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U. S. Department of Labor
Mine Safety and Health Administration
Technical Support
Approval and Certification Center

INVESTIGATIVE REPORT

Diesel Wet Scrubber
Flashing Headlight Warning Circuit
February 2004

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ABSTRACT:

MSHA's Approval and Certification Center presents a design of an electrical control circuit that will flash the headlights of permissible diesel powered equipment when the water in the wet exhaust conditioner system is nearly depleted. The flashing headlights will warn the machine operator that the system water is low and will allow adequate time for the operator to tram to a water source and replenish the water before the machine's safety system shuts down the diesel engine. The permissible electric flashing headlight control circuit was designed for easy retrofit into the existing machine lighting circuit. Field testing of the design at two underground coal mines proved the circuit's mine worthiness in addition to its acceptability as a warning device to the miners operating the diesel powered equipment.

INTRODUCTION:

To meet the diesel particulate emission level (PEL) required in 30 CFR, Part 72.500, mine operators using MSHA Approved diesel powered equipment have added diesel particulate exhaust filters to their equipment. In some cases, the filter media used to filter the diesel particulate from the exhaust has been a cellulose paper-like material. Typically these filter elements are used to filter contaminated engine intake air on heavy-duty construction equipment. Cellulose filter materials of this type may deteriorate or ignite when subjected to hot exhaust gases from an engine that has lost the cooling effects of the equipment's MSHA Approved Safety Component System (SCS) due to a system malfunction. (Note: A requirement of permissible diesel powered equipment is that the exhaust gases discharged from the diesel engine on a wet exhaust system conditioner and a properly functioning Safety Component System are not permitted to exceed 185 degrees Fahrenheit.)

Although the MSHA Approved wet scrubber type SCS is designed with a safety shut down device that will prevent the lost cooling effect, anecdotal reports from the field indicate that the wet scrubber type SCS shut down devices malfunction or are not maintained in operational condition which causes paper-like particulate filters to deteriorate or ignite from the high exhaust gas temperatures. For this reason, MSHA's Approval and Certification Center has designed and tested a prototype electrical control circuit for the machine's permissible electrical system that will give a visual warning by flashing the headlights before certain types of wet scrubber SCS lose their exhaust gas cooling effects.

Similar to battery powered scoops that automatically flash their headlights when the batteries reach a pre-determined low voltage, the circuit designed by MSHA for the wet scrubber type SCS flash the diesel equipment's headlights when the SCS water supply is nearly depleted. The intent of the warning provided by the flashing headlights gives operators of the equipment, as well as other miners on the section, a visual indication that the water supply on the diesel equipment needs to be replenished but allows

enough water in the system for the machine operator to tram to a source of water. The flashing headlight warning occurs before the equipment SCS low scrubber water safety shutdown device shuts down the machine's diesel engine. The Flashing Headlight Warning Control Circuit does not shut down the machine and is not connected to the SCS in any fashion.

The design details of the Flashing Headlight Warning Circuit and results of field trials from two underground coal mines are provided in this report.

DISCUSSION:

REQUIREMENTS

A Federal regulation for the approval of SCS for permissible diesel powered equipment using a wet exhaust conditioner (Wet Scrubber) is provided in 30 CFR Part 7.103 (b) (4). The regulation states: "The low water sensor for the systems using a wet exhaust conditioner shall automatically activate the safety shutdown system and stop the engine at or above the minimum allowable low water level and prevent restarting of the engine".

These low water shutdown sensors required by the regulation provide the means to prevent the hazardous condition of exposing the filter materials to hot exhaust gases.

Requirements for daily, weekly, or monthly operational checks of the low water shutdown system are provided in an operational permissibility checklist that is approved by MSHA for each MSHA-approved diesel powered machine. This operational check should identify a low water shutdown system that is not operating.

Since a low water shutdown sensor is required by regulation and the operational performance of this system must be checked as part of the machine's approval, no other system is required to detect or warn of a low scrubber water condition. Therefore, the Flashing Headlight Warning Control Circuit described in this report is not a system required by Federal Regulations. The addition of the circuit on diesel equipment, however, may serve to further minimize the risk of overheating and fire when paper-type diesel particulate filters are being used. If selected as a supplementary early warning control system, the circuit would be required to meet the applicable requirements of 30 CFR Part 36.32. This regulation states: "(a) Electrical components on mobile diesel powered transportation equipment shall be certified or approved under Part 18, 20, or 27 of this chapter as applicable.....", "(b) Electrical systems on mobile equipment shall meet the requirements of Part 18 or 27 of this chapter, as applicable.

Flashing headlight warning circuit design considerations

The following design issues were considered in the development of an electrical/mechanical system that would detect a low, wet scrubber, water condition and flash the equipment's headlights:

- 1) Existing permissible electrical lighting components/system on-board the equipment
- 2) Water level sensing component
- 3) Design and packaging of a permissible headlight control circuit
- 4) Installing additional components with minimal equipment alteration.

Existing permissible electrical lighting

Permissible diesel powered equipment include a Direct Current (DC) lighting circuit that is powered by a mechanically driven MSHA Certified X/P alternator. The front and rear headlights are controlled by a double pole, double throw (DPDT) switch housed in an MSHA-Certified explosion-proof (X/P) enclosure. Headlights at both the front and rear of the machine are MSHA Certified X/P luminaries. The cabling between the alternator, switch and the lights may be MSHA approved cable routed in MSHA certified hose conduit. Over current protection (fuses) is also provided in the circuit. The components of the lighting circuit are evaluated for compliance with the approval requirements of 30 CFR, Part 18, and the design of the lighting circuit is documented under the approval of the diesel machine.

The addition of the Flashing Headlight Warning Control Circuit into the existing lighting circuit must also meet the permissibility requirements of 30 CFR Part 18. The components that switch the alternator power in order to flash the headlights must be housed in an MSHA-Certified X/P enclosure. The water level sensing may be an Intrinsically Safe sensing circuit originating from within an X/P enclosure. This Intrinsically safe sensing circuit may be activated by a simple resistive contact switch.

The Flashing Headlight Warning Control Circuit's power switching components and the Intrinsically Safe (IS) sensing circuit in the existing lighting circuit must be electrically located between the alternator's regulated DC output and the DPDT switch. In this location, the power switching will affect both the front and rear headlights, regardless of the switch's position. The IS sensing circuit can be designed around the regulated DC output voltage of the alternator.

Water Level Sensing Component

The water level sensing component may be a simple resistive contact switch. The simplest level detecting switch is a float switch. Many suppliers of level float switches offer a variety of designs. Both normally open and normally closed switches can be selected based on the operation of the sensing circuit. Various float specific gravities may be selected depending on the liquid that is monitored by the float. Various float

materials may be selected based on the PH and the corrosiveness of the monitored liquid. Both magnetically or mechanically operated switches are available. With the great variety of switch choices available, the controlling factor in the switch selection was not the switch design, but instead the environment where the switch would be used, namely the wet scrubber system of an MSHA Approved SCS.

All wet scrubber systems include a tank of water where a stream of hot engine exhaust gas pushes through water to be cooled. This cooling water captures large diesel particles and becomes contaminated and corrosive. Due to this contaminated environment within the wet scrubber water tank, it was concluded that the operation of a float switch may be unreliable in the wet scrubber water tank. Therefore, the water Make-Up-Tank, an on-board reservoir of water that automatically refills the wet scrubber water tank, would offer a less harsh environment for the location of the float switch. The majority of permissible diesel powered equipment currently in use is equipped with wet scrubbers that use a water Make-Up-Tank.

The water Make-Up-Tank contains relatively clean mine water that should not compromise the performance of the float switch. Additionally, monitoring the water level in the Make-Up-Tank assures the wet scrubber tank is full when the Make-Up-Tank has just been emptied. When the level of water in the make-up tank reaches a predetermined low level, the headlights flash and warn the equipment operator that the water in the make-up tank is empty and needs replenished. With a full tank of water in the wet scrubber, the equipment operator should have time to tram to a water source to refill before the equipment's safety shutdown system shuts down the engine.

Design of a permissible headlight control circuit

The Flashing Headlight Warning Control Circuit (FHWCC) designed by MSHA followed two fundamental constraints; 1) the design should use commercially available components that are readily available and 2) were low in cost. Following these constraints, automotive components, relays, off-the-shelf intrinsically safe shunt diode safety barriers and MSHA certified X/P enclosure were considered.

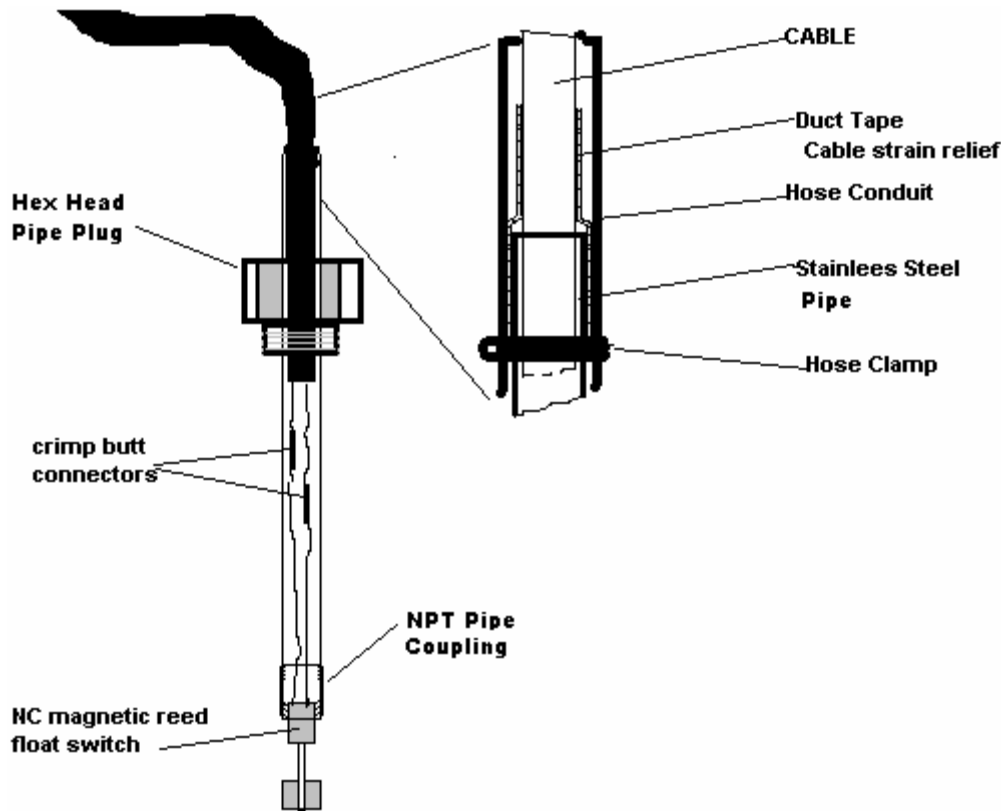
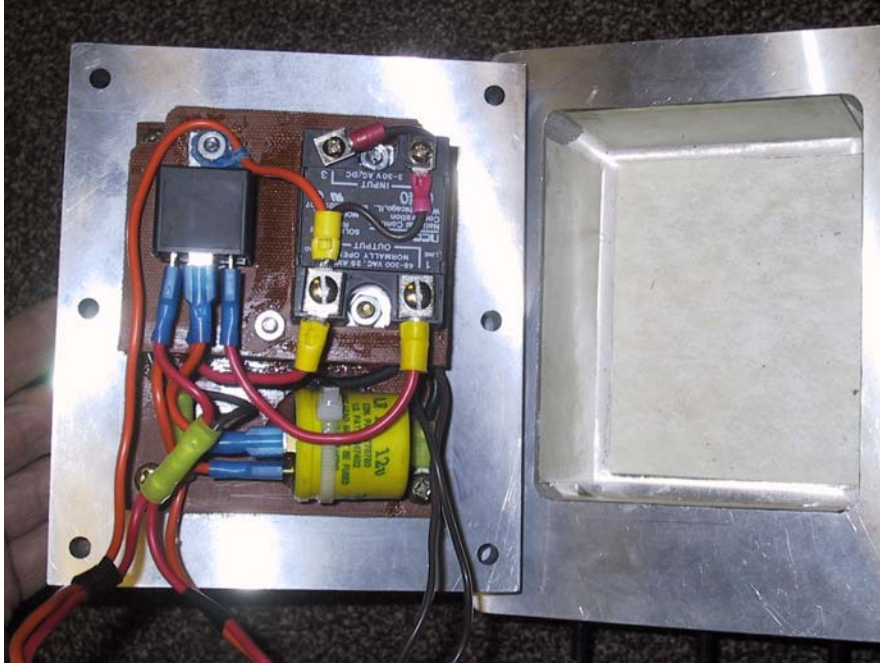


Diagram #2

The packaging of the circuit to fit within an X/P enclosure with the smallest foot print presented the greatest challenge in the system design. Since unused space on diesel powered mining equipment to mount an additional X/P enclosure is difficult to find, the size of the FHWCC X/P must be as small as possible. Using the relays, the automotive flasher and an intrinsic safety barrier in addition to mounting plates, space for wires entering the enclosure through packing glands and wiring connectors required an X/P enclosure with a certain internal volume as shown in photograph #1. An MSHA Certified X/P enclosure meeting the needed internal volume and with a small external foot print was located and was mounted in unused space on the diesel powered equipment used to field test the circuit as shown in photograph #2.

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Photograph #1



Photograph # 2

Installing additional components with minimal equipment alteration

Installation of the FHWCC X/P enclosure on the diesel machine required a rigid surface on the machine that was in the proximity of both the X/P alternator and Make-Up tank. Mounting holes were drilled in the equipment and the X/P enclosure was solidly bolted to the machine forming a solid electrical frame ground for the enclosure. The existing power cable connected between the X/P alternator and the X/P switch enclosure was disconnected in the switch enclosure, fed into the FHWCC X/P enclosure and connected to power the control circuit. An additional cable was used to connect the FHWCC to the switch. All packing glands were properly packed to meet the permissibility requirements.

Float switch installation in make-up-tank

The float switch assembly also used off the shelf components. The float switch assembly consisted of stainless steel pipe, NPT threaded pipe couplings and a magnetic reed type float switch as shown in photographs #3. A 14/3 portable power cable was used to connect the float switch to the FHWCC. The pipe was used to suspend the float switch to the bottom of the make-up-tank. A float switch assembly of this type was installed in the Water Make-Up-Tanks of an Eimco LHD machine at an eastern mine and a Wagner ST machine at a western mine.



Photograph #3

This float switch assembly was installed through a horizontal top surface of the mining machine's make-up-tank. The placement of the float switch with respect to baffles inside the tank was a concern in the installation as well as the depth of the float switch in the tank. Since, the make-up tank contains internal baffles to prevent sloshing, the float switch should be located as near as possible to the center of the tank without making contact with any baffle. The depth of the float switch must be in the lowest level of the tank but above the opening where water is drawn from the make-up-tank to the wet scrubber tank. Additionally the external location of the float switch assembly on the make-up-tank must be considered in the installation. The entrance of the float switch assembly and its intrinsically safe wiring into the make-up-tank must be located to guard it against physical damage.

Machine alterations

At a suitable horizontal top surface on the make-up tank, a 2" diameter hole was cut into the tank. Over this hole, a 2" NPT, stainless steel half-coupling was centered and welded to the tank top as shown in photograph #4.



Photograph #4

A 9/16" diameter hole was drilled through a 2" NPT hex-head pipe plug that would be threaded into the 2" half-coupling on top of the make-up-tank. The float switch assembly pipe with the float switch threaded into its end was fed through the hole in the 2" pipe plug and welded when the float switch was positioned at the desired depth in the make-up-tank. The switch and wiring were removed from the 1/4" pipe prior to welding the pipe to the modified pipe plug.

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With the half-coupling installed in the make-up-tank and the stainless steel pipe welded in the 2" pipe plug at the desired float switch depth, the float switch assembly was completed and electrical connection to the FHWCC was made. The 14/3 cable connected to the intrinsically safe sense circuit in X/P enclosure was fed through the ¼ inch pipe. The float switch and two conductors of the 14/3 cable were connected with insulated crimp butt connectors that were located within the ¼" pipe. All welds and connections were made pressure tight to prevent leaks from the pressurized water make-up-tank. All hose conduit connections were clamped securely at both ends and to the machine. The final installation of the float switch assembly into the make-up-tank is shown in photograph #5.



Photograph #5

Field trial results

Each mine using the MSHA designed FHWCC on their selected Diesel powered equipment were contacted after months of field testing. Both mine operators indicated the FHWCC functioned as designed and flashed the equipment's headlights when water was needed. The western mine reported that the circuit performed its desired function, but indicated that that this device may not be adopted at their mine because their operational procedures minimize the occurrences of equipment water loss. The eastern mine personnel also reported that the circuit performed its desired function and that it proved to be helpful to miners operating the diesel equipment.

Conclusion:

The FHWCC presented in the report may be duplicated without reservation and could be readily accepted by MSHA for use on permissible diesel powered equipment provided the applicable documentation requirements of 30 CFR are satisfied. Equipment manufacturers and mine operators are encouraged to adopt this circuit design or use this design as a building tool in order to design a physically smaller circuit using integrated solid state components and transistor switching. Additionally this design concept could be used as a catalyst to advance the safety shutdown system designs used on Diesel Safety Component Systems.