump grease into the fitting until new grease can be observed coming out of the pin.

Fig. 41: Ejector cylinder lubrication points



accelerator pedal

Lubricate the accelerator pedal (2 places) with Spec. 100-3 grease through the grease fittings located on each pillow block bearing. Pump grease into the fittings until new grease can be observed coming out of the bearings.

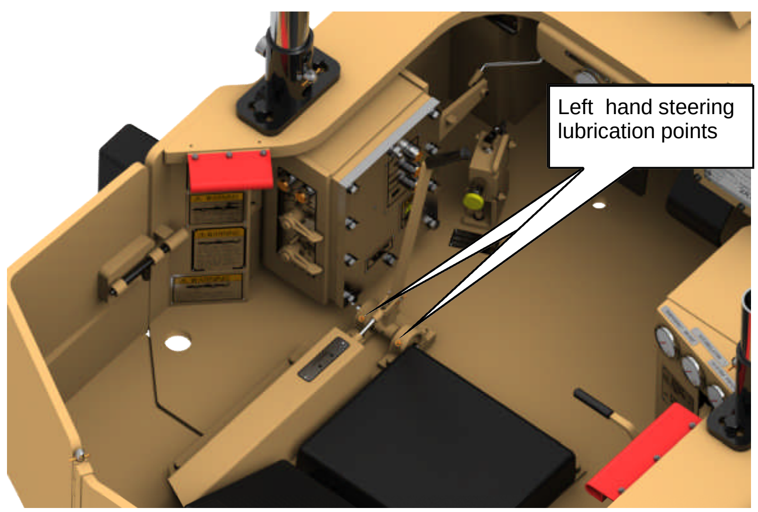
brake pedal

Lubricate the brake pedal with Spec. 100-3 grease through the grease fittings located on each pillow block bearing. Pump grease into the fitting until new grease can be observed coming out of the bearing.

left hand steering

Lubricate the left hand steering handle (2 places) with Spec. 100-3 grease through the grease fitting located on each pillow block bearing (Fig. 42). Pump grease into the fitting until new grease can be observed coming out of the bearing.

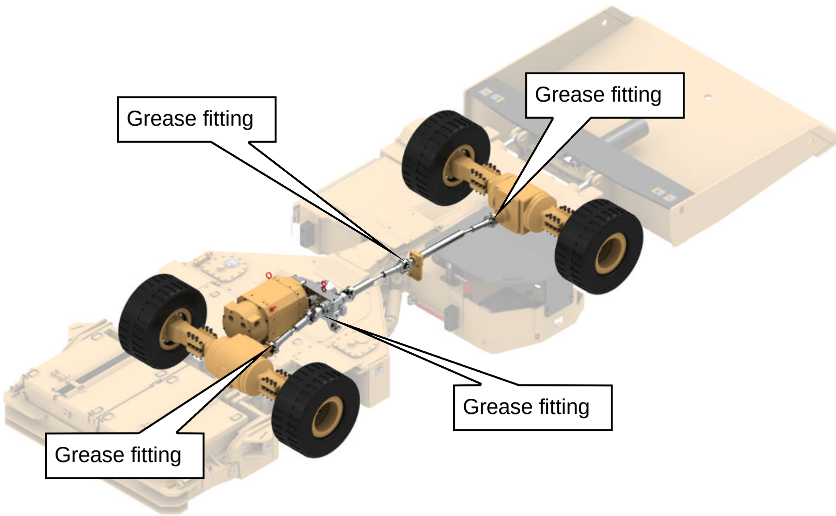
Fig. 42: Left hand steering lever lubrication points



front and rear drive lines

Lubricate the front and rear drive lines (4 places) with Spec. 100-3 grease through the grease fittings located on each cross bearing (Fig. 43). Pump grease into the fittings until new grease can be observed coming out of the bearing.

Fig. 43: Front and rear drive line lubrication points



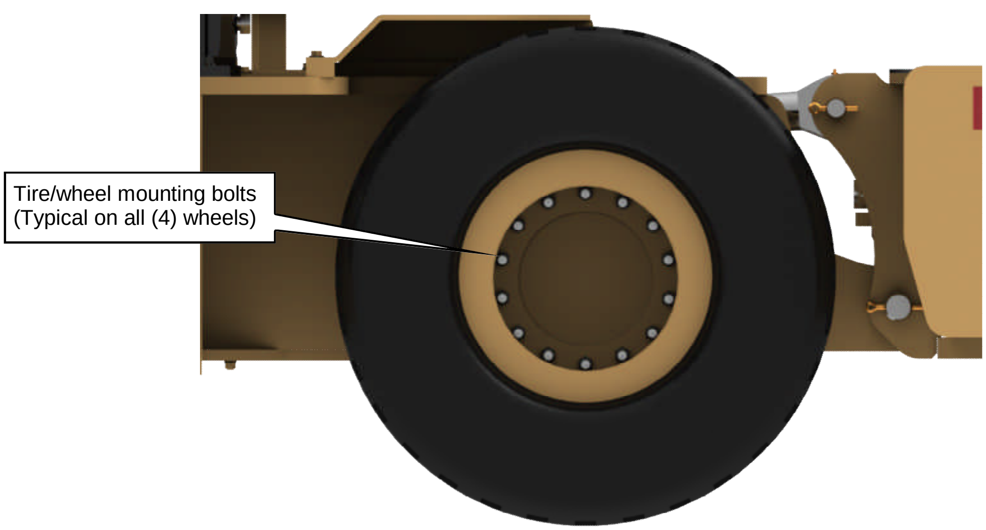
fasteners (nuts, bolts and screws)

Loose fasteners will cause premature wear and failure to machine and components. Visually inspect for loose fasteners and tighten as required.

tire/wheel mounting bolts

Check the wheel mounting bolts (Fig. 44). The mounting nuts should be torqued to 300 ft-lbs lubricated. Use Loctite 242 on wheel mounting bolts.

Fig. 44: Tire/wheel mounting nuts



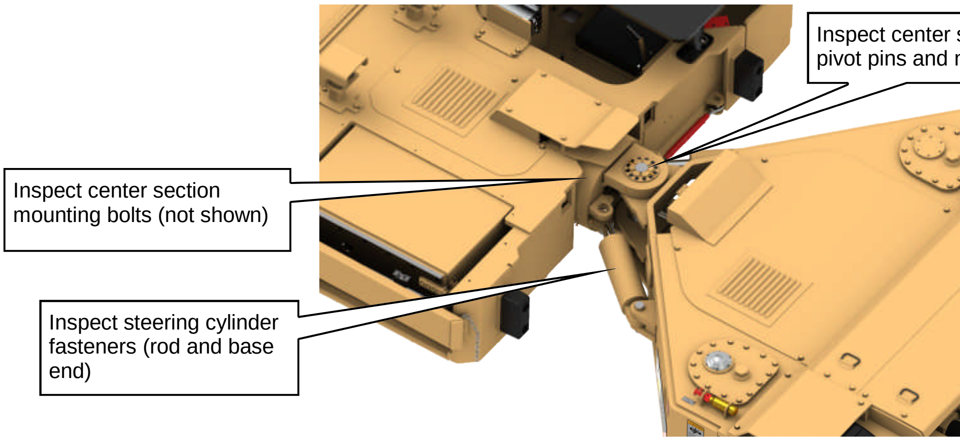
center section pins and nuts

Inspect the center section pins and nuts for looseness or wear (Fig. 45). Tighten where necessary and replace any worn parts.

steering cylinder pins and nuts

Inspect the steering cylinder pins and nuts for looseness or wear (Fig. 45). Tighten (460 ft -lbs lubricated) where necessary and replace any worn parts.

Fig. 45: Center section and steering cylinder pins and nuts



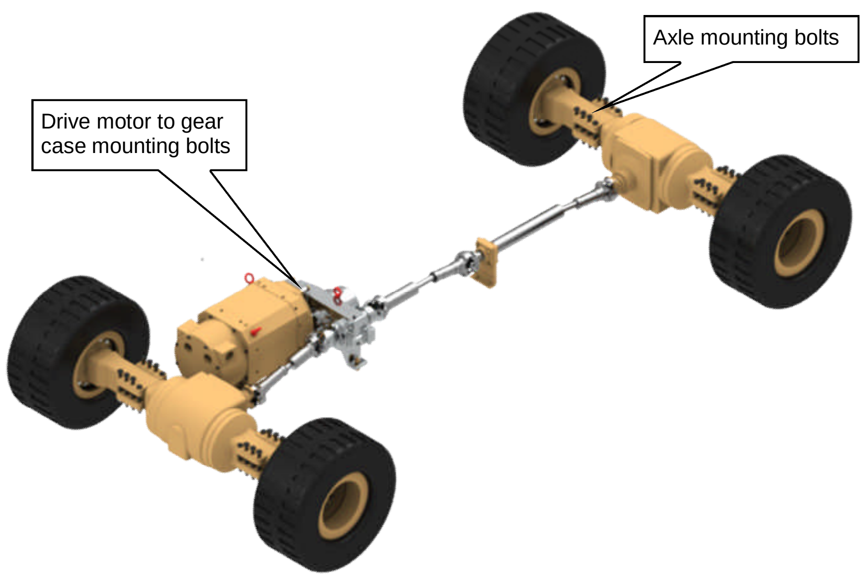
drive motor to gear case mounting bolts

Check the drive motor to gear case mounting bolts on both front and rear drive assemblies (Fig. 46). The mounting bolts should be torqued to 280 - 320 ft-lbs lubricated. Use Loctite 242 on mounting bolts.

axle mounting bolts

Check the axle mounting bolts on both front and rear axles (Fig. 46). The mounting bolts should be torqued to 455 ft-lbs lubricated. Use Loctite 242 on mounting bolts.

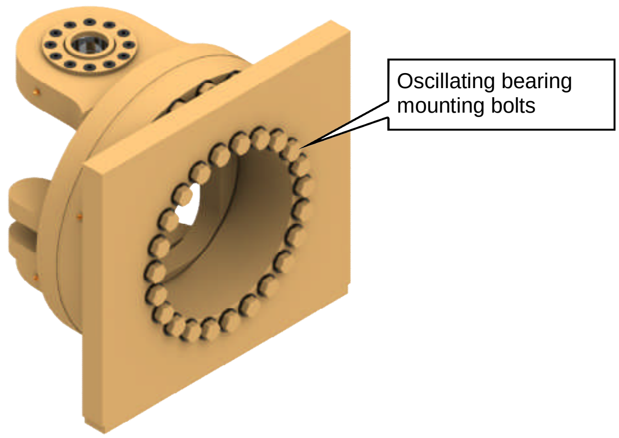
Fig. 46: Drive motor to gear case and axle mounting bolts



oscillating bearing mounting bolts

Check the oscillating bearing mounting bolts (Fig. 47). The mounting bolts should be torqued to 750 ft-lbs, lubricated. Use Loctite 242 on mounting bolts.

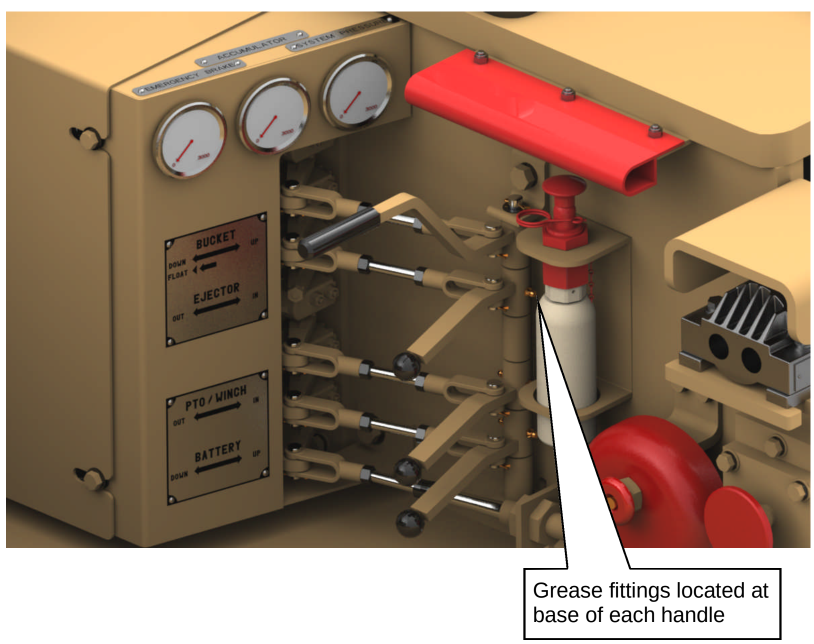
Fig. 47: Oscillating bearing mounting bolts (typical)



valve handles

Lubricate the valve handles (5 places) with Spec. 100-3 grease through the grease fittings located at the base of each handle (Fig. 48). Pump grease into the fittings until new grease can be observed coming out of the fitting.

Fig. 48: Valve handle lubrication points

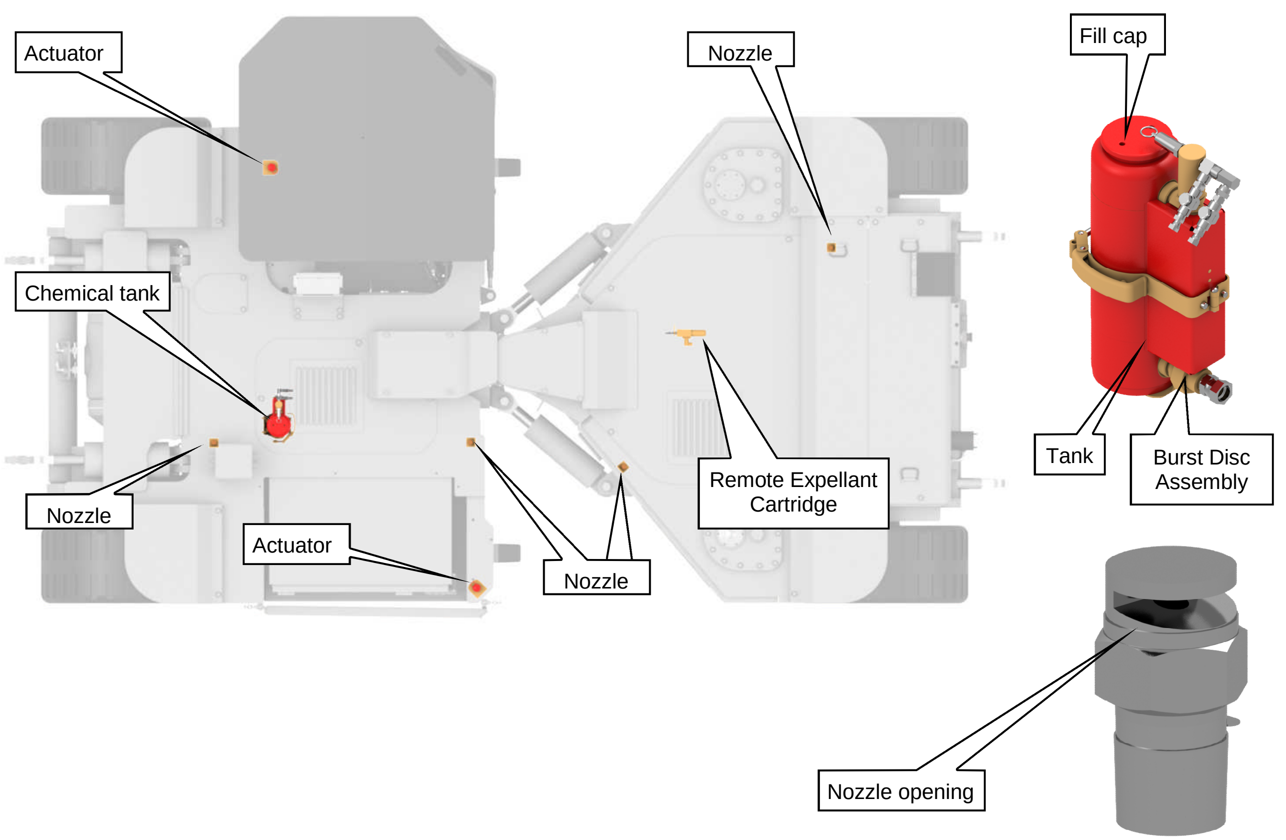


fire suppression system

Check the fire suppression system (Fig. 49).

- Inspect the hoses, fittings, and nozzles and replace any found damaged.
- Check the extinguisher tank for signs of damage or corrosion. The extinguisher tank is located in the middle section of the machine.
- Check the nozzle openings. The slot should be packed with silicone grease. If the nozzles are open or need to be repacked, the lines should be checked for blockage and blown clear before repacking them with clean silicone grease.
- Remove the fill cap.
- Check that the extinguisher is filled with free flowing Ansul multipurpose A, B, C dry chemical to a level not more than 3 inches (75 mm) from the bottom of the fill opening.
- Replace the fill cap, hand tight.
- Disconnect discharge connection union of tank output and inspect burst disc assembly. Replace if damaged to insure proper operation of material discharge.

Fig. 49: Fire suppression system



pressure filter

Inspect the pressure filter dirt alarm (Fig. 50) located on the head of the filter. If the alarm indicates the filter element (s) is dirty, replace element (s).

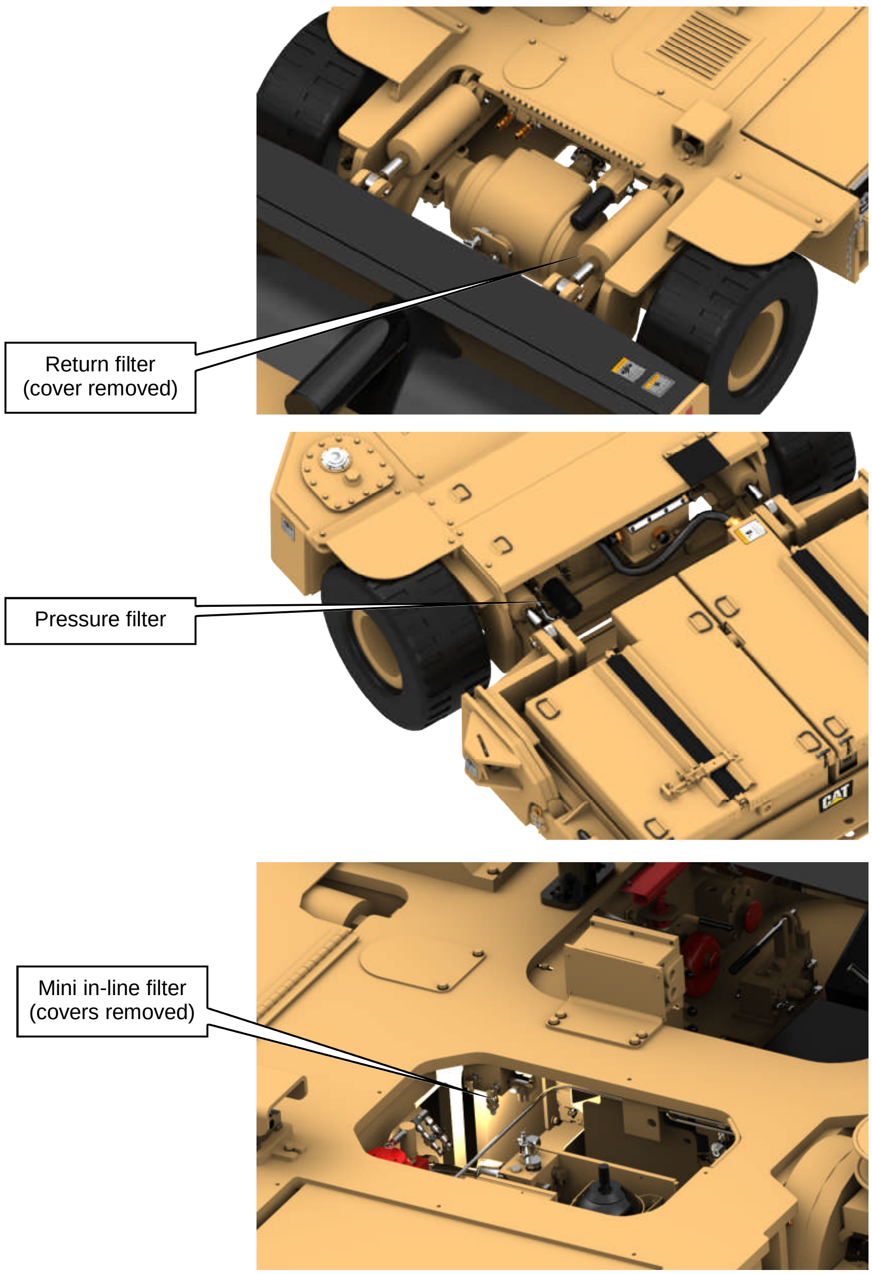
return filter

Inspect the return filter dirt alarm (Fig. 50) located on the head of the filter. If the alarm indicates the filter element is dirty, replace element.

mini in-line filter

Inspect the mini in-line filter screen (Fig. 50) located on the brake solenoid assembly. If the screen is dirty, the screen can be cleaned. If the screen has been damaged, it must be replaced.

Fig. 50: Filter locations



axle oil level

Check the oil levels of both drive axles (Fig. 51).

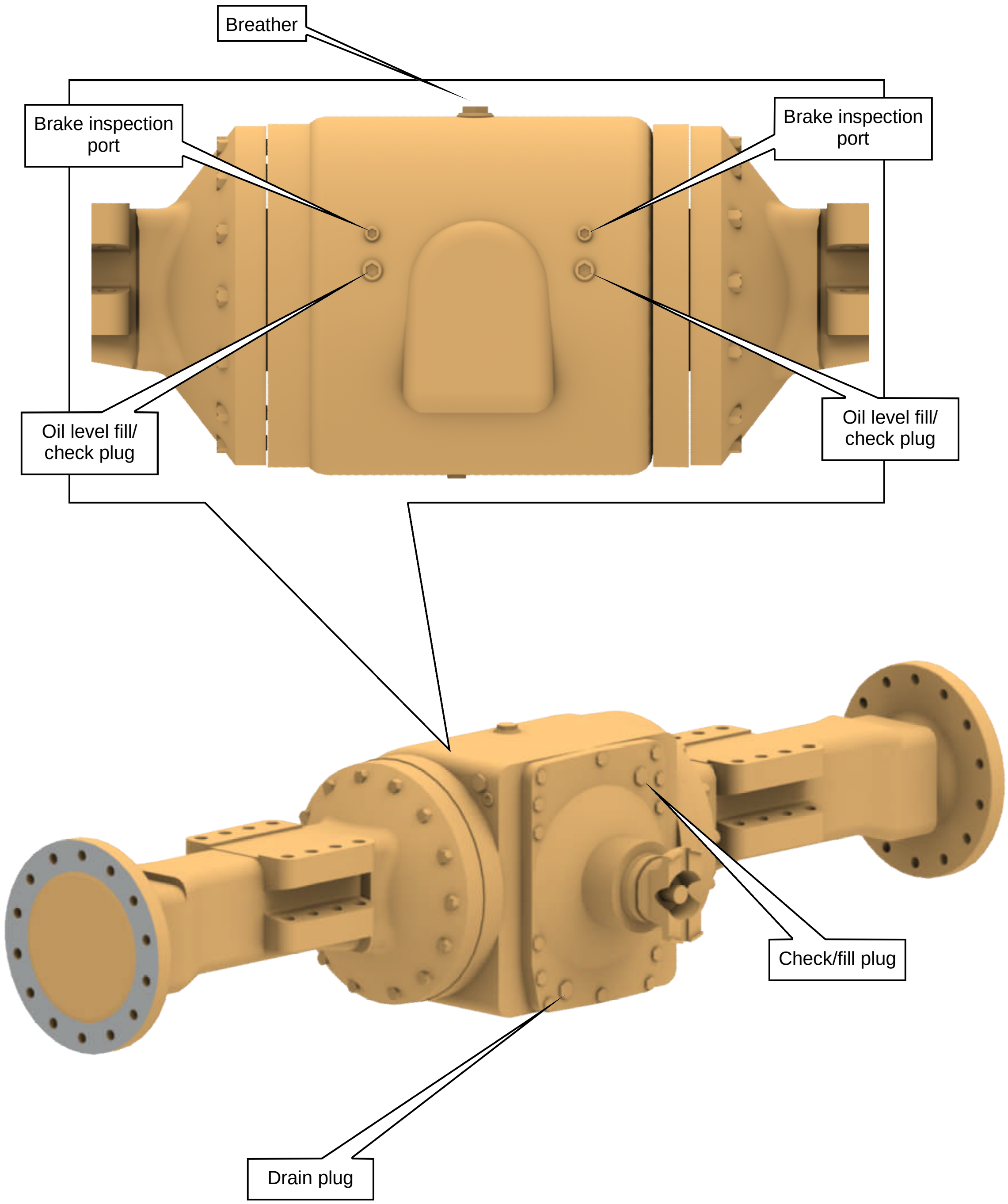
- Park the machine on solid level ground and remove the oil level/fill plug (s).
- Make sure the level/fill hole for the planetary wheel end cover is in the proper position. Rotate the wheel end as required to bring the hole to either the 3 o'clock or 9 o'clock position. (as applicable)
- The oil should just barely flow out from the level/fill hole when full.
- Should it be necessary to add oil, add the oil (John Deere Hy-Gard Oil) through the level/fill plug hole slowly, just until it starts to run back out. Allow time for the oil to travel throughout the axle when filling.

planetary oil level

Check the oil level in each planetary (Fig. 51).

- Park the machine on solid level ground, clean dirt and debris from around the drain plug and remove the plug.
- Make sure the check/fill and drain plugs are in the proper position. Rotate the wheel end as required until the check/fill plug is at the 3 o'clock or 9 o'clock position.
- Clean dirt and debris from around the check/fill plug and remove the plug.
- Oil should just barely flow out of the check/fill hole when full.
- If necessary, add oil (John Deere Hy-Gard Oil) through the check/fill plug hole slowly, just until it starts to flow back out.
- Clean and reinstall check/fill plug.

Fig. 51: Axle, planetary, and wet disc brake oil level

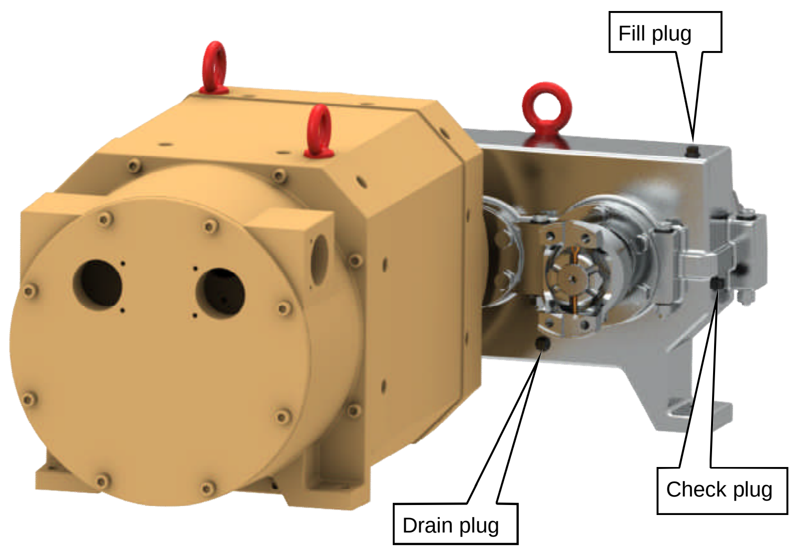


speed reducer (gear case) oil

Check the oil in the speed reducers (Fig. 52).

- Park the machine on solid level ground.
- Remove the check plug from the speed reducer (gearbox). The oil level should be kept at the level of the check plug.
- Should it be necessary to add oil, add the oil (Spec. 100-6) through the fill plug hole slowly until oil flows from the check plug hole. Do not overfill speed reducer.
- Replaced the check and fill plugs.

Fig. 52: Speed reducer (gear case) oil



Every three months

axle oil

Change oil in both axles (Fig. 54).

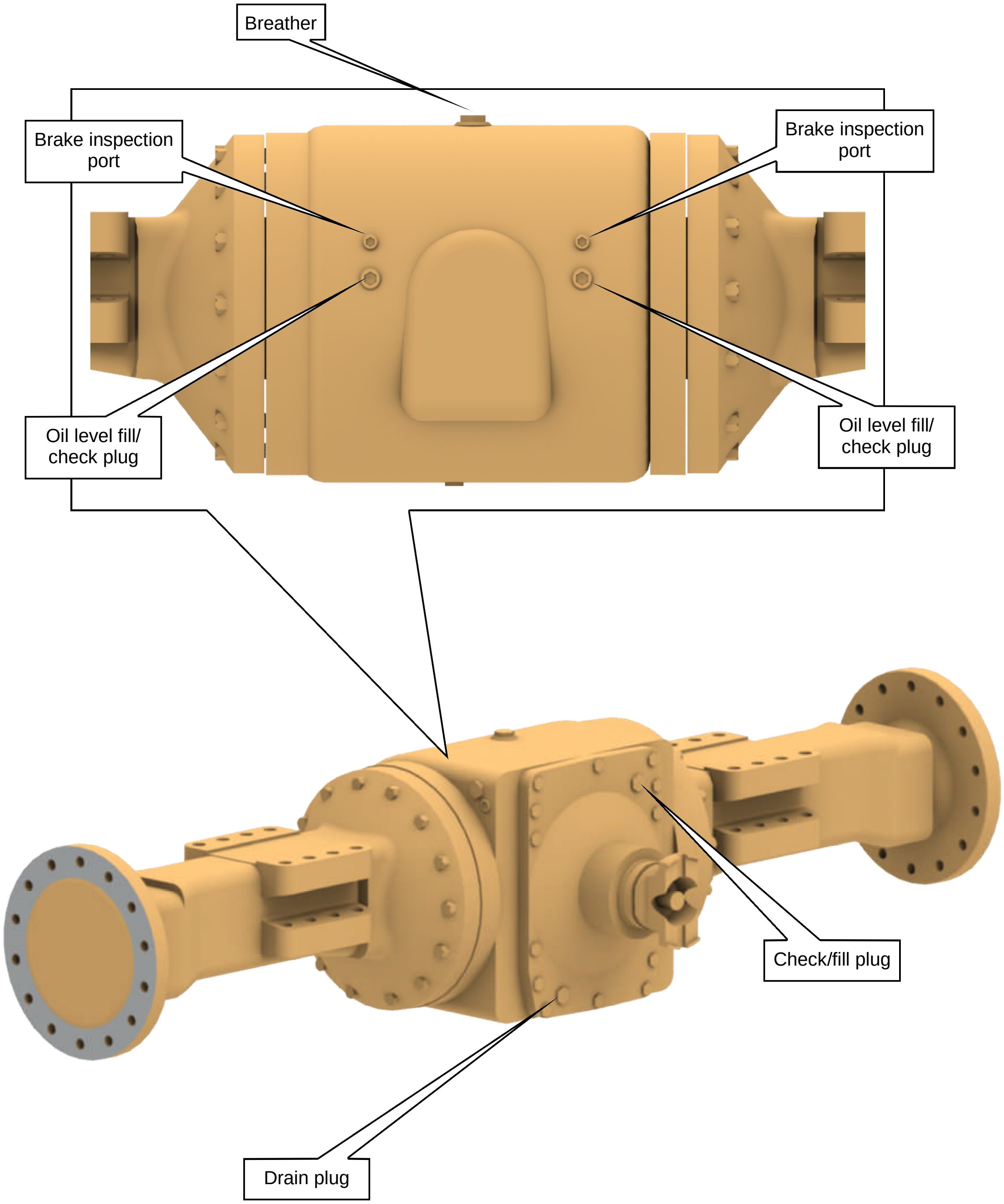
- Park the machine on solid level ground, clean dirt and debris from around the drain plug.
- Remove drain plug and allow oil to completely drain from the axle.
- Clean and reinstall drain plug.
- Clean dirt and debris from around the check/fill plug and remove plug.
- Add oil (John Deere Hy-Gard Oil) through the check/fill plug hole slowly, just until it starts to flow back out. Allow sufficient time for the oil to travel throughout the axle when filling.
- Clean and reinstall check/fill plug.

planetary oil

Change oil in each planetary (Fig. 54).

- Park the machine on solid level ground, clean dirt and debris from around the drain plug and remove the plug.
- Make sure the check/fill and drain plugs are in the proper position. Rotate the wheel end as required until the check/fill plug is at the 3 o'clock or 9 o'clock position and the drain plug is located on the bottom.
- Remove drain plug and allow oil to completely drain from the planetary.
- Clean and reinstall drain plug.
- Clean dirt and debris from around the check/fill plug and remove the plug.
- Add oil (John Deere Hy-Gard Oil) through the check/fill plug hole slowly, just until it starts to flow back out. Allow sufficient time for the oil to travel throughout the planetary wheel end when filling.
- Clean and reinstall check/fill plug.

Fig. 54: Axle and wet disc brake oil level

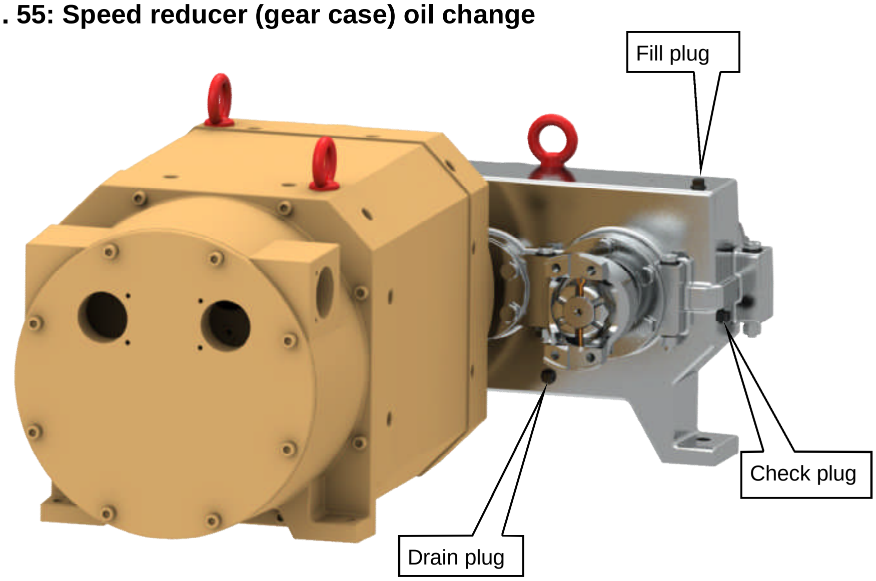


speed reducer (gear case) oil

Change the oil in the speed reducers (Fig. 55) after the first 500 hours of operation and every three months thereafter.

- Park the machine on solid level ground, clean dirt and debris from around the drain plug.
- Remove drain plug and allow oil to completely drain from the speed reducer.
- Clean and reinstall drain plug.
- Clean dirt and debris from around the check plug and remove.
- Clean dirt and debris from around the fill plug and remove.
- Add oil (Spec. 100-6) through the fill hole slowly, just until it starts to flow out of the check hole. Allow sufficient time for the oil to travel throughout the speed reducer when filling.
- Clean and reinstall check/fill plugs.

Fig. 55: Speed reducer (gear case) oil change

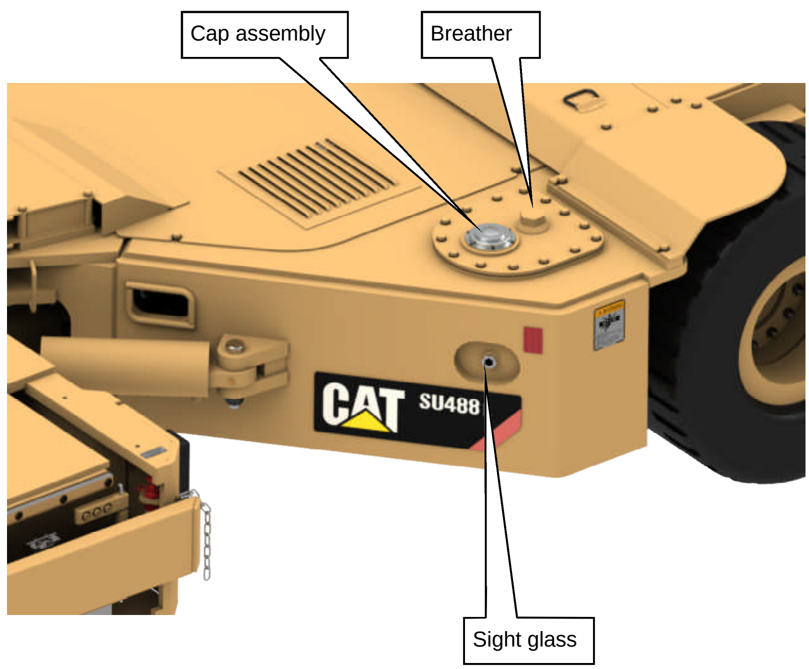


hydraulic oil change

Change oil and clean or change the suction strainer in the hydraulic oil tank (Fig. 56).

- Park the machine on solid level ground, clean dirt and debris from around the drain plug located on the side of the tank.
- Remove drain plug and allow oil to completely drain from the tank.
- Clean and reinstall drain plug.
- Clean dirt and debris from around fill cap.
- Remove the fill cap.
- Reaching down into each tank, unscrew the suction strainer and remove from tank.
- If the strainer is not torn or damaged, it can be cleaned using kerosene and a soft brush and dried thoroughly. If the strainer is damaged, it must be replaced.
- Replace the strainer in the tank and hand tighten.
- Replace the fill cap on the tank.
- Refill the tank to the proper level with Spec 100-1 oil.
- Start the machine and allow the hydraulic pump to run in order to purge air from the system.
- Shutdown the machine and recheck the oil level. Add oil if necessary.

Fig. 56: Hydraulic oil tank (typical both tanks)



The following procedure is for the initial start-up and pressure adjustments of the machine.

1. Insure that the suction port of the pump has been purged of any trapped air by loosening the suction port adapter until oil is present at that point then secure the adapter.
2. Insure that the pump case is full of oil by disconnecting the case drain hose and examining the case drain port for the presence of oil. If oil is not present at the case drain port, it should be filled manually. Once the case is full, secure the case drain connection to the pump.
3. Loosen the compensator adjustment on the pump (Fig. 59) and turn counterclockwise several turns prior to start up to insure that high pressure spikes are avoided during the initial pump operation.
4. The pump circuit control module (Fig. 60) is factory set at 3,500 psi (241 bar). With the pump compensator backed off, this setting will be satisfactory.
5. Install a pressure gauge in the gauge port of the pump circuit control module to monitor system pressure adjustments and to check for correct pump rotation.
6. Preset the brake cooling manifold as follows (as applicable; not required with the John Deere Axle option):
   a. Loosen the jam nut on the relief setting and turn the adjustment stem out (counterclockwise) all the way. Secure the jam nut.
   b. Loosen the jam nuts on the flow control valves and turn the adjustments all the way (clockwise) to close them off; then open each flow control 1½ turns (CCW) and secure the jam nuts.
8. Minimize all pressure reducing valve settings.
9. Insure that the jet fill or power fill tank system controls are closed.
10. Insure that the motor cutback switch cable is disconnected.
11. Bump (turn on then off) the pump two or three times to verify proper pump rotation (pressure should build at the gauge port of the pump circuit control module).
12. After the pump rotation is verified, the pump may be started and allowed to run continuously.
13. Read the system pressure on the gauge installed. Turn the pump compensator adjustment (Fig. 59) in (clockwise) until 2,400 psi (165 bar) is achieved and stable. Continue turning the compensator in (clockwise) to confirm the adjustment for the pump circuit control module (target is 3,500 psi (241 bar)).

Adjustment procedures

Adjust the pump circuit control module relief adjustment (clockwise to increase or counterclockwise to decrease) as required until 3,500 psi (241 bar) is achieved. Secure the adjustment of the pump circuit control module and then adjust the compensator back to 2,400psi (165 bar) and secure it in place.

14. Verify that the valve bank settings are 2,250 psi ± 50 psi (155 bar ± 3.5 bar). Note: When the winch option is not employed, the PTO section should be reduced to 1,800 psi (124 bar)

15. Adjust the pressure limiting devices for the auxiliary circuits.

16. Connect the motor cutback switch and adjust to 150 psi (10 bar). This pressure switch setting should allow the pump motor to cutback after two (2) seconds when the load sense (LS) signal from the valve bank falls below the adjusted setting and then come back up to speed when it senses 150 psi (10 bar).

Fig. 59: Pump

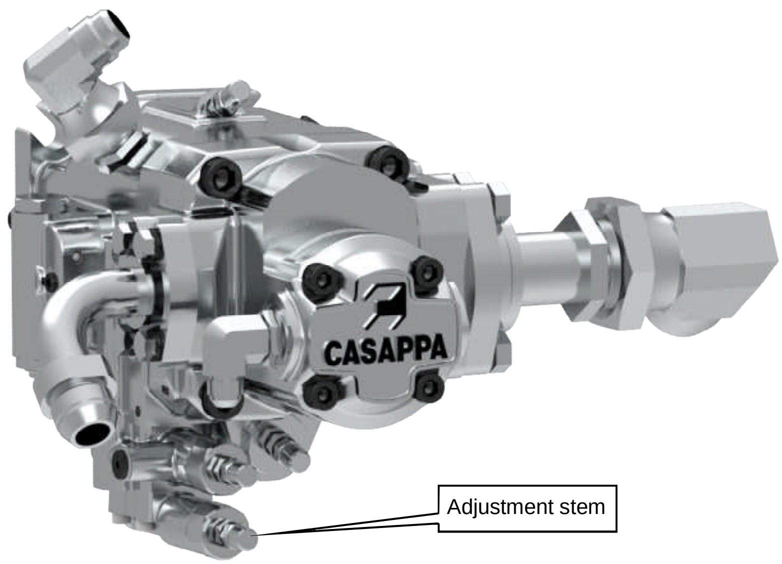
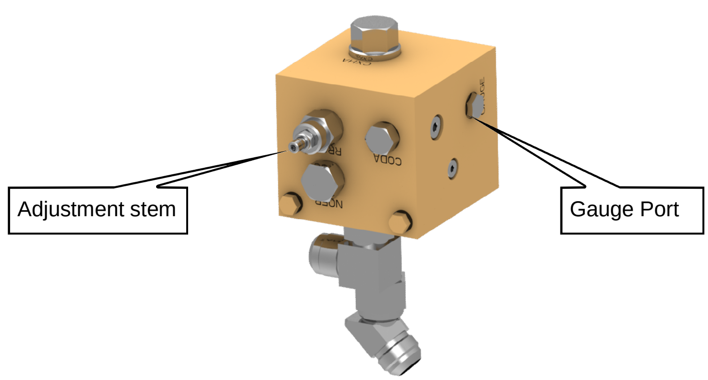


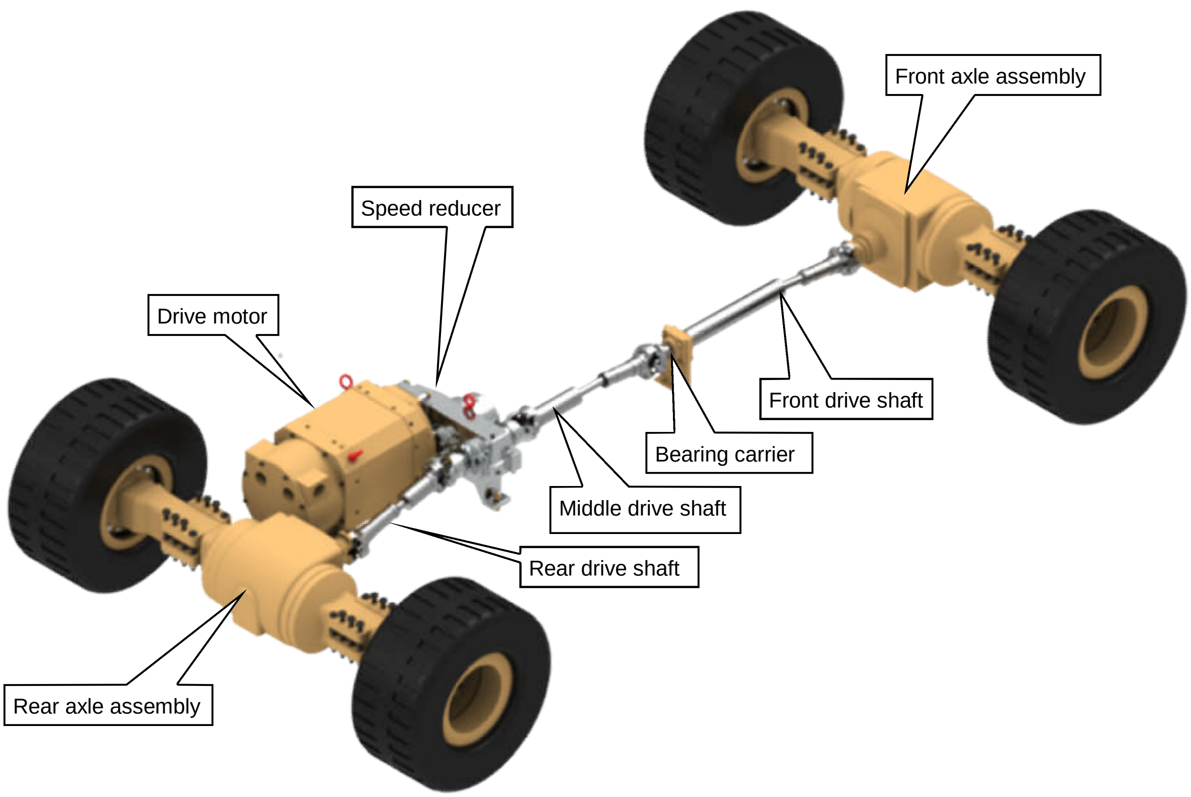
Fig. 60: Pump circuit control module



Drive motor/gearbox (speed reducer) removal and replacement

WARNING!
Power must be removed by unplugging the battery plugs before servicing the motor.

Fig. 61: Drive train components



The following procedures reference Fig. 61.

drive motor removal

- Remove the motor inspection cover and disconnect the power cables to the motor. Unpack the motor gland and completely remove the wiring and conduit from the motor.
- Attach a crane or hoist, capable of lifting the motor, to the eyebolt on top of the motor and take up any slack in hoist chain.
- Remove the four (4) bolts that attach the motor to the gearbox.
- Lift the motor out of the unit.
- Cover the reducer opening to prevent foreign matter from entering the gearbox.

drive motor installation

- ☞ Verify that motor pinion gear is installed.
- ☞ Clean all mating surfaces (motor and gearbox.)
- ☞ Lower motor into unit and align bolt holes.
- ☞ Bolt motor onto gearbox, turning pinion gear as necessary to align gears.
- ☞ Torque bolts to 282 ft./lbs. (382 m-n) (Lubricated threads) 400 ft./lbs. (543 m-n) (Dry threads)
- ☞ Reconnect cable leads.
- ☞ Replace inspection cover.

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drive motor and gearbox removal

- ☞ Remove the motor inspection cover and disconnect the power cables to the motor. Unpack the motor gland and completely remove the wiring and conduit from the motor.
- ☞ Disconnect the drive shafts from both sides of the gearbox.
- ☞ Tag and disconnect the brake lines from the brake calipers on the gearbox.
- ☞ Attach a crane or hoist, capable of lifting the motor and gearbox and take up any slack in the hoist chain.
- ☞ Remove the bolts that attach the gearbox to the frame.
- ☞ Lift the motor/gearbox out of the unit.

---

drive motor and gearbox installation

- ☞ Attach motor to gearbox and torque bolts to 282 ft./lbs. (382 m-n) (lubricated threads) 400 ft./lbs (543 m-n) (dry threads).
- ☞ Clean all mating surfaces (gearbox and frame) thoroughly.
- ☞ Hoist motor/gearbox close to its location in the frame.
- ☞ Align the gearbox mounting feet with the holes in the frame and tighten bolts. Torque the mounting bolts to 282 ft./lbs. (382 m-n) (lubricated threads) 400 ft/lbs. (543 m-n) (dry threads).
- ☞ Connect the drive shafts to the gearbox
- ☞ Connect the brake hoses to the proper calipers and bleed the service brake.
- ☞ Check all oil levels before operating the unit.
- ☞ Bleed the automatic brake.

Tire/wheel installation procedure

The following installation procedures are for general guidance when installing a tire/wheel assembly on most underground mining machines. Any use made of the advisory information contained herein is entirely within the control and discretion of the user and is wholly voluntary.

WARNING!
Mixing parts of different designs or from a variety of sources for wheels with pneumatic tires could cause severe injury or death.

tire/wheel stresses

Rubber tired underground mining machinery is routinely subject to severe abuse due to the conditions in which it is operated. Whether a primary haulage or utility/support vehicle, all are subject to extreme shock, vibration, temperature change and various other loads and stresses that cause maintenance problems. One such problem is found in tire/wheel assemblies.

Many maintenance personnel view installing a tire/wheel assembly on a machine as a relatively simple task. However, if a few simple rules on proper installation are not followed, unnecessary difficulties may be experienced. Tires act like shock absorbers on haulage and support vehicles, transferring cushioned loads to the wheels. Even after proper installation, periodic checks need to be made to insure that tire/wheel assemblies do not loosen, causing wheel studs to break or damaging the mounting bolt pattern.

wheel mounting arrangements

Various mounting arrangements between the wheel and hub or wheel end are used by manufacturers. One of the more common is the taper-lock. This arrangement requires a taper on both wheel and hub where the mating surfaces of the taper carry the loads. Incomplete seating of the taper will allow the wheel to loosen, resulting in stud or bolt shear and possible tire/wheel damage.

Another mounting arrangement is based on holding a very close pilot fit where the tolerance between the wheel and hub is very tight, requiring a clamp-load force to hold the wheel securely in place. If the wheel studs or bolts are allowed to loosen, the load will be transmitted to them, resulting in sheared studs or bolts.

problem areas

Periodic wheel inspection is critical to the life cycle of a tire/wheel assembly. A fractured wheel, broken bolt pattern and missing or broken wheel studs are all contributors to tire/wheel failures. Problems in these areas occur as the result of repeated cyclical loading as the tire/wheel unit rotates during machine travel. Haulage vehicles loaded unevenly, downhill hauls with high speed turns, or operating a vehicle with one tire of a dual assembly damaged or flat are some examples of conditions that produce damaging high stresses in wheel assemblies. Also, the effects of corroding or poorly fitted mating parts can produce surface irregularities that result in cracks and ultimate failure of a wheel.

The most common problem with tire/wheel installations is the incorrect tightening of wheel bolts or studs. Threaded fasteners perform there function of holding things together better when torque control is used in their tightening. Using an accurate torque wrench correctly is the best and most practical way of securing fasteners, Although torque value charts are available as a reference guide to proper tightening, OEM specifications should always be followed when tightening fasteners. However, proper torque values are of little benefit if certain other factors are not considered.

wheel mounting tips

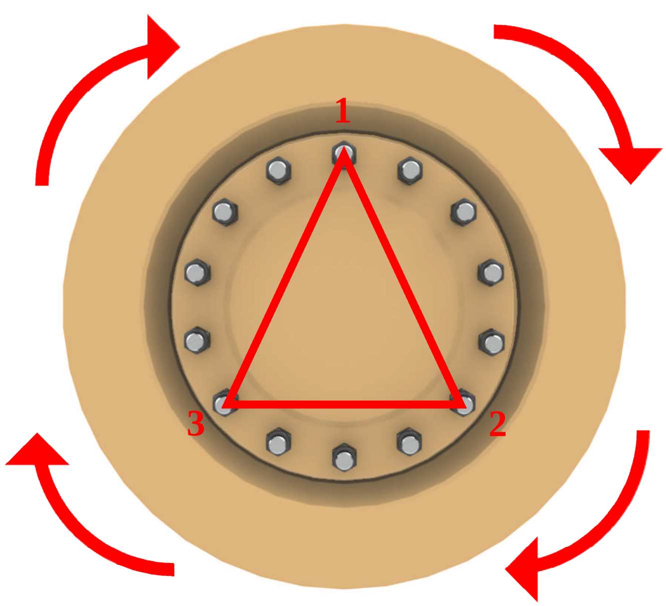
All fasteners should be examined before use. Any fastener that is worn, bent or has damaged threads should be replaced. Fastener threads should also be lightly coated with a protective substance, such as residual oils, wax or Loctite, because any oxidation or rust will upset the torque-to-tension relationship.

Mating surface conditions should also be considered. The tightening surface under the bolt or nut should be carefully inspected. A fastener, when tightened against a softer material, will gall under these conditions, and much of the applied torque may be lost through head friction. It is very important when using higher strength fasteners to have a smooth, even surface under the bolt head. In some cases, hard flat washers and most lock washers will provide a good tightening surface.

Another area of concern is cleanliness. All mating surfaces should be free of rust, dirt, oil, paint, etc. Also no paint of any kind should exist between a fastener and wheel disc surface. Any form of contamination between these surfaces will most likely lead to serious wheel problems.

When torquing any wheel bolt pattern, always torque in a triangular pattern (Fig. 62 and Fig. 63).

Fig. 62: Wheel torque pattern



recommended wheel mounting procedure

- ☞ All steel mating surfaces, including wheel/hub tapers and disc faces, must be free and clean of all dirt, corrosion, paint, etc. **NO PAINT** should be present under bolt heads or nuts.
- ☞ Fasteners should be in good condition. Any fastener with damage (corrosion, bent, worn threads, etc.) should be replaced. Replace all broken wheel studs.
- ☞ After positioning the wheel on the hub, tighten nuts down evenly. Triangulate the bolt pattern tightening sequence as shown in Fig. 62.
- ☞ After operating the machine for a short period of time, check the wheel-mounting bolts or nuts for proper torque.

NOTE: Wheel bolts or nuts “seat in” during normal vehicle operation. Therefore, it is necessary to repeat torquing procedures as necessary to seat the wheel to the hub. Planned periodic checks will help maintain correct torque values. All bolts and nuts, regardless of type, should be regularly checked for tightness.

Precautions

- ■ Do not install or remove tire/wheel assemblies from a machine without proper training.
- ■ Check wheel components periodically for cracks or broken parts. Replace all cracked, badly worn, damaged, or severely rusted components. When in doubt, replace.
- ■ Do not, under any circumstances, attempt to rework, weld, heat, or braze any wheel component that is cracked, broken or damaged. Replace such components with new OEM parts of the correct size and type.
- ■ Mixing wheel parts of different designs or from a variety of sources is potentially dangerous.
- ■ Replace broken studs **AND** each unbroken stud next to the broken one.

Troubleshooting procedures

The following section lists possible problems encountered when servicing the machine and can aid in locating and correcting these problems.

This section covers basic hydraulic components, with each listed in a trouble-cause-remedy format.

To troubleshoot the HiPAC 10 system, see CAT® document A6474X328.

WARNING!
Some procedures must be carried out with the cover of the electrical controller removed and some procedures require the controller to be energized during the tests. It is extremely important that you take all necessary precautions to prevent accidental electrical shock while working within the controller. A certified electrician must supervise and inspect all work performed.

For maintenance procedures and tests that DO NOT require the controller to be energized, these precautions include:

☞ Before removing the controller cover, remove power from the system by unplugging the battery.

☞ When the cover is removed, wait one minute for the capacitors to discharge before working inside the controller. To insure that the capacitors are discharged, connect an insulated 100-ohm, 10-watt resistor between the center buss bar and the outer buss bar of the capacitor bank and hold for 30 seconds.

☞ Use insulated gloves and tools where possible.

☞ All connections must be tight and care must be taken to prevent bolts, nuts, washers and other small metal fasteners from being dropped or lost inside the controller. These lost fasteners could cause electrical shorts inside the controller.

For procedures that DO require that the controller be energized while the cover is off:

☞ At no time should you reach inside the controller while it is energized. If it becomes necessary to make adjustments or to replace parts inside the controller, the machine circuit breaker must be turned to the “OFF” position and the capacitor bank discharged (see above). Once the circuit breaker is in the “OFF” position and the capacitor bank discharged, adjustments or parts replacements can be made.

☞ Use insulated gloves and tools where possible.

- All connections must be tight and care must be taken to prevent bolts, nuts, washers and other small metal fasteners from being dropped or lost inside the controller. These lost fasteners could cause electrical shorts inside the controller.

WARNING!
Never disconnect a hydraulic hose if the circuit is pressurized or there is a load on the circuit. If a hose is disconnected while the cylinder is supporting a load, the load will fall.

Hydraulic system (general)

Table 4: Hydraulic system (general) troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
dirty oil	Components not properly cleaned after servicing.	Disassemble components and clean parts.
	Air breather left off.	Replace breather.
	Hose lines not properly covered after servicing machine.	Clean hose lines after servicing.
	Filter elements not replaced at proper intervals or when indicated.	Replace elements at proper intervals.
foaming oil	Return of tank lines not below fluid level. Check oil level.	Replace broken hoses or lines.
	Oil contaminated with incompatible foreign matter.	Drain out oil and replace with clean oil.
	Suction leak to pump aerating oil.	Replace or tighten fittings and lines.
moisture in oil	Soluble oil solution splashing into poorly sealed tanks or fill holes left open.	Drain out and refill with clean oil. Check fill pipes to see if they are properly closed.
	Moisture in cans or used replacement oil.	Replace with new cans of oil.
	Extreme temperature differential in certain geographical locations.	Replace with recommended oil for correct temperature range.
overheating of system	Fluid viscosity too high.	Check fluid specs.
	Excessive slippage or internal leakage past pump or cylinders.	Fluid viscosity too low.
		Check case and pressure flow of pump

Table 4 (continued): Hydraulic system (general) troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
overheating of system (continued)	☞ Improper air circulation around reservoir.	☞ Check to see if the area around the reservoir is clear.
	☞ System relief valve set too high or too low.	☞ Reset the relief valve to specifications.
	☞ System controls open or by-passed	☞ Inspect auxiliary system controls
foreign matter sources in the circuit	☞ Sealing compound (pipe dope, Teflon tape).	☞ Clean or replace seals.
	☞ Burrs inside piping components.	☞ Disassemble piping components and remove any burrs.
	☞ Tag ends of packing coming loose.	☞ Remove old packing and replace with new.
	☞ Lines left unprotected and dirty, repaired components.	☞ Drain and replace oil.
	☞ Repair parts not properly protected while stored.	☞ Clean parts thoroughly before installation.
accumulator charging cycle repeats frequently when accumulator is not normally being discharged in service	☞ Leaking accumulator lines or fittings.	☞ Check lines and fittings for leaks and correct.
	☞ Accumulator gas charge too low.	☞ Check accumulator gas charge.
	☞ Accumulator gas charge too high.	☞ Check accumulator.
	☞ Line to accumulator plugged.	☞ Replace line.
accumulator starts to charge but doesn't reach high limit	☞ No oil or low oil in tank.	☞ Check oil level.
	☞ Defective or worn pump (pump doesn't deliver full flow or pressure).	☞ Check pump pressure and flow.
	☞ Defective system relief valve (valve leaking or has low setting so full flow and pressure are not available).	☞ Check relief valve.
	☞ Defective dump valve	☞ Inspect dump valve
	☞ Defective charging valve.	☞ Replace valve.

Table 4 (continued): Hydraulic system (general) troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
no steering or inadequate steering when accumulator is charging but steering satisfactory when accumulator is not charging	☞ Pump worn (not delivering full flow or pressure). ☞ Relief valve defective (valve leaking so that full flow and pressure not available). ☞ Defective charging valve.	☞ Check pump pressure and flow. ☞ Check relief valve. ☞ Replace charging valve .
accumulator charging time too long	☞ No oil or low oil level in tank. ☞ Relief valve setting too low. ☞ Pump worn or defective and not delivering full flow or pressure. ☞ Defective charging valve.	☞ Check oil level. ☞ Check valve setting. ☞ Check pump. ☞ Remove charging valve.
accumulator fails to start charging	☞ No oil or low oil level in tank. ☞ Worn or defective pump. ☞ Defective relief valve. ☞ Defective charging valve.	☞ Check oil level. ☞ Check pump pressure and flow. ☞ Check relief valve setting. ☞ Replace charging valve.
very rapid cycling of charging valve	☞ Accumulator gas charge too low. ☞ Accumulator gas charge too high. ☞ No gas charge in accumulator. ☞ Defective charging valve.	☞ Check gas charge. ☞ Check gas charge. ☞ Check gas charge. ☞ Replace charging valve.

Brakes

Table 5: Brakes troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
brakes slow to apply	☞ No gas charge in accumulator.	☞ Check gas charge.
	☞ Defective brakes.	☞ Check brakes.
	☞ Hydraulic lines or fittings leak-ing.	☞ Check for leaks and repair.
	☞ Pedal linkage out of adjustment.	☞ Adjust linkage.
	☞ Damaged hydraulic brake lines.	☞ Check lines for dents that re-strict flow of oil.
brakes won’t release	☞ Pedal linkage out of adjustment or binding.	☞ Check for proper adjustment and binding.
	☞ Defective brakes.	☞ Check brakes .
	☞ Defective brake valve.	☞ Replace brake valve.
insufficient brakes	☞ No oil or low level in tank.	☞ Check oil level in tank.
	☞ Pedal linkage out of adjustment.	☞ Adjust linkage.
	☞ Brake line mashed.	☞ Check lines and replace.
	☞ No gas charge in accumulator.	☞ Check gas charge.
	☞ Defective brakes.	☞ Check brakes.
	☞ Brake valve defective.	☞ Replace valve.
brakes will not release completely	☞ Defective brakes.	☞ Check brakes.
	☞ Pedal linkage out of adjustment.	☞ Adjust pedal linkage.
	☞ Air in brakes.	☞ Bleed brakes.
	☞ Defective brake valve.	☞ Replace brake valve.
	☞ Back pressure on return line too high.	☞ Remove restriction.
excessive braking	☞ Defective brakes.	☞ Check brakes.
	☞ Defective brake valve.	☞ Replace brake valve.

Table 5 (continued): Brakes troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
no brakes	☞ No oil in hydraulic system.	☞ Check oil level in tank.
	☞ Pedal linkage out of adjustment.	☞ Adjust pedal linkage.
	☞ Broken or mashed brake line.	☞ Check lines for breaks or mashed condition.
	☞ Defective system relief valve.	☞ Check pressure in pressure line to tank.
	☞ Worn pump.	☞ Check pressure in pressure line to tank.
	☞ Defective or worn brakes.	☞ Check brakes.
	☞ Defective brake valve.	☞ Replace brake valve.
parking brakes will not release completely	☞ Insufficient pressure.	☞ Check lines.
	☞ Accumulator not fully re-charged.	☞ Recharge accumulator.
excessive accumulator leakage when brakes are not being used	☞ Defective ball valve in charging valve.	☞ Replace ball valve.
	☞ Defective guide in charging valve.	☞ Replace guide.
	☞ Seal leaking in charging valve.	☞ Replace seal.
	☞ Guide sticking in plug due to contamination.	☞ Remove and clean the guides.
insufficient brakes	☞ Broken pressure regulating spring.	☞ Replace pressure regulating spring.
brakes won’t release	☞ Defective ball valve in charging valve.	☞ Replace ball valve.
	☞ Piston and washer binding in charging valve.	☞ Replace piston and washer.
excessive accumulator leakage when brakes are applied	☞ Defective seat on piston in charging.	☞ Replace seat.
	☞ Seal leaking.	☞ Replace seal.
	☞ Defective ball valve.	☞ Replace ball valve.
	☞ Guide sticking in plug due to contamination.	☞ Remove and clean the guide.

Hydraulic cylinders

Table 6: Hydraulic cylinder troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
cylinder drifts	☞ Piston seal leak.	☞ Repair seals or replace cylinder.
	☞ Other circuit leaks.	☞ Correct leaks.
cylinder fails to move the load when actuated	☞ Pressure too low.	☞ Check pressure at cylinder to make circuit requirements.
	☞ Piston seal leak.	☞ Repair seals or replace cylinder.
	☞ Piston rod broken at piston end.	☞ Repair as required or replace cylinder.
	☞ Contamination in hydraulic system resulting in scored cylinder bore.	☞ Replace cylinder.
erratic or chatter in operation	☞ Excessive friction due to misalignment and/or side loading.	☞ Correct cylinder to load alignment.
	☞ Air in circuit.	☞ Cycle cylinder to full stop positions to purge air.
excessive or rapid piston seal wear	☞ Excessive system pressure due to over adjustment.	☞ Correct pressure adjustment to rated limits.
	☞ Excessive friction due to misalignment and/or side loading.	☞ Correct cylinder to load alignment.
cylinder body seal leak	☞ Excessive pressure.	☞ Reduce pressure to rated limits.
	☞ Seal is pinched or extruded.	☞ Replace cylinder body seal.
	☞ Seal deterioration (soft or gummy).	☞ Check compatibility of seal material with operating fluid. Replace oil.
the piston is leaking	☞ Dirt has scored the piston or the rod.	☞ Replace rod.
the piston freezes to the tube	☞ Scoring in the piston.	☞ Replace.
packing and gasket leaks develop	☞ Excessive heat.	☞ Replace packing and gasket.

Hydraulic pump

Table 7: Hydraulic pump troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
pump makes excessive noise	☞ Vacuum leaks in suction line.	☞ Check for leaks in fittings or damaged suction lines.
	☞ Vacuum leaks in the pump shaft seal.	☞ Check pump.
	☞ Poor alignment with drive mechanism.	☞ Align pump and pump motor.
	☞ Incorrect fluid in system.	☞ Check fluid specs.
	☞ Relief valve set too high.	☞ Check relief pressure.
	☞ Seal deterioration (hard or loss of elasticity).	☞ Replace seal.
	☞ Seal deterioration (loss of radial squeeze due to flat spots or wear on O.D. or I. D.).	☞ Replace seal .
seal leak	☞ Torn or worn seals.	☞ Replace seal.
	☞ Gland bearing worn.	☞ Replace gland and seals.
	☞ Seal deterioration (soft or gummy).	☞ Replace seal.
	☞ Seal deterioration (hard or loss of elasticity).	☞ Replace seal.
	☞ Seal deterioration (flat spots on I.D.).	☞ Replace seal.
	☞ Aeration of fluid in reservoir.	☞ Correct air leak.
	☞ Worn or damaged gears and housing.	☞ Replace gears and housing.
	☞ Worn or faulty bearing.	☞ Replace faulty bearing.
	☞ Reversed rotation.	☞ Check pump motor wiring.
	☞ Plugged or restricted suction line or suction strainer.	☞ Clean by removing the plugged area.
	☞ Plugged reservoir filter breather .	☞ Clean reservoir. Clean breather.

Table 7 (continued): Hydraulic pump troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
seal leak (continued)	☞ Oil viscosity too high or operating temperature too low.	☞ Replace with recommended oil.
	☞ Air leak in suction line or fittings.	☞ Replace lines or fittings if badly worn.
	☞ Loose or worn pump parts.	☞ Replace worn pump parts.
	☞ Air leak at pump shaft seal.	☞ Replace pump shaft seals.
	☞ Oil level too low and drawing air in through inlet pipe opening.	☞ Check oil level.
	☞ Air bubbles in intake oil.	☞ Check oil level and tighten any loose fittings.
	☞ Pump housing bolts loose or not properly torqued.	☞ Tighten the housing bolts and re-torque bolts.
pump failure to deliver oil	☞ Low oil Ievel in reservoir.	☞ Fill to proper level.
	☞ Oil intake hose suction strainer plugged.	☞ Clean or replace strainer.
	☞ Air leak in suction line and preventing priming.	☞ Tighten or replace suction lines.
	☞ Pump shaft turning too slowly.	☞ Gears are worn and need replacing.
	☞ Oil viscosity too high.	☞ Replace with recommended oil.
	☞ Wrong shaft rotation.	☞ Check pump motor wiring.
	☞ Pump shaft or parts broken.	☞ Replace shaft or broken parts.
	☞ Dirt in pump.	☞ Clean pump .
oil leakage around pump	☞ Shaft seal worn.	☞ Replace seals.
	☞ Head of oil on suction hose connection leaking.	☞ Tighten bolts. Tighten or replace connections.
	☞ Pump housing bolts loose or improperly torqued.	☞ Tighten bolts.

Table 7 (continued): Hydraulic pump troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
excessive pump wear	☞ Abrasive dirt in hydraulic oil being circulated through the system.	☞ Replace oil with clean hydraulic oil.
	☞ Oil viscosity too low.	☞ Replace with recommended oil.
	☞ System pressure exceeding pump rating.	☞ Relief valve out of adjustment.
	☞ Pump misalignment.	☞ Realign pump.
pump parts inside the housing are broken	☞ Seizure due to lack of oil.	☞ Check oil level.
	☞ Excessive system pressure above maximum pump rating.	☞ Relief valve out of adjustment.
	☞ Excessive torque to housing bolts.	☞ Loosen bolts and then retorque.
	☞ Solid matter being drawn in from reservoir and wedged in pump.	☞ Remove and clean clogged area.

Valves

Table 8: Valve troubleshooting

Trouble, symptom or cause	Probable cause	Test, check and/or remedy
the operating pressure cannot be changed	☞ Valve spring broken.	☞ Replace the spring.
	☞ Open valve in the system.	☞ Find and close open valve.
the valve piston sticks	☞ Dirt in the system.	☞ Remove the valve and clean it thoroughly; flush the system as necessary.
certain passages are blocked or pressure fluctuates	☞ Dirt in the system.	☞ Remove the valve and clean it thoroughly; flush the system as necessary.
the pressure fluctuates and there is extreme noise in the valve	☞ Air in the system.	☞ Check for leaks.
	☞ Pressure or volume too high.	☞ Adjust the pressure or volume.
the valve leaks internally	☞ Valve piston and body worn.	☞ Replace the valve.
excessive leakage or sticking pistons occurs	☞ Valve excessively hot.	☞ Remove the valve and clean it thoroughly; flush the system.
	☞ Dirt in the system.	☞ Replace oil.

6 Technical data

Technical data

This chapter contains the most important technical data on the CAT® SU488 L. Further data can be found in the spare parts lists. At the end of this chapter you will find information on the bolt tightening torques, HFA fluids, greases, etc. Read this chapter through carefully and pay particular attention in particular to the safety instructions.

The technical data listed in this chapter is for stock machines only. Customer specials may not be listed.

CAT® SU488 L

Technical data sheet

general

Length
with bucket: .... approx. 28’ 8”

Overall width
with bucket: .... approx. 9’7”

Wheelbase: .... approx. 12’ 2”

Weight
empty less battery: .... approx. 28,000 lbs
with battery: .... approx. 42,200 lbs

Battery height from ground:
with battery and 35X15-15 tires .... approx. 36.5”

Ground clearance (no axle spacers):
with 35X15-15 tires .... approx. 11”

Minimum adjustable cab height (from ground):
with 35X15-15 tires .... approx. 3’ 6””

Main frame height (from ground):
with 35X15-15 tires .... approx. 2’ 6.75”

Load per axle .... 30% front axle
70% rear axle

Maximum grade 12%

performance

Inside turning radius .... approx. 11’ 11”
Outside turning radius: .... approx. 23’ 3”
Steering articulation: .... 80 degrees total
Tram speed: .... 4-5 mph
Lift capacity: .... approx. 10 tons at 40” from bucket pivot pin

Tightening torques

IMPORTANT!
Due to the application of fasteners being subject to great stresses and heavy or extreme vibration, it is imperative that all bolts be applied with an adequate amount of torque. For this reason this list of recommended torque settings for different types and sizes of fasteners used has been compiled.
The tightening torques stated in the spare parts lists have to be observed, as well, for installation and maintenance.

Set screws

Table 9: Set screws (Socket long-lok)

Nominal diameter	Recommended torque setting
#6	6 in-lbs
#8	9 in-lbs
#10	13 in-lbs
¼”	30 in-lbs
5/16”	5 ft-lbs
3/8”	8 ft-lbs
7/16”	11 ft-lbs
½”	16.7 ft-lbs

Table 10: Set screws (Socket standard steel)

Nominal diameter	Recommended torque setting
#6	9 in-lbs
#8	16 in-lbs
#10	30 in-lbs
¼”	6 ft-lbs
5/16”	12 ft-lbs
3/8”	18 ft-lbs
7/16”	29 ft-lbs
½”	43 ft-lbs
5/8”	100 ft-lbs
¾”	146 ft-lbs
7/8”	199 ft-lbs
1”	262 ft-lbs

Tightening torques

Table 11: FSR hex bolts (SAE 5 and 325 steel)

Nominal diameter	Recommended torque setting
¼”	9 ft-lbs
5/16”	18 ft-lbs
3/8”	31 ft-lbs
7/16”	50 ft-lbs
½”	75 ft-lbs
9/16”	110 ft-lbs
5/8”	150 ft-lbs
¾”	250 ft-lbs
7/8”	378 ft-lbs
1”	583 ft-lbs
1 1/8”	782 ft-lbs
1 ¼”	1,097 ft-lbs
1 3/8”	1,461 ft-lbs
1 ½”	1,748 ft-lbs
1 ¾”	3,114 ft-lbs
2”	4,504 ft-lbs
2 ¼”	6,497 ft-lbs
2 ½”	7,144 ft-lbs
2 ¾”	12,092 ft-lbs
3”	15,744 ft-lbs

Table 12: Socket, flat & button head cap screw (Steel only)

Nominal diameter	Recommended torque setting
#6	26 in-lbs
#8	52 in-lbs
#10	6 ft-lbs
¼”	14 ft-lbs
5/16”	30 ft-lbs
3/8”	50 ft-lbs
7/16”	81 ft-lbs
½”	121 ft-lbs
5/8”	240 ft-lbs
¾”	395 ft-lbs
7/8”	629 ft-lbs
1”	964 ft-lbs
1 1/8”	1,523 ft-lbs
1 ¼”	2,121 ft-lbs
1 3/8”	2,843 ft-lbs
1 ½”	3,402 ft-lbs

Table 134: Untreated screw, black finish (Coarse thread)

Property class	Torque	Recommended torque setting			Nominal diameter			
	Ma	M3	M4	M5	M6	M7	M8	M10
5.6	Nm	0.60	1.37	2.70	4.5	7.8	11	22
	Ft-lbs	0.44	1.01	1.99	3.3	5.6	8.1	16
8.8	Nm	1.37	3.10	6.15	10.5	17.5	26	61
	Ft-lbs	1.01	2.29	4.54	7.7	12.9	19	37
10.9	Nm	1.92	4.40	8.55	15	25	36	72
	Ft-lbs	1.42	3.25	6.38	11	18.4	26	53
12.9	Nm	2.30	5.25	10.4	18	29	43	87
	Ft-lbs	1.70	3.87	7.6	13	21.3	31	64

Table 13: Untreated screw, black finish (Coarse thread, continued)

Property class	Torque	Recommended torque setting			Nominal diameter			
	Ma	M12	M14	M16	M18	M20	M22	M24
5.6	Nm	39	62	85	130	184	250	315
	Ft-lbs	28	45	70	95	135	184	232
8.8	Nm	89	141	215	295	420	570	725
	Ft-lbs	65	103	158	217	308	420	634
10.9	Nm	125	198	305	420	690	800	1020
	Ft-lbs	92	146	224	309	435	590	752
12.9	Nm	150	240	365	500	710	960	1220
	Ft-lbs	110	177	269	368	523	708	899

Table 13: Untreated screw, black finish (Coarse thread, continued)

Property class	Torque	Recommended torque setting		Nominal diameter		
	Ma	M27	M30	M33	M36	M39
5.6	Nm	470	635	865	1111	1440
	Ft-lbs	346	468	637	819	1062
8.8	Nm	1070	1450	1970	2630	3290
	Ft-lbs	789	1069	1452	1885	2428
10.9	Nm	1510	2050	2770	3560	4620
	Ft-lbs	1113	1511	2042	2625	3407
12.9	Nm	1810	2450	3330	4280	5550
	Ft-lbs	1334	1606	2455	3156	4093

Tightening torques

Table 14: Untreated screw, black finish (Fine thread)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M8 X 1	M10 X 1.25	M12 X 1.25
8.8	Nm	27	52	95
	Ft-lbs	19	38	70
10.9	Nm	38	73	135
	Ft-lbs	28	53	99
12.9	Nm	45	88	160
	Ft-lbs	33	64	118

Table 14: Untreated screw, black finish (Fine thread, continued)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M14 X 1.5	M16 X 1.5	M18 X 1.5
8.8	Nm	150	225	325
	Ft-lbs	110	165	239
10.9	Nm	210	315	460
	Ft-lbs	154	232	339
12.9	Nm	260	380	550
	Ft-lbs	184	280	405

Table 14: Untreated screw, black finish (Fine thread, continued)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M20 X 1.5	M22 X 1.5	M24 X 2
8.8	Nm	399	610	780
	Ft-lbs		449	575
10.9	Nm	640	860	1100
	Ft-lbs	472	634	811
12.9	Nm	770	1050	1300
	Ft-lbs	567	774	958

Table 15: Electrically zinc plated (Coarse thread)

Property class	Torque	Recommended torque setting		Nominal diameter				
	Ma	M33	M4	M5	M6	M7	M8	M10
5.6	Nm	0.56	1.28	2.50	4.3	7.1	10.5	21
	Ft-lbs	0.41	0.94	1.84	3.1	5.2	7.7	15
8.8	Nm	1.28	2.90	5.75	9.9	16.5	24	48
	Ft-lbs	0.94	2.14	4.24	7.3	12.1	17.7	35
10.9	Nm	1.80	4.10	8.10	14	23	34	67
	Ft-lbs	1.33	3.02	5.97	10.3	16.9	25	49
12.9	Nm	2.15	4.95	9.70	16.5	27	40	81
	Ft-lbs	1.59	3.65	7.15	12.1	19.9	29	59

Table 15: Electrically zinc plated (Coarse thread, continued)

Property class	Torque	Recommended torque setting		Nominal diameter			
	Ma	M12	M14	M16	M18	M20	M22
5.6	Nm	36	58	88	121	171	230
	Ft-lbs	26	42	54	89	126	169
8.8	Nm	83	132	200	275	390	530
	Ft-lbs	61	97	147	202	287	390
10.9	Nm	117	185	285	390	550	745
	Ft-lbs	86.2	136	210	287	405	549
12.9	Nm	140	220	340	470	660	890
	Ft-lbs	103	162	250	346	486	656

Table 15: Electrically zinc plated (Coarse thread, continued)

Property class	Torque	Recommended torque setting		Nominal diameter			
	Ma	M24	M27	M30			
5.6	Nm	295	435	590	800	1030	1340
	Ft-lbs	217	320	435	590	759	988
8.8	Nm	675	995	1350	1830	2360	3050
	Ft-lbs	497	733	995	1349	1740	2249
10.9	Nm	960	1400	1900	2680	3310	4290
	Ft-lbs	708	1032	1401	1902	2441	3163
12.9	Nm	1140	1680	2280	3090	3980	5150
	Ft-lbs	840	1239	1661	2278	2935	3798

Tightening torques

Table 16: Electrically zinc plated (Fine thread)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M8 X 1	M10 X 1.25	M12 X 1.25
8.8	Nm	25	49	88
	Ft-lbs	18	36	84
10.9	Nm	35	68	125
	Ft-lbs	25	50	92
12.9	Nm	42	82	150
	Ft-lbs	30	60	110

Table 16: Electrically zinc plated (Fine thread, continued)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M14 X 1.5	M16 X 1.5	M18 X 1.5
8.8	Nm	140	210	305
	Ft-lbs	103	154	224
10.9	Nm	195	295	425
	Ft-lbs	143	217	313
12.9	Nm	235	350	510
	Ft-lbs	173	258	376

Table 16: Electrically zinc plated (Fine thread, continued)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M20 X 1.5	M22 X 1.5	M24 X 2
8.8	Nm	425	570	720
	Ft-lbs	313	420	531
10.9	Nm	600	800	1000
	Ft-lbs	442	590	737
12.9	Nm	720	960	1200
	Ft-lbs	531	708	885

Permissible media

Lubrication fluids and greases

NOTICE!
Use only approved lubrication fluids and greases. These fluids and greases have been tested and guarantee reliable operation of the mechanical and hydraulic functions of the machine.

IMPORTANT!
The lubrication fluids and greases listed in the same table can be mixed. Other products may only be used if the supplier can guarantee that they are equivalent.
Differently composed fluids and greases must not be mixed as this may change the consistency, i.e. the mixture can become thinner so that the lubrication effect is not sufficient. It may also be dangerous to use lubricating greases and fluids having the same specification base but different origins.
In case of doubt, the manufacturer of the lubrication to be used should be contacted as to the compatibility of the lubrication in question.

IMPORTANT!
CATERPILLAR® expressly point out that the approval of the listed products relates only to the pure technical use in our mechanical and hydraulic systems. The responsibility for the constituents used in the hydraulic concentrates lies solely with the respective manufacturer.

IMPORTANT!
Be sure to use the manufacturer's instructions for use.

NOTICE!
When performing maintenance on the machine, all used oil and lubricants should be disposed of per your local EPA standards.

Approved suppliers:

Table 17: Anti-wear hydraulic oil (Spec 100-1)

	Supplier	Brand name
1	Amoco Oil Company	Amoco AW oil No.68
2	Gulf Oil	Harmony 68 AW
3	Mobil Oil Corporation	Mobil DTE-16
4	Chevron U.S.A.	Chevron hydraulic Oil Aw ISO 68
5	Sun Oil Company	Sunvis 868
6	Unocal 76	Unax AW 68
7	Shell Oil Company	Shell Hydraulic Oil #33
8	Century Lubricating Oils, Inc.	Hyldraulic AW 68
9	Atlantic Richfield Company	Duro AW S-315 Oil
10	Texaco Lubricants Company	Texaco Rando Oil HD 68
11	Exxon	Nuto 68
12	Pennzoil	Pennzbell AW 68 Hydraulic Oil
13	Standard Oil Company Standard Oil Co. of Ohio Boron Oil Company BP Oil Inc.	 Industron 54 Industron 53 Energol HLP-C68
14	Lubricating Engineers	6120 Monolec Hydraulic Oil
15	Conoco Inc.	Super Hydraulic oil 68
16	Hydrotex	Systems 5K 68
17	Phillips	Maginus A Oils 81350
18	Miners Oil	Hydraulic Oil 68AW

Table 18: Extreme pressure gear oils (Spec. 100-2)

	Supplier	Brand name
1	Amoco Oil Company	Amoco Permagear EP 460
2	Gulf Oil	EP Lubricant HD 460
3	Mobil Oil Corporation	Mobil Gear 634 Mobil Gear 636
4	Chevron U.S.A.	Chevron Gear Compound EP ISO 460
5	Sun Oil Company	Sunep 460
6	Unocal 76	Extra Duty NL Gear Lube 7 EP Extra Duty NL Gear Lube 8 EP
7	Shell Oil Company	Shell Omala 680
8	Century Lubricating Oils, Inc.	Hulbest EP-7 Powergear 460
9	Texaco Lubricants Company	Meropa 680
10	Exxon	Spartan EP 460
11	Pennzoil	Super Maxol EP 460 Gear Lube Super Maxol EP 460 Gear Lube
12	Lubricating Engineers	608 Almosal Vari-Purpose Gear Lubricant
13	Conoco Inc.	Gear oil 460
14	Hydrotex	933 Industrial Gear Lubricant
15	Phillips	All Purpose Gear Oil 85W-90 5EP
16	Miners Oil	Gear Oil EP460

Table 19: Extreme pressure motor bearing grease (Spec. 100-3)

	Supplier	Brand name
1	Amoco Oil Company	Amolith Grease 2 EP Rykon Premium Grease 2 EP
2	Gulf Oil	Gulfcrown Grease EP#2
3	Mobil Oil Corporation	Mobilux EP-2
4	Chevron U.S.A.	Chevron Dura-Lith Grease EP-2 NLGI 2
5	Sun Oil Company	Sun Prestige 742EP
6	Unocal 76	Multiplex EP2
7	Shell Oil Company	Alvania EP-2
8	Century Lubricating Oils, Inc.	Hullith EP2 Multipurpose Grease or Replex2 or Uniwrl 2 or Uniwrl EMB or Hullith GP 2 or Hullith EP 2
9	Texaco Lubricants Company	Texaco Multifak EP 2
10	Exxon	Lidok EP 2
11	Pennzoil	Pennlith EP 712 Grease
12	Lubricating Engineers	3752 Almagard Vari-Purpose Lubricant
13	Conoco Inc.	EP Conolith Grease No. 2 or Super Sta Grease No. 2
14	Hydrotex	LC-65 Hyplex
15	Phillips	Philube EP Grease
16	Atlantic Richfield	Litholine H EP-2 Grease

Table 20: Semi-fluid grease (Spec. 100-4)

	Supplier	Brand name
1	Texaco Lubricants Company	Novatex EP 000
2	Century Oils Limited	Joy Loader Semi-Fluid grease
3	Hydrotex	MPD-60 Ultra E.P. 000
4	Pennzoil	Semi-Fluid 760 Grease
5	Unocal	MM Grease
6	Exxon	Lidok E.P. 000

Table 21: Invert emulsion hydraulic fluid (Spec. 100-5)

	Supplier	Brand name
1	Unocal 76	FR Fluid
2	Conoco Inc.	FR Hydraulic Fluid
3	Atlantic Richfield Company	Duro FR-HD
4	Brooks Oil Company	Brooks Fire Resistant Hydraulic Fluid B
5	Cincinnati – Vulcon Company	Vulcon FR Fluid #1
6	Cities Service Oil Company	Citgo Pacemaker Invert FR Fluid
7	Century Oils Limited	Aquacent Light
8	Fiske Bros. Refining Company	Lubriplate HO-Retard
9	Getty Oil Company (Veedol, Tidewater)	Veedol Auburn FRH
10	Gulf Oil Company	FR Fluid
11	E.F. Houghton	Houghto-Safe 5046 Houghto-Safe 5046W
12	Century Lubricating Oils	Hulsafe 600
13	Imperial Oil and Grease	Astrol 587
14	Mobil Oil Corporation	Pyrogard D
15	National Oil and Chemical Co.	Erifon 1, 2, and 3
16	Pennzoil	Maxmul FRP/G
17	Quaker Chemical Company	Quintolubric 958 Series Quintolubric 958 Series
18	Henery E. Sanson and Sons MFGE Company	Hydra-Mul Premium Emulsion Fluid
19	Southwest Grease and Oil Company, Inc.	Invert Emulsion Fire Resistant Hydraulic Fluid
20	Southwest Petroleum Corp.	Swepco Fire Resistant Hydraulic oil #718
21	Standard Oil Company of Ohio (Boron Sohio)	Staysol FR
22	Sun Oil Company	Sunsafe F
23	Tower Oil Company	Safoil Anti-Wear Hydraulic Fluid
24	Wynn Oil Company	Hydra-Safe Heavy Medium
25	Lubrication Engineers	6455 Monolec Fire Resistant Hydraulic Fluid
26	Hydrotex	HY-Guard

Table 21: Extreme pressure gear oil, SAE 90 (Spec. 100-6)

	Supplier	Brand name
1	Amoco Oil Company	Amoco Premagear EP 320
2	Gulf Oil	EP Lubricant HD 320
3	Mobil Oil Corporation	Mobil Gear 632
4	Chevron U.S.A.	Chevron Gear Compound EP ISO 320
5	Sun Oil Company	Sunep 320
6	Unocal 76	Extra Duty NL Gear Lube 6EP
7	Shell Oil Company	Omala 75
8	Century Lubricating Oils, Inc.	Hulbest EP-6
9	Texaco Lubricants Company	Meropa 320
10	Exxon	Spartan EP 320
11	Pennzoil	Super Maxol EP 220 Gear Lube
12	Lubricating Engineers	605 Almasol Vari-Purpose Gear Lubricant
13	Conoco Inc.	Gear Oil 320
14	Hydrotex	932 Industrial Gear Lube
15	Phillips	Philube All Purpose Gear Oil 85W-90
16	Atlantic Richfield	Pennant NL S-1000
17	Cities Service	Citgo EP Compound 110
18	Pennzoil	Pen Gear #320
19	Miner Oil	Gear Oil EP220
20	Texaco, Lubricants Company	Texaco Multigear EP 80W-90

Table 23: Hydraulic and general purpose oil medium-heavy/R&O inhibited (Spec. 100-7)

	Supplier	Brand name
1	Amoco Oil Company	American Industrial Oil No. 68
2	Gulf Oil	Harmony 68
3	Mobil Oil Corporation	DTE Heavy – Medium
4	Chevron U.S.A.	Chevron Turbine Oil ISO 68 or Chevron Machine Oil R&O ISO 68
5	Sun Oil Company	Sunvis 754
6	Unocal 76	Unax RX68 or Turbine Oil 68
7	Shell Oil Company	Turbo 68
8	Century Lubricating Oils, Inc.	Centraulic R&O 68
9	Texaco Lubricants Company	Regal Oil R&O N-68
10	Exxon	Tresstic 68
11	Pennzoil	Pennzbell RO 68
12	Lubricating Engineers	6120 Monolec Turbine Oil
13	Conoco Inc.	Detol R&O 68 or Turbine Oil 68
14	Hydrotex	Systems 1, System 5K 68
15	Atlantic Richfield	Duro 5.315
16	Cities Service	Citgo Pacemaker A/W68
17	Miner Oil	Hydraulic Oil AW68
18	Texaco, Lubricants Company	TDH 1893

Table 245: Hydraulic and general purpose oil heavy/R&O inhibited (Spec. 100-8)

	Supplier	Brand name
1	Amoco Oil Company	American Industrial Oil No. 150
2	Gulf Oil	Harmony 150
3	Mobil Oil Corporation	DTE Oil EX. Heavy
4	Chevron U.S.A.	Chevron Machine Oil AW ISO 150M or Chevron Machine Oil R&O ISO 150
5	Sun Oil Company	Sunvis 961
6	Unocal 76	Unax RX 700 or Turbine Oil 700
7	Shell Oil Company	Turbo 150
8	Century Lubricating Oils, Inc.	Centraulic R&O 150
9	Atlantic Richfield Company	Duro 600 or S-700
10	Texaco Lubricants Company	Regal Oil R&O 150
11	Exxon	Teresstic 150
12	Pennzoil	Pennzbell RO 150
13	Cities Service	Citgo Pacemaker 150
14	Lubrication Engineers	6405 Monolec Turbine Oil
15	Conoco Inc.	Dectol R&O 76
16	Hydrotex	System 1 150, System 5k 150
17	Phillips	Magnus Oils 700
18	Miner Oil	ISO 150

Table 25: Worm gear lubricant, compounded cylinder oil (Spec. 100-9)

	Supplier	Brand name
1	Amoco Oil Company	Cylinder Oil No. 1000
2	Mobil Oil Corporation	Extra Hecla Super Cylinder Oil
3	Chevron U.S.A.	Chevron Cylinder Oil W ISO 1000
4	Sun Oil Company	Sun Steam Cylinder Oil
5	Unocal 76	Worm Gear Lube 250 or Stevalc
6	Century Lubricating Oils, Inc.	Garwal 680
7	Atlantic Richfield Company	Modoc 195
8	Texaco Lubricants Company	650 T Cylinder Oil 1000
9	Exxon	Cylesstic TK-1000
10	Pennzoil	Cylinder Oil #1000
11	Conoco Inc.	Inca Oil 1000

Table 26: Light gear oil, SAE 40 motor oil (Spec. 100-10)

	Supplier	Brand name
1	Amoco Oil Company	Amoco 300 SAE 40
2	Gulf Oil	Super Duty 40
3	Mobil Oil Corporation	Delvac 1340
4	Chevron U.S.A.	Chevron RPM Heavy Duty Motor Oil 15W-40
5	Sun Oil Company	Sunoco Super C 40
6	Unocal 76	Guardol Motor Oil SAE 40
7	Shell Oil Vompany	Rotella Oil 40 (Automotive) Turbo Oil 150 (Industrial) Rimula CT40 (Foreign) Rotela SX40 (Foreign)
8	Century	Flexe SAE 40
9	Texaco Lubricants Company	Ursa Super Plus SAE 40
10	Exxon	XD-3 Extra SAE 40 or XD-3 SAE 40
11	Pennzoil	Long Life SAE 40 Motor Oil
12	Lubricating Engineers	8440 Monolex GFS Engine Oil
13	Conoco Inc.	Fleet Heavy Duty Motor Oil SAE 40
14	Hydrotex	Hyfilm SAE 40
15	Phillips	Super HD II Motor Oil SAE 15W-40

Table 27: Synthetic EP gear lubricants (Spec. 100-11)

	Supplier	Brand name
1	Century Lubricants Company	Synthetic EP Gear Lubricants

Table 27: Multi-purpose tractor hydraulic fluid (Spec. 100-12)

	Supplier	Brand name
1	Exxon / Mobil	Mobilfluid 424
2	Century / Fuchs	Multitran
3	Shell	Donax TD
4	Chevron	Tractor Hydraulic Fluid
5	BP Lubricants	Tractran UTH
6	Quaker State	Quaker State FCI HD
7	Conoco	Powertran Fluid

BI002292

Permissible media

7 For your information

For your information

Our service

If you need to order spare parts or if technical problems occur, please contact our after-sales service personnel or contact us direct.

Service address

Beckley, WV
200 George Street, Suite 4
Beckley, WV 25801
Phone: (304) 256-5927
Fax: (304) 256-5928

Craig, CO
400 Mack Lane
Craig, CO 81625
Phone: (970) 824-3249
Fax: (970) 824-8851

Duffield, VA
P.O. Box 847
6808 Fraley Avenue
Duffield, VA 24244
Phone: (276) 431-7000
Fax: (276) 431-2464

Houston, PA
2045 West Pike Street
Houston, PA 15342
Phone: (724) 743-1200
Fax: (724) 743-1201

Carrier Mills, IL
9580 State Route 13 West
Carrier Mills, IL 62917
Phone: (618) 982-9000
Fax: (618) 982-9912

Oak Hill, WV
P.O. Box 60
843 Lochgelly Road
Oak Hill, WV 25901
Phone: (304) 469-3302
Fax: (304) 465-0450

Paonia, CO
P.O. Box 566
719 Second Street
Paonia, CO 81428
Phone: (970) 527-3151
Fax: (970) 527-6846

Washington, PA
255 Berry Road
Washington, PA 15301
Phone: (724) 743-1200
Fax: (724) 228-2177

Pulaski, VA
4041 Wurno Road
Pulaski, VA 24301
Phone: 540-980-4530
Fax: 540-980-6211

Our service

Rebuild facility address

Huntington, UT
P.O. Box 1190
Route 10, 1Mile North
Huntington, UT 84528
Phone: (435) 687-9831
Fax: (435) 687-2522

Pearisburg, VA
P.O. Box 463
222 Industrial Park Drive
Pearisburg, VA 24134
Phone: (540) 921-2111
Fax: (540) 921-2711

Norris City, IL
635 Illinois Highway 1
Norris City, IL 62869
Phone: (618) 378-3441
Fax: (618) 378-3106

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Operation and Troubleshooting Manual

HiPAC 10 Controller

Variable Frequency Drive (VFD) for Battery Powered Equipment (Hardwired System)

This manual is intended to provide GENERAL product information. The illustrations, descriptions and procedures contained in this publication apply only to these machines. Caterpillar reserves the right to revise models and designs without prior notice.

This VFD was manufactured under the guidelines, procedures and requirements of the appropriate regulatory agencies.

Any change to the design or structure of this unit without the consent of Caterpillar and these regulatory agencies, or any repair or replacement of parts contrary to Caterpillar's instructions, may render this unit unsafe to operate.

While this manual attempts to anticipate the most important operations and troubleshooting needs for this unit, unforeseen circumstances may arise that have not been addressed in this manual. If any concerns or questions arise, please contact your Service Representative immediately.

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1 About this manual

About this manual

This chapter provides important information making it easier for you to use this manual. You will also be given information on the structure of the manual and the symbols and characters used.

Before starting to work

applicable operating manual

Take care to ensure that the operating manual available to you is applicable for the type of equipment or machine used.

machine type

This operating manual is intended for the model HiPAC 10 Variable Frequency Drives (VFD) for Battery Powered Equipment and is only permitted to be used for equipment of this type.

new operation manual

The operating and troubleshooting manual must be accessible at all times to all persons working on or with the VFD. It should, if possible, always be available at the place of operation.

Send for a new operation and troubleshooting manual immediately if the present manual is no longer complete or has become illegible.

Who is this manual intended for?

This manual is intended for those persons who work with or on battery powered equipment with the HiPAC 10 Controller.

This includes persons who:

- perform assembly / disassembly work
- operate the machine
- eliminate faults
- perform daily routine work on the face or in the entry
- perform maintenance work
- perform repair work

supervisory personnel who:

- initiate and/or supervise the activities just indicated.

What is the purpose of this manual?

cost-effectiveness

This manual is intended to help you work efficiently and safely with our product. It contains important information on operating and trouble-shooting the HiPAC 10 control system.

Read this operating manual completely and at ease. Pay special attention to the safety instructions. Try to memorize the appearance and the meaning of the safety and instruction symbols.

service

If any details are not clearly understood, please contact our service department. Our service address is given in the chapter titled “For your information”.

safety

Read the chapter “For your safety” with special attention. The chapter contains important information indicating possible hazards. Observe the information given and follow the procedural instructions.

Characters and symbols used

The following characters and symbols are used for safety instructions and important information in the operating manual.

Try to memorize the symbols and their meanings.

DANGER!
Points in the text marked with this symbol draw your attention to immediately impending danger. Possible consequences are: very serious injury or even death.

WARNING!
These points contain information on dangerous situations. Possible consequences are: very serious injury or even death.

CAUTION!
This symbol draws attention to dangerous situations. Possible consequences are: light to moderately serious injuries and machine damage.

NOTICE!
Points in the text marked with this symbol draw attention to harmful situations. Possible consequences are: damage to the machine or damage in the immediate vicinity.

IMPORTANT!
Points in the text marked with this symbol contain useful tips and information intended to facilitate work for you. They do not warn about harmful or dangerous situations.

2 Your safety

Your safety

This chapter provides vital information for your safety. Pay special attention to this chapter. The safety instructions and rules of procedure will help you to avoid hazardous situations and to perform the necessary work as safely as possible.

state of the art

This machine has been manufactured in accordance with the state of the art and generally recognized safety standards and regulations. You and others can, nevertheless, be exposed to dangerous situations e.g. as a result of environmental influences, machine damage, or operator errors.

Do not make any alterations or modifications which could impair the safety of the machine. All modifications and changes must be approved by Caterpillar.

Use only original spare parts. Note that the use of parts from other manufacturers will void the guarantees.

In addition to this operating manual be sure to also observe the respective legal provisions and regulations in your country.

Observe the safety and accident prevention regulations:

- of the mine,
- of the mine inspector, and
- of the mining supervisory authorities.

Personnel

Repair

As a fundamental rule, repair work may only be carried out by personnel who have been adequately trained for these particular requirements.

Electrical repair work may only be carried out by service engineers or by specially qualified personnel of the mine. All electrical work is to be done by qualified persons, in accordance with all MSHA, Federal, State, and Local regulations.

Except where allowed by applicable regulatory agencies, before conducting electrical work on this machine:

- The machine circuit breaker shall be turned off.
- The battery circuit breaker shall be turned off.
- The battery plug shall be disengaged/removed, and locked/tagged out.

Safety instructions

General rules

general

Always work with full concentration.

Familiarize yourself with your working environment.

noise emissions

Always wear your personal protective equipment. This also includes ear protectors as the noise emitted by other equipment in the area may at times exceed 85 dB(A).

Inform your colleagues of:

- your exact location,
- the work you are performing, and
- the time that you will probably require.

safety equipment

Start the machine only when it is in a good and safe operating condition and all protective devices, e.g. EMERGENCY STOP devices, cover plates, etc. are correctly installed.

Observe the acoustic and optical start-up warnings of the machine.

symbol plates

Observe the symbol plates on the machine.

emergency stop

Press the machine’s EMERGENCY STOP switch immediately in the event of fault or irregularities in operation. Report any peculiarity to your superior so that necessary measures can be taken immediately.

disconnect battery

Disconnect the battery while performing:

- maintenance work
- inspection work
- repair work

welding

Batteries should be well vented before servicing, particularly if welding or burning on the battery.

Disconnect the battery when working with the electrical system or when welding on the unit to prevent electrical shock.

While welding, the battery must be disconnected to be sure that you do not damage the electrical system and/or any of the electrical components.

WARNING!
Study all warning/caution labels and notes related to working with batteries and electric motors. These labels may be on the battery, the motor, and/or on the machine, as well as in this Operator’s manual. Failure to comply with the safety instructions regarding working with batteries and electric motors can result in death or serious injury by electrocution.

cordon off working area Cordon off your working area widely for the machine.

moving parts Never allow parts of your body to come between parts which could move, such as:

- false bottoms
- pivot points
- battery lifts

steering lockout Connect the steering lockout device before performing maintenance or repairs on the machine.

Storage and transport

Maintain the prescribed storage periods and observe the instructions for storage.

Do not store materials or parts in the travel way or in your working area.

Inform the persons involved about the intended transport route and the anticipated duration of the transport.

transport safety device Ensure that the transport safety devices are correctly fitted.

Fix all moving parts with transport locks.

Never stand under unsupported parts or suspended loads.

means of attachment Connect the lifting equipment only to the points of attachment provided for that purpose. Observe the different load limits of the attachment points. Also observe the instructions on the transport sheet.

Only use means of attachment which are in good condition and have been designed for the loads to be handled.

For round components use transport straps, only. Never use chains or steel cables for this purpose.

Do not damage the treated or polished surfaces of shafts, sealing surfaces, etc.

mobile handling equipment When using mobile handling systems for transport make sure that the center of gravity is as low as possible.

Maintenance and repair

Be sure to observe the prescribed maintenance and inspection intervals.

Inform the supervisory personnel and the face crew of any maintenance and repair operations. Give them information on the intended operations and the anticipated duration.

securing

Secure your working area over a wide range, in order to avoid endangering other persons.

Disconnect and lock out the battery from the machine to prevent unauthorized and unintentional restarting.

Protect your work area against falling rocks.

replacing components

Disconnect and lock out the battery from machine to prevent from restarting before replacing any defective components.

Pass defective components removed on for servicing without delay in order to prevent these parts being reinstalled elsewhere.

original parts

Use only spare parts which satisfy the specified technical requirements. This is only ensured with original spare parts. Please refer to the spare parts lists for the order numbers.

lifting

For raising the machine use only:

- crib blocks with adequate load-holding capacity.
- hoists, jacks or cranes with adequate load-carrying capacity.

maintenance, repair

Only persons who have and can demonstrate a special knowledge of electrics are allowed to work on the electrical system.

Avoid, whenever possible, servicing, cleaning or examining the machine in congested areas.

Avoid, whenever possible, servicing or providing maintenance to the unit unless the wheels are chocked and steering lockout device is connected to prevent accidental movement of the unit.

Do not alter the electrical settings from that indicated in this manual or as set at the factory.

Always replace damaged or lost decals and metal instruction plates.

Disconnect and lock out the battery when working with the electrical system, or when welding on the unit to prevent electrical shock.

Be sure the battery area is well ventilated (clear of fumes) when it is necessary to connect battery charger. Fumes from the battery could ignite from a spark and explode.

Always follow all safety procedures of each particular mine when performing maintenance.

It is important that any procedure not specifically recommended in this guide be thoroughly evaluated from the standpoint of safety before it is implemented.

Some illustrations in this manual show guards or cover panels removed for purposes of clarity. Never operate unit without guards or cover panels in place.

3 Operation

Operation

This chapter contains important information on the operation of the HiPAC 10 variable frequency drive.

Read this chapter carefully and thoroughly. In particular, observe the safety instructions in Chapter 2 “Your safety”.

History

In the early 1970's, solid state peed controls for battery powered underground mining equipment were introduced. Solid state controls increased the range and reliability of the battery powered vehicles along with providing smooth, stepless acceleration. However, even with solid state speed control, direction change was achieved with the use of electromechanical contactors. These contactors provided an endless source of maintenance problems and consumed excessive amounts of valuable controller enclosure space. In addition, most solid state controllers of the past utilized an electromechanical "bypass" contactor to connect the motor directly to the batteries, which resulted in more contactor problems.

In the 1980’s, a contactorless motor controller (X90) was developed. The X90 system used a dual-field motor in combination with SCRs (Silicone Controlled Rectifiers) to achieve solid state direction change.

In the 1990’s, the BUC2000 motor controller was developed. The BUC2000 system used Insulated Gate Bipolar Transistors (IGBTs) to achieve motor control and direction change. Unlike an SCR, an IGBT is turned on and off via a gating electronic signal, eliminating commutating capacitor banks and coils. The microprocessor based BUC2000 logic card provided complete motor control and drove both a diagnostic dashboard display and a handheld calibrator/diagnostic unit.

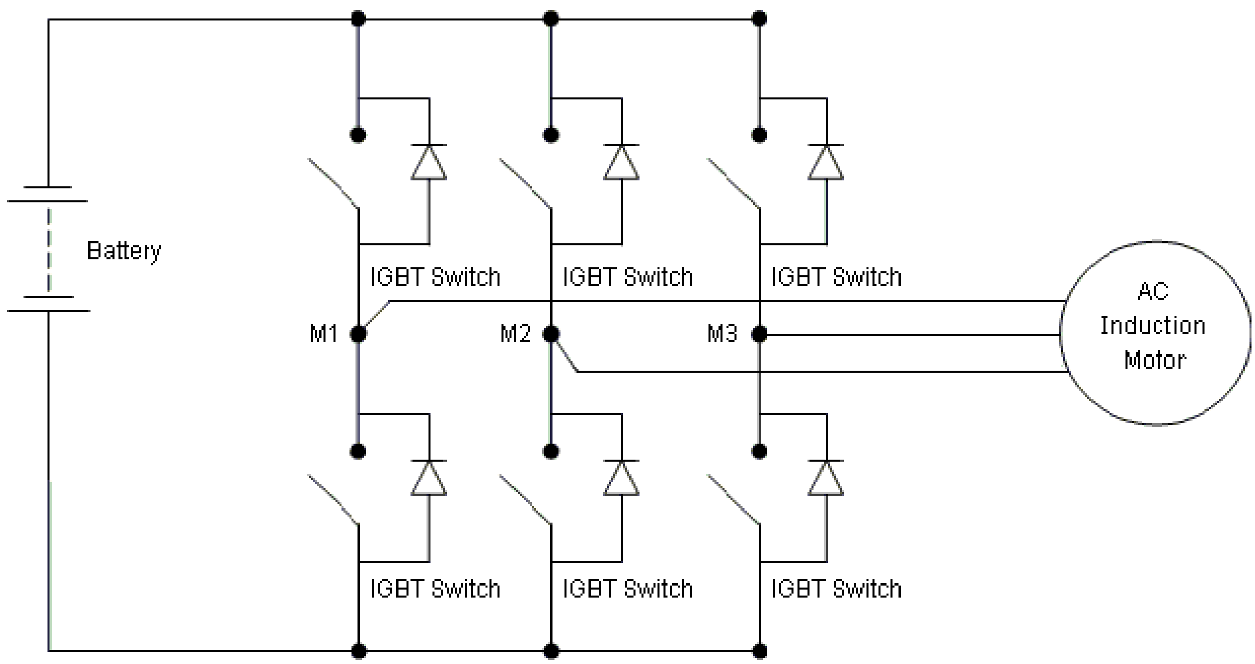
During the early 2000’s, the successful HiPAC 10 motor controller system was developed. The HiPAC 10 system consists of highly efficient AC 3-phase induction motors and variable frequency drives. The HiPAC 10 system provides increased efficiency, higher torque capabilities, increased machine speeds, and has no motor brushes or brush holders.

Innovative Motor Control

The speed of rotation of AC induction motors is directly dependent upon the frequency of the applied AC voltage. Therefore, In order to control the speed of AC induction motors, the motor must be supplied with a voltage of variable magnitude and frequency. Ideally, this voltage is sinusoidal.

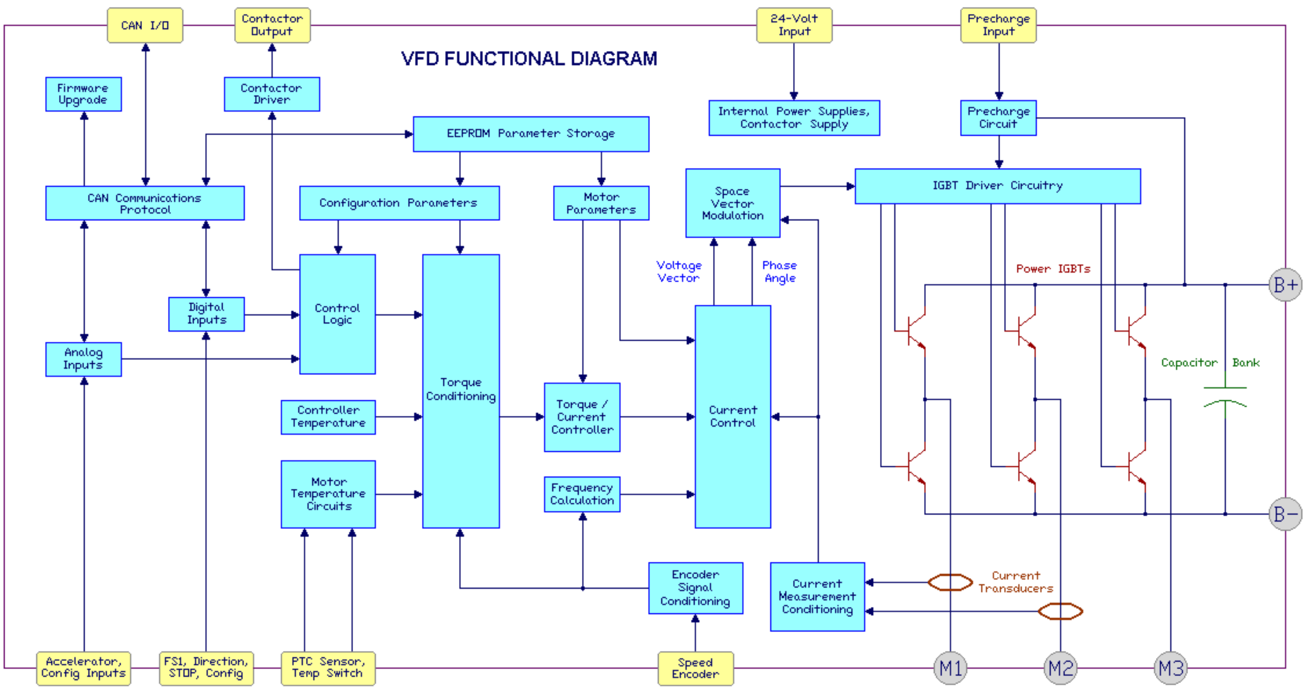
The power circuit stage of the inverter converts a fixed DC voltage from the battery into an AC voltage of variable frequency and magnitude. It achieves this by means of Insulated Gate Bipolar Transistors (IGBTs). These high power, high frequency solid-state switches pulse a DC voltage onto the motor terminals in such a manner to replicate the desired sinusoidal current demand. A simplified schematic of the power circuit is shown in Figure 1; it consists of six power switches (IGBTs), two per motor phase.

Fig. 1: Simplified AC power circuit



The HiPAC 10 VFD is a complex piece of electronic equipment in which hardware and software work together to drive the vehicle in a safe and efficient manner. A functional block diagram (Fig. 2) illustrates how the internal systems work together.

Fig. 2: Functional block diagram of a VFD



In order to produce a sinusoidal output on the motor terminals M1, M2, and M3, the six switches are turned on and off at a very high frequency. Figures 3, 4, 5, and 6 show the switching signal driving one phase of switches and the fundamental sinusoidal waveform which they are replicating. The four figures show: low voltage/low frequency; low frequency/high voltage; high frequency/low voltage; and high frequency/high voltage.

Fig. 3: Low frequency low voltage output

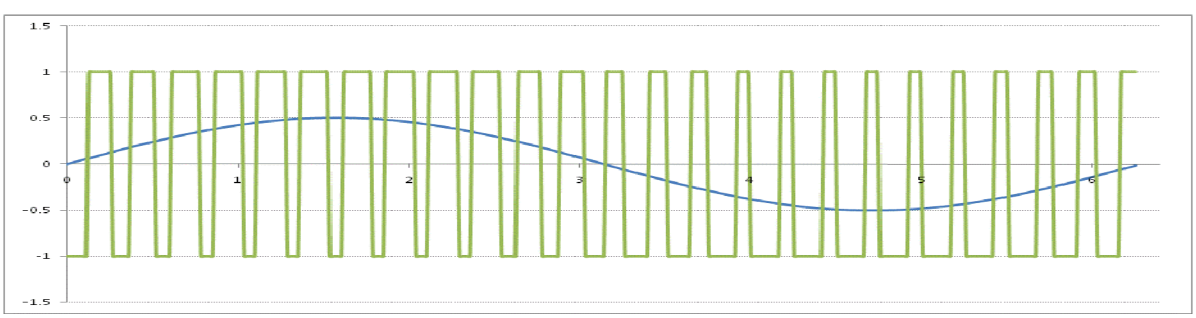


Fig. 4: Low frequency high voltage output

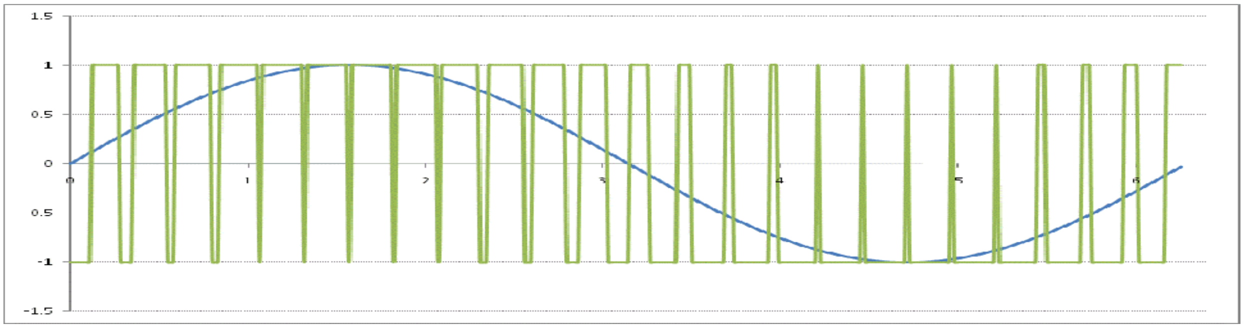


Fig. 5: High frequency low voltage output

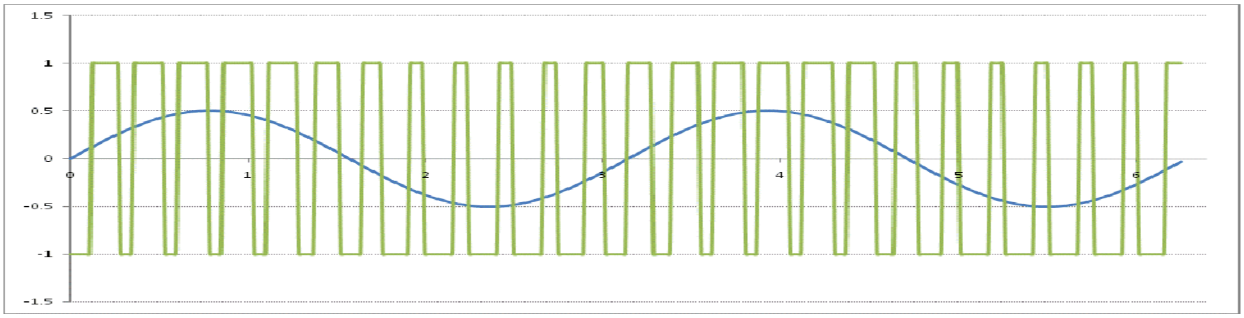
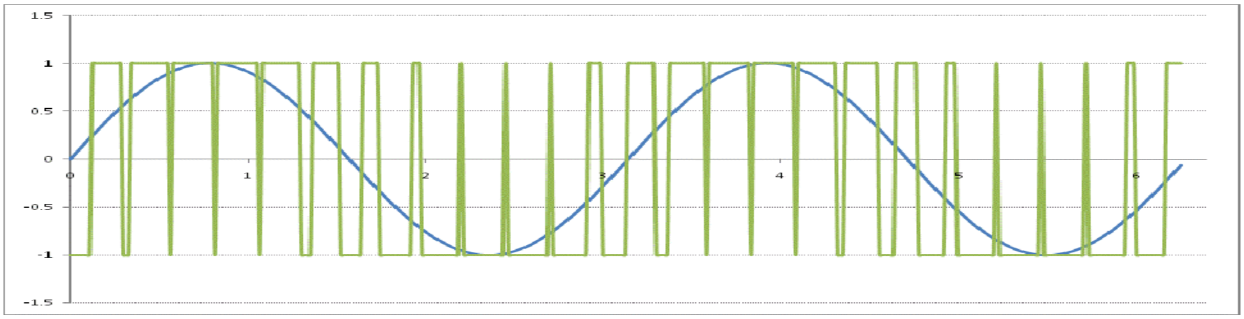


Fig. 6: High frequency high voltage output

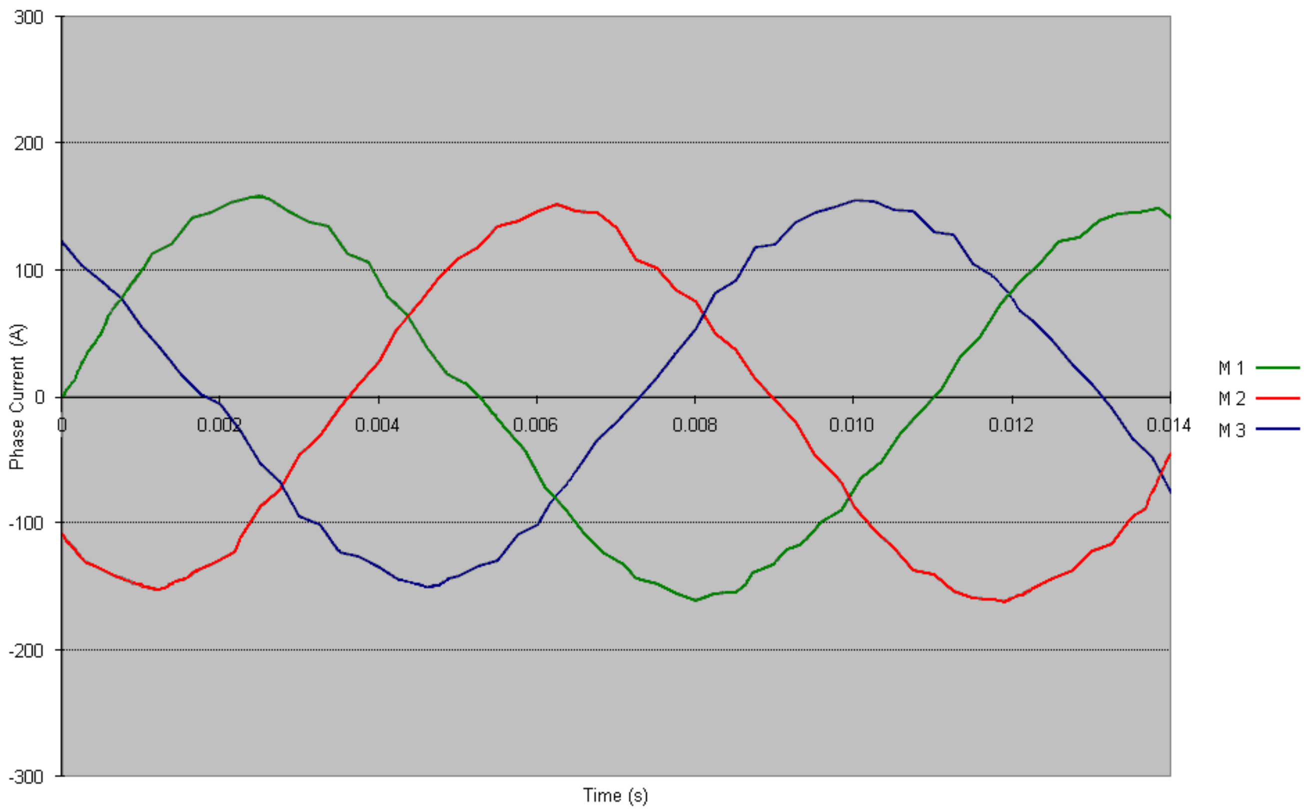


The motor connected is a three phase motor, therefore three of the shown switching signals will be used, each offset by 120°.

Due to the fact that the windings of the motor are inductive, the current in the machine will rise and fall slowly as the voltage is pulsed on and off. The resulting current will be a relatively smooth sinusoidal waveform.

Fig. 7 shows the three phase currents which result from a modulated voltage waveform.

Fig. 7: Three phase current waveform

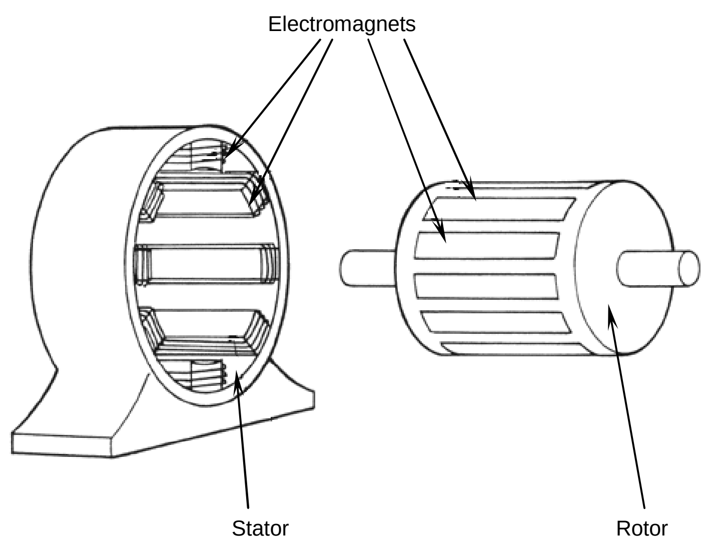


In summary, the power inverter allows a DC voltage to be applied as an AC voltage; this is achieved by pulsing the switching devices at high frequency. Because the AC voltage is created from a series of pulses of DC link voltage, this AC voltage can be varied in both magnitude and frequency. An AC voltage of variable magnitude and frequency is necessary in order to control the speed of an induction machine.

Basic AC motor operation

An AC motor has two basic electrical parts: a stator and a rotor (Fig. 8). The stator is the stationary electrical component, consisting of a group of individual electromagnets arranged in such a way that they form a hollow cylinder, with one pole of each magnet facing toward the center of the group. The rotor is the rotating electrical component, also consisting of a group of electromagnets arranged around a cylinder, with the poles facing the stator poles. The rotor is located inside the stator and is mounted on the motor's shaft. The objective of the rotor and stator is to rotate the motor shaft. This rotation occurs because opposite magnetic poles attract each other and like poles repel. If the polarity of the stator poles is progressively changed in such a way that their combined magnetic field rotates, then the rotor will follow and will rotate with the magnetic field on the stator.

Fig. 8: Basic electrical components of an AC motor



One way to produce a rotating magnetic field in the stator of an AC motor is to use a three-phase power supply for the stator coils. At any one instant, the direction and intensity of each separate current flow is not the same as the other phases. A complete cycle (from zero to maximum in one direction, to zero to maximum in the other direction, and back to zero) takes one complete revolution of the motor. Therefore, a complete cycle is said to have 360 electrical degrees. Each phase is displaced 120 degrees from the other two phases.

To produce a rotating magnetic field in the stator of a three-phase AC motor, each phase of the three-phase power supply is connected to opposite poles and the associated coils are wound in the same direction. The polarity of the poles of an electromagnet are determined by the direction of the current flow through the coil. Therefore, if two opposite stator electromagnets are wound in the same direction, the polarity of the facing poles must be opposite. Thus, as the phases shift their current flow, the resultant north and south poles move clockwise around the stator, producing a rotating magnetic field. The rotor acts like a bar magnet being pulled along by the rotating magnetic field.

Induction is a characteristic of magnetism. It is a natural phenomena that occurs when a conductor is moved through an existing magnetic field or when a magnetic field is moved past a conductor. In either case, the relative motion of the two causes an electric current to flow in the conductor. This is referred to as “induced” current flow. In other words, in an induction motor the current flow in the rotor is not caused by any direct connection of the conductors to a voltage source, but rather by the influence of the rotor conductors cutting across the lines of flux produced by the stator magnetic fields.

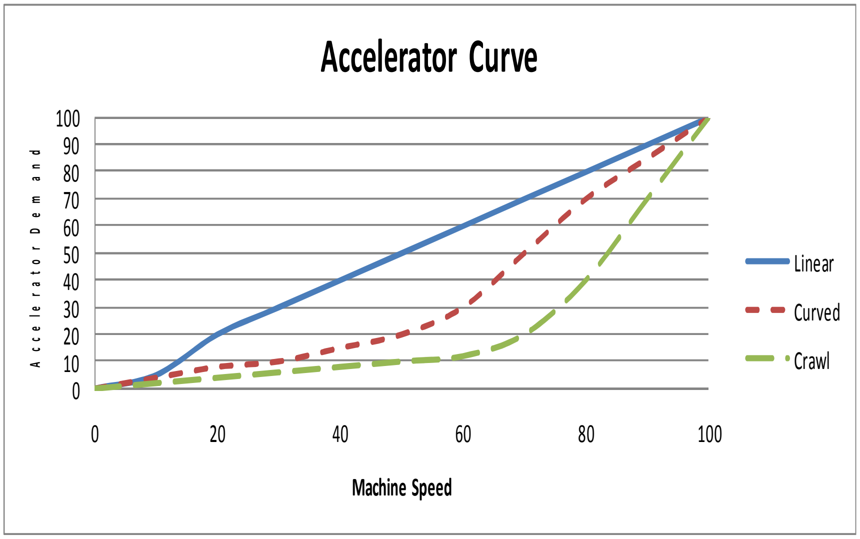
The induced current in the rotor results in a magnetic field around the rotor conductors. This magnetic field will cause each rotor conductor to act like a permanent magnet. As the magnetic field or the stator rotates due to the effect of the three-phase AC power supply, the induced magnetic field of the rotor will be attracted and will follow the rotation. The rotor is connected to the motor shaft, therefore the shaft will rotate and drive the connected load.

General specifications

The HiPAC 10 is designed to operate from a 240 or 128 Volt DC nominal battery and controls one or two AC induction traction motors and one AC induction pump motor.

- The maximum current limit default setting is 800 amps for each traction motor, 800 amps for the VT680 pump motor, and 200 amps for all other the pump motors.
- The current limit is preset and is not adjustable.
- Traction functions operate at a speed that is directly proportional to the accelerator demand. However, the standard linear response can be changed via accelerator parameters. This allows the user to fine-tune pedal responsiveness and “feel”. Fig. 9 shows an example of an accelerator response curve.
- Two pump motor speeds are available: high-speed normal working mode and low-speed energy savings mode. The speeds are selected automatically via a hydraulic pressure switch which senses hydraulic pressure demand.
- Traction and pump motor current is continuously monitored by each motor controller.

Fig. 9: Accelerator curve



Features

The HiPAC 10 incorporates a variety of independent protection systems. These improve reliability, shield the motors and VFDs from overload, protect the machine from inadvertent abuse, and help to protect workers from potential harm from malfunctioning equipment.

The system utilizes the main circuit breaker as a means of failsafe protection by mechanically disconnecting the motor from the battery supply in the event of drive failure. There are two parts to this, look-ahead and failsafe protection:

- The look-ahead feature is where the traction system monitors the vital parts of the controller and motor and, according to their conditions, will or will not allow the circuit breaker to be closed.
- The failsafe feature will engage when the system detects any part of the controller or motor to be non-operational and/or faulty. At this point, the system will open the main circuit breaker.

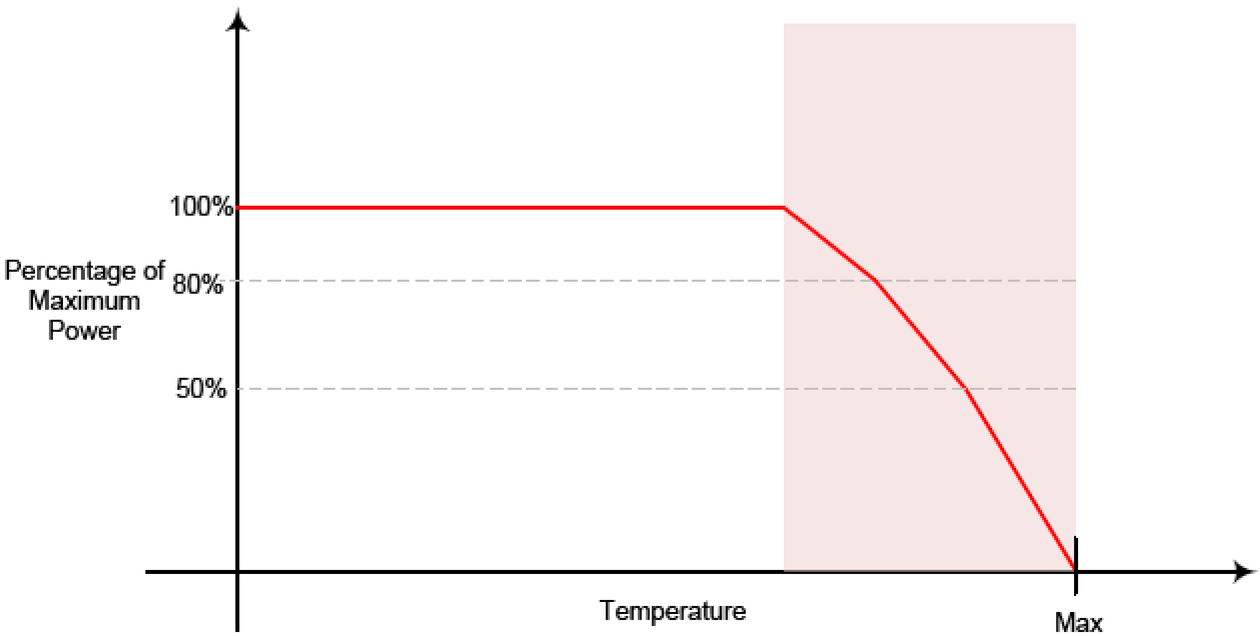
Additionally, due to the inherent advantage of an AC motor, if there is a failure in any of the motor phases or drive controller phases, the motor will come to a stop and can no longer be driven, even if a faulty drive controller were to continue to pulse the remaining two phases.

Motor overload is defined as running the motor beyond the manufacturer's continuous rated specification up to a specified maximum limit. Operating the machine in this way allows more power to be produced for shorter periods of time. This is acceptable use of the motor as long as consideration is given to the extra heating effect in the motor. The HiPAC 10 implements three parallel and independent temperature measurements in the motor:

- PTC temperature probe embedded in the motor: The voltage proportional to temperature formed across this device represents the internal winding temperature and is fed back in to the controller and converted to a real temperature.
- A thermal switch, which changes state above a certain temperature, is attached to the motor. This is fed to the controller and, when activated, cuts the available power to the motor to 30% of maximum (Fig. 10).
- A motor temperature estimate is implemented in software which predicts the motor temperature based upon the current in the motor, its thermal time-constant, and impedance.

In the event of motor over current, the software will attempt to resist the over current by applying voltage to oppose it. However, if the situation is unrecoverable (for example: in the case of a dead short), a hardware trip will disable the inverter, putting the outputs into a high impedance state.

Fig. 10: Power limit cutback



The actual temperatures used to determine the power limit cutback are given Table 1. When the manufacturer specified maximum temperature is reached, shaft output power is reduced to zero.

Table 1: Torque cutback parameters

	Start of cutback	100% Cutback
Pump Motor VFD (except VT680)	95°C (203°F)	105°C (221°F)
Traction Motor VFD **Pump Motor VFD (VT680)**	90°C (194°F)	100°C (212°F)

The HiPAC 10 prevents over voltage of the inverter DC link and the charging voltage of the battery using continuous monitoring of this voltage. The cutback curves for both 240-Volt and 128-Volt systems can be found in Figures 11 and 12, respectively.

IMPORTANT!
Currently, the State of Pennsylvania does not allow regenerative braking. This law is under consideration. However, regenerative braking must currently be disabled in the State of Pennsylvania only. This is done by setting all braking torques to zero. See the adjustable parameters chart.

Fig. 11: Voltage cutbacks for a 240-Volt system

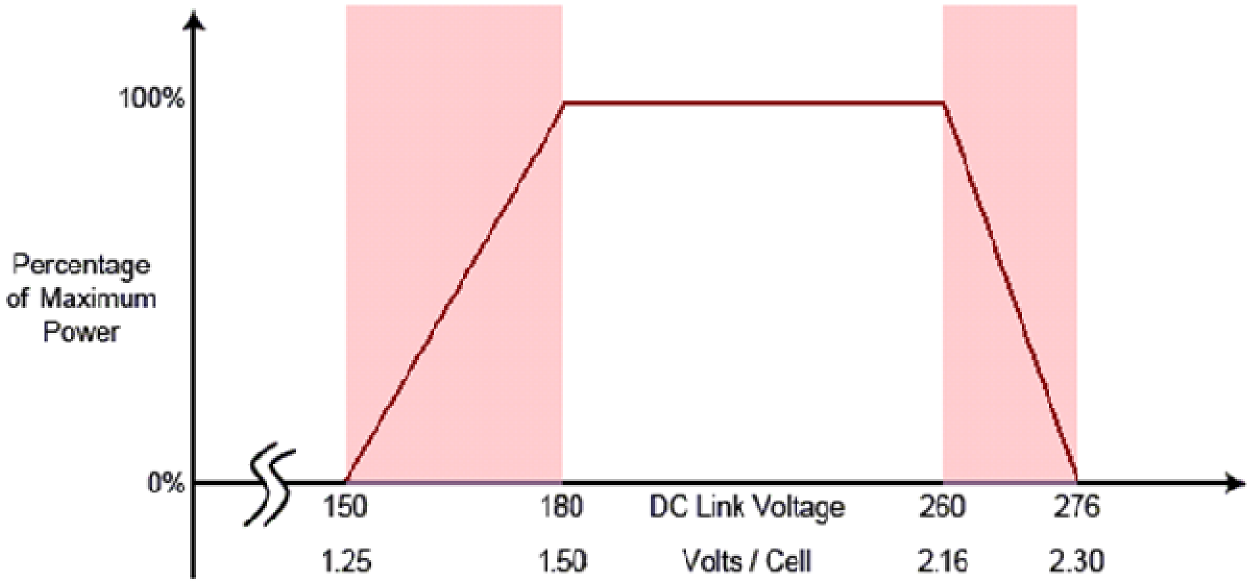
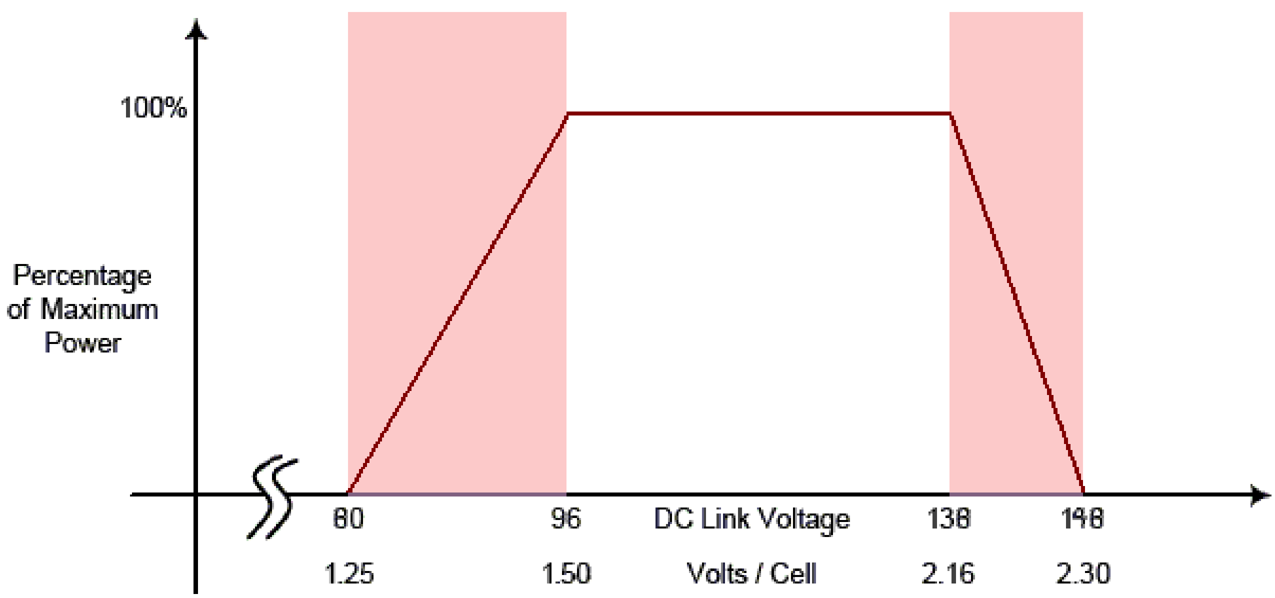


Fig. 12: Voltage cutbacks for a 128-Volt system



As the machine brakes regeneratively, the DC link will rise. If the voltage encroaches into the cutback region, the amount of power generated is reduced, resulting in a reduced braking effort. For 240-Volt systems, the cutback region begins at 260V and ends at 276V. The range is 138V to 148V for 128-Volt systems. The amount of braking effort applied while in cutback is a balance between the amount of generated voltage and the braking effort. As the amount of braking energy is reduced (by reduction of motor shaft input power), the increased voltage situation is reduced and controlled directly. By this scheme, the battery cannot exceed the maximum voltage while braking effort is not completely removed.

Under voltage protection is implemented as a way of preventing the controller from drawing power from a battery that is already discharged, resulting in battery damage. In a 240-Volt system, drive cutback begins at 180V and power drops linearly until cutout at 150V. In a 128-Volt system, cutback begins at 96V and ends at 80V.

Both 240-Volt and 128-Volt ranges are given in Table 2.

Table 2: Battery over voltage/under voltage protection parameters

	Start of Cutback (240V)	**100% Cutback (240V)**	**Start of Cutback (128V)**	**100% Cutback (128V)**
Over Voltage Protection	260 Volts (2.16 V/Cell)	276 Volts (2.30 V/Cell)	138 Volts (2.16 V/Cell)	148 Volts (2.30 V/Cell)
Under Voltage Protection	180 Volts (1.50 V/Cell)	150 Volts (1.25 V/Cell)	96 Volts (1.50 V/Cell)	80 Volts (1.25 V/Cell)

System components

- One, two, or four (VT680 only) AC induction traction motors
- One or two traction motor VFDs
- One AC induction pump motor
- One pump motor VFD
- Dashboard display
- Connecting wire harness “A”
- Connecting wire harness “B”
- Connecting wire harness “C”
- Connecting wire harness “D”

System power connections for each traction and pump motor controller

- Battery positive: 240VDC or 128VDC nominal
- Battery negative
- Each motor connection, 3-phase M1/T1, M2/T2, and M3/T3.

VFD control hard inputs/outputs

Each VFD is equipped with four connectors: “A”, “B”, “C”, and “D”. With dual traction motor systems, the supervisor and auxiliary traction VFDs are the same part number and contain the same software. However, pin A26 hardwired configuration will signal the traction VFD whether to power up as the supervisor or as the auxiliary traction controller.

Tables 3 through 11 give standard pin configurations and tables 12 through 26 give pin configurations for VT680 machines.

Table 3: Supervisor traction VFD, connector "A" (Standard)

Input Description	Connector/Pin
Encoder shield (internally connected to A3) (optional)	A1
V+ to encoder	A2
V- to encoder	A3
Encoder input "A"	A4
Encoder input "B"	A5
Gear configuration (1)	A6
Gear configuration (2)	A7
Gear configuration (3)	A8
Gear configuration (4)	A9
Gear configuration (5)	A10
Tram motor quantity	A11
Circuit breaker auxiliary switch	A12
Stop (and increment down)	A13
Diagnostics & acknowledge	A14
FS1 - foot switch one (digital input)	A15
Not used	A16
Not used	A17
Not used	A18
Not used	A19
Motor thermal sensor input	A20
Tram motor size	A21
Motor temperature switch	A22
Not used	A23
Not used	A24
24VDC common input to VFD	A25
Traction supervisor identifier (digital input)	A26
Traction assist/increment up (control handle) OR Screen Select/increment up (control box)	A27
24VDC common input to VFD	A28
- Supply (for A26)	A29
Not used	A30
24VDC common supply to motor temp sensors	A31
Not used	A32
Not used	A33
CAN high	A34
CAN low	A35

Table 4: Supervisor traction VFD, connector "C" (Standard)

Input Description	Connector/Pin
+24VDC Supply input	C1
(Reserved for service brake)	C2
UVR Driver (24VDC Common)	C3
Park Brake Solenoid Driver (24VDC Common)	C4
Breaker "ON" for headlight relay driver (24VDC common)	C5
Not Used	C6
Not Used	C7
Not Used	C8

Table 5: Supervisor traction VFD, connector "D" (Standard)

Not Used	D1
Pre-Charge Feed from B+	D2
Not Used	D3
Not Used	D4
Not Used	D5
Not Used	D6
Not Used	D7
Not Used	D8

Table 6: Auxiliary traction VFD, connector “A” (Standard)

Input Description	Connector/Pin
Encoder shield (internally connected to A3) (optional)	A1
V+ to encoder	A2
V- to encoder	A3
Encoder input “A”	A4
Encoder input “B”	A5
Speed cutback (payload limit profile)	A6
“Oil Level Low” when connected to 24V common	A7
Hydraulic filter	A8
Payload counter switch	A9
“Oil Temperature High” when connected to 24V common	A10
Sensored Steering when connected to 24V common (DAS enable)	A11
Steer Direction → when connected to 24V common (DAS push)	A12
Steer Direction ← when connected to 24V common (DAS pull)	A13
Open	A14
Open	A15
Not used	A16
Not used	A17
Not used	A18
Not used	A19
Motor thermal sensor input	A20
Tram motor size	A21
Motor temperature switch	A22
+ Supply (for A26)	A23
Not used	A24
Power supply 24VDC common for display	A25
Traction auxiliary identifier (digital input)	A26
Open	A27
24VDC common input to VFD	A28
Not used	A29
Not used	A30
24VDC common supply to motor temp sensors	A31
Not used	A32
Not used	A33
CAN high	A34
CAN low	A35

Table 7: Auxiliary traction VFD, connector “C” (Standard)

Input Description	Connector/Pin
+24VDC Supply input	C1
Not Used	C2
Not Used	C3
Not Used	C4
Not Used	C5
Not Used	C6
Not Used	C7
Not Used	C8

Table 8: Auxiliary traction VFD, connector “D” (Standard)

Input Description	Connector/Pin
Not Used	D1
Pre-Charge Feed from B+	D2
Not Used	D3
Not Used	D4
Not Used	D5
Not Used	D6
Not Used	D7
Not Used	D8

Table 9: Pump VFD, connector "A" (Standard)

Input Description	Connector/Pin
Not used	A1
Not used	A2
Not used	A3
Not used	A4
Not used	A5
Tire configuration (1)	A6
Tire configuration (2)	A7
Tire configuration (3)	A8
Tire configuration (4)	A9
Vehicle type (1)	A10
Vehicle type (2)	A11
→ Tram direction	A12
← Tram direction	A13
Pump motor run/stop	A14
Pump pressure switch	A15
Drain wire connection	A16
Not used	A17
Not used	A18
Supply for A27	A19
Motor thermal sensor input	A20
Motor temperature switch	A21
Open 240VDC system (128VDC system when tied to 24VDC common)	A22
Not used	A23
Not used	A24
Power supply 24VDC common for display	A25
Park brake released/opt pressure switch	A26
Accelerator potentiometer (foot switch) analog input	A27
24VDC common input to VFD	A28
Not used	A29
Not used	A30
24VDC common supply to motor temp sensors	A31
Power supply +24VDC for display	A32
Not used	A33
CAN high	A34
CAN low	A35

Table 10: Pump VFD, connector “C” (Standard)

Input Description	Connector/Pin
+24VDC Supply input	C1
Not Used	C2
Pump motor running output	C3
Not Used	C4
Not Used	C5
Not Used	C6
Not Used	C7
Not Used	C8

Table 11: Pump VFD, connector “D” (Standard)

Input Description	Connector/Pin
Not Used	D1
Pre-Charge Feed from B+	D2
Not Used	D3
Not Used	D4
Not Used	D5
Not Used	D6
Not Used	D7
Not Used	D8

Table 12: Supervisor - Front Traction VFD (Node 1), connector "A" (VT680)

Input Description	Connector/Pin
Not used	A1
V+ to encoder	A2
V- to encoder	A3
Encoder input "A"	A4
Encoder input "B"	A5
Gear Configuration (1)	A6
Gear Configuration (2)	A7
Gear Configuration (3)	A8
Gear Configuration (4)	A9
Gear Configuration (5)	A10
Tram motor quantity	A11
Circuit breaker auxiliary switch	A12
Stop (and increment down)	A13
Supervisor Front Traction ID, connect to pin 16	A14
Supervisor Front Traction ID, connect to pin 16	A15
- Supply for pins A14 and A15	A16
Not used	A17
Not used	A18
Not used	A19
Motor thermal sensor input	A20
Tram motor size	A21
Motor temperature switch	A22
Not used	A23
Not used	A24
Drain wire connection	A25
Supervisor identification, connect to pin A29	A26
Traction assist/increment up (control handle) OR Screen Select/increment up (control box)	A27
24VDC common input to VFD	A28
- Supply for A26	A29
Not used	A30
24VDC common supply to motor temp sensors	A31
Not used	A32
Not used	A33
CAN high	A34
CAN low	A35

Table 13: Supervisor - Front Traction VFD (Node 1), connector "C" (VT680)

Input Description	Connector/Pin
+24VDC Supply input	C1
(reserved for service brake)	C2
UVR driver (24VDC common)	C3
Park brake solenoid driver (24VDC common)	C4
Breaker "ON" for headlight relay driver (24VDC common)	C5
Not Used	C6
Not Used	C7
Not Used	C8

Table 14: Supervisor - Front Traction VFD (Node 1), connector "D" (VT680)

Input Description	Connector/Pin
Not Used	D1
Pre-Charge Feed from B+	D2
Not Used	D3
Not Used	D4
Not Used	D5
Not Used	D6
Not Used	D7
Not Used	D8

Table 15: Pump VFD (Node 3), connector "A" (VT680)

Input Description	Connector/Pin
Not Used	A1
V+ to encoder	A2
V- to encoder	A3
Encoder input "A"	A4
Encoder input "B"	A5
Tire Configuration (1)	A6
Tire Configuration (2)	A7
Tire Configuration (3)	A8
Tire Configuration (4)	A9
Vehicle type (1)	A10
Vehicle type (2)	A11
→ Tram direction	A12
← Tram direction	A13
Pump identification, connect to pin A16	A14
Pump identification, connect to pin A16	A15
- Supply for pins A14 and A15	A16
Not Used	A17
Not Used	A18
Supply for A27	A19
Motor thermal sensor input	A20
Motor temperature switch	A21
towing Mode	A22
+ Supply for pin A26	A23
Not Used	A24
Power supply 24VDC common for display	A25
Aux/Pump Identification, connect to pin A23	A26
Accelerator potentiometer (analog input)	A27
24VDC common input to VFD	A28
- Supply (not used)	A29
Not Used	A30
24VDC common supply to motor temp sensors	A31
Power supply +24VDC for display	A32
Not Used	A33
CAN high	A34
CAN low	A35

Table 16: Pump VFD (Node 3), connector "C" (VT680)

Input Description	Connector/Pin
+24VDC Supply input	C1
Not Used	C2
Pump motor running output	C3
Not Used	C4
Not Used	C5
Not Used	C6
Not Used	C7
Not Used	C8

Table 17: Pump VFD (Node 3), connector "D" (VT680)

Input Description	Connector/Pin
Not Used	D1
Pre-Charge Feed from B+	D2
Not Used	D3
Not Used	D4
Not Used	D5
Not Used	D6
Not Used	D7
Not Used	D8

Table 18: Front Auxiliary Traction VFD (Node 6), connector "A" (VT680)

Input Description	Connector/Pin
Not Used	A1
V+ to encoder	A2
V- to encoder	A3
Encoder input “A”	A4
Encoder input “B”	A5
Speed cutback	A6
Oil level	A7
Hydraulic filter	A8
Payload counter switch	A9
Pump pressure switch	A10
Pump motor run/stop	A11
FS1 foot switch digital input	A12
Diagnostics & Acknowledge	A13
Front Aux. Identification, connect to pin A16	A14
Front Aux. Identification, connect to pin A18	A15
- Supply for pin A14	A16
Not Used	A17
+ Supply for pin A15	A18
Not Used	A19
Motor thermal sensor input	A20
Tram motor size	A21
Motor temperature switch	A22
+ Supply for pin A26	A23
Not Used	A24
Power supply 24VDC common for display	A25
Aux/Pump Identification, connect to pin A23	A26
Park brake released/pressure switch	A27
24VDC common input to VFD	A28
- Supply (not used)	A29
Not Used	A30
24VDC common supply to motor temp sensors	A31
Not Used	A32
Not Used	A33
CAN high	A34
CAN low	A35

Table 19: Front Auxiliary Traction VFD (Node 6), connector "C" (VT680)

Input Description	Connector/Pin
+24VDC Supply input	C1
Not Used	C2
Not Used	C3
Not Used	C4
Not Used	C5
Not Used	C6
Not Used	C7
Not Used	C8

Table 20: Front Auxiliary Traction VFD (Node 6), connector "D" (VT680)

Input Description	Connector/Pin
Not Used	D1
Pre-Charge Feed from B+	D2
Not Used	D3
Not Used	D4
Not Used	D5
Not Used	D6
Not Used	D7
Not Used	D8

Table 21: Rear Auxiliary (1) Traction VFD (Node 2), connector “A” (VT680)

Input Description	Connector/Pin
Not Used	A1
V+ to encoder	A2
V- to encoder	A3
Encoder input “A”	A4
Encoder input “B”	A5
Not Used	A6
Not Used	A7
Not Used	A8
Not Used	A9
Not Used	A10
Not Used	A11
Not Used	A12
Not Used	A13
Rear Aux. (1) Identification, connect to pin A18	A14
Rear Aux. (1) Identification, connect to pin A16	A15
- Supply for pin A15	A16
Not Used	A17
+ Supply for pin A14	A18
Not Used	A19
Motor thermal sensor input	A20
Tram motor size	A21
Motor temperature switch	A22
+ Supply for pin A26	A23
Not Used	A24
Power supply 24VDC common for display	A25
Aux/Pump Identification, connect to pin A23	A26
Not Used	A27
24VDC common input to VFD	A28
- Supply (not used)	A29
Not Used	A30
24VDC common supply to motor temp sensors	A31
Not Used	A32
Not Used	A33
CAN high	A34
CAN low	A35

Table 22: Rear Auxiliary (1) Traction VFD (Node 2), connector "C" (VT680)

Input Description	Connector/Pin
+24VDC Supply input	C1
Not Used	C2
Not Used	C3
Not Used	C4
Not Used	C5
Not Used	C6
Not Used	C7
Not Used	C8

Table 23: Rear Auxiliary (1) Traction VFD (Node 2), connector "D" (VT680)

Input Description	Connector/Pin
Not Used	D1
Pre-Charge Feed from B+	D2
Not Used	D3
Not Used	D4
Not Used	D5
Not Used	D6
Not Used	D7
Not Used	D8

Table 24: Rear Auxiliary (2) Traction VFD (Node 7), connector "A" (VT680)

Input Description	Connector/Pin
Not Used	A1
V+ to encoder	A2
V- to encoder	A3
Encoder input "A"	A4
Encoder input "B"	A5
Not Used	A6
Not Used	A7
Not Used	A8
Not Used	A9
Open	A10
Open	A11
Open	A12
Open	A13
Rear Aux. (2) Identification, connect to pin A18	A14
Rear Aux. (2) Identification, connect to pin A16	A15
Not Used	A16
Not Used	A17
+ Supply for pins A14 and A15	A18
Not Used	A19
Motor thermal sensor input	A20
Tram motor size	A21
Motor temperature switch	A22
+ Supply for pin A26	A23
Not Used	A24
Power supply 24VDC common for display	A25
Aux/Pump Identification, connect to pin A23	A26
Not Used	A27
24VDC common input to VFD	A28
- Supply (not used)	A29
Not Used	A30
24VDC common supply to motor temp sensors	A31
Not Used	A32
Not Used	A33
CAN high	A34
CAN low	A35

Table 25: Rear Auxiliary (2) Traction VFD (Node 7), connector "C" (VT680)

Input Description	Connector/Pin
+24VDC Supply input	C1
Not Used	C2
Not Used	C3
Not Used	C4
Not Used	C5
Not Used	C6
Not Used	C7
Not Used	C8

Table 26: Rear Auxiliary (2) Traction VFD (Node 7), connector "D" (VT680)

Input Description	Connector/Pin
Not Used	D1
Pre-Charge Feed from B+	D2
Not Used	D3
Not Used	D4
Not Used	D5
Not Used	D6
Not Used	D7
Not Used	D8

Configuration chart

The HiPAC 10 system was designed to operate several machine types: UN-A-HAULER®, UN-A-TRAC® , VERSATRAC® , single motor, dual motor, 75 hP, and 100 hP traction motors. To help the maintenance person, and to limit warehouse inventories, each VFD includes software to operate all of the listed equipment. With the maintenance in mind, all essential machine configuration inputs are hardwired at the factory.

NOTICE!
See the machine parts manual and wiring diagram for your machine for the configuration settings.

These inputs provide the supervisor traction VFD with all critical information for normal machine duty, such as tire size, gear ratio, motor size, motor quantity, and vehicle type. Upon power up or change-out of a supervisor traction VFD, this valuable information is automatically supplied to the new supervisor traction VFD without any user input. This saves maintenance time and programming.

NOTICE!
If at any time after a machine is placed in commission, the tire size, motor size, gear ratio, or any other configuration is changed, the configuration input wires should be changed to match the correct sizes.

See the machine wiring diagrams for configurations.

Control System Operation

Controller Start-up

The VFDs are supplied control power from a 24V DC-DC converter and power up when the operator manually closes the battery circuit breaker on the battery assembly (if equipped) and releases the emergency stop push button in the operator's compartment.

A valid start-up sequence is described as follows:

1. Turn the battery circuit breaker and/or disconnect switch (if equipped) to the "ON" position.
2. Press and hold the diagnostics momentary switch. The VFDs energize the pre-charge circuit and the controller start-up device checks are performed (checks are done within a matter of seconds). If all checks are okay, the supervisor traction VFD will energize the main circuit breaker UVR Coil (Pin C3) and the display will signal the operator that it is OK to close the main machine circuit breaker.
3. Release the diagnostics momentary switch.
4. Close the main machine circuit breaker supplying full battery power to the VFDs.

Once the main machine circuit breaker is determined closed by the supervisor VFD through the use of the circuit breaker auxiliary switch (Pin A12 on supervisor VFD), the system is ready for pump motor operation.

Note: Once the main machine circuit breaker is closed, the Diagnostics momentary switch becomes the button to change screens on the display.

See the machine operation manual for machine operation.

NOTICE!
MSHA requirements limit the maximum machine tram speed to 6 mph. This occurs automatically through the VFD software and correct hardwired configuration inputs.

IMPORTANT!
If the operator selects FS1 before selecting a direction, a SRO fault will be produced and direction selection inhibited.

Traction braking

Regenerative braking is done in compliance to the MSHA regulations on battery powered vehicles.

IMPORTANT!
Current Pennsylvania State law does not allow regenerative braking. It must be disabled in the state of Pennsylvania only.

Neutral braking

This helpful braking method is done using Regenerative braking and its strength is set according to an adjustable parameter. This braking occurs when the FS1 switch is opened while driving.

CAUTION!
The service brake and park brake are the primary means for stopping the vehicle.

Direction braking

This helpful braking method is done using Regenerative braking and its strength is set according to an adjustable parameter. It is typically set to a stronger level than neutral braking. This braking occurs when there has been a valid direction change.

CAUTION!
The service brake and park brake are the primary means for stopping the vehicle.

Deceleration braking

This helpful braking method is done using Regenerative braking and its strength is set according to an adjustable parameter. This braking occurs if the accelerator is decreased from a higher speed to a lower speed until the new lower speed level is reached.

CATUION!
The service brake and park brake are the primary means for stopping the vehicle.

Drivability profiles

There are three selectable drivability profiles that can be set in the controller.

- The baseline profile is used to set the vehicle maximum performance characteristics. This is the normal operation mode.
- The payload limit profile is used to set the vehicle maximum performance characteristics to a lower level. This is typically used to lower the maximum machine speed when carrying heavy loads, navigating bad floor conditions, or for operator training.
- The BDI Cutback profile will become active when the BDI cutout level is reached. It is set to limit the vehicle performance to conserve battery and further alert the operator of the low battery condition. Typically the maximum machine speed is set to a lower level in this profile.

Circuit breaker close timer feature

This timer, typically set at 15 minutes, sets the amount of time the operator has to close (set) the circuit breaker once the controller determines it is safe to do so (“SYSTEM OK” message displayed). If the operator does not close the circuit breaker in the given time, the controller will force the operator to do a power recycle in order to try and close the circuit breaker again.

Pump cutback timer feature

This feature will cut back the pump speed if no pump functions are activated through the use of a pump pressure switch input within a set time. Once any function requiring the pump motor speed to increase is activated, the pump pressure switch will activate, signaling the pump VFD to immediately ramp the pump motor to full speed demand. When not active, it will allow cutback of the pump motor speed to conserve energy. The pump cutback ramp rate and cutback delay time are adjustable parameters.

Payload counter feature

This manually activated feature allows the operator to count payload trips. When the counter input is selected, it will increment the counter shown on the display by one. If the operator holds the counter for more than 5 seconds, the counter will reset to zero.

Motor encoder (feedback device)

The HiPAC 10 traction motors and the VT680 pump motor utilize an encoder mounted on back of the motor for motor speed and direction of travel feedback. The use of the encoder is required in the traction application for optimum machine performance. The encoder is a four wire device; two wires are power supply feed and two wires provide a waveform signal to the VFDs for machine speed and direction of travel.

The encoder is required for correct traction motor operation. Reversed waveform signal wires, loose or poor connections, improper installation, or slippage on the motor shaft may cause erratic traction motor performance and DSP (digital signal processor) faults on the system.

The standard 48hp pump motor operates on encoderless, open-loop software.

Roll-off parameter

The roll-off parameters are adjustable and meant to help limit a stationary machine's roll off speed down a grade should the operator release the accelerator, park brake, and service brake.

CAUTION!
The service brake and park brake are the primary means for stopping the vehicle.

Steer feature (800 series machines only)

sensorless steer system

Steering cutback for 800 series coal haulers is required to help with turning, to save energy, and to save tire wear.

During drive, if one motor over speeds the limit for the required demand, the other motor controller will back down the demand to its motor to keep the faster wheel at the desired speed without trying to push it through faster. During a turn, this will inhibit the inside wheel from increasing speed in order to keep demanded speed by pushing the outside wheel. Similarly, it will keep the outside wheel from braking to maintain the demanded speed.

The software is written to prevent one motor from braking if the other motor is driving.

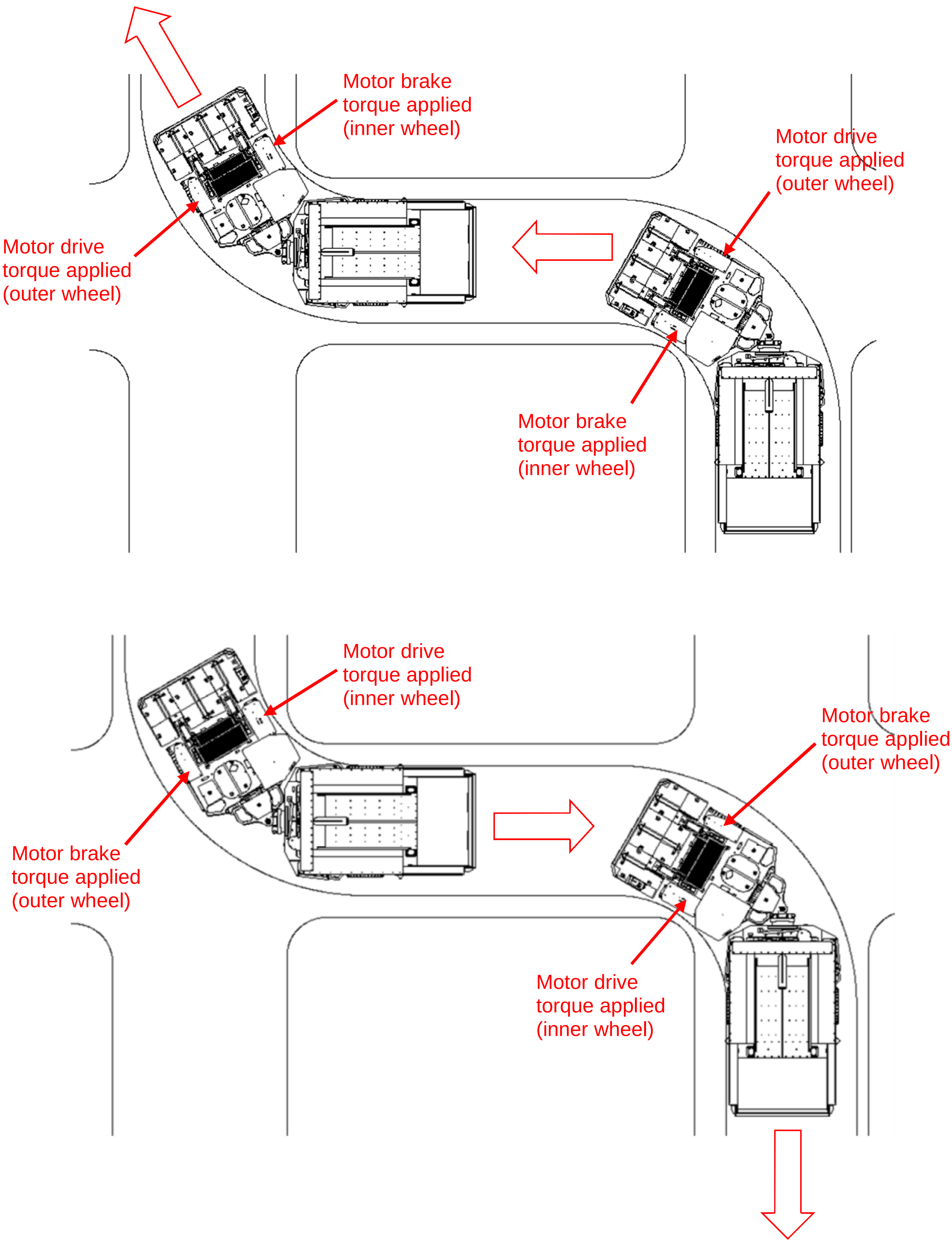
DAS system
(Driver Assisted Steering)

The DAS steer system (Fig. 13) provides increased steering performance, with improved vehicle cornering and improved efficiency.

When going into a turn, the system provides drive torque to the outer wheel and braking torque to the inner wheel.

Coming out of a turn, the inner wheel becomes the outer wheel and drive torque is applied and the outer wheel becomes the inner wheel and braking torque is applied. This results in smooth, controlled, quick cornering of the vehicle.

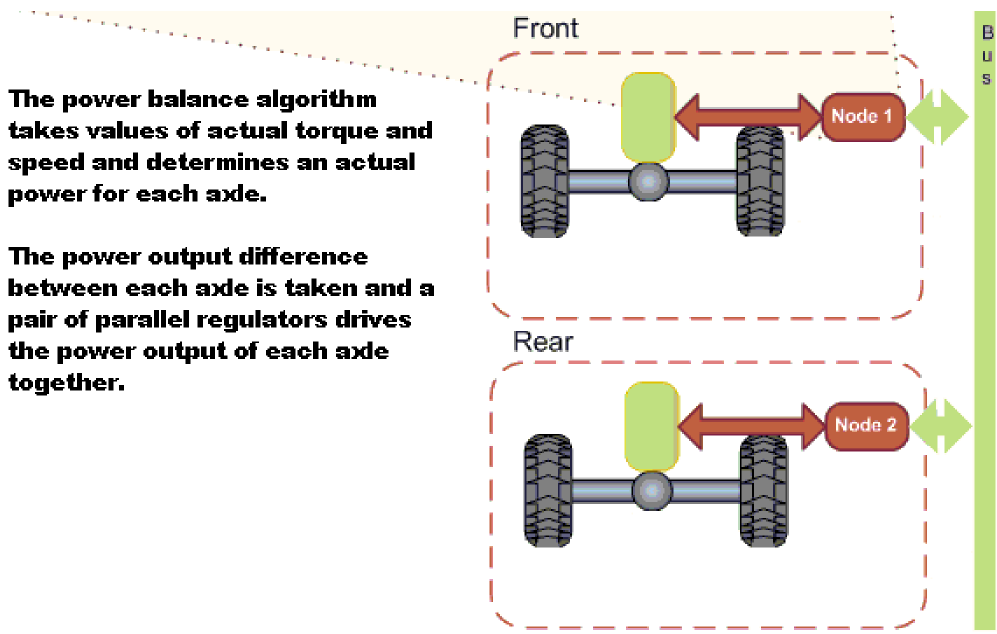
Fig. 13: Steering control system



Traction control algorithm (dual motor 400 and 600 series machines)

Power-balancing software is incorporated into the system as shown in Fig. 14. Its purpose is to force both front and rear traction VFDs and motors to share the torque load as evenly as possible. This prevents one motor from doing the majority of the work required and evenly shares the thermal daily load cycle when possible. Uneven loads on the traction motors can occur from varying floor conditions, tire wear, etc.

Fig. 14: Load-Sharing diagram



Display

The transflective screen on this display module is designed for viewing indoors and out with low light levels. Status items are output to the display across the CAN bus and are intended for the operator to use in determining the status of the drive system and for troubleshooting purposes. The start-up splash screen is shown in Fig. 15.

In addition to faults, warnings, and configuration screens, the display provides many vehicle performance parameters, such as battery voltage and battery shift life remaining.

The display has multiple screens and will toggle among the screens based on the selection of the diagnostics switch input (only after the main circuit breaker is closed). The system will always start with the same splash screen and then, after the main circuit breaker is closed, default to the main operating screen (Fig. 17). When an alternate screen is selected, that screen will remain until the operator selects another alternate screen or the unit is powered down. Alternate screens are selected by toggling the diagnostic twice consecutively in approximately one second activations.

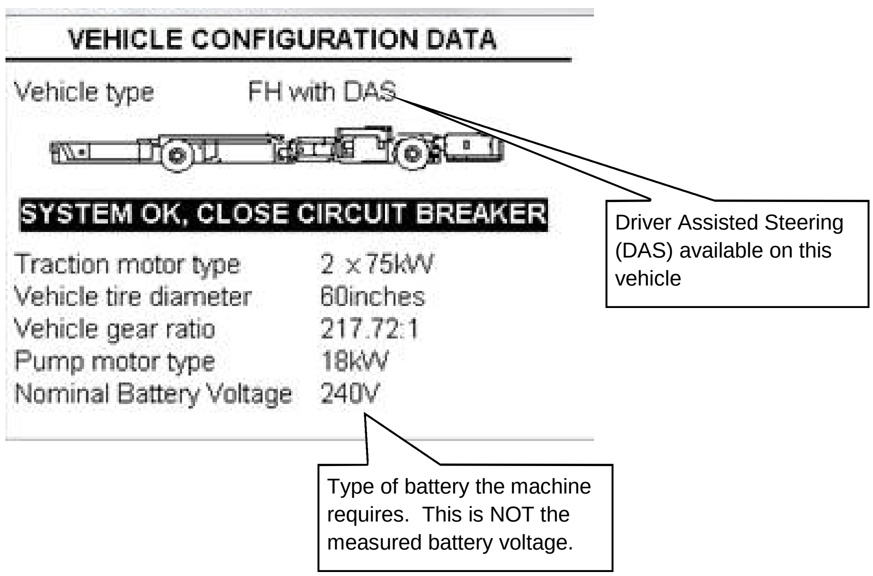
Fig. 15: Initial splash screen when diagnostics is selected

vehicle configuration data

After the diagnostic checks are complete, the “SYSTEM OK, CLOSE CIRCUIT BREAKER” with vehicle configuration data screen (Fig. 16) will be displayed.

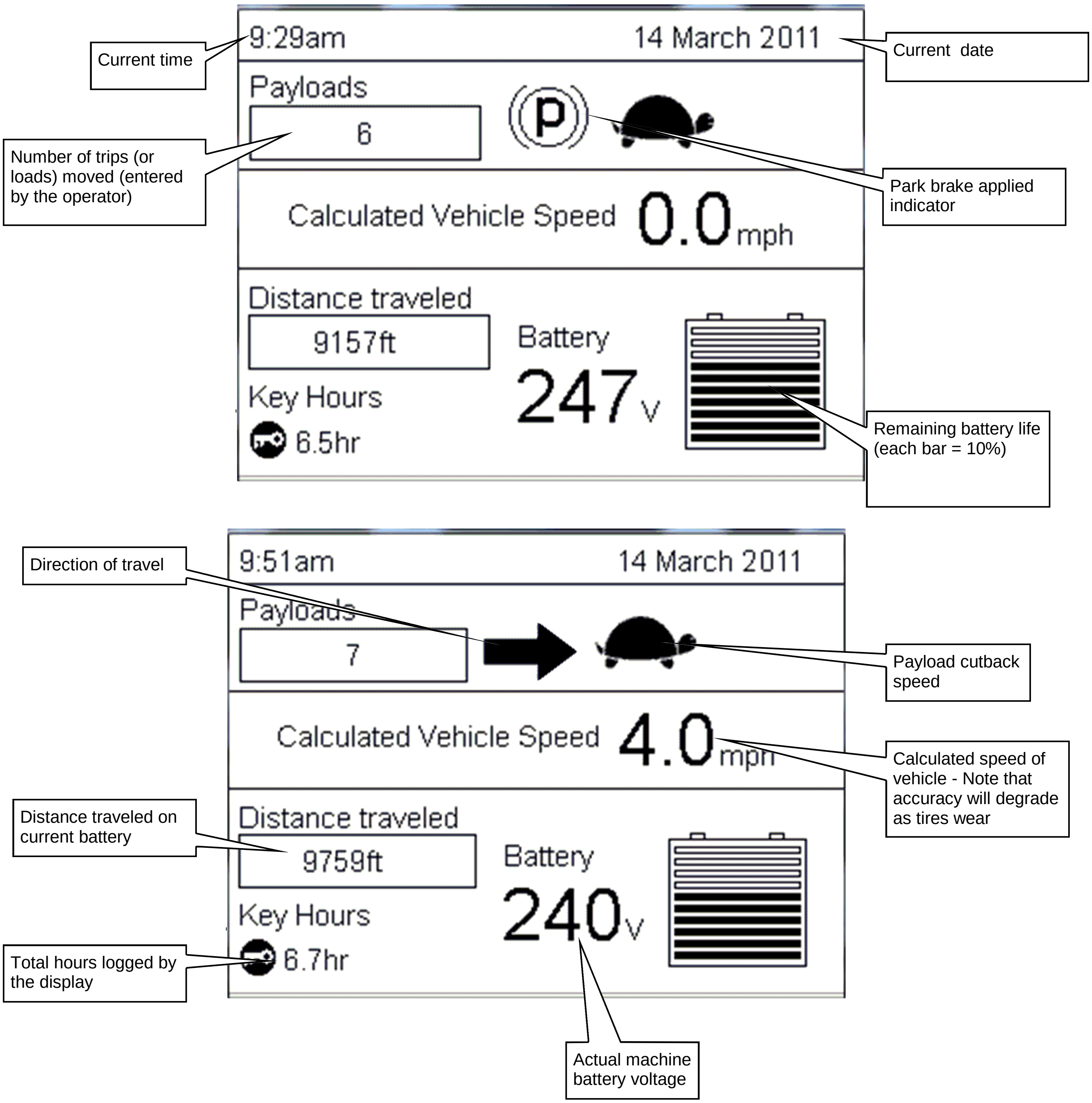
Configuration data is supplied from the machine configuration wiring and may be verified on this screen.

Fig.16: “SYSTEM OK, CLOSE CIRCUIT BREAKER” screen



main screen The main screen (Fig. 17) is displayed after the main circuit breaker is closed (turned on).

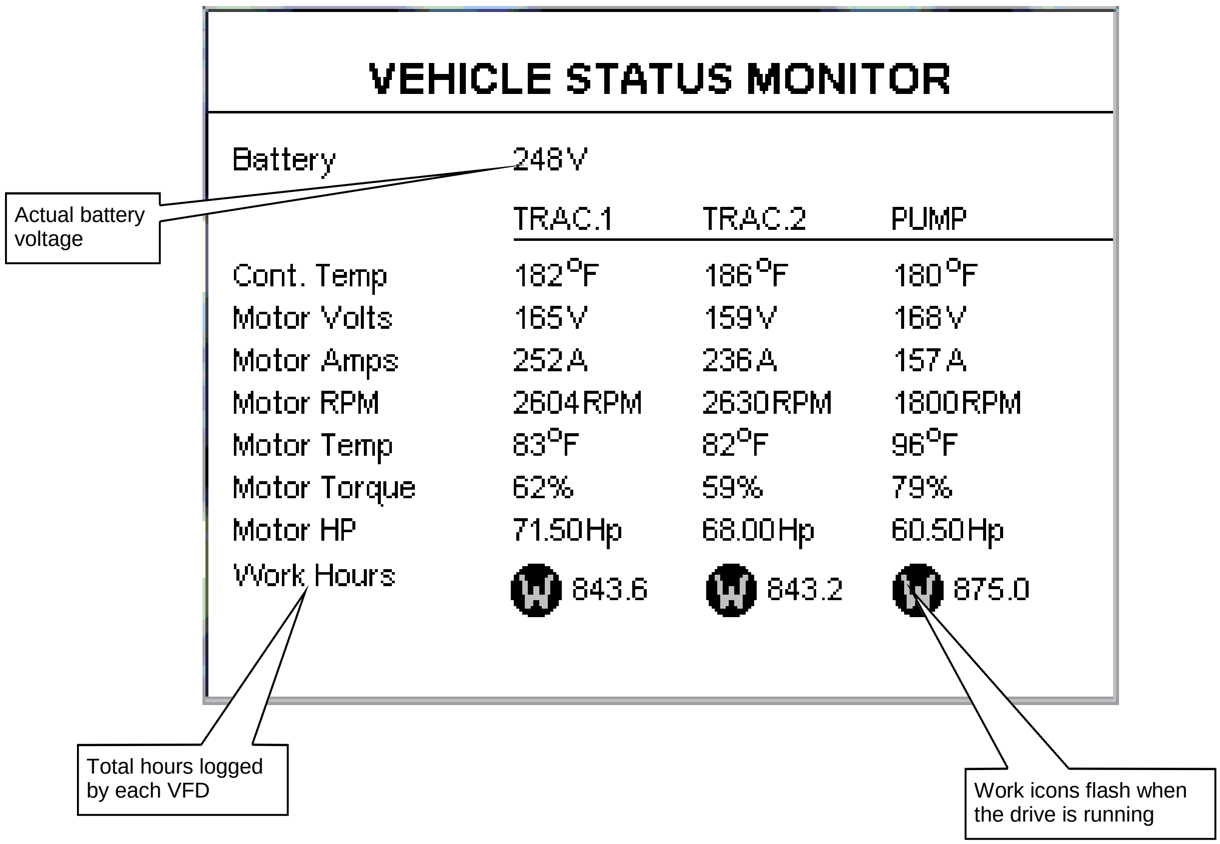
Fig. 17: Main screens



vehicle status monitor screen

Pressing the diagnostic button twice will cycle the display through various other screens. The Vehicle Status Monitor (Fig. 18) display motor and drive operating conditions.

Fig. 18: Vehicle Status Monitor screen

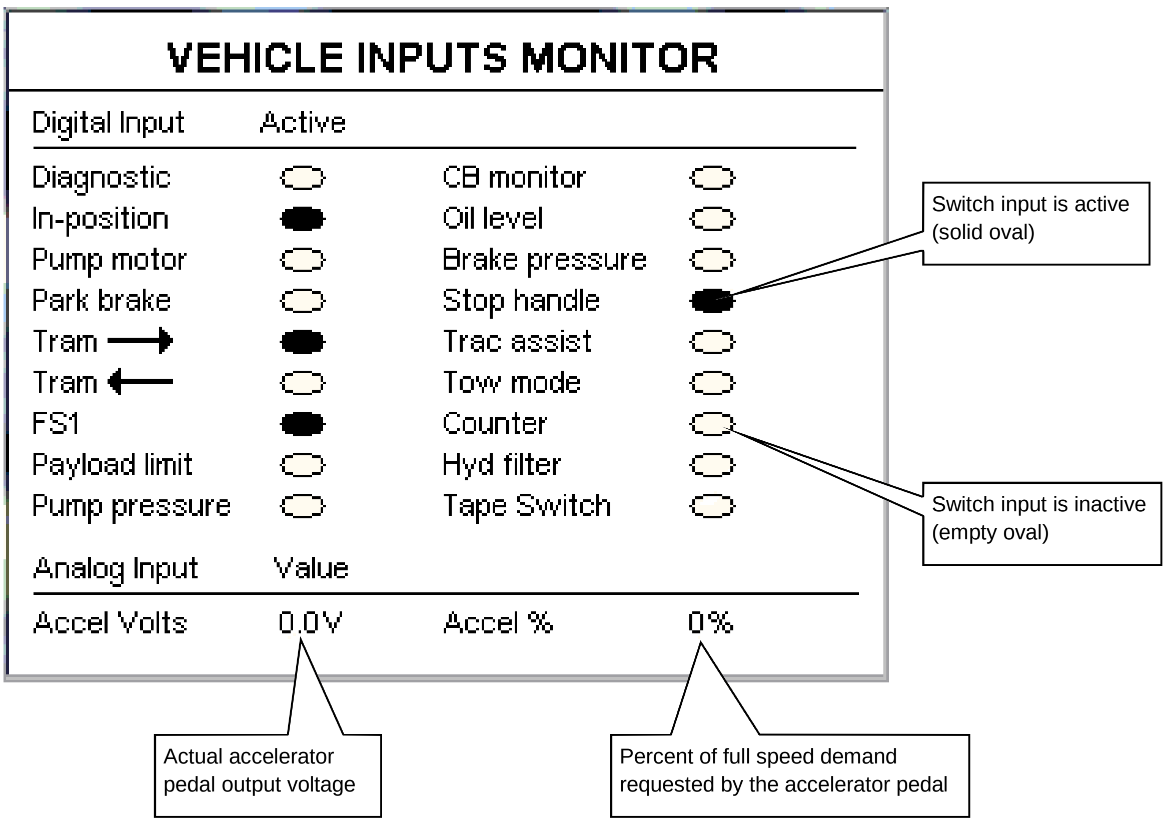


individual inputs monitor screen

Individual inputs can be monitored from the Vehicle Inputs Monitor screen (Fig. 19), which can be very helpful for troubleshooting.

Note: The payload speed limit, oil level, hydraulic filter, and payload counter switches and inputs are not available on single motor systems.

Fig. 19: Vehicle Inputs Monitor screen



distance log

The Distance Log (Fig. 20) displays the total footage accumulated on each of the last 30 battery changes. These are divided across three pages, 10 entries per page. Every entry has a time-date stamp. An odometer near the bottom indicates total vehicle footage recorded by the display.

Fig. 20: Distance log

DISTANCE LOG 1

		M:D:Y	H:M:S
Trip dist 1	1998 ft	01:15:11	08:48:16
Trip dist 2	3625 ft	01:15:11	09:04:57
Trip dist 3	3606 ft	01:15:11	09:30:51
Trip dist 4	3632 ft	01:15:11	09:41:00
Trip dist 5	3327 ft	01:16:11	02:27:36
Trip dist 6	0 ft	00:00:00	00:00:00
Trip dist 7	0 ft	00:00:00	00:00:00
Trip dist 8	0 ft	00:00:00	00:00:00
Trip dist 9	0 ft	00:00:00	00:00:00
Trip dist 10	0 ft	00:00:00	00:00:00
Odometer	516388 ft		

fault log

The Fault Log (Fig. 21) lists all faults that the system has ever recorded. The node, fault identification number, fault description, and number of times the fault has occurred are displayed. Faults are in chronological order, newest at the top.

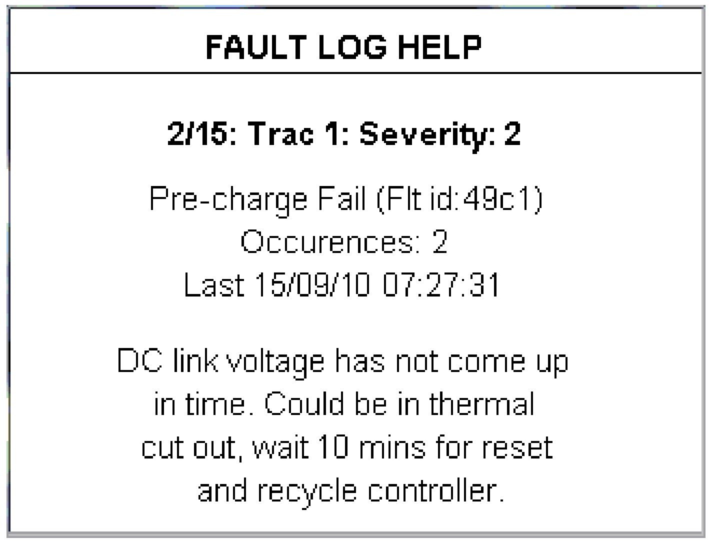
Fig. 21: Fault log

Node	Flt id	Description	Num
Trac 2	5183	Contactor driver over current	01
Trac 1	49c1	Pre-charge Fail	02
Trac 1	54ca	M1 Low IGBT Driver Failed	04
Trac 1	54ce	M3 Low IGBT Driver Failed	01
Pump	530f	CAN Fault	01
Trac 2	54c2	DSP PF Fault	01
Trac 2	5041	Internal Controller Fault	04
Trac 1	45c9	Caps not discharged	01
Trac 1	4883	Two-Direction Fault	03
Disp	1401	CAN Fault	01
Trac 1	54c4	IGBT S/C M1 Bottom	01
Pump	4681	Unit in Preop	01

extended fault log

Extended Fault Log Help (Fig. 22) for each of the recorded faults is available by pressing and holding the diagnostics button for five (5) seconds. After the Fault Log Screen comes up, quick presses of the diagnostics button will toggle to each of the faults on the list. To exit the extended fault log help screen, press and hold the diagnostics button for another five (5) seconds.

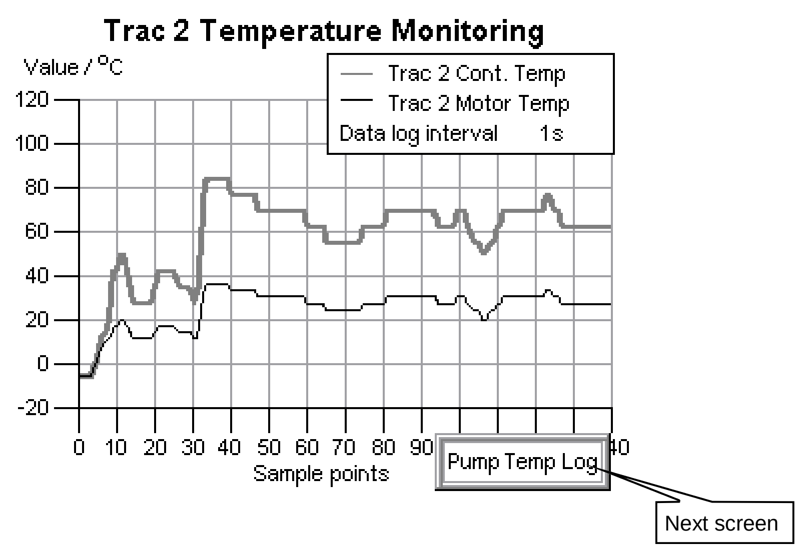
Fig. 22: Extended fault log help screen



temperature monitor screen

Temperature monitor screens (Fig. 23) are provided for the controller, for each tram motor, and for the pump motor. This is helpful for determining how hard the motor and controller have worked during a shift. In the case below, Traction 2 is displayed. A single press of the Diagnostics button will show what screen is next on the lower right corner of the display. A second click toggles to that screen.

Fig. 23: Temperature monitor screen



Fault Handling

The system continually monitors itself for electrical issues. If a fault is detected, the action taken depends on the severity of that particular fault. Faults are divided into 5 levels of severity:

Level 1: Warning - These faults do not stop the vehicle, but are used to warn the operator that something has occurred that may cause a reduction in vehicle performance.

Level 2: Drive Inhibit - These faults result in the vehicle neutral braking to a stop, but are not severe enough to cause the line contactor to open. The fault can be cleared by selecting neutral. Subsequently reselecting drive allows the vehicle to be driven again in the normal manner.

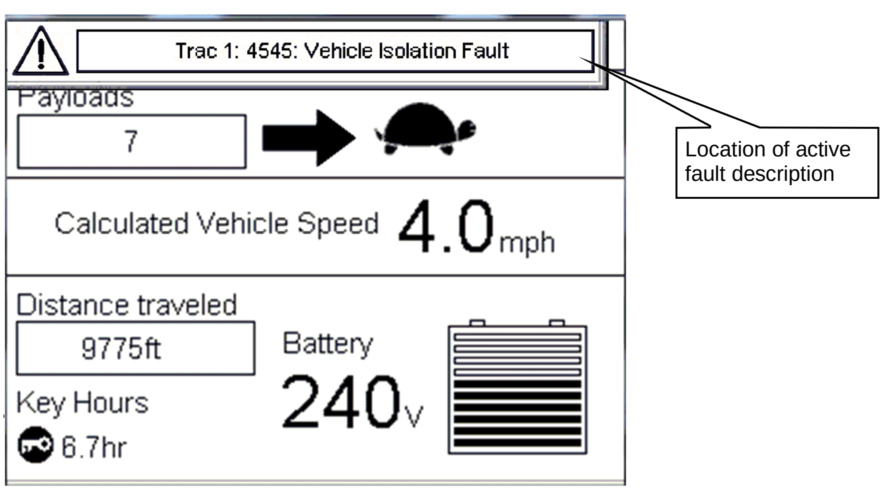
Level 3: Severe - These faults are severe enough to open the line contactor. They can usually be cleared by cycling the key switch.

Level 4: Very Severe - These faults also open the line contactor. They indicate that a potential problem with something external to the controller, such as a power supply or circuit breaker. Clearing these will often require further investigation.

Level 5: Return to Base - These faults also open the line contactor. They indicate that the controller itself may be damaged internally. This is the highest fault classification. Replacing the affected controller is usually the only means to clear this fault.

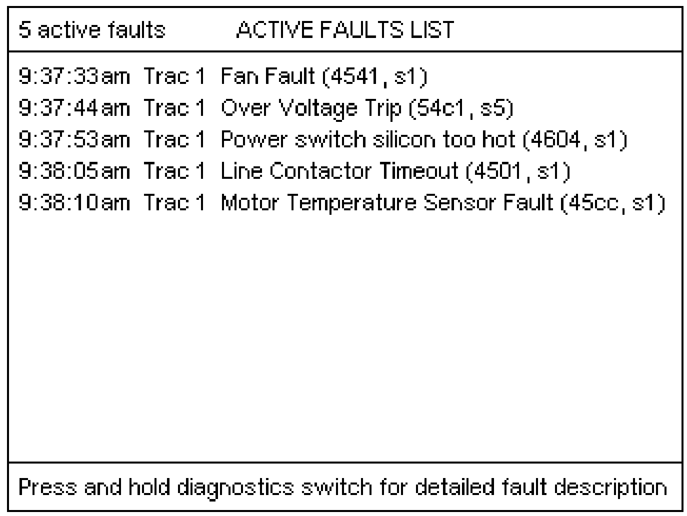
A Level 1 or Level 2 fault will open the Active Fault Window at the top of the display (Fig. 24). If there is more than one active fault, the window will cycle through them one at a time. The vehicle may still drive but have affected performance or the vehicle may stop and require some sort of operator intervention to get moving again. Sometimes a fault will not immediately affect performance. Although the vehicle may appear to operate normally, any fault should still be investigated to maintain system reliability.

Fig. 24: Active Fault Window on Main screen



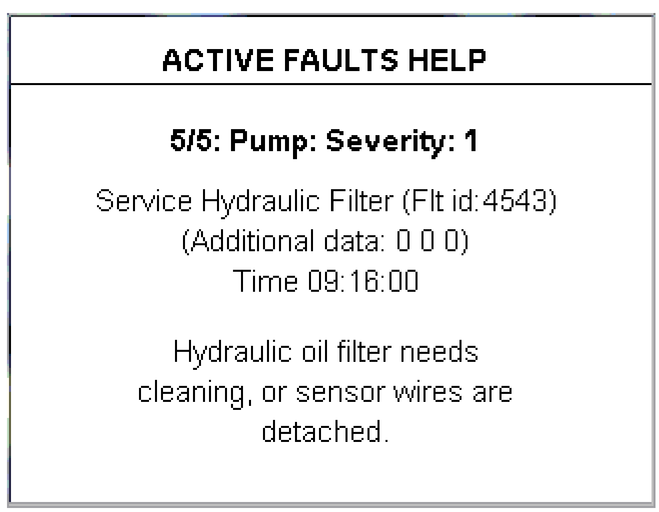
Level 3, 4, and 5 faults will normally drop the breaker. All Traction and Pump drives will shut down, as well. The display will fall into the Active Fault List screen (Fig. 25). Fault events are listed chronologically, oldest first. This can be a valuable troubleshooting aid. When there are multiple faults, it is helpful to know which one occurred first.

Fig. 25: Active Faults List screen



To enter the extended active fault system help screen (Fig. 26), press and hold the diagnostics button for five (5) seconds. After the extended screen comes up, quickly pressing the diagnostics button will toggle to each of the faults logged. To exit the extended active fault system help screen, press and hold the diagnostics button for another five (5) seconds.

Fig. 26: Extended active fault on system help screen



Troubleshooting

Fault information codes

A fault with any of the HiPAC components will trigger a fault message at the top of the display. More information on the fault can be seen by simply holding the diagnostic switch closed for 5 seconds, this will bring up a detailed fault screen. If more than one fault occurs, each detailed fault screen can be seen by toggling through the screens by short presses of the diagnostic switch.

To return to the main screen, simply hold the diagnostics screen closed for another 5 seconds.

Table 27: Fault information codes

Fault ID	Severity	Fault Description	Fault Help
0000	0	No Fault	May briefly appear just as a fault clears.
0001	1	Internal display fault	Cycle Power. If fault does not clear, replace the display.
0841	1	Internal display fault	Cycle Power. If fault does not clear, replace the display.
0842	1	Internal display fault	Cycle Power. If fault does not clear, replace the display.
1000	4	Unrecognized fault	This fault is not recognized. Please contact device manufacturer for details on how to clear this fault.
1401	5	CAN fault	Check wiring and power supplies to affected CAN nodes. Check toroids on CAN bus wires.
1402	5	CAN TX Message Timeout	CAN transmit failed. Ignore if display is standalone. Otherwise, check wiring and CAN bus noise levels.
1403	5	CAN bus OFF	Display is unable to communicate on the CAN bus. Check wiring and CAN bus noise levels.
1404	5	No Data from Supervisor	Display has not received data from Supervisor for the last 5 seconds. Check integrity of the wiring harness.
1481	1	Configuration Error	Drive is in Debug mode. Check code list for information.
2000	4	Generic Current Device Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
2100	4	Current Device Input Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
2200	4	Current Device Internal Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
2300	4	Current Device Output Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
3000	4	Generic Voltage Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
3100	4	Mains Voltage Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
3200	4	Internal Voltage Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.

Table 27: Fault information codes, continued

Fault ID	Severity	Fault Description	Fault Help
3300	4	Output Voltage Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
34c1	5	Internal Software Fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4000	4	Generic Temperature Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
4100	4	Ambient temperature Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
4200	4	Device Temperature Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
4501	1	Line Contactor Timeout	The line contactor time out has expired. Power must now be cycled before the breaker can be closed.
4541	1	Fan Fault	The internal fans are faulty. Blow out fans with air. If fault persists, replace drive to prevent early thermal cutout.
4542	1	Low Oil Fault	Check oil level and switch for proper operation.
4543	1	Service Hydraulic Filter	Hydraulic oil filter needs cleaning, or sensor wires are detached.
4544	1	Pump Current Low	Pump current is not flowing. Pump motor is not attached to drive or drive has no power to B+.
4545	1	Vehicle Isolation Fault	A current leakage path between B+ or B- and 24V or 0V has been detected. This should be investigated. Otherwise controller damage may result.
4546	1	No speed indication	Motor has remained at 0 RPM for 5 seconds with greater than 25% of maximum torque applied. Is encoder signal OK? Check encoder connections and fuses.
4581	1	Motor Temperature Sensor Fault	Motor temperature measurement is invalid. Check motor temperature sensor connections and fuses. Check if sensor is shorted to motor windings.
45c1	1	BDI Warning	The battery charge has reduced to the warning level. Recharge the battery as soon as possible.
45c2	1	BDI Cutout	Battery charge reduced to cutout level. Max speed and torque will be reduced. Recharge the battery immediately.
45c3	1	Low Battery	A battery under voltage condition has occurred for the protection delay time. Check if batteries need charging or are faulty. Check battery water level. Confirm all heavy wiring connections are sound.
45c4	1	High Battery	Can occur during regenerative braking. Check battery connections, UVR, and CB. Possible controller fault.
45c5	1	High Capacitor	Capacitor voltage over 280v. Check all battery and CB connections and heavy wiring. Possible controller fault.

Table 27: Fault information codes, continued

Fault ID	Severity	Fault Description	Fault Help
45c6	1	Precharge Input Voltage Low	Precharge input is below 150V. Check all battery and CB connections. Recharge battery. Check “D” connector wiring and fuse.
45c7	1	Precharge Input Voltage High	Precharge input is above 300V. Check all battery and CB connections. Possible controller fault. Battery may be overcharged.
45c8	1	Vcap above rated maximum	DC link above rated maximum. Check all battery and CB connections. Possible drive fault. Battery may be overcharged.
45c9	1	Caps not discharged	Controller is attempting to discharge the capacitor bank, but lethal voltages may still be present. Exercise extreme caution when servicing.
45ca	1	Motor in low-voltage cutback	Motor performance has been cut back due to low voltage.
45cb	1	Motor in high-voltage cutback	Motor performance has been cut back due to over voltage.
45cc	1	Motor temperature sensor fault	Motor temperature measurement is invalid. Check motor temperature sensor. Check sensor connections and fuses. Make sure it is not shorted to motor windings.
4601	1	Heat sink too cold	Controller is below -30°C. Verify temperature reading. Replace controller if not accurate.
4602	1	Heat sink too hot	Controller is above 85°C. Limit operation or shut down. Check unit temperature is accurate. Make sure there is thermal grease between controller baseplate and vehicle frame. Check for any debris between them.
4603	1	Motor in thermal cutback	This motor is too hot. Limited operation or shutdown. Check motor temp switch and sensor. Also check related wiring and fuses.
4604	1	Power switch silicon too hot (IGBT)	An estimate of the silicon temperature switch (IGBT) is within 10°C of max allowed temp. Ensure adequate cooling of control enclosure. Ensure there is thermal grease between controller baseplate and vehicle frame. Also check for debris between the two.
4681	1	Supervisor not operational	Check other drives are connected to the CANbus and are powered up. Use DVT or Drive Wizard to set into operational mode. Otherwise, replace the drive.
4682	1	Units still initializing	Not all expected CAN messages were received. Cycle power. If fault persists, contact device manufacturer.
46c1	1	Motor Encoder Warning	Encoder signal is corrupted. Check encoder wiring for shorts or breaks. Replace encoder. Vehicle may still be able to drive with reduced power.
4782	1	24V supply low	Check supply input to drives. Cycle power. If fault does not clear, replace controller.

Table 27: Fault information codes, continued

Fault ID	Severity	Fault Description	Fault Help
4783	1	24V supply high	Check supply input to drives. Cycle power. If fault does not clear, replace controller.
47c1	1	Service Required (optional)	The service interval has elapsed. It is recommended that the vehicle undergo specified maintenance.
4881	2	Stop Switch Activated	The STOP switch, tape switch, or FS relay was activated. Check switches, wiring, and I/O module.
4882	2	Seat Fault (currently not used)	Re-select neutral by opening FS1 and the direction switches. Close the seat switch then re-select drive.
4883	2	Two Direction Fault	Both tram direction inputs are seen active. Check either the control station or control handle, switching repeater relays and PLC.
4884	2	SRO Fault	Switch inputs received in wrong sequence. Clear inputs and retry in sequence. Check footswitch, direction switch, and STOP switch.
4885	2	Sequence Fault	Footswitch or direction switch selected at power-up. Repeat selection sequence. Check footswitch, direction switch, and STOP switch.
4886	2	FS1 Recycle Fault	Footswitch must be recycled to complete a direction change.
4887	2	Inch Fault (currently not used)	Invalid selection of inch switches or the seat switch is still closed.
4941	2	Motor Overspeed	Motor has exceeded maximum speed. Check brakes and regen capability.
4981	2	Throttle Fault	Accelerator >20% at power-up or >30% after power up. Verify that the foot pedal is releasing and connections to I/O module are solid. Adjust accelerator linkage. Change accelerator parameters. Replace accelerator module.
49C1	2	Pre-charge Fail	DC link voltage has not come up in time. It could be in thermal cutout. Wait 10 minutes for reset and restart controller.
49C2	2	Pre-charge Timeout	DC link voltage has not come up in time. It could be in thermal cutout. Wait 10 minutes for reset and restart controller.
4b01	2	Control data not received	Drive is not receiving data required for normal operation. Check that all drives are connected to the CAN bus and are powered up.
4c41	3	Too many auxiliaries on network	An invalid number of nodes have been specified in the configuration. Check configuration jumpers and software.
4d01	3	Circuit Breaker open	The main CB is open or has not been closed within the CB close timer parameter. Check CB aux switch operation. Cycle power.
4d02	3	Circuit Breaker welded	The main CB is welded closed or the CB aux switch is faulty. Check CB aux switch operation.
4d03	3	DC Link Collapsed	DC link has collapsed on node indicating a bad connection to B+ on the drive or an internal issue.
4d04	1	Line Contactor Timeout	The line contactor time out has expired. Power must now be cycled before the breaker can be closed.

Table 27: Fault information codes, continued

Fault ID	Severity	Fault Description	Fault Help
4f01	3	CANbus configuration fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that all other drives are connected and powered up. Check configuration wiring.
4f02	3	CAN hardware fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check toroids on CAN bus wires. Look for noise or breaks in CAN wiring. Check configuration wiring.
4f41	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f42	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f43	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f44	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f45	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f46	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f47	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f48	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f49	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f4a	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f4b	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f4c	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f4d	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f4e	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.

Table 27: Fault information codes, continued

Fault ID	Severity	Fault Description	Fault Help
4f4f	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f50	3	Internal hardware fault	Check for shorts to vehicle chassis. Check motor isolation. Check firmware and configuration. If fault persists, replace drive.
4f51	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f52	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f53	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
4f54	3	Current sensor range error	Unable to reset current sensors. Check for motor short circuits. If fault persists, replace controller.
4f55	3	Unable to start motor control	Check configuration of drive and ensure it is able communicate via CAN to other drives.
5000	4	Device Hardware Fault	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
5041	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
5042	4	Drive configuration fault	Error in drive configuration. Check firmware and configuration. Use DVT to find and correct parameter error.
5043	4	Drive configuration fault	Error in drive configuration. Check firmware and configuration. Use DVT to find and correct parameter error.
5044	4	Drive configuration fault	Error in drive configuration. Check firmware and configuration. Use DVT to find and correct parameter error.
5081	4	Invalid Steering Switches (currently not used)	An invalid combination of steering switches such as left and right has been seen. Check pressure transducers and wiring associated wiring.
5101	4	Circuit Breaker Open Circuit	DC Link voltage has not come up after line closure was attempted. Check circuit breaker and heavy wiring.
5102	4	Circuit Breaker Welded	DC Link voltage is already high prior to line closure. Check for shorted breaker contacts.
5181	4	Digital Input Wire Off	Digital input wire off detected. Check integrity of wiring harness. Check pins on “A” connector.
5182	4	Analogue Input Wire Off	Analogue input is out of range or disconnected. Check integrity of wiring harness. Check pins on “A” connector.
5183	4	Contactor driver over current	Contactor (UVR) coil is drawing high current. Check wiring and coil for short circuit. Possible controller fault.
5184	4	Contactor driver failure	Check wiring and contactor (UVR) coil. Possible controller failure.

Table 27: Fault information codes, continued

Fault ID	Severity	Fault Description	Fault Help
5185	4	Contactor driver failure	Check wiring and contactor (UVR) coil. Possible controller failure. Check "C" connector and related wiring on drive.
51c1	4	24 Volt Supply Interrupt	Check DC-DC converter for 24 Volt output. Check 24 Volt wiring. Recycle Power. Possible controller fault.
52c1	4	Motor Encoder Fault	Encoder signal is corrupted. Check wiring to encoder for shorts or breaks. Replace encoder. Make sure encoder is properly aligned.
52c2	4	Motor Over-Current Fault	Excessive current has been seen in the motor; the controller has been unable to bring the current under control by normal means. Check for open or shorted phases on the motor. Check speed encoder. Possible fault in drive.
52c4	4	Motor overspeed fault	Motor has exceeded maximum speed setting. System was shut down to prevent mechanical damage. Check brake system and regen settings.
5301	3	CAN hardware fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check toroids on CAN bus wires. Look for noise or breaks in CAN wiring. Check configuration wiring.
5302	4	Auxiliary node not found	Heartbeat message not received from node. Check node is connected to CAN Bus and is powered up. One or more auxiliary nodes are off the network.
5303	3	CAN hardware fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check toroids on CAN bus wires. Look for noise or breaks in CAN wiring. Check configuration wiring.
5304	3	CAN hardware fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check toroids on CAN bus wires. Look for noise or breaks in CAN wiring. Check configuration wiring.
5305	3	CAN hardware fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check toroids on CAN bus wires. Look for noise or breaks in CAN wiring. Check configuration wiring.
5306	3	CAN hardware fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check toroids on CAN bus wires. Look for noise or breaks in CAN wiring. Check configuration wiring.
5307	3	CAN hardware fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check toroids on CAN bus wires. Look for noise or breaks in CAN wiring. Check configuration wiring.
5308	3	CAN hardware fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check toroids on CAN bus wires. Look for noise or breaks in CAN wiring. Check configuration wiring.
5309	4	Drive configuration fault	Error in drive configuration. Check firmware and configuration. Use DVT to find and correct parameter error.

Table 27: Fault information codes, continued

Fault ID	Severity	Fault Description	Fault Help
530a	4	Drive configuration fault	Error in drive configuration. Check firmware and configuration. Use DVT to find and correct parameter error.
530b	4	No heartbeat from node	Heartbeat message from node not received. Check node is connected to CAN Bus and powered up.
530c	3	CANbus configuration fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that all other drives are connected and powered up. Check configuration wiring.
530d	3	CAN hardware fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check toroids on CAN bus wires. Look for noise or breaks in CAN wiring. Check configuration wiring.
530e	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
530f	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
5310	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
5311	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
5312	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
5313	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
5314	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
5315	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
5316	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.

Table 27: Fault information codes, continued

Fault ID	Severity	Fault Description	Fault Help
5317	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
5318	4	Unable to request data via CAN	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that other drives are connected to the CAN bus and powered up. Check configuration wiring.
5319	4	Drive not responding	One or more drives have stopped responding to the Supervisor. Check for faults on other drive(s) and additional fault messages.
5341	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
5342	3	Internal hardware fault	Check for shorts to vehicle chassis. Check motor isolation. Cycle power. If fault persists, replace affected drive.
5343	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
5344	5	Internal software fault	Potential configuration error on drive. Recycle power. If fault does not clear, check firmware and configuration.
5381	3	CANbus configuration fault	Node has difficulty communicating via CAN. Confirm all drives have unique node ID. Check that all other drives are connected and powered up. Check configuration wiring.
54c1	5	Over Voltage Trip	Capacitor voltage over 280 Volts. Check all battery and circuit breaker connections. Possible drive fault.
54c2	5	DSP PF Fault	Severe over-current or over-voltage occurred. Recycle power. Check encoder, motor, battery cables, and motor cables.
54c3	5	IGBT S/C M1 Top	M1 Terminal shorted to B+. Look for controller, motor, or motor cable short to B+ terminal of controller. Disconnect motor; if fault persists, replace drive.
54c4	5	IGBT S/C M1 Bottom	M1 Terminal shorted to B-. Look for controller, motor, or motor cable short to B- terminal of controller. Disconnect motor; if fault persists, replace drive.
54c5	5	IGBT S/C M2 Top	M2 Terminal shorted to B+. Look for controller, motor, or motor cable short to B+ terminal of controller. Disconnect motor; if fault persists, replace drive.
0xc6	5	IGBT S/C M2 Bottom	M2 Terminal shorted to B-. Look for controller, motor, or motor cable short to B- terminal of controller. If this fault is reported with the motor disconnected, replace the drive.
54c7	5	IGBT S/C M3 Top	M3 Terminal shorted to B+. Look for controller, motor, or motor cable short to B+ terminal of controller. Disconnect motor; if fault persists, replace drive.

Table 27: Fault information codes, continued

Fault ID	Severity	Fault Description	Fault Help
54c8	5	IGBT S/C M3 Bottom	M3 Terminal shorted to B-. Look for controller, motor, or motor cable short to B- terminal of controller. Disconnect motor; if fault persists, replace drive.
54c9	5	IGBT Tests Incomplete	Recycle Power. If fault does not clear, replace controller.
54ca	5	M1 Low IGBT Driver Failed	The controller has not been able to turn on the bottom power switch attached to M1. Disconnect motor and repeat. Possible controller fault.
54cb	5	M1 High IGBT Driver Failed	The controller has not been able to turn on the top power switch attached to M1. Disconnect motor and repeat. Possible controller fault.
54cc	5	M2 Low IGBT Driver Failed	The controller has not been able to turn on the bottom power switch attached to M2. Disconnect motor and repeat. Possible controller fault.
54cd	5	M2 High IGBT Driver Failed	The controller has not been able to turn on the top power switch attached to M2. Disconnect motor and repeat. Possible controller fault.
54ce	5	M3 Low IGBT Driver Failed	The controller has not been able to turn on the bottom power switch attached to M3. Disconnect motor and repeat. Possible controller fault.
54cf	5	M3 High IGBT Driver Failed	The controller has not been able to turn on the top power switch attached to M3. Disconnect motor and repeat. Possible controller fault.
5741	3	Internal hardware fault	Check for shorts to vehicle chassis. Check motor isolation. Check firmware and configuration. If fault persists, replace affected drive.
6000	5	Device Software Fault	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
6100	5	Internal Software Fault	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
6200	5	User Software Fault	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
6300	5	Software Dataset Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
7000	5	Software Module Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.
8000	5	Software Monitor Error	A generic internal error has occurred. Cycle power. If fault returns, replace affected drive.

LED fault information flash codes

The HiPAC 10 display should always be the first choice for fault information. However, should it not be available, the following limited LED flash codes (Table 28) are available.

Table 28: LED flash fault codes

# of Flashes	Fault	Checks/Remedies
Steady on	Normal operation	None
0	LED never lights up, even at power up. Generally signifies a dead controller.	First check for 24V between pin 1 on the “C” connector (positive) and pin 16 on the “A” connector (negative). If voltage is correct, it is likely that the controller has an internal fault. Replace drive. If voltage is at or near zero, check for broken connections or a blown fuse. If you replace the fuse and the new fuse immediately blows, the related drive is bad. If all drives are dead, the DC-to-DC converter may have failed. Disconnect the “C” connector from all drives and recheck the supply. If there is still no output, replace the DC-to-DC converter. If you see 24V after disconnecting all “C” connectors, one of the drives has a shorted input. Check resistance between pin 1 on the “C” connector and pin 16 on the “A” connector of all three drives. The resistance should quickly rise when the leads are connected. If one stays at a low level (less than 100 ohms), the input is shorted. To verify, reconnect the “C” plug on the other drives and apply power. There will be errors because of the missing node, yet the remaining drives will power up. Replace the disconnected drive.
1	Usually means the controller has suffered an internal failure. If a 1 flash fault occurs immediately after updating the software, the software configuration is out of range. The display will often return a “Parameter out of Range” error.	Recycle power. If fault doesn’t clear, replace drive. Change any out of range parameter to the default setting. A computer with Drive Wizard or DVT is usually required. If not available, replace the drive.
2	Drive inhibit (sequence fault)	Recycle power. Check the display to make sure all switches open and close when they are supposed to. The Vehicle Inputs Monitor screen on the display would be more helpful here. If an input stays closed all the time, check for a stuck switch or a short in the wiring harness. One of the repeater relays may be at fault. If an input never closes, check for a bad switch or a broken “A” connector pin on the drive.

Table 28: LED flash fault codes, continued

# of Flashes	Fault	Checks/Remedies
3	Hardware protection fault. If the fault occurs in the Supervisor node, one or more of that driver's IGBTs has failed.	Recycle power. Replace drive if fault doesn't clear. If the fault occurs on the traction Auxiliary node, a seemingly unrelated failure on the Supervisor may actually be the cause. Serious faults, 1, 10 or 12 flash on the Supervisor, can make the Auxiliary Traction appear faulty when it is not. To quickly verify an IGBT failure, power down the system and disconnect the motor cables from the driver then repower the drive. If the fault goes away, the motor is like the issue. If the fault remains, in-depth testing is required as follows: Remove power and completely disconnect the driver from the system. Using a digital multimeter in diode check mode, connect the black meter lead to the B+ terminal. One by one, connect the red lead to M1, M2, and M3 terminals on the driver. Each should read between 300mV and 400mV. If any phase is out of range, replace the drive. Remove the black meter lead from B+ and connect the red lead to B-. One by one, connect the black lead to M1, M2, and M3. Each should read between 300mV and 400mV. If any phase is out of range, replace the drive. With the system still off, connect one meter lead to B- and the other to B+. The meter reading should quickly rise from a low level. Reversing the leads will produce a similar effect except that the start point will be a negative number. A reading that does not rise and remains shorted indicates a faulty drive. Replace the drive. Finally, check between any terminal and the controller case. Any indication on the meter indicates an internal short. Replace the
4	Main circuit breaker fault.	Check wiring. Check for shorted or open circuits on the breaker coil. Check to see if the breaker contacts are stuck open or closed (welded).

Table 28: LED flash fault codes, continued

# of Flashes	Fault	Checks/Remedies
5	Operator warning faults (will not shut down the vehicle). Most commonly, these are the Vehicle Isolation Fault or the No Speed Fault.	
	A Vehicle Isolation Fault indicates that current has been detected between the 24V supply and battery positive or negative. Persistent faults of this type can eventually damage the vehicle electronics.	Clean around the terminals on the drives.
	A No Speed Fault occurs when a controller draws 25% or more of current limit but no vehicle motion has been detected.	Normally occurs when the vehicle is stuck or pushed into a wall. May be caused by a failing speed sensor.
	Hydraulic pump or cooling fan issues.	See troubleshooting for the hydraulic pump and cooling fan.
	Vehicle wiring faults.	Recycle power, replace drive is fault doesn't clear.
6	Analog input fault to VFD.	Check wiring and inputs, recycle power, replace drive if fault doesn't clear.
	Bad accelerator.	Check the accelerator and the wires leading to it.
	Faulty footswitch.	Check the footswitch.
7	Battery voltage faults.	Recharge the battery. If the display was recently replaced, check that the BDI levels are set correctly. If the fault occurs during driving or braking, check the battery and motor connections. Recycle power. Replace drive if fault doesn't clear.
	Capacitor pre-charge circuit failure (rare).	The driver circuit has overheated. Remove power for ten minutes, then retry. If fault does not clear, the driver has suffered an internal failure. Replace drive.
8	Thermal cutback faults (drive or motor has overheated).	Allow vehicle to cool for 20 minutes. Check for contamination between drive heat sink and vehicle frame. Make sure there is enough thermal compound. Check thermistors, temperature switch, and related wiring. Make sure sensor is not shorted to motor windings. Recycle power. Replace drive if fault doesn't clear.
9	Drive has failed.	Replace drive.
10	Drive is stuck in Pre-operational mode.	Only occurs during programming. Drive was not returned to Operational mode after firmware or settings update. Use DriveWizard or DVT to do this.
11	Motor control faults.	Check encoder, wiring, and drive inputs. Recycle power. Replace drive if fault doesn't clear.

Table 28: LED flash fault codes, continued

# of Flashes	Fault	Checks/Remedies
12	CAN bus faults. A failed driver or display, broken CAN wiring, or missing “dummy plug” termination will sometimes cause the fault.	Using a digital multimeter in Resistance mode, measure between pins B5 and B6 on the Supervisor B connector. The reading should be around 60 Ohms. If there is no reading at all or it is very high, a cable is probably bad and needs to be replaced. If the resistance is around 120 Ohms, the display or the wires leading to it are faulty. Otherwise, the “dummy plug” termination is missing from the “B” connector. Check the wiring and connections starting at the “A” connector on the Supervisor driver and working toward the display. If all is okay, replace the display. If the reading is near 0 Ohms, a drive or display CAN input has shorted. Disconnect each node, one at a time, until the resistance rises well above zero. This is the faulty drive. Intermittent CAN faults may be caused by grounding issues. Verify that toroids are installed on all nodes and that all shields and returns are connected. If a CAN problem occurs at startup, make sure the Supervisor is configured with a jumper between A29 and A26 and the Auxiliary with a jumper between A23 and A26.
13	Internal software faults.	Recycle power. Replace drive if fault doesn’t clear.
14	Check CAN bus wiring.	Recycle power. Replace drive if fault doesn’t clear.
15	Service machine faults.	Typically not used.
1 long Several short	Bootloader fault.	Drive was not returned to Operational mode after firmware or settings update. Use DriveWizard or DVT to do this. If this is unsuccessful, replace drive.

Test Measurements

If the cause of a fault remains unknown, simple meter checks can provide useful information to find it. While external measurements will not tell you exactly what is wrong “in the box”, they will often confirm if it is the VFD that has failed. Conversely, such test’s can “clear” a good VFD, saving both time and expense.

Tables 29, 30, 31, and 32 outline a series of tests that should prove useful in the troubleshooting process. All drives can be measured in the same way, regardless of node.

Table 29: Meter checks, “A” connector

Pin	Electrical Description	Expected measurements
A1	15 Volt Encoder Supply -	Zero Volt reference for A2.
A2	15 Volt Encoder Supply +	With 24V supply on, 13V to 15V, reference A1 or A3.
A3	15 Volt Encoder Supply -	Zero Volt reference for A2.
A4	Speed Encoder Input	With 24V supply on, should pulse between 0V and 12V when encoder spins. Reference to A1 or A3.
A5	Speed Encoder Input	With 24V supply on, should pulse between 0V and 12V when encoder spins. Reference to A1 or A3.
A6	Digital Input 1	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A7	Digital Input 2	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A8	Digital Input 3	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A9	Digital Input 4	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A10	Digital Input 5	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A11	Digital Input 6	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A12	Digital Input 7	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A13	Digital Input 8	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A14	Digital Input 9	With 24V supply on, 13V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A15	Digital Input 10	With 24V supply on, 13V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A16	Digital common	Zero Volt reference for Digital Inputs.
A17	Digital output	Zero Volts
A18	12 Volt supply +	With 24V supply on, 12V output. Reference “A” pins 16, 25, 28, or 31.
A19	5 Volt supply -	With 24V supply on, 5V output. Reference “A” pins 16, 25, 28, or 31.
A20	Motor thermal sensor input	With 24V supply on, 5V open circuit, drops to 2.5V when connected to PTC. Reference “A” pins 16, 25, 28, or 31.
A21	Motor temperature switch	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.
A22	Towing Mode	With 24V supply on, 10V with open switch, 0V when switch is closed. Reference “A” pins 16, 25, 28, or 31.

Table 29, continued: Meter checks, "A" connector

Pin	Electrical Description	Expected measurements
A23	Analog Supply 1 +	With 24V supply on, 9.5V with open circuit, 0V when switch is closed. If connected to a potentiometer, voltage can be between 4V and 9V. Reference pin A29 or A30.
A24	Analog Supply 2 +	With 24V supply on, 9.5V with open circuit, 0V when switch is closed. If connected to a potentiometer, voltage can be between 4V and 9V. Reference pin A29 or A30.
A25	Power supply 24VDC common for display	Zero Volt reference for Digital Inputs.
A26	Analog Input 1	With 24V supply on, 8.5V with open switch, 0V when switch is closed. Reference pin A29 or A30.
A27	Analog Input 2	With 24V supply on, 8.5V with open circuit, 0V to 5V if connected to accelerator. Reference pin A29 or A30.
A28	Digital common	Zero Volt reference for Digital Inputs.
A29	Analog Supply 1 -	Zero Volt reference for Analog Inputs.
A30	Analog Supply 2 -	Zero Volt reference for Analog Inputs.
A31	Digital common	Zero Volt reference for Digital Inputs.
A32	24 Volt CAN supply +	24V CAN supply. Reference pin A33 or B2.
A33	24 Volt CAN supply -	Zero Volt reference for CAN supply.
A34	CAN high	With controller connected to CAN bus, power off. Resistance is about 60 Ohms to A35.
A35	CAN low	With controller connected to CAN bus, power off. Resistance is about 60 Ohms to A34.

Table 30: Meter checks, "B" connector

Pin	Electrical Description	Expected measurements
B1	CAN shield	With power off, Zero Ohms to "A" pins 16, 25, 28, or 31.
B2	No connection	None
B3	24 Volt CAN supply +	24V CAN supply. Reference pin B2 or A33.
B4	24 Volt CAN supply -	Zero Volt reference for CAN supply.
B5	CAN high	With controller connected to CAN bus, power off. Resistance is about 60 Ohms to B6 or B8.
B6	CAN low	With controller connected to CAN bus, power off. Resistance is about 60 Ohms to B5.
B7	CAN high termination	With controller NOT connected to CAN bus, power off. Internal resistance is about 120 Ohms to B6 or B8.
B8	CAN low	With controller connected to CAN bus, power off. Resistance is about 60 Ohms to B5.

Table 31: Meter checks, “C” connector

Pin	Electrical Description	Expected measurements
C1	+24VDC Supply input	24V reference “A” pins 16, 25, 28, or 31.
C2	(Reserved for service brake)	Pulls to near Zero Volts when energized. Reference “A” pins 16, 25, 28, or 31.
C3	UVR Driver (24VDC Common)	Pulls to near Zero Volts when energized. Reference “A” pins 16, 25, 28, or 31.
C4	Park Brake Solenoid Driver (24VDC Common)	Pulls to near Zero Volts when energized. Reference “A” pins 16, 25, 28, or 31.
C5	Breaker for headlight relay driver (24VDC common)	Pulls to near Zero Volts when energized. Reference “A” pins 16, 25, 28, or 31.
C6	Contactor output (not used)	Pulls to near Zero Volts if energized. Reference “A” pins 16, 25, 28, or 31.
C7	Contactor output (not used)	Pulls to near Zero Volts if energized. Reference “A” pins 16, 25, 28, or 31.
C8	Contactor output (not used)	Pulls to near Zero Volts if energized. Reference “A” pins 16, 25, 28, or 31.

Table 32: Meter checks, “D” connector

CAUTION!
There is high voltage on this connector!

Pin	Electrical Description	Expected measurements
D1	Not Used	None
D2	128V - 240V input	Battery voltage
D3	Not Used	None
D4	Not Used	None
D5	Not Used	None
D6	Not Used	None
D7	Not Used	None
D8	Not Used	None

Table 33: Meter checks, power and motor terminals

Disconnect all heavy wiring from drive or readings will be inaccurate.

CAUTION!
These must be tested with all power OFF! Make sure the capacitor bank is FULLY DISCHARGED before testing!

Terminals	Electrical Description	Expected measurements
B+ to B-	Battery Input	Meter set to “resistance”. Resistance from B+ to B- will start out low then slowly rise.
M1 to B-	Motor Phase 1	Meter set to “diode check”. Connect black lead to M1 and red lead to B-. Voltage drop will be around 320mV. If leads are reversed, reading will rise toward open circuit. If either result is wrong, the M1 lower IGBT has failed.
M1 to B+	Motor Phase 1	Meter set to “diode check”. Connect red lead to M1 and black lead to B+. Voltage drop will be around 320mV. If leads are reversed, reading will rise toward open circuit. If either result is wrong, the M1 upper IGBT has failed.
M2 to B-	Motor Phase 2	Meter set to “diode check”. Connect black lead to M2 and red lead to B-. Voltage drop will be around 320mV. If leads are reversed, reading will rise toward open circuit. If either result is wrong, the M2 lower IGBT has failed.
M2 to B+	Motor Phase 2	Meter set to “diode check”. Connect red lead to M2 and black lead to B+. Voltage drop will be around 320mV. If leads are reversed, reading will rise toward open circuit. If either result is wrong, the M2 upper IGBT has failed.
M3 to B-	Motor Phase 3	Meter set to “diode check”. Connect black lead to M3 and red lead to B-. Voltage drop will be around 320mV. If leads are reversed, reading will rise toward open circuit. If either result is wrong, the M3 lower IGBT has failed.
M3 to B+	Motor Phase 3	Meter set to “diode check”. Connect red lead to M3 and black lead to B+. Voltage drop will be around 320mV. If leads are reversed, reading will rise toward open circuit. If either result is wrong, the M3 upper IGBT has failed.
All	Heavy Wiring	Meter set to “resistance”. Measure between each terminal and heatsink. Resistance should be very high or open circuit. Otherwise, drive is internally shorted.

Motors

The HiPAC 10 system utilizes highly efficient, higher power density, AC three-phase induction motors resulting in:

- No brush or brush holders.
- Total system approach to insure motor and VFD are matched together for optimum performance.
- Larger rotor design and increased torque and horsepower.
- High power density and smaller frame size.
- High quality Class “H” VPI epoxy resin insulation system for longer life expectancy. It is high temperature, inverter grade, corona eliminating and fully compatible with variable frequency drives.
- Increased RPM capabilities resulting in higher machine speeds.
- Improved efficiency and performance.
- Totally enclosed, MSHA certified, non-vented enclosure prevents ingress of dust, grit, or moisture.

Bearings

The pump motor has a maintenance free sealed bearing. The traction motor(s) have a maintenance free sealed bearing on the non-driven end. The driven end bearing is lubricated by the gear box.

Motor Megger testing

CAUTION!
Disconnect all motor leads including the temperature switch and sensors before Megger testing. Electrical system and/or VFD damage may occur if leads remain connected.

☞ Connect the Megger between a winding and the motor frame.

☞ Per the IEEE 43 version 2000, meg each winding for 60 seconds before taking a reading. If the value is 5 meg Ohms or greater at 40°C, it is okay.

- A value below 5 meg Ohms indicates possible insulation breakdown, shorted winding, contamination in the motor, and/or moisture. The motor is questionable.
- A very low or zero reading means that a motor winding has shorted to ground. Otherwise, the internal temperature sensor may have shorted to one of the windings. Check for broken insulation on the motor terminals and sensor wires. If they are OK, the motor may need to be rewound.

Temperature

Each motor is equipped with a temperature switch and sensor.

Temperature switch operation

- Normally closed for acceptable motor temperature.
- Normally open for abnormal high motor temperatures.

Temperature sensor operation

The temperature sensor resistance changes with temperature. Actual temperature readings may be verified by measurement of the temperature sensor resistance (Table 34).

Table 34: Motor temperature sensor KTY84/130

°C	°F	Resistance (ohms)
-40	-40	359
-30	-22	391
-20	-4	424
-10	14	460
0	32	498
10	50	538
20	68	581
25	77	603
30	86	626
40	104	672
50	122	722
60	140	773
70	158	826
80	176	882
90	194	940
100	212	1000
110	230	1062
120	248	1127
130	266	1194
140	284	1262
150	302	1334
160	320	1407
170	338	1482
180	356	1560
190	374	1640
200	392	1722
210	410	1807
220	428	1893
230	446	1982
240	464	2073
250	482	2166

CANOpen

CANOpen is a standardized network technology that provides communication objects for real time data, configuration data, special functions, and network management. CANOpen systems are often found in medical equipment, off-road vehicles, electronics, maritime, transportation, and automation.

Control System Inputs

Inputs to the PLC may be monitored on the PLC (Fig. 28). Inputs to the HiPAC 10 may be monitored on the vehicle inputs monitor screen (Fig. 27).

Control System Outputs

The PLC outputs may be monitored on either the HiPAC 10 display Vehicle Inputs Monitor Screen (Fig. 27) or on the Programmable Controller (PLC) LED indication card (not used on control station models) (Fig. 28).

Fig. 27: Vehicle inputs monitor screen

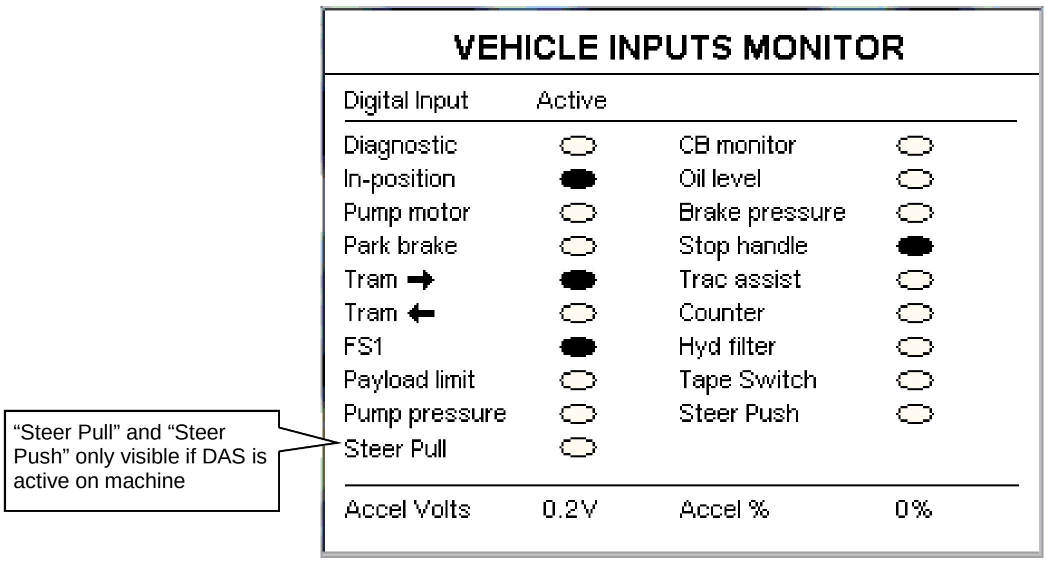
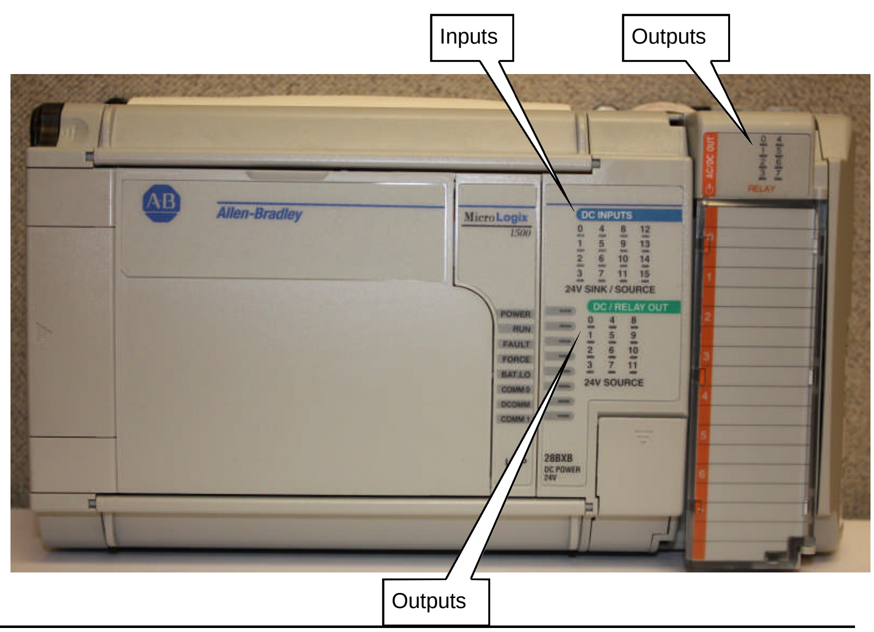


Fig. 28: Programmable controller (PLC) LED indication chart (not used on control station models)



Adjustments

Control Station Adjustable Parameters

Table 35 lists adjustable parameters for each machine type: SU Series Scoops, SH Series Roof Support Carriers, and Face Haulage vehicles.

Upon installation of a new supervisor VFD, and based on the machine hard wired configuration inputs, the adjustable parameters will fall to the default settings based on the machine model.

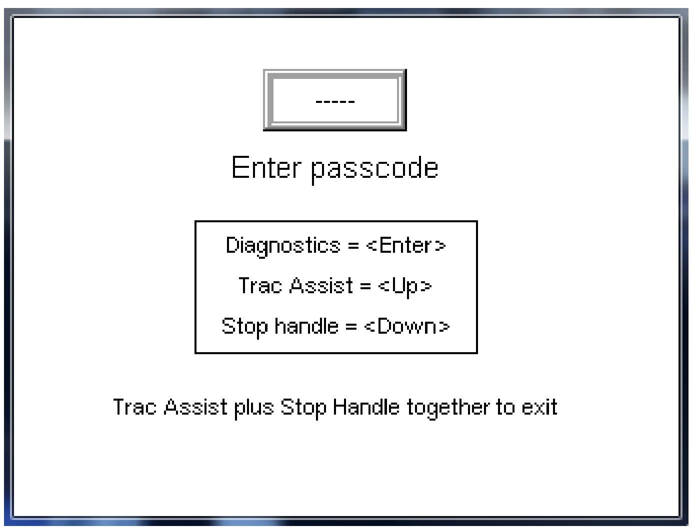
The operator may change the parameters as desired with the appropriate password.

It is recommended that any changes made for operator preference be recorded in the operators manual for future reference.

Should the supervisor VFD be replaced for any reason, all parameters revert back to the default adjustable parameter settings.

To enter the adjustable parameters menu on the display using the control box, press and hold the control box “stop” and “screen select” buttons simultaneously to bring up the password screen (Fig. 29).

Fig. 29: Password screen



The password may be entered by use of the control station diagnostics, screen select, and stop buttons.

- The Diagnostics switch acts as an “enter key” or acknowledgment key.
- The Screen Select button increments the display value up.
- The Stop button increments the display value down.

Once the password has been accepted, the display falls into the Initial Configuration screen (Fig. 30) From here, different menus and functions may be navigated and changed using the same three control box buttons - Diagnostics, Screen Select, and Stop. An example of a Parameter Change screen is on Fig. 31.

Fig. 30: Initial Configuration screen

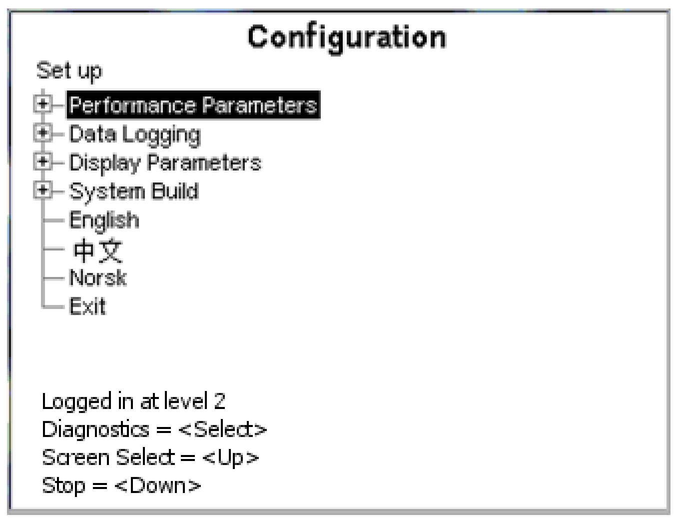
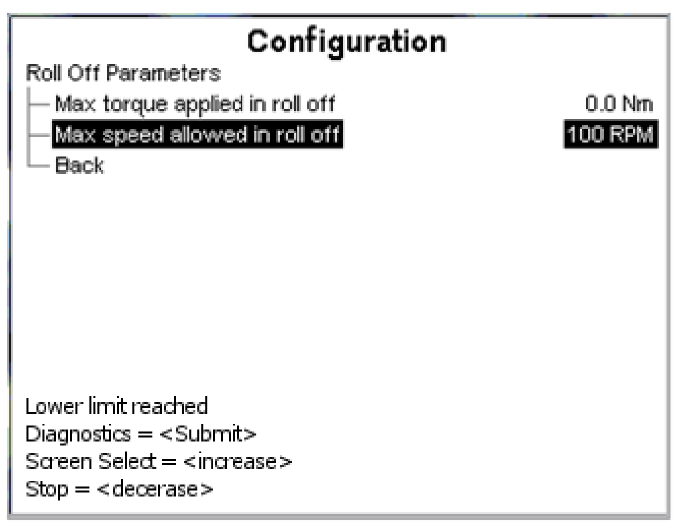


Fig. 31: Typical parameter change screen



To exit the adjustable parameters menu, press and hold the control box Stop and Screen Select buttons simultaneously. The display will return to its normal operating mode.

In a system this complex, simply printing all of the parameter change screens would be impractical. All of the adjustable parameters are instead organized and listed in the Adjustable Parameters table (Table 35).

IMPORTANT!
Currently, the State of Pennsylvania does not allow regenerative braking. This law is under consideration. However, currently regenerative braking must be disabled in the State of Pennsylvania only, via setting all braking torques to zero. See adjustable parameters chart (Table 35): all braking torques to be disabled (set to zero) are shown in red. All indicated braking torques (shown in red) must be set to zero when used in the State of Pennsylvania.

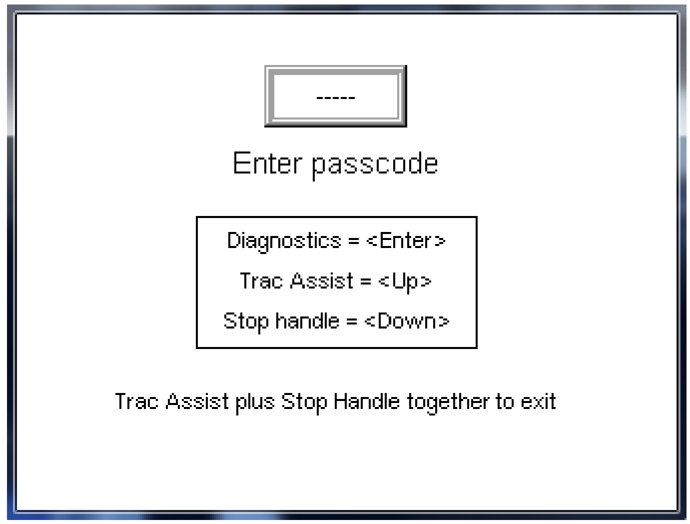
CAUTION!
Caution should be used when adjusting any parameter. Operators should be made aware of changes to such parameters as machine speeds and torques, braking torques and speeds, acceleration rates, roll-off speeds, and accelerator settings (increased machine speed, sudden acceleration or deceleration) may occur.

CAUTION!
The service brake and park brake are the primary means for stopping the vehicle.

Control Handle Adjustable parameters

To enter the adjustable parameters menu on the display using the control handle, press and hold the control handle “stop” and “traction assist” buttons simultaneously to bring up the password screen (Fig. 32).

Fig. 32: Password screen



The password may be entered by use of the control handle diagnostics, traction assist, and stop buttons.

- The Diagnostics switch acts as an “enter key” or acknowledgment key.
- The Traction Assist button increments the display value up.
- The Stop button increments the display value down.

Once the password has been accepted, the display falls into the Initial Configuration screen (Fig. 33) From here, different menus and functions may be navigated and changed using the same three control handle buttons - Diagnostics, Traction Assist, and Stop. An example of a Parameter Change screen is on Fig. 34.

Fig. 33: Initial Configuration screen

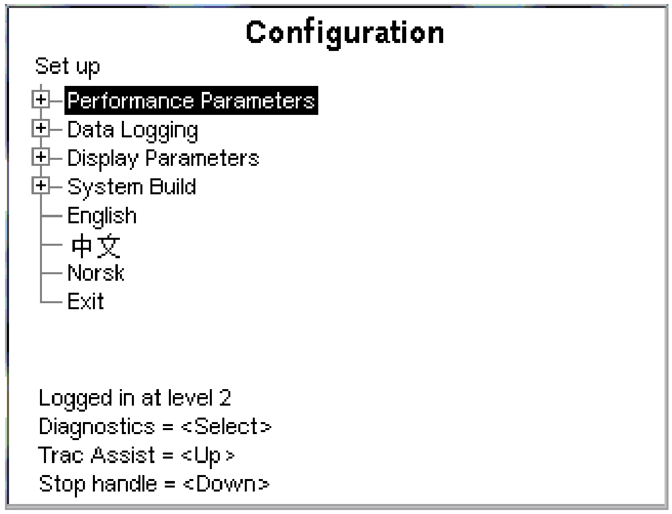
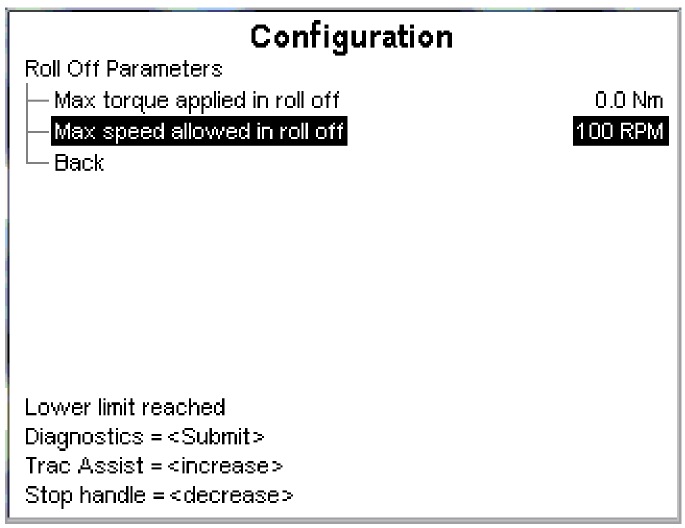


Fig. 34: Typical parameter change screen



To exit the adjustable parameters menu, press and hold the control handle Stop and Traction Assist buttons simultaneously. The display will return to its normal operating mode.

In a system this complex, simply printing all of the parameter change screens would be impractical. All of the adjustable parameters are instead organized and listed in the Adjustable Parameters table (Table 35).

IMPORTANT!
Currently, the State of Pennsylvania does not allow regenerative braking. This law is under consideration. However, currently regenerative braking must be disabled in the State of Pennsylvania only, via setting all braking torques to zero. See adjustable parameters chart (Table 25): all braking torques to be disabled (set to zero) are shown in red. All indicated braking torques (shown in red) must be set to zero when used in the State of Pennsylvania.

CAUTION!
Caution should be used when adjusting any parameter. Operators should be made aware of changes to such parameters as machine speeds and torques, braking torques and speeds, acceleration rates, roll-off speeds, and accelerator settings (increased machine speed, sudden acceleration or deceleration) may occur.

CAUTION!
The service brake and park brake are the primary means for stopping the vehicle.

Table 35: Adjustable parameters

Menu1	Menu2	Menu3	Menu 4	Description	Node	Password Level	Min	Max	SU Series Scoops (240V) Default	SU Series Scoops (128V) Default	SH Series Roof Support Carriers (240V) Default	SH Series Roof Support Carriers (128V) Default	SH680 Roof Support Carriers (240V) Default	FH Series Face Haulage (240V) Default	FH Series Face Haulage (128) Default	Units	Description
Performance Parameters																	
	Setup Items																
		Timers															
				CB close timer	Trac 1	1	0	20	15	15	15	15	15	15	15	Min.	Amount of time operator has to set breaker after system ok.
		BDI Parameters															
				BDI reset	Trac 1	1	0	2.55	2.12	2.12	2.12	2.12	2.12	2.12	2.12	V/Cell	Volts
				BDI empty	Trac 1	1	0	2.55	1.56	1.56	1.56	1.56	1.56	1.56	1.56	V/Cell	Calibration factor
				BDI cutback	Trac 1	1	0	100	4	4	4	4	4	4	4	%	% of battery charge remaining when BDI cutback parameters are activated.
				BDI warning	Trac 1	1	0	100	8	8	8	8	8	8	8	%	% of battery charge remaining when warning message is displayed
				Battery Discharge Rate Adjustment	Trac 1	1	16	200	34	34	34	34	34	34	34	Sec.	time below which battery voltage must drop below discharge threshold for bdi to decrement
		Accelerator Parameters															
				Accel Start	Trac 1	1	0.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	V	Zero Speed Accelerator Starting Voltage
				Accel End	Trac 1	1	3.00	5.00	4.50	4.50	4.50	4.50	4.50	4.50	4.50	V	Full Speed Accelerator Voltage
				Accel type	Trac 1	1	Linear, Curved, Crawl		Curved	Linear	Crawl	Curved	Crawl	Linear	Linear		Acceleration profile curve
	Drivability Items																
		Driveability Items															Baseline is the normal driving mode of the machine
			Driveability Items														
				Baseline max drive torque	Trac 1	2	0	1	0.80	0.80	1	1	0.71	0.55	0.55	%	Maximum Percentage of Available Motor Torque Applied During Driving
				Baseline direction braking	Trac 1	1	0	0.25	0.1	0.1	0.1	0.1	0.1	0.1	0.1	%	Maximum Percentage of Available Motor Torque Applied During braking after a direction change. Must be set to zero in PA.
				Baseline neutral braking	Trac 1	1	0	0.25	0.1	0.1	0.1	0.1	0.1	0.1	0.1	%	Max. % of Available Motor Torque Applied During Braking after going to neutral (Lifting foot from pedal). Must be set to zero in PA.
				Baseline Max speed fwd	Trac 1	1	1.0	6.0	4.5	4.5	4	4	4	4.5	4.5	MPH	Maximum Speed in Forward Direction
				Baseline Max speed rev	Trac 1	1	1.0	6.0	4.5	4.5	4	4	4	4.5	4.5	MPH	Maximum Speed in Reverse Direction
				Baseline acceleration delay	Trac 1	1	10	1800	550	550	500	500	500	550	550	RPM/Sec.	Normal Drive Speed Rate of Rise
			Accel and Decel Rates														
				Baseline Dir Accel Rate	1	1	10	1800	550	550	500	500	500	550	550	RPM/Sec.	Drive Speed Rate of Rise after direction change
				Baseline Neut Accel Rate	1	1	10	1800	550	550	500	500	500	550	550	RPM/Sec.	Drive Speed Rate of Rise after lifting foot from pedal then re-engaging pedal
				Baseline Drive Decel Rate	1	1	10	1800	350	350	350	350	350	350	350	RPM/Sec.	Drive Speed Rate of decline after partially lifting foot from pedal to slow machine
				Baseline Dir Decel Rate	1	1	10	1800	900	900	850	850	850	900	900	RPM/Sec.	Drive Speed Rate of decline during direction change
				Baseline Neut Decel Rate	1	1	10	1800	900	900	850	850	850	900	900	RPM/Sec.	Drive Speed Rate of decline after lifting foot from pedal

Table 35: Adjustable parameters, continued

Menu1	Menu2	Menu3	Menu 4	Description	Node	Pass-word Level	Min	Max	SU Series Scoops (240V) Default	SU Series Scoops (128V) Default	SH Series Roof Support Carriers (240V) Default	SH Series Roof Support Carriers (128V) Default	SH680 Roof Support Carriers (240V) Default	FH Series Face Haulage (240V) Default	FH Series Face Haulage (128) Default	Units	Description
Performance Parameters																	
	Drivability Items																
		Payload Limit parameters															Payload Limit is the driving mode of the machine when the turtle is visible on the display and lower speed settings are invoked
			Torques and Speeds														
				Payload limit max drive torque	Trac 1	2	0	1	0.80	0.80	1	1	0.71	0.55	0.55	%	Maximum Percentage of Available Motor Torque Applied During Driving
				Payload limit direction braking	Trac 1	1	0	0.25	0.1	0.1	0.1	0.1	0.1	0.1	0.1	%	Maximum Percentage of Available Motor Torque Applied During braking after a direction change. Must be set to zero in PA.
				Payload limit neutral braking	Trac 1	1	0	0.25	0.1	0.1	0.1	0.1	0.1	0.1	0.1	%	Max. % of Available Motor Torque Applied During Braking after going to neutral (Lifting foot from pedal). Must be set to zero in PA.
				Payload limit Max speed fwd	Trac 1	1	1.0	6.0	2.5	2	2	1.8	2	2.5	2	MPH	Maximum Speed in Forward Direction
				Payload limit Max speed rev	Trac 1	1	1.0	6.0	2.5	2	2	1.8	2	2.5	2	MPH	Maximum Speed in Reverse Direction
				Payload limit acceleration delay	Trac 1	1	10	1800	350	350	400	400	400	350	350	RPM/ Sec.	Normal Drive Speed Rate of Rise
			Accel and Decel Rates														
				Payload limit Dir Accel Rate	Trac 1	1	10	1800	350	350	400	400	400	350	350	RPM/ Sec.	Drive Speed Rate of Rise after direction change
				Payload limit Neut Accel Rate	Trac 1	1	10	1800	350	350	400	400	400	350	350	RPM/ Sec.	Drive Speed Rate of Rise after lifting foot from pedal then re-engaging pedal
				Payload limit Drive Decel Rate	Trac 1	1	10	1800	350	350	350	350	350	350	350	RPM/ Sec.	Drive Speed Rate of decline after partially lifting foot from pedal to slow machine
				Payload limit Dir Decel Rate	Trac 1	1	10	1800	900	900	850	850	850	900	900	RPM/ Sec.	Drive Speed Rate of decline during direction change
				Payload limit Neut Decel Rate	Trac 1	1	10	1800	900	900	850	850	850	900	900	RPM/ Sec.	Drive Speed Rate of decline after lifting foot from pedal
		BDI Cutback parameters															BDI Cutback is the driving mode of the machine when the battery is nearly discharged and lower speed settings are invoked
			Torques and Speeds														
				BDI max drive torque	Trac 1	2	0	1	0.80	0.80	1	1	0.71	0.55	0.55	%	Maximum Percentage of Available Motor Torque Applied During Driving
				BDI direction braking	Trac 1	1	0	0.25	0.1	0.1	0.1	0.1	0.1	0.1	0.1	%	Maximum Percentage of Available Motor Torque Applied During braking after a direction change. Must be set to zero in PA.
				BDI neutral braking	Trac 1	1	0	0.25	0.1	0.1	0.1	0.1	0.1	0.1	0.1	%	Max. % of Available Motor Torque Applied During Braking after going to neutral (Lifting foot from pedal). Must be set to zero in PA.
				BDI Max speed fwd	Trac 1	1	1.0	6.0	1.8	1.5	1.8	1.5	1.8	1.8	1.5	MPH	Maximum Speed in Forward Direction
				BDI Max speed rev	Trac 1	1	1.0	6.0	1.8	1.5	1.8	1.5	1.8	1.8	1.5	MPH	Maximum Speed in Reverse Direction
				BDI acceleration delay	Trac 1	1	10	1800	350	350	400	400	400	350	350	RPM/ Sec.	Normal Drive Speed Rate of Rise

Table 35: Adjustable parameters, continued

Menu1	Menu2	Menu3	Menu 4	Description	Node	Password Level	Min	Max	SU Series Scoops (240V) Default	SU Series Scoops (128V) Default	SH Series Roof Support Carriers (240V) Default	SH Series Roof Support Carriers (128V) Default	SH680 Roof Support Carriers (240V) Default	FH Series Face Haulage (240V) Default	FH Series Face Haulage (128) Default	Units	Description
Performance Parameters																	
	Drivability Items																
		BDI Cutback parameters															BDI Cutback is the driving mode of the machine when the battery is nearly discharged and lower speed settings are invoked
			Accel and Decel Rates														
				BDI Dir Accel Rate	Trac 1	1	10	1800	350	350	400	400	400	350	350	RPM/ Sec.	Drive Speed Rate of Rise after direction change
				BDI Neut Accel Rate	Trac 1	1	10	1800	350	350	400	400	400	350	350	RPM/ Sec.	Drive Speed Rate of Rise after lifting foot from pedal then re-engaging pedal
				BDI Drive Decel Rate	Trac 1	1	10	1800	350	350	350	350	350	350	350	RPM/ Sec.	Drive Speed Rate of decline after partially lifting foot from pedal to slow machine
				BDI Dir Decel Rate	Trac 1	1	10	1800	900	900	850	850	850	900	900	RPM/ Sec.	Drive Speed Rate of decline during direction change
				BDI Neut Decel Rate	Trac 1	1	10	1800	900	900	850	850	850	900	900	RPM/ Sec.	Drive Speed Rate of decline after lifting foot from pedal
		Pump parameters															
				% of max pump speed	Trac 1	1	25	100	65	65	65	65	65	65	65	%	% Cutback of Pump Motor Speed to Save Battery Life
				Time until Pump speed is cutback	Trac 1	1	0	50	2	2	2	2	2	2	2	Sec.	Elapsed time after pressure switch signal is removed, before going into speed cutback
				Pump Motor Speed	Trac 1	2	0	2000	1700	1350	1700	1350	1700	1800	1350	RPM	Actual Speed Setting of Pump Motor, under normal driving
		Roll off parameters															
				Maximum torque applied in Roll Off	Trac 1	1	0	100.0	28	28	28	28	28	28	28	%	Max. motor braking torque applied to reduce roll speed. Must be set to zero in PA.
				Maximum speed allowed in Roll Off	Trac 1	1	100	2000	300	300	250	250	250	900	900	RPM	Roll off motor speed limit, when braking is allowed, up to available torque limit
		Steering Settings															Steering Control System
			Steering														
				Steering Brake Torque-->	Trac 1	1	0	100						90	90	%	Steering braking torque applied to inside wheel in --> travel direction, (percentage of max drive torque) Must be set to zero in PA.
				Steering Brake Torque <--	Trac 1	1	0	100						90	90	%	Steering braking torque applied to inside wheel in <-- tracel direction, (percentage of max drive torque) Must be set to zero in PA.
				Steering Speed Cutback -->	Trac 1	1	0.0	100.0						30	30	%	Drop in target speed for cutback wheel to force braking in --> direction of travel.
				Steering Speed Cutback <--	Trac 1	1	0.0	100.0						50	50	%	Drop in target speed for cutback wheel to force braking in <-- direction of travel
				Steering Activation delay	Trac 1	1	0.0	5.0						0	0	Sec.	After steer switch is activated, delay before activating steering software.
				Traction Assist Clip speed	Trac 1	1	0.0	5000						2600	2600	RPM	With Screen Select (control Box) OR Traction assist (control handle) button pressed, if machine speed drops below this number, disable steering cutback system and both wheels go to full speed demand
				Target Speed cutback rate	Trac 1	1	0.0	2000						400	400	%/ Sec	Ramp rate of inside wheel to go from full speed to cutback speed setting, 400%=0.25 Sec, 200%=0.5 Sec, 100%=1 Sec, 50%=2 Sec, 33%=3 Sec, and 25%=4 Sec.
				Target Speed recover rate	Trac 1	1	0.0	2000						400	400	%/ Sec	Ramp rate of inside wheel to go back to full speed after releasing steering switch, 400%=0.25 Sec, 200%=0.5 Sec, 100%=1 Sec, 50%=2 Sec, 33%=3 Sec, and 25%=4 Sec.

Table 35: Adjustable parameters, continued

Menu1	Menu2	Menu3	Menu 4	Description	Node	Pass-word Level	Min	Max	SU Series Scoops (240V) Default	SU Series Scoops (128V) Default	SH Series Roof Support Carriers (240V) Default	SH Series Roof Support Carriers (128V) Default	SH680 Roof Support Carriers (240V) Default	FH Series Face Haulage (240V) Default	FH Series Face Haulage (128) Default	Units	Description
Data Logging																	
		Display logs															
				Clear data log	Display	1	No change, reset										clears temperature log
				Set data log interval	Display	1	1	600	300	300	300	300	300	300	300		Seconds
				Clear fault log	Display	1	No change, reset										clears fault log on display only
Display Parameters																	
		Configuration settings															
				Units Format	Display	1	Metric, Imperial		Imperial	Imperial	Imperial	Imperial	Imperial	Imperial	Imperial		
				Clock format	Display	1	12Hour, 24Hour		12Hour	12Hour	12Hour	12Hour	12Hour	12Hour	12Hour		
				Date format	Display	1	DDMMYY, MMDDYY		MMDDYY	MMDDYY	MMDDYY	MMDDYY	MMDDYY	MMDDYY	MMDDYY		
				Display Contrast	Display	1	1	255	133	133	133	133	133	133	133		
				Distance Units	Display	1	feet, meters, miles, kilometers		Feet	Feet	Feet	Feet	Feet	Feet	Feet		
				Flash backlight if BDI low			Yes/No		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes/ No	Yes=Active or No=disable feature (starts flashing when BDI warning is active
		Clock settings															
				hours	Display	1	0	23								Hours	Hours
				mins	Display	1	0	59								Min.	Minutes
				day of month	Display	1	1	31								Day	Day
				month	Display	1	January through December									Month	Month
				year	Display	1	2000	2050								Year	Year
		Vehicle Description															
				Auto-Manual selection	Trac 1	2	Auto or User selections		Auto	Auto	Auto	Auto	Auto	Auto	Auto		These Items Are Set By The Machine Configuration Wiring
				Vehicle Type	Display	2	FH Series, SU Series, SH Series										
				Traction Motor Type	Display	2	2x75HP, 2x100HP, 1x75HP, 1x100HP, 4x100HP										
				Pump Motor Type	Display	2	48HP, 100HP										
				Vehicle Gear Ratio	Display	2	See Wiring Diagram										
				Vehicle Tire Diameter	Display	2	See Wiring Diagram										
				Vehicle orientation	Display	1	Positive or Negative		Neg.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.		Direction Arrow as seen on the Display
				Battery Supply Voltage	Display	1	128VDC or 240 VDC										Battery Voltage setting
				Tow mode	Trac 1	1	Yes or No		No	No	No	No	No	No	NO		When Yes, all driving and braking torque is set to zero.

Table 35: Adjustable parameters, continued

Menu1	Menu2	Menu3	Menu 4	Description	Node	Pass-word Level	Min	Max	SU Series Scoops (240V) Default	SU Series Scoops (128V) Default	SH Series Roof Support Carriers (240V) Default	SH Series Roof Support Carriers (128V) Default	SH680 Roof Support Carriers (240V) Default	FH Series Face Haulage (240V) Default	FH Series Face Haulage (128) Default	Units	Description
System Build																	
		Traction 1 Build															
				Sw. Ver.	Trac 1	1	Not Adjustable										Software Version
				Serial No.	Trac 1	1	Not Adjustable										Serial No.
		Traction 2 Build															
				Sw. Ver.	Trac 2	1	Not Adjustable										Software Version
				Serial No.	Trac 2	1	Not Adjustable										Serial No.
		Pump Build															
				Sw. Ver.	Pump	1	Not Adjustable										Software Version
				Serial No.	Pump	1	Not Adjustable										Serial No.
		Display Build															
				Sw. Ver.	Display	1	Not Adjustable										Software Version
				Serial No.	Display	1	Not Adjustable										Serial No.
English																	Selects English Language
Chinese																	Selects Chinese Language
Norwegian																	Selects Norwegian Language
Exit																	Exit to main screen

Parts replacement

Removal and installation of VFDs

The following section outlines the removal and installation of VFDs.

CAUTION!
Before removing or installing a VFD, verify that the battery has been disconnected from the machine, that the circuit breakers are in the "OFF" position, and that the battery plug has been disconnected and locked/tagged out. Failure to do so may result in machine damage or injury to you or other personnel.

Connectors

Locking type connectors are used on the VFDs (Fig. 35).

To remove a connector:

1. Verify that the battery has been disconnected from the machine, that the circuit breakers are in the "OFF" position, and that the battery plug is disconnected and locked/tagged out.

2. Remove the cover from the machine.

3. Locate the VFD and identify the connectors, labeled "A", "B", "C", and "D".

4. The connectors are equipped with a screwdriver slot to release the latch (Fig. 36). Insert the screwdriver into the latch and lift up.

5. Pull up firmly to remove the connector.

To install a connector:

1. Verify that the correct connector, labeled "A", "B", "C", and "D", is selected.

2. Press connector down firmly to lock in place. Locking latch (Fig. 36) must be firmly fastened for mating.

Fig. 35: Typical VFD

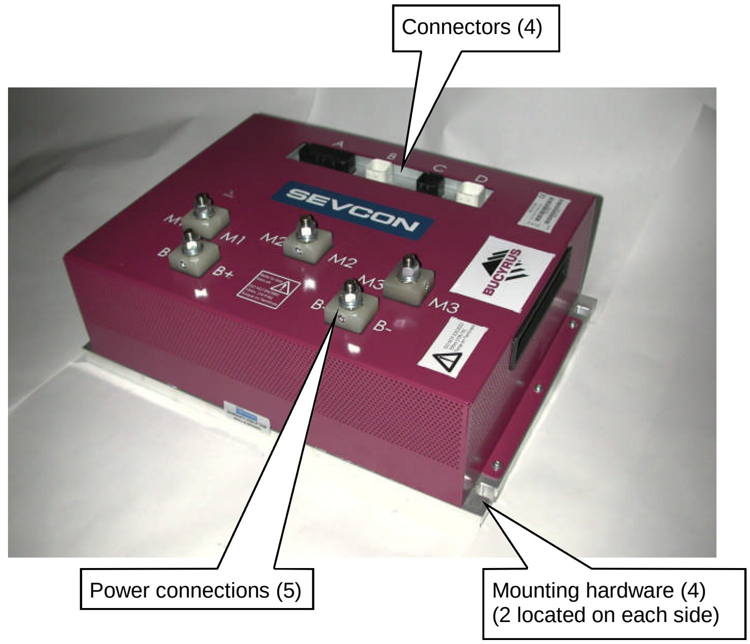
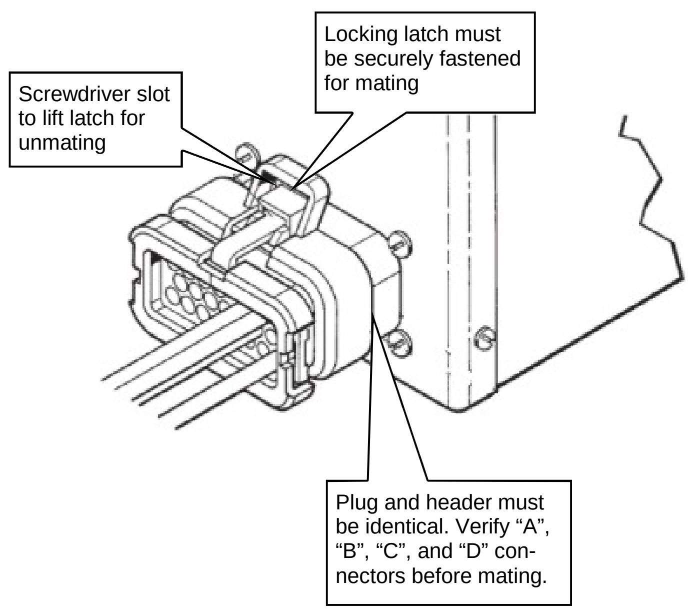


Fig. 36: Connector



Power connections

Power connections utilize studs made of a special current-carrying material, along with nuts, flat washers, and lock washers. Due to the properties of the material, excessive torque values may damage or break the power terminal stud or damage the VFD. The correct torque for the power connections is 9 ft-lbs ± 10% (13.5 Nm ± 10%). Do not exceed this torque value.

NOTICE!
Due to the properties of the stud material, excessive torque may damage or break the power terminal stud or damage the VFD.

VFD mounting

- Remove all old thermal compound from the bottom plate of the controller enclosure. Make sure the plate is free of all debris, rust, etc.

- Apply a thin coat of thermal compound to the VFD. The thermal compound should cover the entire mounting surface of the VFD. Do not apply thick coats of thermal compound as they may leave voids and limit heat transfer.

NOTICE!
Lack of thermal compound, thickly applied thermal compound, and/or debris under the VFD may limit heat transfer from the VFD to the controller bottom plate and may result in thermal cutback of the VFD.

- Mount the VFD to the controller bottom plate. Mounting hardware must be properly installed to insure proper heat transfer from the VFD to the bottom plate of the controller. The correct torque for the VFD mounting hardware is 32 ft-lbs ± 10% (44 Nm ± 10%).

NOTICE!
Improper installation of mounting hardware may limit heat transfer from the VFD to the controller bottom plate and may result in thermal cutback of the VFD.

Wiring diagrams

See your machine parts manual for the complete machine wiring diagram applicable to your particular machine.

Fig. 37: Traction supervisor VFD diagram

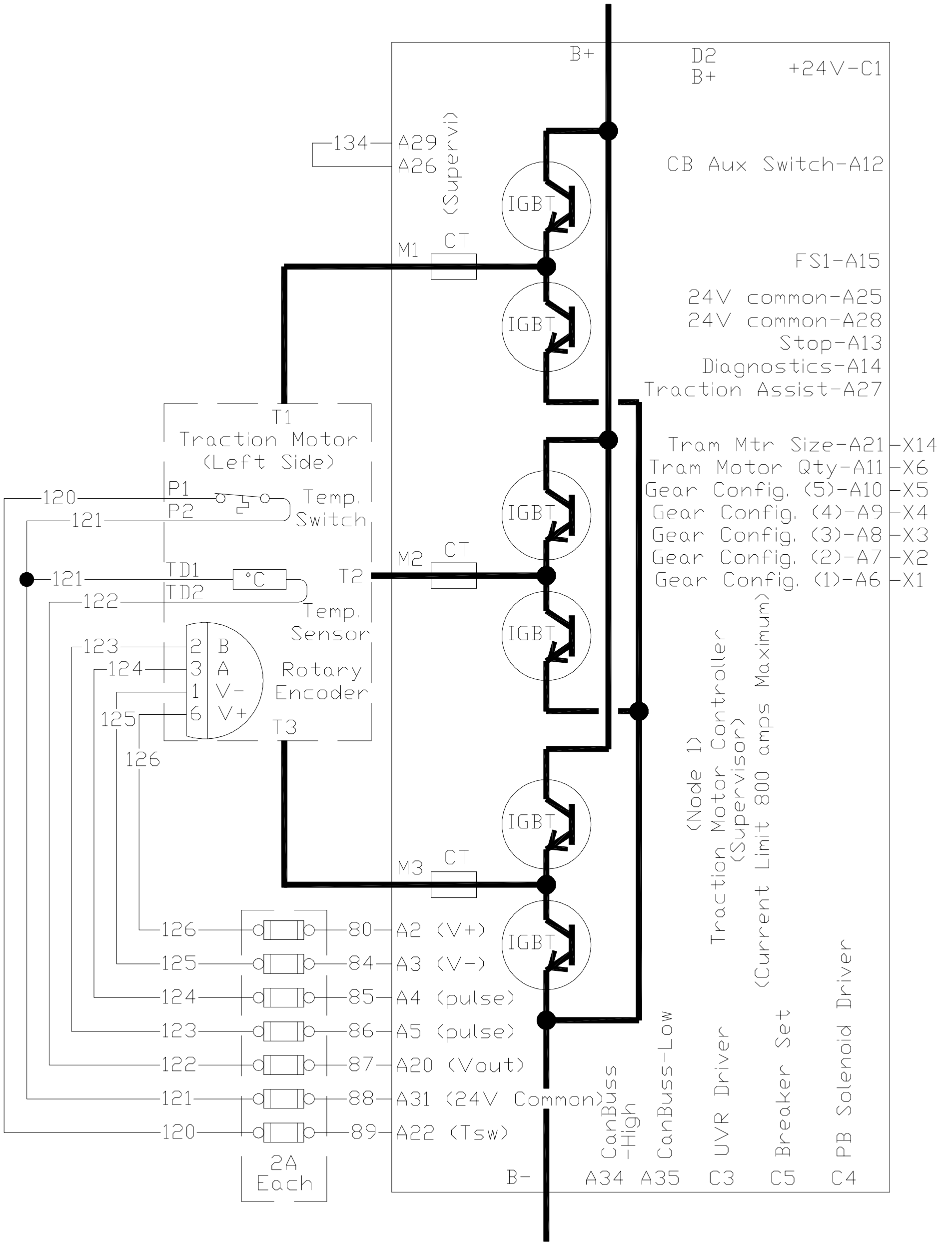


Fig. 38: Traction auxiliary VFD diagram

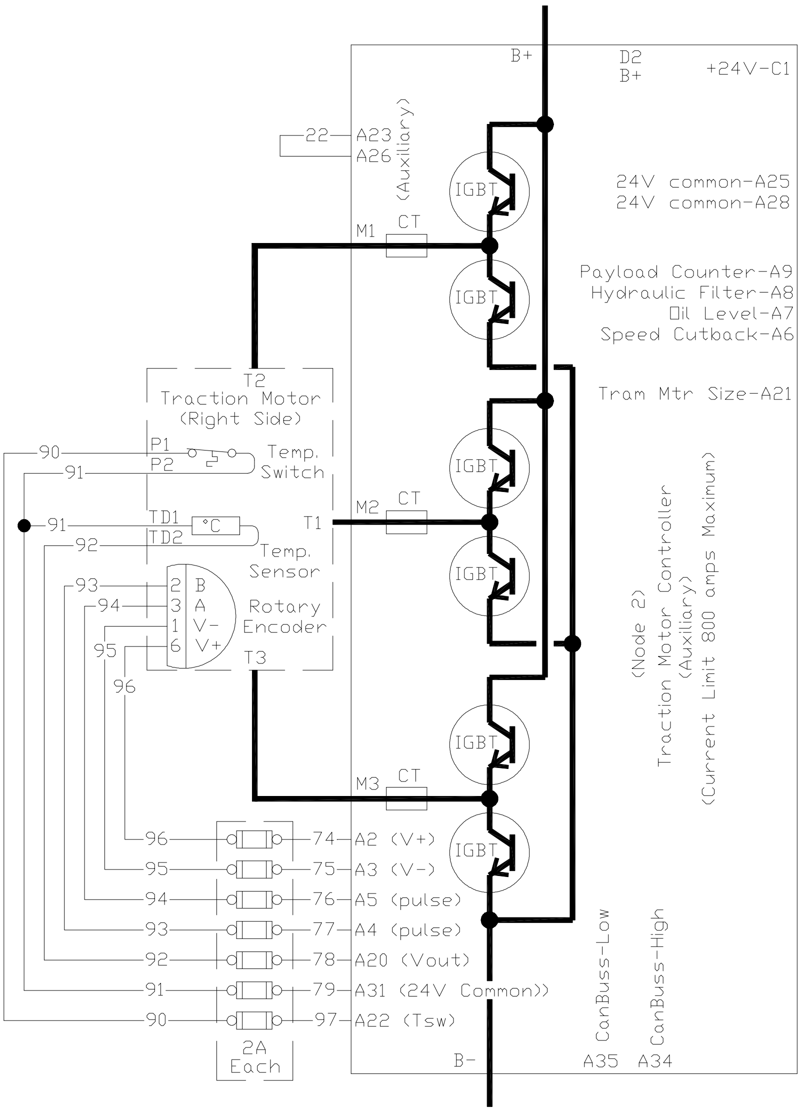
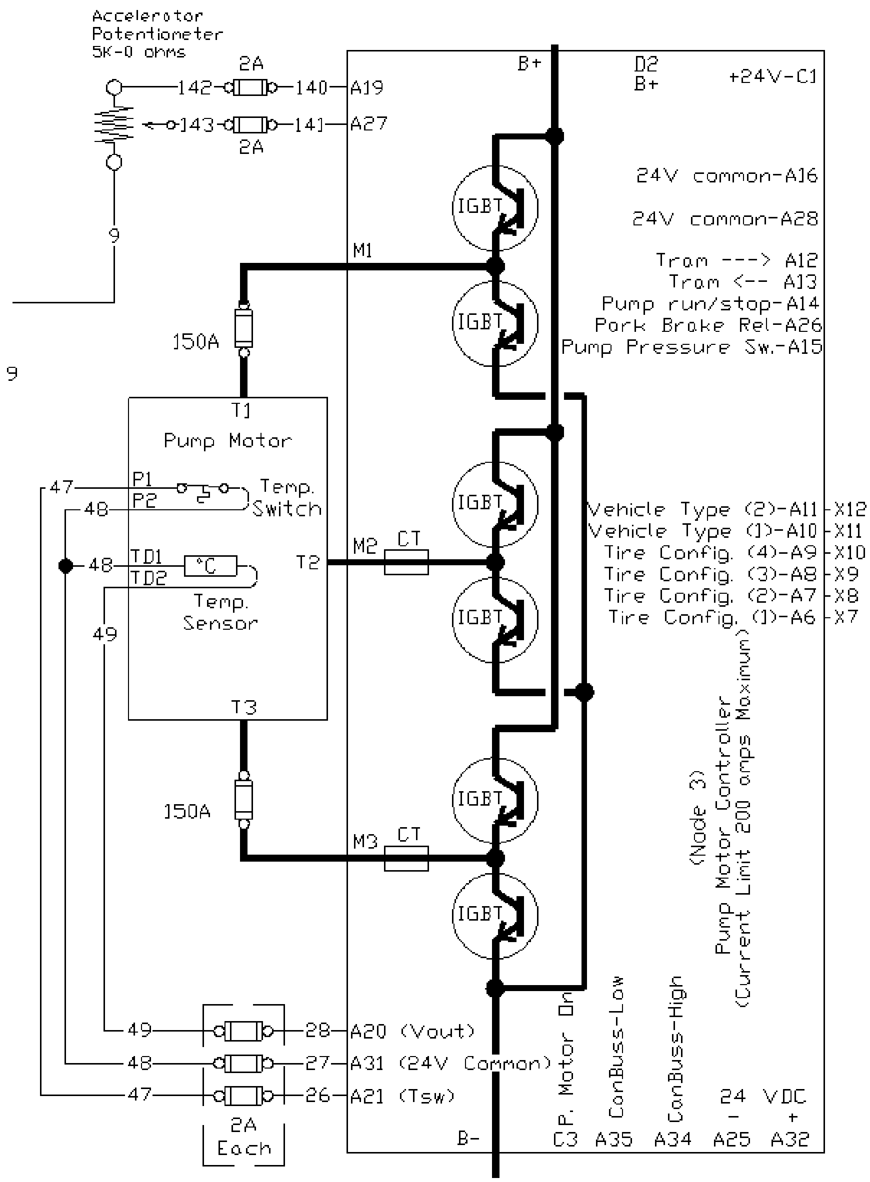


Fig. 39: Pump VFD diagram



4 Technical data

Tightening torques

NOTICE!
Due to the application of fasteners being subject to great stresses and heavy or extreme vibration, it is imperative that all bolts be applied with the correct torque. The tightening torques stated in the spare parts lists have to be observed, as well, for installation and maintenance.

Controller terminal torque:	13.5Nm ± 10% (9 ft-lb ± 10%)
Controller mounting torque:	44 Nm ± 10% (32 ft-lb ± 10%)

BI001951

5 For your information

For your information

Our service

If you need to order spare parts or if technical problems occur, please contact our after-sales service personnel or contact us direct.

Service address

Beckley, WV
351 Ragland Road
Beckley, WV 25801
Phone: (304) 256-5927
Fax: (304) 256-5928

Craig, CO
400 Mack Lane
Craig, CO 81625
Phone: (970) 824-3249
Fax: (970) 824-8851

Duffield, VA
P.O. Box 847
6808 Fraley Avenue
Duffield, VA 24244
Phone: (276) 431-7000
Fax: (276) 431-2464

Houston, PA
2045 West Pike Street
Houston, PA 15342
Phone: (724) 743-1200
Fax: (724) 743-1201

Carrier Mills, IL
9580 State Route 13 West
Carrier Mills, IL 62917
Phone: (618) 982-9000
Fax: (618) 982-9912

Oak Hill, WV
P.O. Box 60
Oak Hill, WV 25901

843 Lochgelly Road
Oak Hill, WV 25901
Phone: (304) 469-3302
Fax: (304) 465-0450

Paonia, CO
P.O. Box 566
Paonia, CO 81428

719 Second Street
Paonia, CO 81428
Phone: (970) 527-3151
Fax: (970) 527-6846

Pulaski, VA
4041 Wurno Road
Pulaski, VA 24301
Phone: 540-980-4530
Fax: 540-980-6211

Washington, PA
255 Berry Road
Washington, PA 15301
Phone: (724) 743-1200
Fax: (724) 228-2177

Rebuild facility address

Huntington, UT
P.O. Box 1190
Route 10, 1Mile North
Huntington, UT 84528
Phone: (435) 687-9831
Fax: (435) 687-2522

Pearisburg, VA
P.O. Box 463
222 Industrial Park Drive
Pearisburg, VA 24134
Phone: (540) 921-2111
Fax: (540) 921-2711

Norris City, IL
635 Illinois Highway 1
Norris City, IL 62869
Phone: (618) 378-3441
Fax: (618) 378-3106

OPERATION,
PREVENTIVE MAINTENANCE,
TROUBLESHOOTING, PARTS
AND SERVICE GUIDE

MODELS
5, 6, 8, 10,
12, AND 14

BATTERY CHARGERS

THIS GUIDE CONTAINS IMPORTANT OPERATION AND SAFETY INFORMATION AND SHOULD BE KEPT AVAILABLE TO THOSE PERSONNEL INSTALLING AND OPERATING THIS EQUIPMENT.

P/N A6474X193
Revision 7, March 2012

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PREFACE

This manual is intended to provide GENERAL product information for Caterpillar Series Battery Chargers. The illustrations, descriptions and procedures contained in this publication apply only to Caterpillar Battery Chargers. Caterpillar reserves the right to revise models and designs without prior notice.

This Battery Charger was manufactured under the guidelines, procedures and requirements of the U. S. Federal Coal Mine Health and Safety Act, Code of Federal Regulations, Title 30, Chapter 1, Subpart 0, Part 75 for underground coal mines, and other applicable non-U.S. regulatory agency standards.

At the completion of the manufacturing process, the charger was issued the appropriate approval numbers and nameplates indicating it met the technical requirements of these regulatory agencies. Any change to the design or structure of the charger, without the consent of Caterpillar, and these regulatory agencies, or any repair or replacement of parts contrary to the instructions, may invalidate these approvals and render the charger unsafe to operate.

Strict compliance with all Federal and State Mining laws, regulations and practices regarding the safe operation and maintenance of underground mining equipment and strict adherence to the instructions in this manual is necessary for the personal safety of those working on or around this charger.

While this manual attempts to anticipate the most important operations and maintenance needs for this charger, unforeseen circumstances may arise that have not been addressed in this manual. If any concerns or questions arise, please contact your Service Representative <u>immediately</u>.

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SYMBOLS AND SPECIAL NOTATIONS

Throughout this manual there are specific notations that are either **UPPERCASE BOLD**, UNDERLINED or *ITALICIZED* for the primary purpose of emphasis. Please pay special attention to such statements as they regard safety or critical maintenance installation information.

You will also see the following:

NOTICE

NOTICE: *THIS NOTATION DENOTES A REFERENCE TO PREVIOUSLY STATED INSTRUCTIONS.*

IMPORTANT

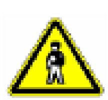
IMPORTANT: *THIS SYMBOL DENOTES THAT SPECIAL ATTENTION MUST BE ADHERED TO IN THE ATTACHED STATEMENT.*

CAUTION

CAUTION: *THIS SYMBOL DENOTES THAT FAILURE TO COMPLY WITH THE ATTACHED STATEMENT COULD RESULT IN A CUT, BRUISE OR ABRASION.*

WARNING

WARNING: *THIS SYMBOL DENOTES THAT FAILURE TO COMPLY WITH THE ATTACHED STATEMENT COULD RESULT IN A LOST TIME ACCIDENT.*



DANGER

DANGER: *THIS SYMBOL DENOTES THAT FAILURE TO COMPLY WITH THE ATTACHED STATEMENT COULD RESULT IN A SERIOUS INJURY OR FATALITY.*

DANGER

ONLY TRAINED AUTHORIZED PERSONNEL SHOULD OPERATE OR PERFORM MAINTENANCE ON THE CHARGER.

FAILURE TO ADHERE TO DANGERS, WARNINGS AND CAUTIONS, NOTED IN THIS MANUAL, COULD RESULT IN SERIOUS INJURY OR DEATH.

FAILURE TO OPERATE OR MAINTAIN THIS CHARGER IN STRICT ADHERENCE TO THESE INSTRUCTIONS AND WARNINGS IN THIS MANUAL COULD VOID THE WARRANTY.

MAJOR HAZARDS

AREA	HAZARD	SAFEGUARDS
WHERE HAZARD CAN OCCUR	**WHAT CAN HAPPEN IF PRECAUTIONS AND SAFEGUARDS ARE NOT OBEYED**	**HOW TO AVOID THE HAZARD**
ELECTRICAL (A.C. Input, Charger, Battery)	Electrical shock could cause irreparable injury or death.	All electrical systems should be maintained by certified electricians. The a.c. input and charger plug should be disconnected before servicing the charger.
	Charging a battery of a size different than that shown on the charger nameplate could cause the battery to burst, or cause damage to the battery or charger.	Chargers should be matched to the size batteries in use at each particular mine.
BATTERY	The battery produces lethal amounts of power whether connected to the machine or charger, or not.	The battery should be maintained by qualified personnel. (Refer to "INSTALLATION, USE, MAINTENANCE, AND REPAIR OF MINE POWER STORAGE BATTERIES," PART NUMBER A6474X26, for complete instructions).
	Battery covers could fall crushing hands or arms.	Be sure cover supports are in place when working on battery.
	Battery hold-down clamps could crush fingers.	Keep fingers away from hold-down clamps.
	Batteries produce explosive gases that could be ignited causing burns or explosions.	Batteries should be well vented before servicing particularly if welding or burning on the battery. Batteries should be maintained by qualified personnel.
	Batteries contain strong acid that could cause severe burns if spilled or splashed on body parts or in the eyes.	Protective clothing, gloves, and eyewear must be worn when working on batteries. Batteries should be maintained by qualified personnel.

SAFETY PRECAUTIONS AND GUIDELINES

Overview

Before you operate, maintain or in any other way, use this unit -

READ and STUDY this guide. KNOW how to safely use the unit's controls and what you must do for safe operation and maintenance.

ALWAYS wear or use the proper safety items required for your personal protection.

If you have ANY QUESTIONS about the safe use or maintenance of this unit:
ASK YOUR SUPERVISOR - NEVER GUESS - ALWAYS CHECK

Location

LOCATE the charging station away from rain, snow, wet conditions or areas of high traffic when possible.

NEVER place this unit directly above a battery. Gases from the battery will corrode and damage equipment.

NEVER allow the battery electrolyte to drop on this unit when reading the specific gravity or filling the battery.

DO NOT operate this unit in a closed in area or restrict ventilation in anyway.

DO NOT set a battery on top of this unit

Pre-Start

Read this entire guide BEFORE attempting to operate this unit. You should be familiar with the controls and their functions before the unit is energized.

INSPECT the charger by doing a pre-operational inspection. Have any broken or missing parts corrected or replaced before use.

VERIFY that all maintenance has been performed.

VERIFY that all the instruction and safety labels are in place and readable. These are as important as any other equipment on the machine.

CLEAN any foreign material from inside the charger cabinet.

Starting

ALWAYS follow all safety rules of each particular mine when operating the charger.

If problems or equipment malfunctions are encountered while operating the unit, it must be properly shutdown and the problem repaired. Continuing to use malfunctioning equipment can not only be unsafe for the operator and other personnel but can lead to further damage to the unit as well.

Before using this equipment, read all instructions and cautionary markings on the charger and the battery.

Maintenance

AVOID, whenever possible, servicing, cleaning or examining the charger in congested areas.

DO NOT alter the electrical settings from that indicated in this operation guide or as set at the factory.

ALWAYS replace damaged or lost decals or metal instruction plates. Refer to the Parts Section for the proper location and part number of decals and plates.

DISCONNECT the battery when working with electrical systems, or when welding on the unit to prevent electrical shock.

To help reduce risk of electric shock, disconnect this unit from the AC power supply and batteries before attempting any maintenance or cleaning. Turning off controls will not reduce this risk.

BE SURE the battery area is well ventilated (clear of fumes) when it is connected to the battery charger or when working on or around the battery with sparks or flames. Fumes from the battery could ignite by a spark and explode.

It is important that any procedure not specifically recommended in this guide be thoroughly evaluated from the standpoint of safety before it is implemented.

WARNING

USE ONLY THE NUMBER AND TYPE OF BATTERIES SPECIFIED ON NAMEPLATE. ATTEMPTING TO CHARGE OTHER TYPES OF BATTERIES COULD CAUSE THE BATTERY TO BURST, CAUSING PERSONAL INJURY OR DAMAGE.

BATTERIES PRODUCE EXPLOSIVE GASES DURING NORMAL BATTERY OPERATION. FOR THIS REASON, IT IS OF THE UTMOST IMPORTANCE THAT EACH TIME BEFORE USING THIS UNIT, YOU READ THIS MANUAL AND FOLLOW THE INSTRUCTIONS EXACTLY.

To reduce risk of battery explosion, follow these instructions and those published by the battery manufacturer and manufacturer of any other equipment you intend to use in the vicinity of the battery. Review cautionary marking on all products.

Personal Precautions

Have someone within range of your voice or close enough to come to your aid when you work near a battery.

Have plenty of fresh water and soap nearby in case the battery electrolyte contacts skin, clothing, or eyes.

Wear complete eye protection and clothing protection. Avoid touching eyes while working near a battery.

If the battery electrolyte contacts skin or clothing, wash immediately with soap and water. If the electrolyte enters the eye, immediately flood the eye with running cold water for at least ten (10) minutes and get medical attention immediately.

NEVER smoke or allow a spark or flame in vicinity of a battery.

Avoid dropping metal tools onto a battery. It might spark or short circuit the battery or other electric parts that could cause an explosion.

REMOVE personal metal items such as rings, bracelets, necklaces, and watches when working with a battery. A battery can produce a short circuit current high enough to weld a ring or the like to metal, causing a severe burn.

NEVER charge a frozen battery.

If it is necessary to remove the battery connections, always remove the grounded terminal from the battery first. Make sure all loads are disconnected and unit is off, so as not to cause an arc.

Be sure the area around the battery is well ventilated while the battery is being charged.
When cleaning battery terminals, be careful to keep corrosion from coming in contact with the eyes.

Study all the battery manufacturer's specific precautions such as do not remove cell caps while charging, recommended rates of charge, and maintenance procedures.

THEORY OF OPERATION FERRORESONANT DESIGN

The transformer in a ferroresonant design is non-linear. It's secondary is operated in saturation while the primary is operated in the linear region of the B-H curve.

A magnetic shunt is used to separate the primary and secondary fluxes, which are at different levels. This non-linear operation means that the transformer no longer obeys the turns ratio laws of the linear transformer. That is, the secondary voltage is no longer a function of the turns ratio times the primary voltage. This means that changes in the primary voltage do not directly affect the secondary voltage value.

The secondary voltage is proportional to the voltage across the resonating winding only. The voltage of the resonating winding is affected by the amount of magnetic coupling to the primary, and by careful selection of magnetic shunts and capacitor values. Thus a battery charging curve can be established. The charging curve is essentially fixed and can only be altered by changes in the transformer design. Under short circuit conditions, the amount of primary to secondary magnetic coupling determines the value of the output current limit.

Rectifiers are added to convert the output of this A.C. regulator into D.C.

The ferroresonant circuit requires a good grade of capacitor in the resonating circuit to improve reliability and a careful design of the transformer. That is the principle of the ferroresonant design.

INTRODUCTION

The Model LA Series Charger can be one of the most useful and safe machines found underground today, IF IT IS OPERATED CORRECTLY BY A PROPERLY TRAINED OPERATOR. Before operating the Model LA SERIES Charger, study the drawings to become familiar with the controls and read the description of each control.

General

The Model LA SERIES Mine Battery Charger combines reliable, rugged components with unmatched circuit simplicity. The ferroresonant design of the Model LA Series Charger eliminates the need for complicated control circuits and lowers the parts count.

Three major components make up the circuit of the LA Series; a ferroresonant step down transformer; silicon rectifiers, and timer.

The magnetics are designed with an extra margin of capacity and have a Class H (180 degrees C) rating. Cores and windings are insulated with Class H Nomex material. The DuPont Nomex system uses a modified polyester baking varnish for further protection. This assures continued operation under the most severe, damp and dirty conditions present in the mine. The full wave rectifier includes conservatively rated silicon diodes and surge suppressors to provide a reliable d.c. output.

The Model LA Series regulates the d.c. output voltage to produce the proper charging curves for the battery. Its charge rate is dependent on the state of charge of your battery. A.C. line voltage compensation prevents any drift from the d.c. charging curve because of surges or drops in voltage. Basic design eliminates the need for voltage sensitive relays.

The Model LA Series automatically limits the output of the charger to approximately 125% of its rating. This prevents battery overheating, fuse blowing and assures long life for both battery and charger.

The Model LA Series is a completely automatic constant voltage charger. Each LA Series is designed to operate on a specific type of battery with a specified number of cells.

RATINGS AND SPECIFICATIONS

Output Ratings

D.C. Voltage

The LA Series Mine Chargers are factory set to finish at approximately 2.5 volts/per cell for lead acid batteries. The chargers are available in 32 cell (64 volt) or 64 cell (128 volt) output.

Output Current

(Refer to table 1).

Regulation

The charge rate is dependent on the state of charge of the battery. Automatic a.c. line voltage compensation regulates the d.c. output and maintains the charging curve.

INPUT CURRENT AND BATTERY CAPACITIES

CHARGER MODEL	APPROX. AC CURRENT DRAW (3-PHASE) 480VAC / 575VAC	BATTERY AMPERE-HOUR CHARGING CAPACITY	OUTPUT RATING
LA5	26 - 22	550	90 AMPS
LA6	32 - 27	680	110 AMPS
LA8	41 - 34	800	140 AMPS
LA10	52 - 44	1050	180 AMPS
LA12	61 - 51	1200	210 AMPS
LA 14	70 - 59	1400	240 AMPS

TABLE 1

Input Ratings

A.C. VOLTAGE

Taps are provided for three phase a.c. input voltages of 480 or 575 Vac with an a.c. input voltage range of +/-10% of nominal.

Input Frequency Range

57 to 63 Hz. (60 HZ nominal).

Input Current & Battery Capacities

(Refer to TABLE 1)

Typical Electrical Specifications

(Refer to TABLE 1)

Standard Features

Input Protection

A. A.C. fuses on each input leg.
B. A.C. contactor to disconnect the unit from the a.c. line.
C. A.C. fuse in one leg of control transformer.

Meters

D.C. AMMETER (STANDARD).

Output Protection

A. D.C. output fuse.
B. Current limiting automatically limits the d.c. output current of the charger to approximately 125% of its rating..

Electronic Timer

8 hour timer with auto start/stop feature on battery connection. (See OPERATION section)

Mounting

Low profile mine case with skids.

Optional Ground Integrity

The Automatic Mine Recharger is designed to operate on a specific type of battery with a specified number of cells. The nameplate on the charger indicates the type of battery, number of cells, and the a.c. input voltage.

To energize the unit with optional ground integrity, the following procedure should be used:

1. Check a.c. input voltage with that specified on the nameplate. i.e.: chargers furnished with 480 volt and 575 volt power lines, are dual input units. Taps within the unit must be set on the 480 volt setting for 480 volt power lines, and 575 volt taps for 575 volt power systems. A schematic is provided with the unit which indicates how the a.c. power connections must be wired. Connect the power lines to the a.c. input terminals, the ground wire to the ground terminal bonded to the case near the input terminals.
2. A ground check wire supplied from the power center must be connected to terminal 3R, near the input terminals.
3. The battery , with a 4 wire plug, must be connected to the unit's output in order to energize the unit.
4. Ground integrity must be made on all systems to energize the unit. If the case ground is more than 5 ohms, the unit will not energize.
5. The emergency stop switch must be pulled out.
6. Push in the green button. The unit should energize, and the charger will automatically start to charge the battery at some rate up to its maximum capacity, depending upon the state of charge of the battery, and charge the battery to full charge, then shutdown to a trickle charge-preserving-charge. The charger will continue the trickle rate until the timer turns the unit completely off.

NOTICE

THIS UNIT IS EQUIPED WITH TWO (2) DOOR DISCONNECT SWITCHES AND ONE (1) COVER DISCONNECT SWITCH. THE TWO ACCESS DOORS AND THE TOP COVER OF THE UNIT MUST BE CLOSED FOR THE UNIT TO OPERATE.

If the unit fails to energize:

1. Check a.c. power on all three phases.
2. Check to make sure voltage taps are wired properly.
3. Check a.c. and d.c. fuses.
4. Make sure battery is connected to unit's output.
5. Check for ground integrity. This can be done by putting a jumper from ground bus #2 to terminal 1R or 2R on two circuit chargers. If unit starts when jumpered, ground integrity is the problem. (Disconnect the jumper after check)
6. Check emergency stop switch. It must be pulled out.
7. Check all ground connections.
8. Start button must be depressed to energize the unit. (Listen for click of control relay) If a second battery is added on two circuit chargers, the start button, again must be depressed.
9. Check all disconnect switches - doors and top must be closed.

Environmental Ratings

Operating Ambient Temperatures

Operation - 0° - 50° C (32° - 122° F)   Storage - -40° to +85° C (-40° to + 185° F)

Humidity

This rectifier is capable of operating in an ambient relative humidity range of 0-95% (non-condensing).

Ventilation

The unit should be placed so that the ventilating openings are not blocked and air entering the cabinet does not exceed 50° C (122° F).

INSTALLATION INFORMATION

Minimum Wire Sizes

Table 2 lists the a.c. input and the d.c. output minimum wire size requirements. At distances exceeding 10 ft., the d.c. wire size should be chosen to keep the voltage difference between the units d.c. output terminals and the battery at less than 1/2 volt when the unit is fully loaded.

FUSE SIZE	WIRE SIZE REQUIREMENT CUSTOMER CONNECTION	EQUIPMENT GROUNDING CONDUCTOR MINIMUM	FUSE SIZE	WIRE SIZE REQUIREMENT CUSTOMER CONNECTION	EQUIPMENT GROUNDING CONDUCTOR MINIMUM
1	#14	#14	150	#1	#6
3	#14	#14	175	#1/0	#6
4	#14	#14	200	#2/0	#6
5	#14	#14	225	#2/0	#4
6	#14	#14	250	#4/0	#4
10	#14	#14	300	250-MCM	#4
15	#12	#12	350	350-MCM	#2
20	#12	#12	400	400-MCM	#2
25	#10	#12	450	500-MCM	#2
30	#10	#10	500	600-MCM	#2
35	#8	#10	600	900-MCM	#1
40	#8	#10	700	1500-MCM	1/0
45	#8	#10	800	2/500-MCM	1/0
50	#8	#10	1000	2/800-MCM	4/0
60	#6	#10	1200	2/1000-MCM	4/0
70	#6	#8	1600	2/2000-MCM	4/0
80	#4	#8	2000		250-MCM
90	#4	#8	2500		350-MCM
100	#4	#8	3000		400-MCM
110	#2	#6	4000		500-MCM
125	#2	#6	5000		700-MCM
130	#2	#6	6000		800-MCM

TABLE 2

Electrical Connections & Field Wiring

Terminal blocks are provided for connecting the a.c. input and d.c. output. A ground wire must be connected to the unit's case ground.

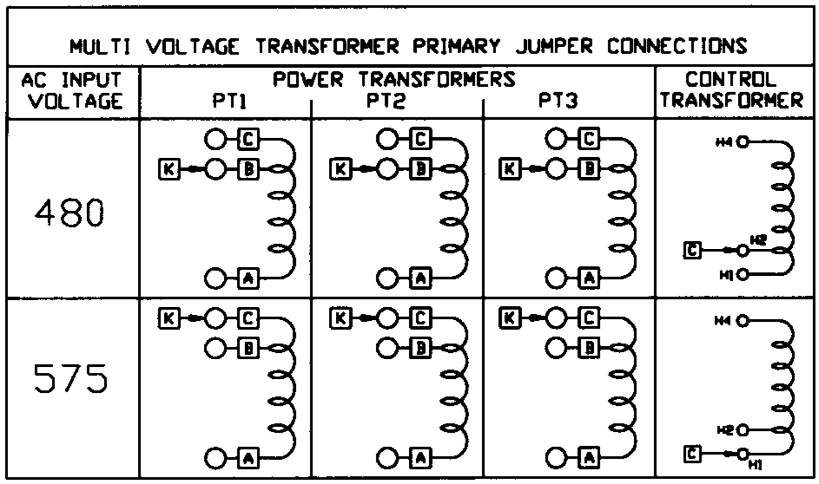
A.C. Input

Make sure that the input source is the same voltage and frequency as that which is marked on the nameplate of the rectifier.

The a.c. input current, specified on the nameplate, is for (nominal) output. A.C. line fuses or breakers must be sized for the overload or current limit point of the charger which is 130% of the nameplate value.

An adequate earth ground lead should be connected to the terminal marked "GROUND" or "GND" on the rectifier terminal board or case.
Be sure the transformer taps are set for the correct a.c. input.
(see Figure 1, page 20).

FIGURE 1 – TRANSFORMER TAP CONNECTIONS



D.C. Output

Make sure that the battery which is being connected to the rectifier matches the cell type and number of cells that is marked on the rectifier nameplate.
OBSERVE PROPER POLARITY!

The negative wire from the battery must be connected to the terminal marked "NEGATIVE" or "NEG" and the positive wire from the battery must be connected, to the terminal marked "POSITIVE" or "POS" on the rectifier.

OPERATION

Start Up (Electronic Timer)

After the installation has been completed, the unit is ready for operation. Be sure that the battery charger is of the correct type for the battery that is to be charged. CAREFULLY READ AND ADHERE TO ALL BATTERY AND BATTERY CHARGER INSTRUCTION AND SAFETY WARNINGS. (ALSO CHECK GROUND INTERGRETY, PAGE 16)

A. With the A.C. input connected to the charger, turn the ON/OFF switch to the "OFF" position.
B. Connect the battery connector to the charger.
C. After the battery is properly connected to charger, place the ON/OFF switch in the “ON” position. After a timed delay the input contactor should close. The battery charger should start to charge and the “ON CHARGE” light should be on. This completes the start sequence.
D. When the "80% CHARGE" point is reached in the charge cycle, the "80%" light will turn on. There will be approximately 3 hours of charging after this point is reached.
E. When the charge cycle is complete, the charge "CHARGE COMPLETE" light will turn on.
F. If the battery does not reach 80% charge, the charge cycle will terminate in 12 hours and 45 minutes. All lights will be off, which will be an indication of a time failure.
G. If for some reason the a.c. input voltage fails, the battery charger will turn off. During this interval the time registers in the auto timer are held at their present count. When the a.c. has returned to normal, the charge cycle resumes where it left off.

NOTICE

TURN THE ON/OFF SWITCH TO THE “OFF” POSITION BEFORE DISCONNECTING BATTERY FROM CHARGER.

FAILURE TO COMPLY WITH THE ABOVE WILL RESULT IN DAMAGE TO THE BATTERY AND CHARGER CONNECTORS.

Adjustments

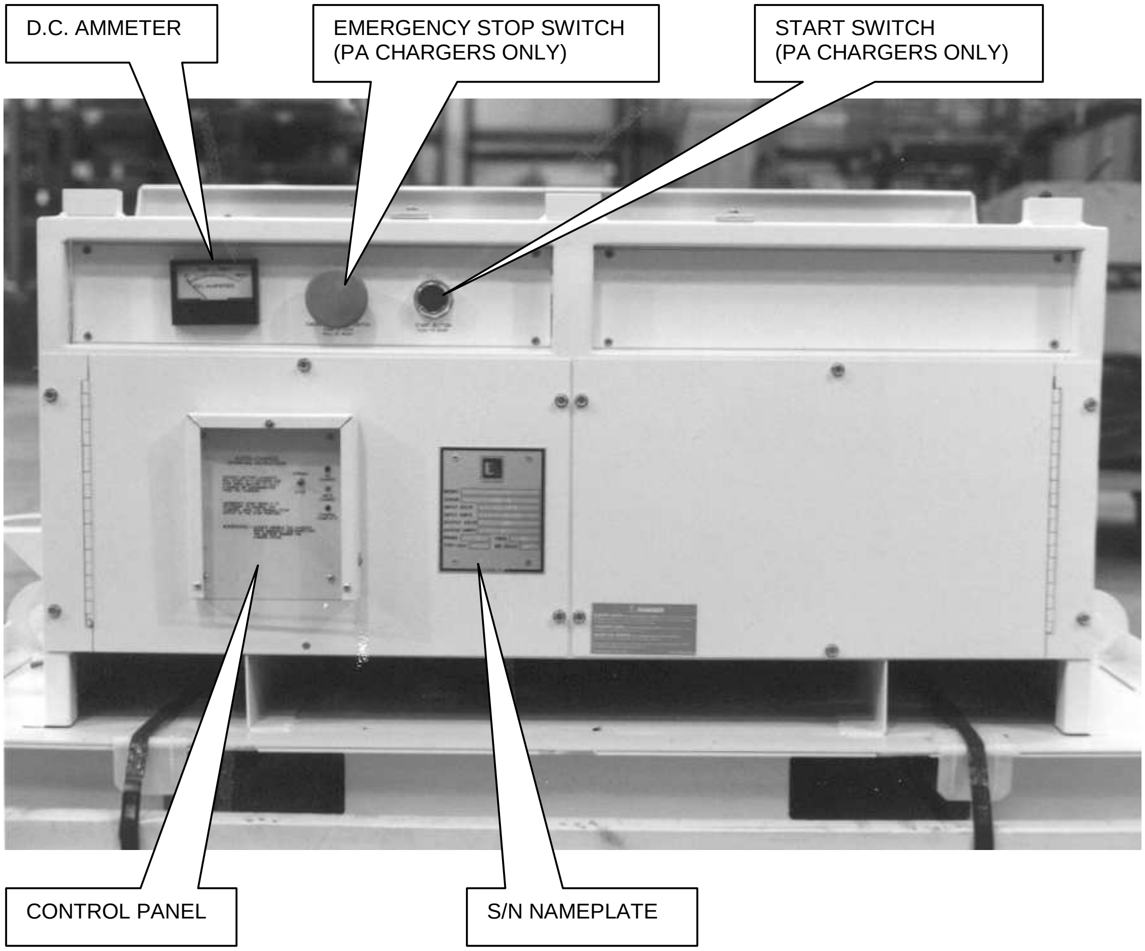
The Model LA Series is a completely automatic constant voltage charger. Each is designed to operate on a specific type of battery with a specified number of cells. THE UNIT IS FACTORY SET AT 2.5 VOLTS PER CELL (V.P.C.).

Circuit Operation

The Model LA Series Ferroresonant Mine battery charger has three basic components; a ferroresonant step down transformer, silicon rectifiers (diodes) and electronic timer. The regulating action of the unit is caused by the current developed in the resonant winding of the power transformer. The resonating capacitor along with the resonant winding of the transformer form a tuned circuit which establishes the correct core saturation point which in turn regulates the units output. The transformer also steps down the a.c. input voltage to the proper voltage to charge the battery. It also provides isolation from the input to the output. The silicon diodes convert the a.c. output from the secondary of the transformer to the d.c. voltage needed to charge the battery.

The automatic timer senses the connection of the battery and turns the unit on, the timer will allow the charger to charge the battery for a period of time (maximum 12 hours), then turns the charger off. It will also turn the charger off when the battery is disconnected.

FIGURE 2 – CHARGER CONTROLS



TROUBLESHOOTING

Troubleshooting should be performed only by trained service personnel or experienced electricians.

HAZARDOUS A.C. AND D.C. VOLTAGES ARE PRESENT WITHIN THE RECTIFIER CABINET.

Equipment: The only equipment required is a multimeter (volt-ohm meter).

General Inspection

On servicing new equipment, before setting up any complicated testing or jumping to any conclusions, give the unit a general inspection. Check the following:

1. Check d.c. output cables, connections, battery type, and number of battery cells with rectifier rating.
2. Check unit specifications with customer order.
3. Check input connections, input voltage and a.c. line breaker size.
4. Check for shipping damage, loose connections, broken wires, etc.
5. Certain failures can be caused by defective batteries and customer loads; make sure batteries and loads are free from defects.
6. Check all safety switches.

IF THE PROBLEM IS FOUND TO BE LOCATED IN THE PRINTED CIRCUIT BOARDS, THE BOARD SHOULD BE REPLACED. NO ATTEMPT SHOULD BE MADE TO REPAIR CIRCUIT BOARDS IN THE FIELD.

Service Information

Information you should have when calling in for troubleshooting assistance:

1. Equipment model number and serial number.
2. The actual a.c. input voltage.
3. The d.c. output voltage with and without the battery.
4. Result of the check of a.c. input fuse and d.c. output fuse.
5. The actual d.c. output current and voltage when measured with battery connected to rectifier.

Symptoms and Causes

SYMPTOM	POSSIBLE CAUSE	REMEDY
OPEN A.C. FUSE	1. Wrong a.c. input voltage. 2.The a.c. input taps on power transformer set incorrectly. (See schematic wiring diagram) 3. An a.c. to d.c. short or a.c. to d.c. short to ground. (See Ground Short Circuit Test, below). 4. Shorted power transformer. 5. Check for shorted power diodes (SD1). (See page 23) 6. Check for shorted coil on d.c. contactor or defective control transformer.	1. Correct input voltage. 2. Set input taps correctly. 3. Correct shorts. 4. Replace transformer. 5. Replace defective diodes. 6. Replace contactor or transformer.
OPEN D.C. FUSE	1. Shorted power diode. 2. Shorted battery cells. 3. Shorted output cables. 4. Shorted capacitors. (See page 23)	1. Replace as required. 2. Repair battery. 3. Repair or replace cables. 4. Replace capacitors.
OPEN SECONDARY FUSE	1. Shorted power diode. 2. Shorted capacitor.	1. Replace as required. 2. Replace capacitor.
CHARGER OPERATES BUT OUTPUT VOLTAGE IS LOW	1.Check a.c. input fuses. 2. Check power diodes. (See diode troubleshooting procedure, page 23)	1. Replace fuse(s). 2. Replace diode(s).

Ground and Short Circuit Test

A simple ohmmeter check can be performed to check the unit for a short to ground, primary to secondary breakdown, a.c.-d.c. short, or d.c. ground. Before installation of a new unit, the above checks should be made before installing. If a short of this type is suspected on a unit in service, check as follows:

1. Disconnect a.c. input power to the unit. Disconnect the d.c. battery and loads from the rectifier.
2. Set ohmmeter scale on ohms scale RX100.
3. Measure from one terminal of the input to one terminal of the output. Meter should not indicate. If the meter reads full scale deflection, this indicates an ac-dc short.

During shipping, an a.c. wire may rub against the d.c. lugs, terminals, etc. and cause a short. These problems may be eliminated by very carefully inspecting the wiring to make certain the a.c. wires are not touching the d.c. wiring. If no wires are touching, then it is possible that the primary and secondary of the transformer is shorted. Disconnect the secondary of the transformer from the diodes. Measure with ohmmeter from input terminal to one of the isolated secondary leads. If there is an ohmmeter indication, there is an insulation breakdown between primary and secondary windings. The transformer should be replaced.

4. Check the input terminals to ground and check the output terminals ground. If the meter indicates full scale deflection, a wire is touching a metal part of the unit. Look for wires that are near any metal part and inspect for possible breakdown caused by shipping. The heatsink of the diodes and the control unit are insulated from ground through the mounting legs.

Troubleshooting and Replacing Power Silicon Diodes

If a portable multimeter is used, set the switches on "ohms", "d.c.", and " Rx1 " scale.

1. Isolate one end of the diode by disconnecting the wires attached to the nipple (or pigtail) end of the diode (only one end of the diode must be disconnected).
2. Clip one lead of the ohmmeter to the anode lead of the diode. Clip the other ohmmeter lead to the cathode.
3. Note the ohmmeter reading. Then reverse the leads to the diode. Again, note the ohmmeter reading. If the diode is good, the meter will indicate a high resistance in one direction, and a low resistance with the leads reversed. If the diode is shorted, the meter will read full scale, or zero ("O") resistance with the leads in either direction. If the diode is "open", the ohmmeter needle will not indicate or it will show infinite resistance in either direction, indicating an open circuit.
4 All diodes must be checked in the event that more than one diode is defective.
5. If the diode is defective, remove it from the heatsink. Clean and smooth the heatsink surface, then using an electrically conductive grease, apply to the new diode and replace it in the heatsink.

Checking Capacitors

When checking capacitors, be sure all power is turned off and the battery is disconnected. Momentarily short circuit the capacitor leads to assure complete discharge. Connect the meter test leads to the capacitor leads or terminals and observe indicated resistance.

A good capacitor will indicate an initial low resistance and gradually increase as the capacitor charges. The final resistance of a good capacitor is usually several hundred thousand ohms approaching a megohm.

Initial high resistance approaching infinity indicates an open capacitor. Initial and continued low resistance readings indicate a shorted capacitor.

When ordering replacement parts, drawings, or schematics, always give model number, serial number and a.c. input voltage.

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Installation, Use Maintenance and Repair Manual

Mine Power Storage Batteries

This manual is intended to provide GENERAL product information for the Caterpillar mine power storage batteries. The illustrations, descriptions, and procedures contained in this publication apply only to Caterpillar mine power storage batteries. Caterpillar reserves the right to revise models and designs without prior notice.

This Caterpillar mine power storage battery was manufactured under the guidelines, procedures, and requirements of the U. S. Federal Coal Mine Health and Safety Act, Code of Federal Regulations, Title 30, Chapter 1, Subpart 0, Part 75 for underground coal mines, and other applicable non-U.S. regulatory agency standards.

At the completion of the manufacturing process, this battery was issued the appropriate approval numbers and nameplates indicating it met the technical requirements of these regulatory agencies. Any change to the design or structure of this battery without the consent of Caterpillar and these regulatory agencies, or any repair or replacement of parts contrary to the instructions, may invalidate these approvals and render this battery unsafe to operate.

Strict compliance with all Federal and State Mining laws, regulations, and practices regarding the safe operation and maintenance of underground mining equipment and strict adherence to the instructions in this manual is necessary for the personal safety of those working on or around this battery.

While this manual attempts to anticipate the most important operations and maintenance needs for this battery, unforeseen circumstances may arise that have not been addressed in this manual. If any concerns or questions arise, please contact your service representative immediately.

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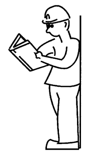

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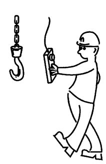

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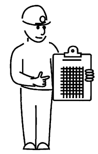

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1 About this manual

About this manual

This chapter provides important information making it easier for you to use this manual. You will also be given information on the structure of the manual and the symbols and characters used.

Before starting to work

applicable operating manual

Take care to ensure that the operating manual available to you is applicable for the type of battery used.

machine type

This operating manual is intended for:

Mine power lead acid storage batteries
Serial No. - N/A

and is only permitted to be used for these batteries.

new operation manual

The operating manual must be accessible at all times to all persons working on or with the batteries.

It should, if possible, always be available at the place of operation.

Send for a new operation manual immediately if the present manual is no longer complete or has become illegible.

Who is this operating manual intended for?

This operating manual is intended for those persons who work with or on the battery.
.
Every person working on the face or in the intersection between face and entry or in the entry must read this operating manual.

This includes persons who:

- are in charge of transport
- perform assembly / disassembly work
- operate the machine
- eliminate faults
- perform daily routine work on the face or in the entry
- perform maintenance work
- perform repair work

supervisory personnel who:

- initiate and/or
- supervise the activities just indicated.

What is the purpose of this operating manual?

cost-effectiveness

This operating manual is intended to help you work efficiently and safely with our product. It contains important information on all the activities related to the battery.

Read this operating manual completely and at ease. Pay special attention to the safety instructions. Try to memorize the appearance and the meaning of the safety and instruction symbols.

service

If any details are not clearly understood, please contact our service department. Our service address is given in the chapter titled “For your information”.

safety

Read the chapter “For your safety” with special attention. The chapter contains important information indicating possible hazards. Observe the information given and follow the procedural instructions.

Characters and symbols used

The following characters and symbols are used for safety instructions and important information in the operating manual.

Try to memorize the symbols and their meanings.

DANGER!
Points in the text marked with this symbol draw your attention to immediately impending danger. Possible consequences are: very serious injury or even death.

WARNING!
These points contain information on dangerous situations. Possible consequences are: very serious injury or even death.

CAUTION!
This symbol draws attention to dangerous situations. Possible consequences are: light to moderately serious injuries and machine damage.

NOTICE!
Points in the text marked with this symbol draw attention to harmful situations. Possible consequences are: damage to the battery or damage in the immediate vicinity.

IMPORTANT!
Points in the text marked with this symbol contain useful tips and information intended to facilitate work for you. They do not warn about harmful or dangerous situations.

- Items in lists are marked with bullets.
  - Points in sub-lists are marked with a long dash at the start of the line.

☞ Points in text marked in this way describe individual operations. Follow these instructions step by step. They will help you carry out your work faster and more importantly, safer.

2 Your safety

Your safety

This chapter provides vital information for your safety.
Pay special attention to this chapter. The safety instructions and rules of procedure will help you to avoid hazardous situations and to perform the necessary work as safely as possible.

state of the art

This battery has been manufactured in accordance with the state of the art and generally recognized safety standards and regulations.
You and others can nevertheless be exposed to dangerous situations e.g. as a result of environmental influences or battery damage.

Do not make any alterations or modifications which could impair the safety of the battery. All modifications and changes must be approved.

Use only original spare parts. Note that the use of parts from other manufacturers will void the guarantee.

In addition to this operating manual be sure to also observe the respective legal provisions and regulations in your country.

Observe the safety and accident prevention regulations:

- of the mine,
- of the Mine Inspector, and
- of the mining supervisory authorities.

Personnel

Operation

training Only trained, authorized personnel should operate or perform maintenance on the battery.

DANGER!
Only trained, authorized personnel should operate or perform maintenance on the battery.

Failure to adhere to dangers, warnings, and cautions noted in this manual could result in serious injury or death.

Failure to operate or maintain this battery in strict adherence to these instructions could void the warranty.

Installation and repair

As a fundamental rule, installation and repair work may only be carried out by personnel who have been adequately trained for these particular requirements.

Installation and repair work on batteries may only be carried out by service engineers or by specially qualified personnel of the mine.

Operating conditions

Intended use

The mine power storage battery has been designed and manufactured purely for providing power for battery powered mining equipment.

Intended uses include:

- providing power for battery powered mining equipment. The correct size battery must be used as specified in the parts manual supplied with your machine.

Unauthorized use

Applications not expressly listed as intended uses are unauthorized uses and are not allowed to be performed with the battery.

The manufacturer accepts no liability for any damage resulting from any such unauthorized use.

Safety instructions

General rules

general Always work with full concentration.

Familiarize yourself with your working environment.

noise emissions Always wear your personal protective equipment. This also includes ear protectors as the noise emitted by other equipment in the area may at times exceed 85 db(A).

Inform your colleagues of:

- your exact location,
- the work you are performing, and
- the time that you will probably require.

safety equipment Put the battery into service only when it is in a good and safe operating condition and all protective devices, e.g. cover plates, are correctly installed.

symbol plates Observe the symbol plates on the battery and the machine being used.

disconnect battery Disconnect the battery while performing:

- maintenance work
- inspection work
- repair work

welding Batteries should be well vented before servicing, particularly if welding or burning on the battery. High concentrations of hydrogen gas are produced by the battery and can potentially be explosive.

Disconnect the battery when working with the electrical system or when welding on the battery to prevent electrical shock.

While welding, the battery must be disconnected to ensure that the electrical system and/or electrical system components are not damaged.

Storage and transport

Maintain the prescribed storage periods and observe the instructions for storage outlined in Chapter 3 of this manual.

Do not store in the way of travel or in the work area.

Inform the persons involved about the intended transport route and the anticipated duration of transport.

transport safety device Ensure that the transport safety devices are correctly fitted.

Never stand under unsupported or suspended loads.

means of attachment Connect the lifting equipment only to the points of attachment provided for that purpose. Observe the different load limits of the attachment points. Also, observe the instructions on the transport sheet.

Only use means of attachment which are in good condition and have been designed for the loads to be handled.

mobile handling equipment When using mobile handling systems for transport, make sure that the center of gravity is as low as possible.

Pre-start inspection

operation Read this entire guide before attempting to operate this battery.

inspection Inspect the battery and have any malfunctioning, broken, or missing parts corrected or replaced before use.

maintenance Verify that all maintenance has been performed.

instruction and safety tags Verify that all instruction and safety tags are in place and readable.

Operation

training Use, maintain, or repair the battery only if you have a profound knowledge of the safe practices required when handling batteries.

protective devices Check that all protective devices are installed on the battery and function properly.

safety rules Always follow all safety rules of each particular mine when using, maintaining, or repairing a battery.

problems and malfunctions If problems or malfunctions are encountered while using, maintaining, or repairing the battery, contact your service representative.

Maintenance and repair

Be sure to observe the prescribed maintenance and inspection intervals.

Inform the supervisory personnel and the face crew of any maintenance and repair operations. Give them information on the intended operations and the anticipated duration.

securing

Secure your working area over a wide range, in order to avoid endangering other persons.

Disconnect the battery from the machine to prevent unauthorized and unintentional restarting.

Protect your work area against falling rocks.

replacing components

Disconnect the battery from machine to prevent from restarting before replacing any defective components.

Pass defective components removed on for servicing without delay in order to prevent these parts from being reinstalled elsewhere.

original parts

Use only spare parts which satisfy the specified technical requirements. This is only ensured with original spare parts.
Please refer to the spare parts lists for the order numbers.

lifting

For raising the battery use only:

- crib blocks with adequate load-holding capacity.
- hoists, jacks or cranes with adequate load-carrying capacity.

maintenance, repair

Only persons who have and can demonstrate a special knowledge of electrics are allowed to work on the electrical system.

Avoid, whenever possible, servicing, cleaning or examining the battery in congested areas.

Always replace damaged or lost decals and metal instruction plates.

Disconnect the battery when working with the electrical system, or when welding on the unit, to prevent electrical shock.

Be sure the battery charging area is well ventilated (clear of fumes). Hydrogen gas from the battery could ignite from a spark and explode.

Always follow all safety procedures of each particular mine when performing maintenance.

It is important that any procedure not specifically recommended in this guide be thoroughly evaluated from the standpoint of safety before it is implemented.

Some illustrations in this manual show guards or cover panels removed for purposes of clarity. Never operate battery without guards or cover panels in place.

Battery hazards

A lead-acid battery can be very useful, safe source of electrical power. However, while installing, using, maintaining, or repairing a motive power battery, opportunities exist for exposure to potentially dangerous situations. This section identifies some of those hazards which could result from improper handling or use.

sulfuric acid

A sulfuric acid solution is used as the electrolyte in lead-acid batteries and has a concentration of approximately 37% by weight of sulfuric acid in water. In this diluted state, it is not as hazardous as strong or concentrated sulfuric acid, but it acts as an oxidizing agent and can burn the skin or eyes and destroy clothing made of many common materials such as cotton or rayon.

explosion

An explosive mixture of hydrogen and oxygen is produced in a lead-acid battery while it is being charged. The gases can combine explosively if a spark or flame is present to ignite them. Because hydrogen is so light, it normally rises and diffuses into the air before it can concentrate into an explosive mixture. If it accumulates into gas pockets with a concentration of 4 - 70% hydrogen gas, as can occur within a cell, it might explode if ignited.

electricity

Lead acid batteries are a constant source of power without any means of shutting off. Electricity is produced by the batteries on discharge and, while most persons cannot "feel" voltages below 35 to 40 volts, all mine power batteries should be regarded as potentially dangerous. A lead-acid battery is capable of discharging at extremely high rates and, under conditions of direct shorting, can cause damage and serious injury.

weight

The weight of these heavy batteries can easily cause painful strains or crushed hands or feet if improperly lifted or handled. Batteries can be damaged if dropped. The average mine power battery weighs more than one ton, so proper equipment must be provided when changing or handling batteries.

The battery covers must be secured with the covers supported, when working or making repairs under the covers. Covers could fall, causing serious injury.

burns

Burns can result from contact with molten lead or hot compound while repairing a battery. Lead can splash when intercell connectors are being reburned and hot compound can be spilled when resealing covers to jars. The protective gear provided, if worn, will prevent such burns.

Safety procedures

federal standards

Congress passed the Occupational Safety and Health Act (OSHA) in 1970. This act established the minimal acceptable standards for safe and healthful working conditions. The safety procedures suggested in this manual have been compiled from standards developed over the years by professional and technical organizations and by battery manufacturers and users. Experience has shown them to be the most effective safety standards. In all cases, they exceed the minimum standards of OSHA for personal safety and include procedures for safeguarding equipment as well.

The safety procedures have been grouped by functional area of most logical application or need.

while handling batteries

- Lift batteries with mechanical equipment, such as an overhead hoist, crane or lift truck. A properly insulated lifting beam, of adequate capacity, should always be used with overhead lifting equipment. Do not use chains attached to a hoist at a single central point forming a triangle. This procedure is unsafe and could damage the steel tray.
- Always wear safety shoes and safety glasses.
- Tools, chains, and other metallic objects should be kept away from the top of uncovered batteries to prevent possible short circuits.
- Battery operated equipment should be properly positioned with switch off, brake set, and battery unplugged when changing batteries or charging them while in the equipment.
- Personnel who work around batteries should not wear jewelry made from a conductive material. Metal items can short circuit a battery and could cause severe burns.
- Only trained and authorized personnel should be permitted to change or charge batteries.
- Reinstalled batteries should be properly positioned and secured in the unit. Before installing a new or different battery, check both the unit nameplate and battery service weight to make sure that the proper weight battery is being used. A battery of the wrong weight could change the center of gravity and cause equipment to upset.

while charging batteries

- Specific areas should be designated for charging batteries.
- Charging areas should be adequately ventilated. The actual amount of ventilation will depend upon such factors as number and size of batteries being charged at the same time, room size, ceiling height and air-tightness of the building. **Hydrogen concentrations above 4% can be explosive.** The National Fire Protection Association (NFPA) only allows hydrogen gas concentrations less than 1%.
- Smoking, open flames, and sparks should all be prohibited in the charging area. Post placards "Hydrogen", "Flammable Gas", " No Smoking", and "No Open Flames".
- Facilities should be provided for flushing and neutralizing spilled electrolyte, for fire protection (including hand-operated fire extinguishers), and for protecting charging equipment from damage by units.
- Fresh water should always be available in case electrolyte is splashed on skin, clothing, or into eyes. The kinds of equipment available for eye-wash and acid neutralization vary widely. A squeeze bottle containing a buffering solution for relief of acid burns should be located in the immediate work area. These should be clearly identified and readily accessible.
- Before connecting a battery to, or disconnecting it from, a charger, the charger should be turned off. Live leads can cause arcing and pitting of battery connector contact surfaces.
- Make sure that all electrical connections are tight and mechanically sound to prevent any arcing or loss of power.
- Wear a face shield or goggles, rubber gloves, apron, and boots when checking, filling, charging, or repairing batteries during periods of possible exposure to acid or electrolyte.
- When charging an enclosed or covered battery, always keep the battery tray cover, or compartment cover, open during the charging period. This will help to keep the battery cool and disperse the gases.

CAUTION!
Be aware of pinch points and proper lifting techniques while raising and lowering battery covers.

- Keep vent caps in place at all times except while servicing or repairing cells. This minimizes the loss of electrolyte and prevents foreign matter from entering the cells.
- Shut off and disconnect both input and output connections to the charger before charging equipment.

while handling acids

- **The splashing of acid Into the eyes is the most dangerous condition encountered while handling sulfuric acid or electrolyte.** If this should happen, the eyes should immediately be gently flooded with clean, fresh, running water for at least 15 minutes, followed as quickly as possible with a physician's examination. If the person is wearing contact lenses, they should be removed before rinsing the eyes.

WARNING!
Do not use a buffering or neutralizing agent in the eyes without medical approval.

- Acid or electrolyte splashed onto the skin should be washed off under running water. Battery electrolyte will usually only cause irritation of the skin; if a burn develops, it should be treated medically.

- When electrolyte is splashed on clothing, use a weak solution of bicarbonate of soda, as soon as possible, to neutralize the acid.

- A carboy tilter or safety siphon should be provided for handling acid from a carboy container. Use the protective box when moving a carboy. Store acid in a cool place out of the direct rays of the sun. Use only glass, rubber, lead, or acid-resistant plastic containers when storing acid or electrolyte.

- When mixing acid to prepare electrolyte, always pour the acid slowly into the water and stir constantly to mix well. Never pour water Into acid. Never use sulfuric acid solutions which are over 1.400 specific gravity when adjusting battery acid.

- Apply a neutralizing solution, such as bicarbonate of soda and water, when acid is spilled on floor. Clean up affected area promptly. A mixture of one pound of soda to one gallon of water is recommended.

while servicing or repairing batteries

- Disconnect the battery from the unit when servicing or repairing either the battery or the equipment. Also, make certain the battery is disconnected from the charger before handling or repairing the battery.
- Before repairing a battery, remove all of the vent caps and blow out each cell with a low pressure air hose to remove any residual gas. Use only a gentle stream of air to avoid splashing electrolyte. **Do not blow breath into cells.**
- Open or "break" the circuit before repairing damaged or dirty terminal plugs or receptacles connected to a battery by removing and insulating one terminal lead at a time.
- When melting sealing compound in preparation for resealing cells, be careful not to puncture the top section of unmelted compound with a screw driver or other pointed object. A build-up of pressure from the melted compound in the bottom could cause liquid compound to squirt and inflict a severe burn. Do not allow compound to ignite by overheating. Compound becomes workable at 400° F to 425° F.
- Check batteries frequently for acid leakage or signs of corrosion.
- Use insulated tools whenever possible when working on batteries. If possible, also cover the terminals and connectors of a battery with a sheet of plywood or other insulating material to prevent short circuits.
- When taking specific gravity readings, use a face shield or goggles and read the hydrometer with your eye at about the same level as the electrolyte. Return all electrolyte to the cell.

Overview of the safety instructions

This is a summary of all the safety instructions which have to be observed in the following chapters. This summary is intended only to give you an overview of all the instructions. In some cases, there is no logical relationship between the individual instructions.

Chapter 3: Storage and transport

WARNING!
Use only load handling devices complying with the technical and legal regulations for the transport of loads.
You could be seriously injured or even killed by falling loads.
Use only suitable load handling devices.

NOTICE!
Whenever batteries are shipped by common carrier, ICC regulations apply.

WARNING!
Lifting devices used to move batteries must be capable of carrying the weight stamped on the battery case. Keep all persons and body parts from under the batteries when they are lifted.

Chapter 4: Installation

CAUTION!
Serious damage can be caused to the battery as a result of incorrect installation. The battery should therefore only be installed under the instruction of specialists.

NOTICE!
The battery was inspected prior to shipment from the factory to ensure proper functioning and installation of all components.

Chapter 5: Operation

CAUTION!
Make certain that the positive terminal of the battery is connected to the positive terminal of the charger and that the negative terminal of the battery is connected to the negative terminal of the charger. Permanent damage to the battery or charger may result if the battery is connected incorrectly.

WARNING!
Proper eye and body protection must be worn at all times when servicing batteries to prevent electrical shock and contact with battery acid. Clean and neutralize any acid spill immediately.

WARNING!
Batteries must be resting securely in a machine, on a battery table, or platform capable of supporting the weight of the battery while performing maintenance or service on the battery. Mine service batteries can weigh several thousand pounds and could cause severe injury or death should the battery fall on a person or on a body part.

WARNING!
The battery produces lethal amounts of current whether connected to the machine or not. Batteries should be maintained and serviced by qualified personnel. The battery should be disconnected before servicing. Electrical shock can cause death or serious injury.

WARNING!
Batteries produce explosive gases that could ignite, causing burns or explosions. Batteries should be well vented before servicing, particularly if welding or burning on the battery. Batteries should be maintained by qualified personnel.

WARNING!
Batteries contain strong acid that could cause severe burns if spilled or splashed on body parts or in the eyes. protective clothing, gloves, and eyewear must be worn when working on batteries. Batteries should be maintained by qualified personnel.

WARNING!
Battery covers must be secured with the cover supported when working under the covers. Battery covers could fall, crushing hands, arms, or fingers.

WARNING!
Batteries, chargers, and related electrical equipment should only be serviced by qualified, properly trained personnel.

NOTICE!
A minimum of one quart of water is required. Consult your sales representative if water analysis is required.

CAUTION!
Vent caps must be tightly in place when the battery top is being cleaned or rinsed. Loose or open vent caps will allow contamination into the battery cell.

IMPORTANT!
Never make a specific gravity adjustment on a cell which does not gas vigorously while on charge.

Overview of safety instructions

CAUTION!
Never add acid with a specific gravity higher than 1.400. Stronger acid may permanently damage the cell. When mixing or cutting acid, always add the acid to the water. Never pour water into the acid; a violent reaction may result which may result in injury to personnel. When working with acid, always use a face shield or goggles, rubber gloves, and an acid resistant apron.

CAUTION!
Do not blow breath into cells. Wear protective face shield or goggles, rubber gloves, and apron.

WARNING!
You could be seriously injured or even killed by falling loads. Observe the safe working load limits of lifting devices.

NOTICE!
When pulling an element from a cell which has been removed from a battery, use jar hold-down clamps.

NOTICE!
Cells from which the elements were pulled, or which had damaged jars replaced, should be given an equalizing charge and acid should be adjusted immediately following repair, before they are returned to service.

NOTICE!
Cells must be connected in series with the positive side of one cell connected to the negative side of the adjacent cell.

WARNING!
Always be sure the cells are purged of gas before using an open flame or burning arc on top of the battery.

3 Storage and transport

Storage and transport

This chapter contains important information on the correct storage and transport of the mine power storage battery.

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Observance of the instructions and tips will increase the service life and availability of the battery. You will also be able to carry out the transport work quicker and more safely. Careful attention to the points in this chapter will help you to simplify your day-to-day work.

Storage

Storage methods

charged and wet batteries

Lead acid batteries may be stored in a charged and wet (filled with electrolyte) condition when necessary for periods of up to several months. During such periods they should be stored in a clean, cool, dry, and well ventilated location away from radiators, hot air ducts, or other sources of heat, and protected from exposure to direct sunlight.

Before being stored, the battery should be fully charged and the electrolyte brought to the proper level. Any leads should be disconnected or insulated to prevent accidental discharge. The top of the battery should be protected from dust, foreign matter, and moisture. **Do not attempt to dismantle the battery.**

If the average storage temperature is 80° F or higher, the specific gravity of the electrolyte should be checked at least monthly. If the temperature is below 80° F, check the specific gravity at least every two months. Whenever the specific gravity, corrected to 80° F, falls to 1.240 or below, the battery should be given a freshening charge as described in Chapter 5 of this manual. A freshening charge is also recommended just before returning a battery to service.

charged and dry batteries

New batteries are often supplied charged and dry (without electrolyte). Batteries in this condition can remain in storage, unattended, for a period of at least two years. They should be stored in a cool, dry place with vent caps tightly closed. Average temperatures should not exceed 80° F.

Batteries should not be stored near radiators, hot air ducts, or other sources of heat, and should be protected from exposure to direct sunlight. The top of the battery should be protected from dust, foreign matter, and moisture.

When removed from storage, charged and dry batteries should be activated as described in Chapter 5 of this manual.

Transport

Load units: dimensions and weights

Observe the transport sheets for the batteries. They contain information on:

- dimensions,
- weight,
- lifting points, etc.

Additional information on the dimensions and weights can be found on the battery case.

WARNING!
Use only load handling devices complying with the technical and legal regulations for the transport of loads.
You could be seriously injured or even killed by falling loads.
Use only suitable load handling devices.

Shipment

charged and wet batteries

Depots or using organizations may make shipments of motive power batteries in a charged and wet condition if intended for use within a period of 90 days. The battery service weight is usually stamped into the steel tray near one of the lifting holes.

Before crating a wet battery for shipment, it should be given a freshening charge as described in Chapter 5 of this manual. A tag should be attached to both the battery and the crate showing the date of the last charge and the specific gravity of the electrolyte at the completion of the charge.

Make certain that the battery is properly protected when crated.

The receiving organization should be alerted to the need for a freshening charge before the battery is put into service.

charged and dry batteries

Depots will normally make domestic and export shipments of new batteries which usually will be in a charged and dry condition. Batteries, and the accompanying electrolyte in separate carboys, which are intended for export shipment must be packaged in accordance with approved methods.

NOTICE!
Whenever batteries are shipped by common carrier, ICC regulations apply.

Unpacking upon receipt

Upon receipt of a mine power storage battery, perform the following:

- It is important first to examine the exterior of the packing for wet spots on bottom or sides which may indicate leaking jars. Inspect also for physical damage to battery package because the battery could be affected as well. Report any damage to your supervisor.
- Make certain that the package is right side up, with skid mounts resting firmly on floor.
- Use a forklift truck or crane of sufficient capacity to remove the packaged battery from the truck or freight car. If a crane is employed, be sure the sling is secured against the bottom of the skid and not around the skid mounts.

WARNING!
Lifting devices used to move batteries must be capable of carrying the weight stamped on the battery case. Keep all persons and body parts from under the batteries when they are lifted.

- Move the crated battery to the uncrating area and remove packaging, including any wrapping or other protection provided to the battery terminal cable connectors.
- Inspect battery and report any damage to your supervisor.
- Use a properly insulated lifting beam of adequate capacity to lift the battery, by means of an overhead hoist, from the battery skid.

When lifting batteries, always use a device which exerts a vertical pull on the lifting eye or tab. If a chain must be used, it should be in combination with a lifting beam with provision for adjusting lifting hook centers to the exact length of the tray. Any method of lifting which tends to squeeze or stretch the battery tray may distort it and could damage jars or disturb cell seals.

A piece of rubber sheet or other insulating material, temporarily laid on the battery while lifting, will prevent any possible short circuits from chains or hooks. As an additional precaution against accidental shorting, the lifting beam hooks should be electrically insulated from each other.

4 Installation

Installation

Points to observe prior to installation

Who is allowed to carry out installation?

Installation is only allowed to be carried out by personnel having received adequate training to perform this task.

Work on the battery should only be carried out by service engineers or by specially trained personnel.

Which tools are required for installation?

No special tools are required to put the battery into service.

tool box

Various items of auxiliary equipment and machines may be required at the point of installation.

These include:

- hoists with adequate lifting capacity
- means of attachment with adequate lifting capacity
- unloading dock
- jacks with adequate lifting capacity
- battery plug and receptacle wrench

Notes on installation

CAUTION!
Serious damage can be caused to the battery as a result of incorrect installation. The battery should therefore only be installed under the instruction of specialists.

Pre-installation check list

NOTICE!
The battery was inspected prior to shipment from the factory to ensure proper functioning and installation of all components.

To ensure that no transit damage has occurred, the following pre-startup checks should be performed:

- perform daily maintenance
- check that all covers and guards are in place and secure
- check that all tags and instruction labels are in place and secure

5 Operation

Operation

This chapter contains important information on the operation and maintenance of the battery. Read this chapter carefully and thoroughly. In particular, observe the safety instructions in chapter 2, “Your safety”.

Definitions

The definitions referenced throughout this manual generally agree with accepted industry standards. For a more complete listing of "Definitions for Lead-Acid Industrial Storage Batteries", see NEMA Standards publication No. 1B 1-1971.

Copies of NEMA standards may be obtained at nominal cost by writing to: National Electrical Manufacturers Association, Department of Engineering and Safety Regulations, 2101 L Street, N.W. Washington, D.C. 20037.

Description and construction

Battery

Mine power lead-acid batteries for electric vehicles typically consist of a steel tray into which the cells are assembled, a battery terminal connector, and various other components necessary to secure and protect the cells and provide the necessary electrical interconnections.

battery identification and data

The essential information necessary for proper care of an industrial motive power battery appears on the battery, either stamped into one of the intercell connectors or on a name plate affixed to the tray. This information usually includes the manufacturer's name and model, number of plates per cell, battery capacity, battery voltage, serial number, suggested charging rate, and fully charged specific gravity of electrolyte.

If vital information is missing or is no longer legible, the information can be obtained by contacting your nearest representative.

Some manufacturers list, as a part of the model or type designation, the rated ampere-hour capacity of a single positive plate, such as "SS75". As an alternate means of determining rated battery capacity, this number should be multiplied by the total number of positive plates in one cell. To find the number of positive plates in a cell, subtract one from the total number of plates and divide by two. To find the capacity of a battery designated "SS75-19," therefore: 19 - 1 = 18; 18 divided by 2 = 9; 9 x 75 = 675 Ah battery capacity.

cell arrangement

The individual cells, which contain the energy generating components of the battery, may be arranged slightly differently for various types of equipment. The cells of all motive power batteries are, however, always connected in series to produce the required voltage. Cell and battery capacity, which is the available ampere-hours or watt-hours, is a function of the total number and size of plates within each cell. Voltage, though, is the same for all cells regardless of size. Each lead-acid cell yields a nominal 2 volts.

connector arrangement

Connections between cells are made by intercell connectors which may be lead-coated copper straps, cable, or may be cast of solid lead. These connections are always welded, in proper sequence, by the application of heat to the terminals of the cells. Energy from the battery is drawn off by terminal cables which extend beyond the steel tray wall and are in turn permanently joined to the battery terminal connector.

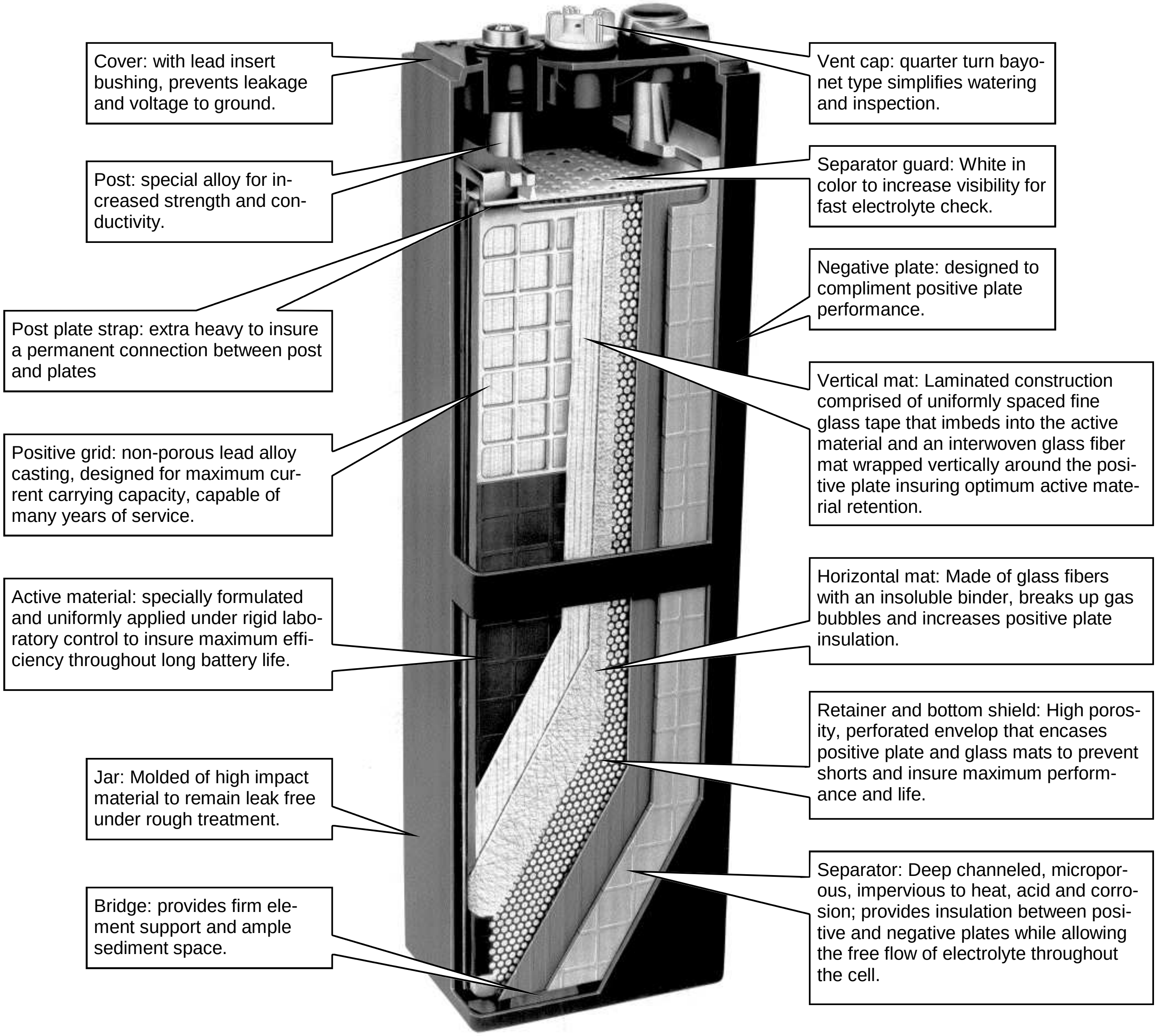
Cell

The cell (Fig. 1) is the basic unit of any battery. It is a galvanic cell which produces electrical energy when connected to an electrical load and, after being discharged, may be restored to its original fully charged condition. It has a nominal voltage of 2 volts and consists of an element from which the energy is derived and an electrolyte. Both the element and the electrolyte are contained by an impact resistant, molded plastic jar.

The element is prevented from contacting the bottom of the jar by means of a high impact bridge, which consists of a series of support ribs. These ribs provide sediment space below the bottom of the element to accommodate particles of active material shed by the positive plates during normal operation of the battery.

The top of each cell is fitted with a molded rubber plastic cover sealed to the jar at the edges. A vent or filler cap is located in the center of the cover. This vent permits the escape of hydrogen and oxygen while the cells are gassing and, when removed, provides an opening through which water may be added to the cell. The positive and negative terminal posts, which are part of the element, fit through openings in the cover. Prior to being connected together, cells are placed so that the positive terminal of one cell is adjacent to the negative terminal of the next. This arrangement permits a conveniently made series connection.

Fig. 1: Cell



Mine batteries incorporate every feature required by today's mines. They are designed by engineering technology and built by master battery craftsmen according to strict quality control guidelines.
These batteries are the finest available to meet today's mining requirements, and our precision construction provides new equipment performance throughout a long life.

element The element of the cell consists of one group each of positive and negative plates meshed together. The plates are insulated from each other by separators which are inserted between all plates. A plastic element protector is positioned on top of the separators. This prevents mechanical damage to the element and aids in preventing electrical shorts which occur when particles of active material bridge the space between plates. Terminal posts are welded to each group and are used to electrically connect one cell to another.

group This is an assembly of plates of like polarity connected in parallel by welding to a common strap or busbar. A cell must contain one positive and one negative group. The negative group always has one more plate than the positive group. One or more terminal posts are welded to each.

plates The plates (also called "electrodes") are either positive or negative and consist of a cast lead alloy grid and active material. The grid provides support to the active material and becomes the primary electrical conductor. The active materials result from the addition of chemicals to lead oxides which are converted, by electrochemical processing, to lead dioxide in the positive and to sponge lead in the negative.

The grid of the pasted plate consists of horizontal and vertical or diagonal cast lead conducting members within a rectangular cast frame. A slurry of active material is pasted or squeezed into the voids, and the surfaces are then covered by porous glass and plastic retainers to prevent the loss of active material.

electrolyte The element within the jar is immersed in an electrolyte, which is a solution of sulfuric acid and "pure" water. This permits the necessary chemical reaction to occur and provides a conducting medium in which the flow of electric current takes place. The electrolyte in a fully charged cell at 77° F normally has a specific gravity of between 1.280 and 1.295 for a standard gravity battery and between 1.320 and 1.330 for a high gravity battery. As a cell discharges, the specific gravity decreases. Measurement of this specific gravity, by means of a hydrometer, indicates the state of charge of a cell. To save time in determining-this state of charge for the battery, a pilot cell or cells may be chosen;. A pilot cell is a selected cell(s) whose condition is assumed to be representative of the condition of the entire battery.

separators Separators are made from microporous plastic, which is resistant to heat and acid. Separators provide mechanical and electrical insulation between positive and negative plates, but are porous enough to permit passage of electrolyte. The grooved or ribbed side of the separator is placed toward the positive plate to allow a free flow of electrolyte to the active material. The flat side faces the negative plate to contain the sponge lead.

positive plate retainers Pasted type plate retainers are added, after pasting, typically by wrapping the plate first with fibrous-type glass tape or mats and then by a perforated plastic envelope complete with bottom boot or by other suitable filtering systems. All types of retainers act to prevent the escape of positive active material during normal use. Retainers are not needed on negative plates.

Charging

When charging a battery, observe the following precautions:

- When connecting the battery to the charger, always connect positive (+) to positive (+) and negative (-) to negative (-).
- Always recharge the battery as soon as possible after discharge.
- Keep vent caps tightly in place while the battery is being charged, except when servicing the cell or when measuring specific gravity or temperature.
- Make sure that the battery and charger voltages and ampere-hour ratings match when preparing to charge a battery.
- Prohibit smoking and open flames in charging area.
- Make certain that charging area is adequately ventilated.
- Do not allow tools or other metal objects to contact intercell connectors.
- Wear proper personal protective equipment.
- Know the location of fresh water for emergency purposes.
- Use proper equipment to lift and move batteries.
- Provide acceptable fire extinguishing equipment.
- Follow all safety guidelines and health practices listed in this manual.

General

Economical and dependable performance from a storage battery depends, to a great extent, upon proper charging. Faulty charging causes a decrease in battery service life and dissatisfaction with its performance. The selection of suitable charging equipment and methods is as important as the application of the correct battery. A mine battery installation is completely satisfactory only when the unit, battery, and charger operate as a smoothly functioning team. **This text on chargers is for general information and guidance only.** If specific data is required on a particular type of charger, contact the nearest sales representative.

When preparing a battery to be charged, make certain that all points of contact between the charger and the battery are clean to assure good conductivity. Also make certain that the positive terminal of the battery is connected to the positive terminal of the charger and that the negative terminal of the battery is connected to the negative terminal of the charger.

CAUTION!
Make certain that the positive terminal of the battery is connected to the positive terminal of the charger and that the negative terminal of the battery is connected to the negative terminal of the charger. Permanent damage to the battery or charger may result if the battery is connected incorrectly.

Charging Principles

Charging, as applied to a storage battery, is the conversion of electrical energy into chemical energy within the cell or battery. This restores the active materials and is accomplished by maintaining a unidirectional current to the battery in the opposite direction to that during discharge. When a cell or battery is said to be charged, it is understood to mean fully charged. The type of battery, service condition, time available for charging, and the variation in battery voltages will strongly influence which charging method is best for a particular situation. Normally lead-acid batteries are recharged in 8 hours following a full discharge. However, they can be recharged within other time periods when desirable. A deeply discharged battery will absorb high current rates when the voltage is low. As the charge progresses, the voltage steadily increases until it reaches gassing voltage, approximately 2.37 volts per cell at 77° F. At this point, battery chargers normally reduce charging rates automatically and taper to finishing rates, which are used to complete the charge. The battery is fully charged when nearly all of the active material has been converted and when the specific gravity of the electrolyte and cell voltage have reached their maximum or constant values (corrected for temperature), as indicated by similar readings over a two or three hour period.

Batteries used in mine power applications are cycled: they are either being charged or discharged. In most circumstances, batteries are charged after each shift of use, so they are cycled many times during their lifetime. Incorrect charging for only a few cycles will do little harm, but if repeated day after day, the battery's service life will be seriously shortened.

Charging rates

Proper charging means charging the battery sufficiently without overcharging, overheating, or excessive gassing. The charge is usually started at high amperage, which is known as the starting rate. Later during the charge, the rate of current flow is reduced to what is called the finishing rate. It is suggested that the finishing rate should not exceed 5 amperes per 100 ampere-hours of rated battery capacity. The starting rate may be as much as four to five times higher than the finishing rate.

Lead-acid batteries should be charged for a sufficient length of time and at a rate which will put back into the battery the same number of ampere-hours removed on discharge, plus approximately 10% additional which is an acceptable, and in fact desirable, overcharge. The specific amount of overcharge depends upon the temperature, age, and history of the battery. In general, it is more harmful to excessively overcharge an older battery, or one which is operating at high temperature, than a new battery or one operating consistently at room temperature. Any charge rate is permissible which does not produce excessive gassing or cell temperatures greater than 110° F.

Control of gassing

Gassing is the evolution of gases from one or more of the electrodes during electrolysis. It is a natural phenomenon which takes place when a battery on charge can no longer accept all of the current being applied to it. Gassing is evidenced by bubbling of the electrolyte. The gases liberated are oxygen (evolved at the positive plates) and hydrogen (evolved at the negative plates).

The point at which significant gassing begins is determined by voltage, but the amount of gas depends upon the portion of the charging current that is not being absorbed by the battery. Normally, noticeable gassing will begin when the voltage exceeds 2.30 volts per cell. At 2.40 volts per cell, gassing will be normal; at 2.50, it will be rapid. The amperage at which gassing becomes excessive depends primarily upon the state of charge and electrolyte temperatures. As the battery approaches full charge, it is necessary to reduce the charging rate to a point at which excessive gassing is prevented. This safe rate is the finishing rate or below. When proper charging equipment is used, the tapering of the charging current to the finishing rate is achieved automatically.

Methods and equipment

The modern storage battery, used with a properly designed, modern, automatic charger, needs only normal water additions, occasional cleaning, and regular checking of both charger adjustment and battery condition to provide long, dependable service.

There are two recommended methods for the normal charging of motive power batteries:

modified constant voltage (potential) method

The modified constant voltage method, in which the tapering of the charging rate is accomplished gradually, requires a source of direct current with a constant bus voltage of approximately 2.63 volts for each cell. This is for an 8-hour charge. Proper series resistance in the output circuit inherently provides the correct starting rate and assures that the rate will automatically be reduced, as the charge progresses, to the recommended finish rate. The constant voltage source may be either a motor-driven generator or rectifier. This method is not recommended for repeated daily charging and should only be used occasionally. Battery service life may be seriously shortened, especially on high specific gravity batteries, if this method is used as the primary means of charging.

taper method

The taper method can be used with either generator or rectifier type equipment. The charger is designed to provide the correct charge rate during a constantly tapering charge. This is accomplished by coordinating the rising battery voltage with the design characteristics of the charger. The shape of the current-taper curve will vary with different types of equipment, but the result is essentially the same. Solid state chargers are available which deliver as much current as the battery can accept, up to maximum charger output, and then taper the input sharply, when cells begin to gas, to keep finish rates low. These chargers do not require adjustment. This method is recommended for conventional lead acid batteries with specific gravity ranges of 1.280 - 1.295. If used on high gravity battery designs, service life will be seriously shortened.

The I-E-I method uses SCR technology and allows for total control of the charging profile. The charger is designed to provide the correct charge rate, ignoring outside influences such as AC line voltage, battery age, and battery temperature. This method provides a constant current starting rate, then switches to a constant voltage stage as the battery approaches 80% of charge. Finally, this method allows for a constant current finishing rate during the last stage of the charging cycle. Although this method can be used to charge any lead acid battery, it is essential for the proper charging of high gravity batteries, sealed, or gel lead acid batteries.

Type of charge

normal charge

The two generally recommended types of normal or routine charges, following a deep discharge, are modified constant voltage charge and taper charge.

boost charge (quick charge)

A boost charge of a storage battery is a partial charge, usually at a high rate for a short period. Such a charge is given in an emergency when it is believed that the amperehour capacity of the battery may be less than normal and insufficient to complete a planned period of work. A boost charge may also be used when it is not possible to give a battery one of the recommended types of normal charge.

equalizing charge

An equalizing charge of a storage battery is a prolonged charge, usually at the finishing rate or less, to correct any inequalities of voltage or specific gravity which may have developed between cells during service. It consists of following a normal charge with an extended charge of 4 hours at a rate no higher than the finishing rate. **In mine power applications, a battery should receive an equalizing charge weekly.**

freshening charge

A freshening charge of a storage battery is a charge given to batteries in storage or during inactive periods to replace losses due to self-discharge and to assure that every cell is periodically brought to a fully charged state.

Principles of operation

Fundamentals of cycling

A cycle is a discharge followed by a charge followed by an eight hour cooling, or rest, period. During the charge, the electrical energy supplied by the charger causes an electromechanical reaction within the battery. This restores the active materials to a fully charged condition.

fully charged cell or battery

The positive and negative plates (electrodes) are separated from each other and immersed in electrolyte. In the fully charged condition, the active material of the positive plate is lead dioxide and that of the negative plate is sponge lead. The electrolyte is a solution of sulfuric acid and water that normally varies in a specific gravity from 1.280 to 1.295 for a conventional lead acid battery and 1.320 - 1.330 for high gravity lead acid battery products.. The combination produces a voltage of approximately 2 volts on open circuit. This voltage potential results from the fundamental characteristic of a storage battery which dictates that when two electrodes of dissimilar metals are immersed in suitable electrolyte, and a circuit is closed between the two, electrons begin to flow. A fully charged cell should normally have an on-charge voltage of from 2.45 to 2.70 volts when charging at the finish rate.

discharging cell or battery

While a battery is being discharged or used, lead dioxide and sponge lead combine with sulfuric acid to form lead sulfate within both plates. This action causes the specific gravity of the electrolyte to decrease. As the discharge progresses, individual cell and battery voltages decline, generally in direct proportion to the rate of discharge.

discharged cell or battery

As the depth of discharge increases, more sulfuric acid is removed from the electrolyte, causing the specific gravity to decrease, possibly below 1.100 as it approaches the specific gravity of water. Almost all of the active material of both positive and negative plates is converted to lead sulfate, and an effective electromechanical reaction is no longer possible. At this point, the battery has reached its discharge limit.

charging cell or battery

The charging action begins when the terminals of the battery are connected to an external source of direct current. The electromechanical reaction is reversed and the positive plates, negative plates, and electrolyte start returning to their original charged condition. Charging causes the battery voltage to rise as active materials are restored. A cell being charged may have a voltage of from 2.12 to 2.70 volts depending upon charging rate and time.

general

Storage batteries do not actually store electrical energy; instead, they accept the electrical energy delivered to them during charging and convert it into chemical energy. During discharging, this chemical energy is reconverted into electrical energy to be used as needed. To obtain the best performance and life from a mine power storage battery, the battery should immediately be charged after each shift of use or whenever the specific gravity of the electrolyte falls below 1.240. It is very important that proper ventilation be provided during charging to make certain that the hydrogen gas, given off toward the end of the charging process, is dissipated and that individual cell electrolyte temperatures, during normal operations, do not exceed 110° F.

Ampere-hour capacity

The electrical capability of a storage battery is usually expressed in ampere-hours. The ampere-hour capacity is the number of ampere-hours which can be delivered under specified conditions of temperature, rate of discharge, and final voltage. Basically, ampere-hours are determined by multiplying the number of amperes which the battery will deliver by the number of hours during which the current is flowing. Total cell or battery capacity then is determined by the size and number of plates which make up the element. Due to the variety of job requirements, batteries are produced with many different sizes of cells. Capacity may also be referred to in kwh ratings. Ohms law (Volts X Amps = Watts) may be used to convert the AH rating to kwh rating.

Voltage

With reference specifically to storage batteries, many "voltage" conditions have been recognized. The most important of these are:

open circuit voltage This is the voltage of a cell or battery at the terminals, when no current is flowing. The nominal open circuit voltage of an individual cell is 2 volts. This is true regardless of cell size. The voltage of a 64 cell lead-acid battery is stated, therefore, as 128 volts.

initial voltage The initial voltage of a cell or battery is the closed circuit voltage at the beginning of a discharge. It is usually taken after current has been flowing for a sufficient period of time for the rate of change of the voltage to become practically constant, usually a matter of minutes.

average voltage The average voltage of the cell or battery is the average value of the voltage during the period of charge or discharge.

final voltage The final or cut-off voltage of a cell or battery is the prescribed voltage at which the discharge is considered complete. It is usually chosen so that the useful capacity of the battery is realized without subjecting it to harmful over discharging. Final voltage will vary with the rate of discharge, cell temperature, and the type of service, but for mine power applications it is considered to be 1.70 volts per cell.

Initial voltage, average voltage, and final voltage are monitored when conducting test discharges.

Rated capacity

The rated capacity of a storage battery is the number of ampere-hours or watt-hours which the battery is capable of delivering when fully charged and under specified conditions of temperature, rate of discharge, final voltage, and specific gravity. United States industry standards for mine power batteries always specify this to be at the 6 hour rate of discharge. The total capacity available from a battery is greatest at low rates of discharge over a long period of time. Discharging at high current rates reduces the total ampere-hours available.

Sulfation

Sulfation occurs when conditions within the cell cause sufficient accumulation of abnormal lead sulfate at both the positive and negative plates, permanently affecting the normal chemical reactions. Habitual over discharging below final voltage, prolonged operation in an undercharged condition, and extended stand periods while in a discharged state are major causes of sulfation. A servicing schedule should be followed to provide frequent monitoring and adequate charging. See the maintenance section in this chapter for methods of restoring a sulfated battery.

Operating cycle

An operating cycle of a storage battery consists of the discharge, subsequent charge cycle to restore its initial condition, and an eight hour cooling, or rest, period following the charge.

Service life

The service life of a storage battery is the period during which it provides useful power while being discharged. It is usually expressed as the time period, or number of cycles, which elapses before the ampere-hour capacity falls below 80% of its rated value. To obtain maximum service life, it is recommended that a battery be restricted to one full cycle per 24 hour day or fewer than 300 cycles per year. Other factors which most often adversely influence service life are:

- Abnormally high or low electrolyte temperatures.
- Frequent over discharging.
- Failure to add water regularly.
- Frequent overcharging.
- Poor, or high, resistance, connections or contacts.
- Overfilling with water, which causes electrolyte loss.

Temperature

The normal operating characteristics of a storage battery are effectedby unusually low or high cell temperatures.

low temperature

Available battery power is reduced by low temperature because electrolyte viscosity and resistance is increased and diffusion throughout the pores of the active material is retarded. For example, a fully charged battery (1.280 to 1.295 specific gravity at 77° F.), when its electrolyte temperature is about 32° F, will deliver only 75% of the capacity which would be available at normal room temperature (see Table 1). This drops to 40% at 0° F. The electrolyte could freeze if a discharged battery were exposed to very cold temperatures for several hours. (See Table 2 for freezing points of various electrolyte concentrations.)

Table 1: Capacity at low temperatures

Internal temperature of cell (° F)	% Capacity
77	100
60	95
40	87
20	73
32	75
0	40

high temperatures

In addition to the discharge-related problems, the charge acceptance of a lead-acid battery is impaired when electrolyte temperatures drop below 60° F. As a result, batteries should always be kept fully charged, especially in cold weather. They should be heated, even during operation or storage, if exposure is severe enough to cause the temperature of the electrolyte to approach 32° F.

Although high temperatures (up to 110° F) do not cause a reduction in available capacity, battery operation is adversely affected. Because most chemical reactions are accelerated at high temperatures, the rate of corrosion of the positive grid is increased and the active material is shed more rapidly. Even electrolyte temperatures above 90° F will cause some reduction in service life and should be avoided whenever possible. Cell temperatures should never be allowed to exceed 110° F.

Table 2: Freezing points of various electrolyte concentrations

Standard Gravity Battery

State of Charge approximate (percent)	Specific Gravity	Freezing Point (° F)
100	1.280	-95
75	1.250	-62
50	1.220	-31
25	1.160	+1
10	1.130	+10

High Gravity Battery

State of Charge approximate (percent)	Specific Gravity	Freezing Point (° F)
100	1.320	-67
75	1.270	-82
50	1.210	-24
25	1.160	+3
10	1.130	+10

Preparation for Use

Establishing battery requirements

The number of batteries required for service depends primarily upon the number of 8-hour shifts in effect. Normally, for operation on a single-shift basis, the minimum number of batteries required will be the same as the number of operating machines and the batteries need not be removed from the unit for charging. For operation on a 2- or 3-shift basis, the minimum number of batteries required will be twice the number of operating machines and it will, therefore, be necessary to exchange discharged batteries for charged batteries at the end of each work shift. Whenever possible, it is recommended that more than the minimum number of batteries be available for multiple-shift operation, providing at least an 8-hour cooling period after charging. In an emergency, any one battery can be used for two 8-hour shifts during a 24-hour period, but this procedure, repeated regularly, will cause high electrolyte temperatures and could seriously affect service life. Therefore, where 3-shift operation is normal, 3 batteries will be required per machine.

Acid to water proportions

Sulfuric acid to water proportions required to make electrolyte are given in Table 3.

Charged and wet batteries

Charged and wet batteries are shipped with cells filled and fully charged. Prepare these batteries for use as follows:

WARNING!
Proper eye and body protection must be worn at all times when servicing batteries to prevent electrical shock and contact with battery acid. Clean and neutralize any acid spill immediately.

☞ Examine battery to see if electrolyte has been accidentally spilled. If so, clean and neutralize any spillage with a cloth that has been dipped in a bicarbonate of soda solution. Rinse area with clear water.

☞ Remove vent caps and check the electrolyte level in each cell. Measure and record the specific gravity, electrolyte temperature, and individual open circuit voltage of each cell. Note any irregularities.

☞ Check to make sure that all cells are properly connected and that terminal connections are tight. If there are irregularities in the electrolyte levels or specific gravity readings, or if the battery has been in storage for more than 30 days, it should be given a freshening charge to assure that every cell is at a fully charged state.

☞ Recheck electrolyte levels after charging and after gassing has stopped. Again, measure and record specific gravity and electrolyte temperatures. If irregularities in electrolyte specific gravity readings still exist, call your service representative.

Table 3: Sulfuric acid to water proportions

Specific Gravity Required	Parts Water Required	Parts Acid Required (spec. grav. = 1.400)
1.375	0.075	1
1.365	0.11	1
1.355	0.14	1
1.350	0.16	1
1.340	0.20	1
1.330	0.24	1
1.325	0.27	1
1.315	0.31	1
1.310	0.33	1
1.300	0.38	1
1.290	0.43	1
1.285	0.46	1
1.280	0.49	1
1.275	0.53	1
1.270	0.56	1
1.260	0.63	1
1.255	0.67	1
1.250	0.70	1
1.245	0.74	1
1.240	0.78	1
1.230	0.85	1
1.225	0.905	1
1.220	0.96	1
1.215	1.00	1
1.210	1.05	1
1.205	1.11	1
1.200	1.16	1

Instructions on maintenance

Maintenance at regular intervals increases the operational safety of and prolongs the service life of the battery.

In particular, observe the safety instructions in chapter 2 “Your safety”.

Important notes

WARNING!
Batteries must be resting securely in a machine, on a battery table, or platform capable of supporting the weight of the battery while performing maintenance or service on the battery. Mine service batteries can weigh several thousand pounds and could cause severe injury or death should the battery fall on a person or on a body part.

WARNING!
The battery produces lethal amounts of current whether connected to the machine or not. Batteries should be maintained and serviced by qualified personnel. The battery should be disconnected before servicing. Electrical shock can cause death or serious injury.

WARNING!
Batteries produce explosive gases that could ignite, causing burns or explosions. Batteries should be well vented before servicing, particularly if welding or burning on the battery. Batteries should be maintained by qualified personnel.

WARNING!
Batteries contain strong acid that could cause severe burns if spilled or splashed on body parts or in the eyes. protective clothing, gloves, and eyewear must be worn when working on batteries. Batteries should be maintained by qualified personnel.

WARNING!
Battery covers must be secured with the cover supported when working under the covers. Battery covers could fall, crushing hands, arms, or fingers.

General

The modern industrial lead acid battery is designed and built to give an average of 1500 cycles of charge and discharge during its life, depending upon the application and the operating environment. The exact length of the service life will depend, to a great extent, upon the care the battery receives. The following maintenance procedures, carried out at the proper time, will do much to prolong the life of the battery and provide efficient, satisfactory service.

WARNING!
Batteries, chargers, and related electrical equipment should only be serviced by qualified, properly trained personnel.

Table 4: Maintenance schedule

Item	Description	Places
	Every shift	
1	Hydrometer reading	Pilot cells
2	Charger functionality	Each charger
	Weekly	
3	Add water as required	Electrolyte level
4	Clean	Battery top
	Monthly	
5	Clean/inspect	Battery terminals
	Quarterly	
6	Specific gravity check	All cells
7	Open circuit voltage	All cells

Specific maintenance procedures

Every shift

charger functionality

Make sure that the charger adjustment, used for control of charging rates and cut-off, is correct. This will ensure that the batteries are properly charged with no excessive overcharge. Batteries that are overcharged regularly will need water more often, and cell temperatures usually will be higher than normal. If either condition is evident, adjust the charge rate downward, in those chargers which have provision for adjustment, so it is between a normal finish rate and one-half normal finish rate.

hydrometer reading

Measure and record the specific gravity:

- With the tip of the hydrometer immersed in the electrolyte, squeeze the syringe bulb and then slowly release it, drawing into the cylinder or barrel just enough electrolyte to permit the hydrometer float to ride free. The float stem must not touch the side of the cylinder nor the top of the syringe. If the float stem touches the upper area of the syringe, too much electrolyte has been drawn up; if the float still rests on the bottom, too little electrolyte has been drawn up. (See Fig. 2.)
- Read the hydrometer float scale with your eye at the same level as the electrolyte. The reading should be taken at the surface of the liquid, disregarding any slight curvature. This reading will be the specific gravity uncorrected for temperature. (See Table 4 for correction factors.)
- Return all electrolyte to cell.

Fig. 2: Hydrometer reading

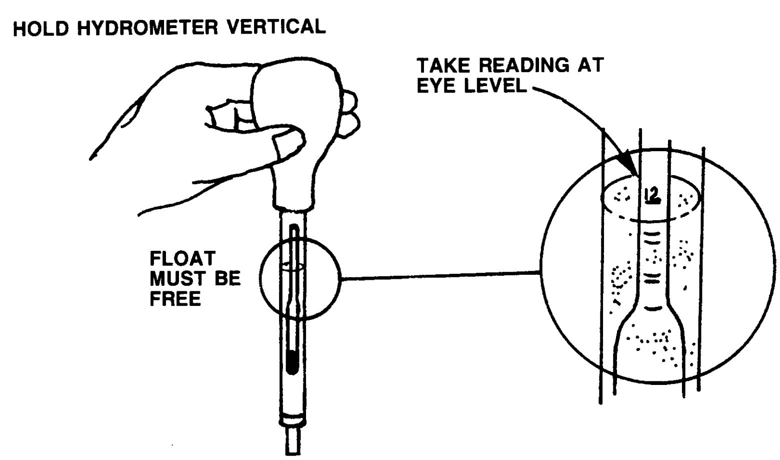


Table 4: Specific gravity temperature correction chart

Electrolyte Temp (°C)	Electrolyte Temp (°F)	Point Correction
54	130	+0.022
53	127	+0.020
51	124	+0.019
49	121	+0.018
48	118	+0.017
46	115	+0.016
44	112	+0.014
43	109	+0.013
41	106	+0.012
39	103	+0.011
38	100	+0.009
36	97	+0.008
34	94	+0.007
33	91	+0.006
31	88	+0.004
29	85	+0.003
28	82	+0.002
26	79	+0.001
24	76	No Correction
23	73	-0.002
21	70	-0.003
19	67	-0.004
18	64	-0.005
16	61	-0.006
14	58	-0.008
13	55	-0.009
11	52	-0.010

Weekly

adding water

A certain amount of water loss in cells is normal and it should be replaced with "pure" tap water or distilled water. In some geographical areas, tap water may contain chemicals or other impurities harmful to batteries. The recommendation for battery replacement water quality, Table 5, lists the maximum allowable impurities..

Table 5: Recommendations for battery replacement water quality

Impurity	Maximum Concentration (ppm)
Total Solids	350
Fixed Solids	200
Chlorides as Cl	25
Nitrates as NO_2	10
Nitrates as NO_3	10
Iron as Fe	4
Organic and Volatiles	150 ppm
Ammonia (NH_4)	5
Manganese	0.07
Calcium and Magnesium	

NOTICE!
A minimum of one quart of water is required. Consult your sales representative if water analysis is required.

Check the height of the electrolyte at least weekly and if water is needed, add just enough to bring the electrolyte to proper level. Do not overfill. Water should only be added to batteries while the batteries are on charge and gassing, or as soon after recharge as possible.

Add water often enough to prevent the electrolyte level from dropping below the perforated separator protector. Ideally, a watering schedule should be established. This schedule should assure adequate watering while taking into consideration those factors which control water consumption, such as (1) frequency of charging, (2) water storage capacity of the specific cell type, (3) age and condition of the battery, and (4) changes in work demand.

battery top

Remove dirt or electrolyte accumulation from the tops of the cells. Wash weekly with clean water. Using a solution of baking soda and water (one pound of baking soda to one gallon of water), neutralize any acid which may be collected at cell or battery terminals to keep them free from corrosion.

Use the solution until all fizzing stops. Work the solution under the connectors. To remove all traces of soda solution and loose dirt, rinse the battery down with clear water from a low pressure hose. Whenever the battery top is being cleaned or rinsed, vent caps must be tightly in place.

CAUTION!
Vent caps must be tightly in place when the battery top is being cleaned or rinsed. Loose or open vent caps will allow contamination into the battery cell.

Monthly

battery terminals

Inspect the battery at least once each month to make certain the terminal connections are tight.

Quarterly

specific gravity and open circuit voltage

When the battery is new, and at least annually thereafter, measure and record the specific gravity and the open circuit voltage for each cell in the battery.

Recordkeeping

The following form will be used by personnel responsible for the receipt, storage, operation, charging, and maintenance of lead-acid storage batteries.

monthly storage battery record

The Monthly Storage Battery Record is to be used to record the services performed on motive power batteries. This record should be prepared and maintained by the using operator and should accompany the battery at all times. (See Fig. 3 for a typical "Monthly Storage Battery Report" form.)

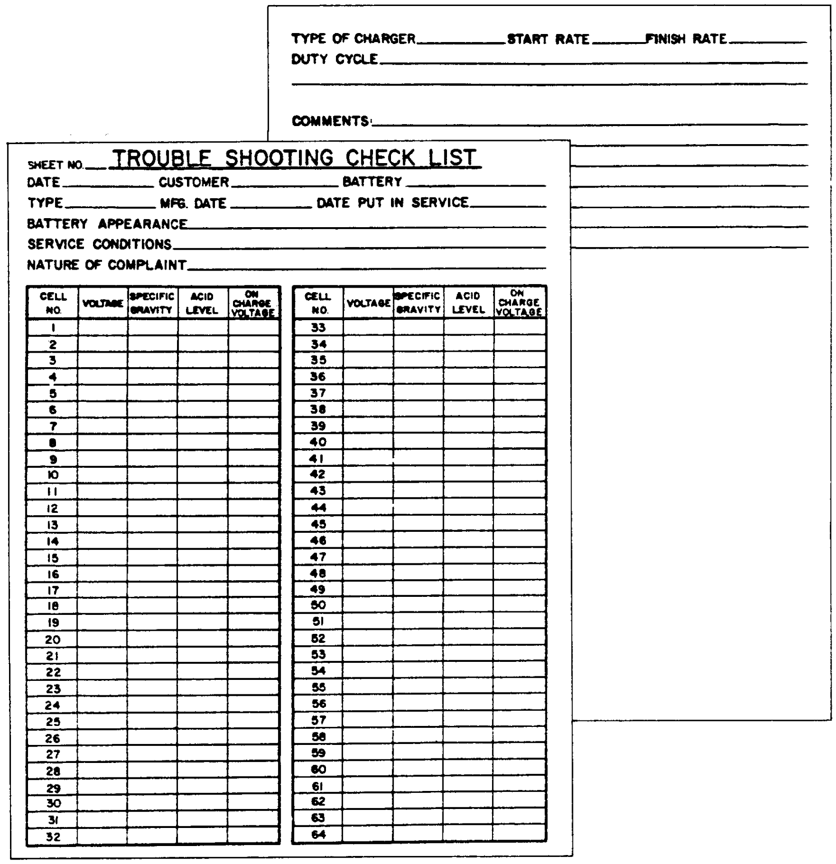
battery cycle and maintenance record

Facilities with more than just a few batteries will find that records of battery cycles, maintenance, and repair are indispensable for an effective battery maintenance program. In addition to those monthly records which require the posting of data each time a battery is charged, the following procedure will be helpful:

- Establish a battery identification system giving each battery a code number. A multiple-digit system is suggested.
- Record specific gravity of the pilot cell or cells before and after each charge. Pilot cells should be selected from those nearest the center of the battery and identified by differently colored vent caps. They should be representative of the balance of the cells in the battery.
- Record the number of cycles on a cumulative basis plus maintenance and repair information. Note any irregularities. The use of a "Battery Cycle and Maintenance Record" form is recommended.

If variations in specific gravity readings exceed 20 points (.020) and on-charge voltage, after an equalizing charge, varies by more than .15 volts, contact your service representative.

Fig. 3: Monthly storage battery record



TYPE OF CHARGER______ START RATE______ FINISH RATE______
DUTY CYCLE______

COMMENTS:______

SHEET NO.___ TROUBLE SHOOTING CHECK LIST
DATE______ CUSTOMER______ BATTERY______
TYPE______ MFG. DATE______ DATE PUT IN SERVICE______
BATTERY APPEARANCE______
SERVICE CONDITIONS______
NATURE OF COMPLAINT______

CELL NO.	VOLTAGE	SPECIFIC GRAVITY	ACID LEVEL	ON CHARGE VOLTAGE	CELL NO.	VOLTAGE	SPECIFIC GRAVITY	ACID LEVEL	ON CHARGE VOLTAGE
1					33				
2					34				
3					35				
4					36				
5					37				
6					38				
7					39				
8					40				
9					41				
10					42				
11					43				
12					44				
13					45				
14					46				
15					47				
16					48				
17					49				
18					50				
19					51				
20					52				
21					53				
22					54				
23					55				
24					56				
25					57				
26					58				
27					59				
28					60				
29					61				
30					62				
31					63				
32					64				

Troubleshooting

In addition to the required routine maintenance, storage batteries may, at some time during their service life, require more extensive or unusual care. Such care should be given as soon as it has been determined that a problem exists or that trouble may be developing. This section deals with the means of identifying existing or impending problems and offers possible solutions.

The Troubleshooting Chart, Table 6, defines the most common problems which could occur during a battery's lifetime. If the suggested operational remedies are ineffective, it may be assumed that there is an internal problem and it will be necessary to disassemble the cell or cells to inspect the elements and sediment well. If the cause of the problem can only be corrected by completely replacing cells or the battery, this information should be reported to the person in authority.

Table 6: Storage battery troubleshooting chart

Symptoms	Probable Cause	Possible Remedy
battery overheats during charge	☞ 1. Malfunctioning charging equipment.	☞ 1. Replace or repair defective charger parts (timer, voltage sensitive relay, control board, etc.)
	☞ 2. Charging equipment out of adjustment.	☞ 2. Adjust start or finish charging rates.
	☞ 3. Defective or weak cell(s).	☞ 3. Replace/repair problem cells.
	☞ 4. Battery worn out and beyond economical repair.	☞ 4. Replace battery.
	☞ 5. High resistance connection within battery.	☞ 5. Check for hot wires, cells, intercell connectors, charging plugs, etc. Repair or replace defective component(s).
	☞ 6. Low electrolyte level.	☞ 6. Add water to just cover separator protector when discharged.
	☞ 7. Battery charge in the vehicle with battery compartment closed or the tray cover closed.	☞ 7. Open compartment during charge or charge battery of the unit with the tray cover opened.
	☞ 8. Battery of 100° F when placed on charge.	☞ 8. Allow battery to cool below 90° F before charging.

Table 6: Storage battery troubleshooting chart, continued

Symptoms	Probable Cause	Possible Remedy
battery overheats during discharge	☞ 1. See causes 3 thru 8 in “battery overheats during charge” section.	☞ 1. See remedies 3 thru 8 in “battery overheats during charge” section.
	☞ 2. Worn out bearings, brakes dragging, or other vehicle problem causing high current draw.	☞ 2. Repair or replace defective unit problems.
	☞ 3. Over discharge of battery.	☞ 3. Require drivers to return battery for recharge earlier so as not to over-discharge batterty; or Put more batteries into service.
battery not completing full work shift	☞ 1. Battery not fully charged before placed into operation.	☞ 1. Ensure that battery has reached full charge specific gravity before placing into operation.
	☞ 2. Weak, leaking, or defective cell(s) in battery.	☞ 2. Repair/replace cell(s) or battery.
	☞ 3. Grounds or shorts in the battery.	☞ 3. Remove grounds or shorts.
	☞ 4. Battery worn out and beyond economical repair.	☞ 4. Replace battery with equal or higher capacity battery.
	☞ 5. Battery too small for the job.	☞ 5. Replace battery with one having a higher capacity; or Purchase extra batteries (with higher capacity, if possible) and change battery more frequently.
	☞ 6. Electrical or mechanical problems.	☞ 6. Troubleshoot vehicle and repair.

Table 6: Storage battery troubleshooting chart, continued

Symptoms	Probable Cause	Possible Remedy
low electrolyte	☞ 1. Cracked or broken jar(s).	☞ 1. Replace jar and adjust specific gravity or replace damage cell.
	☞ 2. Cell missed when watered.	☞ 2. More careful attention when watering.
	☞ 3. Defective or weak cell(s).	☞ 3. Repair/replace cell(s).
	☞ 4. Frequent overcharge.	☞ 4. See items 1 and 2 in "battery overheats during charge" section.
	☞ 5. Battery not regularly watered.	☞ 5. Water battery regularly.
unequal cell voltages	☞ 1. Grounds in battery.	☞ 1. Clean battery.
	☞ 2. There is a "tap" off the battery for auxiliary equipment (radio, lights, etc.).	☞ 2. Use dropping resistor instead of tap; or Equalize battery regularly.
	☞ 3. Battery sluggish due to lack of work.	☞ 3. Give battery a deep discharge and equalizing charge.
	☞ 4. Leaking cell or cover.	☞ 4. Replace jar or cover and adjust specific gravity or replace cell.
	☞ 5. Defective or weak cell(s).	☞ 5. Repair/replace cell(s).
	☞ 6. Battery worn out beyond economical repair.	☞ 6. Replace the battery.
	☞ 7. Acid loss in few cells by tipping battery over.	☞ 7. Call your service representative.

Adjustment procedures

Electrolyte specific gravity

Fully charged cells usually operate at a specific gravity between 1.280 and 1.295. Normally, it should never be necessary to adjust the specific gravity, but upsets, jar breakage, additions of too much water, and careless use of the hydrometer can result in electrolyte loss and possible reductions of battery capacity. Lost electrolyte must be replaced but only after it has been determined that charging will not restore the specific gravity to normal when at the recommended level.

Therefore, a cell or battery should first be given an equalizing charge.

IMPORTANT!
Never make a specific gravity adjustment on a cell which does not gas vigorously while on charge.

If, after the equalizing charge, the specific gravity of any cell, corrected for temperature, is lower than normal, it should be adjusted in the following manner:

- Put battery back on charge at the finish rate until cells are actively gassing to provide proper mixing.
- Remove electrolyte from the low reading cells until level reaches separator protector.
- Slowly add 1.400 specific gravity sulfuric acid to the cell while it is still gassing.
- Wait 15 to 20 minutes for the added acid to become thoroughly mixed, then read the specific gravity. If it is still low, repeat the process until gravity is normal. As a guide, every 1/4" of electrolyte that has been removed and replaced by 1.400 acid will cause the specific gravity to rise 4 to 5 points (.004 to .005).

If the corrected specific gravity of any cell is higher than normal, proceed as follows:

- While the battery is gassing on charge, withdraw from the cell a small amount of electrolyte and replace with approved water.
- Repeat, if necessary, at 20 to 30 minute intervals until the desired reading is obtained. Every 1/4" of electrolyte which is replaced with water will cause the specific gravity of the cell electrolyte to drop 4 to 5 points (.004 to .005).

CAUTION!
Never add acid with a specific gravity higher than 1.400. Stronger acid may permanently damage the cell. When mixing or cutting acid, always add the acid to the water. Never pour water into the acid; a violent reaction may result which may result in injury to personnel. When working with acid, always use a face shield or goggles, rubber gloves, and an acid resistant apron.

Restoring a sulfated battery

Continued under charging a battery, even to a small degree, leads to excessive "sulfation." The same is true of batteries which have been left standing in an uncharged state for an extended period. High temperatures rapidly accelerate sulfation when batteries are left standing in a partially charged or discharged condition. The cells of a sulfated battery will give low specific gravity and voltage readings. The battery will not become fully charged after a single normal charging when sulfation has taken place over a prolonged period.

If the situation has not progressed too far, it may be possible to restore the battery to a serviceable condition by using the following special procedures:

- ☞ Thoroughly clean the battery.
- ☞ Bring the electrolyte level up to a point which is just visible over the separator-protector by adding approved water.
- ☞ Put the battery on charge at the prescribed finishing rate until the rated ampere-hour capacity has been returned to the battery. Record the voltage and specific gravity readings. Correct the specific gravity readings for temperature by using Table 4. If the temperature at any time during these procedures exceeds 110° F, stop the charge and allow the battery to cool to 90° F or below before continuing. Charge the battery until the specific gravity shows no change during a 4 hour period while taking hourly readings. With automatic charging equipment, the battery may have to be placed on equalizing charge two or three times. If a battery is badly sulfated, the specific gravity may rise only 30 to 40 points (.030 to .040) during the first charge.
- ☞ Place the battery into service and discharge it to a fully discharged condition.
- ☞ Charge the battery again until the specific gravity shows no change during a 4 hour period, continuously monitoring the temperature.
- ☞ Repeat the cycling process until the specific gravity rises to within 30 points of a normal fully charged battery, then place the battery back in routine service. Even though specific gravities may be lower than normal, they should not vary much from cell to cell. If they do, problems other than sulfation may be present. If the spread between the highest and the lowest specific gravity reading is 50 points or more, refer to the Troubleshooting Chart, Table 5, for help in identifying the problem. If the battery still has not responded to treatment, call your service representative.

Excessive self-discharge correction

While a storage battery is in a charged state, a local electrochemical reaction takes place within the cells, which causes very gradual discharging. This reaction is known as self-discharge. A small amount is quite normal in mine power batteries where grids are made from antimonial lead. The rate of self-discharge is temperature-related and increases significantly as temperatures rise. Table 7 shows the relationship between temperature and loss of specific gravity. The normal rate at 77° F to 80° F is a loss in specific gravity of about one point (.001) per day. This becomes of concern only when a wet battery is to be stored for weeks at a time. It can be ignored as a factor in normal battery operation.

It is possible, however, particularly during the latter stages of a battery's life, for the rate of discharge to become much greater and even limit the battery's duty cycle. Excessive self-discharge may be caused by defective separators or plates which have become shorted at the edges. Edge shorting is usually caused by loss of positive active material which can fill the sediment well or build up on the top or sides of the plates and eventually bridge the space between the positives and negatives. If a shorted condition seems likely, the element should be pulled for examination and the defective separator replaced, shorts cleared, or cells replaced. Usually, if the sediment well is full, salvage is impractical.

Table 7: Temperature effect on battery self-discharge

Temperature (°F)	Loss of Specific Gravity per Day
120	0.004
100	0.003
80	0.001
50	0.0005

Test discharge

A capacity test is sometimes desirable to determine a battery's actual discharge capability as compared to its 6-hour rated capacity.

This can be a significant diagnostic tool when equipment does not operate as expected and it can help determine when the battery should be replaced. When a battery consistently delivers less than 80% of its rated ampere-hour capacity, either some cells are substandard or the battery has reached the end of its useful life and should be replaced.

A test discharge is performed by discharging a fully charged battery at a fixed rate under carefully controlled test conditions.

Repairing batteries

Storage batteries which have been damaged or which contain defective cells may, if the rebuilding cost and time are justified, be restored to a serviceable condition.

It is important to check a battery thoroughly if it has been involved in an accident or if it is believed to be defective. A neglected battery will continue to deteriorate even when not in use. **Usually, rebuilding is justified if the majority of the cells are in good condition.**

This section explains how to remove cells from a battery and how to repair them if they are to be salvaged. Some special tools and parts will be required, depending upon the work to be done. Reference will be made to the use of such special devices but they will not be further identified in this manual. Each manufacturer identifies all tools, accessories, and replacement parts by an appropriate part number. Use this number when making reference to them.

Purging gas

☞ Before starting any repairs, remove all vent caps from cells to be repaired as well as from all surrounding cells.

☞ The space above the electrolyte must be cleared of hydrogen gas before proceeding with repairs. Introduce a low volume air stream (volume and force equal to that produced by fanning each cell with a stiff piece of cardboard or other suitable nonconducting material) into each cell for at least 30 seconds. Be very careful when using air so that the electrolyte is not splashed out of the cell.

CAUTION!
Do not blow breath into cells. Wear protective face shield or goggles, rubber gloves, and apron.

☞ After cells have been purged, cover all vent openings with several layers of water-dampened cloth before starting repairs.

Removing intercell connectors

Special intercell connector drills, available in different sizes, are designed to cut the bond between the cell post and the connector while permitting the post to remain for later rebuilding.

☞ Make certain vent plugs are in place.

☞ Cut the bond between the cell post and the connector. Be careful to cut only as deep as necessary, usually 1/4" to 3/8". During drilling, try to center on the cover bushing and make sure any lead curl produced does not short across other connectors.

☞ Lift the intercell connectors off with a pair of pliers.

Removing a complete cell

☞ After removing connectors as describe in this section, isolate the cell from adjacent cells. This may require cutting of compound or removal of spacers.

☞ Use a long spatula or similar tool to free the cell from top to bottom.

☞ When the jar walls are free, the cell can be lifted from the battery tray. All cells are heavy so a suitable lifting device, such as an electric hoist, is recommended. Threaded post clamps or cell pullers are available which can be burned or clamped to the posts, and used to pull the cell. Use a non-conducting bar between the loops of the post clamps and hook the hoist to this bar.

WARNING!
You could be seriously injured or even killed by falling loads. Observe the safe working load limits of lifting devices.

☞ After removing the cell, neutralize any acid in the tray with a soda solution and clean up the residue.

When a cell or element is being pulled, it is advisable to have on hand both a replacement jar and a cover in the event that either of the original parts are damaged in the process.

If a wet and charged cell has been pulled and allowed to stand unsupported, the jar walls may bulge and permit the electrolyte level to drop. Do not attempt to adjust electrolyte levels until cells have been reinstalled in the battery.

Removing an element

If the jar is known to be serviceable, it may not be necessary to remove the complete cell. Usually only the element, complete with cover, has to be pulled. This can only be done, however, on those batteries containing a compound type cover-to-jar seal.

To remove the element:

☞ After removing connectors, draw a warm putty knife through the sealing compound close to the inside jar wall. Some batteries are furnished with permanent seals between the cover and jar. With these, if a defect occurs, the complete cell must be pulled and cover-to-jar seal cut or sawed to permit removal of the element. In doing so, both jar and cover must be replaced and resealed in accordance with the correct instructions.

☞ Use a threaded post clamp or cell puller and hoist to raise the element, with cover in place, first to drain position, halfway out of the jar until most of the electrolyte has drained off.

NOTICE!
When pulling an element from a cell which has been removed from a battery, use jar hold-down clamps.

- ☞ Raise the element to clear the top of the jar. Do not, unless absolutely necessary, expose an element to air longer than five minutes. Oxygen in the air combines with the active material in the negative plates, causing them to oxidize and heat. If the exposure persists, negative plates will discharge.

  - ☞ While the element is out of the jar, check the sediment well in the bottom of the jar. If it is full of shed material, the cell will probably have to be replaced.

  - ☞ Inspect plate and separator edges while the element is suspended. A more thorough inspection of separators, plate insulation, grids, and active materials may be indicated. If so, proceed as follows:

    - ☞ Remove the element from the jar.

    - ☞ Lay the element on its side on a clean non-metallic surface with the plates at right angles to the table surface so the element can be fanned slightly to permit the removal of separators, always on negative side.

    To reinstall the separator:

    - ☞ Make certain that the flat side of the separator is against the negative plate and the ribbed side is facing the positive.

    - ☞ Push up until they are flush with the bottom of the element and they project equally on each side of the plates.

- ☞ Before installing an element in a previously used jar, wash out any sediment which may have accumulated in the bottom of the jar and clean all compound from around the inside of the top edge.

- ☞ Clamp the element, if necessary, when reinstalling it in the jar. Make certain that the element is entering the jar properly and that the plates are at right angles to the plate support ribs in the bottom. When installing an element with a cell cover attached, use a putty knife to guide the lip of the cover past the top edges of the jar.

Replacing a cell in battery

NOTICE!
Cells from which the elements were pulled, or which had damaged jars replaced, should be given an equalizing charge and acid should be adjusted immediately following repair, before they are returned to service.

Before lowering a cell into a battery tray, be sure that it is correctly positioned relative to adjoining cells to which it is to be connected.

NOTICE!
Cells must be connected in series with the positive side of one cell connected to the negative side of the adjacent cell.

When the problem has been corrected and the cell is returned to the battery tray, the cover must be resealed to the jar. With the exception of those cells which contain a permanent jar-to-cover seal, a special asphalt type sealing compound is used for this purpose.

- Heat the compound until it melts, but do not let the temperature get above 400° F.
- Pack any large openings between cover lip and jar wall with cold compound.
- Pour the hot compound into the sealing groove in two steps.
  - Pour the groove full and soft flame with a torch to improve the adhesion.
  - Fill the groove a second time and soft flame again.
- Allow compound to cool and trim excess.
- After sealing, pressure test cells for 10 seconds at a maximum of 1.5 psi.
- Reinstall intercell connectors by welding or "burning" them to the terminal posts. A small, hot flame is recommended such as is available from a standard commercial burning torch using natural gas and oxygen or propane and oxygen. Carbon burning outfits are also acceptable.

WARNING!
Always be sure the cells are purged of gas before using an open flame or burning arc on top of the battery.

Replacing a cell cover

The specific methods used to seal cell covers to both the jar and the terminal posts are as follows:

Sealing compound and lead bushing design

This is probably the most commonly used system: an asphalt type compound is applied to seal the cover to both rubber and plastic jars. Lead bushings, molded into the cover as inserts, are welded or "burned" to the terminal posts to prevent electrolyte leakage around the posts.

When replacing a cover of this type:

☞ Cut the compound with a warm putty knife. Cut the full depth of the cover adjacent to the jar wall from corner to corner on each of the four sides.

☞ Reuse of covers which have been removed from the element is not recommended, therefore, use a post trimmer to cut off the post extensions above the cover.

☞ Break the lead bond between post and lead insert by driving the cover down approximately 1/32". The lead insert mold placed over the post and tapped with a hammer serves this purpose.

☞ Insert a hook through the vent opening and lift the cover off.

☞ Remove all sealing compound adhering to jar wall and neutralize these surfaces and upper portion of all terminal posts using a cloth moistened with a soda solution.

☞ Thoroughly dry all of the neutralized surfaces.

☞ Install the new cover

☞ Complete cover-to-jar seal.

☞ Reburn cell connectors.

Epoxy seal and seal nut design

This is one of the newer systems which employs an epoxy, or permanent, hard seal between cover and jar. To disassemble a cell of this design requires that the jar be cut and that both jar and cover be replaced. When reassembling with a new jar and cover, it is very important to adhere to the following procedure to obtain an effective seal:

- Epoxy can be used only on rubber jars and covers.
- Thoroughly clean cover and jar sealing areas first with xylol (xylene), then with isopropyl alcohol. Use a separate cleaning cloth for each.
- Caulk bottom of seal groove with glass cord. Tamp corners in. Make overlap small. Do not use warm compound with epoxy.
- Use special epoxy sealant as recommended by the battery manufacturer. Follow instructions provided.
- Apply epoxy in two pours. Make second pour within two hours after first pour. Fill to top of jar. Do not overfill.
- Pressure test seal after three hours or more from time of final pouring. Pressure test to 1.5 psi for 10 seconds.

Heat bonded plastic cover-to-jar seal and lead bushing design

This is the newest of the sealing systems used with motive power batteries. To disassemble a cell of this design also requires that the jar be cut and both jar and cover be replaced. The seal between jar and cover is, in effect, a plastic weld. It can only be used with jars and covers made from identical plastic molding material.

Since special techniques must be used when resealing these covers, the battery manufacturer recommends that these cover-to-jar seals not be repaired in the field. Manufacturers' instructions request that such repairs be made in their service stations only.

6 Technical data

Tightening torques

IMPORTANT!
Due to the application of fasteners being subject to great stresses and heavy or extreme vibration, it is imperative that all bolts be applied with an adequate amount of torque. For this reason this list of recommended torque settings for different types and sizes of fasteners used has been compiled.
The tightening torques stated in the spare parts lists have to be observed, as well, for installation and maintenance.

Set screws

Table 7: Set screws (Socket long-lok)

Nominal diameter	Recommended torque setting
#6	6 in-lbs
#8	9 in-lbs
#10	13 in-lbs
¼”	30 in-lbs
5/16”	5 ft-lbs
3/8”	8 ft-lbs
7/16”	11 ft-lbs
½”	16.7 ft-lbs

Table 8: Set screws (Socket standard steel)

Nominal diameter	Recommended torque setting
#6	9 in-lbs
#8	16 in-lbs
#10	30 in-lbs
¼”	6 ft-lbs
5/16”	12 ft-lbs
3/8”	18 ft-lbs
7/16”	29 ft-lbs
½”	43 ft-lbs
5/8”	100 ft-lbs
¾”	146 ft-lbs
7/8”	199 ft-lbs
1”	262 ft-lbs

Table 9: Hex bolts, coarse thread (Grade 8)

Nominal diameter	Recommended torque setting
¼”	8 ft-lbs
5/16”	16 ft-lbs
3/8”	28 ft-lbs
7/16”	45 ft-lbs
½”	70 ft-lbs
9/16”	99 ft-lbs
5/8”	135 ft-lbs
¾”	240 ft-lbs
7/8”	390 ft-lbs
1”	545 ft-lbs
1 1/8”	830 ft-lbs
1 ¼”	1,160 ft-lbs
1 3/8”	1,525 ft-lbs
1 ½”	2,030 ft-lbs

Table 10: FSR hex bolts (SAE 5 and 325 steel)

Nominal diameter	Recommended torque setting
¼”	9 ft-lbs
5/16”	18 ft-lbs
3/8”	31 ft-lbs
7/16”	50 ft-lbs
½”	75 ft-lbs
9/16”	110 ft-lbs
5/8”	150 ft-lbs
¾”	250 ft-lbs
7/8”	378 ft-lbs
1”	583 ft-lbs
1 1/8”	782 ft-lbs
1 ¼”	1,097 ft-lbs
1 3/8”	1,461 ft-lbs
1 ½”	1,748 ft-lbs
1 ¾”	3,114 ft-lbs
2”	4,504 ft-lbs
2 ¼”	6,497 ft-lbs
2 ½”	7,144 ft-lbs
2 ¾”	12,092 ft-lbs
3”	15,744 ft-lbs

Table 11: FSR hex bolts (SAE 5 and 325 steel)

Nominal diameter	Recommended torque setting
¼”	9 ft-lbs
5/16”	18 ft-lbs
3/8”	31 ft-lbs
7/16”	50 ft-lbs
½”	75 ft-lbs
9/16”	110 ft-lbs
5/8”	150 ft-lbs
¾”	250 ft-lbs
7/8”	378 ft-lbs
1”	583 ft-lbs
1 1/8”	782 ft-lbs
1 ¼”	1,097 ft-lbs
1 3/8”	1,461 ft-lbs
1 ½”	1,748 ft-lbs
1 ¾”	3,114 ft-lbs
2”	4,504 ft-lbs
2 ¼”	6,497 ft-lbs
2 ½”	7,144 ft-lbs
2 ¾”	12,092 ft-lbs
3”	15,744 ft-lbs

Tightening torques

Table 12: Untreated screw, black finish (Coarse thread)

Property class	Torque	Recommended torque setting			Nominal diameter			
	Ma	M3	M4	M5	M6	M7	M8	M10
5.6	Nm	0.60	1.37	2.70	4.5	7.8	11	22
	Ft-lbs	0.44	1.01	1.99	3.3	5.6	8.1	16
8.8	Nm	1.37	3.10	6.15	10.5	17.5	26	61
	Ft-lbs	1.01	2.29	4.54	7.7	12.9	19	37
10.9	Nm	1.92	4.40	8.55	15	25	36	72
	Ft-lbs	1.42	3.25	6.38	11	18.4	26	53
12.9	Nm	2.30	5.25	10.4	18	29	43	87
	Ft-lbs	1.70	3.87	7.6	13	21.3	31	64

Table 12: Untreated screw, black finish (Coarse thread, continued)

Property class	Torque	Recommended torque setting			Nominal diameter			
	Ma	M12	M14	M16	M18	M20	M22	M24
5.6	Nm	39	62	85	130	184	250	315
	Ft-lbs	28	45	70	95	135	184	232
8.8	Nm	89	141	215	295	420	570	725
	Ft-lbs	65	103	158	217	308	420	634
10.9	Nm	125	198	305	420	690	800	1020
	Ft-lbs	92	146	224	309	435	590	752
12.9	Nm	150	240	365	500	710	960	1220
	Ft-lbs	110	177	269	368	523	708	899

Table 12: Untreated screw, black finish (Coarse thread, continued)

Property class	Torque	Recommended torque setting		Nominal diameter		
	Ma	M27	M30	M33	M36	M39
5.6	Nm	470	635	865	1111	1440
	Ft-lbs	346	468	637	819	1062
8.8	Nm	1070	1450	1970	2630	3290
	Ft-lbs	789	1069	1452	1885	2428
10.9	Nm	1510	2050	2770	3560	4620
	Ft-lbs	1113	1511	2042	2625	3407
12.9	Nm	1810	2450	3330	4280	5550
	Ft-lbs	1334	1606	2455	3156	4093

Tightening torques

Table 13: Untreated screw, black finish (Fine thread)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M8 X 1	M10 X 1.25	M12 X 1.25
8.8	Nm	27	52	95
	Ft-lbs	19	38	70
10.9	Nm	38	73	135
	Ft-lbs	28	53	99
12.9	Nm	45	88	160
	Ft-lbs	33	64	118

Table 13: Untreated screw, black finish (Fine thread, continued)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M14 X 1.5	M16 X 1.5	M18 X 1.5
8.8	Nm	150	225	325
	Ft-lbs	110	165	239
10.9	Nm	210	315	460
	Ft-lbs	154	232	339
12.9	Nm	260	380	550
	Ft-lbs	184	280	405

Table 13: Untreated screw, black finish (Fine thread, continued)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M20 X 1.5	M22 X 1.5	M24 X 2
8.8	Nm	399	610	780
	Ft-lbs		449	575
10.9	Nm	640	860	1100
	Ft-lbs	472	634	811
12.9	Nm	770	1050	1300
	Ft-lbs	567	774	958

Table 14: Electrically zinc plated (Coarse thread)

Property class	Torque	Recommended torque setting		Nominal diameter				
	Ma	M33	M4	M5	M6	M7	M8	M10
5.6	Nm	0.56	1.28	2.50	4.3	7.1	10.5	21
	Ft-lbs	0.41	0.94	1.84	3.1	5.2	7.7	15
8.8	Nm	1.28	2.90	5.75	9.9	16.5	24	48
	Ft-lbs	0.94	2.14	4.24	7.3	12.1	17.7	35
10.9	Nm	1.80	4.10	8.10	14	23	34	67
	Ft-lbs	1.33	3.02	5.97	10.3	16.9	25	49
12.9	Nm	2.15	4.95	9.70	16.5	27	40	81
	Ft-lbs	1.59	3.65	7.15	12.1	19.9	29	59

Table 14: Electrically zinc plated (Coarse thread, continued)

Property class	Torque	Recommended torque setting		Nominal diameter			
	Ma	M12	M14	M16	M18	M20	M22
5.6	Nm	36	58	88	121	171	230
	Ft-lbs	26	42	54	89	126	169
8.8	Nm	83	132	200	275	390	530
	Ft-lbs	61	97	147	202	287	390
10.9	Nm	117	185	285	390	550	745
	Ft-lbs	86.2	136	210	287	405	549
12.9	Nm	140	220	340	470	660	890
	Ft-lbs	103	162	250	346	486	656

Table 14: Electrically zinc plated (Coarse thread, continued)

Property class	Torque	Recommended torque setting		Nominal diameter			
	Ma	M24	M27	M30			
5.6	Nm	295	435	590	800	1030	1340
	Ft-lbs	217	320	435	590	759	988
8.8	Nm	675	995	1350	1830	2360	3050
	Ft-lbs	497	733	995	1349	1740	2249
10.9	Nm	960	1400	1900	2680	3310	4290
	Ft-lbs	708	1032	1401	1902	2441	3163
12.9	Nm	1140	1680	2280	3090	3980	5150
	Ft-lbs	840	1239	1661	2278	2935	3798

Table 15: Electrically zinc plated (Fine thread)

Property class	**Torque**	**Recommended torque setting**	**Nominal diameter**	
	Ma	M8 X 1	M10 X 1.25	M12 X 1.25
8.8	Nm	25	49	88
	Ft-lbs	18	36	84
10.9	Nm	35	68	125
	Ft-lbs	25	50	92
12.9	Nm	42	82	150
	Ft-lbs	30	60	110

Table 15: Electrically zinc plated (Fine thread, continued)

Property class	**Torque**	**Recommended torque setting**	**Nominal diameter**	
	Ma	M14 X 1.5	M16 X 1.5	M18 X 1.5
8.8	Nm	140	210	305
	Ft-lbs	103	154	224
10.9	Nm	195	295	425
	Ft-lbs	143	217	313
12.9	Nm	235	350	510
	Ft-lbs	173	258	376

Table 15: Electrically zinc plated (Fine thread, continued)

Property class	Torque	Recommended torque setting	Nominal diameter	
	Ma	M20 X 1.5	M22 X 1.5	M24 X 2
8.8	Nm	425	570	720
	Ft-lbs	313	420	531
10.9	Nm	600	800	1000
	Ft-lbs	442	590	737
12.9	Nm	720	960	1200
	Ft-lbs	531	708	885

7 For your information

For your information

Our service

If you need to order spare parts or if technical problems occur, please contact our after-sales service personnel or contact us direct.

Service address

Beckley, WV
200 George Street, Suite 4
Beckley, WV 25801
Phone: (304) 256-5927
Fax: (304) 256-5928

Duffield, VA
P.O. Box 847
6808 Fraley Avenue
Duffield, VA 24244
Phone: (276) 431-7000
Fax: (276) 431-2464

Carrier Mills, IL
9580 State Route 13 West
Carrier Mills, IL 62917
Phone: (618) 982-9000
Fax: (618) 982-9912

Paonia, CO
P.O. Box 566
719 Second Street
Paonia, CO 81428
Phone: (970) 527-3151
Fax: (970) 527-6846

Pulaski, VA
4041 Wurno Road
Pulaski, VA 24301
Phone: 540-980-4530
Fax: 540-980-6211

Craig, CO
400 Mack Lane
Craig, CO 81625
Phone: (970) 824-3249
Fax: (970) 824-8851

Houston, PA
2045 West Pike Street
Houston, PA 15342
Phone: (724) 743-1200
Fax: (724) 743-1201

Oak Hill, WV
P.O. Box 60
843 Lochgelly Road
Oak Hill, WV 25901
Phone: (304) 469-3302
Fax: (304) 465-0450

Washington, PA
255 Berry Road
Washington, PA 15301
Phone: (724) 743-1200
Fax: (724) 228-2177

Rebuild facility address

Huntington, UT
P.O. Box 1190
Route 10, 1Mile North
Huntington, UT 84528
Phone: (435) 687-9831
Fax: (435) 687-2522

Pearisburg, VA
P.O. Box 463
222 Industrial Park Drive
Pearisburg, VA 24134
Phone: (540) 921-2111
Fax: (540) 921-2711

Norris City, IL
635 Illinois Highway 1
Norris City, IL 62869
Phone: (618) 378-3441
Fax: (618) 378-3106

BATTERY CHARGING
AND MAINTENANCE INSTRUCTIONS

WARNING

ALWAYS WEAR SAFETY GLASSES AND PROTECTIVE CLOTHING WHEN SERVICING BATTERIES. NEUTRALIZE ANY ACID SPILLS IMMEDATELY. IF ACID CONTACTS ANY PART OF THE BODY, FLUSH IMMEDATELY WITH RUNNING WATER AND SEEK MEDICAL ATTENTION.

WARNING

CARE SHOULD BE TAKEN AT ALL TIMES TO AVOID ELECTRICAL SHOCK FROM THE BATTERY OR CHARGER. THE CHARGER MUST BE TURNED OFF BEFORE CONNECTING OR DISCONNECTING THE LEAD(S) TO THE BATTERY.

I. CHARGING

A. Tray covers should be open during charge.

B. Be sure charger switch is in "OFF" position.

C. Check plugs and receptacles to be sure they are clean and in good condition. Connect the charger to the battery.

WARNING

NEVER CONNECT OR DISCONNECT THE BATTERY AND CHARGER UNLESS THE CHARGER IS TURNED OFF. DAMAGE TO THE PLUGS AND RECEPTACLES WILL OCCUR. ALSO AN ARC WILL BE DRAWN THAT COULD BE A SAFETY HAZARD.

D. Turn switch "ON", and press "START" to start daily charge. Check ammeter to be sure battery is charging and charger is operating correctly.

E. Charger is fully automatic and will stop charging when it recognizes a fully charged battery in approximately 8 hours.

F. Full charge specific gravity reading should be 1.280 to 1.295. Higher readings will result due to low water levels. Do not over water battery as lost acid will result in less work per charge and shorten battery life.

NOTICE

ALL SPECIFIC GRAVITY READINGS ARE BASED ON BATTERY TEMPERATURE OF 25 DEGREES C.

II. EQUALIZING CHARGE

A. After the daily 8-hour charge is complete, turn switch "ON" and press "START" (If equipped) for an equalizing charge once per week.

B. When equalizing charge is completed and automatic electronic timer has turned charger off, read specific gravity of each cell and record. If variations of 10 or 20 points of specific gravity are recorded, call a service technician. If cells show variations of 0.1 or more, call a service technician.

III. OPERATING INSTRUCTIONS

A. Do not charge or operate in service if temperature of battery reaches 46 degrees C. High temperatures are a result of improper charger adjustments, high discharge rates, over discharging, short cycling, and low water levels.

B. Keep plugs and receptacles clean and adjusted for tension. If plug is hot, it is not making good contact. Remember the battery has current at all times. Be careful when working on plugs and receptacles.

C. Vent caps should only be removed to check water level, temperature, and specific gravity, or to add water. Be sure they are in place and tight at all times.

D. Do not weld, grind or allow sparks or allow flame near battery. Do not allow tools or any other metal to be laid on connector of battery.

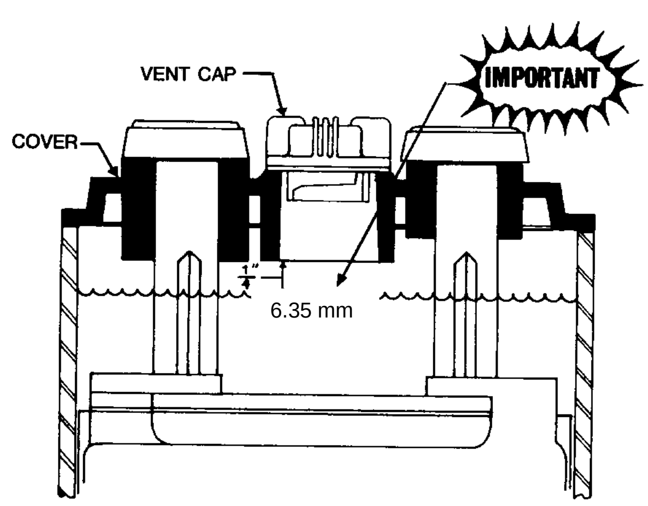
E. Never add anything to the battery except approved water.

F. Never add acid to battery.

IV. WATERING

A. Add approved water to 1/4" (6.35 mm) below vent well only at the end of charge. Filling to this level before charging will cause acid overflow. Acid attacks external battery parts. Any acid loss from the battery will result in power loss and shortened life.

B. Replace vent caps securely.



V. CLEANING

A. Wash battery at least weekly using soda and water, then rinse with plain water 1 lb. (0.45 kg) soda to 1 gal. (3.78 l) water mixture). Vent caps should be in place when washing battery.

B. Dirty batteries create grounds, reduce work time, increase battery cost, and shorten life. Correctly charged, watered, and cleaned batteries give longer work time per shift per charge, reduced cost, and longer life.

COMPLETE SERVICE FOR BATTERIES AND CHARGERS IS AVAILABLE. WE ALSO HAVE COMPLETE BATTERY REBUILD CENTERS FOR QUICK TURNARROUND ON BATTERY AND CHARGER REBUILDS.

BATTERY AUTOMATIC WATERING SYSTEM INSTRUCTIONS

WARNING!
ALWAYS WEAR SAFETY GLASSES AND PROTECTIVE CLOTHING WHEN SERVICING BATTERIES. NEUTRALIZE ANY ACID SPILLS IMMEDATELY. IF ACID CONTACTS ANY PART OF THE BODY, FLUSH IMMEDATELY WITH RUNNING WATER AND SEEK MEDICAL ATTENTION.

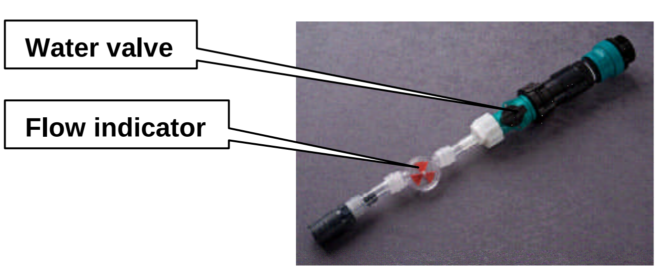
WARNING!
CARE SHOULD BE TAKEN AT ALL TIMES TO AVOID ELECTRICAL SHOCK FROM THE BATTERY OR CHARGER. THE CHARGER MUST BE TURNED OFF BEFORE CONNECTING OR DISCONNECTING THE LEAD(S) TO THE BATTERY.

NOTICE!
Never remove watering caps from battery cell, unless absolutely necessary.

NOTICE!
Never water a battery that has not been fully charged. Water levels rise during the charge cycle.

1. **Water batteries once weekly.**
2. **It is recommended that a particular day of the week be set to water batteries, preferably the beginning of each week (Monday). Always try to water batteries after an equalize charge.**
3. **Clean batteries once weekly:**
   - A. **Wash battery at least weekly using soda and water, then rinse with plain water 1 lb. (0.45 kg) baking soda or soda ash to 1 gal. (3.78 l) water mixture). Vent caps should be in place when washing battery.**
   - B. **Dirty batteries create grounds, reduce work time, increase battery cost, and shorten life. Correctly charged, watered, and cleaned batteries give longer work time per shift per charge, reduced cost, and longer life.**
4. **WATERING**
   - A. **Connect pressure fill hose to battery fill hose.**
   - B. **Turn water valve "ON" (Fig. 1).**
   - C. **Water will flow into hoses and caps. Flow indicator on pressure fill line will spin (Fig. 1).**

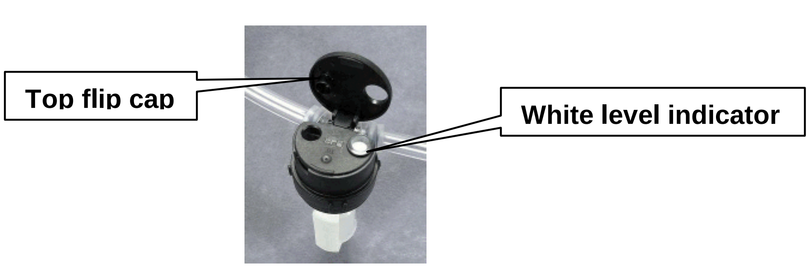
Fig. 1: Water valve and flow indicator



Note:
This process takes approximately between 2 – 12 minutes, depending on the number of cells, battery fill hoses and water levels.

   - D. **When the flow indicator stops turning, a visual inspection will verify that all caps have received water. The white level indicator will rise to the top of the viewing window when cells have filled to the proper level.**
   - E. **If any white indicators do not rise, inspect the watering system for any crimped, mashed and/or bad caps.**
   - F. **If water levels are in question, use a hydrometer and flip open the top flip cap to check water levels (Fig. 2).**

Fig. 2: Top flip cap



NOTICE!
Some batteries are equipped with multiple fill hoses; insure that all fill hoses have been serviced and that all cells have adequate water.

IMPORTANT!
If any watering caps leak in the fill process, tighten or replace watering caps as necessary.

IMPORTANT:
It is common for water levels to be below the separator plate and not visible, especially when the battery is discharged or late in the work week.

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